Yolo County Integrated Groundwater and Surface water Model

Model Development and Calibration

Prepared for:

Yolo County Flood Control and Water Conservation District and Water Resources Association of Yolo County

In Coordination with:

California Department of Water Resources

WRIME Water Resources & Information Management Engineering, Inc.

May 2006

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PROJECT BACKGROUND

The Yolo County Flood Control and Water Conservation District (YCFCWCD), along with other members of the Water Resources Association of Yolo County (WRA) have embarked on development of analytical tools and technologies to:

- Better understand the nature of groundwater flow system in the county;
- Analyze the benefits and impacts of Cache Creek Groundwater Recharge/Recovery Program (CCGRRP);
- Evaluate the effects of the plans and projects considered under the local and regional groundwater management plans; and
- Evaluate the benefits and impacts of the regional water management programs considered under the Integrated Regional Water Management Plan (IRWMP).

In order to select the most suitable analytical tool to meet these needs, the YCFCWCD in coordination with the California Department of Water Resources (DWR) conducted a study on modeling goals, objectives, and strategy for the Yolo groundwater basin (WRIME, 2002). Based on the criteria adopted by the stakeholders, the study recommended using the Integrated Groundwater and Surface water Model (IGSM) as the primary analytical tool for basinwide groundwater-related project planning and design.

The initial funding of model development was through an AB303 grant funding by the DWR awarded to YCFCWCD. The scope of initial model development was to develop a county-wide integrated hydrologic model, with special emphasis on data development, analysis, and model calibration along Cache Creek in the vicinity of the CCGRRP area. Based on this initial scope, the data in other parts of the county were to be at a very course level to produce an operational, but not necessarily a calibrated, model. During the course of model development, the stakeholders in the Yolo county IRWMP decided to refine the remaining portions of the model area, primarily to the south of Cache Creek, at the same level of detail as the CCGRRP area, so that the model be used for analysis of alternative water management scenarios for groundwater management plans, IRWMP, and general plan updates. The funding for this additional work was secured local sources, including the Cities of Davis, Woodland, and Winters, the University of California at Davis (UCD), Yolo County, and YCFCWCD. In addition, the DWR provided additional technical services to complete the task. This additional funding was used to develop sufficiently detailed data in other parts of the model area, as well as calibration of the model in the areas of Davis/UCD, Woodland, and Winters, as well as the main groundwater basin in Yolo County.

PROJECT TEAM ORGANIZATION

YCFCWCD awarded the model development contract to Water Resources & Information Management Engineering, Inc. (WRIME). The project team consisted of the following:

YCFCWCD: Contracting Agency and Project Manager

WRA: Members of the WRA and the WRA Technical Advisory Committee (TAC) served as the oversight committee for decisions regarding model development

Modeling TAC: A Technical Advisory Committee (TAC) was specifically selected and assigned to oversee the technical details, assumptions, and quality control of the model development. The Modeling TAC consisted of representatives of the YCFCWCD, DWR, and consultants, and it provided technical review, guidance, and coordination. The TAC met on a quarterly basis, and participated in discussions, review, and decision-making regarding the technical assumptions and data analysis for the model development.

Members of the TAC were:

- Max Stevenson, YCFCWCD;
- Bill Brewster, DWR – Central District;
- Tasmin Eusuff, DWR – Division of Local Planning and Assistance;
- Fran Borcalli, Wood-Rodgers, Inc., and
- Grant Davids, Davids Engineering.

SCOPES OF WORK

Two scopes-of-work were prepared to develop the Yolo County Integrated Groundwater and Surface water Model (YCIGSM). The first scope of work was associated with the original AB303 grant. The second scope of work was associated with the additional funding provided by DWR and other Yolo County agencies and cities. Each scope is described below.

SCOPE OF WORK FOR INITIAL MODEL DEVELOPMENT

The scope of work of the initial model development funded as part of the AB303 grant included six tasks, as follows:

- Task 1 – Data Collection and Analysis;
- Task 2 – Model Development;
- Task 3 – Model Calibration and Sensitivity Analysis;

- Task 4 – Development of Baseline Conditions Model and CCGRRP Alternative;
- Task 5 – Preparation of Model Report; and
- Task 6 – Project Management and Public Coordination.

Each task is described below.

Task 1 – Data Collection and Analysis

The purpose of Task 1 was to collect and analyze the available data required to develop the YCIGSM. The data collected were analyzed and synthesized for model development and calibration.

Task 2 – Model Development

The purpose of Task 2 was to develop the YCIGSM using the data collected in Task 1. The initial steps of model development included identifying the modeling approach, and determining the hydrogeologic setting. With the completion of the initial tasks, the YCIGSM finite element model grid was developed and the model data files were prepared.

Task 3 – Model Calibration and Sensitivity Analysis

The purpose of Task 3 was to calibrate the YCIGSM to closely match historical data. The historical period chosen to calibrate the model included wet and dry periods having adequate water level and stream flow data.

Task 4 – Development of the Baseline Conditions Model and CCGRRP Alternative

The purpose of Task 4 was to analyze a water management alternative based on the calibrated YCIGSM. The Baseline Conditions model was developed from the calibrated model and on the basis of land and water use data representing the conditions that existed in the year 2000. A single alternative water supply scenario, the CCGRRP, was developed from the Baseline Conditions model. The impacts of CCGRRP were evaluated by comparing the model results from the CCGRRP Alternative with those from the Baseline Conditions.

Task 5 – Preparation of Model Report

The purpose of this task was to prepare this report to document the development, calibration, and application of the YCIGSM.

Task 6 – Project Management and Public Coordination

This task includes the activities required to coordinate with the YCFCWCD and to manage the overall project.

SCOPE OF WORK FOR ADDITIONAL MODEL DEVELOPMENT

The scope of work funded under the additional local funding and technical services provided by the DWR included four tasks, as follows:

- Task 1 – Data Collection and Update Model Input Files;
- Task 2 – YCIGSM Grid Refinement;
- Task 3 – Refine YCIGSM Calibration; and
- Task 4 – Project Management.

Each task is described below.

Task 1 – Data Collection and Update Model Input Files

The purpose of Task 1 was to collect new hydrogeologic data to refine the hydrogeology in the areas outside the CCGRRP area. The refinement of hydrogeologic setting was based on data collected from recently completed studies.

Task 2 – YCIGSM Grid Refinement

The purpose of Task 2 was to refine the YCIGSM grid in the Davis, Woodland, Winters, and other agricultural areas. This was performed so that simulation capabilities of groundwater conditions in these areas would be improved. All model input files associated with the grid refinement were updated.

Task 3 – Refine YCIGSM Calibration

The purpose of Task 3 was to refine the YCIGSM calibration in areas other than CCGRRP area. This refinement included finalizing water budgets, recalibrating regional groundwater flows, recalibration streamflows, and recalibrating local groundwater levels.

Task 4 – Project Management

This task includes the activities required to coordinate with DWR, the Technical Committee of the WRA, and the YCFCWCD and to manage the overall completion of the scope of work.

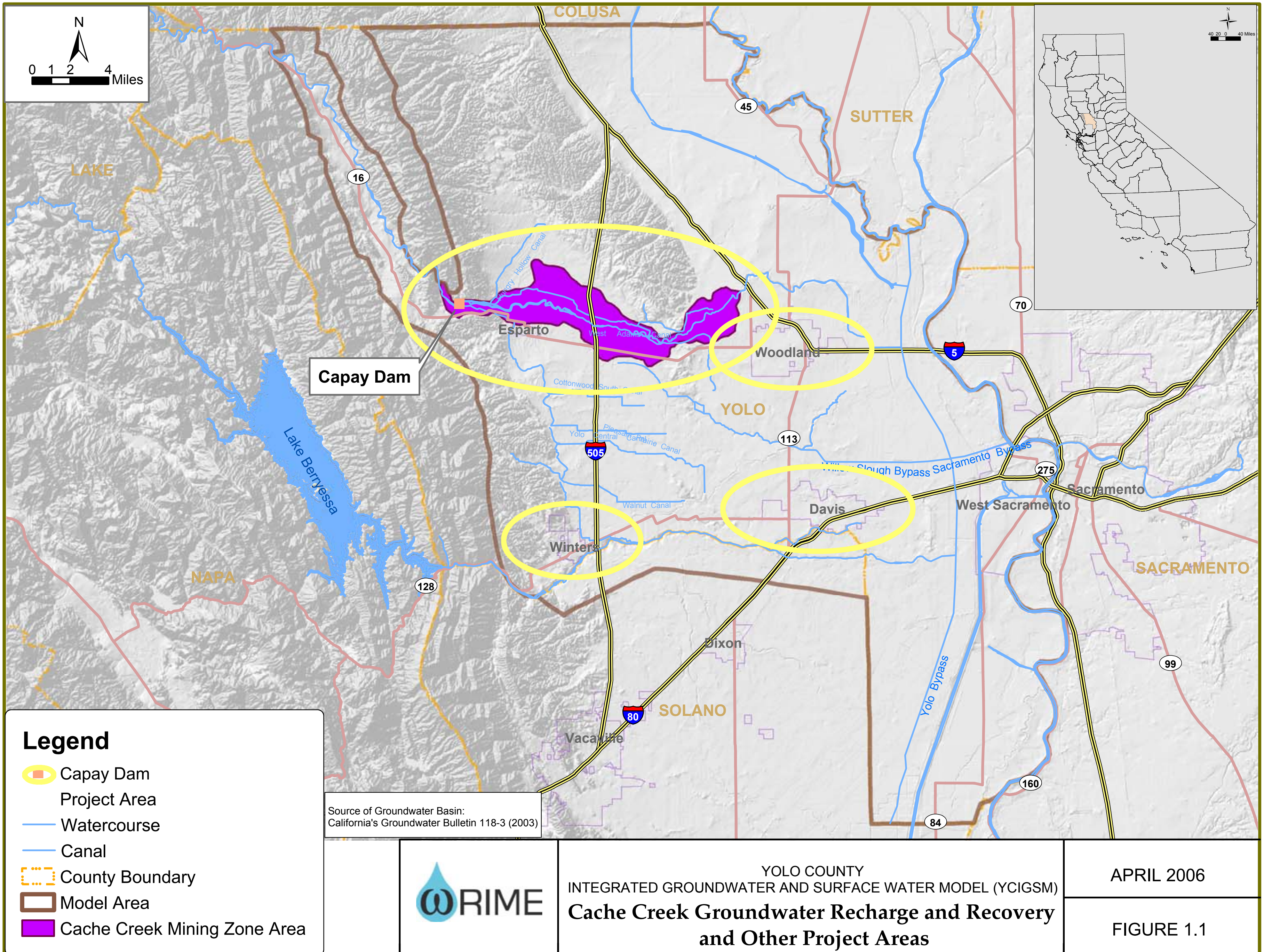
STUDY AREA

The general study area for the model development includes the CCGRRP area (Figure 1.1). The CCGRRP project site consists of the area surrounding Cache Creek downstream from Capay Dam to Woodland. The CCGRRP project area has extensive gravel deposits, which have been mined since the early years of the last century through present day. The remaining portions of the study area consist of agricultural lands within Yolo County, as well as the Cities of Davis, Woodland, and Winters. Other municipal areas within the county were included in the model; however, they were not simulated at the same level of detail as the first three. In order to provide for reasonable boundary conditions to the south, model boundaries were extended south of Putah Creek into Solano County.

The developed portion of Yolo County is predominantly agricultural farmland. Groundwater constitutes a major source of water to the agricultural water users in the county. In addition, surface water stored in Clear Lake and Indian Valley reservoir is provided to commercial farmlands for irrigation. According to the data provided by the California Farm Bureau Federation (http://www.cfbf.com/counties/index.cfm?id=57), the market value of agricultural production in Yolo County was $338 million in 2004. The top five commodities in Yolo County are processing tomatoes, rice, alfalfa hay, wine grapes, and almonds.

The major population centers in Yolo County are all solely dependent on groundwater for their source of drinking water with the exception of West Sacramento, which diverts water from the Sacramento River. As such, the reliability, quality, and stewardship of the groundwater basin is of strategic importance to the cities.

Annually, there is about 20 inches of rainfall in the county, with more than 80% occurring during the non-growing season (from November to March) while less than 20% occurring during the growing season. This out-of-phase feature of water supply (rainfall) and water demand (irrigation) creates water demand that is met by surface water deliveries and groundwater pumping during the growing season. Agricultural demand accounts for 95% of the water demand in Yolo County.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Cache Creek Groundwater Recharge and Recovery and Other Project Areas

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FIGURE 1.1

MODEL DESCRIPTION

The following is brief description of the key components and features of the YCIGSM. Table 1.1 provides a list of IGSM project applications at regional and local levels. For a comprehensive and detailed description of the IGSM model, including its theoretical and mathematical underpinning, *IGSM User's Manual* (WRIME, 2003) may be consulted. The following overview of the YCIGSM is provided to facilitate discussions in subsequent sections on model input data, calibration and sensitivity analysis, and model application.

MODEL OVERVIEW

The YCIGSM is a comprehensive hydrologic model that simulates surface water and groundwater flow systems. The key features of the YCIGSM are:

- Groundwater flow simulation;
- Surface flow simulation;
- Soil moisture accounting;
- Unsaturated flow simulation;
- Stream-aquifer interaction;
- Land & water use analysis; and
- Crop consumptive use computation.

The YCIGSM could simulate reservoir operations and land subsidence if the necessary data becomes available.

HYDROLOGIC PROCESS MODELING

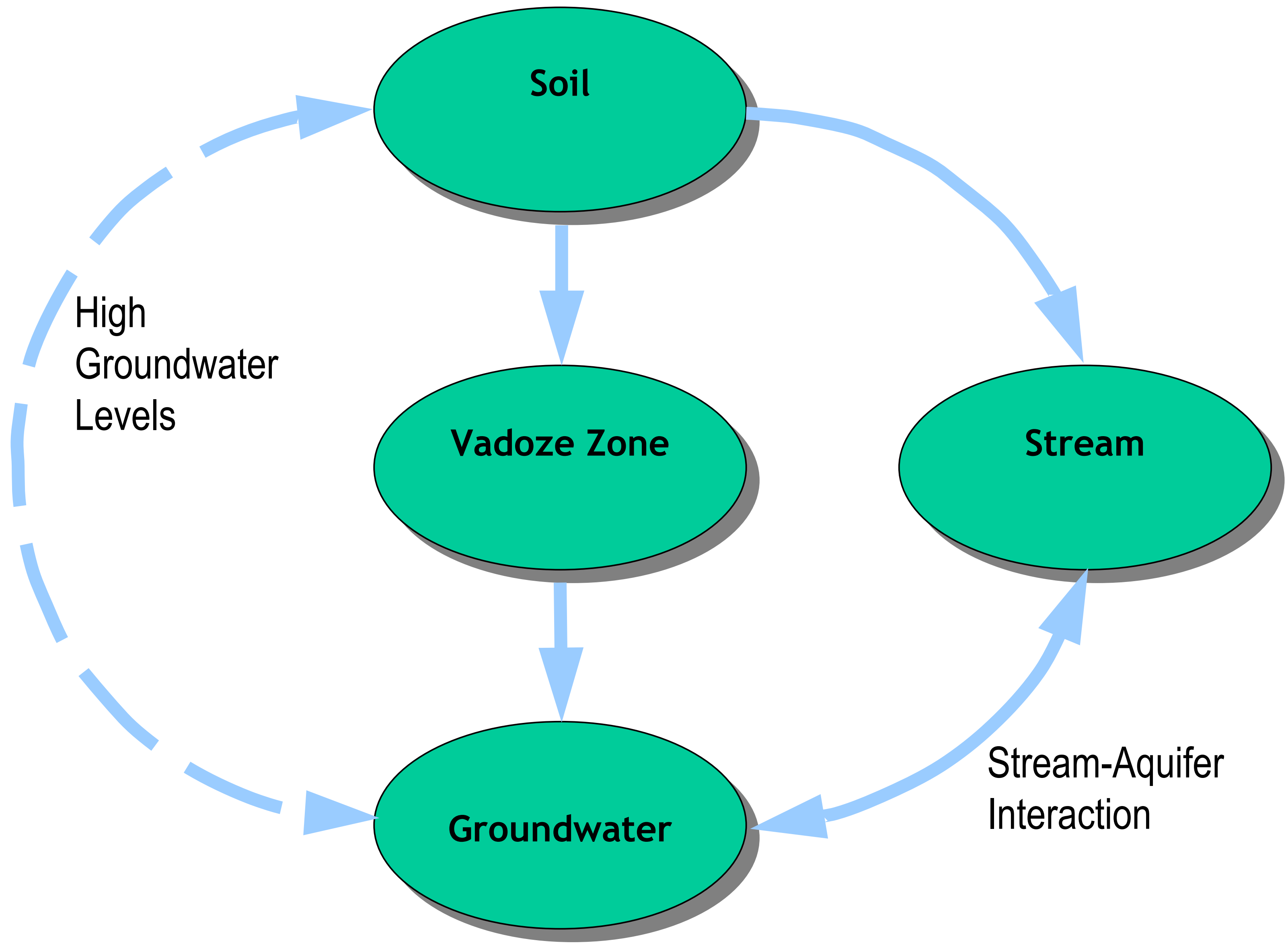
The YCIGSM divides the hydrologic system into four major subsystems as shown in Figure 1.2. These are:

- Soil zone,
- Stream system,
- Vadose or unsaturated zone, and
- Groundwater zone.

The hydrologic components of these four physical subsystems are shown in Figure 1.3 and are briefly discussed below.

Table 1.1
IGSM Project Applications During 1982 - 2006

Application Location	Application Area (Sq. mi.)	Basin Management	Stream / Lake Impact Analysis	Groundwater Recharge	Conjunctive Use	Seawater Intrusion	Groundwater Availability	Water Quality
Alameda County, CA	120	●	●	●		●	●	●
Central Valley, CA	20,000	●	●		●		●	
Cherry Creek, CO	12		●				●	
Chino Basin, CA	270	●					●	●
City of Sacramento, CA	100	●	●		●		●	
East Orange County, FL	900		●	●				
Friant-Kern Service Area	1,000	●			●		●	
Imperial Valley, CA	580	●	●				●	
Kings Basin, CA	1,630	●		●	●		●	
Lower Colusa Basin, CA	460	●		●	●		●	
Niles Cone / South Bay Plain, CA	285	●		●	●			●
Pajaro Valley, CA	120	●		●	●	●	●	●
Pomona Valley, CA	25	●					●	
Sacramento County, CA	1,070	●	●		●		●	
Salinas Valley, CA	780	●	●		●	●	●	●
San Joaquin County, CA	1,580	●	●		●	●		
Stony Creek Fan, CA	1,060	●	●	●	●		●	
Sutter / Placer County, CA	340	●						
West Orange County, FL	120	●	●	●	●			
Yolo County, CA	885	●	●	●	●		●	
Yuba County, CA	270	●	●	●	●		●	



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Hydrologic System Interactions

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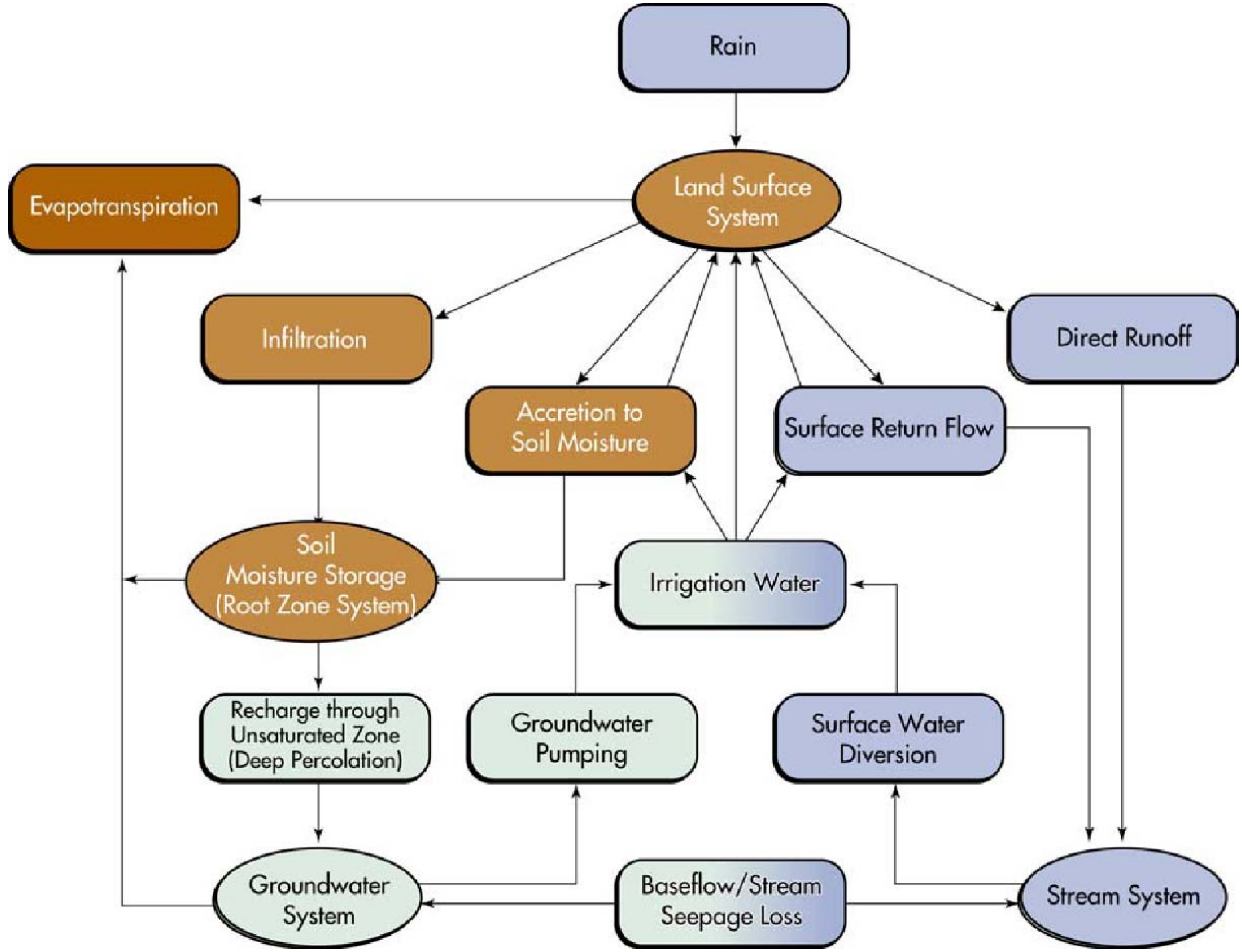
FIGURE 1.2



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Hydrologic Components

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FIGURE 1.3

Soil Zone

The YCIGSM simulates soil zone processes including evapotranspiration, direct runoff, infiltration, and deep percolation from rainfall and applied water. Evapotranspiration is computed based on crop consumptive use requirements and available soil moisture. Direct runoff from rainfall and applied water is computed by using a modified Soil Conservation Service (SCS) runoff curve number method.

Input data for soil zone simulation include:

- Initial soil moisture,
- Rainfall,
- Land use category,
- SCS hydrologic soil group,
- Minimum soil moisture requirements for each crop type,
- Crop consumptive use,
- Root zone depth for each crop, and
- Surface drainage pattern.

Stream System

To simulate streamflow in the YCIGSM, the water balance equation is solved for each stream element. The stream elements are a series of one-dimensional line elements that are used to describe the stream system within the model area. The gain or loss due to stream-aquifer interaction is computed by using mathematical equations that are based on water levels in the stream and the underlying aquifer. The depth of water in the stream is computed using stage-discharge relationships at the corresponding stream node.

Input data for the stream system simulation include:

- Stream configuration,
- Stream node elevation,
- Cross-section,
- Stage-discharge relationship,
- Stream inflows at boundary,
- Tributary inflows,
- Wastewater discharges to streams, and

- Streamflow diversions.

Vadose Zone

Water that percolates down from the soil zone travels through the vadose zone as unsaturated flow and eventually reaches the saturated groundwater zone. For vadose zone simulation, the mathematical equation of unsaturated flow is solved numerically at every time step. The vadose zone is divided into a number of discrete layers of specified thickness. The deep percolation of applied water and precipitation that passes through the soil zone becomes the inflow to the uppermost vadose zone layer. Outflow from the overlying layer becomes inflow to the layer beneath, and so on. The outflow from the last vadose zone layer becomes inflow to the saturated groundwater zone.

Input data for the vadose zone simulation process include the thicknesses of vadose zone layers.

Groundwater Zone

For simulating groundwater flow in the YCIGSM, the model flow domain is broken down horizontally into a collection of small, three-sided or four-sided polygonal areas called finite elements. The vertices of these elements are called nodes. The network of finite elements and nodes is called a model grid. The groundwater flow domain is also broken down vertically into several discrete layers that represent the underlying groundwater aquifers. These aquifers are separated by aquicludes that limit the vertical movement of water. Aquicludes are generally composed of low hydraulic conductivity materials, such as silt and clay, or interbedded sequences where the hydraulic conductivity is governed by silt and clay. The aquifers, on the other hand, are primarily composed of materials with relatively high hydraulic conductivity. The predominant flow paths in groundwater aquifers are horizontal. The horizontal flow system is simulated by solving a two-dimensional groundwater flow equation by the finite element technique. The vertical flow system is simulated by solving a leakage equation based on the groundwater elevations in two adjacent aquifers.

Input data for groundwater flow simulation include:

- Well locations,
- Well diameter and perforation interval of wells,
- Monthly pumping,
- Boundary conditions,
- Initial groundwater elevations,
- Aquifer and aquiclude thickness at each node,

- Hydraulic conductivity of aquifer and aquiclude material,
- Specific yield,
- Specific storage, and
- Leakance.

Hydrologic Water Balance

The primary purpose of hydrologic modeling is to solve the water balance equation of the selected model area or watershed. The YCIGSM is a unique hydrologic model that places significant emphasis on hydrologic water balance. As discussed above, the YCIGSM tracks the movement of all of the primary sources of water coming into and leaving the basin, including rainfall, streamflows, applied water, consumptive use, and subsurface inflows and outflows. As a result, the YCIGSM is capable of generating the following water budget outputs:

1. Land and water use budgets;
2. Groundwater budgets;
3. Stream reach budgets; and
4. Soil moisture budgets.

Review and refinement of the above four budgets generated from the YCIGSM help ensure that the key hydrologic components of the different physical subsystems of the groundwater basin (e.g., soil zone, stream subsystem, vadose zone, groundwater zone) are properly represented in the model. During model calibration, these water budgets are analyzed and refined for the entire model area as well as for previously defined model subareas (termed model subregions), which may represent water districts, irrigation districts, or other organized and unorganized areas within the model.

PREVIOUS GROUNDWATER MODELS IN YOLO COUNTY

The following are models previously developed to simulate groundwater processes in Yolo County.

USGS Regional Aquifer-System Analysis Central Valley Model

This was finite-difference groundwater flow model of the entire Central Valley, covering about 20,000 square miles, including the Yolo County groundwater basin. The model simulated groundwater flow in the Central Valley groundwater basin within a four-layer aquifer system. The study period and calibration period for the model is from 1961 to 1977. Although the model was developed for analysis of regional groundwater impacts, it was used for limited applications and alternatives evaluations.

Cache Creek Recharge and Recovery (CCRR) MODFLOW Model

This MODFLOW application was developed for YCFCWCD and covers most of the county. The purpose of this model is to evaluate the feasibility of the Cache Creek Recharge and Recovery Project and its impact on the groundwater resources of the area. This model used a monthly stress period as its simulation time step. The model data was generally based on the Central Valley Model described above and the geologic units and hydrologic data were interpolated from that model. In 1996, the City of Woodland refined the pumping data in the City area, and used the model for evaluation of several conjunctive use projects.

DWR Yolo County MODFLOW Model

This MODFLOW model was developed for Yolo County. The model area encompasses 900 square miles and includes portions of Yolo, Solano, Sutter, and Sacramento Counties. The purpose of this model was to explore and evaluate regional conjunctive use possibilities in Yolo County. The model was calibrated to approximate the groundwater contours shown on the 1912 groundwater level map published in Bulletin 118-6.

UCD Yolo County Finite Element Model

This was a finite element transient groundwater flow model developed as part of a student's Master's thesis at the UCD. The boundary of this model is Putah Creek on the south, the Sacramento River on the east, the Mountain Front in the west, and Cache Creek on the north. The model area covers about 236,000 acres. The purpose of this model is to identify sources and magnitudes of recharge that contribute to the rapid recovery of groundwater levels in Yolo County after a prolonged period of drought.

Central Valley Ground and Surface water Model

This application of the IGSM covers the entire Central Valley of California from Redding to Bakersfield, an area of about 20,000 square miles. The model was developed under the sponsorship of the U.S. Bureau of Reclamation, DWR, the State Water Resources Control Board, and the Contra Costa Water District. The model was originally developed and calibrated for the 1922–1980 period. USBR later extended the simulation period through 1993. The model was used to evaluate groundwater resources, conjunctive use opportunities, and impacts of water management scenarios.

LOWER COLUSA COUNTY IGSM

This IGSM application covers the southern part of Colusa County and the northeastern part of Yolo County. It has been used to evaluate conjunctive use projects in the Yolo-Zamora Water District in 2003.

ORGANIZATION OF REPORT

This report is organized as follows:

- Section 1 – Introduction: This section.
- Section 2 – Data Collection and Assessment: This section provides a review of the data collected to prepare the YCIGSM.
- Section 3 – Model Input Data: This section provides a discussion of the development of the YCIGSM model data.
- Section 4 – Model Calibration and Sensitivity Analysis: This section provides a discussion and the results of the YCIGSM calibration and sensitivity.
- Section 5 – Baseline Conditions and CCGRRP Alternative: This section provides a discussion and the results of the YCIGSM baseline condition development and application to the CCGRRP alternative.
- Section 6 – Summary: This section summarizes the findings of this project and provides recommendation for future course of action.
- Section 7 – References: This section lists the documents used in connection with the preparation of this report.
- Appendix A – Calibration well hydrographs.
- Appendix B – Calibration streamflow hydrographs.

This section presents the results of the data collection and assessment conducted as part of developing the YCIGSM. The Data Collection and Assessment process focused on the following components:

- **Model Area:** Description of the project area, as described in Section 1, and the YCIGSM model area.
- **Data Collection and Assessment:** Description of the data collection process and the collected data, including an assessment of the collected data in relation to model development. Data categories and types include:
  - Hydrologic Data:
    - Natural stream cross-sections and rating tables;
    - Rainfall data; and
    - Streamflow data.
  - Hydrogeologic Data:
    - Geologic cross-sections;
    - Base of freshwater-aquifer;
    - Groundwater level hydrographs; and
    - Hydrologic soil group.
  - Land and water use data:
    - Land use maps;
    - Irrigated crop acreage data;
    - Groundwater extraction records; and
    - Urban water use data.

All the above are discussed, in detail, in Section 3 – Model File Development. The hydrologic and hydrogeologic data are discussed in this section, also.

MODEL AREA

The model area for the YCIGSM is defined by the political, hydrologic and hydrogeologic settings of the study area and with due considerations for future applications of the YCIGSM. The boundaries of the YCIGSM are based on the Yolo County boundaries overlying the groundwater basin along with a portion of the Solano County. A portion of Solano County was included in the YCIGSM for boundary condition purposes and a discussion of this is included later in this section. The model area is shown in Figure 2.1.

DATA COLLECTION AND ASSESSMENT

The data collection effort was conducted as a two-step process:

- **Step 1** – Initial data search that spanned the entire model area to determine what data were available and where; and
- **Step 2** – This step included collecting and compiling data, assessing the status of data, and conducting follow-up research for additional data in and around the model area.

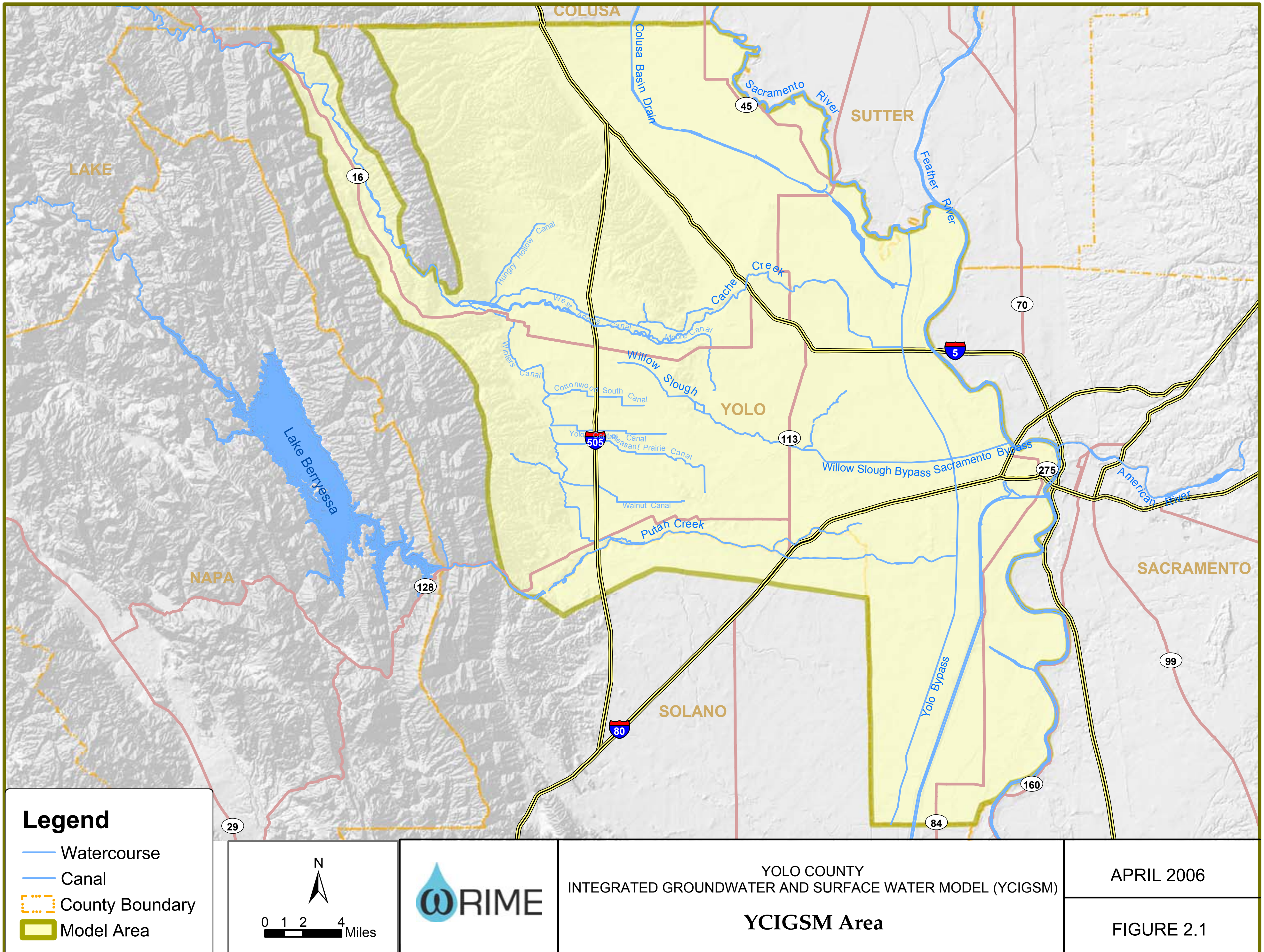
From a data-collection perspective, geographic data search extended beyond the model area in order to ensure that data necessary to develop model boundary conditions were also available during the model development stage of the project.

SIMULATION TIME PERIOD

The IGSM is a dynamic simulation model that simulates groundwater flow and stream flow for a continuous period of time. A time period, 1971–2000, was selected based on discussions with YCFCWCD technical staff and DWR. The primary reason for selecting this period was that substantial amounts of data—needed for model development and calibration—are available from this time period. The features of the time period include:

- A long (30-year) period that provides a reasonable basis for calibration of the model;
- The inclusion of wet, dry, normal, and extreme conditions of the regional hydrology in the basin, such as the 1976–1977 drought, 1983 flood, 1991-1992 drought; and
- Significant changes in land and water use in the model area.

Figure 2.2a shows the annual rainfall total at Davis, California for the 1918–2003 hydrologic period. It can be seen from Figure 2.2a that the average annual rainfall for the 1971–2000 period is 19.2 inches and that the 86-year average is 17.3 inches. Figure 2.2b shows the cumulative departure of annual rainfall from average annual rainfall for Davis. Figure 2.2b shows that, at the Davis gage, the overall hydrologic conditions were dry for the first 51 years of the record. In the last 33 years, the period which includes the selected simulation time period, the overall hydrologic conditions were relatively wet. The average rainfall for the 1971–2000 period is somewhat greater than the long-term average and thus the 1971–2000 hydrology is not



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Area

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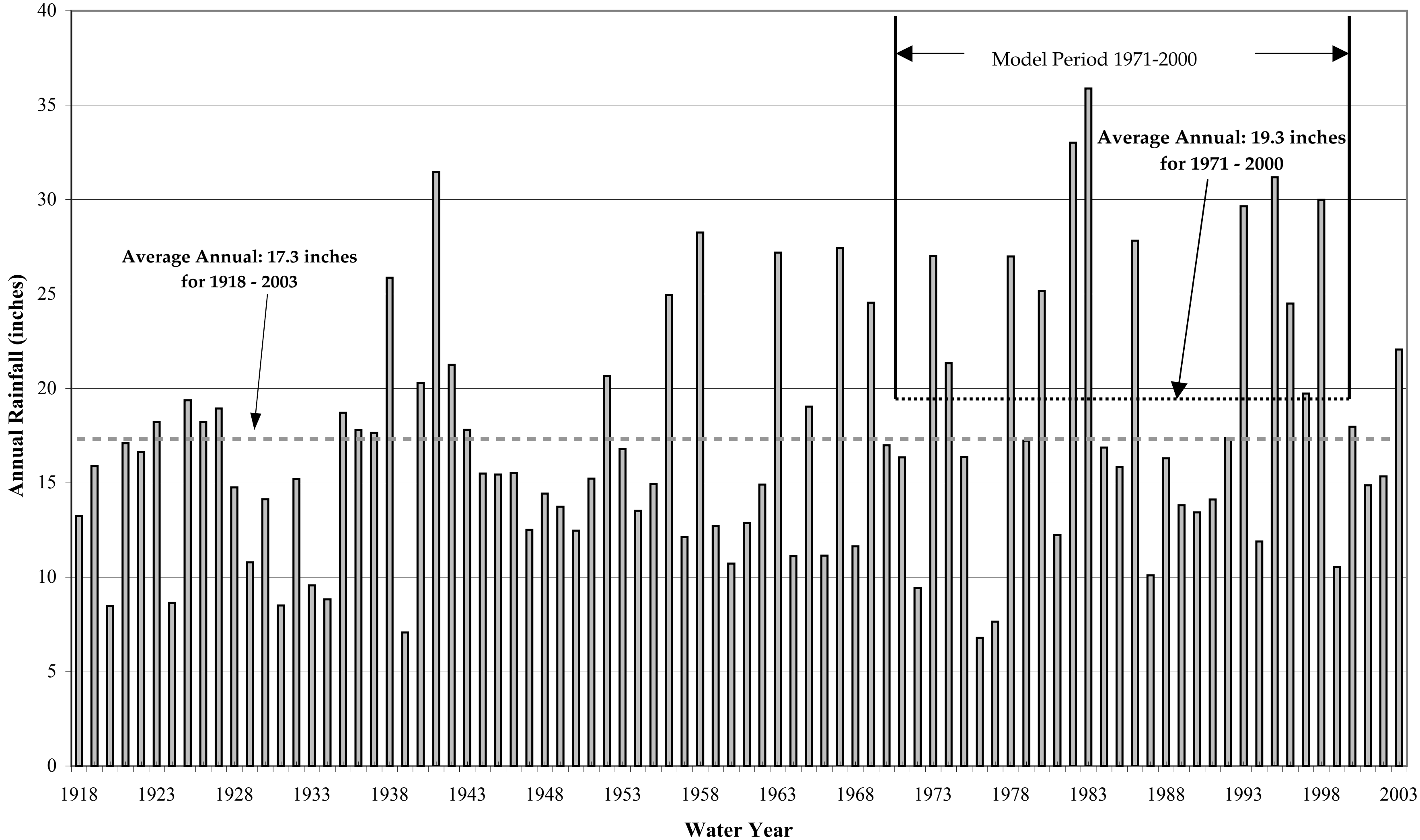
FIGURE 2.1



Source: National Climate Data Center (NCDC) Station # 42294

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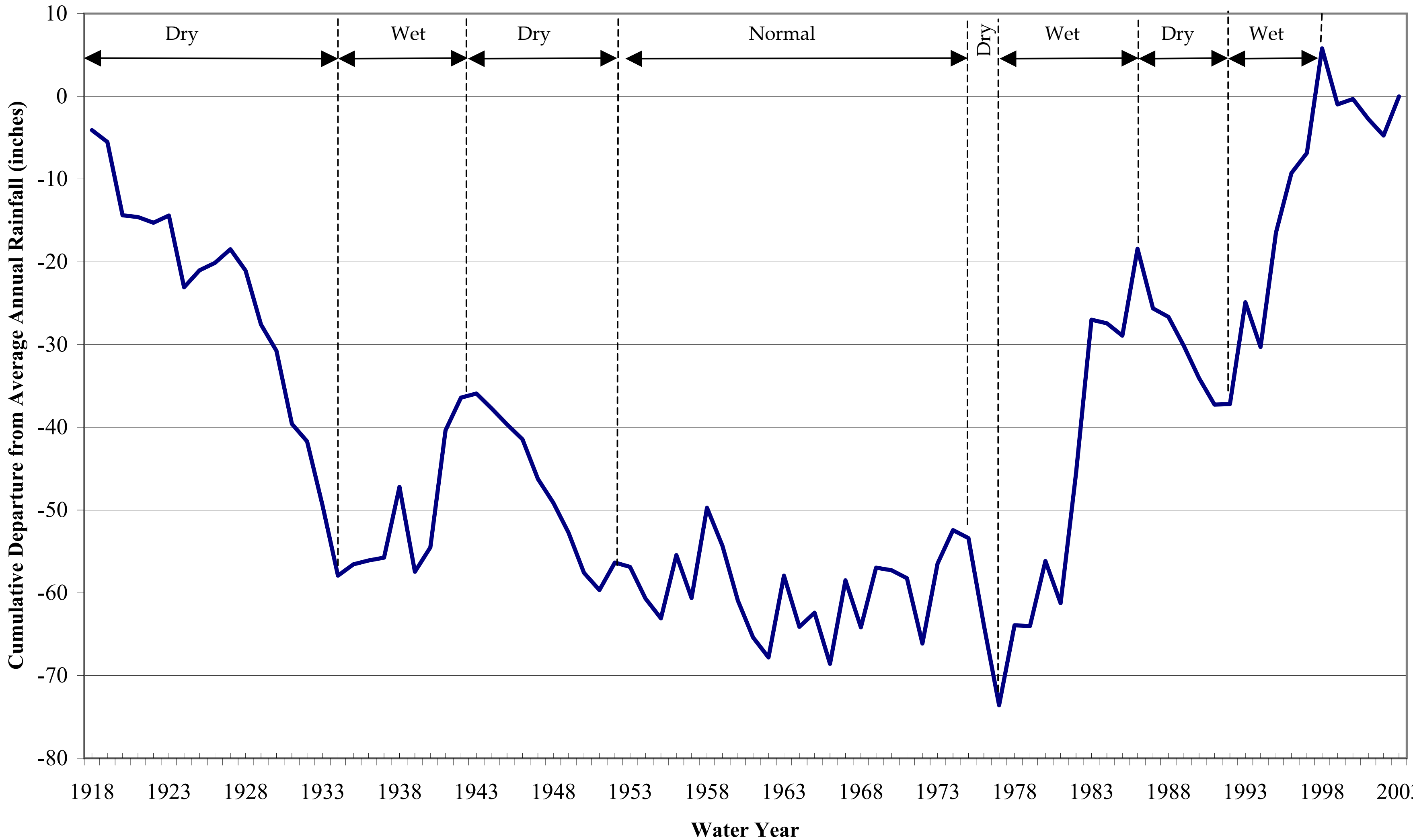
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Annual Rainfall at Davis, 1918 - 2003

FIGURE 2.2a



Source: National Climate Data Center (NCDC) Station # 42294

ωRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Cumulative Departure from Average Annual Rainfall at Davis**	APRIL 2006 FIGURE 2.2b

balanced. Though not a balanced hydrologic period, the use of the hydrologic period in the development of the YCIGSM is not expected to impact its applicability for the model area.

KEY DATA SOURCES

The key data sources used in the development of the YCIGSM are listed below:

1. Department of Water Resources (DWR);
2. U.S. Bureau of Reclamation (USBR);
3. U.S. Geological Survey (USGS);
4. University of California, Davis (UCD);
5. Cities of Davis, Woodland, and Winters;
6. California Irrigation Management Information System (CIMIS);
7. Yolo County Flood Control and Water Conservation District (YCFCWCD);
8. Water Resources Association of Yolo County (WRA);
9. Yolo County Agricultural Commissioner;
10. U.S. Natural Resource Conservation Service (NRCS) (formerly Soil Conservation Service – SCS);
11. National Climatic Data Center (NCDC);
12. Sacramento County Water Agency (SCWA);
13. U.S. Army Corps of Engineers (Corps); and
14. Lower Colusa Basin Integrated Groundwater and Surface water Model (LCBIGSM).

HYDROLOGIC DATA

This section summarizes the general hydrology data collected in the YCIGSM model area. Groundwater flow and quality is typically affected by the basin's hydrology. Therefore, it was essential to understand the hydrologic characteristics of the model area in order to develop a sound conceptual model that would ultimately be the basis for the YCIGSM.

Surface Water

The major components of the surface water system in the YCIGSM are as follows:

- Rainfall;
- Streamflow;

- Stream Reach Delineation, Cross Sections, and Rating Tables; and
- Ungaged Watersheds.

The collected data associated with these components are discussed below.

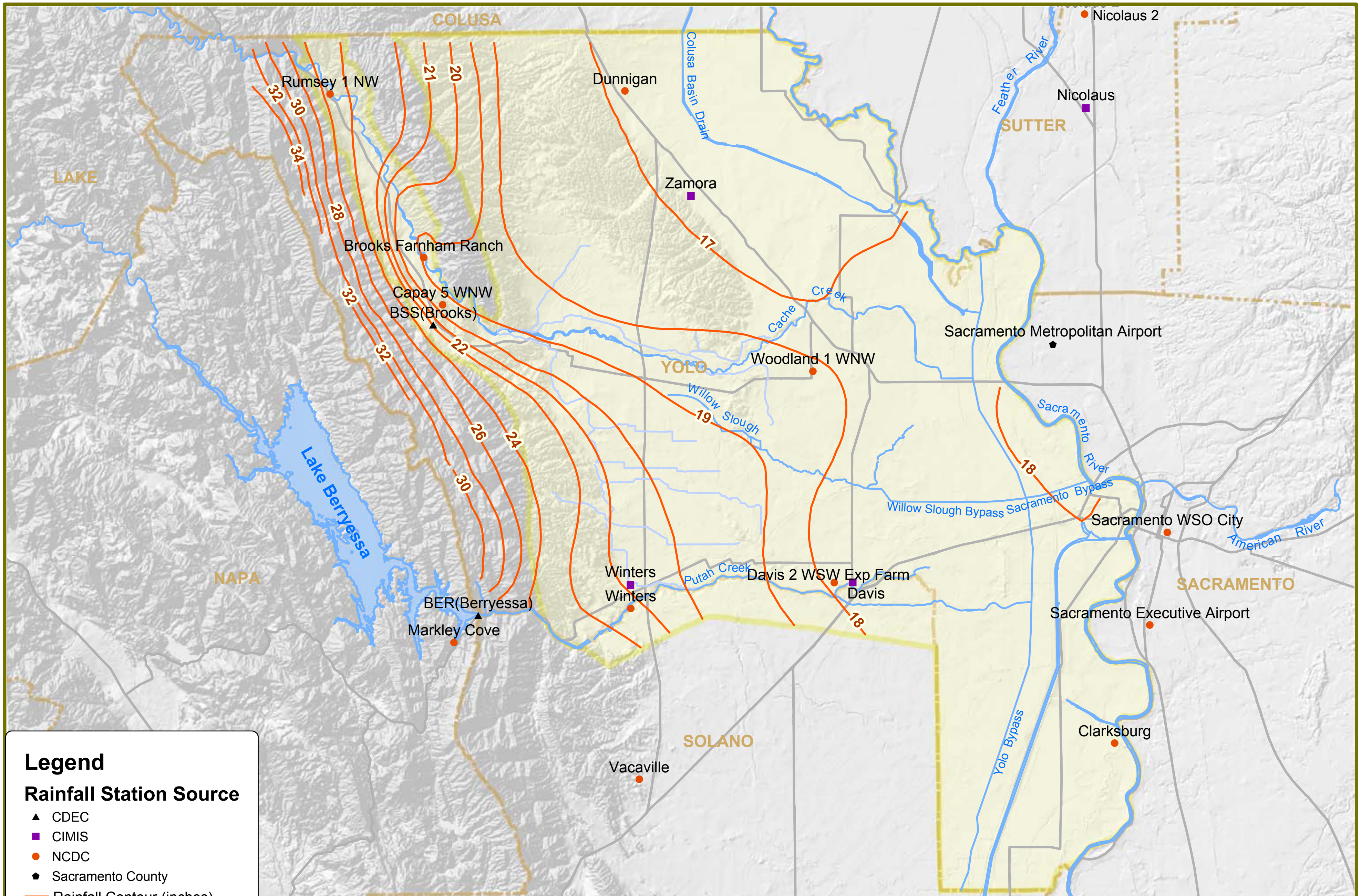
Rainfall Data

Daily rainfall records for weather stations located in and around the study area have been collected from various sources, including NCDC, DWR, CIMIS, and Sacramento County. A list of the identified rainfall gaging stations in the study area is provided in Table 2.1, along with relevant information on the gages. The locations of the rainfall stations that are in and around the YCIGSM area are shown in Figure 2.3.

Table 2.1 YCIGSM Area Rainfall Stations

Station Characteristics			Period of Record		Location		
Name	*Operator*	*Station ID*	*From*	*To*	*Latitude (°N)*	*Longitude (°E)*	*County*
Berryessa	DWR	BER	1997	Present	38.513	-122.104	Yolo
Brooks	DWR	BSS	1986	Present	38.719	-122.142	Yolo
Brooks Farnham Ranch	NCDC	41112	1931	1985	38.7667	-122.15	Yolo
Capay 5 WNW	NCDC	41507	1976	1994	38.7333	-122.1333	Yolo
Clarksburg	NCDC	41784	1935	1975	38.4167	-121.5333	Yolo
Colusa	CIMIS	32	1951	Present	39.2	-122.0167	Colusa
Colusa	NCDC	41948	1948	Present	39.1833	-122.0333	Colusa
Davis	CIMIS	6	1908	Present	38.5333	-121.7667	Yolo
Davis 2 Wsw Exp Farm	NCDC	42294	1931	Present	38.5333	-121.7833	Yolo
Dunnigan	NCDC	42568	1939	1978	38.8833	-121.9667	Yolo
Markley Cove	NCDC	45360	1970	Present	38.4939	-122.1261	Napa
Nicolaus	CIMIS	30	1983	Present	38.8667	-121.55	Sutter
Nicolaus 2	NCDC	46194	1959	Present	38.9333	-121.55	Sutter
Rumsey 1 NW	NCDC	47598	1985	1988	38.8833	-122.2333	Yolo
Sacramento Executive Airport	NCDC	47630	1928	Present	38.5	-121.5	Sacramento
Sacramento Metropolitan Airport	Sacramento County	A17/150	1967	Present	38.7	-121.5833	Sacramento
Sacramento Wso City	NCDC	47633	1893	Present	38.55	-121.4167	Sacramento
Vacaville	NCDC	49200	1931	Present	38.3956	-121.9608	Solano
Winters	CIMIS	139	1951	Present	38.5333	-121.9667	Yolo
Winters	NCDC	49742	1928	Present	38.5167	-121.9667	Yolo
Woodland 1 WNW	NCDC	49781	1931	Present	38.6833	-121.8	Yolo
Zamora	CIMIS	27	1982	Present	38.8083	-121.9081	Yolo

Average annual rainfall contours, prepared for the *YCFCWCD Covell Drainage System Comprehensive Drainage Plan* (Borcalli & Associates, 1993), are shown in Figure 2.3. The IGSM uses average annual rainfall contour data to simulate rainfall distribution pattern in the model area.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Study Area Rainfall Stations and Average Annual Rainfall Contours

Contour Source: Borcalli and Associates (1993)

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FIGURE 2.3

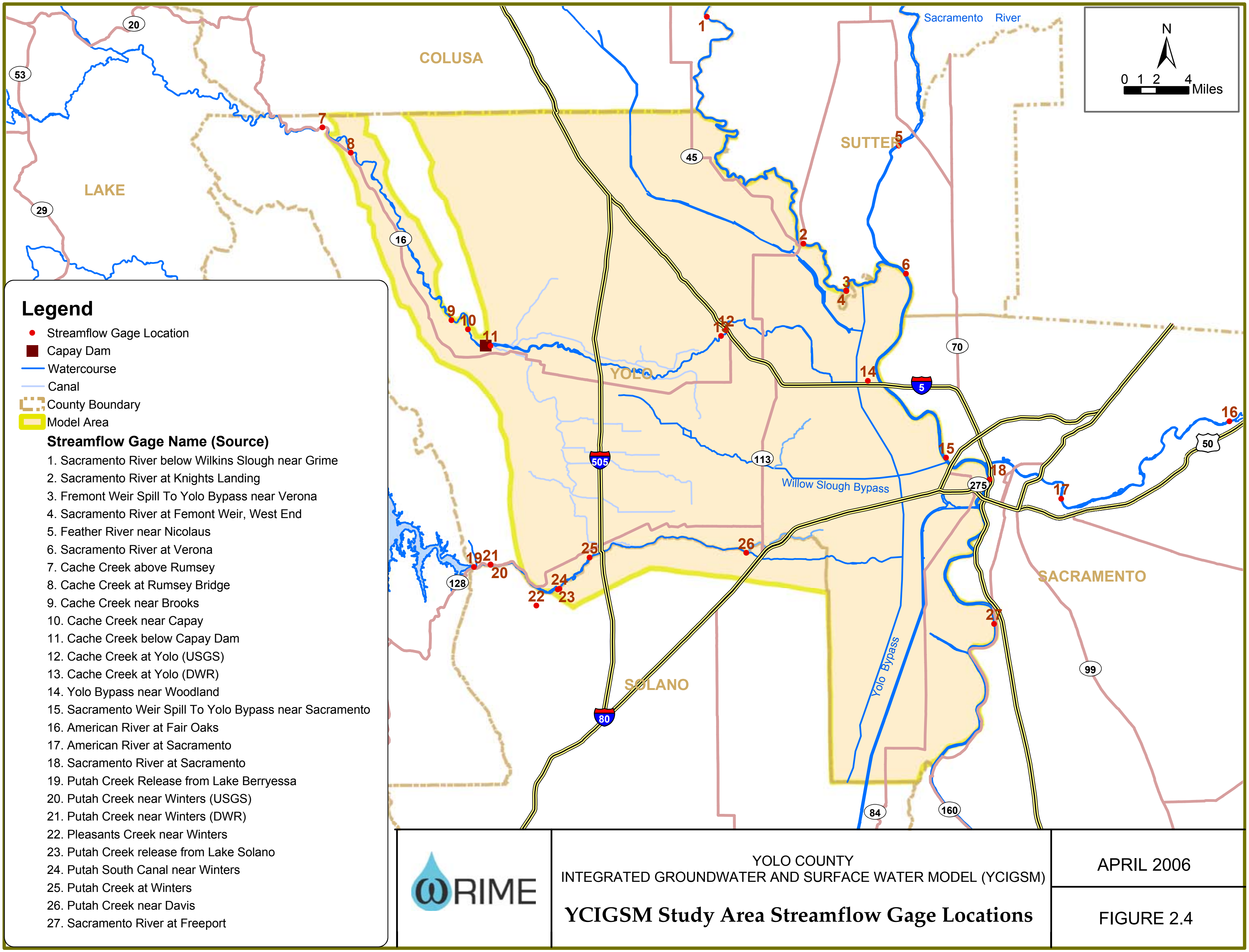
Streamflow Data

Four primary sources of streamflow data are the USGS, USBR, YCFCWCD and the DWR. The USGS data were obtained from the web site http://water.usgs.gov/usa/nwis/sw. USBR data were digitally provided from Central Valley Operations office via personal communication. DWR data were obtained from the California Water Data Library http://wdl.water.ca.gov/hydstra/index.cfm. YCFCWCD data were digitally provided. There are several stream gaging stations in the study area, some of which are now discontinued. All past and current stream gaging stations are listed in Table 2.2. These flow-gaging stations are screened for availability of daily data for the 1971–2000 period and stream coverage in the YCIGSM area.

Table 2.2 YCIGSM Area Streamflow Gaging Stations

Station Characteristics			Period of Record		Location	
Name	*Source*	*Station ID*	*From*	*To*	*Latitude (°N)*	*Longitude (°W)*
American River at Fair Oaks	USGS	11446500	1904	2004	38.636	-121.227
American River at Sacramento	USGS	11447000	1943	1959	38.568	-121.422
Cache Creek above Rumsey	USGS	11451760	1960	1986	38.913	-122.271
Cache Creek at Rumsey Bridge	DWR	RUM	1993	2004	38.89	-122.238
Cache Creek at Yolo	USGS	11452500	1903	2003	38.725	-121.806
Cache Creek at Yolo	DWR	CCY	1998	1998	38.727	-121.806
Cache Creek near Brooks	USGS	11451950	1983	1986	38.738	-122.123
Cache Creek near Capay	USGS	11452000	1942	1976	38.729	-122.104
Cache Creek below Capay Dam	YCFCWCD	-	1979	2000	38.714	-122.083
Feather River near Nicolaus	USGS	11425000	1942	1983	38.891	-121.603
Fremont Weir Spill to Yolo Bypass near Verona	USGS	11391021	1947	1975	38.759	-121.666
Pleasants Creek near Winters	USGS	11454100	1959	1968	38.478	-122.029
Putah Creek at Winters	USGS	11454500	1905	1931	38.521	-121.967
Putah Creek near Davis	USGS	11455000	1948	1962	38.523	-121.786
Putah Creek near Winters	USGS	11454000	1930	2003	38.515	-122.081
Putah Creek near Winters	DWR	PUT	1997	2004	38.515	-122.081
Putah Creek Release from Lake Berryessa	USBR	BER	1959	2004	38.481	-122.102
Putah Creek Release from Lake Solano	USBR	SOL	1959	2004	38.49	-122.003
Putah South Canal near Winters	USGS	11454210	1994	2003	38.493	-122.002
Sacramento River at Freeport	USGS	11447650	1948	2004	38.456	-121.502
Sacramento River at Fremont Weir (West End)	USGS	11391020	1973	1976	38.76	-121.667
Sacramento River at Knights Landing	USGS	11391000	1940	1981	38.803	-121.715
Sacramento River at Sacramento	USGS	11447500	1948	1979	38.587	-121.504
Sacramento River at Verona	USGS	11425500	1929	2004	38.774	-121.597
Sacramento River below Wilkins Slough near Grimes	USGS	11390500	1938	2004	39.01	-121.824
Sacramento Weir Spill to Yolo Bypass near Sacramento	USGS	11426000	1943	2003	38.607	-121.554
Yolo Bypass near Woodland	USGS	11453000	1939	2003	38.678	-121.643

The location of the stream gaging stations listed in Table 2.2 is shown in Figure 2.4.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Study Area Streamflow Gage Locations

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FIGURE 2.4

Stream Reach Delineation, Cross Sections, and Rating Table

The YCIGSM uses stream reaches for streamflow accounting. Criteria commonly used for delineating stream reaches are locations of confluences, inflow locations, dam locations and/or outflow locations. Additional criteria can include the relative importance of the reach to a particular study, and stream-aquifer interaction of the reach. Information in the following reports was evaluated in the context of stream reach delineation of Cache Creek and Putah Creek.

- *Technical Studies and Recommendations for the Lower Cache Creek Resource Management Plan* (EIP Associates et al., 1995)
- *Hydrology of Lower Putah Creek: Preliminary Discussion* (Mann, 1992)

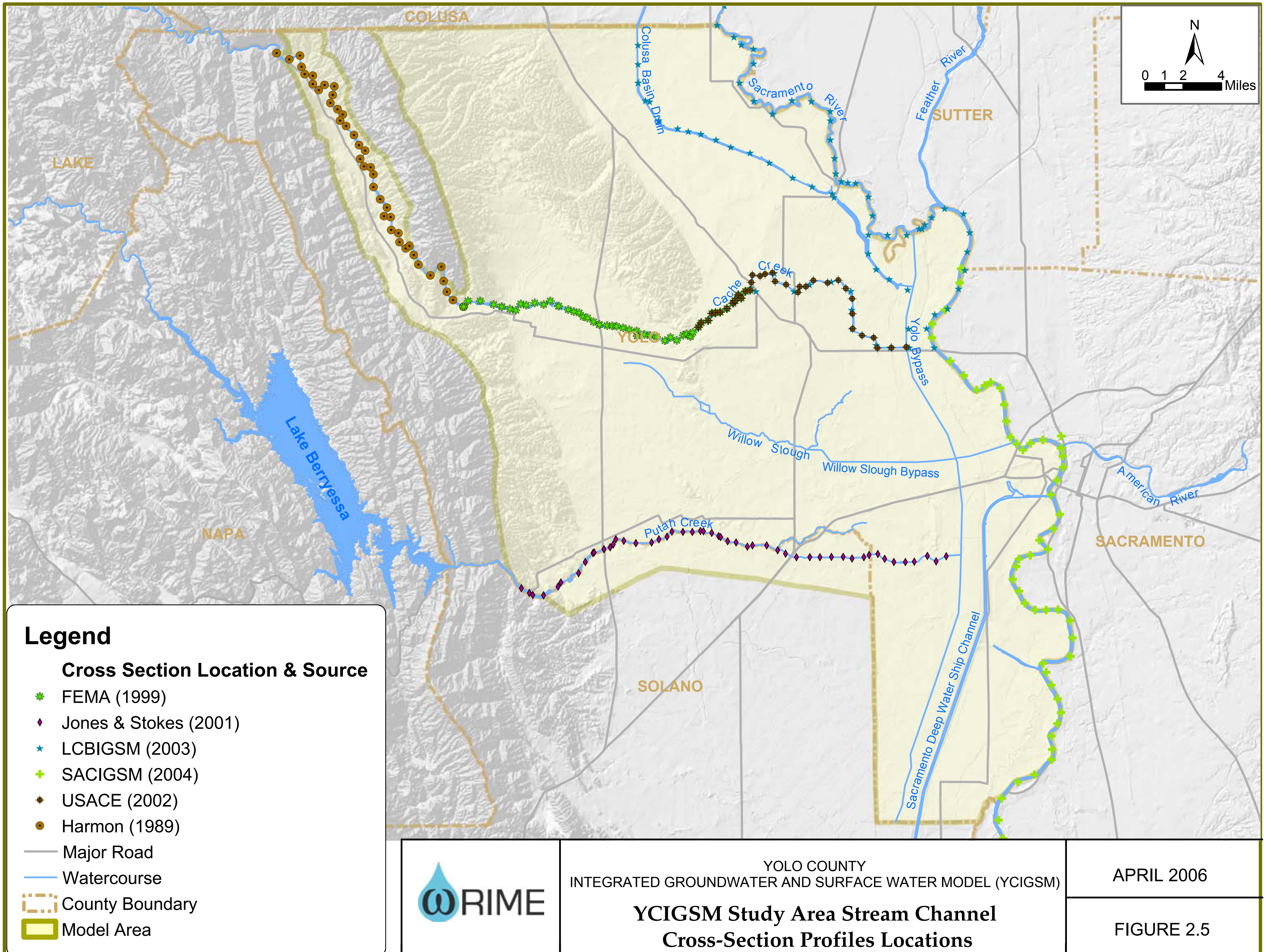
These reports contain discussions regarding the groundwater-surface water interaction for each stream reach. Based on the discussion included in these reports, information was extracted that was ultimately used to configure stream reaches on Cache Creek and Putah Creek.

Stream channel cross-sections, flow rating tables, and wetted perimeter rating tables were collected as part of the development of the YCIGSM. Data were collected from the following studies:

1. HEC-RAS model of Cache Creek County Road 94b to Settling Basin as part of the *Sacramento-San Joaquin River Comprehensive Flood Study* (USACE, 2002);
2. HEC–2 model as part of the *Cache Creek Flood Insurance Study* (FEMA, 1999);
3. HEC-RAS model of Putah Creek as part of the *A Framework for the Future: Yolo Bypass Management Strategy* (Jones & Stokes, 2001);
4. LCBIGSM data for the Sacramento River, Yolo Bypass, Knights Landing Ridge cut, Colusa Basin Drain (WRIME, 2003);
5. Streamflow, Sediment Discharge, and Streambank Erosion in Cache Creek, Yolo County, CA, 1953–1986; and
6. Sacramento County IGSM data for the Sacramento River (WRIME, 2004).

Figure 2.5 shows the location of available stream channel cross-section data.

Data collected from sources 1 through 3 were evaluated for applicability into the YCIGSM. For all sources, the collected data were already processed into flow rating curves for their use in HEC-RAS, HEC-2, and other applications of the IGSM. Data from sources 4 through 6 were used directly into the YCIGSM. After evaluation, the remaining data were synthesized into IGSM format and assigned to the YCIGSM stream nodes. The stream channel thalweg elevation data were collected from these data sources as well.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Study Area Stream Channel Cross-Section Profiles Locations

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FIGURE 2.5

Small Watersheds

There are several small, ungaged intermittent streams along the western boundary of the model area that discharge into the model area. Flow along these streams is not significant enough to be modeled as streams; however, the surface runoff associated with these streams is a source of aquifer recharge and flow into Cache Creek. Figure 2.6 shows the location of the watersheds. The simulation of rainfall/runoff and groundwater flow from watersheds 2 through 10 was included in the YCIGSM.

HYDROGEOLOGIC DATA

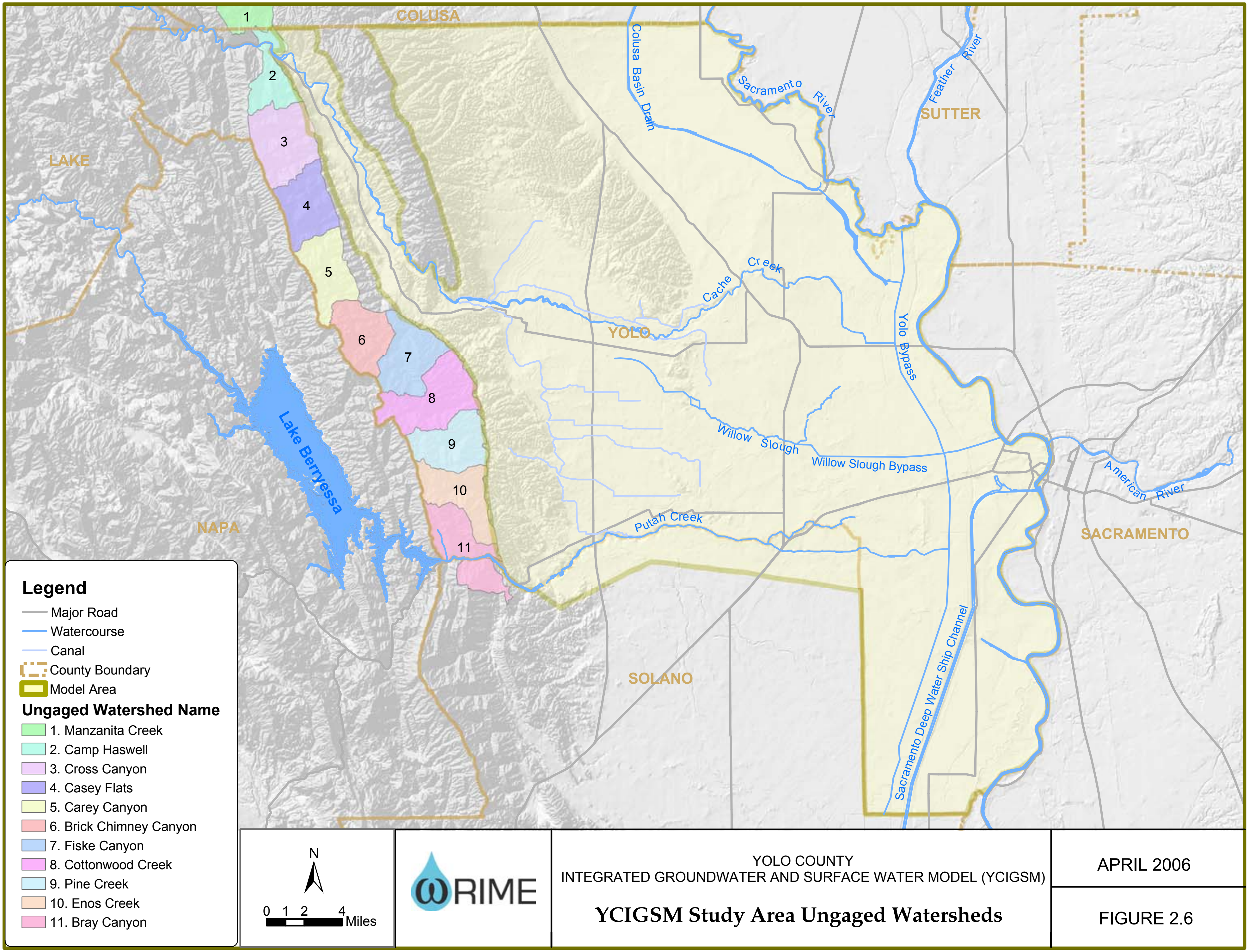
Depositional Environment

The geology of the YCIGSM area consists of both marine deposits and continental deposits. The older marine deposits contain saline water and underlie the younger continental deposits. The freshwater-bearing continental deposits are the geologic units of interest. The surficial geologic units present in the study area are shown in Figure 2.7.

During the Cretaceous Period to the early Miocene Epoch, the present Sacramento Valley trough was inundated by an inland sea, which deposited thousands of feet of marine sediments above the pre-Cretaceous granitic basement rocks. After withdrawal of the marine waters in the Miocene Epoch, there was a period of erosion dominated by the deposition of continental deposits.

During the Pliocene Epoch, the northern Coast Range uplift was initiated and the Sacramento Valley began to assume its current form. Coast Range uplift and related erosion of the uplifted block resulted in deposition of the Tehama Formation onto the heavily eroded, subsiding Valley floor. These thick, widespread deposits overwhelmed the previous topography, creating a relatively flat plain that was repeatedly dissected by meandering and braided streams. Coarse alluvial sediments, known collectively as the Red Bluff formation, were deposited on the eroded Tehama surfaces when the uplift temporarily subsided. Much of the Red Bluff formation was later eroded and folded with the Tehama sediments to create the Dunnigan Hills (Dickenson and Snyder, 1979; Harwood and Helley, 1987).

Fluviatile sedimentation of the Tehama Formation was continuous on the west side of the Sacramento Valley throughout the Pliocene and possibly into the Pleistocene Epoch. During the middle part of the Pleistocene, mountain-building activity brought the Coast Ranges to their current structure and shape. The Tehama Formation deposits, along with older deposits, were involved in this folding and faulting event and formed low hills and dissected uplands.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Study Area Ungaged Watersheds

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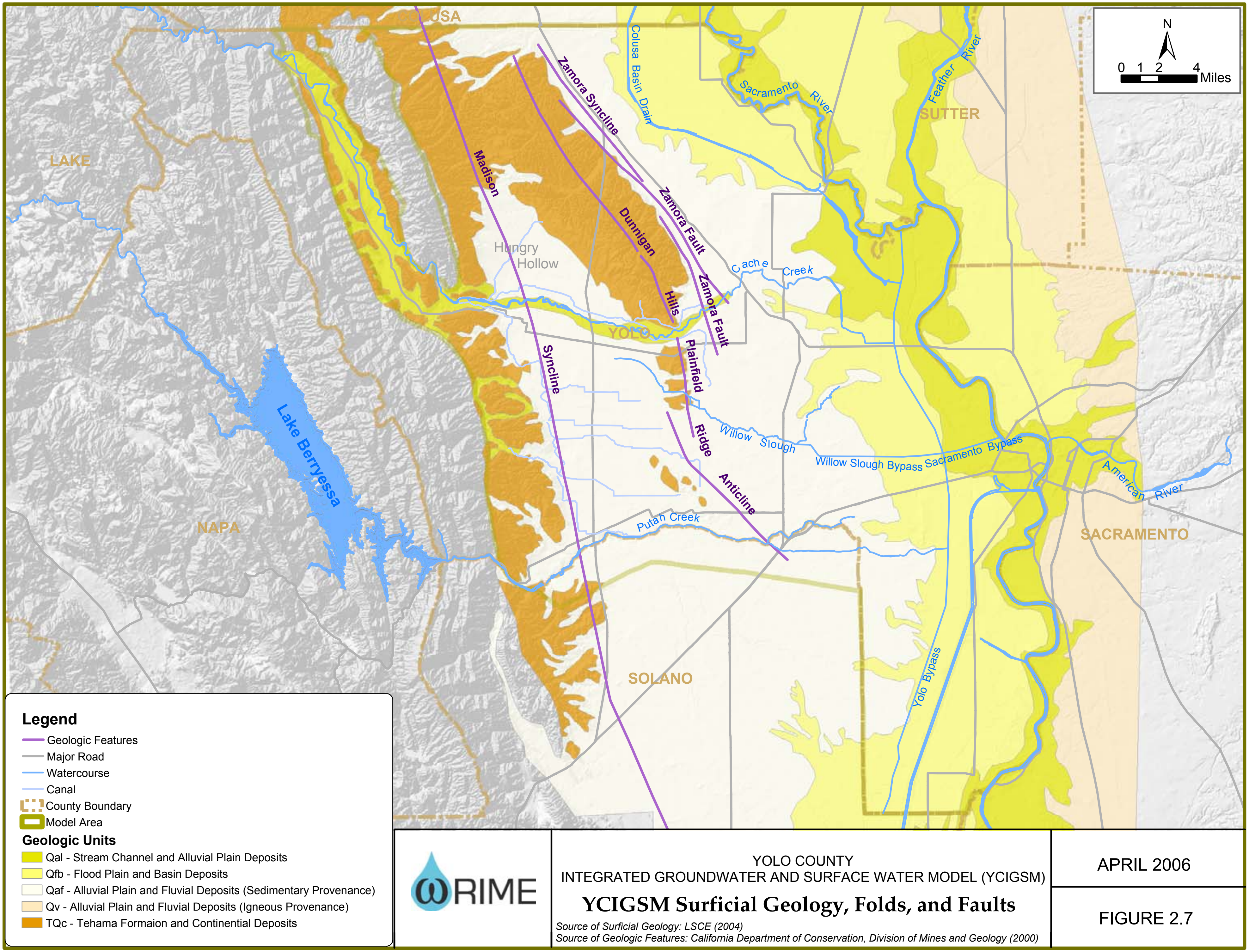
FIGURE 2.6



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Surficial Geology, Folds, and Faults

Source of Surficial Geology: LSCE (2004)
Source of Geologic Features: California Department of Conservation, Division of Mines and Geology (2000)

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FIGURE 2.7

Intense erosion concurrent with and following this orogenic activity reworked the Tehama Formation and redeposited the sediments near the center of the Valley. Much of these sediments were carried by the Sacramento River. The ephemeral, east-flowing foothill creeks and washes have distributed younger Quaternary alluvium to the low-lying areas of Yolo County. Cache and Putah Creeks have also redistributed much of this material toward the Sacramento River. A broad band of recent Quaternary river and flood basin deposits from the Sacramento River lie along the eastern border of Yolo County.

Tehama Formation

The Tehama formation consists of pale green, gray, and tan sandstone and siltstone with lenses of crossbedded pebble and cobble conglomerates derived from the Coast Ranges (Helley and Harwood, 1985). The sediments were distributed by ancestral east-flowing Coast Range drainages and deposited into the Sacramento Valley.

The Tehama formation is generally thin in the west and thickens to the east. Where it is exposed along the east-facing foothills, the formation is estimated to be 1,200 feet thick. Beneath the Plainfield Ridge, its thickness exceeds 2,000 feet (Olmsted and Davis, 1961). Where the Tehama formation is in the subsurface, it generally lies beneath 150 feet or less of younger alluvial and fluvial sediments (Olmstead and Davis, 1961).

Hungry Hollow is within a broad trough that is inclined (plunges) to the south-southeast and is known as the Madison syncline (Harwood and Helly, 1987). The Dunnigan Hills is the companion up-turned anticline. The Dunnigan Hills anticline locally elevated the Tehama formation and overlying younger sediments. The younger sediments were subsequently eroded, exposing the Tehama formation over most of the Dunnigan Hills.

South-southeast of the Dunnigan Hills, the upturned fold projects along and just below the land surface. The anticline is subtly expressed as the Plainfield Ridge, the alignment of very low hills that project into the south central portion of Yolo County, along the western margins of Woodland and Davis. Large patches of the folded Tehama Formation crop out along the Plainfield Ridge, but most of it lies at depth (Harwood and Helly, 1987).

Quaternary Sediments

Alluvial gravels and cobbles from Coast Range drainages were deposited on the eroded surface of the Tehama formation. These sediments, distinctive for their reddish silty or sandy matrix, are known collectively as the Red Bluff formation. The Red Bluff formation was eroded and folded so that it is typically less than 50 feet thick. The subsurface occurrence of the Red Bluff formation can delineate the upper boundary of the Tehama formation.

Other Quaternary sediments include alluvial, flood plain, and stream channel deposits. These sediments overlie both the Red Bluff formation and the Tehama formation. They consist of varying mixes of sands, silts, clays, gravels, and cobbles found on the active alluvial fans, flood plains, and stream and river channels of the Sacramento Valley. Along the west flank of the Sacramento Valley, these alluvial and fluvial deposits are typically less than 150 feet thick (Olmsted and Davis, 1961).

Faults

The Sacramento Valley is an asymmetrical northward-trending syncline partially filled with sedimentary deposits. Several faulting, folding, and uplift events tilted the Sierra Nevada block relative to the Coast Ranges. Faults related to this geologic activity include the Plainfield Ridge-Dunnigan Hills, Zamora, and Madison. The location of the Plainfield Ridge-Dunnigan Hills and Zamora Faults were included in the YCIGSM as they act as disruptions to groundwater flow. The location of geologic faults is shown on Figure 2.7.

Groundwater Basins and Occurrence

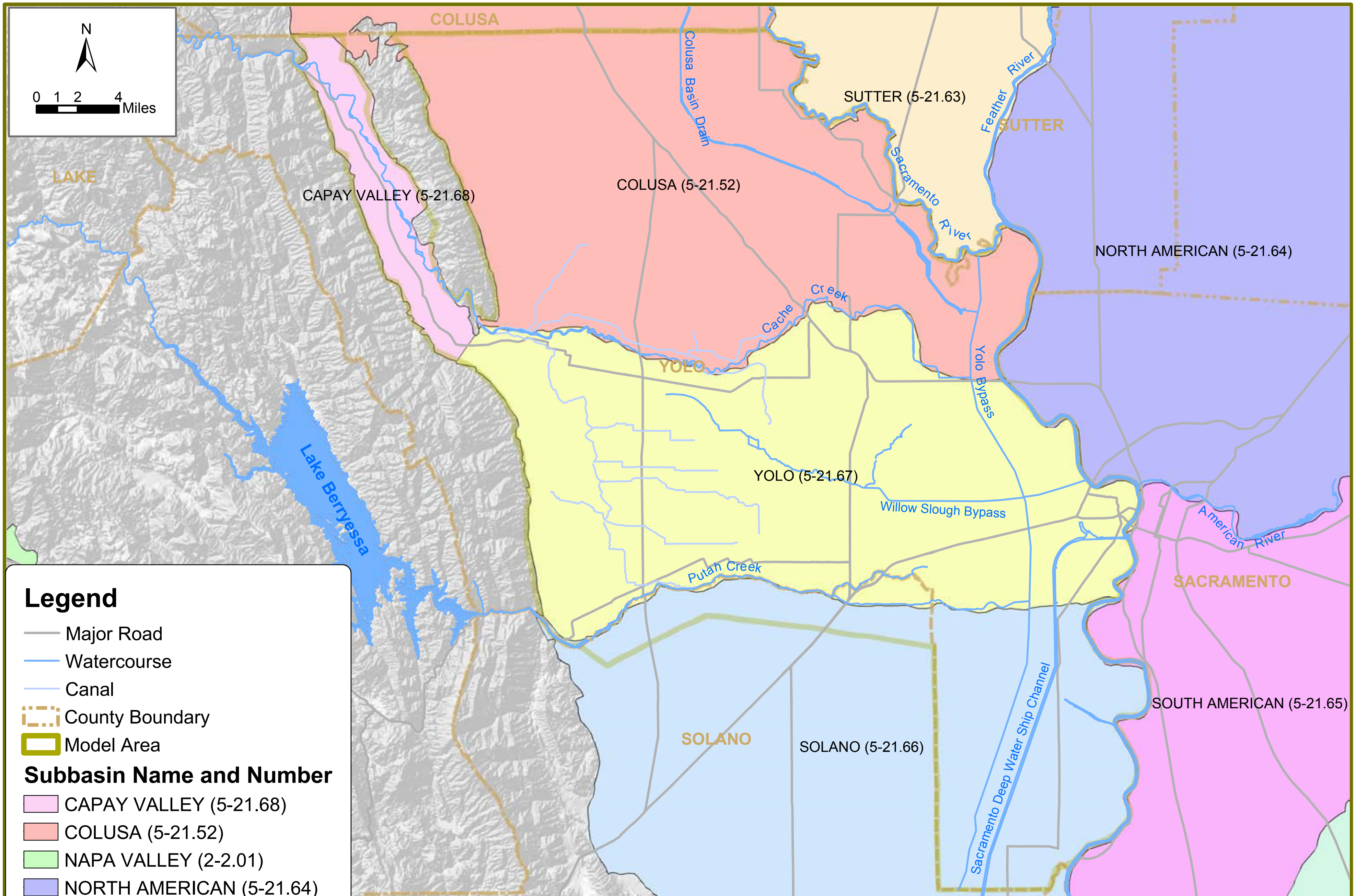
Groundwater Basins

Aquifers in the Yolo County are either entirely within the Tehama formation or within a combination of the Quaternary alluvial sediments and the uppermost Tehama formation. Wells are screened in aquifers as little as 50 feet below ground surface to more than 1,500 feet below ground surface. Yolo County groundwater quantity and quality varies with location within the county. Yolo County was segmented into groundwater subbasins to account for groundwater production and quality in specific areas.

DWR, as part of its *California's Groundwater Bulletin 118-03* (DWR, 2003), and the WRA, as part of its *Yolo County Integrated Regional Water Management Plan* (Draft) (IRWMP), have developed cataloging systems for Yolo County in terms of groundwater subbasins. The DWR cataloging of the groundwater subbasins places the YCIGSM model in the Sacramento Valley Groundwater Basin and includes the following subbasins:

- Colusa (Groundwater Basin Number: 5-021.52);
- Capay Valley (Groundwater Basin Number: 5-21.68);
- Yolo (Groundwater Basin Number: 5-21.67); and
- Solano (Groundwater Basin Number: 5-21.66).

The DWR subbasins are shown on Figure 2.8.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

DWR Groundwater Subbasins in YCIGSM Study Area

Source: California's Groundwater Bulletin 118-3 (2003)

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FIGURE 2.8

The IRWMP subbasin boundaries incorporate the subbasins in the DWR Bulletin 118-03 and others (Scott and Scalmanini, 1975; Luhdorff and Scalmanini, 2004) to develop six subbasins: 1) Capay Valley, 2) Buckeye Creek, 3) Dunnigan Hills, 4) West Yolo, 5) East Yolo, and 6) Sacramento River. The delineation of these IRWMP subbasins was used as criteria in the development of YCIGSM water budget analysis units, referred to as subregions (Section 3 has an expanded discussion regarding subregions). Each subbasin is described below, as they were delineated in the IRWMP, and are shown in Figure 2.9.

Capay Valley Subbasin

The Capay Valley Subbasin's eastern and western boundaries are defined by geologic contact between the older, less permeable marine rocks and the overlying Tehama formation sediments. The north boundary of the subbasin, as defined in the YCIGSM, is also the geologic contact. The south-southeastern extent of the subbasin is the geographic extent of the Valley, where Cache Creek turns east to exit the Valley.

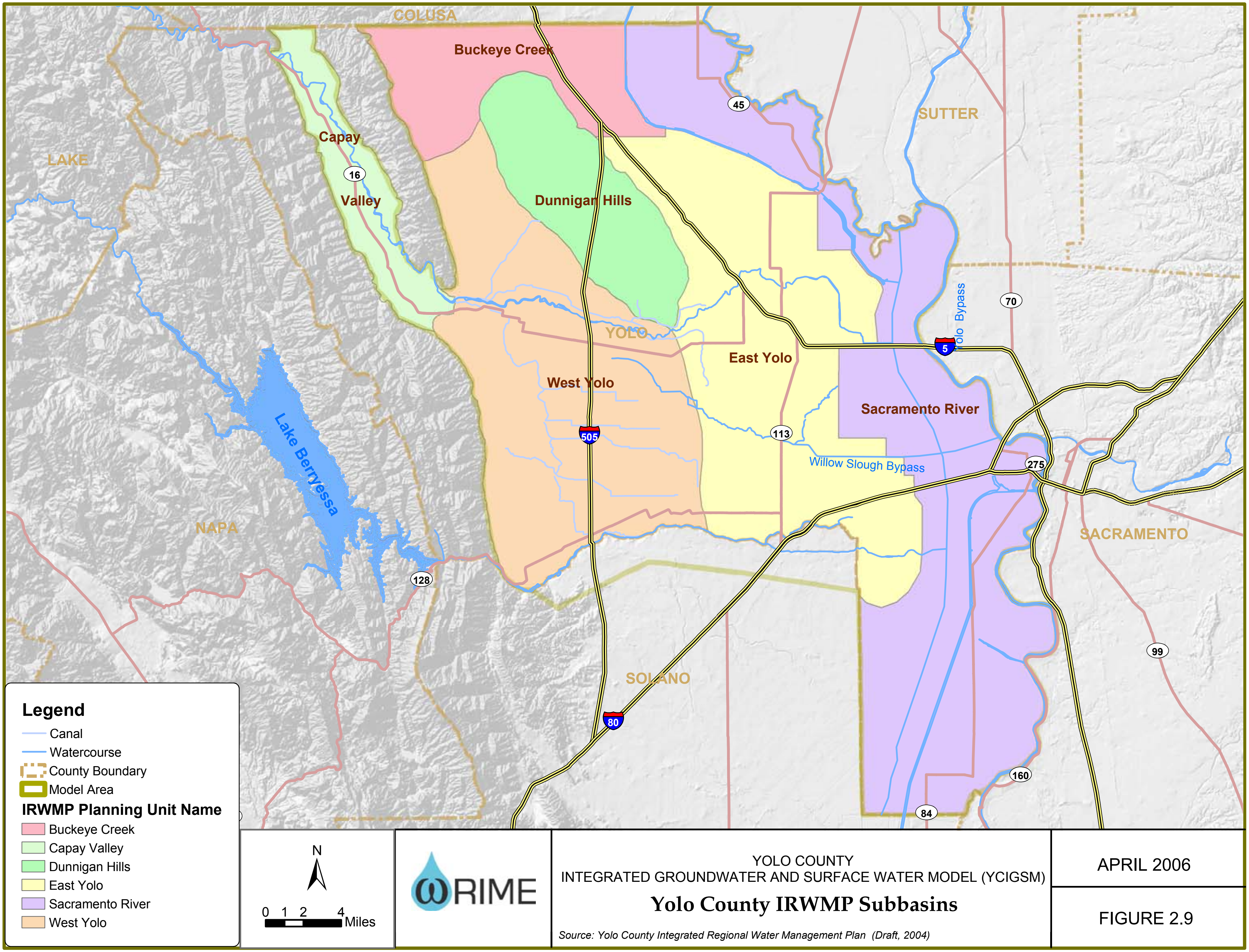
Freshwater-bearing sediments in the Capay Valley subbasin are more than 1,000 feet thick (Luhdorff and Scalmanini, 2004). The sediment is mostly comprised of Tehama formation sediments (Harwood and Helley, 1987) but also include a significant thickness of Quaternary deposits.

Buckeye Creek Subbasin

The Buckeye Creek Subbasin is delineated using geologic and administrative boundaries as well as geographic criteria. Its western boundary is a geologic contact with basement rocks and the overlying Tehama formation sediments. The northern boundary coincides with the northern boundary of Yolo County. The eastern boundary of the subbasin is defined by a portion of the Colusa Basin Drain canal. The southern boundary is defined by the southern watershed boundary of South Fork Buckeye Creek, the northern perimeter of the Dunnigan Hills, and the southern boundary of the Dunnigan Water District. There has been little groundwater development in the subbasin and little data regarding the basin are available.

Dunnigan Hills Subbasin

The Dunnigan Hills Subbasin was delineated using geologic criteria. The Dunnigan Hills are the geographic expression of a doubly plunging anticline. Quaternary sediments have been uplifted and folded along the anticline axis, causing them to erode and exposing the underlying Tehama formation throughout the hills.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Yolo County IRWMP Subbasins

Source: Yolo County Integrated Regional Water Management Plan (Draft, 2004)

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FIGURE 2.9

Groundwater recharge to the subbasin is provided by direct percolation of rainfall by infiltration of water from several streams and smaller creeks, groundwater flow within the Dunnigan Hills is probably influenced by the boundary. The hydrogeologic characteristics of the Dunnigan Hills subbasin are poorly understood although it is documented that in general, wells drilled in the Dunnigan Hills typically produce less than wells tapping the Tehama formation elsewhere in the county (Olmsted and Davis, 1961).

West Yolo Subbasin

The West Yolo Subbasin is bounded by the geologic contact between the impermeable rock and the Tehama formation. The southern watershed line of South Fork Buckeye Creek is the northern boundary. The eastern boundary is delineated by the western boundary of the Dunnigan Hills Subbasin and the fold-line trace of the southward plunging Dunnigan Hills/Plainfield Ridge anticline. The southern boundary is Putah Creek.

Groundwater recharge to the subbasin is provided directly by foothill runoff, by flows from Cache and Putah Creeks and smaller foothill drainages, and by water diverted north and south from Cache Creek to the unlined canals in the subbasin. The Madison syncline underlies the West Yolo subbasin. The Tehama formation sediments and at least the older overlying Quaternary sediments have been folded, creating a broad trough that is slightly inclined southward (Harwood and Helley, 1987). Because the trough inclines southward, younger Quaternary alluvium is thinnest at the north end of the West Yolo subbasin and thicker at the south end of the subbasin.

East Yolo Subbasin

The East-Yolo groundwater subbasin is bounded on the west by the Dunnigan Hills and the trace of the Dunnigan Hills/Plainfield Ridge anticline. The subbasins southern border is Putah Creek. The northern, eastern, and southernmost borders are defined by the Dunnigan Water District and YCFCWCD boundaries. Most of the population of Yolo County resides within the boundaries of the East Yolo subbasin, primarily in the Lower Cache Putah area containing the Cities of Woodland and Davis and the campus of UCD. Woodland, Davis, and UCD rely entirely on groundwater to meet domestic and some irrigation needs. In the Zamora area, the Yolo-Zamora Water District depends entirely on groundwater to meet its needs.

Water for the Cities of Davis and Woodland and UCD is provided by wells that are screened predominantly in the Tehama formation. Studies to better characterize the hydrogeology of the Southern East Yolo Subbasin refer to “intermediate” and “deep” zones within the Tehama formation based on changes in water quality with depth. In general, the deep zone is described as being deeper than 500 feet below ground surface in the Woodland area and deeper than 700 feet below ground surface in the Davis area. The "intermediate" zone is described as being immediately above the "deep" zone. The majority of the historical water supply wells have been completed in the "intermediate" aquifer (Brown and Caldwell, 2005).

Sacramento River Subbasin

The Sacramento River groundwater subbasin is defined by the Sacramento River on the east, which is the east border of Yolo County, the northern and southern borders of Yolo County, and the eastern borders of the Buckeye Creek and East Yolo subbasins. The subbasin has been divided into two areas, Sacramento River North and Sacramento River South, for purposes of geographic reference. The dividing line is the path of Interstate Highway 5, where it traverses the Yolo Bypass.

The Sacramento River subbasin is within the flood plain of the Sacramento River. Quaternary sediments consist of predominately fine-grained sands, silts, and clays. Tehama formation sediments are at depth, extending from approximately 150 feet below ground surface to more than 2,500 feet below ground surface, and are finer-grained than Tehama formation sediments to the west (Olmsted and Davis, 1961).

Groundwater Occurrence and Movement

In the Tehama formation, groundwater flows most easily in the direction of fan growth, in a rough plain of deposition, moving preferentially along the slightly inclined, intertwined paths of abandoned channels. Groundwater flowing vertically downward, or infiltrating, flows at a relatively slow rate because the groundwater must travel through layers of fine- and very fine-grained sediments that interfinger with the channel lenses of the coarser sands and gravels.

On the west flank of the Sacramento Valley, the plain of deposition of the Tehama formation was inclined eastward. The plain of deposition was inclined further eastward by early Quaternary uplift of the Coast Ranges. The plain of deposition was later slanted southward and warped by the folding created by Madison syncline and the Dunnigan Hills/Plainfield Ridge anticline. This resulted in groundwater flow in the Tehama formation to partially deflect to the southeast.

Aquifers in Yolo County are unconfined near the surface and become increasingly confined with depth. There are no regionally continuous barriers to vertical flow; however, interbedded clays and silts create a cumulative impediment to vertical groundwater flow with increasing depth.

Stratigraphic and Aquifer Data

The first step in the collection and assessment of hydrogeologic data is to review the existing studies and reports for the purposes of developing a broad understanding of the geologic and hydrogeologic conditions of the study area. Key reports are cited below.

- *Base And Thickness of the Post-Eocene Continental Deposits in the Sacramento Valley, California* (Page, R.W., 1974);
- *Geologic Features and Ground-water Storage Capacity of the Sacramento Valley, California* (Olmstead H.F., and Davis, G.H., 1961);
- *Geology of the Fresh Groundwater Basin of the Central Valley, California, with texture maps and sections* (Page, R.W., 1986);
- *Phase II Deep Aquifer Study* (Brown and Caldwell, 2005);
- *California Geology: Geologic Structure, Capay Hills* (California Department of Conservation, 1984);
- *Groundwater Monitoring Program, Data Management System, and Update of Groundwater Conditions in the Yolo County Area* (Luhdorff and Scalmanini, 2004);
- *Putah Creek Cone Investigation* (State of California Department of Public Works Division of Water Resources, 1955);
- *Ground-water Flow in the Central Valley, California* (Williamson, A. K. et al., 1989); and
- *Investigation of Groundwater Resources Yolo County, California* (Scott, V. H. and Scalmanini, J. C., 1975).

These reports include regional information on the geology, hydrogeology, aquifer characteristics, and storage capacity of the aquifer system in the study area. The information in these reports was used to develop initial geologic and hydrogeologic data for the YCIGSM modeling effort.

Geologic Cross-Sections

Geologic cross-sections were collected from many different sources. These geologic cross-sections were used to develop a conceptual stratigraphic model of the YCIGSM area. Geologic cross-sections were collected from:

- *Cache Creek Aggregates: Geologic Report: Cache Creek Aggregate Resources* (Wahler Associates, 1982);
- *Putah Creek Cone Investigation* (State of California Department of Public Works Division of Water Resources, 1955);
- *Phase II Deep Aquifer Study* (Brown and Caldwell, 2005);

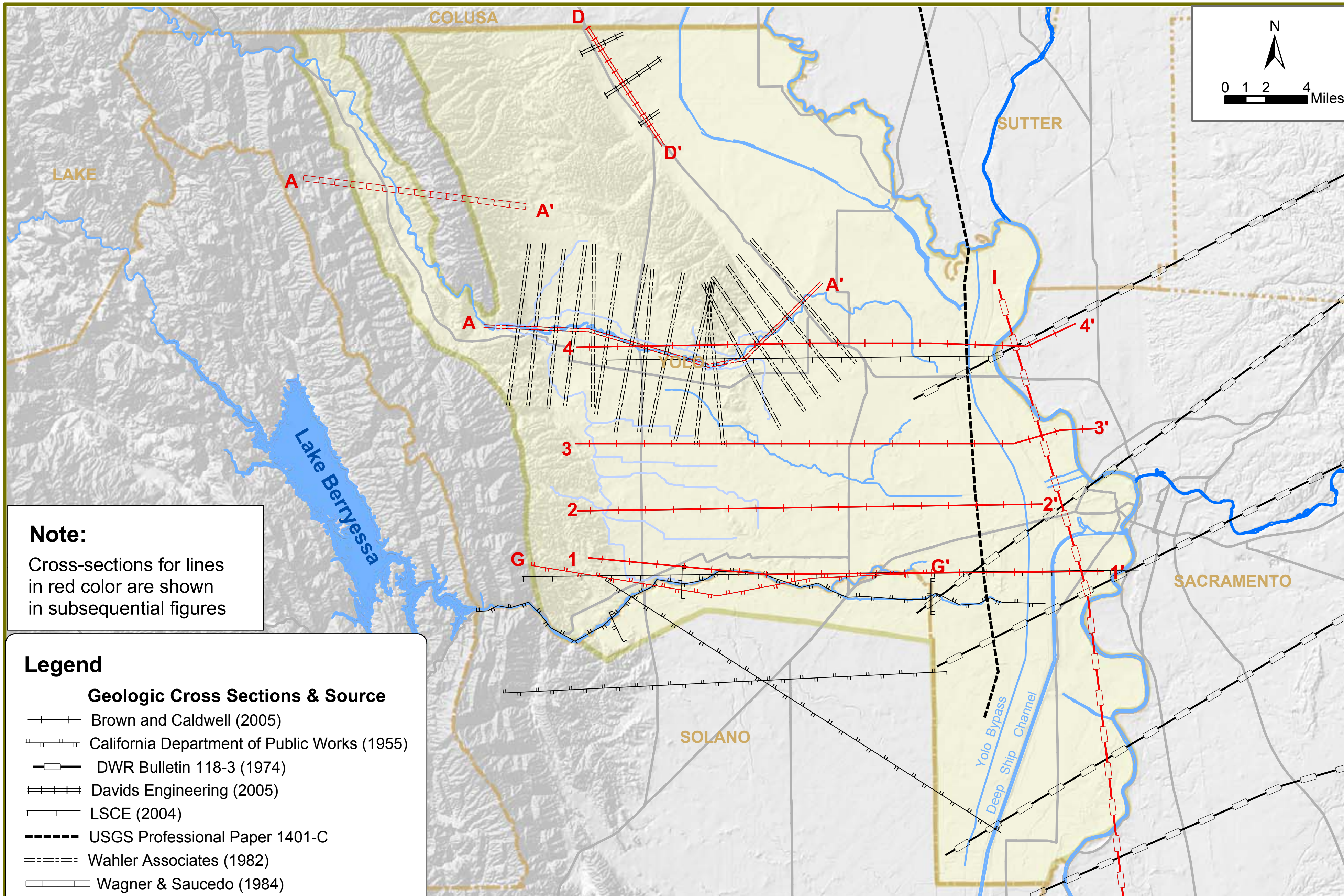
- *California Geology: Geologic Structure, Capay Hills* (Wagner D.L. and Saucedo, G.J., 1984);
- *Groundwater Monitoring Program, Data Management System, and Update of Groundwater Conditions in the Yolo County Area* (Luhdorff and Scalmanini, 2004);
- *Hydrogeologic Characterization Report: Dunnigan Water District* (Davids Engineering, 2005);
- *Geology of the Fresh Groundwater Basin of the Central Valley, California, with texture maps and sections* (Page, R.W., 1986);
- *Bulletin 118-6: Evaluation of Groundwater Resources: Sacramento Valley, CA* (DWR, 1978);
- *Bulletin 118-3: Evaluation of Ground Water Resources: Sacramento County* (DWR, 1974); and
- *SWP Conjunctive Use—Eastern Yolo County* (DWR, 1994).

Approximate locations of the geologic cross sections are shown in Figure 2.10. Representative selections of the cross-sections, collected from the aforementioned reports, are shown in Figures 2.11a through 2.11i. Stratigraphy data, particularly the contact between Tehama and Quaternary Alluvium and upper Tehama Formation and Lower Tehama Formation (as defined in the Phase II Deep Aquifer Study) were digitized from these cross-sections and synthesized. The digitized data included the elevation of the contact between the formations. This digitized data was then georeferenced in to the YCIGSM coordinate system. The data were contoured to develop isopleths of the elevation of the contacts and these contour maps are shown in Figures 2.12 and 2.13. The contours were developed using contour-generating software and may suggest a higher level of accuracy than what the data supports. The contour-generating program used Kriging interpolation to estimate values where data were not present. These values where then subsequently smoothed to the shape shown in Figures 2.12 and 2.13. The contours are a reasonable representation of the data extracted from the geologic cross-sections. It is assumed that where data are not known, that the estimation is reasonable as well. It can be seen from the cross-sections that there are different interpretations of contact elevation in the same location. The contour-generating program was used to create an average of the different interpretations and that average condition is reflected in Figures 2.12 and 2.13.

The above-listed geologic cross-sections and elevation contours were used to develop a conceptual stratigraphic model of the YCIGSM, as discussed in Section 3.

