3. Basin Setting

3.1 Hydrogeological Conceptual Model

A hydrogeological conceptual model (HCM) is a description of the physical system within a basin, including (but not limited to) topography, geology and structure, three-dimensional geometry of water-bearing units (aquifers) and aquitards, land and water use, hydrology, and groundwater quality. The HCM provides a framework for understanding the interrelationships among these components, and their influence on occurrence and movement of groundwater. The HCM can be used to develop numerical modeling tools and water budgets, and to help inform decision making with respect to selection of sustainable management criteria, monitoring networks, and potential management actions. An HCM should be periodically reviewed and revised as new data become available. The following sections describe the HCM of the Enterprise Subbasin.

The Enterprise Subbasin (5-006.04) is one of five groundwater subbasins within the RAGB of Northern California (Figure 2-1). The roughly north/south-oriented subbasin is approximately 15 miles long and 8 miles wide. The Sacramento River forms the western/southwestern boundary of the subbasin; whereas, Cow Creek forms the eastern boundary, and the Klamath Mountains form the northern boundary (DWR, 2004).

3.1.1 Topography

Figure 3-1 presents the topography of the Enterprise Subbasin. The data presented on Figure 3-1 represent topographic data from a number of sources that were compiled into a single surface. These data sources include the following:

- USGS 1/3-arcsecond (approximately 30-foot) digital elevation model data (USGS, 2019b)
- Light detection and ranging (Lidar) data collected as part of a Federal Emergency Management Agency study of the Cow Creek drainage area; 2-foot resolution (USGS, 2018)
- High-resolution (3-foot) Lidar data collected as part of a collaborative effort between COR and Shasta County (COR, 2019b)

Ground surface elevations across the Enterprise Subbasin vary by approximately 450 feet as the foothills of the Klamath Mountains in the north descend to the trough of the Sacramento Valley in the south. The maximum ground surface elevation in the Enterprise Subbasin, 825 feet above North American Vertical Datum of 1988 (NAVD88), is in the foothills of the Klamath Mountains. Where these foothills have been deeply incised by Stillwater Creek and Cow Creek, there is local relief in excess of 100 feet at high grades. Farther south, surficial features transition from sandstone and mudstone deposits to alluvial plains, terrace and channel deposits, and river-flood deposits. Topographic relief generally decreases toward the Sacramento Valley, with a minimum ground surface elevation of approximately 372 feet NAVD88 in the southernmost portion of the Enterprise Subbasin.

3.1.2 Climate

3.1.2.1 Precipitation

Figure 3-2 presents an isohyetal map of 1981–2010 mean annual precipitation for the Enterprise Subbasin (PRISM Climate Group, 2012), showing that precipitation varies along a primarily north-south trend in the Enterprise Subbasin. Based on these 30-year averages from Parameter-elevation Regressions on Independent Slopes Model (PRISM) datasets, the foothills of the Klamath Mountains on the northern periphery of the subbasin receive a mean annual precipitation of 51 inches, and the valley floor on the southern periphery receives 30 inches per year (Figure 3-2). Mean annual precipitation is greater outside the Enterprise Subbasin in the mountains to the north, west, and east. The Redding area

receives about 84 percent of its precipitation in the autumn (35 percent) and winter (49 percent), with only about 16 percent falling in the spring (14 percent) and summer (2 percent) (UCC, 2019a; Station USR0000CREA).

Figure 3-3 presents a chart of water year type based on the Sacramento Valley Water Index (an accounting of the volume and timing of unimpaired runoff at specific stream gauges in the Sacramento, Feather, Yuba, and American Rivers) (DWR, 2020a). The water year index is computed as follows:

Sacramento Valley Water Year Index = 0.4 * Current April-July Runoff Forecast (in million-acre feet [MAF]) + 0.3 * Current October-March Runoff in (MAF) + 0.3 * Previous Water Year's Index

The computed water year index is used to classify the water year as one of the following:

Year Type	Water Year Index
Wet	Equal to or greater than 9.2
Above Normal	Greater than 7.8, and less than 9.2
Below Normal	Greater than 6.5, and equal to or less than 7.8
Dry	Greater than 5.4, and equal to or less than 6.5
Critical	Equal to or less than 5.4

The Redding area (included in the Sacramento Valley Water Year Index) had several notable wet years in the early 1980s and in the late 1990s, interspersed by several critical water years in the late 1980s and early 1990s. Prior to 1986, wet years were more frequent, and critical years were scarce. In the decades since 1986, precipitation has become more inconsistent, with periods of drought interrupted by one or a few very wet years. Furthermore, a recent increase in atmospheric river events is bringing more intense storms to California, with total annual precipitation falling in fewer total storms (Swain et al., 2018).

3.1.2.2 Temperature

Within the Enterprise Subbasin, summers are hot and arid, and winters are cool and typically wet. Based on data from weather stations at Shasta Dam and Whiskeytown Reservoir, the average annual high temperature is approximately 73 degrees Fahrenheit (°F), ranging from a low of 53°F in January to a high of 96°F in July. The average annual low temperature is approximately 51°F, ranging from a low of 38° in January to a high of 66° in July (UCC, 2019b, 2019c; Stations USC00048135 and USC00049621).

3.1.2.3 Evapotranspiration

Reference evapotranspiration (ET_o) in the Enterprise Subbasin has been calculated based on data collected at California Irrigation Management Information System (CIMIS) Station 224 at Shasta College between January 2013 and October 2019. The average annual ET_o measured over the period of record is 55 inches per year, or 4.6 feet per year. The ET_o values calculated from the CIMIS data indicate the amount of water that could be transpired from a reference crop, such as grass or alfalfa if supplied by irrigation. To calculate a specific crop evapotranspiration (ET) rate, the ET_o is multiplied by a crop coefficient that adjusts the water consumption for each specific crop relative to the water consumption of the reference crop.

According to the State of California Reference Evapotranspiration Map developed by CIMIS, the Enterprise Subbasin is located within Zone 14, with an annual average ET_o of 57 inches, or 4.8 feet (CIMIS, 2012). This regional average annual ET_o is comparable to the ET_o measured at CIMIS Station 214.

3.1.3 Hydrology

Many streams cross the Enterprise Subbasin, generally flowing down from the foothills of the Klamath and Cascade Mountains in the north, west, and east to confluences with the Sacramento River. The Sacramento River is the largest and most significant hydrological feature in the subbasin (Figure 3-4).

Data referenced in this section were sourced from USGS and the Sacramento River Watershed Program (SRWP, 2020).

The Sacramento River is the largest river and watershed system in California, carrying 31 percent of the state's total surface-water runoff. Around 6,500 square miles of the 27,000-square-mile Sacramento River watershed drain into the Enterprise Subbasin. Sourced from volcanic plateaus around 40 miles north of the Enterprise Subbasin, its headwaters comprise the Upper Sacramento, McCloud, and Pit Rivers. After being released from Shasta Dam, the Sacramento River flows south, making up the western/southwestern boundary of the Enterprise Subbasin. The Sacramento River is gauged at Keswick Reservoir, where the flow is controlled by releases from Shasta and Keswick Dams. Based on data from this gauge (USGS #11370500, see Figure 2-11, USGS, 2019a) extending back to 1938, the annual average flow in the Sacramento River at this location is approximately 10,000 cubic feet per second (cfs), with peaks as high as 50,000 to 70,000 cfs in wet years and lows around 5,000 cfs during drought periods.

Water from the Trinity River is imported to the Sacramento River watershed through diversions from Lewiston Lake in Trinity County. Water from Lewiston Lake is conveyed via the Clear Creek Tunnel to the Carr Powerhouse on Whiskeytown Lake in Shasta County. Several purveyors in Shasta County, including COR, divert water from Whiskeytown Lake through contracts with Reclamation.

The eastern boundary of the Enterprise Subbasin coincides with Cow Creek. Cow Creek and the northern fork of Little Cow Creek flow west out of the foothills of the Cascade Mountains, a 425-square-mile watershed, and then south along the eastern edge of the Sacramento Valley. Cow Creek reaches a confluence with the Sacramento River south of the Enterprise Subbasin, near the city of Anderson. Cow Creek streamflow is monitored by USGS near the town of Millville with a record extending back to 1949 (USGS #11374000, see Figure 2-11, USGS, 2019a). Average annual flow in Cow Creek at this stream gauge has been around 700 cfs, increasing to around 2,000 cfs during the wet months and decreasing to less than 100 cfs during the summer months. However, Cow Creek is known to produce peak flood flows upwards of 20,000 cfs during heavy storms, comprising up to 21 percent of the peak discharge for the Sacramento River between Shasta Dam and Red Bluff.

Stillwater Creek flows southward along the north-south axis of the Enterprise Subbasin. It is a rainfall-driven stream with a high degree of seasonal variability and rapid response to storm events. Its watershed covers approximately 120 square miles and includes most of the area of the Enterprise Subbasin. There are no gauges in Stillwater Creek, but 10-year peak flow has been estimated at 7,000 cfs (SRWP, 2020).

3.1.4 Regional Geologic Setting

The RAGB consists of 510 square miles in the northern Central Valley of California. It is bounded by the foothills of the Cascade Range in the East, the Klamath Mountains in the north and northwest, the Coast Ranges in the west, and the Red Bluff Arch in the south (Pierce, 1983). The Red Bluff Arch, a subsurface structural feature, defines the boundary between the RAGB and the Sacramento Groundwater Basin to the south. The area of the RAGB is an interior dissected plain, consisting of a sediment-filled, southward-plunging, symmetrical trough, crossed by the valleys of the Sacramento River and of Churn Creek, Clear Creek, Cottonwood Creek, and Stillwater Creek.

Tertiary deposition of material sourced from the Coast and Cascade Ranges created the principal freshwater-bearing formations in the basin: the Tuscan and Tehama Formations. These formations are up to 2,000 feet thick near the confluence of the Sacramento River and Cottonwood Creek and are interbedded throughout the RAGB, with the Tuscan more prominent to the east and the Tehama more prominent to the west. The Tuscan Formation is generally more permeable and productive than the Tehama Formation (DWR, 2003).

3.1.5 Local Geologic Setting

3.1.5.1 Surface Soils

Figure 3-5 presents the distribution of surface soils within the Enterprise Subbasin. Soils are derived from the weathering of underlying geological units and are influenced by lithology as well as climate, biological factors (vegetation, biota, human influences), topography, and hydrologic conditions. The United States Department of Agriculture's NRCS developed a hierarchical classification system consisting of Order, Suborder, Great Group, Subgroup, Family, and Series. This classification system (or taxonomy) is based on quantitative soil properties such as depth, moisture, temperature, texture, structure, cation exchange capacity, base saturation, clay mineralogy, organic matter content, and salt content. The soil distribution presented on Figure 3-5 categorizes surface soils based on taxonomic order. As shown on Figure 3-5, 5 of the 12 NRCS taxonomic orders are present in the Enterprise Subbasin, as follows:

- Alfisols are present across approximately 80 percent of the subbasin. Alfisols are naturally fertile soils, high in aluminum and iron, have clay rich horizons, and form in semi-arid to humid regions with at least several months of vegetation grown throughout the year (sufficient moisture and warmth).
- Entisols are make up approximately 9 percent of the Enterprise Subbasin, primarily present adjacent to surface streams and within stream floodplains. Entisols are young soils with no profile development (that is, they have not been significantly altered from the parent material).
- Mollisols are present over approximately 4 percent of the Enterprise Subbasin, primarily in the dissected highlands in the eastern portion of the subbasin and along Cow Creek. Mollisols are dark-colored naturally fertile (high base nutrient content) soils with a deep, high organic content horizon, typically derived from decaying root material.
- Inceptisols are present over approximately 3 percent of the Enterprise Subbasin, primarily along the Cow Creek floodplain. Inceptisols are generally young soils, with limited soil profile development (more developed than entisols).
- Ultisols are present over approximately 2 percent of the Enterprise Subbasin within stream channels. Ultisols are highly weathered, acidic, clay-rich mineral soils with little base nutrients.

Regions of the subbasin classified as "other" on Figure 3-5 are primarily areas that have been mapped as water.

3.1.5.2 Geologic Units

Figure 3-6a,b presents a geologic map of the RAGB, derived from the *Digital Geologic Map of The Redding 1° X 2° Degree Quadrangle, Shasta, Tehama, Humboldt, And Trinity Counties, California* (USGS, 2012). North-south and east-west trending cross sections are presented on Figures 3-7 and 3-8, respectively. Geologic cross sections were developed based on available lithologic information with the primary objective of displaying the water-bearing units within the subbasin. Because the level of detail and consistency of historical lithologic logging varied greatly, units are presented on the cross section as dominated by either finer- or coarser-grained materials. Lack of detailed lithologic information precludes differentiating major geologic units in section view. Major geologic units underlying the Enterprise Subbasin include (from oldest to youngest) the following:

Basement Complex (Various Units on Figure 3-6a,b)

The pre-Tertiary igneous and metamorphic basement complex is the oldest geologic unit underling the Central Valley. The formations that make up the basement complex formed throughout the Devonian and terminated during the Cretaceous with the inception of the Chico Formation. The basement complex crops out along the steep slopes surrounding the RAGB, forming a nearly impermeable boundary for groundwater. The basement complex is considered non-water bearing, yet scarce water is stored in joints and fractures, permitting small well yields.

Chico Formation (Kc on Figure 3-6a,b)

Unconformably overlying the basement complex is the Cretaceous Chico Formation. The Chico Formation was deposited in a marine and shore zone environment, consisting of a variety of sedimentary rocks—conglomerate, siltstone, sandstone, and shale. Although this formation is generally impermeable, some beds yield small amounts of saline water. In certain places, this water may be under artesian pressures, especially where shale beds are extensive. The thickness of the Chico Formation ranges from zero feet in the northern RAGB to 6,000 feet to the south, forming the base of the southerly tilt of the Central Valley. Because the Chico Formation contains connate water, the top of the Chico Formation defines the base of fresh water in the RAGB.

Nomlaki Tuff (Ttn on Figure 3-6a,b)

The basal member of both the Tuscan and Tehama Formations is the Pliocene-age Nomlaki Tuff. The Nomlaki Tuff unconformably overlies the Chico Formation and thickens to the east. The Nomlaki Tuff is primarily of volcanic origin and consists of pumice fragments in a matrix of volcanic glass and minerals. It is poorly consolidated and has been described by Pierce (1983) as one massive bed.

