ATTACHMENT 4: Supporting Documentation - 1
USGS report documenting regional steady-state model, Phillips, et al., 2007
Excerpts include title page, table of contents, abstract, figure with location of regional model (transient regional model update in progress as of May 2012)

Simulation of Multiscale Ground-Water Flow in Part of the Northeastern San Joaquin Valley, California

SIR 2007–5009

U.S. Department of the Interior
U.S. Geological Survey

Simulation of Multiscale Ground-Water Flow in Part of the Northeastern San Joaquin Valley, California

By Steven P. Phillips, Christopher T. Green, Karen R. Burow, Jennifer L. Shelton, and Diane L. Rewis

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Contents

Abstract 1
Introduction 1
Purpose and Scope 3
Study Area Descriptions 3
Topography and Climate 3
Surface-Water Hydrology 3
Land Use 3
Water Use 3
Site Descriptions 4
Conceptual Understanding of Ground-Water System 5
Geology 6
Geohydrology 6
Aquifer Hydraulic Properties 6
Lithologic Distributions 8
Regional Study Area 8
Local Study Area 8
Ground-Water Occurrence and Movement 10
Water Budget 15
Ground-Water Age 19
Ground-Water Flow Simulations 19
Spatial Discretization 19
Regional Model 19
Local Model 19
Boundary Conditions and Model Stresses 23
Regional Model 23
Local Model 25
Estimation of Aquifer Hydraulic Properties 25
Regional Model 25
Local Model 27
Model Calibration and Sensitivity 27
Regional Model 27
Regional Simulated Hydraulic Heads 30
Local Model 30
Local Simulated Hydraulic Heads 33
Evaluation of Fluxes in Local Model 34
Sensitivity of Local Model Parameter Estimates to Hydrofacies Distribution and Recharge 35
Model Results 38
Limitations and Appropriate Use of the Models 40
Regional Model 40
Local Model 40
Summary 41
Acknowledgments 41
References 42

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Abstract

The transport and fate of agricultural chemicals in a variety of environmental settings is being evaluated as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program. One of the locations being evaluated is a 2,700-km^2 (square kilometer) regional study area in the northeastern San Joaquin Valley surrounding the city of Modesto, an area dominated by irrigated agriculture in a semi-arid climate. Ground water is a key source of water for irrigation and public supply, and exploitation of this resource has altered the natural flow system. The aquifer system is predominantly alluvial, and an unconfined to semiconfined aquifer overlies a confined aquifer in the southwestern part of the study area; these aquifers are separated by the lacustrine Corcoran Clay. A regional-scale 16-layer steady-state model of ground-water flow in the aquifer system in the regional study area was developed to provide boundary conditions for an embedded 110-layer steady-state local-scale model of part of the aquifer system overlying the Corcoran Clay along the Merced River. The purpose of the local-scale model was to develop a better understanding of the aquifer system and to provide a basis for simulation of reactive transport of agricultural chemicals.

The heterogeneity of aquifer materials was explicitly incorporated into the regional and local models using information from geologic and drillers' logs of boreholes. Aquifer materials were differentiated in the regional model by the percentage of coarse-grained sediments in a cell, and in the local model by four hydrofacies (sand, silty sand, silt, and clay). The calibrated horizontal hydraulic conductivity values of the coarse-grained materials in the zone above the Corcoran Clay in the regional model and of the sand hydrofacies used in the local model were about equal (30–80 m/d [meter per day]), and the vertical hydraulic conductivity values in the same zone of the regional model (median of 0.012 m/d), which is dominated by the finer-grained materials, were about an order of magnitude less than that for the clay hydrofacies in the local model.

