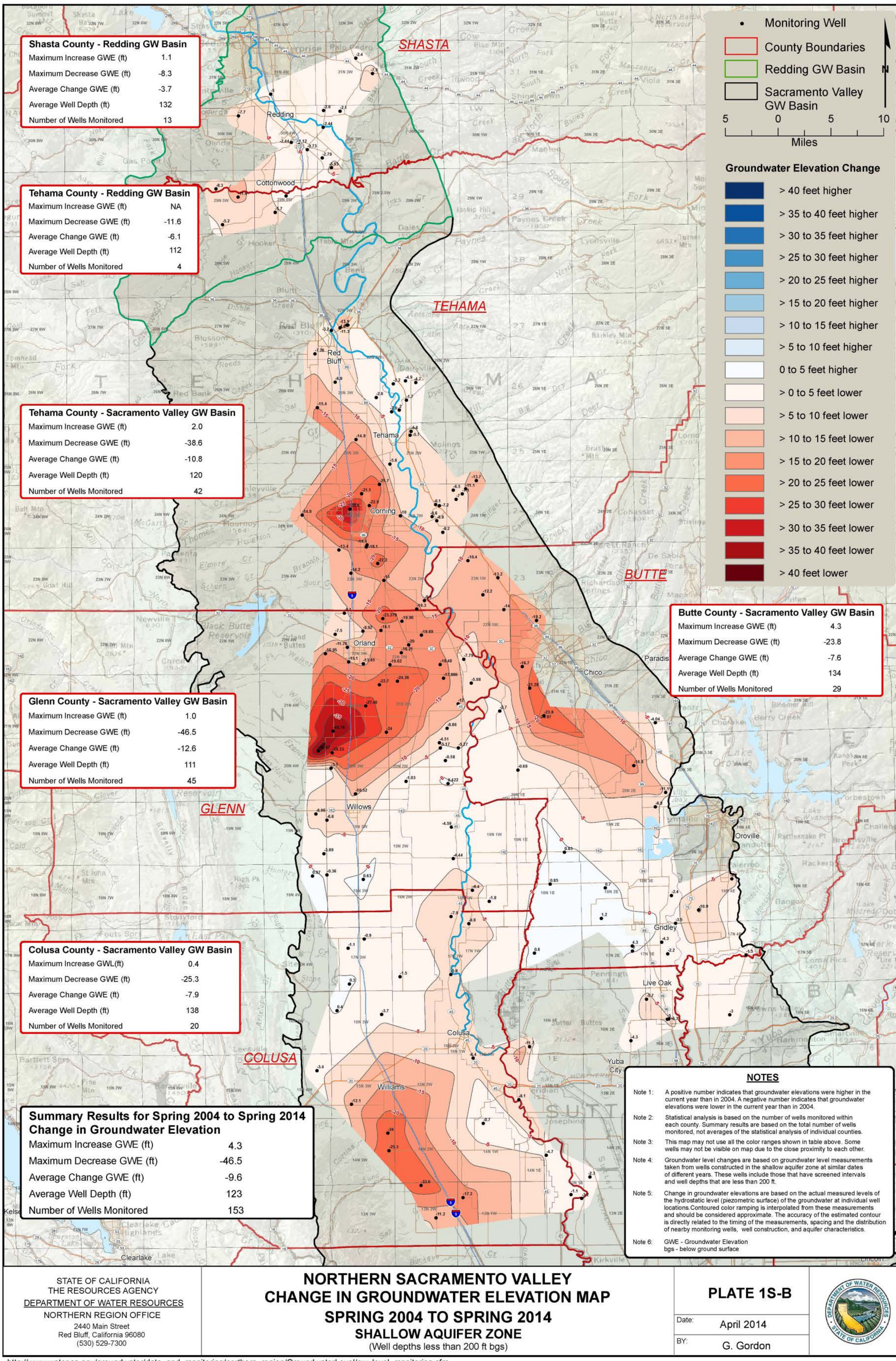

Source: DWR 2015

Figure 3.3-10a. Change in Groundwater Levels between Spring 2004 and Spring 2014 in Shallow Aquifer Zone (less than 200 feet bgs)

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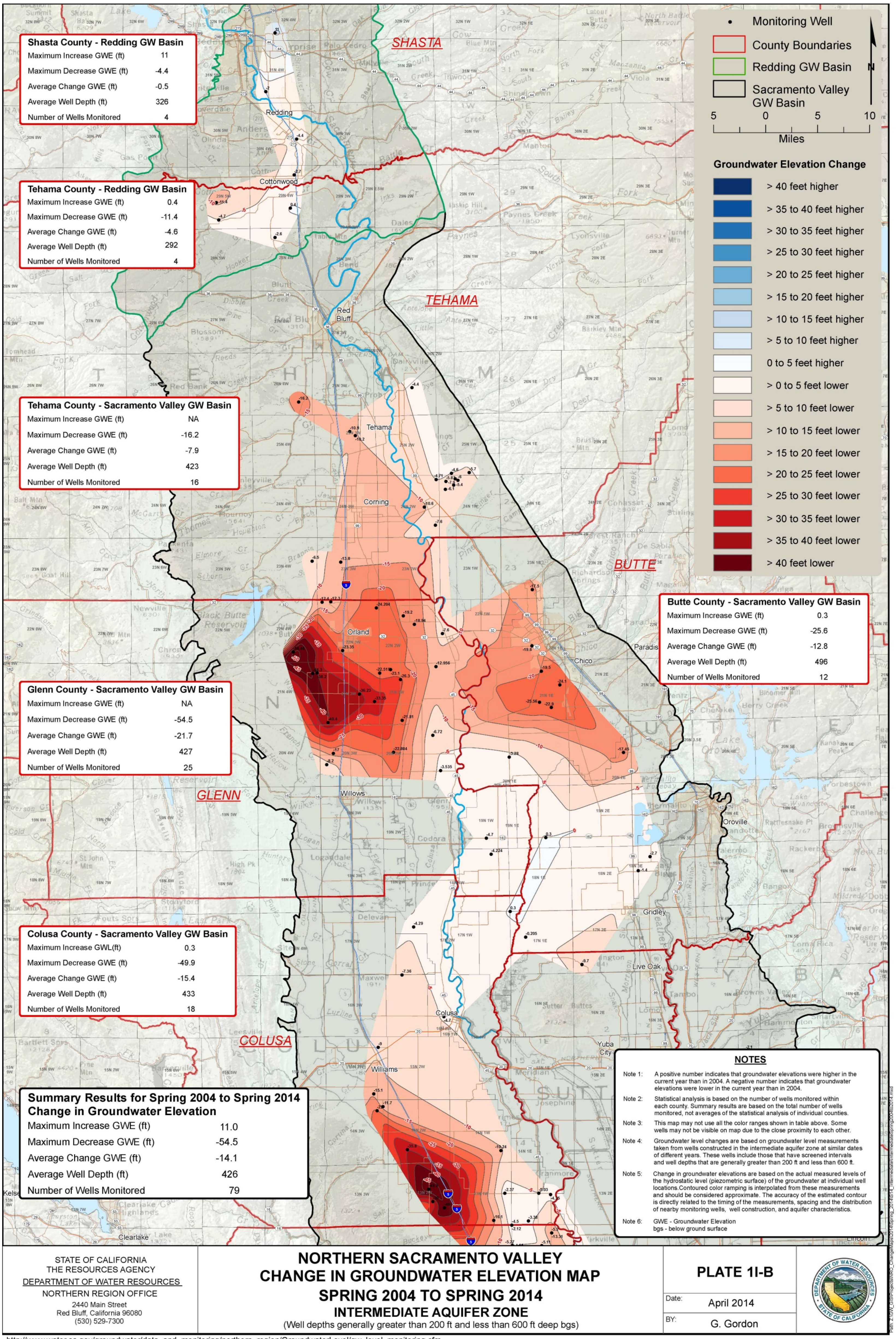