Base of Continental Deposits

The base of continent deposits was selected to be the base of the YCIGSM. The base of continental deposits was selected so that the base of the model would be consistent with other regional groundwater models around the YCIGSM model area. The elevation contours of the



Note:

Cross-sections for lines in red color are shown in subsequential figures

Legend

Geologic Cross Sections & Source

- Brown and Caldwell (2005)
- California Department of Public Works (1955)
- DWR Bulletin 118-3 (1974)
- Davids Engineering (2005)
- LSCE (2004)
- USGS Professional Paper 1401-C
- Wahler Associates (1982)
- Wagner & Saucedo (1984)
- Major Road
- Watercourse
- Canal
- County Boundary
- Model Area

WRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Location of YCIGSM Study Area
Geologic Cross-Sections

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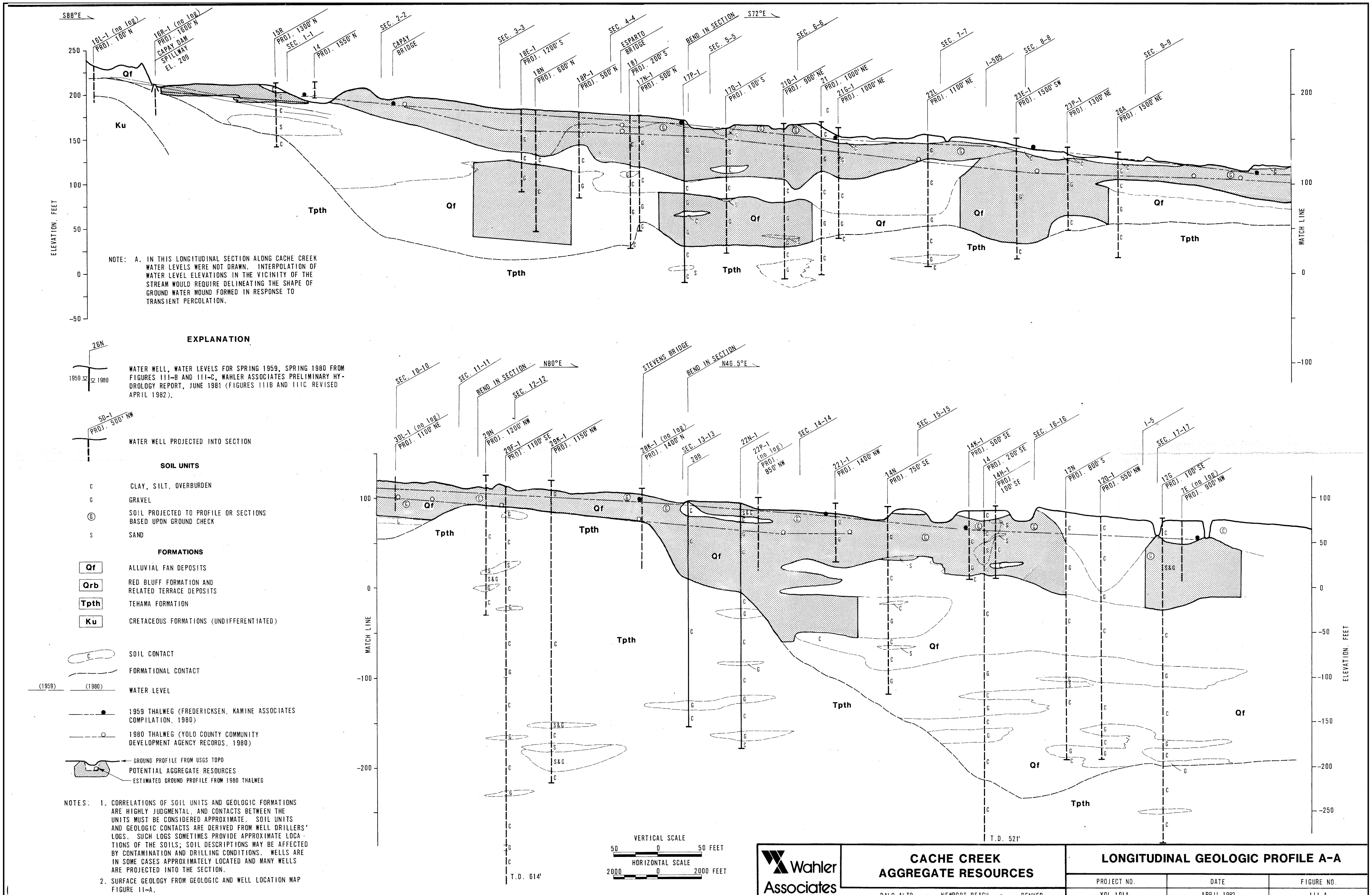
FIGURE 2.10



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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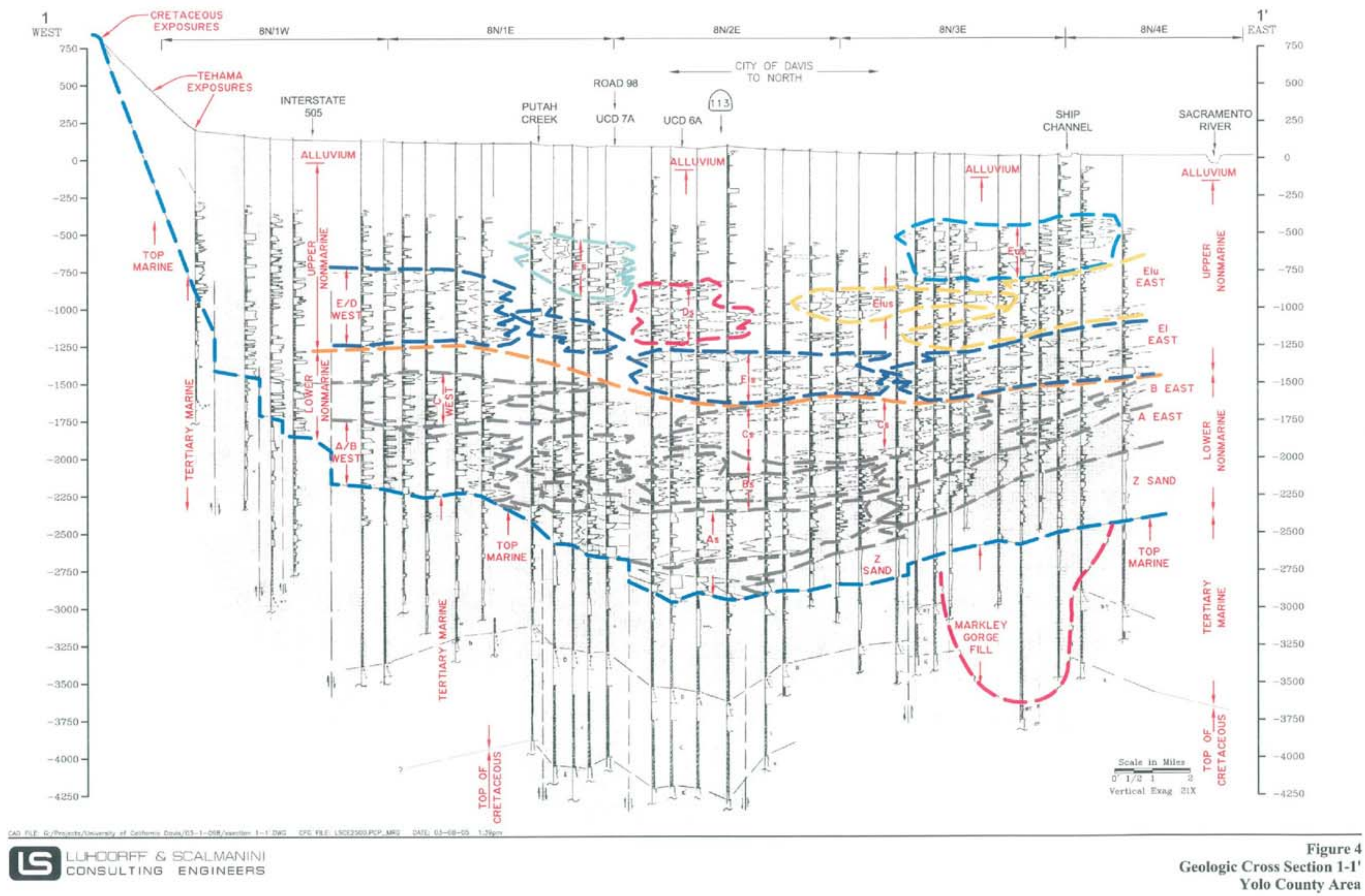
Geologic Cross-Section A-A' from Wahler Associates, 1982

FIGURE 2.11a

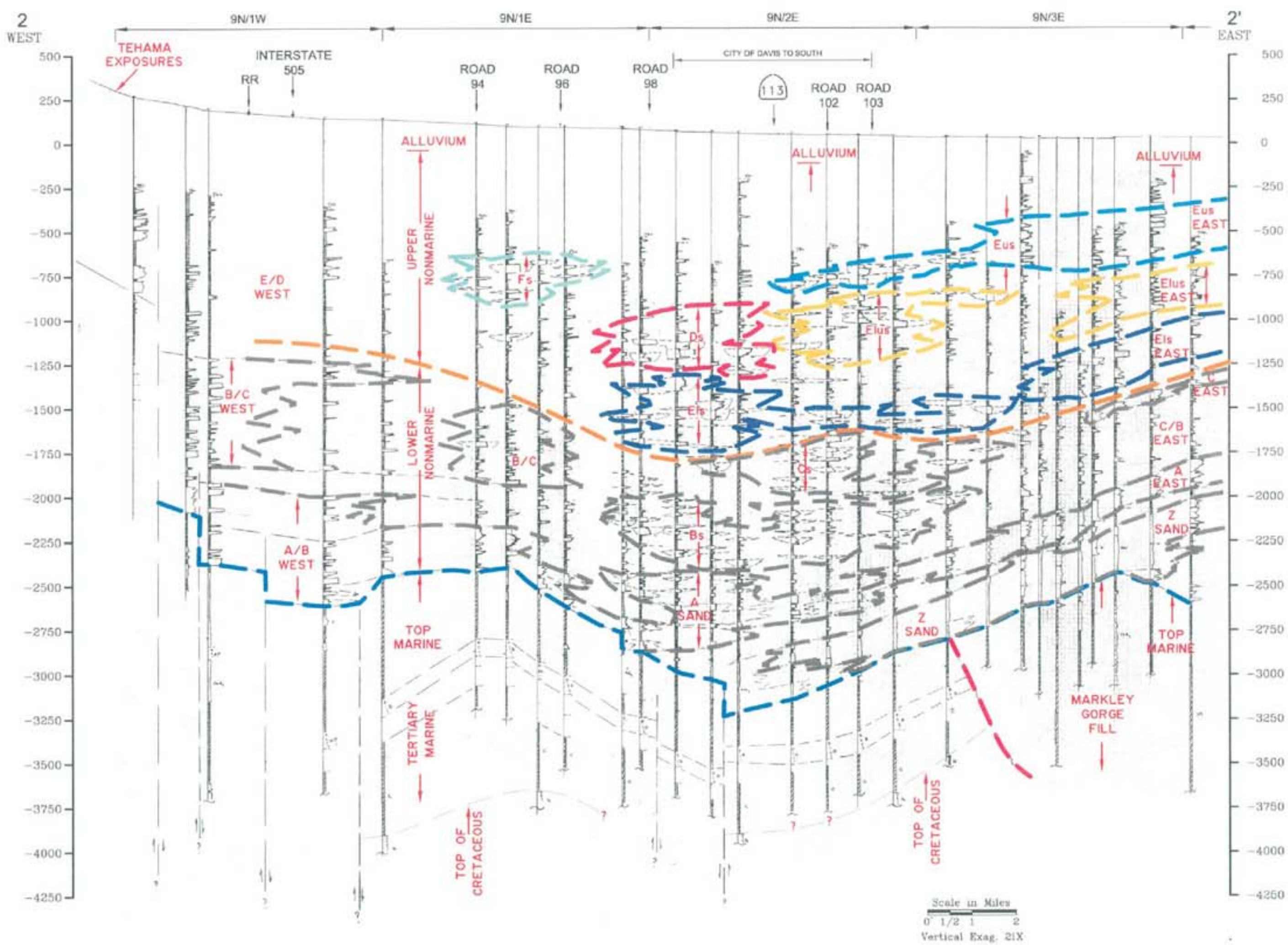


YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section 1-1' from Brown and Caldwell, 2005

APRIL 2006

FIGURE 2.11b



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CONSULTING ENGINEERS

Figure 5
Geologic Cross Section 2-2'
Yolo County Area

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section 2-2' from Brown and Caldwell, 2005

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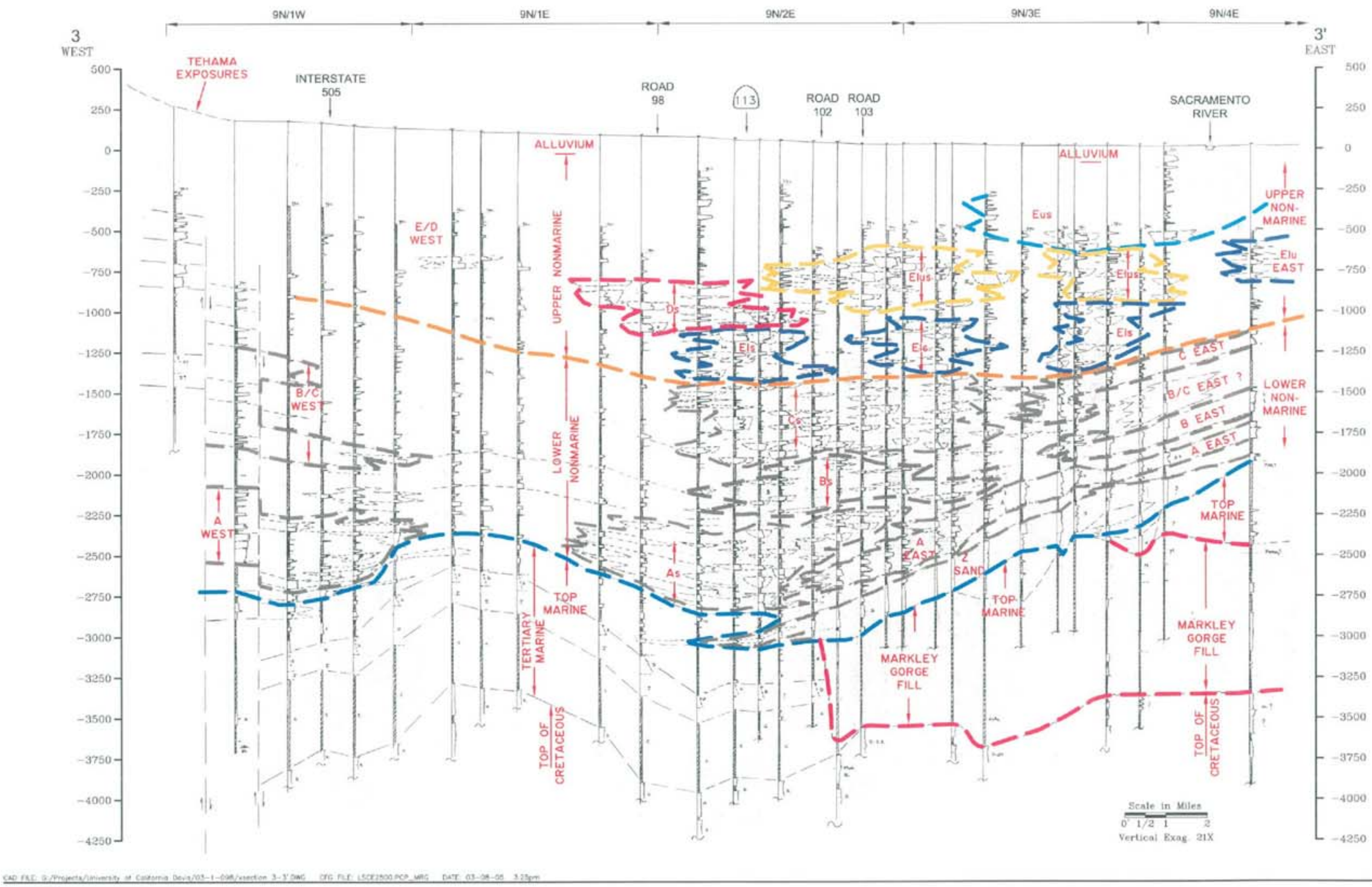
FIGURE 2.11c



LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 6
Geologic Cross Section 3-3'
Yolo County Area

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section 3-3' from Brown and Caldwell, 2005

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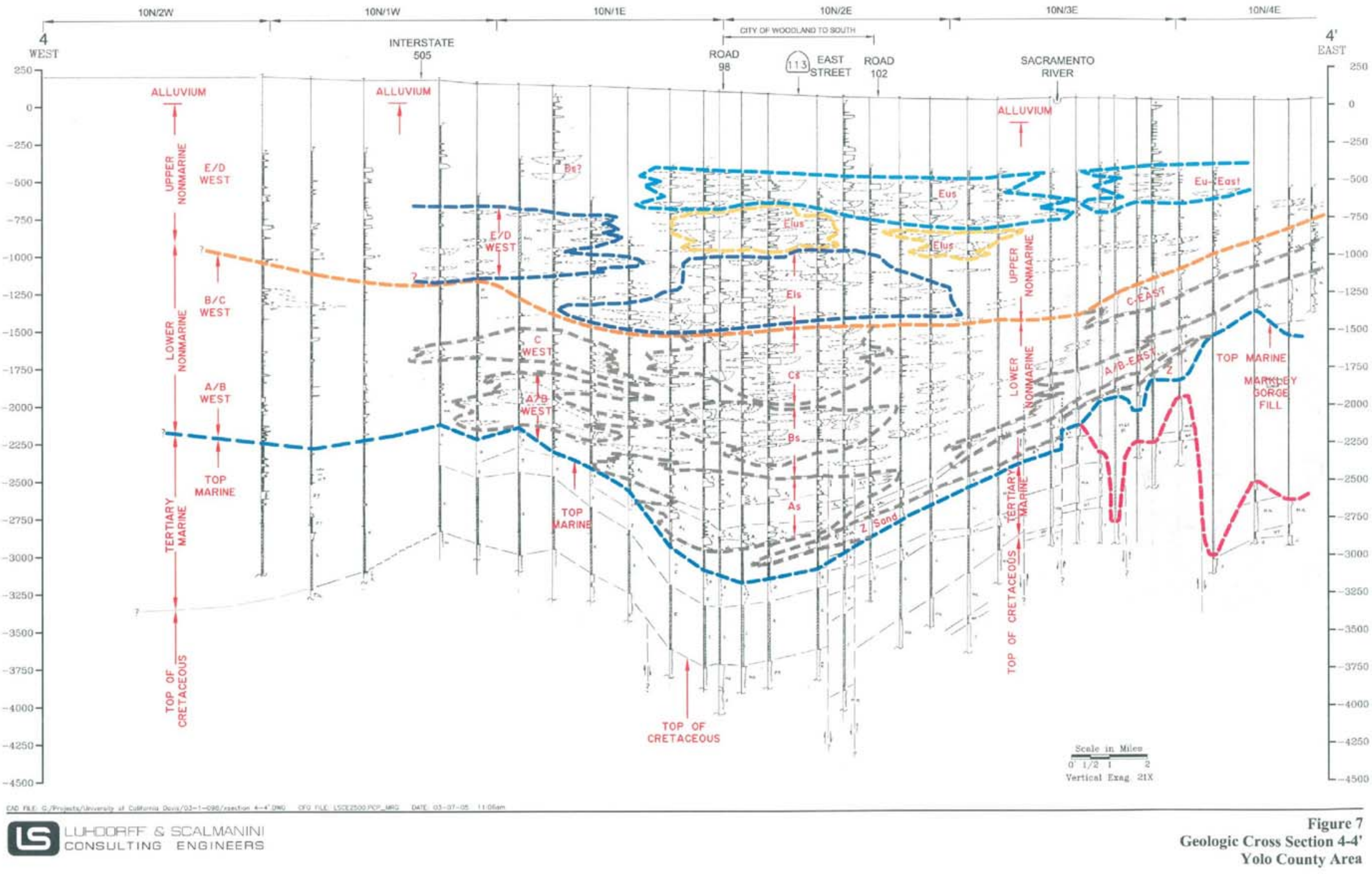
FIGURE 2.11d



PRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section 4-4' from Brown and Caldwell, 2005

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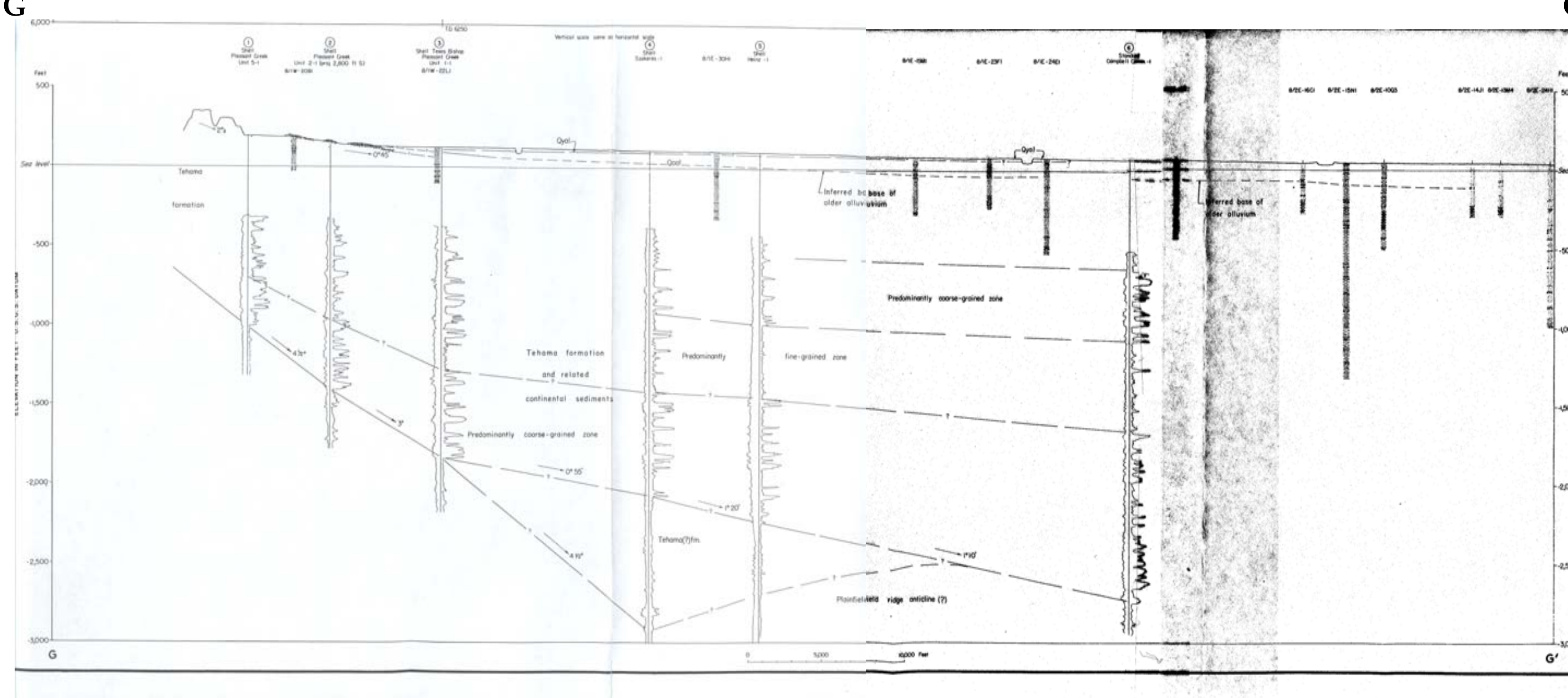
FIGURE 2.11e

G

G'



YOLO COUNTY

INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section G-G' from California Department of Public Works, 1955

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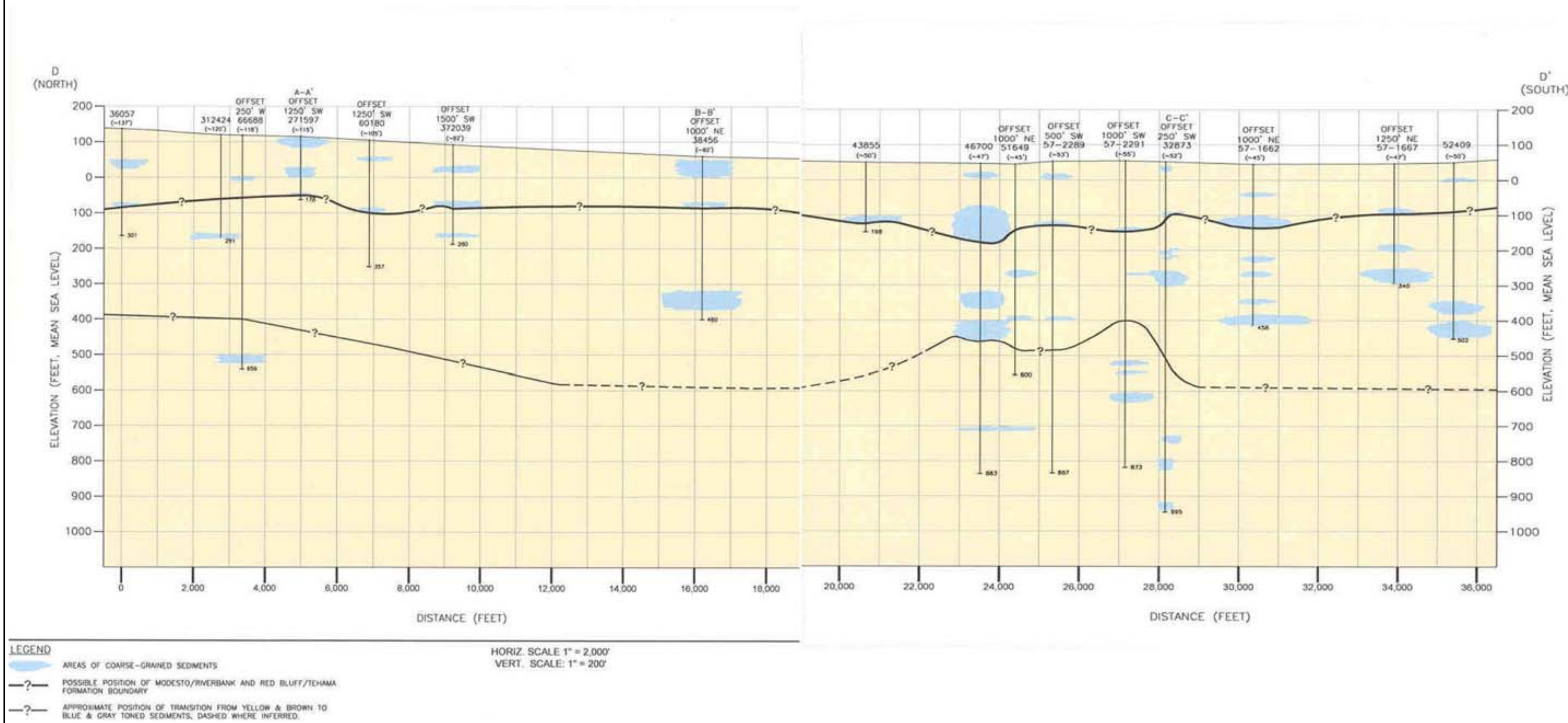
FIGURE 2.11f



YOLO COUNTY

INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section D-D' from Davids Engineering, 2005

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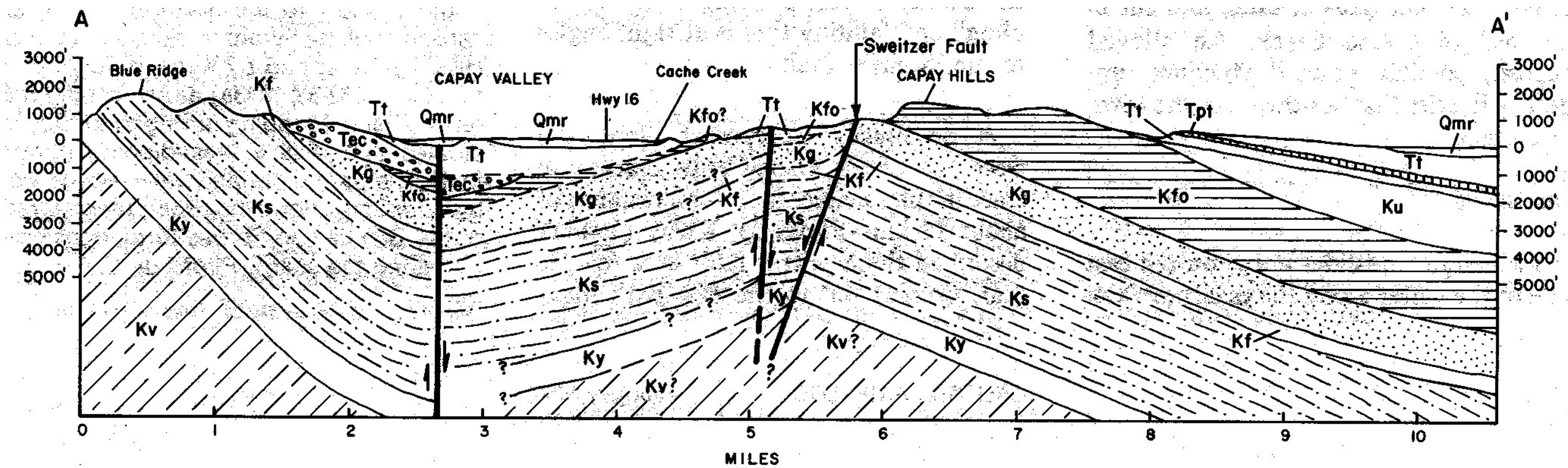
FIGURE 2.11g



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section A-A' from Wagner and Saucedo, 1984

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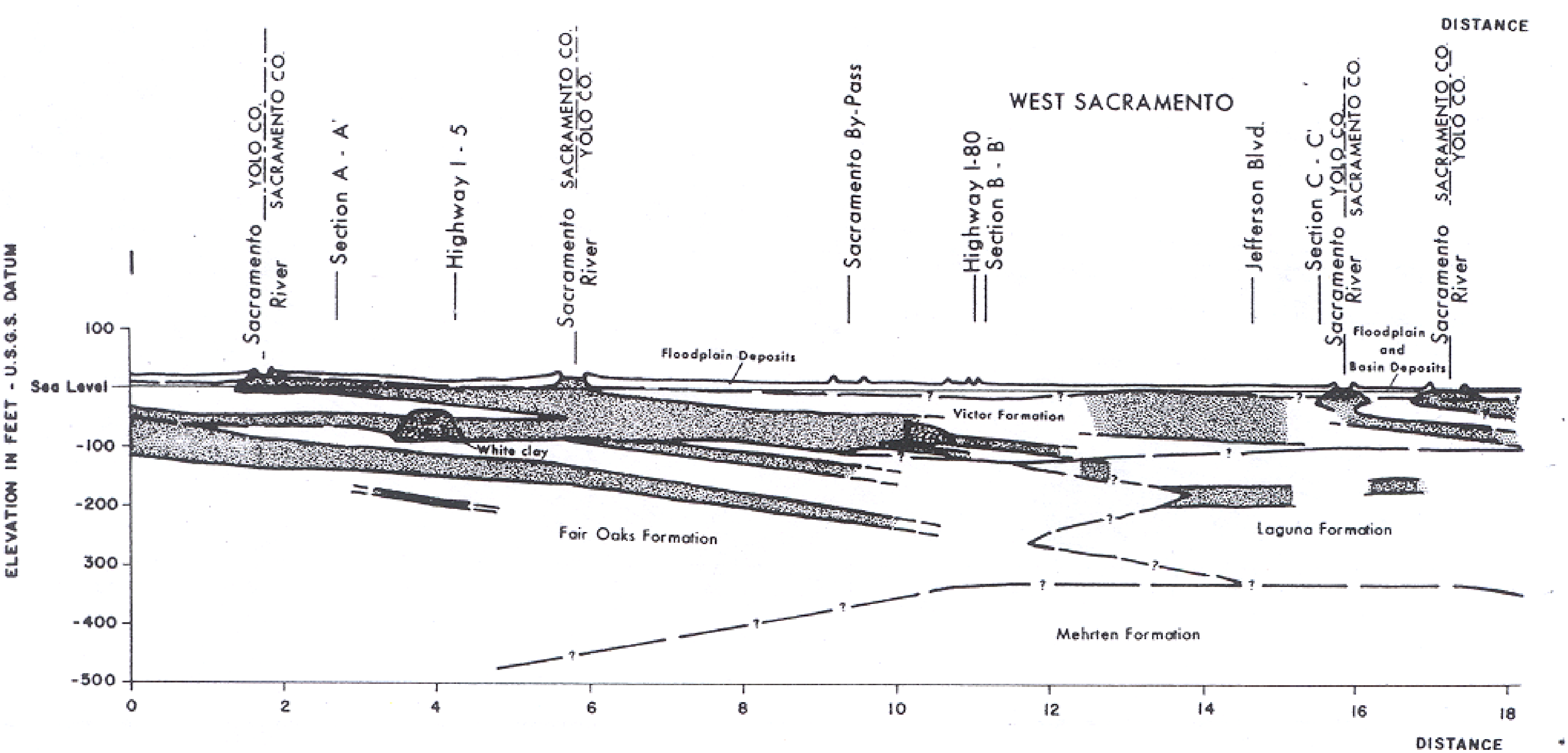
FIGURE 2.11h



WRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section I-I' from DWR, 1974

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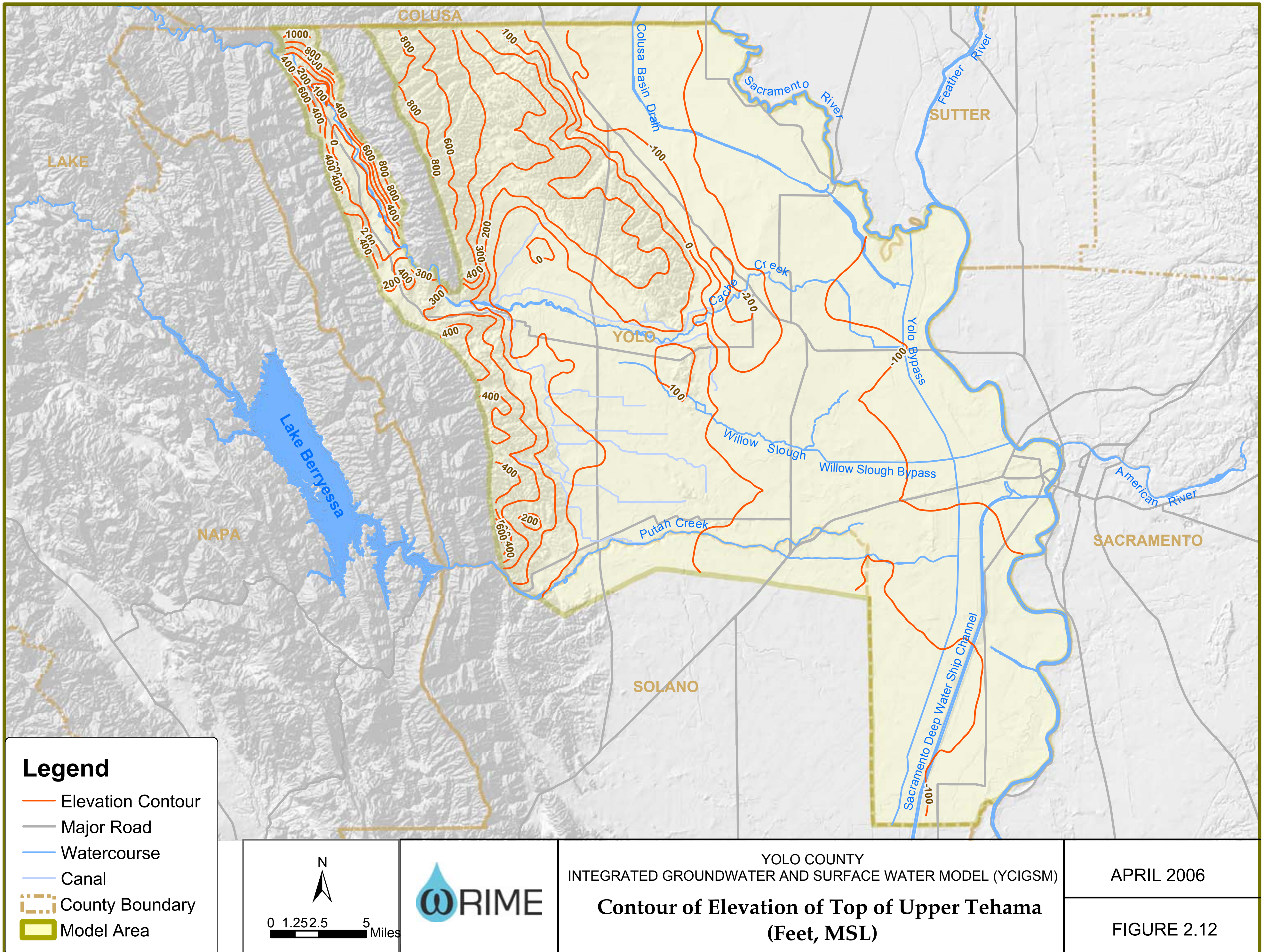
FIGURE 2.11i



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Contour of Elevation of Top of Upper Tehama (Feet, MSL)

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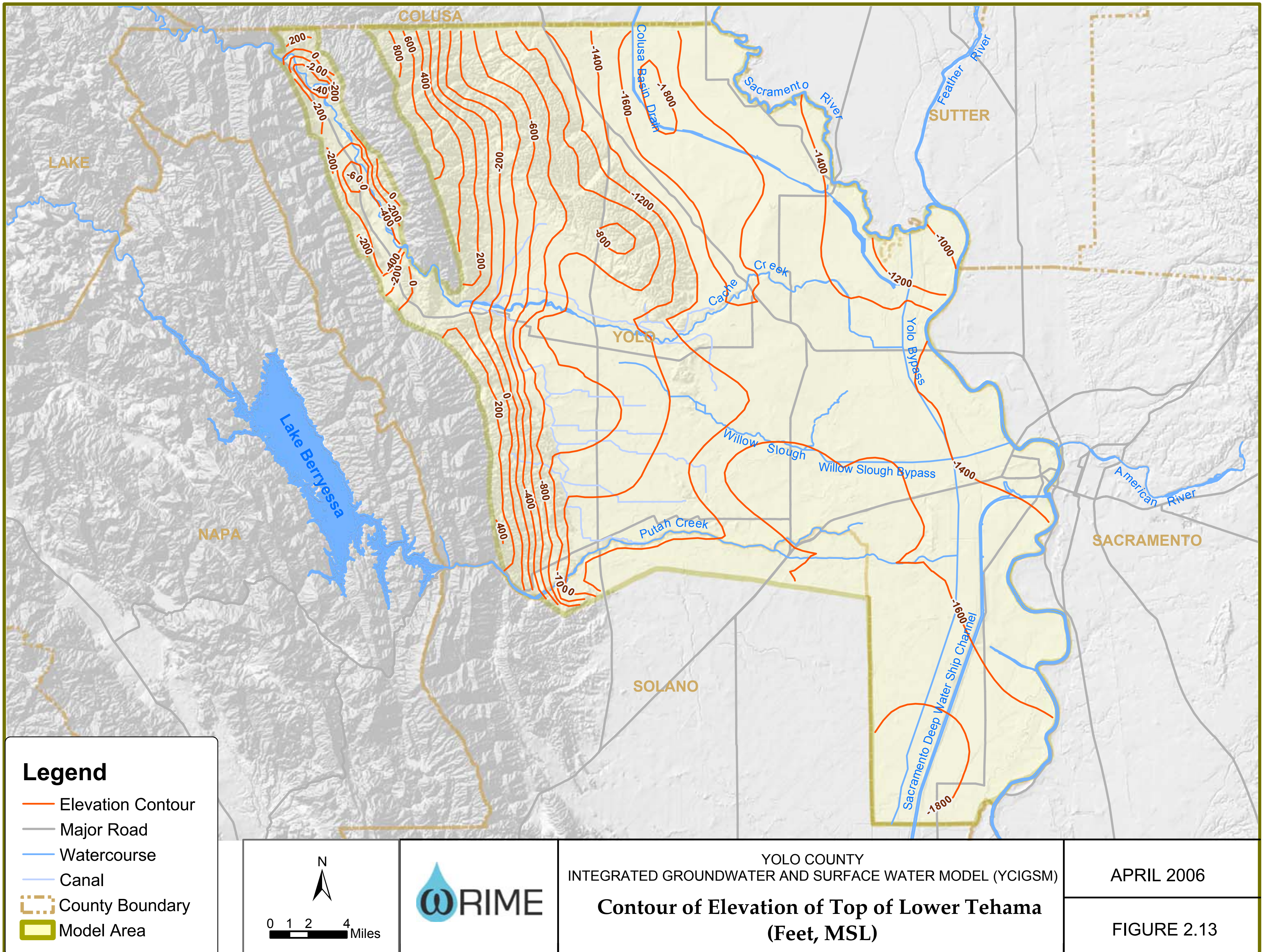
FIGURE 2.12



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Contour of Elevation of Top of Lower Tehama (Feet, MSL)

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FIGURE 2.13

base of continental deposits were developed and presented in *Base And Thickness of the Post-Eocene Continental Deposits in the Sacramento Valley, California* (Page R.W., 1974). These elevation contours are presented in Figure 2.14. Data from elevation contours were digitized and included in the YCIGSM.

Land Surface Elevation Data

A Digital Elevation Model (DEM) was obtained from the California Spatial Information Library. The DEM contains land surface elevation data at 1-second (30-meter) resolution (elevation data is taken on a grid at 30-meter spacing). The DEM data were used to develop the YCIGSM land surface elevation data. Figure 2.15 shows the land surface elevation contours.

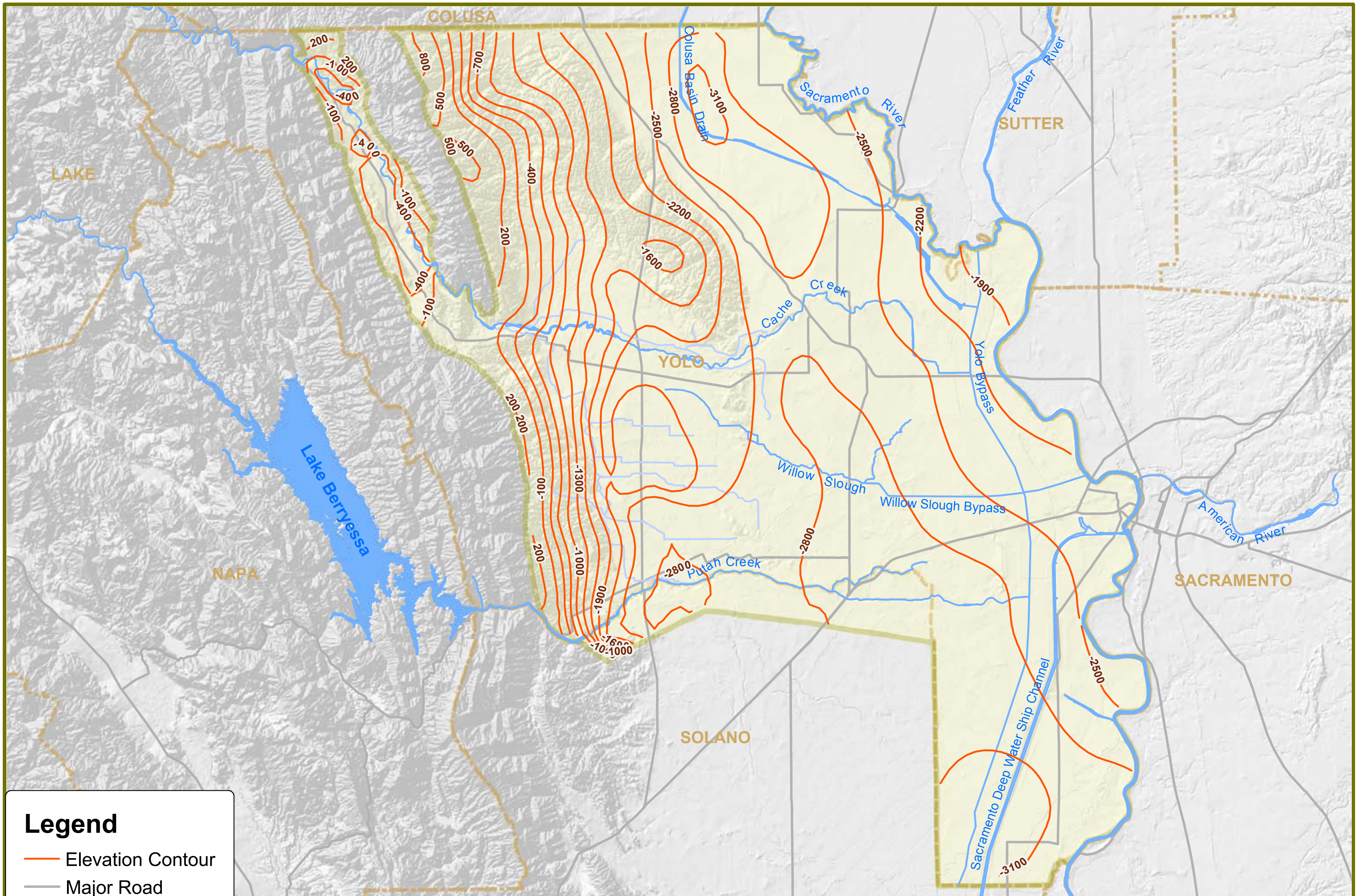
Historic Groundwater Levels

Water levels in the YCIGSM model area have been measured by a variety of agencies. The principal agencies have been YCFCWCD, DWR, and the Cities of Woodland and Davis. The well database associated with *Groundwater Monitoring Program, Data Management System, and Update of Groundwater Conditions in the Yolo County Area* assembled data from these agencies and lists more than 10,000 wells in and around Yolo County. Approximately 3,000 of those wells are in Yolo County and 769 of those have known coordinates and water level measurements taken between 1971 and 2000. Figure 2.16 shows the location of the 769 wells. Data from these wells were evaluated and used in developing the initial condition data for the YCIGSM. In addition, these wells were selected as calibration wells for the model.

Soils Data

Yolo and Solano countywide soil surveys were used to characterize the soils within the YCIGSM. The information contained in these studies provided the data necessary to classify the model elements based on hydrologic soil group.

These soil surveys are compilations of a series of aerial photographs containing soil type boundaries and descriptions providing details of the soil types. All soil surveys are available in hard copy format. The National Resource Conservation Service (NRCS) developed digital mapping of the soil surveys, which are available through the Soil Survey Geographic Database (SSURGO). The SSURGO digital soils mapping is currently available for the entire YCIGSM model area. The SSURGO mapping scales generally range from 1:12,000 to 1:63,000. The SSURGO database contains digital copies of original soils survey maps. Data from these digital soil surveys were incorporated into the YCIGSM.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Contour of Elevation of Base of Continental Deposits (Feet, MSL)

Source: Page (1974)

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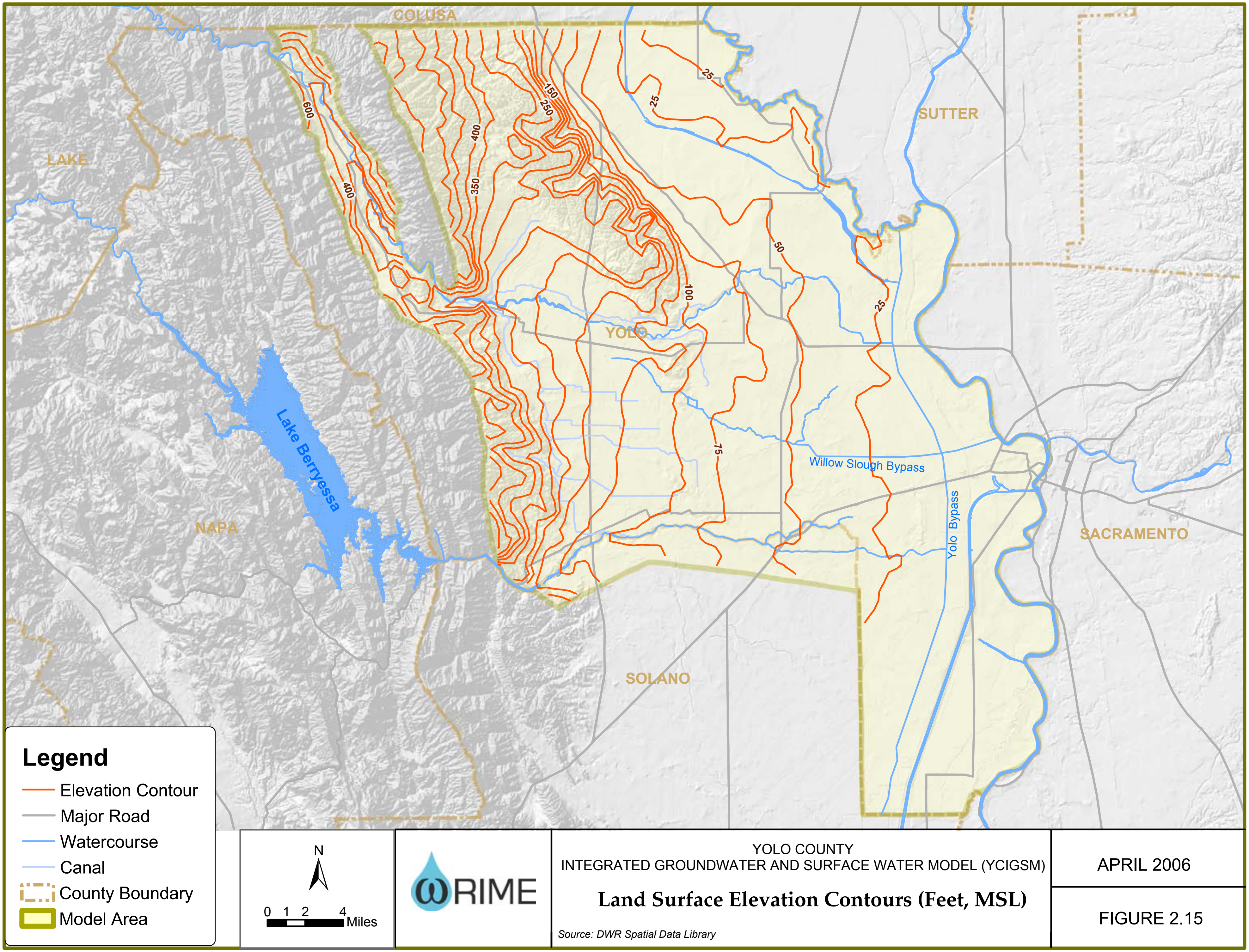
FIGURE 2.14



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Land Surface Elevation Contours (Feet, MSL)

Source: DWR Spatial Data Library

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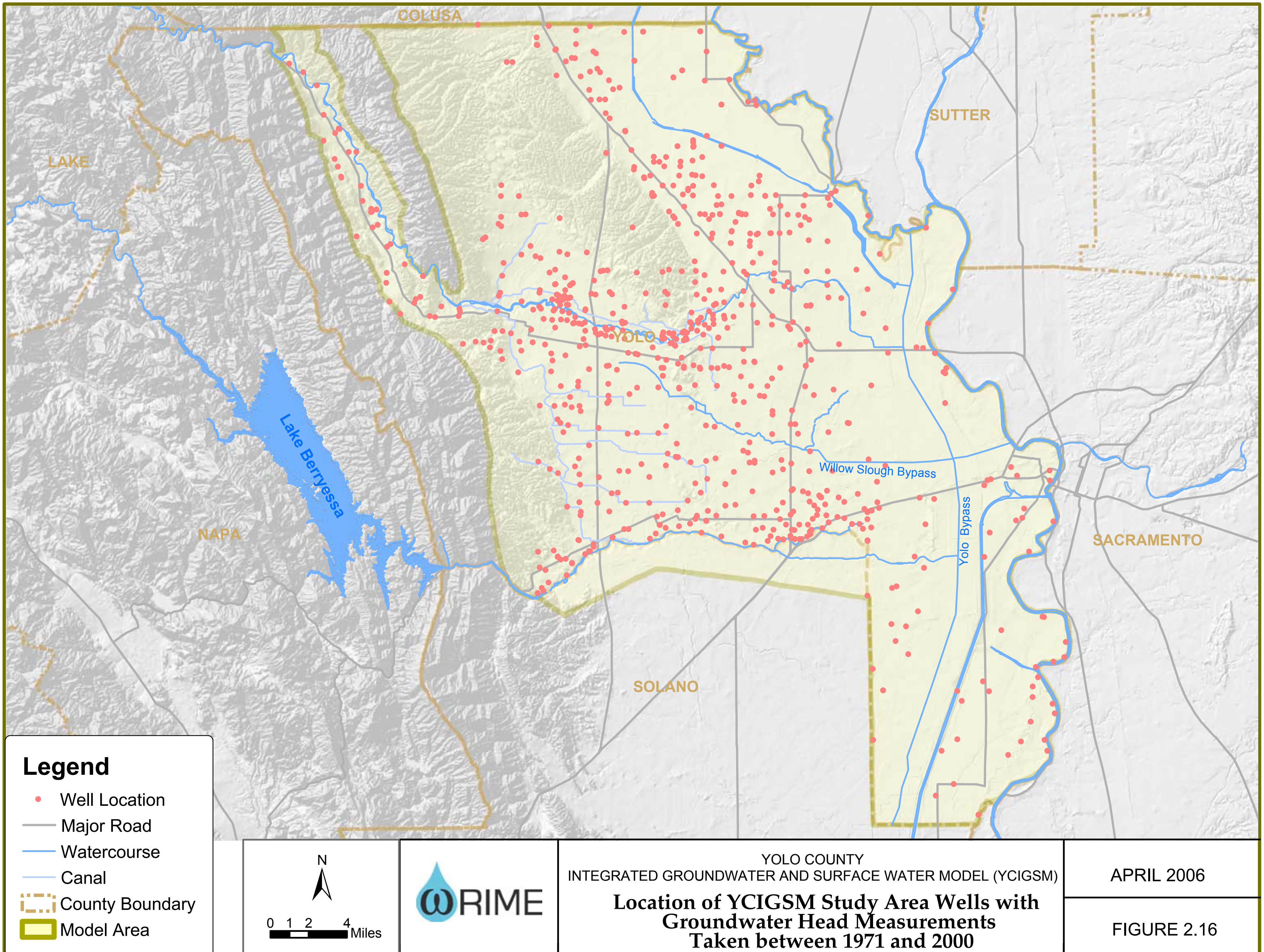
FIGURE 2.15



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Location of YCIGSM Study Area Wells with Groundwater Head Measurements Taken between 1971 and 2000

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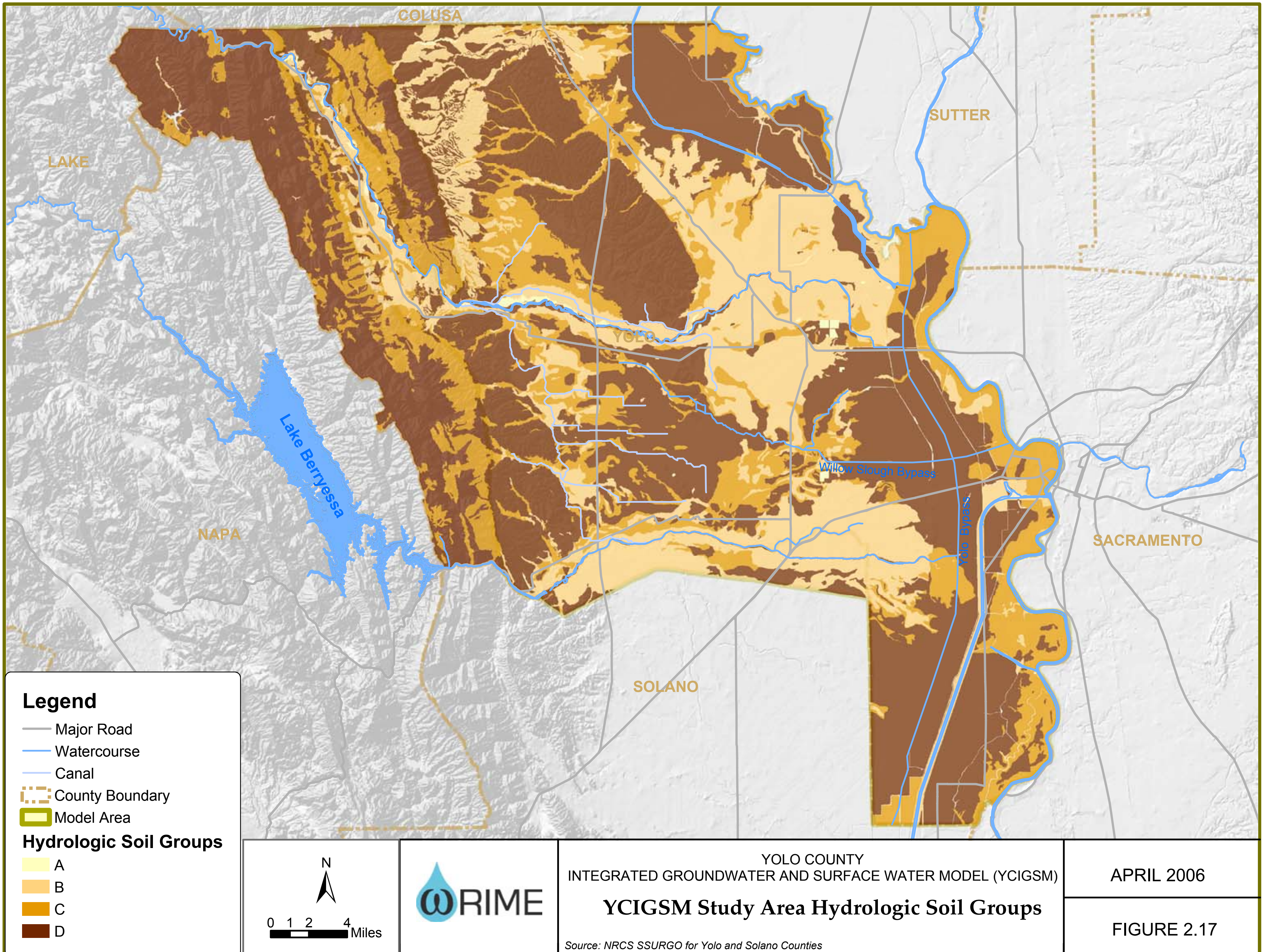
FIGURE 2.16

The soil types identified in the soil survey data are associated with four hydrologic soil groups according to their runoff potential and infiltration characteristics. Table 2.3 lists the hydrologic soil groups and their runoff characteristics.

Table 2.3 Hydrologic Soil Groups

Hydrologic Soil Group	Runoff Characteristics	IGSM Value
A	Low runoff potential: mainly sands and gravel that are deep and well to excessively drained; high transmissivity.	1
B	Low to moderate runoff potential: soils of moderately fine to moderately coarse textures; moderately deep and drained; medium transmissivity.	2
C	Moderate to high runoff potential: soils of moderately fine-to-fine texture, with an impeding clay layer; low transmissivity.	3
D	High runoff potential: mainly clay soils with a high swelling potential, shallow soils over nearly impervious materials and soil with high permanent water table; poor transmissivity.	4

Figure 2.17 shows the distribution of hydrologic soil groups in the YCIGSM.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Study Area Hydrologic Soil Groups

Source: NRCS SSURGO for Yolo and Solano Counties

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FIGURE 2.17

This section describes how the collected data, as described in Section 2, were used to develop the YCIGSM. A summary of input data used in the YCIGSM is presented in Table 3.1. The data are organized into the following categories:

- Model characterization data;
- Hydrogeology and geography data;
- Hydrology and climatology data;
- Land use data;
- Water use data;
- Parameter data; and
- Other data.

Each of these data categories is described below.

MODEL CHARACTERIZATION DATA

The YCIGSM model is physically characterized by the following data groups:

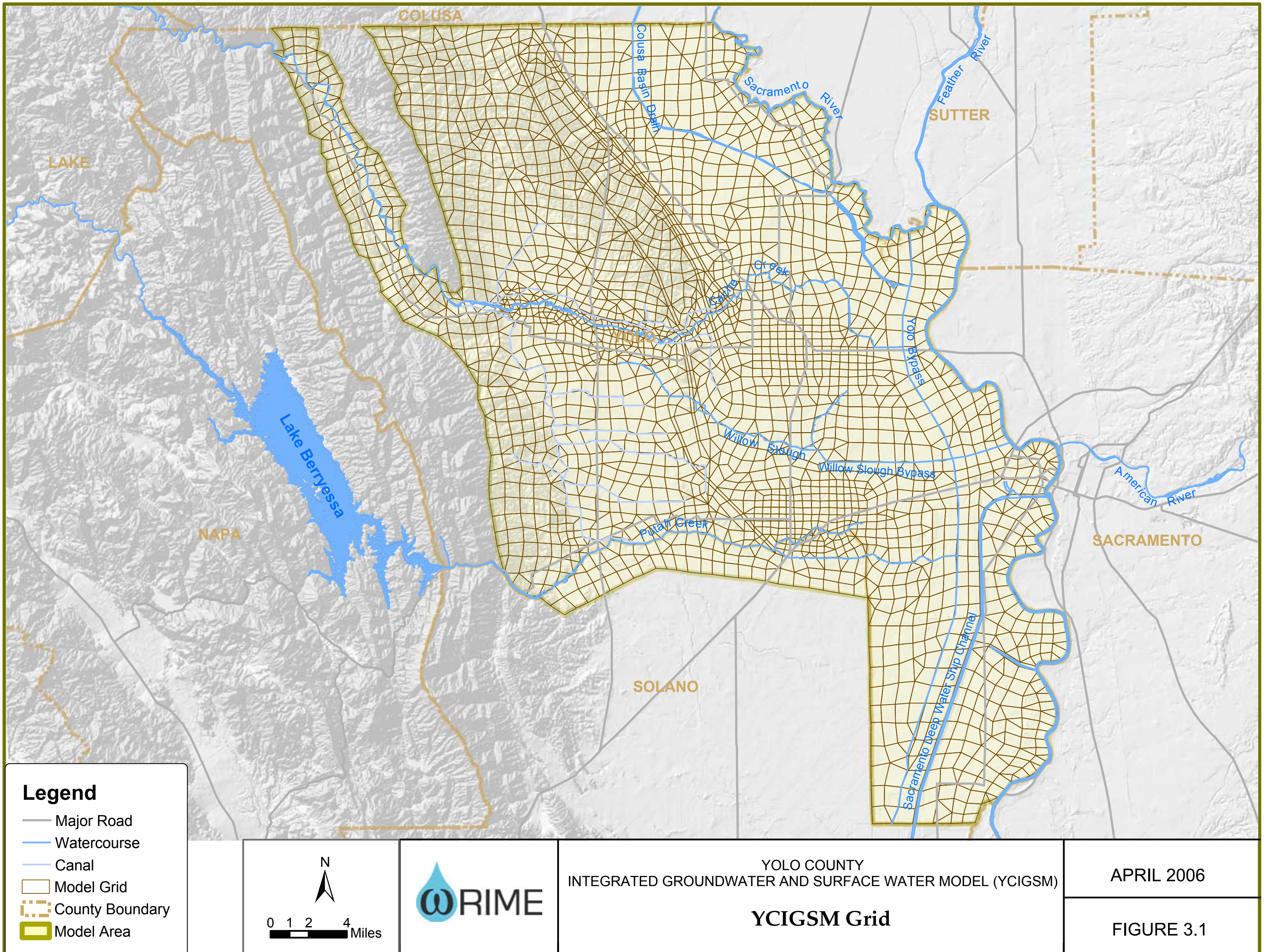
- Element Configuration;
- Nodal Coordinates;
- Surface Hydrology Configuration; and
- Subregion Definition.

MODEL GRID

A two-dimensional, finite element network was developed for the entire model area, as shown in Figure 3.1. The model area is subdivided into a series of triangular and quadrilateral elements. The grid shape allows the model to reasonably reflect the physical features in the model area. The YCIGSM model grid consists of 3,068 elements and 2,840 nodes. The model area covers approximately 884 square miles, with an average element size of about 185 acres and minimum and maximum sizes of 17 acres and 659 acres, respectively. The model grid was developed using a finite element mesh generation software and in coordination with and review by the YCIGSM Technical Advisory Committee.

Table 3.1 Summary of Input Data used in the YCIGSM

Data Group	Data Item	Data Characteristics		Data Sources
		Spatial Scale	*Time Scale*	
Model Characterization	Element configuration	Element	Invariant	USGS, CDMG, CA GIS Library
	Node coordinates	Node	Invariant	USGS, CA GIS Library
	Stream configuration	Stream node	Invariant	USGS, CA GIS Library
	Subregion definition	Element	Invariant	USGS, CDMG, CA GIS Library
	Lake configuration	Element	Invariant	USGS, CA GIS Library
Hydrogeology and Geography	Stratigraphy	Node	Invariant	USGS, YCFCWCD, Davis, Woodland, DWR
	Stream cross-sections	Stream node	Invariant	USGS, COE, YCFCWCD, DWR
	Drainage pattern	Element	Invariant	USGS
	Well locations	Well	Invariant	YCFCWCD
	Well construction	Well	Invariant	DWR, YCFCWCD, Davis, Woodland, Winters
	Well sizes/capacities	Well	Invariant	DWR, YCFCWCD, Davis, Woodland, Winters
Hydrology and Climatology	Rainfall	Gaging station	Daily	NOAA
	Rainfall distribution	Element	Invariant	Goodridge
	Soil classification	Element	Invariant	NRCS
	Evapotranspiration	Subregion	Monthly	DE
	Upstream inflow	Stream node	Daily	USGS, USBR, DWR
Land Use	Land use distribution	Element	Survey years	DWR
	Crop acreage	Subregion	Annual	Yolo County Agricultural Commissioner
Water Use	Surface water diversion	Subregion	Monthly	DWR, USBR, YCFCWCD
	Diversion locations	Subregion	Invariant	DWR, YCFCWCD, USBR
	Groundwater pumping	Subregion	Monthly	UCD, Davis, Woodland, Winters
	Pumping distribution	Element	Invariant	DWR
	Urban water use	Subregion	Monthly	UCD, Davis, Woodland, Winters
	Canal facilities/layout	Element	Invariant	DWR, USBR, YCFCWCD
Parameter Data	Hydraulic conductivity	Node	Invariant	USGS, DWR, YCFCWCD
	Stream bed parameters	Stream node	Invariant	USGS, DWR, YCFCWCD
	Specific yield	Node	Invariant	USGS, DWR, YCFCWCD
	Storage coefficient	Node	Invariant	USGS, DWR, YCFCWCD
	Runoff curve number	Subregion	Invariant	NRCS, TR-55
	Soil percolation parameter	Subregion	Invariant	NRCS, TR-55
Other	Initial conditions	Node	Invariant	DWR, YCFCWCD
	Boundary conditions	Node	Invariant, daily	DWR, YCFCWCD
	Recharge facilities	Element	Invariant	YCFCWCD
	Well hydrographs	Well	Monthly	YCFCWCD
	Groundwater levels	Well, regional contours	Monthly	DWR, YCFCWCD
	Artificial recharge	Element	Monthly	YCFCWCD



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Grid

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FIGURE 3.1

The notable features of the model grid are:

- Model boundary matches the hydrogeologic and hydrologic boundaries of the underlying groundwater basin;
- Grid orientation follows regional groundwater flow streamlines;
- Grid orientation follows the course of significant streams;
- Model elements are smaller in the vicinity of the Cache Creek Mineral Zone Area; and
- Thin strips of elements are used to incorporate the major geologic faults and flow barriers.

NODAL COORDINATES

The model uses the Universal Transverse Mercator (UTM) projection, Zone 10 coordinates, and North American Datum of 1927 for the x-y coordinates of the nodes. The list of connecting nodes for each element was developed by mesh generation software. Two independent sets of sequential numbers were used for nodes and elements identification. These node and element numbers are used in specifying model input data.

SURFACE HYDROLOGY CONFIGURATION

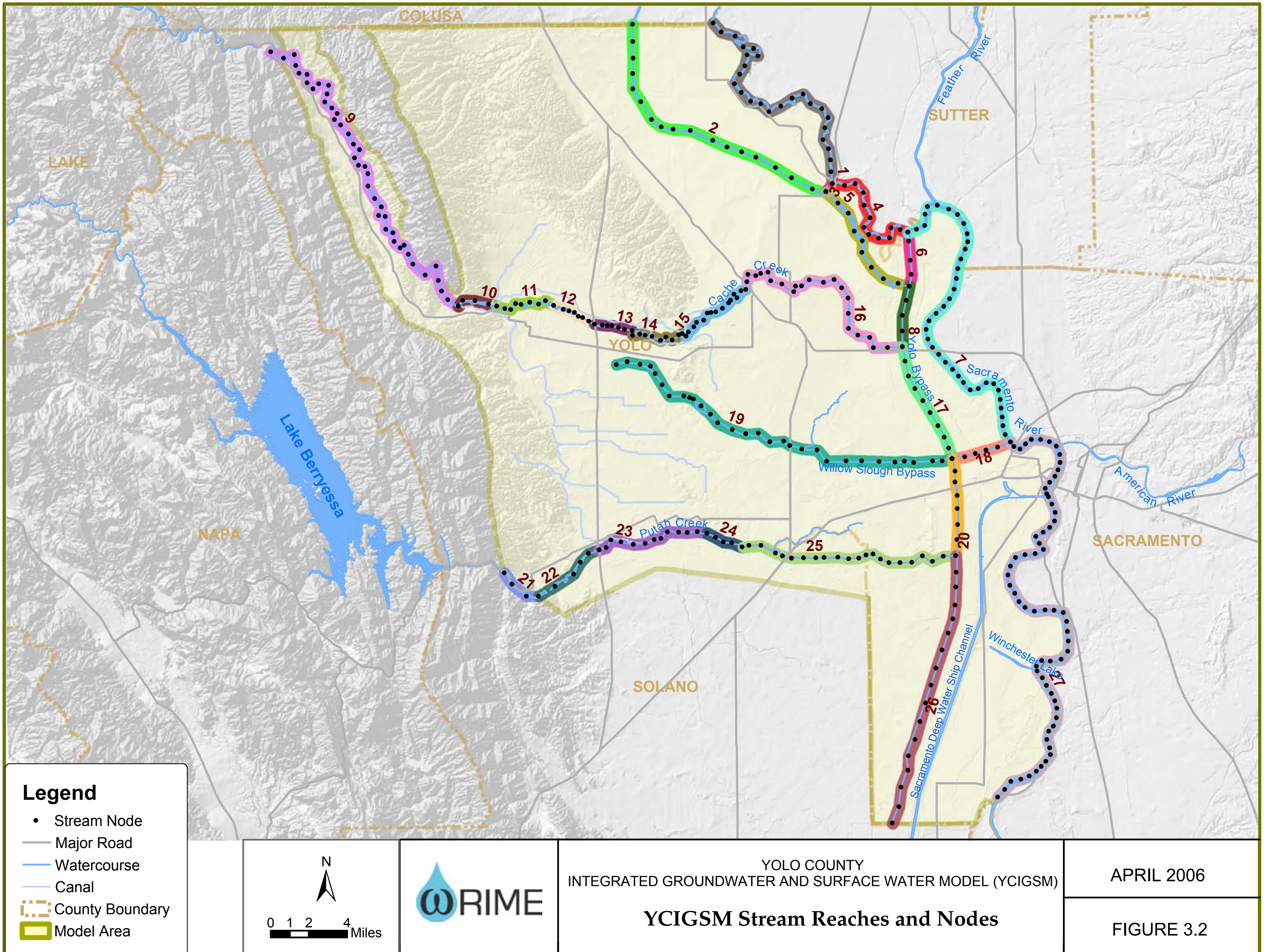
There are nine rivers, creeks, and other waterways simulated in the YCIGSM: Cache Creek, Sacramento River, Putah Creek, Willow Slough, Colusa Basin Drain, Yolo Bypass, Knights Landing Ridge Cut, Sacramento Deep Water Ship Channel, and Winchester Lake. Figure 3.2 shows the location of the simulated water features. The location of these physical features is based on GIS mapping available from the California Spatial Information Library (www.gis.ca.gov).

Surface hydrology configuration is characterized by the following data groups:

- Stream Reach Configuration; and
- Lake Configuration.

Stream Reach Configuration

Each stream course simulated in the YCIGSM is comprised of stream nodes, which correspond to groundwater nodes. A stream reach is defined by a series of sequential stream nodes. There are 27 stream reaches and 424 stream nodes that represent the stream courses listed above. The stream nodes and stream reaches are shown in Figure 3.2 and the names of the stream reaches



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Stream Reaches and Nodes

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FIGURE 3.2

are listed in Table 3.2. The reaches were defined using the criteria described in Section 2, Hydrology subsection.

Table 3.2 YCIGSM Stream Reaches

Stream Reach Number	Stream Reach Definition
1	Sacramento River – above Knights Landing (KLRC)
2	Colusa Basin Drain
3	Sacramento River Bypass to KLRC
4	Sacramento River between KLRC and Yolo Bypass
5	KLRC
6	Yolo Bypass above Confluence of KLRC
7	Sacramento River between Yolo Bypass and Sacramento Bypass
8	Yolo Bypass between KLRC and Cache Creek
9	Cache Creek – above Capay Dam
10	Cache Creek – Capay Dam to CR 85
11	Cache Creek – CR 85 to CR 87
12	Cache Creek – CR 87 to I505
13	Cache Creek – I505 to Moore's Siphon
14	Cache Creek – Moore's Siphon to CR 94B
15	Cache Creek – CR 94B to I-5
16	Cache Creek – I-5 to Settling Basin
17	Yolo Bypass between Cache Creek and Willow Slough
18	Sacramento Bypass
19	Willow Slough and Bypass
20	Yolo Bypass between Willow Slough and Putah Creek
21	Putah Creek – Upstream of Lake Solano
22	Putah Creek – Lake Solano to Winters
23	Putah Creek – Winters to Stevenson Bridge
24	Putah Creek – Stevenson Bridge to State Route 113
25	Putah Creek – Downstream of State Route 113
26	Yolo Bypass below Putah Creek
27	Sacramento River below Sacramento Bypass

Cache Creek and Putah Creek were configured to have multiple stream subreaches. Additional subreaches were assigned to these creeks to capture the changing nature of stream-aquifer interaction of the creeks. Historical data suggest that both creeks have gaining and losing reaches. Based on interaction with YCFCWCD staff and the Technical Advisory Committee, a decision was made to simulate and report the gaining and losing nature of the creeks.

The YCFCWCD and several other districts provide surface water deliveries, for irrigation use, through a series of unlined canals. These canals are not explicitly simulated in the model. However, the model grid in the YCFCWCD service area was configured for future incorporation of such features.

Lake Configuration

The YCIGSM finite element model grid was configured to represent Sacramento Deep Water Ship Channel and Winchester Lake. These bodies of water were defined as lakes because they are primarily stationary water bodies with no significant flow rates and/or flow directions. The Sacramento Deep Water Ship Channel is maintained at a constant level to facilitate ship traffic. This constant level is governed primarily by the water levels in the Sacramento River delta. There is a lock with the Sacramento River but it is no longer in operation. The location of the lakes and reservoirs is based on GIS mapping available from the California Spatial Information Library. Figure 3.2 shows the location of the water features.

SUBREGION DEFINITION

Water and land use management in the model area is represented in the YCIGSM by subdividing the model area into 24 management areas called subregions. The YCIGSM uses subregions to enable independent analysis of water budgets and hydrologic conditions for each management area. In addition, the subregions allow for the proper development of model input data, especially water supply and demand data. The YCIGSM subregions represent individual water districts, irrigation districts, or other organized and/or unorganized areas within the model. The subregions are defined by a collection of finite elements of the model grid, as shown in Figure 3.3. The names of the YCIGSM model subregions, their representative areas, and criteria for selecting the boundaries of the subregion are presented in Table 3.3.

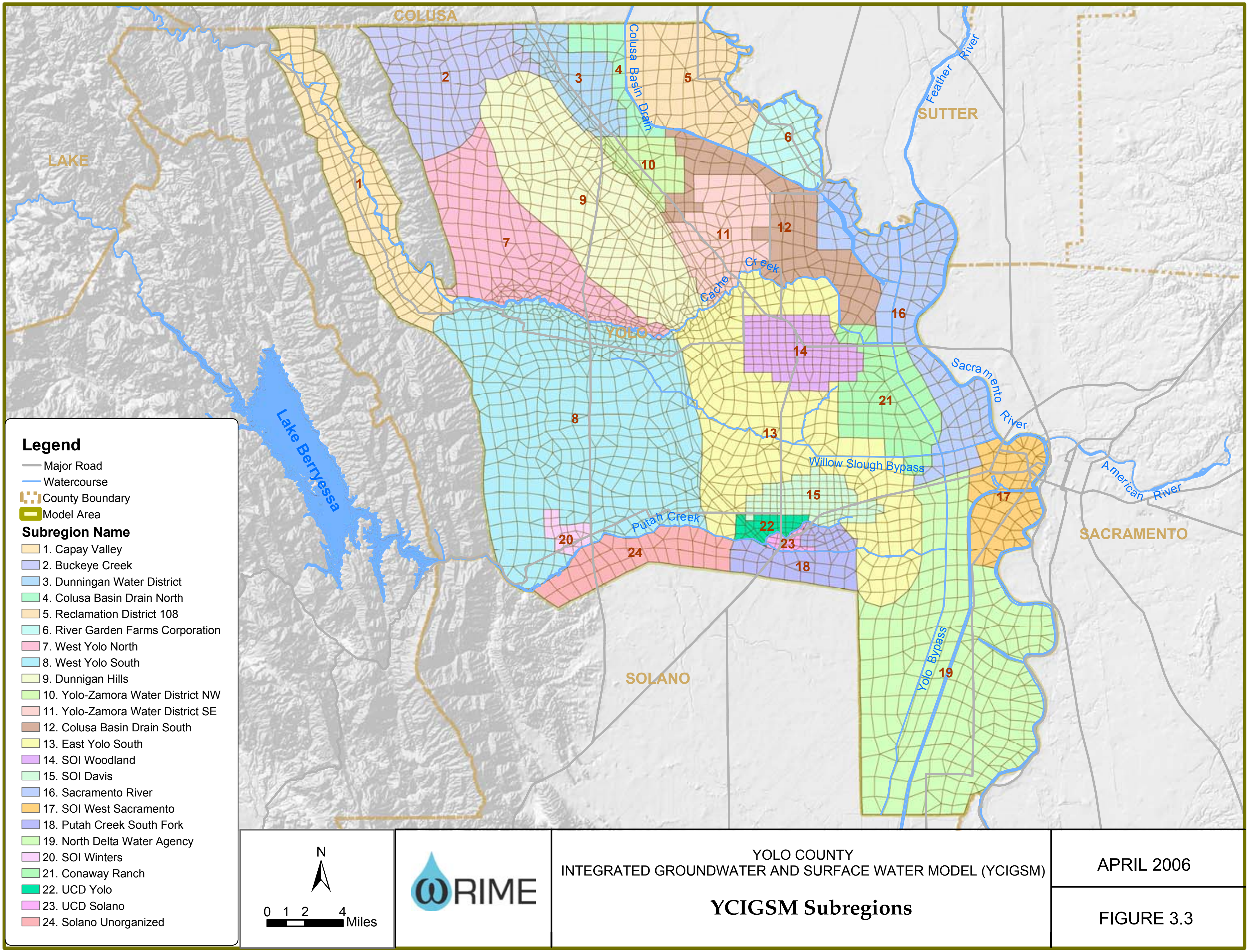
The general criteria used to configure the YCIGSM subregions include:

- Boundaries of water agencies;
- Boundaries of municipalities;
- Administrative boundaries; and
- Principal hydrogeologic and hydrologic features.

Specific criteria used to define the YCIGSM subregions are:

- Yolo Integrated Regional Water Plan;
- Yolo County Urban Spheres-of-Influence; and
- Hydrography and Water Supply.

Each specific criterion is described below.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Subregions

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FIGURE 3.3

Table 3.3 Summary of YCIGSM Subregions

Subregion Number and Name		Area (sq. mi.)	Criterion		
			IRWMP Subbasins	*Spheres-of-Influence*	*Hydrography and Water Supply*
1	Capay Valley	43	Capay Valley	NA	NA
2	Buckeye Creek	38	Buckeye Creek	NA	NA
3	Dunnigan WD	18	Buckeye Creek	NA	Tehama-Colusa Canal Contractor
4	Colusa Basin Drain North	9	Buckeye Creek	NA	NA
5	RD 108	34	Sacramento River	NA	Settlement Contractor
6	River Garden Farms	14	Sacramento River	NA	Settlement Contractor
7	West Yolo North	51	West Yolo	NA	Cache Creek boundary
8	West Yolo South	144	West Yolo	NA	Cache Creek boundary
9	Dunnigan Hills	71	Dunnigan Hills	NA	Cache Creek boundary
10	Yolo-Zamora WD NW	11	East Yolo	NA	NA
11	Yolo-Zamora WD SE	25	East Yolo	NA	Potential YCFCWCD Contractor
12	Colusa Basin Drain South	34	East Yolo	NA	NA
13	East Yolo South	95	East Yolo	NA	Cache Creek boundary
14	SOI Woodland	20	East Yolo	City of Woodland	NA
15	SOI Davis	14	East Yolo	City of Davis	NA
16	Sacramento River	48	Sacramento River	NA	NA
17	SOI West Sacramento	23	Sacramento River	City of West Sacramento	NA
18	Putah Creek South Fork	15	NA	NA	South Fork of Putah Creek
19	North Delta WA	121	Sacramento River	NA	Potential SWP/CVP Contractor
20	SOI Winters	4	West Yolo	City of Winters	NA
21	Conaway Ranch	27	East Yolo	NA	NA
22	UCD Yolo	4	East Yolo	NA	NA
23	UCD Solano	2	NA	NA	NA
24	Solano Unorganized	20	NA	NA	NA

NA: Not applicable

Yolo Integrated Regional Water Management Plan Criterion

YCIGSM subregions were configured to provide geographic coverage similar to geologic subbasins used in the Yolo County Integrated Regional Water Management Plan (IRWMP). The configuration of the IRWMP subbasins was used as criterion for configuring a portion of all the YCIGSM subregions. The configuration of the subbasins was previously defined in Section 2.

Yolo County Urban Spheres-of-Influence Criterion

Four YCIGSM subregions were configured using spheres-of-influence boundaries. These are the Cities of Woodland, Davis, Winters, and West Sacramento.

Hydrography and Water Supply Criterion

YCIGSM subregions were configured primarily based on hydrography or water supply source. Four subregions were based on hydrography and six subregions were based on water supply, primarily based on their access to surface water.

HYDROGEOLOGY/GEOGRAPHY DATA

The hydrogeology data and geography data used as input data in the YCIGSM are briefly discussed below. The hydrogeology and geography data can be categorized into two primary groups:

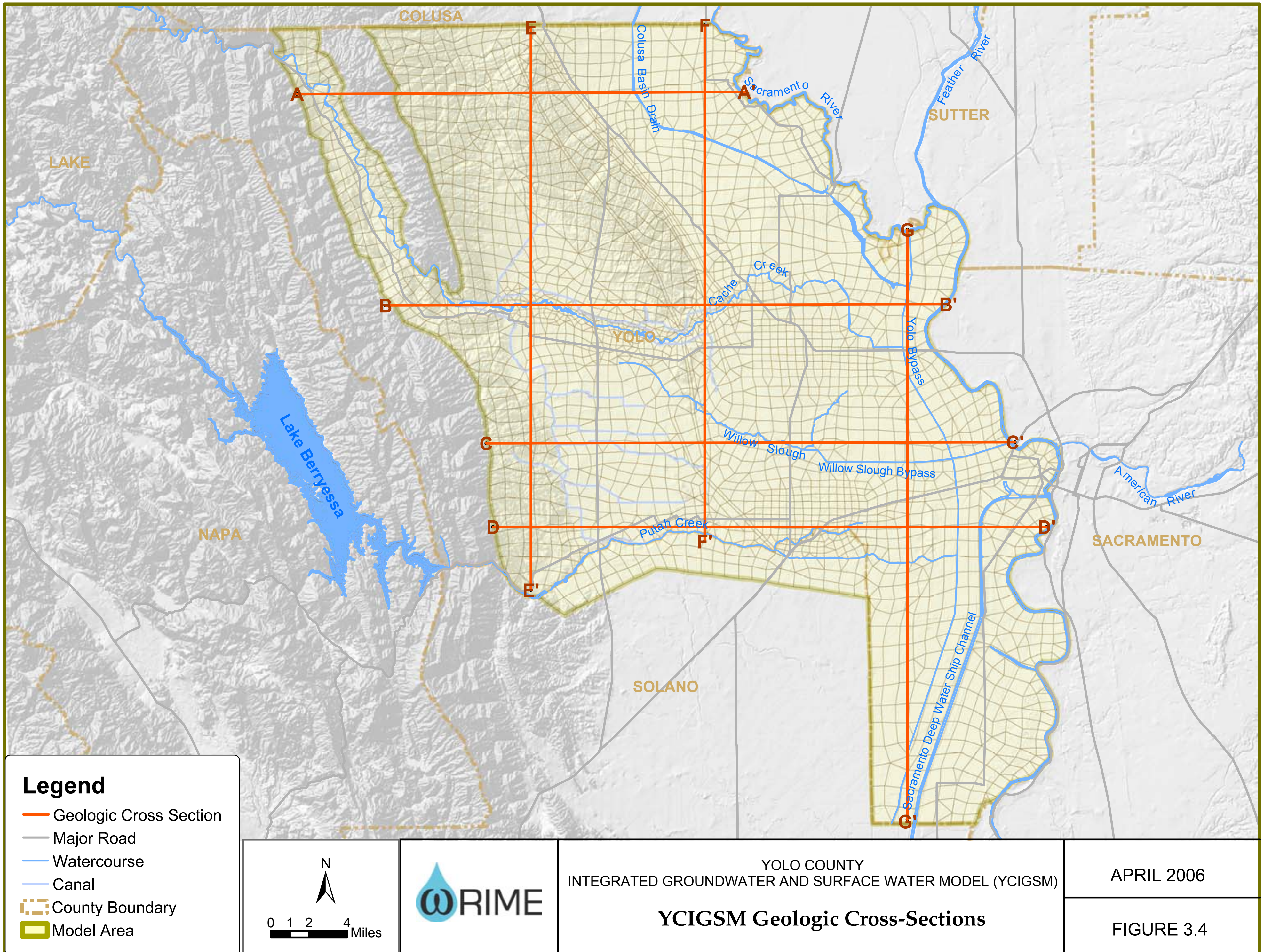
- Stratigraphy Data and
- Surface Drainage Pattern.

STRATIGRAPHY DATA

The YCIGSM input data for geologic characterization of the groundwater basin includes the stratigraphic description of the underlying aquifers at every model node. This includes ground surface elevation, and thicknesses of the aquifers at each of the 2,840 nodes of the YCIGSM. As stated in Section 2, Hydrogeology subsection, the ground surface elevations at the model nodes were obtained from the USGS DEM in the YCIGSM area. Based on the data collected as part of the development of the YCIGSM, it was determined that the aquifer system in the model area is reasonably represented by a 3-model layer aquifer system. The model layers correspond to Quaternary Alluvium (Alluvium – Layer 1), Upper Tehama (Layer 2), and Lower Tehama (Layer 3). Elevation data, as shown in Figures 2.12 through 2.15, were mapped to each model node for each model layer. YCIGSM stratigraphic data were used to create geologic cross-sections. The location of the geologic cross-sections, using YCIGSM stratigraphic data, is shown in Figure 3.4 and the cross-sections are shown in Figures 3.5a through 3.5g. The location of the cross-sections shown in Figure 3.4 does not necessarily correspond with the cross-sections shown in Figures 2.11a through 2.11h. However, YCIGSM cross-sections show spatial variability of the modeled aquifer system thickness. The characteristics and features of the 3-layer aquifer system of the YCIGSM are presented in Table 3.4.

SURFACE DRAINAGE

Surface drainage patterns are used in the YCIGSM to route runoff from rainfall or return flows from irrigation to the appropriate stream node. The drainage patterns are generally a function of the overall topography, as modified by constructed drains or canals (e.g., manipulated drainage). The drainage patterns for the YCIGSM were determined using the DEM (as



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Geologic Cross-Sections

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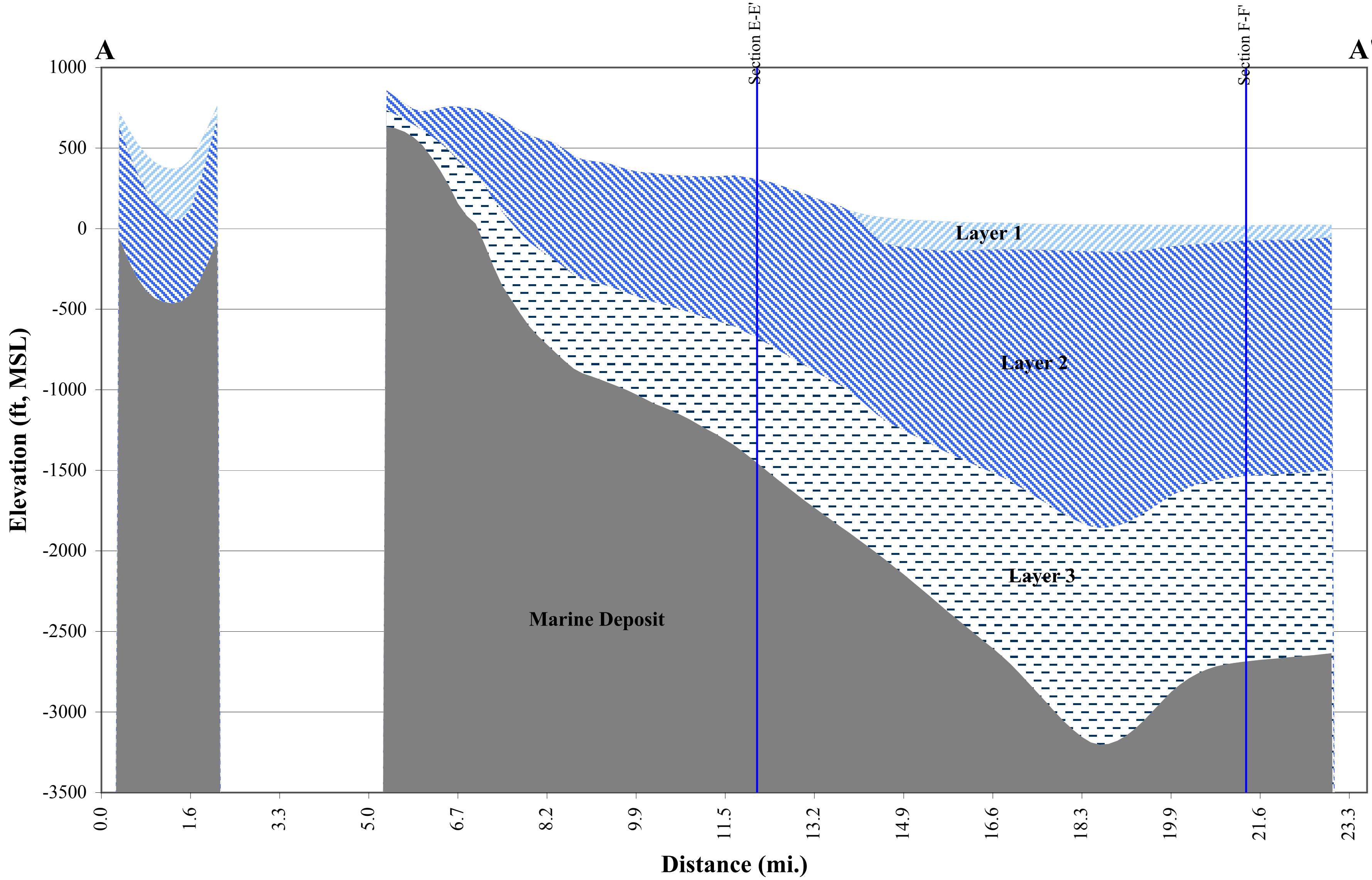
FIGURE 3.4



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section A-A'

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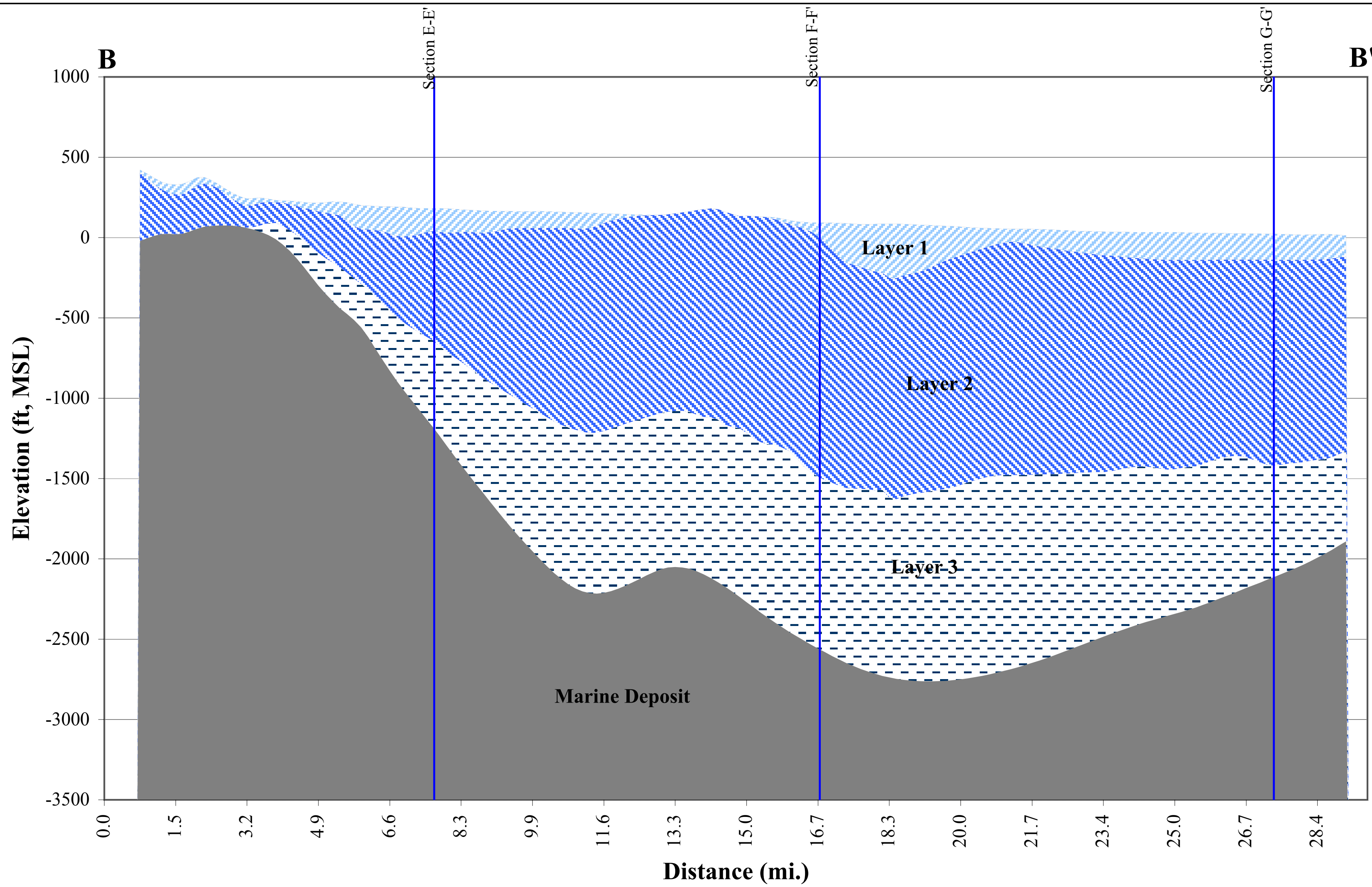
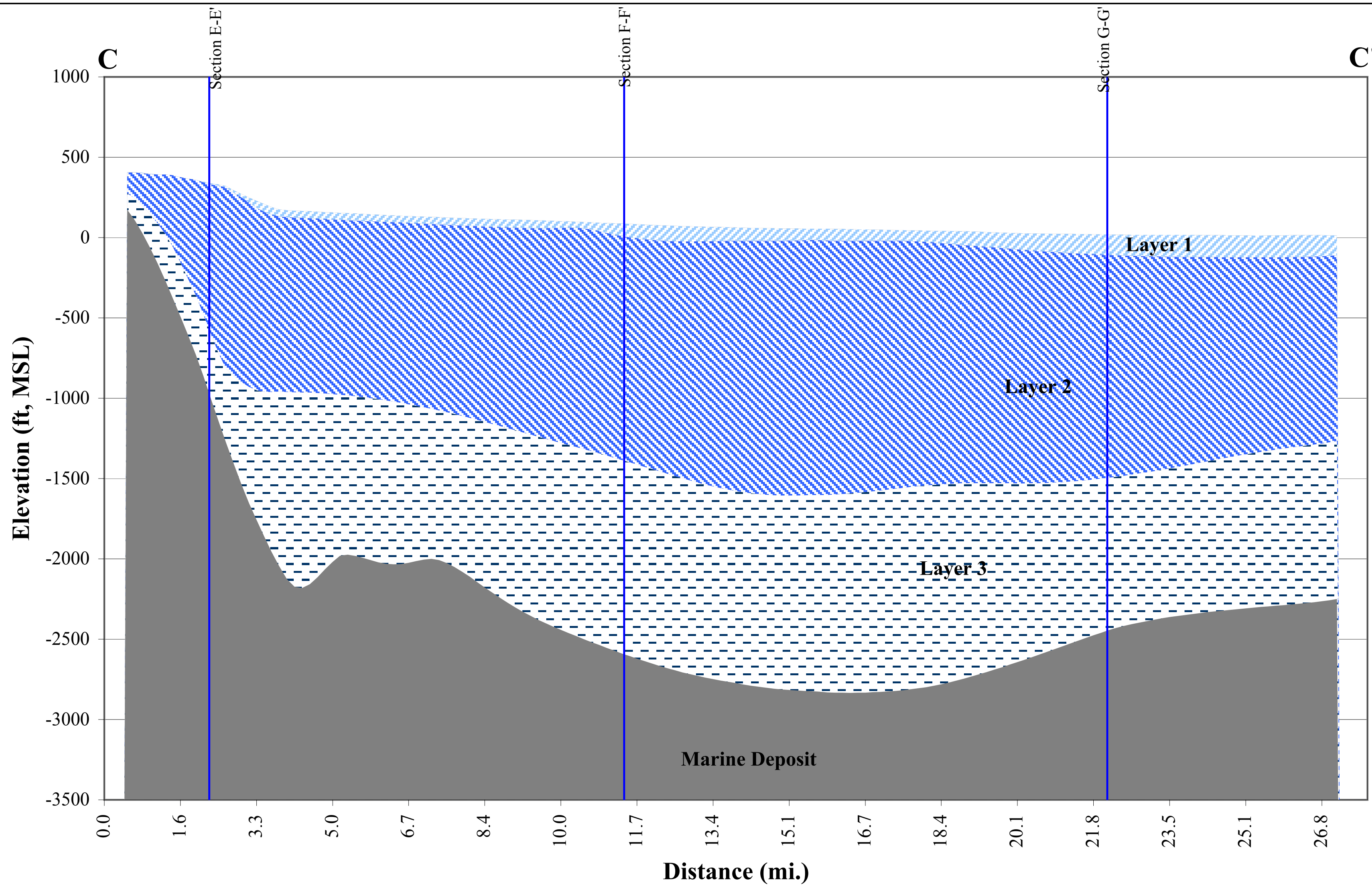
FIGURE 3.5a



RIME	YYOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Geologic Cross-Section B-B'**	APRIL 2006 FIGURE 3.5b



YOLO COUNTY

INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section C-C'

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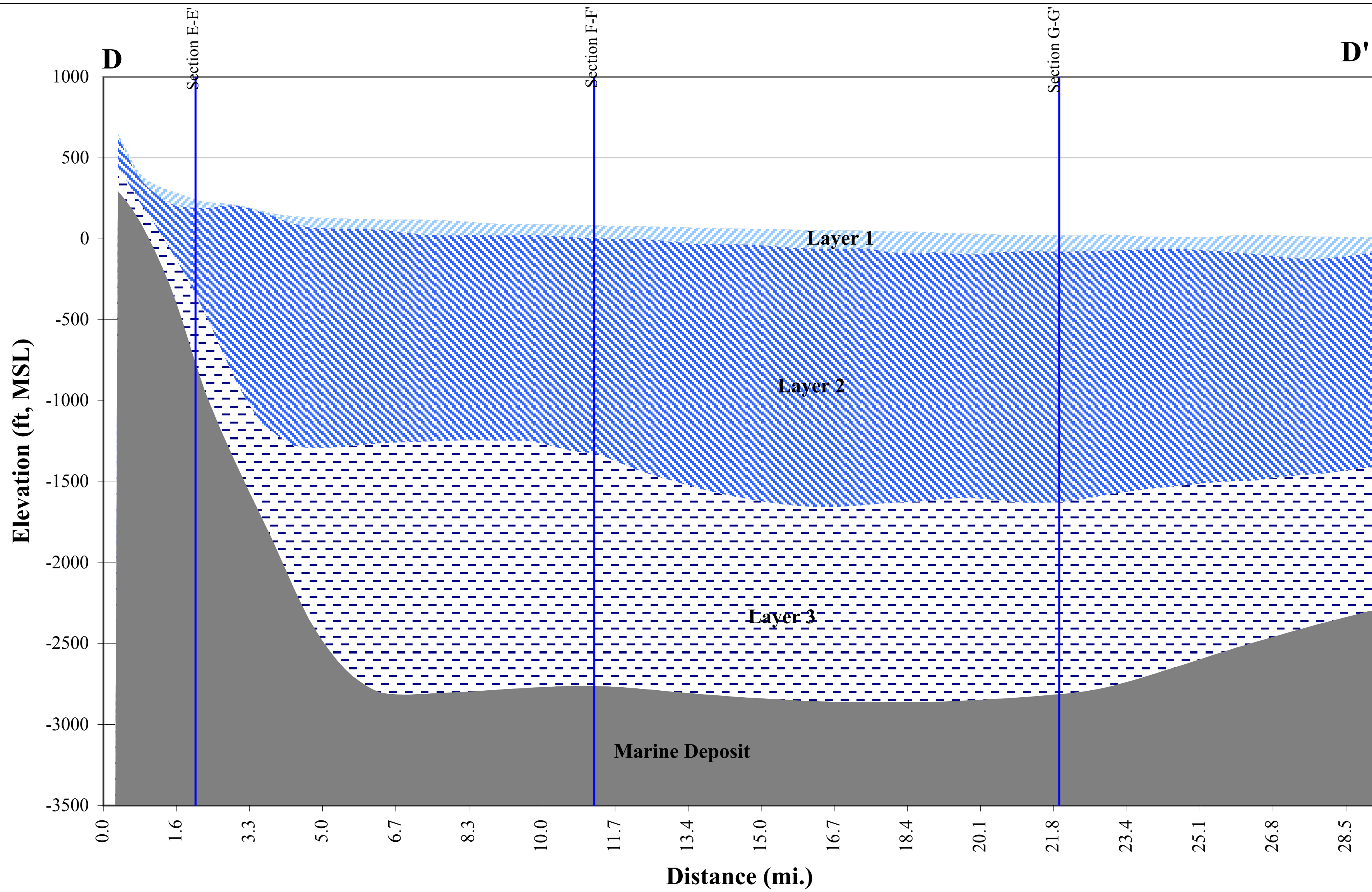
FIGURE 3.5c



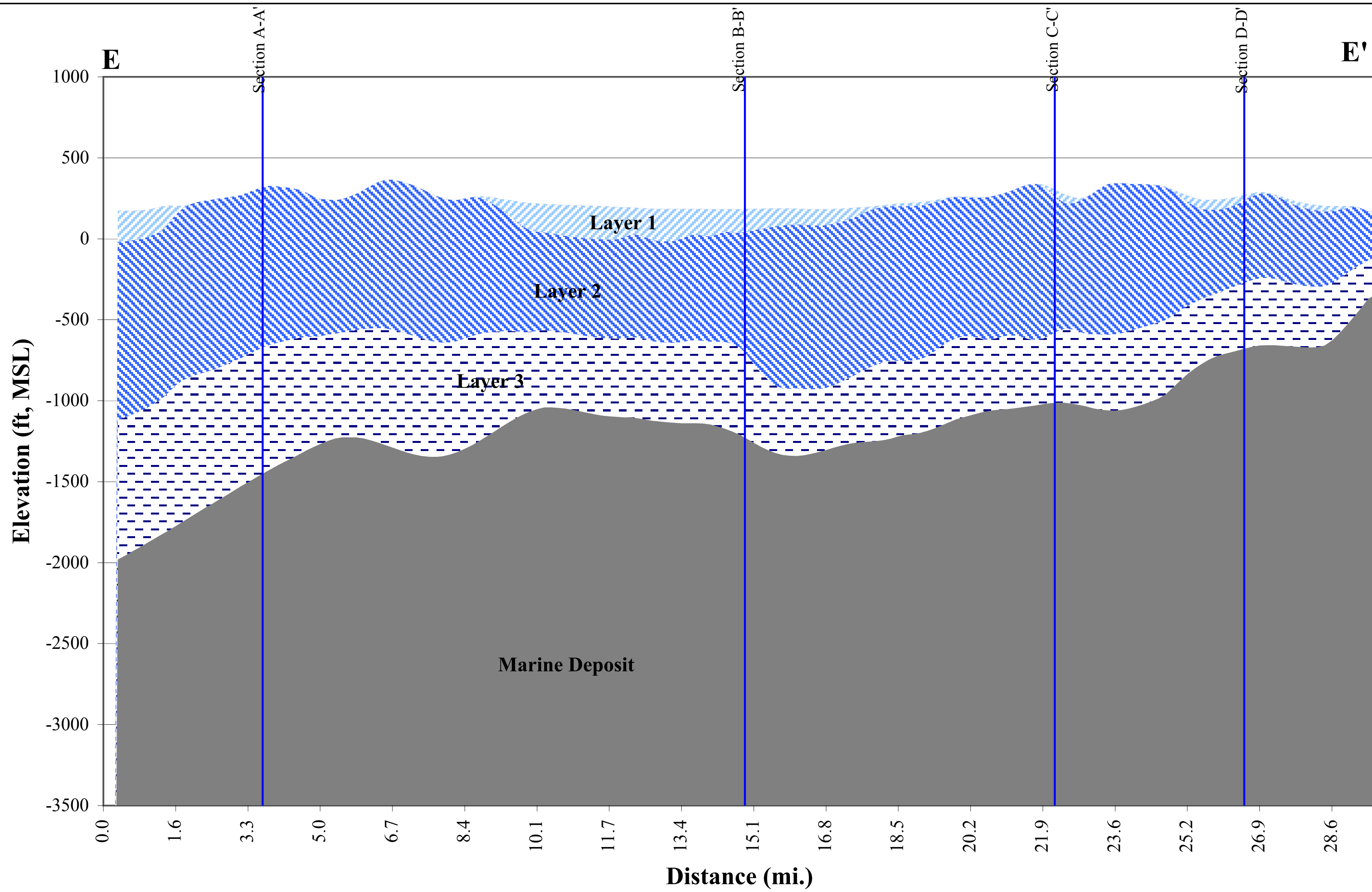
YOLO COUNTY

INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section D-D'

APRIL 2006

FIGURE 3.5d



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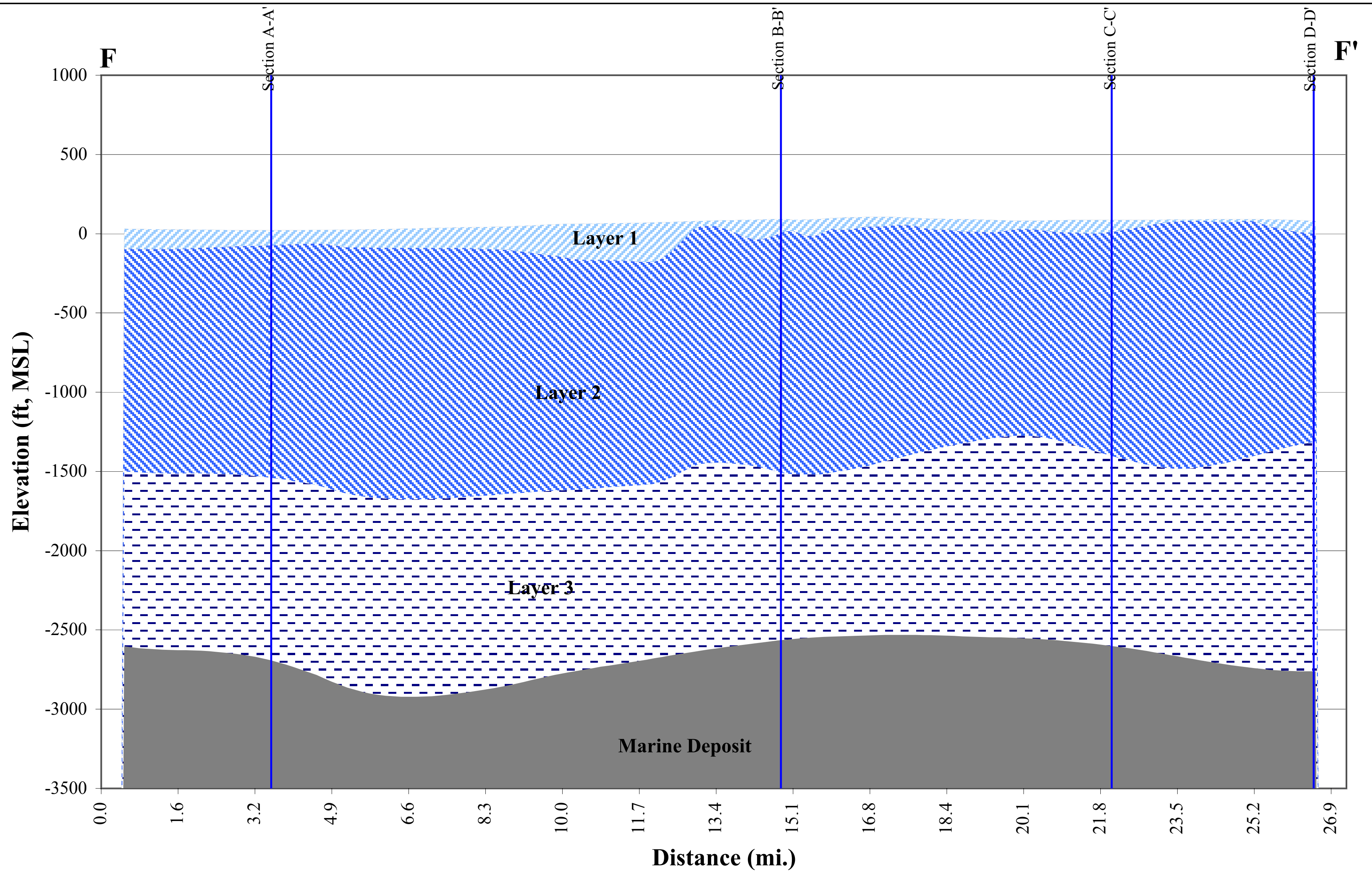
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section E-E'

APRIL 2006

FIGURE 3.5e



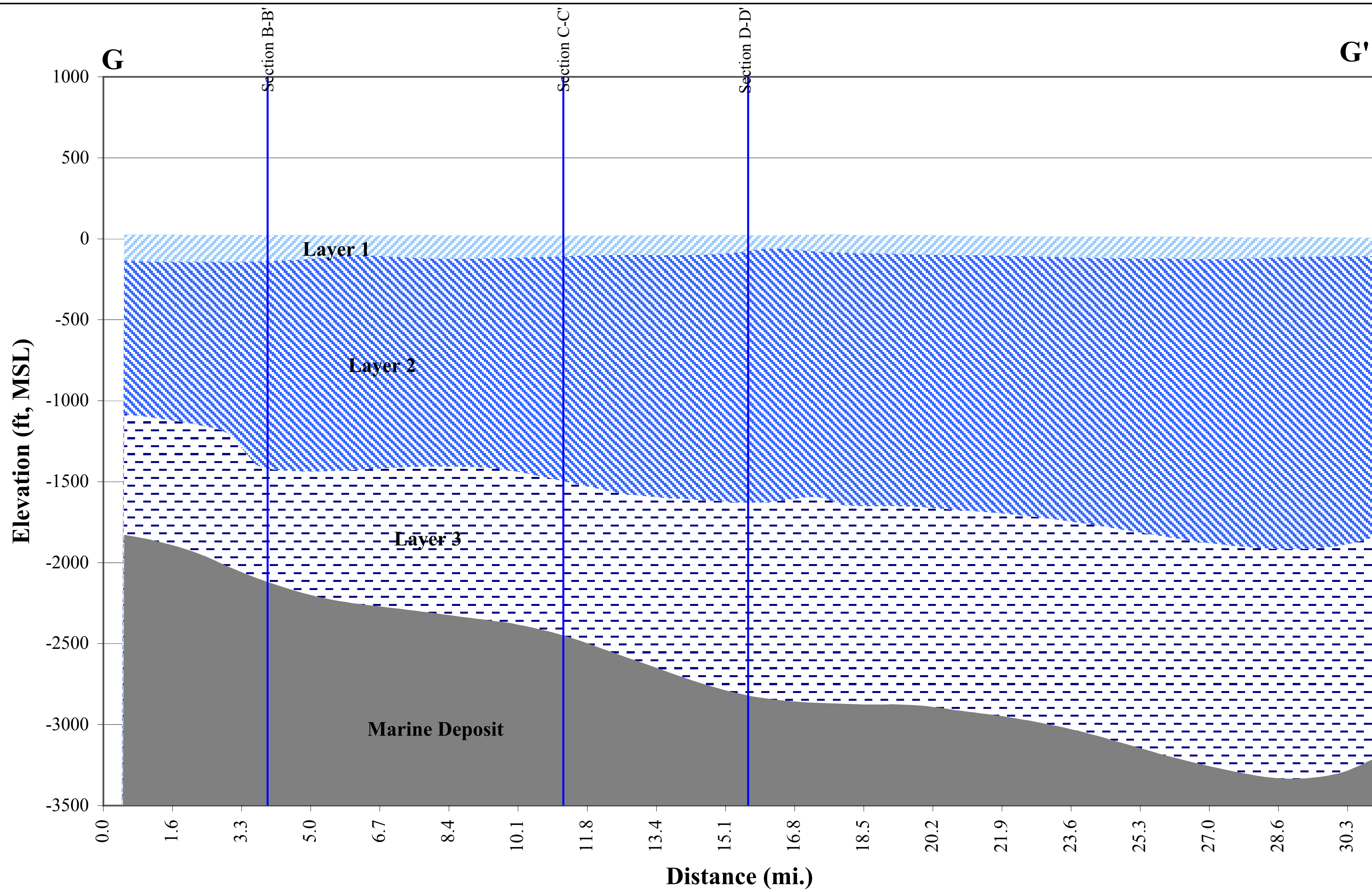
WRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Geologic Cross-Section F-F'

APRIL 2006

FIGURE 3.5f



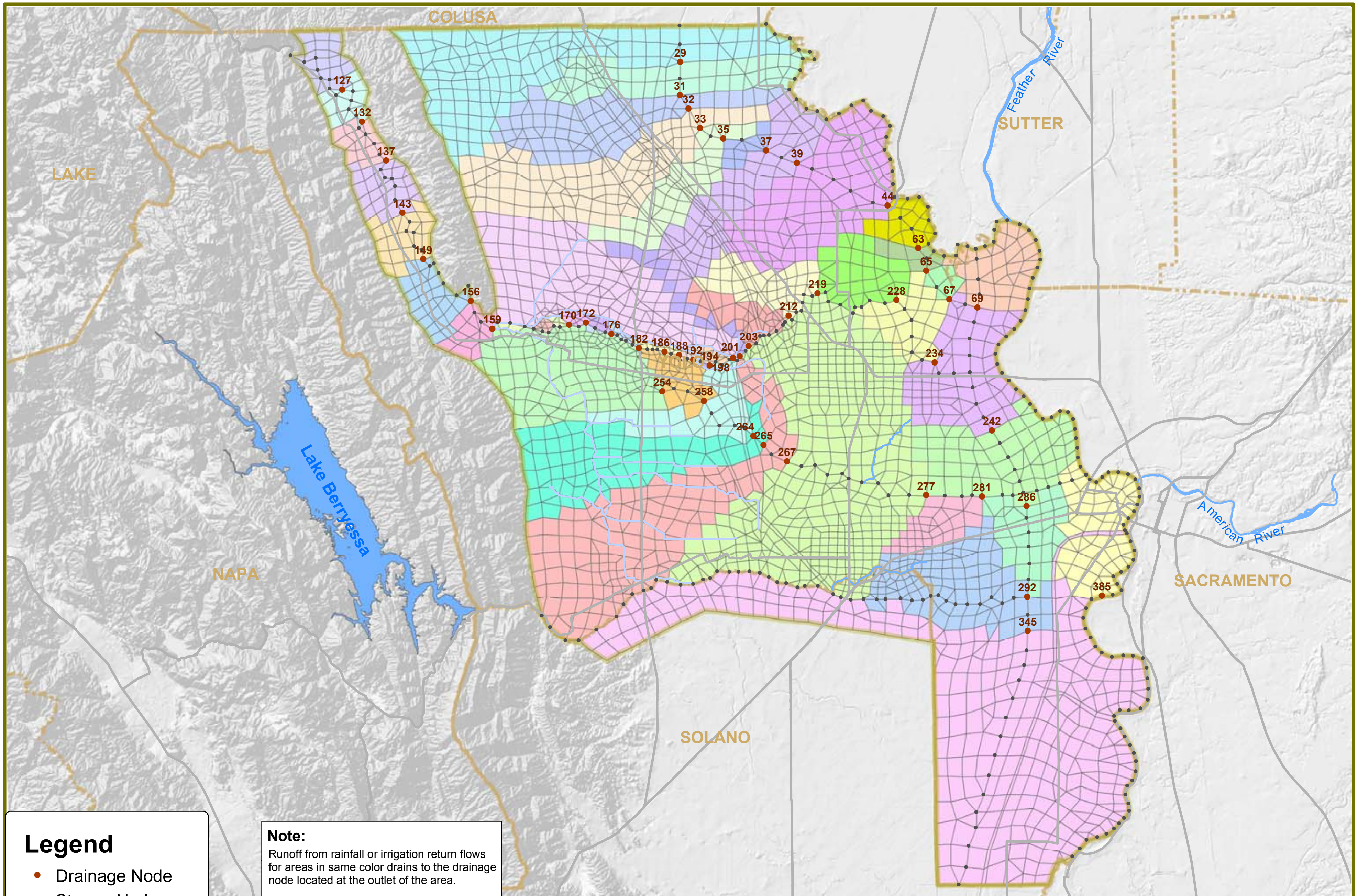
RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Geologic Cross-Section G-G'**	APRIL 2006 FIGURE 3.5g

Table 3.4 YCIGSM Aquifer System

Layer	Geologic Formations	Maximum Thickness (ft)	Lithology	Water Bearing Properties
1	Recent Alluvium, Basin Deposits	500	Deposits near Cache Creek and other streambeds are predominantly gravel and sand with minor amounts of silt and clay. Away from the Cache Creek and other streambeds, deposits are characterized by fine-grained silts and clays.	Supply wells with low to high yields. Water bearing capabilities limited by thickness.
2	Upper Tehama Formation	1,800	Interbedded clays, silts, sands, and gravels of varying permeability; may be partially cemented in some areas. Decreasing permeability and increasingly confined with depth.	Primary water producing layer in model area with overall low to moderate permeability. Water quality in upper portion of the Upper Tehama Formation is worse than that in the lower portion.
3	Lower Tehama Formation	1,700	Interbedded clays, silts, sands, and gravels of varying permeability; may be partially cemented in some areas. Generally less permeable and more compacted than the Upper Tehama Formation.	Not used for water production.

described in Section 2, Hydrogeology subsection) of the model area and the California watershed coverage. Surface topography and stream network patterns, including ephemeral streams, were included in this analysis. Based on the natural and manipulated drainage (due to drains and canals), direction trends were determined and each element was assigned a stream node to which runoff drains.

