Glenn County Water Advisory Committee

Preliminary Plan for Groundwater and Coordinated Water Management

Task B. Water Needs Analysis

Task C. Water Delivery and Distribution Infrastructure

Task E. Groundwater Monitoring Program

May 2007

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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INTRODUCTION

In 2004, the Glenn County Water Advisory Committee (WAC) approved the Preliminary Plan for Groundwater and Coordinated Water Management (Preliminary Plan). The Preliminary Plan was prepared to assist in facilitating a planning process to document and preserve what has been accomplished in Glenn County (Appendix A), and to provide a direction for future activities of the WAC to further the management of water resources in Glenn County. Ten tasks were identified in the Preliminary Plan. The tasks include:

Task A. Formulate Countywide Water Management Goals

Task B. Perform Water Needs Analysis

Task C. Prepare Water Delivery and Distribution Infrastructure Map

Task D. Determine Groundwater Utilization Opportunities and Constraints

Task E. Complete a Comprehensive Groundwater Monitoring Plan

Task F. Formulate Potential Projects

Task G. Evaluate Water Transfer Guidelines

Task H. Formulate Drought Preparedness Plan

Task I. Formulate Public Information and Education Program

Task J. Prepare Groundwater and Coordinated Water Management Plan

In the interest of continuing to enhance the management of water resources in Glenn County, the WAC elected to address three of the ten tasks that were identified in the Preliminary Plan – Task B, Task C, and Task E. With funding through the AB 303 Local Groundwater Assistance Program administered by the California Department of Water Resources, the WAC retained Wood Rodgers, Inc. to address these three tasks. Accordingly, this report addresses the three tasks under the following headings.

- Task B. Water Needs Analysis
- Task C. Water Delivery and Distribution Infrastructure
- Task E. Comprehensive Groundwater Monitoring Program

WATER NEEDS ANALYSIS

TASK B

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FINDINGS AND RECOMMENDATIONS

Presented in this section of the report are Wood Rodgers' findings and recommendations related to the evaluation of water needs for Glenn County from the standpoint of fulfilling the vision of the WAC as articulated in its submittal of the Basin Management Objectives (BMOs) to the Board of Supervisors in August 2001.

Findings

Agriculture is a vital industry in the County and is supported by the availability of substantial surface water supplies acquired from the Sacramento River system, which includes Stony Creek and the Feather River. These surface water supplies are available due to the long-term perspective, foresight, concerted effort, and investments on the part of individuals and entities working together in years past. The surface water supplies supported and sustained the development of a robust agricultural economy for more than 100 years. By virtue of the accomplishments in acquiring these supplies, the "needs" at this time are not water needs, but rather "management" needs. Refinements in the management of the water resources available to the County dictate having a better understanding of the groundwater basin and genuine collaborative relationships in the County and neighboring counties as well. To this end, specific findings from this work are noted below.

1. Water needs or demands are defined sufficiently by historic water use. The changes and locations of those changes can be managed with appropriate communication, coordination, and planning from the standpoint of land use, groundwater monitoring, and conjunctive management of the available supplies.

2. The increase in permanent crops and the potential to increase the irrigated cropland into the foothills dictates greater understanding and management of the available water supplies to protect the investments that have been and will likely continue to be made in the County.

3. Water supplies are sufficient to sustain the agricultural economy of the County through hydrologic conditions recorded in the last 100 years; however, a much better understanding of the groundwater basin and related opportunities and constraints as well as broader collaborative efforts are needed to facilitate management of the resources.

4. Up to 20,000 acre-feet of water is available to water districts served by the Tehama-Colusa Canal; however, it is not being used due to the tiered pricing structure incorporated into the Long-Term Renewal Contracts executed in 2005.

5. Land in permanent crops within BMO subareas not having supplemental surface water would be most vulnerable in the event of an extended drought.

6. No domestic wells within the BMO subareas should be deprived of water if domestic and agricultural production wells are constructed to facilitate effective management of the groundwater resources.

7. All municipal water supplied within the BMO subareas is from groundwater and it does not appear that the use of supplemental surface water supplies are being considered at this time for future planned development within or outside the incorporated areas.

8. The BMOs represent a short-term solution to public concerns; however, they function as a constraint to sound long-term management of the water resources.

9. The effort to develop water policies within the General Plan process that is consistent with water management in the County appears limited at this time.

Recommendations

In view of the findings presented above, the following recommendations were formulated for consideration by the WAC and the County generally.

1. Design and implement programs within the Sacramento Valley Water Resources Monitoring, Data Collection, and Evaluation Framework to improve the understanding of the groundwater basin and the opportunities and constraints to its management.

2. Organize landowners within Subareas 8, 9, and 10 to discuss the prospects of participating in an organized manner in programs referenced in Item 1. above.

3. Investigate opportunities for utilizing the water service contracts, Tier 2, and Tier 3 water available to the water districts along the Tehama-Colusa Canal.

4. Investigate the use of supplemental surface water supplies to support any planned development in Subareas 5, 6, and 10 as part of a conjunctive water-use program.

5. Investigate the opportunities for expanded agricultural production in the foothills along the west side of the County.

6. Develop guidelines for the construction of wells to minimize potential adverse impacts to domestic wells and to facilitate greater utilization of the groundwater basin.

7. Consider implementing Task D. of the Preliminary Plan to gain a better understanding of the constraints and opportunities for managing the groundwater basin.

8. Develop water management policies for consideration in the County's General Plan update.

INTRODUCTION

The work and documents for developing the Basin Management Objectives (BMOs) for Glenn County represent a significant effort and accomplishment by the numerous parties involved in the process. The BMO subareas delineated for the County are presented on Figure B-1. The vision set forth by the WAC in submitting the BMOs to the Board of Supervisors for adoption represents the overall goal of the WAC with respect to water resources management in Glenn County. That vision is as follows:

> *"…that sufficient and affordable water of good quality be available on a sustainable basis to meet the needs of agricultural, industrial, recreational, and municipal users within the county, both now and in the future."*

To ensure that this vision is achieved it was deemed important to address the respective water needs and affordability. Accordingly, the water needs for each of the respective uses is addressed in this section of the report with the intent of providing guidance to the effort and attention devoted by the WAC and the community to enhance the management of the water resources available in the County. Consideration was given to addressing affordability as the cost of water to the water user clearly will influence the amount of water purchased and ultimately land use in the County. Affordability is a complex matter for which there is no absolute solution given the myriad of water supplies and water users in the County. Accordingly, affordability is not addressed in this report as it is beyond the scope of this work; however, the importance of "affordability" is not ignored either.

LAND USE

Water use and land use are integral to each other; however, decisions affecting land use are rendered by the County, whereas water is managed by various water purveyors and individual landowners. The County is currently in the process of updating its General Plan, thus providing a good opportunity to coordinate policy, planning, use, and management of the respective resources. The General Plan planning horizon is 2007 to 2027. Once adopted, it will represent the policy document from which land-use decisions will be made. As a result, input from the water community is important in this process.

With respect to land use, the land use surveys performed by the California Department of Water Resources (DWR) represent the most recent and detailed documentation and provides an excellent source of data for both land and water management. Land-use survey results are available electronically for the years 1993 and 1998. A land-use survey was performed by DWR in 2003; however, compilation of the data is not yet completed.

Presented in Table B-1 is a summary of the 1993 and 1998 land use according to the respective BMO subareas. From the information presented in Table B-1, in 1998 approximately 260,600 acres of the total area within the BMO subareas of 419,257 acres or 62 percent of the BMO subareas, not including rangeland, were devoted to agriculture in 1998. This was down about five percent from the 274,600 acres noted for 1993. The largest crop area was devoted to rice followed by fruits and nuts of 87,111 and 49,231 acres, respectively. The total agricultural cropland according to subarea as presented in Table B-2. As indicated, Subarea 11 and Subarea 13 have the greatest cropland acreage amounting to 26 and 13 percent, respectively. The total permanent crops in 1998, including fruits and nuts, citrus, and vineyards, totaled approximately 56,705 acres (Table B-2). In 1998, only 9,475 acres or less than four percent of the cropland was fallow. The 1998 land use is presented on Figure B-2.

The area in permanent crops in 1998 represents a 37 percent increase from 1993, while the increase in rice represents about a four percent increase. Because of the investment required to establish permanent crops, a more reliable water supply is required. Accordingly, the geographic distribution of the permanent crops among the various BMO subareas is examined more closely.

Presented in Table B-3 is a breakdown of the permanent crops, fruits and nuts, citrus, and vineyard for the respective BMO subareas in 1998. From the information presented in Table B-3 the subareas with permanent crops representing more than 30 percent of the total subarea are 3, 4, 8, 9, and 14. Of the subareas noted, Subareas 3, 8, and 9 rely entirely on groundwater for irrigation whereas Subareas 4 and 14 both have supplemental surface water supplies.

Presented in Table B-4 is the acreage planted in almonds, walnuts, and olives for the years 1988, 1993, and 1998. Since 1998, significant additional plantings of the respective crops have been made in the County; however, the amounts are not fully documented at this time. The planting of high-density olives for premium olive oil is anticipated to continue to increase. This further highlights the fact that the reliability of water to protect these investments warrants more refined management of available water resources.

With respect to land devoted to urban land uses, the information reflects an increase from 6,732 acres in 1993 to 11,149 acres in 1998, or a 66 percent increase during that 5-year period. In 2003, the population of the County was estimated at 27,049, an increase of 1.5 percent over the 2000 census. While the city of Orland with a population of 6,375 is almost equal to that of Willows at 6,275, Orland experienced a 24 percent growth between 1990 and 2000, compared to four percent growth over the same period for Willows. The population in the unincorporated area of the County was 14,399. The population of the two population centers represented nearly 47 percent of the total County population. The population density for the city of Willows in 2000 was approximately 3.4 people per acre.

The General Plan (2003) for the city of Orland projects a 2020 population ranging from about 9,000 to 10,500 depending upon the rate of growth assumed. The city of Willows, in its Land Use Element of its General Plan (1996) shows a projected population in 2010 of 8,844 with an additional population of 3,450 outside the City, but within the City's Urban Limit Line. With the available information, the population projected for Orland and Willows combined is approximately 25,000 in 2020. For comparison, the population projection for the County as a whole as noted by the California Department of Finance for the year 2020 is 31,950 (Table B-5). Using the population density of Willows in 2000 would indicate an increase in land for urban use in the order of 3,700 acres for the two cities. This would amount to approximately a one percent reduction of land in irrigated agriculture.

The various population projections for the cities and County would reflect a significant reduction in the population in the unincorporated area. This seems unlikely; however, for purposes of this work it is important only to note that from a practical standpoint the land for municipal purposes when viewed in the context of the County is relatively small. Of greater significance is the location of the land on which development will occur and its impact on existing irrigation infrastructure, as well as water supply and water quality. With respect to impacts to existing irrigation infrastructure, the Orland Unit Water Users' Association (OUWUA), Subarea 4, is without question encountering the greatest impact as a result of growth from the city of Orland. In addition to being impacted by urbanization associated with the growth of Orland, it is also being impacted by "suburbanization" as a result of land-use decisions made years ago which, for all practical purposes, are not reversible. The situation now exists where nearly 60 percent of the parcels within the OUWUA are 10 acres or less in size and of those nearly 60 percent are 5 acres or less in size.

As noted previously, the County is in the process of updating its General Plan. The 1993 General Plan showed plans to accommodate development through growth of the existing cities and along the Interstate 5 corridor in planning areas referred to as Brighton, Blue Gum, and Echo Glenn. These planning areas are within Subarea 5, which is largely the Orland-Artois Water District. The locations of the respective planning areas are shown on Figure B-2.

WATER USE

General

In keeping with the vision of the WAC, the water use categories to be addressed include agricultural, industrial, recreational, and municipal. In addition, it is deemed appropriate to address domestic and environmental water use.

Agriculture

Agriculture is by far the largest user of water resources in Glenn County and likewise represents the greatest economic industry in the County as well. In 2005, agriculture contributed $393,605,000 in gross sales, which was up 13 percent from $347,896,000 in 2004. Almonds were the largest contributor to the gross receipts followed by rice, which, in 2005, was $195,221,000 and $104,258,000, respectively. It is interesting to note here that 2005 is the first year that rice was not the largest in terms of sales.

With respect to water management, the two major crop categories in the County, rice and almonds together with other permanent fruits and nuts, are quite different. Rice requires considerably more water for managing herbicides and for crop production; however, the amount of land planted in a given year can be adjusted to accommodate water shortages. Permanent crops, which are becoming increasingly more important in the County, require less water to produce a crop; however, have much less flexibility to adjust to water shortages due to the significant investment in establishing the orchards and are therefore subject to greater risk under drought conditions.

An extensive analysis of crop water use and water demand for a large part of the land within the BMO subareas was performed as part of Technical Memorandum No. 3 (TM 3) for the Stony Creek Fan Conjunctive Water Management Program, which was prepared by the Stony Creek Partners. Implicit in the water use for rice is the water diverted for rice straw decomposition and waterfowl. Information presented in TM 3 for individual crop water use and irrigation efficiencies was used for purposes of estimating relative magnitudes of water use for the respective BMO subareas of the County.

Presented in Tables B-6, B-7, and B-8 are estimates of the surface water diverted and/or groundwater extracted for producing the crops reported by DWR in 1998. Table B-6 represents the subareas served largely by Stony Creek, the Sacramento River, and the Feather River. Table B-7 represents the subareas served by the Tehama Colusa Canal, and Table B-8 represents the subareas that rely solely on groundwater. Based upon these estimates, total water diverted from surface water sources or groundwater for irrigation in 1998 is in the order of 950,000 acre-feet. The amounts shown do not include the water diverted for rice-straw decomposition, which is provided primarily from surface water supplies. The total amount of water diverted each year for crop production can vary significantly depending upon the area planted and the crop mix; all of which can be influenced by hydrologic conditions, weather, cultural practices especially for rice, and commodity prices.

Information prepared by DWR in 1993 concurrent with their land-use survey shows land that was determined to be irrigated with surface water, groundwater, or a combination of both. This information is presented on Figure B-3. Presented in Table B-9 is a breakdown of the water sources for the respective subareas in 1993. Based upon the 1993 information, 59 percent of the irrigated land was irrigated with surface water, 34 percent with groundwater, and 7 percent having access to both. Presented in Table B-10 is similar information for 1998, showing 51 percent of the irrigated land being irrigated with surface water, 33 percent with groundwater, and 16 percent with access to both surface water and groundwater.

<u>Industrial</u>

There is no significant industrial water use presently and based upon information from the County Planning Department there does not appear to be any expressed interest for significant agricultural processing or other types of industry to locate in Glenn County.

Recreation

No designated water needs have been identified for recreational purposes in the County. The U.S. Bureau of Reclamation does, however, operate East Park, Stony Gorge, and Black Butte Reservoirs with consideration given to recreation at the respective facilities.

Municipal

All water supplied for municipal uses in the valley part of the County is from groundwater. The city of Orland provides water to its customers and the water for the city of Willows is provided by the California Water Company. The water supply for the communities of Hamilton City and Artois is provided through Community Services Districts. All other community or domestic water supplies in the County are provided from individual wells.

The amount of water utilized by the Orland and Willows in 2006 was approximately 1,820 acre-feet and 1,930 acre-feet, respectively. Based upon the population projections discussed under the land use section, the amount of water to be utilized by the two cities in the 2020 time frame could be in the order of 4,000 acre-feet.

Domestic

All domestic water used within the unincorporated area of the County is derived from groundwater, except for the Elk Creek Community Services District that diverts water from Stony Creek. For the unincorporated areas the estimated water use assuming an average water use of 150 gallons per capita per day amounted to approximately 4,500 acre-feet in 2003 and approximately 5,200 acre-feet in 2020.

From a practical standpoint, the availability of water for domestic purposes over time may be more a function of well construction and not supply.

Environmental

Water designated specifically for environmental purposes in the County are limited to the Sacramento National Wildlife Refuge (Refuge) and Stony Creek. With respect to the Refuge, Section 3406 (d) of the Central Valley Project (CVP) Improvement Act authorized the Secretary of the Interior to provide firm water supplies of suitable quality to certain national wildlife refuges, State of California wildlife management areas, and the Grasslands Resource Conservation District. The U.S. Bureau of Reclamation (BOR) is responsible for delivering CVP water to the refuge boundaries on a year-round basis. This water cannot be reduced more than 25 percent in drought years. The amount of water is based upon the March 1989 report entitled, "Report on Refuge Water Supply Investigations, Central Valley Hydrological Basin, California," prepared by the BOR.

The BOR has a long-term contract with the Glenn-Colusa Irrigation District (GCID) to convey the Sacramento River water from the GCID Hamilton City diversion to the refuge boundary. The refuge, which is in Glenn and Colusa Counties, may utilize up to 50,000 acre-feet per year to meet the wetland habitat management requirements. In the past few years the refuge has used about 40,000 acre-feet per year.

Water for environmental purposes in Stony Creek will be dealt with largely by parties outside of the County. Although the Orland Water Users Association will be involved in the process, Stony Creek is not regarded as a water use for which management decisions or actions are required by the County or entities in the County.

The cultural practice of using water for rice-straw decomposition will continue to provide substantial environmental benefits; however, the applications for purposes here are not regarded as "environmental water."

WATER SUPPLIES

The community of Glenn County collectively enjoys the benefits of substantial water supplies from the Sacramento River system, including Stony Creek and the Feather River, by virtue of the foresight, concerted effort, and investments on the part of individuals and agencies working together to develop and sustain an agricultural economy for more than 100 years. Summarized in Table B-11 are the principal sources of water for use within the respective BMO subareas of the County. Presented in Table B-12 are the amounts of water available through the primary water rights and water service contracts held by the entities serving land within the respective subareas. The amounts of water available through the water right appropriations and water service contracts can vary widely from year to year due to hydrologic conditions. No attempt was made for this work to identify the magnitude of the water supplies available through other water right applications and groundwater. Suffice it to say that the combination of supplies and the management thereof have sustained the people and economic activity of the County for many years.

Presented in TM 3 is an extensive water balance analysis and a detailed analysis of existing and future agricultural water demands projected to 2025 for a project area encompassing about 203,000 acres. Included within the project area were lands within the OUWUA, Orland-Artois Water District, and Glenn-Colusa Irrigation District (Stony Creek Partners) for which supplemental surface water supplies are available and the majority of the land west of the Sacramento River that relies solely on groundwater.

From the results of the evaluation presented in TM 3, it can be concluded that the long-term needs for the project area can be met with the available surface and groundwater supplies under hydrologic conditions similar to the 1921-1991 period. This accounts for anticipated changes in agricultural crop mix and the conversion of existing farm land to urban use. As part of TM3, an analysis of the 2025 water demand was performed using the Stony Creek Fan IGSM. Although the IGSM is merely a tool for evaluating the changes in land use and/or water use, the model results indicate that the groundwater basin could sustain the conditions projected.

Based upon the results of the work reported in TM 3, it is reasonable to conclude that water supplies—surface and groundwater—are adequate to sustain the agricultural economy and population of the County through hydrologic conditions experienced in the last 80 years. The following facts also support this conclusion:

1. The land suitable for agricultural crops is essentially fully developed, although the potential for selected crops being cultivated in the foothills should be examined.

2. No major shifts in higher water using crops are anticipated.

3. The area has significant supplemental water supplies.

4. The overall groundwater basin, as described under Task E., is not stressed.

5. No significant changes in land use are anticipated that would result in substantially greater water use.

In saying this, it is important to point out the fact that there has been a significant increase in the area planted to permanent crops and a large part of the area is within subareas that rely solely on groundwater. Accordingly, the option to fallow cropland during drought conditions has been reduced. The management of water supplies under drought conditions experienced in the past will present different challenges that were encountered then. Understanding this, it is imperative that the capability and constraints of the groundwater basin are better understood so sound management decisions can be made.

The water supplies discussed generally above will continue to be the foundation for the County; however, the management thereof will continue to become increasingly more complex as a result of recently negotiated Settlement and CVP Water Service Contracts, the cost to maintain and protect water rights, the cost to maintain and operate irrigation infrastructure, and the management of supplies to comply with water quality regulations. Under the new CVP water service contracts, the cost of water essentially increased substantially overnight. As a consequence, the goal of providing sufficient water at affordable prices becomes increasingly difficult and presents a "real" challenge to management of the entities with those supplies. Unfortunately, the new CVP Water Service Contracts and the rate structures serve more as disincentive to improve water management.

The ability for agriculture in the County to alter its cropping substantially to produce higher value crops is limited. As a consequence, the future for affordable water in the County will be determined to a great extent on the management of the supplies and resources available. The cost of water could easily become a greater constraint than the supply.

With reference to Figure E-11 and Figure E-12 presented in Section E of this report, the area within BMO Subarea 5 is the only area within the County that reflects a depression in spring groundwater levels. This is not to suggest that there is a groundwater overdraft, but merely to draw attention to the area in order that special consideration may be given in developing the strategy for water management in the area.

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TASK B – TABLES

TABLE B-1

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

LAND USE BY SUBAREA: 1993 AND 1998[1]

Land Use	Subarea 1		Subarea 2		Subarea 3		Subarea 4		Subarea 5		Subarea 6		Subarea 7		Subarea 8		Subarea 9	
	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998
Deciduous Fruits and Nuts	0	0	0	0	1,149	4,784	3,347	3,598	6,039	10,180	168	428	136	1,106	8,007	8,484	3,237	4,333
Citrus and Subtropical	0	0	0	0	50	35	2,658	2,852	1,621	1,887	0	0	0	0	296	375	269	320
Field Crops	0	0	0	0	409	2	449	984	3,503	5,054	1,095	1,977	4,956	6,114	1,208	1,064	3,153	2,550
Grain	0	53	0	36	1,535	521	908	423	7,557	5,040	2,521	1,637	9,281	4,870	1,829	2,118	2,212	1,244
Rice	0	0	0	0	0	1	0	0	3,117	2,950	1,771	2,243	1,621	1,320	0	0	215	201
Truck, Nursery, and Berry Crops	0	0	0	0	27	15	1	15	92	73	0	0	250	924	0	176	0	315
Vineyards	0	0	0	0	0	0	0	0	1,334	1,537	0	0	0	0	0	0	0	0
Semiagricultural and Incidental to Agriculture	0	7	5	3	138	140	611	1,051	491	638	37	36	197	200	350	385	190	126
Pasture	0	0	273	177	1,705	1,707	10,701	9,047	7,322	6,062	408	194	1,706	1,723	5,065	3,558	3,539	4,002
Fallow/Idle	0	0	0	74	1,913	1,353	1,605	400	4,773	1,277	496	74	544	56	1,454	429	507	116
Subtotal	0	60	278	290	6,926	8,558	20,280	18,370	35,849	34,698	6,496	6,589	18,691	16,313	18,209	16,589	13,322	13,207
Barren	0	328	0	27	460	1,442	117	532	0	16	0	0	0	0	0	548	0	286
Native Vegetation[2]	17,346	16,901	1,638	1,578	63,625	59,903	3,256	3,354	7,168	7,649	3,189	2,920	5,325	7,146	2,394	3,075	797	442
Riparian Vegetation	0	36	72	67	447	1,355	416	828	656	439	41	35	82	75	833	839	0	103
Water	94	115	19	45	2,810	2,584	97	239	346	504	100	141	227	202	303	439	27	41
Urban	0	0	0	0	123	549	1,812	2,655	753	1,466	25	166	46	635	534	783	14	81
Subtotal	17,440	17,380	1,729	1,717	67,465	65,833	5,698	7,608	8,923	10,074	3,355	3,262	5,680	8,058	4,064	5,684	838	953
TOTAL	17,440	17,440	2,007	2,007	74,391	74,391	25,978	25,978	44,772	44,772	9,851	9,851	24,371	24,371	22,273	22,273	14,160	14,160

Land Use	Subarea 10		Subarea 11[3,4]		Subarea 12[3]		Subarea 13[3]		Subarea 14[3]		Subarea 15		Subarea 16[3]		Subarea 17		Total	
	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998
Deciduous Fruits and Nuts	758	1,880	4,466	5,522	12	11	0	0	3,605	4,366	3,624	4,110	0	0	168	429	34,716	49,231
Citrus and Subtropical	383	379	16	82	0	0	0	0	0	0	0	0	0	0	0	0	5,293	5,930
Field Crops	5,352	4,950	3,673	3,620	24	81	0	0	2,336	1,212	6,208	8,555	3	4	1,330	1,016	33,699	37,183
Grain	4,498	4,480	4,388	3,244	55	0	0	0	279	300	3,041	563	0	0	460	0	38,564	24,529
Rice	679	255	41,982	45,895	13,906	13,702	87	158	5,147	4,863	1,573	1,809	410	422	13,390	13,292	83,898	87,111
Truck, Nursery, and Berry Crops	4	148	11	667	0	0	0	0	11	136	1,957	1,277	1	0	104	4	2,458	3,750
Vineyards	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,335	1,544
Semiagricultural and Incidental to Agriculture	131	247	1,005	868	104	26	0	0	166	218	110	117	0	0	35	17	3,570	4,079
Pasture	5,275	4,802	4,954	4,333	58	0	85	77	425	206	1,729	1,816	8	0	101	122	43,354	37,826
Fallow/Idle	1,456	423	7,771	3,121	1,012	338	43	0	448	173	2,392	965	9	6	3,326	670	27,749	9,475
Subtotal	18,537	17,571	68,266	67,352	15,171	14,158	215	235	12,417	11,474	20,634	19,212	431	432	18,914	15,550	274,636	260,658
Barren	0	0	0	209	0	0	0	0	2	156	8	242	0	0	0	0	587	3,786
Native Vegetation[2]	1,152	1,638	7,352	6,447	266	25	1	2	147	76	675	359	14	1	316	175	114,661	111,691
Riparian Vegetation	61	149	8,421	8,474	25	39	481	418	1,115	1,232	1,934	2,756	10	17	1,206	3,778	15,800	20,640
Water	14	263	1,662	2,614	102	1,259	0	42	412	1,001	595	998	33	38	0	808	6,841	11,333
Urban	2,100	2,243	1,248	1,853	0	83	0	0	35	189	42	321	0	0	0	125	6,732	11,149
Subtotal	3,327	4,293	18,683	19,597	393	1,406	482	462	1,711	2,654	3,254	4,676	57	56	1,522	4,886	144,621	158,599
TOTAL	21,864	21,864	86,949	86,949	15,564	15,564	697	697	14,128	14,128	23,888	23,888	488	488	20,436	20,436	419,257	419,257

[1] Does not include the total county.
[2] Adjusted to make total area the same for each year.
[3] Glenn County part of the district only.
[4] Includes the Sacramento National Wildlife Refuge.

Source: California Department of Water Resources.

TABLE B-2

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

AGRICULTURAL CROPLAND BY BMO SUBAREA: 1998[1]

BMO Subarea	Total Area, ac	Gross Agricultural Land	
		Area, ac	Area, %
3[2]	74,391	8,558	3
4	25,978	18,370	7
5	44,772	34,698	13
6	9,851	6,589	3
7	24,371	16,313	6
8[2]	22,273	16,589	6
9[2]	14,160	13,322	5
10[2]	21,864	17,571	7
11[3]	86,949	67,352	26
12	15,564	14,158	5
14	14,128	11,474	4
15[2]	23,888	19,212	7
17	20,436	15,550	6
TOTAL	398,625	259,756	100

[1]BMO subareas with more than 500 acres in cropland in 1998.

[2]Subarea regulated solely with groundwater supply.

[3]Includes the Sacramento National Wildlife Refuge.