Tehama Formation (Tte on Figure 3-6a,b)

The Pliocene-age Tehama Formation consists of fluviatile silt, sand, gravel, and clay originating in the Klamath Mountains and Coast Ranges. Sourced from the west, the Tehama Formation is most prominent in the western portion of the RAGB and is interbedded with the Tuscan Formation in the central portion of the RAGB. This unit crops out in the northern, northeastern, and eastern portion of the Enterprise Subbasin, near Bella Vista, dipping and thickening to the south. The thickness of the Tehama Formation is variable, from around 300 feet at the southwestern extent of the Enterprise Subbasin to around 1,000 feet at the confluence of Cow Creek and the Sacramento River (DWR, 2004). Permeability is generally moderate to high with yields of 100 to 1,000 gallons per minute (gpm), making the Tehama Formation one of the principle water-bearing formations in the RAGB (Pierce, 1983).

Tuscan Formation (Tt on Figure 3-6a,b)

The Pliocene-age Tuscan Formation consists of volcanic breccia, tuff-breccia, volcanic sandstone and conglomerate, coarse- to fine-grained tuff, and tuffaceous silt and clay predominately derived from andesitic and basaltic sources. The Tuscan Formation crops out east and south of the Enterprise Subbasin, near Red Bluff; and much of the formation lies east of the Sacramento Valley under a volcanic plateau of the Cascade Range. The Tuscan Formation dips to the southwest and thins from east to west. The maximum thickness of the Tuscan Formation is 1,600 feet in the Cascade Range, thinning to about 1,000 feet near Chico, and farther to around 300 feet where it interfingers with the Tehama Formation in the central portion of the RAGB (Pierce, 1983). Fresh water is found throughout the Tuscan Formation, with a thick and impervious basalt flow separating it from the underlying and saline Chico Formation. It contains moderately permeable beds at a range of depths, with lenticular clay beds resulting in locally confined conditions. Yields are similar to that of the Tehama Formation—100 to 1,000 gpm (Pierce, 1983).

Red Bluff Formation (Qrb on Figure 3-6a,b)

Unconformably overlying the Tehama and Tuscan Formation is the Pleistocene-age Red Bluff Formation. It is composed of coarse gravels and boulders in a matrix of reddish sand, silt, and clay. This formation is discontinuous, with thicknesses ranging from 1 foot to 100 feet. The Red Bluff Formation typically lies above the zone of saturation, but there are areas of perched water. Permeability generally ranges from poor to moderate, and yields are small to moderate and sufficient for domestic wells (Pierce, 1983).

Riverbank Formation (Qr on Figure 3-6a,b)

The Pleistocene-age Riverbank Formation is present as alluvial fan and terrace deposits along streams in the RAGB. The unit consists of weathered reddish gravel, sand, and silt (USGS, 2012). The Riverbank Formation reaches thicknesses of up to 50 feet in the Enterprise Subbasin (DWR, 2004).

Modesto Formation (Qm on Figure 3-6a,b)

The Pleistocene-age alluvial deposits of the Modesto Formation are primarily present along the Sacramento River, Cottonwood Creek, and tributary floodplains in the RAGB. The unit consists of tan and light-gray gravely sand, silt, and clay, except where derived from volcanic rocks of the Tuscan Formation, where it is distinctly red and black with minor brown clasts (USGS, 2012). The Modesto Formation reaches thicknesses of up to 50 feet in the Enterprise Subbasin (DWR, 2004).

Terrace Deposits (Qt on Figure 3-6a,b)

Composed of poorly consolidated silt, sand, and gravels, Holocene and Pleistocene-age terrace deposits are found alongside the Sacramento River and its tributaries, specifically Cow and Cottonwood Creeks. Thickness ranges from 1 to around 50 feet, and permeability is moderate to high (Pierce, 1983 and DWR, 2004).

Alluvium and Overbank Deposits (Qa, Qao, Qo on Figure 3-6a,b)

Alluvium is found in channels and floodplains along the Sacramento River and its tributaries, and has been described by Pierce (1983) as unconsolidated, interbedded, gravel, sand, silt, and clay. Permeability is generally moderate but may be quite high in regions dominated by gravels. Some wells in the alluvium have produced as much as 2,000 gpm, but many others produce only enough for domestic use.

3.1.5.3 Geologic Structures

Red Bluff Arch

A series of northeastward-trending anticlines and synclines located north of Red Bluff, the Red Bluff Arch distinguishes the RAGB from the Sacramento Groundwater Basin. Data are insufficient to determine the groundwater and surface-water relationship in the vicinity of the Red Bluff Arch; however, the effect of the arch is hypothesized to force groundwater toward the surface to induce gaining streams (Pierce, 1983).

3.1.6 Local Hydrogeology

3.1.6.1 Lateral Basin Boundary

The RAGB is bounded by the foothills of the Cascade Range to the east, the Klamath Mountains to the north and northwest, the Coast Range to the west, and the Red Bluff Arch to the south (Pierce, 1983). Unlike the RAGB, the Enterprise Subbasin is not bounded by structural features, but rather by hydrologic features. The Enterprise Subbasin is bounded by Little Cow Creek and Cow Creek to the east, and by the Sacramento River to both the west and south. Because the lateral subbasin boundaries are defined by surface streams, there is likely hydraulic communication between adjacent subbasins. That is, there may be groundwater underflow into Enterprise Subbasin from adjacent subbasins and from the Enterprise Subbasin into adjacent subbasins.

3.1.6.2 Definable Bottom of Basin

The base of fresh water defines the bottom of the basin. In the RAGB, this is the top of the Chico Formation (Figure 3-9). Although water-bearing formations exist below this depth, the saline nature of the groundwater and the depth to formation prevent the Chico Formation from being a viable aquifer. The top

of the Chico Formation in the Enterprise Subbasin ranges from a depth of less than 100 feet in the north to a depth of greater than 1,000 feet in the south (DWR, 1968).

3.1.6.3 Principle Aquifers and Aquitards

Major water supplies in the Enterprise Subbasin, and in the greater RAGB, are stored in surface reservoirs; and as a result, the communities in the region are less dependent on groundwater. This may contribute to the fact that groundwater elevations in the RAGB do not show evidence of continuous decline (as will be discussed further in subsequent sections). Depths to groundwater are shallowest near the Sacramento River and Cow Creek, and are generally within a few feet of land surface. In the more central portions of Enterprise Subbasin, depths to groundwater range between 100 to 150 feet and approach depths of nearly 200 feet in a few streams water bodies. Alluvial deposits have moderate to high permeabilities in the subbasin, but deposits are not significant sources for groundwater use in the subbasin because of the limited lateral and vertical extents. The Red Bluff Formation is generally present above the regional water table; however, local perched zones may yield small quantities of water to domestic wells (DWR, 1968, Pierce, 1983). The principle water-bearing formations in the Enterprise Subbasin, the Tuscan and Tehama Formations, together function as one large, leaky unconfined aquifer with increasing degrees of confinement with depth. Groundwater use of the principle aquifer is for urban, industrial, and agricultural purposes, and is described in greater detail in Chapter 2. Due to the reliability of surface-water storage and the readily available groundwater supply within the Tuscan and Tehama aquifers, few resources have been dedicated to describing other aquifers within the RAGB. As shown on Figures 3-7 and 3-8, although laterally discontinuous fine-grained lenses/beds are present within the subbasin, there is no regional aquitard.

3.1.6.4 Aquifer Properties

Aquifer systems function as a combination of subsurface reservoirs for storage of groundwater and conduits for the transmission of groundwater. The following sections describe the aquifer system properties in the Enterprise Subbasin. The magnitude and distribution of hydrogeologic properties of the principal aquifers in the subbasin have not been well characterized or documented. The scarcity of available quantitative estimates of the aquifer properties of the subbasin's principal aquifers results in uncertainties that will be further refined during implementation of this GSP. This will be accomplished through evaluation of hydraulic data collected during development of the new monitoring well and through calibration of the numerical model being developed as part of this GSP.

Transmissivity and Hydraulic Conductivity

There are two general terms that are used to describe the capacity of an aquifer to transmit water, hydraulic conductivity and transmissivity. Hydraulic conductivity is defined as the coefficient of proportionality describing the rate at which a fluid can move through a permeable medium and is dependent on the fluid density and fluid viscosity and the intrinsic permeability. Transmissivity is defined as the capacity of an aquifer to transmit groundwater through a unit width of the aquifer under a unit hydraulic gradient. Transmissivity is equal to the product of the hydraulic conductivity (which is reported in units of feet per day [ft/day]) and saturated thickness, and is generally reported in units of gallons per day per foot or square feet per day (ft^2/day).

A number of the well completion logs filed with DWR include information that can be used to estimate the specific capacity of the associated well, which can then be used to approximate the transmissivity (DWR, 2020b). In general, estimated transmissivity values are lower in the northern portion of the Enterprise Subbasin and increase to the south, where the thickness of unconsolidated deposits increases. Estimated transmissivities based on reported specific capacity values on well logs by well type are as follows for the Enterprise Subbasin:

- Domestic Wells (100 logs): 2 to 4,000 ft^2/day with a geometric mean of 210 ft^2/day
- Public Wells (4 logs): 120 to 13,750 ft^2/day with a geometric mean of 1,600 ft^2/day
- Industrial and Irrigation Wells (7 logs): 150 to 25,000 ft^2/day with a geometric mean of 1,000 ft^2/day
- Monitoring and Test Wells (6 logs): 35 to 1,600 ft^2/day with a geometric mean of 210 ft^2/day

Hydraulic conductivity was estimated from specific capacity data by dividing the estimated transmissivity by the well screen length, where available. Estimated hydraulic conductivity values for the Enterprise Subbasin are as follows:

- Domestic Wells (66 logs): 0.2 to 350 ft/day with a geometric mean of 9.5 ft/day
- Public Wells (3 logs): 8 to 230 ft/day with a geometric mean of 45 ft/day
- Industrial and Irrigation Wells (4 logs): 1.5 to 40 ft/day with a geometric mean of 9 ft/day
- Monitoring and Test Wells (6 logs): 0.2 to 160 ft/day with a geometric mean of 7 ft/day

Excluding lower yield wells (those with reported pumping rates less than 50 gpm) and relatively shallow wells (those with depths less than 150 feet below ground surface [bgs]), transmissivity ranges from 100 to 25,000 ft^2/day (hydraulic conductivity of 1.5 to 230 ft/day) with a geometric mean of 650 ft^2/day (hydraulic conductivity of 10 ft/day).

In addition to estimating transmissivity based on specific capacity measurements, aquifer properties have been estimated through the process of numerical model calibration, which is a process of adjusting model inputs (such as transmissivity) to achieve a reasonable match to field observations of interest. The most recent version of the Redding Basin Finite Element Model (REDFEM) included transmissivity estimates of less than 1,000 ft^2/day (hydraulic conductivity of 5 ft/day) in the northern portion of the subbasin to more than 200,000 ft^2/day (hydraulic conductivity of 300 ft/day) in the southern portion of the subbasin (CH2M HILL, 2011). These values represent the estimated transmissivity for the entire thickness of unconsolidated materials overlying the Chico Formation (see Figure 3-9) as opposed to aquifer thickness associated with a well screen (as is the case for specific capacity estimates). Estimates of transmissivity and hydraulic conductivity will be further refined in the numerical groundwater flow model being developed to support this GSP.

Storativity

Storativity (or storage coefficient) is the volume of water released from (or taken into) storage in the aquifer system per unit area per unit change in head (i.e., groundwater elevation). In general, unconfined aquifer systems have relatively higher storativity values (typically known as specific yield), whereas confined aquifer systems have lower storativity values. Point estimates of aquifer storage from hydraulic testing within the Enterprise Subbasin are currently unavailable. Values incorporated into REDFEM include a specific yield of 10 percent of the shallow aquifer and a specific storage of the deeper aquifer layers of 2×10^{-6} per foot. Storativity values are computed by multiplying the specific storage value by the aquifer thickness. The assumed resulting storativity values for the deeper model layers in REDFEM range from 1×10^{-4} to 4×10^{-3} (CH2M HILL, 2011). Similar to transmissivity, storage properties will be further refined in the numerical groundwater flow model that is being developed as part of this GSP.

3.1.6.5 Natural Recharge Areas

Recharge to the primary aquifer units (i.e., Tuscan and Tehama Formations) in the Enterprise Subbasin and the shallower, overlying water-bearing units occurs through a combination of the following (DWR, 1968; Pierce, 1983):

- Groundwater recharge from precipitation
- Groundwater recharge from applied water
- Groundwater recharge from streams and irrigation canals
- Subsurface inflow from adjacent subbasins

Recharge to aquifer systems is influenced by a number of parameters including (but not limited to) the following: surface soil infiltration capacity, land use/vegetative cover, topography, lithology, and the frequency, intensity, duration, and volume of precipitation. Figure 3-10 presents the distribution of the Soil Agricultural Groundwater Banking Index (SAGBI) for the Enterprise Subbasin. The SAGBI was developed by the University of California–Davis as part of a study of the potential to bank groundwater, while maintaining healthy crops as a drought management strategy (O'Geen et al., 2015). The SAGBI data

presented on Figure 3-10 are based on the following factors: infiltration capacity of soils, the duration that the root zone would be anticipated to remain saturated, topography, potential for leaching of high-salinity soils to degrade groundwater quality, and the susceptibility of soils to compact and erode. As shown on Figure 3-10, the SAGBI indicates that much of the eastern (between Stillwater and Cow Creeks) and northern portions of the subbasin overlie areas with a poor potential for groundwater recharge while locations within and along stream channels represent areas of good to excellent potential for groundwater recharge. This distribution provides good guidance on where natural recharge to the groundwater system likely occurs. Quantitative estimates of natural and anthropogenic recharge are discussed further in Chapter 4, Water Budgets.

3.1.6.6 Natural Discharge Areas

Natural groundwater discharge areas within the Enterprise Subbasin include groundwater discharge to surface-water bodies (streams, ponds, wetlands), subsurface outflow to adjacent subbasins, and shallow groundwater ET by phreatophytes. Although groundwater discharge to streams has not been mapped, previous numerical modeling efforts indicate that the Sacramento River and at least the lower portions of primary tributaries are gaining streams. REDFEM output indicate that the Sacramento River gains approximately 700,000 acre-feet per year (on average) from groundwater as it flows through the RAGB. Updated estimates of the location and magnitude of natural groundwater discharge are discussed further in Chapter 4, Water Budgets.