Source: DWR 2015

Figure 3.3-10b. Change in Groundwater Levels between Spring 2004 and Spring 2014 in Intermediate Aquifer Zone (between 200 to 600 feet bgs)

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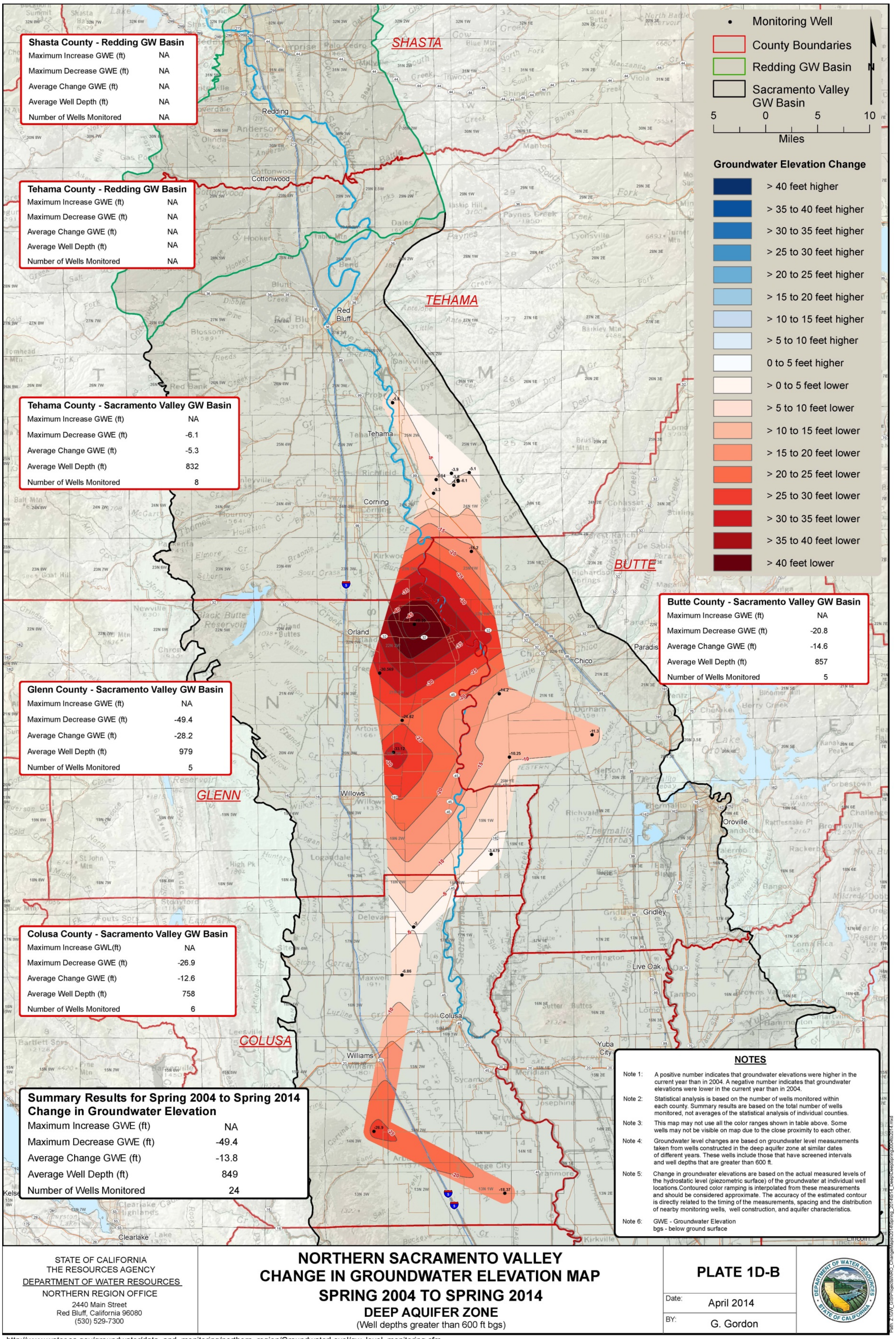

Source: DWR 2015

Figure 3.3-10c. Change in Groundwater Levels between Spring 2004 and Spring 2014 in Deep Aquifer Zone (greater than 600 feet bgs)