In general, the drainage pattern for the model area is from west to east. The area between Cache Creek and Putah Creek is drained by Willow Slough and Dry Slough. The Gordon Slough, which discharges to Cache Creek via Salisbury Spill at County Road 94b, is the outflow for Hungry Hollow area. Colusa Basin Drain receives drainwater from Buckeye Creek, Dunnigan Water District, Yolo-Zamora, RD 108, and RD 787. Yolo Bypass drains water from Colusa Basin Drain, Cache Creek, Willow Slough, Putah Creek, and the Sacramento River. The surface drainage pattern used in the YCIGSM is shown in Figure 3.6. Elements that drain to a common node are depicted in a common color in Figure 3.6.



Legend

- Drainage Node
- Stream Node
- Major Road
- Canal
- County Boundary
- Model Area

Note:
Runoff from rainfall or irrigation return flows for areas in same color drains to the drainage node located at the outlet of the area.

N

0 1 2 4 Miles

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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Drainage Pattern

APRIL 2006

FIGURE 3.6

HYDROLOGY/CLIMATOLOGY

As stated in Section 2, Hydrology subsection, hydrology and climatology data were collected YCIGSM simulation time period. Descriptions of the Hydrologic/Climatologic data included in the YCIGSM are organized as follows:

- Rainfall;
- Rainfall distribution;
- Evapotranspiration; and
- Streamflow.

RAINFALL DATA

Rainfall is a significant component of the hydrologic system being modeled in the YCIGSM. Rainfall in the model area is characterized by a marked seasonal distribution with little or no rainfall in the summer months, with most rainfall occurring during the winter months, as shown for Davis in Figure 3.7. The model area receives an average of about 20 inches of rainfall per year.

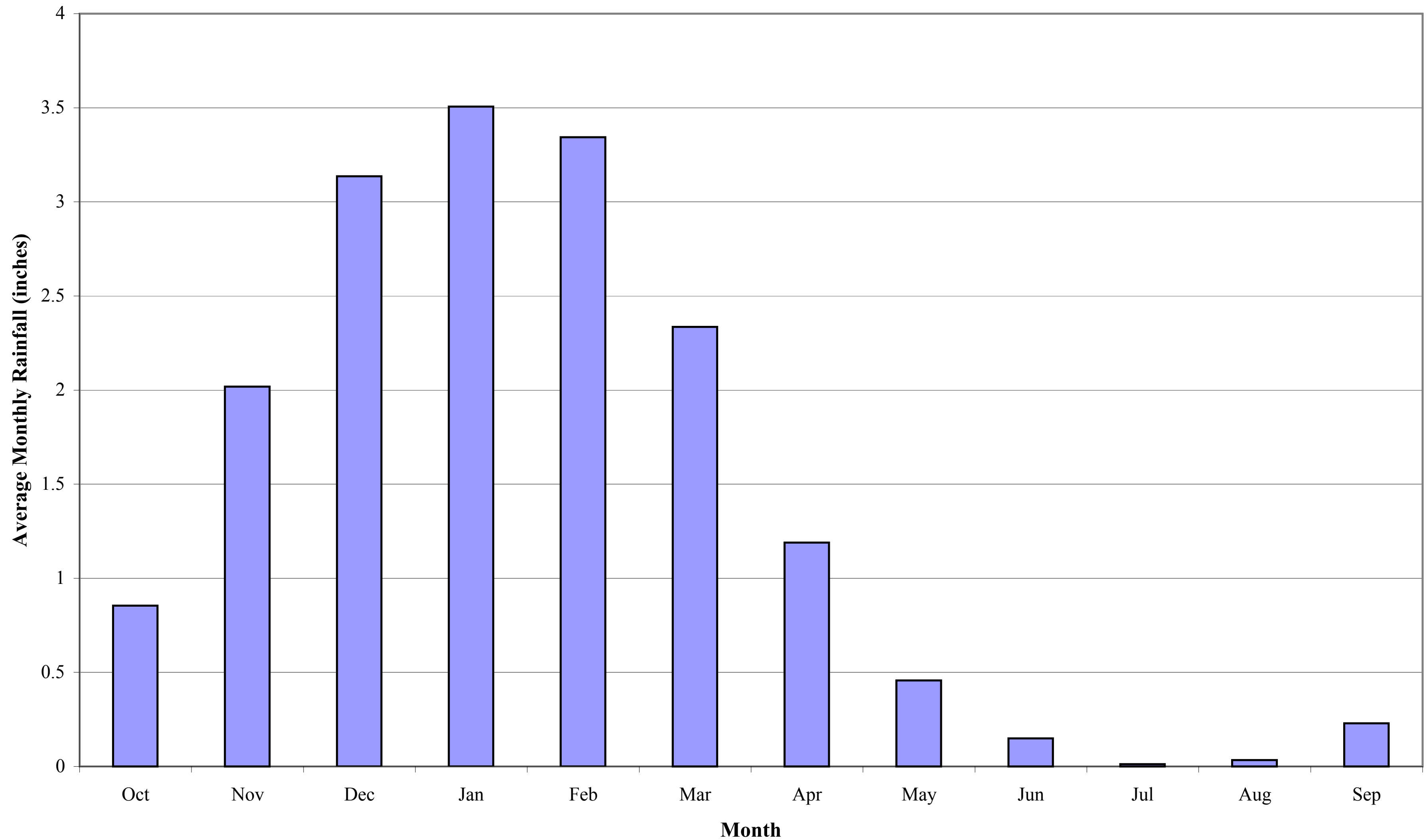
As listed in Table 2.1, there are 22 rainfall stations in and around the YCIGSM study area. These stations were evaluated by their geographic location, length-of-record, and the time interval for which data are available to determine their suitability for inclusion in the YCIGSM.

Four stations were selected to provide rainfall data for the YCIGSM. These stations were selected since the period of record was sufficient, data were not missing, and there was sufficient geographic distribution from the selected stations. Daily rainfall data from the Davis (NCDC # 042294), Sacramento Executive Airport (NCDC # 047630), Woodland (NCDC # 047630), and Winters (NCDC # 049742) were obtained from the National Climatic Data Center. The location of the YCIGSM rainfall stations is shown in Figure 3.8.

These stations were selected to capture rainfall variations throughout the model area. The collected rainfall data were analyzed for accuracy before the input data for the YCIGSM were prepared.

RAINFALL DISTRIBUTION

Each element in the YCIGSM is modeled with unique amount of rainfall in order to capture the spatial distribution of rainfall in the model area. The rainfall at each element is computed from two parameters: (1) an assigned rainfall station for each element; and (2) a weighting factor for



Source: National Climate Data Center (NCDC) Station # 42294

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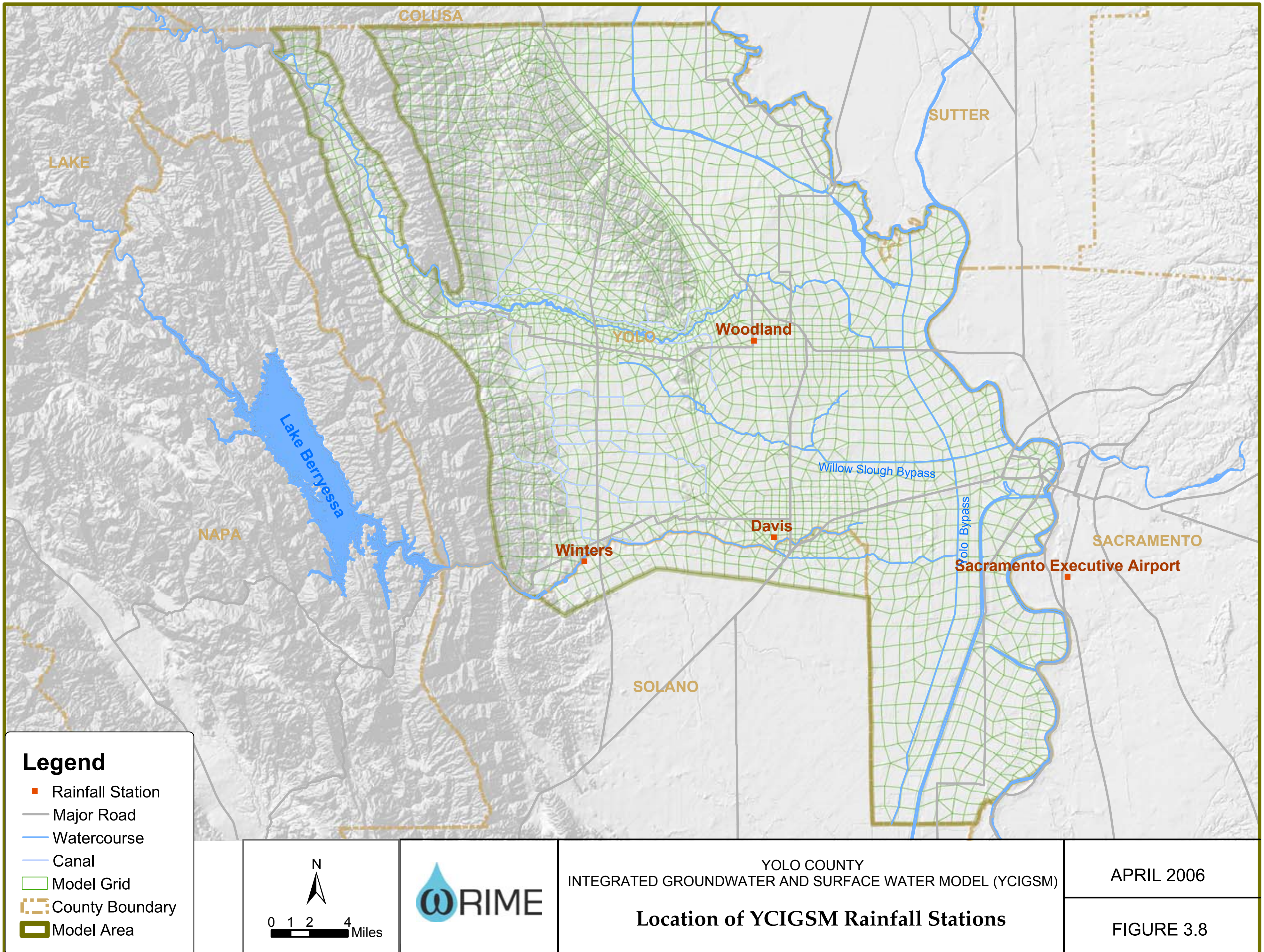
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Davis Average Monthly Rainfall, Water Years 1971-2000

APRIL 2006

FIGURE 3.7



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Location of YCIGSM Rainfall Stations

APRIL 2006

FIGURE 3.8

each element based on the long-term average annual rainfall value at the element, obtained from long-term rainfall isohyetal maps. The weighting factor for an element is the ratio of the long-term average annual rainfall value at the element to the average annual recorded rainfall at the corresponding rainfall station.

As mentioned in Section 2, average annual rainfall contours had been prepared for Yolo County (Borcalli & Associates, 1993). These contours were digitized for the YCIGSM study area and were used to develop the weighting factor for each of the YCIGSM element. The long-term average annual rainfall isohyetal map of the model area is shown in Figure 3.9.

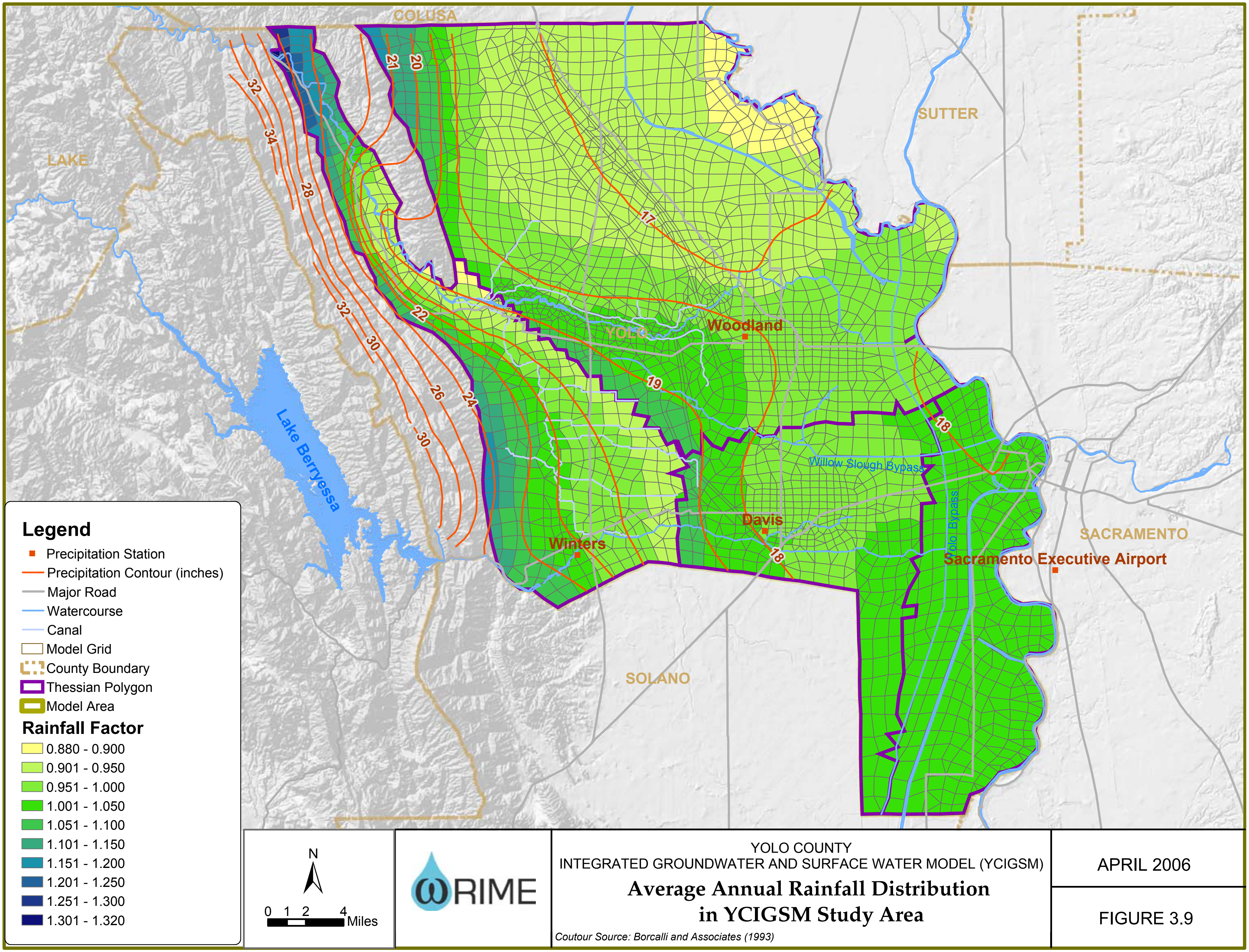
EVAPOTRANSPIRATION DATA

Evapotranspiration (ET) is a measurement of the amount of water loss due to soil evaporation and consumptive use of crops. The rate of evapotranspiration varies by crop type, time of year, and geographic location. Potential evapotranspiration is the maximum amount of consumptive use by crop, if sufficient water were available in the soil environment.

Evapotranspiration data are provided in the YCIGSM as potential evapotranspiration rates varying by (1) crop, (2) time, and (3) model subregion. Davids Engineering (Davids Engineering, 2005) provided reference evapotranspiration data that was based on data from the CIMIS Davis and the NOAA Woodland stations. The provided data were reduced by 7% to reflect lack of vigor in crop growth. The annual reference evapotranspiration for 1971–2000 is shown in Figure 3.10.

STREAM FLOW DATA

The YCIGSM requires daily streamflow data at the boundary of the model. As presented in Section 2, there are 25 stream flow gages that were identified in and near the model area and these data stations were evaluated for proximity to the model boundary, length-of-record, and time interval for which data are available to determine the suitability of including them in the YCIGSM. The stream flow gages that are at the model boundary were selected to provide inflows to the YCIGSM; other stream gage stations were selected for use during model calibration of stream flows. The streamflow gages selected for inclusion to the YCIGSM database are listed in Table 3.5 and their locations are shown in Figure 3.11.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Average Annual Rainfall Distribution in YCIGSM Study Area

Coutour Source: Borcalli and Associates (1993)

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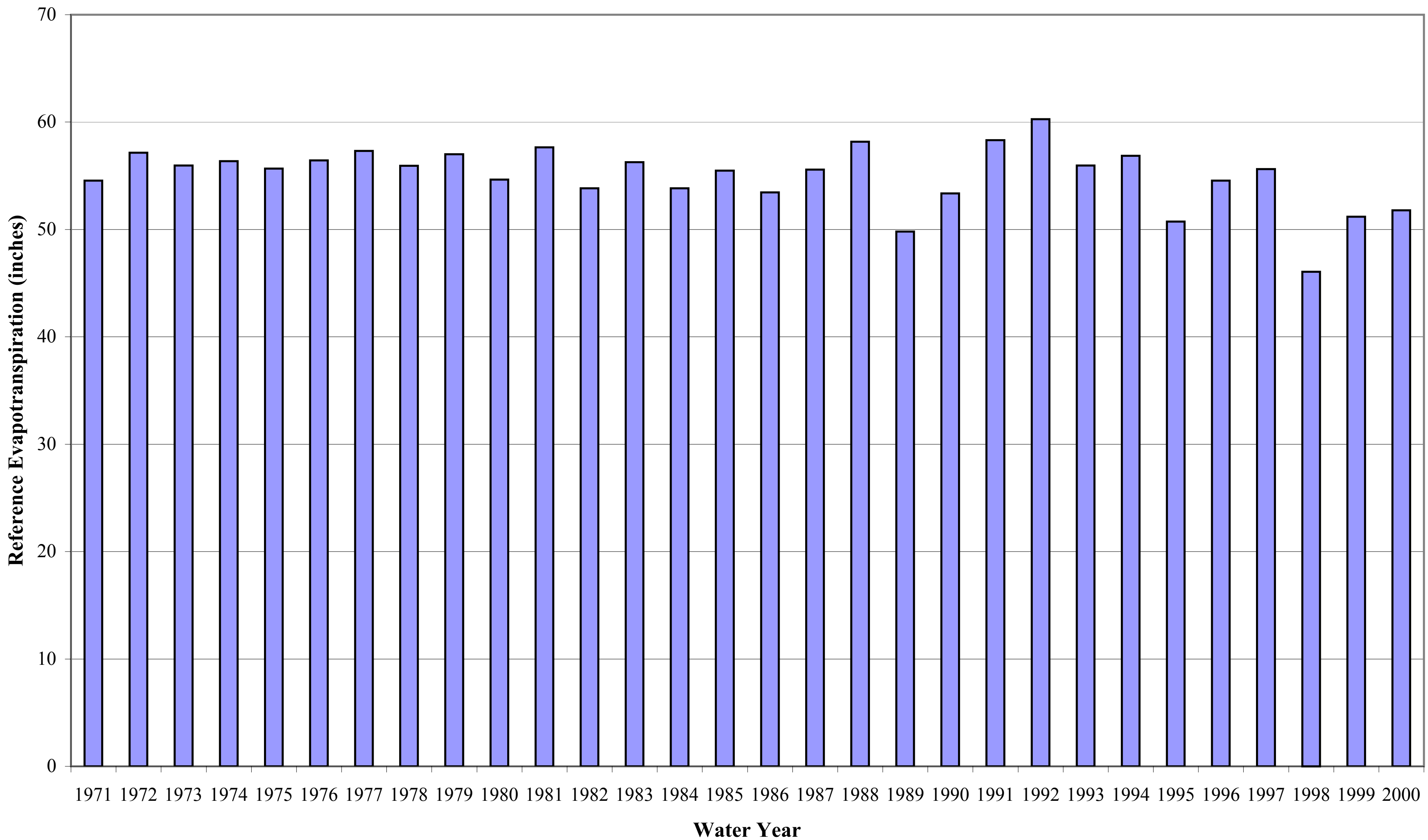
FIGURE 3.9



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Reference Evapotranspiration

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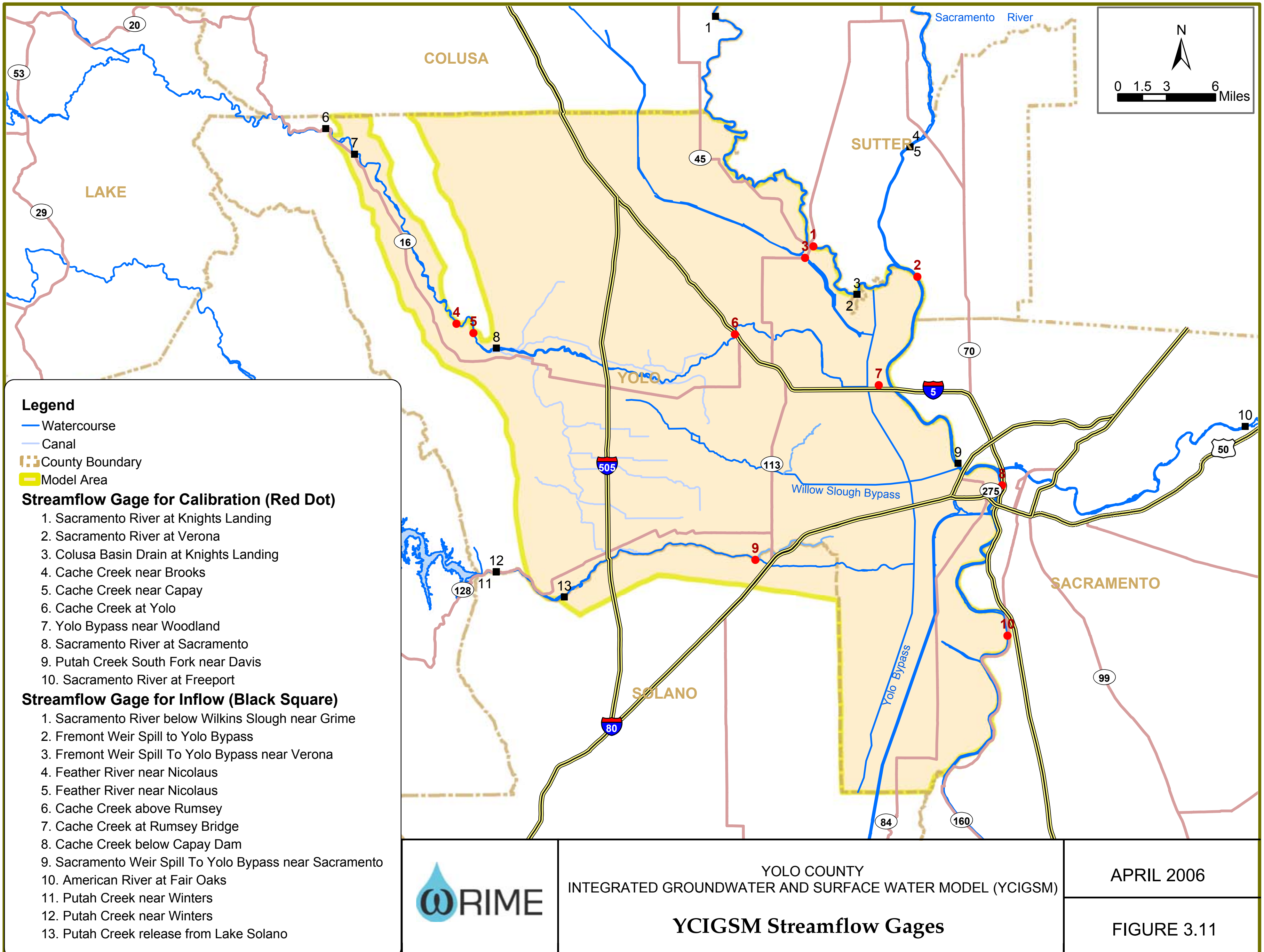
FIGURE 3.10

Table 3.5 Stream Flow Gages used for Inflow Data and Flow Calibration

Site Name	Agency	Site Number	Period of Record
Stream Inflow Data Stations			
Cache Creek above Rumsey	USGS	11451760	1960–2005
	DWR	A81135	
Cache Creek below Capay Dam	YCFCWCD	N/A	1979–2004
American River at Fair Oaks	USGS	11446500	1904–2005
Feather River near Nicolaus	USGS	11425000	1942–1983
	DWR	A05103	1987–2005
Fremont Weir Spill to Yolo Bypass	USGS	11391021	1947–1975
Putah Creek near Winters	DWR	A02930	1978–2003
	USGS	11454000	1930–2005
Putah Creek release from Lake Solano	BOR	SOL	1970–2005
Sacramento River below Wilkins Slough near Grimes	USGS	11390500	1938–2005
Sacramento Weir Spill to Yolo Bypass near Sacramento	USGS	11426000	1943–2005
Streamflow Calibration Data Stations			
Cache Creek near Brooks	USGS	11451950	1983–1986
Cache Creek near Capay	USGS	11452000	1942–1976
Cache Creek at Yolo	USGS	11452500	1903–2004
Colusa Basin Drain at Knights Landing	DWR	A02945	1976–2006
Putah Creek, South Fork, near Davis	DWR	A09115	1976–1987
Sacramento River at Knights Landing	USGS	11391000	1940–1981
	DWR	A02200	1984–2005
Sacramento River at Verona	USGS	11425500	1929–2004
Sacramento River at Sacramento	USGS	11447500	1948–1979
	DWR	A02100	1984–2002
Sacramento River at Freeport	USGS	11447650	1948–2004
Yolo Bypass near Woodland	USGS	11453000	1939–2004



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Streamflow Gages

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FIGURE 3.11

Analysis of Stream Flow Data

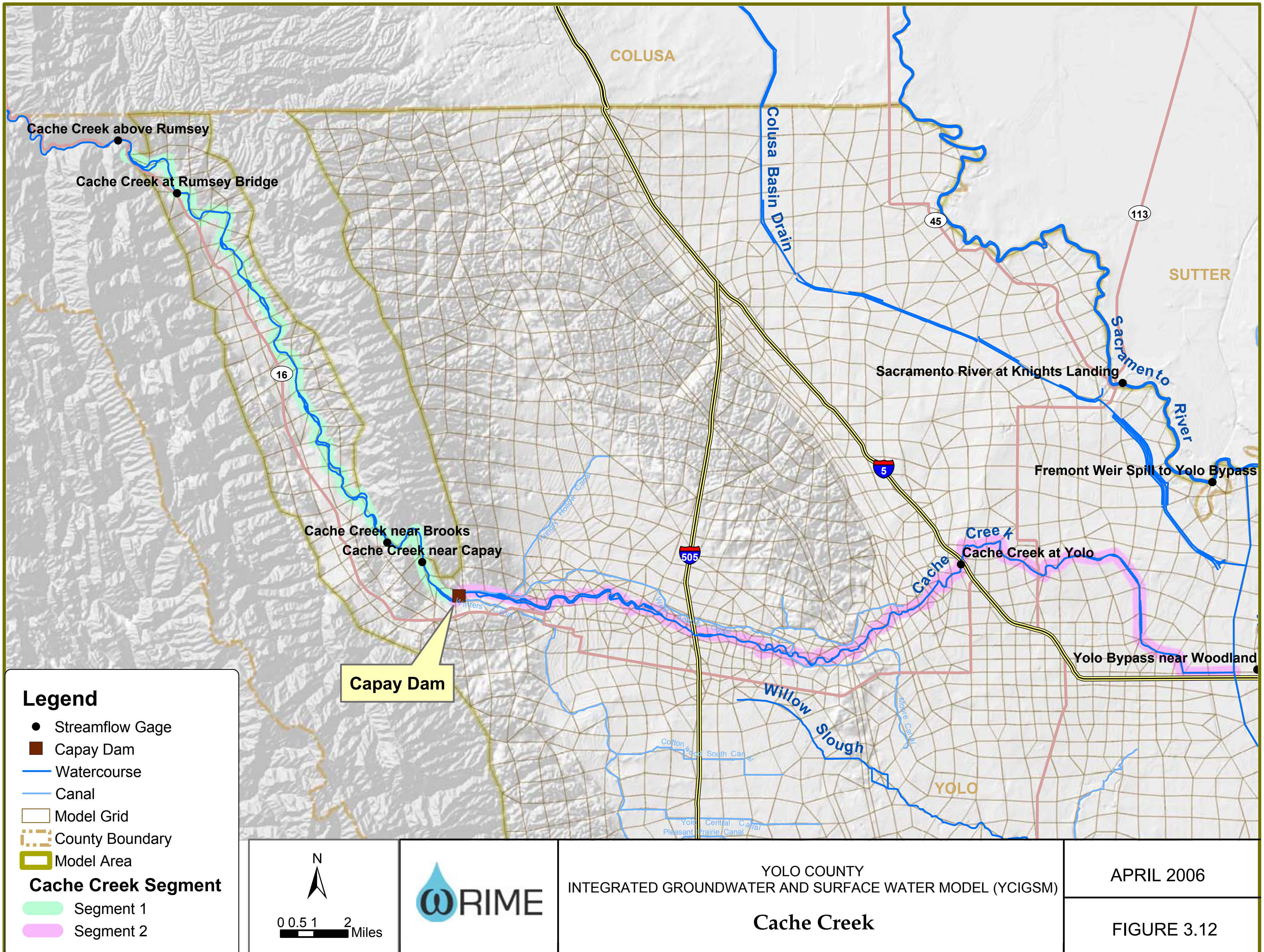
Cache Creek

The inflow and simulation of Cache Creek were evaluated in two segments. The first segment is Cache Creek between the YCIGSM boundary and Capay Diversion Dam (Capay Dam). The second segment is Cache Creek below Capay Dam. Figure 3.12 shows the segments of Cache Creek. For the first segment, the daily stream inflow data for Cache Creek were developed by combining the data from the USGS and DWR gages at Rumsey because their periods-of-record were sequential. The data record is nearly complete. Missing data were estimated by developing regression relationships with upstream and downstream gages. These gages are located on Cache Creek at Brooks and Capay, and at Indian Valley Reservoir and Clear Lake.

For the second segment of Cache Creek, downstream flow is controlled by Capay Diversion Dam (Capay Dam). Capay Dam is an on-stream water storage facility that is operated by the YCFCWCD to provide surface water deliveries during the agricultural growing season. The YCFCWCD does not operate Capay Dam during the non-growing season and, as such, Capay Dam provides no significant storage during this time. Three options were considered for simulating Capay Dam in the YCIGSM because it has significant impact over Cache Creek flow downstream of Capay Dam.

1. The simulation of Capay Dam as a reservoir by YCIGSM was considered but there were insufficient data to simulate Capay Dam as a reservoir; therefore, no further consideration was given to this option.
2. Not simulating Capay Dam in the YCIGSM was considered but it was determined that this was not a reasonable representation of Cache Creek, so no further consideration was given to this option either.
3. The third option was to use daily "head tags," which are recorded observations from Capay Dam operators of their estimates of flow over Capay Dam while the Dam is being operated. These daily data were coupled with estimated Capay Dam flow from daily flow records at Rumsey and at Yolo gages when Capay Dam is not in operation. This option was used in the YCIGSM. The "head tag" data were used from 1979–2000 when Capay Dam was in operation. Capay Dam release data, prior to 1979, were estimated from Yolo Gage data. This estimation was made by using Yolo Gage flow data as Capay Dam release data and then subsequently modifying the release by the difference between simulated streamflow values at Yolo and the observed data.

The YCIGSM was configured to use Capay Dam outflow as inflow data to Cache Creek below Capay Dam. Tables 3.6a and 3.6b show the monthly flow volume of inflow into Cache Creek at Rumsey and Cache Creek below Capay Dam.



Cache Creek

FIGURE 3.12

Table 3.6a Cache Creek Composite Flow Data at Rumsey (acre-feet)*

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Total
1971	4,250	17,600	95,900	147,350	15,950	46,990	34,530	30,030	36,450	38,000	28,320	18,020	513,380
1972	4,380	590	7,480	10,680	15,530	11,480	14,970	19,540	21,850	13,680	50	90	120,320
1973	140	11,300	18,730	188,720	258,270	156,130	27,820	35,210	33,230	33,310	24,010	13,320	800,200
1974	4,520	49,870	109,380	267,170	76,860	258,500	185,920	34,830	37,120	35,740	29,050	11,870	1,100,820
1975	4,350	1,850	2,960	3,280	49,850	169,360	69,670	37,560	36,470	31,420	26,660	11,950	445,370
1976	3,340	2,060	1,580	510	310	13,460	19,670	23,990	21,120	25,510	5,940	130	117,610
1977	80	170	140	570	210	480	70	50	30	0	0	0	1,800
1978	0	600	6,770	102,030	135,520	152,140	78,360	38,380	39,170	38,260	29,870	11,180	632,280
1979	4,600	1,420	1,550	12,630	28,330	18,270	19,740	39,820	42,050	43,460	34,740	12,280	258,890
1980	4,460	3,840	21,220	144,530	195,520	183,380	20,580	27,580	29,860	37,070	25,970	11,590	705,580
1981	4,170	1,780	5,520	22,150	15,780	21,960	26,340	37,650	44,630	45,850	30,540	12,750	269,130
1982	4,100	16,960	82,010	188,200	124,890	102,460	326,080	39,950	36,670	41,130	36,850	16,850	1,016,150
1983	2,300	14,490	100,150	544,420	367,870	681,040	304,110	126,960	57,550	64,530	57,780	42,100	2,363,300
1984	13,490	98,210	323,350	162,930	23,930	34,180	32,220	41,220	44,640	44,740	26,560	10,380	855,840
1985	2,810	10,210	13,300	3,970	9,420	8,600	27,270	42,170	45,310	42,780	24,500	11,140	241,480
1986	1,270	1,800	4,570	14,440	336,180	337,650	43,050	38,320	42,060	40,140	27,950	14,440	901,870
1987	1,790	730	1,070	1,880	6,040	11,790	37,960	48,610	46,940	39,180	26,220	14,180	236,400
1988	1,250	650	7,760	35,150	8,930	24,360	27,930	29,650	39,160	41,100	23,210	11,200	250,340
1989	1,530	3,340	1,470	770	1,250	710,150	56,290	19,450	19,710	13,470	9,380	7,430	844,230
1990	1,510	1,090	1,010	8,030	5,980	3,070	590	750	380	110	70	240	22,820
1991	580	420	660	660	870	32,970	4,750	20,170	25,200	21,090	10,720	6,860	124,940
1992	970	2,000	1,870	1,600	18,020	9,760	8,240	21,460	15,440	15,290	6,790	1,660	103,090
1993	5,430	1,480	19,530	164,580	177,730	110,910	25,070	40,260	37,270	42,670	30,360	20,720	676,000
1994	2,630	960	4,200	3,460	17,080	4,930	27,550	23,190	35,570	28,480	23,250	16,730	188,020
1995	650	660	690	990	790	1,000	890	810	750	780	760	720	9,490
1996	13,210	690	16,590	90,670	282,820	218,800	53,160	40,080	50,110	53,540	42,430	28,020	890,120
1997	12,210	2,860	29,440	400,710	165,280	28,700	31,970	37,520	38,620	38,650	24,680	19,210	829,850
1998	16,800	8,210	19,260	143,180	603,140	357,510	143,250	90,190	98,510	80,920	44,990	24,080	1,630,030
1999	17,830	5,980	21,720	15,210	165,410	187,330	64,830	43,420	40,550	43,500	24,970	14,360	645,100
2000	17,680	3,070	1,290	4,580	47,740	112,800	42,250	49,940	57,110	50,430	32,510	15,310	434,710
Average	5,080	8,830	30,710	89,500	105,180	133,670	58,500	35,960	35,780	34,830	23,640	12,630	574,310

* Developed based on gage records at Rumsey. Missing data were estimated based on surrounding gages.

Table 3.6b Estimated Cache Creek Flow over Capay Dam (acre-feet)

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Total
1971	0	14,750	114,720	159,680	18,810	41,810	3,180	1,110	190	250	300	460	355,250
1972	0	0	3,810	9,560	10,440	3,150	190	0	0	0	0	0	27,140
1973	0	10,890	16,700	211,560	269,650	172,420	1,210	1,840	150	220	140	50	684,820
1974	0	47,990	103,920	276,120	76,300	263,400	190,210	1,780	190	230	330	1,280	961,750
1975	130	0	0	20	54,860	200,590	6,730	2,170	190	200	0	40	264,920
1976	0	0	0	0	0	0	60	0	0	0	0	0	60
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	1,900	94,920	144,890	140,190	63,920	270	460	380	810	410	448,140
1979	120	0	0	13,650	34,620	22,660	470	80	0	220	320	140	72,290
1980	40	1,670	20,590	148,240	230,940	204,480	910	910	120	200	250	140	608,510
1981	3,020	1,280	6,590	30,920	15,830	22,690	920	150	260	310	220	110	82,300
1982	0	19,600	85,020	211,280	130,800	103,770	335,990	2,510	120	180	160	0	889,430
1983	2,170	13,250	107,610	209,220	376,810	667,930	273,500	8,360	200	160	210	60	1,659,460
1984	2,720	96,130	344,140	184,690	24,540	32,170	2,280	2,690	290	290	220	870	691,020
1985	2,010	8,840	15,810	4,830	12,670	4,930	1,050	620	140	150	100	240	51,400
1986	1,830	1,610	4,290	13,290	363,630	388,930	10,840	190	150	140	110	1,670	786,660
1987	2,590	2,440	2,620	3,860	3,630	12,450	270	200	220	220	150	100	28,770
1988	1,060	1,650	10,420	42,210	5,810	2,580	190	190	80	420	80	90	64,750
1989	170	1,110	1,280	3,570	1,860	20,860	320	160	150	90	100	70	29,720
1990	400	0	0	4,860	3,540	2,260	0	0	0	0	0	0	11,060
1991	0	0	0	0	0	30,840	60	60	170	180	120	300	31,730
1992	0	0	0	0	16,050	9,430	180	2,380	170	60	20	0	28,280
1993	0	0	9,690	176,140	187,750	112,260	17,050	680	1,210	610	400	2,430	508,220
1994	2,210	330	8,380	4,840	16,680	5,510	10	60	100	150	190	100	38,560
1995	0	0	1,010	418,680	156,400	425,850	177,630	10,500	1,660	490	330	170	1,192,700
1996	7,540	1,300	19,770	109,130	272,660	180,300	10,630	2,100	380	260	120	160	604,350
1997	800	4,460	45,770	443,220	143,750	9,120	720	460	380	540	790	1,160	651,180
1998	290	2,810	14,100	131,710	703,190	323,890	114,310	43,790	16,160	4,480	2,880	3,000	1,360,600
1999	890	4,170	18,720	9,870	166,350	192,860	59,900	1,080	1,030	930	1,400	1,350	458,550
2000	1,370	2,560	1,740	3,740	62,670	110,640	10,180	1,610	1,000	1,170	630	790	198,100
Average	980	7,890	31,950	97,330	116,840	123,600	42,760	2,860	840	420	350	510	426,330

Sacramento River

The Sacramento River is not gaged at the boundary of the YCIGSM. As such, Sacramento River inflow at the boundary was estimated using data from a gage (Sacramento River at Wilkins Slough) that is located approximately 6 miles from the northern model boundary along the Sacramento River. The inflow data were modified by subtracting surface water diversions made by Sacramento River Central Valley Project Contractors between the Wilkins Slough gage and the model boundary.

Putah Creek

The configuration of Putah Creek is similar to that of Cache Creek. Putah Creek was divided into two segments. The first segment is from the model boundary to Lake Solano. The second segment is downstream of Lake Solano. Lake Solano is an on-stream storage facility operated by the USBR to supply water to Putah South Canal and it controls downstream Putah Creek flows. The first segment inflow data used in the YCIGSM are the gage records of the USGS Putah Creek gage at Winters. The second segment inflow data used in the YCIGSM are the gage records of release from Lake Solano. The YCIGSM was configured to use Lake Solano releases as inflow data to Putah Creek below Lake Solano to accurately represent Putah Creek.

Colusa Basin Drain

The Colusa Basin Drain flow is not measured at the model boundary. Upstream (at Highway 20) and downstream (at Knights Landing) gage records were evaluated as inflow to the Colusa Basin Drain. After evaluating the gage records, it was decided to estimate the Colusa Basin Drain inflow data because of the following:

1. Gage records are not complete for the simulation time period;
2. The measured flow data is inaccurate during high and low flow conditions;
3. Colusa Basin Drain was not a focus area of the YCIGSM development effort; and
4. Colusa Basin Drain flow consists primarily of agricultural return flows.

The Colusa Basin Drain inflow data is based on simulated Colusa Basin Drain flow from the LCBIGSM. Since the LCBIGSM simulation period is from1980–2000, 1971–1979 inflow data were estimated from the simulated LCBIGSM. This was done by ranking the 1971–2000 hydrologic period according to relative wetness or dryness and assigning annual inflow (on a daily basis) based on similar year types. Data development for Colusa Basin Drain was not a priority for this project and as such, the inflow data should be gross estimates.

Feather River

The Feather River is not gaged at the boundary of the YCIGSM. As such, Feather River inflow at the boundary was estimated using data from a nearby gage (Feather River at Nicolas). The gage record is complete through 1983. The remaining data were estimated using regression between the USGS Sacramento River gages at Verona and at Wilkins Slough, and the total surface water diversion amounts between Verona and Wilkins Slough. The resulting regression was

$$\text{Feather River Inflow} = 2.651 * e^{(0.00007 * \text{Sacramento River Flow above Feather Confluence})}$$

The R-Squared for the relationship is 76%.

American River

The American River has a USGS gaging station at Fair Oaks. The values from this gage record were used as inflows to the YCIGSM minus the City of Sacramento River diversions that occur between the gaging station at Fair Oaks and the confluence with the Sacramento River.

Yolo Bypass and Sacramento Bypass

The Yolo Bypass YCIGSM inflow data incorporated the USGS and DWR gages records at Fremont Weir. The Sacramento Bypass inflow data incorporated the USGS gage records from the USGS gage data at that location.

LAND USE AND CROP DATA

The YCIGSM requires two sets of input files for land use: (1) annual crop acreage by model subregions; and (2) elemental land use distribution for land survey years. Both the land use data and crop acreage data are described below.

Land Use Data

The DWR conducts land use surveys by county in order to estimate the changing land and water use patterns. The surveys are completed about every five to seven years for an individual county. Land use data for Yolo and Solano Counties were obtained from the DWR in electronic format for recent years. Older, hardcopy land use surveys were identified but not collected. The survey years for each county differ from one another. The DWR land use survey data that were collected for YCIGSM development are listed in Table 3.7.

Table 3.7 Land Use Surveys used in the YCIGSM

Area	Year of Survey	Comment
Yolo County	1973, 1976, 1981, 1989, 1997	Digital data available for 1989 and 1997
Solano County	1972, 1976, 1980, 1994	Digital data available for 1994

The data from the Yolo County 1989 and 1997 land use surveys and the Solano County 1994 land use survey were directly incorporated into the YCIGSM database. The digitally available land use information was processed for each of the YCIGSM finite element by overlaying the model grid map on the GIS land use map. The YCIGSM elemental land use data requires four general land use categories:

- Agricultural Areas;

- Urban Areas;
- Undeveloped/Native Vegetation; and
- Riparian Vegetation.

Overall, the native vegetation and agricultural areas dominate the general land use in the YCIGSM. The central and eastern portions of the study area are primarily a mixture of agricultural and urban areas, while the western portion of the model area is primarily native vegetation and agricultural. Figure 3.13 shows the predominant land use types associated with YCIGSM model area for the 1994/1997 land use surveys of the corresponding counties.

Crop Data

Irrigated crop acreage data for the Yolo and Solano Counties were obtained from two sources:

- DWR land use surveys (described above); and
- Yolo County Agricultural Commissioner's Annual Reports.

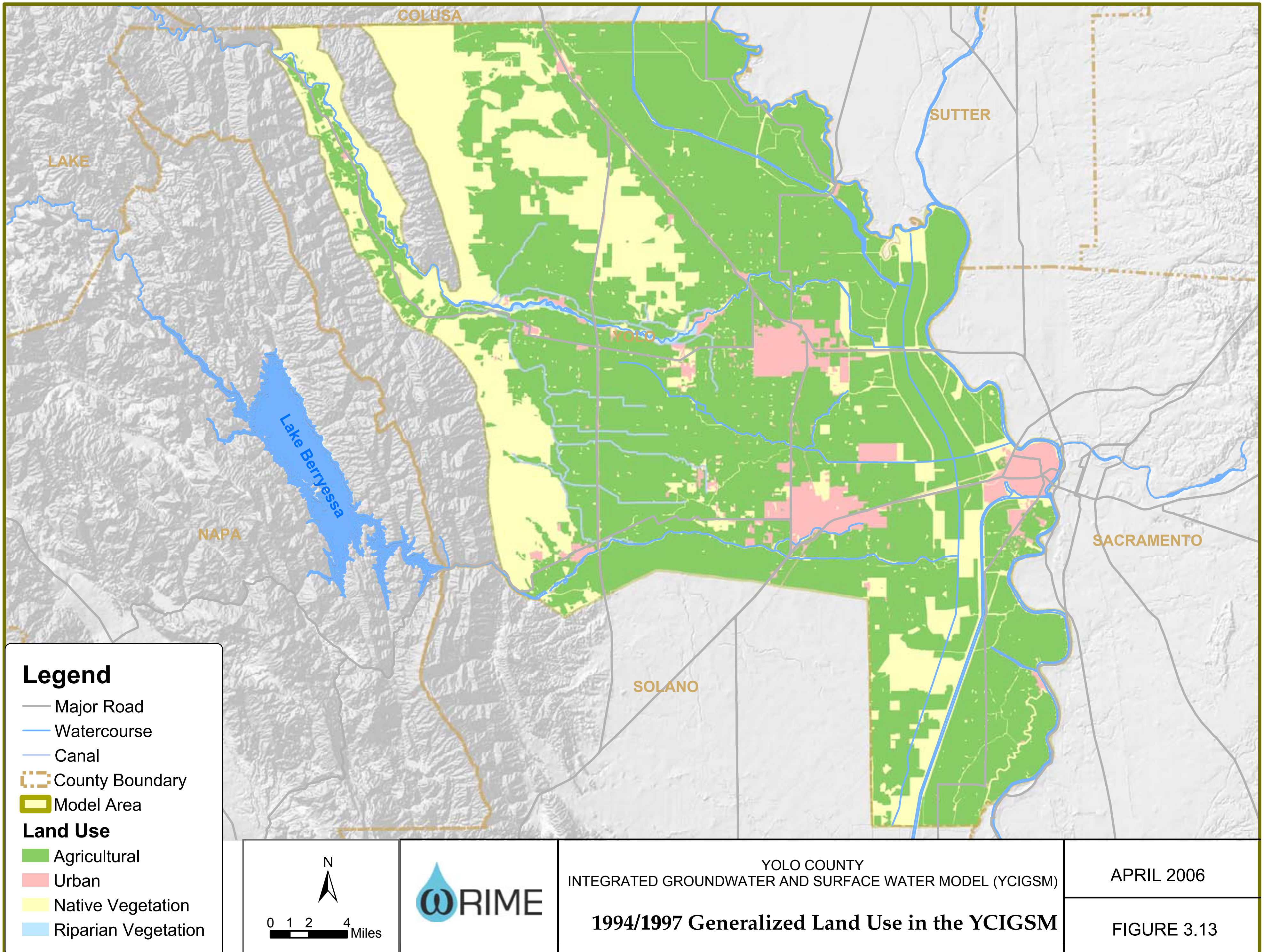
The DWR land use surveys provide the crop distribution and acreage for specific survey years. The Agricultural Commissioner's reports consist of annual countywide agricultural production data based on harvested acreages.

Irrigated Crop Acreage Data

The annual crop data for the YCIGSM study area within Yolo County were developed based the annual Yolo County Agricultural Commissioner's Reports. However, Agricultural Commissioner's Reports contain acreages for more than 40 different crop types. It was decided that only acreage of the most consistently and commonly grown crops would be simulated by the YCIGSM rather than incorporating the acreage of all the different crops that have been grown in Yolo County. Acreage associated with crops that were not included in the YCIGSM was aggregated into generic crop groups. Based on the evaluation of land use surveys and Agricultural Commissioner's Reports, eleven specific crops and six generic crop groups were identified. Table 3.8 lists selected crops and generic crop types and Figure 3.14 shows the crop distribution in the model area.

Table 3.8 YCIGSM Crop Types

Specific Crop Types			
Alfalfa	Almond	Corn	Dry Beans
Prunes	Rice	Tomatoes	Safflower
Sugar Beets	Walnuts	Vineyards	
Generic Crop Types			
Subtropical Fruits	Deciduous Fruits and Nuts	Field Crops	Grain and Hay Crops
Pasture	Trucks, Nursery, and Berry Crops		

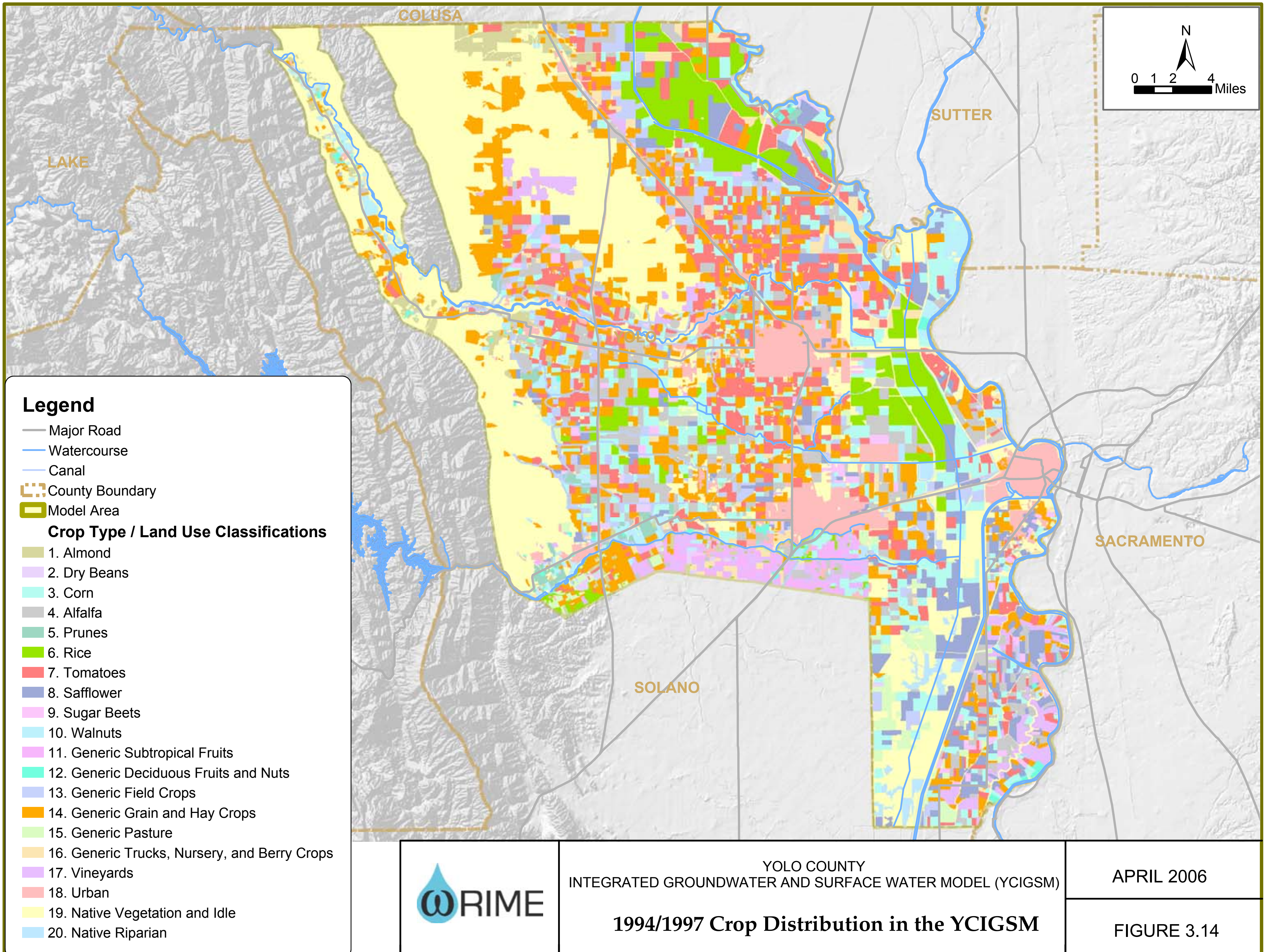


YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

1994/1997 Generalized Land Use in the YCIGSM

APRIL 2006

FIGURE 3.13



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

1994/1997 Crop Distribution in the YCIGSM

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FIGURE 3.14

For Yolo County subregions, the crop acreages listed in the Agricultural Commissioner's Reports were aggregated, on an annual basis, for the crops listed Table 3.8. The resulting 1971-2000 average annual crop acreage values are summarized and shown in Table 3.9. The annual crop acreage data shown in Table 3.9 were disaggregated to the YCIGSM subregions using the crop distribution patterns included in the DWR land use surveys. Crop distribution patterns are the percent of the total crop acreage within a subregion and were determined from 1989 and 1997 digital land use surveys. The 1989 crop distribution pattern was repeated for years prior to 1989, the 1997 crop distribution pattern was repeated for years after 1997, and crop distribution patterns for the intervening years were interpolated.

Table 3.9 Average Annual Crop Acreage (1971–2000)

Subregion	Specific Crop Types											Generic Crop Types						Total		
	Almonds	*Dry Beans*	*Corn*	*Alfalfa*	*Prunes*	*Rice*	*Tomatoes*	*Safflower*	*Sugar Beets*	*Walnuts*	*Vineyards*	*Subtropical Fruits*	*Deciduous Fruits /Nuts*	*Field*	*Grain and Hay*	*Pasture*	*Truck, Nursery, and Berry*	***Agricultural***	***Urban***	***Native Vegetation***
1	2,240	0	20	390	0	0	590	60	0	970	0	0	120	100	2,770	420	50	7,730	80	19,610
2	1,960	0	0	0	0	0	70	0	200	0	0	0	0	0	1,750	0	10	3,990	10	20,470
3	830	50	530	1,740	10	70	600	190	100	40	70	0	10	530	3,070	260	450	8,550	430	2,620
4	0	0	60	830	0	1,330	370	710	100	0	0	0	0	610	310	70	310	4,700	0	1,100
5	0	90	460	420	0	8,310	2,090	2,260	580	130	0	0	0	1,700	2,230	0	600	18,870	10	3,050
6	0	100	300	0	190	2,210	1,480	1,010	0	30	0	0	110	1,790	390	0	190	7,800	0	940
7	300	130	710	1,450	270	0	3,090	130	820	50	80	0	10	2,880	9,360	370	250	19,900	160	12,510
8	2,060	530	2,510	7,860	1,610	2,020	8,190	2,290	580	1,880	50	20	830	6,300	16,980	1,720	310	55,740	1,160	34,950
9	10	30	140	520	0	0	500	260	0	10	880	0	0	440	10,060	270	20	13,140	270	32,250
10	100	10	440	1,230	0	410	1,010	90	670	90	20	0	0	430	1,300	230	70	6,100	30	880
11	260	260	1,350	1,820	0	0	5,210	150	160	210	10	0	20	970	3,730	170	170	14,490	130	1,250
12	0	60	960	1,340	0	1,850	5,850	750	870	190	0	0	0	2,800	3,310	230	370	18,580	80	3,040
13	240	290	5,790	5,890	260	110	12,650	1,960	1,480	570	40	0	60	3,760	15,090	2,390	450	51,030	1,910	8,150
14	0	0	420	320	40	620	760	160	240	20	0	0	0	1,030	1,020	20	50	4,700	5,670	2,330
15	0	230	130	290	0	0	400	80	30	70	50	0	90	490	960	230	90	3,140	3,910	1,650
16	0	400	3,050	1,150	0	6,120	2,330	1,980	1,080	1,370	0	0	70	1,500	2,810	210	480	22,550	110	8,090
17	0	0	430	370	0	0	50	840	270	10	10	0	30	970	1,120	250	110	4,460	5,060	4,920
18	0	120	830	720	0	0	3,230	0	110	50	20	0	0	380	2,810	210	220	8,700	340	480
19	0	60	7,280	4,620	0	50	5,700	8,860	5,550	20	1,690	0	300	6,450	10,110	8,870	250	59,810	230	17,640
20	20	20	140	30	10	0	30	30	0	60	10	0	100	80	100	140	10	780	420	1,240
21	0	210	1,690	710	0	3,280	1,540	1,080	610	730	0	0	40	920	1,740	140	270	12,960	80	4,430
22	0	60	70	110	0	0	190	30	20	20	10	0	20	150	340	70	20	1,110	990	470
23	0	0	50	200	0	0	70	0	0	0	0	0	30	10	10	140	130	640	260	330
24	760	640	20	220	580	0	1,550	100	200	3,130	40	0	1,160	570	2,160	170	100	11,400	100	990
Total	8,780	3,290	27,380	32,230	2,970	26,380	57,550	23,020	13,670	9,650	2,980	20	3,000	34,860	93,530	16,580	4,980	360,870	21,440	183,390

For Solano County subregions, the crop acreage data were calculated from the 1994 land use survey. The data were then assigned to all years of the simulation.

For the YCIGSM, agricultural acreage ranges from about 298,000 acres to 417,000 acres with an average of 361,000 acres through the simulation period. There appears to be a general downward trend in agricultural acreage in the model area as shown in Figure 3.15 even though the annual acreage fluctuates from year-to-year. It should be noted that, on average, grain and hay crops constitute the predominant agriculture in the area, as shown in Figure 3.14 and Table 3.9. Generic grain and hay crops constitute about 26% of the total agricultural acreage in the YCIGSM area.

The YCIGSM also simulates urban acreage. Urban acreage has increased from 17,000 acres in 1971 to about 27,000 acres in 2000, as shown in Figure 3.16. The urban growth is centered on existing urbanized areas in the Cities of Woodland, Davis, and West Sacramento.

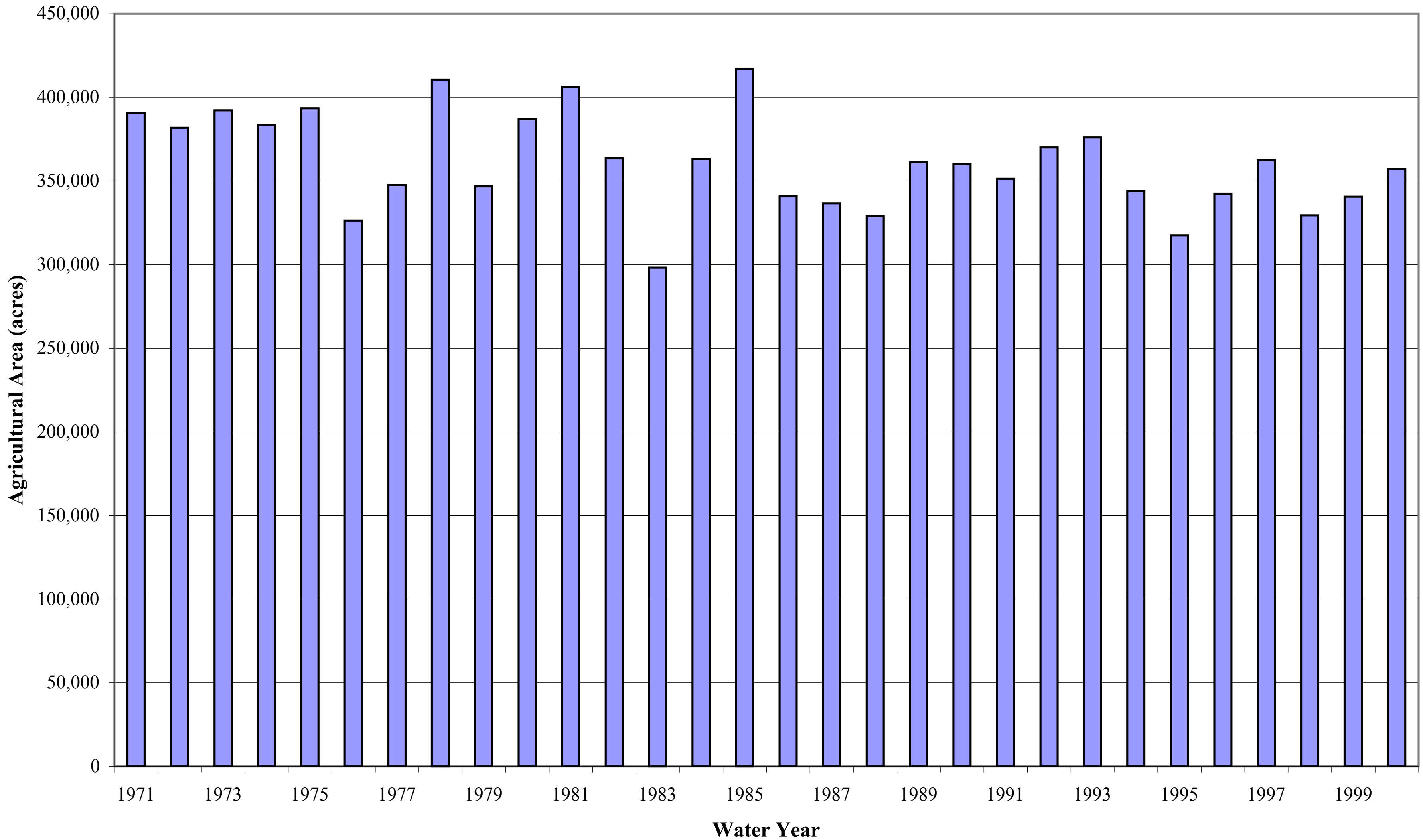
WATER SUPPLY AND DEMAND DATA

The agricultural and urban areas identified in the land use analysis above are the primary areas of water use within the YCIGSM. Agriculture is the single largest user of applied water in the model area (approximately 95% of total water demand in Yolo County). Urban areas are small relative to the agricultural area and their corresponding water use is smaller. The primary source of water supply for agriculture is surface water; groundwater is used by those areas that do not have access to surface water or in years when surface water supplies are scarce because of hydrologic conditions. Groundwater is the primary source of water supply in urban areas. This section describes the water use data within the YCIGSM model area, including:

- Surface Water Diversion Data;
- Groundwater Pumping Data;
- Agricultural Water Demand; and
- Urban Water Demand.

SURFACE WATER DIVERSION DATA

The YCIGSM model area includes several organized water and irrigation districts, which receive substantial amounts of surface water for agricultural purposes. The primary sources of surface water in the model area are Cache Creek, Sacramento River, Colusa Basin Drain, and Putah Creek. Cache Creek water is diverted at the Capay Diversion Dam into the West Adams and Winters Canals for delivery throughout the YCFCWCD service area. Sacramento River water is diverted by many riparian water users and individual water districts. Colusa Basin Drain is diverted by members of the Colusa Basin Drain Association through many riparian diversions. Putah Creek water is diverted at Lake Solano into the Putah South Canal and used by Solano Irrigation District, by UCD for agricultural research, and by other Solano County cities. All Solano County surface water users are outside the YCIGSM. The surface water diversion data were obtained from the DWR–Northern District, the USBR, the YCFCWCD, and



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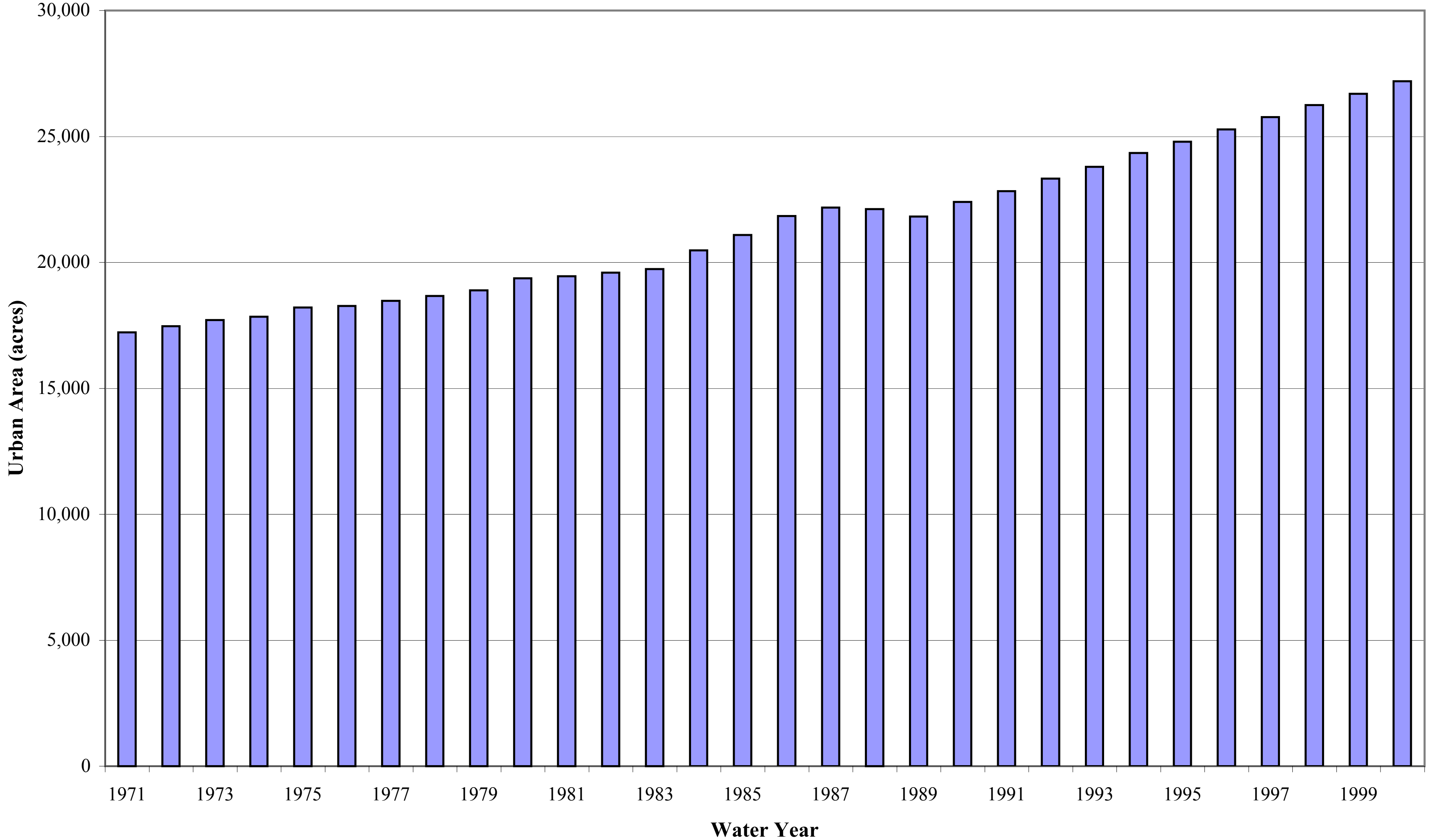
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Agricultural Acreage

APRIL 2006

FIGURE 3.15



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Urban Acreage

APRIL 2006

FIGURE 3.16

the LCBIGSM database. The surface water diversions included in the YCIGSM are described below.

West Adams and Winter Canals

The West Adams and Winters Canals are primary delivery infrastructure for the YCFCWCD. The West Adams and Winter Canals have been in operation since the late nineteenth century. The canals are supplied by Capay Diversion Dam. The diversion dam operates only during the irrigation season which could begin between March and May and end in September or October. During the spring and summer, the peak demand from the canal system could exceed 700 cfs.

Nearly the entire YCFCWCD service areas can potentially use surface water for irrigation. The YCFCWCD surface water supply meets approximately 60% of the agricultural water demand. The YCFCWCD would usually make deliveries in nearly all year types; however, during the 1976–1977 drought and in 1990, the YCFCWCD made no deliveries.

Tehama-Colusa Canal

The Tehama-Colusa Canal service area extends from Red Bluff to Dunnigan and diverts its supply via the Red Bluff Diversion Dam. Diversions to the canal began in 1976. Water districts have been progressively added to the Tehama-Colusa Canal service area as the canal was being constructed. Dunnigan Water District was the last water district to be included in the service area in 1983. There are currently 13 water districts within the Tehama-Colusa service area; Dunnigan Water District is the only one inside the YCIGSM.

Putah South Canal

The Putah South Canal is part of the Solano Project. The Solano Project, which first delivered water in 1959, is a USBR project that stores water in Lake Berryessa for delivery to Solano Irrigation District, Maine Prairie Water District, and several Solano County cities. The contracted water supply for the Solano Project is approximately 207,000 acre-feet per year (AF/yr). All water deliveries of the Solano Project are outside the YCIGSM area. UCD takes Putah South Canal water and it is delivered via gravity-feed pipelines. An annual water supply of 4,000 AF/yr is simulated in the model.

Sacramento River

Several water districts receive water supplies from the Sacramento River. These water districts are referred to as “Settlement Contractors.” There are two types of water supply received by the Settlement Contractors: Base and Project. The "Base" refers to the water supply provided between April and October and that can be diverted without a fee. The "Project" refers to the water supply that is the quantity of Central Valley Project storage water that can be diverted with a fee. The Settlement Contractors within the YCIGSM model area are: RD 108, RD 787, and the City of West Sacramento.

In addition to the Settlement Contractors, there are several farm-scale diverters from the Sacramento River within the YCIGSM model area. These diverters are River Garden Farms, Wallace Construction Company, Hershey, Deseret Farms of California, Conaway Ranch, and Wilson Ranch Partnership.

The YCIGSM includes diverters whose service areas are outside the model area, such as Sutter Mutual Water Company (MWC), Pleasant Grove-Verona MWC, Natomas Central MWC, the City of Sacramento, and 11 other farm-scale growers.

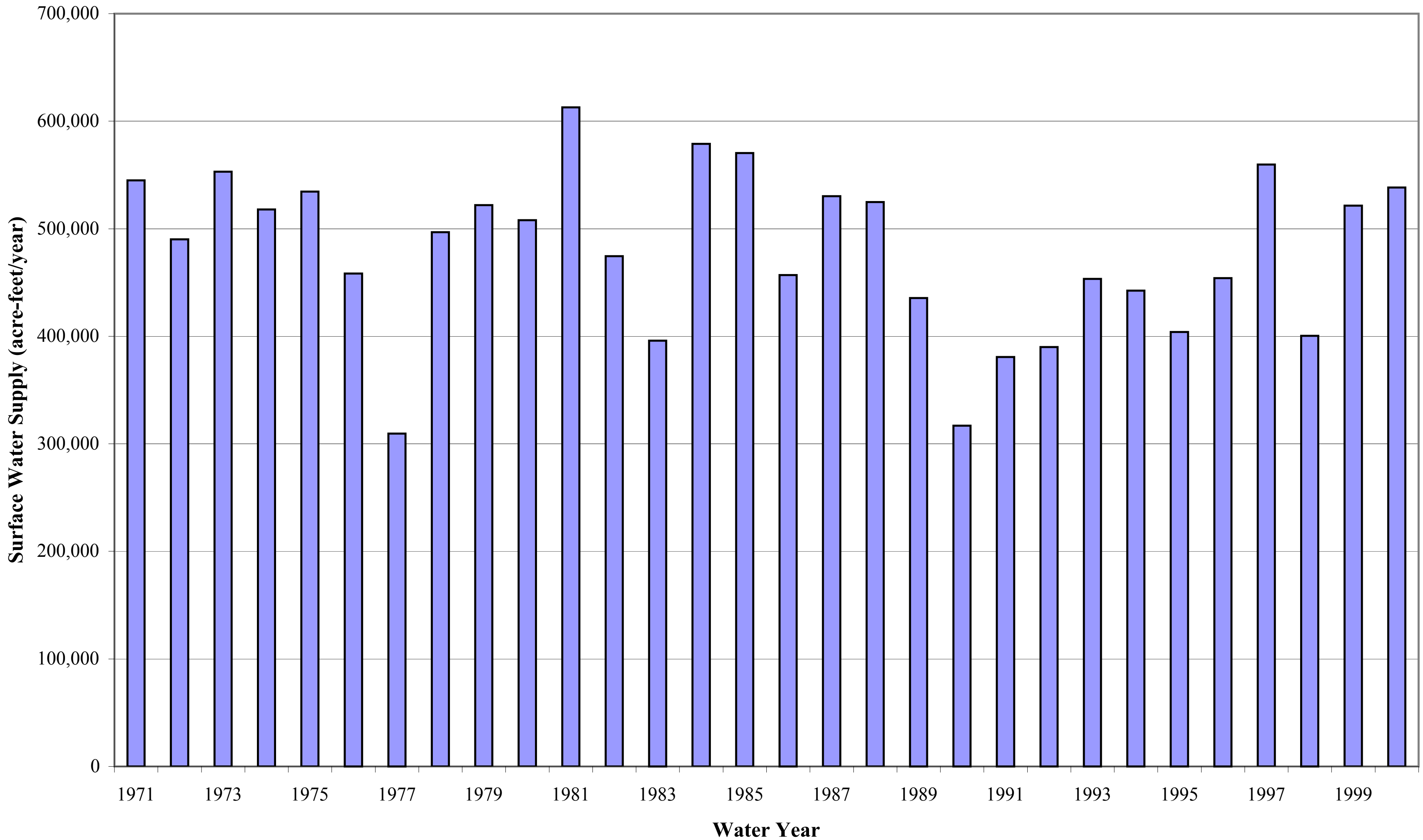
Colusa Basin Drain

The Colusa Basin Drain receives agricultural return flows from Glenn and Colusa County water districts and ephemeral streamflow from western originating creeks. Individual districts utilize the Colusa Basin Drain to make intra-district deliveries. There are no diversion records for the Colusa Basin Drain.

YCIGSM Data

Available surface water diversion and supply data, from the above-listed water delivery systems, were incorporated into the YCIGSM database. The surface water supply data record is nearly complete for all water districts and purveyors in the model area. The average monthly value, for a particular month, was used to complete the surface water diversion data records for those districts without complete records.

Table 3.10 summarizes the average annual surface water diversion data to each YCIGSM subregion. The annual surface water supply for the model area ranges from about 299,000 AF in 1977 to 594,000 AF in 1981 as shown in Figure 3.17.



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Surface Water Supply

APRIL 2006

FIGURE 3.17

Table 3.10 Average Annual Surface Water Supply (1970–2000)

Subregion Name and Number		Annual Average Surface Water Supply by Canal or Water Source (acre-feet)					
		Winters and West Adams	*Tehama-Colusa*	*Colusa Basin Drain*	*Willow Slough*	*Sacramento River*	*Putah South Canal*
1	Capay Valley	-	-	-	-	-	-
2	Buckeye Creek	-	-	-	-	-	-
3	Dunnigan WD	-	6,120	-	-	-	-
4	Colusa Basin Drain North	-	-	2,210	-	-	-
5	RD 108	-	-	30,900	-	31,590	-
6	River Garden Farms	-	-	1,090	-	20,700	-
7	West Yolo North	28,150	-	-	-	-	-
8	West Yolo South	91,130	-	-	-	-	-
9	Dunnigan Hills	1,090	-	-	-	-	-
10	Yolo-Zamora WD NW	-	-	-	-	-	-
11	Yolo-Zamora WD SE	-	-	-	-	-	-
12	Colusa Basin Drain South	-	-	1,200	-	-	-
13	East Yolo South	10,840	-	-	9,690	-	-
14	SOI Woodland	-	-	-	-	-	-
15	SOI Davis	-	-	-	-	-	-
16	Sacramento River	-	-	-	-	64,220	-
17	SOI West Sacramento	-	-	-	-	3,810	-
18	Putah Creek South Fork	-	-	-	-	-	-
19	North Delta WA	-	-	-	-	159,810	-
20	SOI Winters	-	-	-	-	-	-
21	Conaway Ranch	-	-	-	15,790	24,730	-
22	UCD Yolo	-	-	-	-	-	2,500
23	UCD Solano	-	-	-	-	-	1,500
24	Solano Unorganized	-	-	-	-	-	-
Total		**131,210**	**6,120**	**35,400**	**25,480**	**304,860**	**4,000**

GROUNDWATER PUMPING DATA

Groundwater pumping data in the YCIGSM area are not recorded except for municipal pumping. Agricultural groundwater pumping was computed by using the Consumptive Use model component of the YCIGSM. This component of the YCIGSM allows computation of crop consumptive water demand based on irrigated crop acreage, evapotranspiration rate, irrigation efficiency, soil moisture conditions, and rainfall. The agricultural groundwater pumping is calculated to be equal to the crop consumptive water demand minus the surface water deliveries in each subregion. The YCIGSM model is used in this manner to determine the agricultural groundwater pumping for each model subregion.

The source of water for urban water use within the model area is entirely groundwater except for West Sacramento, which started using surface water as its supply source in 1988. Otherwise, urban water demand, supplied by groundwater pumping, was added to the computed agricultural groundwater pumping to determine the total groundwater pumping for each model subregion.

The groundwater supply varies annually due to changes in agricultural demand and hydrologic conditions. The annual groundwater supply ranges from about 386,000 AF in 1998 to 669,000 AF in 1972 as shown Figure 3.18.

AGRICULTURAL WATER DEMAND

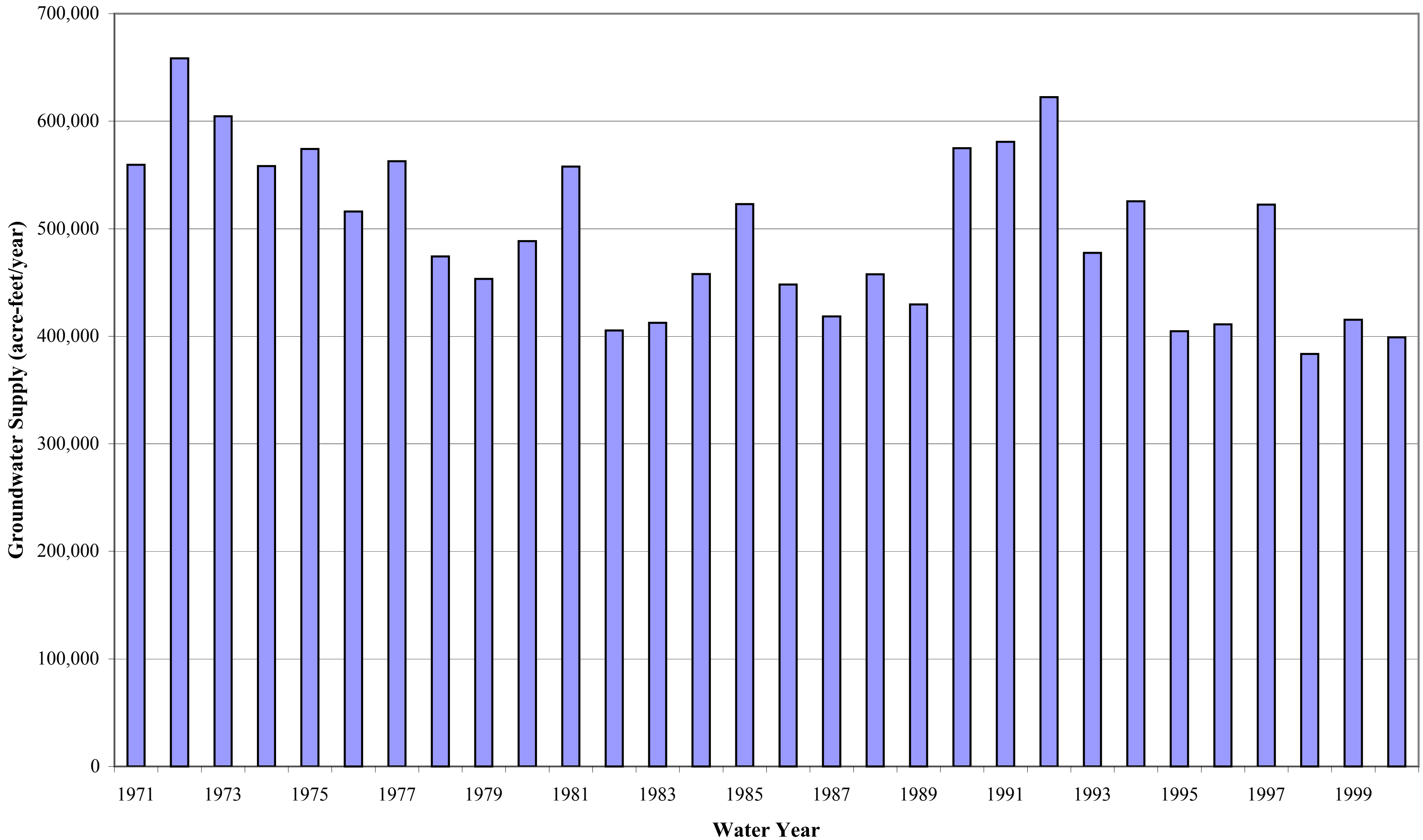
As mentioned above, the agricultural water demand is calculated by using the Consumptive Use model component of the YCIGSM. The consumptive use of a crop is the amount of water required to satisfy evapotranspirative demand of the crop, which includes evaporation and transpiration loss from crop foliage and adjacent soils. The portion of the consumptive use that is met by irrigation water is called the consumptive use of applied water (CUAW). The agricultural water demand is equal to CUAW divided by the irrigation efficiency. The irrigation efficiency data for the model subregions were estimated based on the irrigation efficiency data developed by the DWR–Northern District for Colusa County in an unpublished document. These irrigation efficiencies are reasonably consistent with those included in DWR Bulletin 160-03 and with those used in the LCBIGSM. These irrigation efficiency data were incorporated into the YCIGSM database to compute agricultural water demand.

The calculation of agricultural water demand was modified to consider on-farm irrigation practices. In the Dunnigan WD, grain and hay crops were extensively dry farmed until 1983. This coincided with the completion of the TCC. After completion of the TCC, the dry-farming of grain and hay crops was no longer as extensive. The agricultural water demand of the Dunnigan WD subregion was reduced to reflect dry-farming practices prior to 1983.

The estimated annual agricultural demand ranges from a minimum of about 742,000 AF in 1998 to a maximum of about 1,142,000 AF in 1981 and averages about 940,000 AF/yr over the 1971-2000 study period, as shown in Figure 3.19. The annual variability in agricultural demand results from changes in crop acreage and crop mix and in hydrologic conditions. Agricultural water use accounts for about 95% of the water use in the YCIGSM area.

URBAN WATER DEMAND

Urban water demand consists of municipal and rural water use. Municipal water use has been measured in Woodland, Davis, and UCD for the entire simulation period. The records of municipal water use in Winters and West Sacramento are not complete for the model simulation period and were estimated using annual population and water use per capita values. Estimates of urban/rural water use are not available in the YCIGSM model area. The urban



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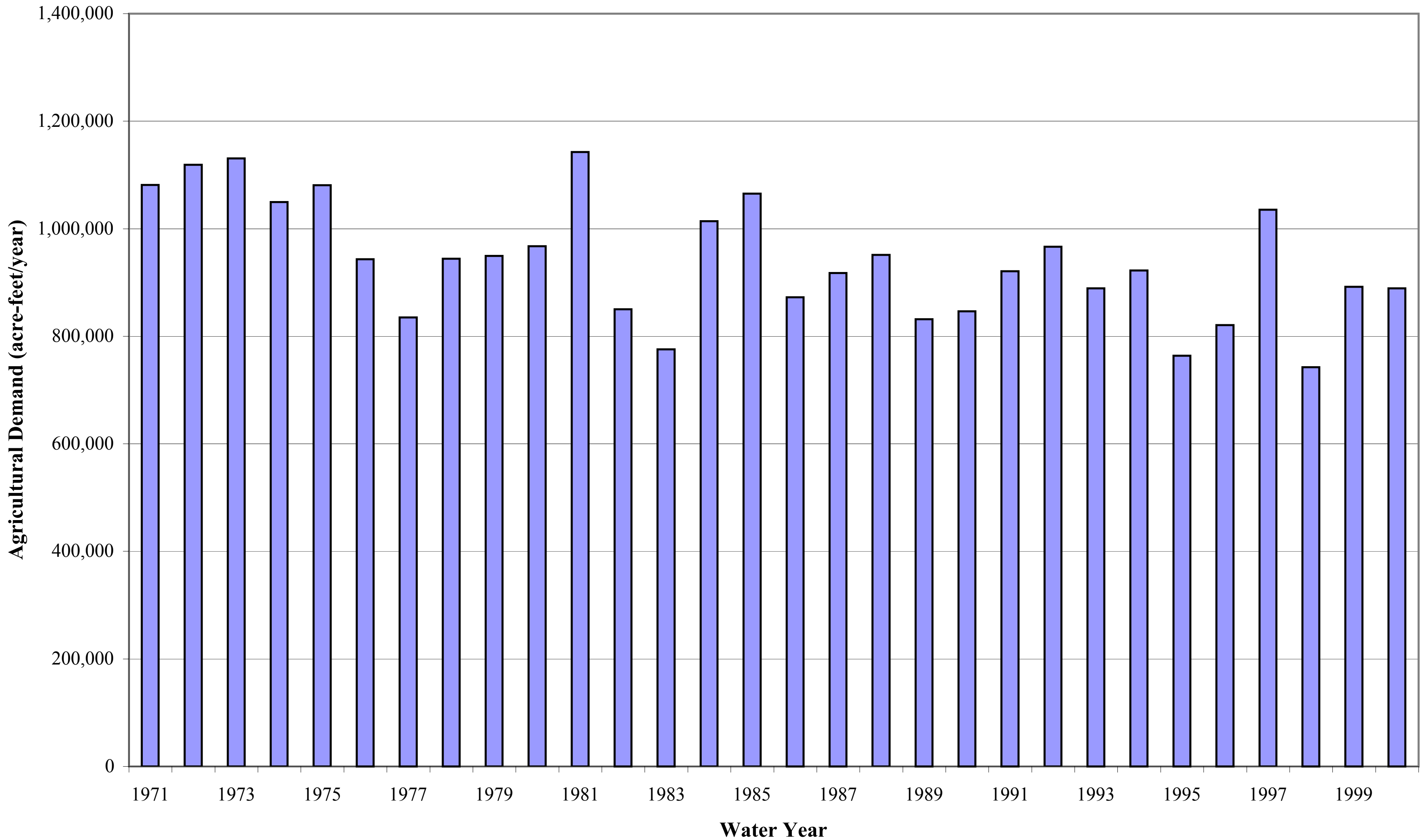
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Groundwater Supply

APRIL 2006

FIGURE 3.18



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Agricultural Water Demand

APRIL 2006

FIGURE 3.19

water demand was assumed equal to the Winters unit water use of 2.1 AF per acre of rural urbanized area in the YCIGSM study area.

The annual urban water use ranges from a minimum of about 34,000 AF in 1971 to a maximum of about 65,000 AF in 2000, as shown in Figure 3.20. The steady increase in urban water use reflects the increase in population and corresponding urban acreage. Urban water use is less than 5% of the total water use in the YCIGSM area.

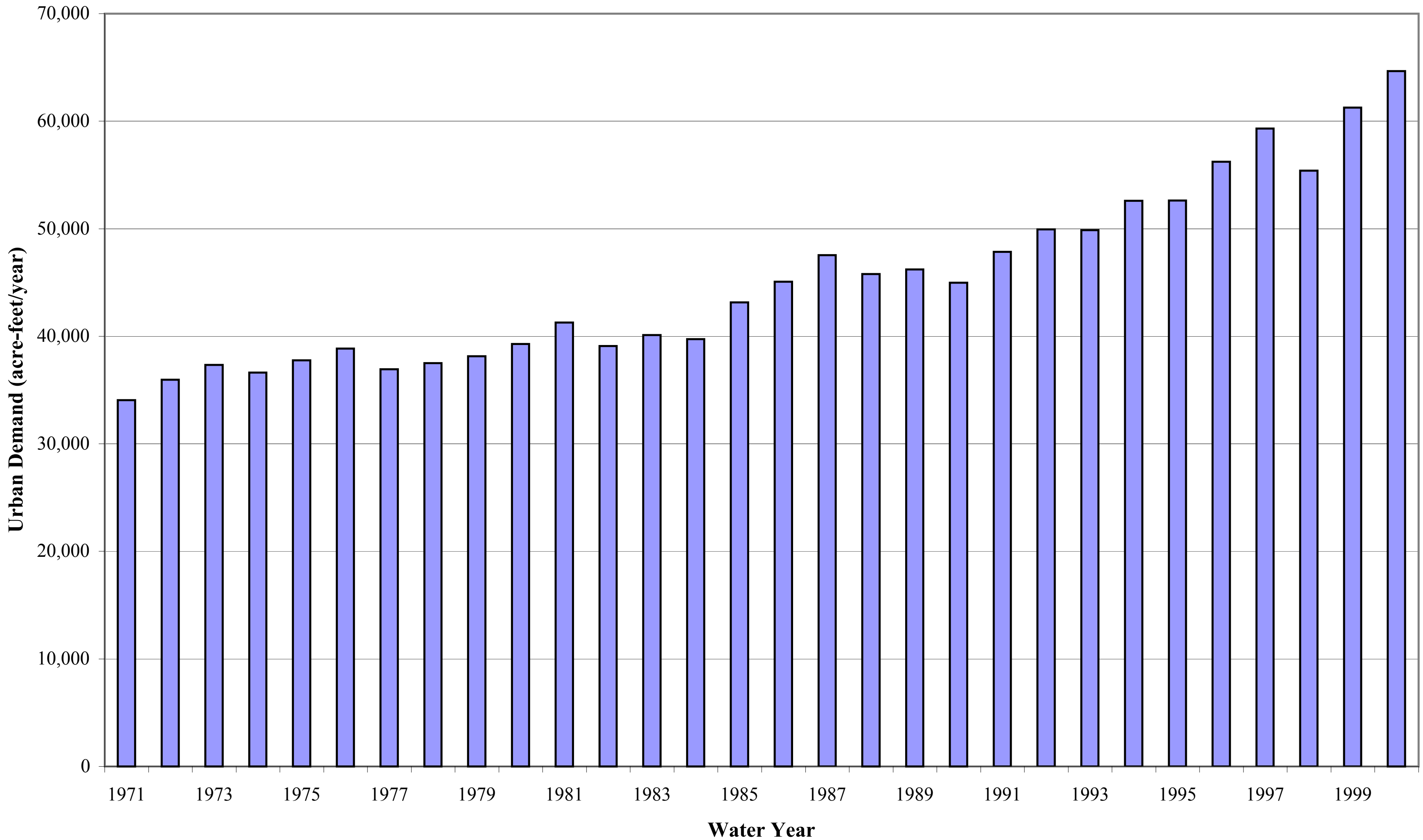
AQUIFER PARAMETER DATA

The geology and hydrogeology of the Sacramento Valley have been investigated since the 1920s. Numerous reports (see Section 7 – References) on the Valley provide regional information on the geology, hydrogeology, aquifer characteristics, and storage capacity of the aquifer system in the study area. Key reports include:

- *Geologic Features and Ground-water Storage Capacity of the Sacramento Valley, California* (Olmstead H. F., and Davis, G. H., 1961);
- *Geology of the Fresh Groundwater Basin of the Central Valley, California, with texture maps and sections* (Page, R. W., 1986);
- *Phase II Deep Aquifer Study* (Brown and Caldwell, 2005);
- *Putah Creek Cone Investigation* (State of California Department of Public Works Division of Water Resources, 1955);
- *Ground-water Flow in the Central Valley, California* (Williamson, A. K. et al., 1989); and
- *Investigation of Groundwater Resources Yolo County, California* (Scott, V. H. and Scalmanini, J. C., 1975).

The available aquifer parameter data, as provided in the reports mentioned above, are summarized in Table 3.11. Hydraulic conductivity estimates are reported to vary over a wide range from 1 ft/day to 400 ft/day. The highest hydraulic conductivity areas coincide with the gravel-mining zone within the Cache Creek area. The hydraulic conductivities are also high in the Lower Colusa Basin area.

The YCIGSM uses a larger finite element grid, called parametric grid, to specify the spatial variation of aquifer parameters in the model area. The aquifer parameters are provided for each layer at the control points (i.e., nodes) of this parametric grid and an interpolation scheme is used to internally calculate aquifer parameter values at model nodes and elements, which are used in the solution of finite element equations of groundwater flow. The parametric grid facilitates the definition of zones of low and high permeability areas within the model area. In addition, the initial estimates of model parameters for the YCIGSM were developed based on



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Annual Urban Water Demand

APRIL 2006

FIGURE 3.20

these previously reported values. It should be noted that the reported ranges of values of aquifer parameters are used in the YCIGSM as initial estimates and are further refined during the model calibration.

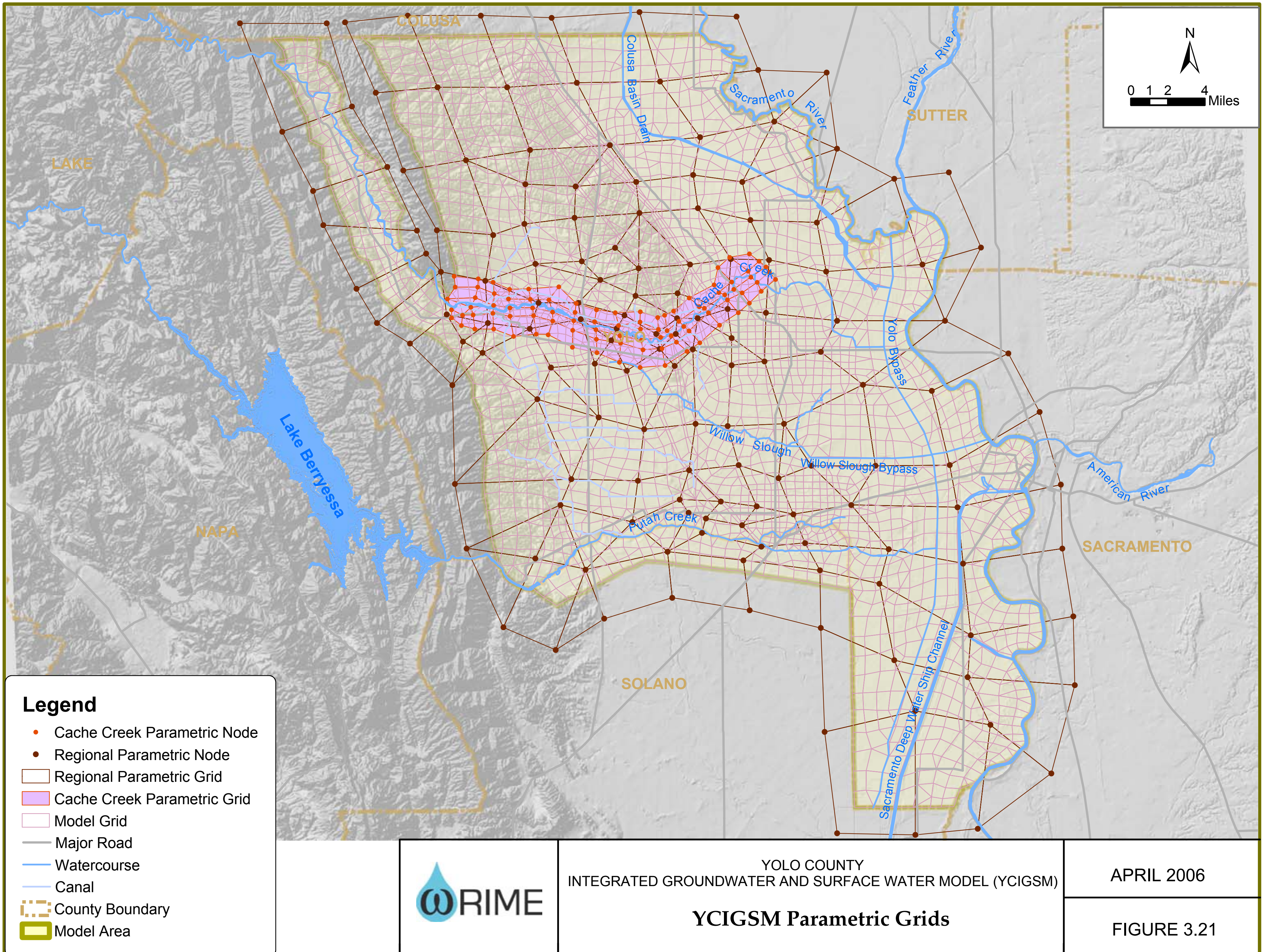
Table 3.11 Summary of Aquifer Parameter Data in the YCIGSM

Location/General Area	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/Day)	Storage Coefficient	Model Aquifer
Dunnigan WD	5,600 – 13,000		9 – 23*10^{-4}	2
Model Wide		8 – 38	0.05 – 0.09	1
		4 – 20	0.05	2
		1 – 20	0.05	3
Yolo County	3,000 – 46,000		0.073	1
			0.065 – 0.072	2
RD 108	26,000 – 52,000	13 – 67	0.08 – 0.09	1
		37 – 174		2
RD 108, RD 787, RD 730, Yolo-Zamora WD	26,000 –65,000	64	0.06 – 0.12	1
		19 – 119		2
Yolo-Zamora WD	9,000 – 26,000	48	0.07 – 0.09	1
		41 – 118		2
Woodland Area	10,000 – 105,000		0.0308	1
Davis Area	4,000 – 18,000			2
Capay Valley	9,000 – 10,000			2
Cache Creek Above Moore's Siphon	25,000 – 260,000			1
Cache Creek Below Moore's Siphon	1,000 – 18,000	400		2
KLRWD	26,000 – 52,000	21	0.06 – 0.11	1
		21 – 139		2

Two parametric grids were developed for the YCIGSM. One parametric grid was developed to cover the entire YCIGSM grid and another local parametric grid was developed for the Cache Creek area. The local parametric grid provided greater control for determining subregional aquifer parameters around Cache Creek. Figure 3.21 shows the parametric grids used in the YCIGSM.