Data used for calibrating both models included long-term hourly water-level measurements in 20 short-screened wells installed by the USGS in the Modesto and Merced River areas. Additional calibration data for the regional model included water-level measurements in 11 wells upslope and 17 wells downslope from these areas. The root mean square error was 2.3 m (meter) for all wells in the regional model and 0.8 m for only the USGS wells; the associated average errors were 0.9 m and 0.3 m, respectively. The root mean square error for the 12 USGS wells along a transect in the local model area was 0.08 m; the average error was 0.0 m. Particle tracking was used with the local model to estimate the concentration of an environmental tracer, sulfur hexafluoride, in 10 USGS transect wells near the Merced River that were sampled for this constituent. Measured and estimated concentrations in the mid-depth and deepest wells, which would be most sensitive to errors in hydraulic conductivity estimates, were consistent. The combined results of particle tracking and sulfur hexafluoride analysis suggest that most water sampled from the transect wells was recharged less that 25 years ago.

Introduction

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is studying the transport and fate of agricultural chemicals in a variety of hydrologic and agricultural settings across the nation. The agricultural chemicals studied include those associated with applied fertilizers, herbicides, and pesticides. One of these settings is in the northeastern San Joaquin Valley near Modesto, California (fig. 1). The regional-scale study area straddled the valley floor and the local-scale study area was focused on a small area along the Merced River south of Turlock (fig. 1). These study areas are hereinafter referred to as "regional" and "local."