Figure 3-11 presents the distribution of potential groundwater-dependent ecosystems (GDEs) within the Enterprise Subbasin contained in the DWR Natural Communities (NC) dataset (DWR, 2020c). The NC dataset is the product of a collaborative effort between DWR, California Department of Fish and Wildlife, and The Nature Conservancy. These agencies compiled and screened information from 48 datasets (such as the National Hydrography Dataset, National Wetlands Inventory, Vegetation Classification and Mapping Program, and Classification and Assessment with Landsat Of Visible Ecological Groupings) to produce the NC dataset. As defined in the NC dataset, the two classifications of GDEs are (1) wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions (NC wetland) and (2) vegetation types commonly associated with the sub-surface presence of groundwater (NC vegetation or phreatophytes). Within the Enterprise Subbasin, NC wetlands typically occur within and immediately adjacent to stream channels, whereas NC vegetation areas are typically present in floodplain areas associated with streams. However, there has been no independent verification that the locations shown on this map constitute actual GDEs; therefore, Figure 3-11 shows only potential GDEs. Additional field reconnaissance may be necessary to further inform the potential existence of these GDEs.

3.2 Groundwater Conditions

This section describes current and historical groundwater conditions in the Enterprise Subbasin. Unless otherwise specified, current conditions will refer to conditions occurring after January 1, 2015, and historical conditions will refer to those occurring prior to January 1, 2015. The groundwater conditions described in the following sections present the current and historical variability of groundwater levels and groundwater quality.

3.2.1 Groundwater Elevations

The assessment of groundwater elevation conditions in the Enterprise Subbasin is largely based on data collected by the DWR from November 7, 1955 to March 18, 2019. The groundwater-level monitoring network in the Enterprise Subbasin comprises 28 groundwater wells gauged by DWR, Shasta County, or USGS (DWR; 2019a; DWR, 2019b; USGS, 2019a). Groundwater wells in the monitoring network have various uses including residential, irrigation, industrial, stock watering, and observation, as well as three wells with unknown groundwater use. The location and type of monitoring program are shown on Figure 2-9 and listed in Table 3-1. All but 1 of the 28 groundwater wells comprising the groundwater-level monitoring network are located in the southern two-thirds of the Enterprise Subbasin.

Groundwater elevation data have been routinely collected by DWR at 20 wells to better understand seasonal changes and to monitor longer-term trends in groundwater levels. Groundwater wells monitored by DWR have generally been accessed monthly to semiannually. Shasta County has monitored one groundwater well in the Enterprise Subbasin under the CASGEM program since 2014. Between October 2017 and April 2019, USGS began monitoring 7 groundwater wells in the Enterprise Subbasin. A summary of the historical groundwater-level monitoring activities conducted within the Enterprise Subbasin since 1955 is described below:

- Between 1955 and 1990, DWR gauged up to 12 groundwater wells monthly to biannually
- Between 1990 and 2016, DWR gauged up to of 16 groundwater wells bimonthly to annually
- Between 2017 and 2018, DWR gauged up to 10 groundwater wells triannually
- Between 2014 and 2019, Shasta County gauged 1 well semiannually to annually
- Between January 2017 and March 2019, USGS gauged 7 groundwater wells once

The amount of available groundwater-level data for a given well varies from 1 measurement at the USGS-monitored wells to over 300 data points at a DWR-monitored location. The period of record for wells included in the DWR dataset ranges from 4 years at well Columbia, to nearly 63 years of groundwater-level monitoring at 31N04W27P001M, with an average period of record of nearly 36 years.

Due to the various regional and local influences on groundwater elevations, characterization of subbasin groundwater elevation conditions was completed using three methodologies: groundwater elevation contour maps, hydrographs, and vertical hydraulic gradients, as follows:

- Groundwater elevation contour maps show the geographic distribution of groundwater elevations at a specific time. Contours and posted groundwater elevations represent the elevation of the groundwater in units of feet NAVD88.
- Hydrographs show variations in groundwater elevations at an individual well over time. A review of hydrographs can provide insight to both seasonal and longer-term temporal trends in groundwater elevations.
- Vertical hydraulic gradients provide information on the potential for vertical groundwater flow at a given location.

A summary of current and historical groundwater elevations and evaluations of vertical and horizontal flow directions are included herein.

3.2.1.1 Groundwater Elevation Contours and Horizontal Groundwater Gradients

Because the Enterprise Subbasin comprises a portion of the larger RAGB and groundwater flow is not affected by jurisdictional boundaries (such as subbasin boundaries), a regional review of groundwater-level data is important for understanding groundwater flow on a basin-wide scale. Consistent with GSP requirements, groundwater-level data for two recent timeframes, March 19 through April 3, 2018 (spring) and October 16 through October 26, 2018 (fall), were used to create groundwater elevation contour maps for the RAGB. Groundwater levels from wells within the Enterprise Subbasin were measured between March 19 and March 22, 2018 (spring) and October 16 and October 17, 2018 (fall). These groundwater measurements represent the most recent groundwater-level data as of the time of this evaluation.

The first step in the process of groundwater elevation contouring was to identify wells representative of groundwater conditions across the RAGB (that is, completed at consistent depths within the primary aquifer units). With some exceptions, wells included in the contouring were generally completed between depths of 50 and 150 feet bgs. A limited number of wells completed deeper (between 150 to 770 feet bgs) were considered outlier data and were not included in the contouring.

As mentioned in Section 2.2.1.3, Sacramento River and Cow Creek serve as western and southwestern, and eastern boundaries for the Enterprise Subbasin, respectively. These surface-water bodies are gaining streams, or streams in which the stream stage is at a lower elevation than the underlying water

table. Thus, groundwater moves from the aquifer into the stream channel. A gaining stream is hydraulically connected to the water table; and as a result, surface-water elevations in perennial streams that are coupled with the underlying aquifer must be considered when generating water table surface contours. Because the Sacramento River is perennial and coupled with the groundwater system, the river surface elevation was included in groundwater contouring. The river gauge below Keswick Reservoir (11370500) and the river gauge at Bend Bridge in Red Bluff (11377100) served as upper and lower extents for consideration of Sacramento River stages in groundwater elevation contouring (USGS, 2019a). The topographic data (discussed in Section 3.1.1) were used to help inform Sacramento River stage between Keswick Reservoir and Bend Bridge. The average surface-water elevations between March 19 through April 3, 2018 (spring) and October 16 through October 26, 2018 (fall) at the Keswick Reservoir and Bend Bridge river gauges were computed. The average surface-water elevations at the two river gauges during the dates above were compared to the surface-water elevations in the digital elevation model near these two locations. The average spring surface-water elevation was more similar to the topographic elevation measured in the digital elevation model, and the topographic elevations along the Sacramento River were extracted from the digital elevation model to represent spring 2018 surface-water elevations. The fall 2018 Sacramento River surface-water elevations were interpolated from the previously extracted elevations from the digital elevation model and the difference between the spring 2018 and fall 2018 surface-water elevations at the river gauges. Because there is a lack of measured groundwater-level data in the northern portion of Enterprise Subbasin, groundwater elevation output from REDFEM (CH2M HILL, 2011) were used to augment the dataset used in the contouring in the northern portion of the Enterprise Subbasin. Groundwater elevation contours for the Enterprise Subbasin for spring and fall 2018 are shown on Figures 3-12 and 3-13, respectively.

During spring and fall 2018, groundwater flow in the Enterprise Subbasin was generally south-southeast toward the confluence of Cow Creek and the Sacramento River. Groundwater flow directions and variations in groundwater elevation generally mimic a muted version of ground surface topography. Horizontal hydraulic gradients are estimated to be steeper in the northern and central portions of the Enterprise Subbasin where transmissivity estimates are lower, and flatter in the southeastern portion of the subbasin, near the Cow Creek and Sacramento River confluence, where transmissivity estimates are higher. The steepest horizontal hydraulic gradient is near 31N03W06H001M, with both a spring and fall 2018 hydraulic gradient of approximately 0.004 foot per foot (ft/ft). The shallower horizontal gradients in the southeast near 30N03W06K001M are approximately 0.001 ft/ft in spring 2018 and 0.0007 ft/ft in fall 2018. Measured spring 2018 groundwater elevations considered in the contouring ranged from a high of 463.34 feet NAVD88 at 31N03W06H001M in the central portion of the subbasin to a low of 390.07 feet NAVD88 at 30N03W06K001M farthest south. Measured fall 2018 groundwater elevations considered in the contouring ranged from a high of 459.14 feet NAVD88 at 32N04W33G001M farthest north to a low of 389.17 feet NAVD88 at 30N03W06K001M farthest south.

A comparison of Figures 3-12 and 3-13 shows that wells with groundwater levels measured in both spring and fall 2018 generally exhibit a decrease in groundwater levels between spring and fall. Generally, most groundwater recharge occurs from increased precipitation and less groundwater pumping in winter and spring. Conversely, groundwater recharge decreases during summer and fall when there is less precipitation and more groundwater pumping. Seven of the ten wells with measurements in both spring and fall demonstrated declining groundwater levels, ranging from 0.9 foot at wells 30N03W06K001M and 31N04W29R003M to a maximum decrease of 14 feet observed at Columbia. Groundwater levels in wells 31N04W29R004M, 31N04W29R005M, and 31N04W29R006M have slightly increasing groundwater levels between spring and fall 2018 (up to 4 feet). These wells are part of a quadruple well cluster near the Sacramento River.

3.2.1.2 Hydrographs

As mentioned above, the Enterprise Subbasin groundwater monitoring network consists of USGS- and DWR-monitored groundwater wells. Each of the seven USGS-monitored groundwater wells has only one groundwater-level measurement, whereas the datasets associated with the DWR-monitored groundwater wells are more robust, with an average of approximately 105 datapoints per groundwater well. With the

USGS and DWR datasets combined, temporal groundwater-level data for the Enterprise Subbasin date as far back as November 7, 1955, with some locations continuing to be updated annually.

Temporal trends in groundwater elevations can be assessed with hydrographs that plot changes in groundwater elevations over time. Figure 3-14 depicts locations and hydrographs of representative wells in the Enterprise Subbasin. The points on the plots represent groundwater elevation measurements, whereas the color-coded bars on the hydrographs represent the Sacramento Valley Water Year Index (as discussed in Section 3.1.2.1). Representative wells were chosen based on their distribution across the subbasin, and the timeframe and continuity of their monitoring record. A complete set of hydrographs is included in Appendix C.

Historical groundwater-level records for the Enterprise Subbasin indicate groundwater levels have been relatively consistent, generally without long-term trends of increasing or decreasing groundwater levels (30N03W06K001M**,** Figure 3-14). However, groundwater levels at locations 32N04W33G001M, 31N04W09D001M, and 31N04W09C001M depict increasing water levels from the 1970s to current in the central portion of the Enterprise Subbasin. At groundwater well 32N04W33G001M, groundwater levels increased by approximately 40 feet, from approximately 500 feet elevation in the early 1980s to approximately 540 feet elevation in 2010. Groundwater levels at 31N04W09C001M and 31N04W09D001M were plotted together because of their proximity to each other, the similar total depths, and the succeeding periods of record. Similar to groundwater levels at 32N04W33G001M, groundwater levels at 31N04W09C001M and 31N04W09D001M increased by nearly 50 feet, from approximately 405 feet elevation in the late 1970s to approximately 455 feet in the early 2010s.

Although there have been relatively few long-term changes in groundwater levels, there are seasonal variations in groundwater levels that are evident in hydrographs. Figure 3-14 shows that groundwater levels in many wells can fluctuate between 0 and 10 feet within a year. Groundwater levels increase during the rainy season only to decrease during the dry season. As discussed in Section 3.1.2.1, precipitation has been variable in the RAGB, with multi-year droughts (critical and dry water years) occurring between 1976 and 1977, 1987 to 1992, 2007 to 2009, and 2013 to 2015, and wet years occurring between 1970 to 1975, 1982 to 1984, and 1995 to 2000.

Groundwater levels in most of the wells shown on Figure 3-14 depict some influence from droughts and wet periods. Despite the general increasing trend, groundwater levels in the centrally located groundwater wells 31N04W09C001M and 31N04W09D001M and the northernmost groundwater well 32N04W33G001M are responsive to sustained wet and dry periods. Sustained droughts between 1987 to 1992 and 2013 to 2015 had a large impact on groundwater levels in the vicinity of these wells, with groundwater levels decreasing by approximately 10 to 20 feet during droughts. Conversely, even brief wet periods have resulted in increasing groundwater levels at these locations.

Wet and dry climatic periods are less pronounced in the groundwater-level records of the remaining wells in the Enterprise Subbasin.

3.2.1.3 Vertical Hydraulic Gradients

The potential for groundwater to move vertically within an aquifer system is evaluated by comparing groundwater elevations in wells screened at different depths. Because groundwater elevations change spatially, the potential for vertical movement is computed between wells of differing depths that are in proximity to each other (that is, a well cluster or a multiple completion well). For the purposes of this analysis, the vertical hydraulic gradient is computed as the groundwater elevation at the shallower well minus the groundwater elevation at the deeper well divided by the vertical distance between the well screen midpoints. Based on this calculation method, a positive vertical hydraulic gradient represents the potential for downward groundwater flow, and a negative vertical hydraulic gradient represents the potential for upward groundwater flow. The larger the value of the vertical hydraulic gradient (either positive or negative), the stronger the potential for upward or downward groundwater flow.

Because of their proximity to each other (they are part of a quadruple well cluster or within 40 feet of each other), the groundwater wells 31N04W29R003M, 31N04W29R004M, 31N04W29R005M, and 31N04W29R006M were used for evaluating vertical hydraulic gradients in spring and fall 2018. The groundwater well pair represented by 31N04W29R005M and -R004M is the shallowest; Well R005M screened at 330.6 to 320.6 feet NAVD88, and 31N04W29R004M screened at 275.6 to 235.6 feet NAVD88. The groundwater well pair represented by wells 31N04W29R003M and 31N04W29R006M is the deepest with Well R003M screened from 200.6 to 119.6 feet NAVD88 and Well R006M screened from 199.6 to 119.6 feet NAVD88. Hydrographs of these four wells show that historical vertical hydraulic gradients have been downward, with smaller downward gradients within the shallower well pair and much larger downward gradients within the deeper well pair. Vertical hydraulic gradients calculated from groundwater well data are summarized in Table 3-2. Figure 3-15 illustrates groundwater-level hydrographs associated with the quadruple well cluster. Vertical hydraulic gradients are downward, ranging between 0.02 ft/ft to 0.21 ft/ft. Downward vertical gradients generally increased between spring and fall 2018, likely due to deeper agricultural pumping.