INITIAL CONDITIONS DATA

The calibration period for the YCIGSM is 1971–2000. The groundwater elevation at each node for each aquifer layer at the initial time of simulation provides the starting conditions for the groundwater flow simulation in the YCIGSM. The initial groundwater levels for the YCIGSM were developed based on observed October 1970 water level data from the 769 wells identified



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Parametric Grids

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FIGURE 3.21

in Figures 2.16. A contour map (Figure 3.22) was developed using this data and the initial groundwater elevation at each node of the YCIGSM was developed by overlaying the contour grid and the model grid.

BOUNDARY CONDITIONS DATA

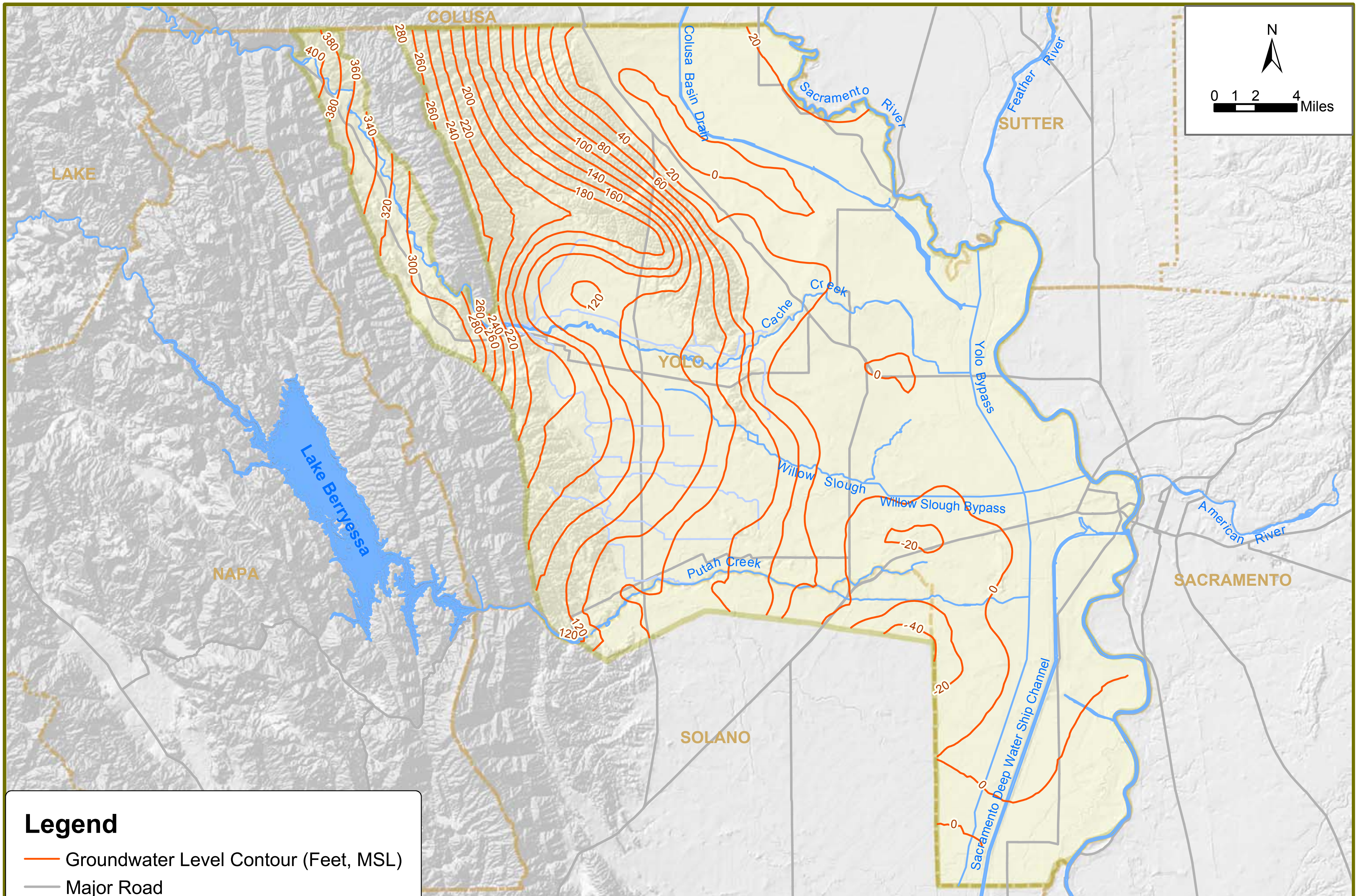
The boundary conditions are specified in the YCIGSM at all boundary nodes to account for both surface and subsurface flows through the model boundary. There are five types of boundary conditions that can be specified in the YCIGSM:

- Specified flux;
- Fixed head;
- General head (the flux depends on the specified head value outside the model area);
- Head-discharge rating table; and
- Mountain or ungaged watershed inflows.

The boundary conditions for the YCIGSM were developed for the boundaries of the model area and for areas tributary to the model area. The boundaries of the groundwater model include:

- Northern Boundary along the Yolo/Colusa County line;
- Eastern Boundary along the Sacramento River;
- Southern Boundary along the Yolo/Solano County line;
- Southern Boundary along the Solano Irrigation District (ID) boundary;
- Western Boundary along the geologic contact with the marine deposits of the Coast Range; and
- Inflow from mountain watersheds in the foothills of the Coast Range that drain into the YCIGSM study area.

The boundary conditions for each model layer are summarized on Table 3.12 and are described below.



Legend

- Groundwater Level Contour (Feet, MSL)
- Major Road
- Watercourse
- Canal
- County Boundary
- Model Area

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INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Initial Groundwater Level Conditions in Fall 1970

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FIGURE 3.22

Table 3.12 YCIGSM Boundary Conditions

Layer Number	YCIGSM Boundary			
	North	South	East	West
	Colusa County	Solano County	Sacramento River	Geologic Contact
1 (Alluvium)	General Head (Variable Head)	General Head (Variable Head)	General Head (Variable Head)	Ungaged Watershed
2 (Upper Tehama)	General Head (Variable Head)	General Head (Variable Head)	General Head (Variable Head)	No Flow (Impermeable)
3 (Lower Tehama)	General Head (Variable Head)	General Head (Variable Head)	General Head (Variable Head)	No Flow (Impermeable)

Northern Boundary along Yolo County Boundary

The northern boundary of the YCIGSM is coincident to the Yolo/Colusa County boundary. The Yolo County boundary bifurcates the Colusa Groundwater Subbasin. Historical observations and anecdotal information suggest that there is no or little groundwater flow across Yolo/Colusa County boundary. The groundwater contours for initial conditions shown previously in Figure 3.22 are almost perpendicular across the county boundary, indicating that there is little groundwater flow across the boundary. A general-head boundary condition was established along this boundary for all layers of the YCIGSM.

Eastern Boundary along the Sacramento River

It is believed that the Sacramento River interacts with the groundwater basin along the eastern edge (boundary) of the YCIGSM. While the Sacramento River is in direct connection with top alluvium (YCIGSM Layer 1), it is generally accepted that the Sacramento River also interacts with the top portion of the Tehama formation (YCIGSM Layer 2). An analysis of the historical groundwater levels across the Sacramento River showed that the groundwater levels do not fluctuate much across the river. However, there are no previous estimates of subsurface flux across the Sacramento River. In order to account for this historical observations and lack of specific data about subsurface flux across the river, it was concluded during the model development process that general head boundary conditions for all layers of the YCIGSM along the Sacramento River provided the best estimates of field conditions. This general head boundary condition was refined during the calibration process.

Southern Boundary along the Yolo/Solano County Boundary and the Solano ID Boundary

The YCIGSM southern boundary is defined in two segments. The first segment is the Yolo/Solano County boundary and the second segment is along the Solano ID boundary. Both boundaries are discussed below.

The southern boundary of the YCIGSM, located along the Yolo County boundary, was selected for the model based on constraints of the modeling effort. However, historical observations indicate that there is groundwater flow across the Yolo County boundary. There are no previous estimates of the subsurface flux across the boundary. In order to account for this historical observation and lack of specific data about subsurface flux across the boundary, it was concluded during the model development process that a general head boundary condition for all layers of the YCIGSM along the boundary provided the best estimates of field conditions.

The second segment along the southern boundary is located along the Solano ID boundary. This boundary was selected so that there was sufficient distance between the model boundary and Putah Creek. The model boundary was originally located at Putah Creek. However, research indicated that Putah Creek is a dynamic stream in relation to its interaction with the underlying groundwater system. In addition, groundwater pumping in the City of Davis and at UCD has created noticeable flow gradients towards their wells and land subsidence in the Davis area has been measured. Based on these, it was decided that the YCIGSM model boundary should be moved away from Putah creek and into Solano County. Two options were considered for the model boundary. The first option was to move the boundary to the northern boundary of Solano ID. The Solano ID water supply is surface water from the Solano Project. The surface water supply has allowed groundwater levels to recover and stabilize within the Solano ID service area. The area between Putah Creek and the Solano ID is unorganized and uses groundwater as its water supply source. This option was used in the YCIGSM because the model boundary, at this distance from Putah Creek and Davis, would have little impact on the simulation of Putah Creek groundwater/surface water interaction and on any future simulation of land subsidence processes in the Davis area. The second option was to move the model boundary to the Sacramento/San Joaquin River delta area so that the boundary condition would be a no-flow condition. The second option was dropped since it was determined that data requirements for this option would be significant (e.g., water demand and supply data would need to be collected from the Cities of Dixon, Vacaville, and Vallejo; the geology data of the Solano Groundwater Basin would need to be collected; and agricultural water supply for Solano ID and RD 2068 would need to collected). Thus, the Solano ID boundary is defined by a general head boundary for all layers of the YCIGSM and is believed to provide the best estimates of field conditions.

Western Boundary along Geologic Contact

The western boundary of the model area is the geologic contact, which defines the western extent of the groundwater basin. Therefore, a no-flow boundary was incorporated in the YCIGSM for all layers along the western boundary.

Ungaged Watershed Boundary Conditions

There are nine small, ungaged, watersheds located in the foothills of the Coast Range along the western boundary of the model. These watersheds are ungaged and drain into the YCIGSM model area. Most of these ungaged watersheds drain into the Capay Valley above the Capay Diversion Dam. These ungaged watersheds along the western boundary are included in the YCIGSM to account for ungaged surface flow and subsurface flow into the model area. The locations of these watersheds are shown on Figure 3.23. Six of the ungaged watersheds drain into Subregion 1 – Capay Valley, above Capay Dam. Three ungaged watersheds drain into Subregion 8 – West Yolo – South.

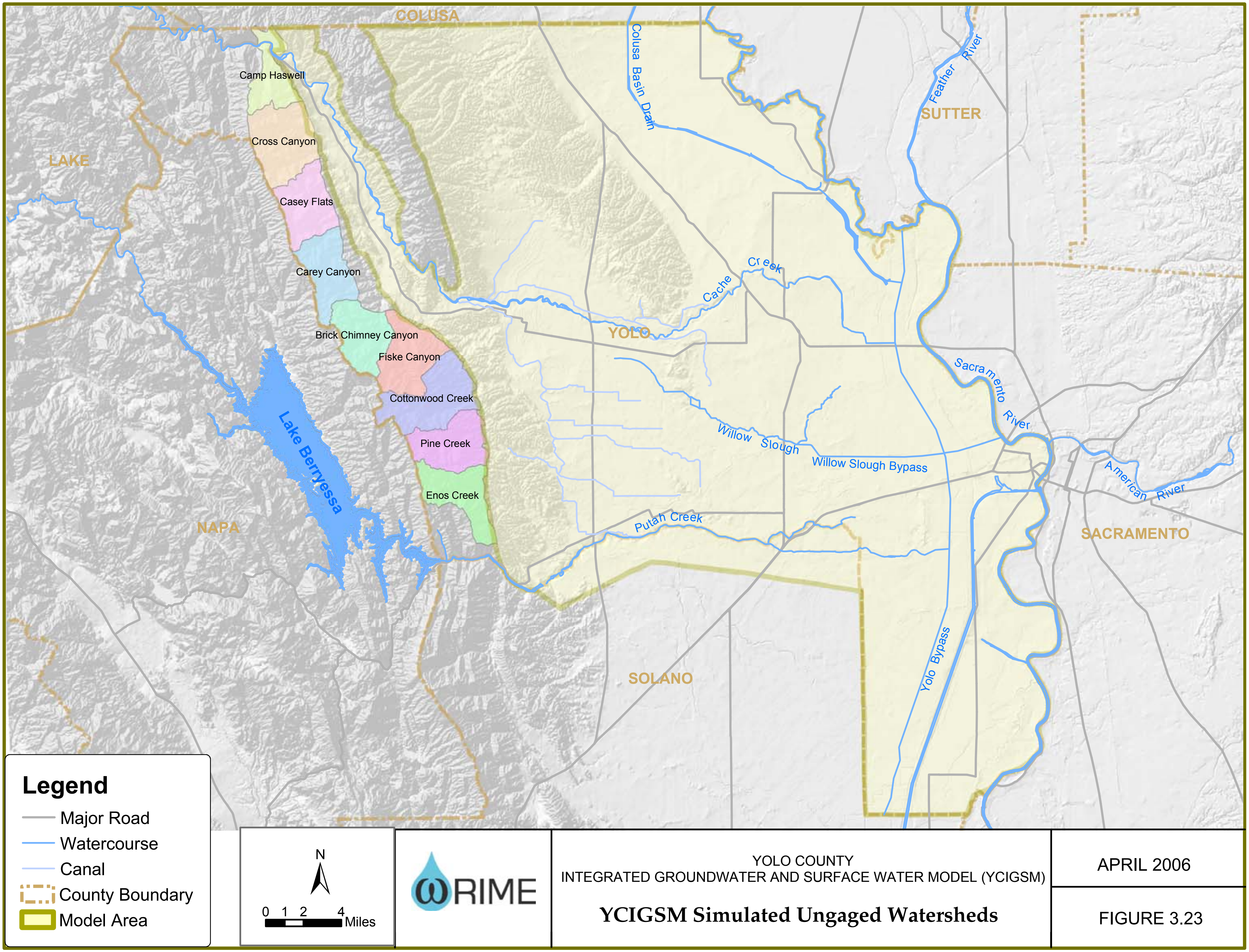
SELECTION OF GROUNDWATER CALIBRATION DATA

The YCIGSM is calibrated with historical groundwater observations by adjusting aquifer parameters. Two sets of groundwater data are required for calibration:

1. Regional groundwater elevation contours showing the regional flow directions and trends; and
2. Local groundwater observations at monitoring or pumping wells, showing the seasonal variations of groundwater elevations at point locations.

This section outlines the process used to identify the available water level data and the selection of calibration wells.

As previously stated in Section 2, there are 796 wells within the YCIGSM area with measured water level data for the 1971–2000 simulation period. Data from these wells were analyzed and groundwater calibration data were selected to provide adequate data for regional groundwater contours as well as for local time history of groundwater elevations at selected monitoring wells. The following seasons and years were selected for regional groundwater contours as being representative of dry, wet, and average conditions: Fall 1977, Spring 1983, and Fall 2000.



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Simulated Ungaged Watersheds

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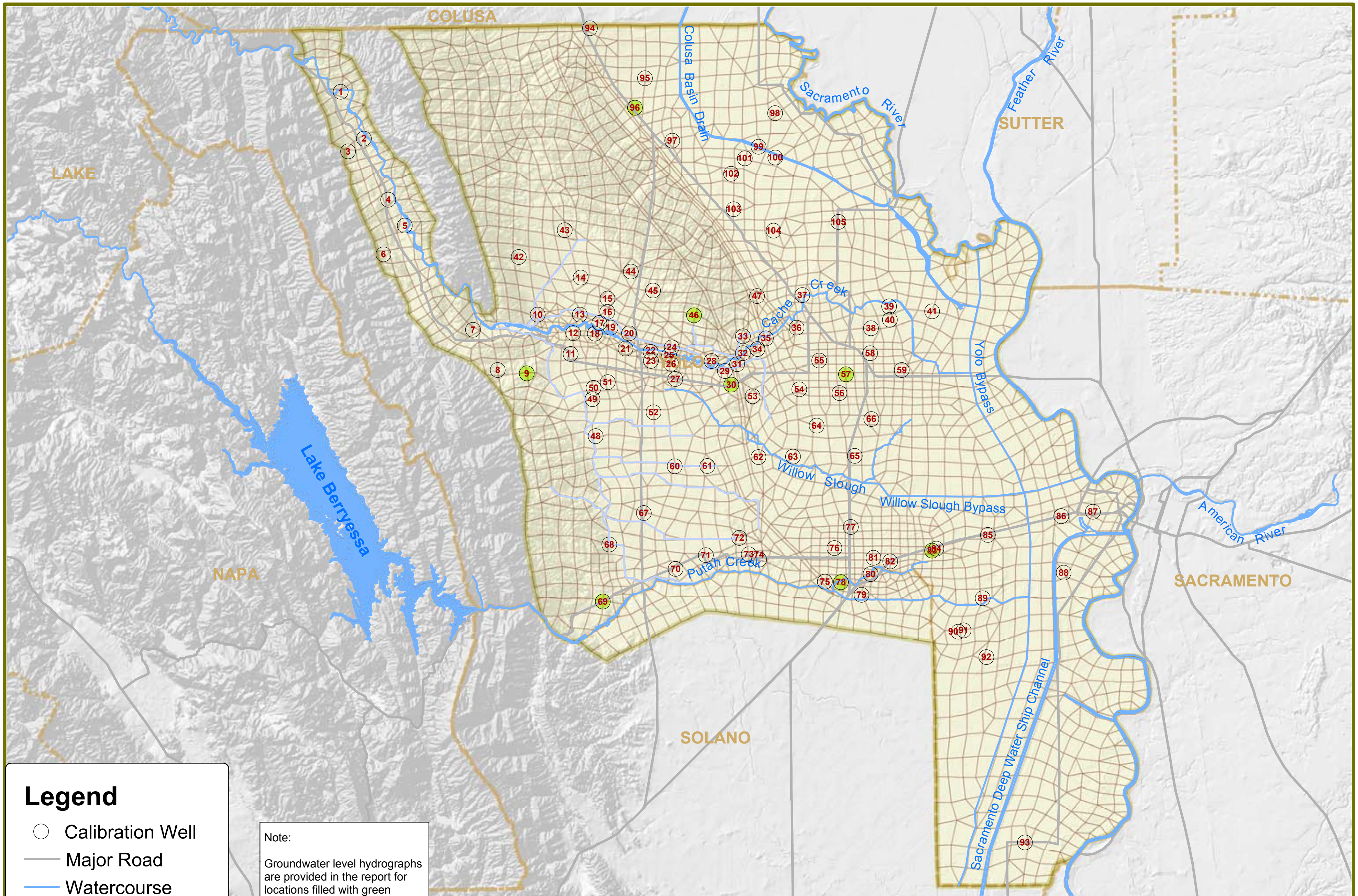
FIGURE 3.23

The selection of calibration wells for local groundwater level calibration was based on the following criteria: length of the period of record and availability of information on well location, depth, and perforation data. The criteria was applied so that there was sufficient geographic coverage with calibration wells with emphasis around Cache Creek. The selected wells had either a record of 8 years or at least 30 measurements during the simulation period. Well construction data were not discriminating criteria unless multiple wells were located near each other and had similar record lengths and measurements. Wells with construction data were selected for use as calibration wells. Of the wells with water level measurement data, 105 were selected as calibration wells for the YCIGSM. Information pertaining to these wells is summarized in Table 3.13. The locations of these wells are shown in Figure 3.24.

Table 3.13 YCIGSM Calibration Wells

Calibration Well Number	SWN	Start Date	End Date	Records with Study Period	Well Depth (ft)	Hole Depth (ft)	Depth of Perforation Interval (ft)	
							Top	*Bottom*
1	12N03W20D001M	1971	2004	39	26	No data	No data	No data
2	12N03W33F001M	1962	2004	61	75	No data	No data	No data
3	12N03W32Q001M	1970	2001	32	238	No data	No data	No data
4	11N03W15G001M	1970	2000	59	100	No data	No data	No data
5	11N03W23L001M	1980	2004	29	No data	No data	No data	No data
6	11N03W34C001M	1970	2004	61	140	No data	No data	No data
7	10N02W17J001M	1953	2004	61	24	No data	No data	No data
8	10N02W28J001M	1956	2004	56	No data	280	180	280
9	10N02W26P001M	1973	2004	53	205	205	174	204
10	10N02W14A001M	1951	2004	58	No data	135	76	128
11	10N01W19Q004M	1952	2004	62	146	No data	No data	No data
12	Syar_Mast	1991	2002	105	211	No data	80	210
13	10N01W18A001M	1959	2004	59	No data	No data	No data	No data
14	10N01W05E001M	1951	2004	62	No data	247	133	164
15	10N01W09F002M	1965	2004	63	No data	No data	No data	No data
16	Teichert_M-3	1990	2003	99	65	No data	45	65
17	Teichert_R-4A	1989	2003	77	No data	No data	23.5	33
18	Syar_Stephens	1990	2003	115	No data	No data	95	112
19	Teichert_M-2	1990	2003	99	No data	No data	44.5	64.5
20	10N01W15P002M	1978	2002	42	No data	No data	44	52
21	Syar_Truck Shop	1980	2002	120	No data	No data	43	64
22	Rinker_Solano-1A	1973	2003	287	No data	No data	77	97
23	Rinker_Solano-2	1981	2003	215	No data	No data	80	130
24	10N01W24L002M	1931	1985	36	No data	No data	35	44
25	Rinker_OW-4	1990	2003	111	No data	No data	35	75
26	Rinker_OW-9	1990	2003	111	No data	No data	50	80
27	10N01W36B002M	1948	2004	61	No data	115	No data	No data
28	Teichert_TA-4	1986	2003	138	No data	No data	No data	No data
29	Teichert_YFC-West	1986	2003	135	No data	No data	No data	No data
30	10N01E33L002M	1972	2004	60	395	416	323	395
31	Teichert_TA-9R	1987	2003	125	No data	No data	No data	No data
32	Teichert_TA-12	1986	2003	138	No data	No data	15	35
33	Teichert_TA-14	1986	2003	96	No data	No data	20	35
34	Teichert_TA-17	1986	2003	78	No data	No data	20	50
35	Teichert_TA-18	1986	2003	121	No data	No data	30	60
36	10N01E13L001M	1951	2004	57	290	334	242	290
37	10N01E12B004M	1977	2003	265	260	No data	178	251
38	10N02E15N001M	1952	2004	61	No data	280	No data	No data
39	10N02E10R001M	1952	2004	63	350	350	No data	No data
40	10N02E14E001M	1952	2004	63	123	123	115	123
41	10N02E12R001M	1953	2004	58	352	365	268	352
42	11N02W35E001M	1970	1984	34	312	No data	No data	No data
43	11N01W19N001M	1971	2000	48	390	No data	89	102
44	11N01W34P001M	1970	2000	62	193	192	150	193
45	10N01W02Q001M	1973	2004	53	270	350	250	270
46	10N01E18C001M	1952	2004	63	No data	110	No data	No data
47	10N01E10G001M	1956	2004	63	No data	212	No data	No data
48	09N01W08Q001M	1952	2004	60	No data	425	No data	No data
49	09N01W05B001M	1952	2004	61	No data	305	No data	No data
50	10N01W32E001M	1948	2004	60	188	No data	No data	No data
51	10N01W33F001M	1956	2004	52	344	372	125	344
52	09N01W02Q002M	1952	2004	59	128	No data	No data	No data
53	09N01E03C003M	1941	2004	59	No data	567	440	524

Calibration Well Number	SWN	Start Date	End Date	Records with Study Period	Well Depth (ft)	Hole Depth (ft)	Depth of Perforation Interval (ft)	
							Top	*Bottom*
54	10N01E36Q002M	1951	2004	59	No data	199	121	194
55	Woodland Well 10	1996	2000	50	No data	No data	449	496
56	Woodland Well 5	1996	2000	50	No data	No data	168	448
57	Woodland Well 1	1970	2000	351	No data	No data	420	477
58	Woodland Well 12	1996	2000	48	No data	No data	406	424
59	10N02E26Q001M	1952	2000	56	385	No data	100	385
60	09N01W24G001M	1949	2004	46	615	615	500	615
61	09N01E20E001M	1951	2004	59	401	No data	No data	No data
62	09N01E22B001M	1951	2003	252	180	No data	No data	No data
63	09N01E24D001M	1951	2004	59	300	No data	No data	No data
64	09N02E07L001M	1933	2004	61	425	425	249	419
65	09N02E16N001M	1963	2003	337	176	No data	156	176
66	09N02E10E001M	1971	2004	61	254	254	204	254
67	09N01W35M001M	1952	2004	303	295	No data	No data	No data
68	08N01W09C001M	1949	2004	144	386	No data	No data	No data
69	08N01W20R005M	1960	2004	55	300	No data	No data	No data
70	08N01W13G003M	1949	2004	155	127	No data	No data	No data
71	08N01E07R001M	1975	2004	44	143	268	119	143
72	08N01E04Q002M	1949	2002	154	No data	159	No data	No data
73	08N01E10M001M	1948	2004	155	490	490	110	490
74	08N01E15B001M	1931	1994	282	116	No data	No data	No data
75	08N02E19B001M	1931	2002	340	174	No data	94	174
76	DAVIS_WELL25	1987	2004	120	466	486	233	446
77	DAVIS_WELL27	1991	2004	107	364	368	296	354
78	UCD - DW6A	1989	2000	18	1470	No data	1218	1450
79	UCD - DW4	1989	2000	18	1430	No data	1120	1400
80	UCD - DW2	1989	2000	17	1368	No data	1180	1350
81	DAVIS_WELL23	1981	2000	210	419	505	No data	No data
82	DAVIS_WELL24	1982	2000	170	460	480	No data	No data
83	08N03E07M001M	1963	1986	178	No data	No data	No data	No data
84	DAVIS_WELL21	1981	2004	202	448	502	No data	No data
85	08N03E04R001M	1968	2003	283	132	No data	124	132
86	08N04E06C001M	1974	2002	61	430	No data	No data	No data
87	09N04E32R001M	1972	1991	164	No data	No data	No data	No data
88	08N04E18L001M	1977	2003	43	187	No data	162	179
89	08N03E21P002M	1970	1997	45	No data	No data	No data	No data
90	08N03E32L001M	1966	2002	53	628	No data	420	628
91	08N03E32G001M	1966	1999	52	34	No data	No data	No data
92	07N03E04Q001M	1949	2003	46	96	No data	No data	No data
93	06N03E23P001M	1953	2003	57	145	No data	No data	No data
94	12N01W05B001M	1970	2003	338	150	No data	No data	No data
95	12N01W14M001M	1970	2002	56	594	No data	428	594
96	12N01W22R001M	1970	1997	278	198	No data	No data	No data
97	12N01W36K002M	1978	2000	41	633	720	301	633
98	12N01E26A002M	1996	2003	38	No data	No data	470	480
99	385020121503603	1979	2000	232	947	2501	No data	No data
100	11N01E02D002M	1996	2003	37	No data	No data	480	490
101	384951121512401	1979	2003	206	260	No data	No data	No data
102	11N01E09F002M	1957	1979	56	600	No data	No data	No data
103	11N01E16P001M	1977	2003	254	172	184	156	172
104	11N01E23P001M	1970	2002	58	563	563	203	563
105	11N02E20K004M	1970	2003	276	232	No data	220	232



Legend

- Calibration Well
- Major Road
- Watercourse
- Canal
- Model Grid
- County Boundary
- Model Area

Note:

Groundwater level hydrographs are provided in the report for locations filled with green

N

0 1 2 4 Miles

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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Wells

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FIGURE 3.24

SECTION 4 MODEL CALIBRATION AND SENSITIVITY ANALYSIS

Model calibration can be defined as "..a process that uses a model to achieve a match between the recorded (i.e., historical) and simulated distribution(s) of dependent variable(s) by choosing a range of possible values of the independent variable(s)" (AWWA, 2001). In a hydrologic modeling situation such as the YCIGSM, the challenge is to solve the inverse problem, that is, the distribution of the dependent variable (such as groundwater elevation) is known and measurable, while the distribution of the independent variable (such as hydraulic conductivity of an aquifer) is unknown or can only be estimated within a range of possible values. In such a situation, the independent variables are adjusted for model calibration and these variables are called model '*parameters*'. For example, in the YCIGSM, the most important model parameters are the aquifer properties such as hydraulic conductivity, specific yield, specific storage, and leakance.

It should be noted that "a calibrated groundwater model provides 'best' or 'most reasonable' estimates of such model parameters, which are then used to predict the future response of a dependent variable (such as groundwater elevation) under a changed land use or water use plan" (AWWA, 2001).

The purpose of this section is to present the process used to calibrate the YCIGSM and conduct sensitivity analysis of selected model parameters and inputs. This section is organized as follows:

- Calibration Process,
- Calibration Targets,
- Calibration Steps,
- Calibration Results, and
- Sensitivity Analysis.

CALIBRATION PROCESS

The purpose of model calibration is to evaluate the scientific adequacy of the model in representing a physical system and to corroborate scientific hypotheses that are already established through data analyses and field observations. A well-calibrated model confirms the model's ability to adequately represent the physical system and its suitability for use in the analysis of water management planning.

The model calibration begins after the data development and input are complete. The intent of calibration is to compare model output with observed conditions and values and to adjust model parameters so that simulated conditions reasonably represent observed conditions.

The model calibration can be considered a systematic process, which includes the following series of activities:

1. Set calibration targets;
2. Calibrate to overall water budgets for the model area;
3. Calibrate simulated groundwater levels to observed groundwater levels;
4. Compare calibration performance with the calibration targets established in Step 1; evaluate and refine the calibration targets with reference to the available data, modeling and data assumptions, and potential use of the models;
5. Calibrate simulated streamflows to the observed streamflows; and
6. Conduct additional refinements to calibration as necessary.

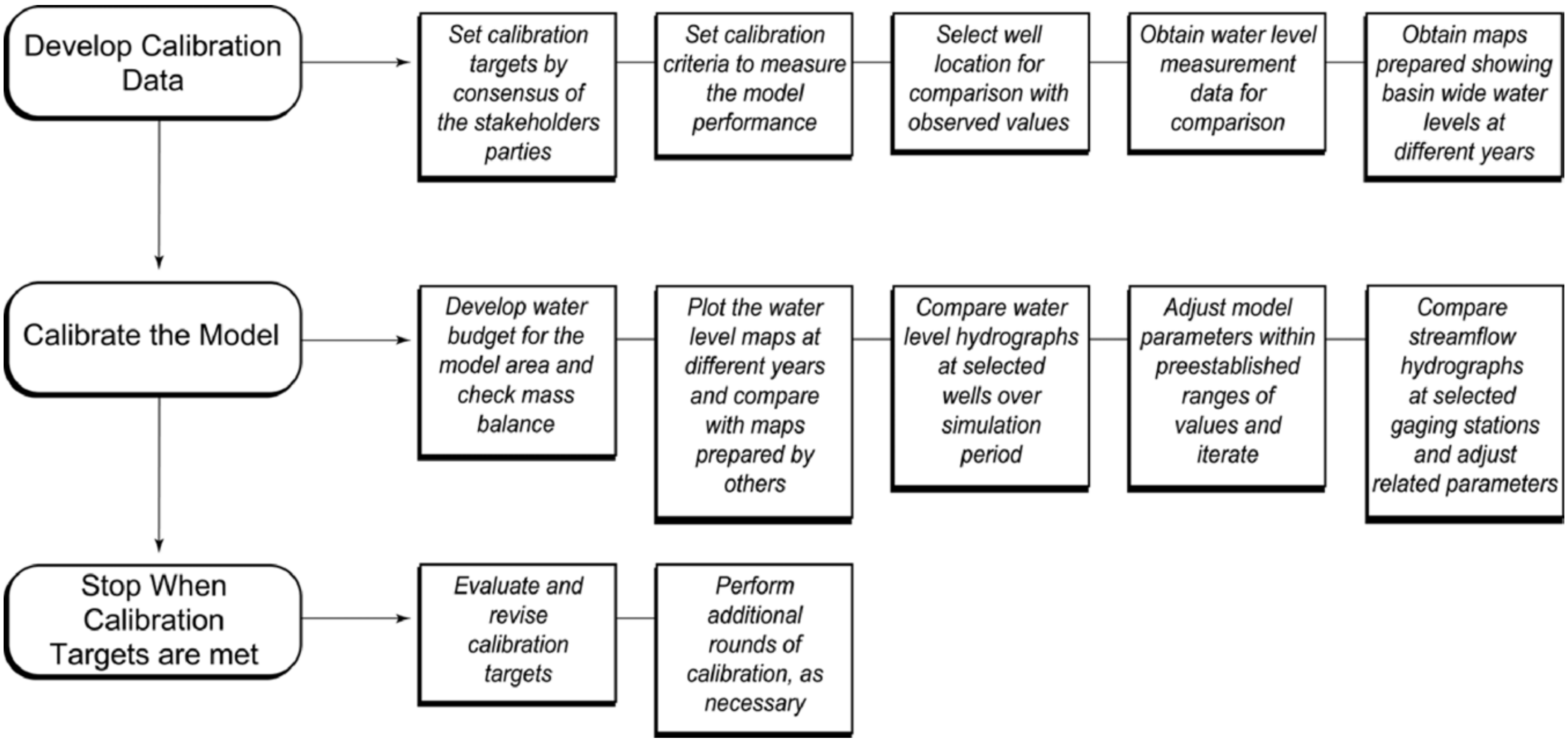
A detailed process diagram for the model calibration is shown in Figure 4.1.

CALIBRATION TARGETS

Calibration targets are typically designed to set specific calibration targets that are numerically measurable. The initial calibration targets for the YCIGSM are summarized in Table 4.1. These initial targets are based on an evaluation of available data in the basin and in discussions with TAC. It should be noted that the initial calibration targets are often refined and revised as data, assumptions, water budget, and additional information are further evaluated during the model development and calibration process. The calibration performance of the YCIGSM will be evaluated with reference to these targets.

Table 4.1 Calibration Performance Targets

Criterion	Target
Mean absolute residual between simulated and observed groundwater levels	15 feet
Percent of simulated water levels within 20 feet of observed groundwater levels	75%
Percent of simulated water levels within 10 feet of observed groundwater levels	60%



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Model Calibration Process

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FIGURE 4.1

CALIBRATION STEPS

Model calibration for the YCIGSM consisted of the following steps:

1. Water budgets (inflows and outflows);
2. Groundwater levels; and
3. Streamflows.

Each step is discussed below.

WATER BUDGET CALIBRATION

This step of model calibration is intended to ensure that the model is properly representing the key hydrologic components of the groundwater basin. The YCIGSM outputs that are reviewed and refined during this stage of calibration include annual and monthly water budgets for groundwater, streamflow, soil moisture, and land and water use for the entire model area and selected subregions. The key components for each of these water budgets are listed in the Table 4.2.

Table 4.2 Water Budget Components

	Budgets			
	Groundwater	*Streamflow*	*Soil Moisture*	*Water Use*
Components	Deep Percolation	Upstream Flow	Rainfall	Agricultural Use
	Stream Recharge	Rainfall Runoff	Irrigation Applied Water	Urban Use
	Boundary Flows	Groundwater Gain	Evapotranspiration	Pumping
	Pumping	Diversions	Direct Runoff	Diversions
	Change in Storage	Return Flows	Return Flow	Imports
		Downstream Flow	Percolation	Shortages

Some of the key model data and/or parameters that are adjusted during this phase include soil moisture parameters (field capacity, soil hydraulic conductivity, SCS curve numbers, and root zone depth); boundary conditions; water use data; and streambed parameters (hydraulic conductivity and thickness). An important piece of data in this stage of calibration is typically the water use data, including the location, amount, and timing of surface water diversion and groundwater pumping.

GROUNDWATER LEVEL CALIBRATION

This step of model calibration involves adjustment of the hydrogeologic parameters to obtain a reasonable fit between the observed and simulated groundwater levels. The groundwater level calibration is performed in two stages:

1. The initial groundwater level calibration effort is focused on conforming to the regional scale, i.e., the simulated groundwater level contours are compared with the historic groundwater level contours for selected years. This step ensures that overall groundwater flow directions are representative of the field conditions. In the YCIGSM, the following years were selected for regional groundwater level calibration: 1977, 1983, and 2000. These years were selected because they represent dry, wet, and average conditions in the model area.
2. The focus of the final groundwater level calibration is the local calibration wells; comparisons are made between the historic time series observations at each calibration well and the corresponding simulated time series groundwater levels. In the YCIGSM, 105 calibration wells were selected for the purpose of local water level calibration. These wells were selected, in general, to provide a broad geographic coverage of the entire YCIGSM area, and in particular, to enable comparison of local water levels in the focus areas of the present study. These focus areas include Capay Valley, Cache Creek, and the Cities of Woodland, Davis, and Winters. Additionally, it was ensured that observed data for a reasonable time period was available for a majority of the wells selected. It may be noted that nearly 40 of the calibration wells are located along Cache Creek, which was a major focus area of the calibration effort.

During this phase of calibration, adjustments are made to aquifer parameters, including: hydraulic conductivity, specific storage, specific yield, and leakance between aquifer layers.

STREAMFLOW CALIBRATION

The streamflows are calibrated by comparing the historical time series data at selected stream gages within the model area with corresponding simulated streamflows. The streamflow calibration is focused on achieving a level of model accuracy that will provide a reasonable agreement between the simulated and observed streamflow measurements throughout the study area. This step ensures that the overall streamflow amounts are representative of the field conditions. During this phase of calibration, adjustments are made to model streambed parameters, including streambed thickness, hydraulic conductivity, and amounts of water returned to the aquifer system. For calibrating the YCIGSM, simulated streamflows were compared with observed data from 10 streamflow gages within the model area.

CALIBRATION RESULTS

The YCIGSM was calibrated in accordance with the calibration methodology described above. Through that process, the following ranges of aquifer parameters were determined, as presented in Table 4.3.

Table 4.3 YCIGSM Range of Aquifer Parameter Values

Parameter	Range of Parameter Values		
	Layer 1	*Layer 2*	*Layer 3*
Hydraulic Conductivity (feet/day)	2 – 400	0.05 – 100	0.05 – 100
Transmissivity ($feet^2$/day)	–	50 – 100,000	20 – 60,000
Storage Coefficient (unitless)	–	10^{-8} – 10^{-5}	10^{-8} – 10^{-5}
Specific Yield (%)	1 – 20	0.1 – 15	–
Leakance (1/day)	10^{-3} – 1	10^{-5} – 10^{-1}	10^{-4} – 1

YCIGSM calibration results are presented below under the following categories:

- Water Budget
- Groundwater Level
  - Regional Groundwater Levels
  - Local Groundwater Levels
- Streamflow

WATER BUDGET

The YCIGSM output results are summarized in the following four water budgets tables.

- Land and Water Use Budget,
- Soil Moisture Budget,
- Stream Reach Budget, and
- Groundwater Budget.

These tables can be generated by the model in either monthly or annual time steps for the period of simulation. Although the model simulation time step is daily, the water budget results are reviewed on an annual scale and a monthly scale because a daily time step is not reasonable for this purpose nor can it be supported by field data. The annual water budget tables for the entire YCIGSM area for water years 1971–2000 are presented below.

Land and Water Use Budget

The land and water use budget demonstrates the balance between water supply and water demand in the study area. Calculation of this balance ensures that the model is properly representing the key hydrologic components of the study area. This balance includes agricultural and urban land use, agricultural and urban water demand, and overall water supply, consisting of surface water supply and groundwater pumping. The average annual land and water use budget for water years 1971–2000 is presented in Table 4.4. Based on this table, the total water demand in the model area is approximately 986 thousand acre-feet (TAF) per year. This water demand is met by approximately 490 TAF per year of surface water supply and 496 TAF per year of groundwater pumping. The surface water supply to the model area consists of the surface water diversion plus imports minus exports and losses. Table 4.4 indicates that there are approximately 22 TAF per year of losses through the canal system in the form of recoverable losses (seepage from canals) and non-recoverable losses (evaporation from canals). It may also be noted that the average agricultural water use in the model area is 2.6 acre-feet per acre and generally ranges between 2.0 and 3.4 acre-feet per acre, with a low 1.5 acre-feet per acre for Dunnigan Hills subregion, which is a predominantly a dry farming area. The average urban water use is 2.1 acre-feet per acre and generally ranges between 1.7 and 3.0 acre-feet per acre, with a low 0.8 acre-feet per acre for the Putah S. Fork subregion, for which data development was not a priority for this project and the data/results should be considered gross estimates.

Table 4.4 Average Annual Simulated Water Use Budget (Water Years 1971–2000, acre-feet/year)

No.	Subregions	Area (ac)		Demand		Groundwater Pumping	Surface Water Supply	Canal Losses	Imports	Exports	Unit Water Use (acre-feet/acre)	
		Ag	*Urban*	*Ag*	*Urban*						*Ag*	*Urban*
1	Capay Valley	7,732	83	21,928	172	22,100	0	0	0	0	3	2
2	Buckeye Cr	3,989	9	10,685	19	10,705	0	0	0	0	3	2
3	Dunnigan WD	8,555	425	17,458	888	12,224	0	533	6,123	0	2	2
4	CBD – North	4,697	0	13,904	0	11,689	35,363	2,767	0	30,319	3	
5	RD 108	18,876	14	62,488	29	29	48,195	3,333	34,037	16,437	3	2
6	River Garden Farms	7,801	4	26,467	9	4,686	47,412	939	10,994	35,676	3	2
7	West Yolo North	19,888	159	44,251	328	16,435	0	2,448	28,146	0	2	2
8	West Yolo South	55,746	1,163	143,857	2,421	55,146	0	7,925	91,132	0	3	2
9	Dunnigan Hills	13,117	275	19,127	574	18,610	0	95	1,092	0	1	2
10	Y-Z WD NW	6,086	32	18,102	67	18,169	0	0	0	0	3	2
11	Y-Z WD SE	14,504	127	35,363	264	35,627	0	0	0	0	2	2
12	CBD-South	18,586	81	49,125	170	48,093	1,309	104	0	0	3	2
13	East Yolo South	51,019	1,904	120,057	3,972	103,497	6,929	943	20,532	6,929	2	2
14	Woodland	4,700	5,666	12,411	11,464	23,875	0	0	0	0	3	2
15	Davis	3,144	3,907	7,452	10,854	16,961	0	0	1,345	0	2	3
16	Sacramento River	22,548	109	68,535	228	12,869	194,964	2,491	0	135,308	3	2
17	West Sacramento	4,460	5,062	9,890	8,469	14,546	44,197	331	0	40,053	2	2
18	Putah Cr – S. Fork	8,697	335	19,611	266	19,877	0	0	0	0	2	1
19	North Delta WA	59,808	228	159,809	478	478	0	0	159,809	0	3	2
20	Winters	798	421	2,426	1,032	3,458	0	0	0	0	3	2
21	Conaway Ranch	12,970	82	39,661	171	4,429	10,728	0	24,733	0	3	2
22	UCD Yolo	1,131	987	2,675	2,677	2,855	0	0	2,496	0	2	3
23	UCD Solano	640	263	2,093	553	2,488	0	0	1,504	1,345	3	2
24	Solano Unorganized	11,391	101	34,430	67	34,497	0	0	0	0	3	1
	Total	**360,882**	**21,437**	**941,807**	**45,173**	**493,345**	**389,097**	**21,909**	**314,551**	**198,677**	**3**	**2**

Soil Moisture Budget

The YCIGSM incorporates a soil moisture accounting system to track the hydrologic processes within the soil zone. The components of the soil moisture budget for agricultural, urban, and undeveloped areas as simulated by the YCIGSM are: rainfall; irrigation applied water; crop consumptive use during growing season; actual evapotranspiration during the entire year; direct runoff due to rainfall; return flow from agricultural and outdoor urban water use; and deep percolation. The average annual soil moisture budget for water years 1971–2000 is presented in Table 4.5. The soil moisture budget is presented by agricultural and urban areas, as sources of water supply may be different for each land use area.

Table 4.5 Average Annual Simulated Soil Moisture Budget
(Water Years 1971–2000, inches/year)

No.	Subregions	Agricultural Area							Urban Area					
		Rainfall	*Applied Water*	*Consumptive Use*	*ET*	*Direct Runoff*	*Return Flow*	*Deep Perc*	*Rainfall*	*Consumptive Use*	*ET*	*Direct Runoff*	*Return Flow*	*Deep Perc*
1	Capay Valley	21.9	33.9	22.3	31.4	4.9	3.4	15.9	21.2	24.9	14.3	11.1	0.7	19.9
2	Buckeye Cr	20.5	31.9	22.1	31.6	4.3	3.2	13.1	20.1	26.5	17	10.8	0.8	17.9
3	Dunnigan WD	19.7	24.8	18.9	28.2	4.6	2.5	9	19.6	25.1	17.8	11.1	0.8	15.1
4	CBD – North	19.4	35.9	26	34.8	6.5	4.2	9.7	0	0	0	0	0	0
5	RD 108	19.1	39.6	27.9	35.9	9	5.8	8	18.9	25.5	17.7	10	10.8	5.8
6	River Garden Farms	18.9	41.1	27.5	35.1	7.4	4.1	13.2	6.7	8.7	6.7	4.3	3.7	0.8
7	West Yolo North	20.9	26.7	18.8	27.2	4.8	1.3	14.1	20.9	24.9	14.4	10.8	10.7	9.9
8	West Yolo South	22.4	31	21.3	30	7.3	3.1	12.9	21.7	25	15.1	13	10.7	8
9	Dunnigan Hills	20.3	17.9	14.1	24.2	6.9	1.8	5.2	20.4	25.1	18.2	12.5	10.8	4
10	Y-Z WD NW	19.6	35.5	21.3	30.3	3	3.5	18.1	19.3	25.6	13.4	9.4	11	11.2
11	Y-Z WD SE	19.6	29.3	16.8	26.2	2.2	2.9	17.6	19.6	25	12	8.9	10.7	13
12	CBD-South	19.8	31.8	20.1	29.3	3.5	3.2	15.5	19.7	25.1	13.9	9.7	10.8	10.4
13	East Yolo South	20.3	28.2	18.7	27.8	4.5	2.8	13.3	20.1	25.1	14.6	10.9	10.7	8.8
14	Woodland	20.9	31.4	20.3	29.5	5.1	3.1	14.6	20.8	24.2	12	13.9	10.4	8.7
15	Davis	19.4	28.2	17.8	26.4	3.3	2.8	15	19.1	33.3	14.3	12.7	14.3	11.1
16	Sacramento River	19.8	36.3	23.6	33	3.9	3.6	15.7	19.8	25.1	14.7	10	10.8	9.3
17	West Sacramento	18.7	26.4	17.1	26.3	4.5	2.6	11.4	18.3	20	10.8	12.5	0.6	6.3
18	Putah Cr – S. Fork	19.4	27.1	17.8	26.7	4	2.7	12.9	19.4	9.5	8.7	10.3	0.3	5.3
19	North Delta WA	18.8	31.9	20.3	29.3	3.7	3.2	14.4	18.5	25.2	15.4	10.1	0.8	7.4
20	Winters	23.4	36.4	22.8	31.3	8.1	3.6	16.7	23.4	29.4	16.1	14.3	12.6	9.8
21	Conaway Ranch	20.2	36.6	24.3	33.1	6.2	3.7	13.8	20.7	25	15.5	12.6	0.8	6.9
22	UCD Yolo	19.6	28.2	18	26.7	3.4	2.8	14.7	19.2	32.6	15.7	9.3	1	12.8
23	UCD Solano	19.4	39.3	23.9	32	2.8	3.9	19.8	19.3	25.2	12.1	9.2	0.7	10.8
24	Solano Unorganized	22.2	36.3	23	31.8	4.6	3.6	18.4	23.6	8	8.1	12.3	3.9	7.4
Average		**20.2**	**31.3**	**20.8**	**29.7**	**5.1**	**3.2**	**13.5**	**19.8**	**25.2**	**13**	**12.5**	**7.8**	**8.8**

The two primary sources of water to the soil zone in agricultural and urban areas are rainfall and applied water. As shown in Table 4.5, urban areas have the highest amount of direct runoff: an average of about 13 inches per year; this high amount of direct runoff is primarily because of the imperviousness of urban areas. In contrast, agricultural areas have only 5 inches of direct runoff. Average annual deep percolation (Perc) in agricultural areas is about 14 inches per year. This annual percolated water is primarily from irrigation applied water (31 inches) and from rainfall (20 inches). The amount of percolation from urban areas is smaller, with an annual average of 9 inches. The annual average evapotranspiration in the agricultural area is 29 inches.

It may be noted that the average applied water for agricultural area is 31 inches, with a low 18 inches for Dunnigan Hills subregion, which is a predominantly a dry farming area. It may also be noted that the average consumptive use for agricultural area is about 20 inches, with a low 11 inches for the subregions in Solano County. Similarly, the average deep percolation for agricultural area is about 14 inches, with a high of 28–29 inches for the subregions in Solano County. For the subregions in Solano County, data development was not a priority for this project and the data/results should be considered gross estimates.

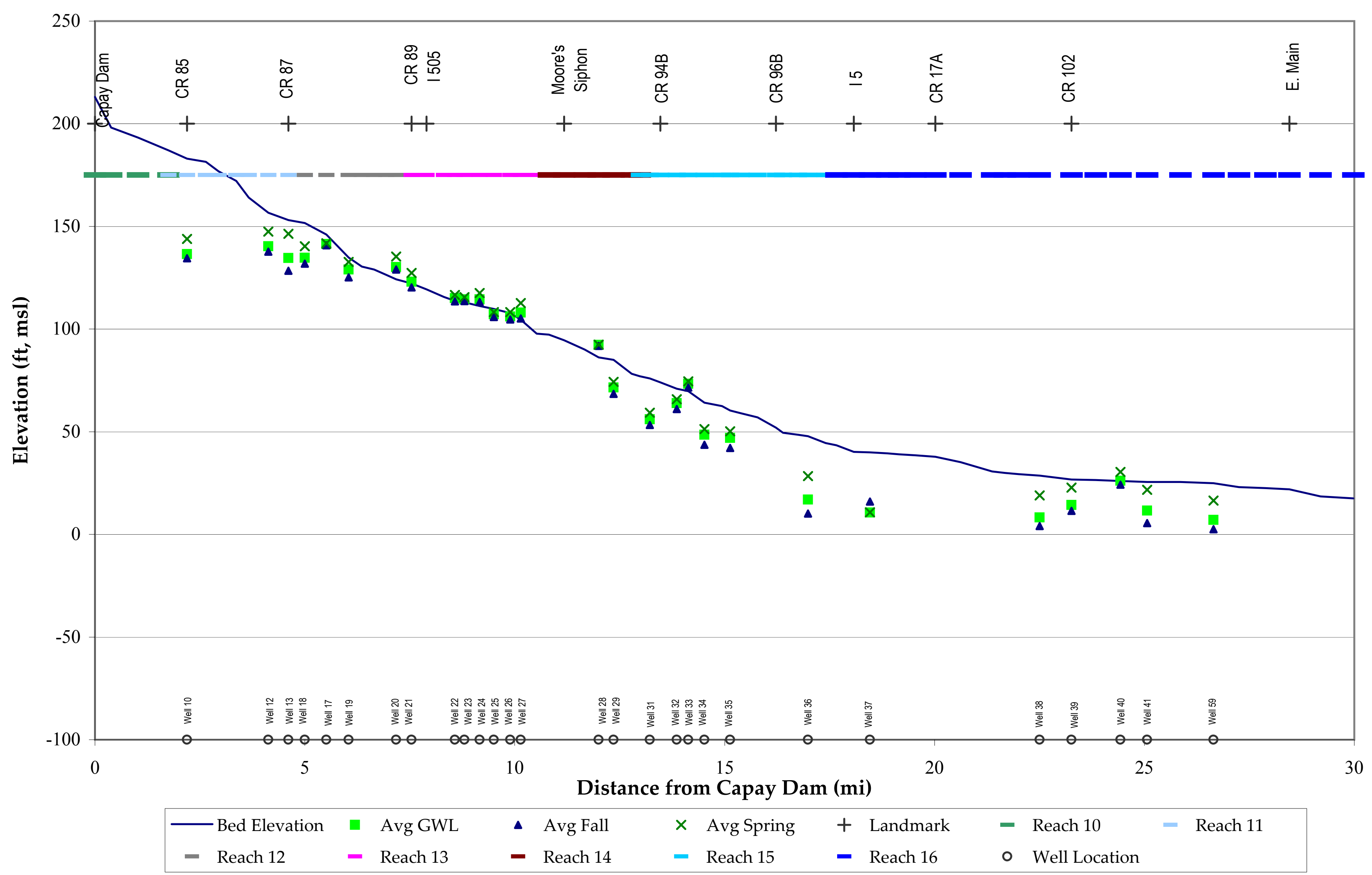
Stream Budget by Reach

The major components of water budget by stream reach are: upstream flow; runoff from mountain watersheds; direct runoff from rain; gain and loss due to stream-aquifer interaction; surface water diversions; and downstream outflow. There are 27 stream reaches simulated in the YCIGSM. The locations of these reaches have been shown previously in Figure 4.2. Their associated budgets in the YCIGSM are summarized in Table 4.6.

It can be seen from Table 4.6 that the Sacramento River is simulated with four stream reaches. It can be seen from those reaches the downstream flow of the upper reach does not necessarily equal the upstream flow of the lower reach. This is due to that upstream flow includes the contribution of the upper reach plus any tributary flow and minus bypass flows. It should be noted that all settlement contractor surface water diversions are simulated in the YCIGSM.

Cache Creek Stream Reach Evaluation

There were eight stream reaches configured in the YCIGSM to simulate Cache Creek streamflow. The seven reaches below Capay Dam—and, in particular, the gaining or losing nature of these reaches—are of interest. From Table 4.6, it can be seen that the YCIGSM, on an annual average, simulates Reach 10 and 11 as losing reaches, Reaches 12 and 13 as gaining reaches, and Reaches 14 through 16 as losing reaches. The losing and gaining nature of Cache Creek reaches were compared with groundwater level data from adjacent wells along the longitudinal profile of Cache Creek. Figure 4.2 shows the longitudinal thalweg elevation profile of Cache Creek with demarcation for the Cache Creek stream reaches and other landmarks, the location of the calibration wells along the longitudinal profile, and average groundwater levels. Figure 4.2 shows that Wells 10 through 19 have average groundwater level elevations that are lower than the Cache Creek thalweg elevation. These wells are located in Reaches 10 and 11, which are both simulated in the YCIGSM as losing reaches. It is reasonable to assume that when the average groundwater level is lower than adjacent streambed elevation, then the stream is probably losing. In contrast, when the average groundwater level is higher than adjacent streambed thalweg elevation, then it could be assumed that the stream is probably gaining. It appears that there is an agreement between average groundwater levels and stream reach budget results as simulated in the YCIGSM. For example, Reaches 12 and 13 are simulated as gaining reaches and this is in agreement with the wells in those reaches. That is,



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Longitudinal Profile of Cache Creek

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FIGURE 4.2

the average groundwater levels in wells in Reaches 12 and 13 are generally higher than the Cache Creek thalweg elevation in those reaches. For the remaining reaches (14 through 16), the average groundwater levels in wells around Cache Creek are lower than the Cache Creek thalweg elevation and Cache Creek is simulated as a losing stream in those reaches. Therefore, it can be concluded that the YCIGSM is simulating the gaining and losing nature of Cache Creek reaches reasonably well.

Table 4.6 Average Annual Simulated Stream Reach Budget (Water Years 1971–2000, TAF/year)

Reach	Stream Reach Definition	Upstream Flow	Return Flow	Runoff	Stream Loss (-) Stream Gain (+)	Diversion	Downstream Flow
9	Cache Creek – above Capay Dam	574.3	2.2	27.2	2.6	0.0	606.4
10	Cache Creek – Capay Dam to CR 85	426.3	0.0	0.0	-1.4	0.0	424.9
11	Cache Creek – CR 85 to CR 87	424.9	0.1	0.3	-6.1	0.0	419.2
12	Cache Creek – CR 87 to I505	419.2	0.1	0.1	5.8	0.0	425.2
13	Cache Creek – I505 to Moore's Siphon	425.2	0.1	0.4	2.9	0.0	428.6
14	Cache Creek – Moore's Siphon to CR 94B	428.6	0.1	0.2	-1.3	0.0	427.7
15	Cache Creek – CR 94B to I-5	427.7	2.8	14.3	-15.7	0.0	429.0
16	Cache Creek – I-5 to Settling Basin	429.0	4.5	5.6	-22.1	0.0	417.0
2	Colusa Basin Drain	255.1	24.0	64.6	1.3	36.7	308.3
3	Knights Landing Ridge Cut	0.0	0.0	0.0	0.3	0.0	0.3
5	Knights Landing Ridge Cut	308.6	3.4	4.3	4.6	1.2	319.7
21	Putah Creek – Upstream Lake Solano	357.8	0.0	0.0	-0.5	0.0	357.3
22	Putah Creek – Lake Solano to Winters	151.7	0.0	2.4	-2.1	0.0	152.1
23	Putah Creek – Winters to Stevenson Bridge	152.1	0.0	0.0	-10.3	0.0	141.8
24	Putah Creek – Stevenson Bridge to Road 113	141.8	0.0	0.0	-2.7	0.0	139.1
25	Putah Creek – Downstream 113	139.1	0.0	0.0	-6.2	0.0	132.9
1	Sac River – above Knights Landing	7,722.0	0.0	0.0	-3.3	95.6	7,623.1
4	Sac River between Knights Landing Ridge Cut and Yolo Bypass	7,623.1	0.0	0.0	-1.3	1.3	7,374.5
7	Sac River between Yolo Bypass and Sac Bypass	7,374.5	0.0	0.0	-0.1	138.1	13,217.6
27	Sac River below Sac Bypass	13,217.6	1.1	7.3	20.0	44.2	15,791.2
18	Sacramento Bypass	208.1	0.0	0.0	0.4	0.0	208.5
19	Willow Slough and Bypass	0.0	36.4	97.2	-14.1	17.7	101.7
6	Yolo Bypass above Confluence of KLRC	3,339.5	0.0	0.0	3.4	0.0	3,342.9
8	Yolo Bypass between KLRC and Cache Creek	3,662.6	0.0	0.0	10.2	0.0	3,672.8
17	Yolo Bypass between Cache Creek and Willow Slough	417.0	3.8	7.1	8.4	0.0	4,109.1
20	Yolo Bypass between Willow Slough and Putah Creek	4,419.3	6.1	10.9	2.8	54.3	4,384.7
26	Yolo Bypass below Putah Creek	4,517.6	5.2	6.3	16.9	0.0	4,546.1

Groundwater Budget

YCIGSM incorporates the major hydrologic processes that affect the flow of groundwater in the model area. The primary components of the groundwater budget are as follows:

Inflows

- Deep percolation from rainfall and irrigation applied water;
- Recharge due to stream seepage;
- Recharge from other sources such as irrigation canals;
- Boundary inflows from outside model area; and
- Subsurface inflows from adjacent subregions.

Outflows

- Groundwater pumping; and
- Boundary outflows.

The average annual groundwater budget for water years 1971–2000 is presented in Table 4.7. The budget table shows that the primary source of aquifer recharge is deep percolation, and Table 4.5 – Soil Budget Summary also indicates that a significant source of the groundwater percolation in the study area results from percolation of applied irrigation water. The net boundary outflow is about 1,750 AF/year with 16,500 AF/year discharging through the North Delta WA subregion (Subregion 18). During the same period, Capay Valley and Buckeye Creek (Subregions 1 and 2) receive boundary inflow of about 11,500 AF/year.

GROUNDWATER LEVEL CALIBRATION

The calibration of the YCIGSM to the observed groundwater levels is performed in two stages:

1. Calibration to the regional observed groundwater levels at specific times; and
2. Calibration to the long-term trends and seasonal fluctuations of groundwater levels at specific well locations during the period of observation. Following are the assumptions and results of each stage of the calibration.

Table 4.7 Average Annual Simulated Groundwater Budget (Water Years 1971–2000, acre-feet/year)

No.	Subregions	Inflow					Outflow	Inflow minus Outflow
		Deep Percolation	*Gain from Stream*	*Recharge*	*Boundary Inflow*	*Subsurface Inflow*	*Groundwater Pumping*	
1	Capay Valley	18,422	-2,600	0	7,156	56	22,100	934
2	Buckeye Cr	12,733	0	0	4,385	-4,560	10,705	1,854
3	Dunnigan WD	7,622	0	181	1,093	4,117	12,224	788
4	CBD – North	4,000	951	194	-2	6,653	11,689	108
5	RD 108	12,923	573	1,205	-285	-14,025	29	361
6	River Garden Farms	8,577	2,687	502	0	-6,971	4,686	108
7	West Yolo North	29,473	-211	2,207	75	-14,735	16,435	374
8	West Yolo South	73,215	1,466	4,876	1,011	-22,782	55,146	2,641
9	Dunnigan Hills	9,728	0	22	1,019	-3,871	18,610	-11,712
10	Y-Z WD NW	9,571	0	20	0	8,671	18,169	93
11	Y-Z WD SE	21,965	0	0	115	13,591	35,627	45
12	CBD – South	25,538	-4,201	179	136	26,944	48,093	503
13	East Yolo South	61,351	41,340	266	0	3,303	103,497	2,777
14	Woodland	10,964	0	0	0	14,374	23,875	1,463
15	Davis	8,400	0	0	0	9,658	16,961	1,097
16	Sacramento River	32,900	-16,488	68	52	-3,453	12,869	417
17	West Sacramento	8,702	1,046	117	-176	5,021	14,546	279
18	Putah Cr. – S. Fork	9,794	3,420	0	-147	7,609	19,877	799
19	North Delta WA	77,141	-39,095	0	-16,345	-18,077	478	3,145
20	Winters	1,928	0	94	0	1,518	3,458	83
21	Conaway Ranch	16,378	3,677	706	0	-15,661	4,429	670
22	UCD Yolo	2,686	0	0	0	403	2,855	234
23	UCD Solano	1,496	0	0	0	1,114	2,488	122
24	Solano Unorganized	18,242	15,028	0	166	1,112	34,497	50
Average		**483,751**	**7,593**	**10,637**	**-1,747**	**0**	**493,345**	**7,226**

Regional Water Levels

In order to evaluate the performance of the YCIGSM during dry, average, and wet hydrologic conditions, the following periods were selected to calibrate regional groundwater levels:

- Fall 1977, representing dry hydrologic conditions;
- Spring 1983, representing wet hydrologic conditions; and
- Fall 2000, representing average hydrologic conditions.

The YCIGSM simulated groundwater levels for Fall 1977, Spring 1983, and Fall 2000 are presented in Figures 4.3, 4.4, and 4.5, respectively. These figures also show observed groundwater levels at the monitoring locations as reported in the YCFCWCD database. The figures indicate that, in general, the model simulates the groundwater elevation trends, flow directions, and slope of the groundwater level gradients reasonably well. These figures show areas where simulated values are very close to the observed values and areas where they differ substantially. The major source of differences between simulated and observed groundwater levels are:

- Deficiencies in the model input data;

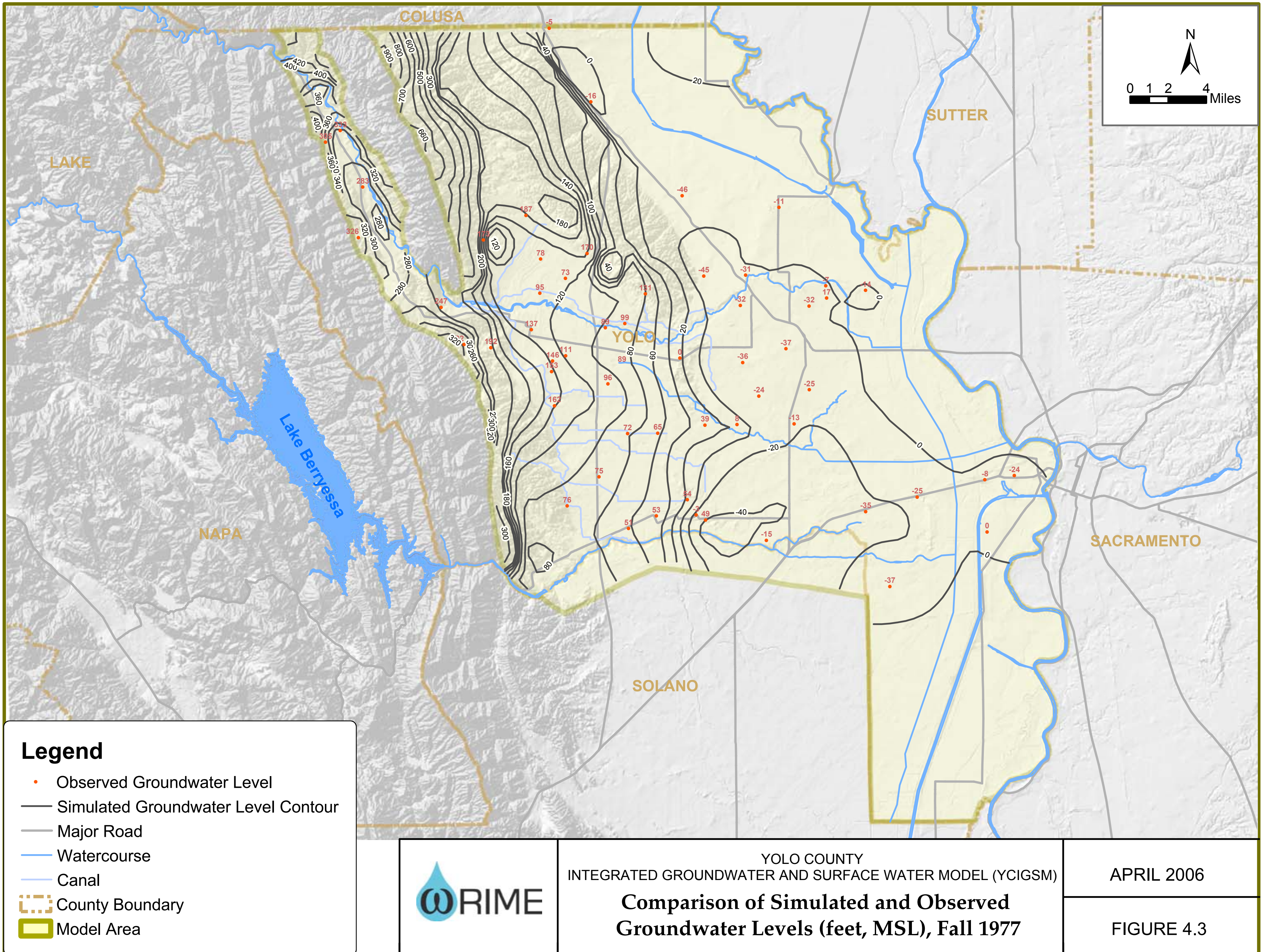
COLUSA
LAKE
SUTTER
YOLO
NAPA
Lake Berryessa
SOLANO
SACRAMENTO
N
0 1 2 4 Miles
Legend
Observed Groundwater Level
Simulated Groundwater Level Contour
Major Road
Watercourse
Canal
County Boundary
Model Area
WRIME
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)
Comparison of Simulated and Observed Groundwater Levels (feet, MSL), Fall 1977
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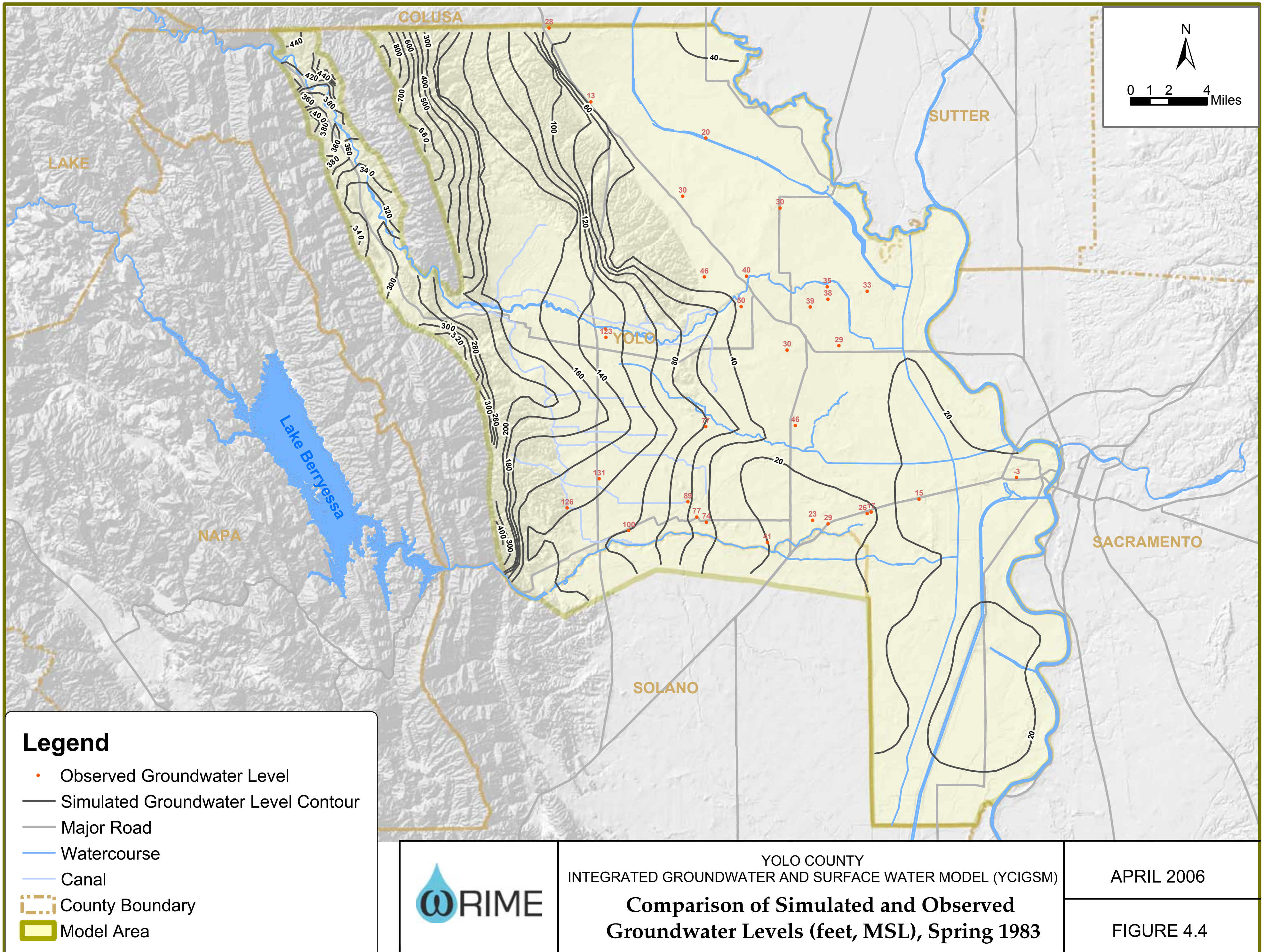
FIGURE 4.3

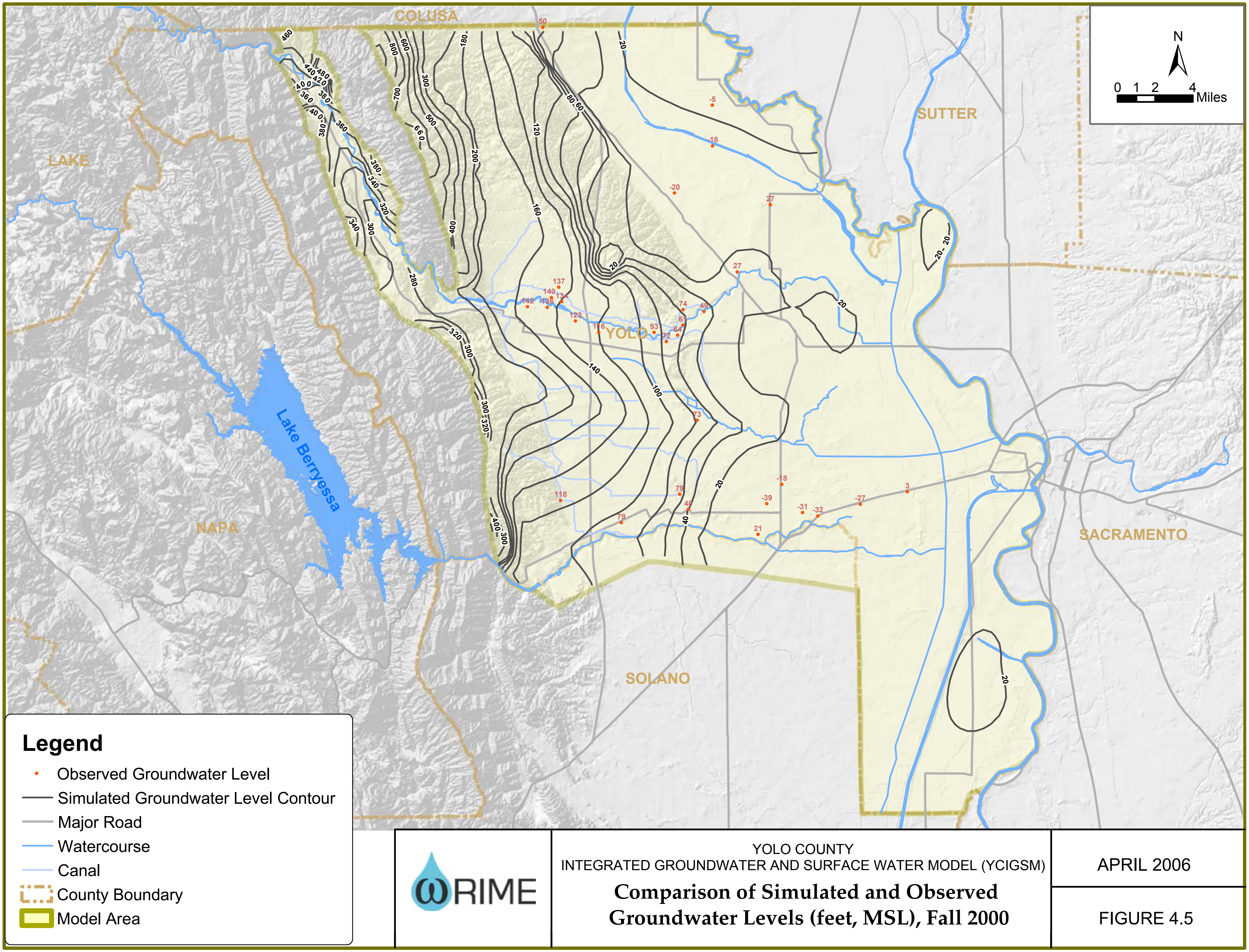


YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Comparison of Simulated and Observed Groundwater Levels (feet, MSL), Spring 1983

APRIL 2006

FIGURE 4.4



RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Comparison of Simulated and Observed Groundwater Levels (feet, MSL), Fall 2000

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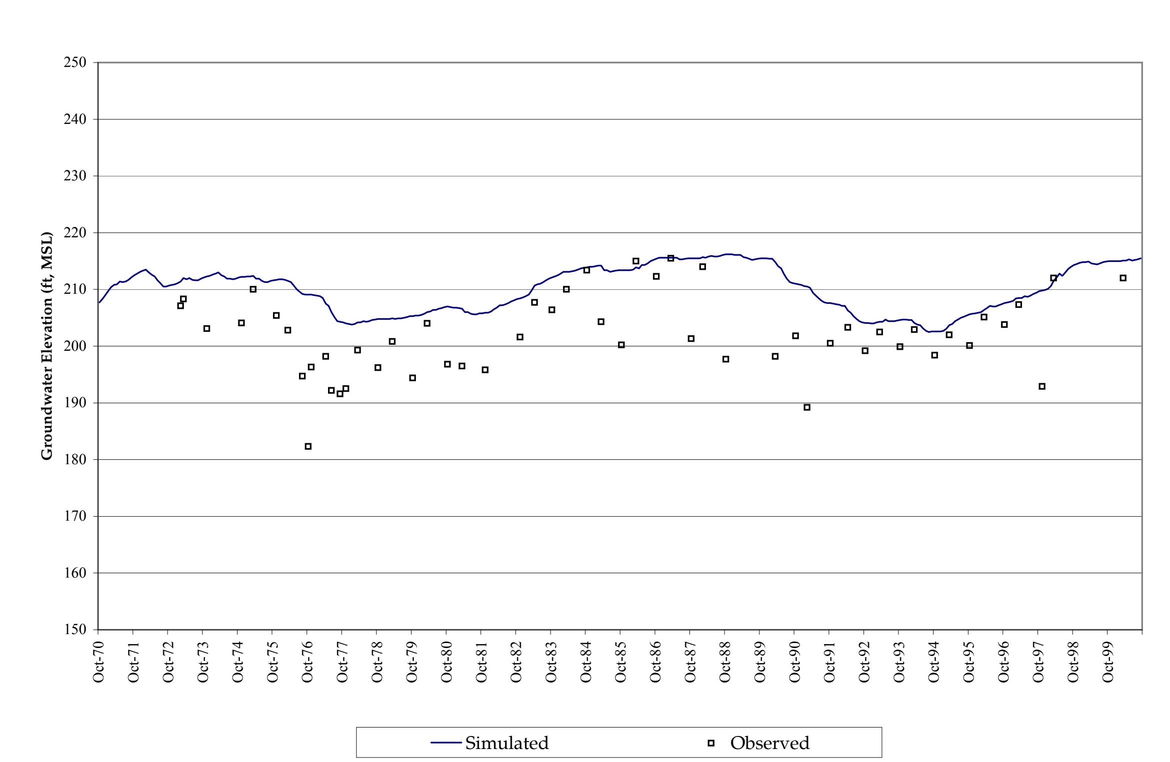
FIGURE 4.5

- Estimation error in Capay Dam release data;
- Estimation error in Gordon Slough outflow to Salisbury Spill;
- Model assumptions;
- Errors in the measurements of the observed groundwater levels;
- Insufficient recovery time from active production wells between shut down and measurement; and
- Assignment of model layers to observed measurements.

The differences between simulated and observed values are acceptable based on the errors that exist in the development of the contours.

Local Groundwater Levels

The second stage of calibration of the groundwater levels is to use the observed groundwater level measurements at specific wells. Simulated groundwater elevations at 105 wells were compared with corresponding observed values for long-term trends as well as seasonal fluctuations. The locations of the calibration wells have been shown previously in Figure 3.24. The goal of this stage of calibration is to achieve a reasonable agreement between the simulated and observed groundwater levels at as many of the calibration wells as possible with the main focus on groundwater wells located within the YCFCWCD service area and in the Cities of Davis, Woodland, and Winters. Aquifer parameters, such as hydraulic conductivity, specific storage, specific yield, and leakance parameters, are modified throughout the model area to achieve the calibration targets. The comparisons of monthly simulated and observed values over an extended period of time provide information on the overall model performance during the simulation period. The results of this calibration stage indicate that the YCIGSM reasonably simulates the long-term hydrologic responses at the local wells under various hydrologic conditions. Appendix A presents the simulated and observed groundwater levels at 105 calibration wells and Figures 4.6a–h show a subset of those hydrographs. Figure 4.7 shows the histogram of residuals between the simulated and observed groundwater levels in the model area. This figure shows that approximately 61% of the simulated values fall within 10 feet of the observed values, and approximately 82% of the simulated groundwater levels are within 20 feet of the observed values. The mean absolute residual between simulated and observed groundwater levels is 12 feet. A discussion regarding individual wells, in areas of focus of the YCIGSM calibration effort, follows.



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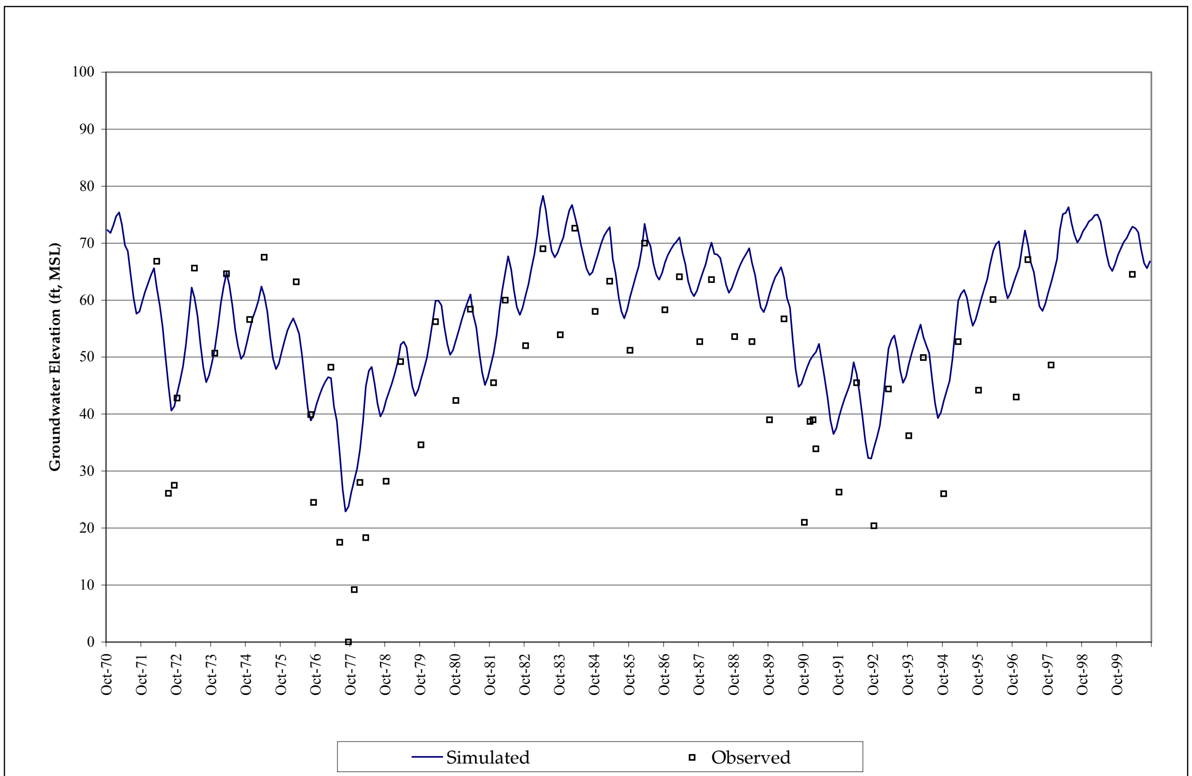
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Well 9 Groundwater Level Hydrograph

APRIL 2006

FIGURE 4.6a



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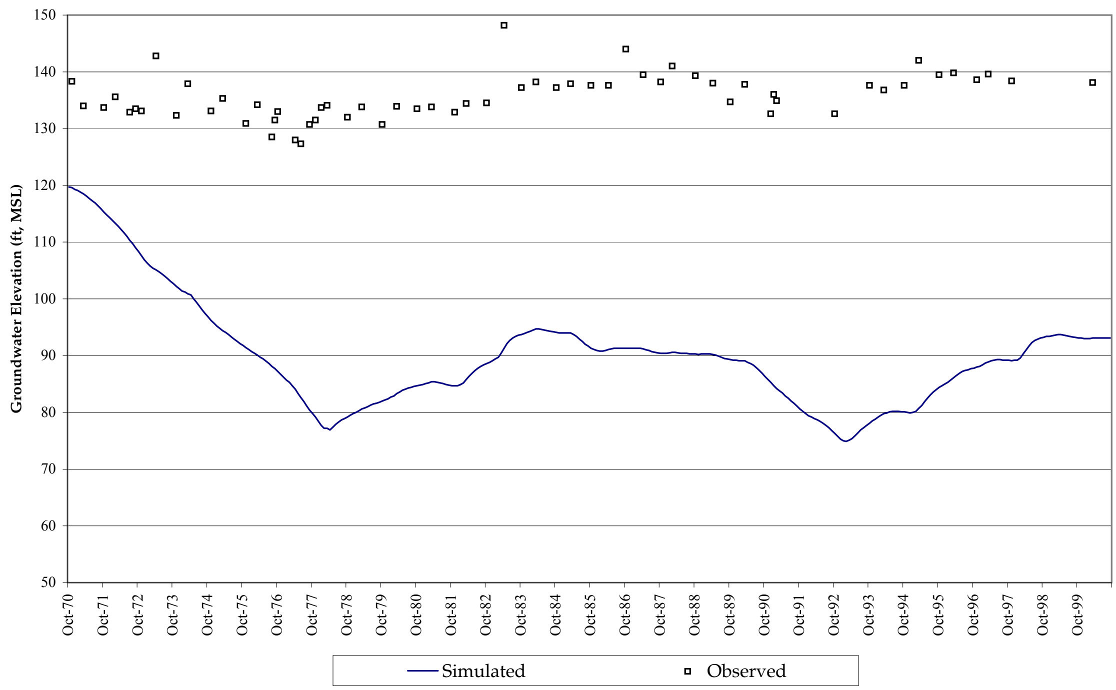
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Well 30 Groundwater Level Hydrograph

APRIL 2006

FIGURE 4.6b

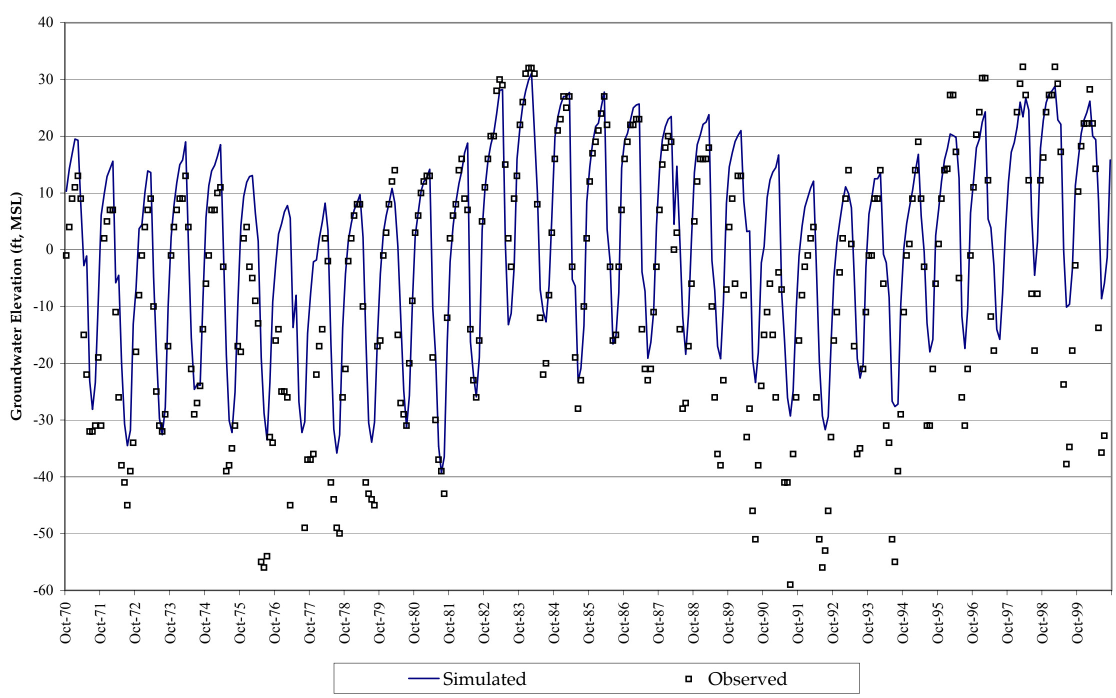


YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

YCIGSM Calibration Well 46 Groundwater Level Hydrograph

FIGURE 4.6c

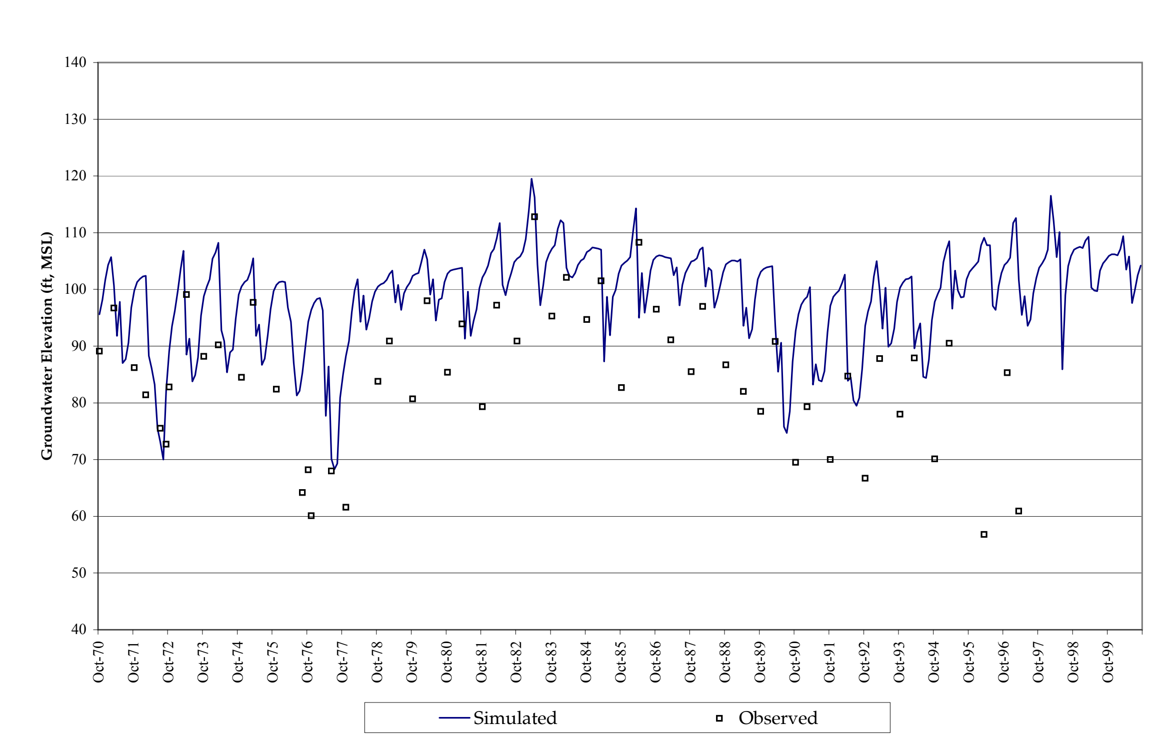


YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

YCIGSM Calibration Well 57 Groundwater Level Hydrograph

FIGURE 4.6d



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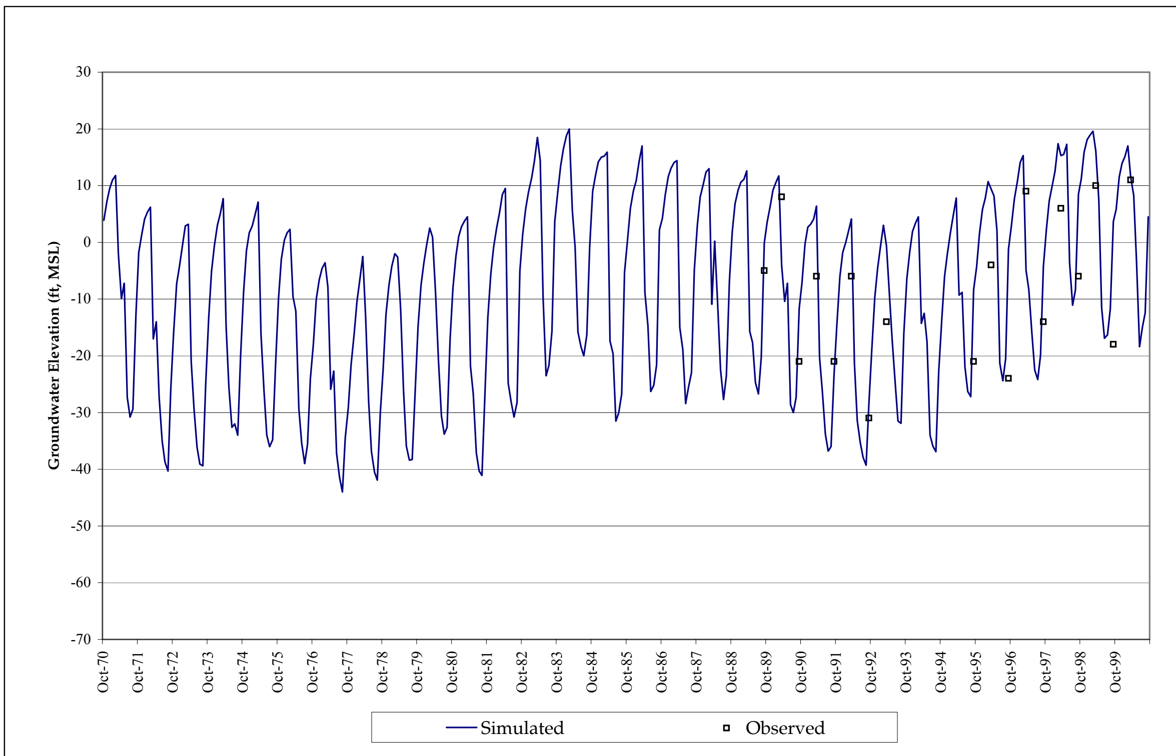
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Well 69 Groundwater Level Hydrograph

APRIL 2006

FIGURE 4.6e



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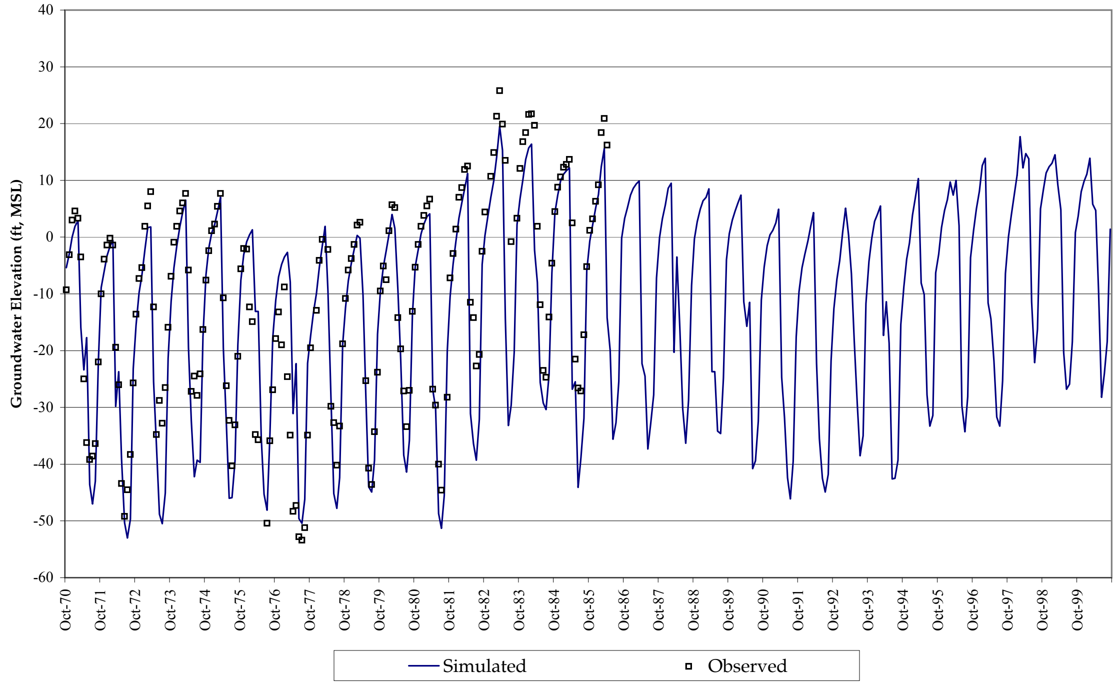
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Well 78 Groundwater Level Hydrograph

APRIL 2006

FIGURE 4.6f



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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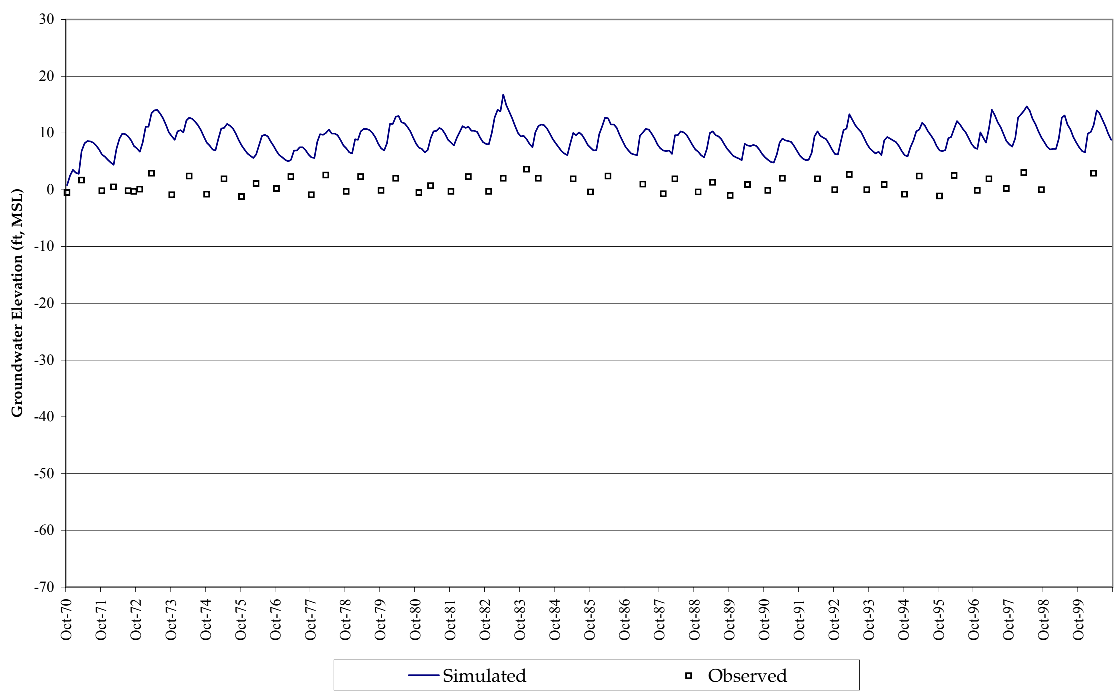
YCIGSM Calibration Well 83 Groundwater Level Hydrograph

FIGURE 4.6g



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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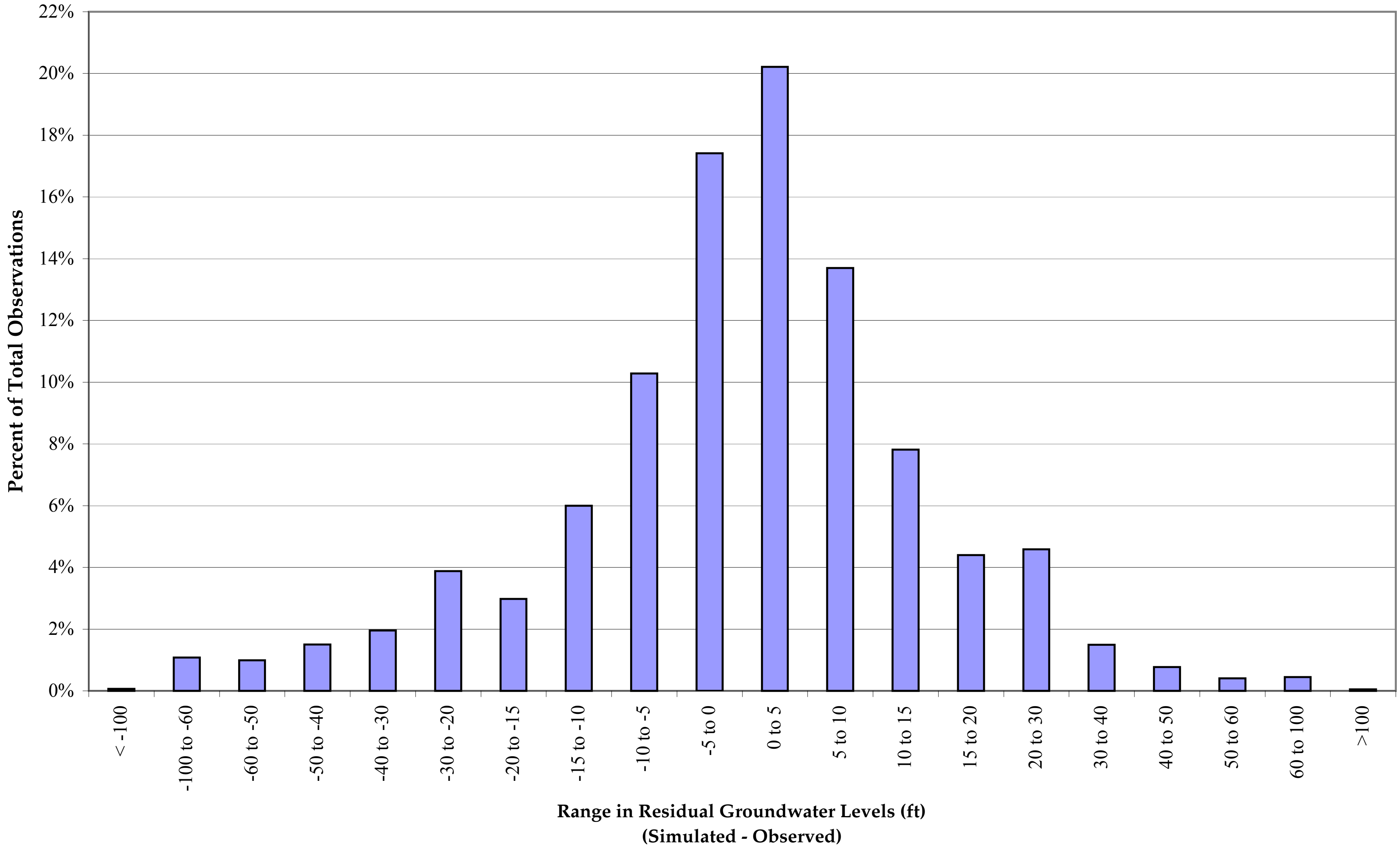
YCIGSM Calibration Well 96 Groundwater Level Hydrograph

FIGURE 4.6h



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Histogram of Deviations between Simulated and Observed Groundwater Levels

APRIL 2006

FIGURE 4.7

Capay Valley Simulated Groundwater Levels

Calibration Wells 1 through 7 are located in Capay Valley. The hydrographs of the wells are shown in Appendix A, Figures A.2–A.8. The simulated groundwater levels reasonably match with the observed water levels for all wells except for Well 3. Lack of data associated with boundary conditions and stratigraphy in this area of the YCIGSM could have affected the groundwater level simulation at Well 3. The mean absolute residual between simulated and observed groundwater levels is 6.6 feet for calibration wells in this area.

Well 3 is located near the boundary of the model where the boundary condition type is ungaged watershed. The contributions of these watersheds to the Capay Valley groundwater/surface water system have not been measured and are estimated by the YCIGSM. Stratigraphy data in the area around Wells 3 and 6 were estimated from a single datum location and then interpolated as required to develop the model stratigraphy in the area. This could be a significant source of error in the simulation of groundwater levels at these wells.

Cache Creek above Moore's Siphon Simulated Groundwater Levels

Calibration Wells 10–13 and 16–27 are located along the Cache Creek corridor, below Capay Dam and above Moore's Siphon. The hydrographs associated with these wells are shown in Appendix A, Figures A.11–A.14, and A.17–A.28. The simulations of groundwater levels reasonably represent the observed measurements for all wells, except for Well 10. The mean absolute residual between simulated and observed groundwater levels is 6.3 feet for calibration wells in this area.

Well 10 is located on the north side of Cache Creek, near the Hungry Hollow canal. For Well 10, the YCIGSM simulated water levels are consistently higher than observed measurements; however, the YCIGSM does simulate the hydrologic trend of the observed data reasonably well. The discrepancy between simulated and observed measurements is suspected to be related to stratigraphy data in the Hungry Hollow area, as explained subsequently in the discussion of "Hungry Hollow Area Simulated Groundwater Levels."

Cache Creek below Moore's Siphon Simulated Groundwater Levels

Calibration Wells 28–41 are located along the Cache Creek corridor, below Moore's Siphon to the Settling Basin. The hydrographs associated with these wells are shown in Appendix A, Figures A.29–A.42. The simulated groundwater levels reasonably represent the observed measurements for Wells 28–31 and Wells 34–41. The mean absolute residual between simulated and observed groundwater levels is 9.2 feet for calibration wells in this area.

For Wells 28 and 32 (Figures A.29 and A.33), there appears to be a high correlation between Cache Creek flows and observed groundwater levels. The observed measurements show that water levels remain relatively constant even when regional conditions are dry (1989–1991) and that water levels spike during wet conditions and return to constant levels soon after the wet conditions end. Available information shows that both wells are shallow (well screens are less that 50 feet below ground surface). It may be inferred that there is some type of perched aquifer/clay layer present in that area preventing water levels from declining during dry periods, as illustrated in the observed data for Wells 28 and 32. Unfortunately, no information is available at present on this speculated perched aquifer/clay layer and therefore, this layer could not be simulated in the YCIGSM. However, when such information becomes available in the future, it would be possible to include this perched aquifer/clay layer in the YCIGSM to improve model calibration further.