TABLE B-3

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B: WATER NEEDS ANALYSIS

PERMANENT CROPS IN RELATION TO TOTAL CROPPED AREA: 1998

Crop	Subarea 1		Subarea 2		Subarea 3[1]		Subarea 4		Subarea 5		Subarea 6		Subarea 7		Subarea 8[1]		Subarea 9[1]	
	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%
Deciduous Fruits and Nuts	0	0	0	0	4,784	55.9	3,598	19.6	10,180	29.3	428	6.5	1,106	6.8	8,007	48.3	4,333	32.8
Citrus and Subtropical	0	0	0	0	35	0.4	2,852	15.5	1,887	5.4	0	0.0	0	0.0	296	1.8	320	2.4
Vineyards	0	0	0	0	0	0.0	0	0.0	1,537	4.4	0	0.0	0	0.0	0	0.0	0	0.0
Subarea Total	60	100	290	100	8,558	100	18,370	100	34,698	100	6,589	100	16,313	100	16,589	100	13,207	100

Crop	Subarea 10[1]		Subarea 11[2]		Subarea 12[2]		Subarea 13		Subarea 14[2]		Subarea 15[1]		Subarea 16		Subarea 17		Total	
	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%	Area, ac	%
Deciduous Fruits and Nuts	1,880	10.7	5,522	8.2	11	0.1	0	0.0	4,366	38.1	4,110	21.4	0	0.0	429	2.8	49,231	19
Citrus and Subtropical	379	2.2	82	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5,930	2
Vineyards	7	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1,544	1
Subarea Total	17,571	100	67,352	100	14,158	100	253	100	11,474	100	19,212	100	432	100	15,550	100	260,658	100

[1]Private groundwater pumpers.

Source: California Department of Water Resources.

TABLE B-4

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B - WATER NEEDS ANALYSIS

ALMONDS, WALNUTS, AND OLIVES: 1988, 1993, AND 1998

Crop	1988	1993	1998	% Increase, 1988-1998
Almonds	15,285	17,609	27,993	83
Walnuts	6,992	6,965	9,335	34
Olives	2,590	4,073	4,796	85

Source: California Department of Water Resources.

TABLE B-5

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

GLENN COUNTY POPULATION PROJECTION

Year	Population
2000	26,718
2010	29,348
2020	31,950
2030	34,379
2040	37,182
2050	40,167

TABLE B-6

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B - WATER NEEDS ANALYSIS

ESTIMATED IRRIGATION DIVERSION/EXTRACTION FOR SURFACE WATER SUBAREAS: 1998
(acre-feet)

Land Use	Stony Creek	Sacramento River			Feather River	Total
	Subarea 4	Subarea 11	Subarea 12	Subarea 14	Subarea 17	
Alfalfa	3,310	4,380	0	1,160	650	9,500
Almonds	9,780	15,150	50	3,050	30	28,060
Apples	40	0	0	0	0	40
Apricots	20	0	0	0	0	20
Barley	40	0	0	0	0	40
Beans	50	730	0	790	10	1,580
Clover	0	520	0	0	0	520
Corn	12,540	5,000	270	1,110	1,850	20,770
Cotton	0	1,430	0	0	0	1,430
Eucalyptus	190	4	0	0	0	194
Grain Sorghum	70	580	0	0	0	650
Kiwis	110	40	0	0	0	150
Misc. Deciduous	340	0	0	0	0	340
Misc. Field	0	20	0	0	0	20
Mixed Pasture	47,440	19,480	0	0	30	66,950
Oats	0	1	0	0	0	1
Olives	9,480	250	0	0	0	9,730
Oranges	820	0	0	0	0	820
Peahces/Nectarines	130	0	0	0	0	130
Pistachios	1,350	0	0	0	0	1,350
Prunes	4,450	3,760	0	4,460	2,040	14,710
Rice	0	233,240	69,630	24,710	67,550	395,130
Sudan	340	30	0	0	20	390
Sugar Beets	0	20	0	0	0	20
Sunflowers	0	2,130	0	790	440	3,360
Truck	40	40	0	370	10	460
Unknown Grain	730	5,630	0	540	0	6,900
Walnuts	770	6,630	4	12,390	20	19,814
Wheat	0	260	0	0	0	260
TOTAL	92,040	299,325	69,954	49,370	72,650	583,339

TABLE B-7

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

ESTIMATED IRRIGATION DIVERSION/EXTRACTION FOR TEHAMA-COLUSA CANAL SUBAREAS: 1998
(acre-feet)

Land Use	Subarea 5	Subarea 6	Subarea 7	Total
Alfalfa	12,270	1	5,230	17,501
Almonds	29,200	1,150	2,690	33,040
Barley	80	0	0	80
Beans	1,030	70	0	1,100
Clover	4,900	0	1,530	6,430
Corn	9,780	3,680	8,410	21,870
Cotton	0	0	790	790
Eucalyptus	710	0	0	710
Grain Sorghum	130	0	210	340
Kiwis	20	0	0	20
Misc. Deciduous	140	0	0	140
Misc. Field	20	0	0	20
Misc. Grain and Hay	350	0	0	350
Mixed Pasture	9,570	810	940	11,320
Oats	10	0	0	10
Olives	3,640	0	0	3,640
Oranges	1,070	0	0	1,070
Pistachios	450	410	470	1,330
Prunes	6,060	0	640	6,700
Rice	11,680	8,880	5,230	25,790
Sudan	950	330	2,380	3,660
Sugar Beets	260	340	1,800	2,400
Sunflowers	1,220	750	3,190	5,160
Truck	160	0	1,980	2,140
Unknown Grain	6,220	2,130	6,440	14,790
Vineyard	3,840	0	0	3,840
Walnuts	1,310	0	240	1,550
Wheat	490	190	470	1,150
TOTAL	105,560	18,741	42,640	166,941

TABLE B-8

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

ESTIMATED IRRIGATION/EXTRACTION FOR PRIVATE PUMPER SUBAREAS: 1998
(acre-feet)

Land Use	Subarea 3	Subarea 8	Subarea 9	Subarea 10	Subarea 15	Total
Alfalfa	0	2,200	0	11,880	6,880	20,960
Almonds	16,220	11,370	11,910	3,430	440	43,370
Beans	0	1,020	660	1,740	2,560	5,980
Cherries	0	30	0	0	0	30
Clover	0	0	2,110	5,510	0	7,620
Corn	5	1,180	3,540	6,550	9,610	20,885
Eucalyptus	20	30	0	10	0	60
Grain	690	0	0	0	0	690
Grain Sorghum	0	0	90	540	0	630
Kiwis	10	0	5	0	0	15
Misc. Deciduous	0	40		0	0	40
Misc. Field	0	40	0	30	0	70
Misc. & Mixed Grain	0	0	5,650	0	0	5,650
Mixed Pasture	0	11,790	3,050	2,810	0	17,650
Native Pasture	0	10	0	0	0	10
Oats	0	20	0	80	0	100
Olives	70	1,010	790	860	0	2,730
Oranges	0	0	70	140	0	210
Pasture	6,670	0	0	0	0	6,670
Pears	0	0	0	10	0	
Pistachios	0	660	0	1,010	0	1,670
Prunes	2	13,350	1,340	1,310	4,830	20,832
Rice	2	0	740	940	6,690	8,372
Sudan	0	0	470	990	2,020	3,480
Sugar Beets	0	0	700	970	0	1,670
Sunflowers	1	110	590	1,420	3,650	5,771
Truck	30	350	630	300	2,550	3,860
Turf Farms	0	0	0	0	610	
Unknown Grain	0	2,770	1,640	0	740	5,150
Vineyard	0	0	0	20	0	20
Walnuts	0	3,680	1,420	630	8,420	14,150
Wheat	0	0	0	190	0	190
TOTAL	23,720	49,660	35,405	41,370	49,000	198,535

TABLE B-9

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

IRRIGATION WATER SOURCES - 1993

Irrigation Water Source	Area, ac																	
	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Subarea 7	Subarea 8	Subarea 9	Subarea 10	Subarea 11	Subarea 12	Subarea 13	Subarea 14	Subarea 15	Subarea 16	Subarea 17	Total
Surface Water	0	273	1,426	17,702	15,559	6,169	14,761	159	243	1,625	65,993	15,065	132	5,903	2,451	427	17,345	165,233
Groundwater	0	0	4,656	1,371	8,734	219	1,193	17,199	12,472	16,075	6,769	5	0	5,972	17,714	4	1,625	94,008
Mixed	0	0	709	653	11,127	71	2,541	513	367	789	1,839	15	546	375	368	0	0	19,913
Not Surveyed	17,440	1,734	67,600	6,252	9,352	3,392	5,876	4,402	1,078	3,375	12,348	479	19	1,878	3,355	57	1,466	140,103
TOTAL	17,440	2,007	74,391	25,978	44,772	9,851	24,371	22,273	14,160	21,864	86,949	15,564	697	14,128	23,888	488	20,436	419,257

Source: California Department of Water Resources, 1993

TABLE B-10

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

IRRIGATION WATER SOURCES - 1998

Irrigation Water Source	Area, ac																	
	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Subarea 7	Subarea 8	Subarea 9	Subarea 10	Subarea 11	Subarea 12	Subarea 13	Subarea 14	Subarea 15	Subarea 16	Subarea 17	Total
Surface Water	0	251	1,747	14,288	7,170	4,513	12,549	656	20	279	59,740	11,799	11	3,993	1,402	414	15,620	134,452
Groundwater	0	0	6,309	1,701	7,325	2	515	14,071	12,920	14,437	6,789	11	0	5,593	14,535	0	1,338	85,546
Mixed	0	0	279	1,162	18,002	1,019	1,856	0	139	1,558	7,088	2,334	642	1,793	3,619	18	1,592	41,101
Not Surveyed	17,440	1,756	66,056	8,827	12,275	4,317	9,451	7,546	1,081	5,590	13,332	1,420	44	2,749	4,332	56	1,886	158,158
TOTAL	17,440	2,007	74,391	25,978	44,772	9,851	24,371	22,273	14,160	21,864	86,949	15,564	697	14,128	23,888	488	20,436	419,257

Source: California Department of Water Resources, 1993

TABLE B-11

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK B - WATER NEEDS ANALYSIS

SUMMARY OF WATER SOURCES FOR BMO SUBAREAS[1]

BMO Subarea	Water Sources
3	Groundwater
4	Pre-1914 Water Rights, Appropriated Water Rights, and Groundwater
5	CVP Water Service Contract and Groundwater
6	CVP Water Service Contract and Groundwater
7	CVP Water Service Contract and Groundwater
8	Groundwater
9	Groundwater
10	Groundwater
11	CVP Water Service and Settlement Contract, Pre-1914 Water Rights, Appropriated Water Rights, and Groundwater
12	CVP Water Service and Settlement Contract, Appropriated Water Rights, and Groundwater
14	CVP Water Service and Settlement Contract, AppropriatedWater Rights, and Groundwater
15	Groundwater
17	Pre-1914 Water Rights and Groundwater

[1]BMO subareas with more than 500 acres in cropland in 1998.

TABLE B-12

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

SUMMARY OF PRIMARY WATER RIGHTS AND CONTRACTS FOR SURFACE WATER

(acre-feet)

Subareas			USBR Contract		
		Other	Base Supply	Project Water	Total
1	West Corning Basin Private Pumpers				
2	Stony Creek Water District				
3	West Colusa Basin Private Pumpers				
4	Orland Unit Water Users' Association [1]	135,250			135,250
5	Orland-Artois Water District			53,000[2]	
6	Glide Water District			10,500[2]	
7	Kanawha Water District			45,000[2]	
8	East Corning Basin Private Pumpers				
9	Bos District Five Pumpers				
10	Bos District Three Pumpers				
11	Glenn-Colusa Irrigation District [3]		720,000	105,000	825,000
12	Provident Irrigation District [3]		49,730	5,000	54,730
13	Willow Creek Mutual Water Company [3]				
14	Princeton-Codora-Glenn Irrigation District [3]		52,810	15,000	67,810
15	Reclamation District No. 2106				
17	Western Canal Water District [4]	295,000			295,000

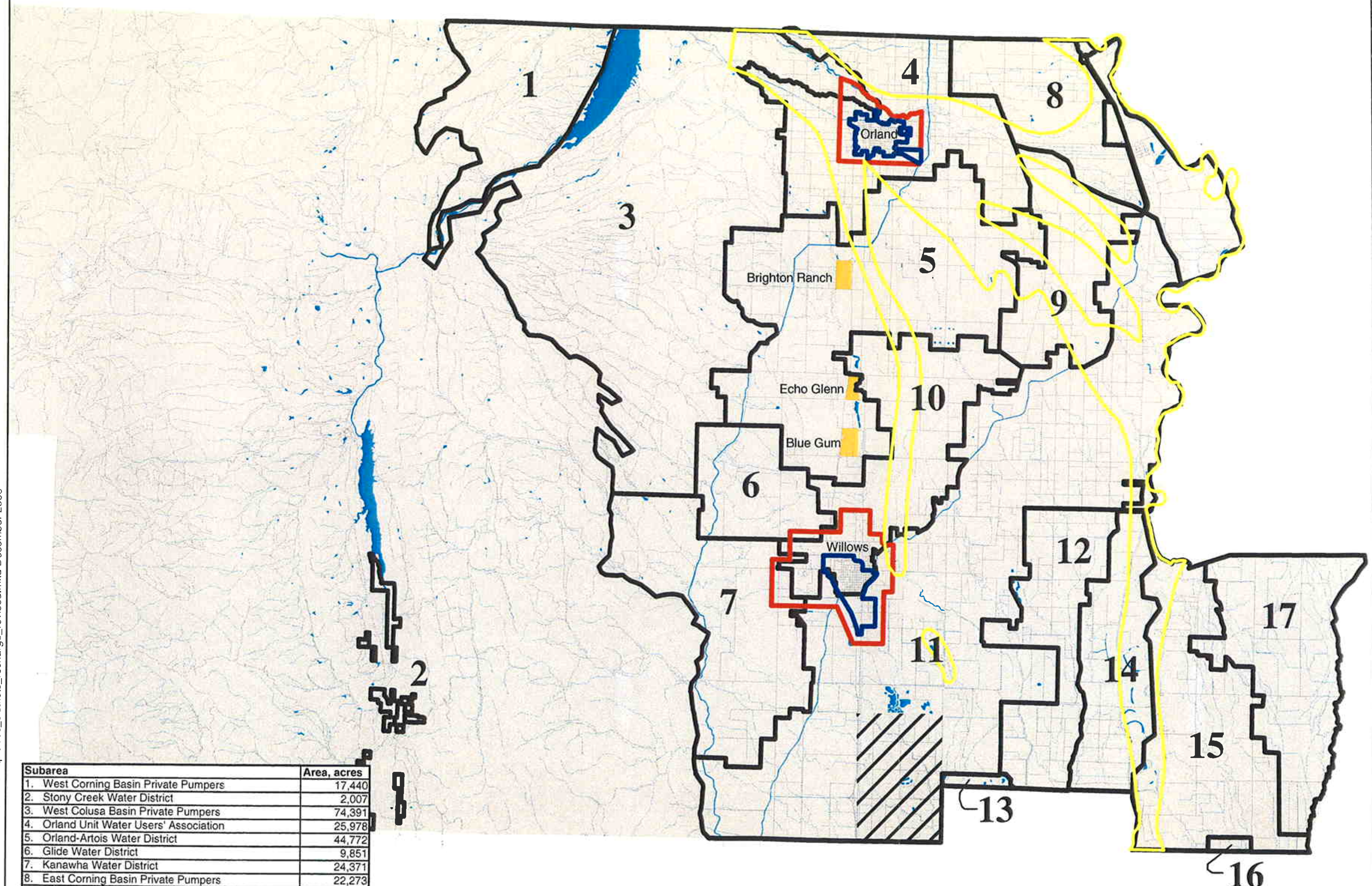
[1]Maximum available under pre-1914 and water rights appropriation from the Orland and Stony Gorge projects combined.

[2]Tiered pricing contracts where affordability of 10 to 20 percent of the contract amount is problematic.

[3]District service is in both Glenn and Colusa Counties. The District has other water rights/permits for providing water for rice straw decomposition.

[4]The District service area is in both Glenn and Butte Counties and has 150,000 acre-feet of pre-1914 surface water rights of natural flow on the Feather River and 145,000 acre-feet of stored water on the N. Fork Feather River.

TASK B – FIGURES



Subarea	Area, acres
1. West Corning Basin Private Pumpers	17,440
2. Stony Creek Water District	2,007
3. West Colusa Basin Private Pumpers	74,391
4. Orland Unit Water Users' Association	25,978
5. Orland-Artois Water District	44,772
6. Glide Water District	9,851
7. Kanawha Water District	24,371
8. East Corning Basin Private Pumpers	22,273
9. BOS District Five Private Pumpers	14,160
10. BOS District Three Private Pumpers	21,864
11. Glenn-Colusa Irrigation District	86,949
12. Provident Irrigation District	15,564
13. Willow Creek Mutual Water Company	697
14. Princeton-Codora-Glenn Irrigation District	14,128
15. Reclamation District No. 2106 (Private Pumpers)	23,888
16. Reclamation District No. 1004	488
17. Western Canal Water District	20,436
TOTAL	**419,257**

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LEGEND

Subarea Boundary[1]

City Boundary[2]
Orland: 1,525 acres
Willows: 1,845 acres

Planning Area[3]
Orland: 4,045 acres
Willows: 8,360 acres

Groundwater Recharge Overlay[4]

1993 General Plan Planning Areas

Sacramento National Wildlife Refuge

City of Orland:

Subarea	City Area, ac	Planning Area, ac
3	5	445
4	1,520	3,600
Total	1,525	4,045

City of Willows:

Subarea	City Area, ac	Planning Area, ac
6	-	210
7	-	835
10	1,095	4,325
11	750	2,990
Total	1,845	8,360

SOURCES:
1 Glenn County Groundwater Management Ordinance No. 1115.
2 City of Orland and City of Willows General Plans. City Boundary is defined as the incorporated area.
3 City of Orland and City of Willows General Plans. Planning area is assumed to be the Sphere of Influence as defined by LAFCO.
4 Glenn County General Plan.

0 4 8 Miles

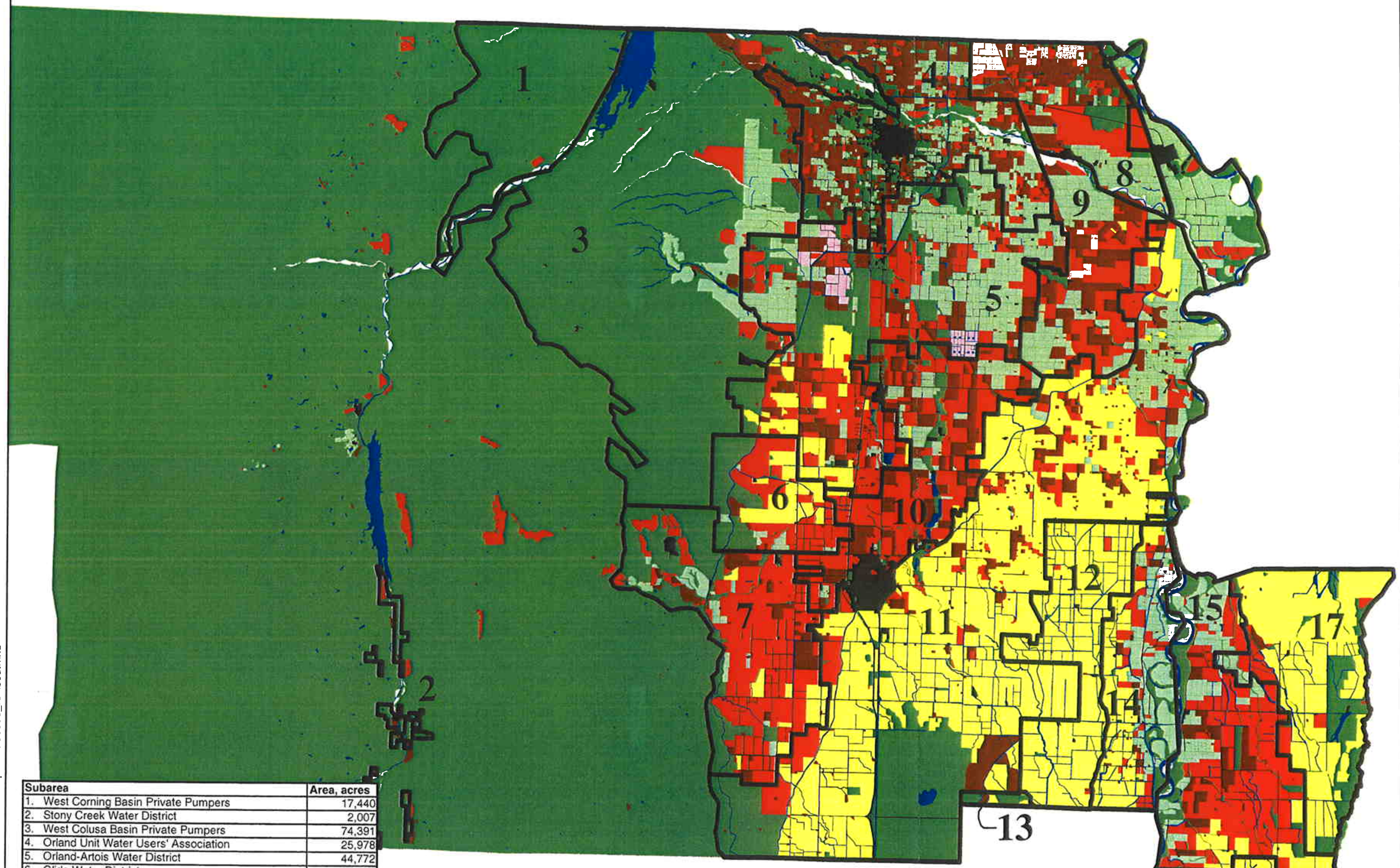
GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

BASIN MANAGEMENT OBJECTIVE - SUBAREAS

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

FIGURE B-1



Subarea	Area, acres
1. West Corning Basin Private Pumpers	17,440
2. Stony Creek Water District	2,007
3. West Colusa Basin Private Pumpers	74,391
4. Orland Unit Water Users' Association	25,978
5. Orland-Artois Water District	44,772
6. Glide Water District	9,851
7. Kanawha Water District	24,371
8. East Corning Basin Private Pumpers	22,273
9. BOS District Five Private Pumpers	14,160
10. BOS District Three Private Pumpers	21,864
11. Glenn-Colusa Irrigation District	86,949
12. Provident Irrigation District	15,564
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15. Reclamation District No. 2106 (Private Pumpers)	23,888
16. Reclamation District No. 1004	488
17. Western Canal Water District	20,436
TOTAL	**419,257**

SOURCES:
Department of Water Resources, 1998
Glenn County

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Glenn County

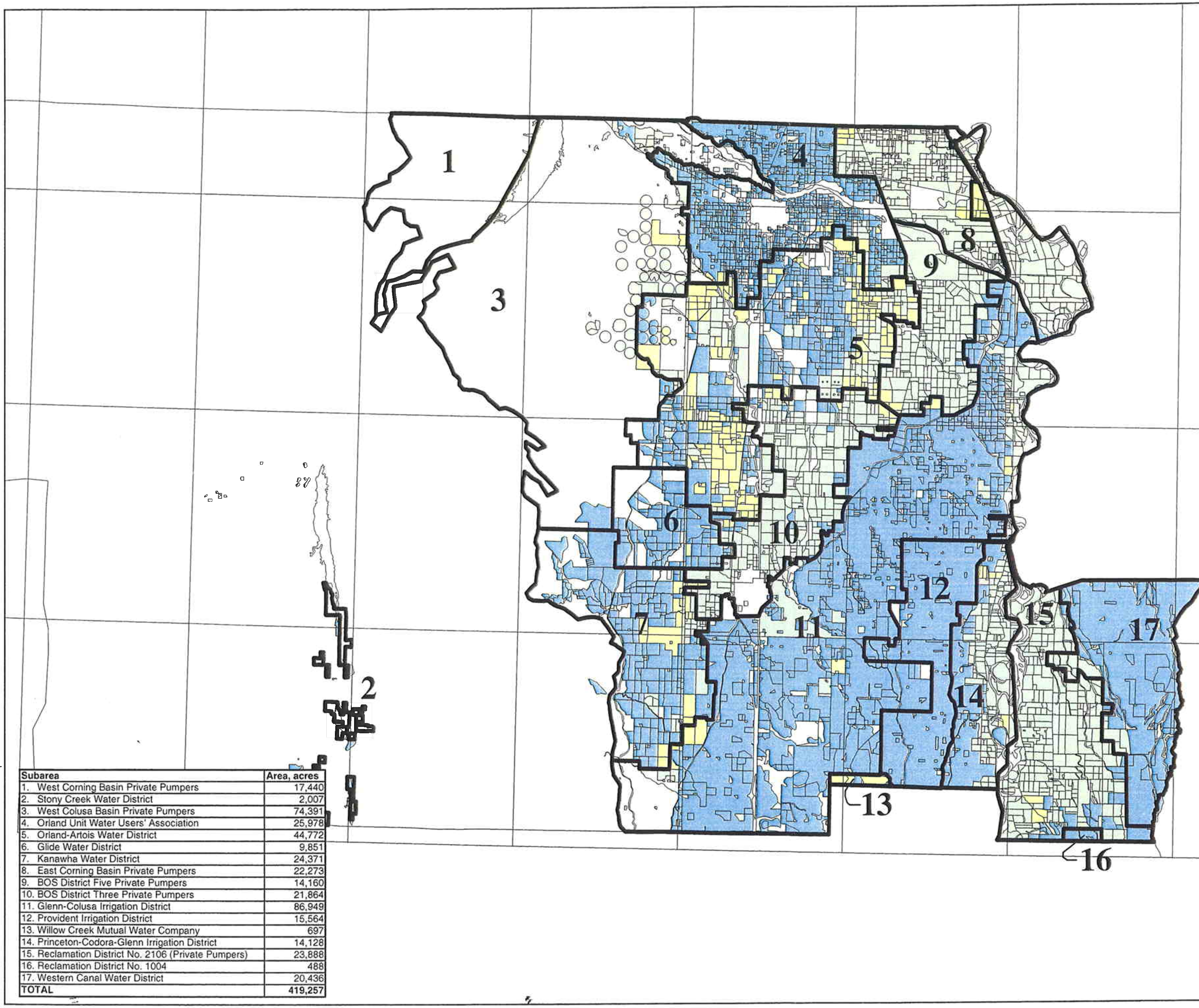
GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

LAND USE - 1998

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

FIGURE B-2



Subarea	Area, acres
1. West Corning Basin Private Pumpers	17,440
2. Stony Creek Water District	2,007
3. West Colusa Basin Private Pumpers	74,391
4. Orland Unit Water Users' Association	25,978
5. Orland-Artois Water District	44,772
6. Glide Water District	9,851
7. Kanawha Water District	24,371
8. East Corning Basin Private Pumpers	22,273
9. BOS District Five Private Pumpers	14,160
10. BOS District Three Private Pumpers	21,864
11. Glenn-Colusa Irrigation District	86,949
12. Provident Irrigation District	15,564
13. Willow Creek Mutual Water Company	697
14. Princeton-Codora-Glenn Irrigation District	14,128
15. Reclamation District No. 2106 (Private Pumpers)	23,888
16. Reclamation District No. 1004	488
17. Western Canal Water District	20,436
TOTAL	419,257

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LEGEND

- Surface Water
- Groundwater
- Mixed Surface and Groundwater
- Not Surveyed

SOURCES:
Department of Water Resources, 1993
Glenn County

0 4 8 Miles

Glenn County

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK B. WATER NEEDS ANALYSIS

IRRIGATION WATER SOURCES

WOOD RODGERS
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FIGURE B-3

WATER DELIVERY AND DISTRIBUTION INFRASTRUCTURE

TASK C

TASK C. IRRIGATION WATER DELIVERY AND DISTRIBUTION INFRASTRUCTURE

The opportunity for the management of water supplies—surface water and groundwater— and the coordination of supplies during emergencies or in times of drought can be best identified with a map that shows the existing irrigation water delivery and distribution infrastructure throughout the County. This map can also be used to facilitate the initial planning and the consideration of impacts that may occur from future development. For this reason, a map showing the existing irrigation infrastructure in the County was prepared. (Figure C-1). The irrigation infrastructure in Glenn County consists of open canals and pipelines as noted on Figure C-1. Information on the capacity, size, and specific location of the facilities is available from the respective districts.

