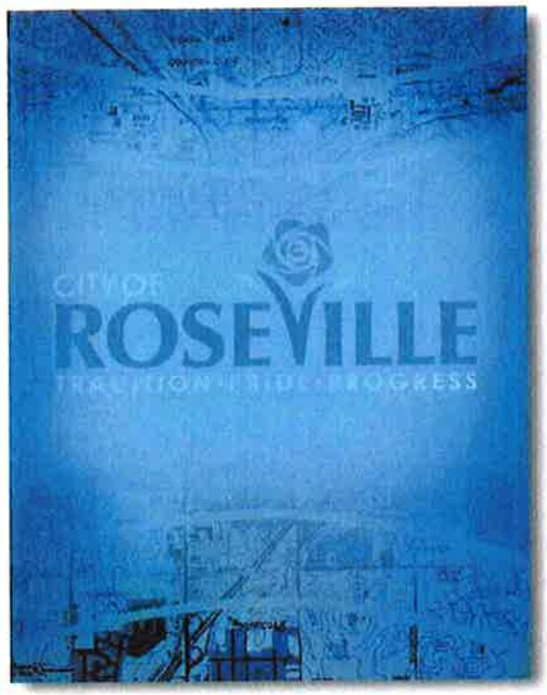
APPENDIX H-2
ATTACHMENT 7:

GROUNDWATER IMPACT ANALYSIS FOR PROPOSED REASON FARMS LAND RETIREMENT PLAN



Groundwater Impact Analysis for Proposed Reasons Farms Land Retirement Plan

MWH
MONTGOMERY WATSON HARZA

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1.1 BACKGROUND

The City of Roseville (City) is considering whether to provide water service to urban growth areas along the western boundary of the City. In particular, the City is considering delivery of water to the West Roseville Specific Plan (WRSP) area and the "City of Roseville/Placer County Memorandum of Understanding Transition Area" (together referred to as the "MOU area"). These areas are outside the existing City limits.

Before obligating itself to providing water service to the MOU area, the City is evaluating its ability to provide long-term, reliable water supplies to this area while maintaining service to its existing and future customers within the current City limits. Additionally, the City has adopted the policy that the cost of delivering water supplies to the MOU Area must not negatively impact the City's existing ratepayers financially.

City Environmental Utilities (EU) staff and MWH completed a preliminary evaluation of potential water supply alternatives for serving the MOU area in February 2002. The results of the evaluation were presented to the Roseville City Council. The preliminary evaluation identified a range of water supply alternatives that could potentially provide the City with the ability to provide long-term, reliable water supplies to the MOU area while maintaining service to its existing (and future) customers within the City limits. Based on the results, the City Council directed staff to more fully develop and evaluate the most promising alternatives, and to return with a recommended course of action.

In November 2002, EU staff and MWH completed a water supply strategy memorandum identifying "portfolios" of water supply sources that could meet the projected water demands of the WRSP area on a stand-alone basis, as well as the entire MOU area, under any hydrologic conditions. Groundwater extractions were an integral part of those portfolios, particularly in dry years. [Note: The use of groundwater in dry years is also part of the City's planned water supplies for the City's existing customers. The City's Water Forum Agreement (WFA) [1] identifies the extraction of up to 7,400 acre-feet per year (AF/year) of groundwater in dry years.]

The volumes of groundwater identified for delivery to the WRSP or MOU areas in dry years are not included in the City's WFA "water balance". Consequently, as a matter of policy, the City intends to implement measures to mitigate for any potential impacts to the groundwater basin that may result from the extraction of groundwater to meet demands in the WRSP area (or the MOPU area). One potential mitigation measure being contemplated is an "in-lieu" groundwater

[1] Begun in 1993, the Sacramento Area Water Forum (Water Forum) is comprised of representatives from the business, environmental, public interest, and water purveyor communities (including the Cooperating Agencies). The co-equal objectives of the Water Forum are 1) to provide a reliable and safe water supply for the region's economic health and planned development through the year 2030, and 2) to preserve the fishery, wildlife, recreational, and aesthetic values of the lower American River. The Water Forum Agreement prescribed a conjunctive use plan for Folsom Lake, the lower American River, and the adjacent groundwater basins to achieve those goals.

banking program accomplished through the annual fallowing or permanent retirement of agricultural lands currently irrigated with groundwater.

1.2 OBJECTIVE OF THIS STUDY

The primary objective of this study is to estimate the potential impacts on groundwater conditions resulting from an increase in groundwater extractions to meet a portion of the water demand associated with the **WRSP area** in dry years and to evaluate the potential mitigation of such impacts through the permanent retirement of agricultural lands currently irrigated with groundwater. [Note: This study addresses only the groundwater extractions anticipated to serve the water demands in the WRSP area.]

1.3 OVERVIEW OF MEMORANDUM

Previous memoranda provided estimates of existing and projected water demands for the existing City, the WRSP area, and the entire MOU area, and identified water supply alternatives for meeting those demands. This memorandum summarizes the results of those memoranda, and describes and summarizes the results of the groundwater impact analyses. This memorandum is organized into the following sections:

- **Section 1: Introduction** provides background information and a brief description of investigation objectives.
- **Section 2: Project Description** reviews water demand and water supply alternatives for the existing City, the WRSP area, and the entire MOU area.
- **Section 3: Geohydrology** characterizes the groundwater basin underlying the project area and provides a conceptual model on which the groundwater modeling application is based.
- **Section 4: Evaluation Scenarios** describes the methodology applied to complete the investigation and the various scenarios investigated.
- **Section 5: Modeling Results and Discussion** provides a summary of the modeling results and discusses potential impacts that may result the extraction of groundwater based on those modeling results.
- **Section 6: Principal Findings and Conclusions** describes the principle findings of the analyses and provides a conclusion of whether the proposed mitigation measures can meet the City's objectives.

Figures and tables are interspersed throughout the text. **Appendix A** presents groundwater elevation contour maps and hydrographs for all model runs. **Appendix B** includes a description of the numerical model used to complete the analysis.

2.1 INTRODUCTION

The City is located in the western Placer County (see **Figure 2.1**). The City currently relies predominately on surface water to meet potable water demand within its service area. Groundwater is extracted for peaking and emergency use, and for water supply reliability in dry years. Some non-potable demand is met with recycled wastewater.

The City overlies the regional Sacramento Valley groundwater basin. Sources of groundwater recharge include the American, Sacramento, Feather, and Bear Rivers; subsurface inflow from the foothills of the High Sierra; small streams and drainage canals; and deep percolation from rainfall and applied irrigation water.

2.2 CURRENT AND PROJECTED WATER DEMANDS

The preliminary evaluation provided estimates of current and projected water demands within both the existing City boundaries and the MOU area. Three "levels" of water demand were considered: 1) the City only, 2) the City plus the WRSP area, and 3) the City plus the entire MOU Area. These estimated water demands provided the basis for evaluating potential water supply alternatives and for determining the facilities required to make those alternative supplies available.

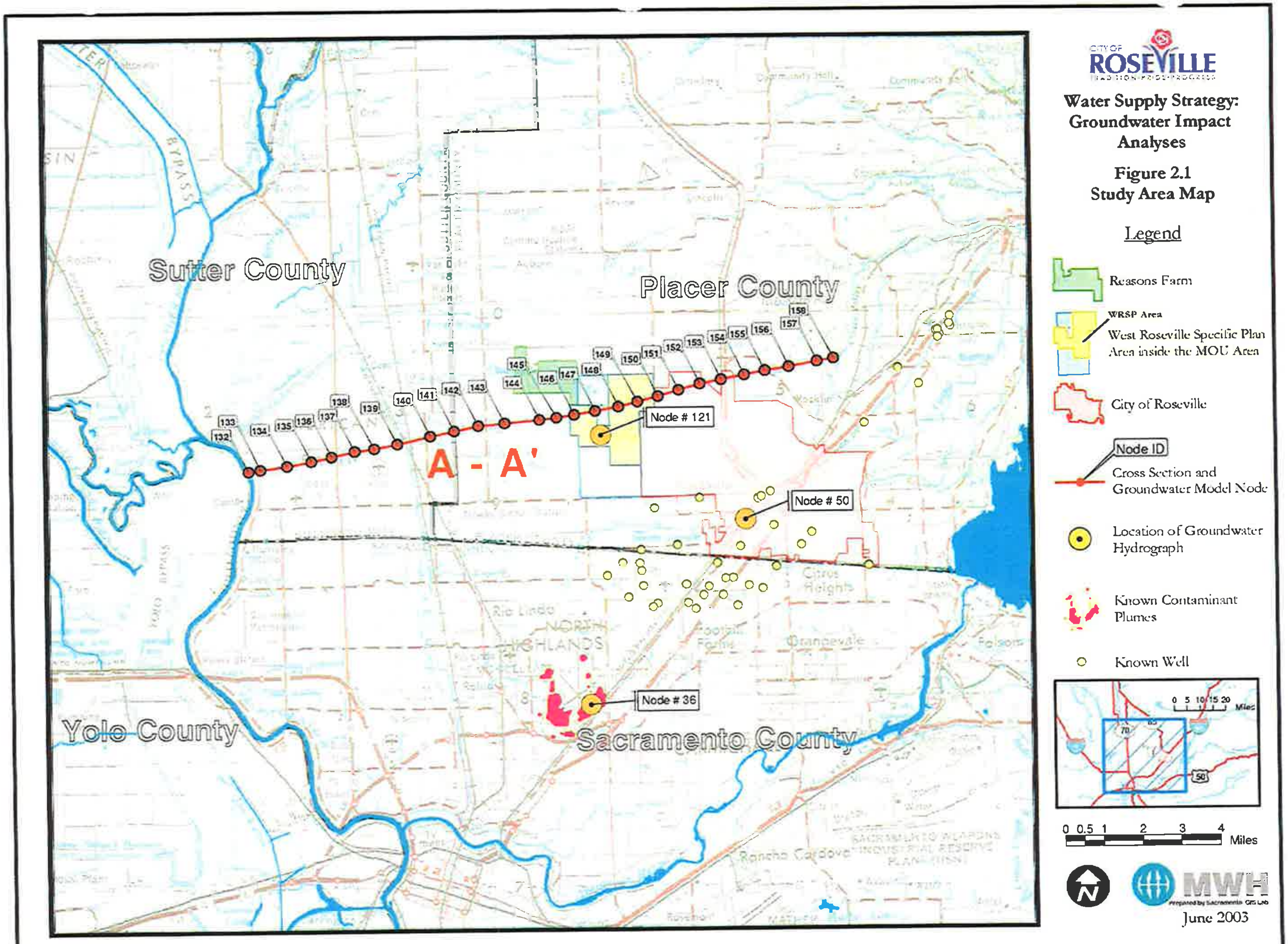
The *General Plan Update Water System Study* (Spink, August 1993) served as the City's initial basis for the estimates of water demand. "Revised" estimates of current and projected water demands were determined utilizing recently gathered water meter information. The new data indicate that unit water demands for the majority of land use categories in the City have decreased relative to the estimates used in the 1993 Spink study by almost 25 percent. The primary reason for this decline has been attributed to improved water conservation required for new construction within the City.

Table 2.1 presents the land use categories and total projected water demand for the City's existing service area, the WRSP area, and the entire MOU Area. The projected water demands include that portion of the City served with supplies contracted from the San Juan Water District (namely, Doctor's Ranch and the Foothills Business Park). **Table 2.1** presents water demands based on the revised unit demand factors.

Use of the revised unit water demand factors results in an estimated ultimate water demand for the City of 51,620 AF/year (see **Table 2.1**). The estimated ultimate water demand for the existing City plus the WRSP area is 58,662 AF/year, with 7,042 AF/year estimated for the WRSP area based on the proposed land use plan. The estimated ultimate water demand for the existing City plus the entire MOU area is 64,093 AF/year, with 12,473 AF/year estimated for the MOU area based on the proposed land use plan.

The City's current maximum surface water diversion from Folsom Lake under the WFA is 55,700 AF/year. This is also the total volume of water which the City is currently planning to provide on a reliable basis. This volume is 4,080 AF/year greater than the existing City's revised projected water demand shown on **Table 2.1** of 51,620 AF/year. The intent of the City is to make a portion of this water supply available for use in the MOU area.

The projected deficiency in the City's current water supply, assuming annexation of the entire MOU area is 8,393 AF/year (64,093 AF/year minus 55,700 AF/year). The projected deficiency



G:\City of Roseville\Water and Wastewater MP Update\Task 7\GW Contour maps_4_03\CrossSection.mxd in the City's current water supply assuming only the WRSP area develops is 2,962 AF/year (58,662 AF/year minus 55,700 AF/year).

Table 2.1 Estimated City of Roseville Average Annual Water Demands Based on Revised Unit Demand Factors

	Land Use Category	City of Roseville (AF/year)		West Roseville Specific Plan		Entire MOU Area	
				West Roseville Specific Plan (WRSP) Only (AF/year)	WRSP Combined with City (AF/year)	MOU Area Only (AF/year)	MOU Area Combined with City (AF/year)
		Estimated Existing Demand	Estimated Ultimate Demand	Estimated Ultimate Demand	Estimated Ultimate Demand	Estimated Ultimate Demand	Estimated Ultimate Demand
Residential	LDR (<3.5 DU's/Ac)	4,943	5,903	1,523	7,426	1,523	7,426
Residential	LDR (3.5 to 5.0 DU's/Ac)	8,222	13,524	2,339	15,863	5,741	19,265
Residential	LMDR (>5.0 to 6.0 DU's/Ac)	2,880	3,301	228	3,592	228	3,529
Residential	LMDR (>6.0 to 8.0 DU's/Ac)	1,594	2,030	214	2,244	570	2,600
Residential	MDR (>8.0 to 12.0 DU's/Ac)	401	761	157	918	157	918
Residential	HDR (>12.0 to 16.0 DU's/Ac)	32	115	229	344	229	344
Residential	HDR (>16.0 DU's/Ac)	1,347	1,948	211	2,159	534	2,482
Commercial/Other	Commercial/Retail	2,323	4,929	95	5,024	302	5,231
Commercial/Other	Business Professional	987	2,267	57	2,324	203	2,470
Commercial/Other	Light Industrial	858	4,120	258	4,378	258	4,378
Commercial/Other	Industrial	1,599	3,002	98	3,100	98	3,100
Commercial/Other	Railroad Yard	87	72	-	72	-	72
Commercial/Other	Elementary Schools	648	573	211	784	478	1,051
Commercial/Other	High Schools	408	597	242	839	242	839
Commercial/Other	Public (Fire Station, etc)	1,199	1,290	-	1,290	-	1,290
Commercial/Other	Park/Recreation	4,628	6,176	1,042	7,218	1,665	7,841
Commercial/Other	Open Space/Major ROW	-	-	-	-	-	-
Commercial/Other	Vacant/Unassigned	-	-	-	-	-	-
Sub-Total		32,155	50,608	6,904	57,512	12,228	62,836
Assumed System Losses (2%)		638	1,012	138	1,150	245	1,257
TOTAL:		32,794	51,620	7,042	58,662	12,473	64,093

2.3 CITY'S WATER SUPPLY ALTERNATIVES

2.3.1 CITY'S EXISTING WATER SUPPLIES

The City currently has three surface water contract entitlements for diversions from the American River totaling 62,800 AF/year: 1) a 30,000-AF/year contract with the Placer County Water Agency (PCWA) supplied from the Middle Fork Project (MFP); 2) a 32,000-AF/year contract with the United States Bureau of Reclamation (USBR) for a Central Valley Project (CVP) supply; and 3) an 800-AF/year contract with the San Juan Water District (San Juan) for delivery to the City's service area utilizing a portion of San Juan's PCWA contract water supply (also provided from the MFP).

The MFP supply is derived from reservoirs on the Middle Fork of the American River operated by PCWA for purposes of power generation for the Pacific Gas & Electric (PG&E) Company, as well as for water supply. The MFP supply is assumed to be 100 percent reliable (absent a catastrophic event) in all hydrologic year types. The City's CVP contract provides for a diversion from Folsom Lake. This water is considered to be less reliable than the MFP water and is currently subject to up to 25% deficiencies in accordance with CVP shortage provisions.

The WFA provides a framework for future surface water and groundwater supplies in the region through the year 2030. The City's WFA prescribes a pattern of surface water diversions based on unimpaired inflow into Folsom Lake [2]. Diversions by the City are restricted in drier and driest years with the objective of supporting environmental needs in the lower American River. In particular, the City is obligated to provide water for instream flows in the lower American River to the confluence with the Sacramento River under certain hydrologic conditions. This water is made available through re-operation of the MFP by PCWA. The principal consequence of this obligation is that the availability and reliability for diversions by the City out of Folsom Lake are impacted under certain hydrologic conditions.

Under the WFA, the maximum surface water diversion by the City in wet/average years is limited to 55,700 AF/year. In the "driest" (or critically dry) years, the maximum diversion is limited to 39,800 AF/year [3]. In between (i.e., in the years in which unimpaired inflow ranges between the volumes established for wet/average and driest years), the City may divert a pro rata amount between 55,700 and 39,800 AF/year based on unimpaired inflow into Folsom Lake. Based on the 70-year hydrologic period of record used for analyses conducted in support of the WFA, the entire 55,700 AF/year will be available for diversion by the City in about 83 percent of the years. Consequently, in 17 percent of the years the City must develop supplemental supplies potentially totaling up to 15,900 AF/year to make up for deficiencies (55,700 AF/year minus 39,800 AF/year). The City's current supplemental supply strategy includes the development of up to 3,000 AF/year of recycled water supplies (for non-potable use), development of up to 7,400 AF/year of sustainable groundwater supplies, and the implementation of up to 5,500 AF/year of additional conservation efforts, including rationing, in the driest years (this represents a 10% reduction in water use).

The total volume of American River water available for diversion by the City in a given year is also dependent on hydrologic availability; that is, the WFA provides for only a potential maximum diversion. In wet/average years, the WFA maximum amount of 55,700 AF/year will typically be available for diversion by the City. In the drier and driest years, however, it is likely that hydrologic conditions will impact surface water availability for the City. It is anticipated that CVP deficiencies will decrease the availability of surface water supplies to the City relative to the City's WFA in approximately 30 percent of the years. As a result, the entire 55,700 AF/year is estimated to be available for diversion by the City in about 63 percent of the years (versus the 83 percent potential availability provided for in the WFA).

As indicated on **Table 2.1**, the revised ultimate water demand projection for the City and the entire MOU area is 64,093 AF/year. If only the WRSP develops, the demand is 58,662 AF/year.

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[2] The WFA categorizes hydrologic years as "wet/average", "drier", or "driest" based on unimpaired inflow to Folsom Lake.

[3] The wet/average-year volume includes the 800 AF/year supply contracted from the San Juan Water District for service to Doctor's Ranch and the Foothill Business Park. That supply is not available in the driest years.

These demands exceed both the City's available dry-year surface water supply of 39,800 AF/year and the wet/average-year available surface water supply of 55,700 AF/year. Thus, if the entire MOU area develops, the City must implement its current plan to provide for up to 15,900 AF/year of supplemental supplies in critically dry years and develop an additional 8,393 AF/year of supplemental supplies (64,093 AF/year minus 55,700 AF/year). Similarly, if only the WRSP area develops, the City must develop 2,962 AF/year of supplies (58,662 AF/year minus 55,700 AF/year) in addition to the planned 15,900 AF/year of supplemental supplies.

2.3.2 POTENTIAL WATER SUPPLY ALTERNATIVES INVESTIGATED

The preliminary investigation identified five potential supplemental water supply alternatives for supplementing the City's existing water supplies with the objective of serving the WRSP and MOU areas:

- Re-allocation of a portion of the 55,700 AF/year wet/average-year water supply previously earmarked for the City's existing customers made available through recalculation and revision of the unit water demand factors
- An additional surface water contract entitlement from San Juan
- Recycled water supplies made available for non-potable use
- A future diversion of surface water from the Sacramento River
- Sustainable groundwater supplies for use in "drier" and "driest" years. [NOTE: The City's "Guiding Principles" require that the use of groundwater result in no net impact to the basin. Consequently, this alternative includes making a groundwater supply available by the permanent retirement of agricultural lands currently irrigated with groundwater and/or implementation of an aquifer storage and recovery (ASR) program.]

In addition to these five alternatives, the water supply strategy includes implementation of extraordinary water conservation efforts, including rationing, in the "drier" and "driest" years. The objective of these efforts is to reduce water demands by an additional 5 percent during drought. Such efforts parallel the City's existing WFA that requires a 10 percent reduction in water use during drought.

Results from the preliminary evaluation indicate that none of the identified potential supplemental supplies can entirely meet the anticipated additional water demands associated with the entire MOU area. However, a number of potential combinations of these supplemental supply sources will likely provide enough supply to meet those demands. The challenge for the City is one of timing. That is, the City must be assured that as the water demand associated with MOU area increases over time, the specific supplemental water supplies intended to meet that demand are available and operational.

2.3.3 GROUNDWATER EXTRACTION AND IMPACT MITIGATION

The use of groundwater during certain years is part of the City's current water supply planning. As discussed previously, the City's WFA includes the extraction of up to 7,400 AF/year of groundwater during the drier and driest Water Forum hydrologic year types. The City's current plan is to make those groundwater resources available to its existing customers.

The City also intends to consider the use of groundwater resources to meet water demand within the WRSP area in drier and driest years. Such use of groundwater is not explicitly considered in the WFA water balance. Consequently, the City intends to implement measures to mitigate for any potential impacts to the groundwater basin resulting from the extraction of groundwater to meet demands within the WRSP area. Two potential mitigation measures are currently being contemplated: 1) in-lieu groundwater recharge accomplished through the permanent fallowing of lands currently under irrigation, or 2) direct groundwater recharge through an aquifer storage and recovery (ASR) program. In particular, the Reasons Farms property (see **Figure 2.1**) is being evaluated from a physical standpoint to estimate the potential yield of an in-lieu groundwater banking program.

The proposed water supply strategies for the WRSP area and the entire MOU area developed in previous memorandum are shown on **Tables 2.2** and **2.3**, respectively. **Figures 2.2** through **2.4** illustrate the water supply strategy for the City, the WRSP area, and the entire MOU area, respectively.