For Well 33 (Figure A.34), the YCIGSM simulates water levels that are lower than observed measurements. The observed measurements are constant, aside from insignificant seasonal variations, suggesting that there could be a constant headwater source near the well. The well is located near the East Adams Canal and the canal may be acting as a recharge source for the well. It may be noted that the YCIGSM does not explicitly simulate water flow in the East Adams Canal but the model grid has been configured such that the canal could be simulated in the model, if desired.

Hungry Hollow Area Simulated Groundwater Levels

Calibration wells 14, 15, 42, and 43 are located in the Hungry Hollow area. The hydrographs associated with these wells are shown in Appendix A, Figures A.15, A.16, A.43, and A.44. Simulated water levels in Wells 14 and 15 are generally higher than observed values but follow the hydrologic trends indicated by the observed values. The observed values show that during drought periods, water levels drop more than 40 feet. The simulated values do not show that severe of a decline. For Well 42, simulated water levels match reasonably well with observed data. However, a steep seasonal water level variation is simulated that is not seen in the observed data. For Well 43, simulated water levels are lower than observed values. The mean absolute residual between simulated and observed groundwater levels is 18.4 feet for calibration wells in this area.

The discrepancy between simulated and observed measurements in the Hungry Hollow area could be related to improper and/or inadequate delineation of hydrology, inability to capture changes in stream channel geometry and bed elevation over time, inaccuracies in the well reference point elevations, and geology of the area in the YCIGSM. The discrepancy could also be related to potential errors in observed well records data with which simulated model results are compared. Stream channel data in the YCIGSM are time-invariant, meaning that the values don't change in time. It is possible that simulation of groundwater levels at these wells are impacted by the fact that Cache Creek stream channel characteristics have changed in time. However, based on all available information, it appears likely that the major source of the discrepancy between simulated and observed measurements is related to the seriously deficient stratigraphy data in the Hungry Hollow area. There are fewer sources of stratigraphy data in the Hungry Hollow area in comparison with other areas in the YCIGSM. As such, stratigraphy data in the Hungry Hollow area (where data are severely lacking) were estimated and incorporated in the YCIGSM based on the little data that were available. The representation of stratigraphy data in the YCIGSM can be improved as more hydrologic studies are conducted in the Hungry Hollow area and as more stratigraphy data become accessible. Availability of new stratigraphic data for this area is expected to improve the YCIGSM simulation of groundwater levels for the area.

Woodland Area Simulated Groundwater Levels

Calibration Wells 55–59 and 66 are located in and around Woodland. The hydrographs associated with the wells are shown in Appendix A, Figures A.56–A.60 and A.67. Simulated water levels in Wells 55–58 match reasonably well with observed values during the late fall through early summer measurements. Observed water levels taken for municipal wells during mid-summer through mid-fall are generally not considered reasonable measurements of water levels in the regional groundwater aquifer because water level measurements at these wells are taken within several hours after well shutdown and do not necessarily represent fully recovered groundwater levels. Based on discussions with engineers and operators of well systems in the area, it is concluded that water levels can take up to 24 hours for recovery, particularly, during the summer and fall months when the stresses on the regional groundwater system are the greatest. As such, groundwater levels in the Woodland area were calibrated to late fall through early summer measurements to represent regional groundwater levels in the aquifer. The mean absolute residual between simulated and observed groundwater levels when summer and fall observations are removed from the analysis is 9.6 feet.

Winters Area Simulated Groundwater Levels

Calibration Wells 68 and 69 are located around Winters. The hydrographs associated with these wells are shown in Appendix A and Figures A.69 and A.70. Simulated water levels in the wells match reasonably well with observed values. The mean absolute residual between simulated and observed groundwater levels is 9.6 feet for calibration wells in this area.

Davis Area Simulated Groundwater Levels

Calibration Wells 75–84 are located in and around the Davis Area. The hydrographs associated with these wells are shown in Appendix A and Figures A.76–A.85. Simulated water levels in Wells 76, 77, and 81–84 match reasonably well with observed values during the late fall through early summer measurements. As with the Woodland area wells, water levels taken from City of Davis wells (Wells 76, 77, 81, and 82) during the summer and fall months do not necessarily reflect static regional groundwater levels. Thus, similar to the wells in the Woodland area, groundwater levels in the Davis area were calibrated to late fall through early summer measurements to represent regional groundwater levels in the aquifer. The mean absolute residual between simulated and observed groundwater levels when summer and fall observations are removed from the analysis is 11.5 feet.

Calibration Wells 78–80 are UCD water supply wells. It is reported that UCD well operators take water level measurements at least 24 hours after shutdown, so that water levels measurements are more reflective of regional conditions. Unfortunately, for the available data, the dates of the water level measurement were not recorded and the water level measurements were assigned as a spring or fall measurement. For purposes of calibrating the YCIGSM, spring water level measurements were assigned to March and fall water level measurements were assigned to September. Given these assumptions, the simulated values by the YCIGSM match reasonably well with observed water level measurements in Wells 78 and 80. Simulated water levels in Well 79 appear to be out-of-phase with the observed measurements. This could be because of a lack of data on measurement dates.

STREAMFLOW CALIBRATION

The YCIGSM simulates the streamflow in several major rivers and creeks in the model area, including the Sacramento River, Cache Creek, Putah Creek, the Colusa Basin Drain, and the Yolo Bypass. The model also simulates the interaction between the stream and the aquifer system on a daily time step. Calibration of the simulated streamflows is performed by comparing them with recorded streamflows at the locations listed in Table 3.5. Streamflow hydrographs for these stations are included in Appendix B. Figures B.2–B.11 show a reasonable simulation of the flows in Cache and Putah Creeks, as well as in the Sacramento River. The following provides a more detailed discussion on the streamflow calibration of Cache Creek.

Cache Creek Simulated Streamflow

There were three streamflow gages used in the calibration of Cache Creek streamflow. The simulated and observed streamflow hydrographs of Cache Creek at Brooks, Cache Creek at

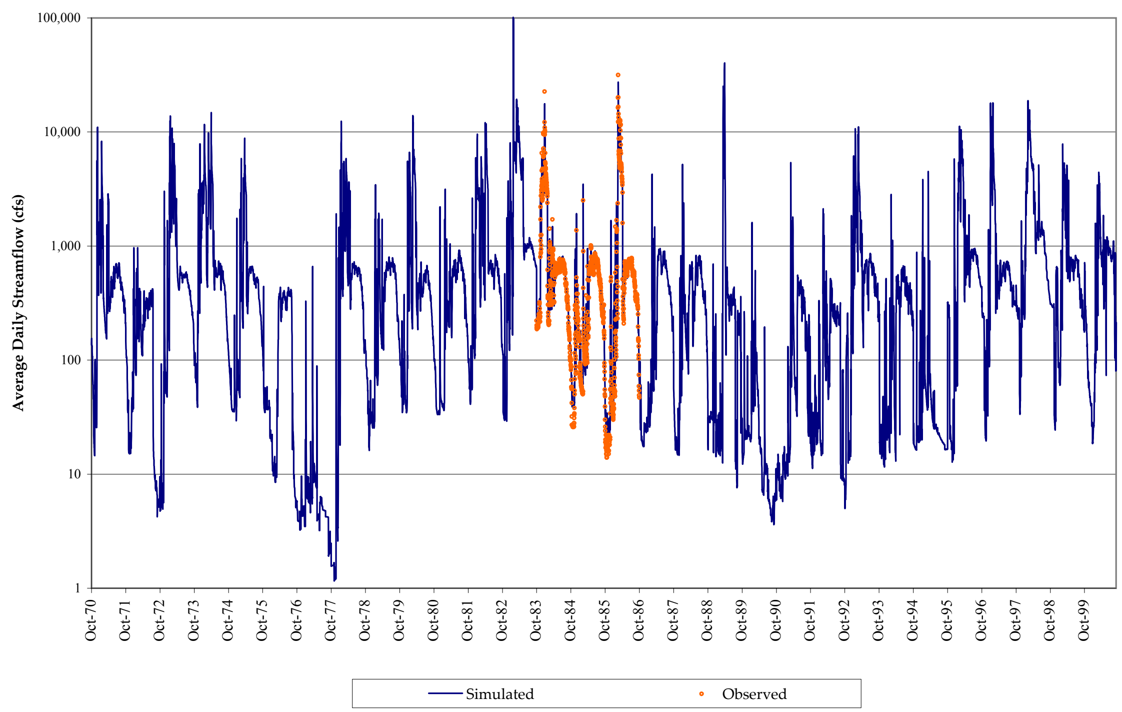
Capay, and Cache Creek at Yolo are shown in Figures 4.8, 4.9, and 4.10, respectively. Brooks and Capay are located above Capay Dam and the period of record for both gages, relative to the model simulation period, is short. Figures 4.8 and 4.9 show that YCIGSM simulated streamflows, at both gage locations, closely match the observed values.

The Cache Creek at Yolo gage has a period of record that encompasses the YCIGSM simulation period. Figure 4.10 shows that the simulated streamflow values closely match the observed data during periods when Capay Dam is not in operation. A flow exceedance chart for Cache Creek was also prepared for observed and simulated flows. Figure 4.11, referred to as an exceedance chart, shows that approximately 60% of the flows are greater than 10 cfs in the observed record and 50% in the simulated values. The likelihood of the model simulating 1 cfs or greater occurs approximately 90% of the time in the simulation period whereas the observed data indicate that this occurs approximately 70% of the time. Based on available information, it can reasonably be concluded that the discrepancies between observed and simulated Cache Creek flows at Yolo could have resulted from several potential sources. These include missing data associated with the releases from Capay Dam, groundwater pumping near Cache Creek, and surface water return flow from the Salisbury Spill. The daily release record from Capay Dam, when in operation, is available from 1979 to present. However, the release record is not complete for every day of operation and there are issues regarding the accuracy of the available Capay Dam release data. Groundwater pumping near Cache Creek has not been measured and, therefore, no such data are available. The Gordon Slough is the principal drain of the Hungry Hollow area. The Gordon Slough discharges to Cache Creek via the Salisbury Spill. This discharge to Cache Creek is not measured and, thus, could not be explicitly simulated in the YCIGSM. All these factors are believed to have contributed significantly to the inaccuracies in the simulated Cache Creek flows at Yolo when Capay Dam is in operation.

SENSITIVITY ANALYSIS

Sensitivity analysis is an important step in the model development process. It is defined as "the study of distribution of dependent variables (e.g., groundwater elevations in a groundwater model) in response to changes in the distribution of independent variables, initial conditions, boundary conditions, and physical parameters" (AWWA, 2001). In general, a sensitivity analysis of an integrated groundwater and surface water model is performed for the following purposes:

- To test the robustness and stability of the model by establishing tolerance within which the model parameters can vary without significantly changing the model results;



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Simulated and Observed Cache Creek Streamflow Hydrograph at Brooks

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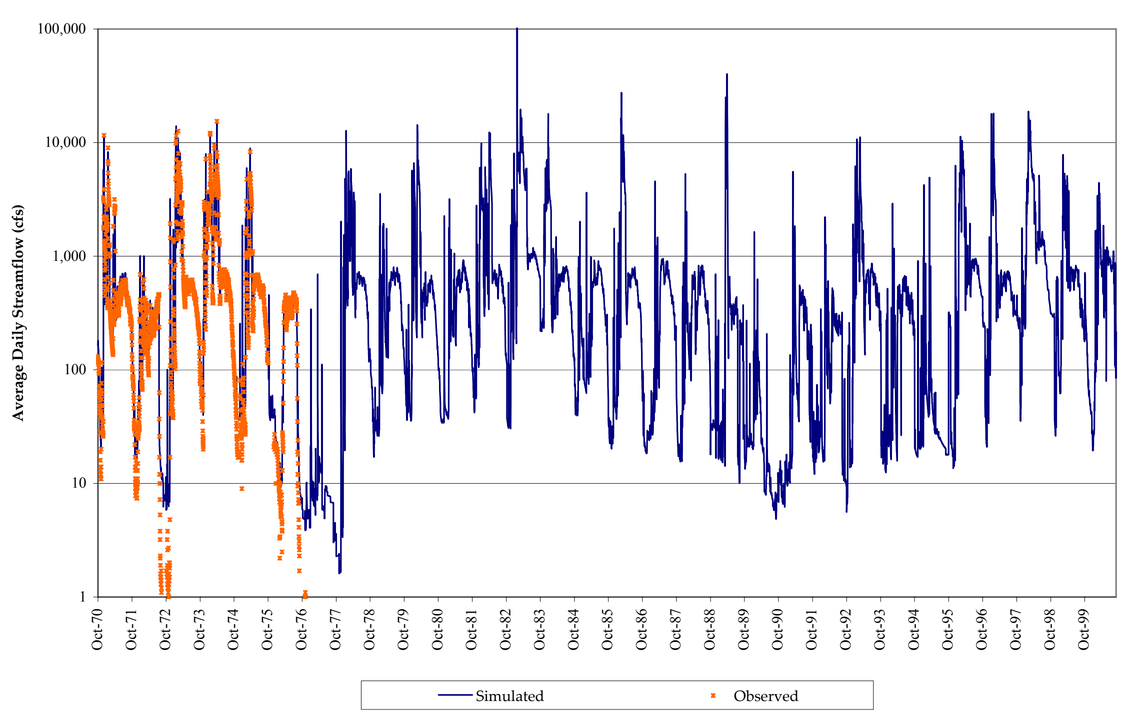
FIGURE 4.8



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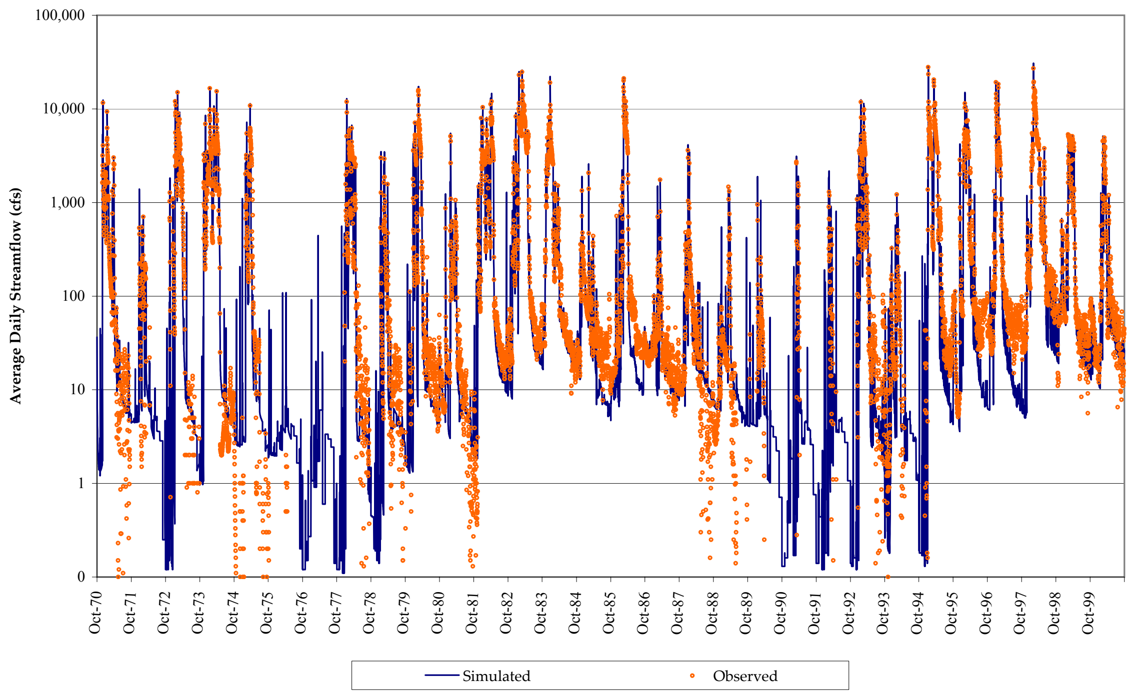
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

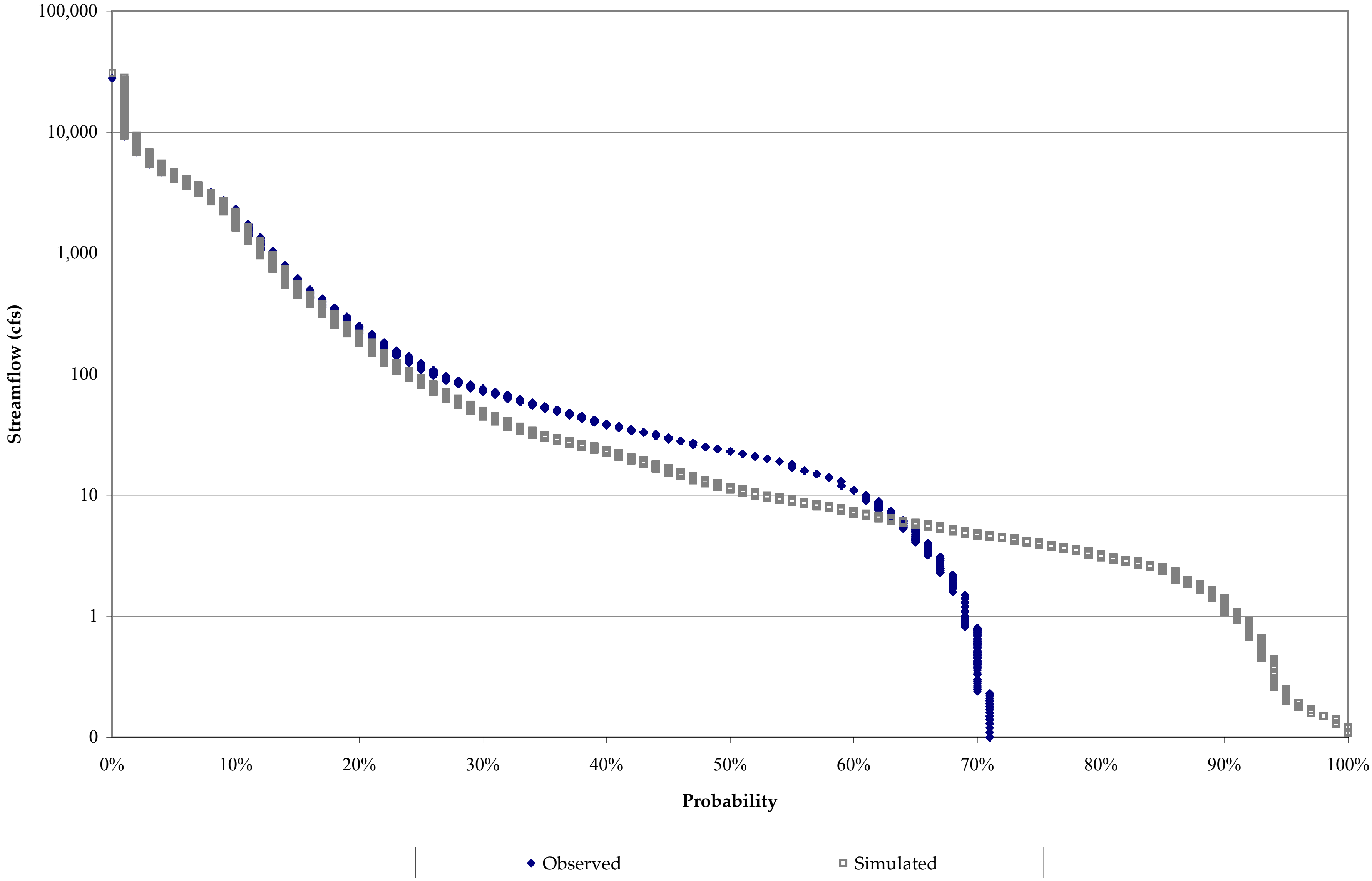
Simulated and Observed Cache Creek Streamflow Hydrograph at Capay

APRIL 2006

FIGURE 4.9



RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Simulated and Observed Cache Creek Streamflow Hydrograph at Yolo	FIGURE 4.10



YOLO COUNTY

INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Exceedance Chart for Cache Creek Streamflow at Yolo

APRIL 2006

FIGURE 4.11

- To understand the impact of inaccuracies in input data on model results (e.g., how model results can change because of a 10% error in the estimation of agricultural pumping; and
- To develop an understanding of the relative sensitivity of the components of the hydrologic cycle and data, so that an effective data collection and monitoring plan can be developed.

METRICS OF SENSITIVITY ANALYSIS

A sensitivity analysis was performed using the YCIGSM to assess the sensitivity of model results to specific model parameters and input data. Two different metrics were selected to measure the sensitivity of the YCIGSM. A sensitivity metric is a single number derived from the YCIGSM model results and has a unique value for each model run corresponding to a given set of data or parameter value. The sensitivity metrics used in the study are:

- Average groundwater elevation in study areas, and
- Average root mean square (RMS) error aggregated from selected calibration wells.

Average groundwater elevation in study areas is defined as a three-way average of simulated groundwater elevations at model nodes. The average is taken over:

- Layers,
- Nodes, and
- Time.

This can be mathematically expressed by:

$$\overline{H} = \frac{1}{M}\sum_{k=1}^{M} H_k$$

and,

$$H_k = \frac{1}{N}\sum_{i=1}^{N} \left[\frac{1}{L}\sum_{j=1}^{L} h_j\right]_i^k$$

where,

M	total number of simulation months,
H_k	average head in the model area at k-th time step,
N	number of model nodes,
L	number of model layers in aquifer,
h_j	groundwater elevation at layer j,
i, j, k	are indices for node, layer, and time, respectively

The average RMS error at selected calibration wells is defined as the average of individual RMS error at each calibration well. The RMS error at a calibration well is defined as follows:

$$RMS_w = \sqrt{\left\{ \frac{1}{N_o} \sum_{k=1}^{No} [h_{k,w}^o - h_{k,w}^s]^2 \right\}}$$

where,

N_o	is the number of observations at well, k
$h_{k,w}^o$	is the observed groundwater elevation at month k, at well, w
$h_{k,w}^s$	is the simulated groundwater elevation at month k, at well, w

RESULTS OF YCIGSM SENSITIVITY ANALYSIS

Sensitivity analyses were performed for the YCIGSM for the following model parameters and input data.

- Hydraulic conductivity,
- Specific yield,
- Storage coefficient,
- Streambed hydraulic conductivity,
- Groundwater pumping, and
- Crop acreage.

The sensitivity analysis was performed model-wide over the entire basin. However, the impacts of the sensitivity analysis were evaluated in seven impacts areas. These impacts areas are:

1. Capay Valley,
2. Cache Creek area above Moore's Siphon,
3. Cache Creek area below Moore's Siphon,
4. Hungry Hollow,
5. Woodland,
6. Winters, and
7. Davis.

YCIGSM nodes were selected within each impact area and an evaluation of groundwater levels were conducted for each area. Calibration wells were selected from each impact area for the

RMS error evaluation. Figure 4.12 shows the impact areas used in the sensitivity analysis and the selected groundwater wells.

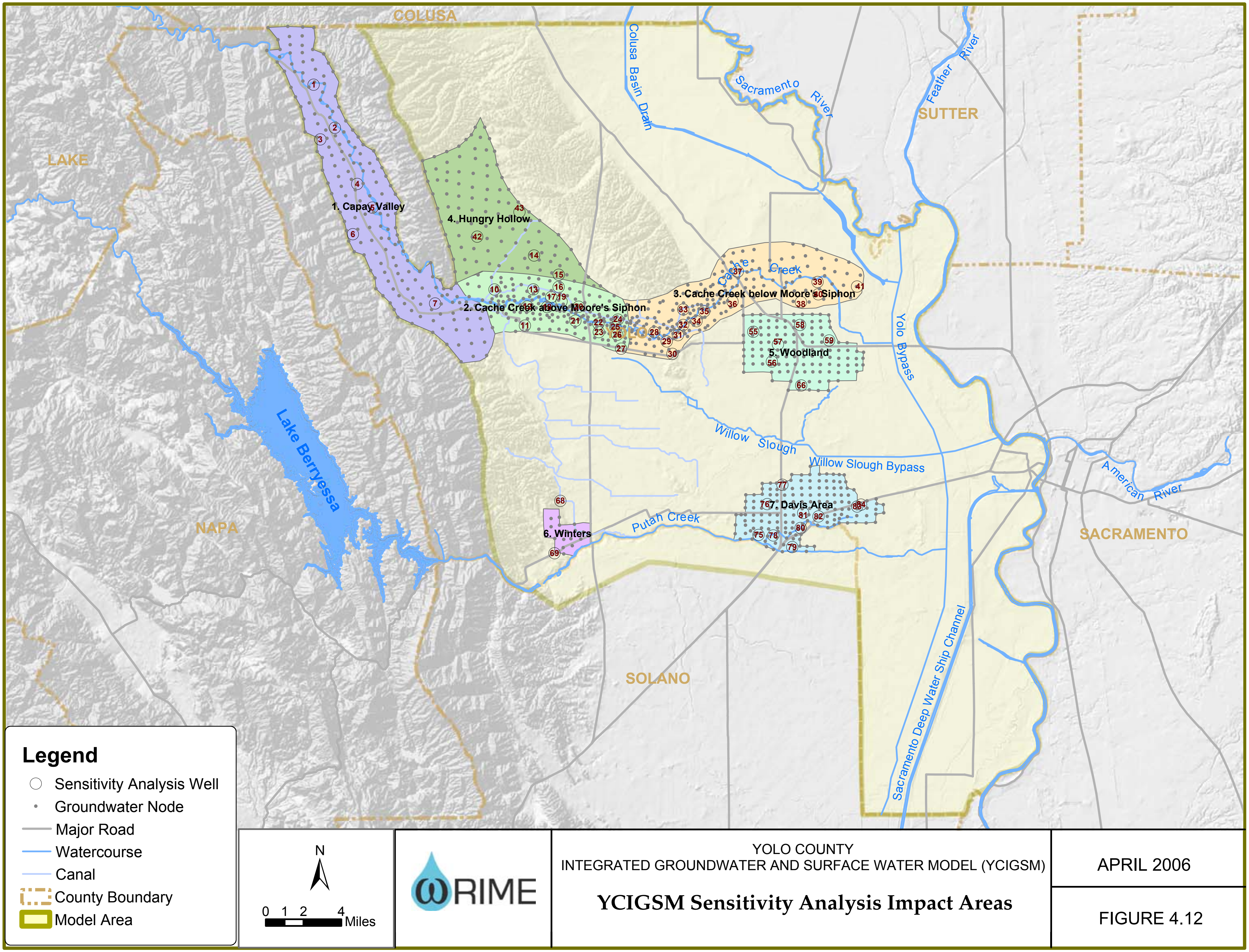
The results of the sensitivity analyses for the YCIGSM are presented in Figures 4.13a–d through4.18a–d.

The results are presented with reference to the calibrated YCIGSM model, using the corresponding value as the reference value for the average groundwater level. For example, the average groundwater level in a particular sensitivity analysis impact area was shown as difference from the corresponding value for the calibration run; in other words, the average groundwater level in the impact area for the calibration run of the YCIGSM was subtracted from the corresponding value for each sensitivity run of the YCIGSM. Figures 4.13a–d indicate that if the estimated hydraulic conductivity is twice the calibration value in the entire basin, the range of the change in average groundwater levels in the seven impact areas is 10 feet lower to 10 feet higher than that of in calibration. This corroborates the fact that the higher conductivity material allows faster water movement across the basin, which results in lower groundwater levels in western areas of the YCIGSM and higher groundwater levels in eastern areas of the YCIGSM.

The RMS error for the impact area calibration wells was also shown as a relative value with reference to the corresponding value for the calibration run; that is, the RMS error value for each sensitivity run of the YCIGSM was divided by the corresponding value for the calibration run. For example, Figures 4.13a–d shows that the RMS error values increase for all hydraulic conductivity values other than those used in the calibration run of the YCIGSM. This implies the calibrated hydraulic conductivity value provides the minimum RMS error for the evaluation wells at the seven impact areas.

The sensitivity of the YCIGSM to changes in specific yield is presented in Figures 4.14a–d for Layer 1 (unconfined aquifer) only. Figures 4.14a–d indicate that if the specific yield is reduced by half over the entire basin, the range of the change in average groundwater levels in the seven impact areas will be 0 to 5 feet lower than that of in calibration. If the specific yield is doubled, the range of the change in average groundwater levels will be 2 feet lower to 2 feet higher than that of in calibration. Figures 4.14a–d show that the RMS error remains relatively unchanged as specific yield values are increased and the RMS error increases in all impact areas, except in the Davis impact area, as specific yield values are decreased.

The sensitivity of the YCIGSM to changes in specific storage is presented in Figures 4.15a–d for Layer 2 (semi-confined to confined layer). It can be seen from the figures that reducing specific storage by one order of magnitude or increasing it by three orders of magnitude over the entire basin has relatively little impact on changes in average groundwater levels in the seven impact areas or on RMS values for the evaluation wells at the impact areas



YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Sensitivity Analysis Impact Areas

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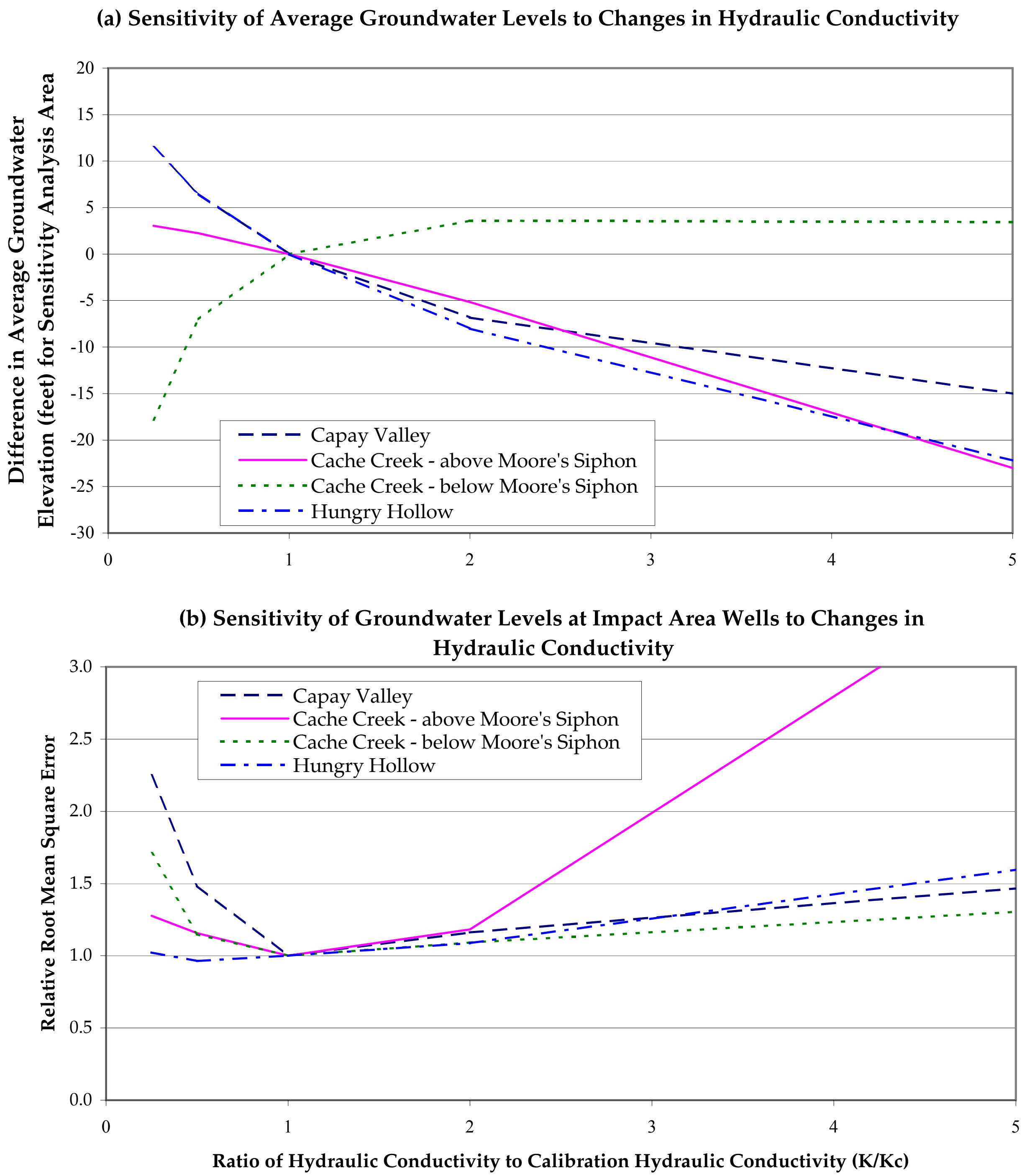
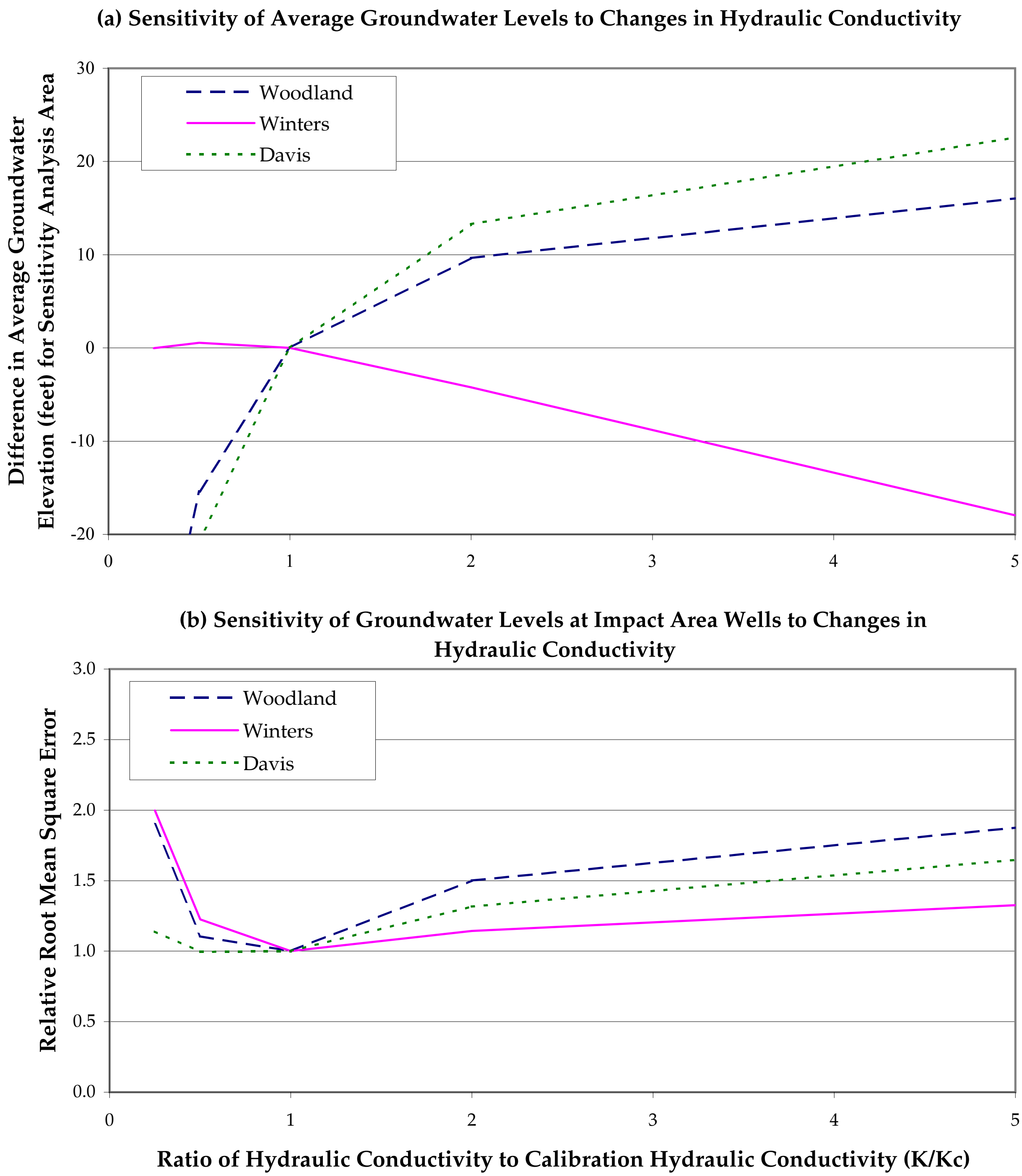
FIGURE 4.12



WRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Hydraulic Conductivity**	APRIL 2006 FIGURE 4.13a&b



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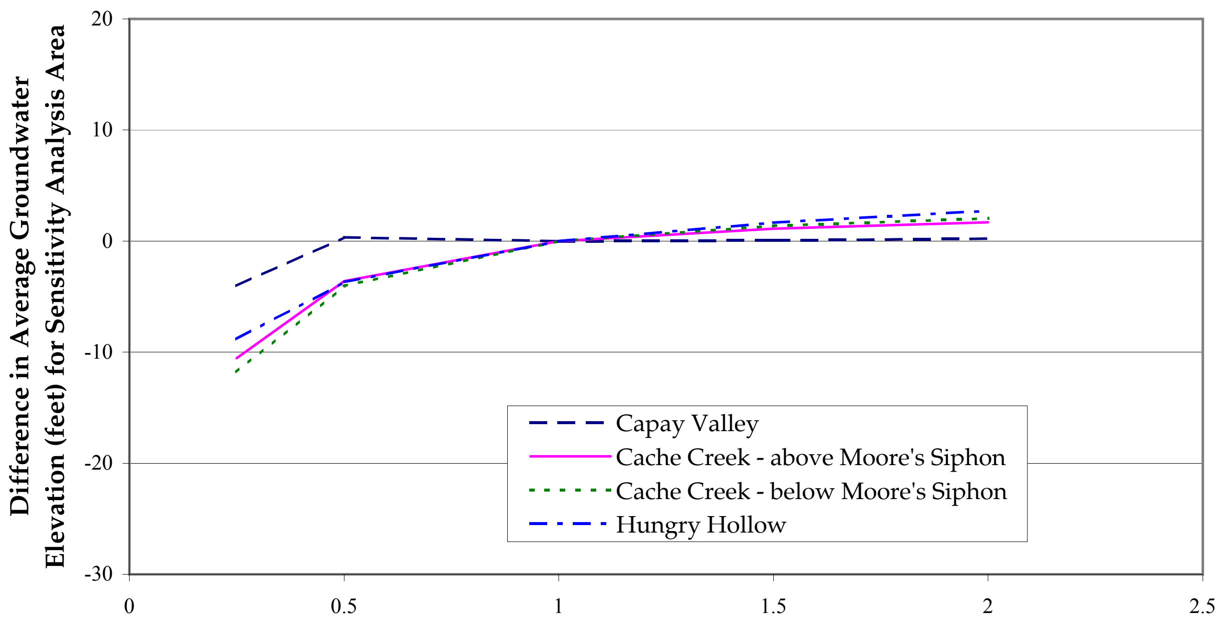
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Hydraulic Conductivity

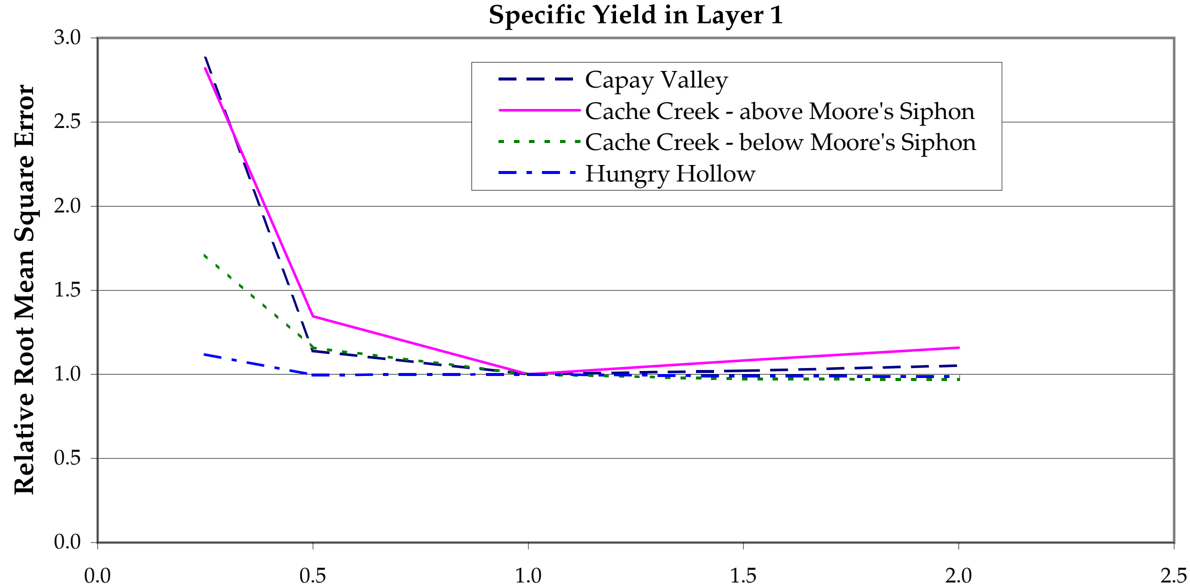
APRIL 2006

FIGURE 4.13c&d

(a) Sensitivity of Average Groundwater Levels to Changes in Specific Yield in Layer 1



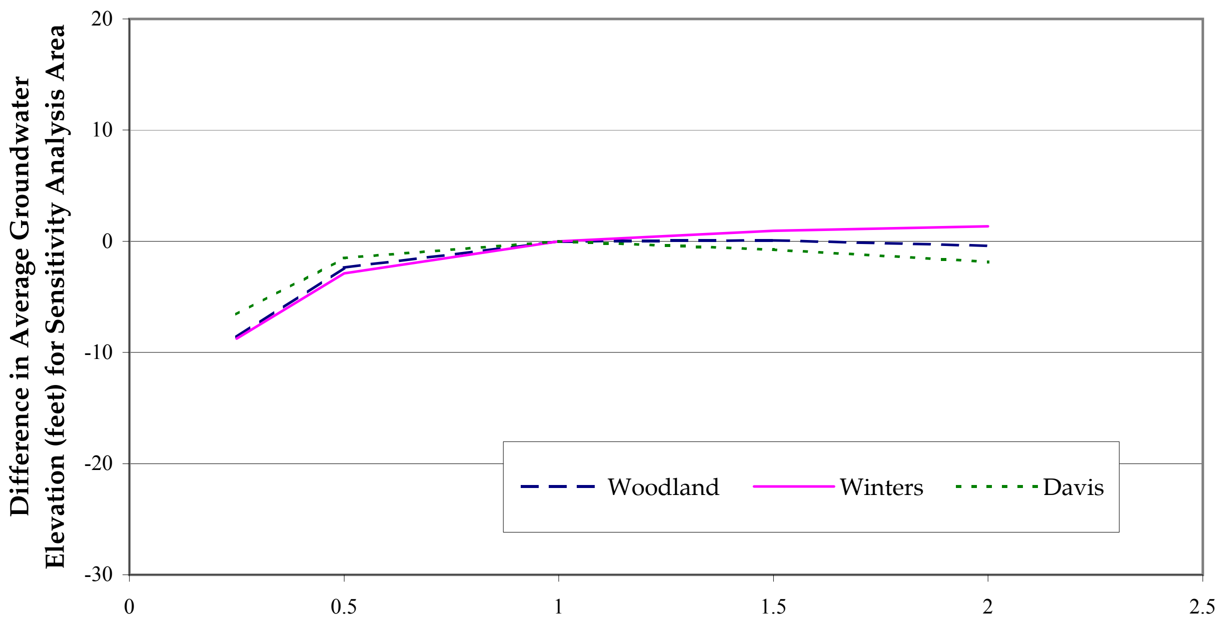
(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Specific Yield in Layer 1



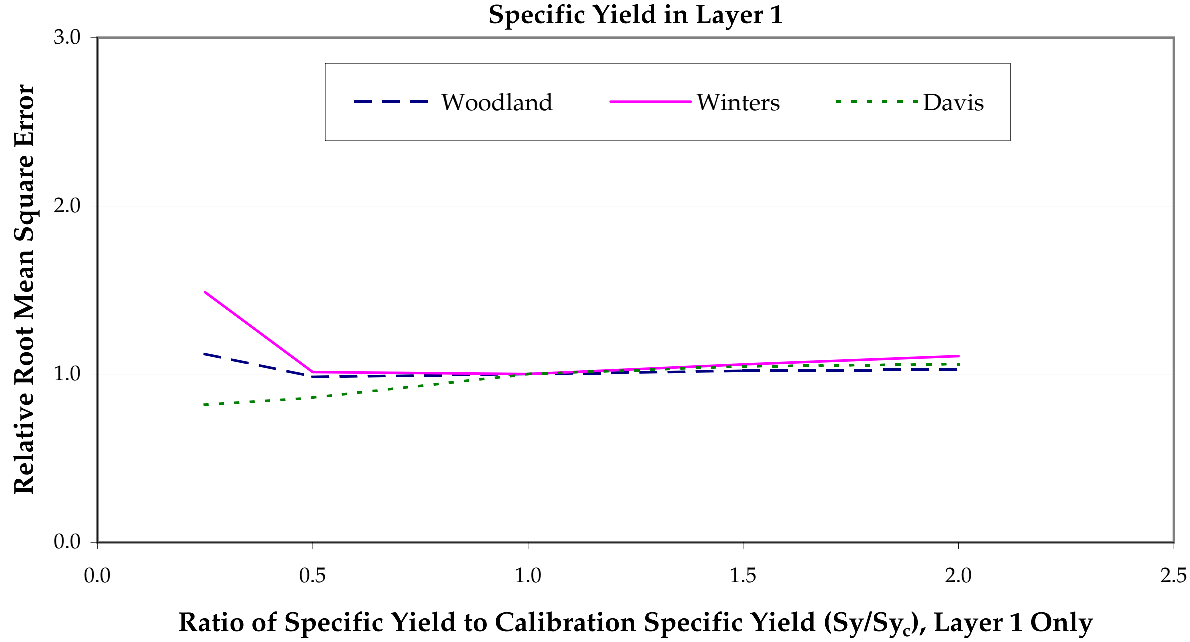
Ratio of Specific Yield to Calibration Specific Yield (Sy/Sy_c), Layer 1 Only

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Specific Yield in Layer 1**	APRIL 2006 FIGURE 4.14a&b

(a) Sensitivity of Average Groundwater Levels to Changes in Specific Yield in Layer 1

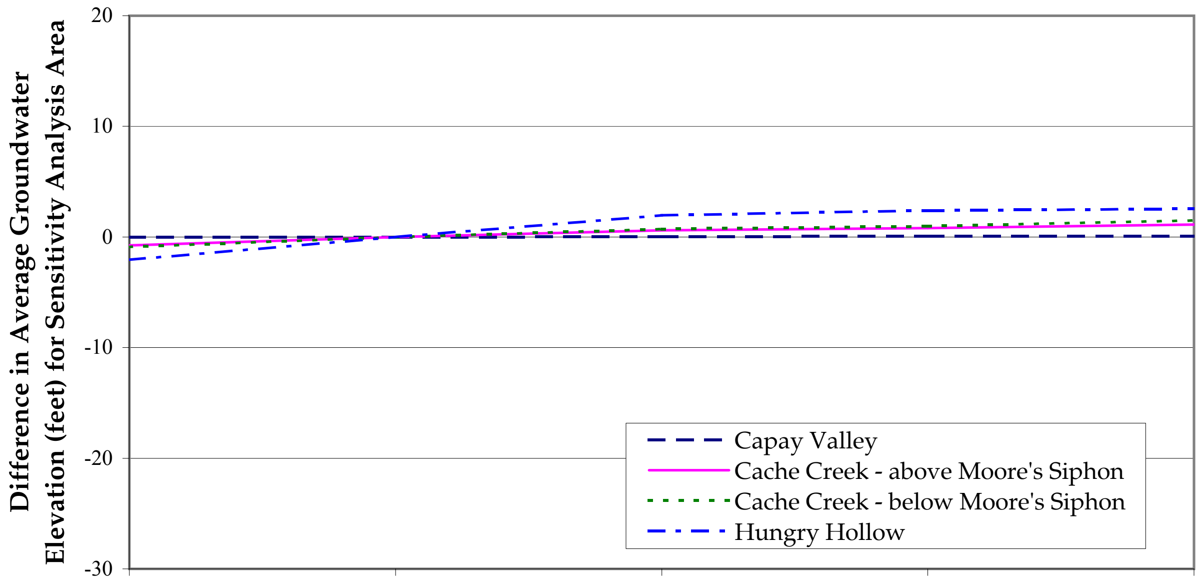


(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Specific Yield in Layer 1

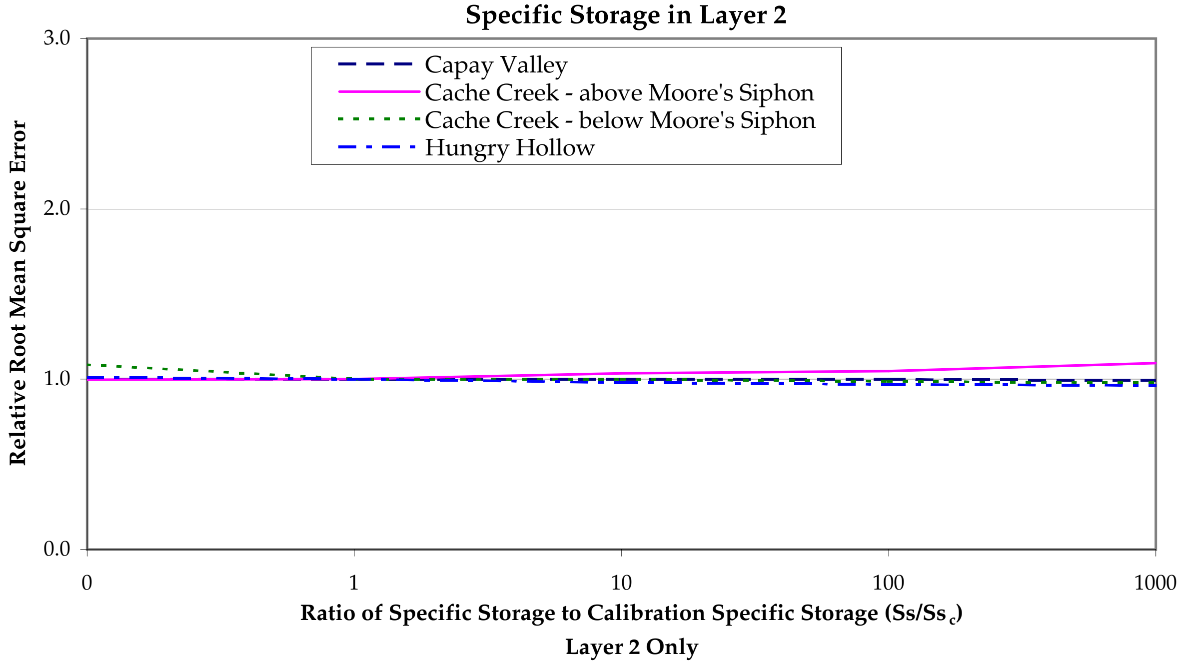


RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Specific Yield in Layer 1**	APRIL 2006 FIGURE 4.14c&d

(a) Sensitivity of Average Groundwater Levels to Changes in Specific Storage in Layer 2

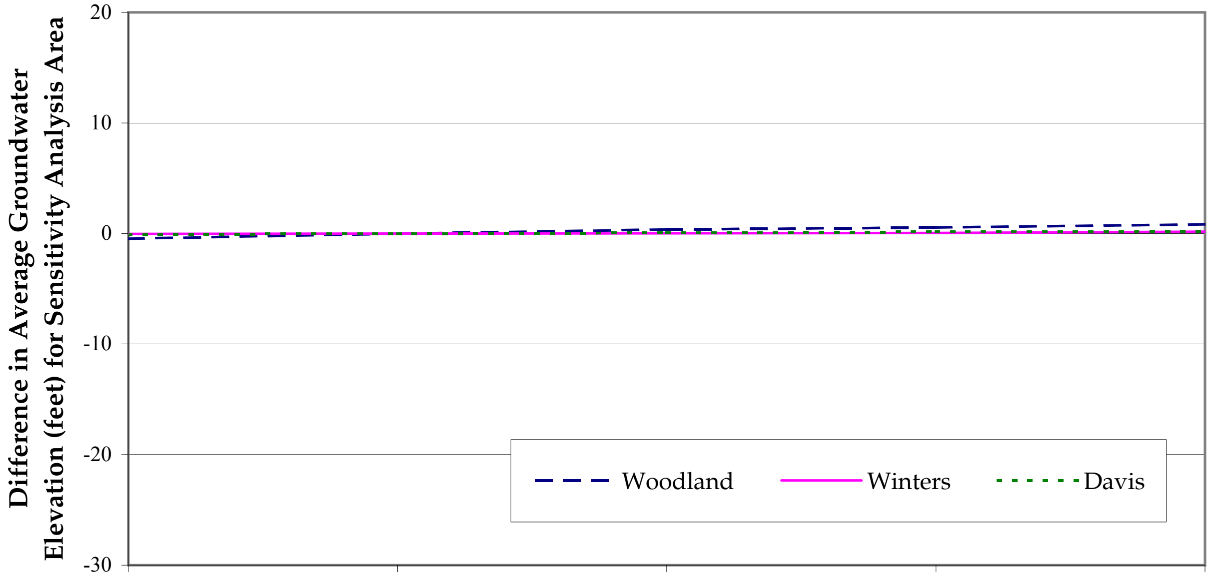


(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Specific Storage in Layer 2

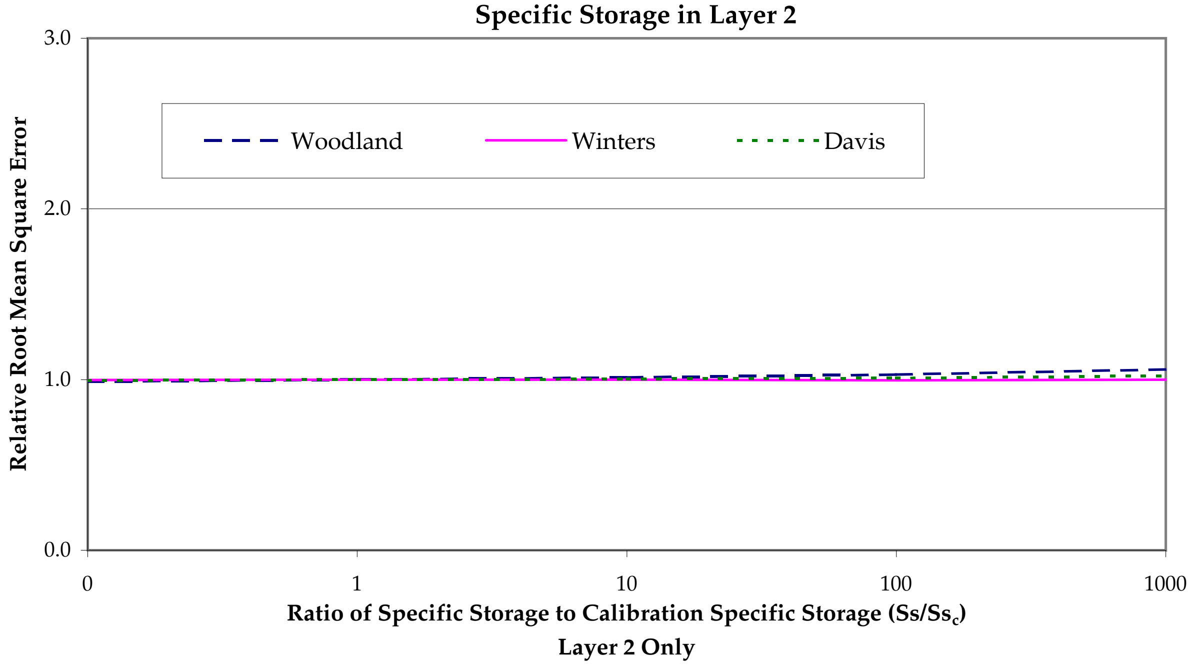


RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Specific Storage in Layer 2**	APRIL 2006 FIGURE 4.15a&b

(a) Sensitivity of Average Groundwater Levels to Changes in Specific Storage in Layer 2



(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Specific Storage in Layer 2



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Specific Storage in Layer 2

APRIL 2006

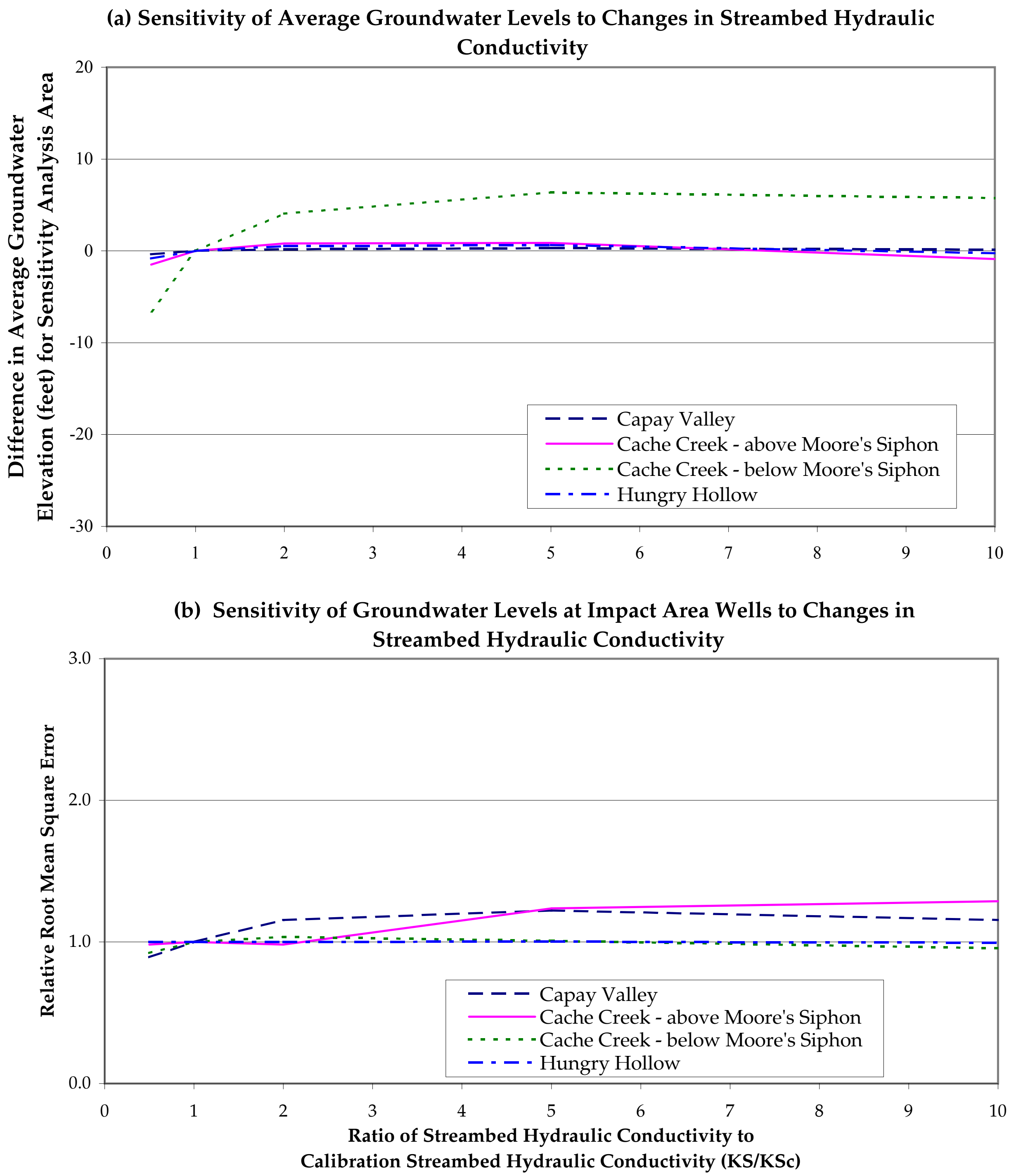
FIGURE 4.15c&d

The sensitivity of the YCIGSM to changes in streambed hydraulic conductivity is presented in Figures 4.16a–d. It can be seen from the figures that a reduction of streambed hydraulic conductivity to one half of the calibrated value over the entire basin results in 5 feet lower groundwater level in Woodland to 1 foot higher groundwater level in Winters. When streambed hydraulic conductivity values are increased by an order of magnitude, the range of the change in average groundwater levels in the seven impact areas is from 10 feet lower in Winters to 7 feet higher in Cache Creek (below Moore's Siphon) than that of in calibration. For the impact area evaluation wells, there is little change in the RMS error when streambed hydraulic conductivity is reduced by one half of the calibrated value. The RMS error values increase slightly when streambed hydraulic conductivities are increased.

The sensitivity of the YCIGSM to changes in groundwater pumping is shown in Figures 4.17a-d. It can be seen from the figures that a reduction of groundwater pumping to one half of the calibrated value over the entire basin results in 4 feet higher groundwater levels in Winters to more than 20 feet higher groundwater levels in Davis. When groundwater pumping is increased by 50% of the calibrated value, the range of the change in average groundwater levels in the seven impact areas is from 10 feet lower in Winters to from 30 feet lower in Davis. For the impact area evaluation wells, any changes in pumping result in higher RMS error values except in Hungry Hollow, where a reduction in pumping results in a slight reduction of RMS error.

The sensitivity of the YCIGSM to reductions in crop acreage is shown in Figures 4.18a–d. It should be noted that increases in crop acreage were not evaluated, since for several subregions nearly the entire subregion area was developed agriculturally. It can be seen from the figures that, in response to reductions in crop acreage over the entire basin, the average groundwater levels in the seven impact areas increase. The range of the change in average groundwater levels is an increase of 10 feet in Winters to an increase of 30 feet in Woodland. For the impact area evaluation wells, the RMS error values increase in all areas because of reductions in crop acreage. It should be noted that there was no changes made to groundwater pumping as a result of this analysis.

The results of the sensitivity analysis for the YCIGSM indicate that the model is a stable model and the system responds in the expected manner because of changes in aquifer parameters and input data.



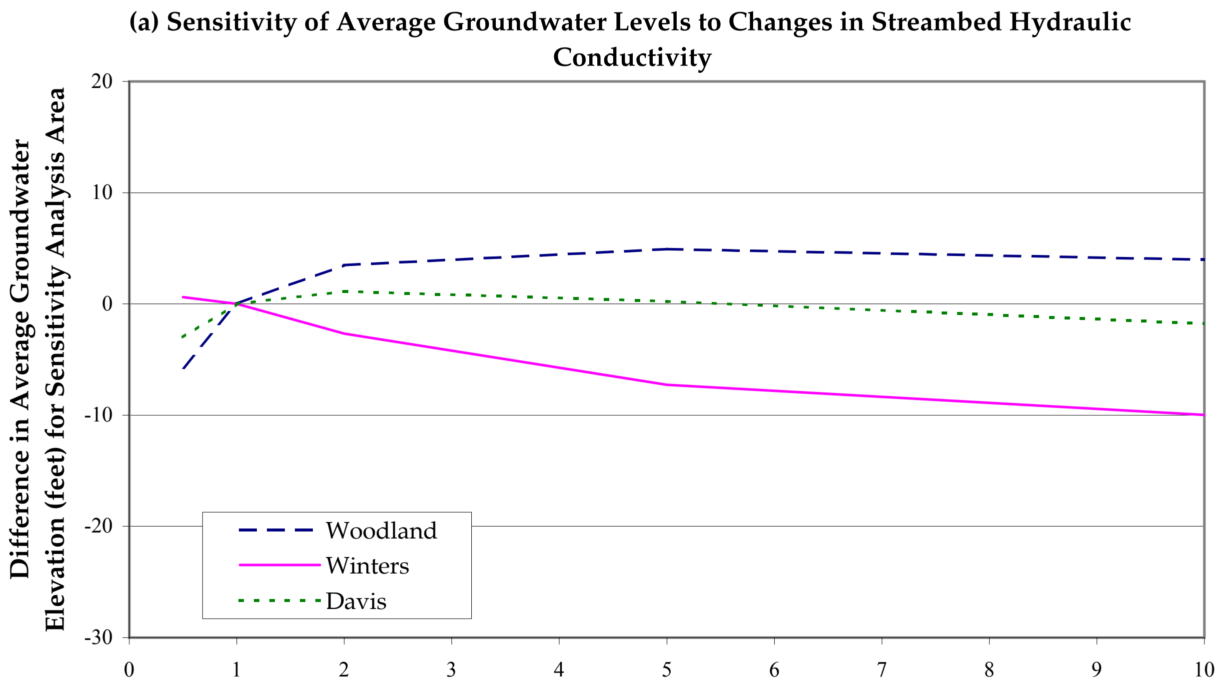
RIME

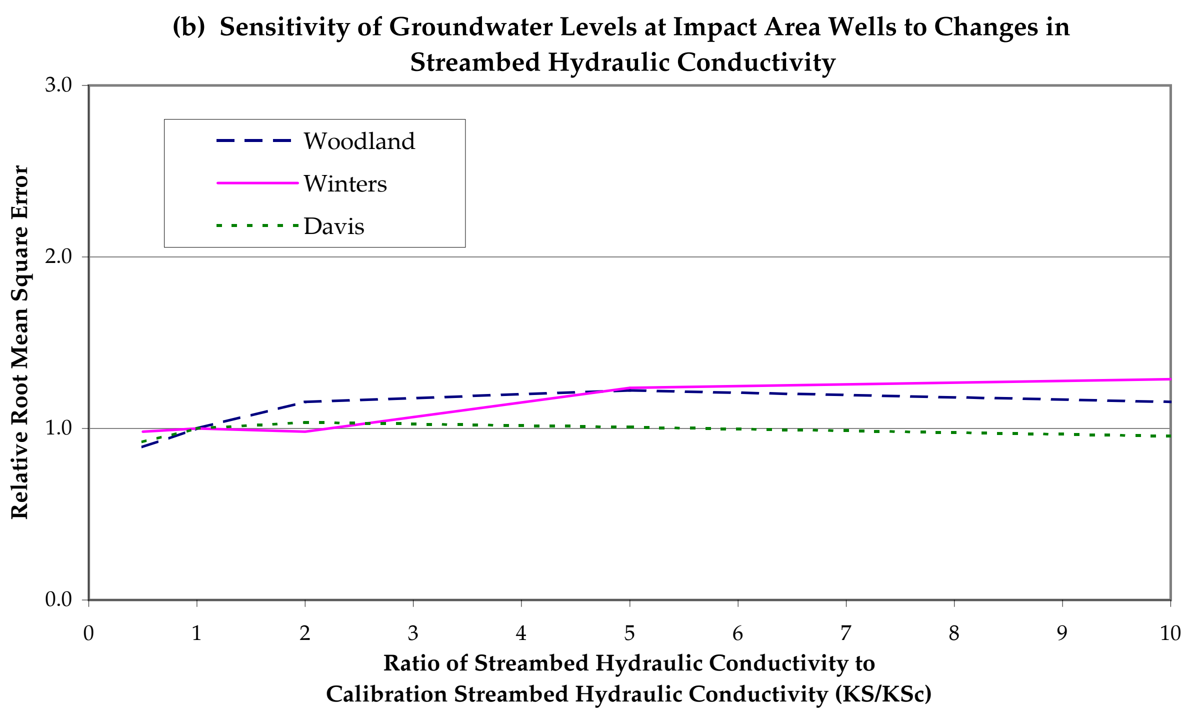
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Streambed Hydraulic Conductivity

APRIL 2006

FIGURE 4.16a&b





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YOLO COUNTY

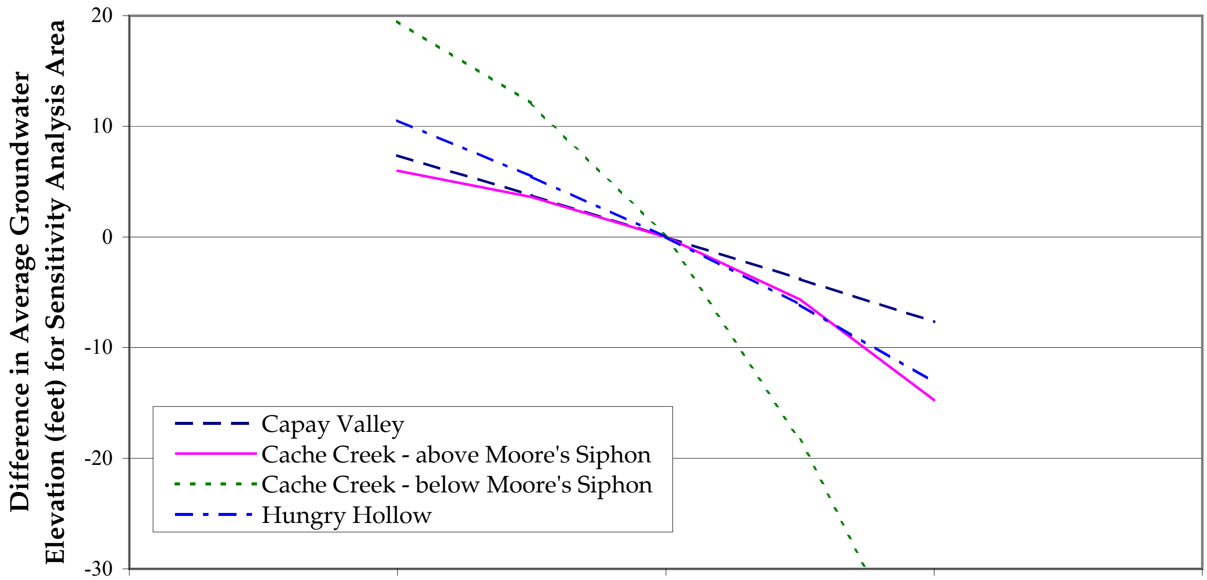
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Streambed Hydraulic Conductivity

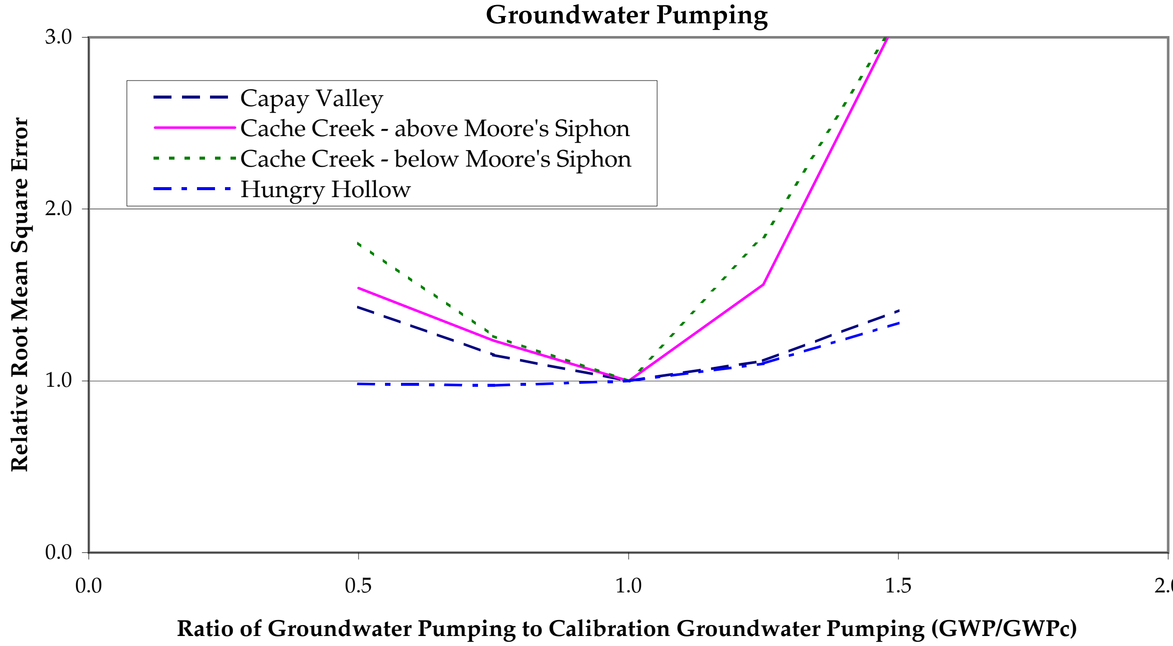
APRIL 2006

FIGURE 4.16c&d

(a) Sensitivity of Average Groundwater Levels to Changes in Groundwater Pumping (GWP)

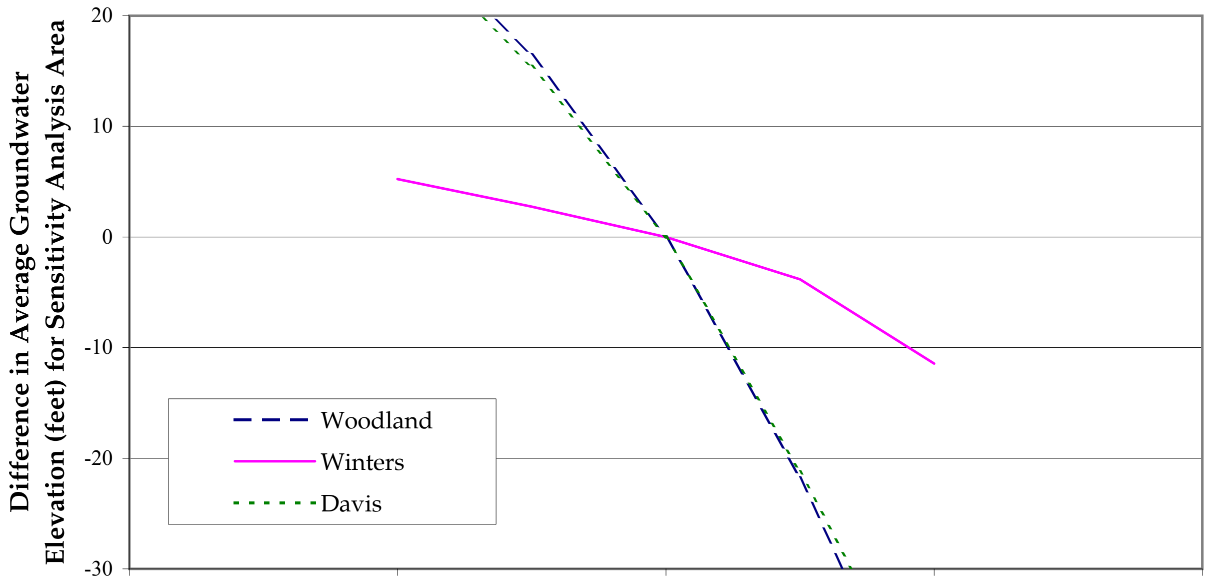


(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Groundwater Pumping

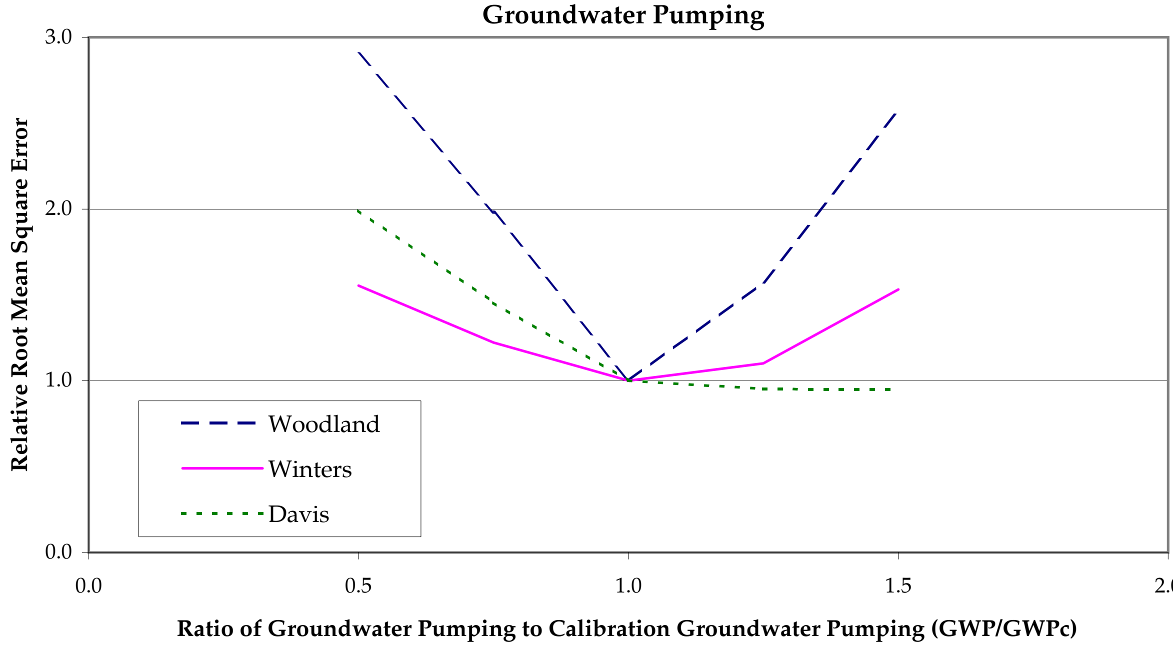


RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Groundwater Pumping**	APRIL 2006 FIGURE4.17a&b

(a) Sensitivity of Average Groundwater Levels to Changes in Groundwater Pumping (GWP)

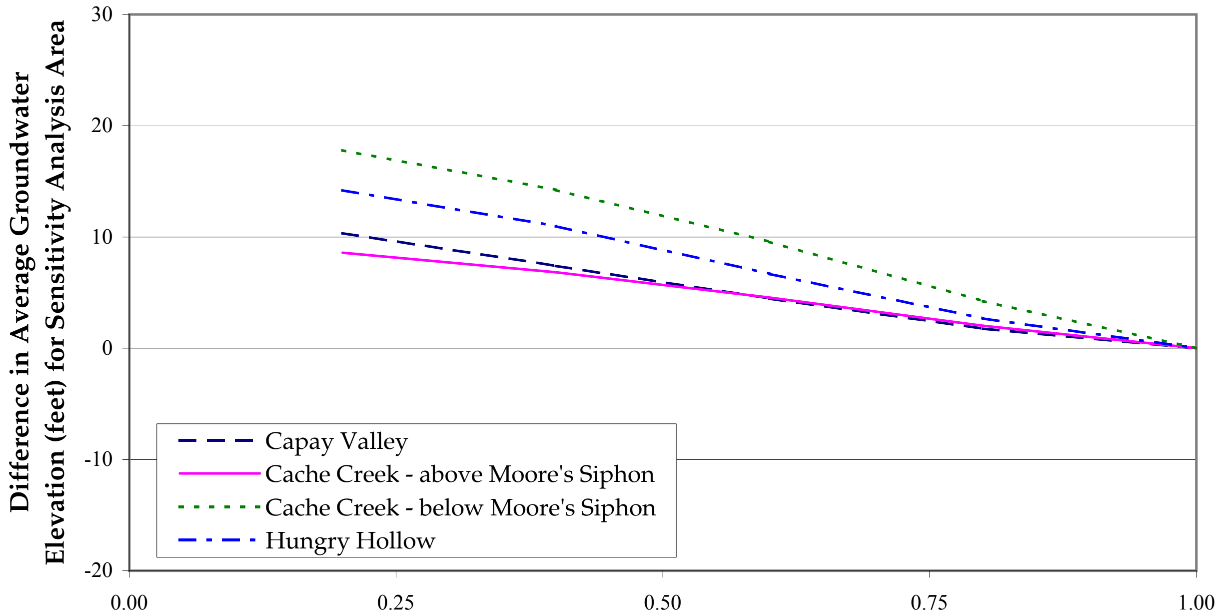


(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Groundwater Pumping

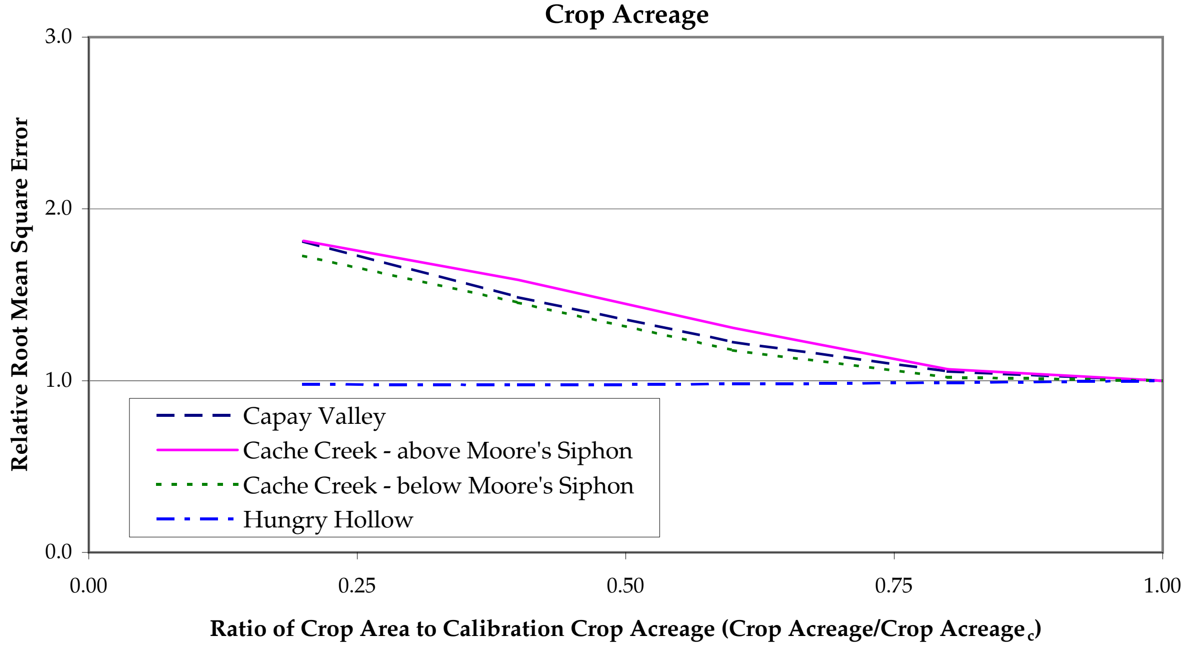


RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Groundwater Pumping**	APRIL 2006 FIGURE 4.17c&d

(a) Sensitivity of Average Groundwater Levels to Changes in Crop Acreage



(b) Sensitivity of Groundwater Levels at Impact Area Wells to Changes in Crop Acreage



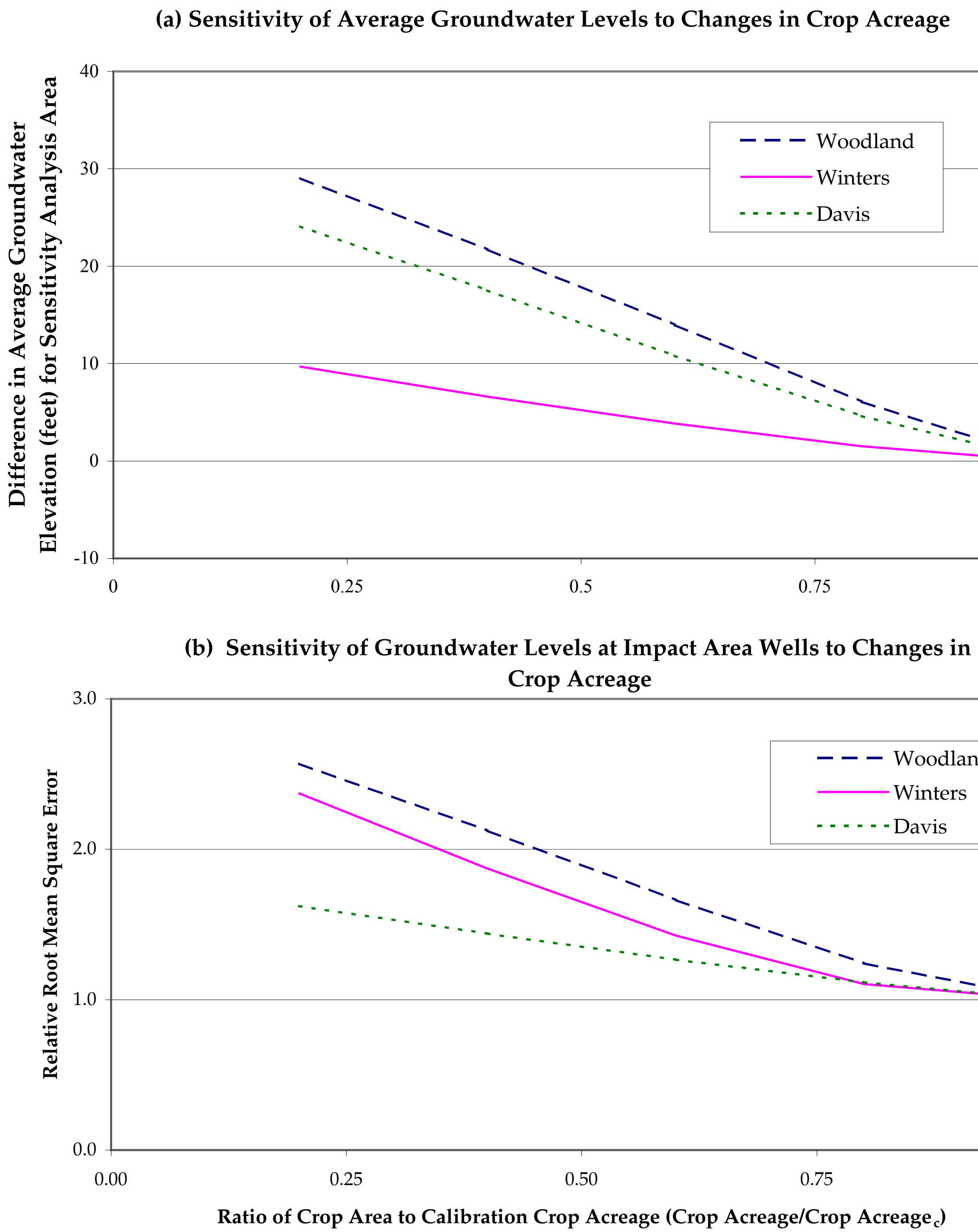
WRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Capay, Cache Creek, and Hungry Hollow Impact Areas - Crop Acreage

APRIL 2006

FIGURE 4.18a&b



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Sensitivity Analysis in Woodland, Winters, and Davis Impact Areas - Crop Acreage

APRIL 2006

FIGURE 4.18c&d

SECTION 5 BASELINE CONDITION AND CCGRRP ALTERNATIVE

This section describes the definition, preliminary assumptions, and preliminary results of the Baseline Condition and the Cache Creek Groundwater Recharge/Recovery Program (CCGRRP) Alternative. In a broader framework, the CCGRRP is expected to be evaluated from hydrologic and hydrogeologic, engineering, institutional, legal, and economic perspectives. The focus of the present analysis was a preliminary evaluation of the CCGRRP from hydrologic and hydrogeologic perspectives. To that end, the YCIGSM was used to evaluate the surface water and groundwater conditions resulting from the CCGRRP project at a feasibility level. The CCGRRP as defined in this section is at a conceptual level, and additional work is needed to further define the location of recharge basins, extraction locations, rates and timing of recharge and extraction.

The project evaluation process using the YCIGSM consisted of the following steps:

- Development and analysis of the Baseline Condition,
- Development and analysis of CCGRRP project condition, and
- Comparison of model results from the CCGRRP project with those from the Baseline Condition.

The Baseline Condition is defined as hydrologic and hydrogeologic conditions that are resulted from a specific land and water use, water demand and supply mix, and facilities that are in-place to store, transfer, and distribute the water supplies to meet the demands. The Baseline Condition is typically defined over a time period that includes ranges of hydrologic conditions, such as wet and dry cycles. The Baseline Condition represented in this study are based on the 2000 level of land use, water demand, and water supply mix in Yolo County during the hydrologic period 1970-2000.

In general terms, the Baseline Condition provides a frame of reference for comparison of water management actions in the study area. The hydrologic impacts of action alternative are typically measured as the conditions under the action alternative relative to those under the Baseline Conditions.

BASELINE CONDITION DATA

Table 5.1 lists the data and related assumptions used for developing the Baseline Condition. As mentioned earlier, the Baseline period incorporates hydrologic data from October 1971 through September 2000.

RESULTS OF THE BASELINE CONDITION

The YCIGSM Baseline Condition model was simulated for the 1971–2000 hydrologic period using the data shown in Tables 5.1 and 5.2 and in Figures 5.1–5.3. The model was used to simulate the Baseline Conditions on a daily time step. Baseline Condition groundwater levels for dry (Fall 1977 conditions), wet (Spring 1983 conditions), and average (Fall 2000 conditions) hydrologic conditions were developed using the model results (Figures 5.4–5.6). Based on these figures, the groundwater levels in the vicinity of Cache Creek near I-505 would be approximately 100 feet above mean sea level during extreme dry periods, and would increase to approximately 140 feet in wet conditions. These results are in the range of estimated groundwater levels in the model calibration. In the Davis area, a depression of –40 feet is observed in dry conditions (Figure 5.4), and water levels of approximately 20 feet are estimated in wet conditions (Figure 5.6).

Figures 5.4 and 5.6 confirm that the model reasonably estimates the groundwater levels under the Baseline Conditions.

CACHE CREEK GROUNDWATER RECHARGE & RECOVERY PROJECT (CCGRRP)

The CCGRRP is conceived as a conjunctive use project, such that excess surface water during winter months is released from Clear Lake and Indian Valley reservoir for recharge in recharge pits along Cache Creek. In exchange, groundwater would be extracted during summer months from Project wells for delivery to agricultural water users through the YCFCWCD canals. It is expected that the groundwater extraction along Cache Creek would result in sufficient drop in groundwater levels to provide storage for recharge water in subsequent season. The goal is to gain additional groundwater water storage near Cache Creek. Initial estimates of potential storage yield of the CCGRRP have been 20,000–30,000 AF/year. Central to the CCGRRP is the use of inactive gravel quarries that are adjacent to Cache Creek and the YCFCWCD West Adams and Moore Canals. The YCFCWCD is proposing to use these quarries as recharge ponds and as extraction facilities. Figure 5.7 shows preliminary location of the recharge ponds and extraction facilities initially deemed suitable for use in the CCGRRP.

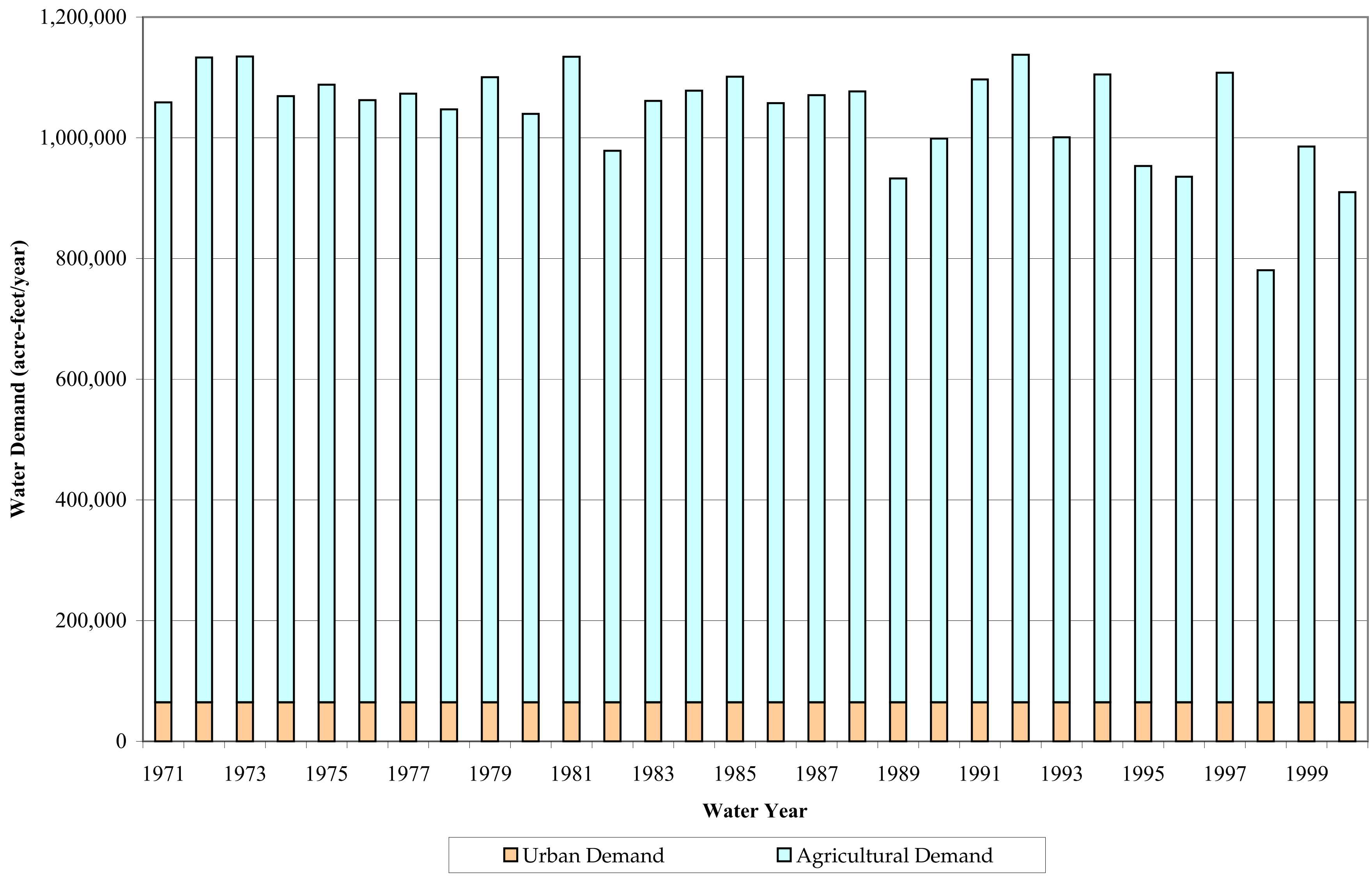
As part of the CCGRRP, the two most western ponds would be used for recharge. The eastern area would be used for recovery of the recharged water. The recharge is planned to occur from November through March. The recharged water is to be pumped out from May through September. The recovery amount is equal to the recharge amount and this water would then be delivered to YCFCWCD customers through their canal system.

Table 5.1 Baseline Condition Data

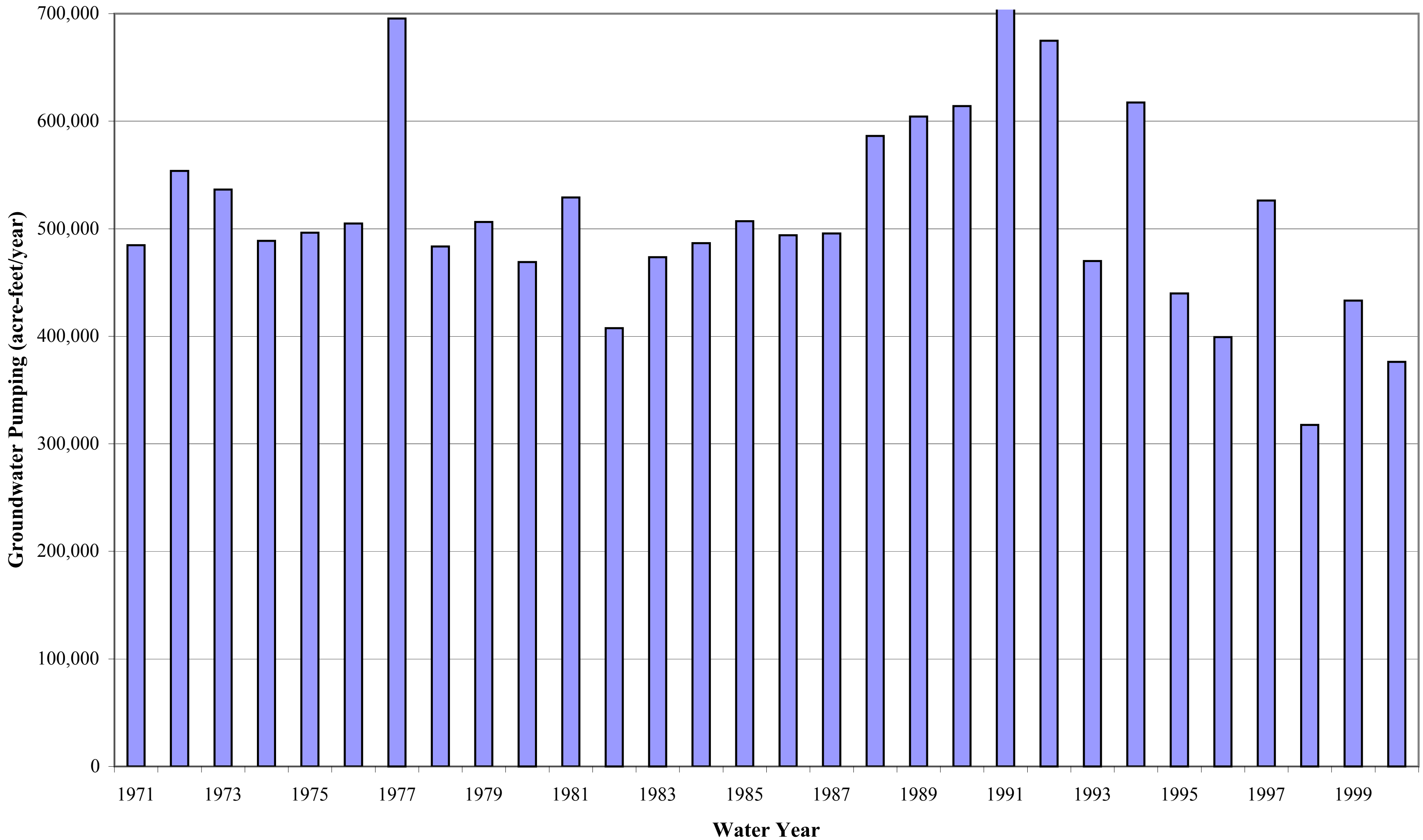
Data Type	Assumption and Source of Data
Initial Groundwater Level	Groundwater levels are equal to the September 2000 levels as determined by the calibrated YCIGSM.
Land Use Acreage	Land use acreages are equal to the year 2000 values used in the calibrated YCIGSM. The Baseline Condition land use acreages are provided in Table 5.2.
Rainfall	Rainfall data for the period 1971–2000 were incorporated from the calibrated YCIGSM.
Agricultural Water Demand	Agricultural water demands were estimated based on the level of development fixed at year 2000 land and water use conditions. However, changes in irrigation water demands due to hydrologic variability for the period October 1970 through September 2000 was simulated. This estimation takes into account evapotranspiration, irrigation efficiency, and soil moisture requirement data from the historical model data sets. The resulting agricultural water demands are presented in Figure 5.1.
Urban Water Demand	Urban water demands are equal to the year 2000 values used in the historical model. The urban water demands are presented in Figure 5.1.
Groundwater Pumping	Groundwater pumping to meet agricultural water demands is estimated based on the difference between agricultural water demands and surface water supplies. Urban groundwater pumping data were assumed equal to urban demands. The resulting annual groundwater pumping data are shown in Figure 5.2.
Surface Water Diversion	Surface water diversion data for the 1971–2000 period were incorporated from the historical model, except for YCFCWCD surface water diversions from Cache Creek. The Baseline Condition YCFCWCD surface water diversion data were developed for the YCFCWCD Cache Creek System Operations Model and incorporated into the YCIGSM. Annual YCFCWCD surface water diversion data are shown in Figure 5.3.
Stream Inflow	Stream inflow data for the 1971–2000 period were incorporated from historical model, except for Cache Creek inflow data. The Baseline Condition Cache Creek inflow data at Rumsey were developed for the YCFCWCD Cache Creek System Operations Model and incorporated into the YCIGSM. Annual volumes of YCFCWCD Cache Creek inflow at Rumsey are shown in Figure 5.3.