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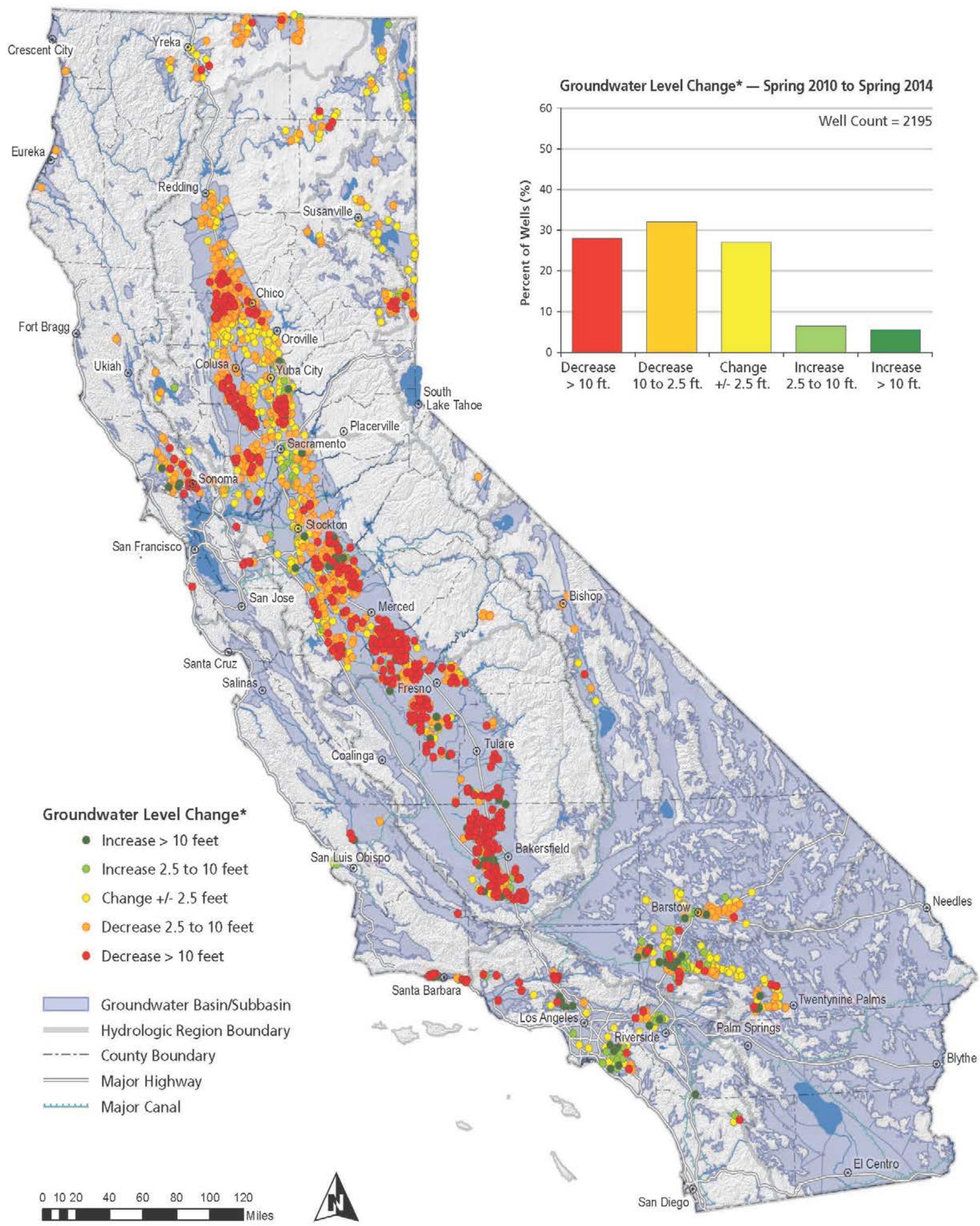