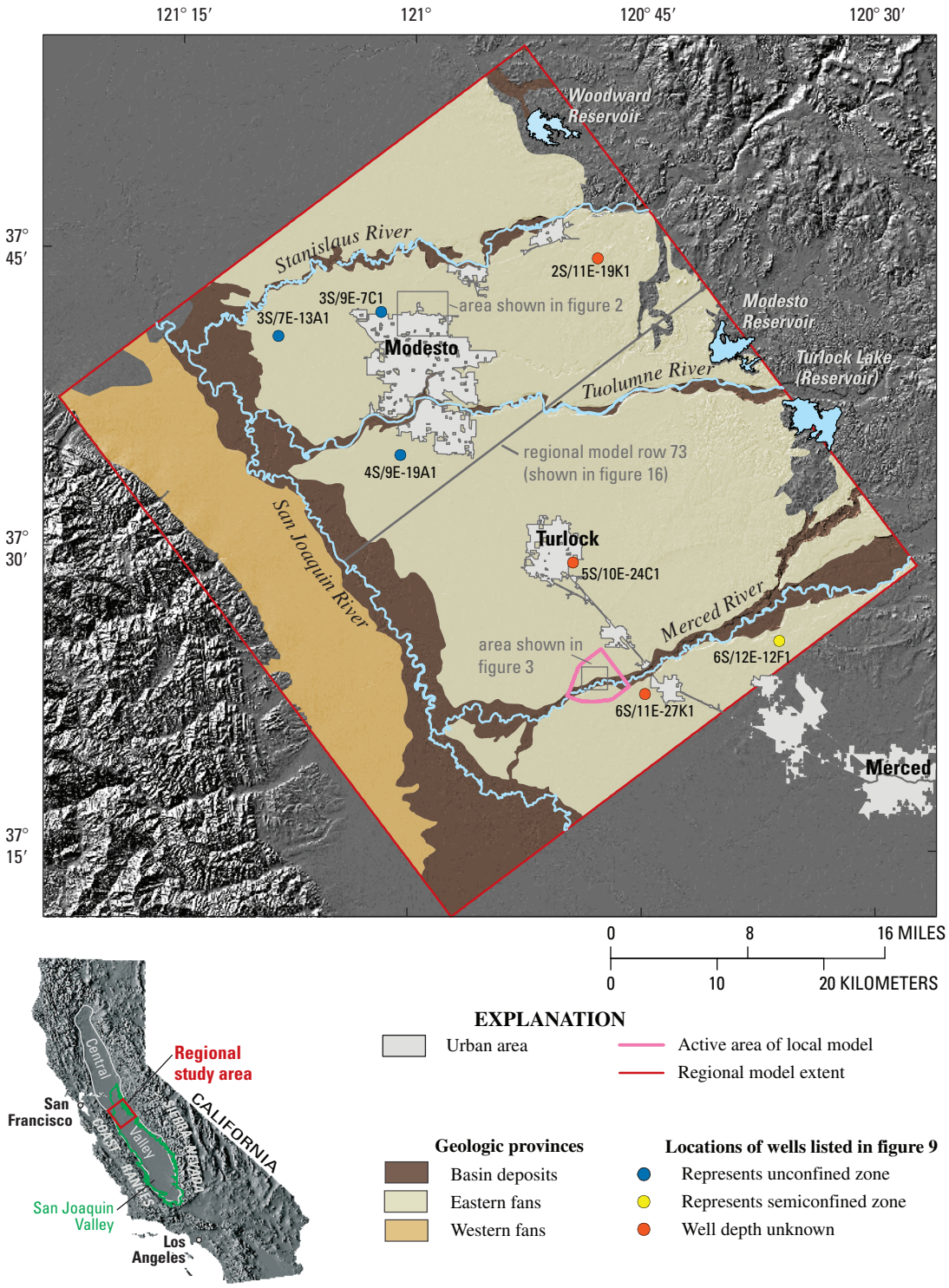

Figure 1. Locations of San Joaquin regional and local study areas within the Central Valley, California.

ATTACHMENT 4: Supporting Documentation - 2
ESIRWMP MOU - Signatories, statements, and goals

MEMORANDUM OF UNDERSTANDING

AMONG CITY OF MODESTO, CITY OF TURLOCK, CITY OF HUGHSON, AND CITY OF CERES FOR INTEGRATED REGIONAL WATER MANAGEMENT PLANNING

This Memorandum of Understanding (MOU) dated _____, 2011 is entered among the City of Modesto, City of Turlock, City of Hughson, and City of Ceres (collectively known as the East Stanislaus Regional Water Management Partnership or Partnership) for the purposes of coordinating water resources planning activities undertaken by the cities / water agencies and to establish mutual understandings of East Stanislaus area agencies with respect to their joint efforts in developing an Integrated Regional Water Management Plan (Plan) that will increase regional coordination, collaboration and communication and help in obtaining funding for water-related projects.

WHEREAS, the California Legislature enacted SBX2 1 (Perata, Chapter 1 Statues of 2008), the Integrated Regional Water Management Planning Act, which provides that a regional water management group may prepare and adopt an Integrated Regional Water Management Plan.

WHEREAS, In November 2006, the Safe Drinking Water, Water Quality and Supply, Flood Control, Rover and Coastal Protection Act (Prop 84), authorized the Legislature to appropriate funding for competitive grants for projects included in Integrated Regional Water Management Plans.

WHEREAS, on June 22, 2010 the Cities of Ceres, Hughson, Turlock and Modesto adopted and entered into a cost sharing agreement for the preparation of an Integrated Regional Water Management Plan.

WHEREAS, the Partnership is submitting an application for an Integrated Regional Water Management Plan Region approval, which includes descriptions of the regional boundary, the Partnership, Committees, and governance structure, among other topics, through the Department of Water Resources (DWR) Region Acceptance Process.

WHEREAS, the signatories of this MOU anticipate the potential need for future agreements on specific projects or programs and with other affected agencies to further coordinate long-term water resources planning.

WHEREAS, this MOU does not prevent any signatory from pursuing other projects individually and participation in Plan planning is nonbinding, and in no way impacts an agency's ability to plan and undertake efforts to plan for projects or secure project funding from any source. An agency may withdraw from Partnership participation at any time.

Now, therefore, the following is mutually understood and agreed:

1. GOALS

The goals of the Plan are:

DRAFT

1.1. To develop a comprehensive planning document to facilitate regional cooperation in providing water supply reliability, water recycling, water conservation, water quality improvement, storm water capture and management, flood management, wetlands enhancement and creation, and environmental and habitat protection and improvement.

1.2. To foster coordination, collaboration and communication Partnership agencies responsible for water-related issues and interested stakeholders, to achieve greater efficiencies, enhance public services, and build public support for vital projects.