Table 5.2 Baseline Condition YCIGSM Crop Acreage

Subregion	Specific Crop Types											Generic Crop Types						Total		
	Almonds	*Dry Beans*	*Corn*	*Alfalfa*	*Prunes*	*Rice*	*Tomatoes*	*Safflower*	*Sugar Beets*	*Walnuts*	*Vineyards*	*Subtropical Fruits*	*Deciduous Fruits / Nuts*	*Field*	*Grain and Hay*	*Pasture*	*Truck, Nursery, and Berry*	***Agricultural***	***Urban***	***Native Vegetation***
1	1,212	0	36	409	0	0	338	61	0	1507	2	0	323	324	2,178	380	205	6,975	182	20,266
2	1,857	0	0	0	0	0	221	0	0	0	0	0	0	0	1,069	9	0	3,156	6	21,302
3	809	0	354	743	27	102	942	121	0	54	368	0	4	2483	2,127	92	1422	9,648	451	1,498
4	0	0	274	721	0	1,955	403	192	0	0	0	0	0	1748	488	0	15	5,796	0	0
5	0	0	606	685	0	11,598	3,734	1,613	0	159	0	0	0	656	1,210	0	1657	21,918	17	0
6	0	0	365	0	243	2,140	1,999	1,376	0	37	0	0	169	1,269	0	0	453	8,051	23	669
7	235	0	1027	2,129	279	0	3,251	177	147	94	385	0	21	4,709	6,817	366	840	20,477	420	11,657
8	1,128	0	5,371	11,527	2,382	3,858	5,986	1,091	157	2,451	96	0	437	8,218	11,334	1,974	923	56,933	1,864	33,061
9	20	0	62	297	0	0	549	220	0	2	3578	0	0	697	5,785	502	49	11,761	265	33,620
10	0	0	152	1,236	0	269	842	287	10	112	29	0	0	1380	1,838	80	38	6,273	84	642
11	94	0	1,309	1,086	0	0	5,340	402	0	221	0	0	33	2895	2,731	40	683	14,834	196	849
12	0	0	1281	779	0	2,967	5,238	1177	92	248	0	0	0	6,041	2,363	0	1158	21,344	77	288
13	188	0	5,935	6,693	292	275	10,452	2,570	159	744	81	0	109	5,734	10,761	1,966	1991	47,950	3,185	9,942
14	0	0	399	315	41	445	727	194	37	23	0	0	0	761	906	2	211	4,061	6,860	1,781
15	0	0	42	171	0	0	299	163	10	82	151	0	142	224	295	71	497	2,147	5,047	1,503
16	0	0	3,004	3,424	0	8,019	2,189	1,769	43	1,695	1	0	125	832	1,032	55	1388	23,576	129	7,046
17	0	0	320	238	0	0	169	1150	62	8	26	0	3	425	1,072	227	272	3,972	5,473	4,998
18	0	116	826	719	0	0	3,234	0	114	50	22	0	0	382	2,806	212	216	8,697	335	476
19	0	0	5,568	6,021	0	284	3,462	10,837	283	33	6,556	0	565	6,368	3,922	8,335	309	52,543	192	24,945
20	7	0	1	1	34	0	1	106	0	82	34	0	99	128	46	167	72	778	639	1,044
21	2	0	1,680	1891	3	4,314	1,429	993	27	906	1	0	66	695	729	48	787	13,571	105	3,809
22	1	0	51	88	2	2	146	58	3	25	38	0	36	95	147	31	137	860	1279	442
23	0	0	46	202	0	0	72	0	0	2	0	0	34	9	5	139	131	640	263	331
24	762	635	19	221	577	0	1,548	103	199	3,130	38	3	1,157	570	2,156	169	104	11,391	101	992
Total	6,315	751	28,728	39,596	3,880	36,228	52,571	24,660	1,343	11,665	11,406	3	3,323	46,643	61,817	14,865	13,558	357,352	27,193	181,161



RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Annual Agricultural and Urban Demands for YCIGSM Baseline Condition	FIGURE 5.1



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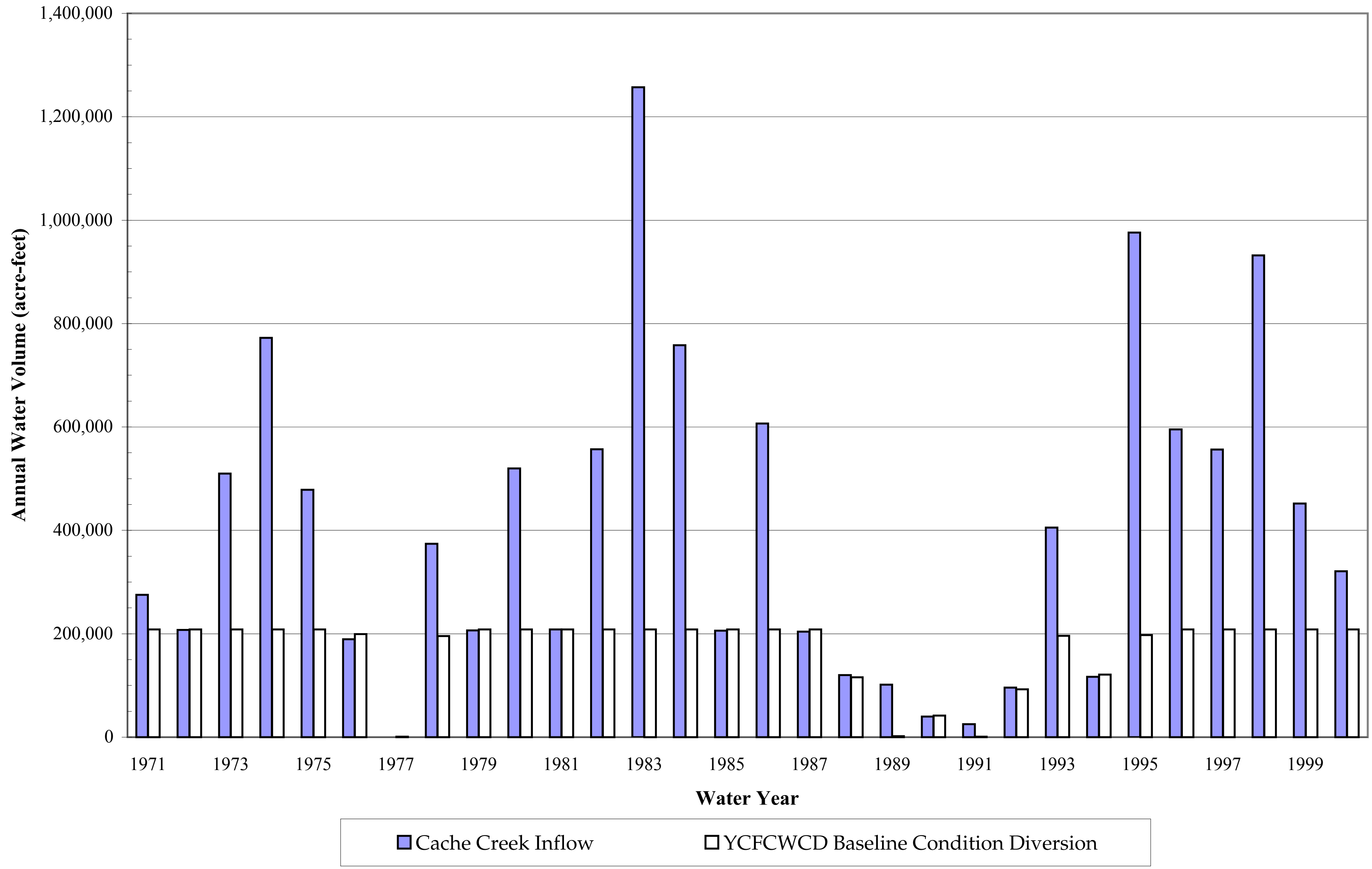
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Annual Groundwater Pumping for YCIGSM Baseline Condition

APRIL 2006

FIGURE 5.2



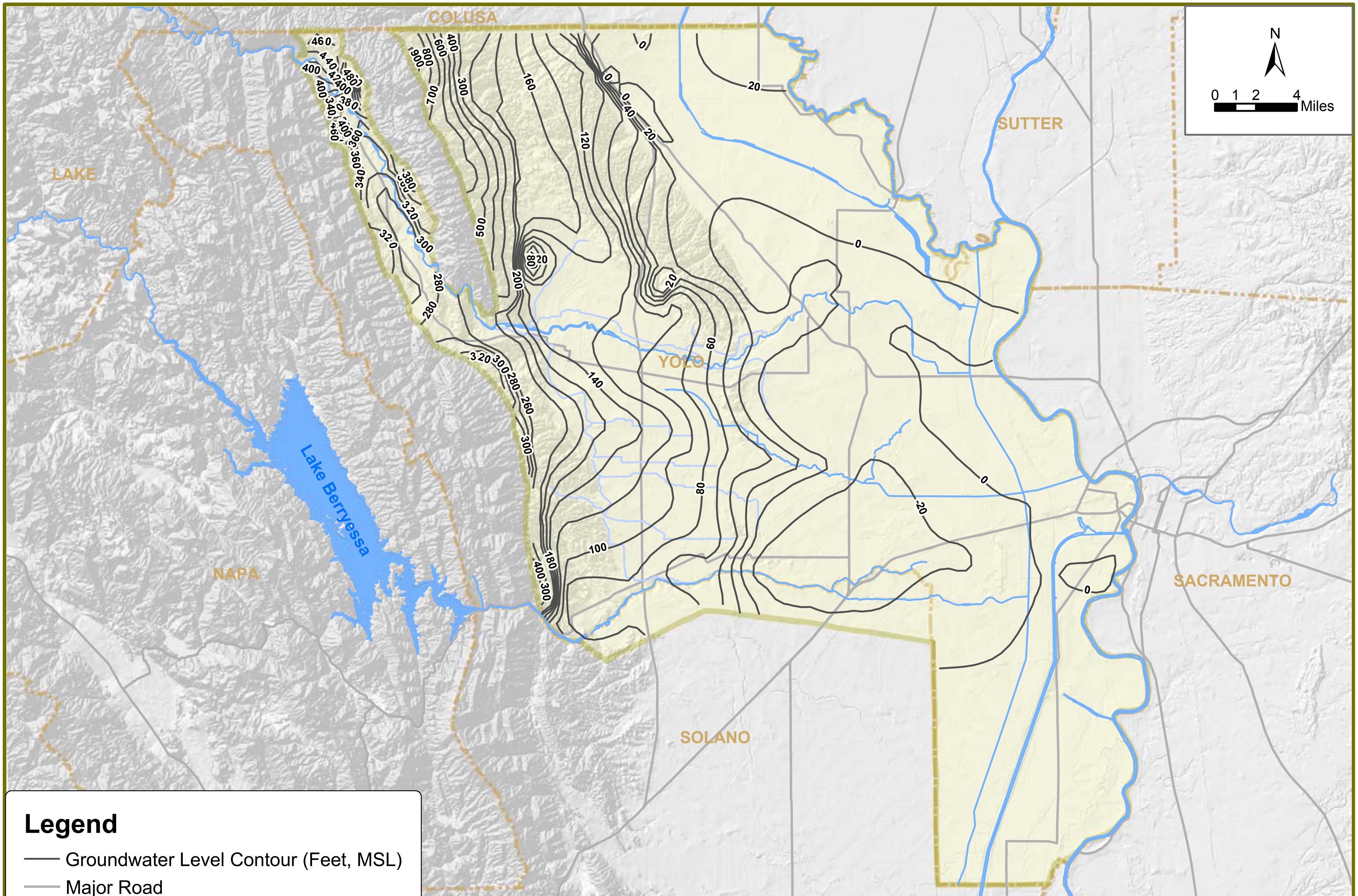
PRIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Cache Creek Inflow and YCFCWCD Surface Water Diversions for YCIGSM Baseline Condition

APRIL 2006

FIGURE 5.3



Legend

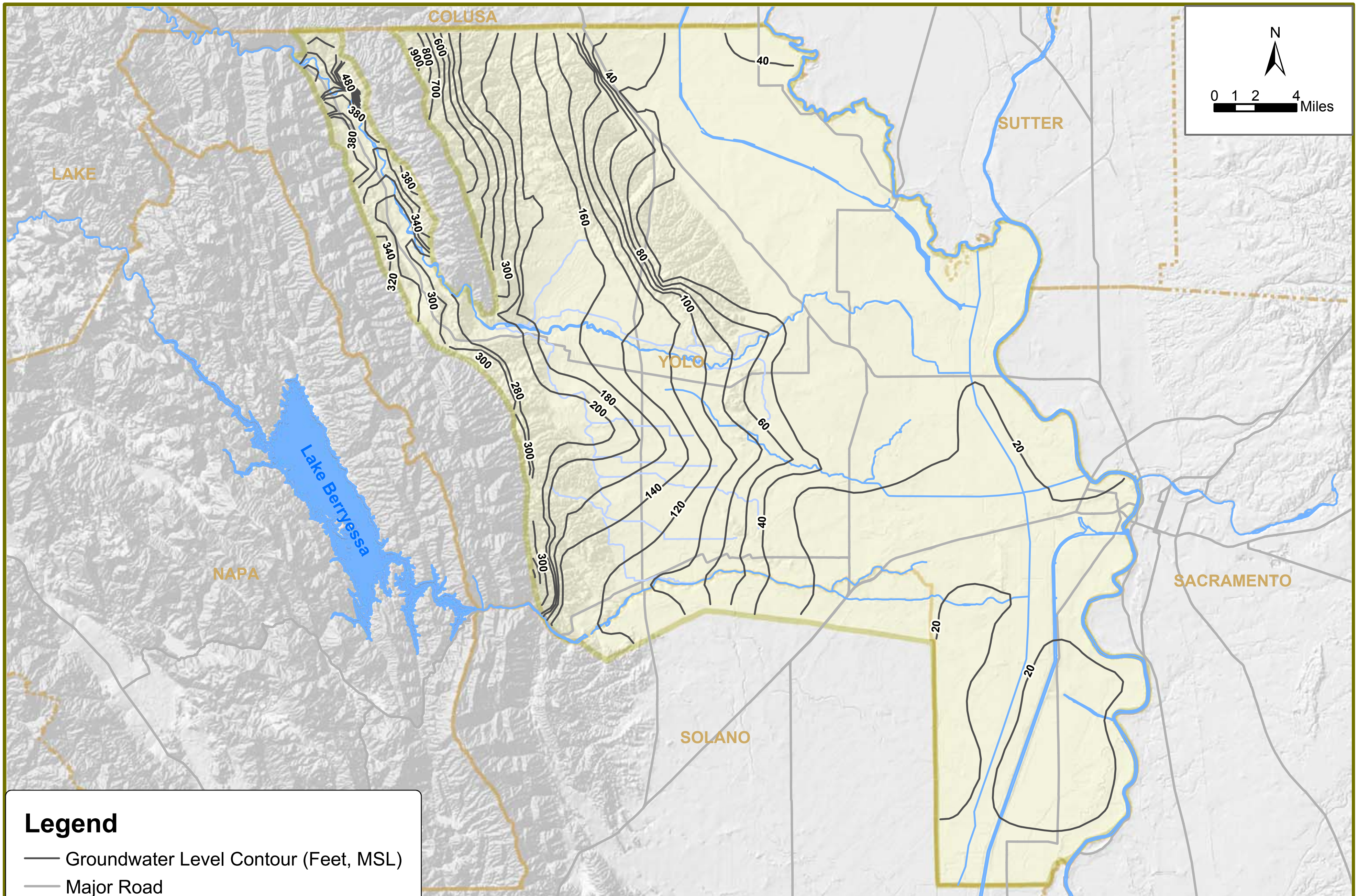
- Groundwater Level Contour (Feet, MSL)
- Major Road
- Watercourse
- Canal
- County Boundary
- Model Area

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Baseline Condition
Fall-1977 Groundwater Level Contours

APRIL 2006

FIGURE 5.4



Legend

- Groundwater Level Contour (Feet, MSL)
- Major Road
- Watercourse
- Canal
- County Boundary
- Model Area

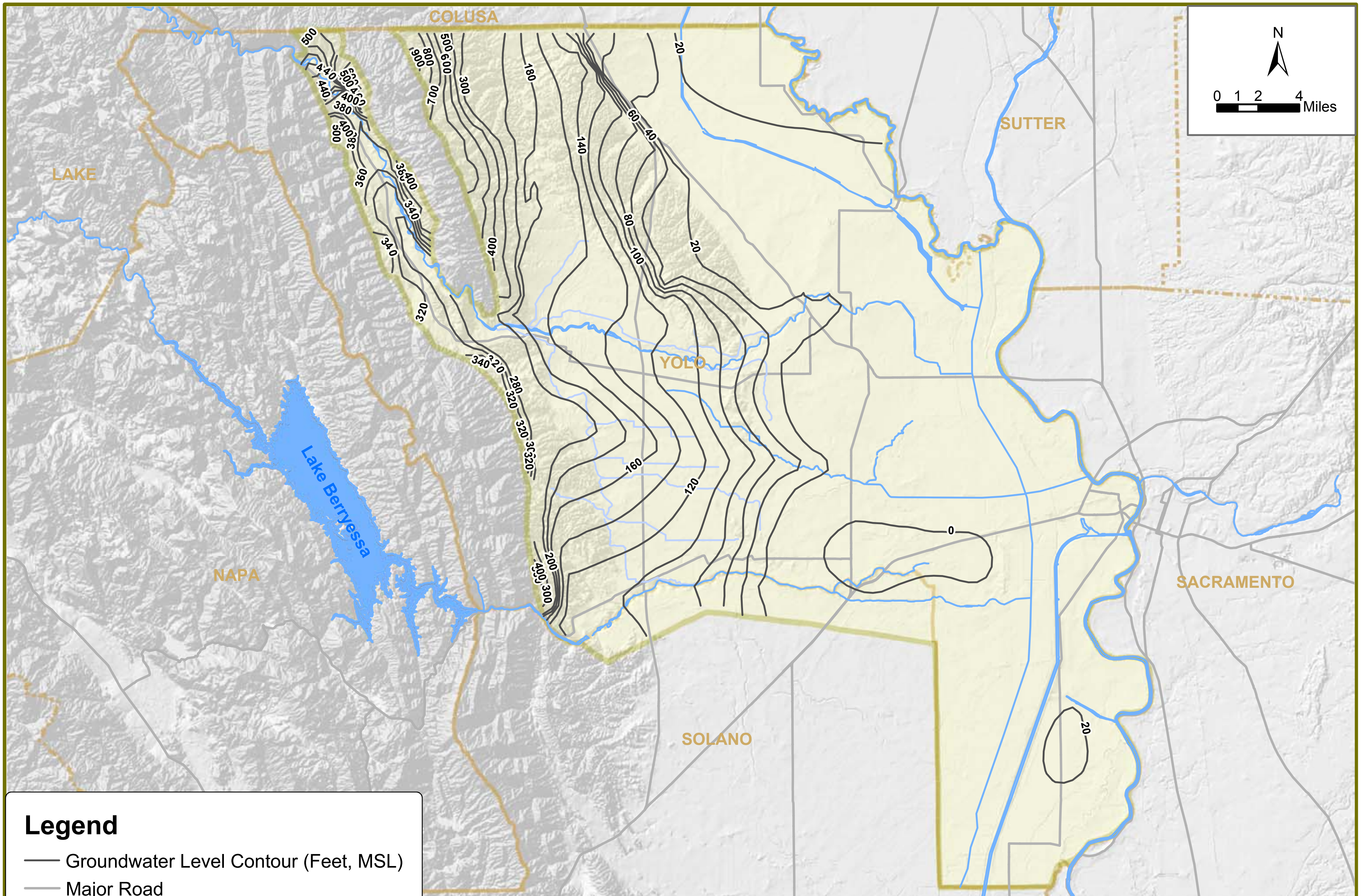
RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Baseline Condition
Spring-1983 Groundwater Level Contours

APRIL 2006

FIGURE 5.5



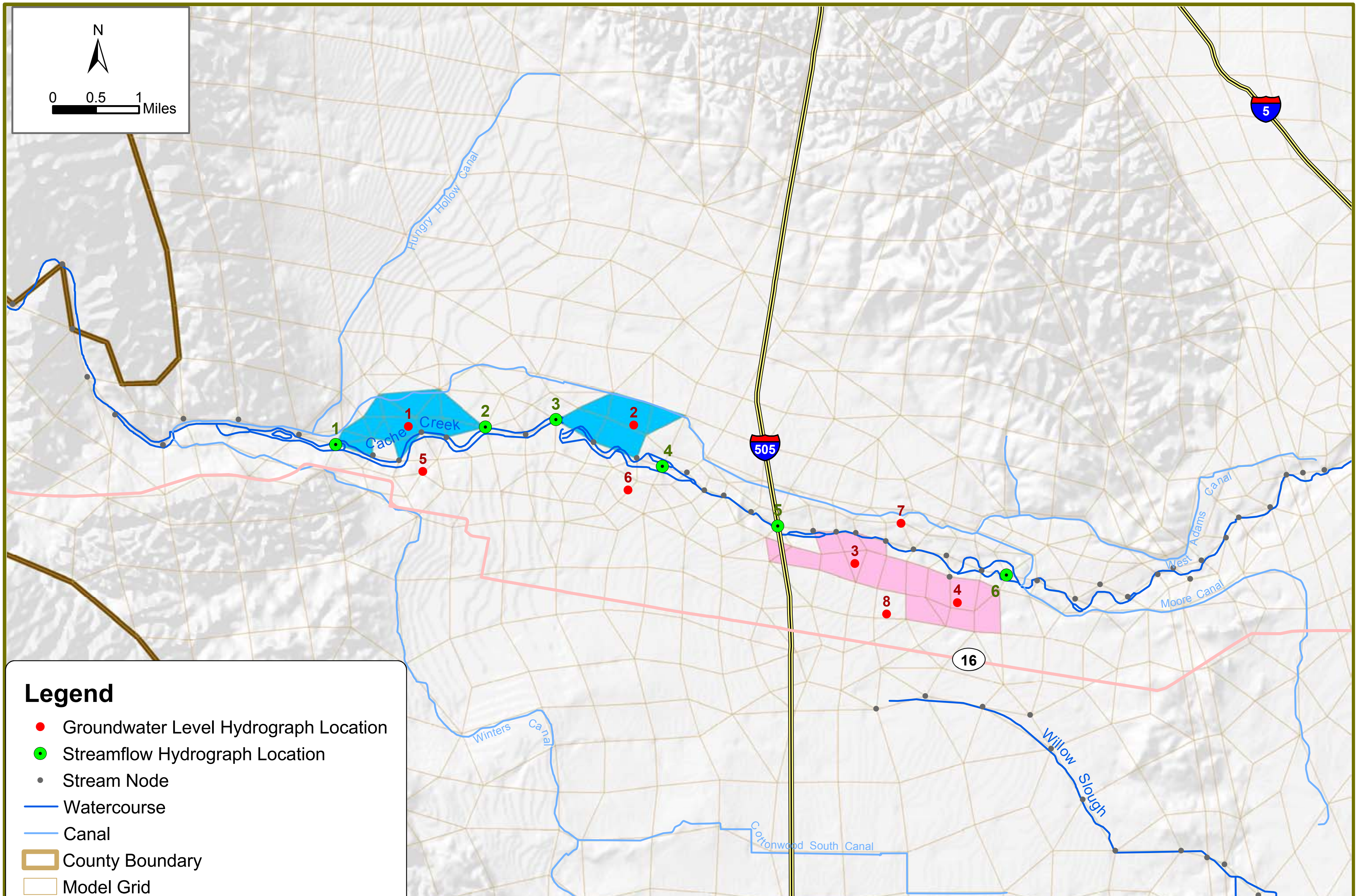
RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Baseline Condition
Fall-2000 Groundwater Level Contours

APRIL 2006

FIGURE 5.6



Legend

- Groundwater Level Hydrograph Location
- Streamflow Hydrograph Location
- Stream Node
- Watercourse
- Canal
- County Boundary
- Model Grid
- Model Area Outline

Project Areas

- Pumping Area
- Recharge Area

RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Cache Creek Recharge/Recovery Program Alternative

APRIL 2006

FIGURE 5.7

ANALYSIS OF THE CCGRRP

The preliminary evaluation of CCGRRP, as conceptualized, required specific assumptions in location, timing, and rate of recharge and extraction. As the results of preliminary analysis is evaluated, and CCGRRP definition is further refined, it is expected that the modeling assumptions will also be refined. The specific assumptions considered are:

- Recharge water is only available in water years when YCFCWCD is making more than 100,000 AF of surface water deliveries;
- Recharge is uniformly divided over the surface area of the two recharge areas;
- The recharge area is 835 acres;
- Recharge and recovery volume is 4 TAF per month. Figure 5.8 shows the specified volume of monthly recharge and recovery;
- Recharge is dynamically simulated; i.e., the YCIGSM determines whether there is sufficient vacant groundwater storage available for recharge at every time step; and
- Groundwater extraction is assumed to occur from upper Tehama formation (model layer 2), because the Alluvium (model layer 1) may not have sufficient storage to support the pumping rates specified.

RESULTS OF THE CCGRRP MODELING ANALYSIS

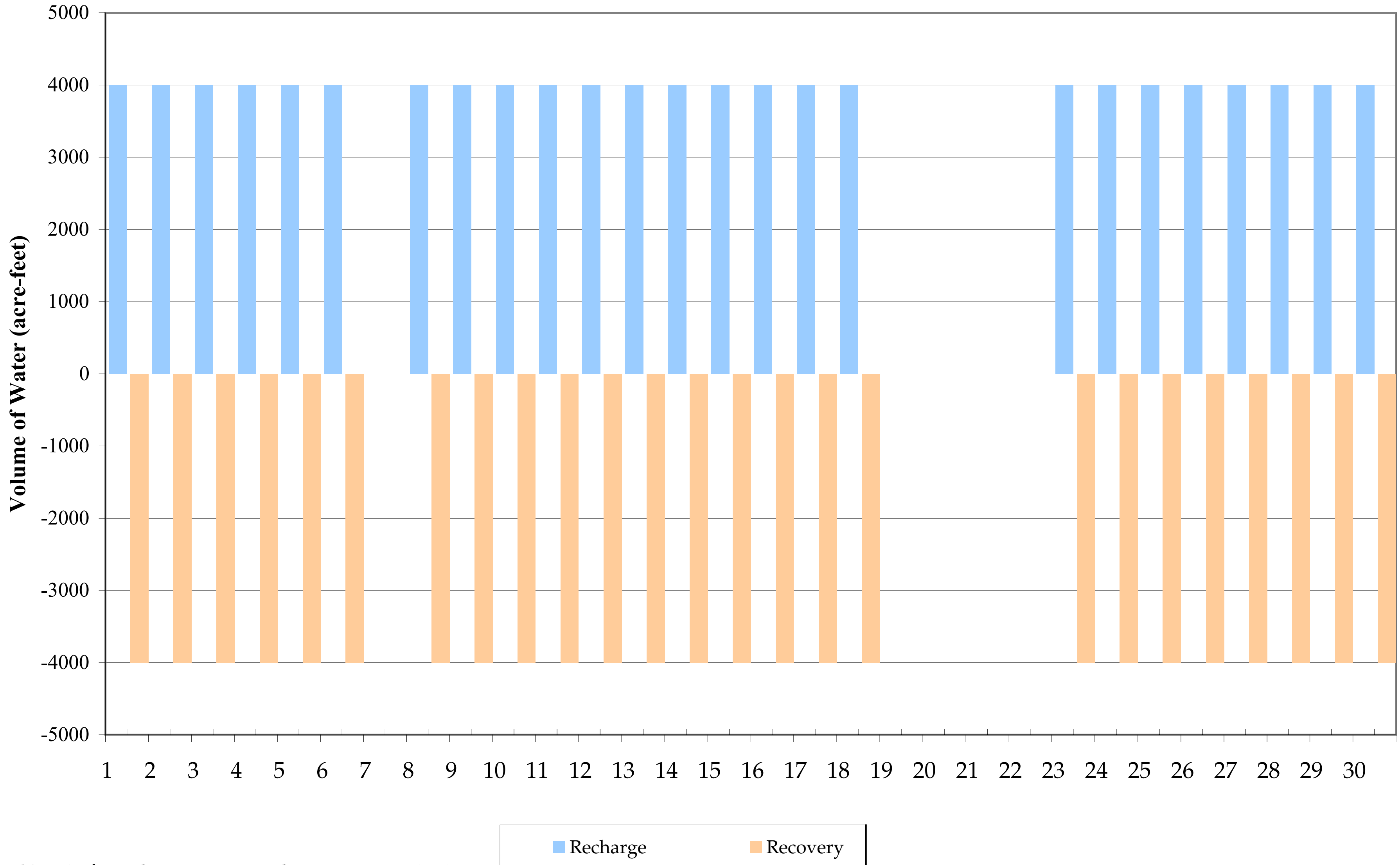
The results of the simulation of the CCGRRP are presented as changes in groundwater levels and streamflow conditions from the Baseline Condition. Several metrics were developed to measure the impacts of the CCGRRP alternative. These metrics are:

- Impacts on groundwater recharge;
- Impacts on Cache Creek streamflow;
- Impacts on groundwater levels.

As previously stated, Figure 5.8 shows the monthly volumes of water used for recharge and recovery. Due to high groundwater levels, recharge was not possible during extreme wet conditions.

Impacts on Groundwater Recharge

Figure 5.9 shows that Cache Creek groundwater gains and loses between Capay Dam and Moore's Siphon. The values shown in Figure 5.9 are changes in groundwater levels relative to the Baseline Conditions. Figure 5.9 indicates that Cache Creek groundwater gains are higher under the Project conditions than the Baseline Conditions during the recharge operation



Note: Year 1 of simulation corresponds to water year 1971

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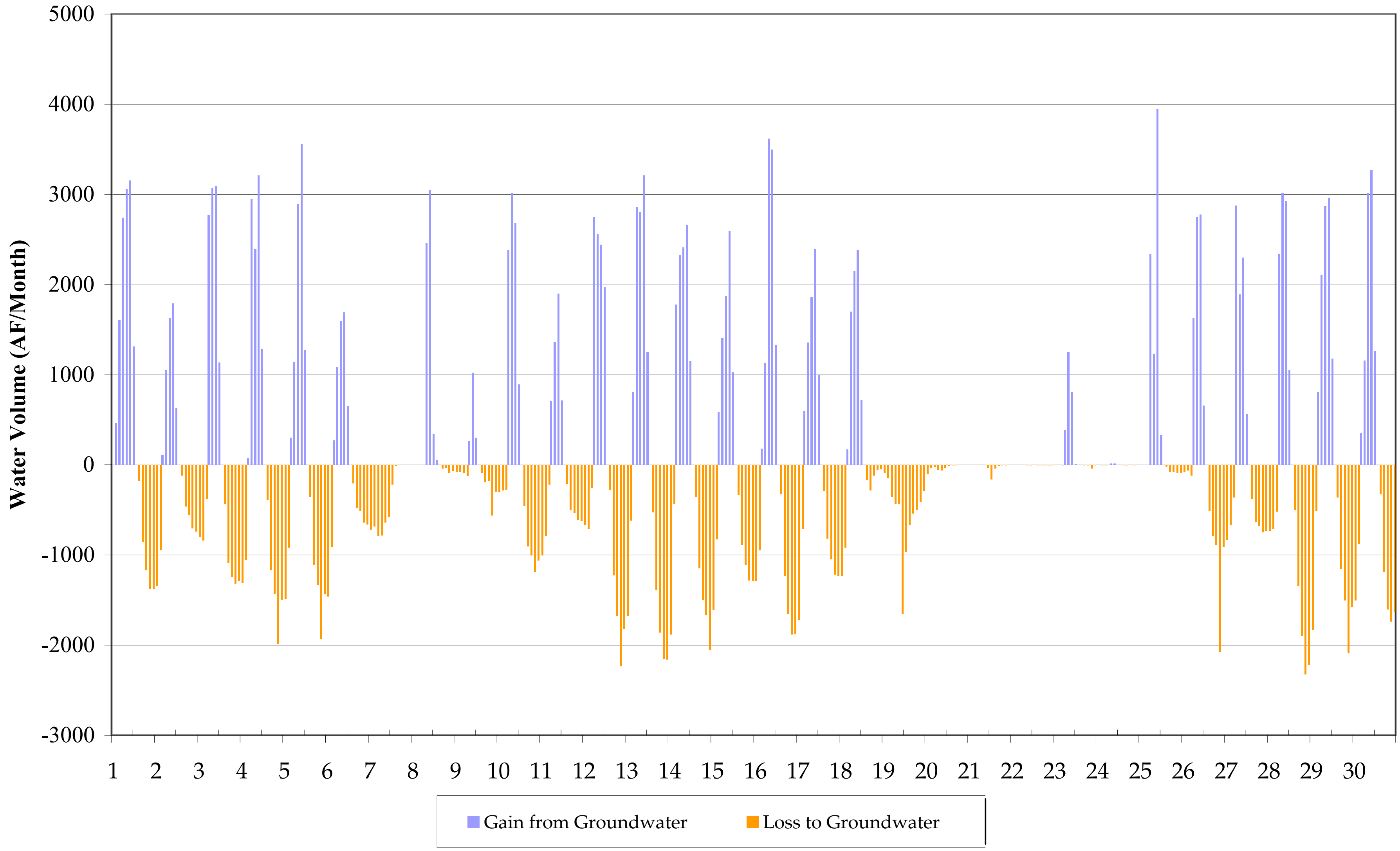
YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

CCGRRP Specified Monthly Volume of Recharge and Recovery Water

APRIL 2006

FIGURE 5.8



Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **CCGRRP Streamflow Gains and Losses along Cache Creek from Capay Dam to Moore's Siphon**	APRIL 2006 FIGURE 5.9

months. The average annual change in the groundwater gain is approximately 6,300 AF/year when the CCGRRP is operational. It is also evident from Figure 5.9, that the average annual Cache Creek losses are approximately 5,200 AF/year higher than those under Baseline Conditions.

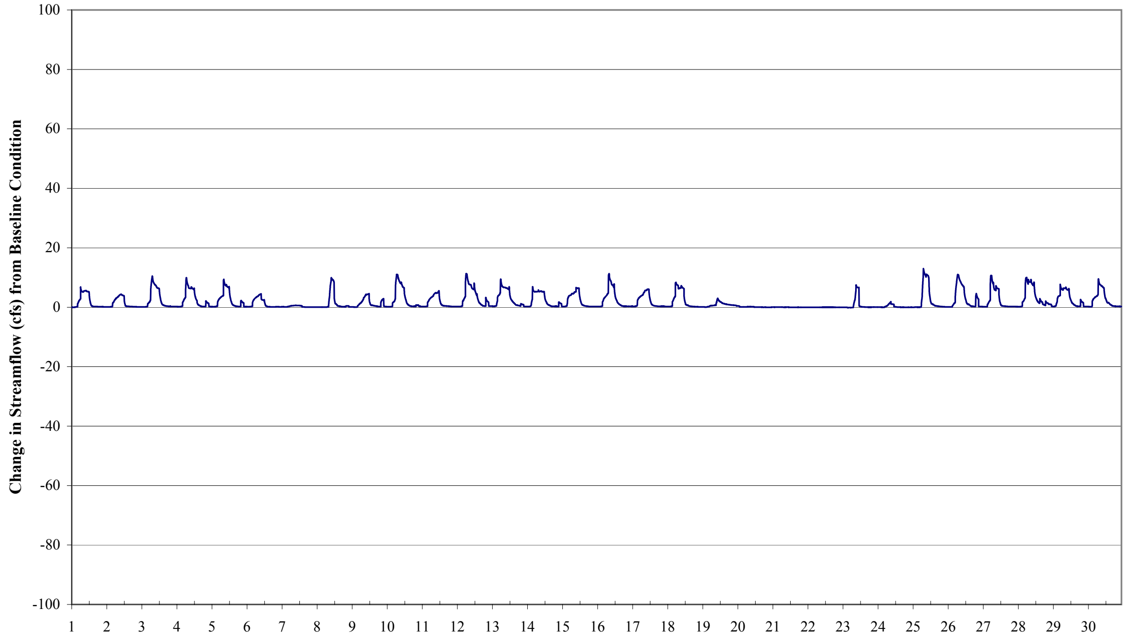
Impacts on Cache Creek Streamflow

The impacts of the CCGRRP on Cache Creek streamflow rates were also evaluated. Streamflow conditions were evaluated at six locations as shown in Figure 5.7. Changes in streamflow conditions, relative to the Baseline Condition, are shown in Figures 5.10a–5.10f. It can be seen from Figure 5.10d that the Cache Creek streamflow rate increases by over 40 cfs for nearly every year that the CCGRRP is recharging water. It can bee seen in Figure 5.10f that the Cache Creek streamflow rate decreases by 20 cfs for nearly all months when the CCGRRP is recovering groundwater. This corresponds well with the analysis regarding stream gains and losses discussed above.

Impacts on Groundwater Levels

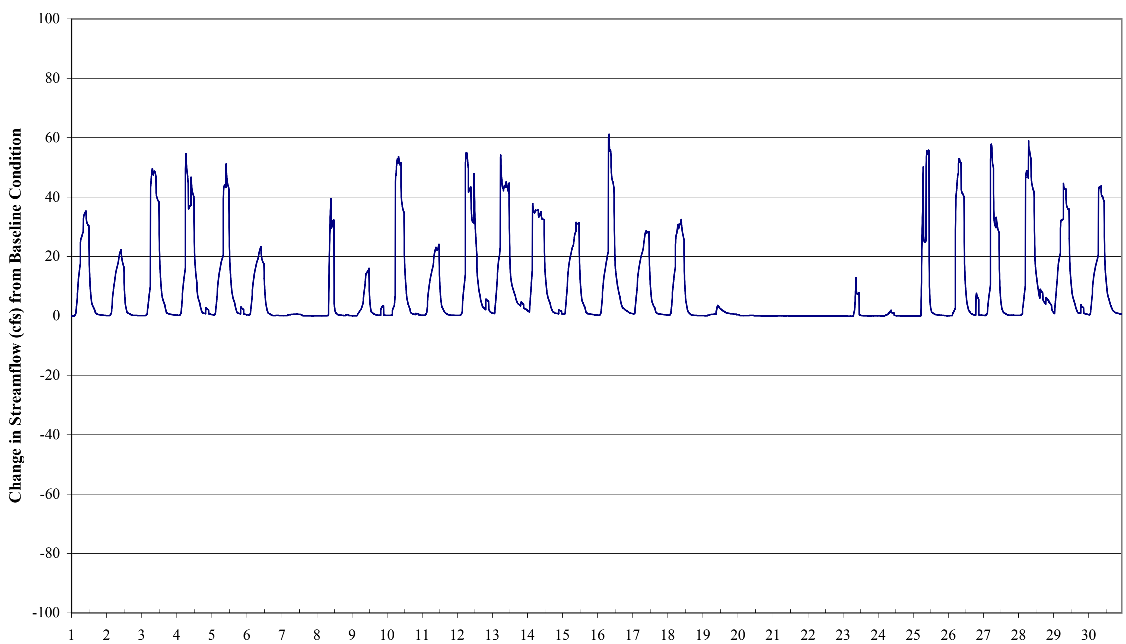
The impacts of the CCGRRP at eight groundwater hydrograph locations were evaluated. These locations are shown in Figure 5.7. The hydrographs from the eight locations are shown in Figures 5.11a–5.11h. Figure 5.11a shows changes in groundwater levels, relative to the Baseline Condition, for hydrograph location 1, located in the western-most recharge basin. The hydrograph shows that water levels are at least 10 feet higher during periods of recharge and that, on average, is approximately 2–5 feet higher during recovery periods. Figure 5.11d shows the groundwater levels, relative to the Baseline Condition, at a location in the recovery basin. The figure shows that groundwater levels can be more than 30 feet lower than under the Baseline Condition during recovery periods. However, the groundwater levels recover to within 5 feet of Baseline Condition levels during the recharge period.

The potential aerial extents of impacts of the CCGRRP were considered by evaluating contours of changes in groundwater level from Baseline Conditions. The groundwater level changes were then mapped for dry, wet, and normal hydrologic conditions. Figures 5.12-5.14 show the contour maps for each of these hydrologic conditions. It is evident that in dry conditions (Figure 5.12) the groundwater levels are nearly 5 feet lower at the western boundary of Woodland. Groundwater levels are approximately 8 feet lower in and around the extraction area. It is apparent from Figure 5.12 that the cone of depression is centered to east of the recovery area. It is expected that the depression area in the recovery area would be centered in that area, if CCGRRP was operational. Since the CCGRRP was not operational in this year, the cone of depression associated with the CCGRRP operations was not formed. The depressed



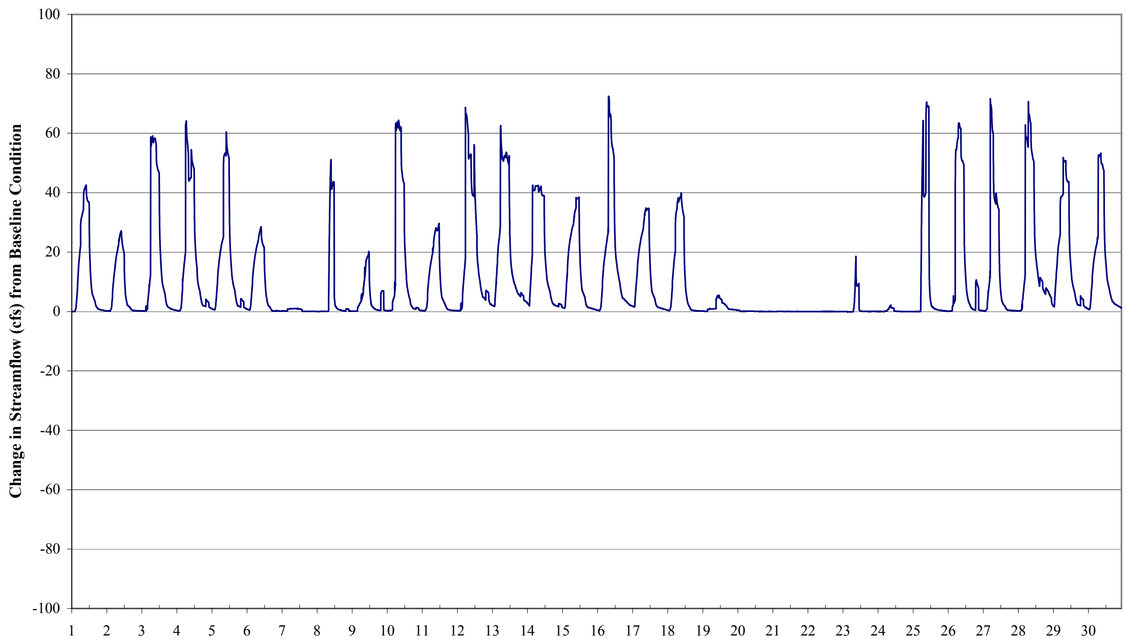
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 1)	FIGURE 5.10a



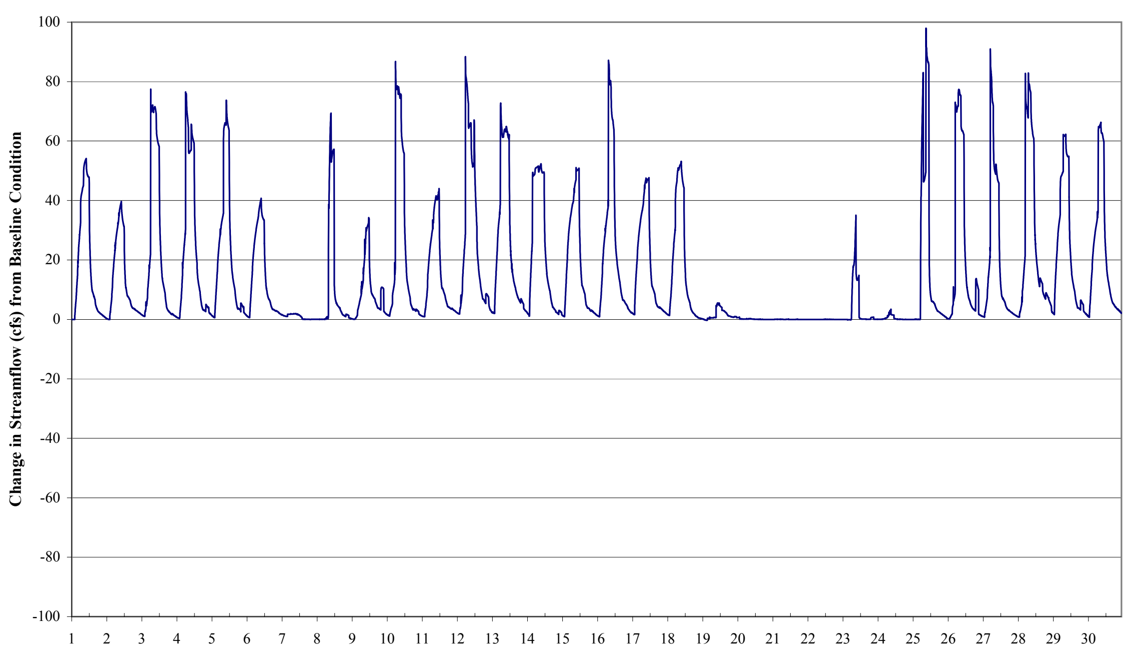
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 2)	FIGURE 5.10b



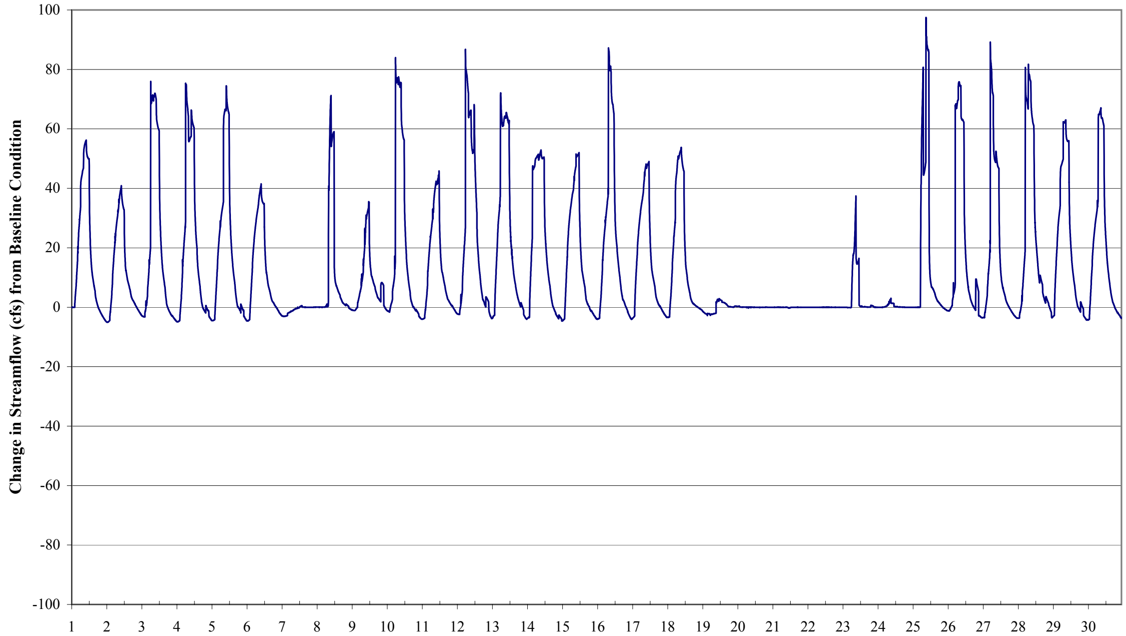
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 3)	FIGURE 5.10c



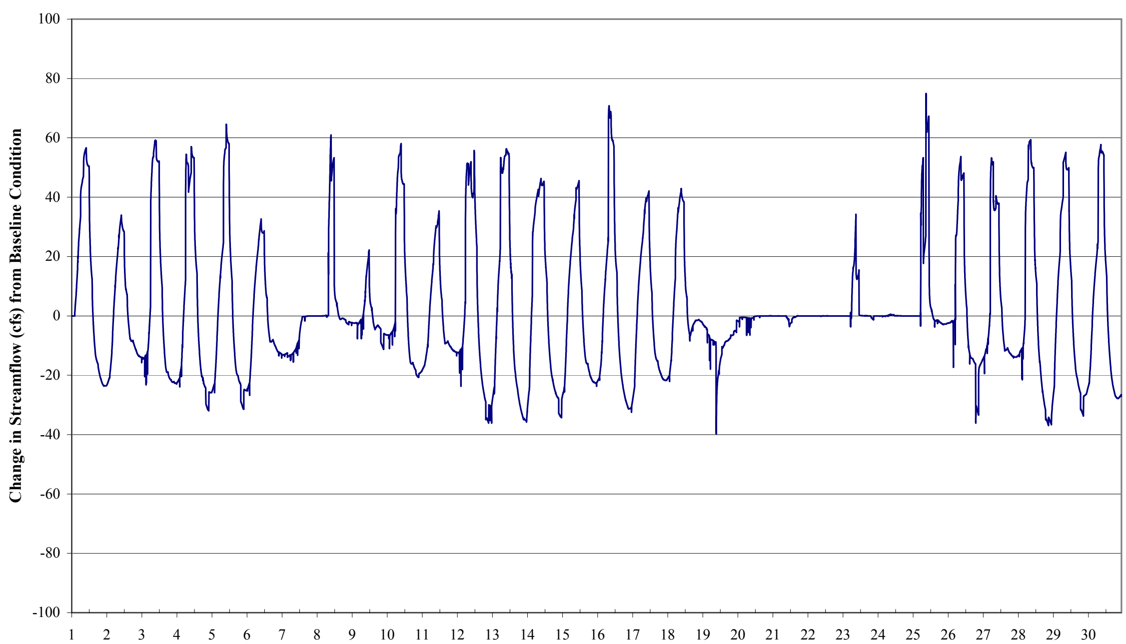
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 4)	FIGURE 5.10d



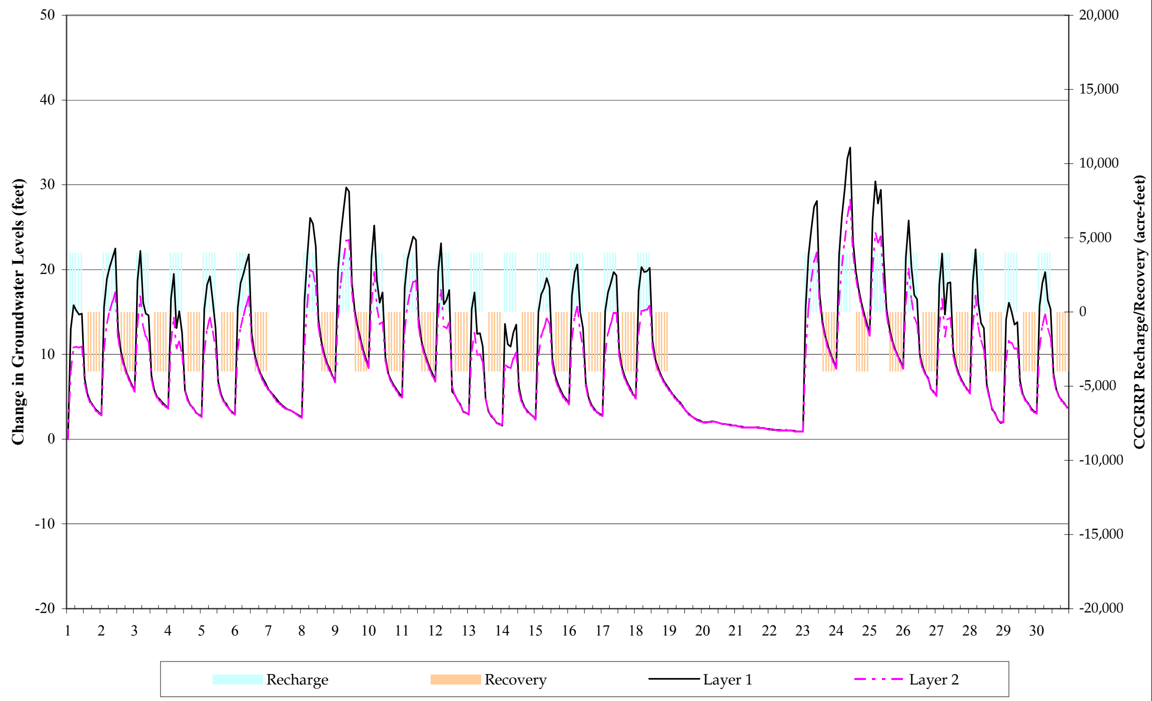
Note: Year 1 of simulation corresponds to water year 1971

WRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 5)	FIGURE 5.10e



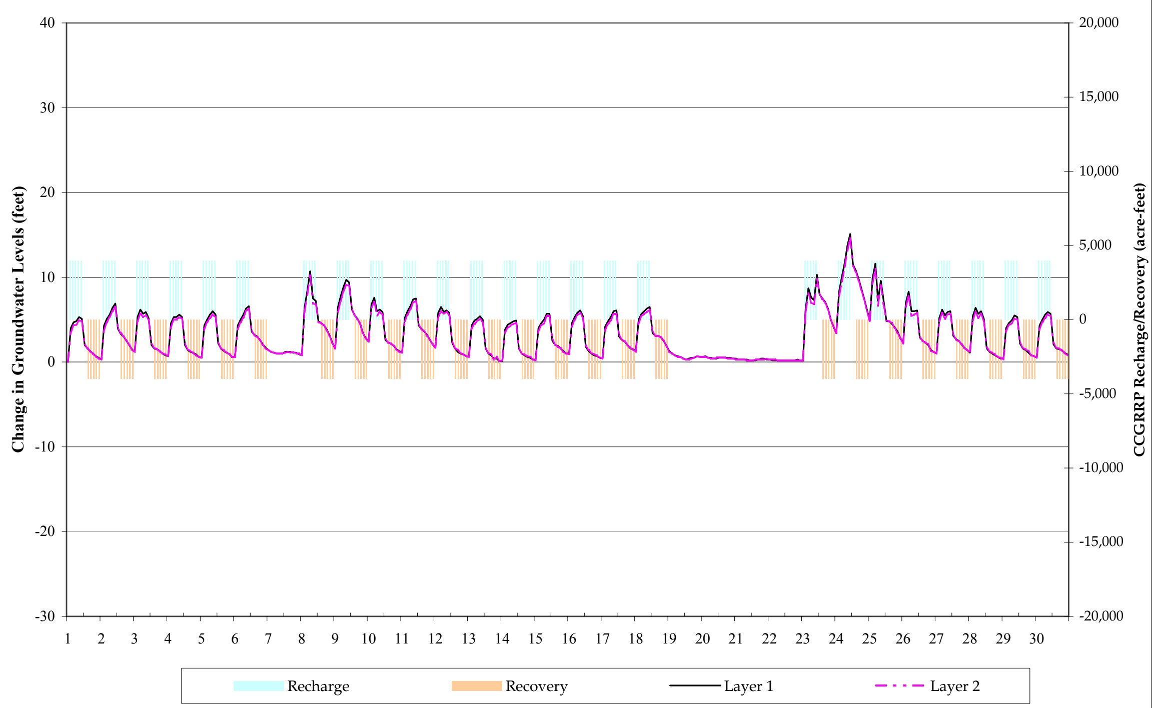
Note: Year 1 of simulation corresponds to water year 1971

WRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Monthly Change in Streamflow; CCGRPP Less Baseline (Location 6)	FIGURE 5.10f



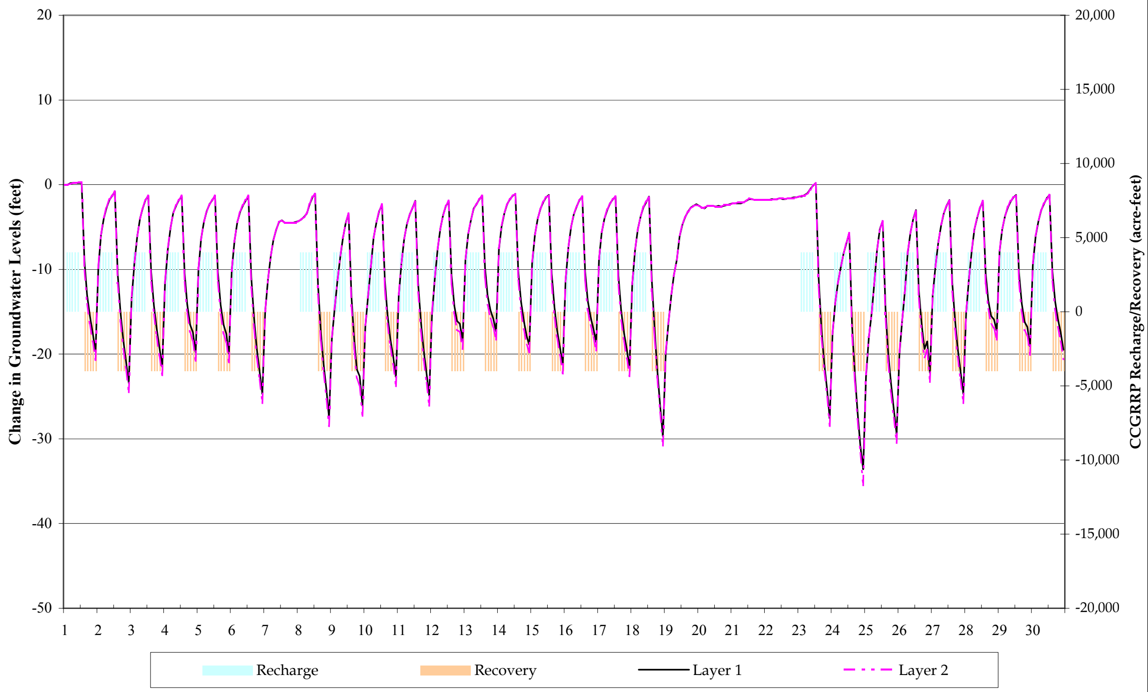
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 1)**	APRIL 2006 FIGURE 5.11a



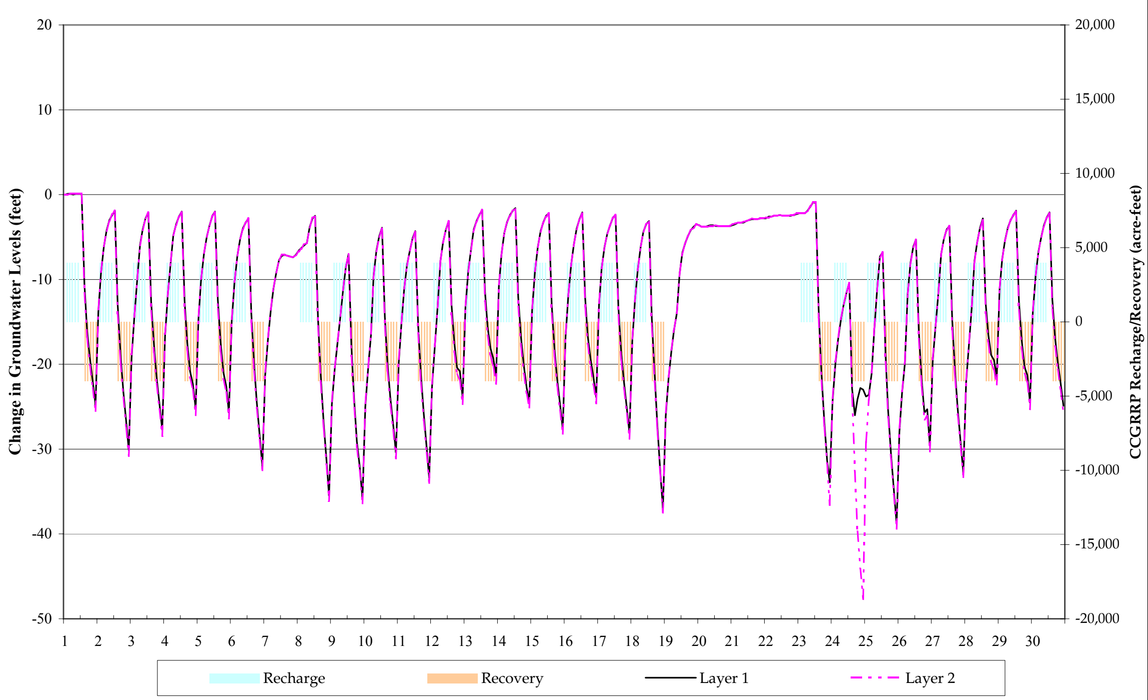
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 2)**	APRIL 2006 FIGURE 5.11b



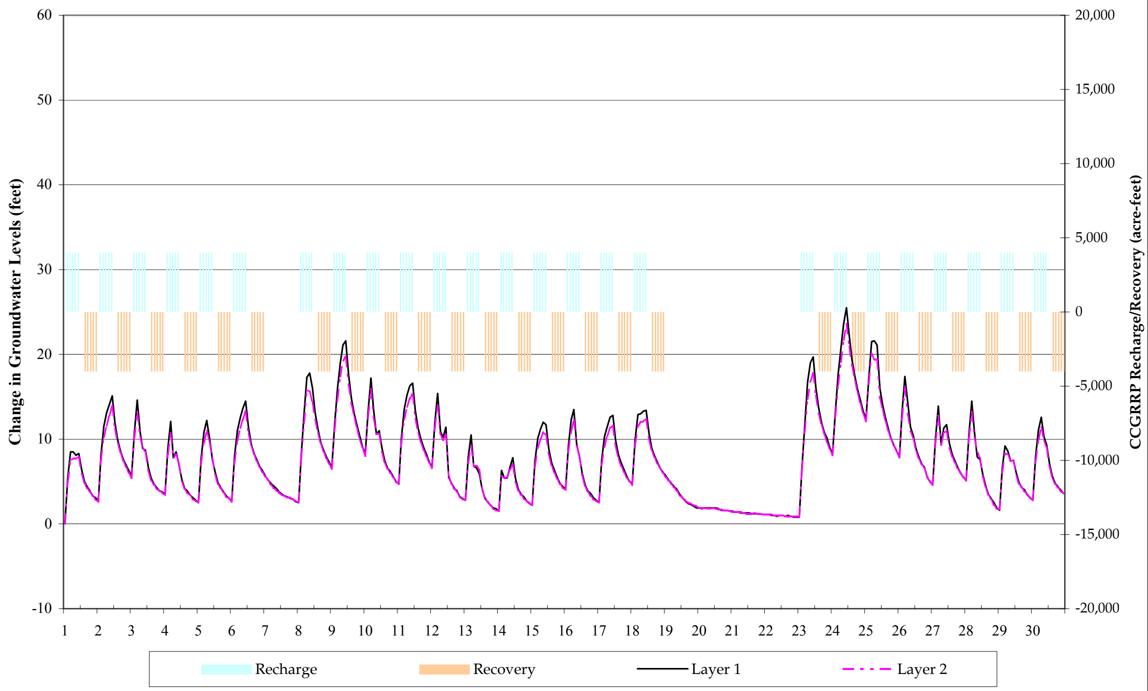
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 3)**	APRIL 2006 FIGURE 5.11c



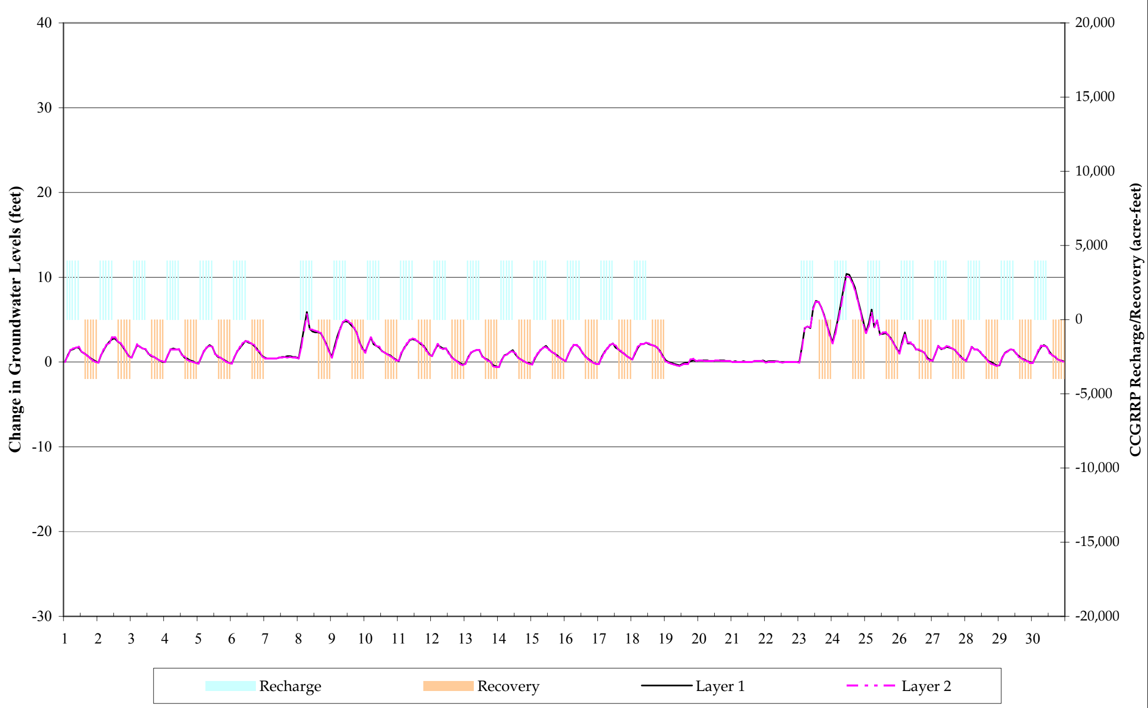
Note: Year 1 of simulation corresponds to water year 1971

RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 4)**	APRIL 2006 FIGURE 5.11d



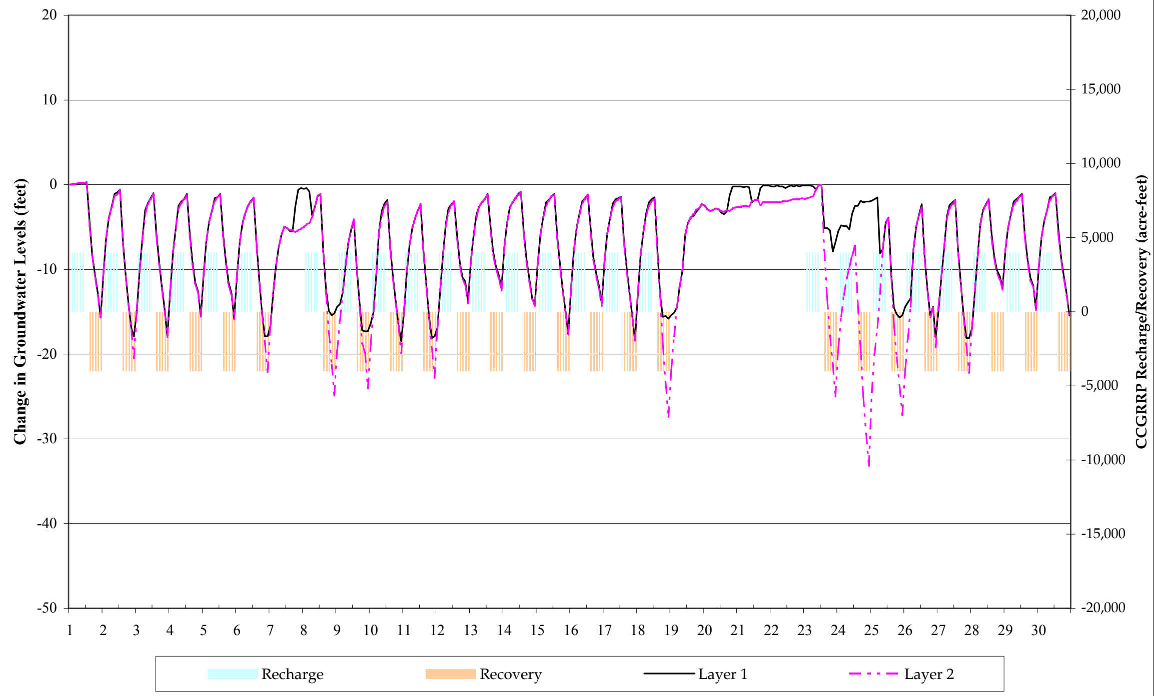
Note: Year 1 of simulation corresponds to water year 1971

PRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 5)**	APRIL 2006 FIGURE 5.11e



Note: Year 1 of simulation corresponds to water year 1971

PRIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) **Change in Groundwater Level; CCGRRP Less Baseline (Location 6)**	APRIL 2006 FIGURE 5.11f



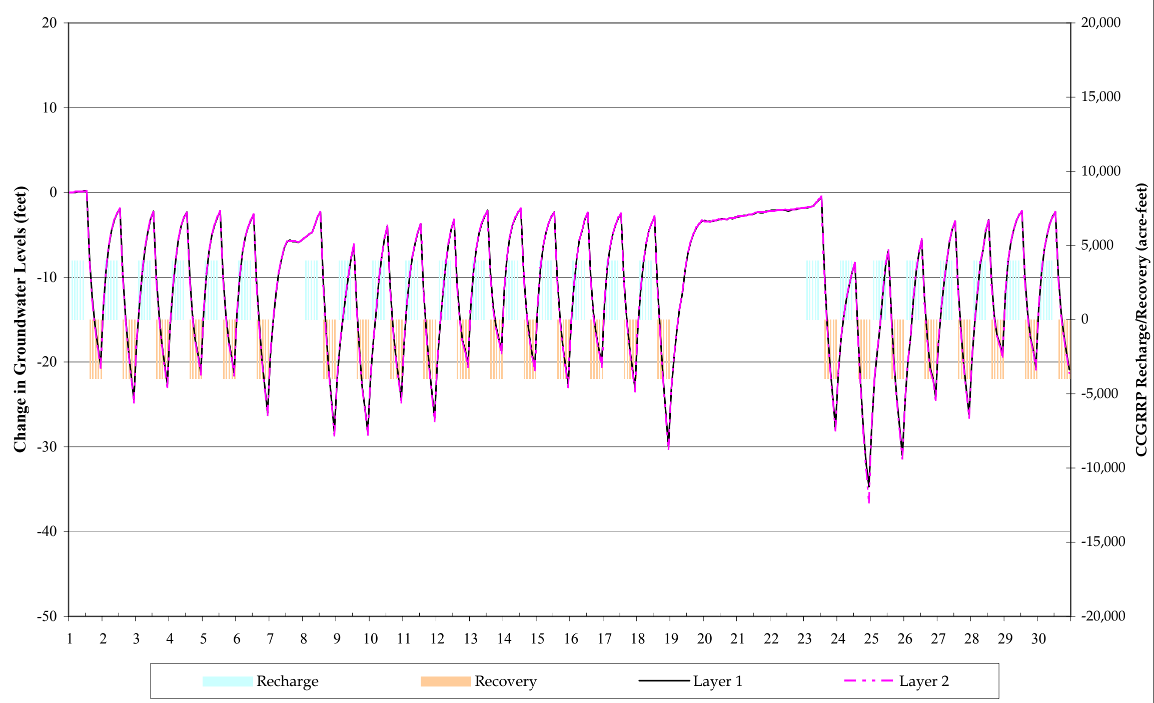
Note: Year 1 of simulation corresponds to water year 1971

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Change in Groundwater Level; CCGRRP Less Baseline (Location 7)

APRIL 2006

FIGURE 5.11g



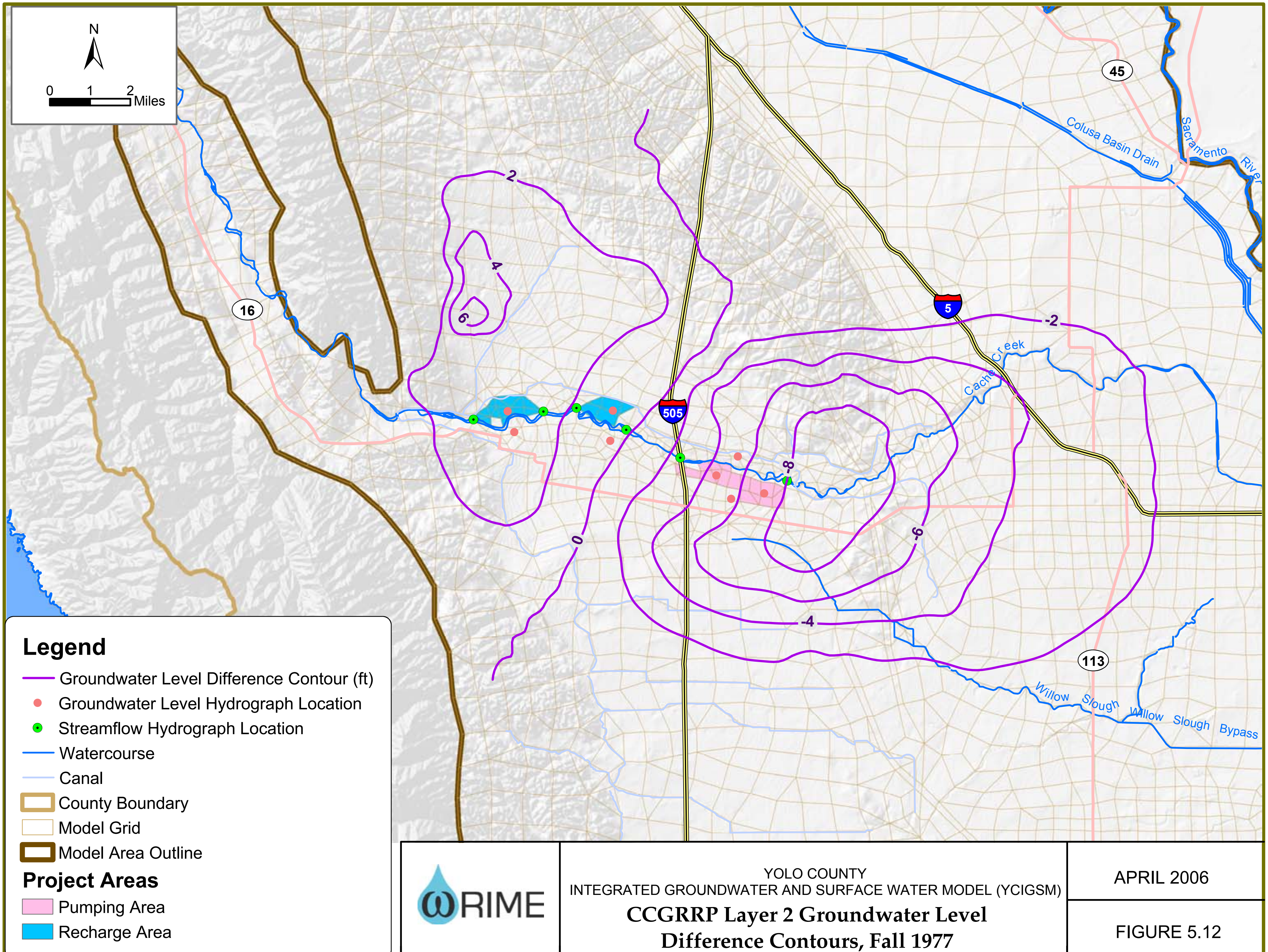
Note: Year 1 of simulation corresponds to water year 1971

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Change in Groundwater Level; CCGRRP Less Baseline (Location 8)

APRIL 2006

FIGURE 5.11h



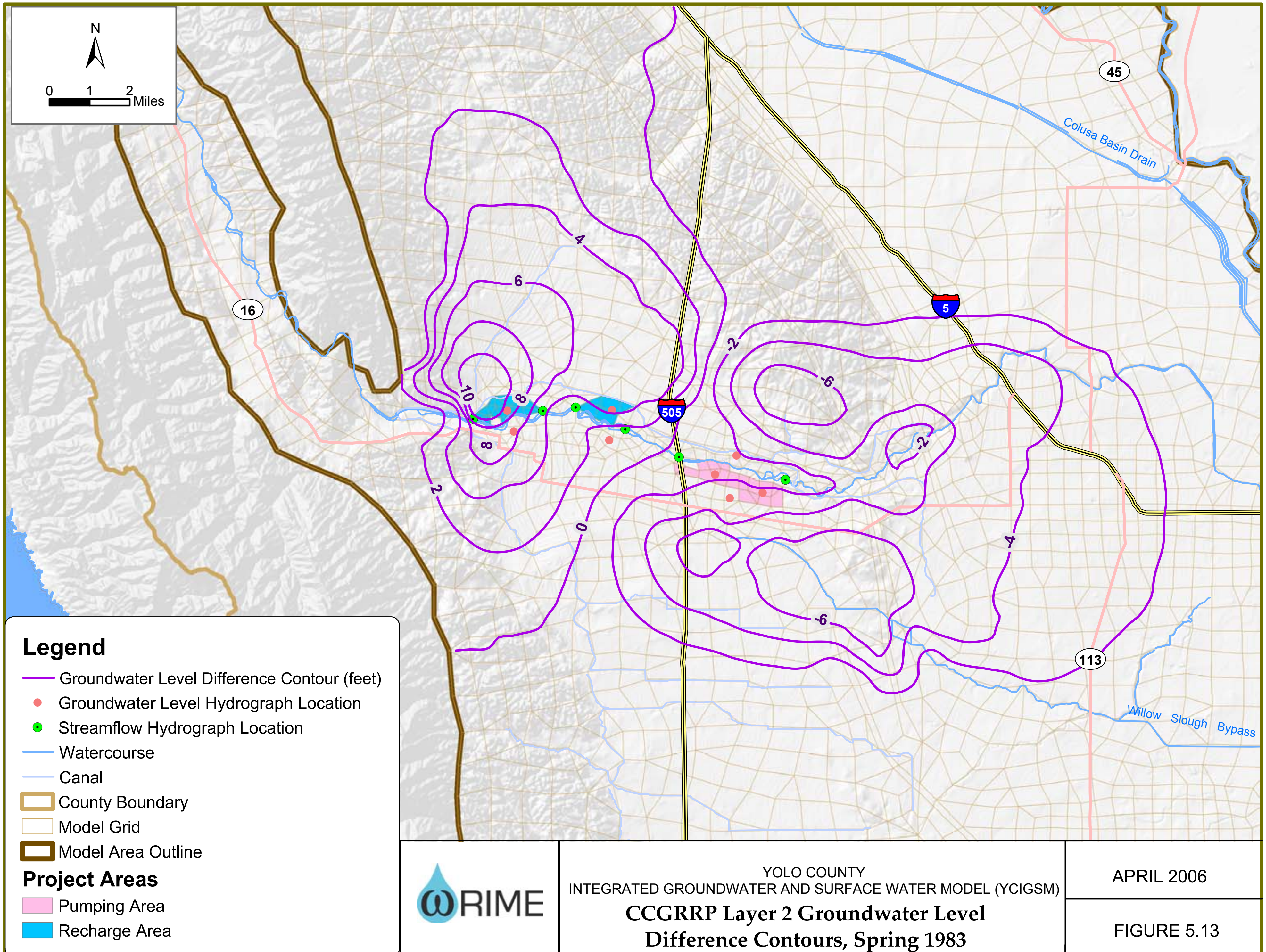
RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

CCGRRP Layer 2 Groundwater Level Difference Contours, Fall 1977

APRIL 2006

FIGURE 5.12



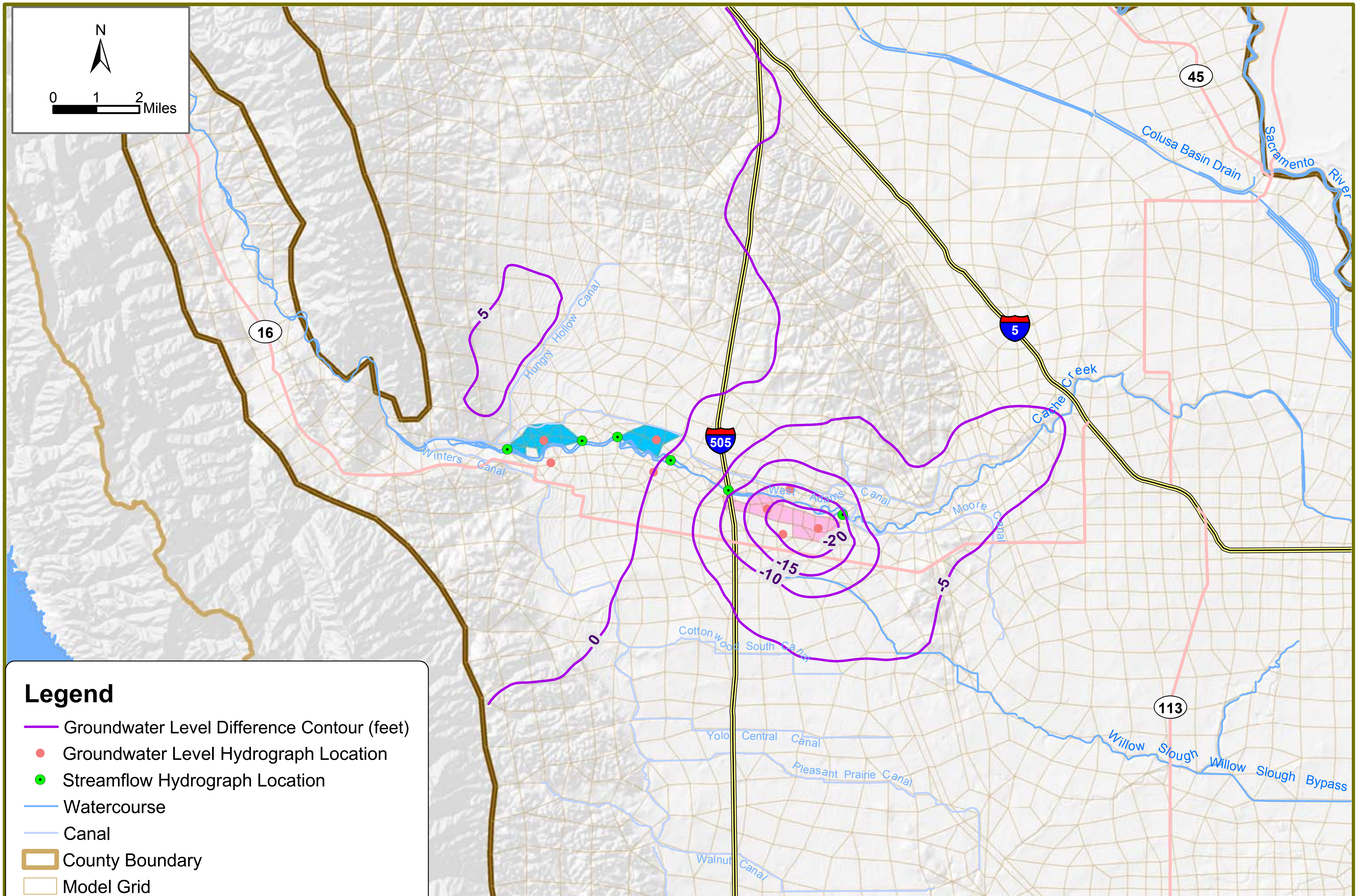
RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

CCGRRP Layer 2 Groundwater Level Difference Contours, Spring 1983

APRIL 2006

FIGURE 5.13



Legend

- Groundwater Level Difference Contour (feet)
- Groundwater Level Hydrograph Location
- Streamflow Hydrograph Location
- Watercourse
- Canal
- County Boundary
- Model Grid
- Model Area Outline

Project Areas

- Pumping Area
- Recharge Area

RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

CCGRRP Layer 2 Groundwater Level Difference Contours, Fall 2000

APRIL 2006

FIGURE 5.14

area shown in Figure 5.12 is the result of previous years' operation and subsequent natural recharge. During the dry hydrologic conditions, Cache Creek did not completely recharge the CCGRRP recovery area. Figure 5.13 shows that in Spring 1983, groundwater levels increase more than 10 feet in the recharge area and groundwater levels increase 2 feet near I-505, north of Cache Creek. Figure 5.13 shows that groundwater levels are 6 feet lower in and around the recovery area. Figure 5.13 shows that the impact of recharge from Cache Creek. Recharge from Cache Creek has deformed the groundwater level difference contours such that the contours are not concentric around the recovery area and isolated depression areas have formed outside the recovery area. Figure 5.14 shows that groundwater levels are 20 feet lower than the Baseline Condition in the recovery area. Lowered groundwater levels are tightly centered around the recovery area.

CCGRRP recharge operations result in groundwater level rises in the Cache Creek recharge area. The increases in groundwater levels spread to the Hungry Hollow area as well (Figures 5.12-5.14). The groundwater mound is located to the north and to the west. A possible reason for this could be that CCGRRP recharge and recovery areas are located apart from each other and on opposite sides of Cache Creek. It is anticipated that the recharge operation would cause a concentric mound forming over the recharge area. However, higher groundwater levels cause additional groundwater discharge to Cache Creek, which would eventually flow downstream to the recovery area. Therefore, the expected concentric mound does not necessarily form over the recharge area. As a result, areas with greatest increase in groundwater levels occur over the western portion of the recharge area and extend north into the Hungry Hollow area. During recovery operations, the recovery well field does not appear to visibly impact the area on the north of the recharge mound, in the Hungry Hollow area. As such, this area continues to maintain elevated groundwater levels even during recovery operations.

Summary of Impacts of the CCGRRP

Table 5.3 summarizes average characteristics of the CCGRRP. It can be seen that, on average and when CCGRRP is recharging water, 6,300 acre-feet of water is discharged back to Cache Creek. During recovery periods, 5,200 acre-feet of additional streamflow losses are induced from Cache Creek. Over the 30-year simulation period, there appears to be an overall reduction of groundwater levels of less than 5 feet in the recovery area. Although not explicitly simulated and analyzed at this time, it is expected that the groundwater system will respond in a similar manner with several proposed modifications for the CCGRRP. These modifications include 1) recovery of 20 TAF in all years and recovery in years when water is available and 2) using Cache Creek as the sole recharge mechanism for the CCGRRP.

Table 5.3 Summary Statistics for CCGRRP, AF/Yr (Average during 1971-2000)

Recharge during years of operation	20,000
Discharge to Cache Creek in years of recharge operation	6,300
Recovery during years of operation	20,000
Recharge induced from Cache Creek in years of extraction operation	5,200

The model simulation results indicate that the CCGRRP can potentially be a successful project to increase the yield of overall system, with combining the groundwater storage with surface water storage facilities. Additional detailed analysis is required to fine tune the locations and rates of recharge and recovery, so as to maximize the overall yield of the system.

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

The YCIGSM was developed and calibrated to meet the need of the YCFCWCD for an analytical tool for basinwide project planning and design. The initial funding of the project was secured through an AB303 grant awarded to the YCFCWCD. The initial scope of the project was limited to the development of the countywide integrated hydrologic model, with special emphasis on data development, analysis, and model calibration around the CCGRRP area. Subsequently, because of the need to apply the model for analysis of water management scenarios to support the local and regional groundwater management plans, as well as the integrated regional water management plan, additional funding was secured through local sources, including the Cities of Davis, Woodland, and Winters, UCD, Yolo County, and the YCFCWCD, as well as technical support by the DWR. This additional funding was used to develop sufficiently detailed data for other parts of the model area and to calibrate the model for areas of Davis/UCD, Woodland, and Winters, as well as for the main groundwater basin in Yolo County. A project TAC, formed with representatives of the YCFCWCD, the DWR, and consultants, provided the necessary technical review, guidance, and coordination during the model development and calibration process.

The YCIGSM is a comprehensive hydrologic model, which simulates both groundwater flow and stream flow including stream-aquifer interactions. The model simulates the historical hydrology on a daily time step for the 30-year simulation period from1971–2000. This study period was selected because it included historical dry and wet periods in the basin. The YCIGSM was calibrated on the basis of four key criteria: (1) water budgets; (2) regional groundwater trends; (3) local groundwater elevations at 105 calibration wells distributed throughout the model area; and (4) stream flow hydrographs at 10 stream gaging stations. The water budgets were developed for 24 model subregions, which corresponded to water districts and irrigation districts in the model area. In order to assess the sensitivity of model results to specific model parameters and input data, a sensitivity analysis was conducted using the YCIGSM by evaluating two different error metrics: average groundwater elevation in selected impact areas and average RMS error aggregated from selected calibration wells in the impact areas. The YCIGSM was also used for evaluating the Baseline Condition (developed on the basis of existing conditions represented by the year 2000 level of development) and the CCGRRP project conditions. The model simulation results indicate that the CCGRRP can potentially be a successful project to increase the yield of overall system, with combining the groundwater storage with surface water storage facilities. Additional detailed analysis is required to fine tune the locations of recharge and recovery, so as to maximize the overall yield of the system.

The conclusions resulting from the present study, potential limitations on the use of the YCIGSM, and recommendations for future course of actions to gather more accurate data and refine model calibration are furnished below.

CONCLUSIONS

- **Water Budgets -** The water budgets, developed on the basis of the best available data on the historical land use, urban and agricultural water demands, surface water deliveries and groundwater pumping, water operations, and other field conditions, were concluded to be reasonably accurate representations of the water budgets for the entire model area as well as for the 24 subregions.
- **Regional Groundwater Levels -** The simulated regional groundwater elevation contours from the YCIGSM were found to reproduce the historical regional groundwater elevation trends reasonably well.
- **Local Groundwater Elevations -** For the local groundwater elevations, the calibration performance of the YCIGSM was found to meet or exceed the calibration targets set at the beginning of the calibration process. Compared with 10,000 observed measurements at 105 calibration wells, 61% of the YCIGSM simulated groundwater levels were found to be within 10 feet of the observed values (calibration target was 60%). Similarly, 82% of the simulated groundwater levels were found to be within 20 feet of the observed values (calibration target was 80%).
- **Streamflow Hydrographs -** The YCIGSM simulated streamflow hydrographs also showed reasonable agreement with observed streamflow hydrographs at the selected 10 stream gaging stations.
- **Gaining/Losing Reaches of Cache Creek -** The YCIGSM was found to be able to simulate the gaining and losing nature of the various stream reaches along Cache Creek reasonably well.
- **Sensitivity Analysis -** The results of the sensitivity analysis for the YCIGSM indicate that the model is a stable model and the system responds in the expected manner to changes in aquifer parameters and input data.
- **Baseline Condition/CCGRRP Project -** The results of the Baseline Condition and CCGRRP Project analyses, conducted as part of this study, demonstrated the reasonable utility of the YCIGSM for evaluation, screening, comparison, and selection of current and future water management alternatives for the modeled area in Yolo County, including the Cache Creek area.

MODEL LIMITATIONS

A numerical model is an approximate mathematical representation of the physical conditions in the field. Unfortunately, field data on all model components are not equally available or reliable. Therefore, reasonable assumptions are made during the model development process regarding missing data and information on the physical system. These approximations and assumptions lead to the model's inability to exactly replicate the historical observations at all locations at all times. The differences between field observations and model simulations can be, in a loose sense, termed "modeling errors." Truly speaking, these are the limitations of the model. It is very important to understand these limitations or "sources of errors" before a numerical model, such as the YCIGSM, is applied to conduct evaluation of water management alternatives. These limitations of the YCIGSM are discussed below under the subheadings modeling errors, input data errors, and measurement errors.

Modeling Errors

The YCIGSM represents physical processes occurring in nature by a series of mathematical approximations. Due to the randomness associated with the governing physical processes, both in their phenomenological description and in their quantification, it is not possible to develop a complete mathematical description of the physical world without introducing certain simplifying assumptions. These simplifying assumptions provide us with the Darcy's equation and the governing differential equation of groundwater flow that are universally used in all groundwater models, including the YCIGSM. These equations are valid on a representative equivalent volume (Bear, 1979), which are characterized by the level of spatial discretization (i.e., the size of the finite elements) in the YCIGSM. On the other hand, data are available on a much larger scale, such as a water district or irrigation district. As a consequence, the YCIGSM is able to predict hydrologic responses on a macro scale basis by replicating regional historical trends; certain discrepancies in simulated streamflows and groundwater levels are expected on a local scale.

Input Data Errors

Input data used in the YCIGSM represents the best information available at the time of this study. Missing data were estimated by (i) statistical methods, (ii) engineering judgment, and (iii) inference from other sources. The estimation of data necessarily leads to certain limitations in the developed model. These potential limitations of the YCIGSM associated with input data errors are provided below.

Generic Data Estimation Errors

Estimation errors associated with any input data have effects on YCIGSM results. As discussed previously, the data used in developing the YCIGSM input files were available in different temporal and spatial scales with different degrees of reliability. These limitations of the input data combine to produce discrepancies between simulated results and observed values.

Groundwater Pumping Data Estimation Error

Groundwater pumping is one of the most critical sets of input data that affect the response of the YCIGSM model area. Agricultural water use accounts for about 95% of the water use in the YCIGSM model area. Groundwater pumping data and the distribution of pumping in the area are not recorded except for municipal pumping. In the absence of field data, agricultural groundwater pumping was estimated by the YCIGSM on the basis of crop water requirements and other related information obtained from previous studies. Estimation errors in the pumping data are believed to have contributed to some of the discrepancies between observed and simulated results by the YCIGSM.

Model Simulation Capabilities in Major Geographic Areas

This section provides the context on the simulation capabilities and limitations of the calibration and application of the YCIGSM in major geographic that included the YCFCWCD service area and the Cities of Davis, Woodland, and Winters.

Cache Creek above Moore's Siphon

For the area located along the Cache Creek corridor, below Capay Dam and above Moore's Siphon, there was very good agreement of simulated groundwater levels with observed measurements for all wells except one, located on the north side of Cache Creek near the Hungry Hollow canal. The discrepancy between simulated and observed measurements for this well was suspected to be related to stratigraphy data in the Hungry Hollow area, as elaborated subsequently in the discussion of Hungry Hollow Area.

Cache Creek below Moore's Siphon

For the area located along the Cache Creek corridor, between Moore's Siphon to the Settling Basin, the simulated groundwater levels reasonably represented the observed measurements for most wells. However, for some wells, an analysis of model results and observed wells data revealed that there could be a high correlation between Cache Creek flows and observed groundwater levels in that area. The observed measurements showed that water levels remained relatively constant even when regional conditions were dry and that water levels spiked during wet conditions and returned to constant levels soon after the wet conditions ended. Available information shows that some of the observed wells are shallow (well screens are fewer than 50 feet below ground surface). It may be inferred that there is some type of perched aquifer/clay layer present in that area preventing water levels from declining during dry periods. Unfortunately, no information is available at present on this speculated perched aquifer/clay layer and, therefore, this layer could not be simulated in the YCIGSM. This is believed to have caused some of the discrepancies of simulated results with observed data.

East Adams Canal

An analysis of model results and observed wells data showed that in areas near East Adams Canals, the observed measurements were constant, aside from insignificant seasonal variations, suggesting a constant headwater source nearby. It was concluded that the East Adams Canal was acting as a recharge source for the wells in the vicinity of the canal. The YCIGSM does not explicitly simulate water flow in the East Adams Canal but the model grid has been configured such that the canal could be simulated in the model, if desired, to eliminate some of the anomalies in the simulated results.

Hungry Hollow

The model results for the Hungry Hollow area and its vicinity showed gross discrepancies between simulated groundwater levels and observed well measurements. It was concluded from an analysis of model results that the major source of discrepancy between simulated results and observed measurements in the Hungry Hollow area was related to the seriously deficient stratigraphy data for that area. There are fewer sources of stratigraphy data in the Hungry Hollow area in comparison with other areas in the YCIGSM. As such, stratigraphy data in the Hungry Hollow area (where data are severely lacking) were estimated and incorporated in the YCIGSM based on the limited data that were available, leading to the relatively inferior simulation results for the area. Also, the time invariant simulation of stream channel geometry and bed elevation may also affect simulated groundwater levels in this area.

Woodland Area

For the Woodland area, simulated water levels showed reasonable agreement with observed values during the late fall through early summer measurements. Observed water levels taken at municipal wells during mid-summer through mid-fall are generally not considered reasonable measurements of water levels in the regional groundwater aquifer, because water level measurements at these wells are taken within several hours after well shutdown and do not necessarily represent fully recovered static, regional groundwater levels. Based on discussions with engineers and operators of well systems in the area, it was concluded that water levels could take up to 24 hours for recovery, particularly during the summer and fall months when the stresses on the regional groundwater system are the greatest. As such, groundwater levels in the Woodland area were calibrated to late fall through early summer measurements to represent regional groundwater levels in the aquifer, which resulted in better agreement of simulated groundwater levels with observed ones.

Winters Area

For the Winters area, simulated water levels in the wells matched reasonably well with observed values.

Davis Area

For the Davis area, simulated water levels showed reasonable agreement with observed values during the late fall through early summer measurements. As with the Woodland area wells, observed water levels taken at City of Davis wells during the summer and fall months do not necessarily reflect static, regional groundwater levels. Thus, similar to the wells in the Woodland area, groundwater levels in the Davis area were calibrated to late fall through early summer measurements to represent regional groundwater levels in the aquifer, which resulted in better agreement of simulated groundwater levels with observed ones.

UCD Area

For UCD water supply wells, it was reported that UCD well operators took water level measurements at least 24 hours after shutdown, so that water level measurements were more representative of regional conditions. Unfortunately for the available data, the dates of the water level measurement were not recorded and the water level measurements were assigned as a spring or fall measurement. For purposes of calibrating the YCIGSM, spring water level measurements were assigned to March and fall water level measurements were assigned to September. Although the simulated values generally showed reasonable agreement with observed water level measurements in wells, the lack of data on measurement dates and the resulting arbitrary assignment of measurement dates could have contributed to the mismatch and out-of-phase status between simulated groundwater levels and observed well measurements in this area.

Areas Not Focused on in the Current Study

Dunnigan Water District, Lower Colusa Basin, Reclamation District 108, Dunnigan Hills, West Sacramento, and Solano County were not the focus areas for model development and calibration. In addition, for areas in Solano County, data were not readily available and, because data development for these areas was not a priority, the data used were gross estimates. Therefore, some deficiencies in simulation results for all these areas are expected.

MEASUREMENT ERRORS

The YCIGSM calibration performance should be evaluated on the basis of both the availability and quality of historical streamflow data at gage stations and groundwater levels at observation wells.

Cache Creek

An analysis of model results and observed data for Cache Creek at Yolo gage showed that simulated streamflow values closely matched observed data during periods when Capay Dam was not in operation. However, when Capay Dam was in operation, the simulated values did not appear to be in close agreement with observed data. Based on available information, it was concluded that the discrepancies between observed and simulated Cache Creek flows at Yolo resulted from several potential sources. These included missing and/or error-prone data associated with the releases from Capay Dam, groundwater pumping near Cache Creek, and surface water return flows from the Salisbury Spill. The daily release record from Capay Dam, when in operation, is available from 1979 to present. However, the release record is not complete for every day of operation and there are issues regarding the accuracy of the available Capay Dam release data. Groundwater pumping near Cache Creek has not been measured and therefore, no such data are available. The Gordon Slough is the principal drain of the Hungry Hollow area. The Gordon Slough discharges to Cache Creek via the Salisbury Spill. This discharge to Cache Creek is not measured and, thus, could not be explicitly simulated in the YCIGSM. All these factors are believed to have contributed significantly to the inaccuracies in the simulated Cache Creek flows at Yolo when Capay Dam is in operation.

Water Level Measurements

The water level measurements data are sometimes influenced by nearby pumping and, therefore, do not necessarily represent regional water level conditions; sometimes the reported water levels include measurement errors. As observed for Woodland and Davis wells, measurements taken from municipal wells are quite frequently taken too soon after well shutdown and, thus, the groundwater level measurements reflect a well in recovery instead of the regional groundwater level. As also observed, for the UCD water supply wells, the recorded measurement at a well is on a specific day within a month. In contrast, the corresponding simulated groundwater level is an average value over an entire layer or multiple layers and is the end-of-month value. In addition to the above, the perforations of wells are often estimated in the YCIGSM because of lack of data or insufficient data. Due to these differences in how the observed values are measured and how the simulated values are computed, differences of model results with observations at local wells are expected.

RECOMMENDATIONS

The following actions are recommended to improve the capability of YCIGSM to simulate the regional surface water and groundwater conditions in the model area more accurately.

- **Capay Dam Release Data -** Conduct controlled flow release experiments from Capay Dam. The effects of flow release on groundwater levels in the vicinity of Cache Creek downstream of Capay should be monitored. This experiment will provide information about stream-aquifer interaction below Capay Dam and that information can be used to improve simulation of Cache Creek flow at Yolo in the YCIGSM.
- **Agricultural Groundwater Pumping -** Conduct a field survey within the YCFCWCD service area for agricultural pumping wells that are in use to provide better estimates of agricultural groundwater pumping quantity and distribution data and thus improve model simulation results.
- **"Hungry Hollow" Area Stratigraphy Data -** Conduct additional hydrogeologic studies with particular focus on collecting stratigraphy data for the Hungry Hollow area within the West Yolo North Subregion. The representation of stratigraphy in the YCIGSM would improve as more accurate stratigraphic data become available, which, in turn, is expected to improve groundwater level simulation for the area.
- **Dunnigan Hills Subregion Water Level Data** – Water level data from wells within the Dunnigan Hills Subregion are lacking. This data would allow for a better characterization of groundwater flow under the Dunnigan Hills eastward toward the center of the Sacramento Valley. Additionally, this data would help interpret the influence of the Zamora Fault on groundwater flow.
- **"Cache Creek below Moore's Siphon" Area Hydrogeologic Data -** Conduct additional hydrogeologic studies to obtain better information for the suspected perched aquifer/clay layer in this area. Availability of such information would allow the inclusion of this perched aquifer/clay layer in the YCIGSM to improve model calibration further.
- **Buckeye Creek, Bird Creek and Oat Creek Streamflows –** Streamflow measurement of these three creeks would be beneficial in calibrating their contribution to groundwater recharge and surface water supply in the northern portion of Yolo County.
- **"Cache Creek below Moore's Siphon" Area Explicit Canal Simulation -** Include and simulate East Adams Canal explicitly in the YCIGSM to improve simulation of groundwater levels in the area.

- **Data/Calibration Refinement for Areas Not Focused on in the Current Study -** Obtain and/or estimate more reliable data for urban and agricultural water demands for the areas in Solano County to enable more accurate simulation of model results. Put additional effort into calibration of Dunnigan Water District, Lower Colusa Basin, Reclamation District 108, Dunnigan Hills, West Sacramento, and Solano County to improve further overall model calibration.
- **Calibration Wells –** Many of the wells used for calibrating groundwater levels lack depth and/or perforation interval data. Identifying additional water wells that have well construction data could provide a better set of calibration wells. Calibration wells are lacking in areas with known water level monitoring programs, including RD 2035 and RD 108. Monitoring wells in these areas should be considered for inclusion into the set of calibration wells.
- **Water Level Measurements in the Woodland and Davis Area** – Water level data collected from municipal water wells, which are typically cycled on and off at relatively frequent intervals, proved to be unreliable. Locating and/or constructing observation wells specifically designed to provide water level data (and potentially water quality data) would provide a more accurate depiction of groundwater levels within the Woodland and Davis areas.