Source: DWR 2014a

Figure 3.3-11. Change in Groundwater Levels between Spring 2010 and Spring 2014

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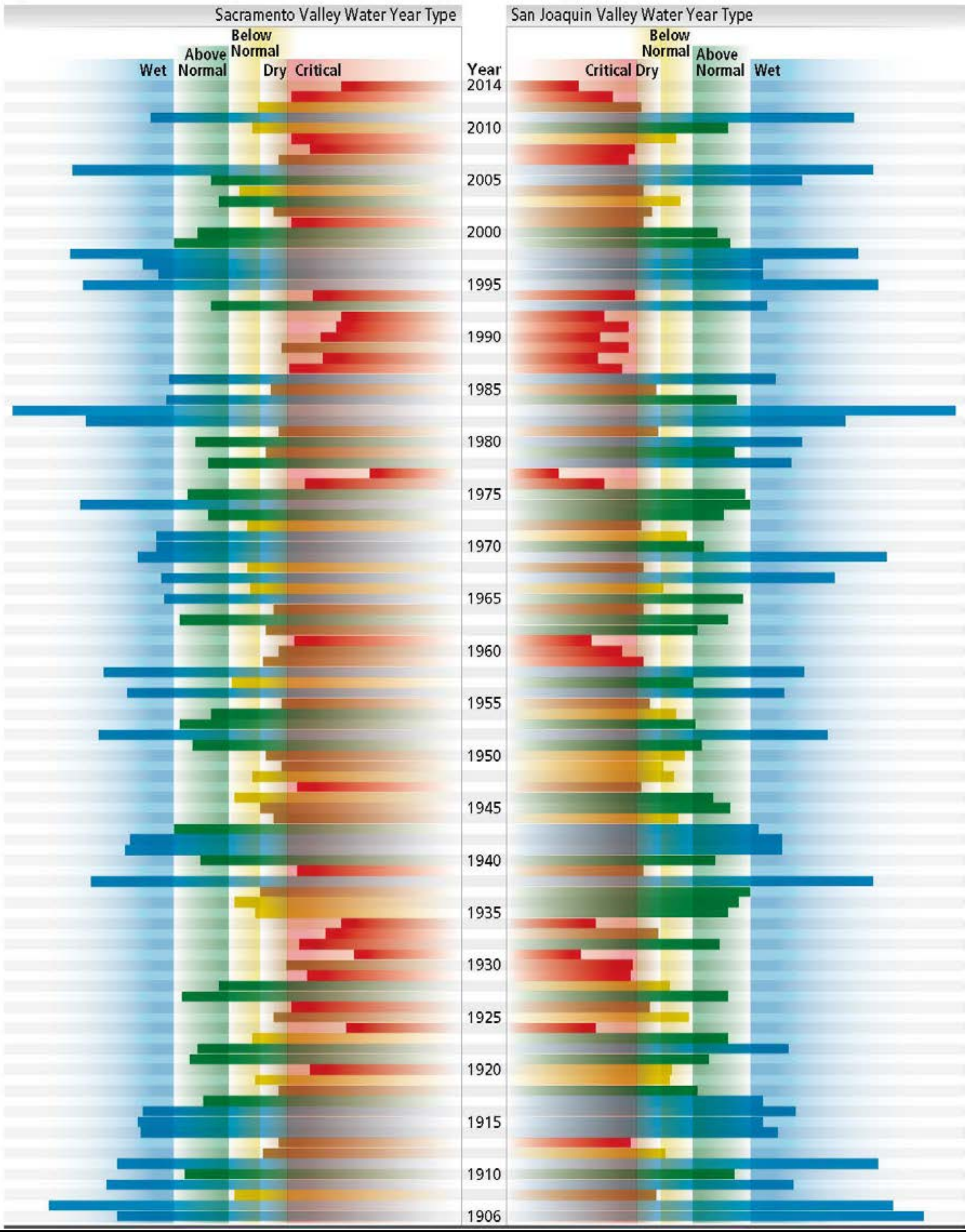
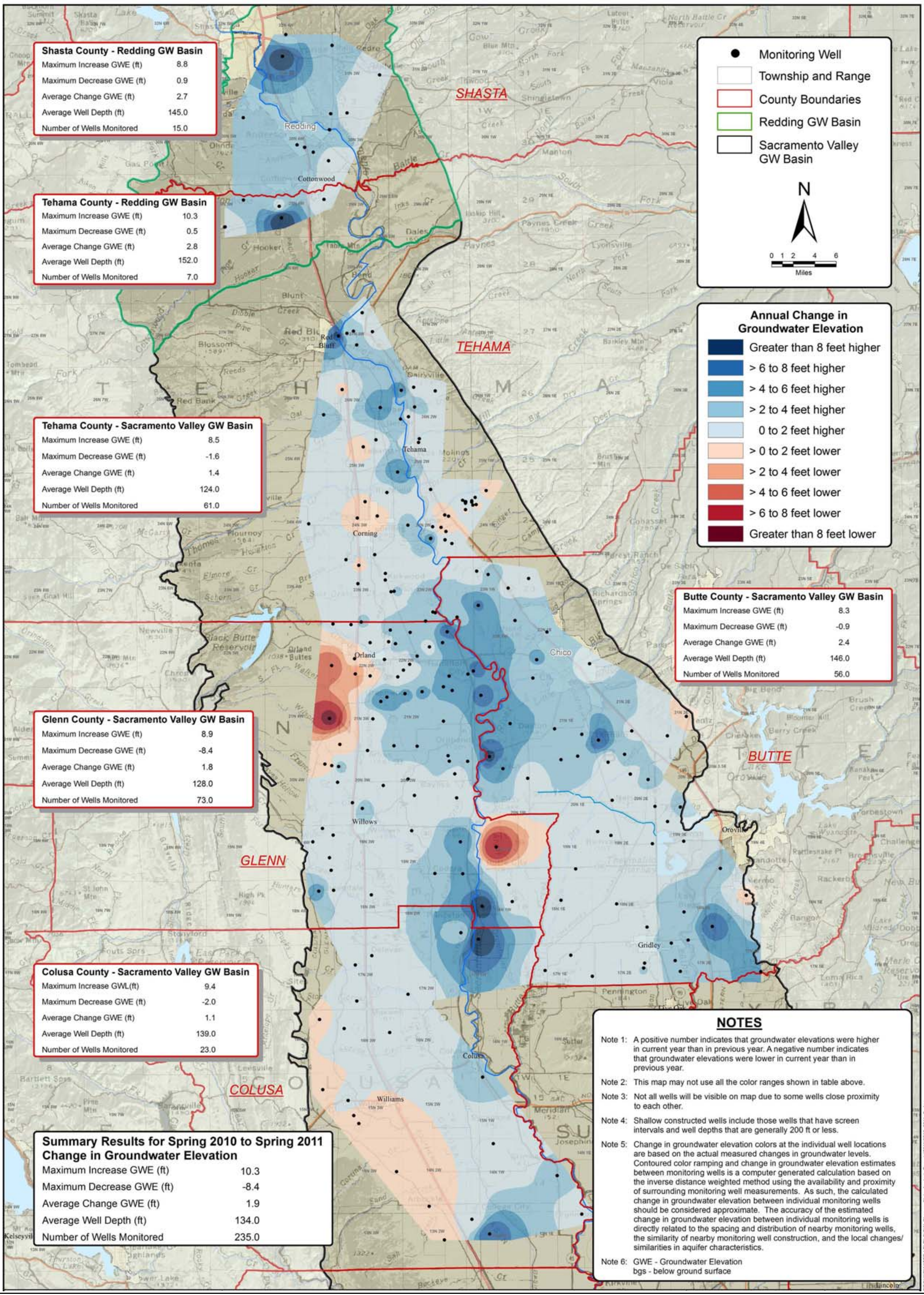
As shown in Figure 3.3-12, California has been experiencing dry weather conditions since 2000. WY 2011 has been the only year since 2006 classified as a wet water year. Figures 3.3-13a, 3.3-13b and 3.3-13c show the change in groundwater elevation between Spring 2010 and Spring 2011. Figures 3.3-13a, 3.3-13b and 3.3-13c indicate an overall increasing trend up to eight feet in the shallow aquifer (less than 200 feet bgs). Recovery in the intermediate aquifer (between 200 to 600 feet bgs) was approximately +7.5 feet. Recovery in the deep aquifer (greater than 600 feet bgs) was lower (up to +4.5 feet). Increases in groundwater levels in 2011 occurred after four consecutive years of dry or critical dry conditions in the Sacramento valley (WY 2007 to WY 2010). Though Sacramento Valley and other parts of California are currently noticing declining groundwater level trends, past groundwater trends are indicative of groundwater levels declining moderately during extended droughts and recovering to pre-drought levels after subsequent wet periods.