3.2.2 Interconnected Surface Water and Groundwater

Surface water that is in hydraulic communication with the groundwater flow systems is referred to as interconnected surface water. If the groundwater elevation beneath a stream is higher than the stream stage (i.e., surface-water elevation), the stream is considered to be a gaining stream, because it gains water from the underlying groundwater. If the groundwater elevation is lower than the stream stage, the stream is considered to be a losing stream, because it loses water to the underlying groundwater. If the groundwater elevation is below the streambed elevation, the stream and groundwater are considered to be disconnected (or decoupled).

As previously discussed, the RAGB is bounded on the east by the Cascade Range, on the north and northwest by the Klamath Mountains, and on the west by the Coast Range. Following rain and snowmelt events, the resulting discharge to surface-water channels and infiltration to the aquifer system produces flow within the multiple tributaries to the perennial Sacramento River and recharges the aquifer within the RAGB. The shallow groundwater and perennial nature of surface-water flow in the RAGB suggest there is potential for interconnected surface waters to be present. To identify areas where interconnected surface waters may be present, an analysis was performed based on reviewing depth to groundwater data. The underlying assumption of this analysis is that the shallower the depth to groundwater, the more likely that area is in hydraulic connection to surface water.

To document this relationship, the groundwater elevation contours for spring of 2018 were compared to ground surface elevations presented in Section 3.1.1 to estimate the depth to groundwater across Enterprise Subbasin. Spring 2018 was selected because it represents a period of seasonal high groundwater levels that would be anticipated to result in greater connection between groundwater and surface-water features in the Enterprise Subbasin. Figure 3-16 presents the results of that analysis and shows that groundwater in Enterprise Subbasin is generally greater than 20 feet bgs in most of the subbasin.

Most areas of interconnected surface water are located along the Sacramento River and Cow Creek, where surface water flows perennially. An additional area of potentially interconnected surface water is located along portions of upper and lower reaches of Stillwater Creek and its tributaries and Churn Creek.

This analysis of locations of interconnected surface water is based on available data but contains significant uncertainty. Additional data are needed to reduce uncertainty and refine the map of interconnected surface waters. The main source of these data will be the numerical model being developed as part of this GSP.

3.2.3 Groundwater Storage

To be included in a future draft of this chapter.

3.2.4 Seawater Intrusion

The RAGB is not vulnerable to seawater intrusion, given its distance from the Pacific Ocean.

3.2.5 Groundwater Quality

This section presents a summary of current groundwater quality conditions. The EAGSA does not have regulatory authority over groundwater quality and is not charged with improving groundwater quality in Enterprise Subbasin under SGMA. Although there may be localized areas of impairment, the overall quality of groundwater in the Enterprise Subbasin is good and suitable for the designated beneficial uses of the subbasin. Under SGMA, projects and actions implemented by a GSA are not required to improve groundwater quality; however, the management actions and projects recommended under SGMA must not further degrade groundwater quality, as compared with baseline (i.e., January 2015) conditions.

The SWRCB monitors and regulates activities and discharges that can contribute to constituents that are released to groundwater over large areas. The SWRCB's GAMA program compiles groundwater quality data from a variety of sources and makes these data available to the public for download by county (SWRCB, 2019a). Groundwater quality monitoring programs incorporated into the dataset include the following:

- Data from a GAMA domestic well sampling program
- USGS GAMA program
- Lawrence Livermore National Laboratory GAMA program
- Data from the Department of Pesticides Regulation groundwater sampling program
- Data from groundwater sampling programs conducted by DWR
- Data from the California Department of Public Health's sampling of public water supply wells
- Data from sampling of environmental monitoring wells at regulated sites

The Shasta County dataset was downloaded, and a compiled dataset of publicly available groundwater quality results from Enterprise Subbasin were used for establishing baseline groundwater quality in the subbasin. Groundwater quality data were then compared to an applicable regulatory standard including the following:

- Primary MCLs established by either the U.S. Environmental Protection Agency (EPA) or the California EPA (Cal/EPA), whichever was more strict
- Secondary maximum contaminant levels (SMCLs) established by either EPA or Cal/EPA, whichever was more strict
- Federal Action Level established by EPA
- Cancer or non-cancer Health Based Screening Level established by USGS
- Chronic non-cancer Human Health Benchmark for Pesticides established by EPA
- Federal Health Advisory Level established by EPA
- Reference Dose as a drinking water level
- National Academy of Science Health Advisory Level
- California Cancer Potency Factor
- California Proposition 65 Safe Harbor Levels as a drinking water level
- SWRCB notification levels

The following analyses used analytical data collected between 2000 and 2019 to compare to state or federal groundwater limits. Detected concentrations of constituents based on groundwater analytical data were compared to the associated regulatory limit to evaluate whether the concentration was higher (an

exceedance) or lower (a non-exceedance) than the limit. Most tested constituents were either nondetect or detected at concentrations below regulatory limits. Constituents with low detection frequencies do not represent pervasive groundwater quality issues throughout Enterprise Subbasin; therefore, these constituents will not be considered further in this GSP.

Figures 3-18 and 3-19 present the distribution of sampled locations and locations of exceedances for each constituent that exceeded the applicable regulatory limit at 10 percent or more of the sampled locations. The locations are symbolized as either non-exceedance (indicating that the constituent has not exceeded the applicable limit in any of the samples at a given well) or symbolized by the number of exceedances over time at a given location. Groundwater quality data included in the analysis of recent subbasin groundwater quality are presented in Appendix D.

In the Enterprise Subbasin, the following water quality constituents were identified to have exceedances in 10 percent or more of tested groundwater wells: iron, manganese, lead, arsenic, aluminum, benzene, gasoline, tert-butyl alcohol (TBA), and methyl-tert-butyl ether (MTBE). Naturally occurring water quality constituents include the metals iron, manganese, lead, arsenic, and aluminum; whereas groundwater quality constituents related to human activity include the fuel-related compounds, such as benzene and gasoline and the non-hydrocarbon solvents TBA and MTBE. Table 3-3 summarizes the analytical results for each of the above water quality constituents. Although available data show localized areas of potential groundwater impairments, the overall quality of groundwater in the Enterprise Subbasin is good and suitable for the designated beneficial uses of the subbasin.

3.2.5.1 Point-Source Contamination

Point-source contamination data collection activities take place in the Enterprise Subbasin in response to known or potential sources of groundwater contamination. These sources include leaking underground storage tank (LUST) sites and a sewage settling pond.

SWRCB and DTSC have the responsibility for cleanup and monitoring of point-source pollutants. Both entities make all related materials available to the public through two public portals: GeoTracker managed by SWRCB (SWRCB, 2019b) and EnviroStor managed by DTSC (DTSC, 2019). Figure 3-20 presents a map with locations of active remediation sites within the Enterprise Subbasin, and Table 3-4 summarizes the active remediation sites.

The SWRCB's GeoTracker database identifies three open LUST remediation sites with potential or actual groundwater contamination within Enterprise Subbasin. DTSC's EnviroStor database identifies the same three open LUST remediation sites but includes one additional remediation site that may be open with potential or actual groundwater contamination within Enterprise Subbasin. The EnviroStor database redirects the user to the GeoTracker database for more information; however, attempts to locate this site have been unsuccessful as the GeoTracker database does not contain an entry for this remediation site. Resolution of the status of the fourth potentially open remediation site remains a data gap that will be filled via additional communication with DTSC and/or SWRCB.

As indicated in Table 3-4, point-source contaminants include gasoline, sewage sludge, and solvents or non-petroleum hydrocarbons. Although these constituents are of concern, only fuel-related compounds and metals were detected in more than 10 percent of sampled wells within the Enterprise Subbasin to warrant inclusion in the GSP monitoring program.

3.2.5.2 Connate Water

In addition to the above potential constituents of concern, there exists a potential source of saline water intrusion from the Chico Formation. The Chico Formation, which underlies the primary aquifer units of the RAGB, contains saline water under artesian pressure (Pierce, 1983). The Chico Formation is composed of marine deposits of sandstone, conglomerates, and shale, most of which are considered impermeable with a few exceptions. Pumping at depths near the top of the Chico Formation may induce upward

migration of the connate water into the primary aquifer units. Currently, migration of connate water into the primary aquifer is not an issue.

3.2.6 Land Subsidence

Land subsidence was recently measured across the Sacramento Valley by DWR, and results were published in the report *2017 GPS Survey of the Sacramento Valley Subsidence Network* (DWR, 2018). The DWR document provides no indication of inelastic subsidence to have occurred in the entire RAGB. As such, land subsidence from groundwater extraction in the Enterprise Subbasin is not considered a current issue of concern.

Table 3-1. Enterprise Subbasin Groundwater Monitoring Network

Location ID	Easting	Northing	Well Type	Monitoring Agency	Ground Surface Elevation (ft NAVD88)	Reference Point Elevation (feet NAVD88)	Total Well Depth (feet bgs)	Top of Well Screen (feet bgs)	Bottom of Well Screen (feet bgs)
30N03W06J001M	6495383.401	2059689.186	Irrigation Well	California DWR	405.87	406.57	128	--	--
30N03W06K001M	6494035.689	2059865.925	Residential Well	California DWR	412.57	413.07	66	--	--
30N04W02E001M	6480263.49	2060382.618	--	U.S. Geological Survey	475	--	120	--	--
30N04W03Q001M	6478024.495	2059050.431	Residential Well	California DWR	475.88	477.58	140	--	--
31N03W06H001M	6495194.984	2092445.357	Residential Well	California DWR	523.14	523.64	96	--	--
31N03W07R002M	6494954.583	2084219.027	--	U.S. Geological Survey	456.628	--	360	--	--
31N03W18B001M	6493918.04	2082861.892	Stockwatering	California DWR	460.23	460.63	210	--	--
31N03W29N001M	6495629.42	2068358.543	Unknown	California DWR	418.99	419.59	130	--	--
31N04W07D001M	6459364.886	2088187.852	--	U.S. Geological Survey	476	--	64	--	--
31N04W09C001M	6471050.589	2087708.813	Residential Well	California DWR	537.64	538.84	215	188	215
31N04W09D001M	6471014.643	2088874.31	Residential Well	California DWR	546.64	545.64	160	--	--
31N04W11P001M	6481586.967	2084562.911	--	U.S. Geological Survey	496	--	178	--	--
31N04W12B001M	6488433.775	2088815.676	Residential Well	California DWR	597.24	597.64	180	--	--
31N04W15K001M	6477587.337	2080190.11	Irrigation Well	California DWR	517.63	518.63	352	120	350
31N04W16H001M	6474352.322	2082195.613	Unknown	California DWR	514.64	515.64	140	--	--
31N04W16M001M	6470315.769	2080316.118	Residential Well	California DWR	524.63	525.63	140	--	--
31N04W25Q001M	6487781.792	2068498.013	Irrigation Well	California DWR	491.59	494.59	770	220	770
31N04W27P001M	6476693.034	2068089.369	Irrigation Well	California DWR	494.59	494.59	300	90	296
31N04W27R001M	6478187.957	2067968.831	--	U.S. Geological Survey	492	--	395	--	--
31N04W29R002M	6468990.251	2067935.307	Residential Well	California DWR	444.6	445.7	40	--	--
31N04W29R003M	6467601.519	2068341.346	Industrial Well	California DWR	444.6	445.9	325	244	325
31N04W29R004M	6467601.379	2068304.918	Observation Well	California DWR	444.6	445.6	210	169	209
31N04W29R005M	6467601.379	2068304.918	Observation Well	California DWR	444.6	445.5	126	114	124
31N04W29R006M	6467601.238	2068268.49	Unknown	California DWR	444.6	445.8	325	245	325
32N04W26K001M	6482614.995	2101640.693	--	U.S. Geological Survey	633	--	128	--	--
32N04W33G001M	6472631.92	2098084.886	Residential Well	California DWR	632.64	633.64	208	188	208
33N04W34G001M	6476924.372	2128678.187	--	U.S. Geological Survey	691	--	247	--	--
Columbia	6476433.763	2097269.833	Observation Well	California DWR	622	624	270	222	270

Notes:

-- = information not available
bgs = below ground surface
DWR = Department of Water Resources
NAVD88 = North American Vertical Datum of 1988

The horizontal datum for well coordinates is North American Datum 1983, State Plane California Zone I in feet.

Table 3-2. Enterprise Subbasin Vertical Head Differences during Spring and Fall 2018

Location ID of Shallow Well	Location ID of Deep Well	Distance Between Wells (feet)	Measured Groundwater Elevation in Shallow Well (feet NAVD88)	Measured Groundwater Elevation in Deep Well (feet NAVD88)	Difference in Groundwater Elevation (feet)	Measurement Date of Groundwater Levels	Screen Elevation of Shallow Well (feet NAVD88)	Screen Elevation of Deep Well (feet NAVD88)	Calculated Vertical Hydraulic Gradient (foot/foot)
31N04W29R005M	31N04W29R004M	0	415.5	412.1	3.4	3/22/2018	330.6-320.6	275.6-235.6	0.05
31N04W29R005M	31N04W29R003M	36.7	415.5	395.9	19.6	3/22/2018	330.6-320.6	200.6-119.6	0.12
31N04W29R005M	31N04W29R006M	36.1	415.5	406.4	9.1	3/22/2018	330.6-320.6	199.6-119.6	0.05
31N04W29R004M	31N04W29R003M	36.7	412.1	395.9	16.2	3/22/2018	275.6-235.6	200.6-119.6	0.17
31N04W29R004M	31N04W29R006M	36.1	412.1	406.4	5.7	3/22/2018	275.6-235.6	199.6-119.6	0.06
31N04W29R005M	31N04W29R004M	0	417.6	416.2	1.4	10/17/2018	330.6-320.6	275.6-235.6	0.02
31N04W29R005M	31N04W29R003M	36.7	417.6	395.9	21.7	10/17/2018	330.6-320.6	200.6-119.6	0.13
31N04W29R005M	31N04W29R006M	36.1	417.6	407.6	10	10/17/2018	330.6-320.6	199.6-119.6	0.06
31N04W29R004M	31N04W29R003M	36.7	416.2	395.9	20.3	10/17/2018	275.6-235.6	200.6-119.6	0.21
31N04W29R004M	31N04W29R006M	36.1	416.2	407.6	8.6	10/17/2018	275.6-235.6	199.6-119.6	0.09

Notes:

Positive vertical hydraulic gradient indicates downward flow.
NAVD88 = North American Vertical Datum of 1988

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Table 3-3. Summary of Enterprise Subbasin Analytical Chemistry for Potential Analytes of Concern, 2000–2010