Table 2.2 Proposed Water Supply Strategy for the WRSP Area

WFA Water Year Type	Source of Water Supply	Quantity of Water (AF/year)
Wet/Average years	Recycled Water	1,526
	City Demand Reduction	2,316
	San Juan Entitlement	3,200
	Total:	**7,042**
Drier and Driest years	Recycled Water	1,526
	City Demand Reduction	2,316
	Conservation	352
	Groundwater Extraction	2,848
	Total:	**7,042**

Table 2.3 Proposed Water Supply Strategy for the Entire MOU Area

WFA Water Year Type	Source of Water Supply	Quantity of Water (AF/year)
Wet/Average years	Recycle Water	2,638
	City Demand Reduction	4,080
	San Juan Entitlement	3,200
	Sacramento River Diversion	2,555
	Total:	**12,473**
Drier and Driest years	Recycle Water	2,638
	City Demand Reduction	4,080
	Conservation	620
	Sacramento River Diversion and/or Groundwater Extraction	5,135
	Total:	**12,473**

Figure 2.2 Water Supplies for City of Roseville under WFA (Estimated Demand: 51,620 AF/year in Year 2030)

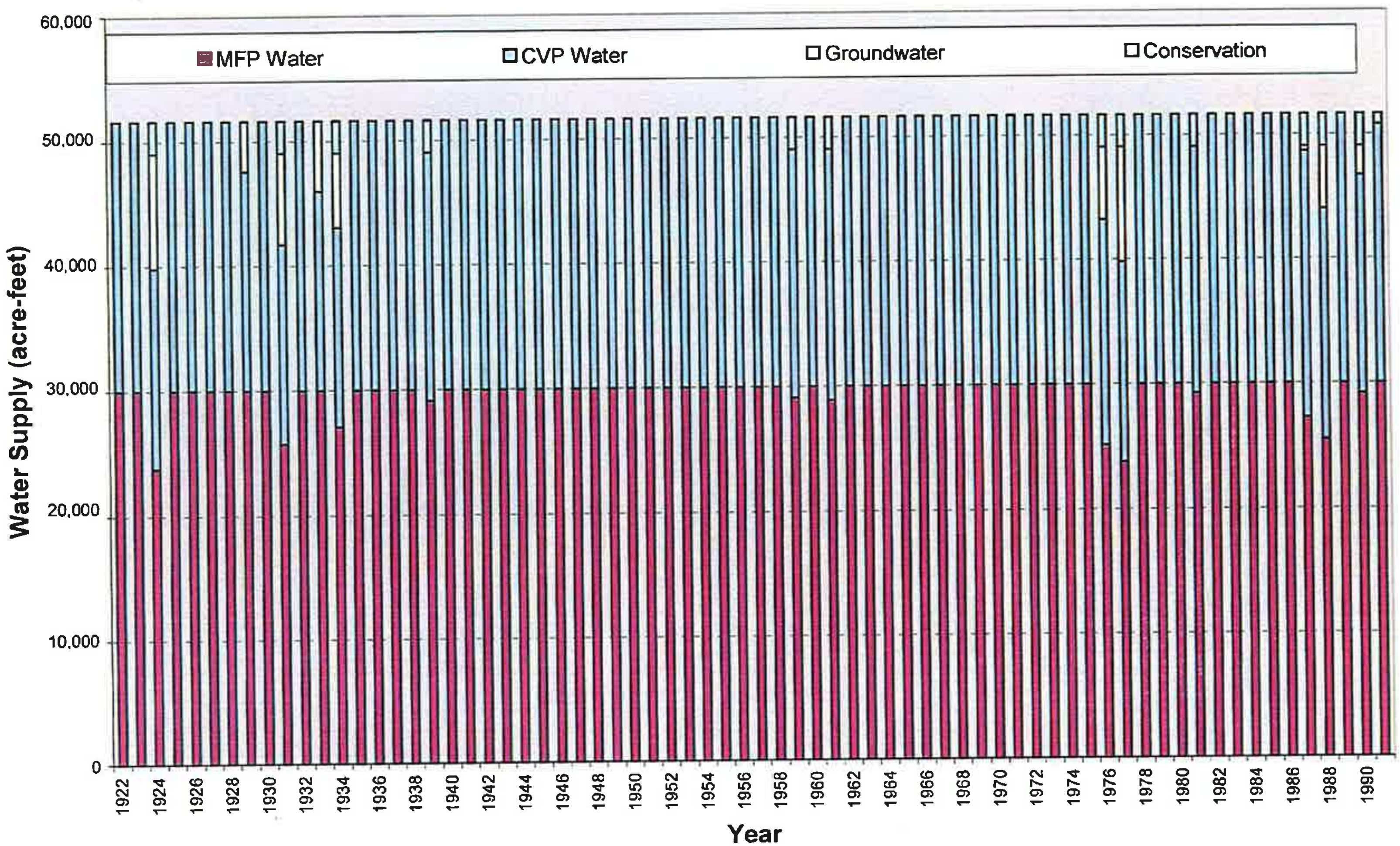


Figure 2.3 Proposed Water Supply Strategy for the WRSP Area (Estimated Demand: 7,042 AF/year at Buildout)

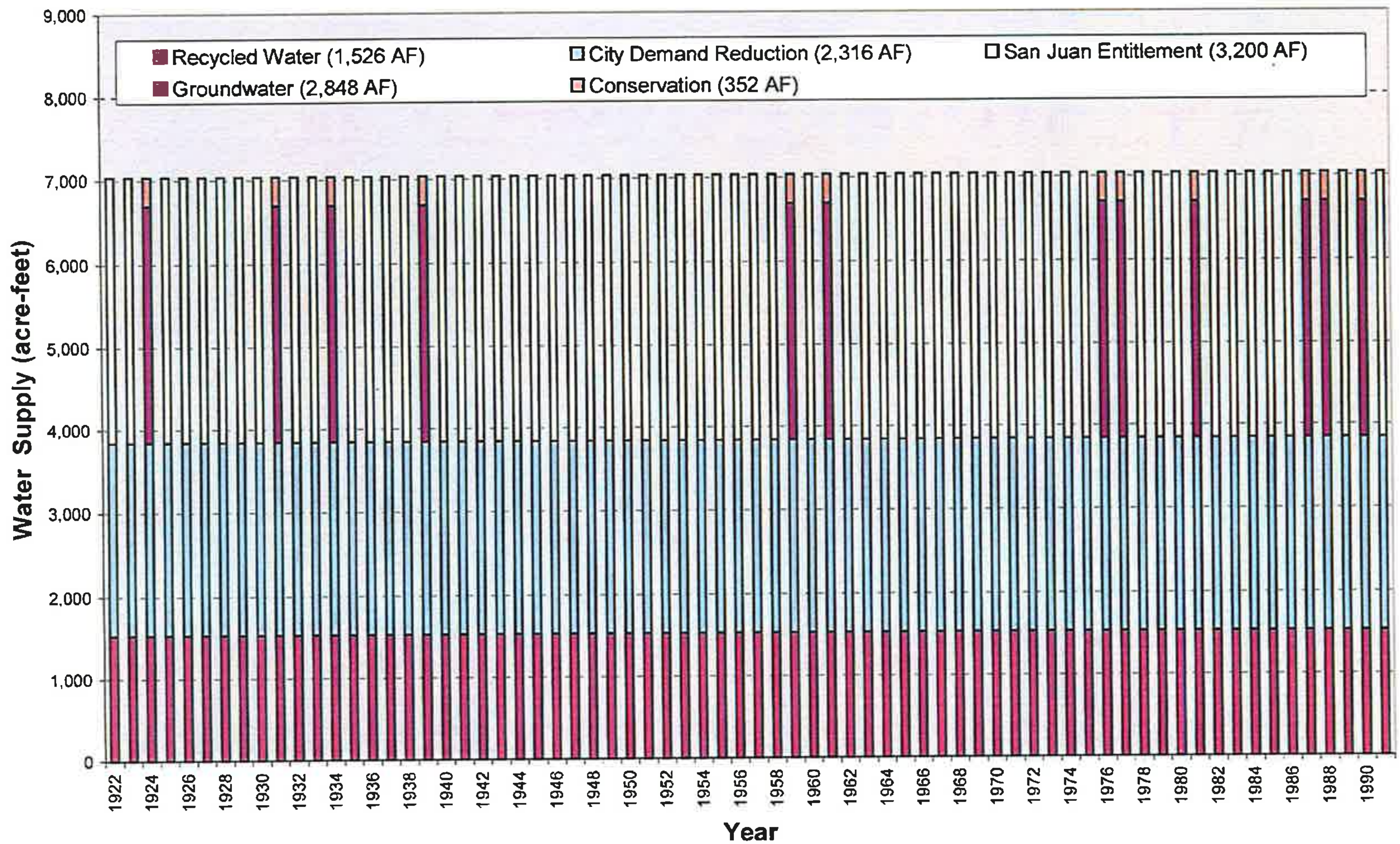
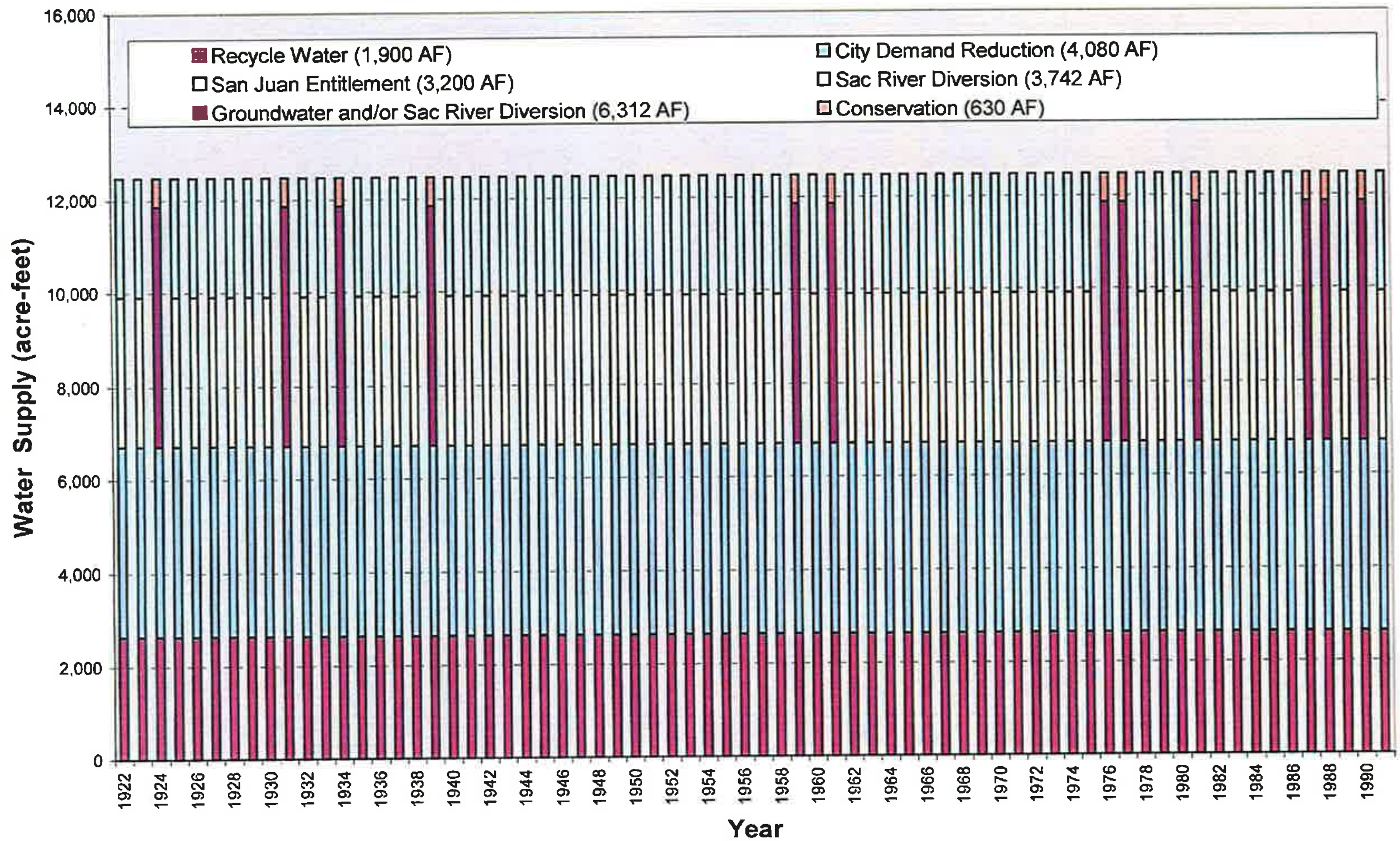


Figure 2.4 Proposed Water Supply Strategy for the Entire MOU Area (Estimated Demand: 12,473 AF/year at Buildout)



3.1 INTRODUCTION

The California Department of Water Resources (DWR) previously investigated groundwater resources in north Sacramento County. The results of this investigation are reported in *Bulletin 118-3, Evaluation of Ground Water Resources: Sacramento County* (DWR, July 1974). *Bulletin 118-3* identifies and describes the various geologic formations that constitute the water-bearing deposits underlying the project area. **Figure 3.1** at the end of this section presents a conceptual cross-section of the aquifer underlying the project area. These formations include an upper aquifer system (referred to as Aquifer 1 in this study) consisting of the Victor, Fair Oaks, and Laguna Formations, and a lower aquifer system (referred to as Aquifer 2) consisting primarily of the Mehrten Formation. These formations are typically composed of lenses of inter-bedded sand, silt, and clay, interlaced with coarse-grained stream channel deposits. These deposits form a wedge that generally thickens from east to west to a maximum thickness of about 2,000 feet under the Sacramento River.

Groundwater occurs in unconfined to semi-confined states throughout northern Sacramento County, western Placer County, and southern Sutter County [4]. Semi-confined conditions occur in localized areas; the degree of confinement typically increases with depth below the ground surface. Groundwater in the Victor, Fair Oaks, and Laguna Formations is typically unconfined. The deeper Mehrten Formation exhibits semi-confined conditions.

The water quality in the upper aquifer system is regarded as superior to that of the lower aquifer system. The upper aquifer is preferred over the lower aquifer principally because the lower aquifer system (specifically the Mehrten formation) manifests low concentrations of iron, manganese, and arsenic, which must often be removed through treatment. Water from the upper aquifer generally does not require treatment other than disinfection. The upper aquifer is typically targeted for development by private domestic wells.

The lower aquifer system also has higher concentrations of total dissolved solids (TDS, a measure of salinity). In general, at depths of approximately 1,200 feet or greater, the total dissolved solids concentration exceeds 2,000 milligrams per liter (mg/L). At such concentrations, the groundwater is no longer considered potable without treatment. For modeling purposes in this investigation, an artificial boundary was created over much of the model to distinguish between potable and non-potable groundwater supplies. The resulting low quality deep aquifer (referred to as Aquifer 3) was used to evaluate the potential for upwelling of poor quality water into the upper aquifer systems.

3.2 GROUNDWATER HYDRAULIC PRINCIPLES

Evaluating changes in groundwater conditions requires an understanding the dynamic processes and interactions that occur during groundwater extraction and recharge. Descriptions of induced groundwater recharge, changes in aquifer storage, and differences between localized and regional effects on the aquifer are presented below. These discussions are meant to clarify

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[4] The groundwater elevation is the elevation of the water surface in an unconfined aquifer. Groundwater under a confined state is described in terms of its piezometric surface elevation, rather than a water surface elevation. The piezometric surface elevation is the elevation to which water will rise within a well screened in a confined or semi-confined aquifer.

concepts. Not all aspects of groundwater hydraulics are described. Some of the concepts presented pertain only to the northern Sacramento County and western Placer County aquifer systems.

3.2.1 GROUNDWATER RECHARGE

Groundwater in the region generally moves from sources of recharge to areas of discharge. Recharge to a groundwater system occurs along active stream channels where extensive sand and gravel deposits exist. Locally, the highest groundwater elevations typically occur near the American River, Sacramento River, Feather River, and Bear River stream channels. Other sources of recharge include subsurface recharge from fractured geologic formations to the east, and deep percolation from applied irrigation water, precipitation, and small streams.

Changes in groundwater surface elevations result from changes in groundwater recharge, discharge, or extraction. In some instances within northern Sacramento County and western Placer County, this movement can induce natural recharge at locations where the river and aquifer are hydraulically connected. To the extent that a hydraulic connection exists, as groundwater conditions change, the slope or gradient of the groundwater surface may change as well. A steeper gradient away from the stream can induce additional recharge from surface streams.

The rate of recharge from streams that are hydraulically disconnected from the groundwater surface is indifferent to changes in groundwater elevations or gradient. This is typically true with smaller streams where the groundwater surface is located far below the streambed. In such cases, surface water percolates through the unsaturated zone to the groundwater and is a function of the aquifer materials underlying the streambed. As mentioned above, the rate of infiltration under these conditions is not governed by the gradient of the underlying groundwater.

3.2.2 CHANGES IN GROUNDWATER STORAGE

When a well first begins extracting groundwater from an aquifer, groundwater is initially extracted from aquifer storage. The result is a localized cone of depression that fluctuates with operation of the well. Over time, a well can also induce an incremental decline in regional groundwater elevations. The total amount of water lost from aquifer storage as a result of such well operation is the volume needed to induce an amount of recharge equal to the extraction rate of the well. This assumes that the induced recharge is sufficient to balance the groundwater system at the higher extraction rate. The period of time over which this balance occurs is typically measured in years.

3.2.3 LOCALIZED WELL IMPACTS

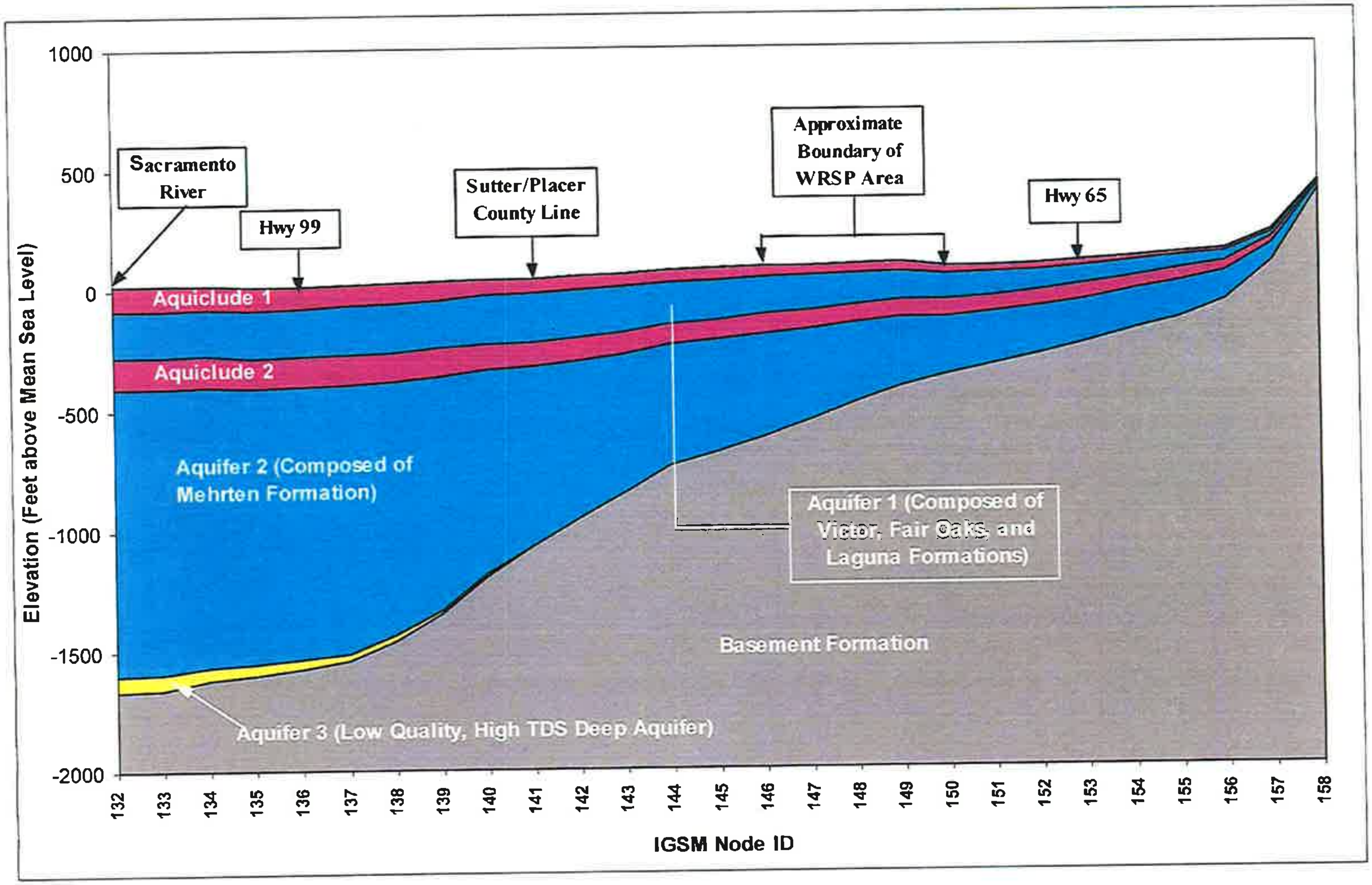
When extractions occur from a single well, a localized cone of depression is formed around the well. The shape and depth of the localized cone of depression depends on many factors including (but not limited to): 1) the rate of extraction, 2) the presence of nearby sources of recharge and extraction, 3) the volume of water stored in the aquifer, 4) aquifer transmissivity, and 4) the confined or unconfined state of the aquifer. Over a period of time, extraction from an unconfined aquifer can de-water the aquifer around the well. However, when extraction ceases, the aquifer often recharges back to its pre-extraction condition.

Confined or semi-confined aquifers behave differently than unconfined aquifers since the water is under pressure from a recharge source. Instead of de-watering the aquifer, a change in confining pressure occurs as a result of extractions. However, the aquifer remains saturated. In a confined aquifer, the pressure or piezometric surface elevation decline is more dramatic than in an unconfined aquifer; however, the recovery to pre-extraction conditions is much faster and the loss in aquifer storage is spread over a larger area.

3.2.4 REGIONAL GROUNDWATER IMPACTS

Cones of depression with a larger aerial extent can form in areas where multiple groundwater extraction wells are in operation. The location and shape of a regional cone of depression is influenced by the same factors as a single well. Fluctuations in regional cones of depression are measured over years and can result from: 1) changes in recharge, and 2) changes in volumes of groundwater extraction from increasing and decreasing water demands. A sequence of successive dry years can decrease the amount of natural recharge to the aquifer, creating an imbalance between natural recharge and extractions. To overcome the imbalance, the aquifer elevations lower to include more natural recharge. Over time, the shape and location of the aquifer's regional cone of depression fluctuates. Controlling the fluctuation within an acceptable range is often a principal focus of groundwater management efforts.

Figure 3.1 Conceptual Cross Section for Aquifer Underlying Project Area (See Cross Section A-A' in Figure 2.1)



4.1 INTRODUCTION

For this investigation, groundwater extraction and in-lieu recharge were simulated using the North American River and Sacramento County Combined Integrated Groundwater and Surface Water Model (IGSM). This model was originally developed for the American River Water Resources Investigation (ARWRI) and later updated by the American River Basin Cooperating Agencies for the Regional Water Master Plan. **Appendix B** presents information regarding development of the IGSM. The modeling approach applied for this investigation is discussed below.

4.2 STATIC RUN/INCREMENTAL IMPACT ANALYSIS

4.2.1 Static Run

A "Static Run/Incremental Impact" analysis approach was utilized for this study. With the static run approach, model parameters related to land use and water demand are set to certain values anticipated to prevail at some point in time. For modeling purposes, these anticipated levels of land use and water demand are assumed to occur in the first year of the groundwater simulation and in every subsequent year (that is, land use and water demand are held "static"). There is no "phasing" of water demand or changes in land use.

After water demand and land use parameters have been set, the simulation model is executed through the historical 70-year hydrologic record (1922 through 1991) used for the WFA. Approximately the first 10 to 20 years of the simulation are characterized by falling groundwater elevations as the model of the groundwater system achieves a quasi-equilibrium state in which the groundwater system is no longer affected by the initial conditions. Subsequent to the equilibration period, groundwater elevations in the model continue to fluctuate, but do so primarily in response to changing hydrologic conditions and operations of associated conjunctive use programs. The range within which the groundwater elevations fluctuate prescribes the estimated long-term response of the groundwater system to the assumed land use and water demand under the historical 70-year hydrologic sequence.

4.2.2 Incremental Impact

For purposes of this work, groundwater impacts were defined as the incremental changes between groundwater conditions corresponding to a "baseline" condition that does not include the proposed project and groundwater conditions resulting after the proposed project has been implemented. As the term is typically used for purposes of the California Environmental Quality Act ("CEQA"), a "baseline" is generally equated with the existing conditions in an area in which a project is proposed. For other planning purposes, a "baseline" condition can be defined as conditions that can reasonably be expected to occur in the future absent implementation of the proposed project. This second approach to defining a "baseline" is commonly referred to as a "cumulative without project" analysis, in that it predicts what the future would look like without the project. Both types of "baselines" provide useful information to the public and decision-makers. Consistent with this general discussion, two baselines are of interest in this work: 1) existing groundwater conditions, and 2) projected year 2030 groundwater conditions without the proposed project (i.e., a "cumulative without project" analysis).