With respect to water management, there is no question that the most effective means for recharging the groundwater basin in Glenn County is by "in-lieu" recharge. This allows for the recharge to occur where the recharge is most desired.

As noted in the discussion in Task B., Water Needs Analysis, permanent crops are becoming increasingly important in the agricultural economy of Glenn County, including the subareas that presently rely solely on groundwater. In the event of an extended drought, these areas are subject to a greater risk with respect to the investment in permanent crops than areas where supplemental water supplies have been acquired. Presently, there is no opportunity to transfer water to these areas; however, this could be considered in the future. Similarly, consideration could be given to providing surface water supplies to support future development, thereby assisting in the conjunctive use of the available supplies.

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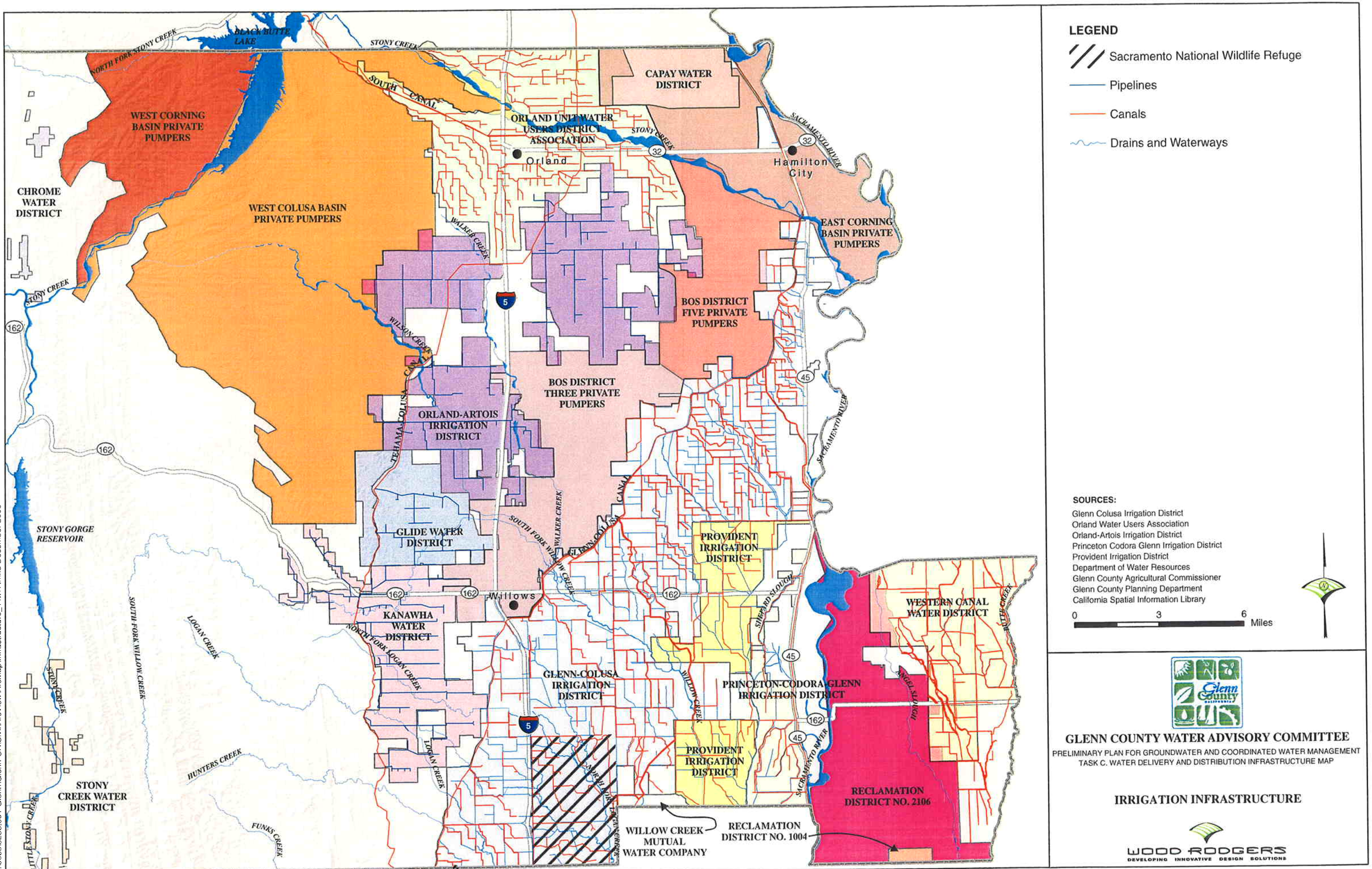

FIGURE C-1

GROUNDWATER MONITORING PROGRAM

TASK E

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TABLES

FIGURES

OVERVIEW OF GROUNDWATER MONITORING

Groundwater monitoring is the process of collecting the data necessary to support specific evaluations of a groundwater system. Some major components of most evaluations include:

- determining changes in overall groundwater conditions over time;
- characterizing the groundwater system in a defined geographical area in detail; and
- understanding the effects of specific actions on groundwater conditions.

Depending upon the desired evaluations, groundwater monitoring can vary widely in area covered, types of data collected, and frequency of measurements. Monitoring that is adequate for one purpose (e.g., determining changes in overall groundwater conditions over time) may not be adequate for another purpose (e.g., understanding the effects of a specific action on groundwater conditions).

A monitoring plan is a strategy for gathering the data necessary to support the desired evaluations. Monitoring plans can be formal documents, but are often informal procedures that are followed, like when a water district makes routine measurements of water levels in a group of wells. In order to formulate an effective monitoring plan, the desired evaluations of the groundwater system must be well-understood to ensure that the monitoring provides the data necessary to support these evaluations.

OBJECTIVES OF GROUNDWATER MONITORING IN GLENN COUNTY

Glenn County's "Basin Management Objectives for Groundwater Surface Elevations in Glenn County, California," provides the following statement of objectives for groundwater within the County:

> "The objective of these BMOs is to maintain the groundwater surface elevation at a level that will assure an adequate and affordable irrigation supply. It is the intent of this objective to assure a sustainable agricultural water supply now and into the future. The objective also assures an adequate groundwater supply for all domestic users in Glenn County."

Although the body of the BMO document does not include specific water quality and land subsidence objectives, the accompanying cover letter to the Board of Supervisors, prepared by the Glenn County Water Advisory Committee, includes "interim" objectives:

1. No deterioration in groundwater quality from current [2001] conditions.

2. No additional land subsidence.

These objectives and related intents can be restated as follows to make them easier to interpret with regard to groundwater monitoring:

1. Groundwater levels should remain similar to current and historic levels, so farmers will not need to drill new wells, lower pumps, or pay increased electricity costs associated with lifting water from greater depths. Groundwater quality should remain acceptable for irrigation use without treatment.

2. There should be no changes in groundwater levels or quality that are significant enough to prevent using groundwater for agricultural and domestic supply now and in the future.

3. There should be no inelastic land subsidence that results in a permanent loss of aquifer storage or adversely impacts infrastructure.

Glenn County has adopted specific BMOs for water levels in key monitoring wells to evaluate whether these objectives are being met. The BMOs set three "alert" stages that are triggered when spring groundwater levels fall below two pre-established levels.

The objectives outlined above have the basic goal of preserving the usefulness of the overall groundwater resources within Glenn County over the long term. Glenn County's groundwater management ordinance (County Code 20.003) mandates the development of a monitoring program that includes groundwater levels, groundwater quality, and land subsidence, for the purpose of evaluating compliance with the established BMOs. This Monitoring Plan has been developed to ensure that the necessary data is being collected to allow for a full evaluation of whether the underlying objectives (as outlined above) are being met. This plan is not intended to be specific to existing or future BMOs. However, the plan includes an analysis of existing groundwater monitoring, including existing BMO monitoring, and recommendations for improvements.

BACKGROUND

Glenn County is located in the Central Valley and Coast Ranges of northern California, approximately midway between Sacramento and Redding. The County covers approximately 1,319 square miles, and has a population of 26,453 (2000 Census). Land use within the County is largely agricultural, with approximately 260,000 acres in production (1998 California Department of Water Resources Land Use).

There are seven groundwater basins within Glenn County (Figure E-1), as defined by the California Department of Water Resources (DWR) in "California's Groundwater, Bulletin 118 – Update 2003": the Chrome Town Area, Elk Creek Area, Stony Gorge Reservoir, Squaw Flat, Stonyford Town Area, Funks Creek, and Sacramento Valley Groundwater Basin. Of these, all except the Sacramento Valley Groundwater Basin are small (less than 10 square miles) isolated basins located in the Coast Ranges in the central to western portions of the County; they have not been divided into subbasins. The Stonyford Town Area and Funks Creek Groundwater Basins also extend into Colusa County. Due to the lack of available data, further discussion of these small basins is not included in this Monitoring Plan.

The Sacramento Valley Groundwater Basin, in contrast to the smaller basins described above, covers over 5,900 square miles and 10 counties, and has been divided into 18 subbasins. According to DWR,

> "A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined […] features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. […]
>
> "A subbasin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries […]. These subbasins are created for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins."

Glenn County overlies portions of three subbasins of the Sacramento Valley Groundwater Basin: the Corning, Colusa, and West Butte Subbasins. Stony Creek is the boundary between the Corning Subbasin to the north and the Colusa Subbasin to the south. The Sacramento River bounds the Corning and Colusa Subbasins on the east and the West Butte Subbasin on the west. These surface water features are occasionally described as barriers to groundwater flow in the shallowest aquifers; however, data to support or oppose this theory is limited. The bulk of groundwater monitoring in Glenn County is in the Colusa Subbasin, which covers the largest area in the county.

Glenn County is also fortunate to have extensive surface water supplies. A number of the water districts in the County (Figure E-2) deliver surface water from the Sacramento River or Stony Creek. Water districts in Glenn County have settlement or water service contracts with the United States Bureau of Reclamation for over 850,000 acre-feet of base supply and over 200,000 acre-feet of project supply. In addition, the Orland Project provides over 100,000 acre-feet of surface water to water districts in Glenn County. The Tehama-Colusa Canal and the Glenn-Colusa Canal are major canals used to deliver surface water within and outside of Glenn County.

REGIONAL GEOLOGY AND STRUCTURE

To develop a comprehensive groundwater monitoring plan for Glenn County, it is critical to understand the groundwater system within the county. Groundwater resides in subsurface aquifers that store water. In Glenn County, these aquifers consist of layers of gravel, sand, clay, and in some cases ash. The groundwater that is pumped from wells comes from the pore space between the grains of sand and gravel that make up aquifers. The characteristics of different aquifers, and zones within each aquifer, are related to how the aquifer materials (sands, gravels, clays, etc.) were deposited. It should be noted that although the subbasins described above have been established for different regions within the Basin, many of the water-bearing units discussed below are continuous units that are present in other subbasins and other counties.

The Sacramento Valley Groundwater Basin acts as a trough that is filled with layers of different sediments. The deepest portions of the Basin generally consist of marine sedimentary rocks, ranging in age from Late Jurassic to early Miocene. These marine units are overlain by younger alluvial and locally prominent volcanic rocks of early Miocene to Holocene age (Harwood and Helley, 1987). Within the Basin, these deposits are disrupted by deformational stresses derived from east-west compressional forces associated with regional uplift along the western margin of the valley and extensional forces within the Basin and Range Provenance (Harwood and Helley, 1987). Over time, these forces have applied great stresses and strain on valley deposits, creating complex and diversely-oriented fold and fault structures.

One of the prominent fault systems that occur along the western portion of the valley in Glenn County is the Willows-Corning Fault. The Willows-Corning Fault is an active northwest-trending fault that dips steeply to the east and shows reverse displacement. This fault is located immediately east of the City of Orland and spans north toward Red Bluff and southeast just below the Sutter Buttes toward Sacramento. Redwine (1972) traced the Willows-Corning Fault in the subsurface southeast towards the Sutter Buttes and suggested that it extended northwest; possibly connecting with the surface fault mapped to the west of the Orland Buttes (Anderson and Russell, 1939; Jennings and Strand, 1960). Harwood and Helley (1987) extended the Willows-Corning Fault northwest into Tehama County based on available seismic profiles north of the Orland Buttes. The Willows-Corning Fault has several associated faults that splay off the main system, a prominent one being the Corning Fault. The Corning Fault has a more northward trend than the Willows Fault, but shares a similar dip, oriented steeply to the southeast.

A prominent structural feature in Glenn County is the Orland Buttes, located at Black Butte Reservoir. At this location, Upper Cretaceous rocks, Lovejoy Basalt, and the Tehama Formation, on the up-thrown side of the Willows Fault, are juxtaposed against the Tehama Formation on the down-thrown block of the Willows Fault to the west (Harwood and Helley, 1987).

REGIONAL STRATIGRAPHY

The prominent non-marine water-bearing stratigraphic units found within the Corning, Colusa, and West Butte Subbasins include (from youngest to oldest): the present-day stream channel and basin deposits, the Modesto Formation, the Riverbank Formation, the Tehama Formation, and the Tuscan Formation. Subareas of importance include the Stony Creek Fan, which is discussed separately below. The stratigraphic descriptions presented herein are based primarily upon the California Department of Water Resources "Bulletin 118 – California's Groundwater," and are shown in the geologic cross section (Figure E-3). The location of this cross section is shown in Figure E-1.

Younger Alluvial Deposits

Stream channel deposits are Holocene in age and were deposited between 11,000 years ago and present day. The stream channel deposits occur along the current and historic paths of streams and rivers in the Glenn County. Where present, the stream channel deposits extend from ground surface to a depth of 1 to 80 feet below ground surface (bgs). The stream channel deposits consist of unconsolidated gravels, sand, silt, and clay, derived from the erosion and reworking of the Quaternary stream terrace deposits (Modesto and Riverbank Formations) and the Tehama Formation. This unit is moderately to highly permeable, but because of its shallow depth and limited thickness, it possesses limited water-bearing capacity. The exception is in areas with significant surface recharge, such as locations near Stony Creek, where the stream channel deposits may be a widely-used local water source.

Basin deposits are Holocene in age and, like stream channel deposits, were deposited between 11,000 years ago and present day. Basin deposits occur where sediment-laden floodwaters breached natural stream and river levees and spread across lower-lying topography. Where present, the basin deposits extend from ground surface to a depth of 1 to 150 feet bgs. The basin deposits consist mainly of silt and clays. These units have low permeability and generally yield small quantities of water to wells.

The Modesto Formation is Pleistocene in age and was deposited between two million and 500,000 years ago. The Modesto Formation is a stream terrace deposit consisting of gravels, sands, and clays derived from the reworking and deposition of the Riverbank and Tuscan Formations. The Modesto Formation was probably deposited by the same stream and river systems that flow today, because it generally borders existing channels (Blake et. al., 1999). Where present, the Modesto Formation begins between ground surface and 100 feet bgs and extends to a depth of approximately 150 feet bgs. The units of the Modesto Formation are moderately to highly permeable and can yield limited quantities of water to wells.

The Riverbank Formation is Pleistocene in age and was deposited between two million and 500,000 years ago. The Riverbank Formation consists of pebbles and small cobble gravels, interlayered with reddish clay, sands and silts. Like the Modesto Formation, the Riverbank Formation is a stream terrace deposit; however, the Riverbank Formation is older than the Modesto Formation. The Riverbank Formation has two units. The lower unit of the Riverbank Formation is lithologically similar to the Red Bluff Formation (which occurs further north in the Sacramento Valley) and has a similar brick-red color. It occurs on the higher of two terraces that have been cut and filled into the surface of the Red Bluff and/or Tehama Formations. The upper unit of the Riverbank Formation consists of extensive flat stream terraces along major creeks in the valley (Helley and Harwood, 1985). The Riverbank Formation begins between ground surface and 150 feet bgs and extends to a depth of approximately 200 feet bgs. The Riverbank Formation is moderately to highly permeable and can yield moderate quantities of water to wells.

The Modesto and Riverbank Formations are both stream terrace deposits that have been cut and filled into the surface of older sediments. Within the Modesto Formation are sediments derived from the reworking and deposition of the Tehama and Riverbank Formations. Within the

Riverbank Formation are sediments derived from the reworking and deposition of the Red Bluff and/or Tehama Formations. The Modesto and Riverbank formation existed as a complex network of interconnected streams cutting through existing sediments within the valley and creating an interconnected relationship. As such, it is likely that many channels or pathways exist that allow groundwater to move among the younger alluvial deposits, Modesto Formation, and Riverbank Formation.

Stony Creek Fan

The Stony Creek Fan is an unconfined aquifer system in the vicinity of Stony Creek, between the Sacramento River on the east and the Coast Ranges on the west. The Stony Creek Fan lies in the northern portion of the Colusa Subbasin, and extends from southern Tehama County south to the city of Willows. The fan consists of alluvial deposits of unconsolidated gravels, sands, silts and clays, ranging in thickness from 50 to 80 feet (DWR, 2003). Deposits in the Stony Creek Fan are from two sources: alluvial fan deposits from Stony Creek, and alluvium deposits from the Sacramento River (DWR, 1978). According to well logs, the bottom of the fan is not easily distinguished, and does not appear to be uniform. A substantial clay layer, up to 100 feet thick, separates the Stony Creek Fan from the underlying Tehama Formation (Bergfeld, 1995). This clay layer has low permeability and may impede vertical downward movement of groundwater from the deposits of the Stony Creek Fan; however, the degree of hydraulic conductivity between the different zones has not been established and this may warrant additional research. Further, breaks in this clay layer (either natural or caused by well bores) may create pathways for migration of groundwater between the Stony Creek Fan and the Tehama Formation.

"Older" Deposits

The Tehama Formation is Pliocene in age and was deposited between four million and one million years ago. The Tehama Formation was deposited by coalescing alluvial fan deposits from the Coast Ranges, and consists of interbraided gravel, sand, silt, and clay. The Tehama Formation outcrops in the low foothills of the Coast Ranges at the western edge of the Sacramento Valley. Throughout the flat areas of the western Sacramento Valley, the Tehama Formation is overlain by one or more of the younger deposits described above. Toward the center of the Sacramento Valley, near the Sacramento River, the Tehama Formation interfingers with the Sierra Nevada- and Cascade Mountains-sourced Tuscan and Laguna Formations. Within the Tehama Formation, the gravel, sand, and silt materials are separated into distinct zones by impermeable and semi-permeable layers of clay and other fine-grained materials. The gravel and sand zones are generally less than 50 feet thick, and may lack lateral continuity. Although the Tehama Formation is the principal water-bearing formation in the western half of the Sacramento Valley, the units of the Tehama Formation have not been studied in detail in Glenn County. The Tehama Formation begins between ground surface (in the outcrop areas) to 200 feet bgs and becomes thicker toward the center of the Sacramento Valley, extending to a depth of up to 1,700 feet bgs. The units of the Tehama Formation are moderately permeable, but because of its extent and thickness, the Tehama Formation can yield moderate to high volumes of water to wells.

The geologic cross section (Figure E-3) shows vertical offset and a difference in formation thickness within the basal portion of the Tehama Formation across the Willows-Corning Fault. To the west of the Willows-Corning Fault, on the down-thrown portion of the block, a thicker sequence of basal Tehama Formation is observed. To the east of the fault on the up-thrown block, the sequence of basal Tehama Formation is thinner. The exact amount of offset across the fault is hard to determine because of constraints placed on available well data. This occurrence can be explained by the documented displacement on the Willows-Corning Fault. It can be assumed that before or during the deposition of the basal Tehama Formation sequence, the Willows-Corning Fault system was actively moving. Harwood and Helley (1987) observed this type of movement and deposition in Tehama outcrop patterns in the Elder Creek area. A distinctive marker bed within the basal portions of the Tehama Formation is the Nomlaki Tuff member, which was deposited approximately 3.4 million years ago (Harwood and Helley, 1987). Changes in formation thickness within the basal Tehama Formation are substantiated by the change in position of the Nomlaki Tuff member across the Willows Fault system, as observed in outcrops north of Glenn County. Northeast of the Willows-Elder Creek Fault, the Tehama Formation dips gently to the east and the Nomlaki Tuff member is at its base. Southwest of the Willows- Elder Creek Fault, the Tehama Formation dips steeply eastward into the Sacramento Valley, and the Nomlaki Tuff is a few hundred meters above the base of the Tehama Formation (Harwood and Helley, 1987).

The Tuscan Formation is Plio-Pleistocene in age and was deposited between four million and two million years ago. The Tuscan Formation was derived by alluvial deposition associated with erosion of volcanic material derived from Cascadian Volcanics. It outcrops from Red Bluff, in the northern part of the Sacramento Valley, to Oroville, southeast of Chico, and has been recognized in the subsurface at a distance of about 15 miles west of the Sacramento River (DWR, 2003a). The deposits of the Tuscan Formation thin from east to west, from about 1600 feet thick in the foothills of the Sierra Nevada to about 300 feet thick in the subsurface in the Sacramento Valley (Lydon 1969). In outcrop, the exposures of the Tuscan Formation are described as four separate but lithologically similar units, Units A through D (Helley and Harwood, 1985); Units A, B, and C are found within Glenn County in the subsurface (DWR, 2006). All of the units of the Tuscan Formation contain volcanic mudflows, volcanic conglomerates, volcanic sandstones, siltstones, and tuff deposits. In the subsurface, the Tuscan Formation consists largely of black volcanic sands and gravels, with interbedded layers of tuff breccias and tuffaceous clays (Ferriz, H., 2001). Unit A is the oldest water-bearing unit and is distinguished from Units B and C by the presence of metamorphic clasts. Unit B contains equal distributions of volcanic mudflows, conglomerates, and tuffaceous sandstones. Units A and B are referred to as the “Lower Tuscan Formation”. Unit C is capped by massive volcanic mudflows with some interbedded conglomerates, and sandstones. In the subsurface, the volcanic mudflows of Unit C act as a confining layer to movement of groundwater in the more permeable deposits of the Lower Tuscan Formation (Helley and Harwood, 1985).

Interaction Between the Tuscan and Tehama Formations

The interaction between the Tuscan and Tehama Formations within the Sacramento Valley remains unclear at present. Ages obtained from radiometric dating of the Nomlaki Tuff present strong evidence for contemporaneous deposition of the Tuscan and Tehama Formations because, in most areas, the Nomlaki Tuff is positioned in the basal portions of both formations. In a few cases, limited well data and e-log information has allowed inferences to be made about the nature of the contact between the Tuscan and Tehama Formations. Available information obtained during the preparation of the geologic cross section for this project (e-logs obtained from the Division of Oil and Gas and well logs from DWR) show possible inter-fingering between the Tuscan and Tehama Formations. Unfortunately, data in the region where the two formations meet is limited. To better understand the interaction between the Tuscan and Tehama Formations, more work needs to be done to collect clear and comparable lithologic data in the region where the two formations meet. More detailed lithologic data, combined with further evaluation of the formation outcrop areas in the northern part of the Sacramento Valley, could provide a basis for refining the understanding of the interaction between the Tuscan and Tehama Formations.

EXISTING MONITORING NETWORK

The existing groundwater monitoring in Glenn County includes water levels, water quality, and land subsidence. These parameters relate directly to the objectives outlined previously and are also consistent with the County's groundwater management ordinance. Precipitation, stream flow, and surface water quality are also monitored.

Water Levels

DWR monitors 192 wells in Glenn County, including 88 dedicated observation (monitoring) wells and 104 wells with other uses, as summarized in Table E-1. There are a number of dedicated monitoring wells in the County, which represent an extensive network that includes 22 groups of nested and/or clustered monitoring wells (81 total well completions), and 7 single monitoring wells.

The 104 wells with other uses include unused wells, and wells that supply water for domestic, irrigation, park, and stock watering uses. Water level measurements from these wells are somewhat less reliable than from dedicated monitoring wells, for several reasons: water levels may be influenced by pumping in the well, oil-lubricated pumps may leak into the well and raise the fluid level in the well, and access to the well to make measurements on an ongoing basis may be sporadic or limited. Of the 104 wells with other uses, 38 have either no information that allows designation of the targeted aquifer, or are completed in multiple aquifer zones. Of the remaining 66 wells with other uses that only target a single aquifer zone, 5 wells are completed in younger alluvium, 35 wells are completed in the Modesto and/or Riverbank Formations, and 26 wells are completed in the Tehama Formation.

Each observation well targets a single aquifer zone, with the exception of 6 wells; 5 are completed in both the Tuscan Formation Units A and B (Lower), and 1 is completed in the Modesto/Riverbank and Tehama Formations. Of the wells that target only a single aquifer zone, 8 wells are completed in younger alluvium, 22 wells are completed in the Modesto and/or Riverbank Formations, 35 wells are completed in the Tehama Formation, 14 wells are completed in the Tuscan Formation Unit C (Upper), 1 well is completed in the Tuscan Formation Unit B (Lower), and 1 well is completed in the Tuscan Formation Unit A (Lower).

Figures E-4, E-5, E-6, and E-7 show the location of DWR monitoring wells in multiple formations or without construction information, in the Modesto/Riverbank Formations or younger alluvium, in the Tehama Formation, and in the Tuscan Formation, respectively. These figures show monitoring wells with Spring 2005 water level data, and newer dedicated monitoring wells.

Water level measurements are generally made twice each year, in spring and fall. In addition, a number of monitoring wells in Glenn County are equipped with transducers and data loggers to obtain near-continuous water level data. Twice-annual (spring/fall) water level measurements are generally sufficient for the purpose of determining changes in overall groundwater conditions over time. However, these measurements should reflect the annual high (spring) and low (fall) water levels. More frequent (i.e., at most monthly) measurements are necessary to confirm that the months chosen for spring and fall measurements reflect the months with the highest and lowest groundwater elevations, on average.

Vertical Groundwater Gradients – Nested and/or Clustered Monitoring Wells

The vertical gradients between aquifer zones are important because they give an indication of the direction (up or down) that groundwater will migrate if a pathway, such as a well that connects multiple aquifer zones, is present. Generally, it is most important to consider vertical gradients between adjacent aquifer zones, because most pathways connect adjacent aquifer zones. To evaluate the vertical gradient between aquifer zones, it is ideal to have data for different aquifer zones at a single location. The preferred way to accomplish this is with nested and/or clustered monitoring wells. Nested monitoring wells have multiple wells within a single borehole, with each well isolated from the others by seals; clustered monitoring wells have a single well in each borehole, with the boreholes in close proximity to one another. Figure E-8 shows the locations of the 22 nested and/or clustered monitoring wells in Glenn County; Table E-2 provides a summary of the adjacent aquifer zones that are targeted in these wells. All of these wells are dedicated monitoring wells. To simplify further discussion in this section, both nested and clustered monitoring wells will be referred to as “clustered” monitoring wells.