Analyte	Limit Type	Regulatory Limit (µg/L)	Number of Wells Sampled	Number of Samples Collected	Number of Wells with Exceedances
Aluminum	CA MCL	1,000	77	210	8
Arsenic	CA MCL	10	82	370	12
Iron	EPA SMCL	300	114	359	41
Lead	U.S. Federal Action Level	15	76	159	8
Manganese	U.S. Health Advisory Level	50	102	479	38
Benzene	CA MCL	1	198	2,399	54
Gasoline	U.S. Health Advisory Level	5	49	158	34
Methyl-Tert-Butyl Ether	CA MCL	13	197	2,462	75
Tert-Butyl Alcohol	Federal Notification Level	12	171	2,267	48

Notes:

µg/L = micrograms per liter
CA MCL = California Maximum Contaminant Limit
EPA SMCL = Environmental Protection Agency Secondary Maximum Contaminant Limit

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Table 3-4. Enterprise Subbasin Active Remediation Sites

Site Name	Site Type	Status	Constituents of Concern	Address	City
76 SS# 2611241	LUST	Open - Remediation	Other Solvent or Non-petroleum Hydrocarbon	5101 Churn Creek Road	Redding
Churn Creek Chevron	LUST	Open - Remediation	Gasoline	4746 Churn Creek Road	Redding
Tay Van Car Wash	LUST	Open - Remediation	Gasoline	1803 Hilltop Drive	Redding
Sewage Settling Pond	Under Evaluation	Unknown	Sludge - Sewage	4001 Victor Avenue	Redding

Note:
LUST = leaking underground storage tank

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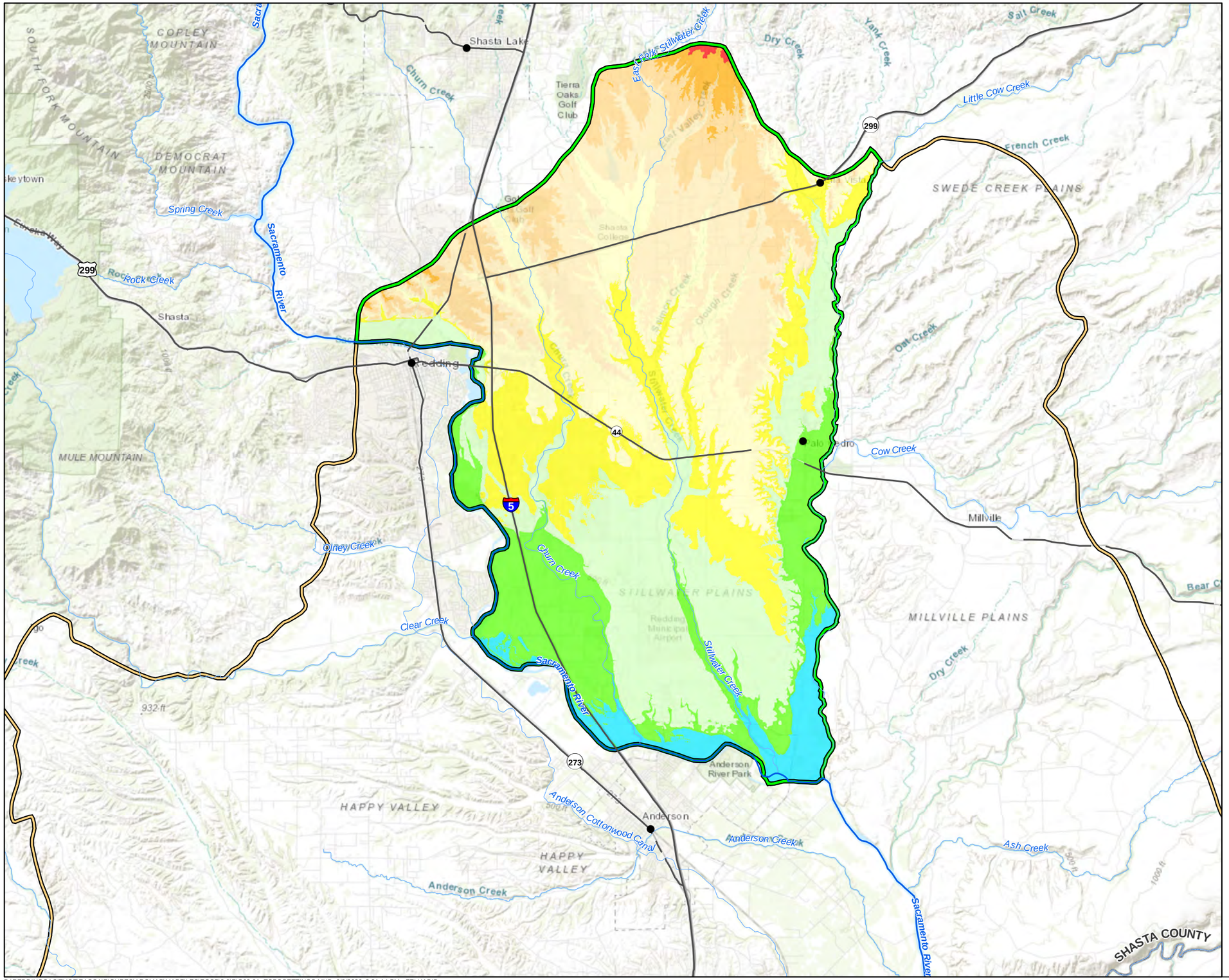

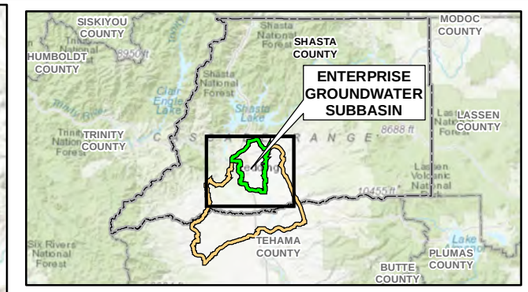

LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

GROUND SURFACE ELEVATION (feet NAVD88)

- 772 to 819.21
- 722 to 772
- 672 to 722
- 622 to 672
- 572 to 622
- 522 to 572
- 472 to 522
- 422 to 472
- 372.48 to 422
- 372.48

NOTES:

DATA SOURCE: SURFACE DATA REPRESENTS TOPOGRAPIC DATA FROM MULTIPLE SOURCES THAT WERE COMPILED INTO A SINGLE SURFACE (USGS, 2018; USGS, 2019b; AND COR, 2019)

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

N

FIGURE 3-1
TOPOGRAPHIC SETTING
Enterprise Subbasin Groundwater Sustainability Plan

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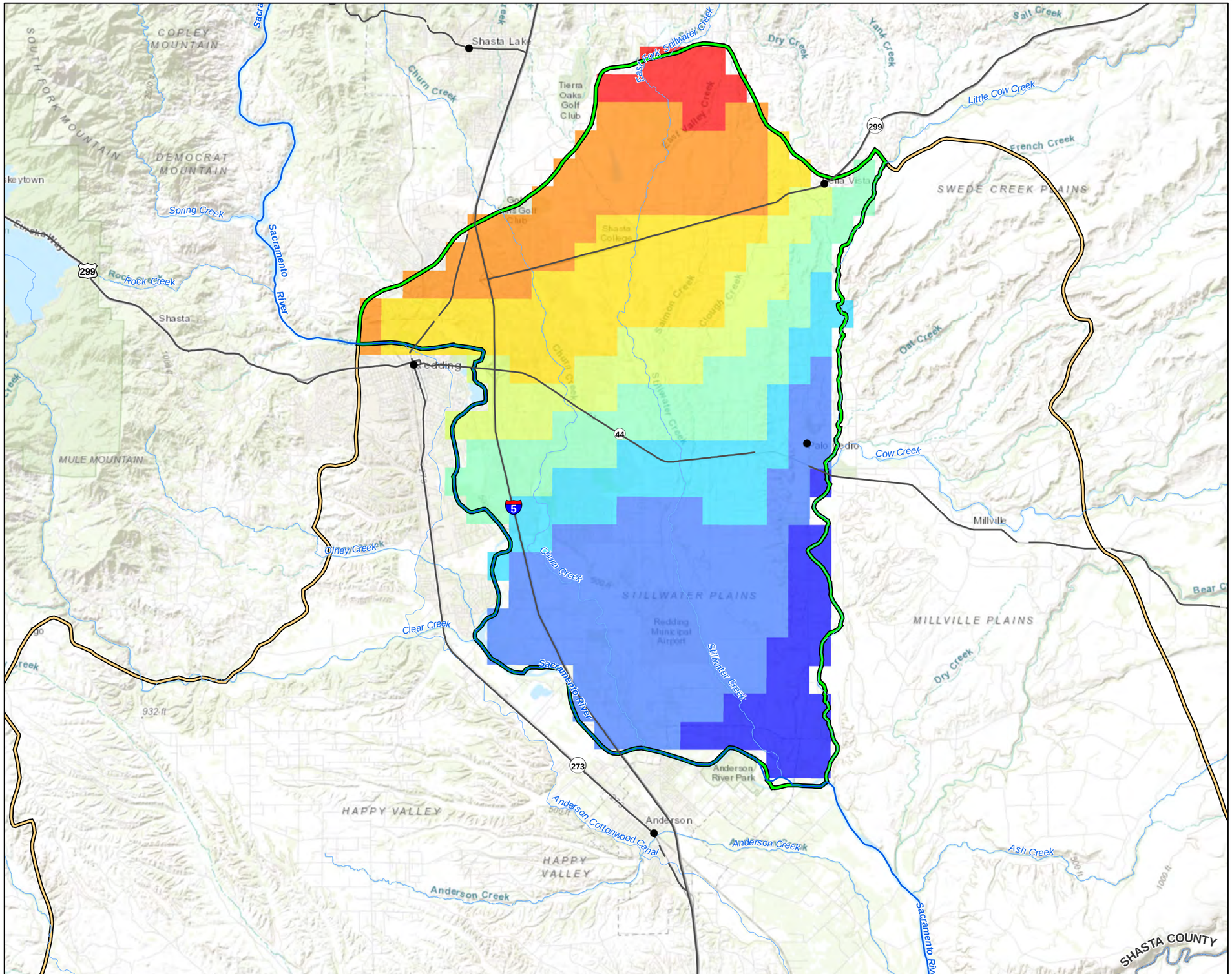

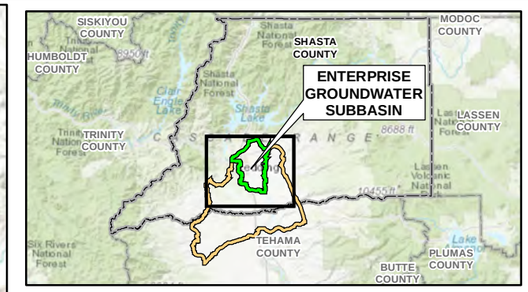

LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

MEAN ANNUAL PRECIPITATION (inches)

- 31.25 to 34
- 34 to 36
- 36 to 38
- 38 to 40
- 40 to 42
- 42 to 44
- 44 to 46
- 46 to 48.63

NOTES:

DATA SOURCE: PRISM CLIMATE GROUP, OREGON STATE UNIVERSITY, HTTP://PRISM.OREGONSTATE.EDU. ACCESSED MARCH 2020 (PRISM CLIMATE GROUP, 2012)

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP

0 2 4 Miles

N

FIGURE 3-2
MEAN ANNUAL PRECIPITATION
Enterprise Subbasin Groundwater Sustainability Plan

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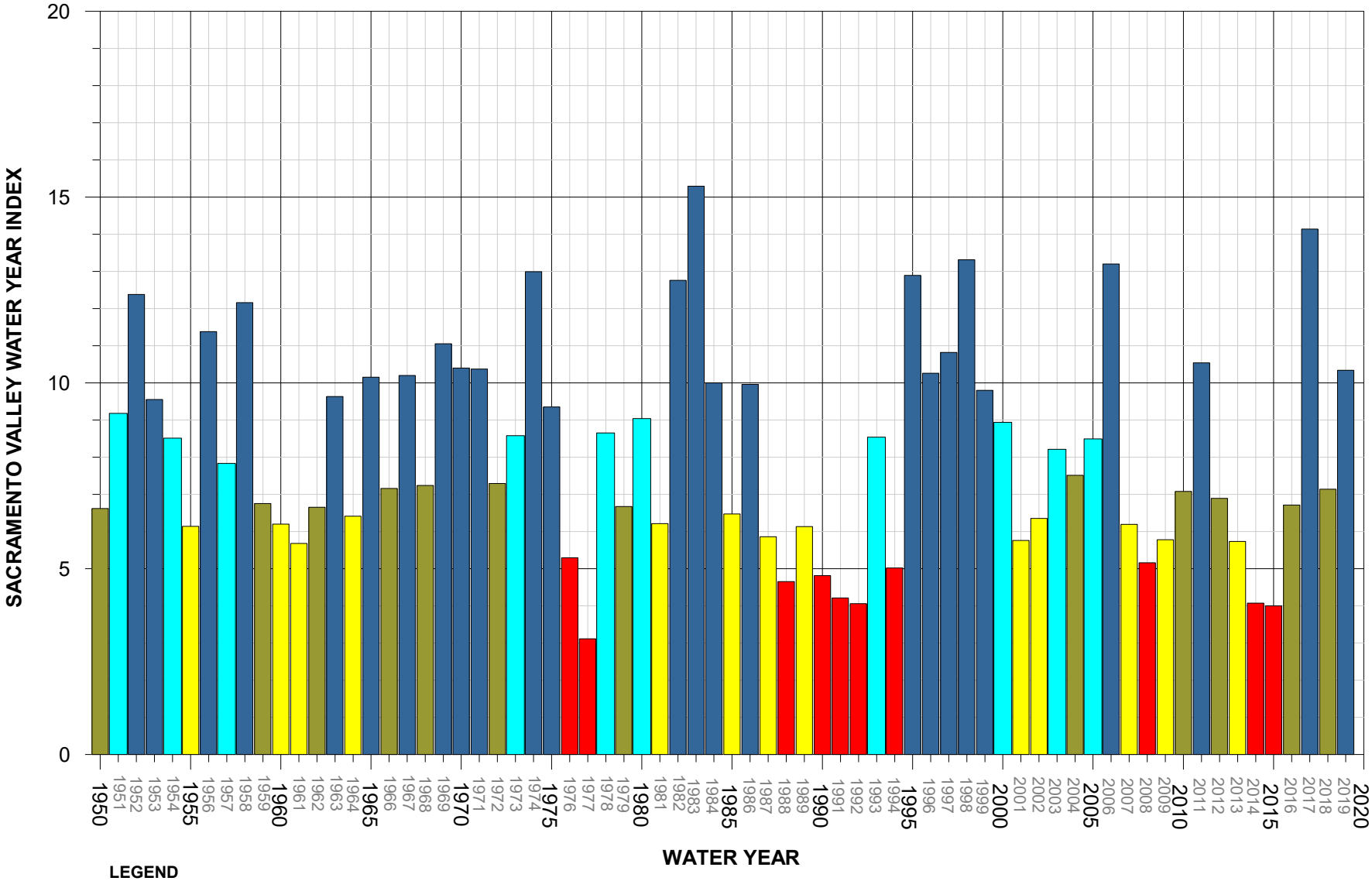