1.3. To improve regional competitiveness for State and Federal grant funding.

2. DEFINITIONS

2.1. Integrated Regional Water Management Plan. The Integrated Regional Water Management Plan envisioned by state legislators and state resource agencies that integrates the projects and management plans of all water-related agencies and stakeholders in a region, in this case the East Stanislaus Region, in order to foster coordination, collaboration and communication among those entities and to assist decision-makers in awarding grants and other funding. The Plan will address water supply, water quality, wastewater, stormwater/flood control, watershed planning and habitat protection and restoration.

2.2. Agency. A public entity, be it a special district, city or other governmental entity, responsible for providing one or more services in the areas of water supply, water quality, wastewater, recycled water, water conservation, stormwater/flood control, watershed planning and habitat protection and restoration.

2.3. Service function. A water-related individual service function provided by an agency, i.e. water supply, water quality, wastewater, recycled water, water conservation, stormwater/flood control, watershed planning, and habitat protection and restoration.

2.4. Project. A comprehensive list of resource-related projects or programs that yield multiple benefits including one or more of the following: water supply reliability, water conservation and water use efficiency; stormwater capture, storage, clean-up, treatment and management; removal of invasive non-native species, the creation and enhancement of wetlands, and the acquisition, protection, and restoration of open space and watershed lands; non-point source pollution reduction, management and monitoring; groundwater recharge and management; contaminant and salt removal through reclamation, desalting, and conveyance of reclaimed water to users; water banking, exchange, reclamation and improvement of water quality; planning and implementation of multipurpose flood management programs; watershed protection and management; drinking water treatment and distribution; ecosystem and fisheries restoration and protection.

2.5. Management plan. An agency's or organization's plan, based in part on the land-use plans within the entity's jurisdiction, that addresses how that entity will provide service in the future in one or more of the following service functions: water supply, water quality, wastewater, recycled water, water conservation, stormwater/flood control, watershed planning or habitat protection and restoration.

DRAFT

ATTACHMENT 4: Supporting Documentation - 3
JPA among Cities for Surface Water Supply, Title page only

DRINKING WATER SUPPLY PROJECT

JOINT EXERCISE OF POWERS AGREEMENT BETWEEN THE CITIES OF CERES, MODESTO AND TURLOCK, FOR THE PURPOSE OF CREATING A JOINT POWERS AUTHORITY RESPONSIBLE FOR DECISIONS IN CERTAIN MATTERS PERTAINING TO THE MUNICIPAL AND INDUSTRIAL WATER SUPPLY PROGRAMS FOR THE AFOREMENTIONED PUBLIC ENTITIES

THIS AGREEMENT, dated for convenience as of _____, 2011, is by and between the Cities of Ceres, Modesto & Turlock, hereinafter "Participants", being municipal corporations duly organized and existing under the laws of the Sate of California.

WHEREAS, the intent of the parties to this Agreement is to create a Joint Powers Authority that would purchase water from the Turlock Irrigation District (hereinafter referred to as “TID”), would treat such water and would make such treated water available At Cost to the Participants; and

WHEREAS, Participants are interested in finding and evaluating surface water supply options and facilities to serve municipal and industrial water to the customers within their service areas; and

WHEREAS, Participants desire to develop a safe, dependable, economical, and long-term municipal and industrial water supply system; and

WHEREAS, the Participants desire to tailor the project to individual community needs; and

WHEREAS, each of the Participants has heretofore been participating in a Project to seek an alternative surface water supply; and

WHEREAS, All Participants desire to establish a joint powers authority by this Agreement so they may collectively discuss, develop and negotiate alternatives regarding the aforementioned Project; and

WHEREAS, The Participants desire to secure a reliable source of surface water for municipal and industrial water and other municipal purposes; and

WHEREAS, each of the Participants is authorized to develop, obtain, and serve a municipal and industrial water supply, pursuant to California law.