The existing groundwater conditions "baseline", although somewhat self-explanatory, requires definition. It is, of course, representative of current groundwater conditions throughout northern

Sacramento County and western Placer County. However, it also is representative of how the groundwater basin is projected to respond over the historical 70-year hydrologic record if current land use and water demand were to remain unchanged. It is important to note that the groundwater basin will fluctuate in response to changing hydrologic conditions even if current land use and levels of water demand remain unchanged.

Although for land use projects such an inflexible "snapshot in time" approach is typical, projects involving water supply typically take a different approach in order to account for the variability of hydrological conditions in California. Consequently, as is discussed in more detail below, the projected year 2030 "cumulative without project" condition was used as the baseline against impacts were evaluated for this study. This baseline builds upon the extensive environmental and technical analyses prepared as part of the environmental review for the WFA.

4.3 EVALUATION SCENARIOS

Three scenarios were evaluated in this study: 1) a "Cumulative without Project Baseline" condition; 2) a "Project without Mitigation" condition; and 3) a "Project with Mitigation" condition. Each is discussed separately in the following sections.

4.3.1 CUMULATIVE WITHOUT PROJECT BASELINE CONDITION

The year 2030 cumulative without project baseline condition was evaluated for this investigation. Specifically, this baseline condition corresponds to the groundwater condition variations expected to result from implementation of the WFA in the City and all other areas of Placer and Sacramento counties, with the exception of the WRSP area. This baseline condition was selected for two principle reasons:

- First, the WFA reflects projected land use and water demand throughout Placer County and Sacramento County in the year 2030 pursuant to the current approved general plans
- Second, the WFA currently represents the most likely long-term plan for development of groundwater and surface water supplies in Placer County and Sacramento County.

The baseline condition for this investigation originates from the ARWRI version of IGSM used for the "Draft Water Forum Solution Model" developed for the WFA. The selection of this model (with the modifications described below) provides an estimate of how the groundwater basin would respond if elements of the WFA are implemented. Modifications to the model made for purposes of this study include:

- A reduction in frequency of delivery of PCWA transfer water to the Sacramento Suburban Water District (SSWD). The WFA simulation assumed delivery of 29,000 AF/year to SSWD in approximately 83% of the years. Then adopted pattern assumes these deliveries occur in 65% of the years. This assumption is more consistent with the terms and condition of the PCWA/SSWD transfer agreement.
- An update of the water demands for the City based on the revised unit demand factors as discussed in a previous memorandum. The revised built-out annual water demand for the City is 51,620 AF/year as compared to the original 54,900 AF/year.
- Under the WFA, the maximum surface water diversion by the City in wet/average years is limited to 55,700 AF/year. In critically dry years, the maximum diversion is limited to 39,800 AF/year. In below average to dry years, the City may divert an amount between

55,700 and 39,800 AF/year based on unimpaired inflow into Folsom Lake. In years that the surface water supply is less than the water demand, groundwater extraction is assumed to satisfy the unmet water demand (see **Figure 2.3**).

- In order to investigate the potential maximum impact of the development of the WRSP area on regional groundwater conditions, the land use in the WRSP area was changed to "native" (rather than "urban" or "agriculture" land uses). "Native" land use assumes zero water demand in IGSM model. Consequently, this modification will maximize groundwater extractions after the development of the WRSP area.

4.3.2 PROJECT WITHOUT MITIGATION CONDITION

The MOU area is planned to develop in two phases. It is assumed the WRSP area will develop first, followed by the development of the remainder of the MOU area in the future. The project without mitigation condition for the groundwater investigation here considers only the first phase of development (i.e., the WRSP area) for the following reasons:

- The development of the entire MOU area is dependent upon the implementation of Sacramento River Water Reliability Program. A feasibility study is currently being completed for this project.
- If the Sacramento River Water Reliability Program is implemented, the City anticipates potential delivery of up to 7,100 AF/year of additional surface water supplies. Under such a scenario, the need for groundwater extraction could potentially be avoided (see **Table 2.3**).
- The anticipated date for the operation of the Sacramento River Water Reliability Program is year 2010. Therefore, assuming reliance of the WRSP area on groundwater in dry years for a portion of its water supply represents a "worst case" scenario for groundwater extraction.

Modifications to the baseline condition model made to reflect the project without mitigation condition included:

- Land use in the WRSP area was changed from "native" to "urban" to maximize the water demand increase from the baseline. With the land use change in the project without mitigation condition, the urban water demand was changed to the estimated build-out urban water demand for the WRSP area.
- The ultimate water demand for the WRSP area is 7,042 AF/year based on the revised unit water demand factors and proposed land use plan of the WRSP area. As indicated in **Table 2.2**, the City demand reduction (2,316 AF/year) and water conservation in dry years (352 AF/year) were identified as part of the water supply. These water supplies are made available by conservation (that is, they are not actually "wet" water supply). The "actual" water demand for the WRSP area was input to the IGSM model by subtracting these two water supplies from the total water demand based on hydrologic conditions. As a result, the "net" water demand was 4,726 AF/year (7,042 minus 2,316) in wet/average years, and 4,374 AF/year (7,042 minus the sum of 2,316 and 352) in driest years.
- As indicated in **Table 2.2**, the water supply strategy is different for wet/average years and the drier and driest years. The water supplies were input in the IGSM model in a manner consistent with **Figure 2.3.** In wet/average years, water supplies included recycled water supplies of 1,526 AF/year and a San Juan entitlement of 3,200 AF/year. In the drier and driest years, the San Juan entitlement is not available. Thus, water supplies consisted of

recycled water of 1,526 AF/year and groundwater extraction of 2,848 AF/year. Note that the City demand reduction and conservation are excluded as water supplies because "net" water demand is used.

- The potential maximum amount of groundwater extraction modeled was 2,848 AF/year. Currently, the specific locations of the groundwater extraction wells have not been proposed. For modeling purposes, groundwater extraction was assumed at three locations within the WRSP area (which is the number of wells anticipated to meet water demand on a max day basis). Each of these locations is represented by a small area (or, computational element) over which groundwater extraction was assumed to occur uniformly. For each well, groundwater was assumed to be extracted from both the unconfined layer (Aquifer 1) and the confined layer (Aquifer 2). Each layer was assigned 50 percent of the total extraction volume.

4.3.3 PROJECT WITH MITIGATION CONDITION

Fallowing of the Reasons Farm has been proposed as a mitigation measure for the groundwater extraction contemplated for the WRSP area. Reasons Farm is a rice farm located in the area northwest to the WRSP area that is currently irrigated with groundwater. A total area of approximately 1,080 acres is currently under irrigation. By fallowing, the amount of groundwater currently used to irrigate Reasons Farm could be "banked" to alleviate (or eliminate) groundwater impacts associated with the development of WRSP area.

The groundwater conditions under this project with mitigation condition were also evaluated using the IGSM. The IGSM was modified from the project without mitigation to reflect the fallowing of the Reasons Farm. Modifications included:

- The land use for the Reasons Farm was changed from "agricultural" to "native" to reflect the fallowing of the Reasons Farm. This change reduces the agricultural water demand for Reasons Farm to zero.
- The estimated water demand for Reasons Farms (assuming rice production) is 6,483 AF/year (on average). Since a portion of the groundwater extracted and applied as irrigation water will return to groundwater basin through deep percolation, the actual recharge to the groundwater basin is equal to 6,483 AF/year minus the returning deep percolation. Results from the IGSM estimate that about 2,632 AF/year return to the groundwater via deep percolation. Consequently, the volume of groundwater recharge resulting from the fallowing of Reasons Farms is estimated to be 3,851 AF/year (6,483 AF/year minus 2,632 AF/year).

5.1 INTRODUCTION

The objective of this study is to estimate the potential impacts on groundwater conditions that would result from an increase in groundwater extractions to meet a portion of the water demand associated with the WRSP area and to evaluate the mitigation of such impacts through the permanent fallowing of agricultural lands (namely, Reason Farms) currently irrigated with groundwater. Specific impacts evaluated during this study included:

- Impacts on regional and local groundwater and piezometric surface elevations
- Impacts on groundwater and piezometric surface elevations in and around existing adjacent wells
- Impacts on groundwater elevations, piezometric surface elevations, and groundwater and piezometric surface gradients in and around adjacent known contaminant plumes
- Impacts on groundwater quality

To evaluate potential impacts and the effectiveness of the proposed mitigation measure, two principal types of information were developed: 1) groundwater and piezometric surface elevation contour maps, and 2) groundwater and piezometric surface elevation hydrographs at selected locations. The results of the groundwater modeling analyses are presented and discussed below. The principal findings and conclusions drawn from these results are presented in Section 6.

5.2 MODELING RESULTS

5.2.1 ELEVATION CONTOUR MAPS

Groundwater and piezometric surface elevation contour maps were developed for Aquifers 1 and 2, respectively, based on the results of the groundwater modeling. Elevation contour maps were generated to illustrate projected groundwater conditions at two times in the 70-year hydrologic period of record used in these analyses (from 1922 through 1991). The two times selected were at the end of simulation water year 15 (or, water year 1937) and at the end of simulation water year 62 (or, water year 1984). [Note: Water years run from October 1st of the first year through September 30th of the subsequent year.]

Simulation water year 15 occurs at the end of a sequence of drought years and is representative of the basin in a highly stressed condition. Conversely, simulation water year 62 occurs at the end of series of wet years and is representative of groundwater conditions at the end of a recovery period.

"Dry year" and "wet year" elevation contour maps (that is, at the ends of water years 15 and 62, respectively) were developed for the baseline condition, the project without mitigation condition, and project with mitigation condition for Aquifers 1 and 2. In addition, "difference contour" maps were developed to illustrate the incremental impacts to the basin resulting from changes in groundwater extraction and recharge.

Elevation contour maps are presented in **Appendix A.** Groundwater and piezometric surface elevation contours for the baseline condition are presented in **Figures A.1** through **A.4**. Groundwater and piezometric surface elevation contours for the project without mitigation are presented in **Figures A.5** through **A.12**. **Figures A.9** through **A.12** are difference contour maps that illustrate the incremental change between the baseline condition and the project without mitigation condition. Groundwater and piezometric surface elevation contours for the project with mitigation are presented in **Figures A.13** through **A.20**. **Figures A.17** through **A.20** are difference contour maps that illustrate the incremental change between the baseline condition and the project with mitigation condition.

Table 5.1 summarizes the modeling results for the project without and with mitigation based on **Figures A.9** through **A.12** and **Figures A.17** through **A.20**. The results are displayed to illustrate the difference between the project with and without mitigation relative to the baseline condition.

Table 5.1 Impacts on Elevations for the Project Without and With Mitigation

Project Conditions	Maximum Difference in Groundwater Elevation for Aquifer 1 in Dry Year [1] (ft)	Maximum Difference in Piezometric Surface Elevation for Aquifer 2 in Dry Year (ft)	Maximum Difference in Groundwater Elevation for Aquifer 1 in Wet Year [2] (ft)	Maximum Difference in Piezometric Surface Elevation for Aquifer 2 in Wet Year (ft)
Project without Mitigation	-3	-6	3	1.5
Project with Mitigation	4	2	9	8

1) The differences in groundwater elevation from baseline condition (1937 Hydrologic Year). Negative values represent a decline in groundwater elevation from the baseline condition. See figures in **Appendix A**.
2) The differences in groundwater elevation from baseline condition (1986 Hydrologic Year). Negative values represent a decline in groundwater elevations from the baseline condition. See figures in **Appendix A**.

5.2.2 GROUNDWATER HYDROGRAPHS

Hydrographs were developed at various locations to evaluate changes in elevations under different hydrologic conditions (see **Figures A.21** through **A.32**). Hydrographs were developed at the following locations (see **Figure 2.1**):

- **Within the WRSP area** – located in the center of the project area
- **Southern Pacific Roseville Railyard (SPRR)** – site of a known contaminant plume
- **McClellan Air Force Base (AFB)** – site of a known contaminant plume

Figures A.21 and **A.22** present the groundwater elevation hydrograph for aquifer 1 and the piezometric surface elevation hydrograph for aquifer 2 underlying the WRSP area, respectively. **Figures A.23** and **A.24** illustrate the differences in elevations at the same location for the project with and without mitigation. **Figures A.25** through **A.28** present similar hydrographs for the SPRR. In the same manner, **Figures A.29** through **A.32** represent hydrographs for McClellan AFB.

5.3 DISCUSSIONS OF MODELING RESULTS

The IGSM modeling results presented above were used to evaluate both 1) the potential impacts of groundwater extraction to meet a portion of the water demands of the WRSP area, and 2) the effectiveness of the proposed mitigation plan (i.e., the fallowing of Reasons Farm).

5.3.1 IMPACTS ON REGIONAL ELEVATIONS

5.3.1.1 Project without Mitigation

As discussed in Section 2, groundwater will be extracted in "dry" years to meet a portion of the water demand in the WRSP area (see **Figure 2.3**). Potential impacts identified based on IGSM modeling results included:

- In "dry" years, although groundwater extraction to serve water demands in the WRSP area do not result in an apparent cone of depression in either Aquifer 1 or Aquifer 2 (see **Figures A.5** and **A.6**), there are impacts versus the baseline condition (see **Figures A.9** and **A.10**). Groundwater surface elevations are up to three feet lower within the WRSP area; piezometric surface elevations are up six feet lower (see also the summary presented in **Table 5.1**). However, the impacts are largely confined to the boundaries of the MOU area and the City. To the extent that impacts extend beyond those boundaries, those impacts are positive (i.e., elevations are higher), even though mitigation measures have not been put in place. This is a consequence of the conversion of the WRSP area to an urban environment and the delivery of surface water (see also the hydrographs shown on **Figures A.21** through **A.24**).
- In "wet" years, there is no significant impact on groundwater or piezometric surface elevations because no groundwater is being extracted. In fact, similar to the dry years, to the extent there are impacts, these impacts are positive relative to the baseline condition (see **Figures A.11** and **A.12** and the hydrographs shown on **Figures A.21** through **A.24**).

5.3.1.2 Project with Mitigation

Reasons Farms is currently under agriculture production for rice. An estimated annual average of 6,483 AF/year of groundwater extracted from the aquifer underlying the property is applied for irrigation purposes each year to the approximate 1,080-acre site. Part of that water is lost to evapotranspiration (ET); however, part of that water returns to the groundwater through deep percolation. The City is purchasing the Reasons Farms property for use as a stormwater detention basin and has the option of fallowing that land on either an annual or permanent basis.

Permanent fallowing of the Reasons Farms property would result in the "banking" of groundwater [5]. The amount of groundwater banked is equal to the groundwater amount applied to the Reasons Farm minus the deep percolation. With the implementation of this mitigation plan (i.e., the permanent fallowing of Reasons Farm), the following potential benefits could be achieved:

[5] "Banking" means that groundwater that would have been extracted for irrigation purposes is left in the aquifer, in essence, "banked" for future use. The volume of banked groundwater is roughly equal to the groundwater lost to ET. [Note: The portion of the applied water that normally returns to the groundwater through deep percolation is not considered banked].

- Fallowing Reasons Farm would result, on average, I the banking of approximately 3,851 AF/year. The banking volume was obtained by subtracting the estimated deep percolation (approximately 2,632 AF/year) from the total groundwater extraction (6,483 AF/year).
- The decline in groundwater and piezometric surface elevations relative to the baseline condition resulting from groundwater extraction to serve a portion of the water demand in the WRSP area can be eliminated. In fact, fallowing Reasons Farms results in higher groundwater and piezometric surface elevations regionally (see **Figures A.17** and **A.20**). The hydrographs shown **Figures A.21** through **A.24** also indicate that groundwater and piezometric surface elevations with mitigation are higher relative to the baseline condition.
- With the fallowing of Reasons Farm, banked water would accumulate in the groundwater basin. This cumulative banked storage would result in a continuing increase in groundwater elevations until the groundwater system reaches a new equilibrium condition (see **Figures A.23** and **A.24**). In "dry" years, the groundwater extraction will decrease this storage, but elevations will recover rapidly. The rising portion of the curve in **Figure A.23** shows a groundwater level increase rate of four to five feet per year for Aquifer 1. **Figure A.24** shows a piezometric surface elevation increase rate of two to three feet per year.

5.3.2 POTENTIAL LOCAL IMPACTS ON GROUNDWATER ELEVATIONS

When extractions occurs from a single well, a concentrated localized cone of depression is formed around the well. The shape and depth of the localized cone of depression depends on many factors including but not limited to: 1) the rate of extraction, 2) the presence of nearby sources of recharge and extraction, 3) the volume of water stored in the aquifer, 4) aquifer transmissivity, and 4) the "confined" or "unconfined" state of the aquifer. Over a period of time, extraction from an unconfined aquifer can de-water the aquifer around the well. However, when extraction ceases, the aquifer typically recharges back to its pre-extraction condition.

A confined or semi-confined aquifer behaves differently since the water is under pressure from a recharge source. Instead of de-watering the aquifer, a change in confining pressure occurs as a result of extractions; the aquifer remains saturated. In a confined aquifer, the pressure or piezometric surface elevation decline is more dramatic than in an unconfined aquifer; however, the recovery to pre-extraction conditions is much faster and the loss in aquifer storage is spread over a larger area.

5.3.3 POTENTIAL IMPACTS ON SHALLOW DOMESTIC WELLS

In northern Sacramento and western Placer County, changes groundwater elevations in the upper aquifer will have the most effect on private domestic wells. [Note: Most domestic wells in the region are completed in the upper unconfined aquifer because of superior water quality of the upper aquifer.] As shown on **Figures A.17** and **A.19**, with the proposed mitigation plan in place, groundwater elevations in the upper aquifer are higher than they would have been relative to the baseline condition. In fact, even without mitigation groundwater extraction to serve a portion of the demands of the WRSP area should not negatively affect adjacent shallow domestic wells. (see **Figures A.9** and **A.11**).

5.3.4 POTENTIAL IMPACTS ON KNOWN CONTAMINANT PLUMES

As a consequence of past industrial, remedial, and waste management practices, a number of known groundwater contaminant plumes exist adjacent to the WRSP area. Two known contaminant plumes that could potentially be impacted by groundwater extraction in the WRSP area include (see **Figure 2.1**):

- Southern Pacific Roseville Railyard (SPRR)
- McClellan Air Force Base (AFB)

These sites are described below.

5.3.4.1 Site Descriptions

South Pacific Roseville Railyard

The SPRR site is an active railyard covering several hundred acres in Roseville. It is owned and operated by the Southern Pacific Transportation Company. Railyard activities have been carried out at the site for more than 80 years. The California Department of Toxic Substances Control (DTSC) files identify the site as SP-Roseville. Within the boundaries of the SPRR site, there are three separate operable units: SP Roseville – Area A; SP Roseville – Diesel Shop; and SP Roseville overall site. Known contaminants at the SPRR include: fuel oil; lubrication oils; solvents; volatile organics; polynuclear aromatic hydrocarbons (PAHs); and heavy metals. Additional detail on these sites can be found in the DTSC's "Site Cleanup/Site Mitigation and Brownfields Reuse Program Database".

McClellan AFB

The McClellan AFB site is currently subject to active remediation efforts. Known contaminants at McClellan AFB include: fuel oil; lubrication oils; solvents; volatile organics; polynuclear aromatic hydrocarbons (PAHs); and heavy metals.

5.3.4.2 Potential Impacts Evaluation

As shown on **Figures A.1** through **A.4**, there is a regional groundwater gradient from east to west/southwest away from the WRSP area. The McClellan AFB plumes are down-gradient from the WRSP area; the SPRR plumes are cross-gradient. It is highly unlikely that either plume could migrate onto the WRSP site or threaten the proposed groundwater extraction wells. In addition, as shown on **Figures A.9** through **A.12** and **A.17** through **A.20**, with or without the proposed mitigation measures in place, the groundwater and piezometric surface elevations and gradients are largely unaffected by the proposed project relative to the baseline condition. The change in elevations are negligible (several feet). The gradients are essentially unchanged.

5.3.5 GROUNDWATER QUALITY

The groundwater below the City is not currently used actively for municipal water supply. The City operates four wells within the City limits for emergency supply only. Two of these wells are located in downtown Roseville; two are located to the south near Interstate 80.

Specific laboratory analyses for groundwater quality were not conducted in this study. However, data were available from current efforts to develop the Diamond Creek Well located near the western boundary of the City (adjacent to the WRSP area). Groundwater quality at the Diamond Creek site is believed to be representative of the quality anticipated to be found beneath the WRSP area.

The Diamond Creek Well was developed recently and a well completion analysis was conducted in October 2002. **Table 5.2** provides a summary of the water quality results, along with historical data (from 1992 through 2002) in the City's other four wells.

Table 5.2 Summary of Selected Groundwater Quality Constituents at Diamond Creek Well

Constituent	Maximum Concentration	
	Diamond Creek Well [1]	Existing City Wells
Chloride, mg/L	170	81
Fluoride, mg/L	<0.5	0.4
Iron, mg/L	<0.05	0.1
Manganese, mg/L	<0.01	<0.03
Nitrate (as N), mg/L	7	21
Nitrite (as N), mg/L	<0.05	<0.4
pH, units	7.1	7.8
Sodium, mg/L	78	62
Total Dissolved Solids, mg/L	460	410

[1] Based on single sample collected during well operation test

The data in **Table 5.2** indicate that the groundwater below the WRSP area can be characterized as a highly mineralized. There are high levels of minerals and salts, but generally low levels of metals. The pH is neutral and nitrate appears to have contaminated some areas of the region. This water is treatable to potable water standards. Groundwater quality underlying the WRSP area will not be affected by the implementation of the WRSP.

5.3.6 SENSITIVITY ANALYSES

5.3.6.1 Sensitivity Analysis on Groundwater Elevation Impacts

Sensitivity analyses were conducted for the project without mitigation condition assuming 10 percent extraction Aquifer 1 and 90 percent extraction from Aquifer 2. The purpose of increasing the groundwater extraction percentage in Aquifer 2 is to investigate the sensitivity of the groundwater impacts to well construction.

Model results indicate that the groundwater elevation changes will not be significantly affected. The maximum decrease in elevations for the "10/90 case" were two feet in Aquifer 1 and eight feet in Aquifer 2, as compared to three feet in Aquifer 1 and six feet in Aquifer 2 for the "50/50 case". Consequently, the 50/50 groundwater extraction assumption was more conservative in estimating the groundwater impacts for Aquifer 1. For Aquifer 2, the declining piezometric surface elevation represents the decrease in pressure in the lower confined aquifer instead of dewatering as in the unconfined upper aquifer.

5.3.6.2 Sensitivity Analysis on Proposed Mitigation Measure

Sensitivity analyses were conducted to investigate the sensitivity of the impacts of the mitigation measures to change in the fallowed acreage. **Table 5.3** and **Figure 5.1** summarize the modeling results for water year 1977 to represent "dry" year conditions.

Results indicate that the fallowing of Reasons Farm is more effective on Aquifer 1 than on Aquifer 2 in restoring groundwater elevations. As shown in **Figure 5.1**, the groundwater elevation in Aquifer 1 can be restored to the baseline condition by fallowing approximately 500 acres of Reasons Farm. However, 850 acres is required to mitigate the impact for Aquifer 2.

Table 5.3 Results of Sensitivity Analysis on Proposed Mitigation Measure

No.	IGSM Model Runs	Acres of Fallowed Rice Land in the Reasons Farm	Maximum Difference in Groundwater Elevation for Aquifer 1 in Dry Year [1] (ft)	Maximum Difference in Piezometric Surface Elevation for Aquifer 2 in Dry Year (ft)
1	Without Fallowing Reasons Farm	0	-3	-6
2	Fallowing northern portion of Reasons Farm	584	0.5	-2
3	Fallowing northern portion plus half south portion of Reasons Farm	848	2.5	0
4	Fallowing entire Reasons Farm	1,080	4	2

1) The differences in groundwater elevation from "baseline condition" (1977 Hydrologic Year). Negative values represent a decline in groundwater levels from the "baseline condition".