In general, groundwater flows inward from the edges of the basin and south, parallel to the Sacramento River in the Sacramento Valley. In some areas there are groundwater depressions associated with pumping that influence local groundwater gradients and flow direction. Prior to the completion of CVP facilities in the area (1964-1971), pumping along the west side of the basin caused groundwater levels to decline. Following construction of the CVP, the delivery of surface water and reduction in groundwater extraction resulted in a recovery to historic groundwater levels by the mid to late-1970s. Throughout the basin, individuals, counties, cities, and special legislative agencies manage and/or develop groundwater resources. Many agencies use groundwater to supplement surface water; therefore, groundwater production is closely linked to surface water availability. Climatic variations and the resulting surface water supply directly affect the demand and the amount of groundwater required to meet agricultural and urban water demands (Faunt 2009).



Source: DWR et al. 2014

Figure 3.3~~-8.~~-12. Sacramento Valley and San Joaquin Valley Water Year Types (1906 to 2014)



Source: DWR 2015

Figure 3.3-13a. Change in Groundwater ~~Basin Historic Groundwater Elevations~~Levels between Spring 2010 and Spring 2011 in Shallow Aquifer Zone (less than 200 feet bgs)

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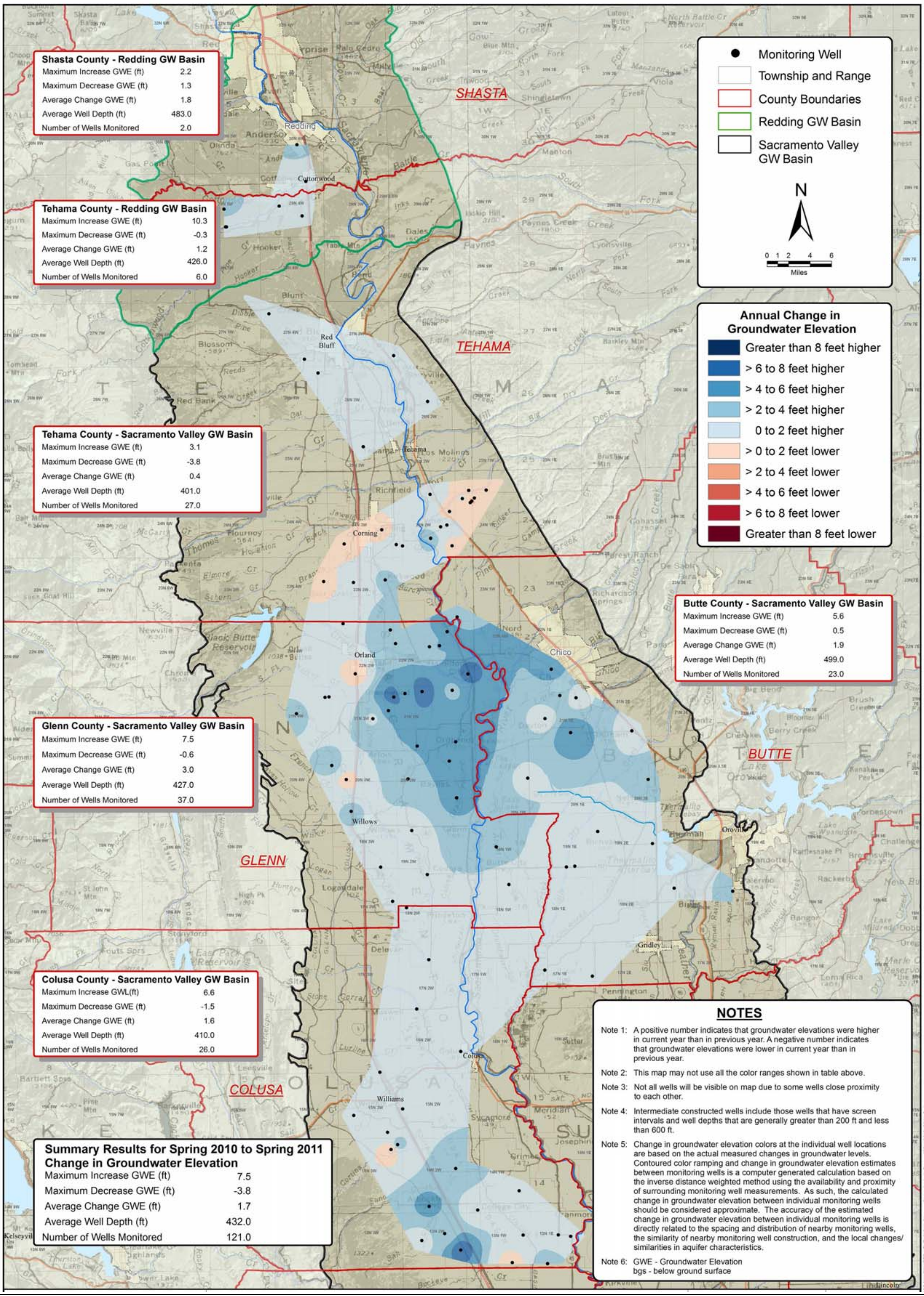

Source: DWR 2015

Figure 3.3-~~9. Sacramento Valley~~-13b. Change in Groundwater ~~Basin Historic Groundwater Elevations~~Levels between Spring 2010 and Spring 2011 in Intermediate Aquifer Zone (between 200 feet to 600 feet bgs)