NOW, THEREFORE, the Participants, for and in consideration of the mutual promises and agreements herein contained, do agree as follows:

ARTICLE I. DEFINITIONS:

Section 1.01. Definitions. Unless the context otherwise requires, the words and terms defined in this Article shall, for the purpose hereof, have the meaning herein

ATTACHMENT 4: Supporting Documentation - 4
Durbin, 2003 - excerpts (Introduction and Water Budget Results

TURLOCK GROUNDWATER BASIN
WATER BUDGET
1952-2002

December 2003

Prepared for
Turlock Groundwater Basin Association

Prepared by
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TIMOTHY J. DURBIN, INC.
CONSULTING HYDROLOGISTS

1.0 INTRODUCTION

1.1 Purpose of the Study

The Turlock Groundwater Basin Association was established to coordinate the common interests of local public agencies in the utilization and protection of groundwater within the Turlock basin. The members include the City of Ceres, City of Hughson, City of Modesto, City of Turlock, Denair Community Services District, Hilmar County Water District, Ballico-Cortez Water District, Eastside Water District, Merced Irrigation District, Turlock Irrigation District, Stanislaus County, and Merced County. A particular common interest of the Association is the groundwater budget for the Turlock basin. This report describes the groundwater budget for the Turlock basin for 1952-2002, which was prepared for the Association. The Delhi County Water District participated in the study, but it is not a member of the Association.

The groundwater budget represents a quantification of the water inflows to, and outflows from the groundwater basin. The inflows represent the replenishment of groundwater. The principal inflow is the deep percolation water from agricultural irrigation. The outflows represent the depletion of groundwater. The principal outflow is groundwater pumping for agricultural and municipal uses. The difference between the inflows and outflows determines the groundwater-level trends within the basin. If the total inflows exceed the total outflows, groundwater levels rise and the volume of groundwater stored increases within the basin. Likewise, if the total outflows exceed the total inflows, groundwater levels decline and the volume of groundwater stored decreases within the basin.

The Turlock groundwater basin comprises an area of about 350,000 acres or 540 square miles. The basin is bounded on the north by the Tuolumne River, on the west by the San Joaquin River, on the south by the Merced River, and on the east by the rocks of the Sierra Nevada foothills (Figure 1.1). These boundaries for the most part isolate the Turlock basin from the groundwater conditions outside its boundaries, and the groundwater conditions outside the Turlock basin for the most part have little impact within the basin. Correspondingly, the groundwater conditions within the Turlock basin for the most part have little impact on the groundwater conditions outside the basin. However, where significant groundwater pumping occurs near the Tuolumne or Merced

6.0 SUMMARY WATER BUDGET FOR TURLOCK GROUNDWATER BASIN

The water budget for the Turlock groundwater basin is listed in Table 6.1 for the five-year periods during 1953-2002. For each five-year period, the component inflows to and outflows from the groundwater basin are listed. Additionally, the changes in groundwater storage are listed. The groundwater inflows include recharge from irrigated areas, recharge from non-irrigated areas, seepage from Turlock Lake, underflow from the Sierra Nevada foothills, and upward seepage from deep geologic formations. The groundwater outflows include pumping from wells, groundwater discharge to rivers, groundwater discharge from subsurface agricultural drains, and groundwater consumption by riparian vegetation.

Table 6.1 indicates the groundwater storage within the Turlock groundwater basin was depleted during 1963-1992. The cumulative storage depletion was about 1.6 million acre-ft, which represents an average depletion of about 53,000 acre-ft/yr. However, depletions have mostly ceased. In fact, the storage within the Turlock groundwater basin has increased somewhat. The cumulative increased storage during 1993-2002 was 74,000 acre-ft, which represents an average accretion of about 7,000 acre-ft/yr. Nevertheless, groundwater storage remains substantially depleted with respect to groundwater conditions in 1962.