Figure 5.1 Plot of Sensitivity Analysis Results

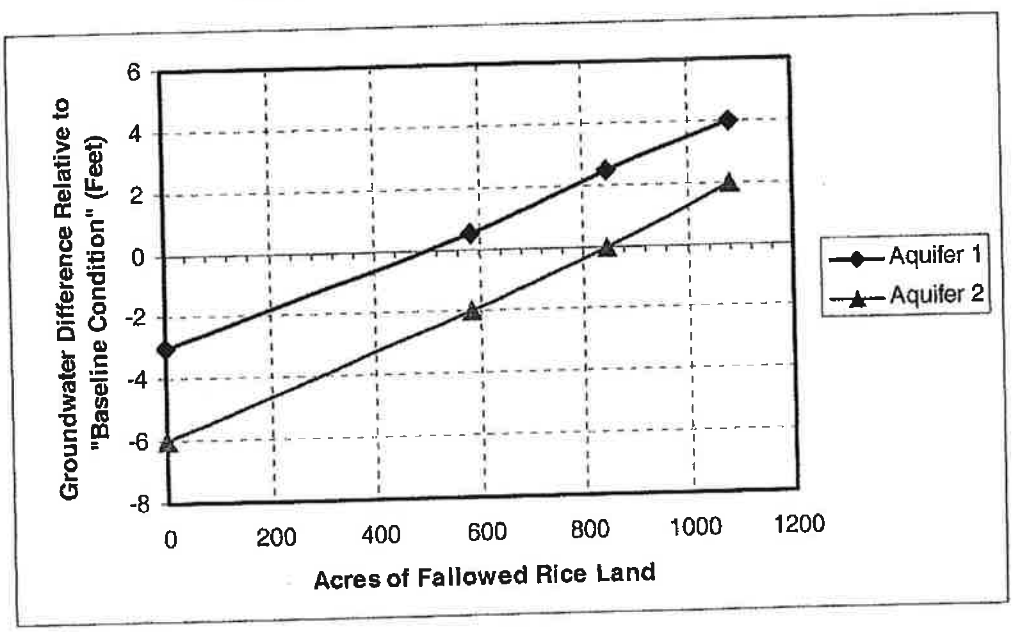


Table 5.4 shows the groundwater amount can be banked by fallowing various acres of the Reasons Farm.

Table 5.4 Groundwater "Banking" by Fallowing Various Acres of the Reasons Farm

No.	IGSM Model Runs	Acres Fallowed on Reasons Farm	Groundwater Supply (acre-feet)	Deep Percolation (acre-feet)	Banked Volume (acre-feet)
1	Fallowing north portion of the Reasons Farm	584	3,539	1,541	1,998
2	Fallowing north portion plus half south portion of the Reasons Farm	848	5,111	2,131	2,980
3	Fallowing the entire Reasons Farm	1,080	6,483	2,632	3,851

6.1 PRINCIPAL FINDINGS

Three conditions were evaluated in this study to investigate potential groundwater impacts associated with the development of the WRSP area and the proposed mitigation measure of fallowing Reasons Farm on a permanent basis.

- If the City extracts groundwater for the purpose of meeting water demands in the WRSP area as estimated under the proposed water supply strategy, the resulting impacts on groundwater basin without mitigation would be include a maximum decrease in groundwater surface elevations in Aquifer 1 of about three feet and a maximum decrease in piezometric surface elevation in Aquifer 2 of about six feet.
- The Reasons Farms property is currently under agriculture production for rice. About 6,483 AF/year of groundwater, extracted from the aquifer underlying the property, is applied for irrigation purposes each year to the 1,080-acre site. The major portion of that water is lost to ET while a small amount returns to the groundwater through deep percolation (about 2,632 AF/year). The City has the option of purchasing the Reasons Farms property and of fallowing that land on either an annual or permanent basis. Permanent fallowing of the Reasons Farms property would result in the "banking" of about 3,851 AF/year of groundwater.
- The City's proposed water supply strategy for the WRSP area contemplates extraction of up to 2,848 AF/year of groundwater under certain hydrologic conditions. Permanent fallowing of the Reasons Farms property fully mitigates for impacts to groundwater elevations resulting from the extraction of groundwater to serve a portion of the water demand of the WRSP area.
- The impacts resulting from groundwater extraction are largely limited to the MOU area. The groundwater extraction will not significantly affect the groundwater quality, the movement of known contaminant plumes, or adjacent shallow domestic wells.

6.2 CONCLUSIONS

The permanent fallowing of the Reasons Farms property provides sufficient groundwater banking to fully mitigate for the anticipated groundwater extraction under the City's proposed water supply strategy for meeting water demands in the WRSP area.

APPENDIX A

Contour Maps and Hydrographs From IGSM Modeling Results

LIST OF FIGURES

Figure A.16 – Project with Mitigation Aquifer 2 Piezometric Surface Elevation Contours Wet Year

Figure A.17 - Project with Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours Dry Year

Figure A.18 - Project with Mitigation Aquifer 2 Piezometric Surface Elevation Difference Contours Dry Year

Figure A.19 - Project with Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours Wet Year

Figure A.20 - Project with Mitigation Aquifer 2 Piezometric Surface Elevation Difference Contours Wet Year

Figure A.21 Groundwater Elevation Hydrograph for Aquifer 1 Underlying the WRSP Area (Node #151)

Figure A.22 Groundwater Piezometric Surface Elevation Hydrograph for Aquifer 2 Underlying the WRSP Area (Node #151)

Figure A.23 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying the WRSP Area (Node #151)

Figure A.24 Groundwater Piezometric Surface Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying the WRSP Area (Node #151)

Figure A.25 Groundwater Elevation Hydrograph for Aquifer 1 Underlying South Pacific Roseville Railyard (Node #50)

Figure A.26 Groundwater Elevation Hydrograph for Aquifer 2 Underlying South Pacific Roseville Railyard (Node #50)

Figure A.27 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying South Pacific Roseville Railyard (Node #50)

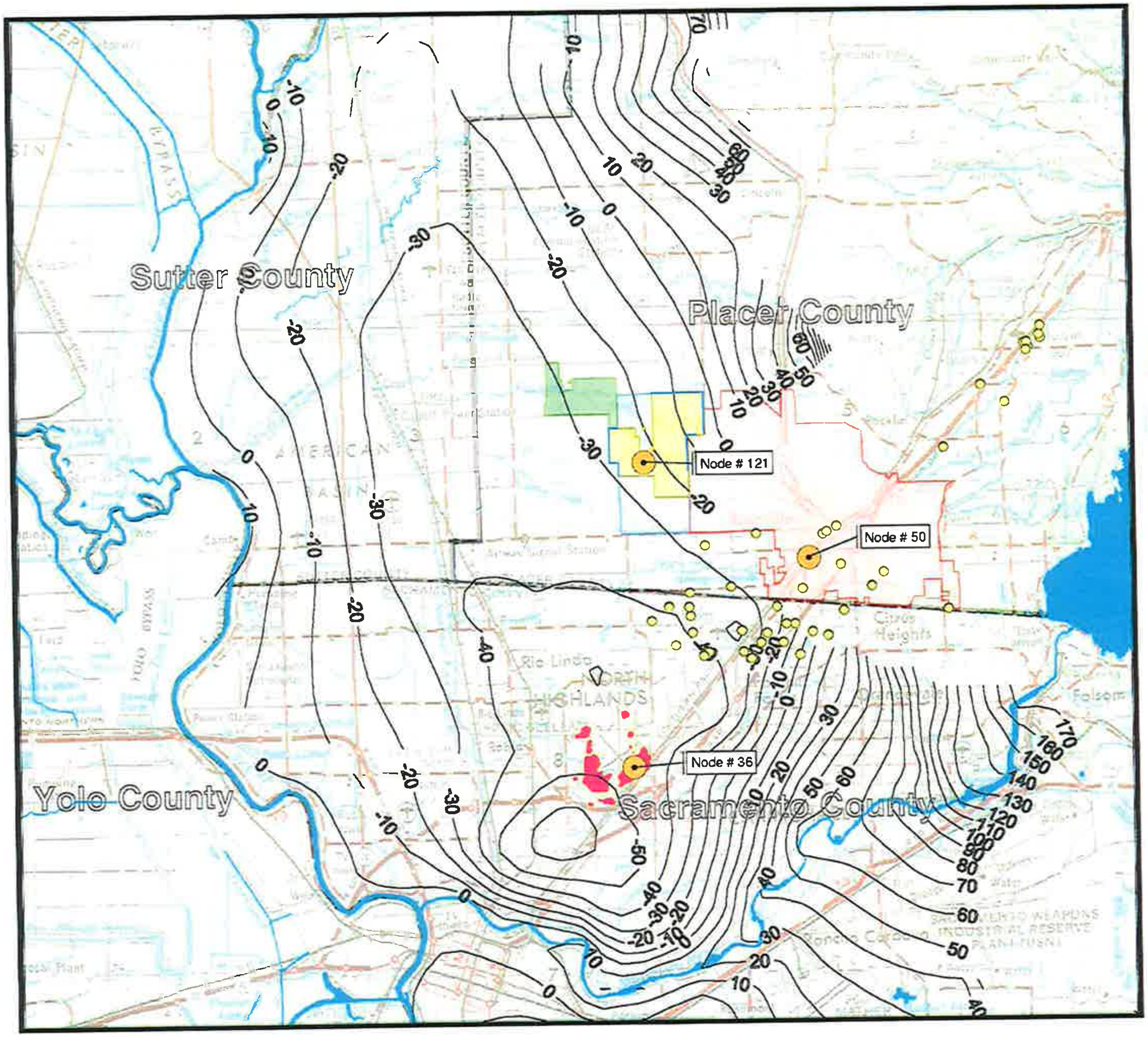
Figure A.28 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying South Pacific Roseville Railyard (Node #50)

Figure A.29 Groundwater Elevation Hydrograph for Aquifer 1 Underlying McClellan Contaminant Plumes (Node #36)

Figure A.30 Groundwater Elevation Hydrograph for Aquifer 2 Underlying McClellan Contaminant Plumes (Node #36)

Figure A.31 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying McClellan Contaminant Plumes (Node #36)

Figure A.32 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying McClellan Contaminant Plumes (Node #36)



CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.1
Baseline Condition Aquifer 1 Groundwater Surface Elevation Contours Dry Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- —20— Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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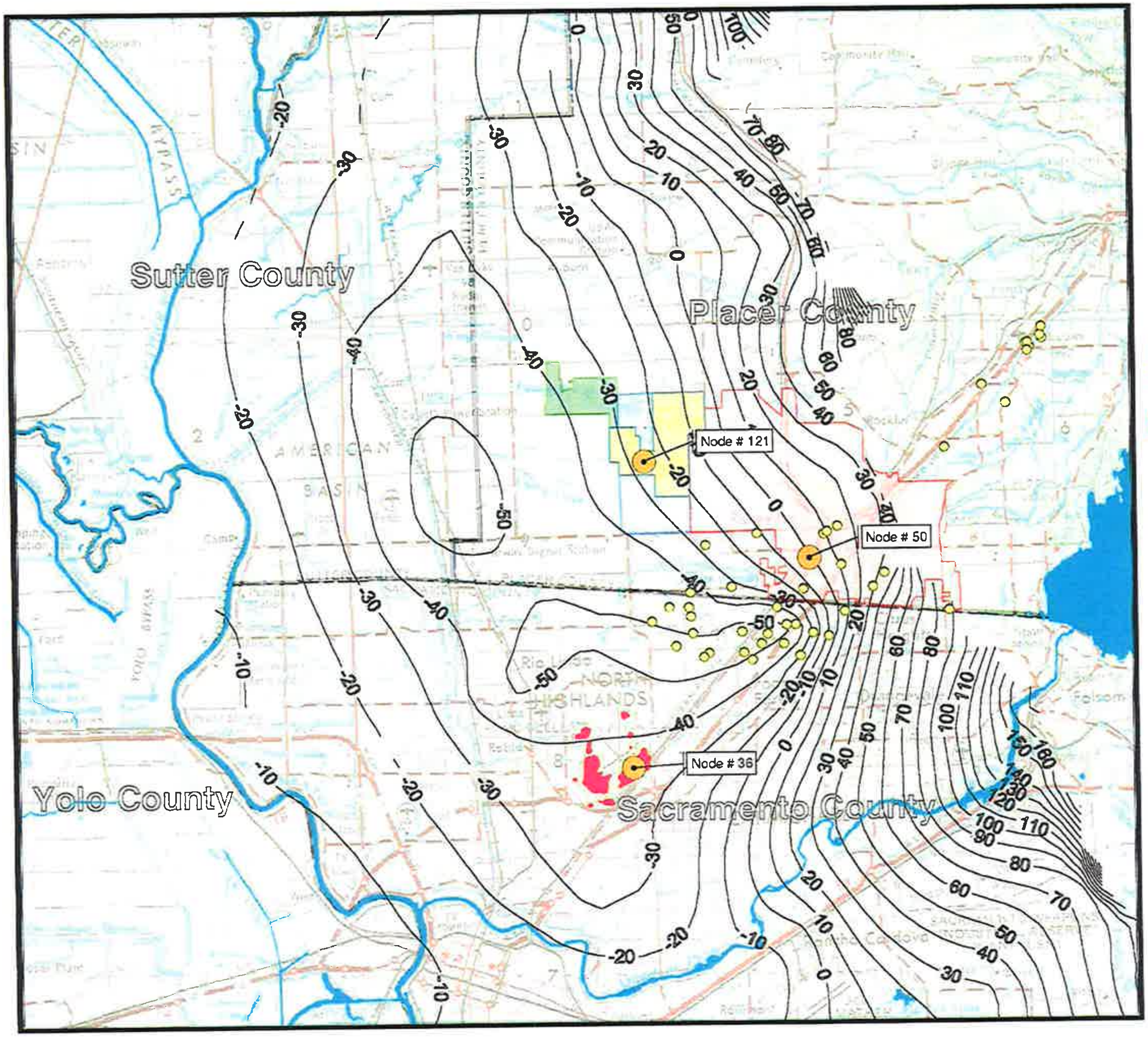
CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.2
Baseline Condition
Aquifer 2 Piezometric Surface Elevation Contours
Dry Year



__Legend__

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- —20— Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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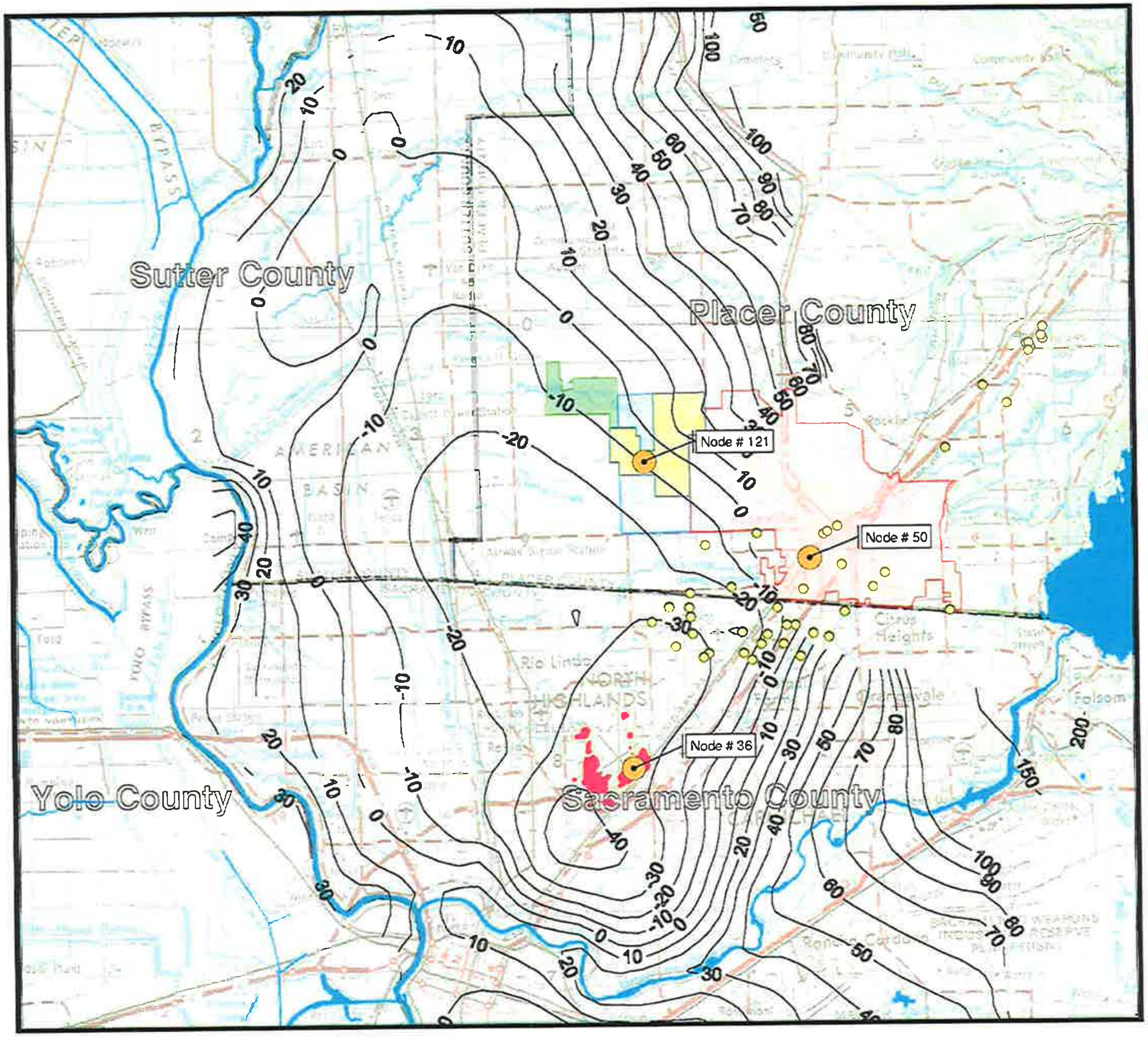

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.3
Baseline Condition
Aquifer 1 Groundwater Surface Elevation Contours
Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- —30— Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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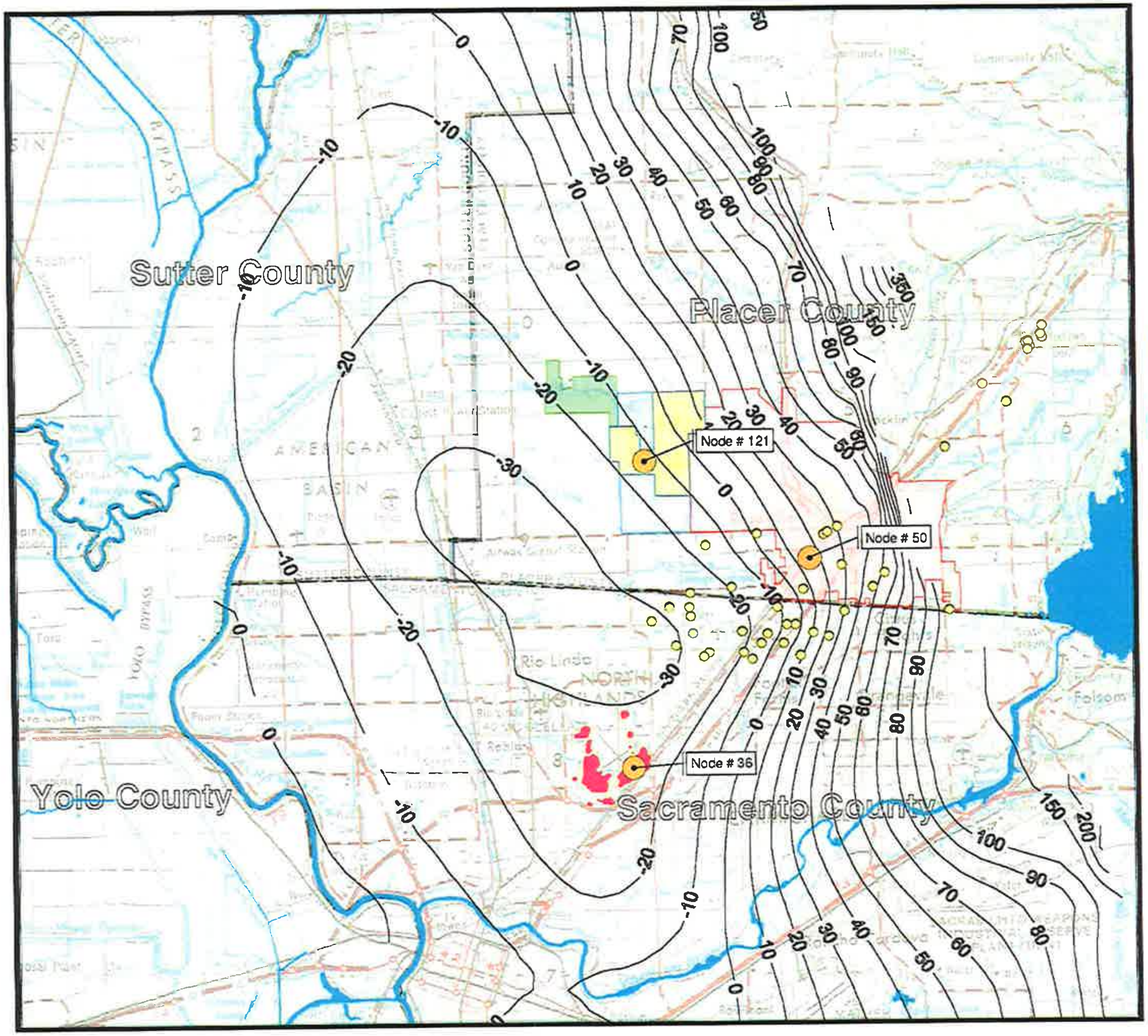

ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.4
Baseline Condition
Aquifer 2 Piezometric Surface Elevation Contours
Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- —20— Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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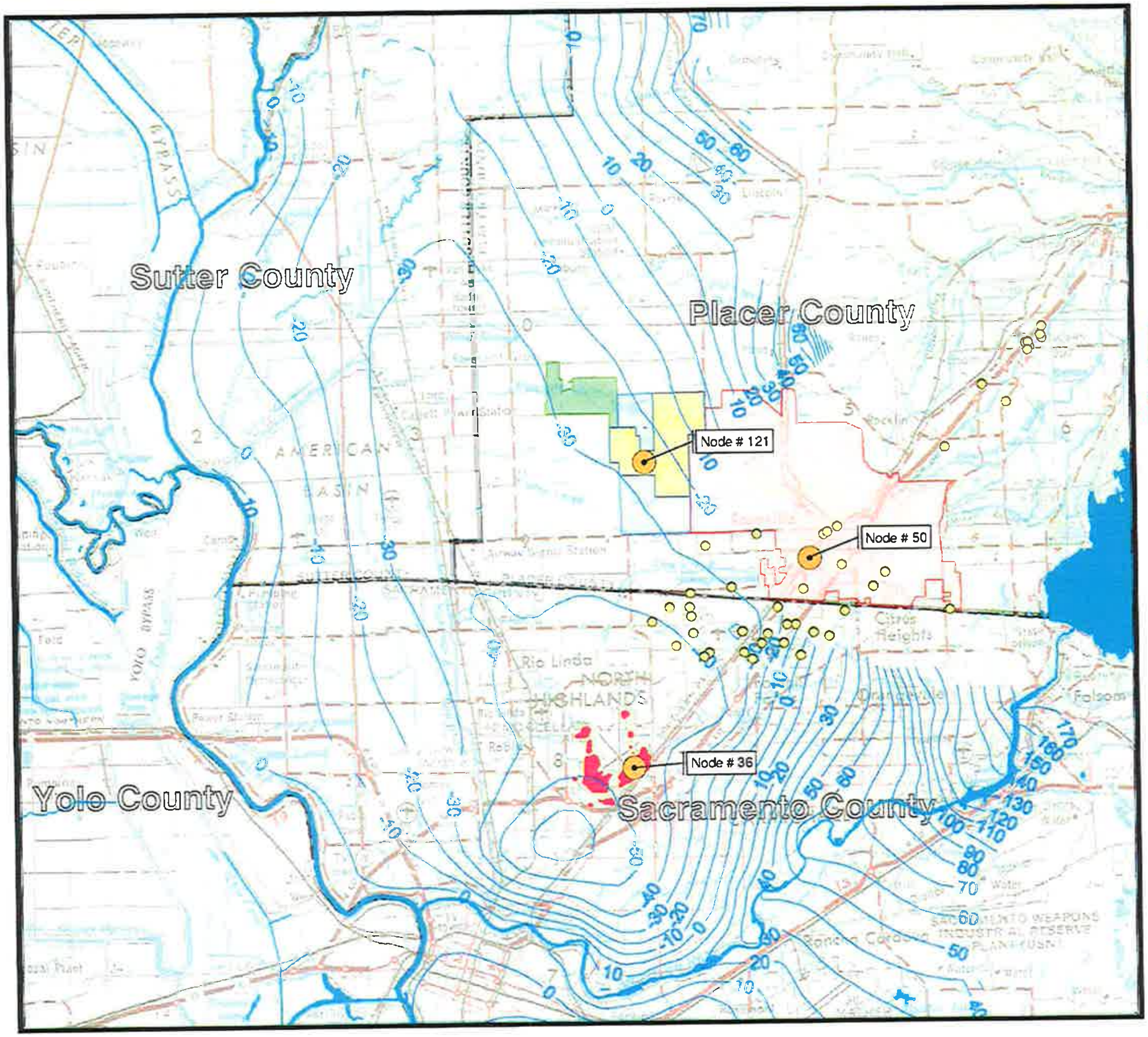

Water Supply Strategy: Groundwater Impact Analyses

Figure A.5
Project without Mitigation
Aquifer 1 Groundwater
Surface Elevation Contours
Dry Year

Legend

Reasons Farm

City of Roseville

WRSP Area

West Roseville Specific Plan Area inside the MOU Area

Piezometric Surface Elevation Contour in feet above Mean Sea Level

Location of Groundwater Hydrograph

Known Contaminant Plumes

Known Domestic Well

0 1 2 4 Miles

June 2003

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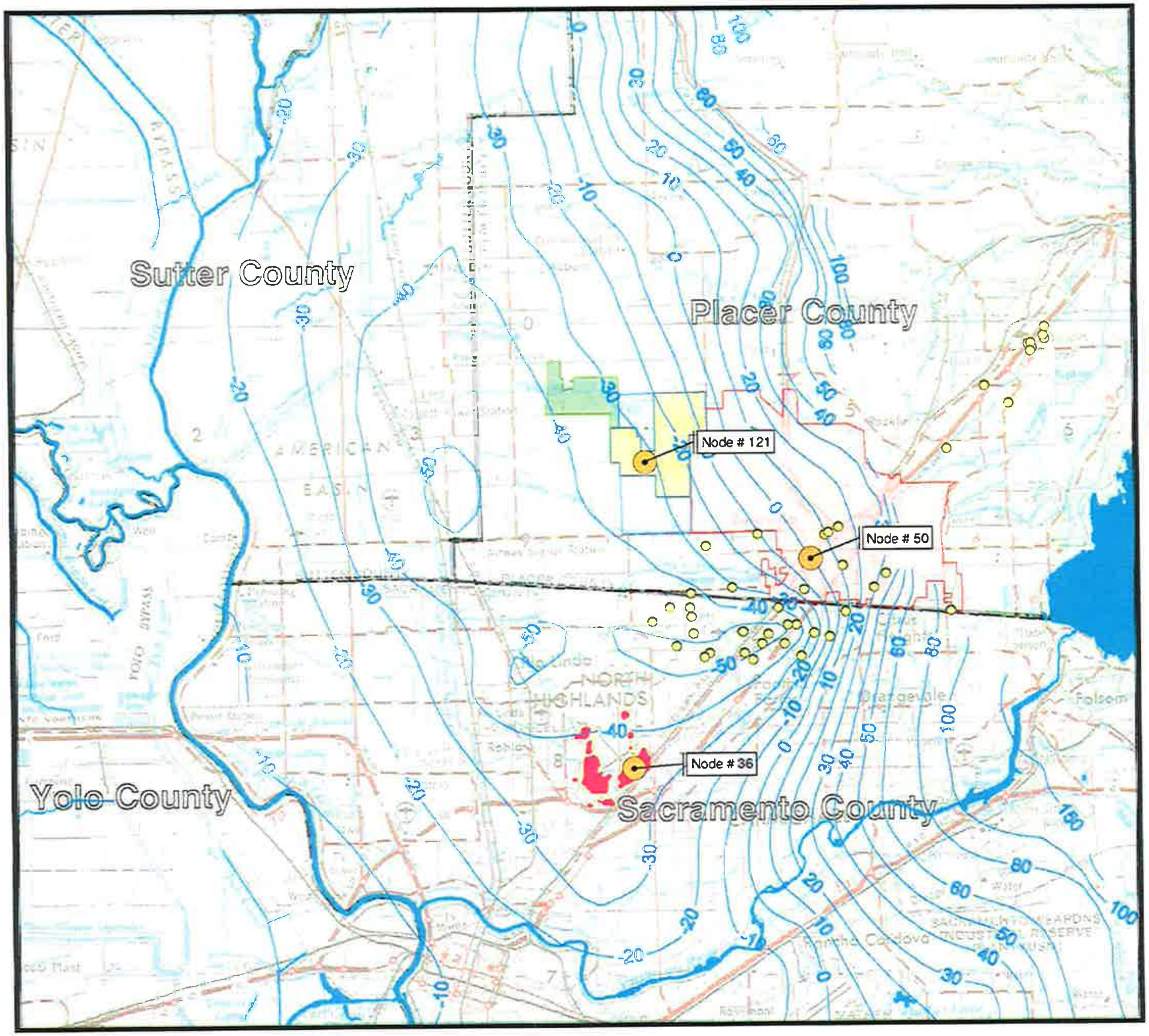
Water Supply Strategy: Groundwater Impact Analyses

Figure A.6
Project without Mitigation Aquifer 2 Piezometric Surface Elevation Contours

Dry Year



Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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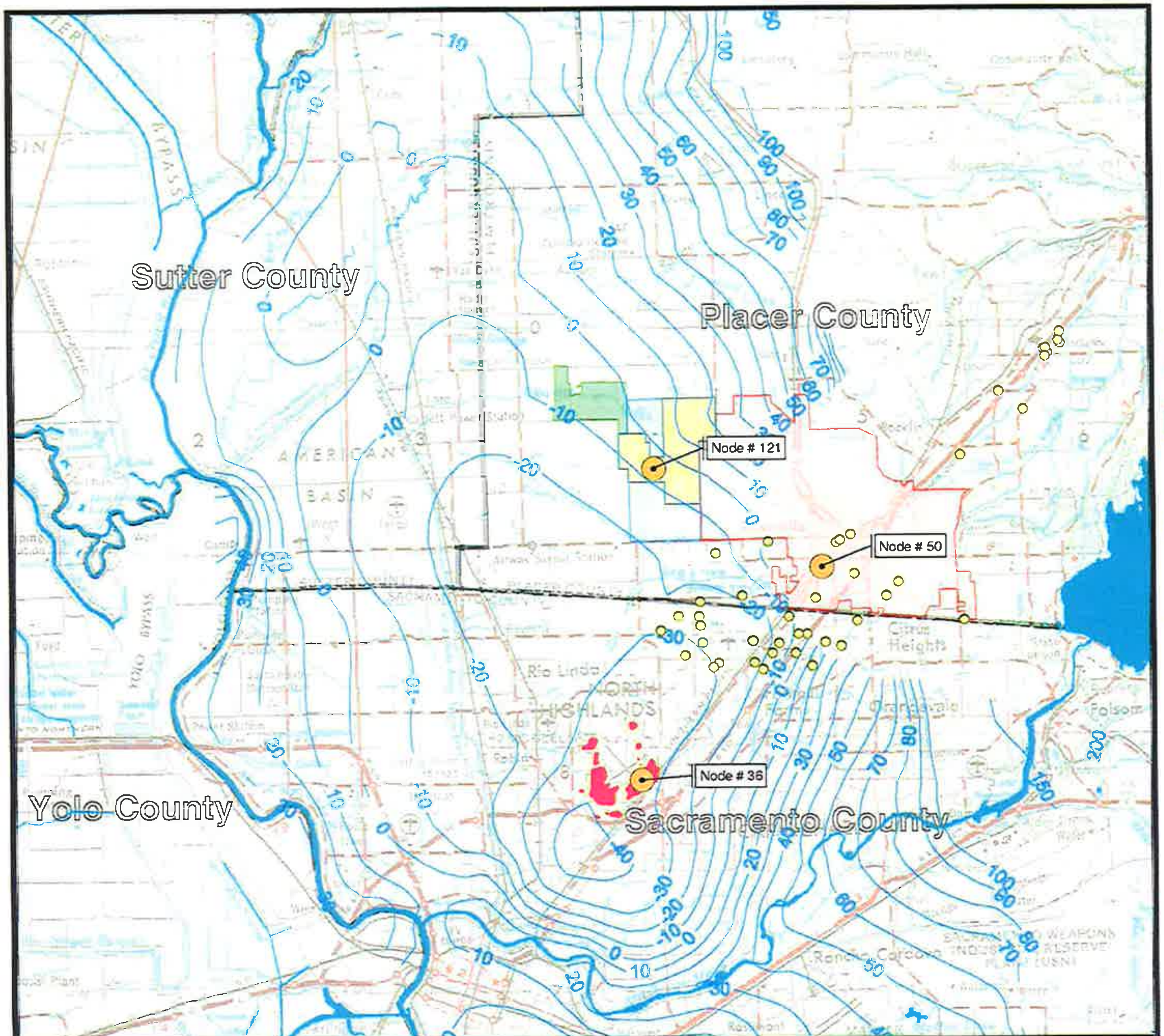

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.7
Project without Mitigation Aquifer 1 Groundwater Surface Elevation Contours

Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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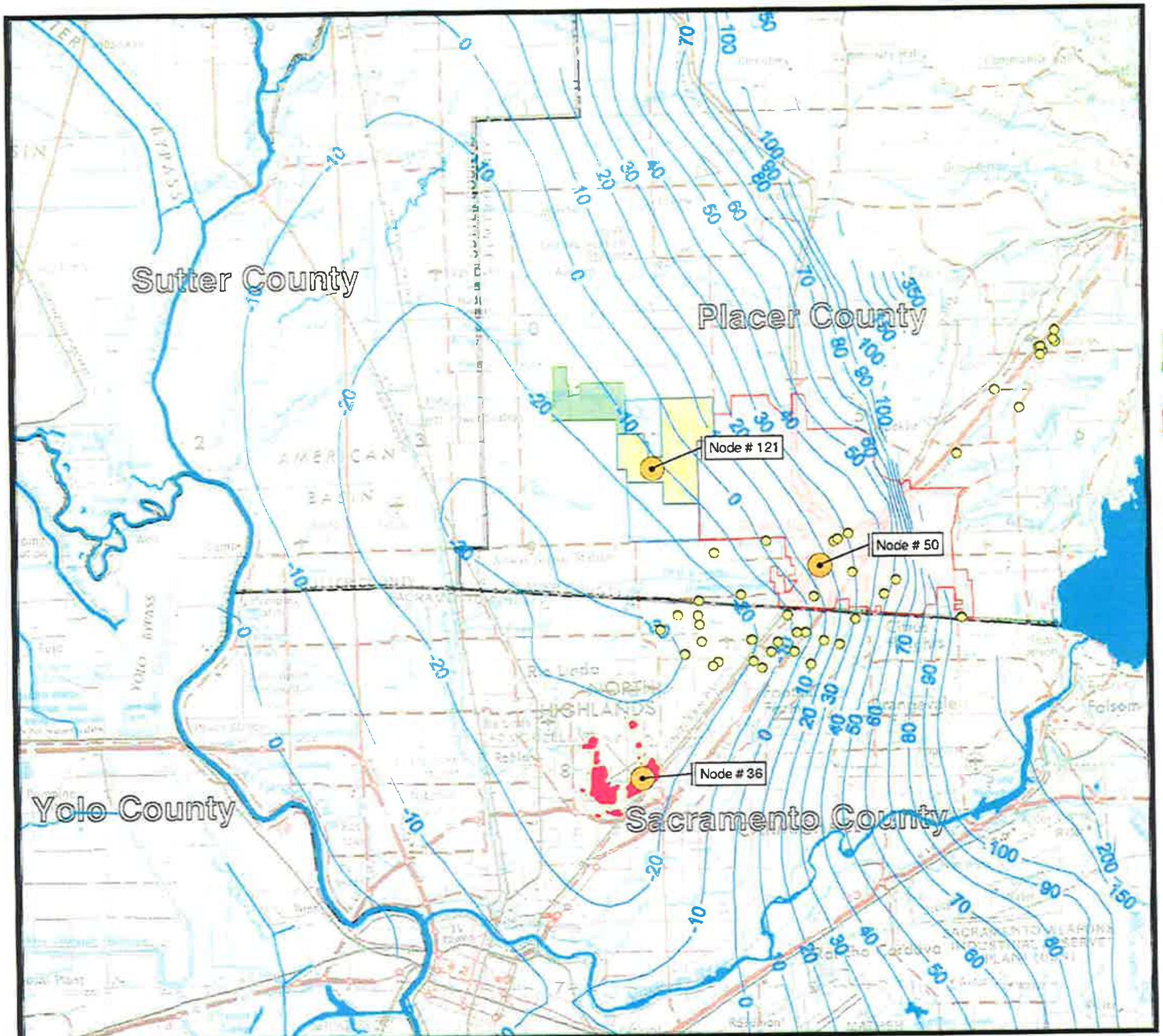

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.8
Project without Mitigation Aquifer 2 Piezometric Surface Elevation Contours
Wet Year

Legend

Reasons Farm

City of Roseville

WRSP Area

West Roseville Specific Plan Area inside the MOU Area

Piezometric Surface Elevation Contour in feet above Mean Sea Level

Location of Groundwater Hydrograph

Known Contaminant Plumes

Known Domestic Well

0 1 2 4 Miles

MWH

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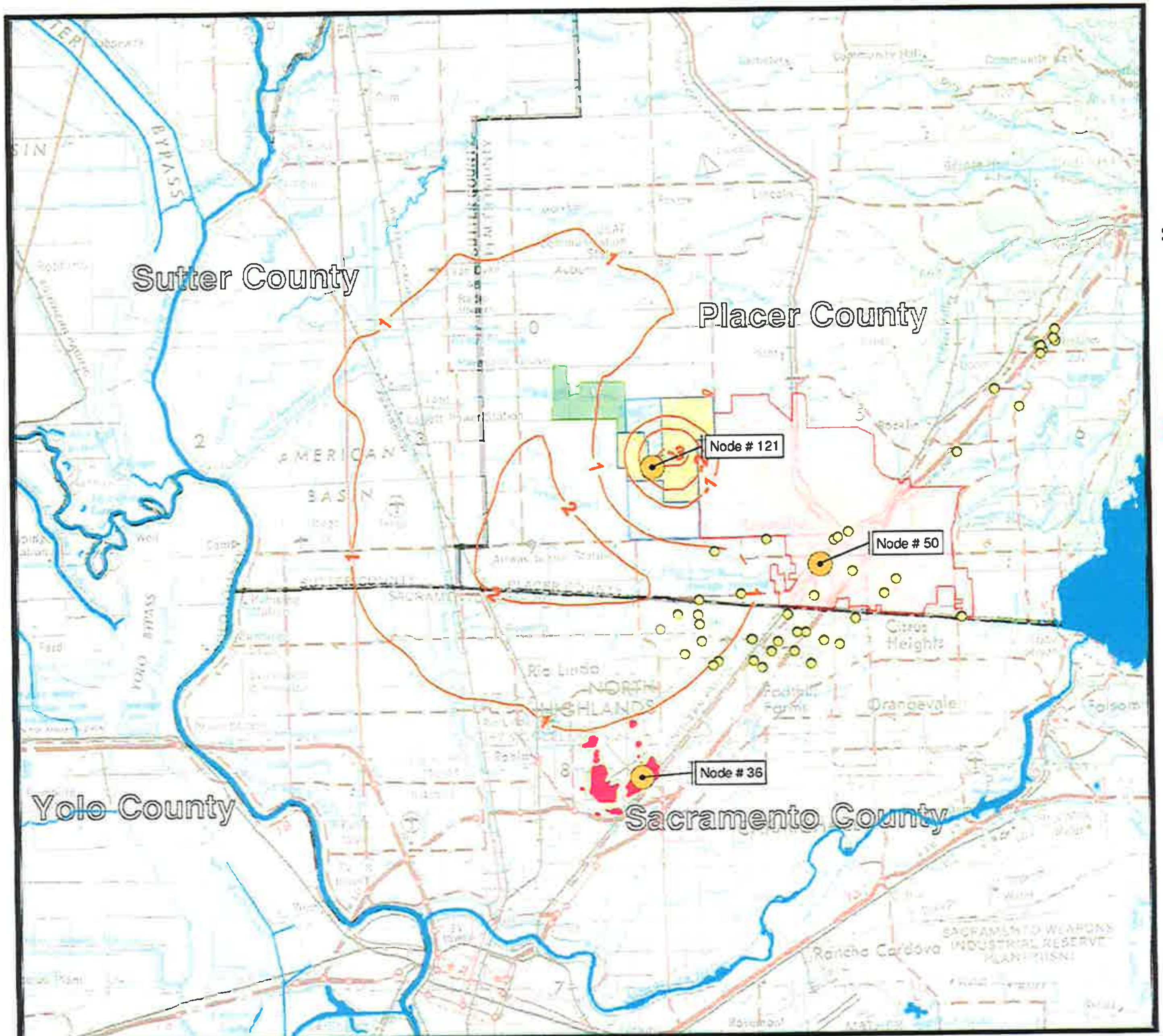

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.9
Project without Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours
Dry Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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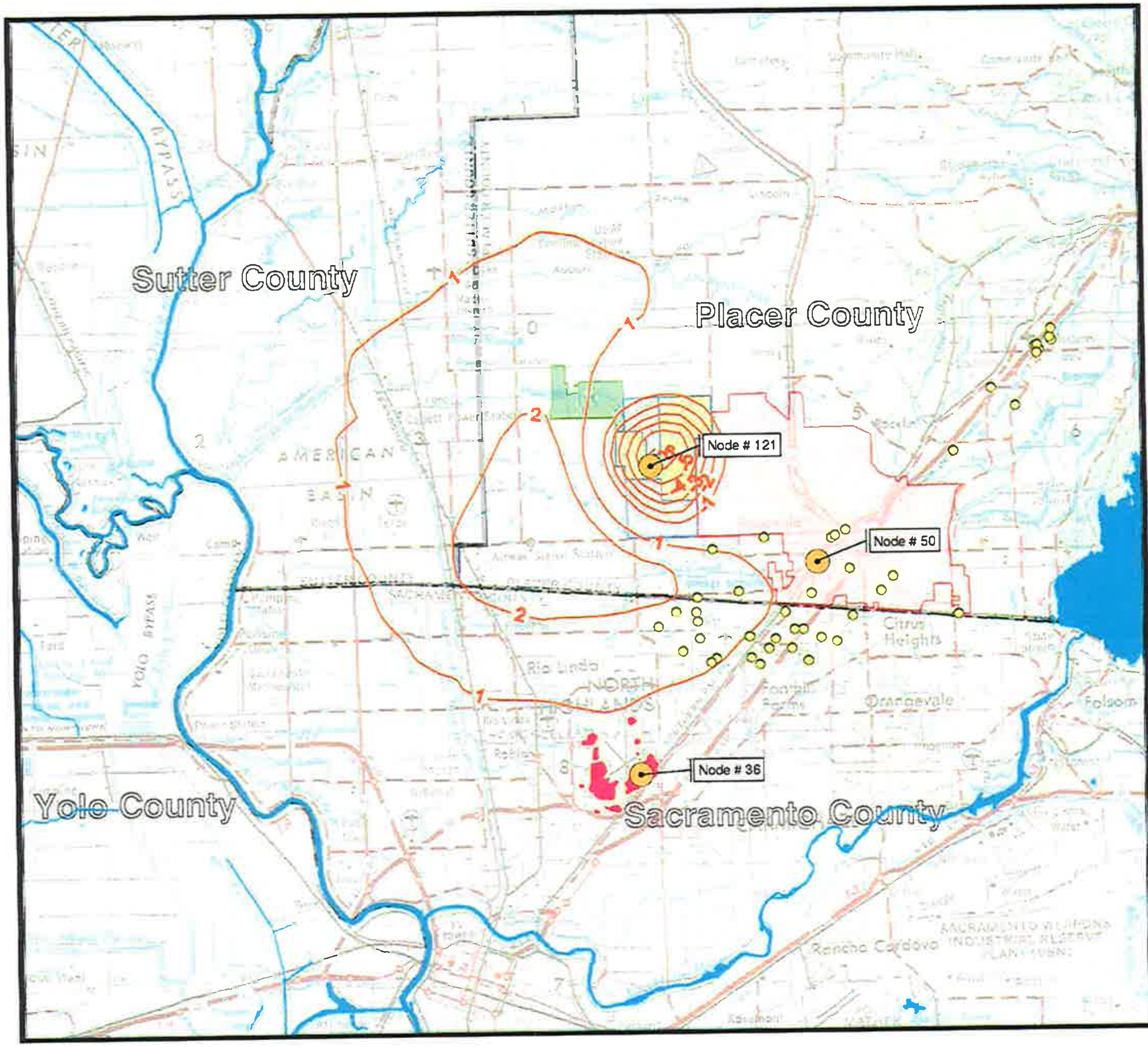

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.10
Project without Mitigation Aquifer 2 Piezometric Surface Elevation Difference Contours