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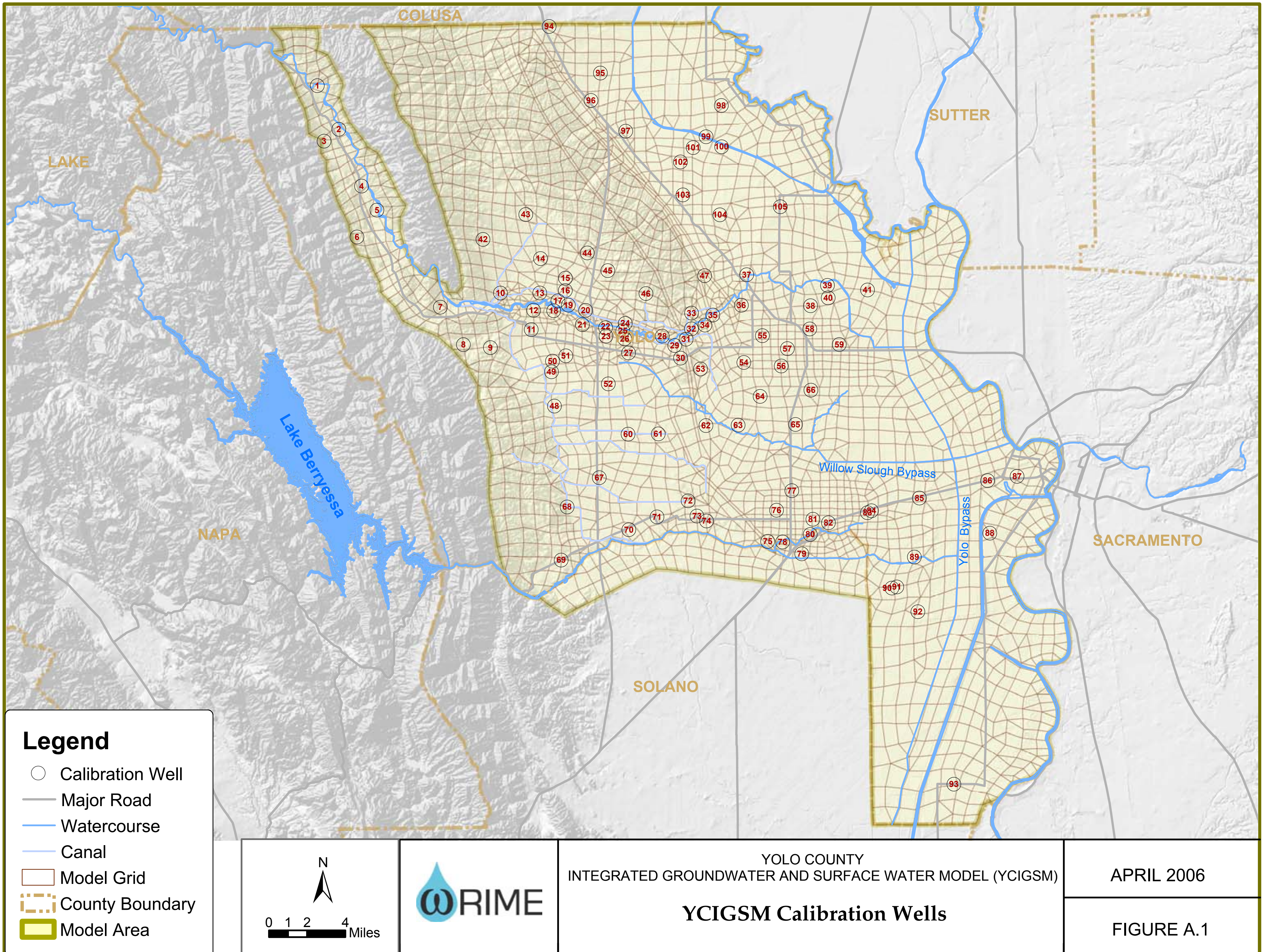
Groundwater hydrograph location map

105 calibration well hydrographs



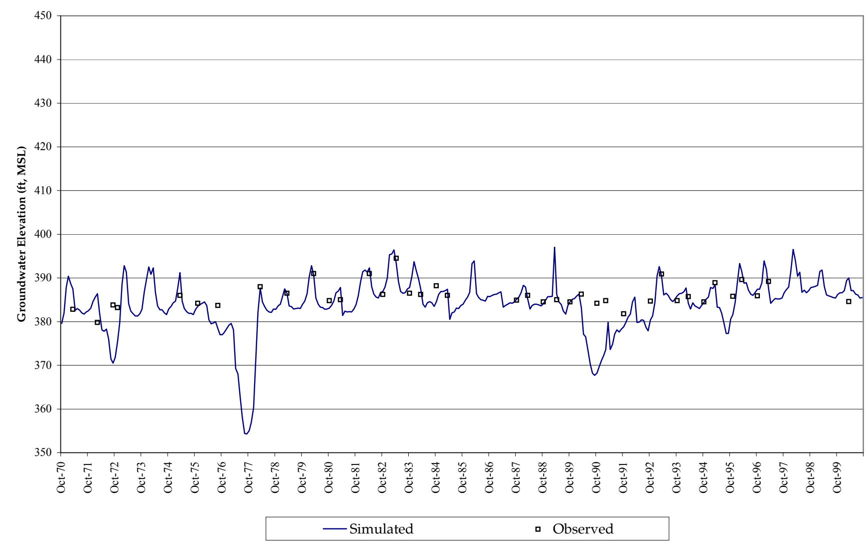
RIME

YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

YCIGSM Calibration Wells

APRIL 2006

FIGURE A.1



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 1 (12N03W20D001M), Subregion 1
GSE - 410 ft, Layer 1 Thickness - 310 ft, L2 T - 610 ft, L3 T - 0
Well Depth - 26, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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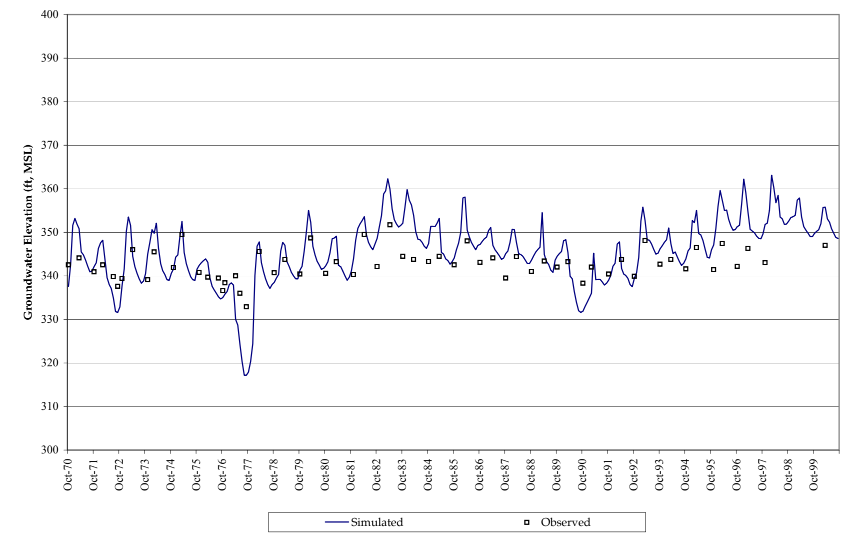
FIGURE A.2



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 2 (12N03W33F001M), Subregion 1
GSE - 390 ft, Layer 1 Thickness - 400 ft, L2 T - 500 ft, L3 T - 0
Well Depth - 75, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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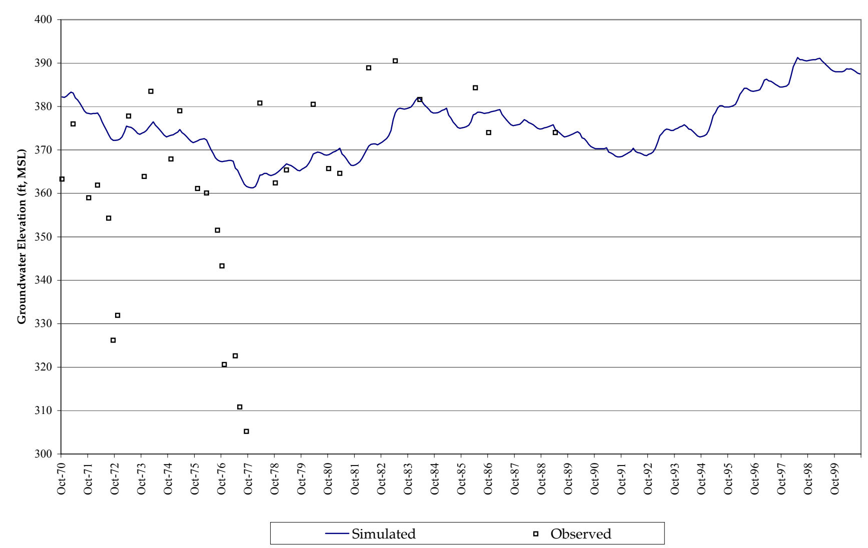
FIGURE A.3



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 3 (12N03W32Q001M), Subregion 1
GSE - 450 ft, Layer 1 Thickness - 220 ft, L2 T - 470 ft, L3 T - 0
Well Depth - 238, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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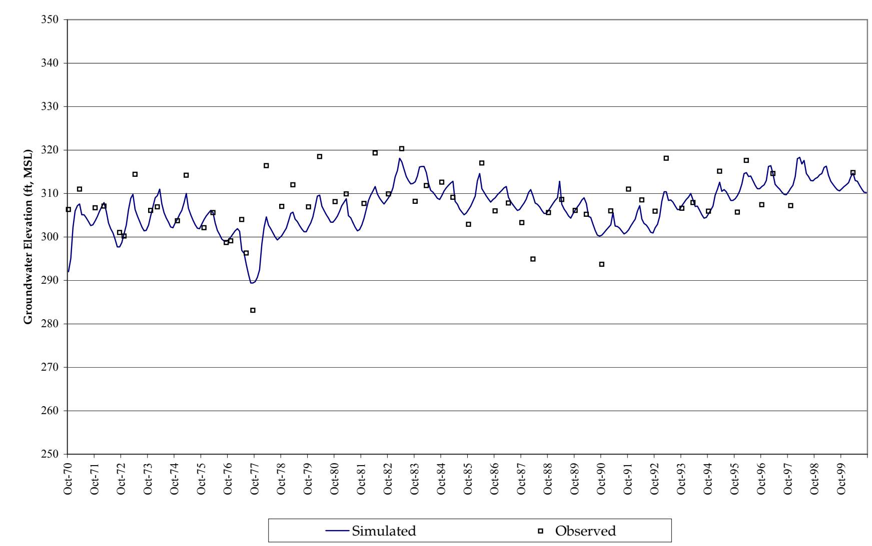
FIGURE A.4



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 4 (11N03W15G001M), Subregion 1
GSE - 340 ft, Layer 1 Thickness - 390 ft, L2 T - 510 ft, L3 T - 0
Well Depth - 100, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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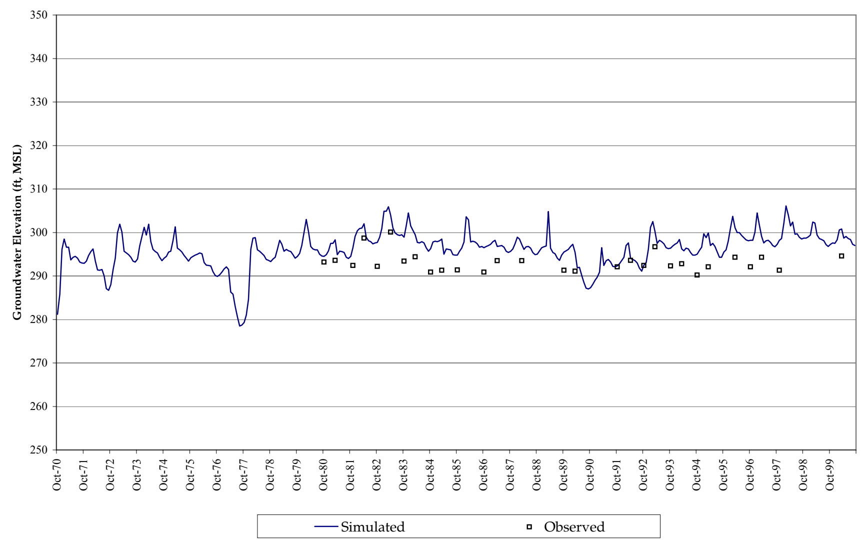
FIGURE A.5



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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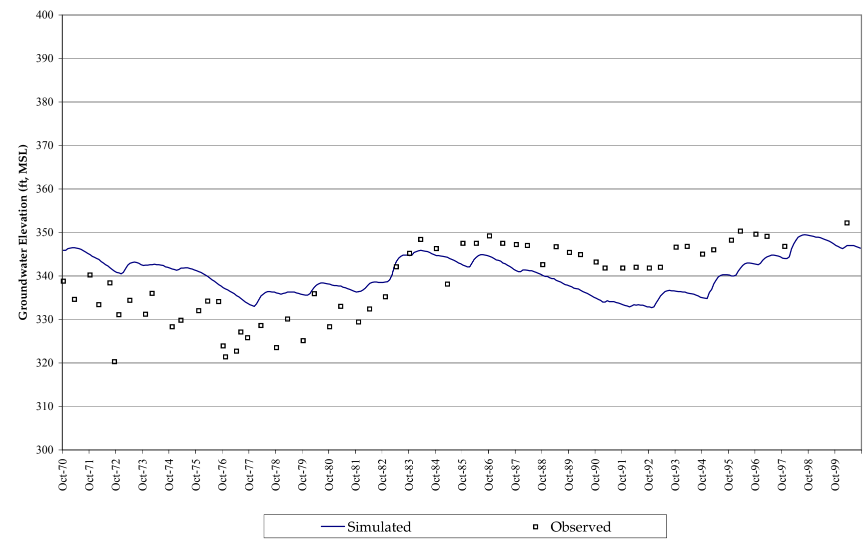
Calibration Well 5 (11N03W23L001M), Subregion 1
GSE - 320 ft, Layer 1 Thickness - 370 ft, L2 T - 420 ft, L3 T - 0
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.6

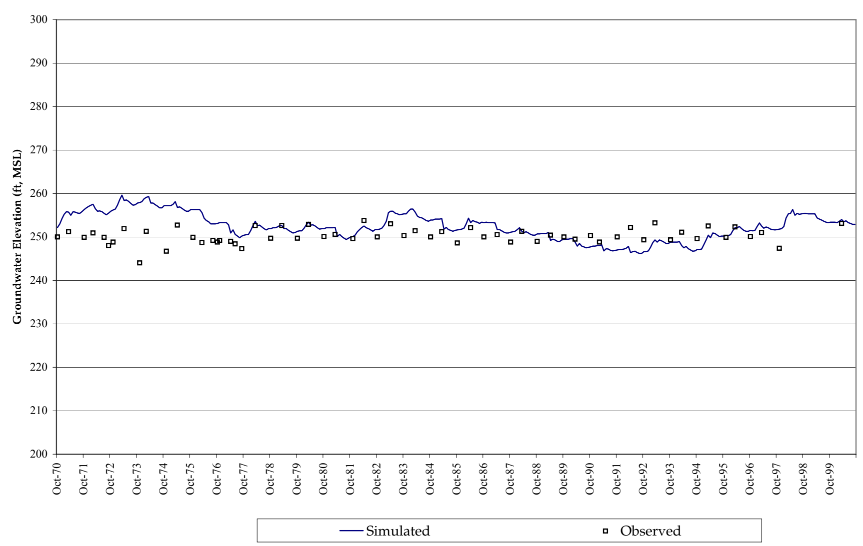


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 6 (11N03W34C001M), Subregion 1
GSE - 460 ft, Layer 1 Thickness - 100 ft, L2 T - 560 ft, L3 T - 0
Well Depth - 140, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.7

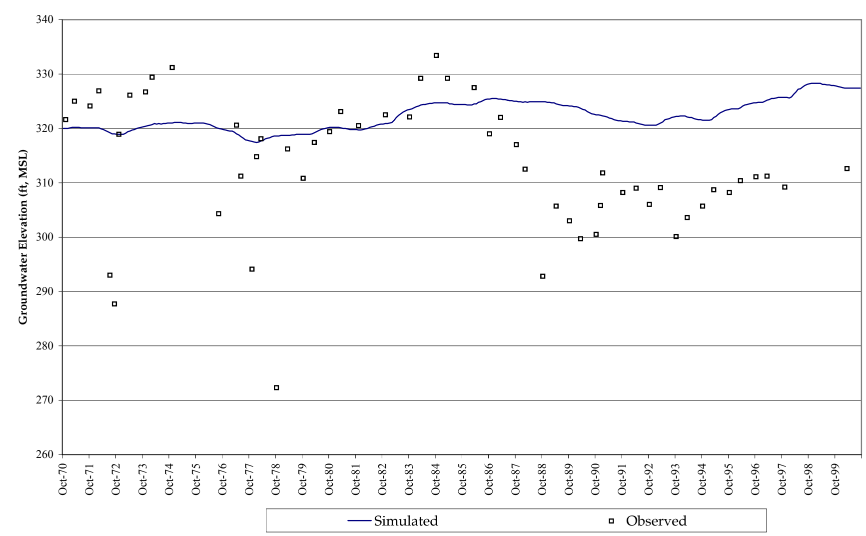


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 7 (10N02W17J001M), Subregion 1
GSE - 320 ft, Layer 1 Thickness - 40 ft, L2 T - 210 ft, L3 T - 0
Well Depth - 24, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.8

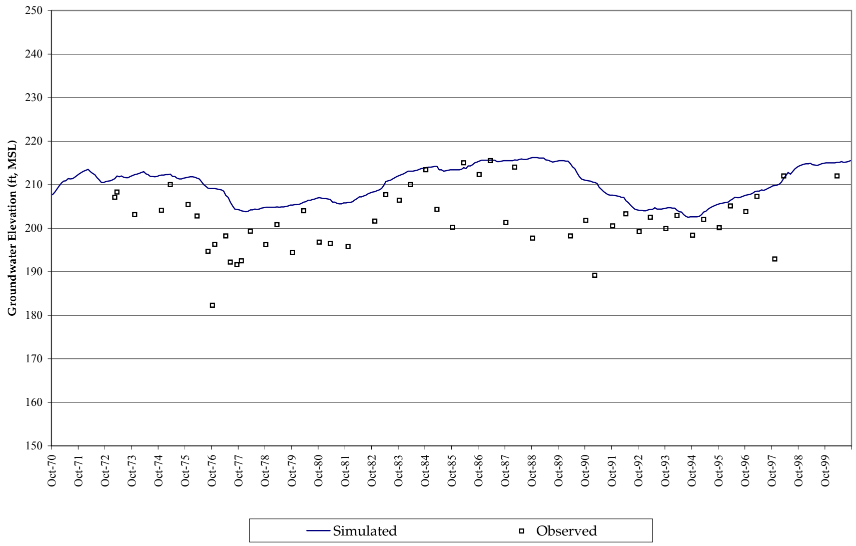


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 8 (10N02W28J001M), Subregion 8
GSE - 440 ft, Layer 1 Thickness - 0 ft, L2 T - 190 ft, L3 T - 150
Well Depth - nd, Hole Depth - 280, Top Perforation - 180, Bottom Perforation - 280

FIGURE A.9



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 9 (10N02W26P001M), Subregion 8
GSE - 320 ft, Layer 1 Thickness - 0 ft, L2 T - 270 ft, L3 T - 210
Well Depth - 205, Hole Depth - 205, Top Perforation - 174, Bottom Perforation - 204

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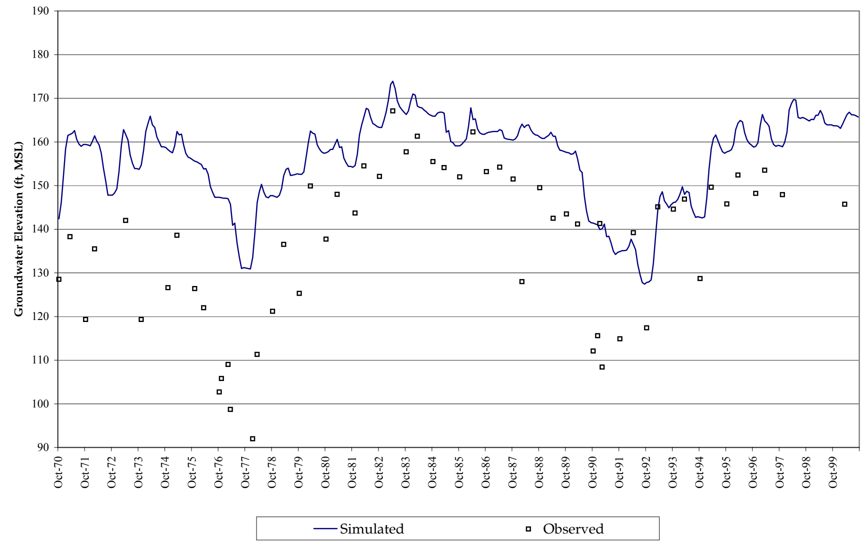
FIGURE A.10



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 10 (10N02W14A001M), Subregion 7
GSE - 200 ft, Layer 1 Thickness - 160 ft, L2 T - 290 ft, L3 T - 230
Well Depth - nd, Hole Depth - 135, Top Perforation - 76, Bottom Perforation - 128

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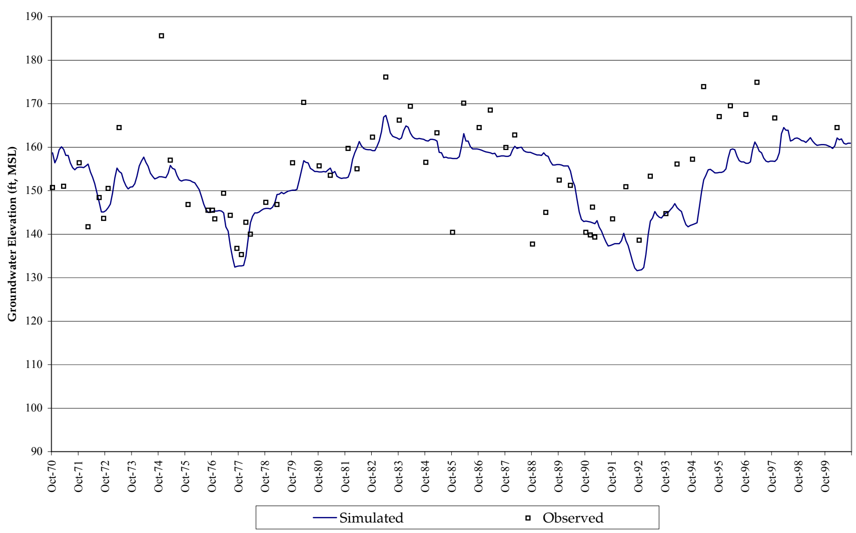
FIGURE A.11



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 11 (10N01W19Q004M), Subregion 8
GSE - 190 ft, Layer 1 Thickness - 110 ft, L2 T - 970 ft, L3 T - 390
Well Depth - 146, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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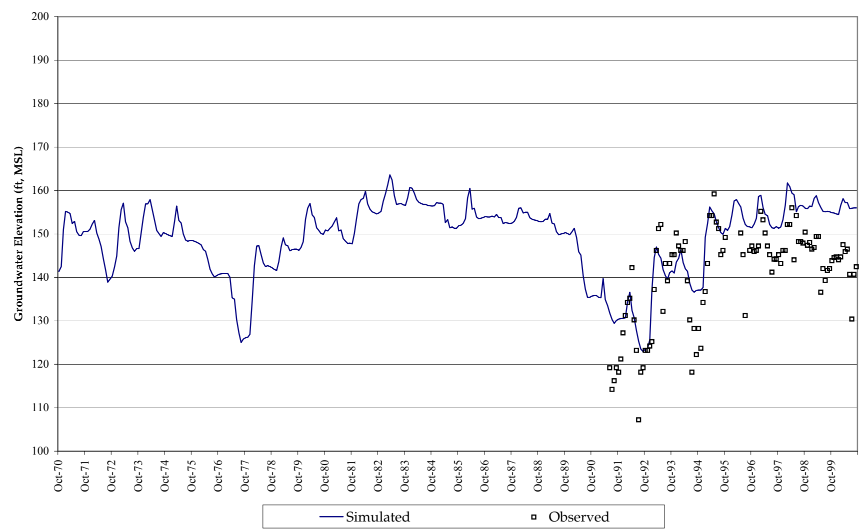
FIGURE A.12

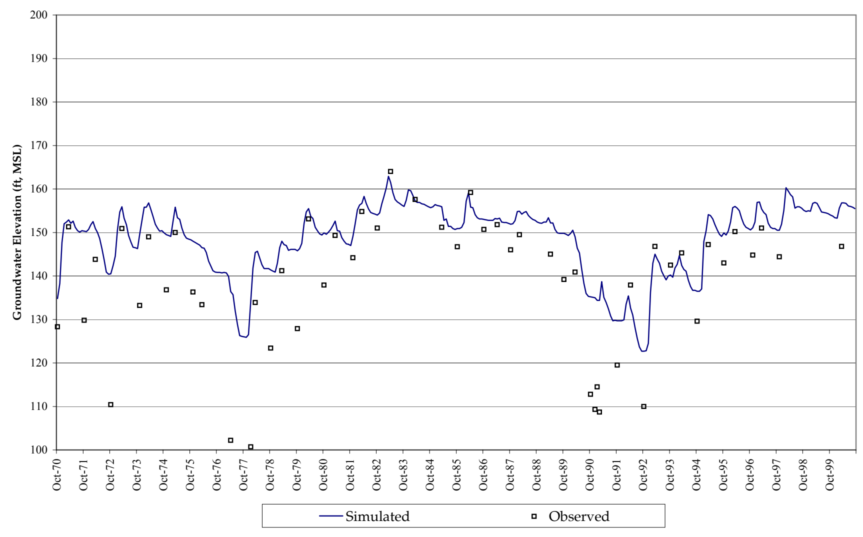


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 12 (Syar_Mast), Subregion 8
GSE - 180 ft, Layer 1 Thickness - 140 ft, L2 T - 810 ft, L3 T - 550
Well Depth - 211, Hole Depth - nd, Top Perforation - 80, Bottom Perforation - 210

APRIL 2006

FIGURE A.13

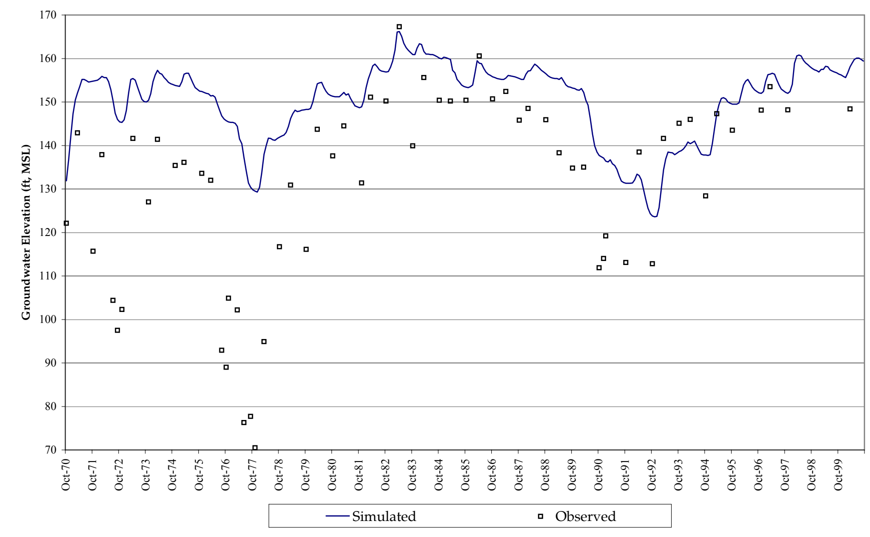


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 13 (10N01W18A001M), Subregion 7
GSE - 180 ft, Layer 1 Thickness - 160 ft, L2 T - 740 ft, L3 T - 580
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.14

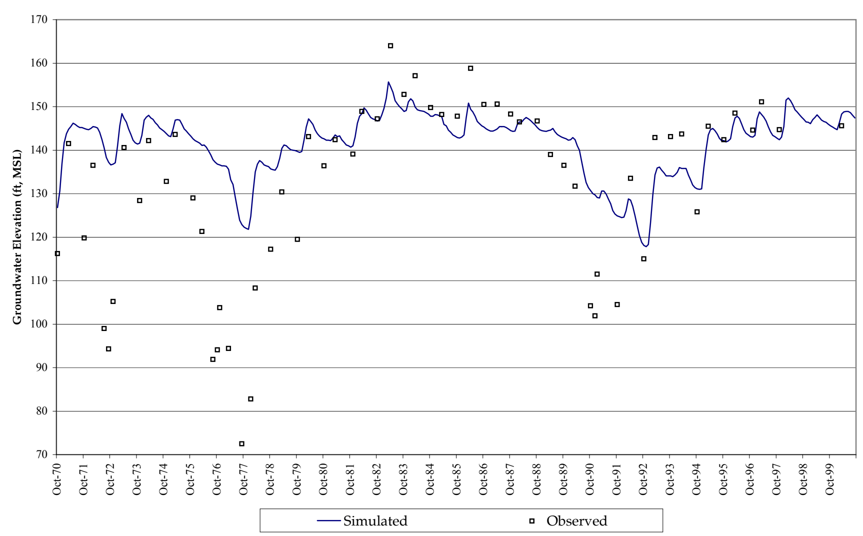


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 14 (10N01W05E001M), Subregion 7
GSE - 190 ft, Layer 1 Thickness - 190 ft, L2 T - 790 ft, L3 T - 620
Well Depth - nd, Hole Depth - 247, Top Perforation - 133, Bottom Perforation - 164

FIGURE A.15

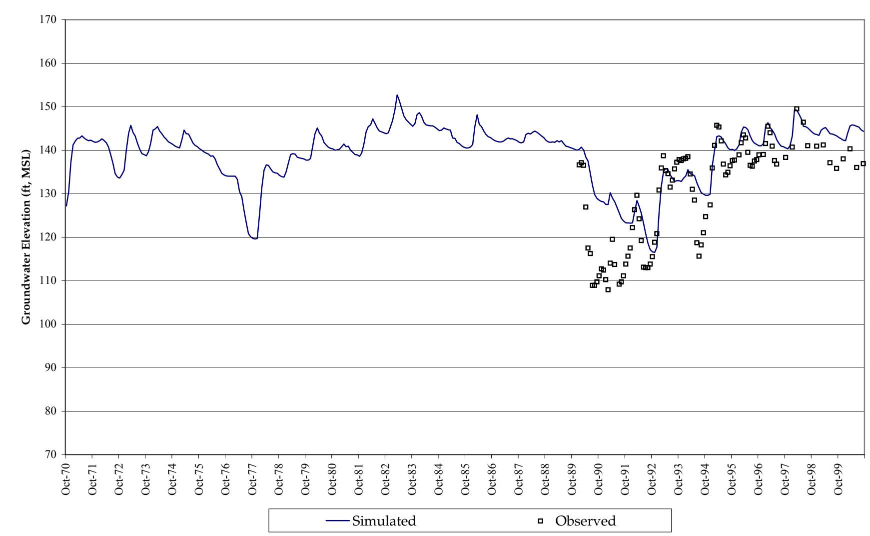


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 15 (10N01W09F002M), Subregion 7
GSE - 170 ft, Layer 1 Thickness - 150 ft, L2 T - 1030 ft, L3 T - 810
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.16

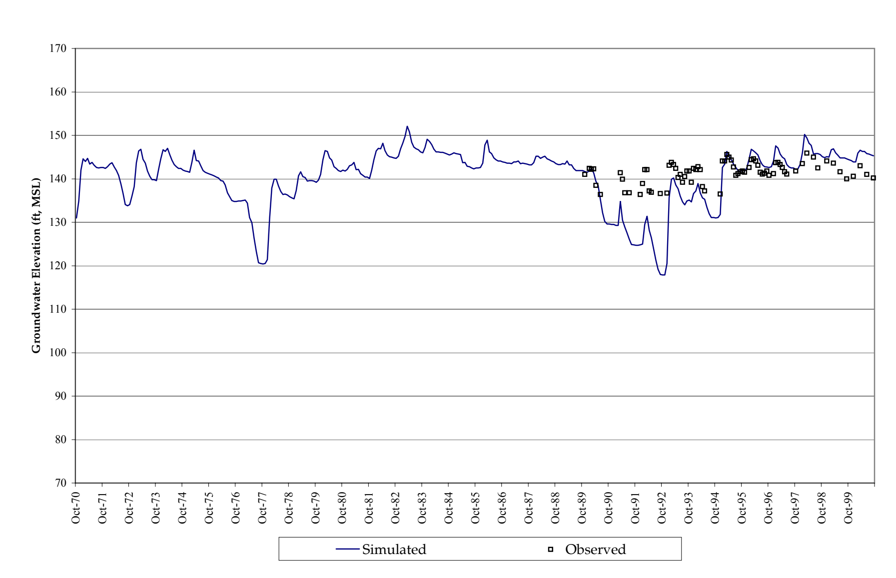


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

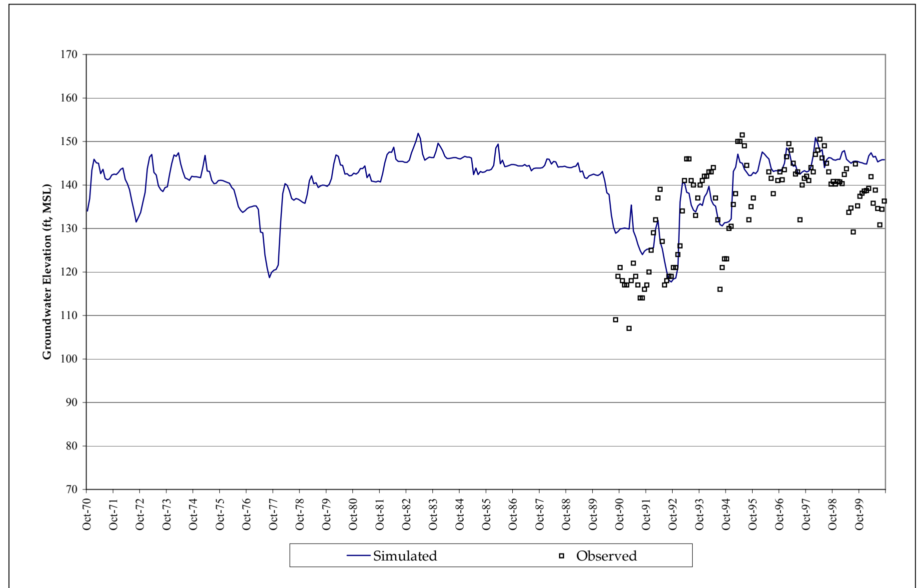
APRIL 2006

Calibration Well 16 (Teichert_M-3), Subregion 7
GSE - 170 ft, Layer 1 Thickness - 120 ft, L2 T - 1030 ft, L3 T - 810
Well Depth - 65, Hole Depth - nd, Top Perforation - 45, Bottom Perforation - 65

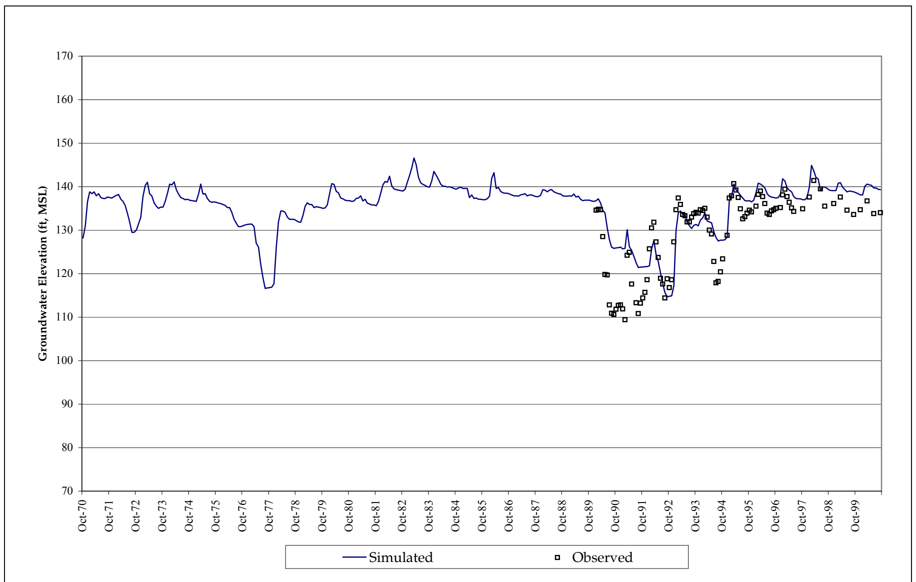
FIGURE A.17



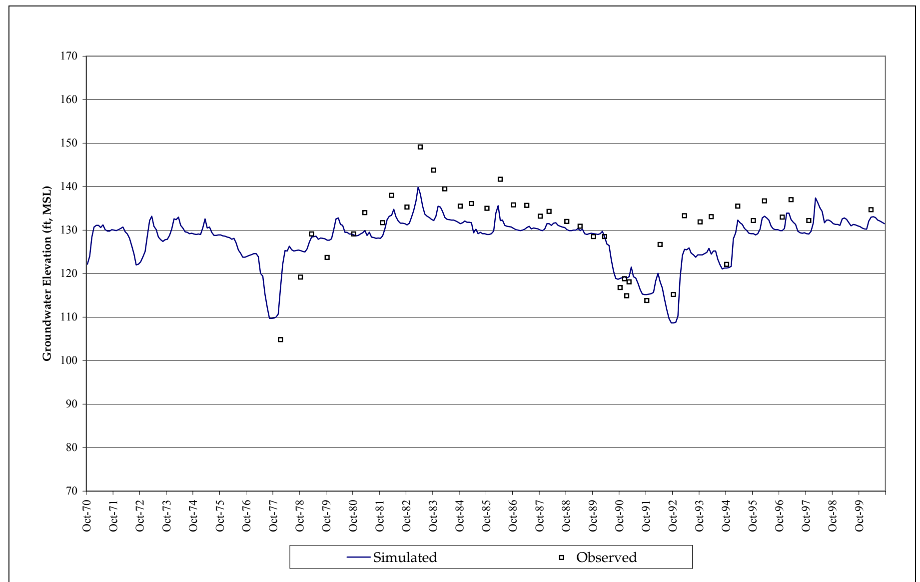
RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Calibration Well 17 (Teichert_R-4A), Subregion 7 **GSE - 170 ft, Layer 1 Thickness - 120 ft, L2 T - 980 ft, L3 T - 770** **Well Depth - nd, Hole Depth - nd, Top Perforation - 23.5, Bottom Perforation - 33**	FIGURE A.18



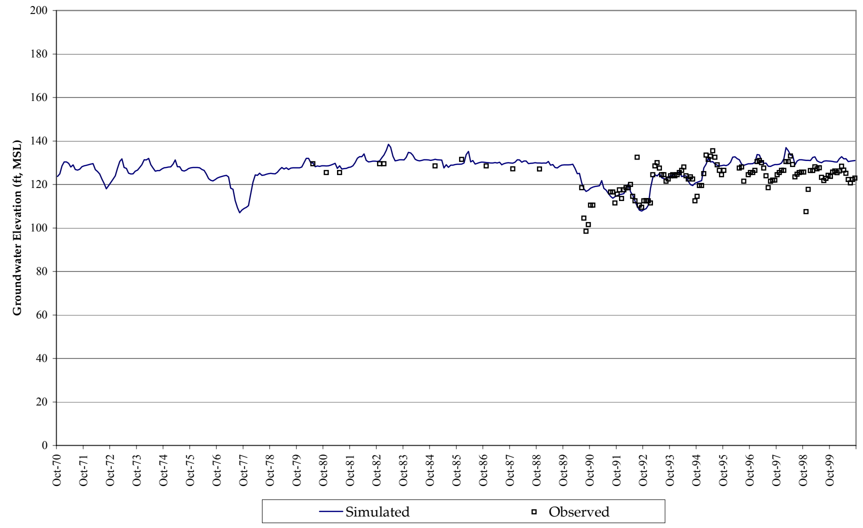
RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Calibration Well 18 (Syar_Stephens), Subregion 8 **GSE - 170 ft, Layer 1 Thickness - 130 ft, L2 T - 940 ft, L3 T - 740** **Well Depth - nd, Hole Depth - nd, Top Perforation - 95, Bottom Perforation - 112**	FIGURE A.19



RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Calibration Well 19 (Teichert_M-2), Subregion 7 **GSE - 160 ft, Layer 1 Thickness - 110 ft, L2 T - 1080 ft, L3 T - 850** **Well Depth - nd, Hole Depth - nd, Top Perforation - 44.5, Bottom Perforation - 64.5**	FIGURE A.20



RIME	YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)	APRIL 2006
	Calibration Well 20 (10N01W15P002M), Subregion 7 **GSE - 160 ft, Layer 1 Thickness - 100 ft, L2 T - 1210 ft, L3 T - 970** **Well Depth - nd, Hole Depth - nd, Top Perforation - 44, Bottom Perforation - 52**	FIGURE A.21



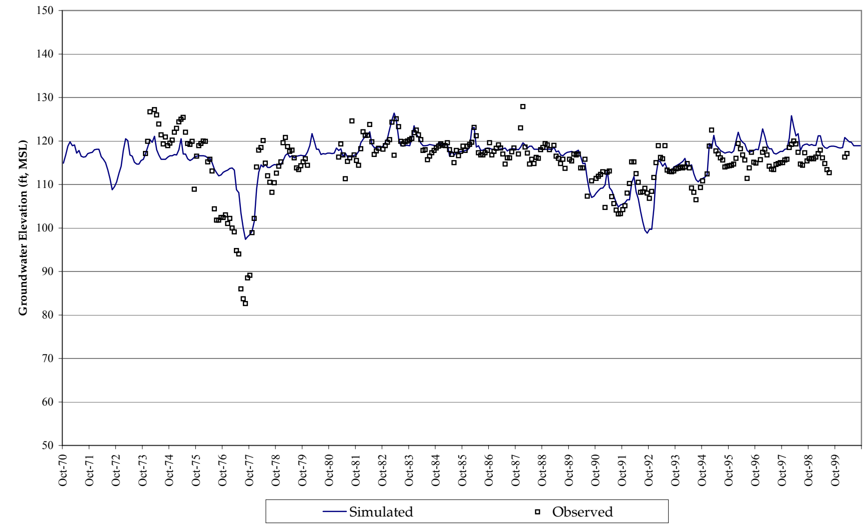
PRIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 21 (Syar_Truck Shop), Subregion 8
GSE - 150 ft, Layer 1 Thickness - 100 ft, L2 T - 1240 ft, L3 T - 1100
Well Depth - nd, Hole Depth - nd, Top Perforation - 43, Bottom Perforation - 64

APRIL 2006

FIGURE A.22



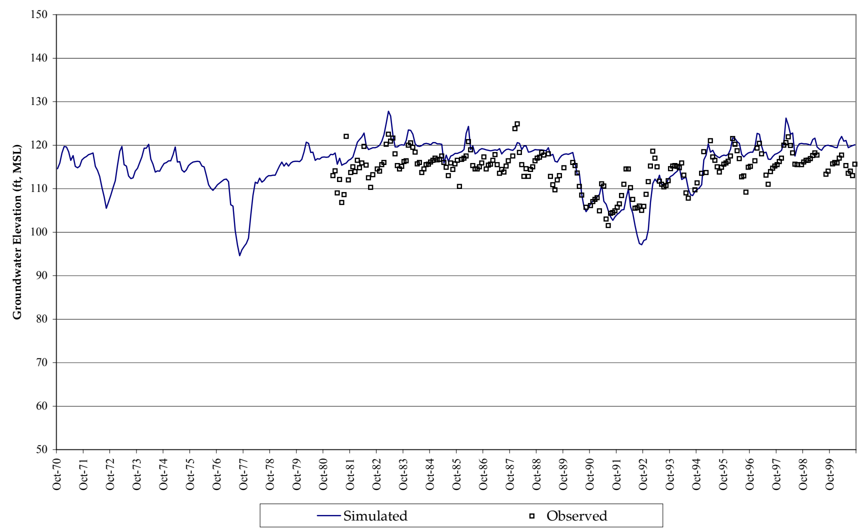
PRIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 22 (Rinker_Solano-1A), Subregion 8
GSE - 140 ft, Layer 1 Thickness - 100 ft, L2 T - 1220 ft, L3 T - 1240
Well Depth - nd, Hole Depth - nd, Top Perforation - 77, Bottom Perforation - 97

APRIL 2006

FIGURE A.23



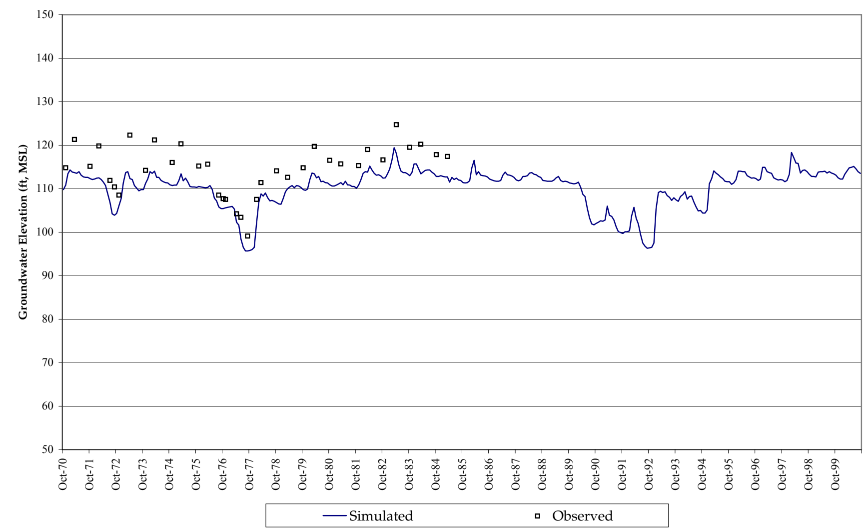
PRIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 23 (Rinker_Solano-2), Subregion 8
GSE - 140 ft, Layer 1 Thickness - 100 ft, L2 T - 1220 ft, L3 T - 1230
Well Depth - nd, Hole Depth - nd, Top Perforation - 80, Bottom Perforation - 130

APRIL 2006

FIGURE A.24



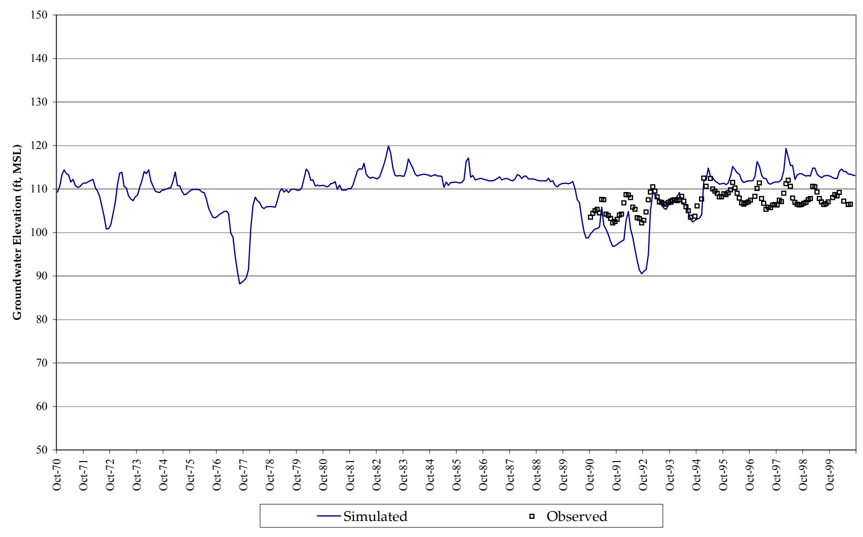
PRIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 24 (10N01W24L002M), Subregion 7
GSE - 140 ft, Layer 1 Thickness - 40 ft, L2 T - 1260 ft, L3 T - 1120
Well Depth - nd, Hole Depth - nd, Top Perforation - 35, Bottom Perforation - 44

APRIL 2006

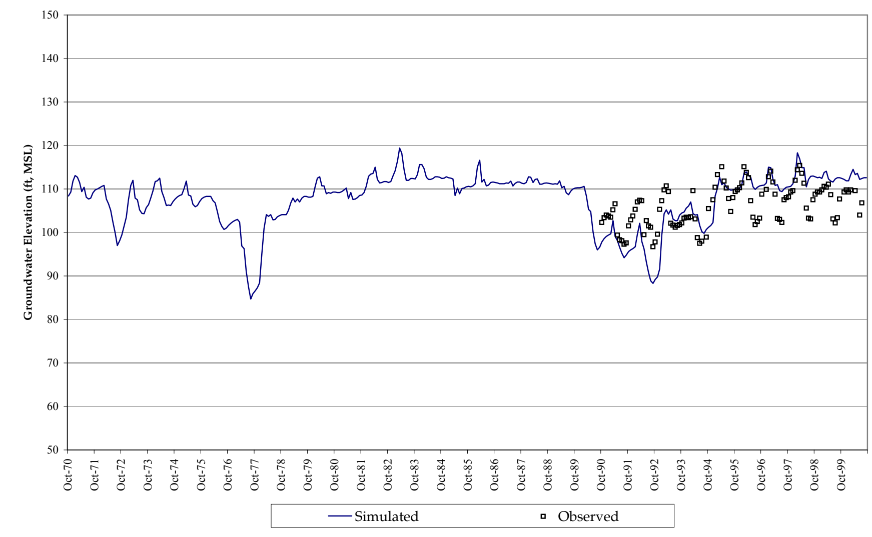
FIGURE A.25



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) | APRIL 2006

Calibration Well 25 (Rinker_OW-4), Subregion 8
GSE - 130 ft, Layer 1 Thickness - 60 ft, L2 T - 1250 ft, L3 T - 1190
Well Depth - nd, Hole Depth - nd, Top Perforation - 35, Bottom Perforation - 75

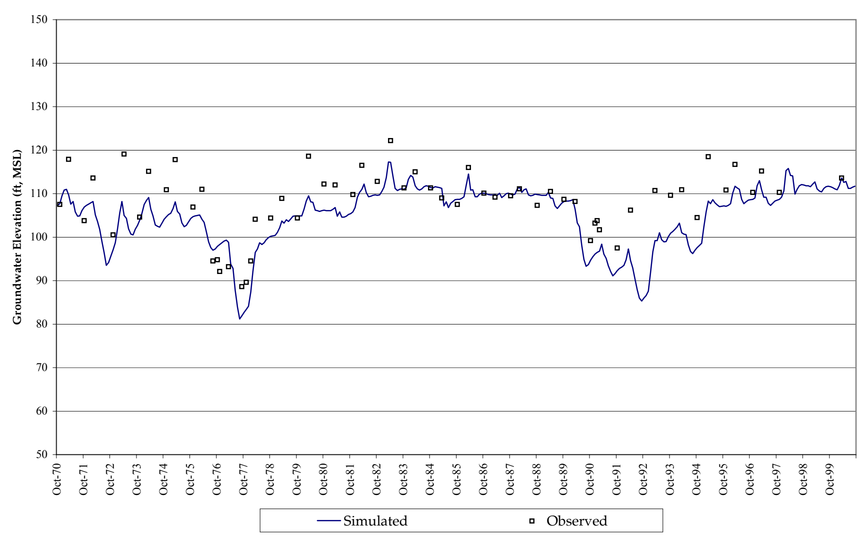
FIGURE A.26



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) | APRIL 2006

Calibration Well 26 (Rinker_OW-9), Subregion 8
GSE - 130 ft, Layer 1 Thickness - 90 ft, L2 T - 1220 ft, L3 T - 1200
Well Depth - nd, Hole Depth - nd, Top Perforation - 50, Bottom Perforation - 80

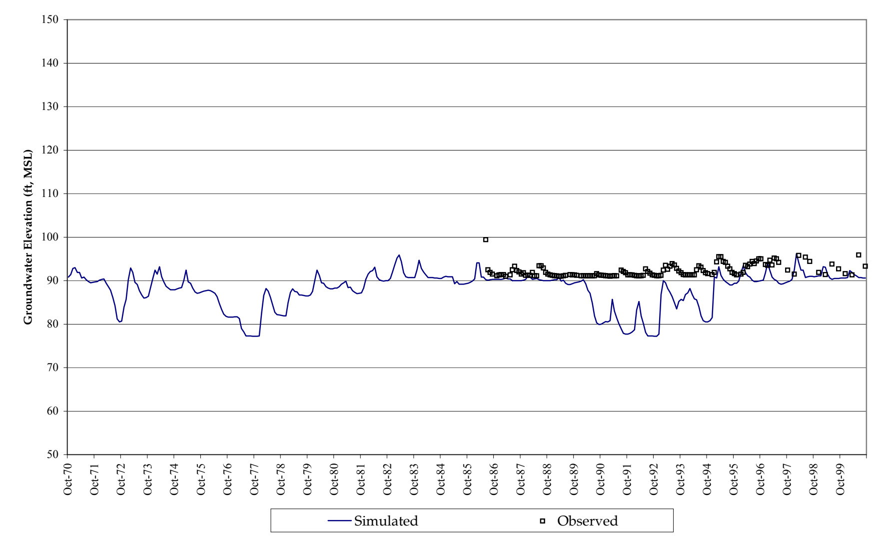
FIGURE A.27



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) | APRIL 2006

Calibration Well 27 (10N01W36B002M), Subregion 8
GSE - 130 ft, Layer 1 Thickness - 80 ft, L2 T - 1200 ft, L3 T - 1230
Well Depth - nd, Hole Depth - 115, Top Perforation - nd, Bottom Perforation - nd

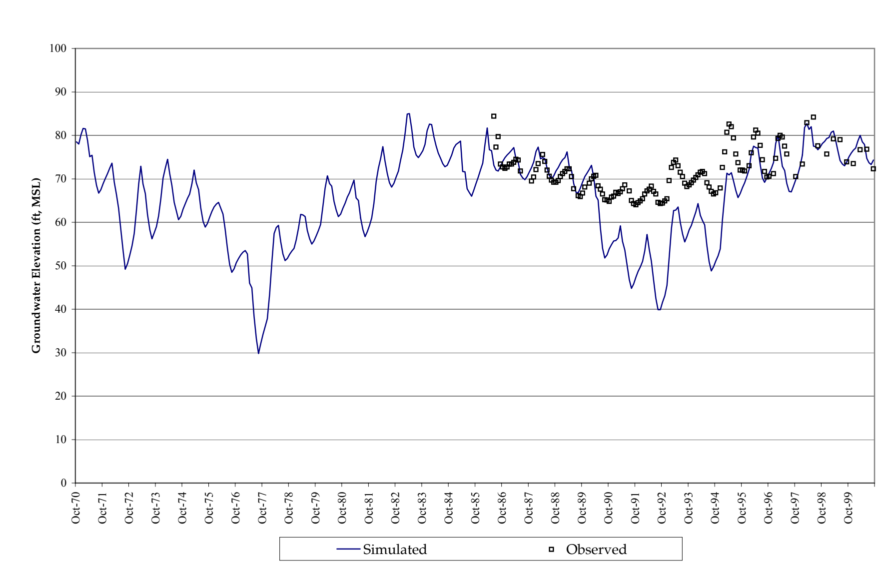
FIGURE A.28



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) | APRIL 2006

Calibration Well 28 (Teichert_TA-4), Subregion 7
GSE - 120 ft, Layer 1 Thickness - 40 ft, L2 T - 1390 ft, L3 T - 1010
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.29



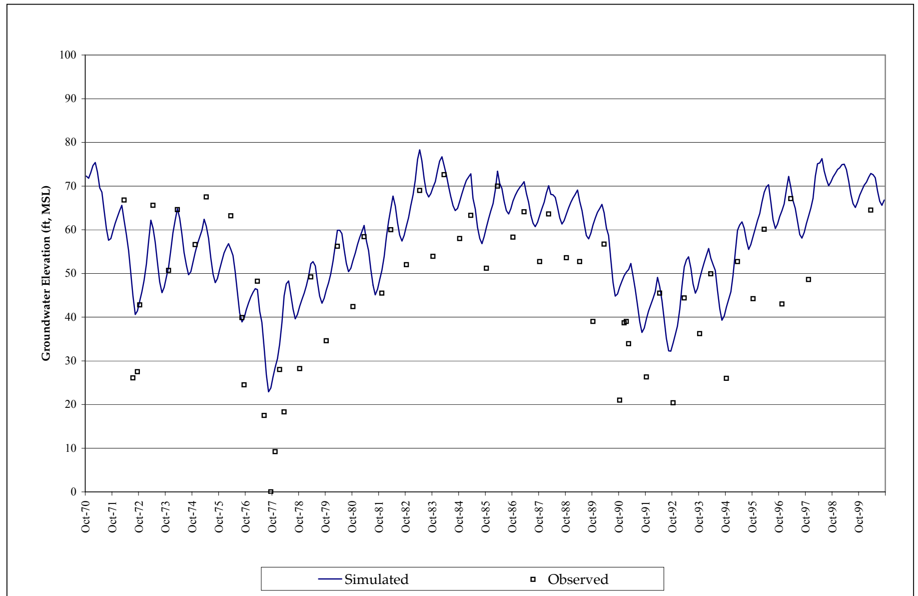
RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 29 (Teichert_YFC-West), Subregion 8
GSE - 120 ft, Layer 1 Thickness - 0 ft, L2 T - 1430 ft, L3 T - 1050
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.30



RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 30 (10N01E33L002M), Subregion 8
GSE - 120 ft, Layer 1 Thickness - 0 ft, L2 T - 1430 ft, L3 T - 1060
Well Depth - 395, Hole Depth - 416, Top Perforation - 323, Bottom Perforation - 395

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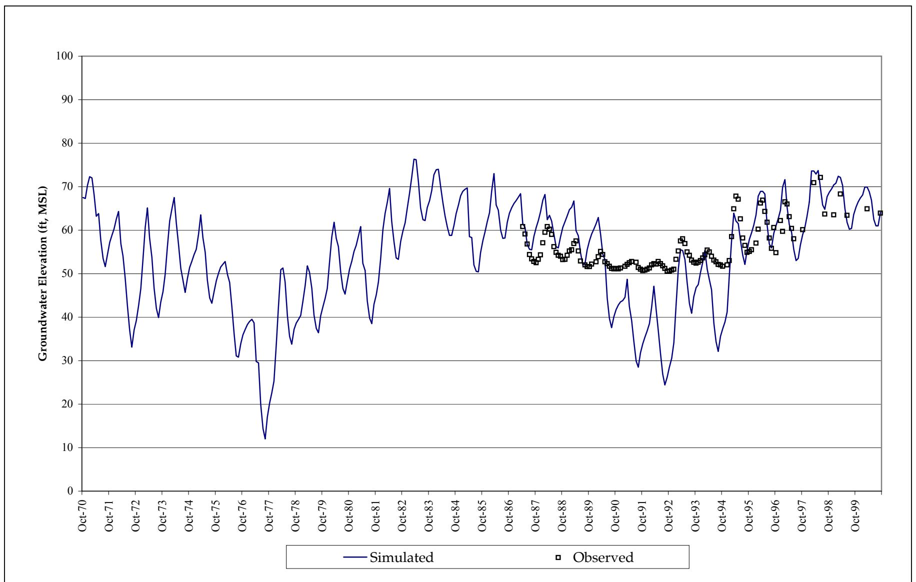
FIGURE A.31



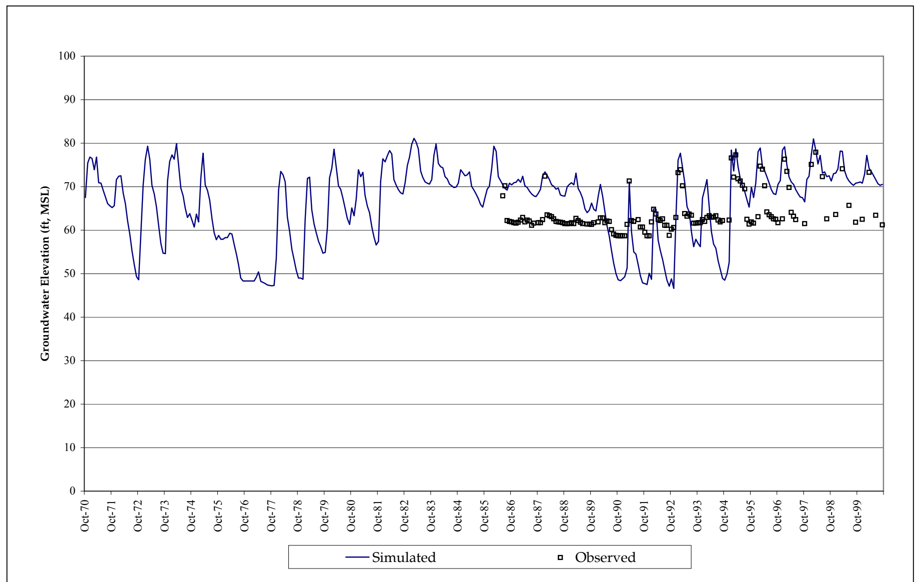
RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 31 (Teichert_TA-9R), Subregion 13
GSE - 110 ft, Layer 1 Thickness - 50 ft, L2 T - 1500 ft, L3 T - 950
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.32



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 32 (Teichert_TA-12), Subregion 9
GSE - 110 ft, Layer 1 Thickness - 50 ft, L2 T - 1520 ft, L3 T - 940
Well Depth - nd, Hole Depth - nd, Top Perforation - 15, Bottom Perforation - 35

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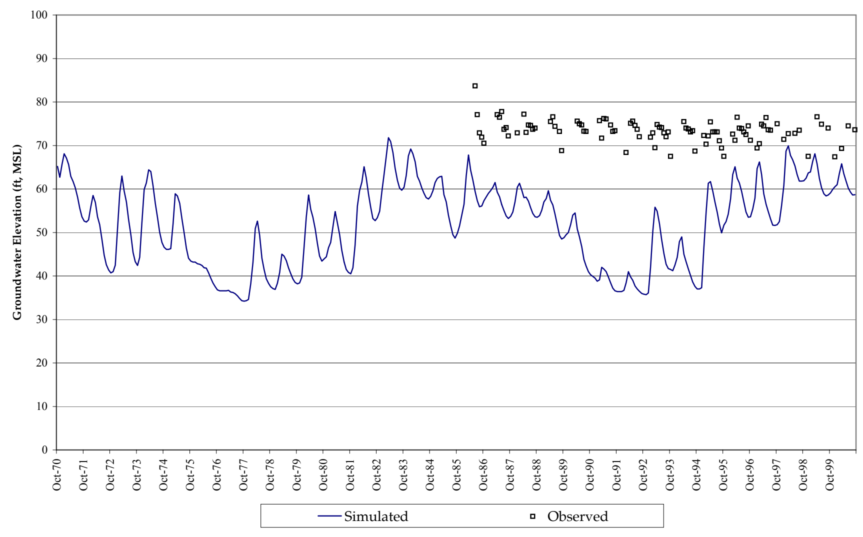
FIGURE A.33



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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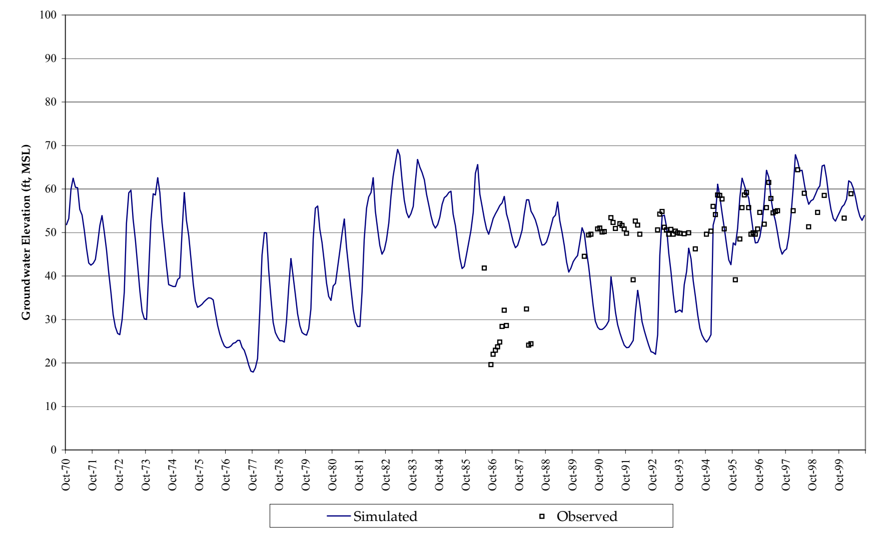
Calibration Well 33 (Teichert_TA-14), Subregion 9
GSE - 100 ft, Layer 1 Thickness - 80 ft, L2 T - 1520 ft, L3 T - 950
Well Depth - nd, Hole Depth - nd, Top Perforation - 20, Bottom Perforation - 35

FIGURE A.34

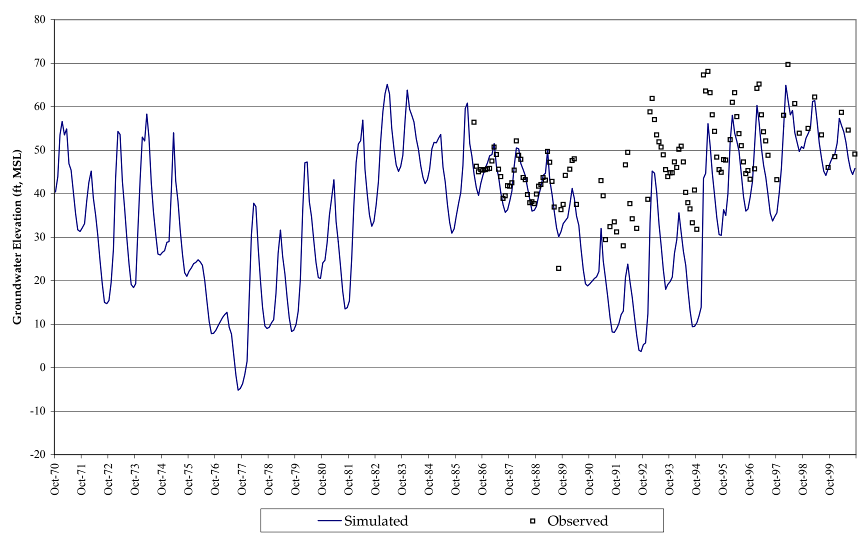


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 34 (Teichert_TA-17), Subregion 13
GSE - 100 ft, Layer 1 Thickness - 80 ft, L2 T - 1530 ft, L3 T - 1010
Well Depth - nd, Hole Depth - nd, Top Perforation - 20, Bottom Perforation - 50

FIGURE A.35



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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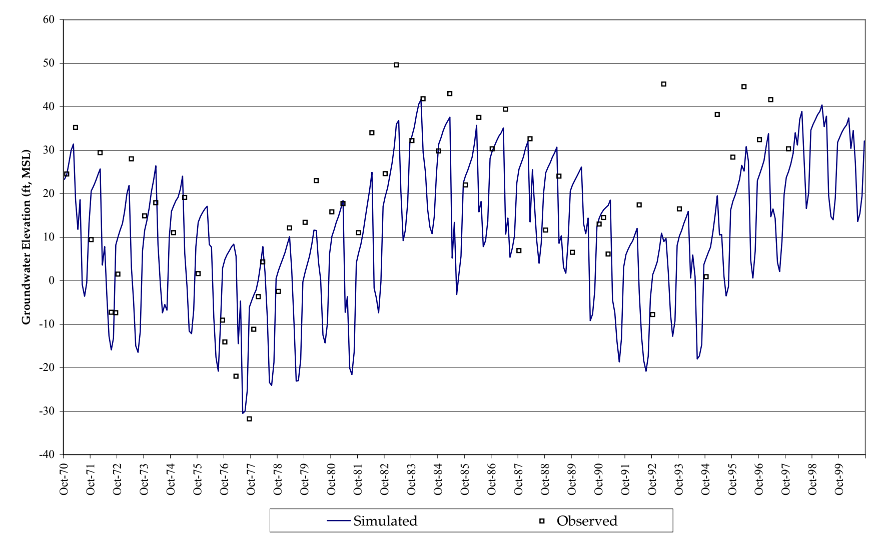
Calibration Well 35 (Teichert_TA-18), Subregion 13
GSE - 90 ft, Layer 1 Thickness - 200 ft, L2 T - 1410 ft, L3 T - 1100
Well Depth - nd, Hole Depth - nd, Top Perforation - 30, Bottom Perforation - 60

FIGURE A.36



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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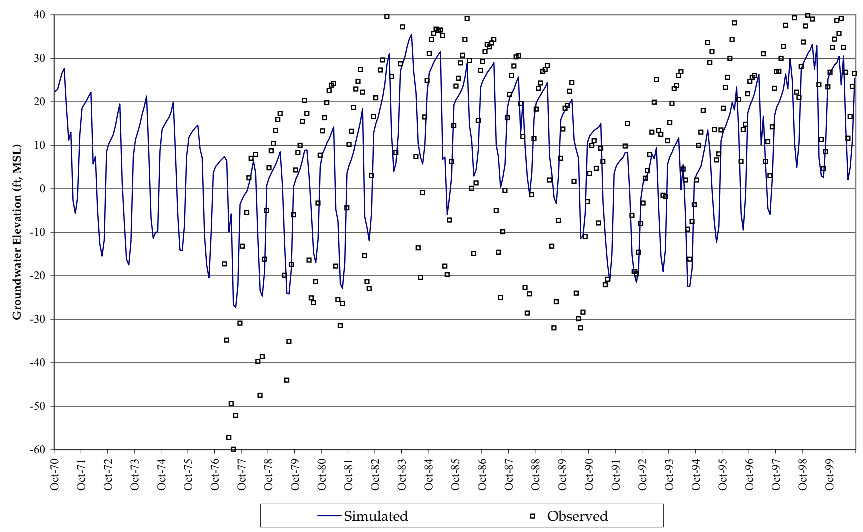
Calibration Well 36 (10N01E13L001M), Subregion 13
GSE - 80 ft, Layer 1 Thickness - 290 ft, L2 T - 1370 ft, L3 T - 1180
Well Depth - 290, Hole Depth - 334, Top Perforation - 242, Bottom Perforation - 290

FIGURE A.37



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 37 (10N01E12B004M), Subregion 11
GSE - 70 ft, Layer 1 Thickness - 220 ft, L2 T - 1470 ft, L3 T - 1150
Well Depth - 260, Hole Depth - nd, Top Perforation - 178, Bottom Perforation - 251

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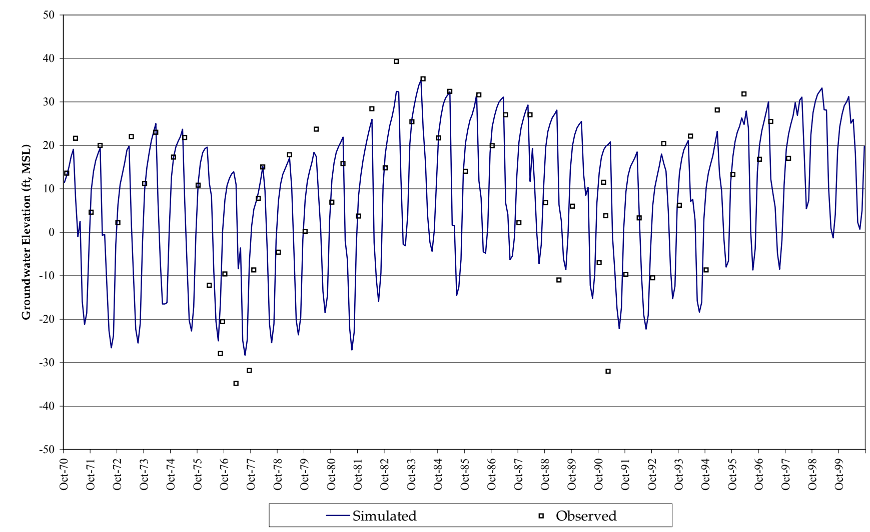
FIGURE A.38



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 38 (10N02E15N001M), Subregion 13
GSE - 50 ft, Layer 1 Thickness - 110 ft, L2 T - 1410 ft, L3 T - 1150
Well Depth - nd, Hole Depth - 280, Top Perforation - nd, Bottom Perforation - nd

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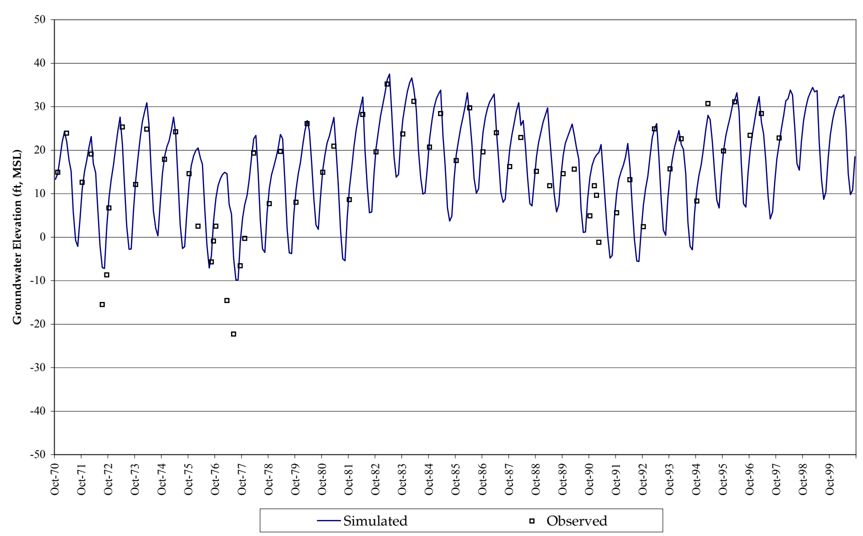
FIGURE A.39



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 39 (10N02E10R001M), Subregion 13
GSE - 40 ft, Layer 1 Thickness - 140 ft, L2 T - 1300 ft, L3 T - 1020
Well Depth - 350, Hole Depth - 350, Top Perforation - nd, Bottom Perforation - nd

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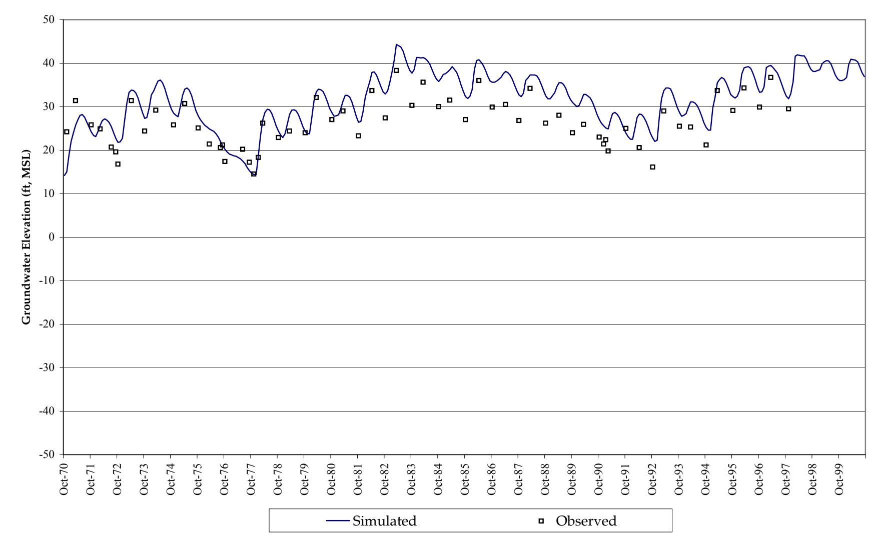
FIGURE A.40



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 40 (10N02E14E001M), Subregion 13
GSE - 40 ft, Layer 1 Thickness - 140 ft, L2 T - 1360 ft, L3 T - 1060
Well Depth - 123, Hole Depth - 123, Top Perforation - 115, Bottom Perforation - 123

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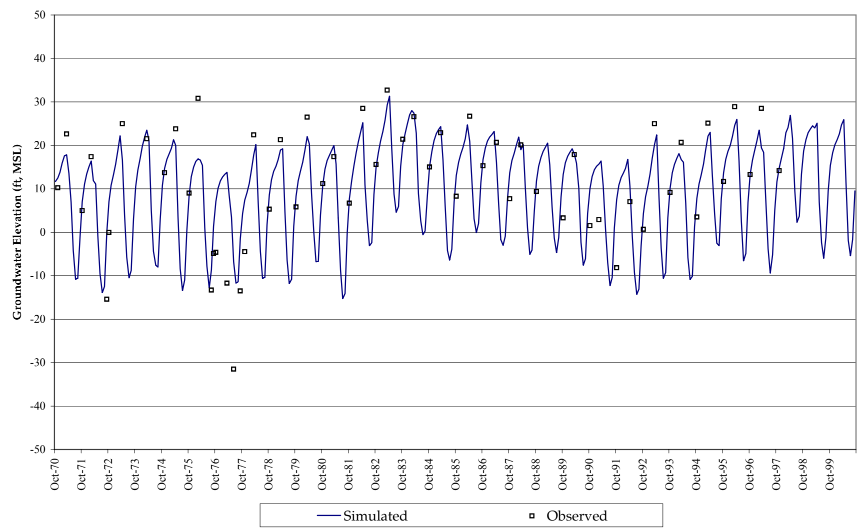
FIGURE A.41



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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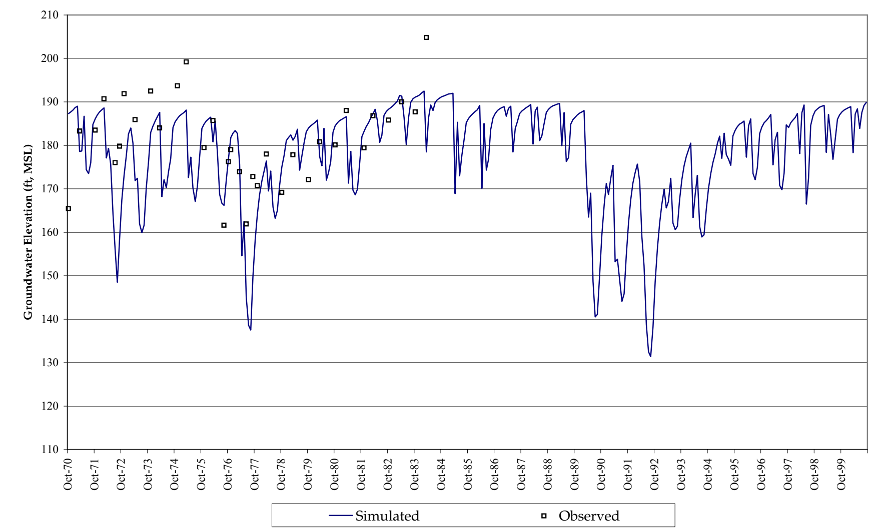
Calibration Well 41 (10N02E12R001M), Subregion 12
GSE - 30 ft, Layer 1 Thickness - 180 ft, L2 T - 1140 ft, L3 T - 890
Well Depth - 352, Hole Depth - 365, Top Perforation - 268, Bottom Perforation - 352

FIGURE A.42



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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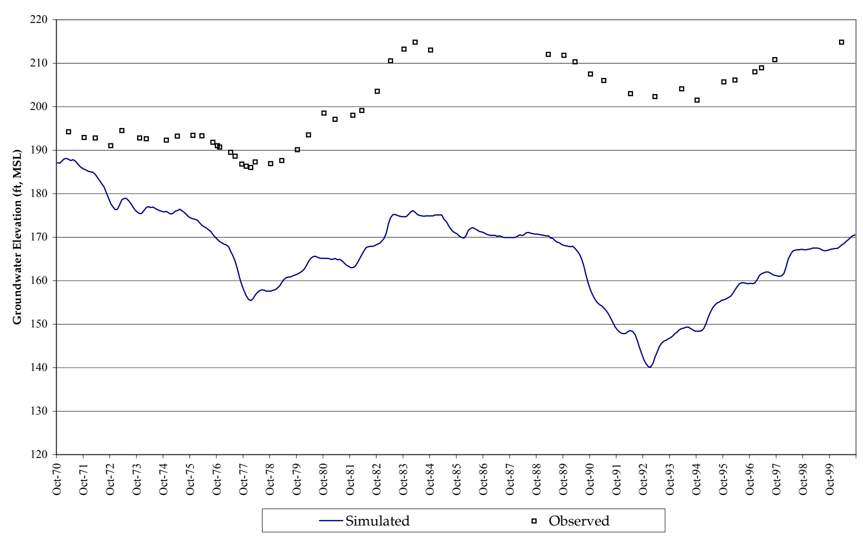
Calibration Well 42 (11N02W35E001M), Subregion 7
GSE - 320 ft, Layer 1 Thickness - 80 ft, L2 T - 140 ft, L3 T - 110
Well Depth - 312, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.43

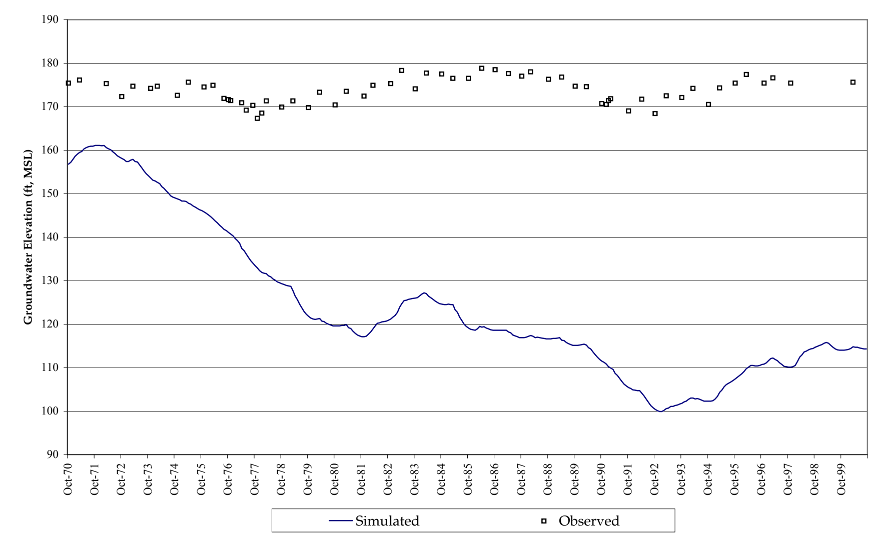


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 43 (11N01W19N001M), Subregion 7
GSE - 240 ft, Layer 1 Thickness - 160 ft, L2 T - 540 ft, L3 T - 430
Well Depth - 390, Hole Depth - nd, Top Perforation - 89, Bottom Perforation - 102

FIGURE A.44

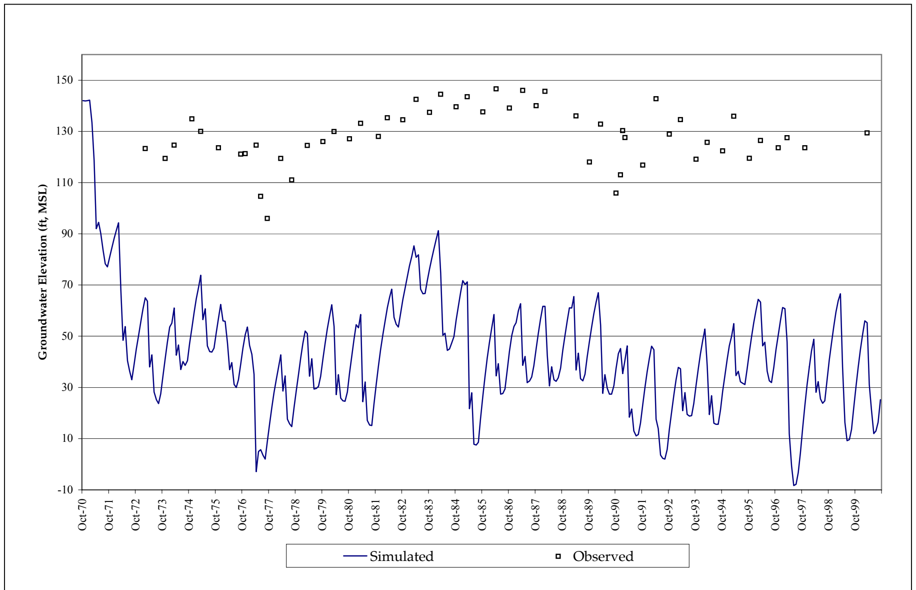


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 44 (11N01W34P001M), Subregion 9
GSE - 200 ft, Layer 1 Thickness - 0 ft, L2 T - 1150 ft, L3 T - 900
Well Depth - 193, Hole Depth - 192, Top Perforation - 150, Bottom Perforation - 193

FIGURE A.45

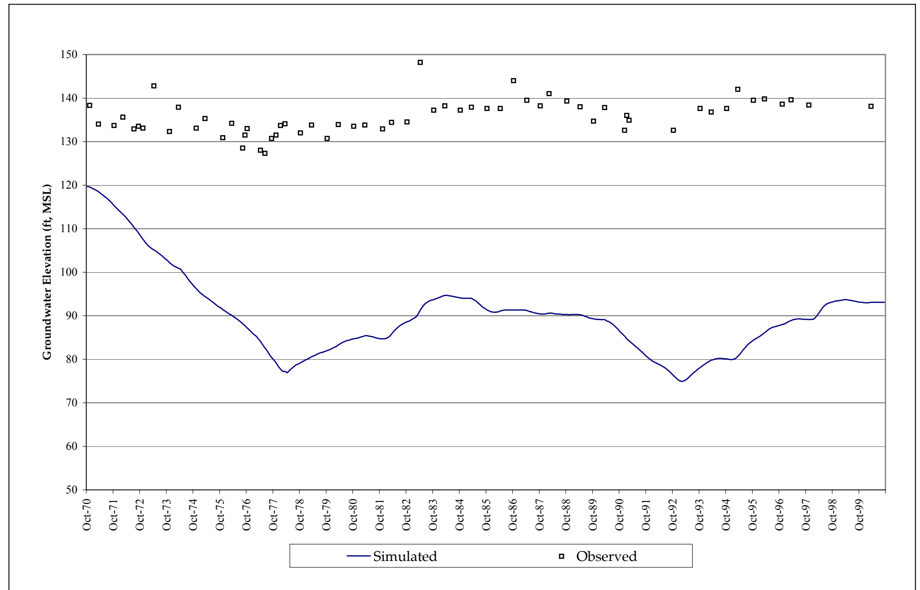


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 45 (10N01W02Q001M), Subregion 9
GSE - 210 ft, Layer 1 Thickness - 0 ft, L2 T - 1130 ft, L3 T - 890
Well Depth - 270, Hole Depth - 350, Top Perforation - 250, Bottom Perforation - 270

APRIL 2006

FIGURE A.46

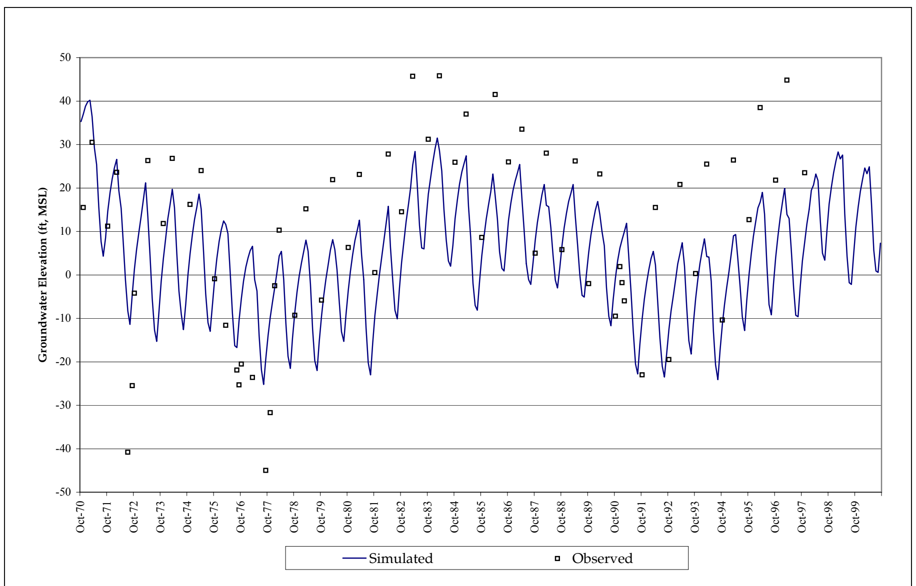


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 46 (10N01E18C001M), Subregion 9
GSE - 170 ft, Layer 1 Thickness - 0 ft, L2 T - 1210 ft, L3 T - 950
Well Depth - nd, Hole Depth - 110, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.47

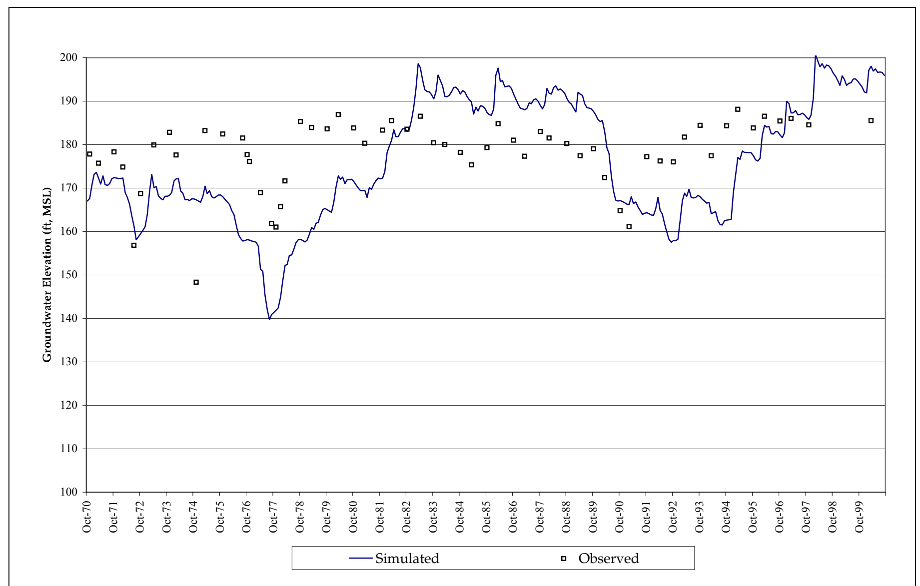


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 47 (10N01E10G001M), Subregion 11
GSE - 80 ft, Layer 1 Thickness - 70 ft, L2 T - 1480 ft, L3 T - 1170
Well Depth - nd, Hole Depth - 212, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.48

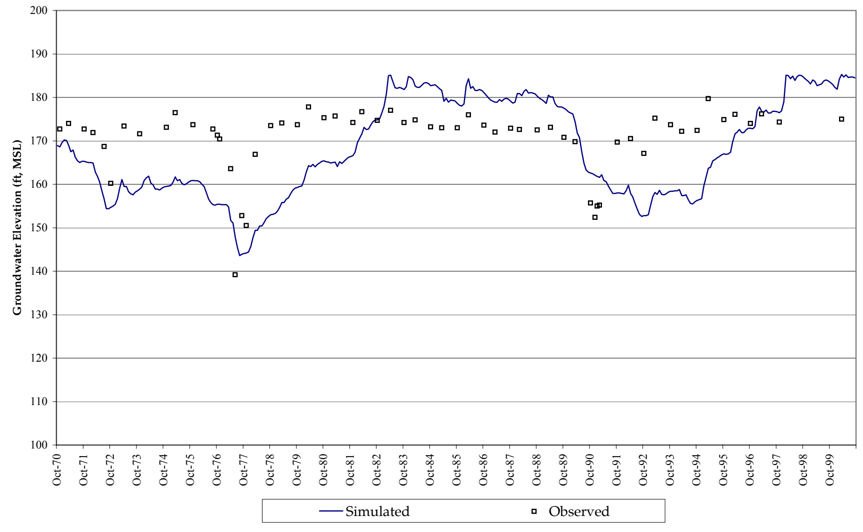


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 48 (09N01W08Q001M), Subregion 8
GSE - 190 ft, Layer 1 Thickness - 100 ft, L2 T - 960 ft, L3 T - 1280
Well Depth - nd, Hole Depth - 425, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.49

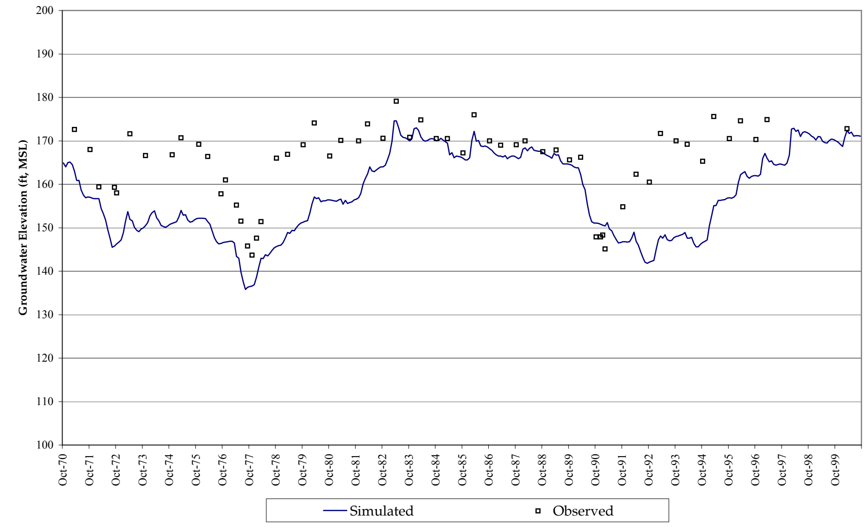


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 49 (09N01W05B001M), Subregion 8
GSE - 190 ft, Layer 1 Thickness - 40 ft, L2 T - 1050 ft, L3 T - 890
Well Depth - nd, Hole Depth - 305, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.50

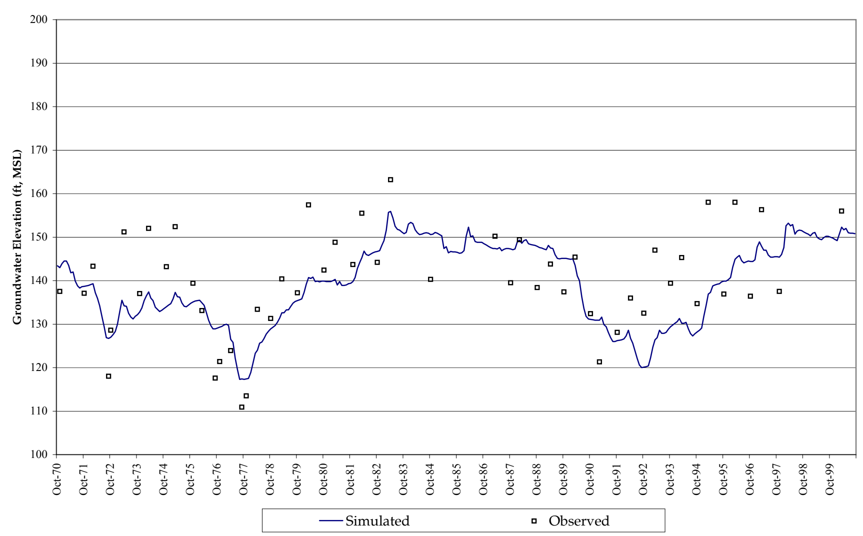


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 50 (10N01W32E001M), Subregion 8
GSE - 190 ft, Layer 1 Thickness - 40 ft, L2 T - 1060 ft, L3 T - 720
Well Depth - 188, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.51

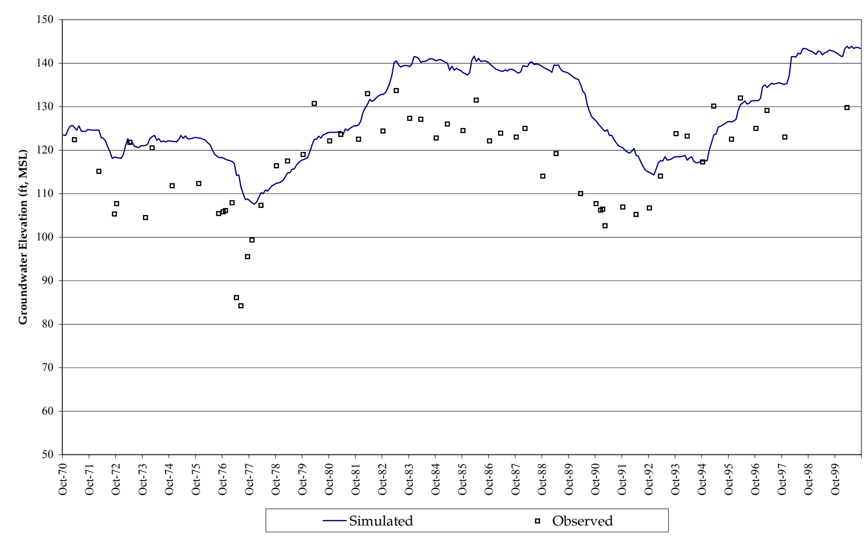


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 51 (10N01W33F001M), Subregion 8
GSE - 160 ft, Layer 1 Thickness - 70 ft, L2 T - 1150 ft, L3 T - 1170
Well Depth - 344, Hole Depth - 372, Top Perforation - 125, Bottom Perforation - 344

FIGURE A.52

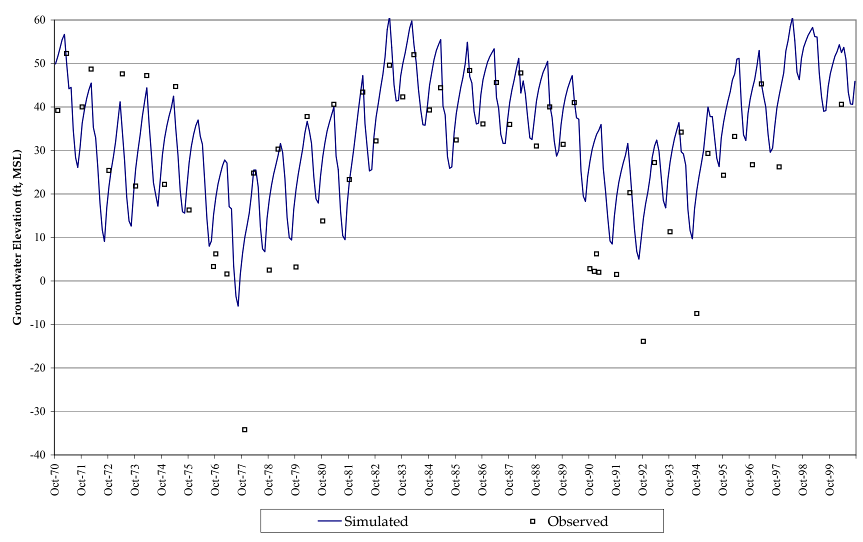


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 52 (09N01W02Q002M), Subregion 8
GSE - 140 ft, Layer 1 Thickness - 80 ft, L2 T - 1080 ft, L3 T - 1020
Well Depth - 128, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.53



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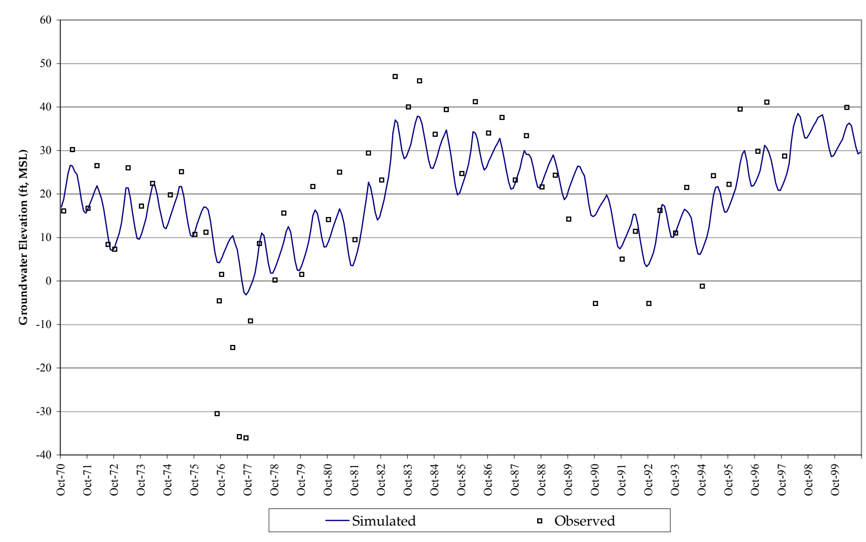
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 53 (09N01E03C003M), Subregion 13
GSE - 100 ft, Layer 1 Thickness - 50 ft, L2 T - 1400 ft, L3 T - 1140
Well Depth - nd, Hole Depth - 567, Top Perforation - 440, Bottom Perforation - 524

APRIL 2006

FIGURE A.54



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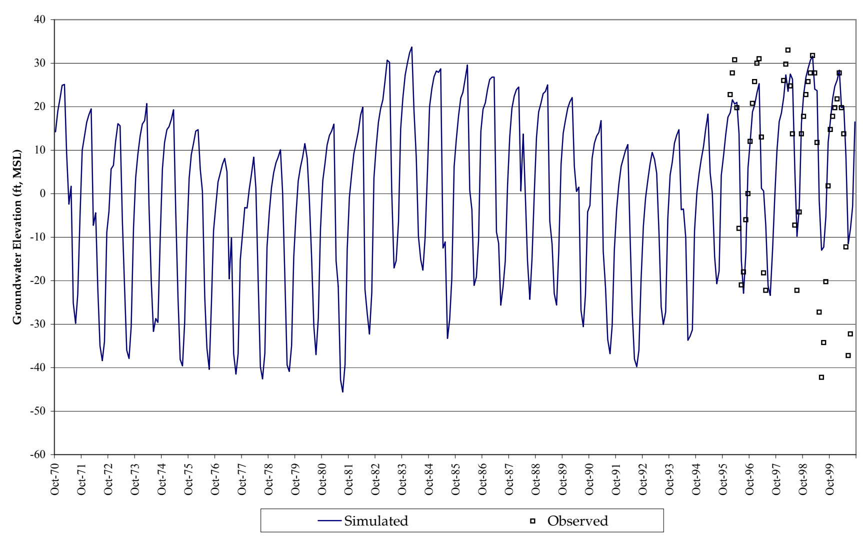
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 54 (10N01E36Q002M), Subregion 13
GSE - 80 ft, Layer 1 Thickness - 200 ft, L2 T - 1350 ft, L3 T - 1370
Well Depth - nd, Hole Depth - 199, Top Perforation - 121, Bottom Perforation - 194

APRIL 2006

FIGURE A.55



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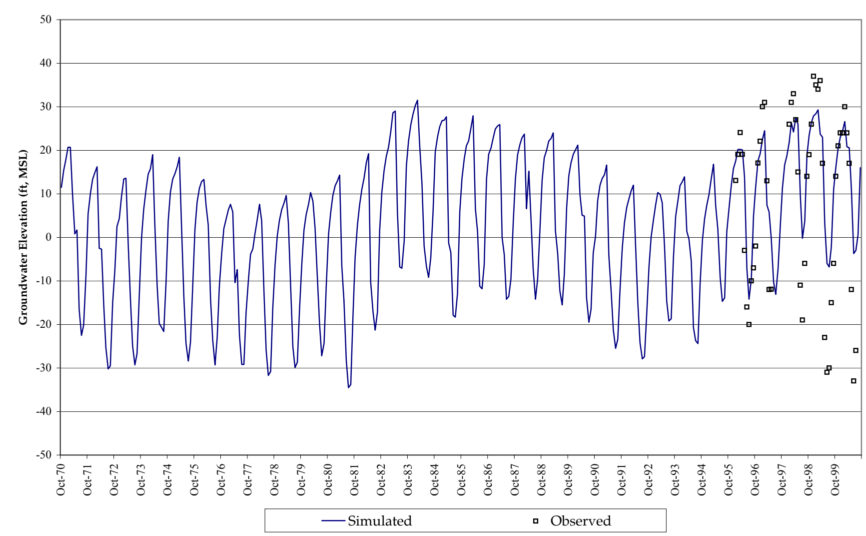
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 55 (Woodland Well 10), Subregion
GSE - 70 ft, Layer 1 Thickness - 200 ft, L2 T - 1380 ft, L3 T - 1280.5
Well Depth - nd, Hole Depth - nd, Top Perforation - 449, Bottom Perforation - 496

APRIL 2006

FIGURE A.56



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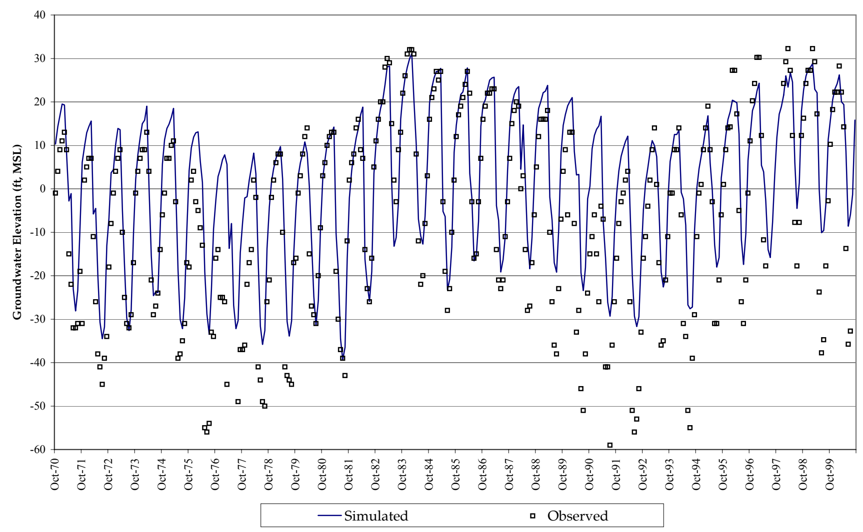
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 56 (Woodland Well 5), Subregion
GSE - 70 ft, Layer 1 Thickness - 80 ft, L2 T - 1450 ft, L3 T - 1333.75
Well Depth - nd, Hole Depth - nd, Top Perforation - 168, Bottom Perforation - 448

APRIL 2006

FIGURE A.57

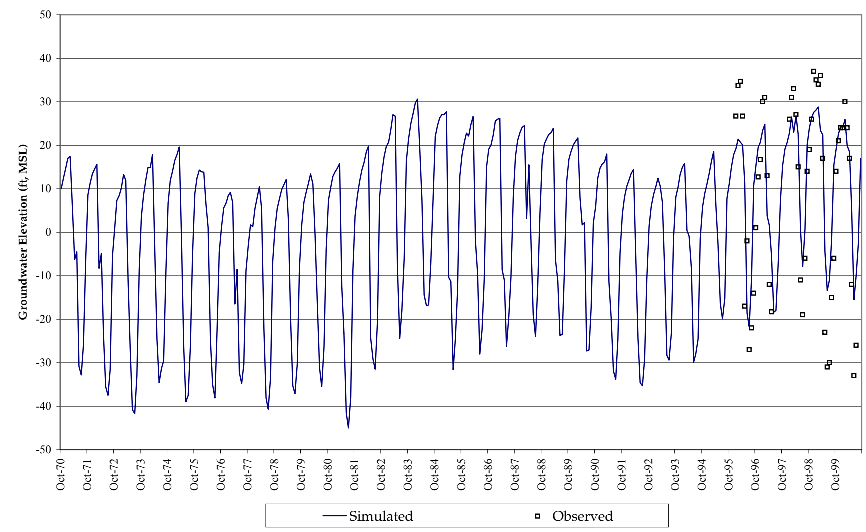


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 57 (Woodland Well 1), Subregion
GSE - 60 ft, Layer 1 Thickness - 110 ft, L2 T - 1440 ft, L3 T - 1277
Well Depth - nd, Hole Depth - nd, Top Perforation - 420, Bottom Perforation - 477

APRIL 2006

FIGURE A.58



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 58 (Woodland Well 12), Subregion
GSE - 50 ft, Layer 1 Thickness - 90 ft, L2 T - 1440 ft, L3 T - 1183.75
Well Depth - nd, Hole Depth - nd, Top Perforation - 406, Bottom Perforation - 424

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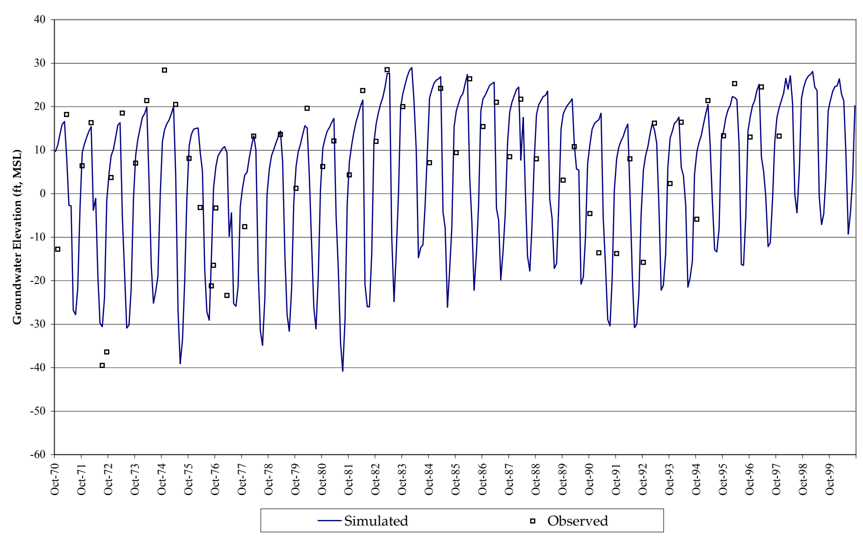
FIGURE A.59

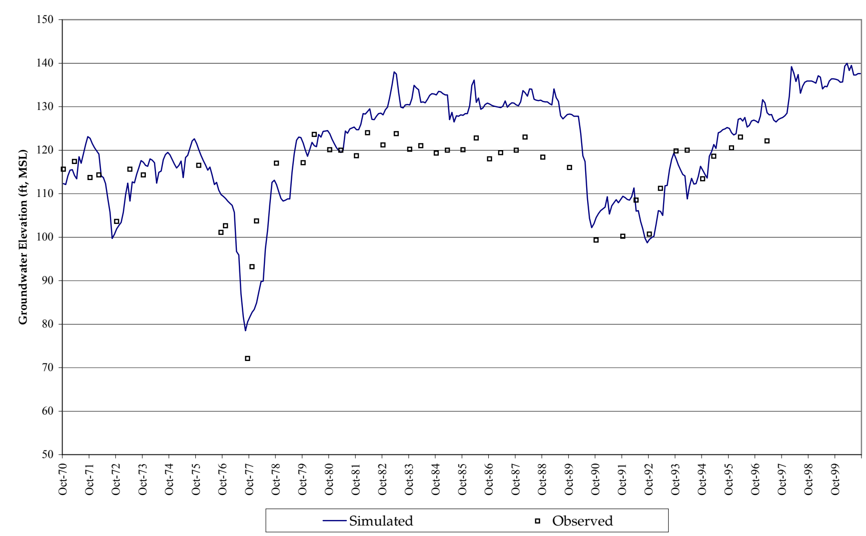


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 59 (10N02E26Q001M), Subregion 14
GSE - 40 ft, Layer 1 Thickness - 120 ft, L2 T - 1380 ft, L3 T - 1120
Well Depth - 385, Hole Depth - nd, Top Perforation - 100, Bottom Perforation - 385

APRIL 2006

FIGURE A.60



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 60 (09N01W24G001M), Subregion 8
GSE - 120 ft, Layer 1 Thickness - 50 ft, L2 T - 1160 ft, L3 T - 980
Well Depth - 615, Hole Depth - 615, Top Perforation - 500, Bottom Perforation - 615

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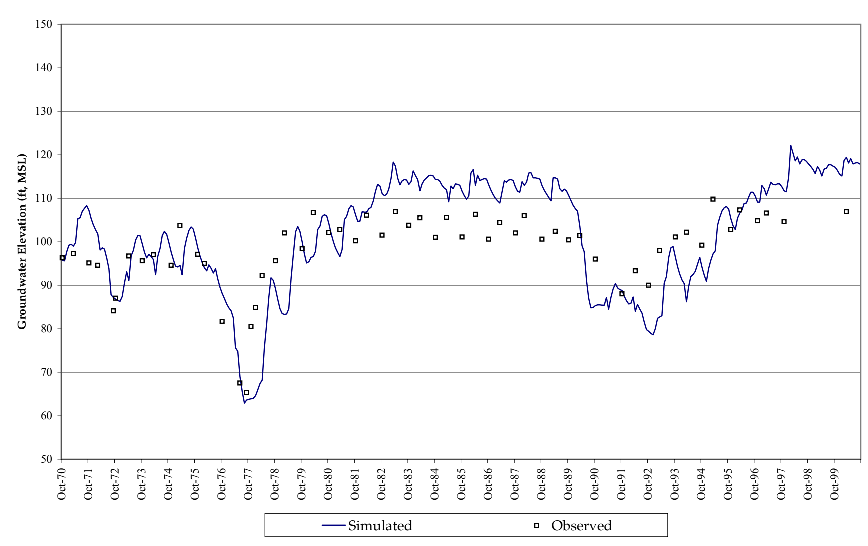
FIGURE A.61



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 61 (09N01E20E001M), Subregion 8
GSE - 110 ft, Layer 1 Thickness - 50 ft, L2 T - 1260 ft, L3 T - 1110
Well Depth - 401, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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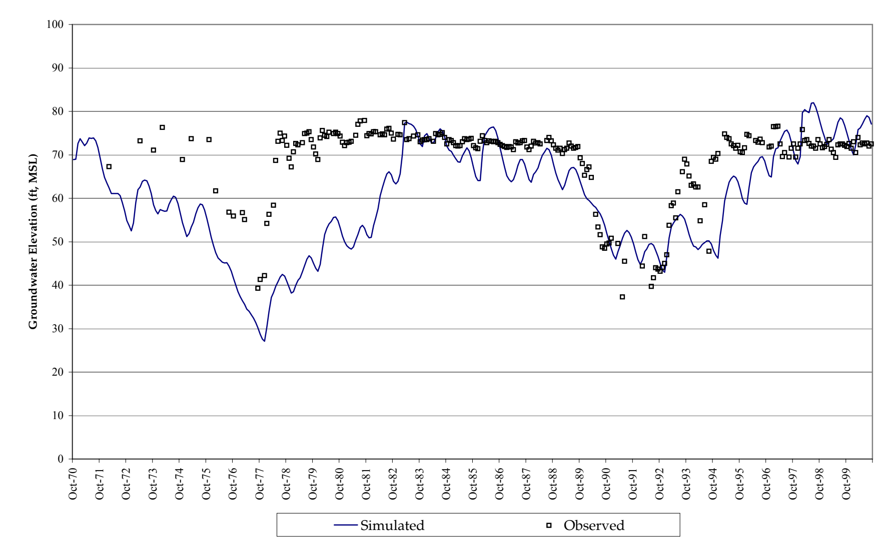
FIGURE A.62