Five clustered monitoring wells in Glenn County are completed in both the younger alluvium and the Tehama Formation; these wells are located throughout the county. Twelve clustered monitoring wells are completed in both the Modesto/Riverbank and Tehama Formations; these wells are all located north of Willows. Of the younger alluvial formations, only the Modesto/Riverbank Formations or the younger alluvium is present in most areas, so it may not be possible to complete wells in both the younger alluvium and the Modesto/Riverbank Formations at a single site.

Eleven clustered monitoring wells are completed in both the Tehama Formation and the Tuscan Formation Unit C (Upper); these wells are located fairly evenly across the portion of the County that overlies the Tuscan Formation. Five clustered monitoring wells are completed in both the

Tehama Formation and the Tuscan Formation Units A and B (Lower) and 1 clustered monitoring well is completed in both the Tehama Formation and the Tuscan Formation Unit B (Lower); these wells are all located north of County Road 39. One additional clustered monitoring well is completed in both the Tehama Formation and the Tuscan Formation Unit A (Lower) and is located near the south County line. In both of the clustered monitoring wells that are only completed in one unit of the Lower Tuscan Formation, only that unit was present in the well bore. A total of 6 clustered monitoring wells target both the Tuscan Formation Unit C (Upper) and at least one unit of the Lower Tuscan Formation.

Figure E-9 shows groundwater elevations in different aquifer zones for selected clustered monitoring wells.

Groundwater Flow Direction – Contour Maps

The direction of groundwater flow is evaluated with water level contour maps. Maps showing contours of equal groundwater elevation were prepared for Spring 2005. Attempts were made to prepare separate contour maps for each aquifer zone; however, during preparation of the contour maps, it became evident that groundwater elevations in the Modesto/Riverbank Formations were essentially the same as in the younger alluvium. This is consistent with the depositional environment of these formations, which can create interconnections among the formations. For these reasons, a single contour map was prepared using groundwater elevations from wells in both the Modesto/Riverbank Formations and the younger alluvium (Figure E-10). A separate contour map was prepared for wells in the Tehama Formation (Figure E-11). Figure E-12 shows groundwater elevation contours for Spring 1977, 1986, and 2005, along with groundwater elevation in the Tehama Formation at four selected locations. The wells in Glenn County that are completed in the Tuscan Formation are all in the eastern portion of the County, the only area where the Tuscan Formation exists. Because of the spacing of Tuscan Formation wells within Glenn County, it is not possible to generate representative groundwater elevation contours of the Tuscan Formation using only wells in Glenn County – the contours would indicate the north-south groundwater gradient, but would not have good control to show the east-west gradient. To prepare contour maps for the Tuscan Formation, it will be necessary to use data from Tuscan wells in Butte County.

BMO Water Level Monitoring Network

Eighty-four wells in Glenn County are monitored for compliance with the established water level BMOs. These wells are summarized in Table E-1 and Figure E-13. Of these 84 BMO water level wells, 26 have either no information that allows designation of the targeted aquifer, or are completed in multiple aquifer zones. Of the remaining 58 BMO water level wells that only target a single aquifer zone, 6 wells are completed in younger alluvium, 26 wells are completed in the Modesto and/or Riverbank Formations, 24 wells are completed in the Tehama Formation, and 2 wells are completed in the Tuscan Formation Unit C (Upper). No BMO water level wells are completed in the Tuscan Formation Units A and B (Lower).

Water level measurements in the BMO water level wells are made three times each year, in spring, summer, and fall.

Water Quality

Seventy-nine wells in Glenn County are monitored for water quality for BMOs. These wells are summarized in Table E-3. Of these 79 BMO water quality wells, 18 have either no information that allows designation of the targeted aquifer, or are completed in multiple aquifer zones. Of the remaining 61 BMO water quality wells that only target a single aquifer zone, 29 wells are completed in Modesto/Riverbank Formations or younger alluvium, 23 wells are completed in the Tehama Formation, and 9 wells are completed in the Tuscan Formation Unit C (Upper). No BMO water quality wells are completed in the Tuscan Formation Units A and B (Lower). Water quality data is obtained from the BMO water quality wells annually during the summer months. The water is tested for temperature, pH, and specific conductance.

DWR has monitored 29 wells in Glenn County for water quality. These wells are summarized in Table E-3. Of these DWR water quality wells, 19 are not part of the DWR water level monitoring network. Construction information for some of these wells may exist, but was not readily available for this project. Of the remaining 10 DWR water quality wells that only target a single aquifer zone, 3 wells are completed in Modesto/Riverbank Formations or younger alluvium, 6 wells are completed in the Tehama Formation, and 1 well is completed in the Tuscan Formation Unit C (Upper). No DWR water quality wells are completed in the Tuscan Formation Units A and B (Lower). The DWR water quality wells were sampled once, either in Winter 2000 or Spring/Summer 2004.

The United States Geological Survey (USGS) National Water Information System (NWIS) has water quality records for 179 wells in Glenn County. These wells are summarized in Table E-3. Many of these wells were only sampled once, so the data spans many years. Detailed construction information is not available for these wells, so the wells were classified by depth. Wells shallower than 200 feet were assumed to be completed only in the Modesto/Riverbank Formations and/or younger alluvium, and wells 200 feet or deeper were assumed to be completed only in the Tehama and/or Tuscan Formations. One hundred and forty nine USGS wells are shallower than 200 feet, and 30 USGS wells are 200 feet or deeper.

For the purpose of evaluating overall water quality, there are several analyses that can be used. The most common are specific conductance or total dissolved solids, which are indicators of the total concentration of minerals in the water. Lower specific conductance or concentrations of total dissolved solids generally indicate better water quality, while higher specific conductance or concentrations of total dissolved solids generally indicate poorer water quality. For Glenn County, specific conductance was selected as an indicator of overall water quality, because there were more records for specific conductance than for total dissolved solids. To provide a frame of reference for evaluating levels of specific conductance, comparison with the Department of Health Services (DHS) standards for public drinking water systems is useful, even though these standards do not apply to irrigation or domestic wells. DHS's secondary (aesthetic) standards for specific conductance includes a recommended level of 900 umhos/cm, upper level of 1,600 uhmos/cm, and short term level of 2,200 umhos/cm. Since the specific conductance of groundwater within the County is generally below 900 umhos/cm, additional comparison levels of one-half and two-thirds of the recommended level have been used.

Figure E-14 and Figure E-15 show the location of water quality monitoring wells in the Modesto/Riverbank Formations and younger alluvium, and in the Tehama and Tuscan Formations, respectively.

Land Subsidence

Land subsidence is the compaction of subsurface materials. Land subsidence is typically caused by decreasing subsurface pressure because of extractions of groundwater, oil, or gas. There are two types of land subsidence: elastic and inelastic. Elastic land subsidence is cyclical and does not result in permanent compaction of subsurface materials. One example of elastic land subsidence is seasonal fluctuations in ground surface elevation that coincide with fluctuations in groundwater elevation (and associated aquifer pressure). In elastic land subsidence, the subsurface pressures do not decrease enough so that subsurface materials permanently compact. In inelastic land subsidence, subsurface pressures decrease to a point where subsurface materials permanently compact, resulting in a permanent loss in subsurface storage capacity. Inelastic land subsidence can be caused by excessive extractions of groundwater, oil, or gas. In discussing land subsidence, it is important to note that *elastic* land subsidence is normal, whereas *inelastic* land subsidence has associated negative impacts and should be avoided.

The land subsidence monitoring network in Glenn County includes surface subsidence survey stations and extensometers. Surface subsidence survey stations are monuments installed at the land surface that are surveyed with Global Positioning System (GPS) equipment. Decreases in the elevation of the surface subsidence survey stations are an indication of land subsidence. To most accurately measure inelastic land subsidence, rather than seasonal elastic land subsidence, surface subsidence surveys should be conducted at the same time of year and when water levels are highest, typically in spring. GPS surveying only measures land subsidence at the ground surface and cannot identify where the land subsidence is occurring in the subsurface. Extensometers in Glenn County are installed in dedicated monitoring wells and are designed to measure the land subsidence occurring between the bottom of the well and the ground surface. This is accomplished by measuring the distance between the bottom of the well and the ground surface. The reported accuracy of GPS surveying is approximately 0.1 feet, and the accuracy of extensometers is approximately 0.01 feet (DWR Northern District).

Figure E-16 shows the location of land subsidence monitoring in Glenn County. The monitoring network includes 58 surface subsidence survey stations (52 within Glenn County and 6 outside of the County), and 3 extensometers, located fairly evenly throughout the areas of the County where land subsidence is a possibility (the hard-rock areas in the western portion of the County are not considered vulnerable to subsidence). All 3 extensometers are greater than 800 feet deep and extend over the majority of the freshwater formations. When used in conjunction with surface subsidence survey data, these extensometers can identify whether subsidence is occurring over the depth of the monitoring well, or in deeper marine aquifer zones; however, if the extensometers show subsidence is occurring over the depth of the monitoring well, they cannot provide data to determine the freshwater zone in which any subsidence occurs. Surface subsidence survey stations were constructed and initially surveyed in 2004, and are planned to be surveyed again in 2007. Extensometers were constructed within the last five years and are equipped with automatic data recorders that record measurements hourly.

DISCUSSION OF GROUNDWATER CONDITIONS

Groundwater conditions must be evaluated separately for each distinct aquifer zone. As discussed previously, available data indicates that the Modesto/Riverbank Formations and younger alluvium are interconnected and can be treated as a single aquifer zone for the purpose of evaluating groundwater conditions. The Tehama Formation, Tuscan Formation Unit C (Upper), and Tuscan Formation Units A and B (Lower) are the other major aquifer zones that exist within Glenn County. All groundwater elevations discussed in this section are in NGVD 29.

<u>Modesto/Riverbank Formations and Younger Alluvium</u>

Contours of equal groundwater elevation in Spring 2005 (Figure E-10) show that groundwater elevations within the Modesto/Riverbank Formations and younger alluvium are highest (at an elevation of approximately 230 feet) in the vicinity of Orland, and decrease toward the southeast at a gradient of 5-20 feet per mile. The lowest groundwater elevations in the Modesto/Riverbank Formations and younger alluvium occur in the southeast corner of the County, where groundwater elevations are approximately 65 feet. No groundwater depressions are evident in the Modesto/Riverbank Formations and younger alluvium.

Hydrographs of groundwater elevation in several nested monitoring wells (Figure E-9) show that water levels in the Modesto/Riverbank Formations and younger alluvium have seasonal fluctuations of up to 20 feet in some parts of Glenn County, and less than 5 feet in other parts of the county. It is interesting to note that the Spring 2005 groundwater elevations in the Modesto/Riverbank Formations and younger alluvium throughout Glenn County are virtually identical to the November 1913 groundwater elevations presented in USGS's 1923 Water Supply Paper 495, *Geology and Ground-Water Resources of The Sacramento Valley, California,* which at that time represented the lowest seasonal depth to water. Given the seasonal fluctuations of 5 to 20 feet (meaning that fall groundwater elevations are that much lower than spring groundwater elevations), we can assume that groundwater elevations in the Modesto/Riverbank Formations and younger alluvium may have declined 5 to 20 feet over the past 85 years.

Groundwater elevation in the Modesto/Riverbank Formations and younger alluvium is generally higher than in the Tehama and Tuscan Formations in the north portion of the county. In the vicinity of Orland, groundwater elevations in the Modesto/Riverbank Formations and younger alluvium are up to 45 feet higher than in the Tehama Formation. However, in the vicinity of Artois, groundwater elevations in the Modesto/Riverbank Formations and younger alluvium are essentially the same as in the Tehama Formation, and toward the southeast corner of Glenn County, groundwater elevations in the Modesto/Riverbank Formations and younger alluvium may be up to 10 feet lower than in the Tehama Formation. These variations could be due to more recharge to the Modesto/Riverbank Formations and younger alluvium in the vicinity of Stony Creek, more pumping in the Tehama Formation in the north portions of the County, more pumping in the Modesto/Riverbank Formations and younger alluvium in the southeast corner of the County, or other reasons.

Recharge to the Modesto/Riverbank Formations and younger alluvium likely occurs throughout Glenn County along stream channels and through surface infiltration. It is clear, however, from the groundwater elevation contours in Figure E-10, that Stony Creek is a source of recharge, especially in the vicinity of Orland, where groundwater elevations in the Modesto/Riverbank Formations and younger alluvium are the highest.

Water quality in the Modesto/Riverbank Formations and younger alluvium, as indicated by specific conductance, is shown in Figure E-14. In most areas, specific conductance is less than two-thirds of the DHS recommended level of 900 umhos/cm. Several areas show elevated levels of specific conductance: southeast of Orland, in the vicinity of Willows, and between Willow Creek and the Sacramento River. The reasons for these differences are unknown and generally do not appear to relate to land use differences. The area of slightly elevated levels of specific conductance southeast of Orland is downstream of Orland's wastewater treatment plant (WTP), but there is no data to suggest conclusively that the WTP contributes to the elevated levels of specific conductance, since similar levels are found in other areas of Glenn County that are not near WTPs.

Tehama Formation

Contours of equal groundwater elevation in Spring 2005 (Figure E-11) show that groundwater elevations within the Tehama Formation are highest (at an elevation of approximately 200 feet) in the vicinity of Orland, and decrease toward the southeast at a gradient of 5-10 feet per mile. The lowest groundwater elevations in the Tehama Formation occur in the southeast corner of Glenn County, where groundwater elevations are approximately 75 feet. A groundwater depression exists in the Tehama Formation northwest of Artois. Groundwater elevations in this area are approximately 30 feet lower than would be expected in the absence of the groundwater depression. To evaluate this current groundwater depression in the context of historic conditions, additional groundwater elevation contour maps were prepared for the Tehama Formation for Spring 1977 and Spring 1986 (Figure E-12).

Groundwater elevations in the Tehama Formation in the southeastern portion of Glenn County have remained very constant since 1960, at approximately 80 feet, as shown in the hydrograph of DWR well 19N02W34F01 (Figure E-12). Seasonal fluctuations in groundwater levels at this location are generally less than 10 feet. Similarly, groundwater elevations in the Tehama Formation in the northeastern portion of the County (as shown in DWR well 22N02W11Q01) have remained fairly constant, with spring groundwater elevations generally ranging from 135 to 160 feet. Seasonal fluctuations in groundwater levels have apparently increased significantly in the last 10 years, to 25-60 feet, possibly indicating increased groundwater pumping in this area.

In contrast, groundwater elevations in the Tehama Formation in the north- and central-western portion of the valley (west of I-5) have varied substantially over time. West of Orland (as shown in DWR well 22N03W30C01), groundwater elevations have varied from approximately 175 feet in Spring 1977, to 205 feet in Spring 1986, to 190 feet in Spring 2005. Northwest of Artois (as shown in DWR well 21N03W20D02), in the area with the current groundwater depression, groundwater elevations have varied from approximately 120 feet in Spring 1977, to 170 feet in Spring 1986, to 130 feet in Spring 2005. Looking at the specific area of the current groundwater depression, no depression is evident in Spring 1977, even though groundwater elevations then were at least 10 feet lower than in Spring 2005. In Spring 1986, there appears to be a very slight (less than 5 feet) groundwater depression.

These fluctuations in groundwater elevations, and the development of the current pumping depression to the northwest of Artois, are likely a result of changes in groundwater pumping in the county. Before 1976, when the Tehama-Colusa Canal was constructed, groundwater elevations west of I-5 may have been declining for up to 25 years (as shown in 21N03W20D02). This decline could have been due to increased agriculture in that area, and (since surface water supplies were not available) associated increased groundwater pumping. With the availability of surface water from the Tehama-Colusa Canal, groundwater pumping likely decreased (and recharge from applied surface water for irrigation may have increased), and groundwater levels increased steadily until about 1990, reaching (in 21N03W20D02) elevations that equaled or exceeded previously recorded highs. After 1990, groundwater elevations slowly decreased until about 2002. It appears that this decrease may have slowed or stopped in the last several years, but data over several more years will be required to determine if this is actually the case. It is possible that, after surface water became available, additional agricultural land uses developed in areas that were not served with groundwater, so that groundwater pumping has increased in some areas over time to levels approaching those before the Tehama-Colusa Canal was constructed, and that groundwater elevations are also at levels similar to before the Tehama-Colusa Canal was constructed.

Groundwater elevation in the Tehama Formation is higher than in the Tuscan Formation in some areas, and lower than in the Tuscan Formation in other areas (Figure E-9). North of Stony Creek, groundwater elevations in the Tehama Formation and in the Tuscan Formation Unit C (Upper) are virtually identical, and spring groundwater elevations in the Tuscan Formation Units A and B (Lower) are generally lower. East of Artois, groundwater elevations are higher in the Tehama Formation than in the Tuscan Formation Unit C (Upper), which are higher than in the Tuscan Formation Units A and B (Lower). South of Artois, in the eastern portion of Glenn County, groundwater elevations in the Tehama Formation are lower than in the Tuscan Formation Unit C (Upper). The reasons for these differences are not known. West of Artois (where the Tuscan Formation does not occur), a deeper unit of the Tehama Formation exists with groundwater elevations 40 feet higher than in the other units of the Tehama Formation, and very similar to those in the Modesto/Riverbank Formations and younger alluvium. This difference is likely due to a lack of pumping in the deeper unit of the Tehama Formation.

Recharge to the Tehama Formation likely occurs along the western edge of the valley, where the Tehama Formation outcrops at the surface. Recharge in this area may be limited by clay units within the Tehama Formation. It is evident from the Spring 2005 groundwater elevation contours (Figure E-11) that there is significant recharge to the Tehama Formation in the vicinity of Orland. In this area, groundwater elevations in the shallower Modesto/Riverbank Formations and younger alluvium are up to 45 feet higher than in the Tehama Formation, so there is a substantial downward gradient that would "push" water to migrate downward if given a pathway. Although the upper portion of the Tehama Formation generally consists of competent clay layers that would prevent this migration, there are many wells in the vicinity of Orland that are completed in both the Modesto/Riverbank Formations and younger alluvium and the Tehama Formation, which would provide a pathway for recharge to the Tehama Formation from the Modesto/Riverbank Formations and younger alluvium. In the Spring 1977 and Spring 1986 contours (Figure E-12), groundwater elevations are also highest in the vicinity of Orland, but it is not clear (as it is in the Spring 2005 contours) that there is a groundwater "mound" in this area. In order to better evaluate recharge to the Tehama Formation, it will be necessary to incorporate data from Tehama County to understand the role of Stony Creek in recharge to the Tehama Formation.

Spring groundwater elevations in the Tehama Formation have fluctuated over time and with area, but do not indicate conditions of overdraft within Glenn County. Although groundwater elevations have declined in some areas, historic data has shown that, when pumping is reduced and/or recharge increases, groundwater elevations recover to historic highs. As described previously, after the Tehama-Colusa Canal was constructed, groundwater elevations recovered over 50 feet, to historic highs, within approximately 10 years.

Water quality in the Tehama Formation, as indicated by specific conductance, is shown on Figure E-15. In most areas, specific conductance is less than two-thirds of the DHS recommended level of 900 umhos/cm. It appears that there may be higher levels of specific conductance in the south portion of Glenn County, but the data is too limited to be conclusive.

Tuscan Formation

Hydrographs from nested monitoring wells (Figure E-9) show that in Glenn County, groundwater elevations within the Tuscan Formation Unit C (Upper) are highest (at an elevation of approximately 160 feet) between Orland and Hamilton City, and decrease toward the south at a gradient of approximately 2-6 feet per mile. As discussed previously, there is insufficient data within Glenn County to quantify the east-west gradient within the Tuscan Formation. The lowest groundwater elevations in the Tuscan Formation Unit C (Upper) occur in the southeast corner of the County, where groundwater elevations are approximately 80 feet. Water levels in the Tuscan Formation Unit C (Upper) have seasonal fluctuations of up to 60 feet in some parts of the County, and less than 5 feet in other parts of the county. Groundwater elevations within the Tuscan Formation Units A and B (Lower) are also highest (at an elevation of approximately 145 feet) between Orland and Hamilton City. Water levels in the Tuscan Formation Units A and B (Lower) have seasonal fluctuations 10-20 feet in the parts of the Glenn County with available data.

As described previously groundwater elevations in the Tuscan Formation Unit C (Upper) are generally similar to those in the Tehama Formation in the northeastern portion of Glenn County, lower than in the Tehama Formation in the central portion of the County, and higher than in the Tehama Formation in the south portion of the county. The similarity in seasonal fluctuations in the Tuscan Formation Unit C (Upper) and the Tehama Formation in DWR well 22N/2W-15C (Figure E-9) indicates a probable hydraulic connection between the formations at this location. This may be due to interfingering between the formations at this location, but the current dataset is not adequate to fully evaluate the reasons for differences in groundwater elevations between the Tuscan Formation Unit C (Upper) and the Tehama Formation in Glenn County. The limited data for groundwater elevations in the Tuscan Formation Units A and B (Lower) indicate that spring groundwater elevations in the Tuscan Formation Units A and B (Lower) are generally lower than in the Tuscan Formation Unit C (Upper), but that in some areas there may be a gradient reversal during the summer months.

Recharge to the Tuscan Formation is reportedly at the eastern edge of the Sacramento Valley where the Tuscan Formation outcrops. Data in Glenn County is too limited to make any conclusive statements about recharge to the Tuscan Formation. Spring groundwater elevations in the Tuscan Formation appear to be stable for the limited period of record, without any indication of continual decline.

Water quality in the Tuscan Formation, as indicated by specific conductance, is shown on Figure E-15. The limited available data indicates that water quality in the Tuscan Formation is very similar to in the Tehama Formation. As in the Tehama Formation, it appears that there may be higher levels of specific conductance in the south portion of Glenn County, but the data is too limited to be conclusive.

Land Subsidence

There are no known reports of land subsidence within Glenn County.

EVALUATION OF EXISTING MONITORING NETWORK AND RECOMMENDATIONS FOR FUTURE MONITORING

Water Level Monitoring Network

Glenn County has an extensive network of DWR monitoring wells, both dedicated monitoring wells and wells with other uses. Although monitoring wells with unknown construction, and those completed in multiple formations, are of limited usefulness, the monitoring wells that are completed in a single known aquifer zone still provide very good coverage within the county. For the Modesto/Riverbank Formations and younger alluvium, the 68 DWR monitoring wells in the County have excellent coverage north of Willows, and fair coverage south of Willows, with a notable lack of coverage in the area southeast of Willows. This lack of coverage makes it difficult to create groundwater contour maps for that area, although because it is likely not a high-pumpage area this may not be a significant issue. For the Tehama Formation, the 60 DWR monitoring wells in the County have generally excellent coverage. For the Tuscan Formation, the 12 single-formation DWR monitoring wells and the 4 monitoring wells completed in both Tuscan Formation Units A and B (Lower) provide very good coverage north of Artois and good coverage south of Artois. As in the Modesto/Riverbank Formations and Younger Alluvium, there is a notable lack of coverage in the area southeast of Willows.

Representative groundwater contour maps cannot be prepared for the Tuscan Formation using only wells in Glenn County. It will be necessary to incorporate groundwater elevations from wells in Butte County to achieve east-west control on groundwater gradients in the Tuscan Formation. For the Tehama Formation, characterizing the nature of the higher groundwater elevations in the vicinity of Orland will require the use of groundwater elevations from wells in Tehama County. It would also be beneficial to incorporate data from wells in Tehama County into groundwater elevation contours for the Modesto/Riverbank Formations and younger alluvium to better understand groundwater recharge in the vicinity of Orland.

The network of 20 nested and/or clustered monitoring wells in Glenn County is extensive and provides numerous locations to evaluate vertical gradients between aquifer zones. The 16 clustered monitoring wells with completions in the Modesto/Riverbank Formation or younger alluvium and the Tehama Formation are concentrated in the northern portion of the County; only 1 clustered monitoring well that targets both of these aquifer zones is located south of Willows. The 10 clustered monitoring wells with completions in the Tehama Formation and the Tuscan Formation Unit C (Upper) are located fairly evenly across the County, with a greater concentration in the area between Orland and the Sacramento River. The 6 total clustered monitoring wells with completions in the Tehama Formation and the Tuscan Formation Units A and/or B (Lower) are concentrated north of Willows; only 1 clustered monitoring well that targets both of these aquifer zones is located south of Willows. The 5 clustered monitoring wells with completions in the Tuscan Formation Unit C (Upper) and the Tuscan Formation Units A and/or B (Lower) are mainly north of Artois; only 1 clustered monitoring well that targets both of these aquifer zones is located south of Artois.

The current BMO water level monitoring network is not as extensive as the DWR water level monitoring network and has several problems. The BMO water level monitoring network makes no distinction between different aquifer zones, even though (as discussed above) conditions are different in the different zones. Thirty percent of the wells in the BMO water level monitoring network have unknown construction or are completed in multiple formations, rendering them less useful for monitoring groundwater conditions. There are areas with poor well coverage for the Modesto/Riverbank Formations and younger alluvium and for the Tehama Formation. In the Modesto/Riverbank Formations and younger alluvium, coverage is good around Orland, but there is notable poor coverage northeast of Artois and in the south portion of the county. In the Tehama Formation, coverage east of I-5 and south of Orland is spotty, although there is good coverage in Orland and west of I-5 between Orland and Willows. There is inadequate BMO water level monitoring in the Tuscan Formation. Only two BMO water level monitoring wells are completed in the Tuscan Formation, both in Unit C (Upper), and both east of Orland in the north portion of the county. Also, for the purposes of BMO monitoring, too many wells may be being monitored in some locations. Monitoring many wells concentrated in a small area and completed in a single formation may be unnecessary to fulfill the BMO objectives. The available resources for monitoring could be better used to monitor wells over a wider area. Additionally, although it is convenient to coordinate monitoring by water district, as in the current BMO areas, these boundaries do not correspond to hydrogeologic conditions and are thus arbitrary with regard to accomplishing the stated objectives of Glenn County's groundwater management program.

Recommendation 1

Reconfigure the BMO water level monitoring network to better meet stated objectives.

The BMO water level monitoring network should be reconfigured to:

- reduce or eliminate wells without construction information and those completed in multiple formations, since monitoring these wells does not provide significant benefits;
- use dedicated monitoring wells, rather than wells with other uses, to the fullest extent possible to provide high quality data and reliable ongoing monitoring locations;
- add wells in the Modesto/Riverbank Formations and younger alluvium, the Tehama Formation, and the Tuscan Formation Unit C (Upper) to eliminate current gaps in coverage;
- add wells in the Tuscan Formation Units A and B (lower) to provide coverage for those formations;
- eliminate excessive coverage in a single formation (i.e., where there are many wells monitored in a single area) to free up resources for monitoring over a wider area; and
- consider the BMO water level monitoring network on a county-wide basis, rather than by BMO area.

Recommendation 2

When evaluating groundwater conditions, include groundwater level data from outside of Glenn County.

As described previously, groundwater elevation data from Butte County will be necessary to prepare groundwater contour maps for the Tuscan Formation. Data from Tehama County is necessary to better understand groundwater recharge in the vicinity of Orland in the Modesto/Riverbank Formations and younger alluvium and in the Tehama Formation. Including groundwater level data from Butte, Tehama, and Colusa Counties will allow for a more complete evaluation of groundwater conditions in Glenn County.

Recommendation 3

Use nested and/or clustered monitoring wells to the fullest extent possible.

These wells provide some of the best monitoring data because in addition to monitoring specific aquifer zones, they provide data about vertical gradients among aquifer zones, allowing for better understanding of the aquifer system. Existing nested and/or clustered monitoring wells should be used for BMO monitoring. Where new wells are installed to fill gaps or expand the existing monitoring network, nested and/or clustered monitoring wells should be considered preferential to single-completion monitoring wells in most cases.