The slight recovery of the Turlock groundwater basin suggests that an equilibrium state, or steady state, condition has been established. The outflows from the groundwater basin are about balanced by the inflows to the basin. Correspondingly, the year-to-year groundwater storage and groundwater levels are not changing over time. This equilibrium state has been established even though groundwater pumping has increased over the last three decades. While the groundwater pumping during 1953-1957 was 404,000 acre-ft/yr, the groundwater pumping during 1998-2002 was 507,000 acre-ft/yr, which represents a 25 percent increase in pumping. The increased pumping was accompanied by a decrease in the groundwater discharges to the Tuolumne, Merced, and San Joaquin rivers. As indicated in Table 6.1, the average annual net discharge to the rivers was about 85,000 acre-ft/yr during 1953-62, but about 41,000 acre-ft/yr during 1993-2002. The increased pumping was accompanied also by the depletion of groundwater storage. As can be

derived from Table 6.1, the average storage-depletion rate during 1953-2002 was about 30,000 acre-ft/yr, which occurred primarily in the eastern part of the Turlock groundwater basin.

While the groundwater basin currently is in an equilibrium state, that state most likely will not be permanent. The current equilibrium will be disrupted by any change in groundwater recharge or discharge. The most immediate disruption will be caused by increased urbanization of irrigated agricultural land within the Turlock groundwater basin. The effects of urbanization are to increase pumping and to decrease recharge, both of which will produce renewed groundwater-storage depletions. Groundwater pumping can be increased as urbanization converts agricultural land irrigated mostly with surface water to developed land supplied from groundwater. Groundwater recharge can be decreased as urbanization reduces the irrigated area and the corresponding recharge from irrigation and precipitation on irrigated areas. Without urbanization, crops cover nearly 100 percent of the land area. With urbanization, landscape vegetation covers only a small percentage of the original crop area.

Changes in crop acreages and irrigation practices also can disrupt the equilibrium of the groundwater basin. If the acreage of crops irrigated with groundwater were to increase, groundwater pumping necessarily would increase. If the acreage of crops irrigated with surface water were to change to more advanced irrigation practices groundwater recharge could decrease. This occurs because advanced irrigation technologies typically result in increased irrigation efficiency, and reduced recharge. If crops, which historically were irrigated with surface water move to groundwater, along with these advanced irrigation technologies, the impact to groundwater would be two-fold. Not only would there be reduced recharge, but there would also be additional extractions from the groundwater basin. Conversely, changes to advanced irrigation technologies for existing crops irrigated with groundwater will typically have essentially no water-budget impact. This occurs because increased irrigation efficiency through advanced irrigation technologies decreases equally both pumping and the irrigation recharge resulting from the application of the pumped water.

ATTACHMENT 4: Supporting Documentation - 5
Durbin, 2008 - Executive Summary

Assessment of Future Groundwater Impacts Due to Assumed Water-Use Changes Turlock Groundwater Basin, California

September 11, 2008

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TIMOTHY J. DURBIN, INC.
CONSULTING HYDROLOGISTS

Executive Summary

The groundwater impacts within the Turlock basin were evaluated for a particular scenario of future land and water-use changes. The impacts were evaluated using the groundwater model of the Turlock basin. The groundwater model was developed and has been periodically updated by Turlock Irrigation District since 1988. Given inputs of historical or assumed future groundwater and surface water-use throughout the basin, the model calculates the corresponding groundwater levels.

A future scenario was constructed for potential land and water-use conditions through 2036. The basic elements of the scenario are that: Urban communities within the Turlock basin will grow at the rates contained in planning documents produced by the respective communities. Urban growth will occur on irrigated farmland within the Turlock Irrigation District, which results in a corresponding reduction in the irrigated acreage. The urban communities will supplement groundwater use with surface water obtained from the Turlock Irrigation District. Irrigated acreages within the Eastside Water District, Ballico-Cortez Water District, and Merced Irrigation District will remain unchanged. Likewise, irrigated land outside an irrigation district and along either of the Tuolumne, San Joaquin, or Merced rivers will remain unchanged. However, the irrigated acreage within the foothills region of the Turlock basin will increase at the rate of 2 percent per year.

Simulations were run with three versions of the groundwater model because the actual characteristics of the eastern region of the groundwater basin are very uncertain. The model uses inputs of the physical properties of the groundwater basin, which include the extents and thicknesses of the geologic formations constituting the basin, the transmissivity and storage characteristics of each formation. For the eastern region of the Turlock basin, the sparse available data limit the ability to characterize the geologic formations, and that translates into highly uncertain model predictions. To address the unavoidable model uncertainty, simulations were made of future conditions with three different assumptions about the basin characteristics, with the intent of bracketing the reasonable range of possible actual conditions.