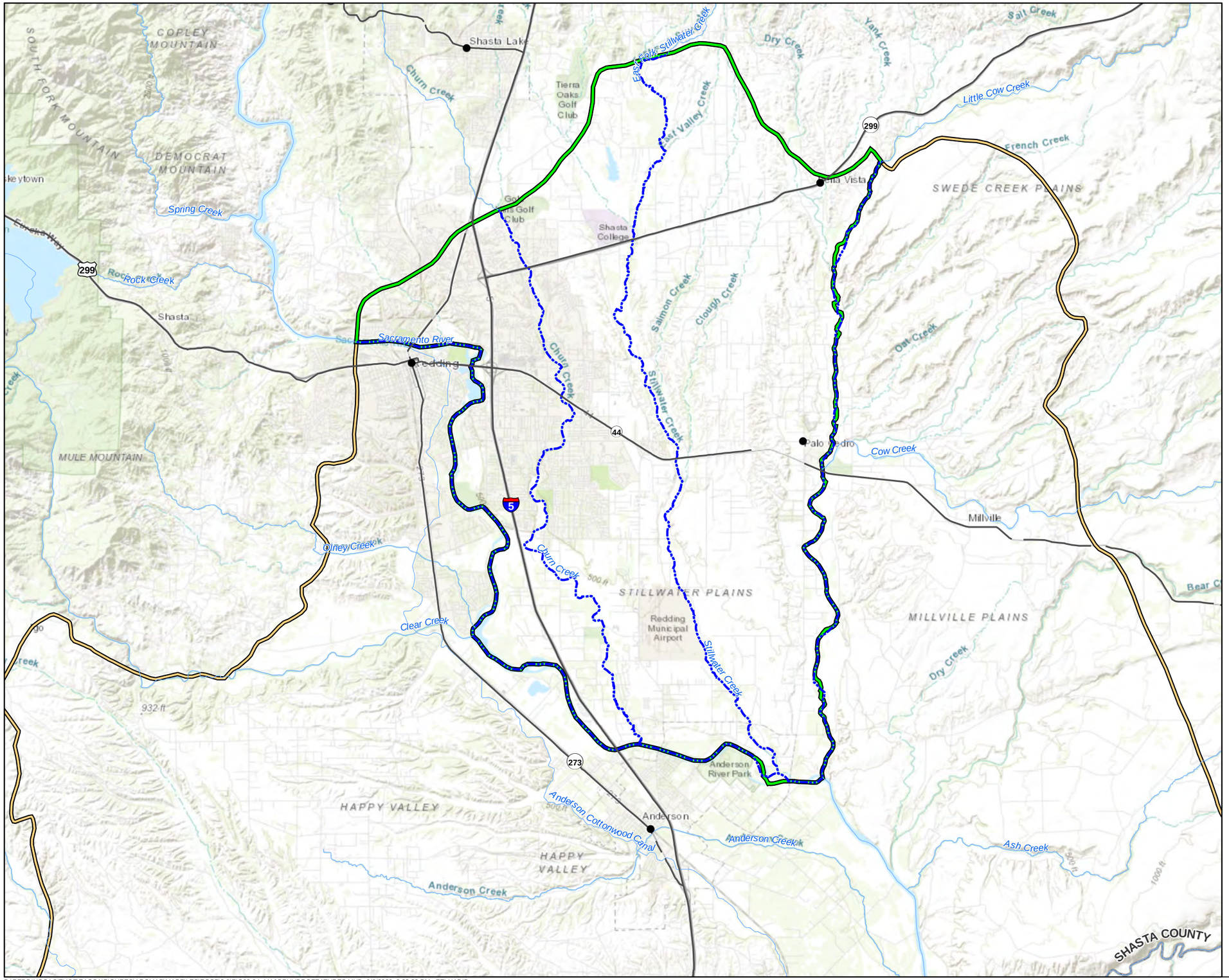
LEGEND

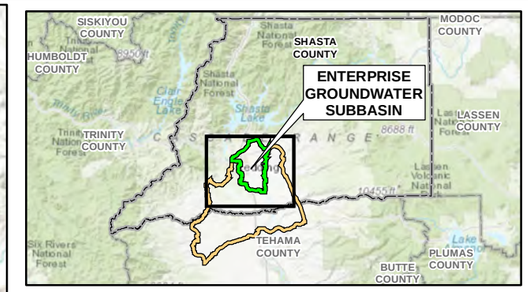
- WET YEAR
- ABOVE NORMAL YEAR
- BELOW NORMAL YEAR
- DRY YEAR
- CRITICAL YEAR

NOTE:

HTTP://CDEC.WATER.CA.GOV/REPORTAPP/JAVAREPORTS?NAME=WSIHIST

FIGURE 3-3
WATER YEAR TYPE
Enterprise Subbasin Groundwater Sustainability Plan





LEGEND

- CITY
- MAJOR HYDROLOGIC FEATURE
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTES:

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

N

FIGURE 3-4
MAJOR HYDROLOGIC FEATURES
Enterprise Subbasin Groundwater Sustainability Plan

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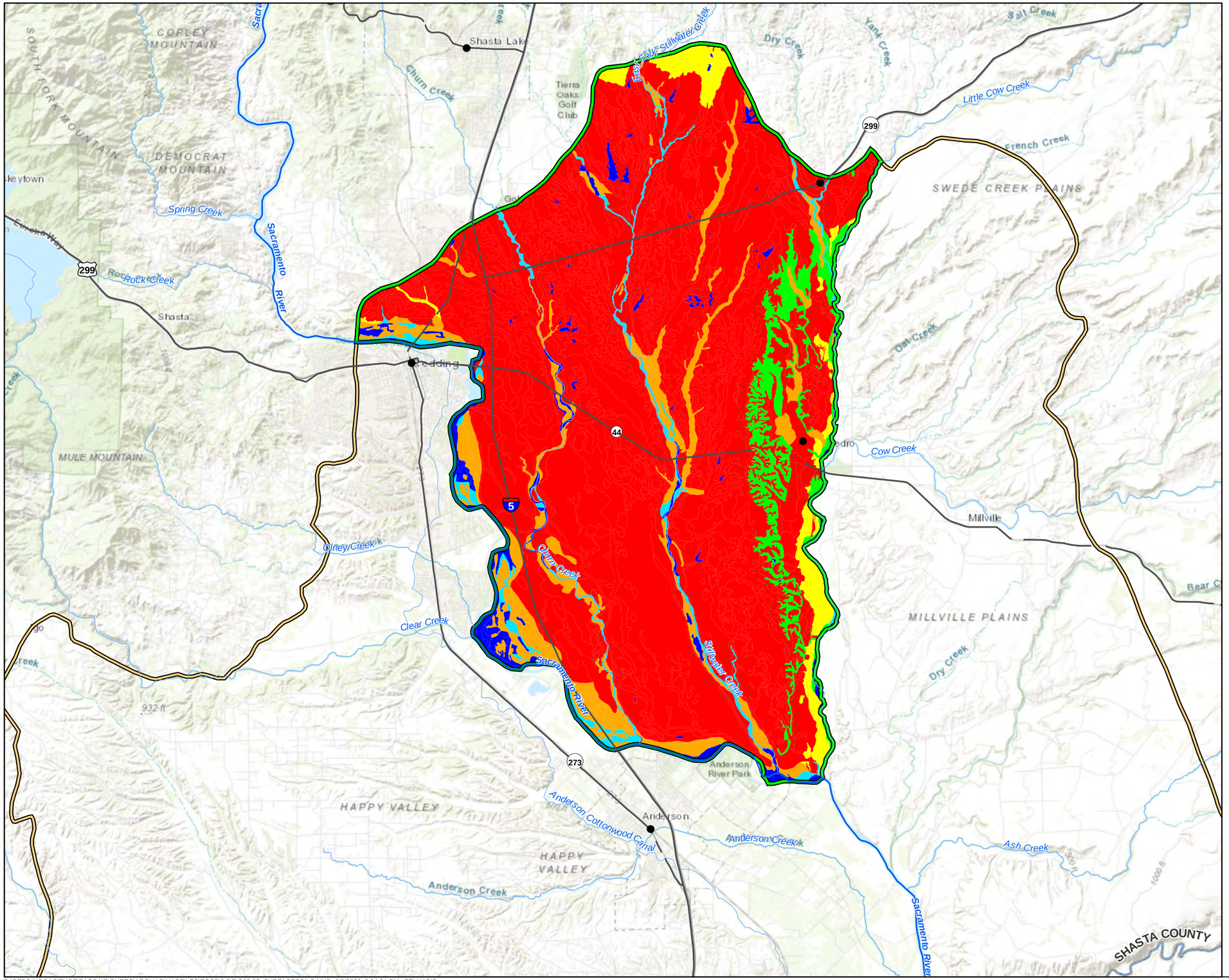

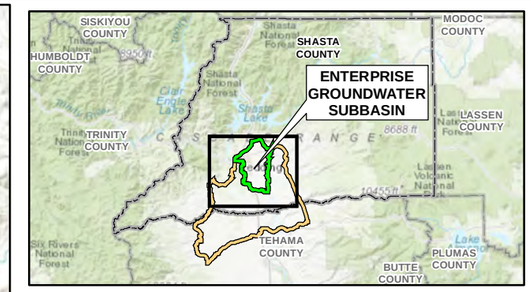

LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

ENTERPRISE SUBBASIN SURFACE SOIL

- ALFISOLS
- ENTISOLS
- INCEPTISOLS
- MOLLISOLS
- ULTISOLS
- OTHER

NOTES:

DATA SOURCE: SURFACE SOILS ARE BASED ON TAXONOMIC ORDER, DEVELOPED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE'S (USDA) NATIONAL RESOURCES CONSERVATION SERVICE (USDA, 2019)

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

N

FIGURE 3-5
ENTERPRISE SUBBASIN SURFACE SOILS
Enterprise Subbasin Groundwater Sustainability Plan

JACOBS

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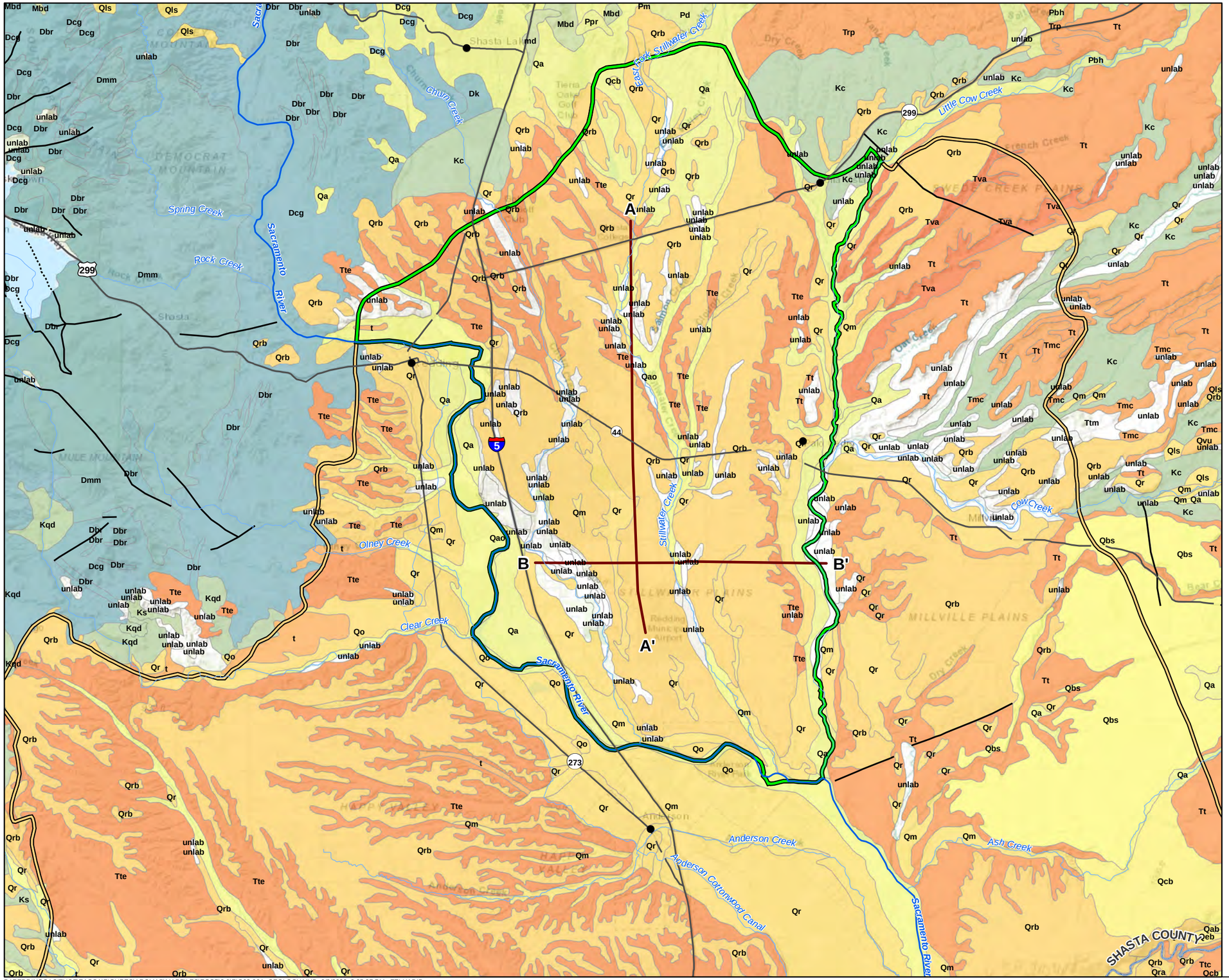

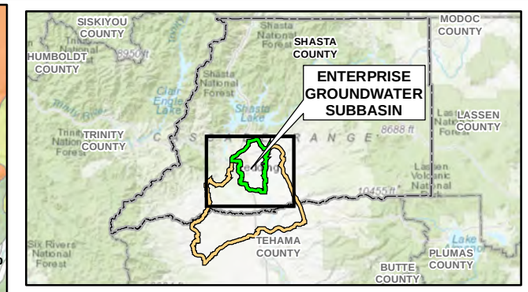

LEGEND

- CITY
- LOCATION OF CROSS SECTION
- FAULT LINE
- FAULT LINE (CONCEALED)
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTES:

GEOLOGY DERIVED FROM THE DIGITAL GEOLOGIC MAP OF THE REDDING 1° X 2° DEGREE QUADRANGLE, SHASTA, TEHAMA, HUMBOLDT, AND TRINITY COUNTIES, CALIFORNIA (USGS, 2012). FIGURE 3-6b PRESENTS EXPLANATION OF MAP UNITS.