Water Quality Monitoring Network

Water quality monitoring in Glenn County has been somewhat limited, in that much monitoring has been performed sporadically, rather than consistently at selected locations over time. The BMO water quality monitoring network is only a few years old, but provides a good opportunity to obtain more consistent data.

Recommendation 4

Cooperate with DHS-permitted public water systems to obtain water quality data.

Public water systems are required to collect an analyze water quality samples on a regular basis (generally every three years). This data is publicly available and could be used as additional monitoring for groundwater quality within the County. Work will be required to evaluate well construction, aquifer zones completed, and well locations, all of which will require cooperation with public water systems.

Recommendation 5

In addition to annual monitoring, consider more frequent monitoring in select wells.

Water quality can fluctuate seasonally, and although annual monitoring of key water quality parameters (such as specific conductance) provides good long-term data, it is also beneficial to look at monthly fluctuations in water quality. Wells for more frequent monitoring should be selected by aquifer zone and by convenience for monitoring. For this reason, wells with other uses (i.e., those that are pumped regularly) are often the best choice for more frequent monitoring. Two to 3 wells in each aquifer zone (1 near Orland, 1 east of Willows, and 1 in the southeastern corner of the County) should be adequate.

Land Subsidence Monitoring Network

Land subsidence monitoring in Glenn County is fairly recent, with surface subsidence survey stations installed in 2004 and surveyed at that time; the second round of surveying is planned for 2009. The surveys are scheduled during the spring when groundwater pumping for irrigation is generally not occurring to any great extent. According to Glenn County's groundwater management ordinance, surveys are to be conducted a minimum of every five years. Surface subsidence survey stations are located evenly throughout the County and provide a good network to monitor overall land subsidence within the County without determining specific zones where subsidence is occurring.

Extensometers were installed within the last five years, and extend into the deepest freshwater formations: the Tuscan Formation Units A and B (Lower, two stations) or the deepest portion of the Tehama Formation (one station). When used in conjunction with surface subsidence survey data, these extensometers can be used to determine whether subsidence is occurring in the freshwater formations or in deeper marine sediments. The extensometers cannot provide data to determine the freshwater zone in which any subsidence occurs.

Within the Modesto/Riverbank Formations and younger alluvium, generally coarse materials, coupled with fairly constant groundwater elevations over time, may make land subsidence from groundwater extraction unlikely in these zones. The Tehama and Tuscan Formations both include fine-grained sediments that might be vulnerable to compaction. In the main portions of the Tehama Formation, groundwater elevations are currently higher than the lowest recorded values. Since land subsidence associated with groundwater extraction would occur the first time groundwater elevations are lowered to a specific point, we can assume that no land subsidence would occur as long as groundwater elevations remain above historic lows. The limited period of record for groundwater elevations in the Tuscan Formation and basal portions of the Tehama Formation in Glenn County do not allow for a determination of how current groundwater elevations relate to historic levels; however, current groundwater extractions within the County from the both formations are likely limited by the number of wells constructed within the formations. If additional wells are constructed in the Tuscan Formation or basal portions of the Tehama Formation, and groundwater extractions increase significantly, it must be assumed that the potential for land subsidence would increase.

Recommendation 6

Conduct surface subsidence surveys at the same time of year, preferably in spring.

Each round of surface subsidence surveying should be conducted at the same time of year to ensure that data from each monitoring round can be meaningfully compared to previous monitoring data. The goal of surface subsidence surveys is to measure inelastic land subsidence. If surveys are conducted when water levels are seasonally low (i.e., in summer or fall), the measured ground surface will be lower because of seasonal elastic subsidence. Because seasonal elastic subsidence varies from year to year, the best measurement of inelastic subsidence will be when seasonal elastic subsidence is lowest, i.e., when water levels are highest – in spring.

Recommendation 7

If groundwater elevations in any of the aquifer zones approach historic lows, or if Tuscan Formation groundwater extractions are planned to increase significantly, consider installing nested and/or clustered extensometers.

As described, if groundwater elevations in these zones remain above historic lows, no land subsidence should occur. However, if groundwater pumping in Glenn County changes or increases such that groundwater elevations in the Modesto/Riverbank Formations and younger alluvium, or in the Tehama Formation, reach new lows, land subsidence is a possibility. Similarly, if groundwater extractions from the Tuscan Formation or basal portions of the Tehama Formation is planned to increase significantly, it must be assumed that land subsidence is a possibility.

If these conditions occur, installation of new nested and/or clustered extensometers should be considered. These installations would consist of a series of progressively deeper extensometers, with one ending in each aquifer zone to be monitored. These nested and/or clustered extensometers will provide data to determine the aquifer zone in which any subsidence occurs. These installations should be before new historic lows are reached. The extensometers should be integrated into the broader Sacramento Valley land subsidence monitoring network.

General Recommendations

Glenn County has made significant progress in developing a comprehensive groundwater monitoring network. Most of the limitations of the monitoring network are related to the understanding of the groundwater system underlying the county. For example, the interaction between the Tehama Formation and Tuscan Formation is not well understood. The general recommendations outlined below are designed to further the understanding of the groundwater system, provide enhanced "target" monitoring as appropriate, and further the objective of maintaining the sustainability of the county's groundwater resources.

Recommendation 8

Make monitoring data publicly available as much as possible.

In order to foster collaboration with others, and to further the understanding of groundwater within Glenn County, the County should share monitoring data with the public as much as possible. Although some information, particularly well construction, is confidential and cannot be shared without owner permission, general information on geology, summarized well characteristics, groundwater levels, and groundwater quality should be made public. The Glenn County Water Advisory Committee, Butte County Water and Resource Conservation, and DWR's Northern District maintain excellent websites with a large amount of groundwater information that is available to the public. Glenn County should publicize the existence of these websites and encourage their use by the public to obtain groundwater data.

www.glenncountywater.org

www.buttecounty.net/waterandresource

www.nd.water.ca.gov

Recommendation 9

Coordinate with others to obtain data from other projects.

Although coordination can be challenging, it is beneficial to obtain data from as many sources as possible. When new irrigation wells are constructed by others, Glenn County could pay for geophysical logs to be conducted, which would be helpful for well design and would also provide geologic data for the County at minimal cost. Monitoring that is performed by others (e.g., water districts or municipal water suppliers) could supplement data collected by the County and DWR. The California Well Sample Repository has available samples from boreholes within the County that can be viewed for a small fee; this could help further the understanding of geology within the County without having to drill new boreholes. Many other opportunities exist to make use of data collected by others, and the County should pursue these opportunities and obtain available data before undertaking new work. The County should encourage water districts and municipal water suppliers to share data from their projects.

As described previously, it will also be important to continue to coordinate with adjacent counties. The groundwater resources in Glenn County are interconnected with those in Tehama, Butte, and Colusa Counties, and coordination with those counties will be fundamental to successful groundwater monitoring for all four counties.

Recommendation 10

Advocate projects that will further the understanding of the county's groundwater resources.

Glenn County has been very active in pursuing research of groundwater resources within the County, which has resulted in a number of studies that have furthered the understanding of the county's groundwater resources. Glenn County should continue to advocate projects that will contribute to the understanding of the county's groundwater resources. Such projects could include: data compilation and review, geologic studies, exploratory drilling, new well construction, pump testing, water quality sampling and analysis, etc. These projects should be coordinated as much as possible to make the best use of available resources and avoid duplicating work.

Recommendation 11

Conduct pump testing to characterize interaction between aquifer zones.

As described previously, the interaction between aquifer zones, particularly between the Tehama and Tuscan Formations, appears to vary by area and is not well-understood. Pump testing is one of the best methods for characterizing interactions between different aquifer zones. A production well, completed in a single aquifer zone, is pumped at a constant flow rate for a defined period of time. During pumping, groundwater levels are monitored (generally with automated equipment) in nearby monitoring wells that are also completed in single formations. In general, monitoring within the production aquifer zone should include at least two locations at different distances from the production well; one monitoring well should be within approximately 100 feet of the production well, and the second monitoring well should be at least one-quarter mile from the production well. Care must be taken to locate the monitoring wells closer to the production well for short-term tests and further away for long-term (multiple-day) tests. For monitoring inter-aquifer connections, monitoring wells in different aquifer zones from the production zone are used. These monitoring wells should generally be within 100 feet of the production well, since vertical gradients between the production zone and other aquifer zones will be greatest near the production well. Although these guidelines will be applicable to most situations, in order to obtain the best data during pump testing, the location of monitoring for each pump test should be evaluated individually.

It is often most practical to conduct pump testing during the development of new production wells, which means that water districts and municipal water suppliers will often be in the best position to undertake the work. Glenn County should work with water districts and municipal water suppliers to coordinate water level monitoring during pump testing, and to share the resulting data.

Recommendation 12

Consider "target" monitoring for specific areas or events.

Although Glenn County's overall network of monitoring wells provides very good coverage for monitoring changes in overall groundwater conditions over time, it may not be adequate for other purposes (e.g., understanding the effects of a specific action on groundwater conditions).

As described previously, in order to formulate an effective monitoring plan, the desired evaluations of the groundwater system must be well-understood to ensure that the monitoring provides the data necessary to support these evaluations. For specific areas of concern (e.g., groundwater depressions, areas with poor water quality) or events (e.g., increased pumping, changes in groundwater use), a special "target" monitoring program may be necessary. The "target" monitoring programs should include the following components:

- A clear statement of the desired evaluations to be made (e.g., determine the effects of pumping a specific well).
- A defined study area and duration.
- Interpretation of the required monitoring to allow for the desired evaluations.
- Use of the county-wide monitoring network and other existing monitoring to the fullest extent possible.
- Identification of additional monitoring.
- Location, parameters, and time of planned monitoring.
- Description of how the collected data will be evaluated.
- Procedures for reporting the results of monitoring.

Recommendation 13

Update the Glenn County groundwater monitoring network as new data becomes available.

As additional monitoring and studies are undertaken, it is likely that the understanding of Glenn County's groundwater resources, and possibly objectives for groundwater management within the County, will expand and change. The groundwater monitoring network must be updated to reflect the best understanding of the aquifer system, and also to reflect changes in objectives for groundwater and coordinated water management within the County.

TASK E – TABLES

TABLE E-1

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E – GROUNDWATER MONITORING PROGRAM

GLENN COUNTY WATER LEVEL MONITORING NETWORK
DWR MONITORING WELLS

Well Type	Aquifer								Total
	Unknown	Multiple	Younger	Modesto/ Riverbank	Tehama	Tuscan			
						C	B	A	
Dedicated Monitoring (Single)	1	1[1]	1	2	2	-	-	-	7
Dedicated Monitoring (Multiple)		5[2]	7	20	33	14	1	1	81
Subtotal	1	6	8	22	35	14	1	1	88
Other	38		5	35	26	-	-	-	104
Total	**45**		**13**	**57**	**61**	**14**	**1**	**1**	**192**

BMO WELLS

	Aquifer							Total
	Unknown or Multiple	Younger	Modesto/ Riverbank	Tehama	Tuscan			
					C	B	A	
Total	**26**	6	**26**	**24**	**2**	-	-	**84**

[1] Completed in Modesto/Riverbank and Tehama Formations.
[2] Completed in Tuscan Formation Unit A and Unit B.

TABLE E-2

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

TASK E – GROUNDWATER MONITORING PROGRAM

GLENN COUNTY WATER LEVEL MONITORING NETWORK
NESTED MONITORING WELLS

Aquifer					
Younger	Modesto/ Riverbank	Tehama	Tuscan C	Tuscan B	Tuscan A
●	5	●			
	●	12 ●			
		● 11	●		
		●	4	●	●
		●	1	●	
		●	1		●
			● 1	●	
			●	1	●
			● 4	●	●

TABLE E-3

GLENN COUNTY WATER ADVISORY COMMITTEE

GLENN COUNTY WATER QUALITY MONITORING NETWORK
BMO WELLS

	Aquifer						Total[1]
	Unknown or Multiple	Modesto/Riverbank or Younger Alluvium	Tehama	Tuscan			
				C	B	A	
Total	**18[2]**	**29**	**23**	**9**	**-**	**-**	**79**

DWR WELLS

	Aquifer						Total
	Unknown or Multiple[3]	Modesto/Riverbank or Younger Alluvium	Tehama	Tuscan			
				C	B	A	
Total	**19**	**3**	**6**	**1**	**-**	**-**	**29[4]**

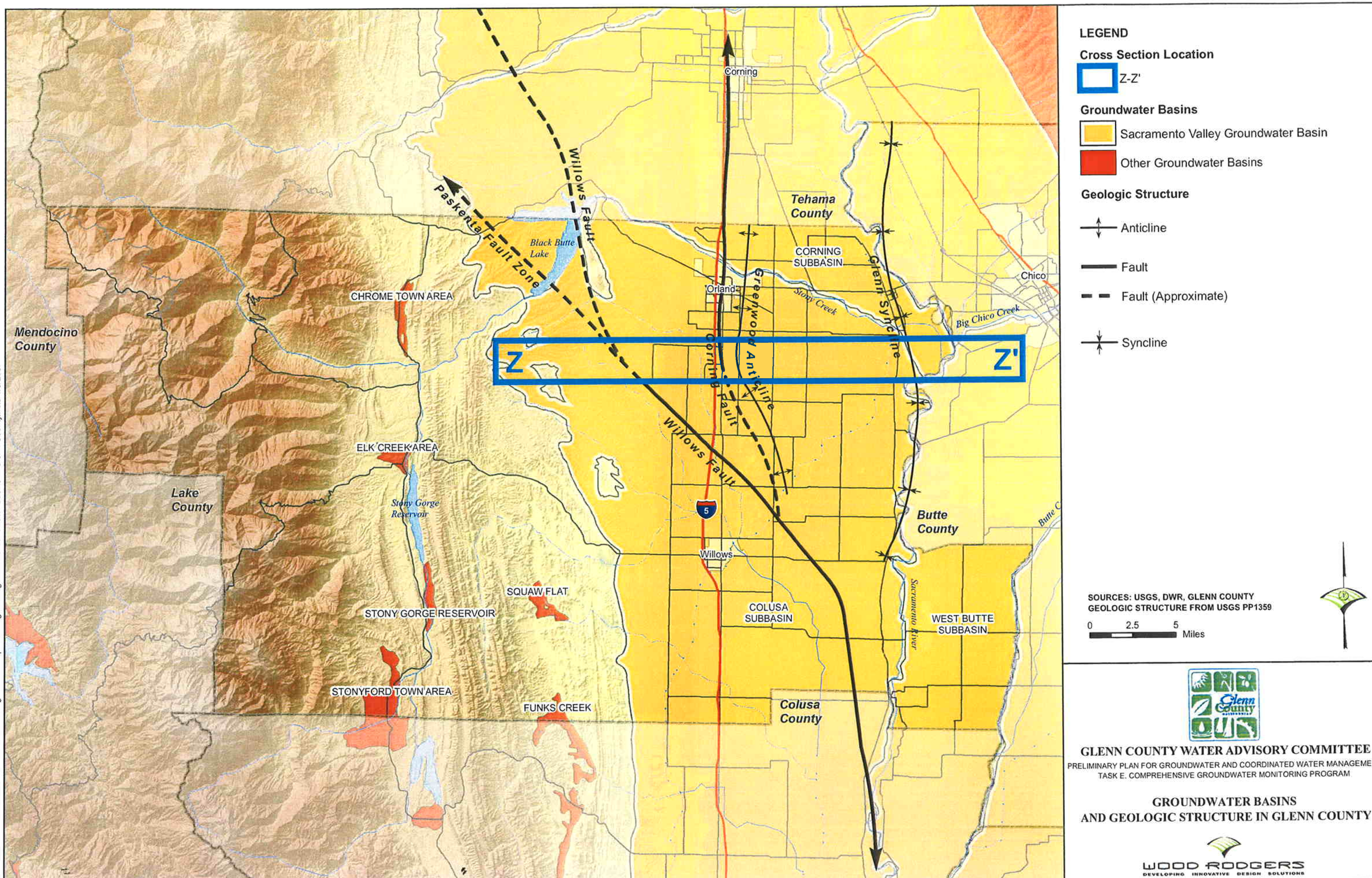
USGS WELLS[5]

	Well Depth[6]		Total[7]
	<200 Feet	200 Feet or Greater	
Total	**149**	**30**	**179**

---

[1] Omits two wells without X-Y coordinates.
[2] Includes three wells completed in Tuscan Formation Unit A and Unit B.
[3] These wells are not in DWR's water level monitoring network. Construction information may be available for some of these wells.
[4] Several of these wells are also BMO water quality wells.
[5] USGS data is historic water quality data, not ongoing monitoring.
[6] The USGS database did not include well construction information, so it was assumed that wells shallower than 200 feet were completed only in the Modesto/Riverbank Formations and/or younger alluvium, and that wells 200 feet deep or greater were completed only in the Tehama and/or Tuscan Formations.
[7] Includes all wells within Glenn County with USGS recorded measurements of sp :cific conductance.

TASK E – FIGURES



J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 1 - Groundwater Basins in Glenn County.mxd 1/5/2007

Glenn County

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

GROUNDWATER BASINS AND GEOLOGIC STRUCTURE IN GLENN COUNTY

WOOD RODGERS
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FIGURE E-1

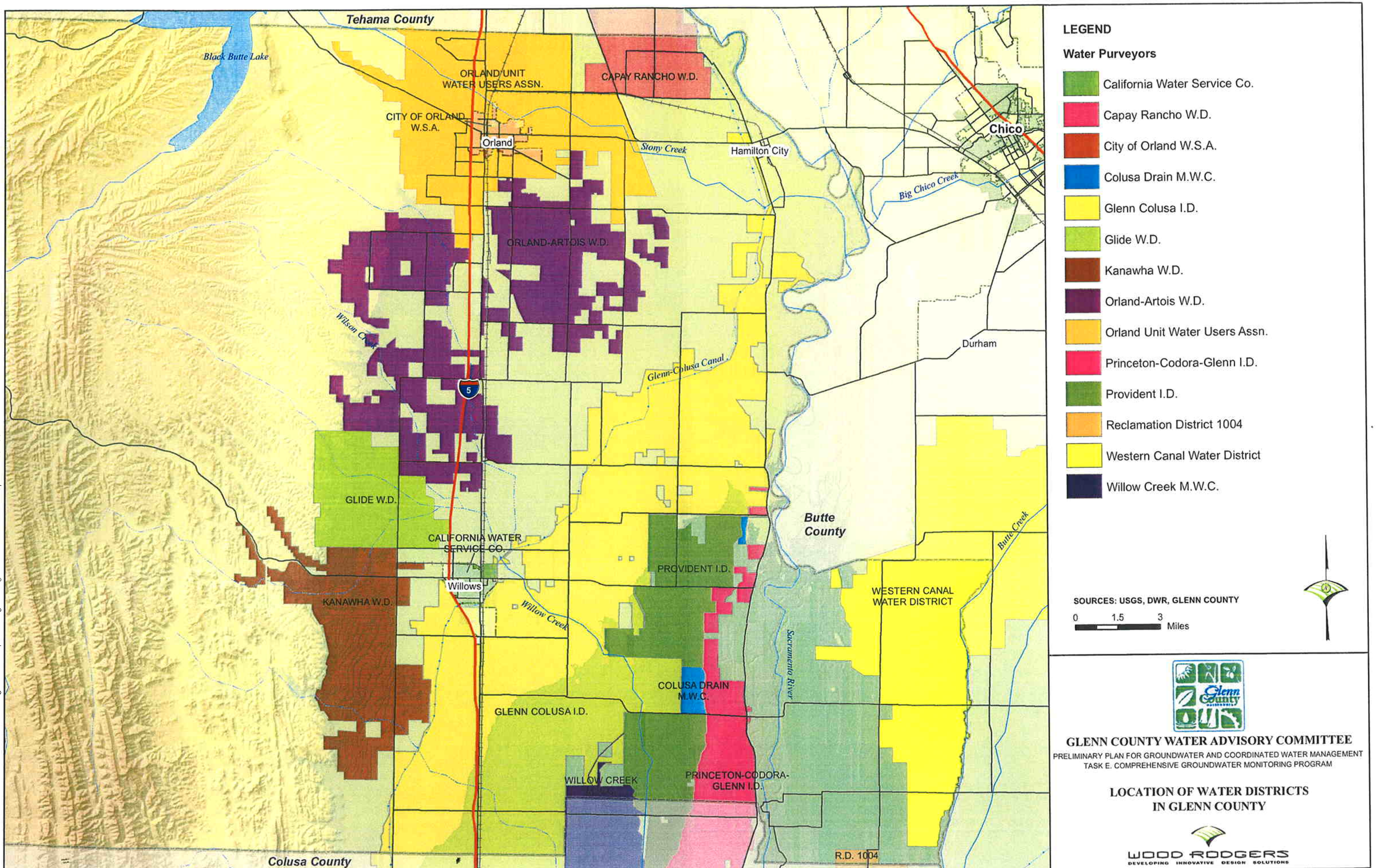
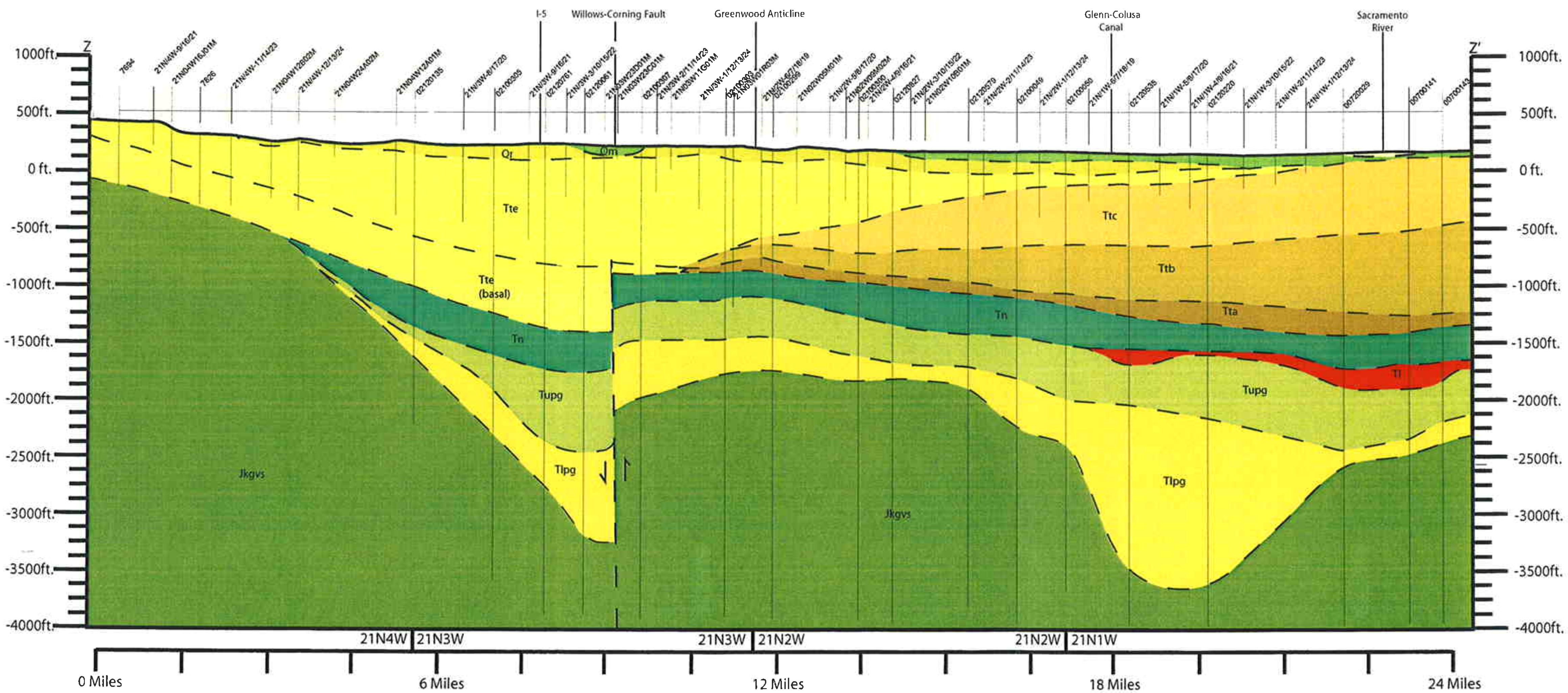


FIGURE E-2

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 2 - Water District Map.mxd 1/5/2007



(6 X Vertical Exaggeration)

Note:
1. Vertical lines indicate locations and depths of wells used for geologic control.
2. Dip angle on fault appears steeper due to vertical exaggeration.

Well Identifier:
1. Division of oil and gas- API #'s 007 & 021
2. State well #'s 21N 4,3,2,1W

Map Units

Symbol	Unit	Epoch	Period	Era
Qa	Alluvium	Holocene	Quaternary	Cenozoic
Qm	Modesto Formation	Pleistocene	Quaternary	Cenozoic
Qr	Riverbank Formation	Pleistocene	Quaternary	Cenozoic
Tte	Tehama Formation	Pliocene	Tertiary	Cenozoic
Tte	Tehama Formation (Basal Deposits)	Pliocene	Tertiary	Cenozoic
Ttc	Tuscan Unit C	Pliocene	Tertiary	Cenozoic
Ttb	Tuscan Unit B	Pliocene	Tertiary	Cenozoic
Tta	Tuscan Unit A	Pliocene	Tertiary	Cenozoic
Tn	Neroly Formation	Miocene	Tertiary	Cenozoic
Tl	Lovejoy Basalt	Miocene	Tertiary	Cenozoic
Tupg	Upper Princeton Gorge	Oligocene	Tertiary	Cenozoic
Tlpg	Lower Princeton Gorge	Eocene	Tertiary	Cenozoic
Jkgvs	Great Valley Sequence	Jurassic / Cretaceous		Mesozoic

Map Legend

Geologic contact- dashed where inferred.

Fault- dashed where inferred

Cross-Section Scale

Vertical: 1000 ft. / 500 ft. / 0 ft.