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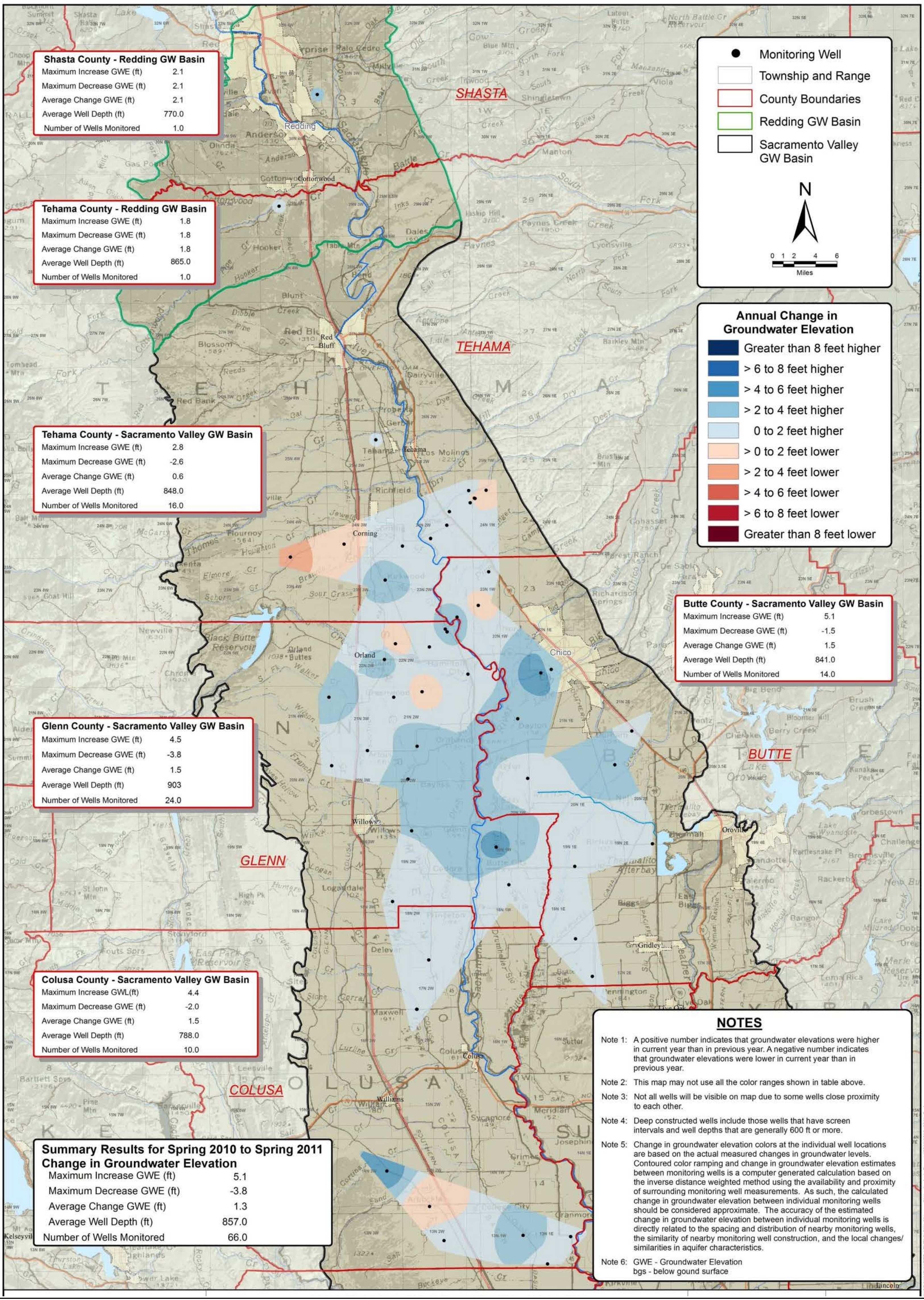

Source: DWR 2015

Figure 3.3-13c. Change in Groundwater Levels between Spring 2010 and Spring 2011 in Deep Aquifer Zone (greater than 600 feet bgs)

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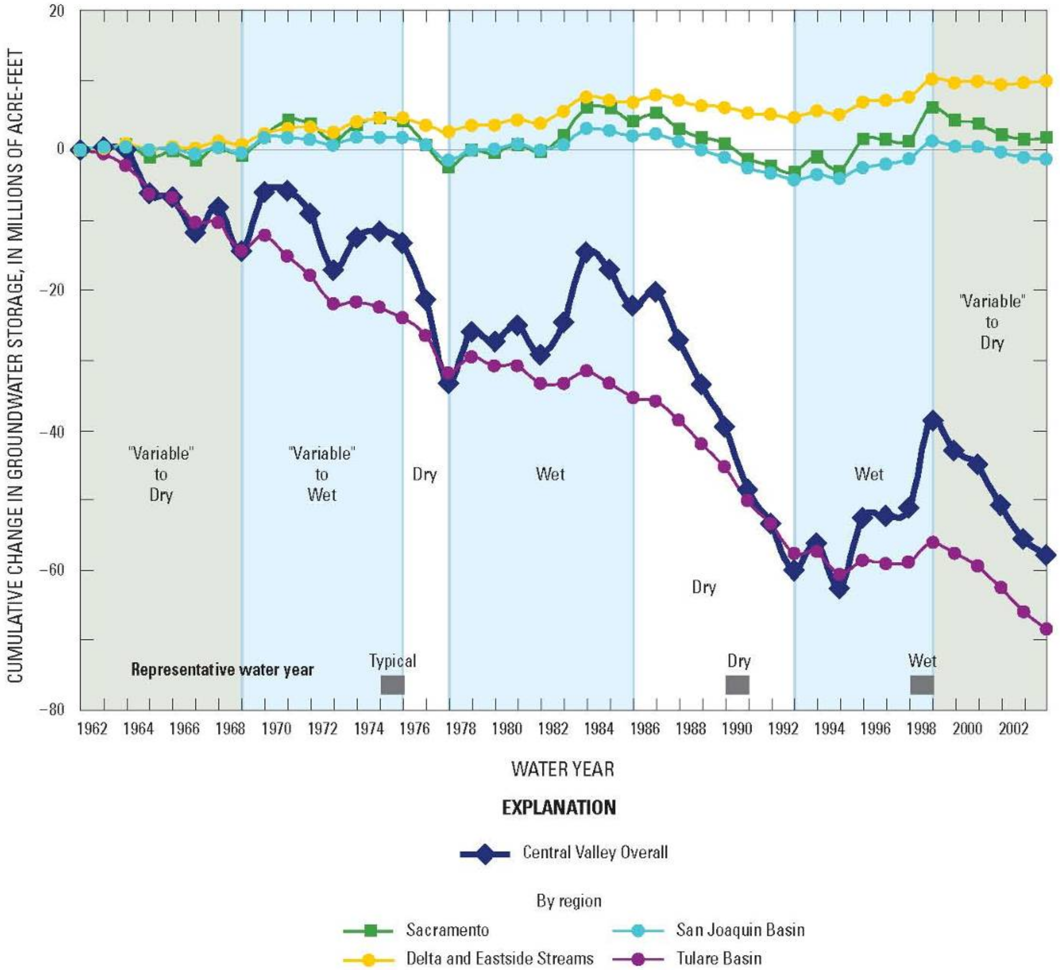
Table 3.3-3 below summarizes the number of wells reported dry in 2014 within the area of analysis.