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

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FIGURE 3-6a
ENTERPRISE SUBBASIN GEOLOGY
Enterprise Subbasin Groundwater Sustainability Plan

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FIGURE 3-6a MAP UNIT EXPLANATION

SURFICIAL DEPOSITS

- **t** Man-made materials (Holocene)
- **Qa** Alluvium and colluvium (Holocene)
- **Qo** Overbank deposits (Holocene)
- **Qao** Alluvial and overbank deposits, undivided (Holocene)
- **Qls** Landslide deposits (Holocene)
- **Qm** Modesto formation of Davis and Hall (1959) (Pleistocene)
- **Qr** Riverbank Formation (Pleistocene)
- **Qrb** Red Bluff formation of Diller (1894) (Pleistocene)
- **Qvu** Volcanic rocks of the Millville quadrangle (Pleistocene)

VOLCANIC ROCKS

- **Qbs** Basalt of Shingletown Ridge (Pleistocene)
- **Qeb** Olivine basalt of Eagle Canyon (Pleistocene)
- **Qab** Andesite of Brokeoff Mountain (Pleistocene)
- **Qra** Rockland ash bed of Sarna-Wojcicki and others (1982)
- **Qcb** Basalt of Coleman Forebay (Pleistocene)
- **Tva** Andesitic breccia (Pliocene)
- **Kqd** Shasta Bally Batholith (Lower Cretaceous)

PLUTONIC ROCKS

- **Tte** Tehama Formation (Pliocene)
- **Tt** Tuscan Formation, undivided (Pliocene)
- **Ttc** Lahars with minor interbedded volcanic conglomerate and sandstone

SEDIMENTARY ROCKS

- **Tmc** Montgomery Creek Formation (Eocene)
- **Kc** Chico Formation (Upper Cretaceous)
- **Ks** Sedimentary Rocks (Lower Cretaceous)
- **Trp** Pit Formation (Permian(?) or Triassic))
- **Pbh** Bully Hill Rhyolite (Permian(?)–Middle Triassic(?))
- **Pd** Dekkas Andesite (Permian)
- **Pm** McCloud Limestone (Pennsylvanian(?) and Permian)

EASTERN KLAMATH TERRANE

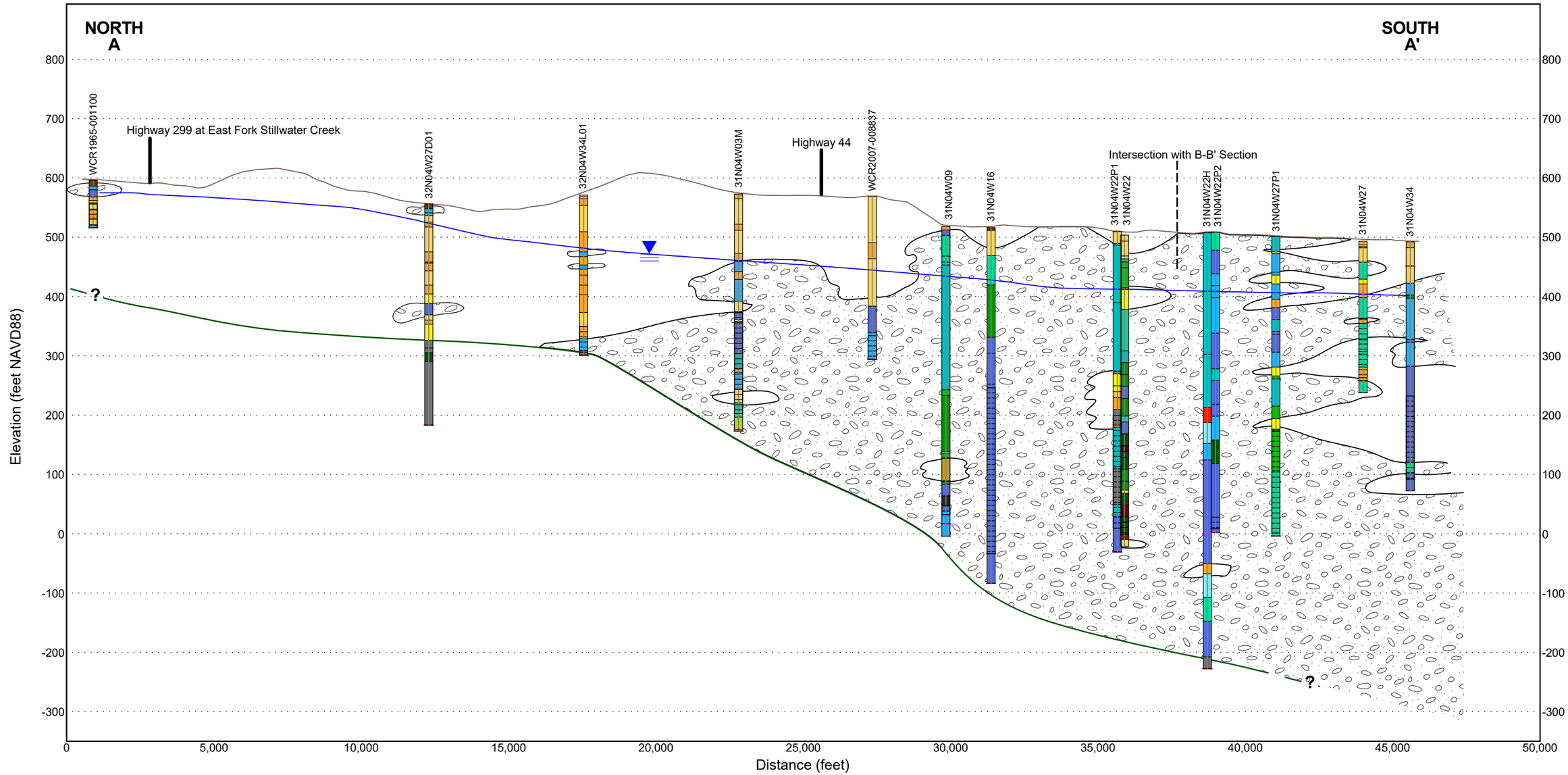
- **Ppr** Pit River stock (Permian)
- **md** Mafic rocks (Permian(?))
- **Mbd** Bragdon Formation (Mississippian)
- **Dk** Kennett Formation (Devonian)
- **Dmm** Mule Mountain stock (Devonian)
- **Dbr** Balaklala Rhyolite (Devonian(?))
- **Dcg** Copley Greenstone (Devonian(?))

NOTES:

GEOLOGY DERIVED FROM THE DIGITAL GEOLOGIC MAP OF THE REDDING 1° X 2° DEGREE QUADRANGLE, SHASTA, TEHAMA, HUMBOLDT, AND TRINITY COUNTIES, CALIFORNIA (USGS, 2012).

MAP UNIT (Ttm) LABELED ON THE MAP IS OF UNKNOWN IDENTITY AND AGE; OTHER AREAS (unlab) ARE OF UNKNOWN IDENTITY AND AGE. BOTH ARE UNFILLED ON THIS MAP.

FIGURE 3-6b
LIST OF MAP UNITS
Enterprise Subbasin Groundwater Sustainability Plan



GROUND SURFACE ELEVATION (feet NAVD88)

TOP OF CHICO FORMATION (DASHED WHERE UNCERTAIN)

GROUNDWATER ELEVATION (feet NAVD88)

SCREEN INTERVAL

SCALE EXAGGERATION – 20:1 (H:V)

SOIL AND LITHOLOGY

SAND	GRAVEL	CLAY	BASALT	FINE-GRAINED UNITS
CLAYEY SAND	CLAYEY GRAVEL	SANDY CLAY	HARD PAN	COARSE-GRAINED UNITS
GRAVELLEY SAND	SANDY GRAVEL	GRAVELLEY CLAY	SHALE	
SILTY SAND	SILTY GRAVEL	SILT	UNDIFFERENTIATED ROCK	
SANDSTONE	TUFF	SILTSTONE	UNDIFFERENTIATED SOIL	

NOTES:

LOCATION OF CROSS SECTION SHOWN ON FIGURE 3-6.

GROUNDWATER ELEVATION IS ESTIMATED FROM GROUNDWATER LEVELS MEASURED BETWEEN OCTOBER 16 AND OCTOBER 26, 2018 (DWR, 2019b) (SEE FIGURE 3-13).

TOP OF CASING ELEVATION OF SOME WELLS DIFFER FROM THE ELEVATION OF THE PROFILE BECAUSE THOSE WELLS ARE NOT COLLINEAR WITH THE SECTION LINE.

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988.

FIGURE 3-7
GEOLOGIC CROSS SECTION A-A'
Enterprise Subbasin Groundwater Sustainability Plan

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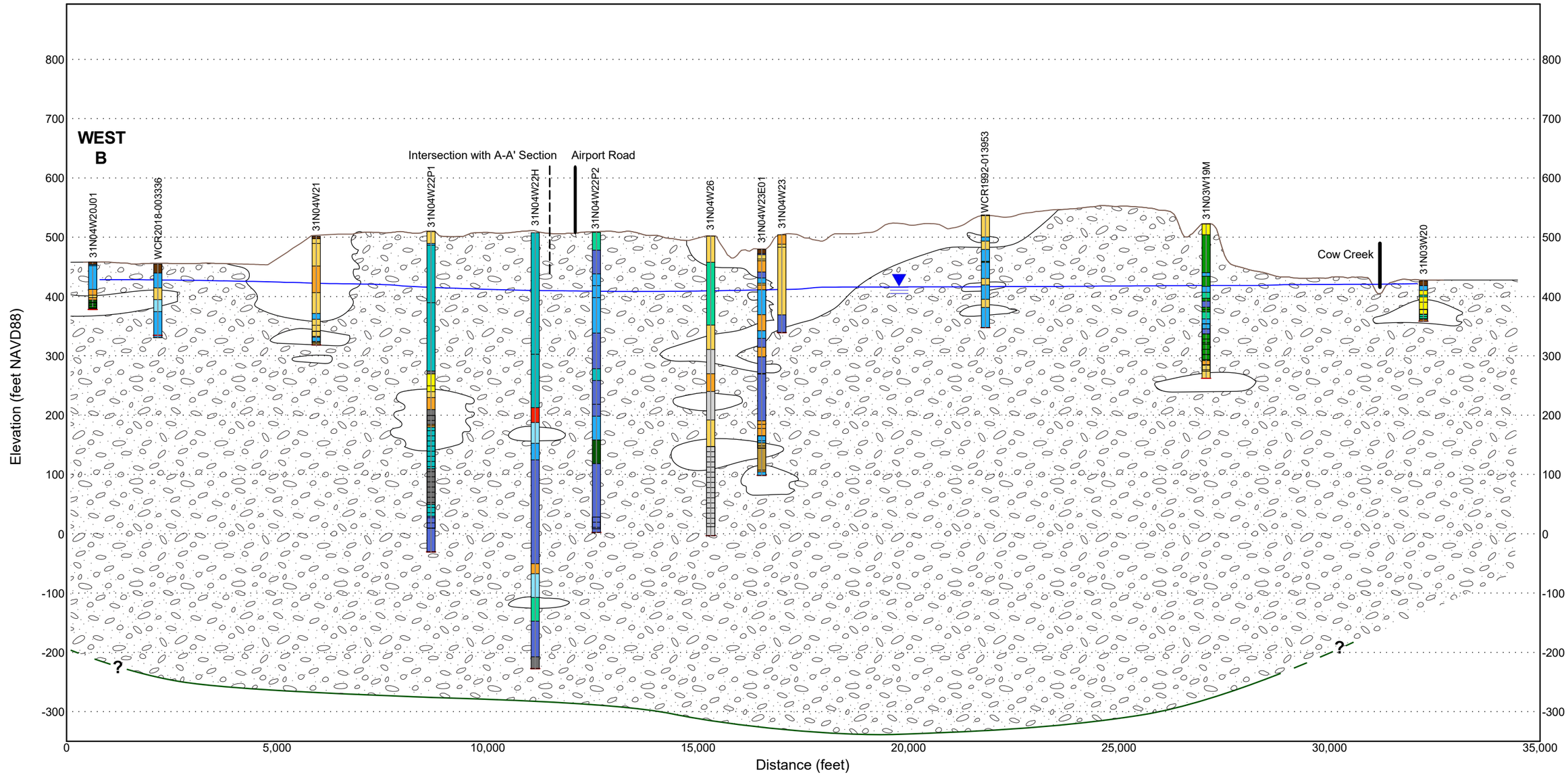

GROUND SURFACE ELEVATION (feet NAVD88)

TOP OF CHICO FORMATION (DASHED WHERE UNCERTAIN)

GROUNDWATER ELEVATION (feet NAVD88)

SCREEN INTERVAL

NOTES:

LOCATION OF CROSS SECTION SHOWN ON FIGURE 3-6.

GROUNDWATER ELEVATION IS ESTIMATED FROM GROUNDWATER LEVELS MEASURED BETWEEN OCTOBER 16 AND OCTOBER 26, 2018 (DWR, 2019b) (SEE FIGURE 3-13).

TOP OF CASING ELEVATION OF SOME WELLS DIFFER FROM THE ELEVATION OF THE PROFILE BECAUSE THOSE WELLS ARE NOT COLLINEAR WITH THE SECTION LINE.

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988.