Horizontal: 0 Miles — 1.5Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

GEOLOGIC CROSS SECTION

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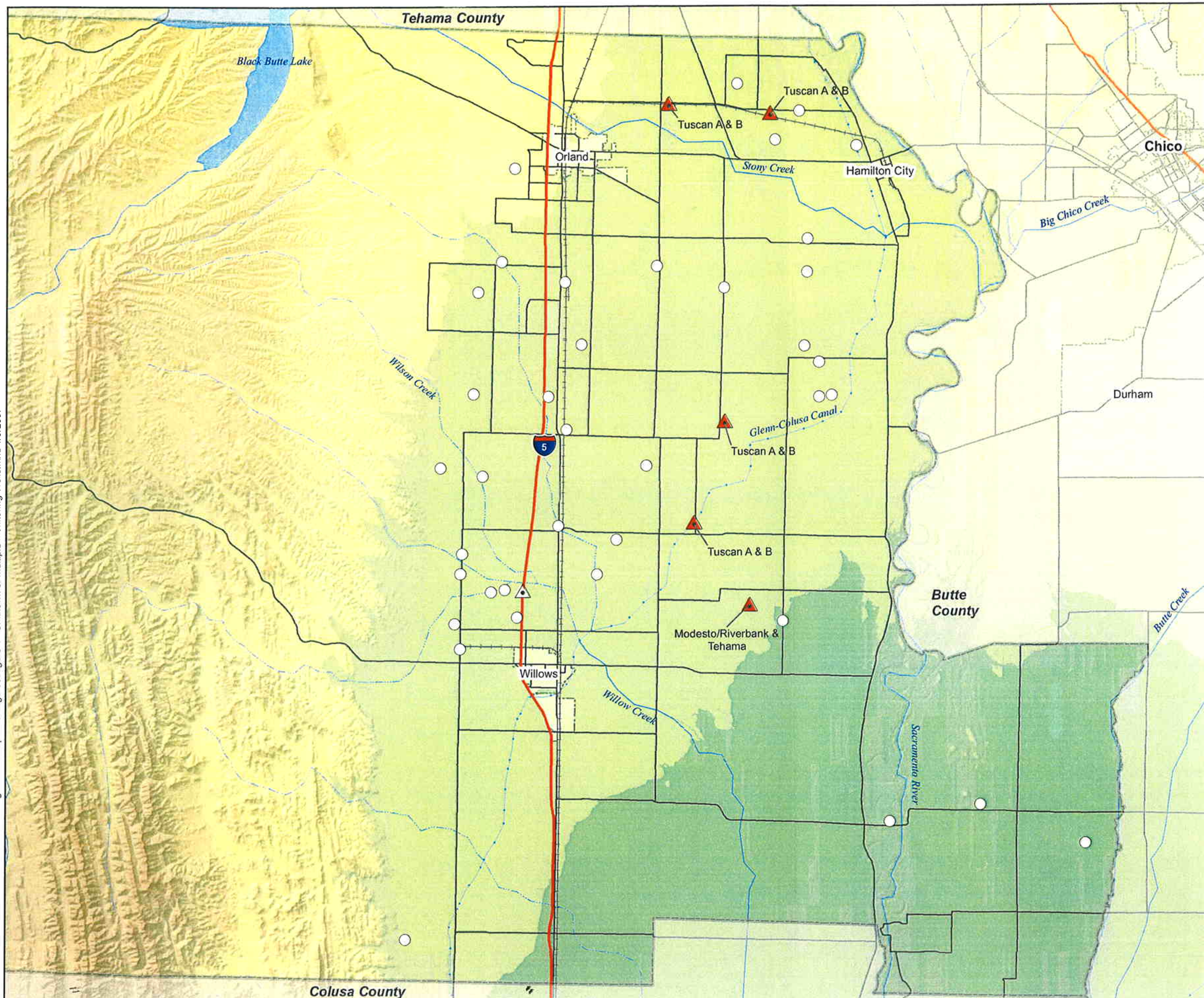
J:\Jobs\8233.001 - Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 3 - Glenn County Geologic Cross-Section 1/02/2007

FIGURE E-3



LEGEND

Dedicated Monitoring Wells

- Well Completed in Multiple Formations
- Well Without Construction Information

Other Wells

- Well Completed in Multiple Formations or Without Construction Information

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

MONITORING WELLS COMPLETED IN MULTIPLE FORMATIONS OR WITHOUT CONSTRUCTION INFORMATION

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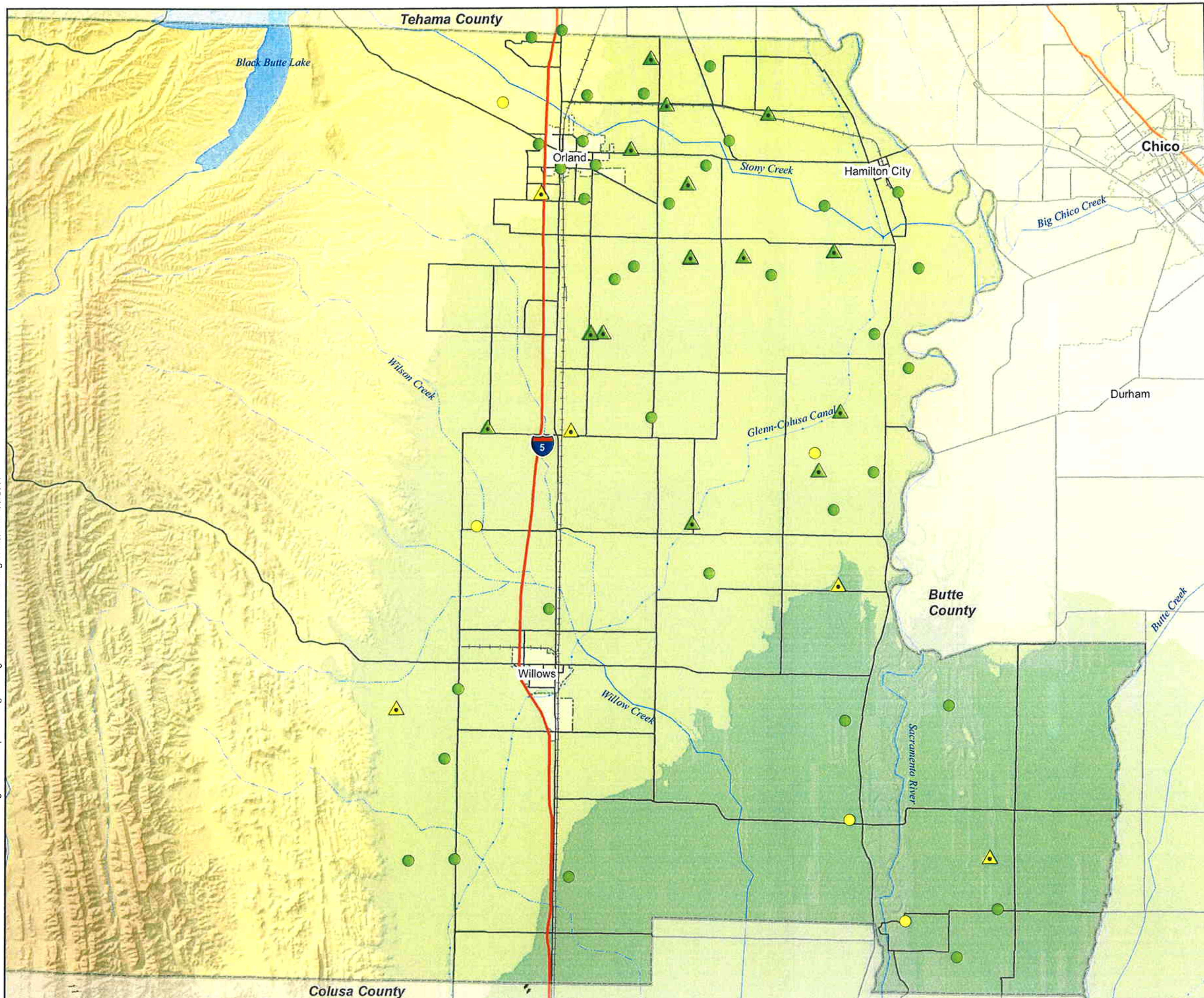
J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 4 - Unknown or Multiple Monitoring Wells.mxd 1/5/2007

FIGURE E-4



LEGEND

Dedicated Monitoring Wells

- Well Completed in Modesto/Riverbank Formation
- Well Completed in Younger Alluvium

Other Wells

- Well Completed in Modesto/Riverbank Formation
- Well Completed in Younger Alluvium

Note: This figure shows wells completed in only the Modesto/Riverbank Formations or younger alluvium.

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

MONITORING WELLS COMPLETED IN MODESTO/RIVERBANK FORMATIONS OR YOUNGER ALLUVIUM

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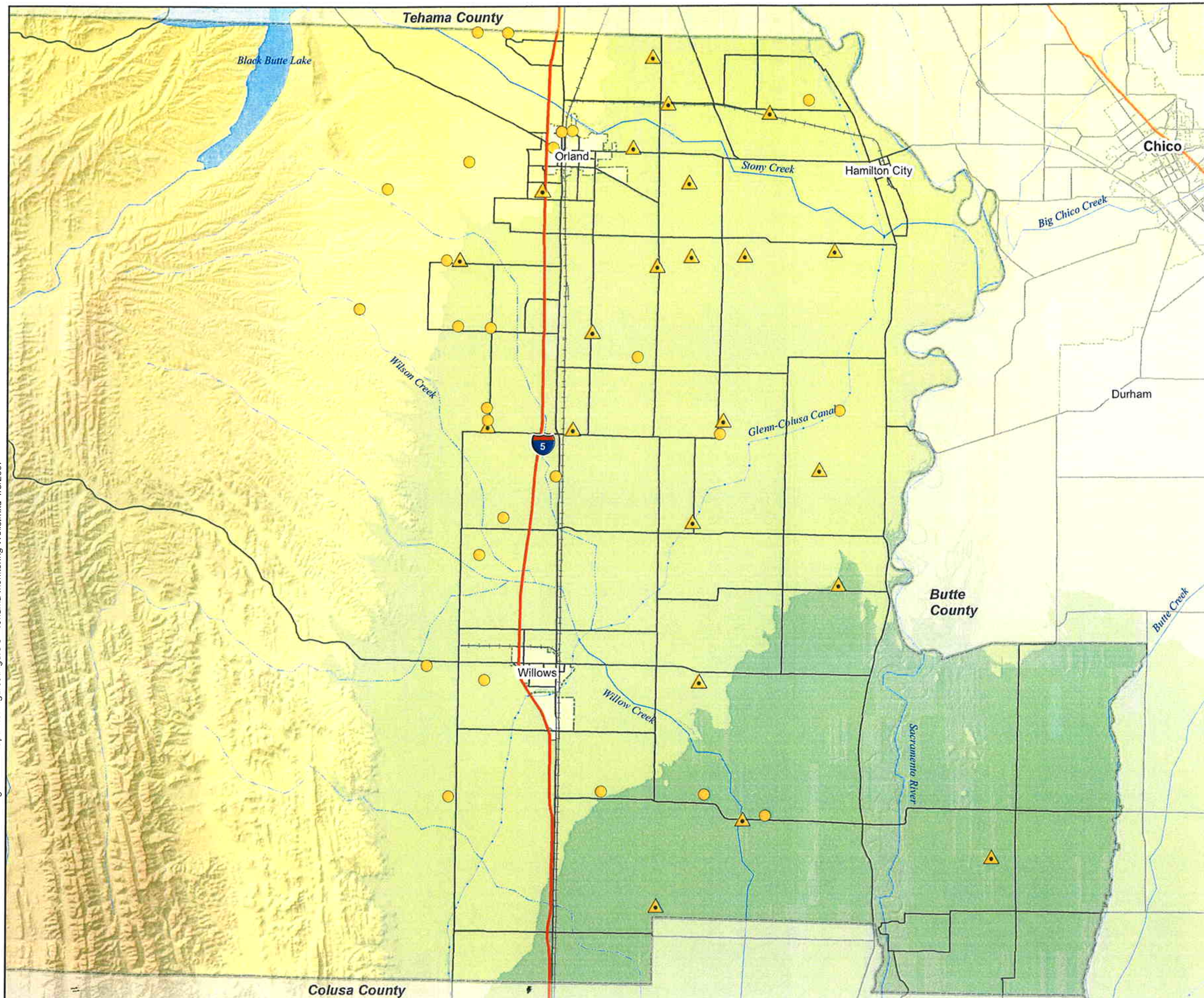
FIGURE E-5

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 5 - MRY Monitoring Wells.mxd 1/5/2007



LEGEND

Dedicated Monitoring Wells

Well Completed in Tehama Formation

Other Wells

Well Completed in Tehama Formation

Note: This figure shows wells completed in only the Tehama Formation.

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

MONITORING WELLS COMPLETED IN TEHAMA FORMATION

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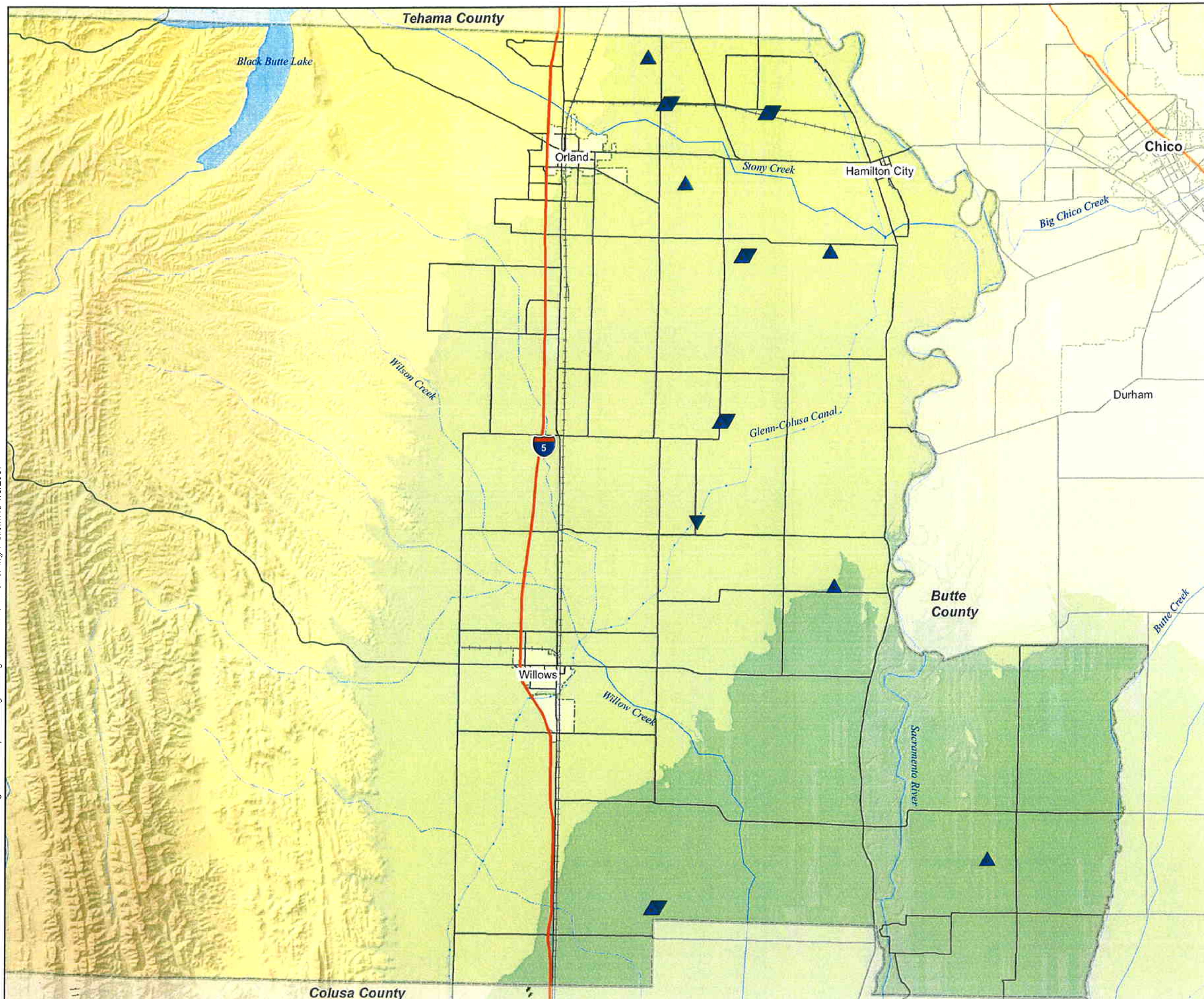
FIGURE E-6

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 6 - Tehama Monitoring Wells.mxd 1/5/2007



LEGEND

Dedicated Monitoring Wells

- ▲ Well Completed in Tuscan Formation Unit C (Upper)
- ▼ Well Completed in Tuscan Formation Unit A and/or B (Lower)

Note: This figure shows wells completed in only the Upper (Unit C) or Lower (Units A and/or B) Tuscan Formation.

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

MONITORING WELLS COMPLETED IN TUSCAN FORMATION

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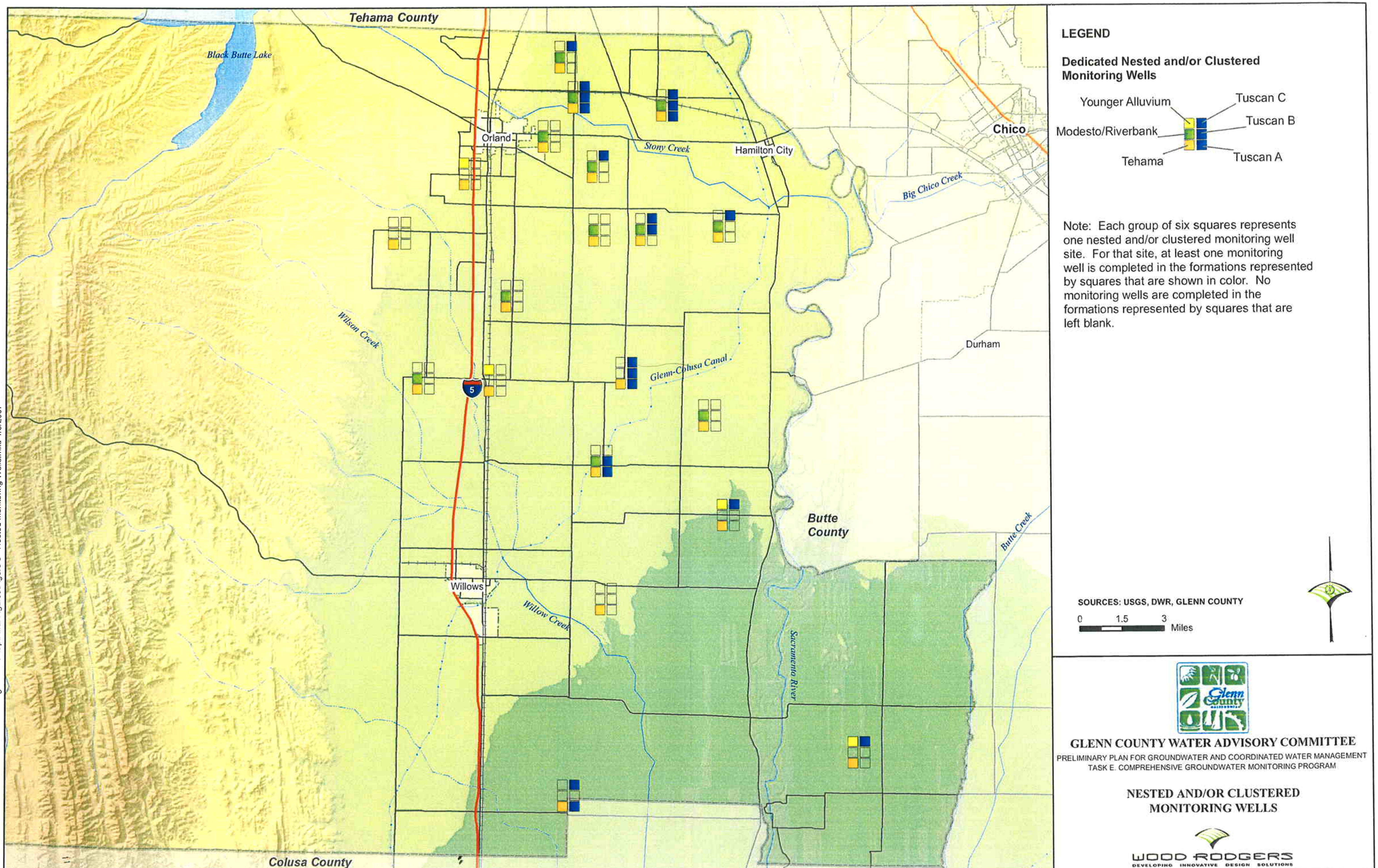
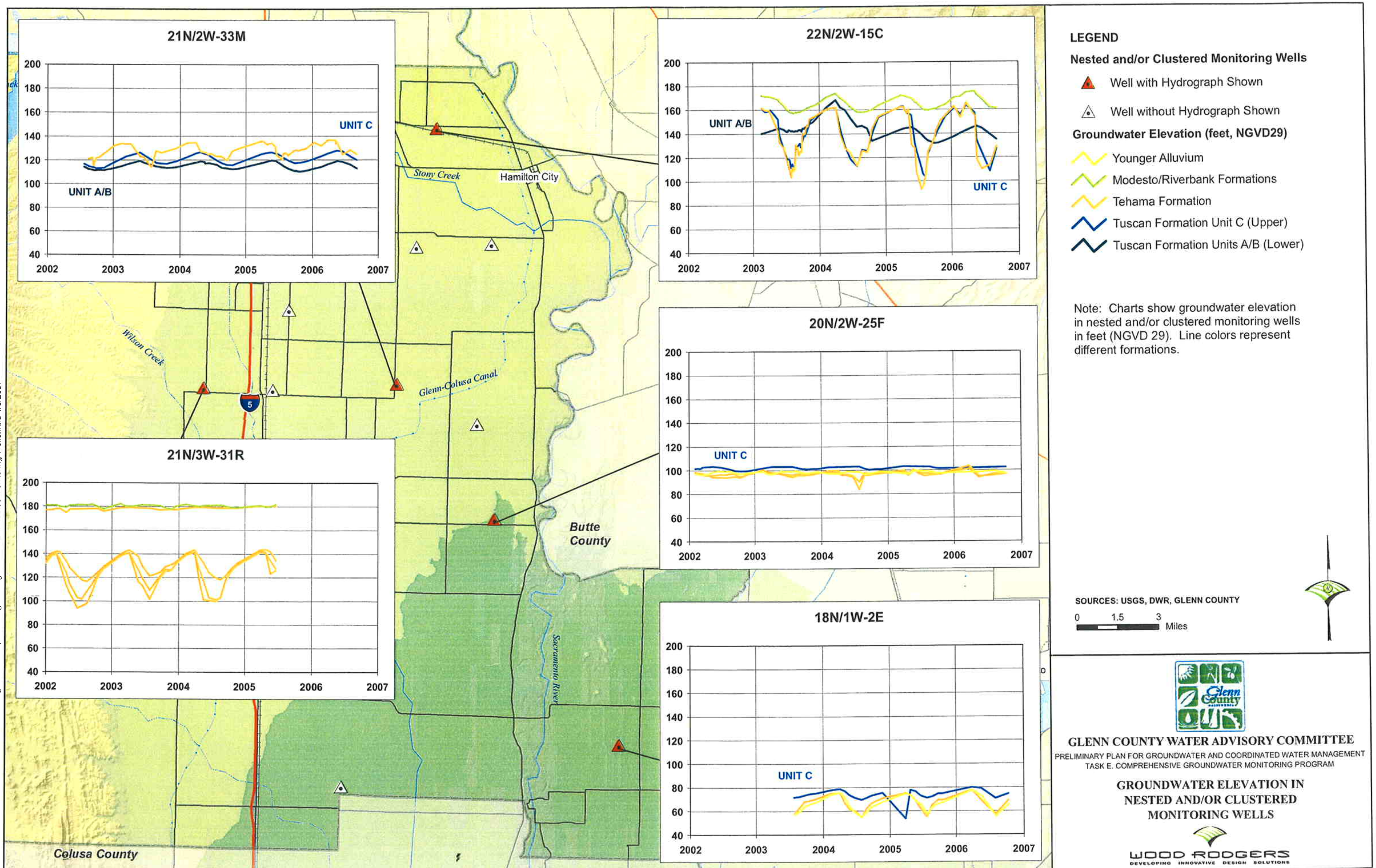
J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 7 - Tuscan Monitoring Wells.mxd 1/5/2007

FIGURE E-7



J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 8 - Nested Monitoring Wells.mxd 1/5/2007

FIGURE E-8



21N/2W-33M
UNIT C
UNIT A/B
22N/2W-15C
UNIT A/B
UNIT C
20N/2W-25F
UNIT C
21N/3W-31R
18N/1W-2E
UNIT C
Stony Creek
Hamilton City
Wilson Creek
Glenn-Colusa Canal
Butte County
Sacramento River
Colusa County
LEGEND
Nested and/or Clustered Monitoring Wells
Well with Hydrograph Shown
Well without Hydrograph Shown
Groundwater Elevation (feet, NGVD29)
Younger Alluvium
Modesto/Riverbank Formations
Tehama Formation
Tuscan Formation Unit C (Upper)
Tuscan Formation Units A/B (Lower)
Note: Charts show groundwater elevation in nested and/or clustered monitoring wells in feet (NGVD 29). Line colors represent different formations.
SOURCES: USGS, DWR, GLENN COUNTY
0 1.5 3 Miles
GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM
GROUNDWATER ELEVATION IN NESTED AND/OR CLUSTERED MONITORING WELLS
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FIGURE E-9