For the western region of the Turlock basin (which includes Hughson, Denair, and Delhi, and the region westward), the results for the three simulations are nearly identical. Furthermore, the simulation results indicate that groundwater levels will change little in response to the assumed water-use changes. At the end of the simulation period (2036), groundwater levels will be within 10 ft of current levels. However, during assumed repetitions of the historical 1976-1977 and 1987-1992 droughts, groundwater levels during each drought will decline about 15 ft near the San Joaquin and Merced Rivers from the pre-drought conditions. Such declines are similar to those actually experienced for the historical water-use conditions. Nevertheless, groundwater levels along most of the Highway-99 corridor will rise about 15 ft, due to the surface-water use by the cities.

The simulation results lead to different conclusions regarding the western and eastern regions of the Turlock basin. For the western region of the basin, the simulation

results suggest that the Turlock basin can support the projected groundwater demands. The expected long-term trend is for essentially unchanged groundwater levels. Furthermore, the conversion from agricultural to urban uses will not cause drought-induced groundwater-level fluctuations any worse than those actually experienced during the historical 1976-1977 and 1987-1992 droughts. For the eastern region of the basin, the simulation results suggest possible water-supply problems, depending on the actual physical characteristics of the geologic formations underlying that region. The simulations indicate long-term groundwater-level declines (relative to 2006) of about 85 ft within the Eastside Water District and 65-175 ft within the foothills region, depending on the storage characteristics assigned the geologic formations underlying the eastern part of the basin. Furthermore, drought induced declines are about 105 ft within the Eastside Water District and 95-265 ft within the foothills region.

Even though the western region of the basin is not expected to experience problems with respect to groundwater levels, water-quality problems could occur. Poor-quality groundwater occurs at depth within areas of the western region of the Turlock basin. The groundwater is characterized in part by the occurrences of elevated dissolved solids, arsenic, nitrates, and uranium. The depth to the poor-quality groundwater decreases westward across the basin to the San Joaquin River. Near the eastern boundary of the Turlock Irrigation District, the depth to poor-quality water is about 1,000 ft. Near the center of the District, the depth to poor-quality water is about 500 ft. Near the San Joaquin River, the depth to poor-quality water is about 10 ft, which represents the position of the groundwater table. The projected increased groundwater pumping by the urban communities has the potential of inducing the upward groundwater flow and corresponding upward migration of the poor-quality groundwater into current production zones. Ultimately, groundwater quality could represent the limits to groundwater used, even though the basin can sustain the projected volumetric demands.

Groundwater quality could become a constraint on groundwater use within the eastern region of the basin, but little information is available to assess the risk. The source of poor-quality water within the western region is the geologic formations that underlie the groundwater basin, and the naturally occurring saline groundwaters within those formations. The existing distribution of poor-quality water within the Turlock groundwater basin is a result of natural upward groundwater flow from the deeper formations into the basin. Those deeper formations occur also within the eastern region of the basin, but they have not produced poor-quality water within that part of the basin because the likely direction of groundwater flow is downward from the basin into the older geologic formations. However, the groundwater-level declines within the eastern region of the basin probably have reversed the natural downward groundwater flow. Furthermore, that reversal probably has induced the upward migration of saline groundwater from the deep geologic formations into the basin, but the significance is unknown.

To enhance the ability to predict future groundwater conditions, better information is needed on hydrogeologic, groundwater, and water-use conditions within the eastern region of the Turlock basin. The existing information is sparse, and that

translates (through the model-calibration process) into uncertain model predictions. Better data are needed on the thicknesses and hydraulic properties of the geologic formations underlying the eastern region of the basin. Better information is needed on groundwater levels. Finally, better information is needed on water use, including information on well locations, well constructions, pumping rates, crop acreages, and irrigation practices.