Dry Year

Legend

Reasons Farm

City of Roseville

WRSP Area

West Roseville Specific Plan Area inside the MOU Area

Piezometric Surface Elevation Contour in feet above Mean Sea Level

Location of Groundwater Hydrograph

Known Contaminant Plumes

Known Domestic Well

0 1 2 4 Miles

MWH

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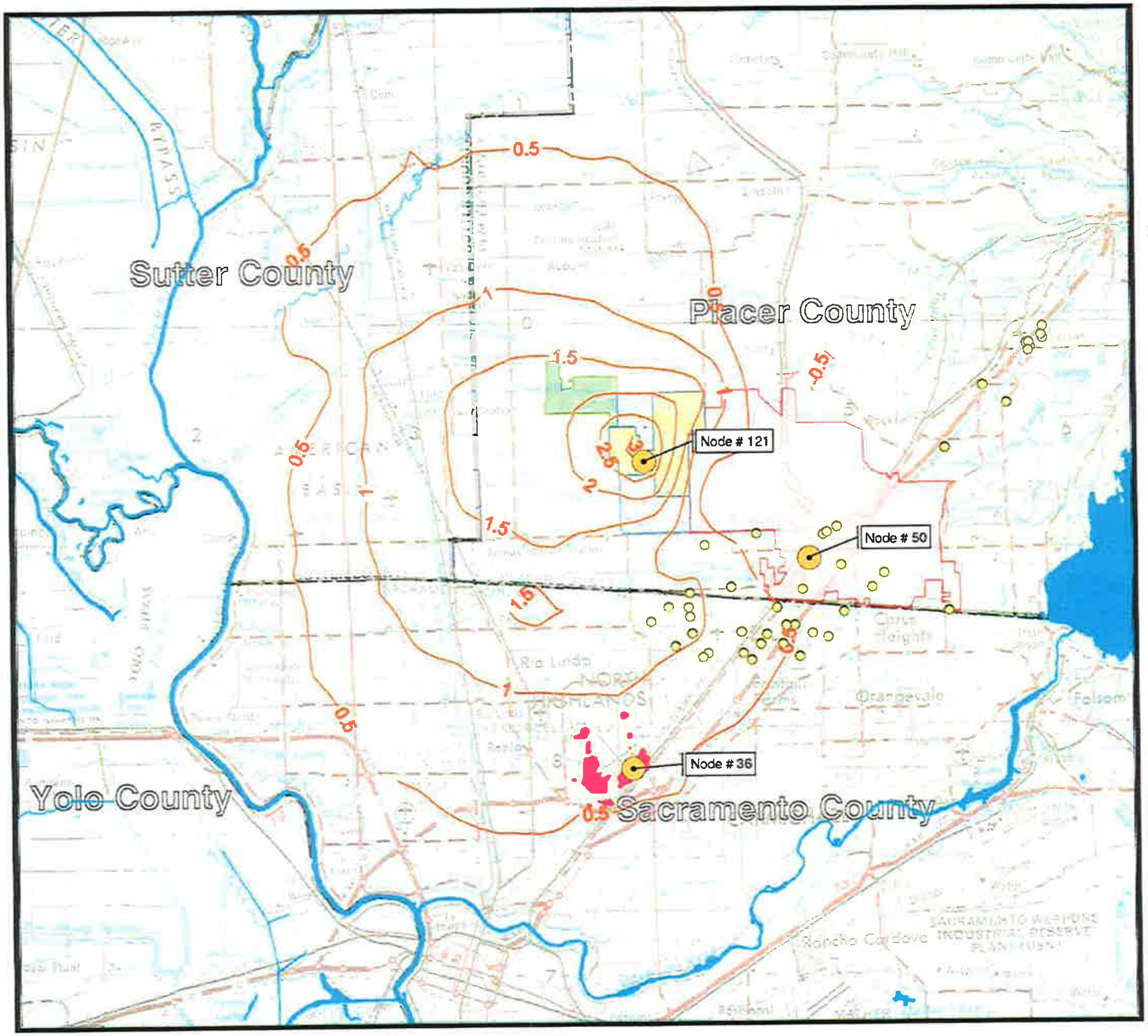
CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.11
Project without Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours

Wet Year



Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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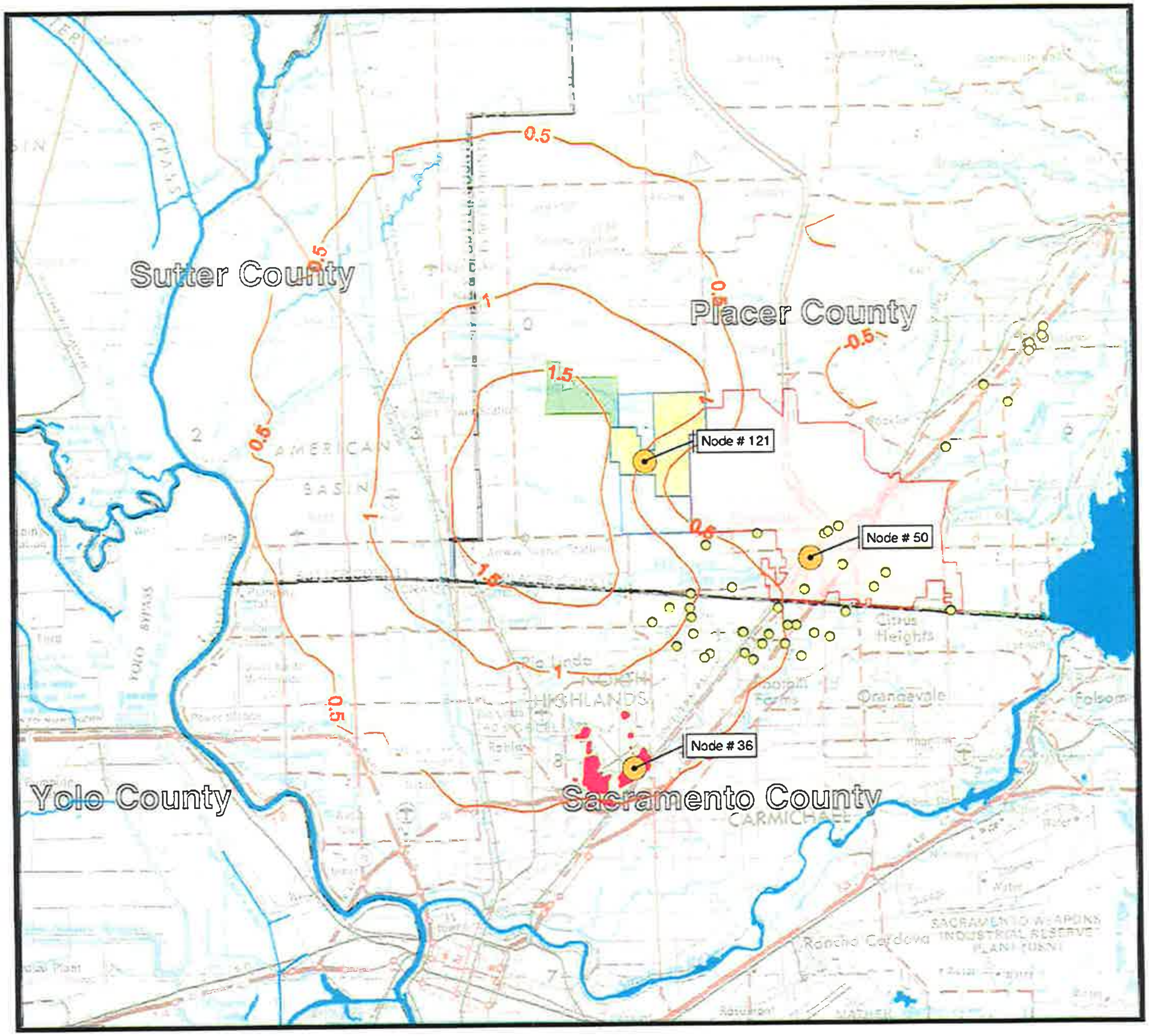

ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.12
Project without Mitigation Aquifer 2 Piezometric Surface Elevation Difference Contours
Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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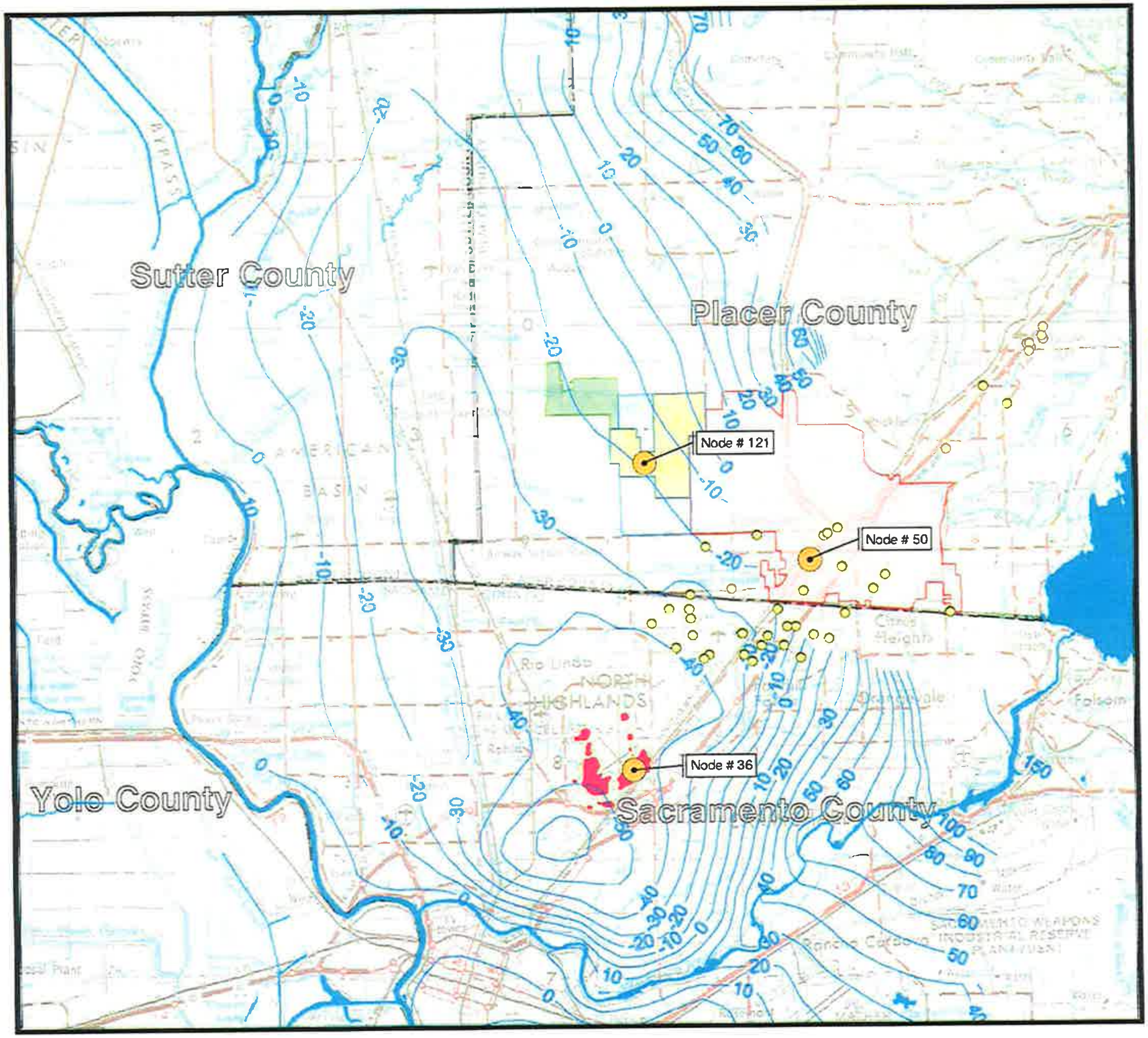

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.13
Project with Mitigation Aquifer 1 Groundwater Surface Elevation Contours Dry Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area: West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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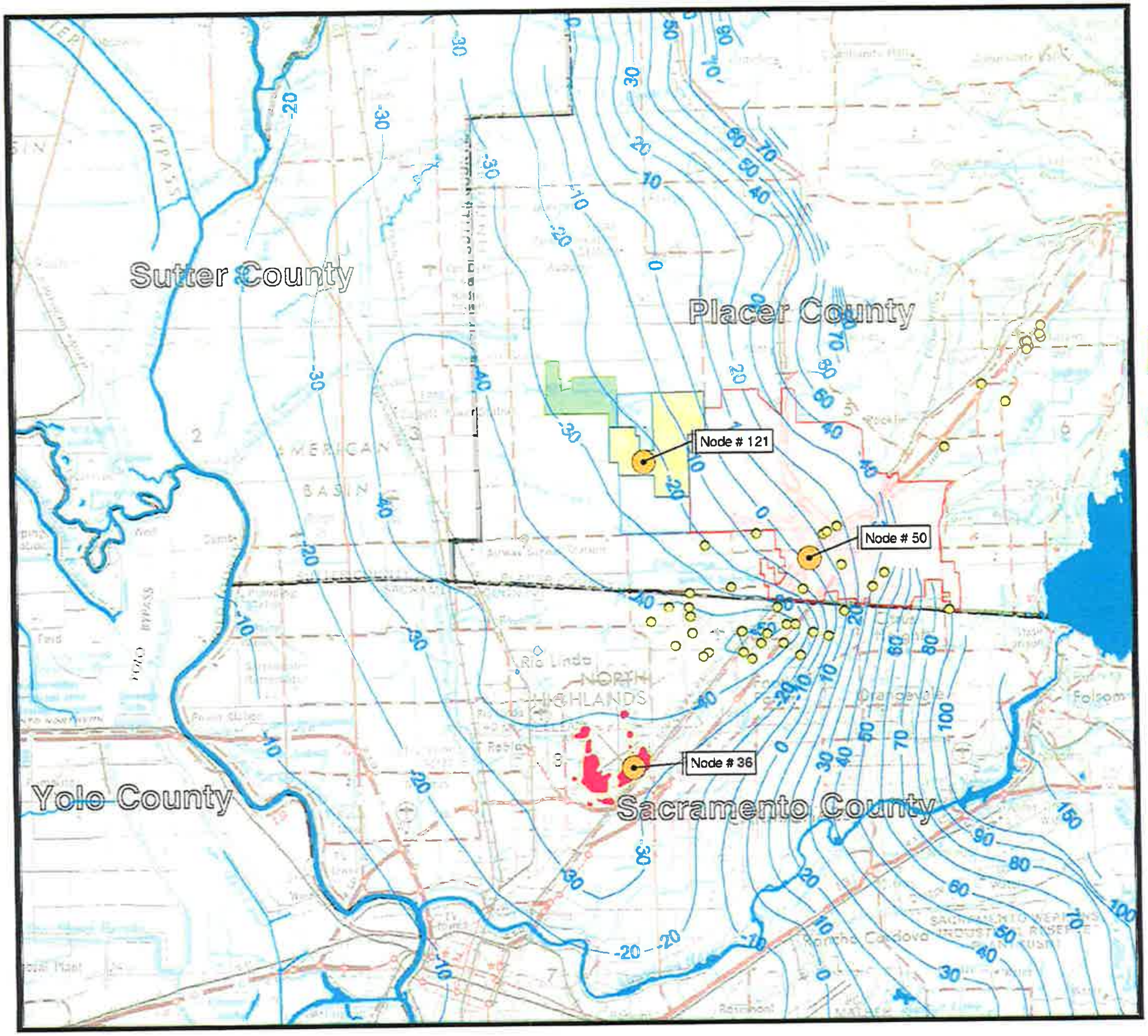

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.14
Project with Mitigation Aquifer 2 Piezometric Surface Elevation Contours Dry Year

Legend

Reasons Farm

City of Roseville

WRSP Area

West Roseville Specific Plan Area inside the MOU Area

Piezometric Surface Elevation Contour in feet above Mean Sea Level

Location of Groundwater Hydrograph

Known Contaminant Plumes

Known Domestic Well

0 1 2 4 Miles

MWH

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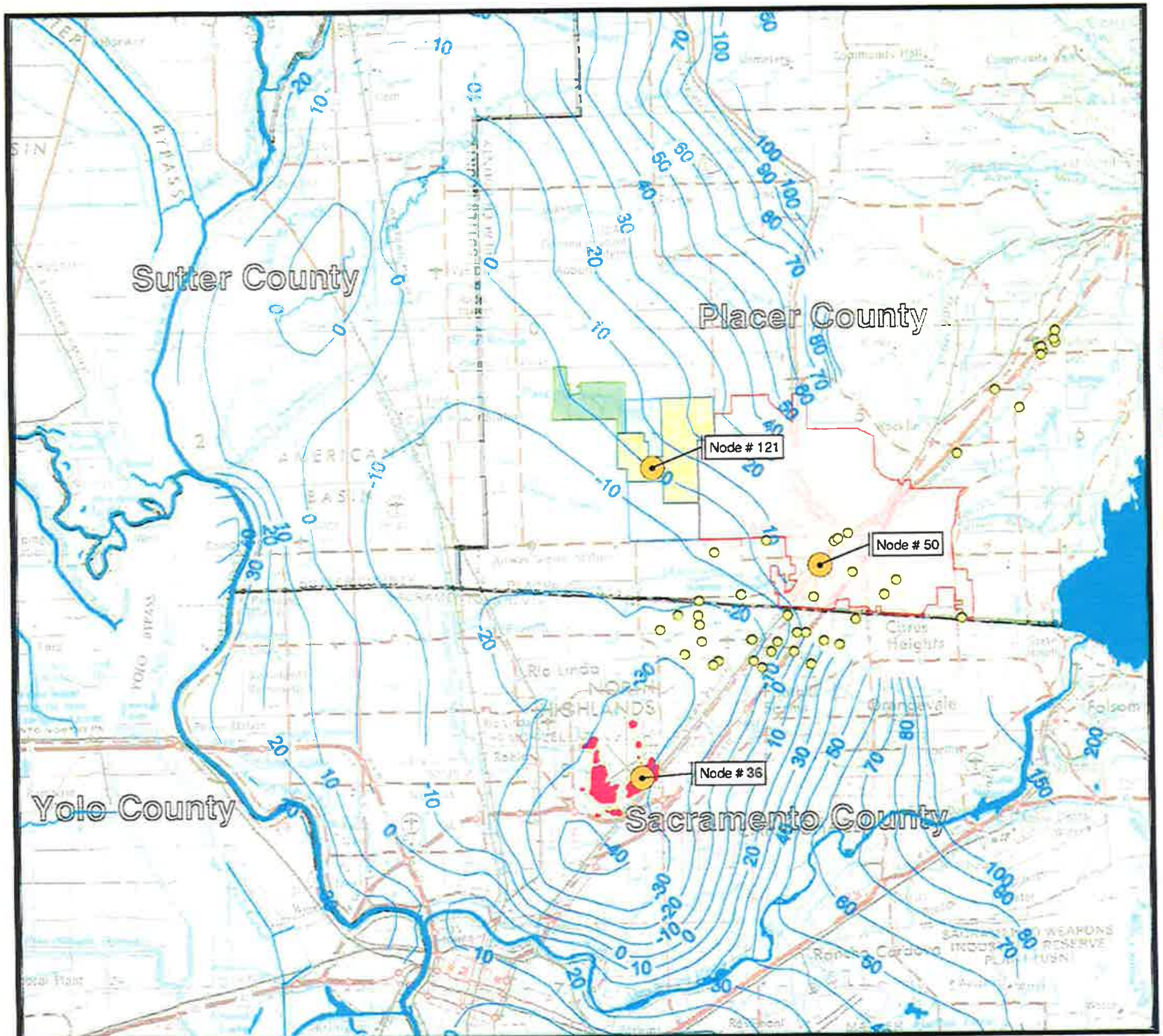

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TRADITION • PRIDE • PROGRESS

Water Supply Strategy: Groundwater Impact Analyses

Figure A.15
Project with Mitigation Aquifer 1 Groundwater Surface Elevation Contours

Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area: West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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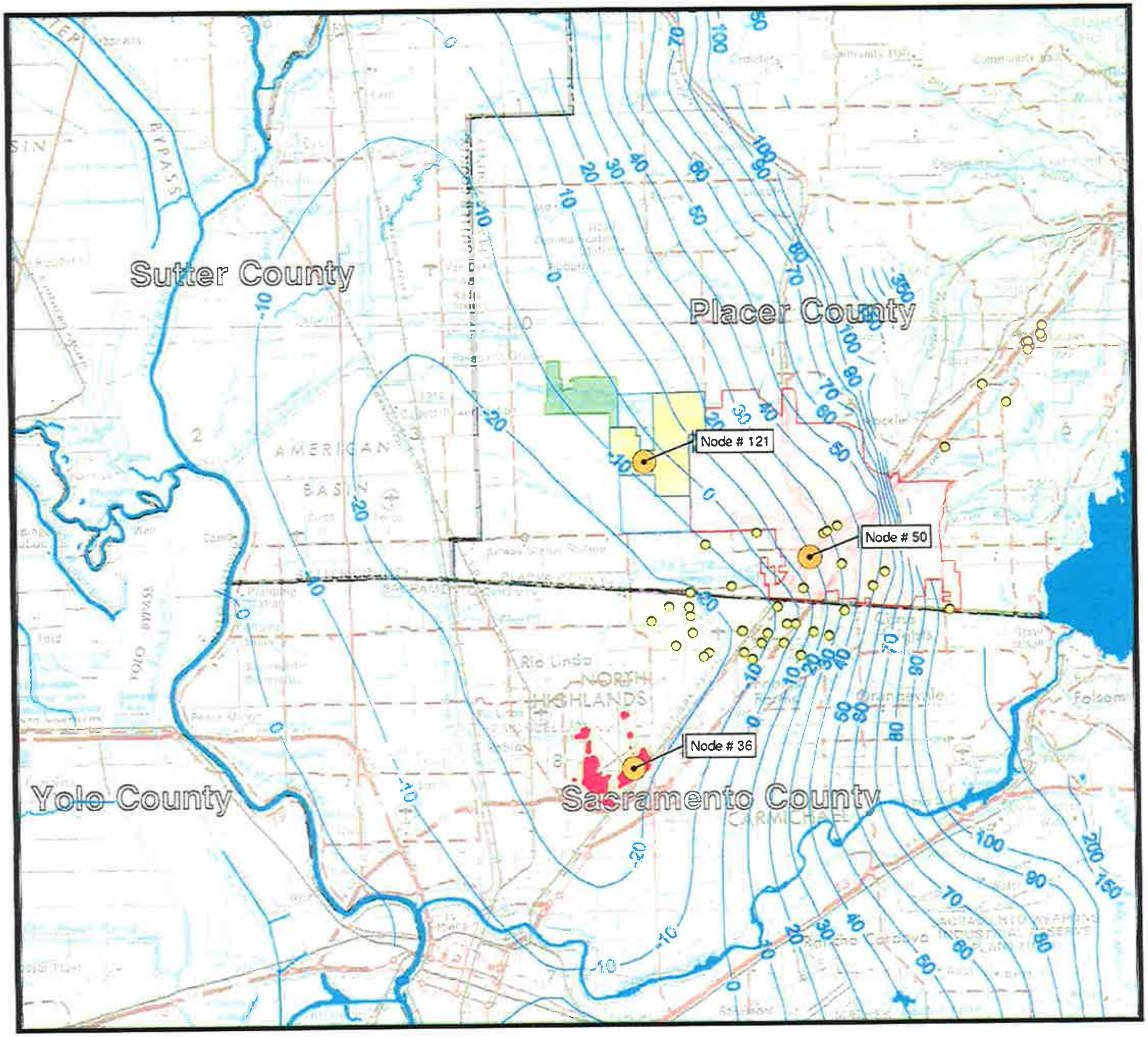

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.16
Project with Mitigation
Aquifer 2 Piezometric Surface Elevation Contours