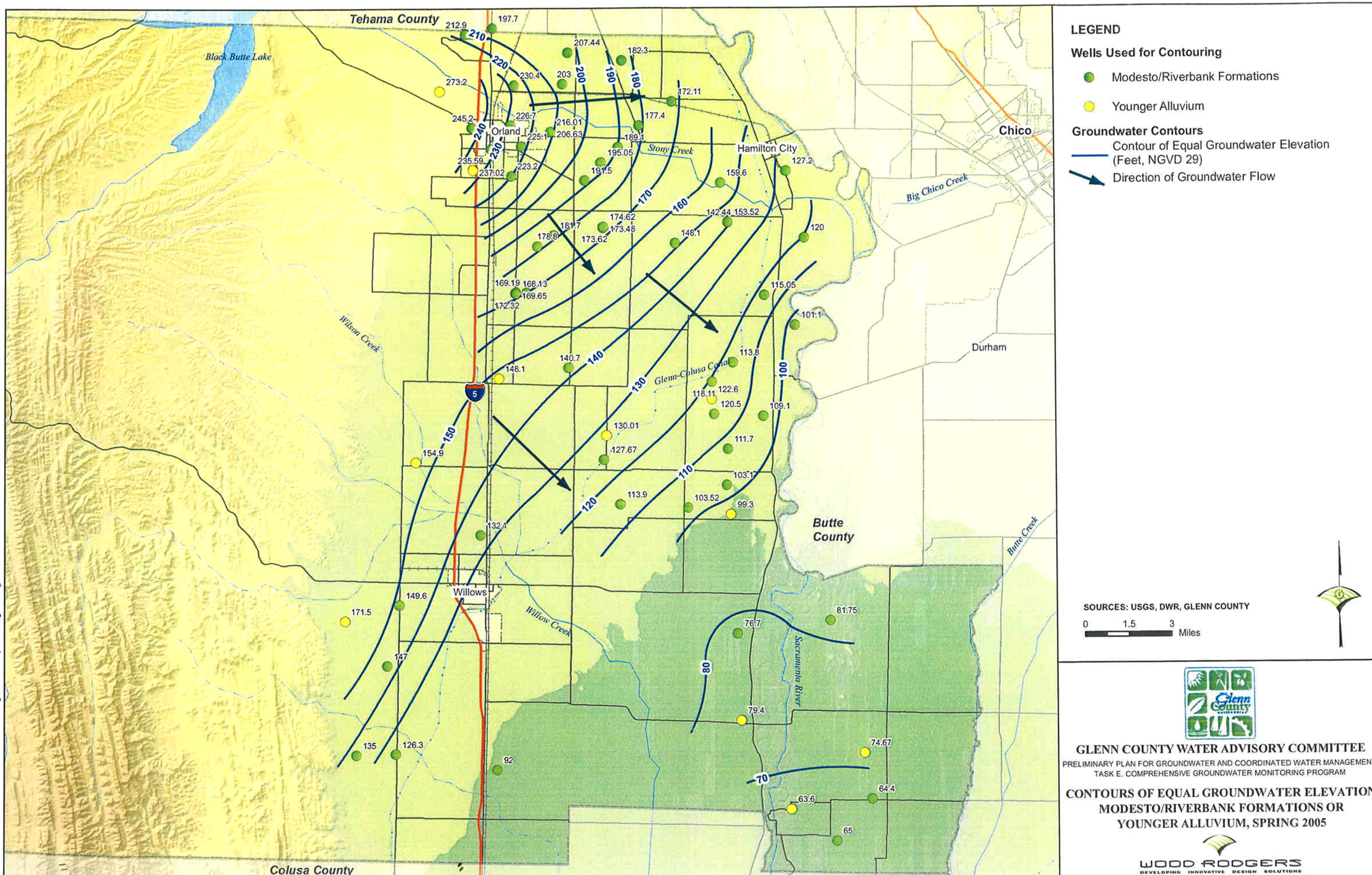
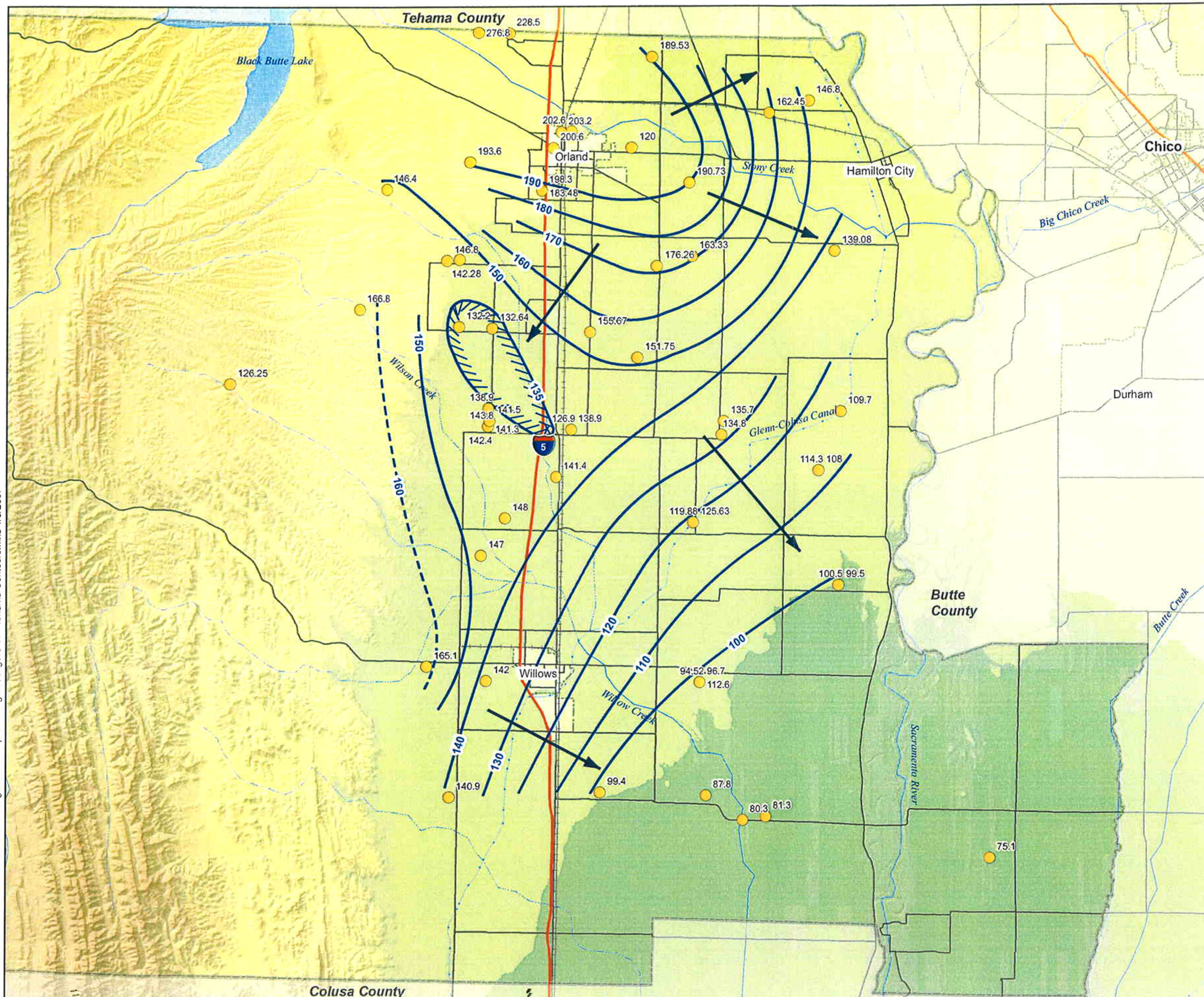


FIGURE E-10

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 10 - MRY Contours.mxd 1/5/2007



LEGEND

Wells Used for Contouring

Tehama Formation

Groundwater Contours

Contour of Equal Groundwater Elevation (Feet, NGVD 29)

Direction of Groundwater Flow

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

CONTOURS OF EQUAL GROUNDWATER ELEVATION
TEHAMA FORMATION, SPRING 2005

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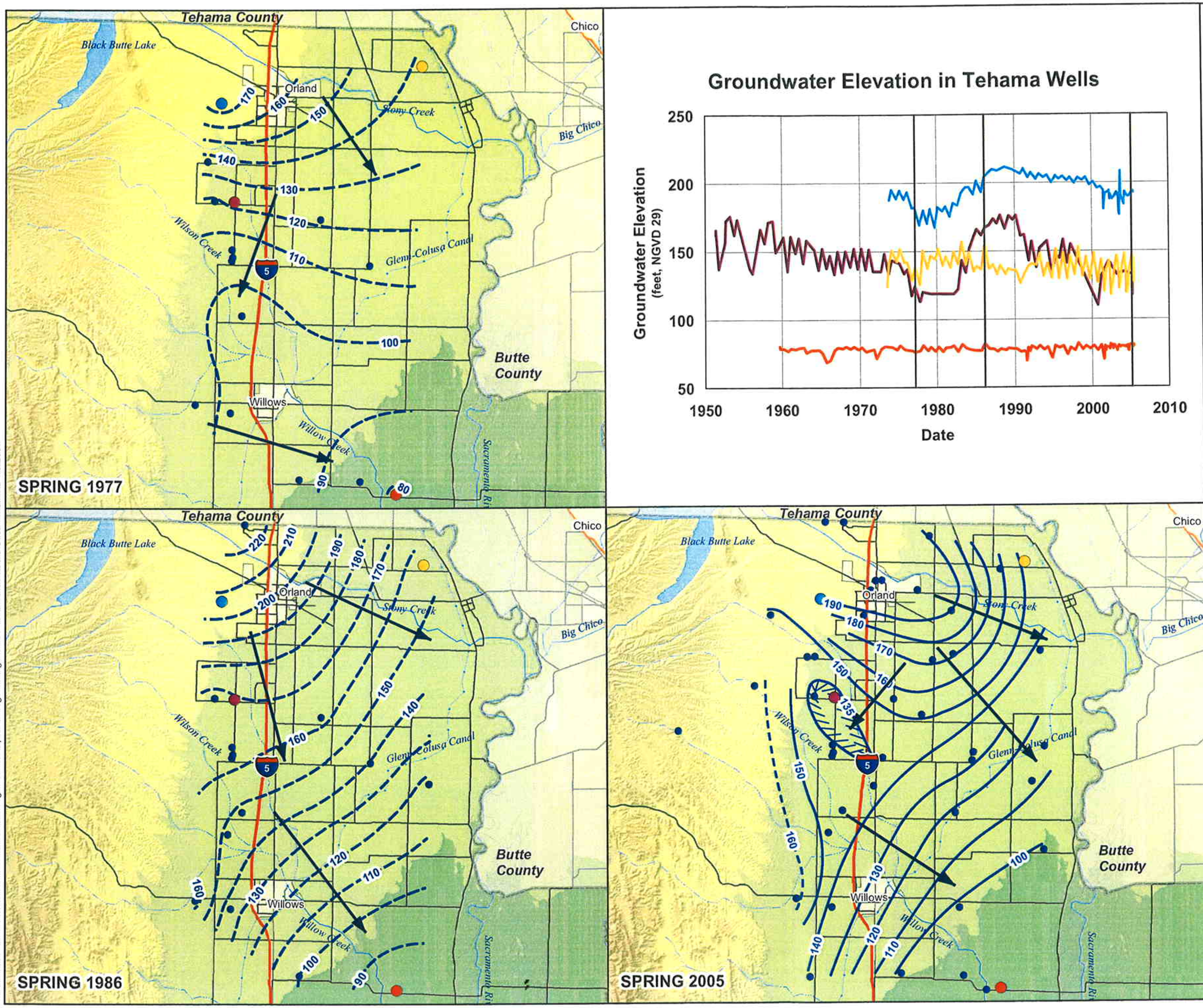
FIGURE E-11

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 11 - Tehama Contours.mxd 1/5/2007



LEGEND

Wells Used for Contouring

- Not Shown in Chart
- 19N02W34F01M
- 21N03W20D02M
- 22N02W11Q01M
- 22N03W30C01M

Groundwater Contours

- Contour of Equal Groundwater Elevation (Feet, NGVD 29)
- Direction of Groundwater Flow

SOURCES: USGS, DWR, GLENN COUNTY

0 2.5 5 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

CONTOURS OF EQUAL GROUNDWATER ELEVATION OVER TIME, TEHAMA FORMATION

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FIGURE E-12

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 12 - Tehama Contours Over Time.mxd 1/5/2007

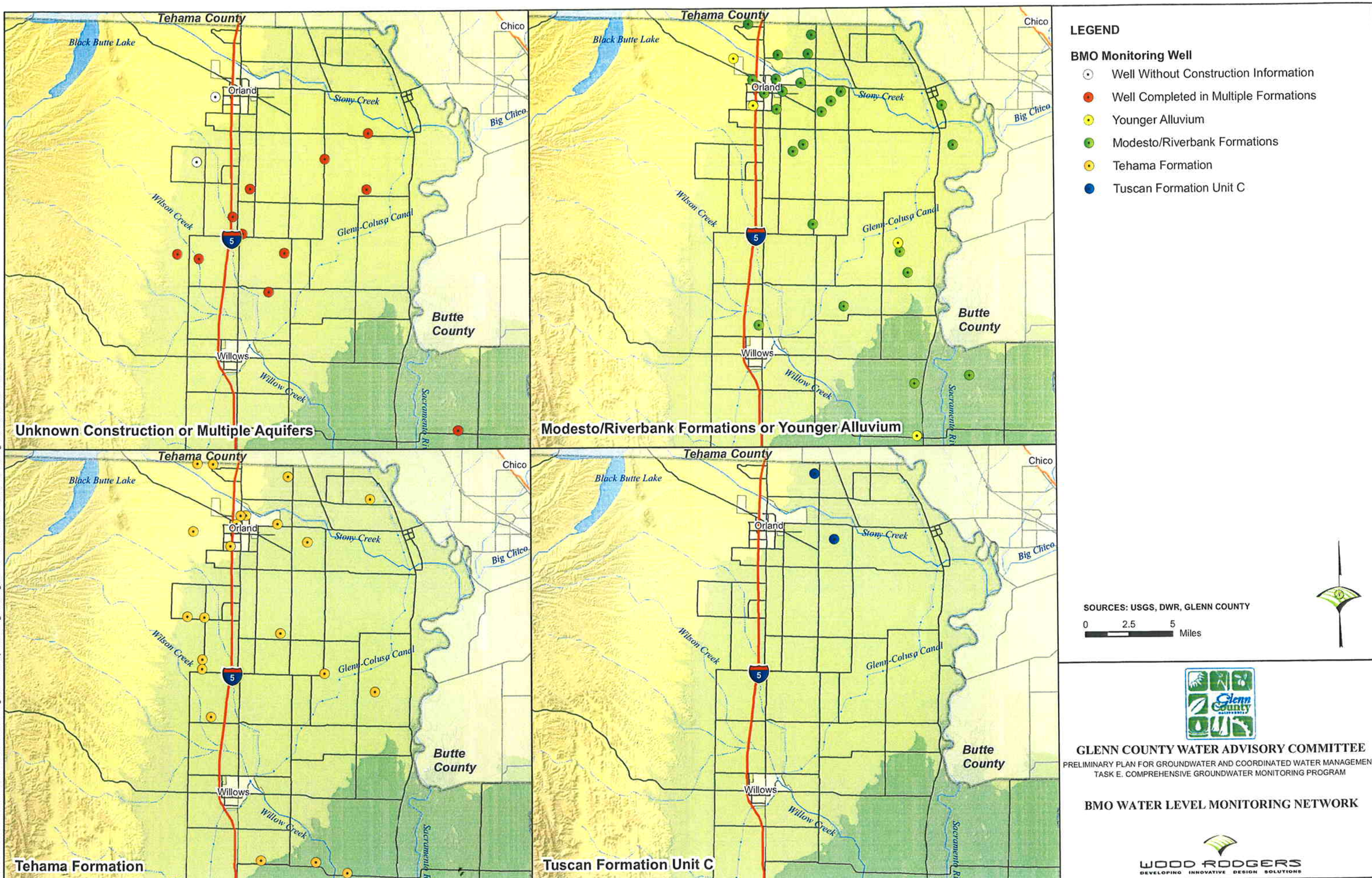
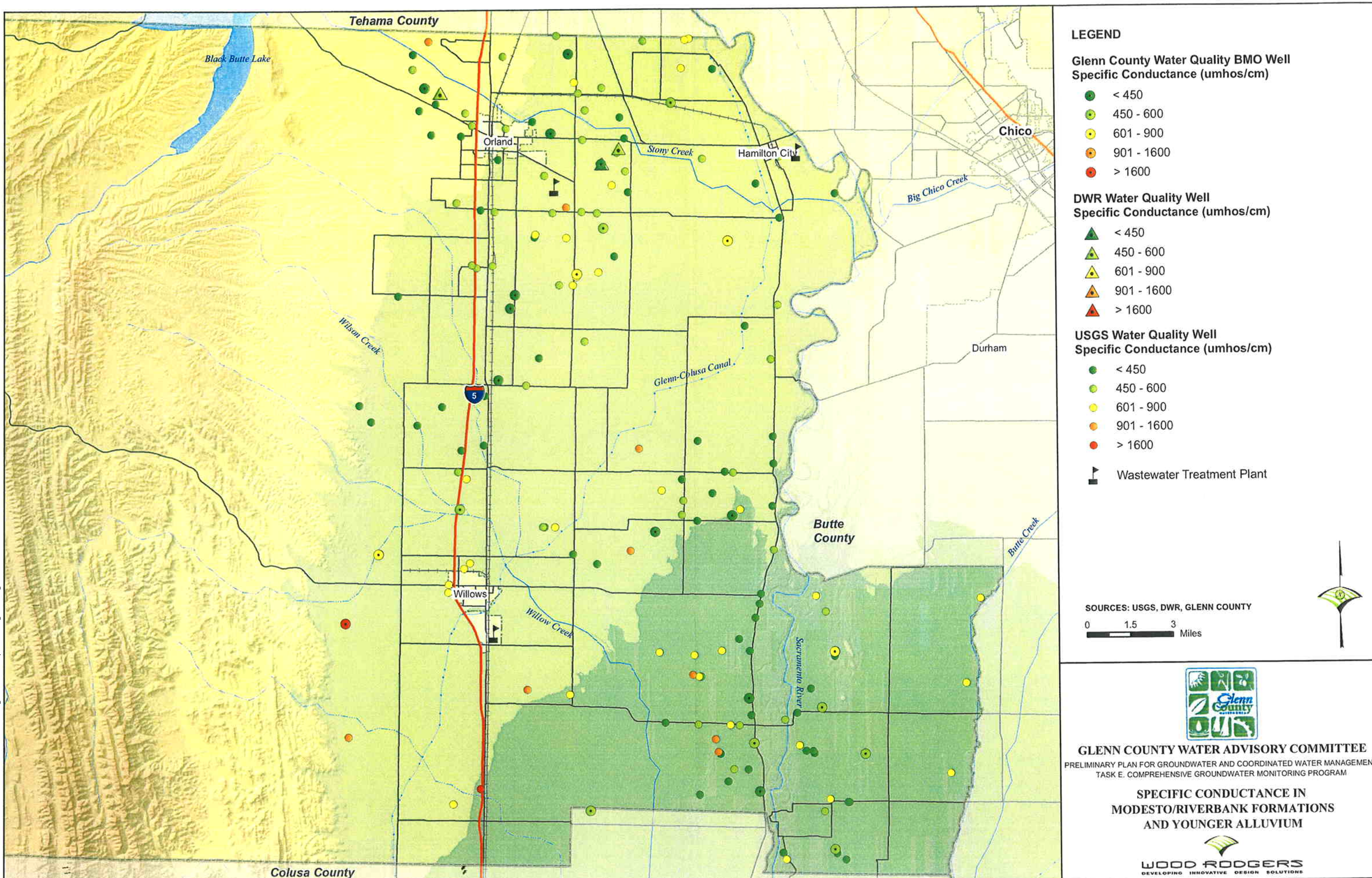


FIGURE E-13

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 13 - BMO Water Level Monitoring Network.mxd 1/5/2007



GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

SPECIFIC CONDUCTANCE IN MODESTO/RIVERBANK FORMATIONS AND YOUNGER ALLUVIUM

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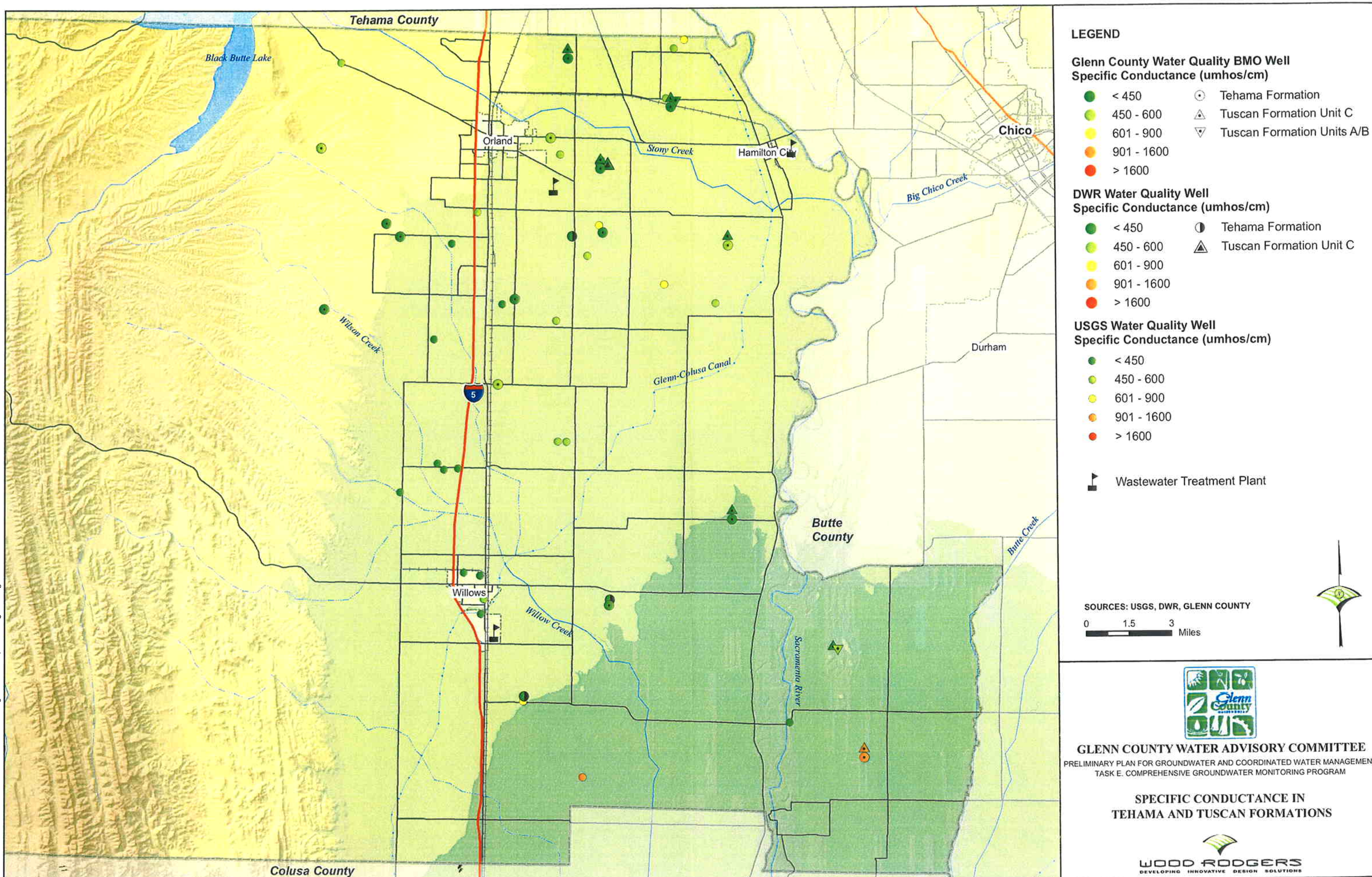
FIGURE E-14

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 14 - MRY EC.mxd 1/5/2007



GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

SPECIFIC CONDUCTANCE IN TEHAMA AND TUSCAN FORMATIONS

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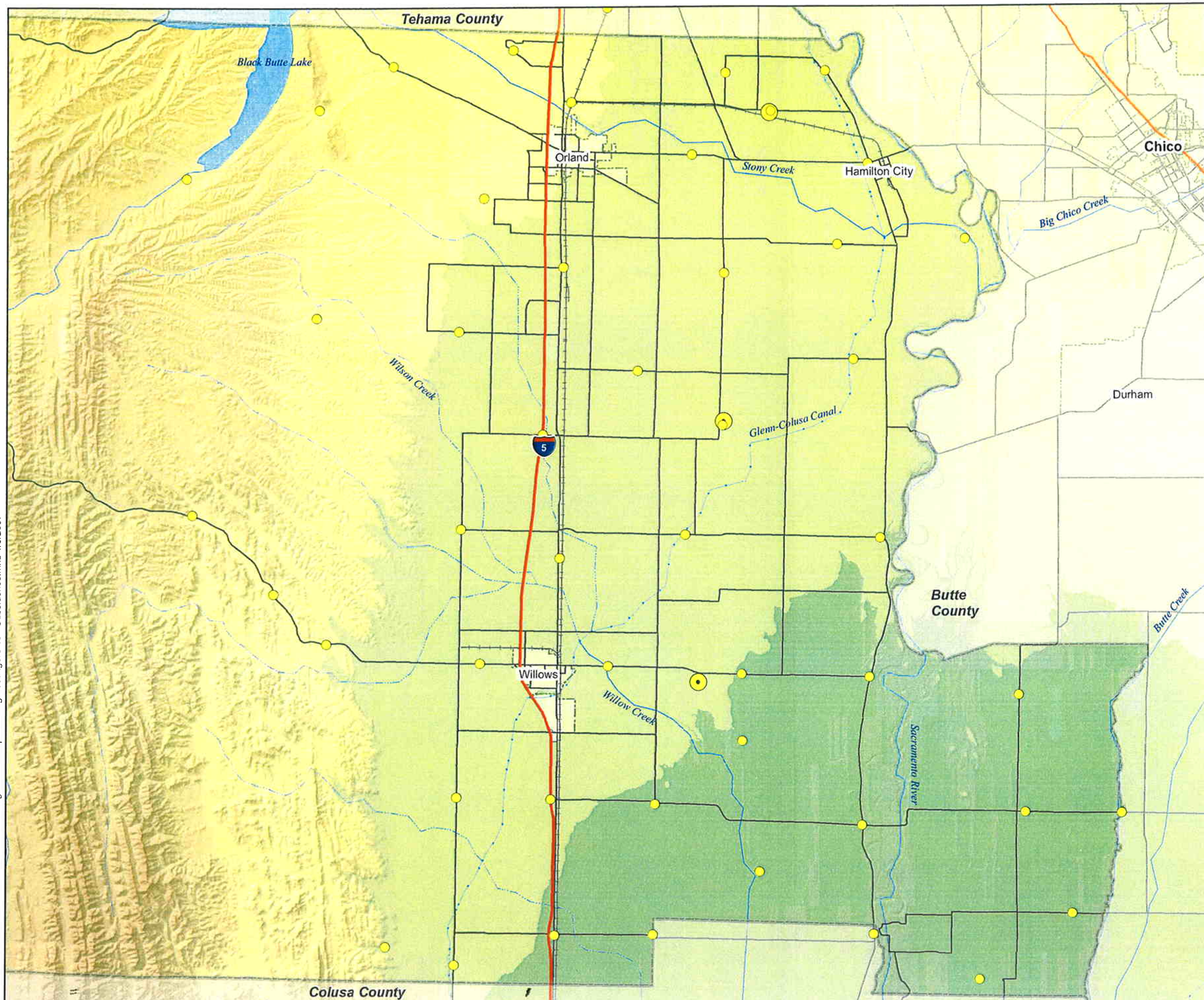
FIGURE E-15

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 15 - Tehama and Tuscan EC.mxd 1/5/2007



LEGEND

Subsidence Monitoring Stations

- Surface Subsidence Survey Station
- Extensometer

SOURCES: USGS, DWR, GLENN COUNTY

0 1.5 3 Miles

GLENN COUNTY WATER ADVISORY COMMITTEE

PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT
TASK E. COMPREHENSIVE GROUNDWATER MONITORING PROGRAM

SUBSIDENCE MONITORING NETWORK

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FIGURE E-16

J:\Jobs\8233.001-Glenn\8233.003 GW Monitoring\GIS\ArcMap\Final Figures\Figure 16 - Subsidence.mxd 1/5/2007

APPENDIX

APPENDIX

WOOD RODGERS

MEMORANDUM

TO: Glenn County Water Advisory Committee

FROM: Francis E. Borcalli, P.E.

DATE: November 13, 2003

SUBJECT: Preliminary Plan for Groundwater and Coordinated Water Management – Discussion Document

INTRODUCTION

The Glenn County Water Advisory Committee (WAC) retained the services of Wood Rodgers, Inc. in February 2003, to assist in facilitating a planning process to document and preserve what has been accomplished and provide a direction for the future of the WAC.

In carrying out this assignment, Wood Rodgers interviewed representatives of water districts, agricultural support entities, and agriculturists; reviewed documents describing completed as well as relevant work in progress, city/county general plans, and county codes and ordinances. Additionally, Wood Rodgers attended meetings of the WAC and Technical Advisory Committee (TAC).

Based upon information assimilated, Wood Rodgers prepared this Memorandum to initiate discussion aimed at facilitating the management of water resources "available" to Glenn County. Use of the term "available" is purposeful in that Glenn County, not necessarily as a jurisdiction but as a community, has the innate responsibility of being stewards of those resources for the community of Glenn County as well as the region and State as a whole.

By virtue of the geographic and hydrologic setting of Glenn County and the foresight and actions of people in years past, Glenn County is in an enviable position in relation to many other areas of the State. More importantly, Glenn County has, in recent years, continued to demonstrate foresight by virtue of measures implemented to safeguard its groundwater resources. Measures that are being implemented in Glenn County are being used to set standards statewide by virtue of being incorporated into legislation of statewide significance.

The efforts of Glenn County relative to formulating and codifying measures to safeguard its groundwater resources and the progress made in implementing stipulated monitoring programs are commendable. This effort to chart the "next" step to facilitate improved management of the available water resources is commendable as well.

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San Francisco Office: 1005 Sansome Street, Suite 330 • San Francisco, CA 94111 • 415.627.0777 • Fax 415.627.0778
www.woodrodgers.com

BACKGROUND

Glenn County is clearly an agricultural community with nearly 30 percent of its 850,000 acres in agriculture and one percent devoted to urban uses (Table 1). Over the 10-year period from 1988 to 1998, land devoted to agricultural use decreased from 283,517 acres to 263,503 acres, or seven percent, while land devoted to urban use increased from 6,114 aces to 11,314 acres, or 85 percent. Virtually all land suitable for irrigated agriculture is developed, thus, increases in water use for agriculture would be attributed to changes in crop mix and/or intensity of farming or improved reliability in supply.