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 62 (09N01E22B001M), Subregion 8
GSE - 90 ft, Layer 1 Thickness - 80 ft, L2 T - 1350 ft, L3 T - 1230
Well Depth - 180, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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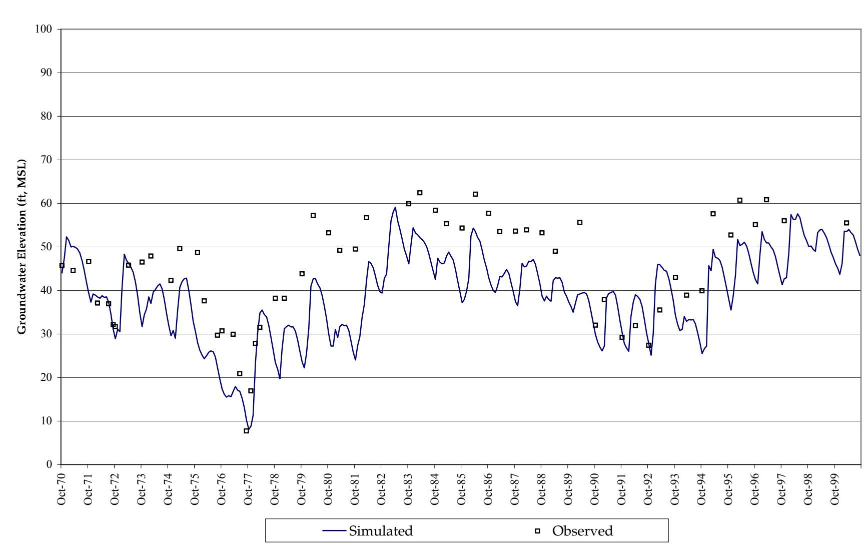
FIGURE A.63



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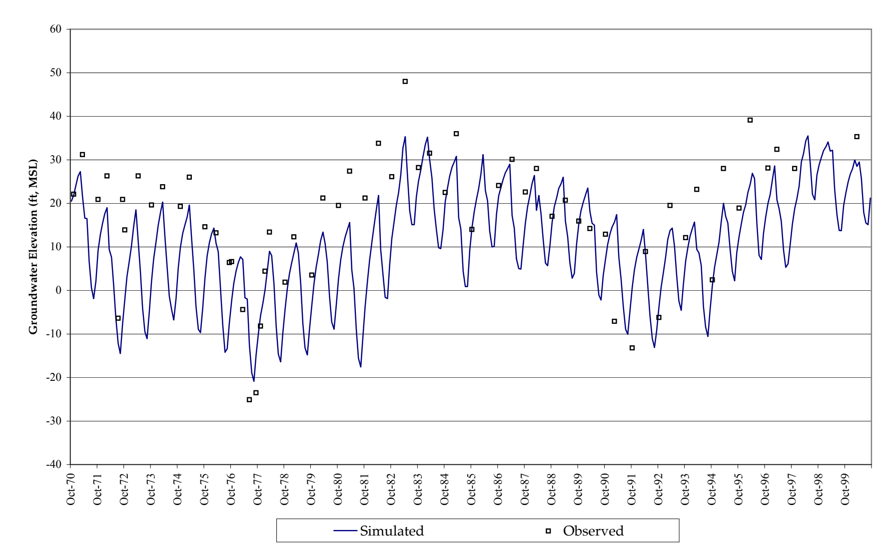
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 63 (09N01E24D001M), Subregion 13
GSE - 70 ft, Layer 1 Thickness - 80 ft, L2 T - 1440 ft, L3 T - 1310
Well Depth - 300, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.64



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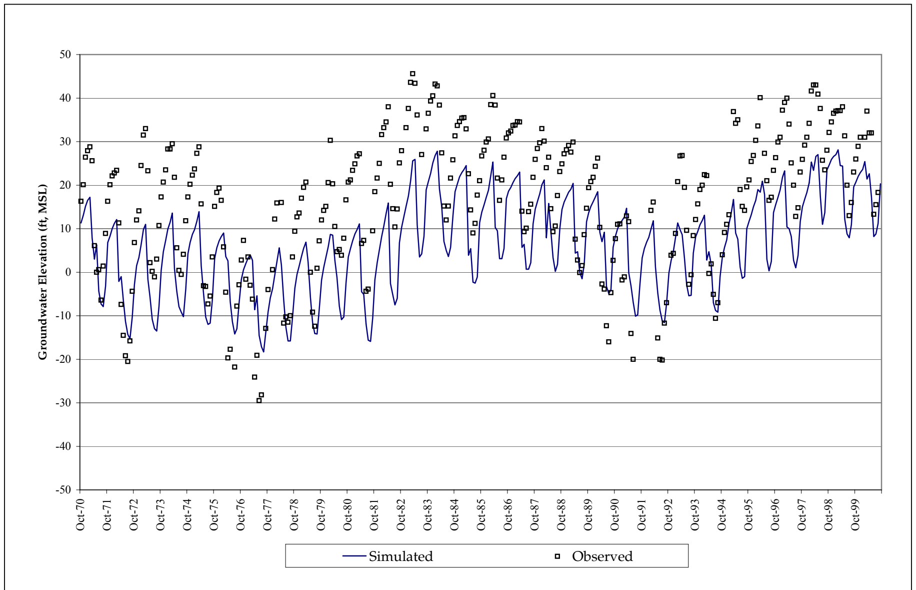
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 64 (09N02E07L001M), Subregion 13
GSE - 70 ft, Layer 1 Thickness - 70 ft, L2 T - 1420 ft, L3 T - 1420
Well Depth - 425, Hole Depth - 425, Top Perforation - 249, Bottom Perforation - 419

APRIL 2006

FIGURE A.65



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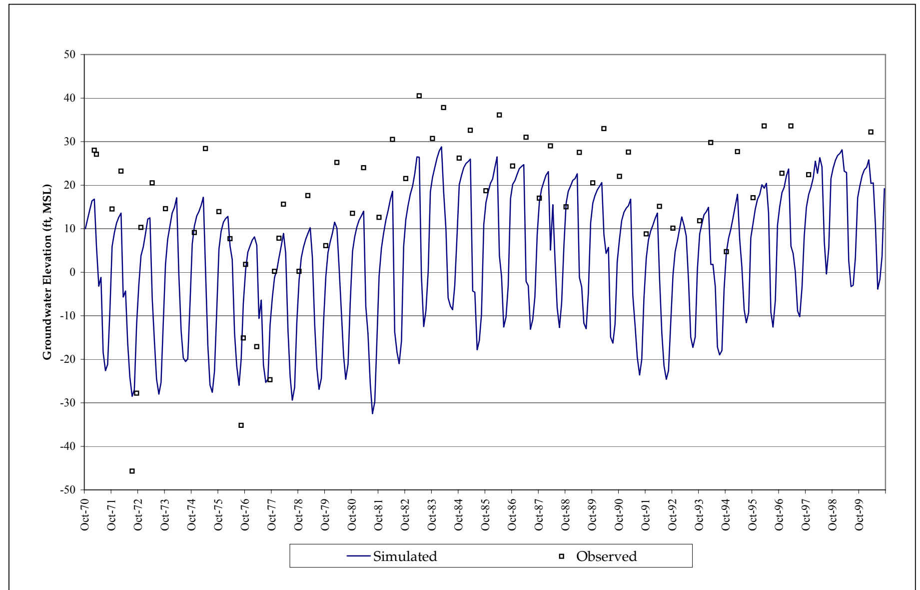
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 65 (09N02E16N001M), Subregion 13
GSE - 50 ft, Layer 1 Thickness - 80 ft, L2 T - 1490 ft, L3 T - 1330
Well Depth - 176, Hole Depth - nd, Top Perforation - 156, Bottom Perforation - 176

APRIL 2006

FIGURE A.66



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 66 (09N02E10E001M), Subregion 14
GSE - 50 ft, Layer 1 Thickness - 90 ft, L2 T - 1390 ft, L3 T - 1350
Well Depth - 254, Hole Depth - 254, Top Perforation - 204, Bottom Perforation - 254

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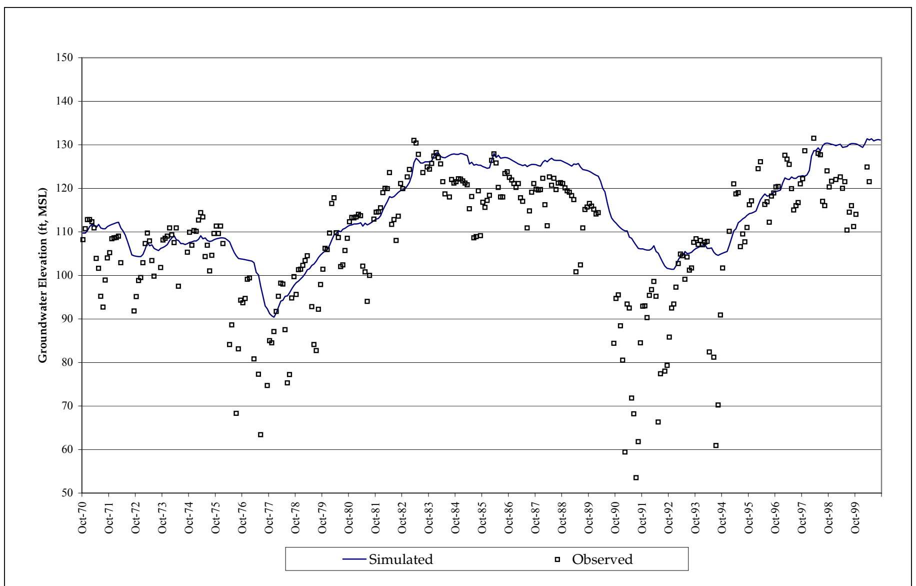
FIGURE A.67



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 67 (09N01W35M001M), Subregion 8
GSE - 150 ft, Layer 1 Thickness - 60 ft, L2 T - 1230 ft, L3 T - 1520
Well Depth - 295, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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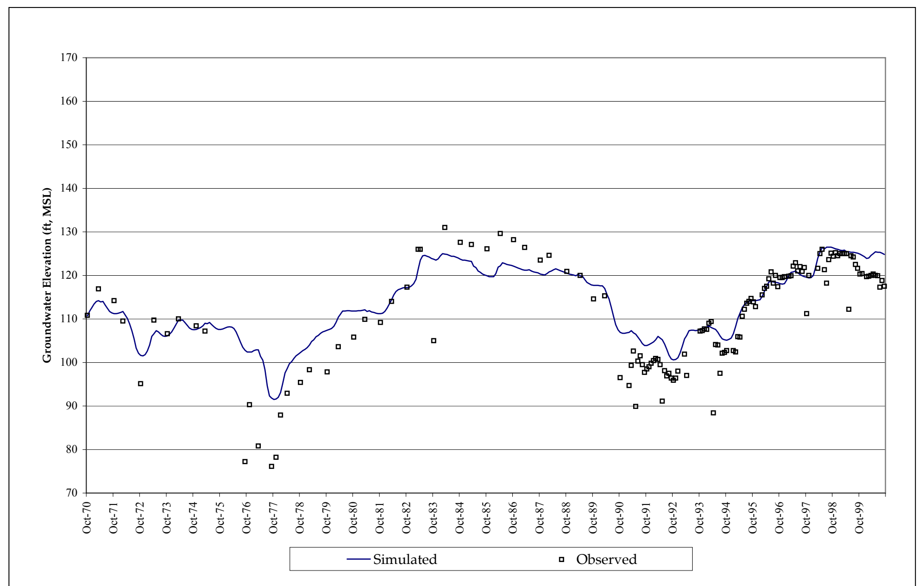
FIGURE A.68



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 68 (08N01W09C001M), Subregion 8
GSE - 160 ft, Layer 1 Thickness - 70 ft, L2 T - 1340 ft, L3 T - 790
Well Depth - 386, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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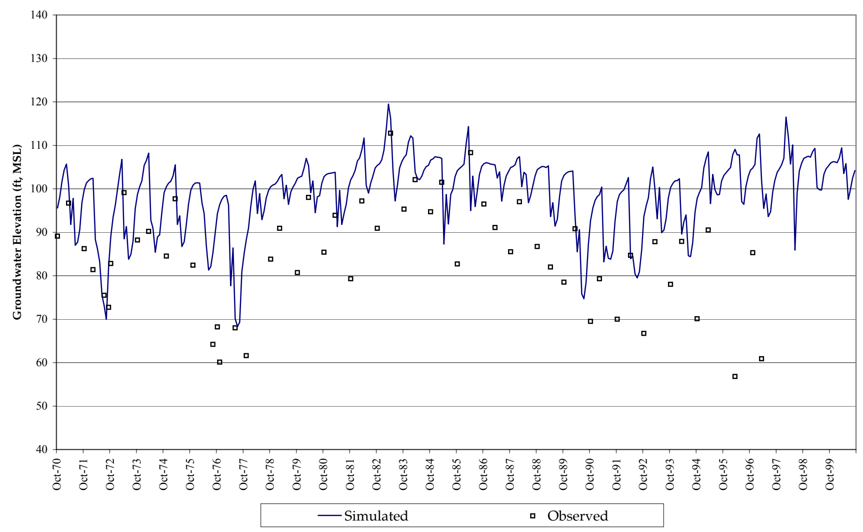
FIGUREA.69

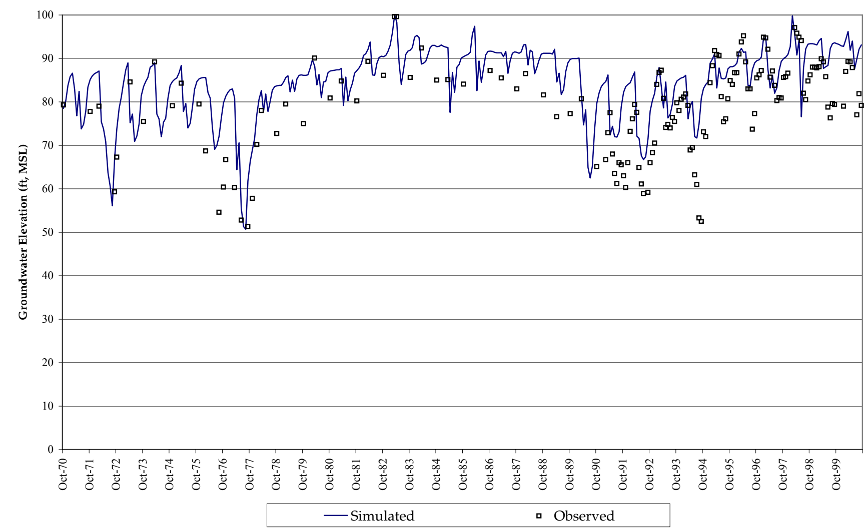


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 69 (08N01W20R005M), Subregion 8
GSE - 150 ft, Layer 1 Thickness - 30 ft, L2 T - 1060 ft, L3 T - 830
Well Depth - 300, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.70



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 70 (08N01W13G003M), Subregion 8
GSE - 110 ft, Layer 1 Thickness - 90 ft, L2 T - 1280 ft, L3 T - 1560
Well Depth - 127, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

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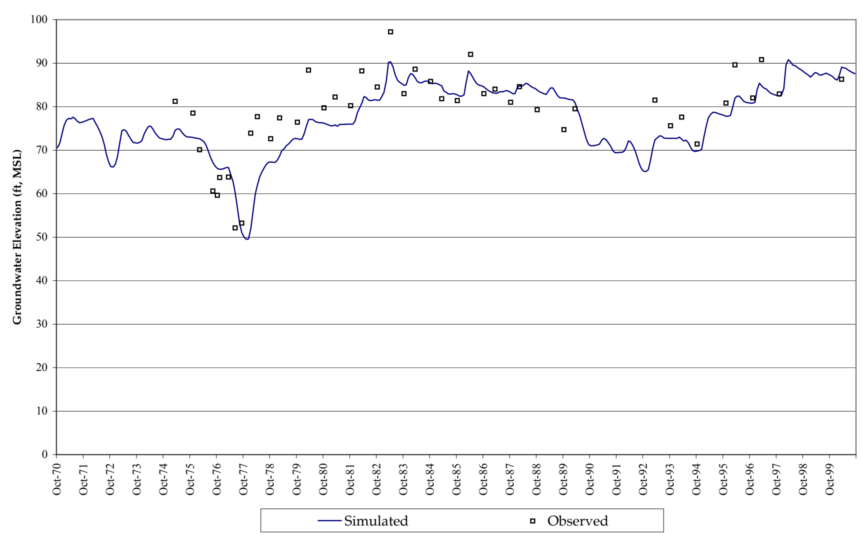
FIGURE A.71

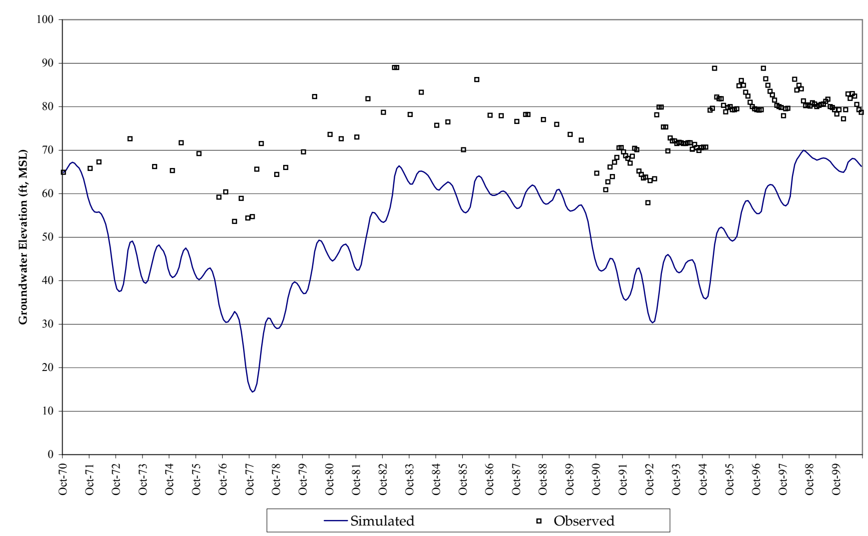


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 71 (08N01E07R001M), Subregion 8
GSE - 110 ft, Layer 1 Thickness - 70 ft, L2 T - 1280 ft, L3 T - 1540
Well Depth - 143, Hole Depth - 268, Top Perforation - 119, Bottom Perforation - 143

APRIL 2006

FIGURE A.72

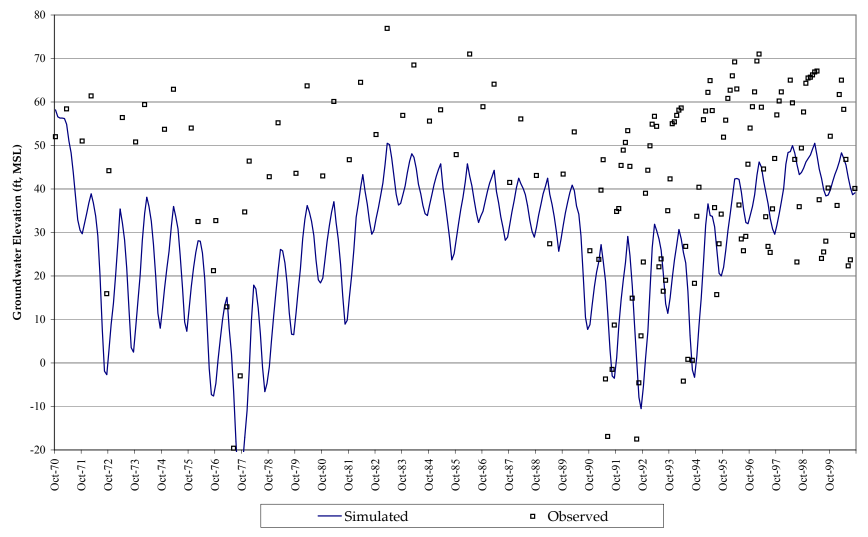


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 72 (08N01E04Q002M), Subregion 8
GSE - 100 ft, Layer 1 Thickness - 30 ft, L2 T - 1410 ft, L3 T - 1380
Well Depth - nd, Hole Depth - 159, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.73



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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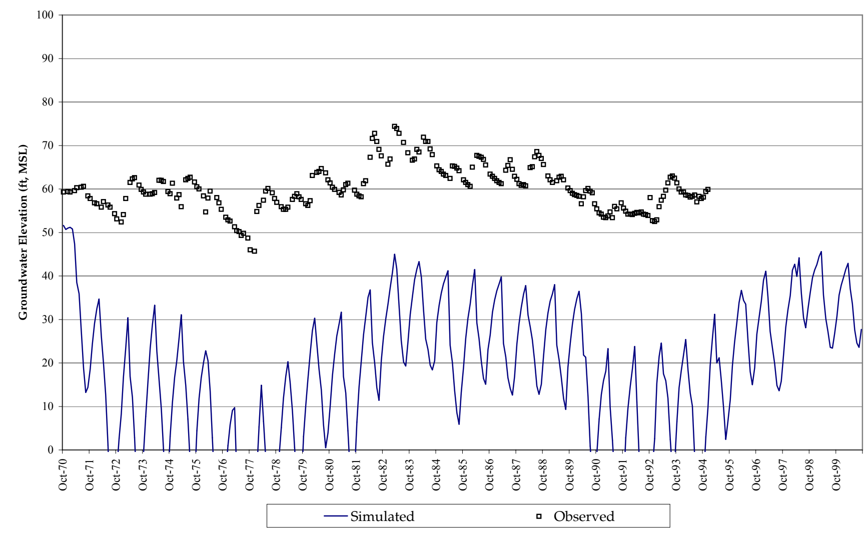
Calibration Well 73 (08N01E10M001M), Subregion 8
GSE - 90 ft, Layer 1 Thickness - 60 ft, L2 T - 1380 ft, L3 T - 1410
Well Depth - 490, Hole Depth - 490, Top Perforation - 110, Bottom Perforation - 490

FIGURE A.74

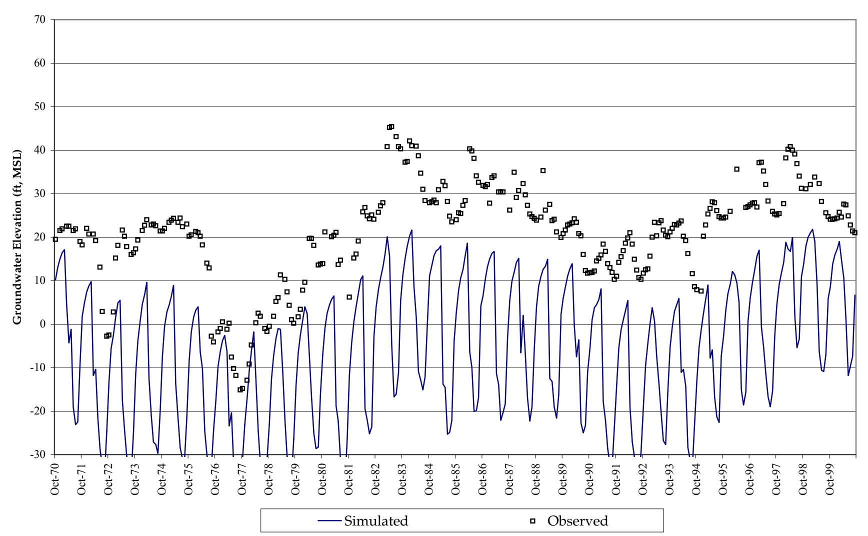


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 74 (08N01E15B001M), Subregion 8
GSE - 90 ft, Layer 1 Thickness - 60 ft, L2 T - 1390 ft, L3 T - 1390
Well Depth - 116, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.75

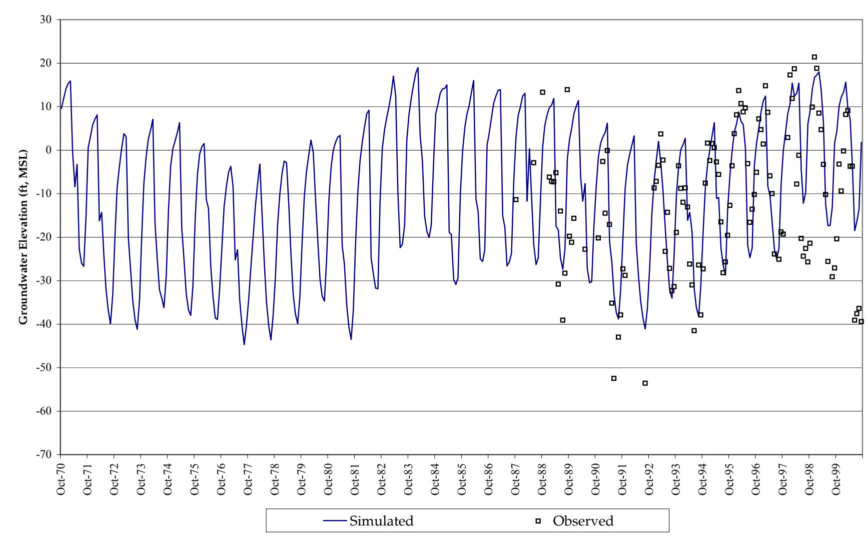


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 75 (08N02E19B001M), Subregion 22
GSE - 60 ft, Layer 1 Thickness - 100 ft, L2 T - 1500 ft, L3 T - 1280
Well Depth - 174, Hole Depth - nd, Top Perforation - 94, Bottom Perforation - 174

FIGURE A.76

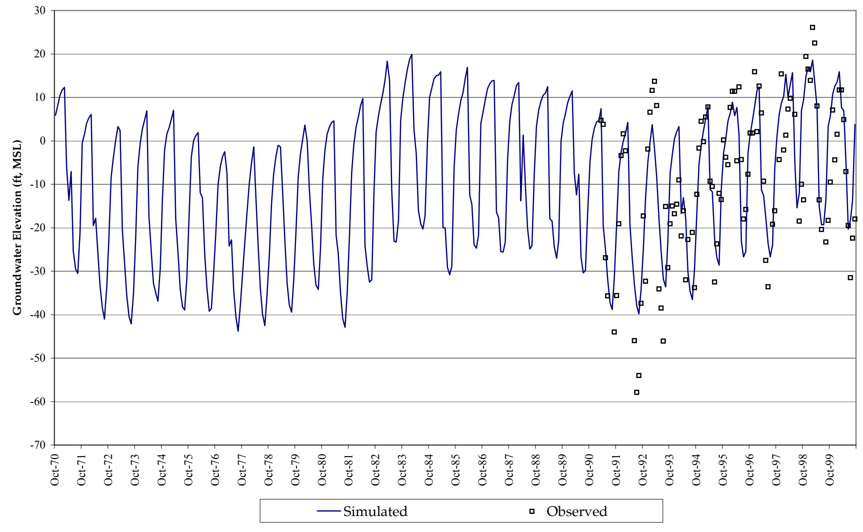


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 76 (DAVIS_WELL25), Subregion 15
GSE - 60 ft, Layer 1 Thickness - 80 ft, L2 T - 1640 ft, L3 T - 1160
Well Depth - 466, Hole Depth - 486, Top Perforation - 233, Bottom Perforation - 446

FIGURE A.77

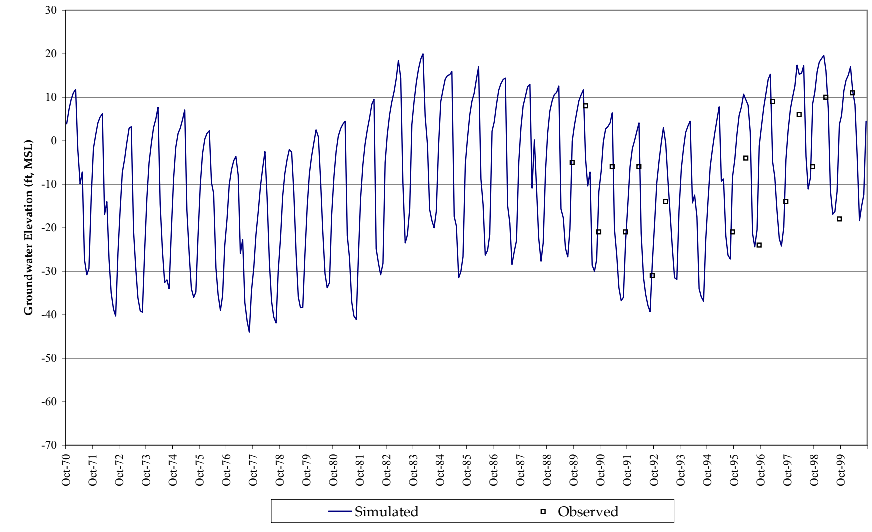


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 77 (DAVIS_WELL27), Subregion 15
GSE - 50 ft, Layer 1 Thickness - 70 ft, L2 T - 1720 ft, L3 T - 1100
Well Depth - 364, Hole Depth - 368, Top Perforation - 296, Bottom Perforation - 354

APRIL 2006

FIGURE A.78

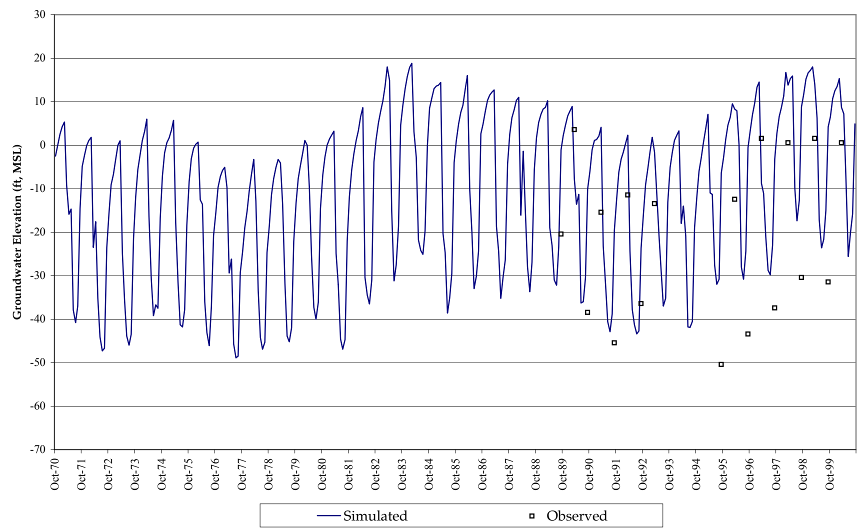


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 78 (UCD - DW6A), Subregion 15
GSE - 60 ft, Layer 1 Thickness - 110 ft, L2 T - 1540 ft, L3 T - 1250
Well Depth - 1470, Hole Depth - nd, Top Perforation - 1218, Bottom Perforation - 1450

APRIL 2006

FIGURE A.79

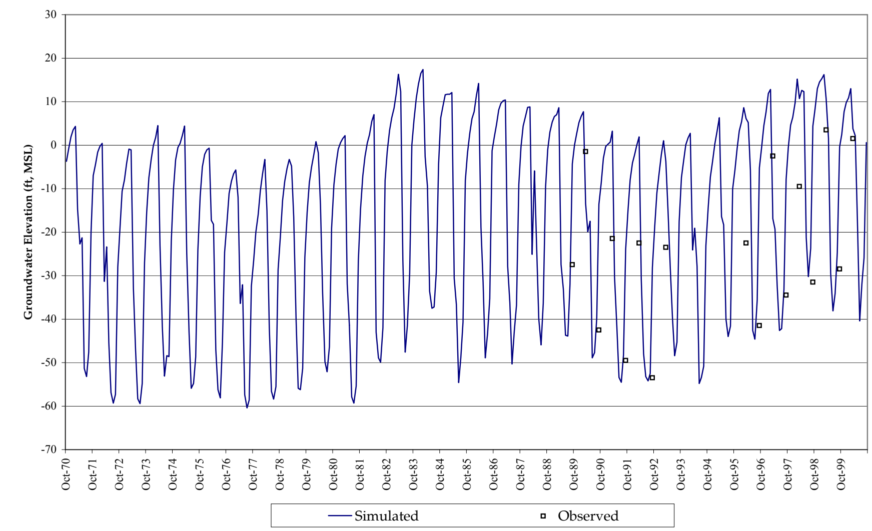


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 79 (UCD - DW4), Subregion 15
GSE - 50 ft, Layer 1 Thickness - 100 ft, L2 T - 1540 ft, L3 T - 1260
Well Depth - 1430, Hole Depth - nd, Top Perforation - 1120, Bottom Perforation - 1400

APRIL 2006

FIGURE A.80

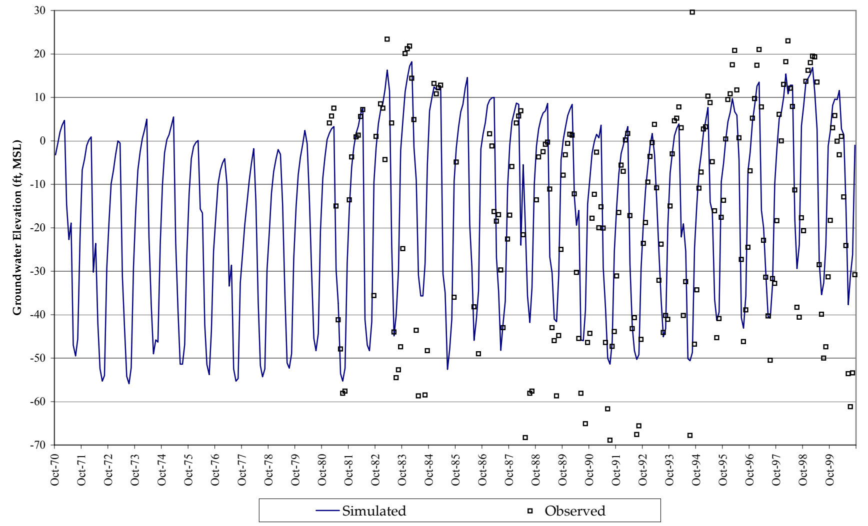


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 80 (UCD - DW2), Subregion 15
GSE - 50 ft, Layer 1 Thickness - 120 ft, L2 T - 1580 ft, L3 T - 1220
Well Depth - 1368, Hole Depth - nd, Top Perforation - 1180, Bottom Perforation - 1350

APRIL 2006

FIGURE A.81

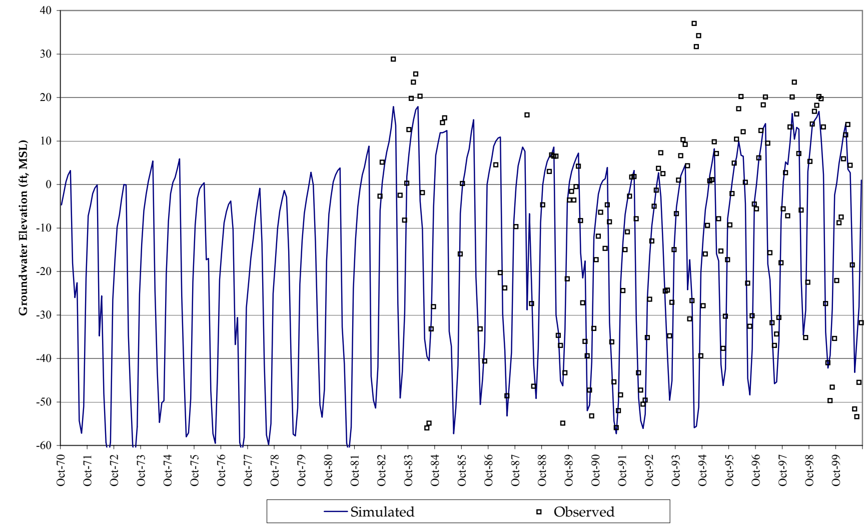


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 81 (DAVIS_WELL23), Subregion 15
GSE - 50 ft, Layer 1 Thickness - 110 ft, L2 T - 1610 ft, L3 T - 1190
Well Depth - 419, Hole Depth - 505, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.82

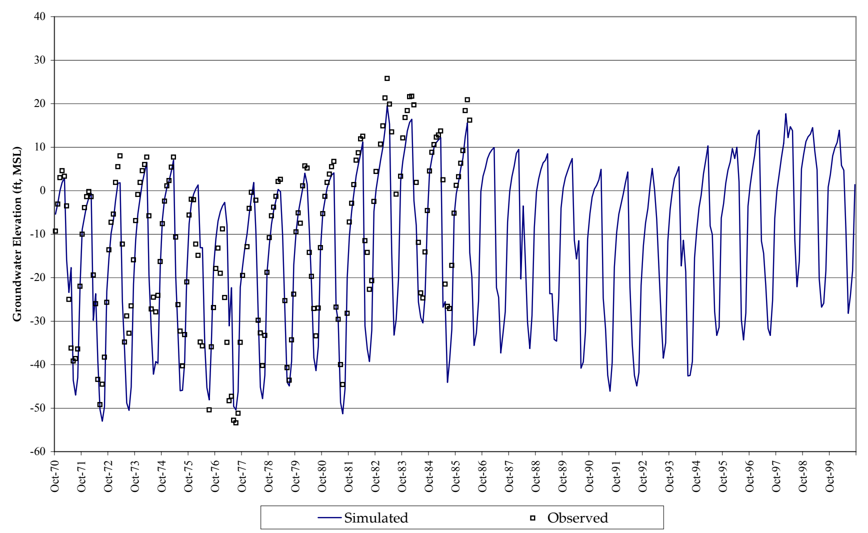


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 82 (DAVIS_WELL24), Subregion 15
GSE - 40 ft, Layer 1 Thickness - 110 ft, L2 T - 1580 ft, L3 T - 1210
Well Depth - 460, Hole Depth - 480, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.83

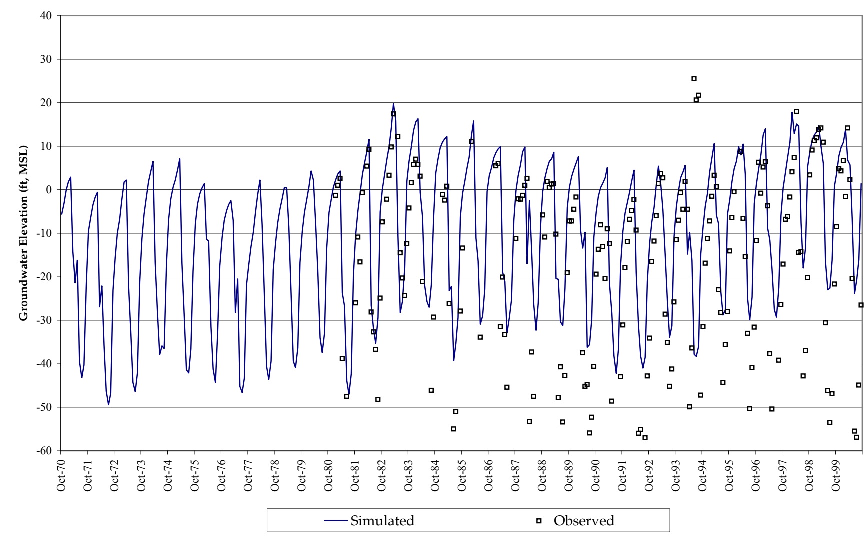


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 83 (08N03E07M001M), Subregion 15
GSE - 40 ft, Layer 1 Thickness - 130 ft, L2 T - 1540 ft, L3 T - 1200
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.84

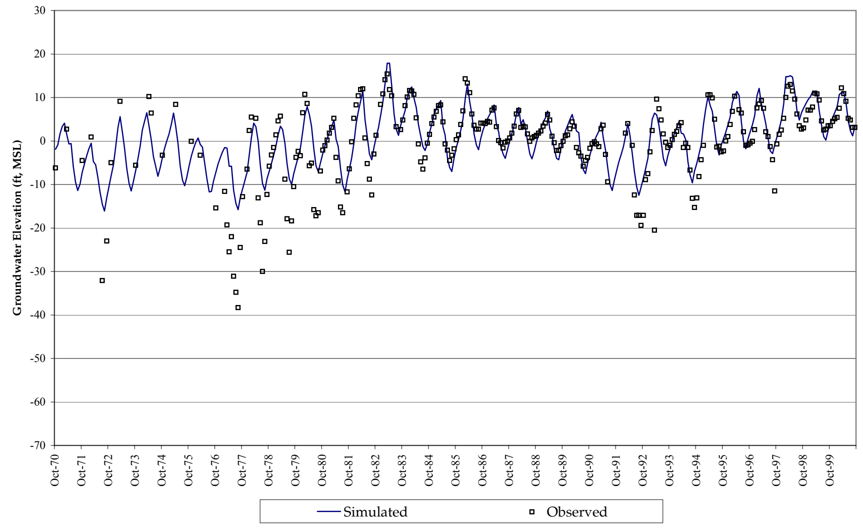


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 84 (DAVIS_WELL21), Subregion 15
GSE - 30 ft, Layer 1 Thickness - 130 ft, L2 T - 1530 ft, L3 T - 1190
Well Depth - 448, Hole Depth - 502, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.85

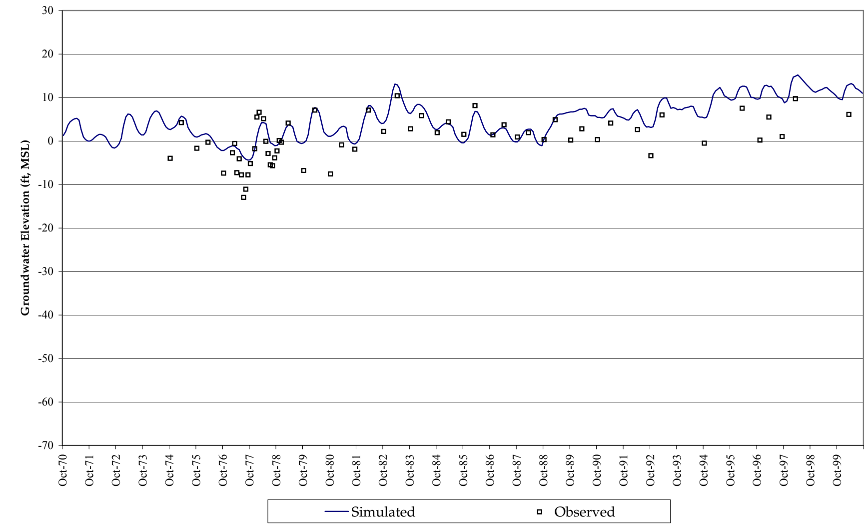


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 85 (08N03E04R001M), Subregion 13
GSE - 20 ft, Layer 1 Thickness - 120 ft, L2 T - 1470 ft, L3 T - 1090
Well Depth - 132, Hole Depth - nd, Top Perforation - 124, Bottom Perforation - 132

APRIL 2006

FIGURE A.86

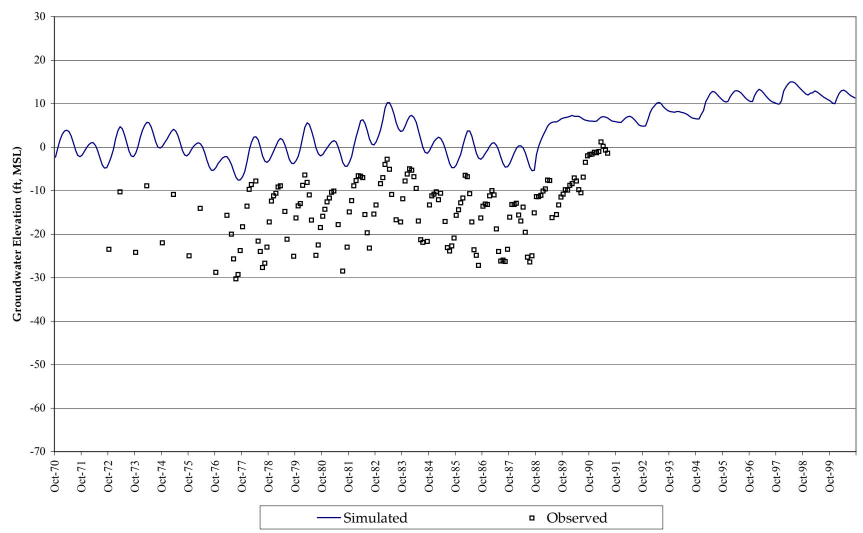


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 86 (08N04E06C001M), Subregion 17
GSE - 10 ft, Layer 1 Thickness - 130 ft, L2 T - 1270 ft, L3 T - 1000
Well Depth - 430, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.87

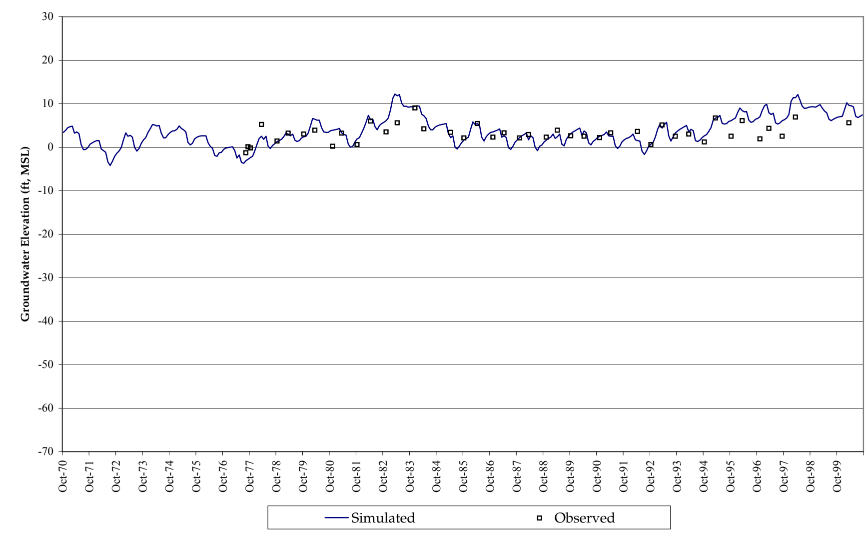


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 87 (09N04E32R001M), Subregion 17
GSE - 20 ft, Layer 1 Thickness - 120 ft, L2 T - 1220 ft, L3 T - 970
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.88

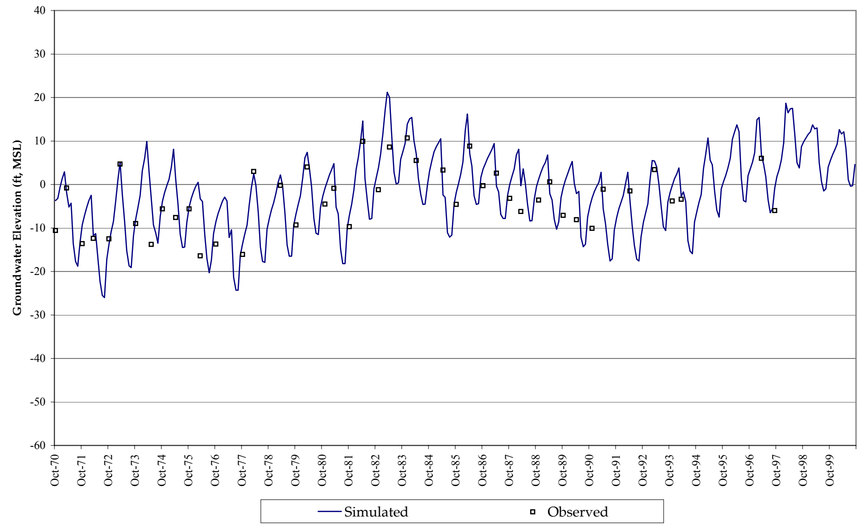


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 88 (08N04E18L001M), Subregion 17
GSE - 20 ft, Layer 1 Thickness - 110 ft, L2 T - 1410 ft, L3 T - 1020
Well Depth - 187, Hole Depth - nd, Top Perforation - 162, Bottom Perforation - 179

APRIL 2006

FIGURE A.89



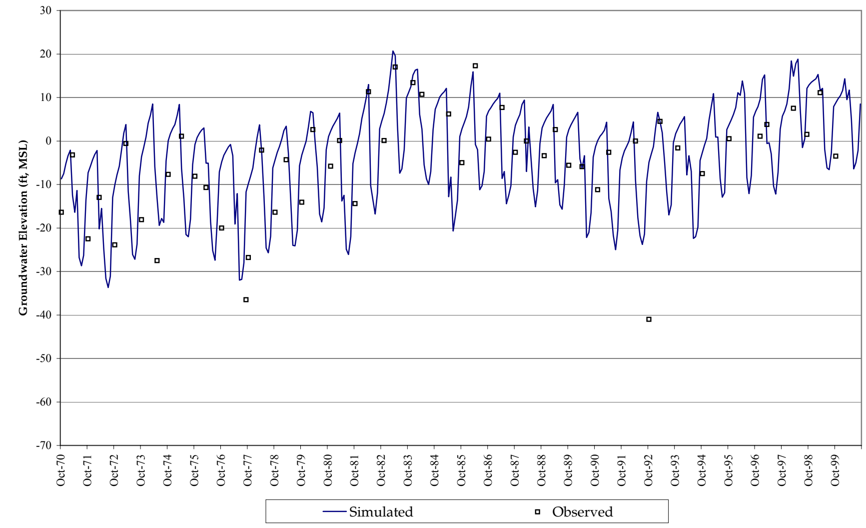
RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 89 (08N03E21P002M), Subregion 13
GSE - 20 ft, Layer 1 Thickness - 90 ft, L2 T - 1530 ft, L3 T - 1250
Well Depth - nd, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.90



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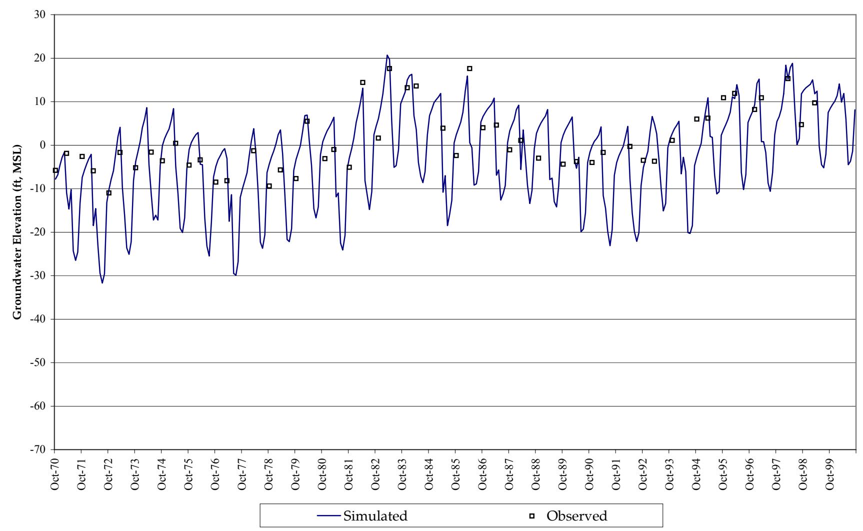
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 90 (08N03E32L001M), Subregion 13
GSE - 30 ft, Layer 1 Thickness - 130 ft, L2 T - 1570 ft, L3 T - 1230
Well Depth - 628, Hole Depth - nd, Top Perforation - 420, Bottom Perforation - 628

APRIL 2006

FIGURE A.91



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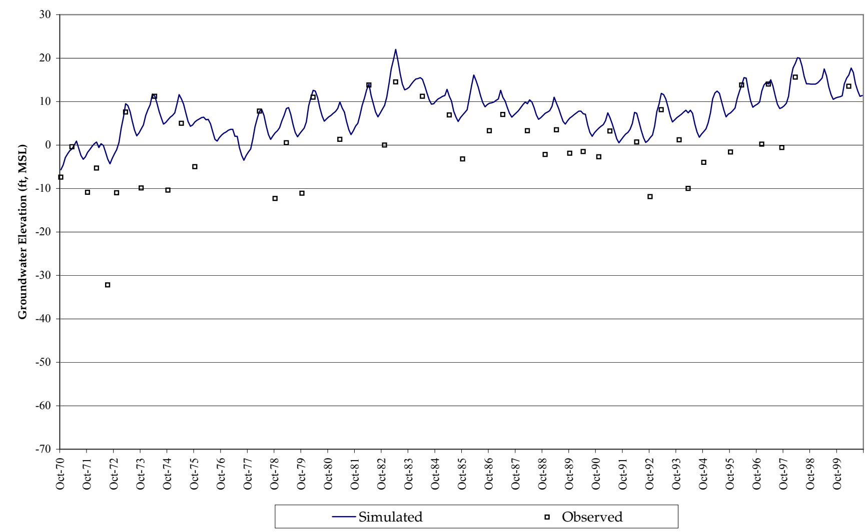
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 91 (08N03E32G001M), Subregion 13
GSE - 20 ft, Layer 1 Thickness - 120 ft, L2 T - 1560 ft, L3 T - 1230
Well Depth - 34, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.92



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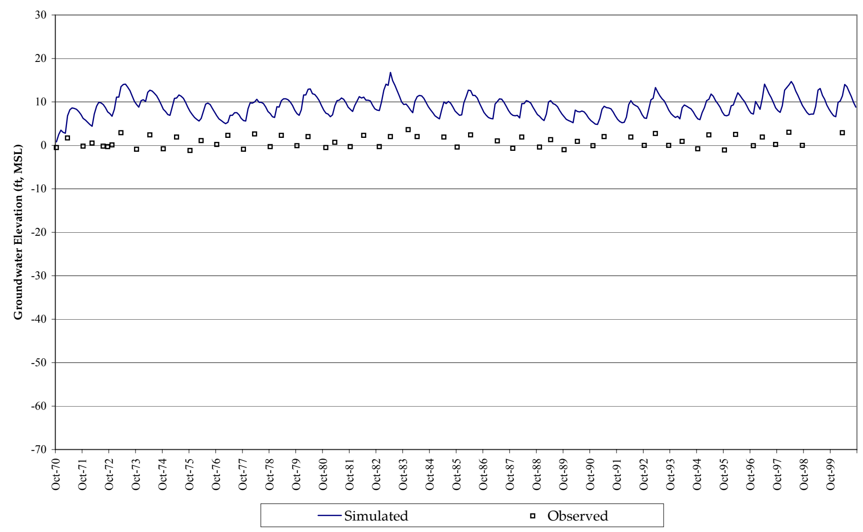
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 92 (07N03E04Q001M), Subregion 19
GSE - 20 ft, Layer 1 Thickness - 110 ft, L2 T - 1550 ft, L3 T - 1220
Well Depth - 96, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.93

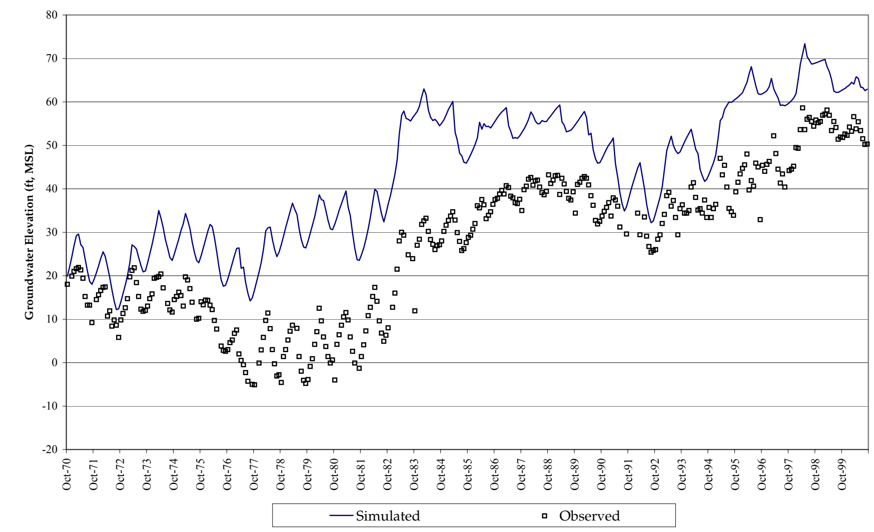


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 93 (06N03E23P001M), Subregion 19
GSE - 10 ft, Layer 1 Thickness - 100 ft, L2 T - 1750 ft, L3 T - 1380
Well Depth - 145, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.94

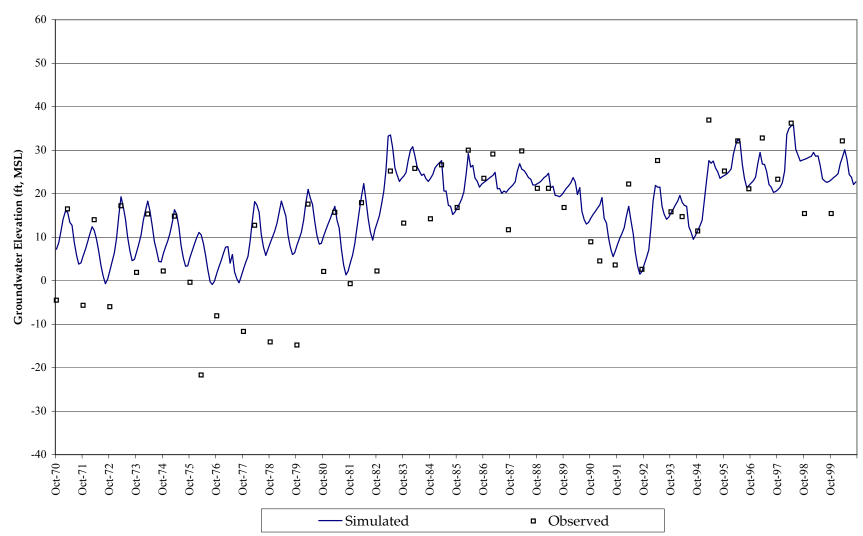


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 94 (12N01W05B001M), Subregion 3
GSE - 130 ft, Layer 1 Thickness - 210 ft, L2 T - 1160 ft, L3 T - 910
Well Depth - 150, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.95

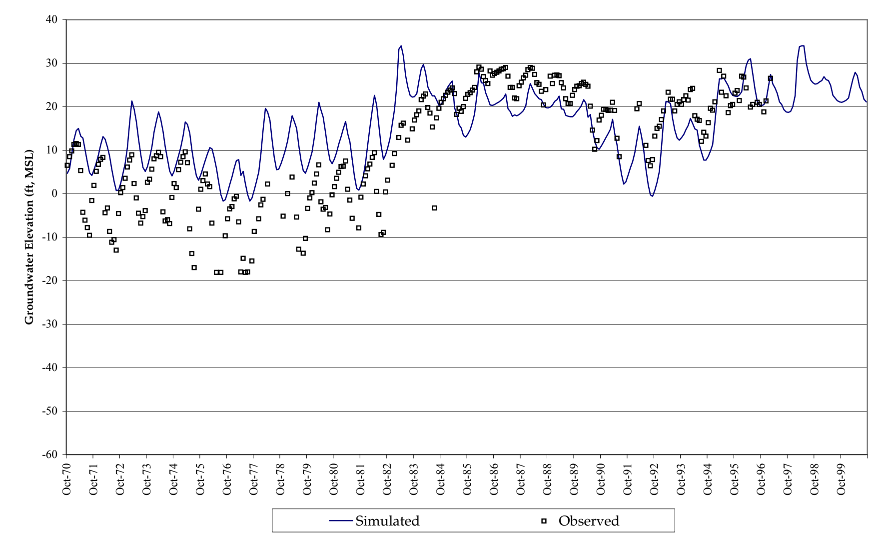


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 95 (12N01W14M001M), Subregion 3
GSE - 40 ft, Layer 1 Thickness - 180 ft, L2 T - 1340 ft, L3 T - 1050
Well Depth - 594, Hole Depth - nd, Top Perforation - 428, Bottom Perforation - 594

FIGURE A.96

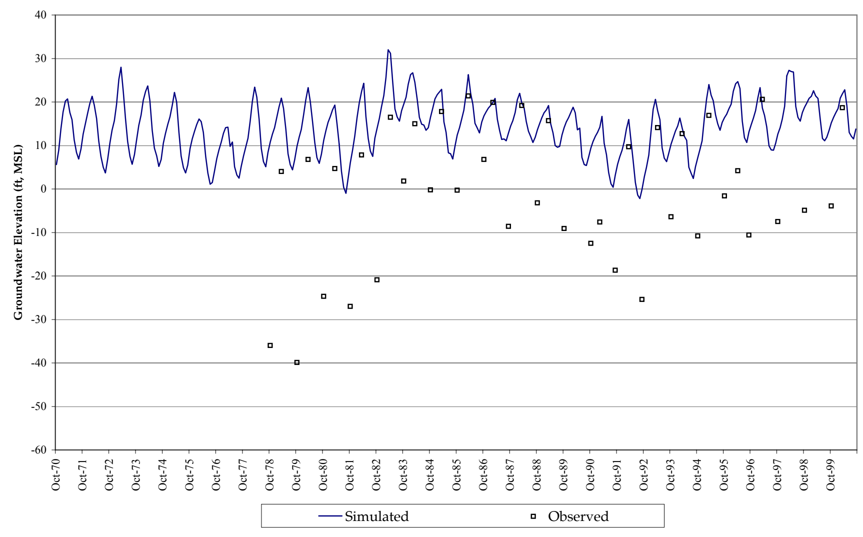


YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Calibration Well 96 (12N01W22R001M), Subregion 3
GSE - 50 ft, Layer 1 Thickness - 180 ft, L2 T - 1220 ft, L3 T - 960
Well Depth - 198, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

FIGURE A.97



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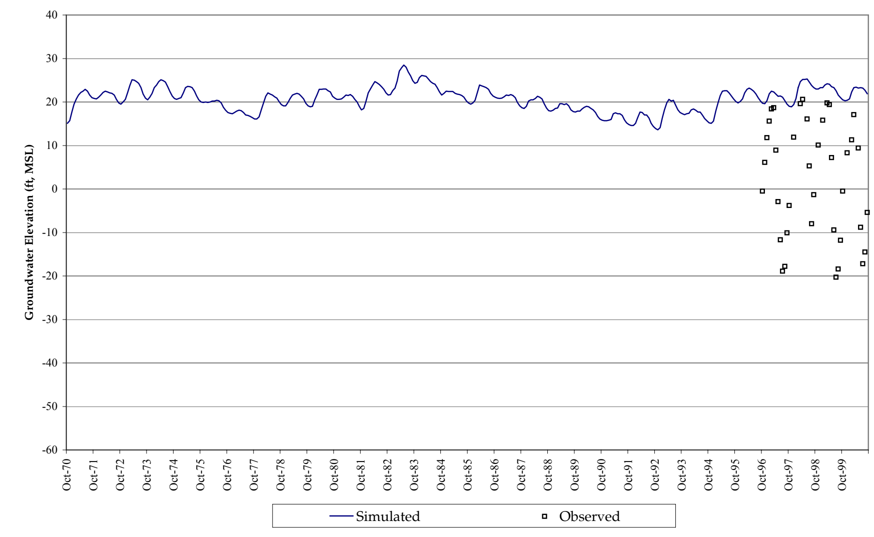
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 97 (12N01W36K002M), Subregion 3
GSE - 40 ft, Layer 1 Thickness - 140 ft, L2 T - 1450 ft, L3 T - 1140
Well Depth - 633, Hole Depth - 720, Top Perforation - 301, Bottom Perforation - 633

APRIL 2006

FIGURE A.98



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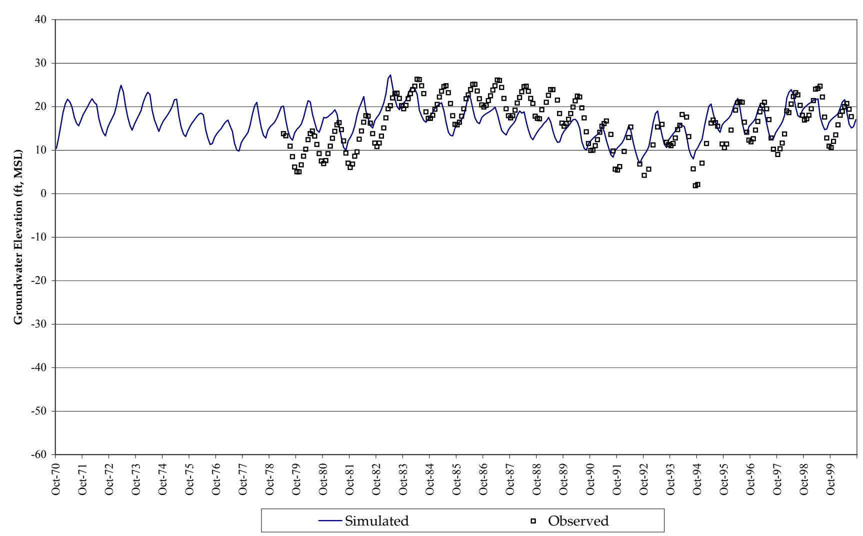
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 98 (12N01E26A002M), Subregion 5
GSE - 20 ft, Layer 1 Thickness - 90 ft, L2 T - 1470 ft, L3 T - 1160
Well Depth - nd, Hole Depth - nd, Top Perforation - 470, Bottom Perforation - 480

APRIL 2006

FIGURE A.99



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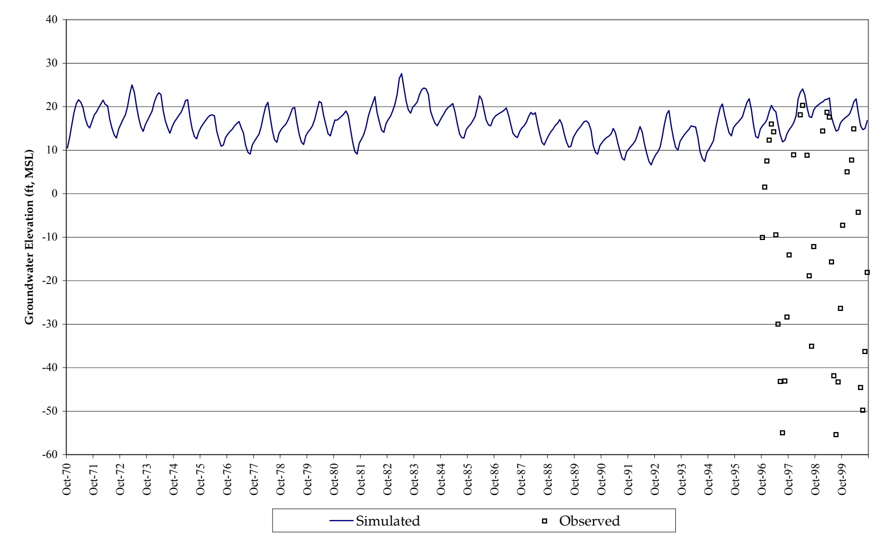
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 99 (385020121503603), Subregion 5
GSE - 30 ft, Layer 1 Thickness - 120 ft, L2 T - 1580 ft, L3 T - 1240
Well Depth - 947, Hole Depth - 2501, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.100



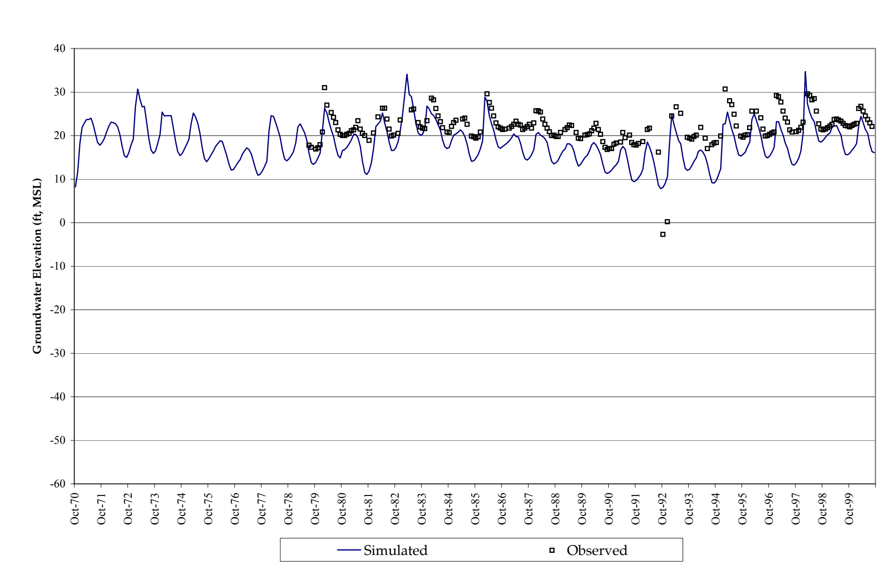
PRIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 100 (11N01E02D002M), Subregion 12
GSE - 30 ft, Layer 1 Thickness - 110 ft, L2 T - 1570 ft, L3 T - 1230
Well Depth - nd, Hole Depth - nd, Top Perforation - 480, Bottom Perforation - 490

APRIL 2006

FIGURE A.101



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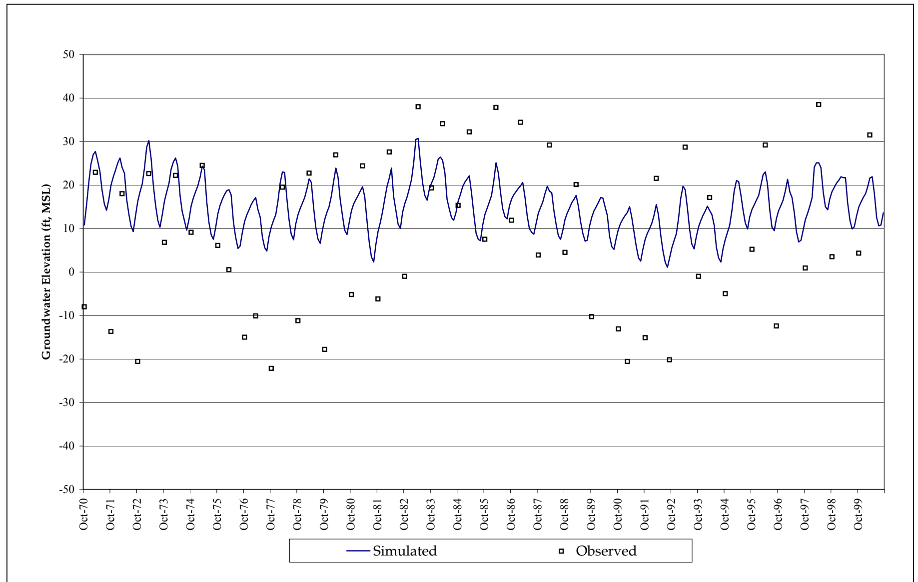
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 101 (384951121512401), Subregion 12
GSE - 30 ft, Layer 1 Thickness - 160 ft, L2 T - 1600 ft, L3 T - 1260
Well Depth - 260, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.102



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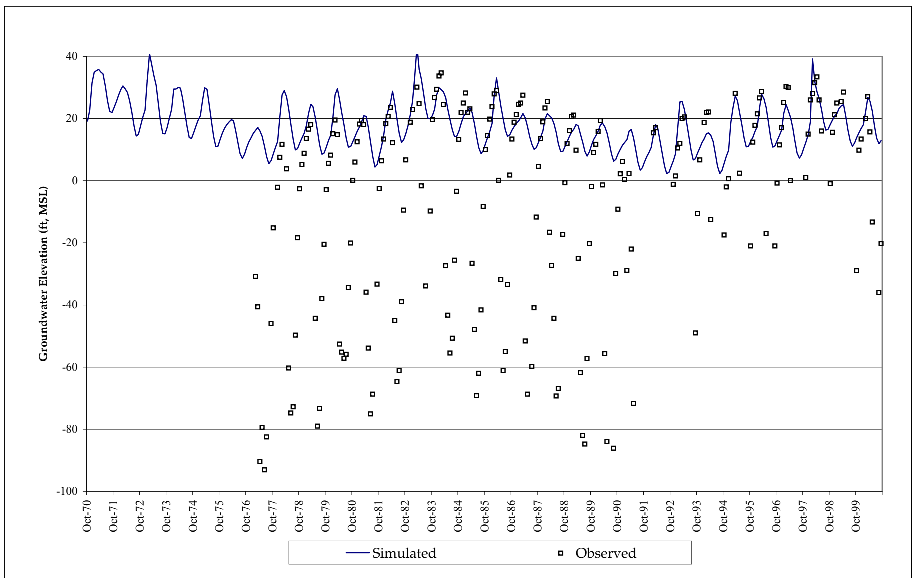
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 102 (11N01E09F002M), Subregion 10
GSE - 40 ft, Layer 1 Thickness - 170 ft, L2 T - 1560 ft, L3 T - 1230
Well Depth - 600, Hole Depth - nd, Top Perforation - nd, Bottom Perforation - nd

APRIL 2006

FIGURE A.103



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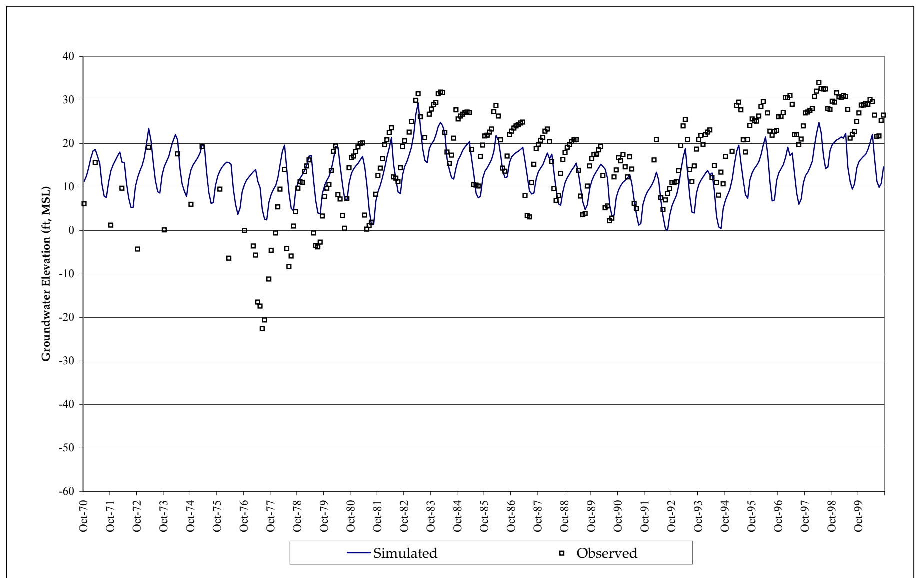
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 103 (11N01E16P001M), Subregion 10
GSE - 50 ft, Layer 1 Thickness - 170 ft, L2 T - 1500 ft, L3 T - 1180
Well Depth - 172, Hole Depth - 184, Top Perforation - 156, Bottom Perforation - 172

APRIL 2006

FIGURE A.104



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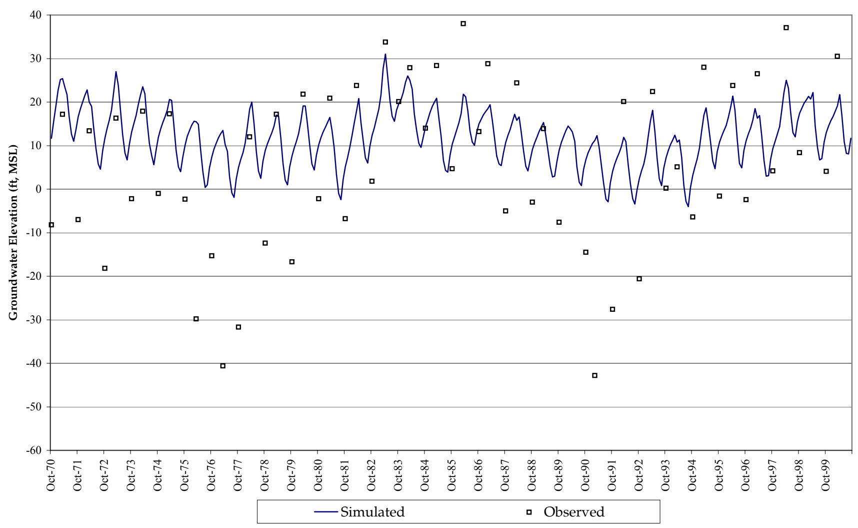
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 104 (11N01E23P001M), Subregion 11
GSE - 50 ft, Layer 1 Thickness - 160 ft, L2 T - 1530 ft, L3 T - 1200
Well Depth - 563, Hole Depth - 563, Top Perforation - 203, Bottom Perforation - 563

APRIL 2006

FIGURE A.105



RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Calibration Well 105 (11N02E20K004M), Subregion 12
GSE - 50 ft, Layer 1 Thickness - 70 ft, L2 T - 1520 ft, L3 T - 1200
Well Depth - 232, Hole Depth - nd, Top Perforation - 220, Bottom Perforation - 232

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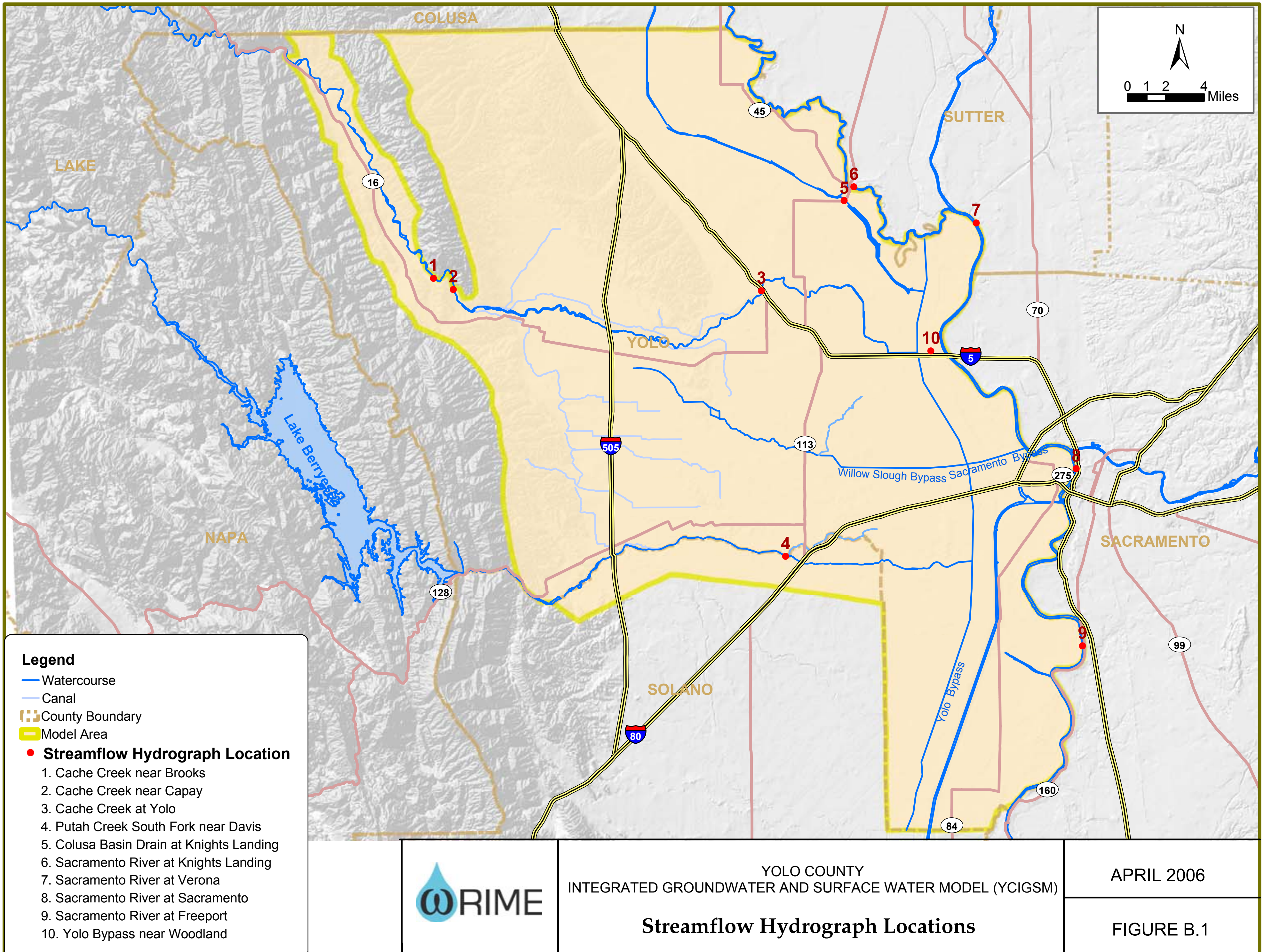
FIGURE A.106

APPENDIX B CALIBRATION STREAMFLOW HYDROGRAPHS

Streamflow hydrograph location map

10 calibration streamflow hydrographs



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YOLO COUNTY
INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Streamflow Hydrograph Locations

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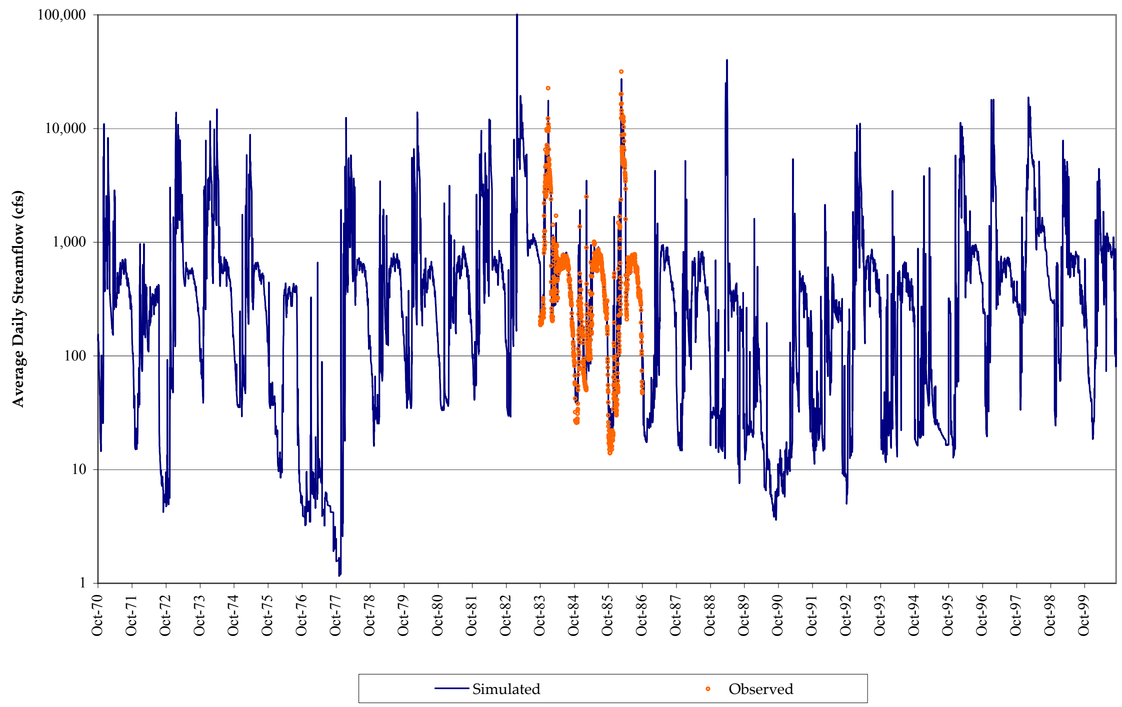
FIGURE B.1



RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Simulated and Observed Cache Creek Streamflow at Brooks

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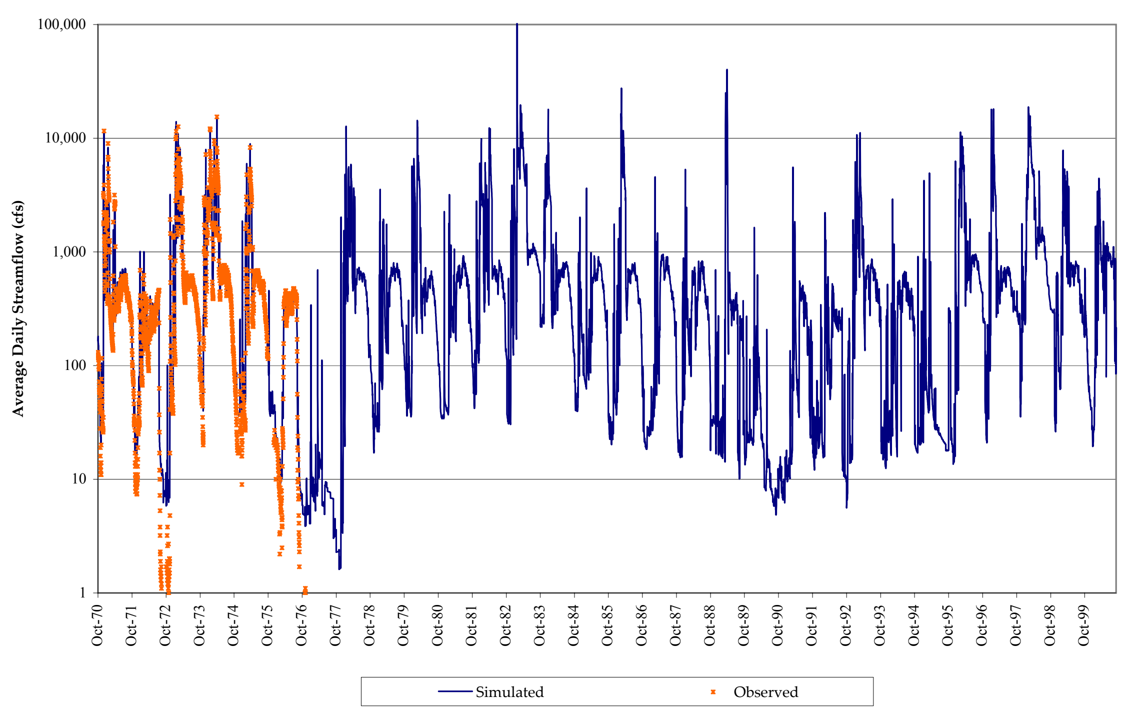
FIGURE B.2



RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Simulated and Observed Cache Creek Streamflow at Capay

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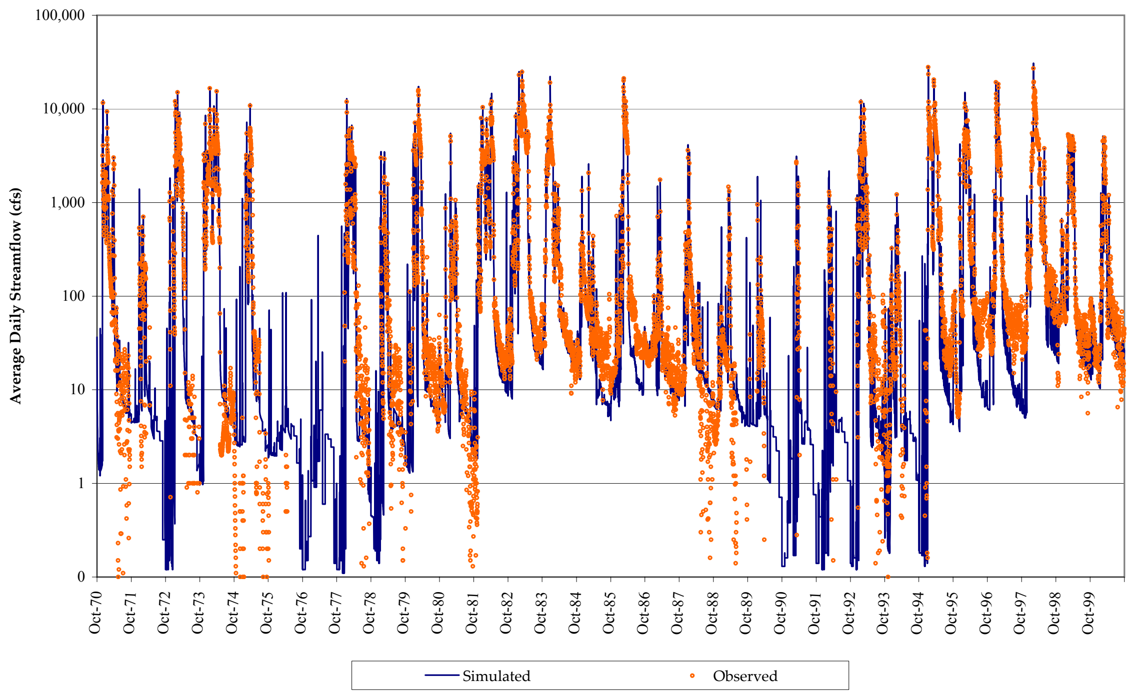
FIGURE B.3



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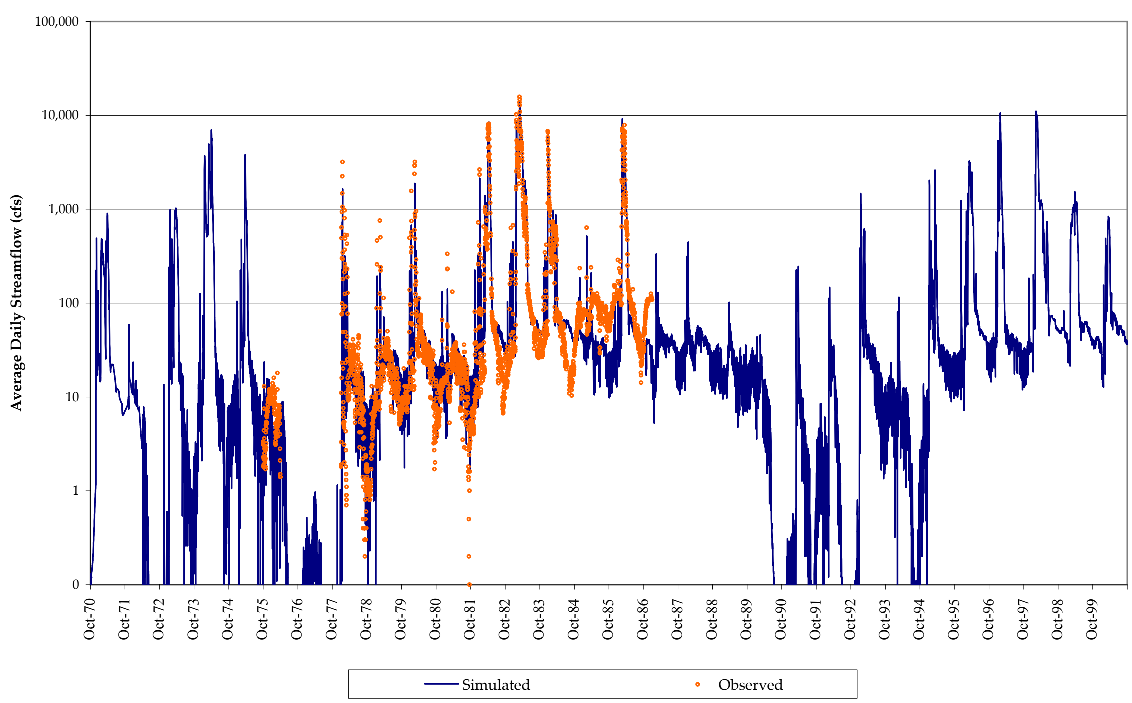
YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Simulated and Observed Cache Creek Streamflow at Yolo

FIGURE B.4



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YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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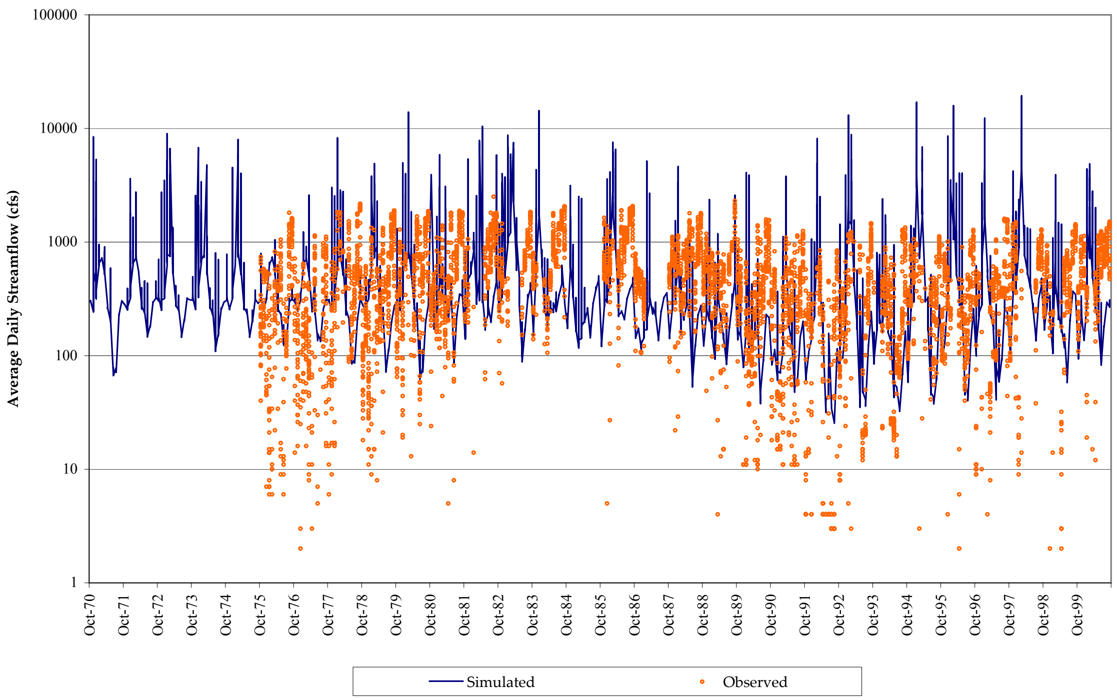
Simulated and Observed Putah Creek Streamflow at Davis

FIGURE B.5



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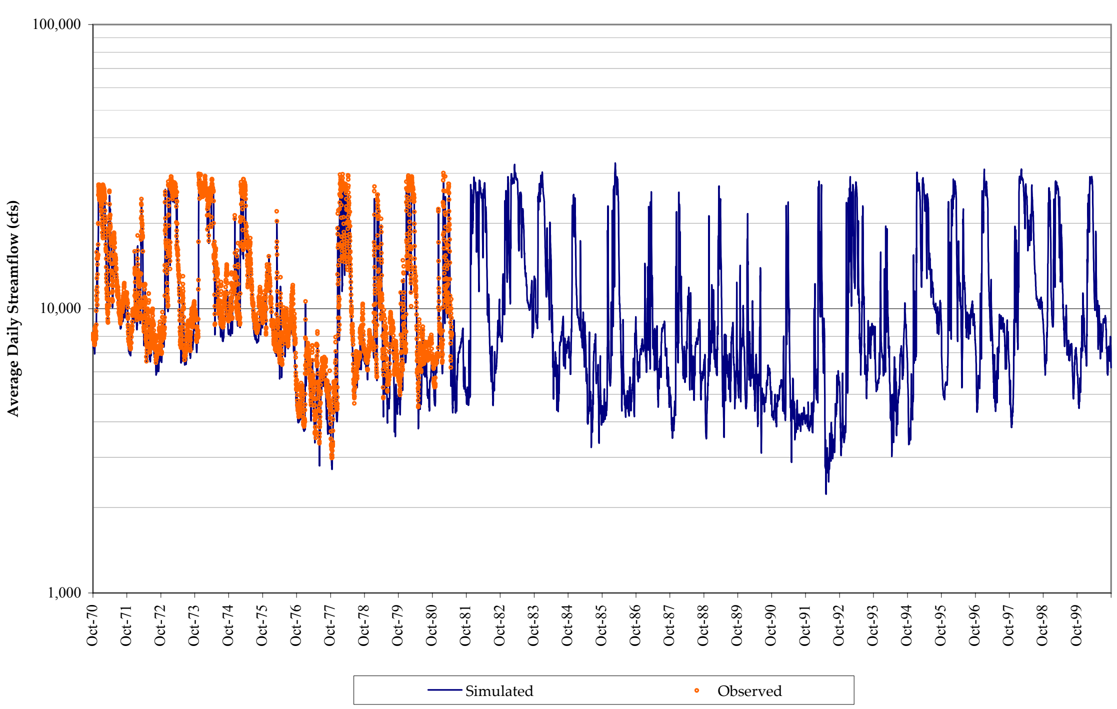
Simulated and Observed Colusa Basin Drain Streamflow at Knights Landing

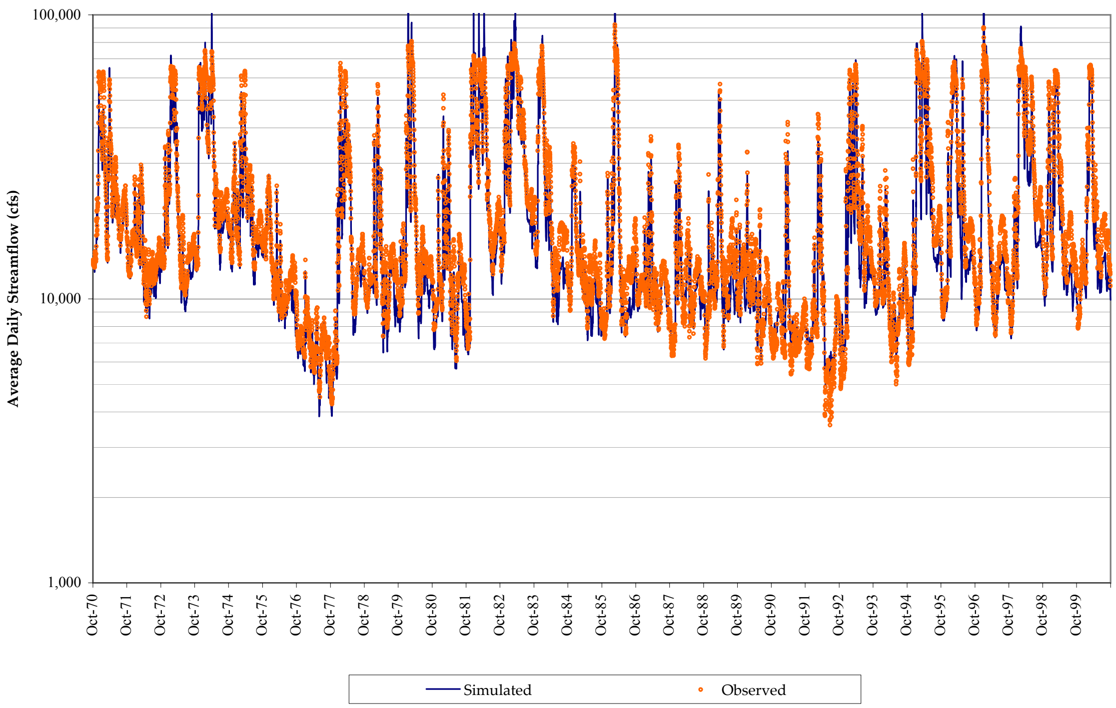
FIGURE B.6



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM) | APRIL 2006

Simulated and Observed Sacramento River Streamflow at Knights Landing

FIGURE B.7



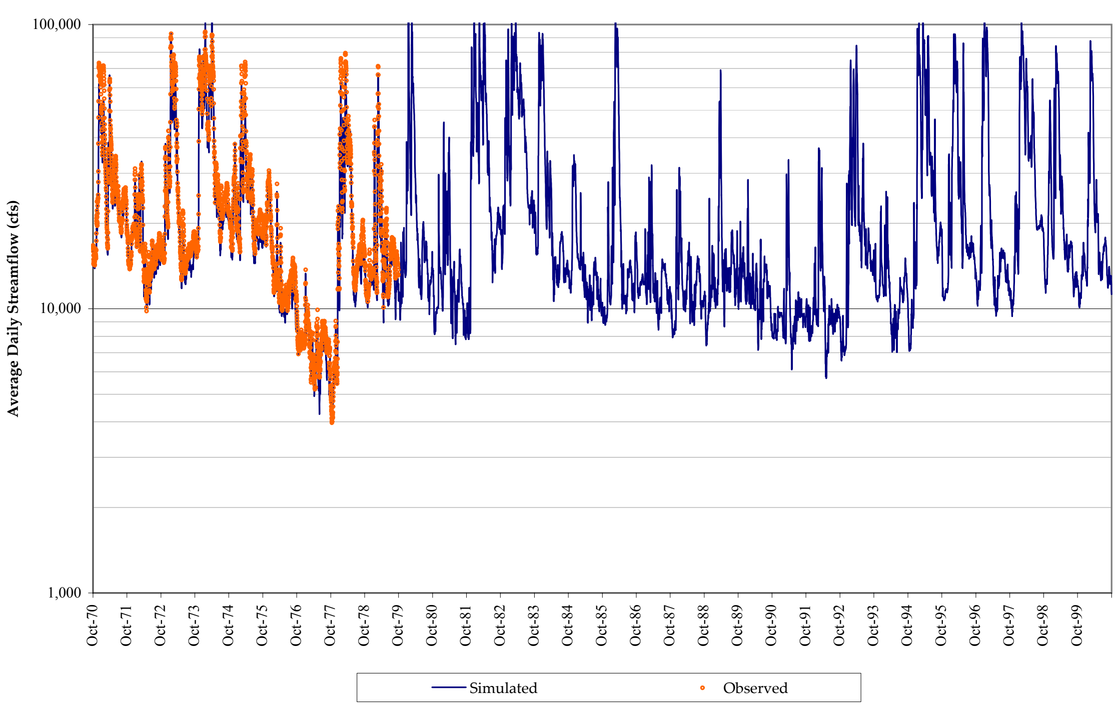
RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Simulated and Observed Sacramento River Streamflow at Verona

APRIL 2006

FIGURE B.8



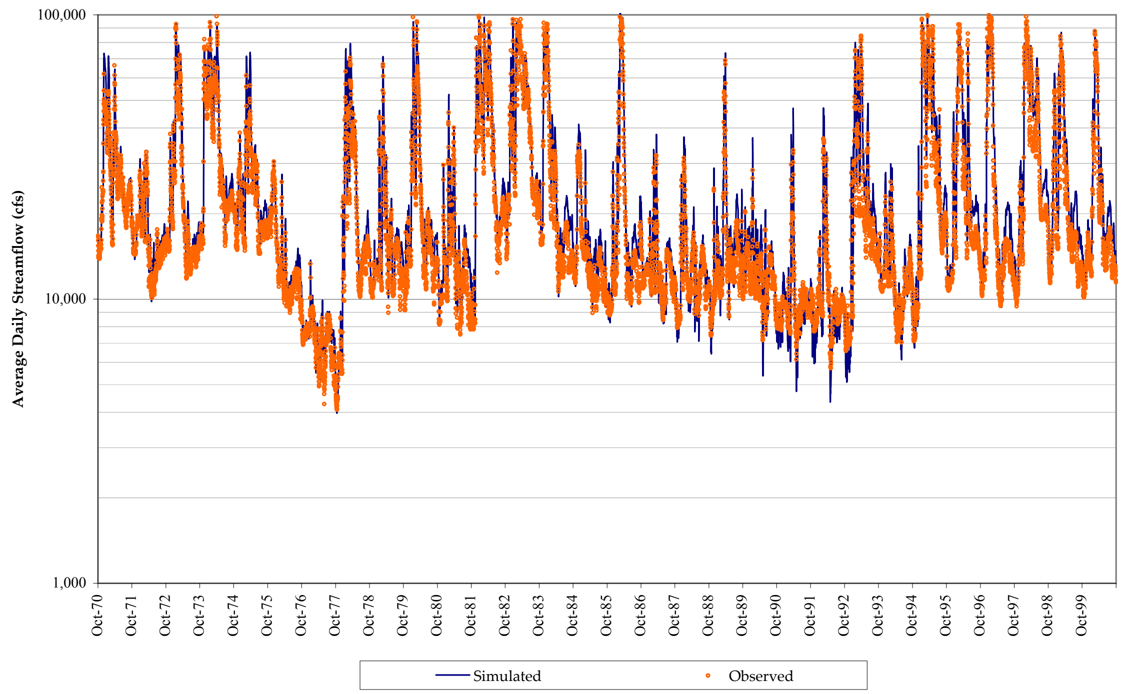
RIME

YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

Simulated and Observed Sacramento River Streamflow at Sacramento

APRIL 2006

FIGURE B.9



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

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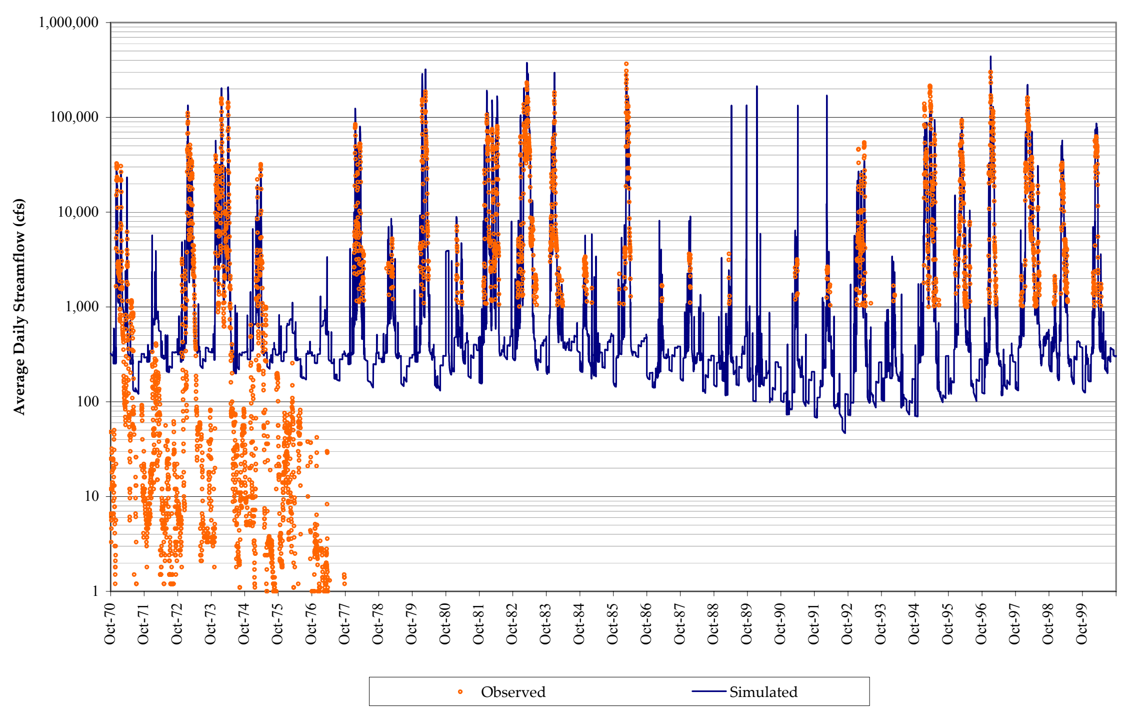
Simulated and Observed Sacramento River Streamflow at Freeport

FIGURE B.10



YOLO COUNTY INTEGRATED GROUNDWATER AND SURFACE WATER MODEL (YCIGSM)

APRIL 2006

Simulated and Observed Yolo Bypass Streamflow near Woodland

FIGURE B.11