Table 3.3-3. Summary of Dry Wells Reported In 2014

Counties	Number of wells reported dry in 2014	Information received as of
Shasta	3	9/16/2014
Tehama	34	10/2/2014
Glenn	26	10/23/2014
Butte	60	12/4/2014
Colusa	8	7/7/2014
Sutter	Data not available	Data not available
Yuba	Data not available	Data not available
Solano	1	11/12/2014
Yolo	2*	10/21/2014
Sacramento	1	10/16/2014

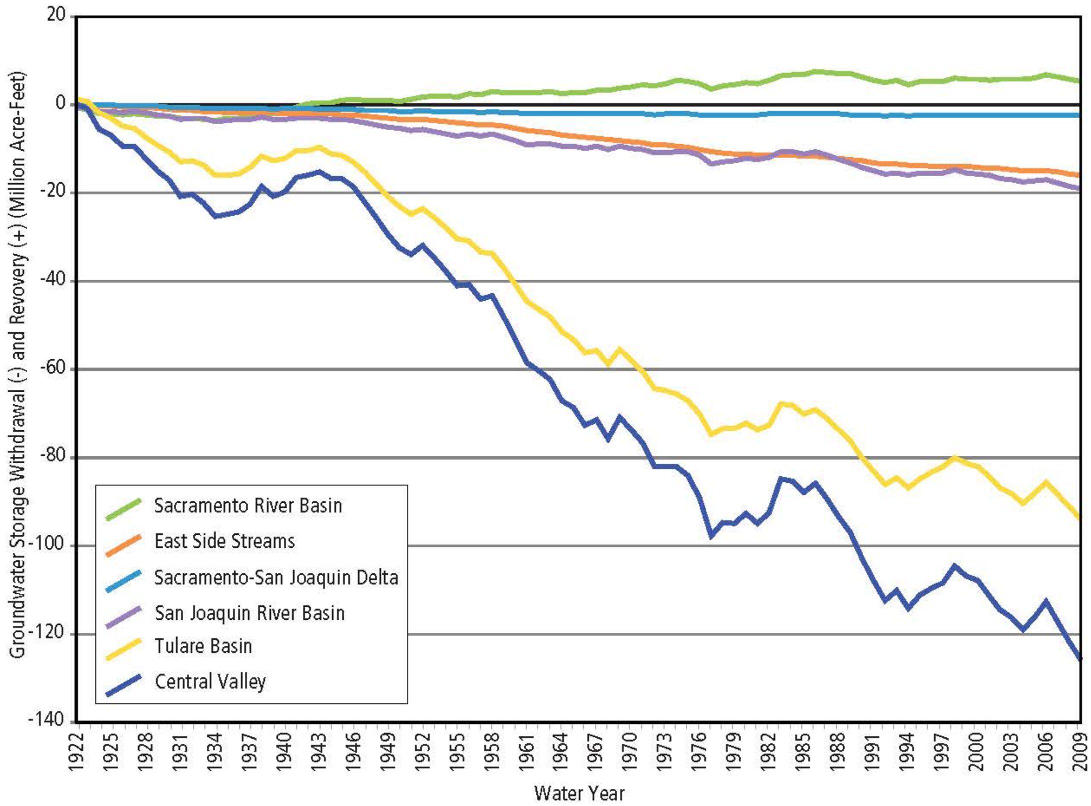
Source: Data collected by UC Davis
**Number of dry wells reported includes data only for October; data for prior months not reported*

Figure 3.3-~~10~~14a shows the simulated cumulative annual change in groundwater storage in the Sacramento Valley Groundwater Basin ~~since 1962, along with the other major groundwater basins in the Central Valley of California. As shown in this figure,~~and other major groundwater basins in the Central Valley since 1962 as modeled in USGS's Central Valley Hydrologic Model (CVHM). Figure 3.3-14b shows the simulated change in groundwater storage in the Sacramento Valley Groundwater Basin and other major groundwater basins in the Central Valley since 1922 as modeled in DWR's Central Valley Groundwater-Surface Water Simulation Model (C2VSim). Figure 3.3-14c shows the change in monthly groundwater storage as observed and analyzed by Gravity Recovery and Climate Experiment (GRACE). As shown in Figure 3.3-14c there was no significant change in groundwater storage prior to 2006 (from 2003 to 2006), the change in storage was in the magnitude of -1.4 ± 12.7 millimeter/year i.e. approximately 0.4 ± 3.9 million acre-feet/ year. Between April, 2006 to March, 2010 change in storage decreased by 38.9±9.5 mm/year (i.e., approximately 31.5±7.7 million acre-feet/year). The GRACE results shown in Figure 3.3-14c are combined results for the Sacramento and San Joaquin Valleys and are not representative of conditions in Sacramento Valley alone. Figures 3.3-14a and 3.3-14b show, for the periods graphed, groundwater storage in the Sacramento Valley Groundwater Basin has been relatively constant over the long term. Storage ~~tends to~~ decreased during dry years and increased during wetter periods.