The land within the incorporated cities of Orland and Willows is approximately 3,400 acres although the land within the planning area or Sphere of Influence of the two cities is approximately 12,400 acres. The latter represents approximately 4.7 percent of the land in agriculture in 1998. The total county population in 2012 is projected at 47,000, which represents an increase of nearly 22,000 people above the 1993 population.

In establishing the WAC and TAC; adopting Ordinance No. 1115; developing and adopting initial Basin Management Objectives (BMOs); and implementing programs to monitor groundwater levels, water quality, and land subsidence monitoring programs represents very significant accomplishments that separates Glenn County from most other counties. Having "tested" the BMO process for addressing conflicts reinforces the utility of the process established for safeguarding groundwater resources.

GOALS FOR WATER MANAGEMENT

To identify the goals for water management in Glenn County, certain documents were reviewed to determine the extent to which the community is unified in this regard. The respective documents and specified goals are presented below. Where deemed appropriate, some commentary or comments are provided that relate to the purpose of this assignment.

Basin Management Objective (BM0) for Groundwater Surface Elevations in Glenn County, California, August 21, 2001

The vision set forth by the WAC in submitting the Basin Management Objectives to the Board of Supervisors for adoption, is "*that sufficient and affordable water of good quality be available on a sustainable basis to meet the needs of agricultural, industrial, recreational, environmental, residential, and municipal users within the County, both now and in the future.*"

The intent of the vision is well meaning; however, at this time the water needs and affordability of the respective users are not known. Absent some quantification of the needs and affordability, it is very difficult to formulate water resource projects and programs to fulfill the vision.

Policy Plan Glenn County General Plan Volume I, June 1993

Goals and policies are set forth in the General Plan that relate to the subject of this Memorandum. A relevant goal and policies were selected from the document and are presented below.

Goal:

NRG-2 Protection and management of local water resources.

Policies: It shall be the policy of Glenn County to:

NRP-22 Oppose the exportation of groundwater resources outside the county.

NRP-23 Support legislation which will provide for a locally controlled Glenn County groundwater management district.

NRP-24 Recognize the following local priorities when dealing with questions of ground and surface water use:

Highest (1) Household/Domestic
(2) Agriculture
(3) Industrial/Commercial
(4) Wildlife/Conservation

Lowest (5) Exportation

NRP-25 Protect groundwater recharge areas in the county from overcovering and contamination by carefully regulating the type of development that occurs within these areas.

Other policies and implementation strategies are presented in the General Plan, however, are not presented here.

It is recognized these policies were developed in 1993, and that a great deal of work and effort were expended since then to better understand and manage water resources available to the Glenn County. Nevertheless, these policies are not necessarily consistent with current management strategies.

Feasibility Report, OUWUA AND TCCA Regional Water Use Efficiency Project, January 2003

The long-term management goals for the OUWUA and TCCA as stated in the feasibility report include the following:

- Insure a long-term reliable water supply to the OUWUA, and improve conveyance system and on-farm water use efficiency by modernizing the existing open channel distribution system
- Support the long-term Stony Creek environmental restoration and fishery resource management objectives of the various state and federal resource agencies
- Provide supplemental water supply to the TCCA service area
- Provide supplemental water supply and operating flexibility to support other beneficial water uses within the Sacramento Valley

Glenn-Colusa Irrigation District Water Transfer Policy, February 16, 1995

The Glenn-Colusa Irrigation District (GCID) adopted its water transfer policy in February 1995. The policy articulates a priority to allocate its water supplies. Summarized below is GCID's policy to allocate water supplies available after meeting the needs within the District. Water available in excess of the District's needs would be marketed as follows:

1. A portion of the available water to other agricultural areas within the Sacramento River watershed with consideration given to the buyers "ability to pay,"
2. To environmental purposes.
3. To urban water agencies north of the Delta.
4. To agricultural or urban water users south of the Delta.
5. To the USBR/DWR on a case-by-case basis with the same priority as south of the Delta water users.

It is not essential that goals and policies of entities involved with water management be the same, however, it is important from the standpoint of the message delivered to people within and outside the county, that:

- The goals and policies from a countywide perspective be consistent.
- The goals and policies at the countywide level facilitate sound water management by local entities.

ORGANIZATION FOR WATER MANAGEMENT

Existing organization for addressing water-related issues in Glenn County includes the WAC and TAC, the membership of which are both appointed by the Board of Supervisors. The WAC and TAC have been instrumental in implementing groundwater monitoring programs to address groundwater levels, water quality, and land subsidence and in assessing compliance with the BMOs. Additionally, meetings of the respective committees have provided a forum for discussing a variety of water-related matters. More important, or at least equally important, to the work accomplished, is the strength of the organization, which comes from successfully dealing with contentious and controversial issues. The WAC is comprised of 22 members, 17 of which represent specific geographic subareas, four individually representing the cities of Orland and Willows, the Resource Conservation District, the Glenn County Farm Bureau, and one ex-officio member from the Board of Supervisors. The subareas and geographic locations are identified on Map 1. The area of each subarea is presented on Table 2. A further definition of each subarea in terms of land use for years 1993 and 1998 is presented on Table 3. The TAC is a nine-person committee nominated by the WAC and appointed by the Board.

Work of the WAC/TAC is at a threshold in that a milestone has been reached in terms of the initial focus of groundwater management being achieved. This is not to say that the work is completed but rather, the program for groundwater monitoring, an important element of the BMOs, is being implemented. This will be an ongoing effort in terms of the monitoring network and the data compiled.

The question being addressed at this time is, "What is the next step toward advancing the management of water resources available to Glenn County?" In other words, what is the role of the WAC/TAC and what activities should be implemented to build on the good works completed to date. Improved water management is accomplished one step at a time. Each step should build on work completed from the previous step. Clearly, each step will be followed by another, as the task of water management is never completed. Instead, it becomes more refined with well-directed effort over time. An essential element of ongoing success is the unconditional cooperation and partnerships formed to implement well-conceived programs and projects. Accordingly, the roles and responsibilities of the involved parties need to be clearly defined.

A specified purpose of the County in adopting the BMOs is to work cooperatively with interested local agencies to further develop and implement joint groundwater management practices. To this end, to the extent efforts are directed to facilitate improved management of available water resources by local agencies or entities, the people of Glenn County will be well served.

Management of available water resources by local agencies or entities can be improved with information that is more global in scope or countywide, readily accessible, and provides the foundation for monitoring conditions and identifying opportunities for improved water management and partnerships for implementing particular programs and projects.

For purposes of advancing the management of water resources available within Glenn County, it is suggested that the role of the WAC be expanded to include the coordination of other water resources activities that are countywide. Thus far the effort of the WAC has been directed primarily at administering the BMOs. The composition of the existing committees, although considered by some as not well balanced, does provide a good cross section of the water community of Glenn County. Furthermore, the ability to work together to deal with contentious issues has been demonstrated.

The water resource activities or tasks should be aimed at formulating a Glenn County Groundwater and Water Coordination Plan. The activities undertaken that are of a countywide nature should in no way interfere with the day-to-day operations of local entities, long term planning, or management of resources. On the other hand, the effective implementation of such activities should facilitate more effective planning, implementation, and management of local entities individually and/or jointly.

To reflect a broader role, the WAC could be referred to as the Water Advisory and Coordination Committee or other name as may be deemed appropriate. The duties related to the BMOs would not change.

PROGRAM TO FACILITATE GROUNDWATER AND COORDINATED WATER MANAGEMENT

Tasks have been identified as components of a program to facilitate the management of water resources by local entities within Glenn County. The product from the respective tasks would provide information that can be used to facilitate improved water management and benefit Glenn County. It is suggested implementing the tasks with oversight of the WAC in its expanded role as discussed above. The respective tasks, together with a brief description, are presented below.

A. Formulate Countywide Water Management Goals

As noted previously, goals for water management at the county level are not consistent and in some sense contradict the goals and policies of local entities. For the benefit of the community at large and entities responsible for water management, it would be beneficial to revisit this matter to develop water management goals that would serve to unify the governing and regulatory bodies and those responsible for water management.

B. Perform Water Needs Analysis

Having the water needs of Glenn County as a priority for water management is certainly endorsed by all parties. A difficulty is that the water needs for Glenn County are not identified. Addressing this priority in a responsible manner could be done if the water needs for the various water uses were quantified in terms of amount, location, timing, and quality. Addressing the water needs, or better stated, unmet water needs, dictates that water supplies also be quantified.

C. Prepare Water Delivery and Distribution Infrastructure Map

Having a map that displays all existing infrastructure for the delivery and distribution of irrigation water would be beneficial for identifying opportunities to interconnect or extend facilities to exchange or transfer water within the county. This information would be helpful to identify opportunities meeting water needs in particular areas, and/or providing service in the event of an emergency situation.

D. Determine Groundwater Utilization Opportunities and Constraints

BMOs have been set for various sub-areas in the county. To a large extent the BMOs were established using historic groundwater level data. The BMOs and the applied methodology provides safeguards for protecting the groundwater basin, however, it may also be limiting the opportunity for managing the available water resources. A better understanding of the extent to which the groundwater basin can be utilized without causing adverse impacts could aid substantially in meeting the water needs of the county under normal or emergency conditions.

Glenn County is fortunate to have a groundwater model that was prepared for the Orland-Artois Water District, the Orland Unit Water Users' Association, and Glenn-Colusa Irrigation District. Water Resources & Information Management Engineering, Inc. (WRIME) developed the Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM) in coordination with the California Department of Water Resources. By virtue of having the model, Glenn County, again, sets itself apart from most other counties. Although the model was developed for the Stony Creek Fan Conjunctive Water Management Program, the model is a "public domain" model and it is understood that the model is available for use by other entities in Glenn County.

The SCFIGSM is a "tool" that can be used to simulate groundwater flow, streamflow, reservoir operations, rainfall runoff processes, land use processes, unsaturated zone flow, and land subsidence. The utility of the SCFIGSM , as stated in WRIME's report, is that it can be used to:

1. Re-examine the assumptions made during the development of the BMOs.

2. Enhance the information background of an existing decision or a revised decision related to the Groundwater Management Ordinance or the BMOs.

3. Identify sensitive areas where additional monitoring may be required to check compliance with the BMOs.

4. Develop general response characteristics and/or sensitivity ranges among different physical and operational elements.

5. Enhance the understanding of the groundwater system behaviors, characteristics, and constraints.

The SCFIGSM can perform "what if" scenarios that can greatly improve the overall understanding of the groundwater basin and general response to hypothetical changes in land use and water management.

E. Complete Comprehensive Groundwater Monitoring Program

Through the efforts of the WAC and TAC, Glenn County has initiated a sound groundwater monitoring program consistent with the BMOs that includes groundwater levels, groundwater quality, and land subsidence. The program is not complete and will be improved and refined with time as additional information is obtained and the needs and understanding of the basin are better known. This program should be completed to the extent existing data and information permits to expand and refine the program and network over time as funding permits. The groundwater model discussed above could be useful in refining the program.

F. Formulate Potential Projects

It would be useful to conduct "brainstorming" sessions to identify, at a conceptual level, potential projects and programs that could help to improve water reliability, quality, or mitigate the impact of extended droughts. Attention should be given to seeking multiple benefits such as reducing impacts from flooding/storm drainage, environmental enhancements, etc.

The benefit of such an exercise would be twofold. First, it would establish a potential list of projects that cold be considered for advanced study when funding opportunities are available. Second, it would provide a broader understanding of the potential projects in which participants might consider being a partner in at a future time.

G. Formulate Water Transfer Guidelines

Glenn County, by virtue on its physical and hydrologic setting and foresight of its residents in the past, enjoys an enviable water supply situation in relation to many counties in California. The fact that water transfers within and/or outside the county can be considered is a fortunate circumstance.

As stewards of the water resources available to Glenn County the resource should be managed to meet the needs of Glenn County, the Sacramento Valley, and California, to the extent practicable. Water law and guidelines or parameters for water use exist. It would be helpful to the community to have guidelines documented that represent established water law and water use parameters that represent the basis for particular types of water transfers. Types of water transfers that should be considered include:

- Surface water with groundwater substitution.
- Surface water with fallowing.
- Groundwater.

To the extent water transfers are configured consistent with adopted guidelines, there should be no need for discussion of a mitigation fund or third party impacts. Having water transfer guidelines in place can facilitate the management of water resources within the county.

H. Formulate Drought Preparedness Plan

The results of tree-ring studies performed on behalf of DWR indicate the occurrence of dry periods of greater duration and severity than the recorded history much of the water planning is based upon. It is not practical to develop or have water supplies available to cover severe events. Nevertheless, such events should be anticipated and measures identified in advance to prepare a community for managing the resources for the well being of the community.

The groundwater model provides an excellent tool by which "what if " scenarios can be examined to identify the most sensitive areas from the standpoint of potential adverse impacts to the groundwater basin. Measures and protocol for response in such events can be used to refine the BMOs.

I. Formulate Public Information and Education Program

The WAC, with an expanded role, could be very effective in disseminating water resource information on a regular basis and facilitating public involvement for projects in which local agencies are involved. Utilizing the excellent relationship with the U.C. Extension Service and DWR could be very effective as a cooperative effort.

J. Prepare Groundwater and Coordinated Water Management Plan

Implementing the tasks described above could help to facilitate the management of water resources available to Glenn County.

These activities lend themselves to being addressed at a countywide level and will support the work of local entities and facilitate management of supplies for which each is responsible. Opportunities for partnerships to improve water management could emerge from the work as well.

SUMMARY

The information presented above is intended to provide a basis for discussion of items Wood Rodgers views as important to strengthen and build on the product of very significant efforts expended by numerous individuals in the county to date. From Wood Rodgers' standpoint, the work product from the program can facilitate improved management of water resources for the overall benefit of the county.

TABLE 1

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

LAND USE: 1988, 1993, 1998
(acres)

Land Use	1988	1993	1998
Deciduous Fruits and Nuts	30,798	34,953	49,344
Citrus and Subtropical	4,075	5,367	6,102
Field Crops	27,967	33,731	37,210
Grain	43,078	38,680	26,120
Rice	82,785	84,000	87,145
Truck, Nursery, and Berry Crops	3,741	2,458	3,746
Vineyards	1,451	1,335	1,548
Semiagricultural and Incidental to Agriculture	2,859	3,584	4,282
Pasture	44,165	44,080	38,450
Fallow/Idle	42,598	27,923	9,556
Subtotal	283,517	276,111	263,503
Barren	0	587	4,642
Native Vegetation	542,552[1]	541,137	535,282[1]
Riparian Vegetation	13,725	16,579	21,483
Water	3,836	8,597	13,520
Urban	6,114	6,733	11,314
Subtotal	566,227	573,633	586,241
TOTAL	849,744	849,744	849,744

[1]Adjusted to make total area the same for each year.

Source: California Department of Water Resources

TABLE 2

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

BMO SUBAREAS

Subarea	Area	
	acres	percent
1. West Corning Basin Private Pumpers	17,440	0.04
2. Stony Creek Water District	2,007	0.00
3. West Colusa Basin Private Pumpers	74,391	0.18
4. Orland Unit Water Users' Association	25,978	0.06
5. Orland-Artois Water District	44,772	0.11
6. Glide Water District	9,851	0.02
7. Kanawha Water District	24,371	0.06
8. East Corning Basin Private Pumpers	22,273	0.05
9. BOS District 5 Pumpers	14,160	0.03
10. BOS District 3 Pumpers	21,864	0.05
11. Glenn-Cousa Irrigation District	86,949	0.21
12. Provident Irrigation District	15,564	0.04
13. Willow Creek Mutual Water Company	697	0.00
14. Princeton-Codora-Glenn Irrigation District	14,128	0.03
15. Reclamation District No. 2106	23,888	0.06
16. Reclamation Distict No. 1004	488	0.00
17. Western Canal Water District	20,436	0.05
TOTAL	419,257	1.00

TABLE 3

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

LAND USE BY SUBAREA: 1993 AND 1998
(acres)

Land Use	Subarea 1		Subarea 2		Subarea 3		Subarea 4		Subarea 5		Subarea 6		Subarea 7		Subarea 8		Subarea 9	
	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998
Deciduous Fruits and Nuts	0	0	0	0	1,149	4,784	3,347	3,598	6,039	10,180	168	428	136	1,106	8,007	8,484	3,237	4,333
Citrus and Subtropical	0	0	0	0	50	35	2,658	2,852	1,621	1,887	0	0	0	0	296	375	269	320
Field Crops	0	0	0	0	409	2	449	984	3,503	5,054	1,095	1,977	4,956	6,114	1,208	1,064	3,153	2,550
Grain	0	53	0	36	1,535	521	908	423	7,557	5,040	2,521	1,637	9,281	4,870	1,829	2,118	2,212	1,244
Rice	0	0	0	0	0	1	0	0	3,117	2,950	1,771	2,243	1,621	1,320	0	0	215	201
Truck, Nursery, and Berry Crops	0	0	0	0	27	15	1	15	92	73	0	0	250	924	0	176	0	315
Vineyards	0	0	0	0	0	0	0	0	1,334	1,537	0	0	0	0	0	0	0	0
Semiagricultural and Incidental to Agriculture	0	7	5	3	138	140	611	1,051	491	638	37	36	197	200	350	385	190	126
Pasture	0	0	273	177	1,705	1,707	10,701	9,047	7,322	6,062	408	194	1,706	1,723	5,065	3,558	3,539	4,002
Fallow/Idle	0	0	0	74	1,913	1,353	1,605	400	4,773	1,277	496	74	544	56	1,454	429	507	116
Subtotal	0	60	278	290	6,926	8,558	20,280	18,370	35,849	34,698	6,496	6,589	18,691	16,313	18,209	16,589	13,322	13,207
Barren	0	328	0	27	460	1,442	117	532	0	16	0	0	0	0	0	548	0	286
Native Vegetation[1]	17,346	16,901	1,638	1,578	63,625	59,903	3,256	3,354	7,168	7,649	3,189	2,920	5,325	7,146	2,394	3,075	797	442
Riparian Vegetation	0	36	72	67	447	1,355	416	828	656	439	41	35	82	75	833	839	0	103
Water	94	115	19	45	2,810	2,584	97	239	346	504	100	141	227	202	303	439	27	41
Urban	0	0	0	0	123	549	1,812	2,655	753	1,466	25	166	46	635	534	783	14	81
Subtotal	17,440	17,380	1,729	1,717	67,465	65,833	5,698	7,608	8,923	10,074	3,355	3,262	5,680	8,058	4,064	5,684	838	953
TOTAL	17,440	17,440	2,007	2,007	74,391	74,391	25,978	25,978	44,772	44,772	9,851	9,851	24,371	24,371	22,273	22,273	14,160	14,160

Land Use	Subarea 10		Subarea 11		Subarea 12		Subarea 13		Subarea 14		Subarea 15		Subarea 16		Subarea 17		Total	
	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998	1993	1998
Deciduous Fruits and Nuts	758	1,880	4,466	5,522	12	11	0	0	3,605	4,366	3,624	4,110	0	0	168	429	34,716	49,231
Citrus and Subtropical	383	379	16	82	0	0	0	0	0	0	0	0	0	0	0	0	5,293	5,930
Field Crops	5,352	4,950	3,673	3,620	24	81	0	0	2,336	1,212	6,208	8,555	3	4	1,330	1,016	33,699	37,183
Grain	4,498	4,480	4,388	3,244	55	0	0	0	279	300	3,041	563	0	0	460	0	38,564	24,529
Rice	679	255	41,982	45,895	13,906	13,702	87	158	5,147	4,863	1,573	1,809	410	422	13,390	13,292	83,898	87,111
Truck, Nursery, and Berry Crops	4	148	11	667	0	0	0	0	11	136	1,957	1,277	1	0	104	4	2,458	3,750
Vineyards	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,335	1,544
Semiagricultural and Incidental to Agriculture	131	247	1,005	868	104	26	0	0	166	218	110	117	0	0	35	17	3,570	4,079
Pasture	5,275	4,802	4,954	4,333	58	0	85	77	425	206	1,729	1,816	8	0	101	122	43,354	37,826
Fallow/Idle	1,456	423	7,771	3,121	1,012	338	43	0	448	173	2,392	965	9	6	3,326	670	27,749	9,475
Subtotal	18,537	17,571	68,266	67,352	15,171	14,158	215	235	12,417	11,474	20,634	19,212	431	432	18,914	15,550	274,636	260,658
Barren	0	0	0	209	0	0	0	0	2	156	8	242	0	0	0	0	587	3,786
Native Vegetation[1]	1,152	1,638	7,352	6,447	266	25	1	2	147	76	675	359	14	1	316	175	114,661	111,691
Riparian Vegetation	61	149	8,421	8,474	25	39	481	418	1,115	1,232	1,934	2,756	10	17	1,206	3,778	15,800	20,640
Water	14	263	1,662	2,614	102	1,259	0	42	412	1,001	595	998	33	38	0	808	6,841	11,333
Urban	2,100	2,243	1,248	1,853	0	83	0	0	35	189	42	321	0	0	0	125	6,732	11,149
Subtotal	3,327	4,293	18,683	19,597	393	1,406	482	462	1,711	2,654	3,254	4,676	57	56	1,522	4,886	144,621	158,599
TOTAL	21,864	21,864	86,949	86,949	15,564	15,564	697	697	14,128	14,128	23,888	23,888	488	488	20,436	20,436	419,257	419,257

[1]Adjusted to make total area the same for each year.

Source: California Department of Water Resources

N

NOT TO SCALE

SUBAREAS:
1. WEST CORNING BASIN PRIVATE PUMPERS
2. STONY CREEK WATER DISTRICT
3. WEST COLUSA BASIN PRIVATE PUMPERS
4. ORLAND UNIT WATER USERS' ASSOCIATION
5. ORLAND-ARTOIS WATER DISTRICT
6. GLIDE WATER DISTRICT
7. KANAWHA WATER DISTRICT
8. EAST CORNING BASIN PRIVATE PUMPERS
9. BOS DISTRICT FIVE PUMPERS
10. BOS DISTRICT THREE PUMPERS
11. GLENN-COLUSA IRRIGATION DISTRICT
12. PROVIDENT IRRIGATION DISTRICT
13. WILLOW CREEK MUTUAL WATER COMPANY
14. PRINCETON-CODORA-GLENN IRRIGATION DISTRICT
15. RECLAMATION DISTRICT 2106
16. RECLAMATION DISTRICT 1004
17. WESTERN CANAL WATER DISTRICT

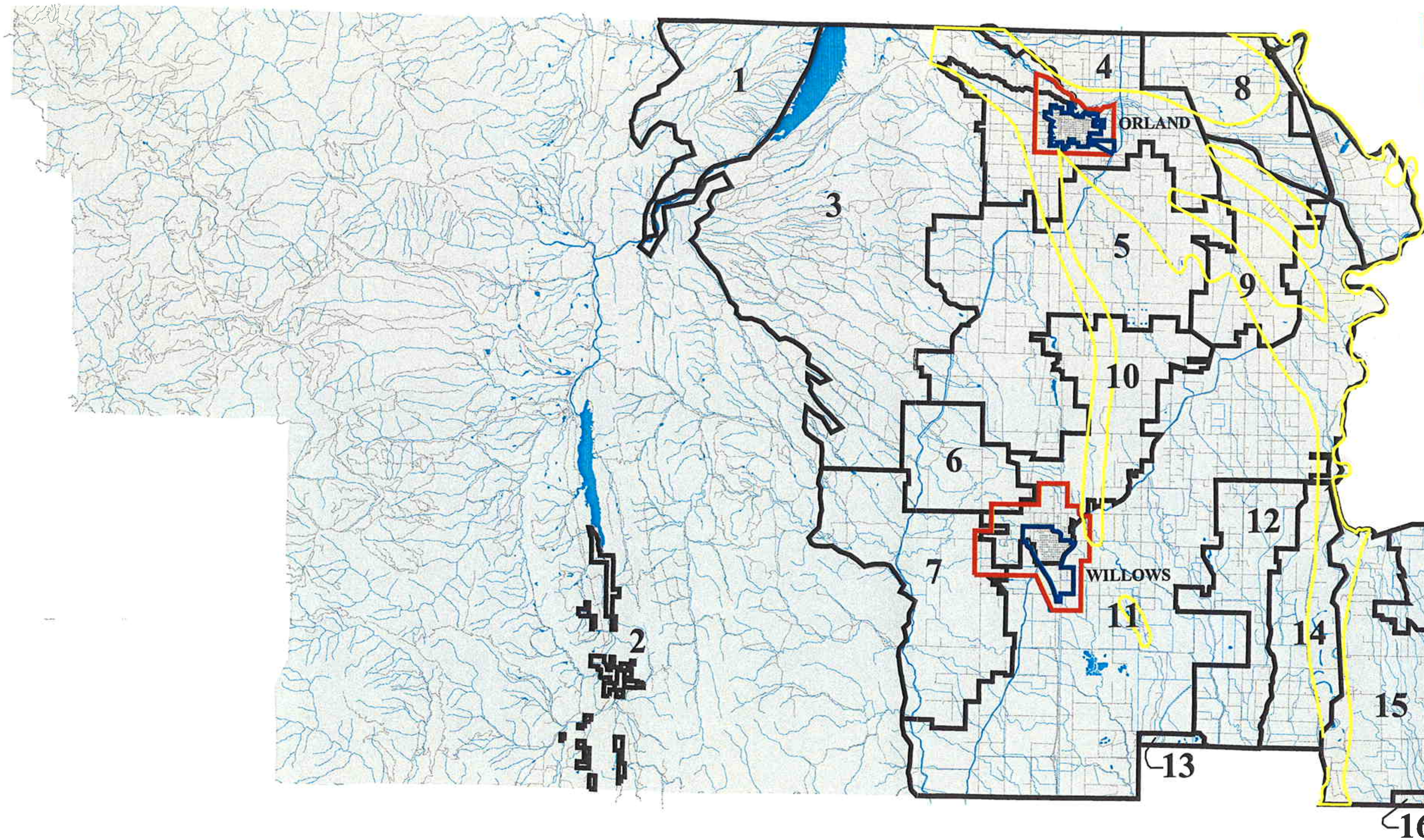
LEGEND

SUBAREA BOUNDARY[1]

CITY BOUNDARY[2]
Orland: 1,525 acres
Willows: 1,845 acres

PLANNING AREA[3]
Orland: 4,045 acres
Willows: 8,360 acres

GROUNDWATER RECHARGE OVERLAY[4]



City of Orland:

Subarea	City Area, acres	Planning Area, acres
3	5	445
4	1,520	3,600
Total	1,525	4,045

City of Willows:

Subarea	City Area, acres	Planning Area, acres
6	-	210
7	-	835
10	1,095	4,325
11	750	2,990
Total	1,845	8,360

Sources:
[1] Glenn County Groundwater Management Ordinance No. 1115.
[2] City of Orland and City of Willows General Plans. City boundary is defined as the incorporated area.
[3] City of Orland and City of Willows General Plans. Planning area is assumed to be the Sphere of Influence as defined by LAFCO.
[4] Glenn County General Plan.

GLENN COUNTY WATER ADVISORY COMMITTEE
PRELIMINARY PLAN FOR GROUNDWATER AND COORDINATED WATER MANAGEMENT

BASIN MANAGEMENT OBJECTIVE - SUBAREAS

WOOD RODGERS
ENGINEERING · PLANNING · MAPPING · SURVEYING

MAP 1