Wet Year

Legend

Reasons Farm

City of Roseville

WRSP Area

West Roseville Specific Plan Area inside the MOU Area

Piezometric Surface Elevation Contour in feet above Mean Sea Level

Location of Groundwater Hydrograph

Known Contaminant Plumes

Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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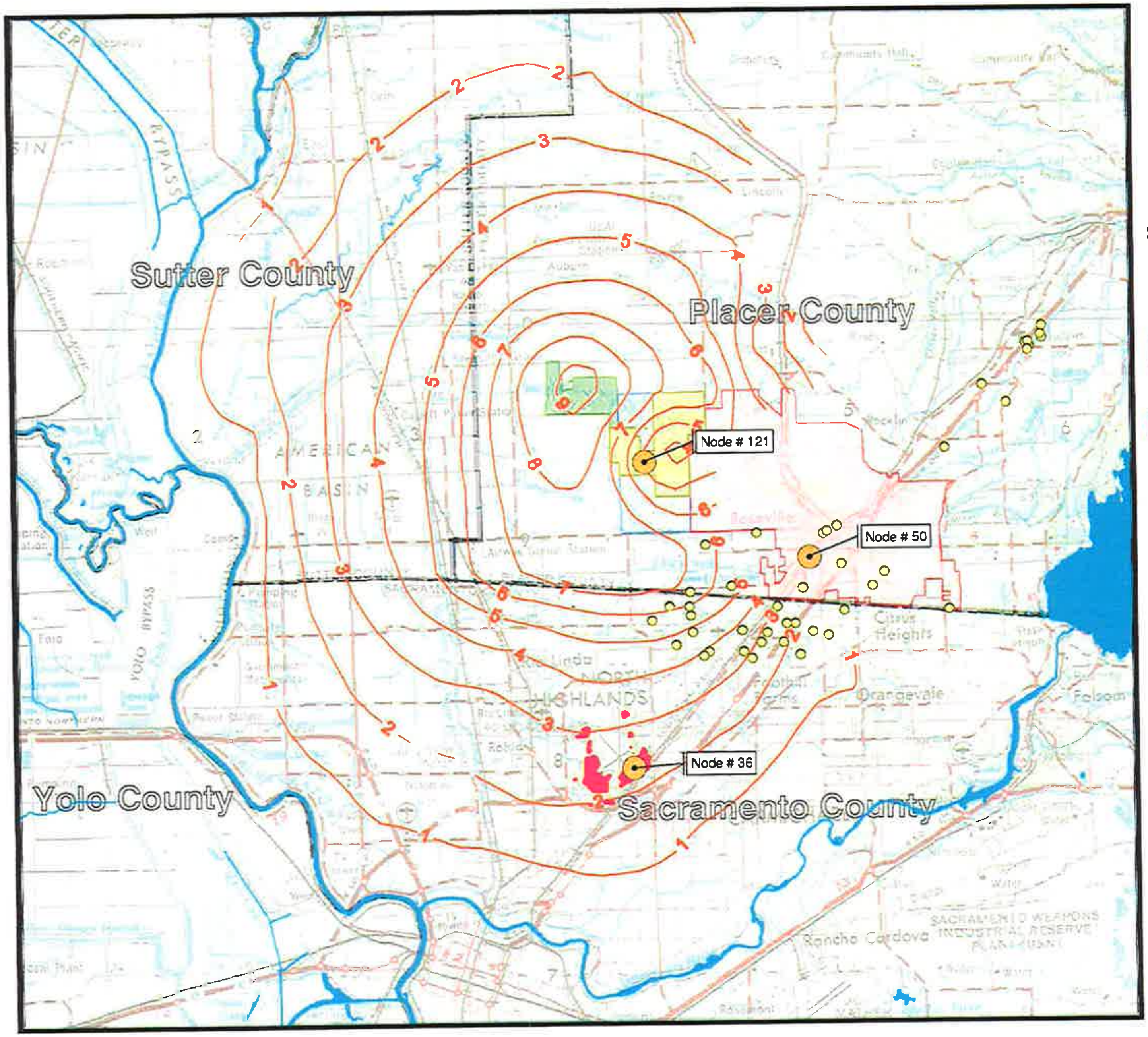

Water Supply Strategy: Groundwater Impact Analyses

Figure A.17
Project with Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours

Dry Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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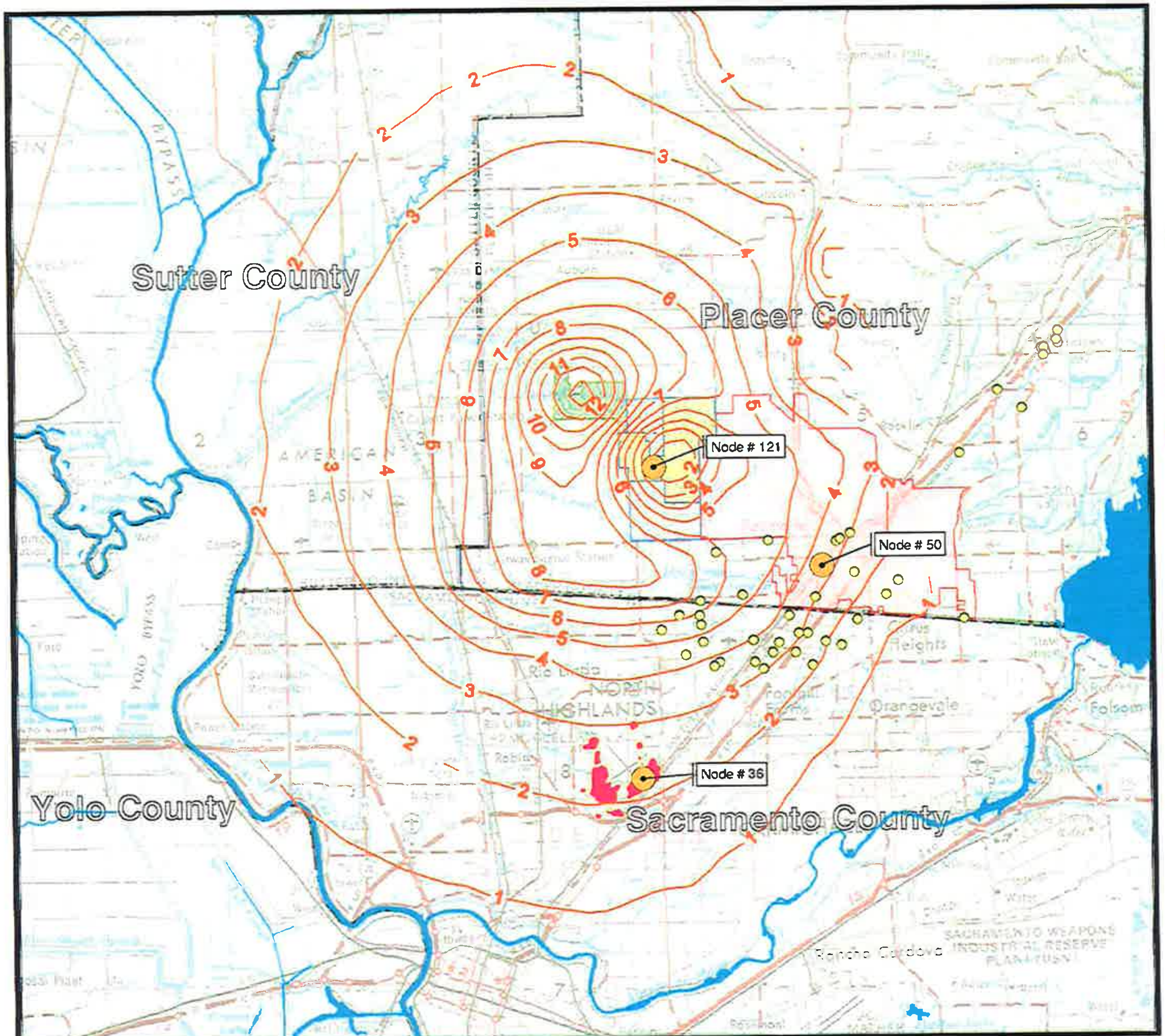

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.18
Project with Mitigation Aquifer 2 Piezometric Surface Elevation Difference Contours
Dry Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

June 2003

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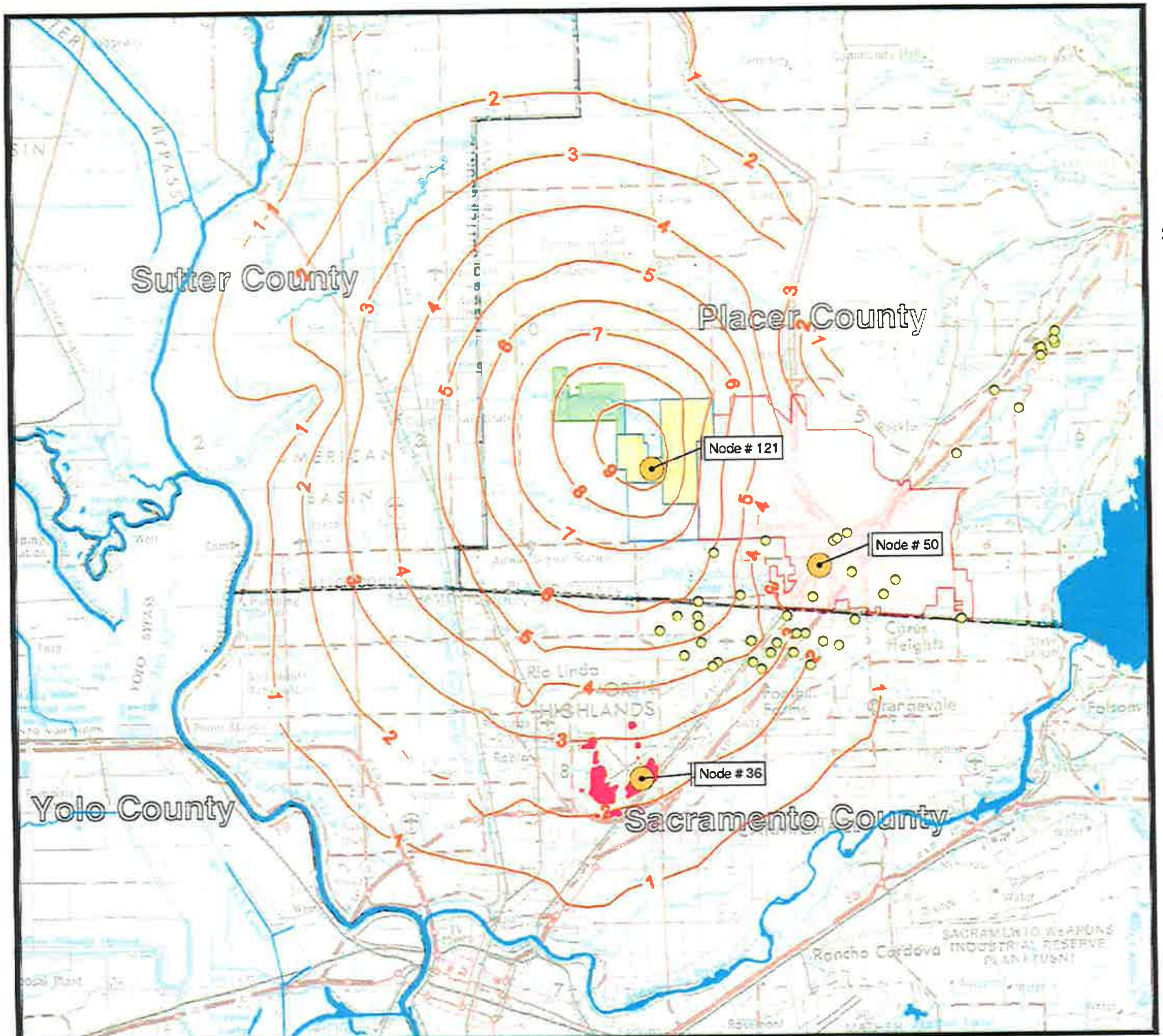

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.19
Project with Mitigation Aquifer 1 Groundwater Surface Elevation Difference Contours
Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area
- West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

0 1 2 4 Miles

MWH

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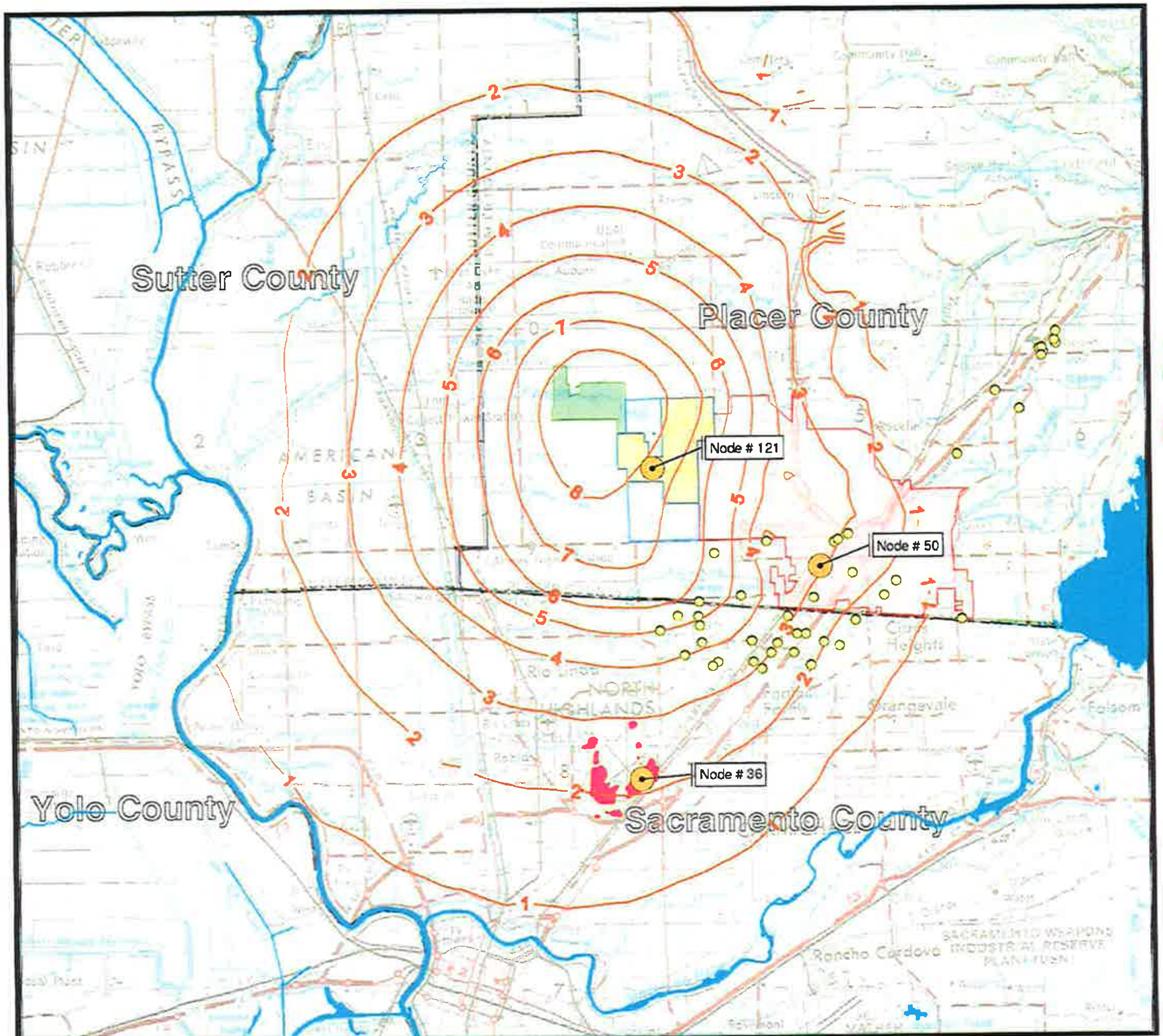

CITY OF ROSEVILLE

Water Supply Strategy: Groundwater Impact Analyses

Figure A.20
Project with Mitigation Aquifer 2 Piezometric Surface Elevation difference Contours
Wet Year

Legend

- Reasons Farm
- City of Roseville
- WRSP Area — West Roseville Specific Plan Area inside the MOU Area
- Piezometric Surface Elevation Contour in feet above Mean Sea Level
- Location of Groundwater Hydrograph
- Known Contaminant Plumes
- Known Domestic Well

June 2003

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Figure A.21 Groundwater Elevation Hydrograph for Aquifer 1 Underlying the WRSP Area (Node #151)

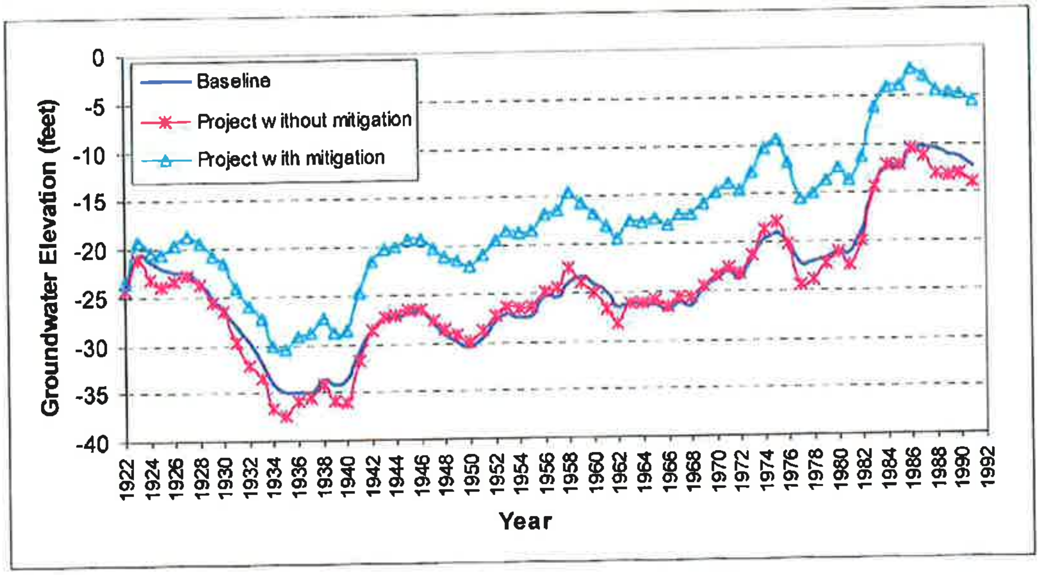


Figure A.22 Groundwater Piezometric Surface Elevation Hydrograph for Aquifer 2 Underlying the WRSP Area

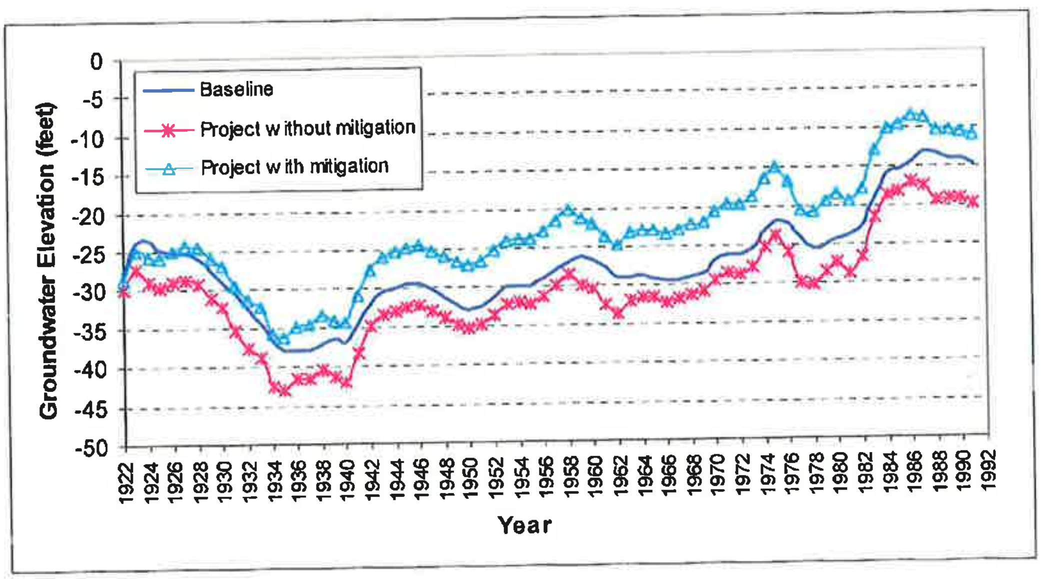


Figure A.23 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying the WRSP Area (Node #151)

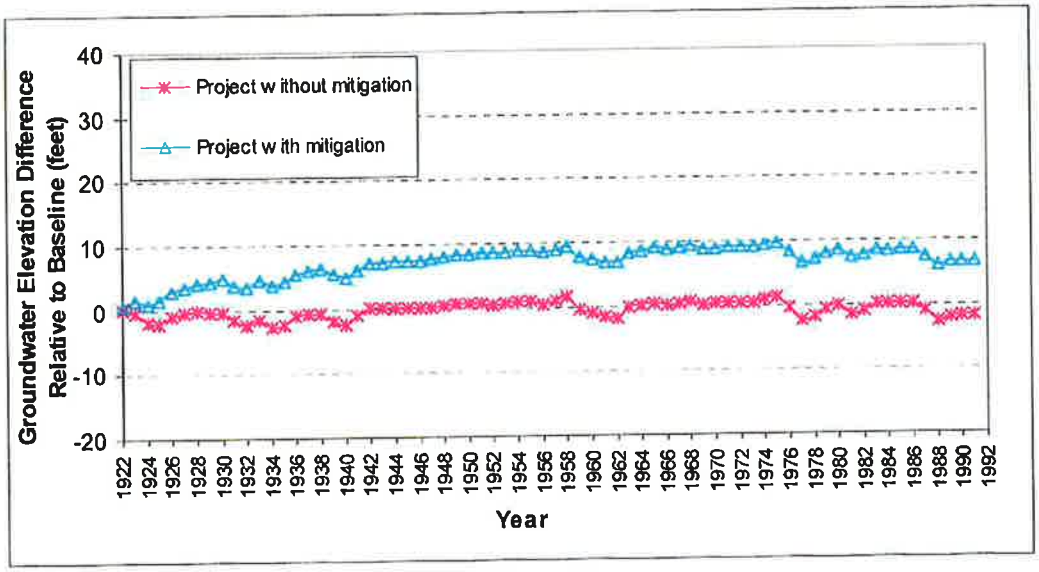


Figure A.24 Groundwater Piezometric Surface Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying the WRSP Area (Node #151)

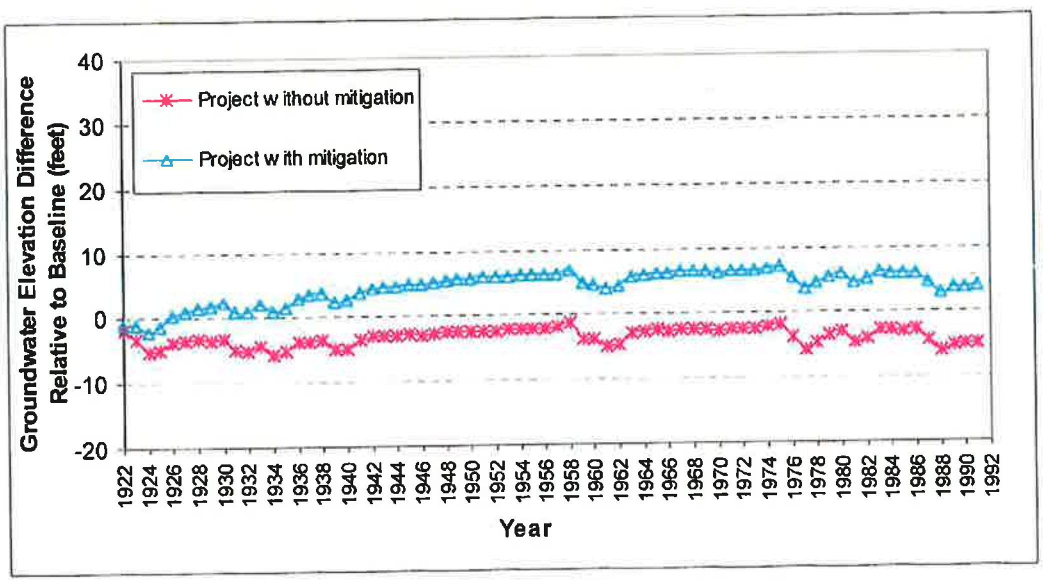


Figure A.25 Groundwater Elevation Hydrograph for Aquifer 1 Underlying South Pacific Roseville Railyard (Node #50)