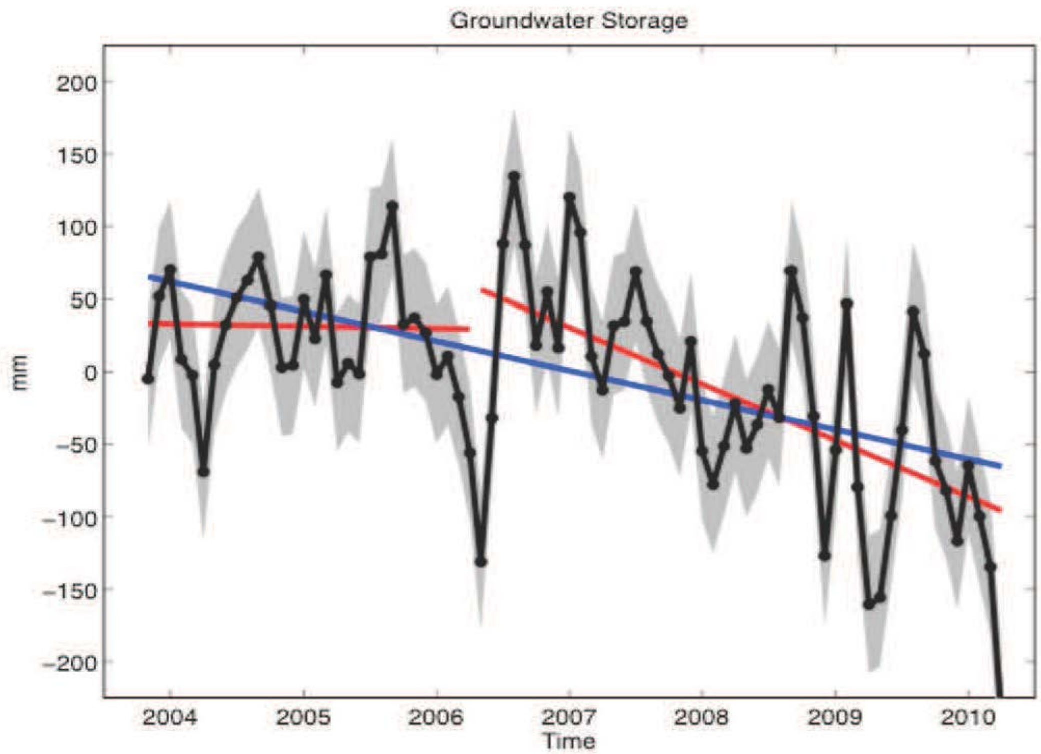
Source: Faunt 2009

Figure 3.3-~~10.~~-14a. Cumulative Annual Change in Storage, as simulated by the USGS's Central Valley Hydrologic Model



Source: Brush et al 2013

Figure 3.3-14b. Cumulative Annual Change in Storage, as simulated by DWR's Central Valley Groundwater-Surface Water Simulation Model



Source: Famiglietti et al 2011

Figure 3.3-14c. Monthly Groundwater Storage for Sacramento and San Joaquin Valley, as observed by Gravity Recovery and Climate Experiment (GRACE)

Note:
[1] Gray shading represents error zone;
[2] Blue line represents the overall trend in groundwater storage changes for the 78-month period;
[3] Red line represents the trends from October 2003 and March 2006 and April 2006 through March 2010.

Groundwater-Related Land Subsidence

This section discusses land subsidence due to groundwater extraction. Groundwater-related land subsidence is a process that causes the elevation of the ground surface to lower in response to groundwater pumping occurring in the region. Non-reversible land subsidence occurs where groundwater extraction lowers groundwater levels causing loss of pore pressure and subsequent consolidation of clay beds in aquitards within a groundwater system. Subsidence is typically a slow process that occurs over a large area. Because of the slow rate of subsidence, the general appearance of the landscape may not change; however, subsidence can lead to problems with flood control and water distribution systems due to changes in elevation. Subsidence can reduce the freeboard of levees, allowing water to over top them more easily. It also can change the slope, and even the direction of flow, in conveyance and drainage systems, including canals, sewers, and storm drains. In addition, subsidence can also damage infrastructure, including building foundations and collapsed well casings.

Subsidence generally occurs in small increments during dry years when groundwater pumping lowers groundwater levels below historical lows in areas that are geologically susceptible because they have compressible clays. There are several methods used to measure land subsidence. Global Positioning System (GPS) surveying is a method used for monitoring subsidence on a regional scale. DWR is using this method to monitor subsidence in the ~~Tulelake~~Tule Lake Basin, Glenn and Yolo counties, and the Sacramento-San Joaquin Delta. The GPS network consists of 339 survey monuments spaced about seven kilometers apart and covers all or part of ten counties within the Sacramento Groundwater basin (DWR 2008). It extends from northern Sacramento County eastward to the Bureau of Reclamation's Folsom Reservoir network, southwest to DWR's Delta/Suisun Marsh network, and north to Reclamation's Shasta Reservoir network. The network is scheduled to be re-surveyed on a three-year frequency to measure elevation changes over time.

Vertical extensometers are a more site specific method of measuring land subsidence. DWR's subsidence monitoring program within the Sacramento Valley Groundwater Basin includes 11 extensometer stations that are located in Yolo (2), Sutter (1), Colusa (2), Butte (3), and Glenn (3) counties. Figure 3.3-~~11~~15 shows the areas within the Sacramento Valley Groundwater Basin that have experienced subsidence due to significant declines in groundwater levels as a result of increased groundwater pumping (DWR 2008).

Figure 3.3-~~11~~15 shows the locations of DWR's extensometers and extent of subsidence at the locations. Data from the GPS subsidence monitoring network and complementary groundwater levels in monitoring wells revealed a correlation between land subsidence and groundwater declines during the growing season (DWR 2008). DWR found that the land surface partially rebounds as aquifers recharge in winter (DWR 2008). Out of the 11 extensometers five show potential subsidence over time:

- 09N03E08C004M, in Yolo County within Conaway Ranch: DWR observed~~ inelastic~~ land subsidence estimated at approximately 0.2 foo~~ee~~t from 2012 to 201~~4~~3 and an additional 0.6 foot from 2013 to 2014 (DWR 2014b). In comparison, slightly less than 0.1 ~~feet~~ foot of subsidence occurred over the previous 22 years (1991-2012);

- 11N01E24Q008M, in Yolo County near the Yolo-Zamora area: 0.5 to 0.6 foot decline from 1992 to present;

- 11N04E04N005M, in Sutter County: approximately 0.01 foot decline from 1994 to present;

- 21N02W33M001M, in Glenn County: 0.05 foot decline from 2005 to present; this extensometer is located in areas in which the Tehama Formation is mapped in the subsurface and indicates the potential for inelastic subsidence (West Yost Associates 2012); and
- 16N02W05B001M, in Colusa County: 0.04 foot decline from 2006 to present.

Historically, land subsidence occurred in the eastern portion of Yolo County and the southern portion of Colusa County, due to extensive groundwater extraction and that region's geology. The earliest studies on land subsidence in the Sacramento Valley occurred in the early 1970s when the U.S. Geological Survey (USGS), in cooperation with DWR, measured elevation changes along survey lines containing first and second order benchmarks. As much as four feet of land subsidence due to groundwater withdrawal occurred east of Zamora over the last several decades. The area between Zamora, Knights Landing, and Woodland has been most affected (Yolo County 2009). Subsidence in this region is generally related to groundwater pumping and subsequent consolidation of compressible clay sediments.