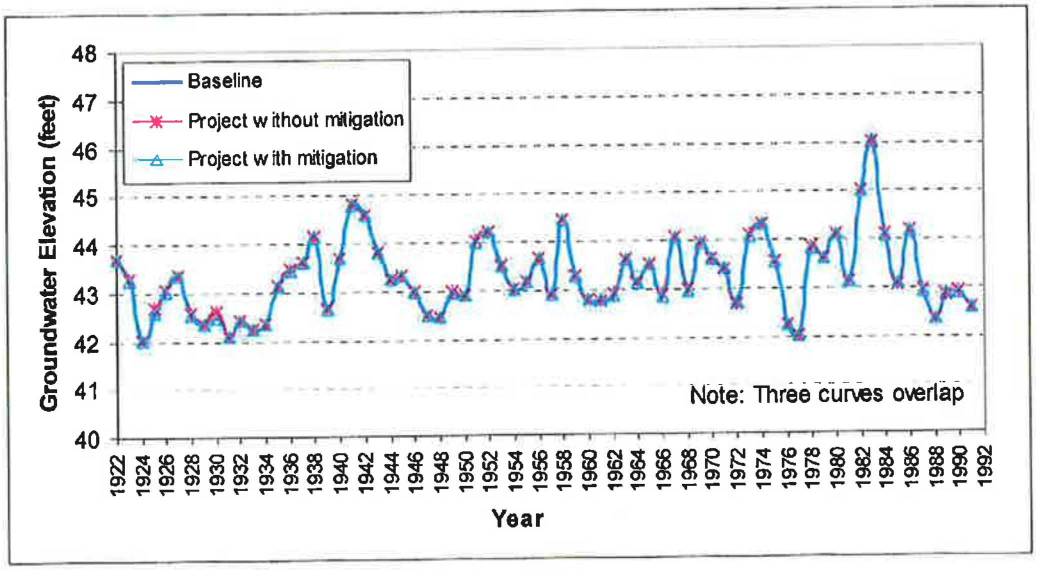


Figure A.26 Groundwater Elevation Hydrograph for Aquifer 2 Underlying South Pacific Roseville Railyard (Node #50)

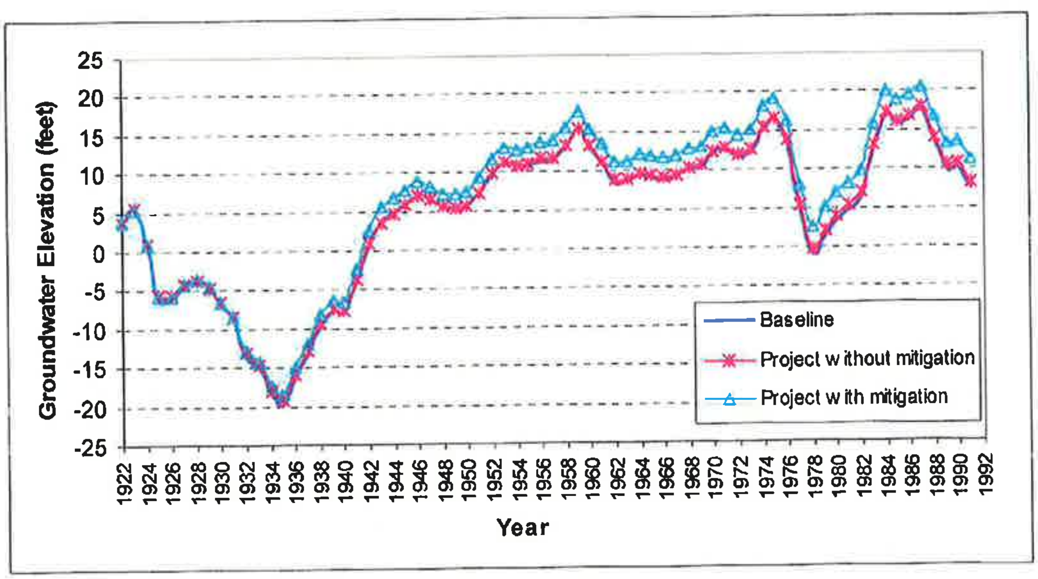


Figure A.27 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying South Pacific Roseville Railyard (Node #50)

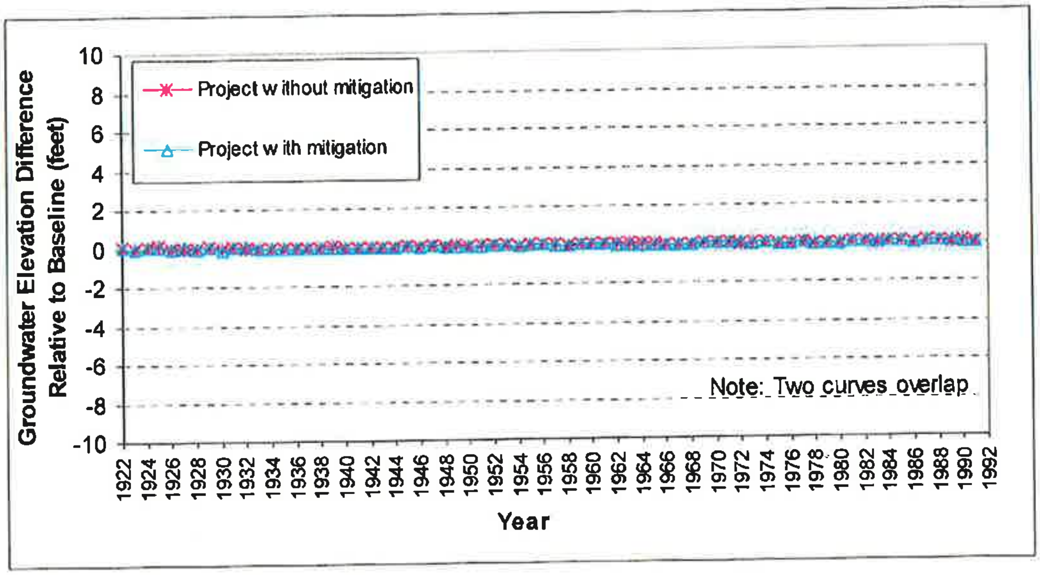


Figure A.28 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying South Pacific Roseville Railyard (Node #50)

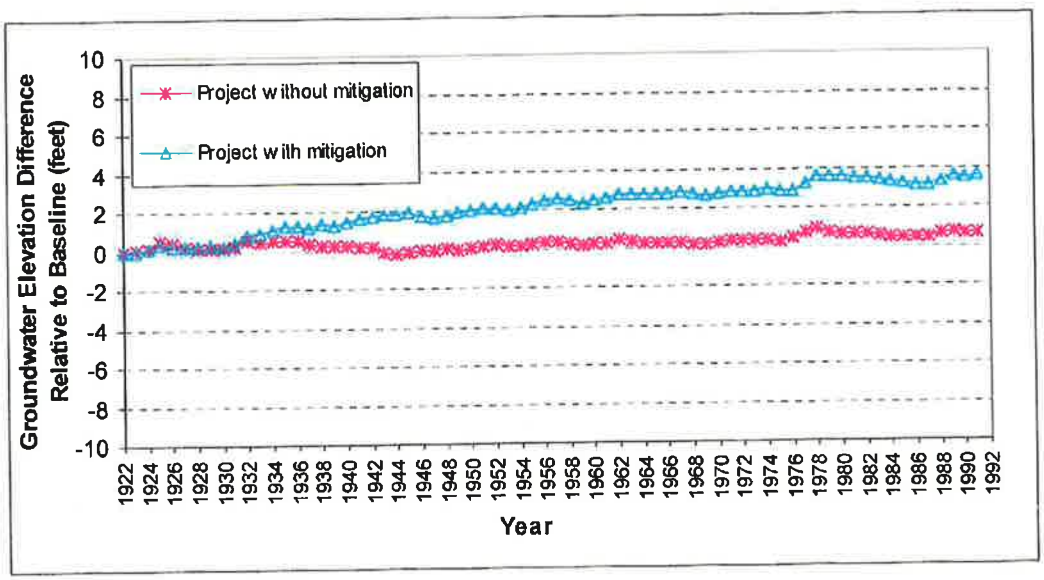


Figure A.29 Groundwater Elevation Hydrograph for Aquifer 1 Underlying McClellan Contaminant Plumes (Node #36)

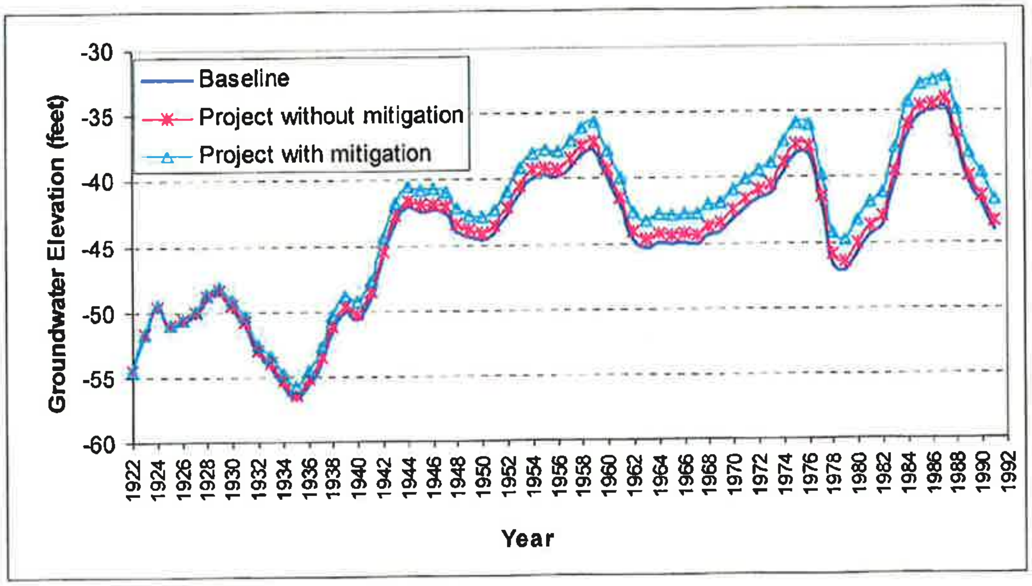


Figure A.30 Groundwater Elevation Hydrograph for Aquifer 2 Underlying McClellan Contaminant Plumes (Node #36)

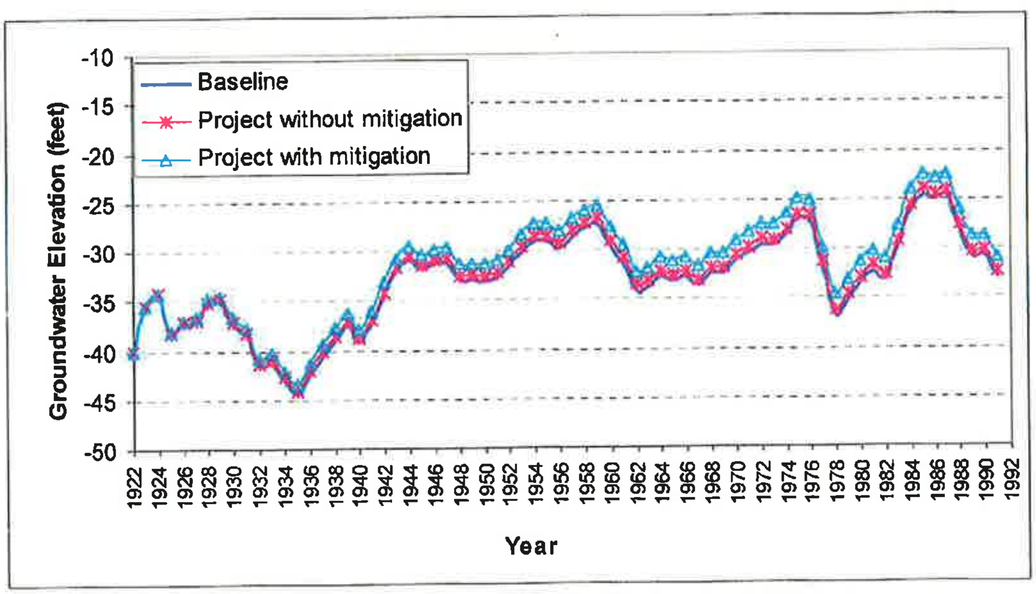


Figure A.31 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 1 Underlying McClellan Contaminant Plumes (Node #36)

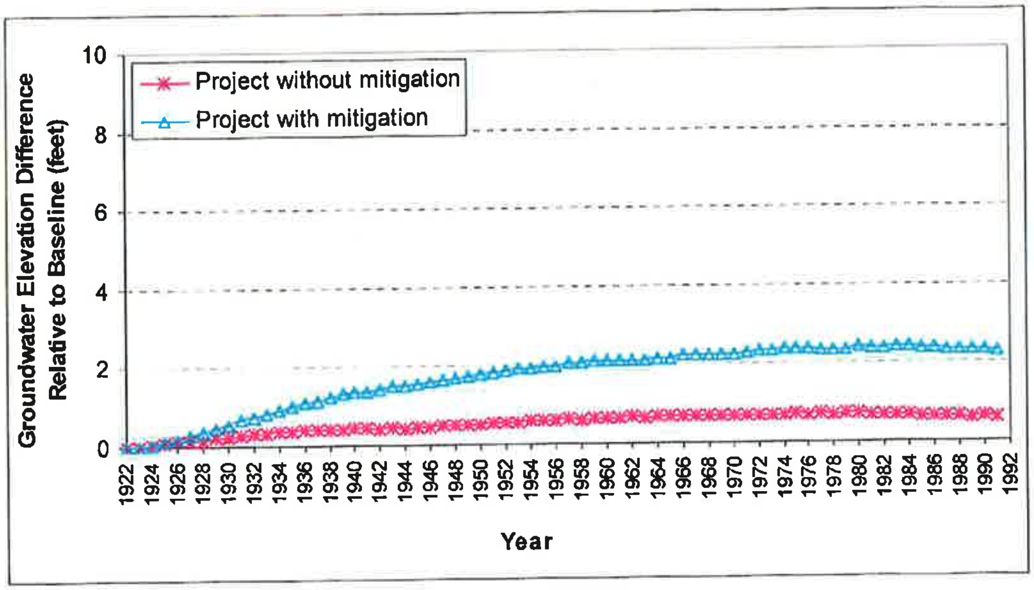
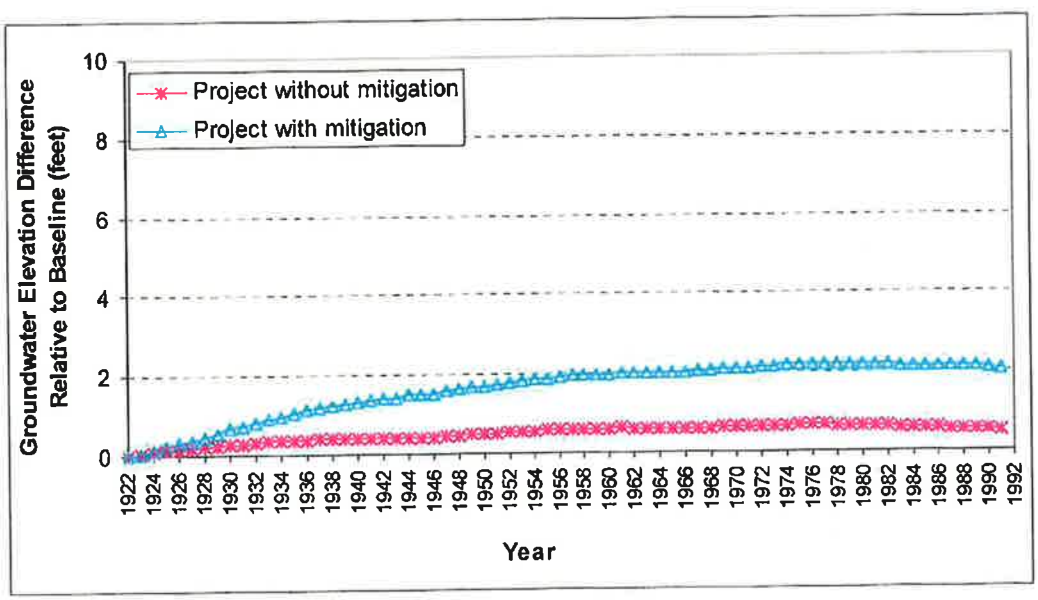


Figure A.32 Groundwater Elevation Difference Relative to "Baseline Condition" for Aquifer 2 Underlying McClellan Contaminant Plumes (Node #36)



APPENDIX B

Description of Integrated Groundwater/Surface Water Model (IGSM)

BACKGROUND

The North American River Integrated Groundwater and Surface Water Model (IGSM) was originally developed through the American River Water Resources Investigation (ARWRI) completed cooperatively between the United States Bureau of Reclamation and the State Department of Water Resources in the mid 1990's. The model was later used in the Sacramento Area Water Forum process in the evaluation of acceptable groundwater yields and conjunctive use alternatives. The model in its current form was further developed by the American River Basin Cooperating Agencies for the Regional Water Master Plan to be used for evaluation of conjunctive use alternatives. The model used for this analysis is referred to as the "Draft Water Forum Solution Model" and includes 2030 levels of water demand for Sutter, Placer, San Joaquin, and Sacramento counties with proposed conjunctive use of surface water and groundwater.

MODEL OVERVIEW

The North American River IGSM is a finite element computer model that provides a comprehensive simulation of all major components of the hydrologic cycle in accordance with mass balance and water budget accounting procedures. The model consists of three models that are linked so that data at the boundary of one model can be transferred to the adjacent model. The three models are the Sutter/Placer Model, the Sacramento County Model, and the San Joaquin Model.

Elements of the hydrologic cycle addressed by the IGSM include precipitation, runoff, groundwater surface recharge, evaporation, consumptive use, groundwater extraction and injection, and subsurface inflow and outflow. The simulation also includes the interaction between surface streams and the regional groundwater aquifer.

The model is data intensive, requiring hydrogeologic, hydrostratigraphic, land use, water use, precipitation, and other hydrologic data. Water and land use budget accounting are performed on a subregion-by-subregion basis (see **Figure B.1** for subregion boundaries within the investigation area). General statistics of the Sutter/Placer County Model include:

- Total model area - 340 square miles
- Average element size - 0.64 square miles, or approximately 410 acres
- Number of model subregions - 13
- Number of model aquifer layers - 3
- Simulation period hydrology - Water years 1922 through 1991

The model boundaries of the North American River IGSM correspond roughly to the Sacramento and San Joaquin Rivers to the West, the Feather and Bear River to the North, and the Stanislaus River to the South. The eastern boundary of the model is the eastern edge of the underlying aquifer where it rises and surfaces in the foothills.

IGSM CONCEPTUAL MODEL

The geology and geohydrology in western Placer County and northern Sacramento County, and in particular portions of the investigation area, are complex. Consequently, the IGSM is based on a conceptual model of the groundwater basin represented by a three-layer aquifer system. **Figure 3.1** (in the body of this report) illustrates a cross section of the basin as modeled in the IGSM. As illustrated on the figure, important assumptions of the conceptual model include:

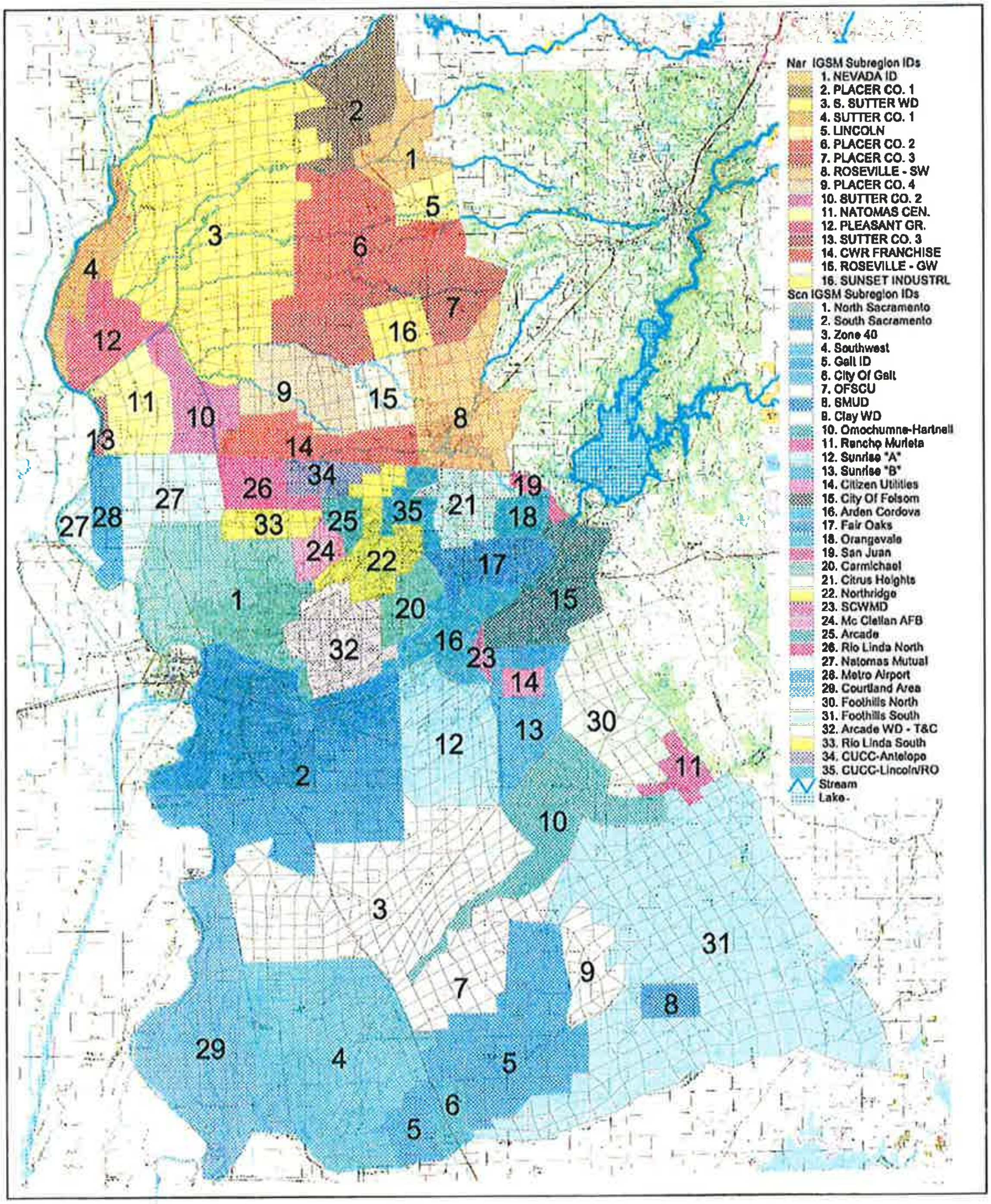
- Aquiclude 1 - A discontinuous semi-confining layer near the ground surface
- Aquifer 1 - Water bearing deposits overlain by Aquiclude 1
- Aquiclude 2 - A discontinuous semi-confining clay layer between Aquifers 1 and 2
- Aquifer 2 - Water bearing deposits between Aquiclude 2 and the base of high quality groundwater with low total dissolved solids (TDS)
- Aquifer 3 - Non-potable groundwater above the base of the usable aquifer with high TDS

The conceptual model is largely based on geologic, hydrologic, and geohydrologic information presented in *Bulletin 118-3* (DWR, July 1974) supplemented by additional local studies.

MODELING PARAMETERS

A set of aquifer parameters was developed for the aquifers and aquicludes of the conceptual model described above. Aquifer parameters (specifically, horizontal hydraulic conductivity within an aquifer and vertical leakance though an aquiclude) were estimated and refined during the IGSM calibration process. Although all pertinent information available was used during calibration, these parameters were sometimes estimated using best judgement.

Figure B.1
Subregion Map



N W E S

1 0 1 2 Miles

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MONTGOMERY WATSON HARZA
SACRAMENTO, CALIFORNIA