SOIL AND LITHOLOGY

SAND	GRAVEL	CLAY	BASALT	FINE-GRAINED UNITS
CLAYEY SAND	CLAYEY GRAVEL	SANDY CLAY	HARD PAN	COARSE-GRAINED UNITS
GRAVELLEY SAND	SANDY GRAVEL	GRAVELLEY CLAY	SHALE	
SILTY SAND	SILTY GRAVEL	SILT	UNDIFFERENTIATED ROCK	
SANDSTONE	TUFF	SILTSTONE	UNDIFFERENTIATED SOIL	

SCALE EXAGGERATION – 14:1 (H:V)

FIGURE 3-8
GEOLOGIC CROSS SECTION B-B'
Enterprise Subbasin Groundwater Sustainability Plan

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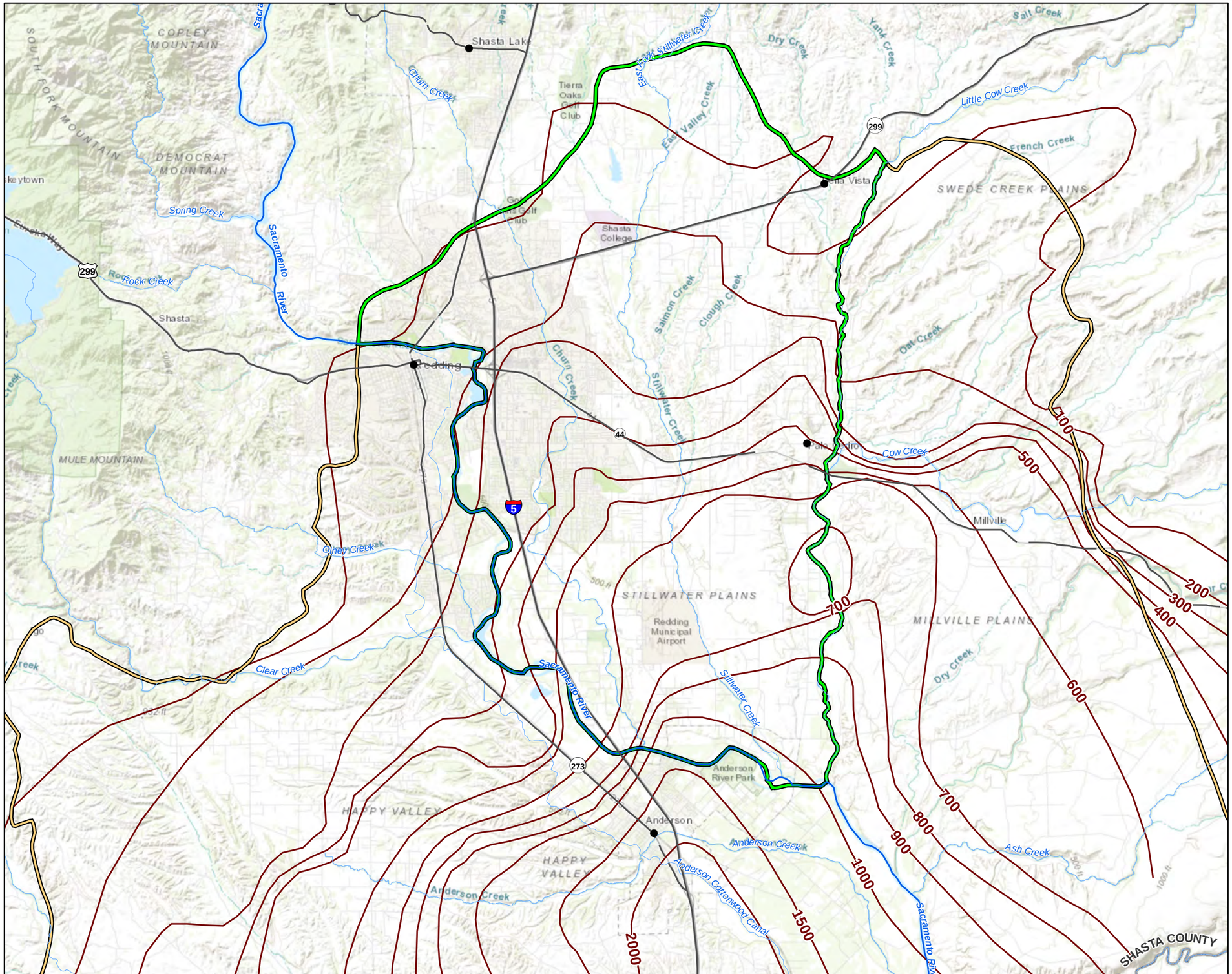

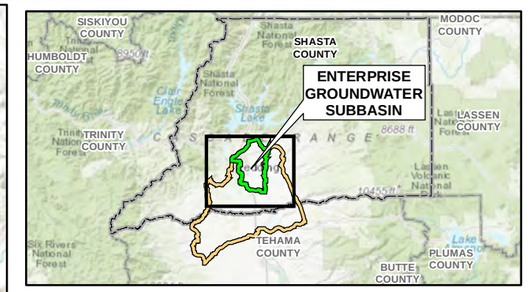

LEGEND

- CITY
- DEPTH TO CHICO FORMATION (feet BGS)
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTE:

DATA SOURCE: DIGITIZED FROM DWR, 1968

BGS = BELOW GROUND SURFACE

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

N

FIGURE 3-9
DEPTH TO THE TOP OF THE CHICO FORMATION
Enterprise Subbasin Groundwater Sustainability Plan

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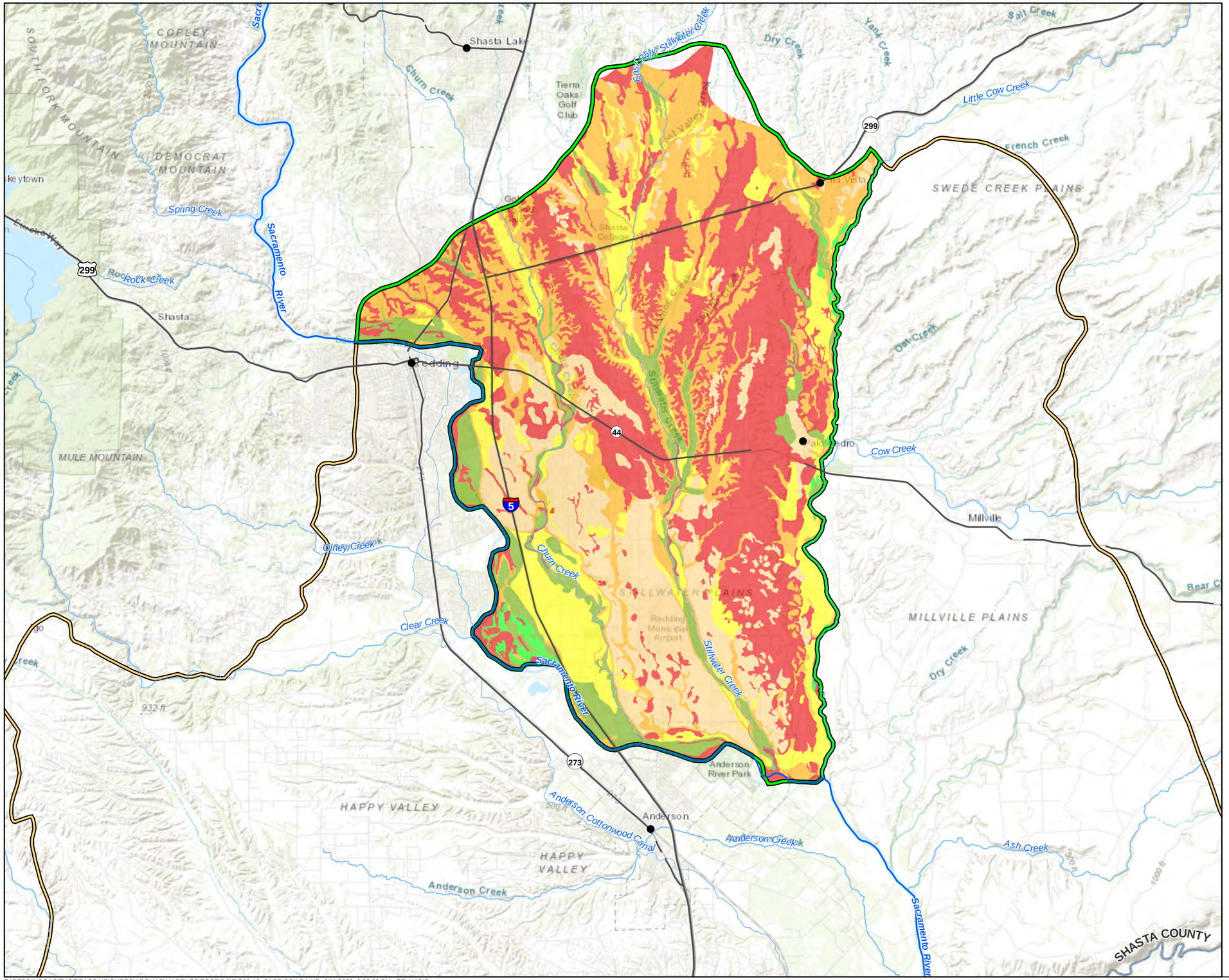

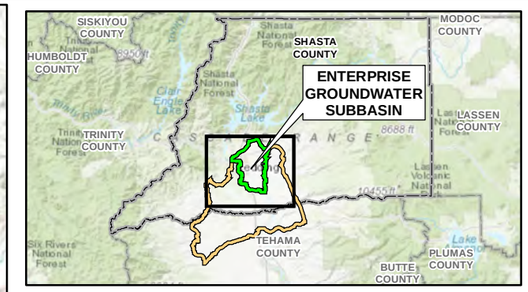

LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

SAGBI RATING (RATING CLASS)

- 85 to 100 (EXCELLENT)
- 69 to 85 (GOOD)
- 49 to 69 (MODERATELY GOOD)
- 29 to 49 (MODERATELY POOR)
- 15 to 29 (POOR)
- 0 to 15 (VERY POOR)

NOTES:

DATA SOURCE: SOIL AGRICULTURAL GROUNDWATER BANKING INDEX (SAGBI) (O'GEEN ET AL., 2015)

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

N

FIGURE 3-10
SOIL AGRICULTURAL GROUNDWATER BANKING INDEX MAP
Enterprise Subbasin Groundwater Sustainability Plan

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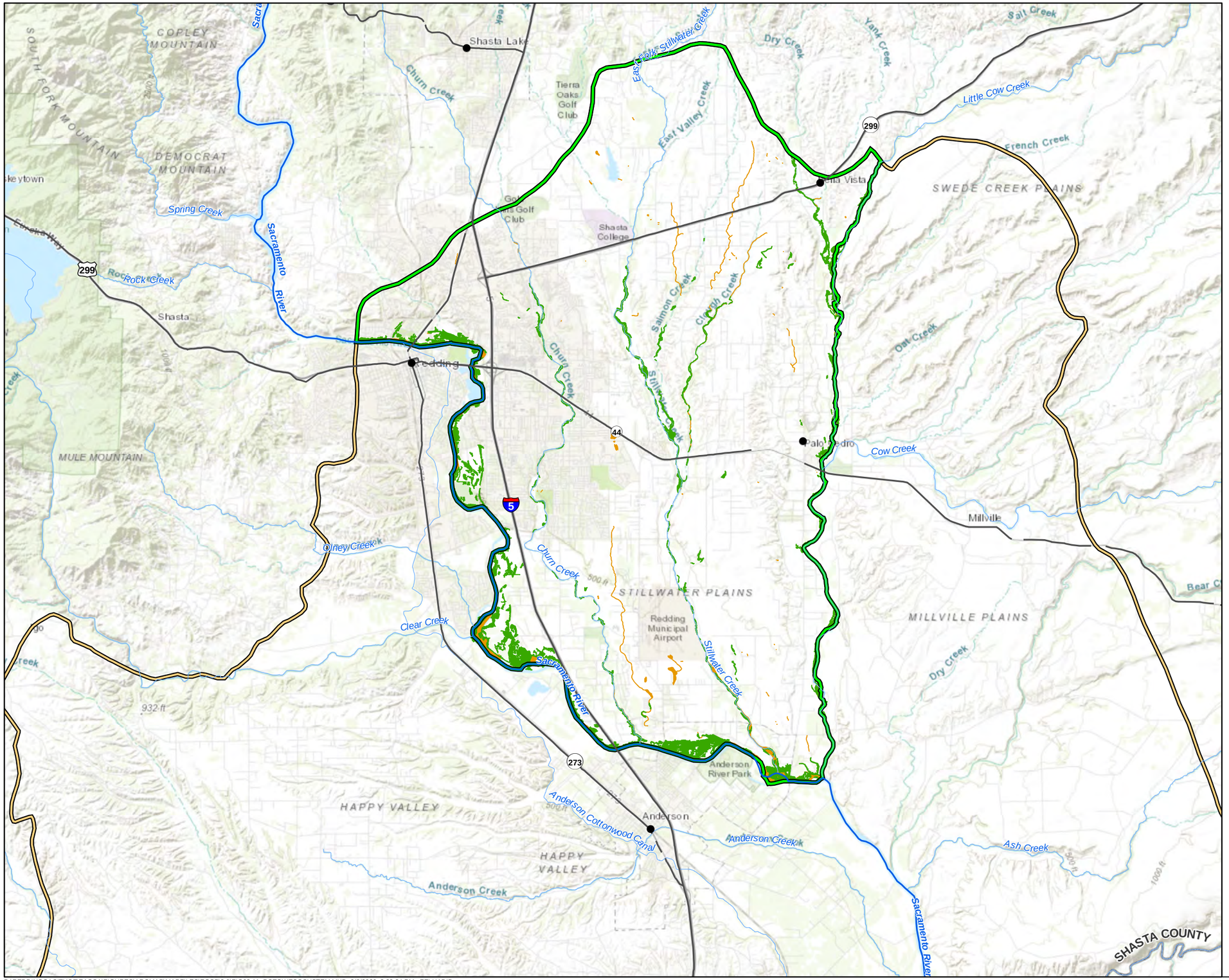

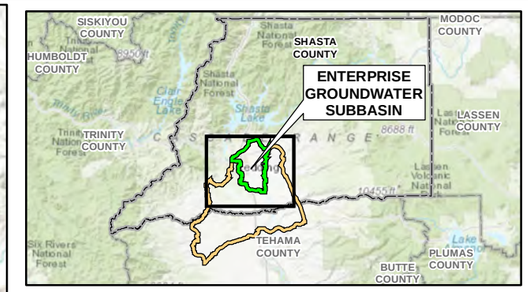

LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN
- NATURAL COMMUNITIES COMMONLY ASSOCIATED WITH GROUNDWATER VEGETATION
- NATURAL COMMUNITIES COMMONLY ASSOCIATED WITH GROUNDWATER WETLANDS

NOTES:

DATA SOURCE: HTTPS://GIS.WATER.CA.GOV/APP/NCDATASETVIEWER/#. ACCESSED MARCH 2020 (DWR, 2020c)

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

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FIGURE 3-11
POTENTIAL GROUNDWATER-DEPENDENT ECOSYSTEMS
Enterprise Subbasin Groundwater Sustainability Plan

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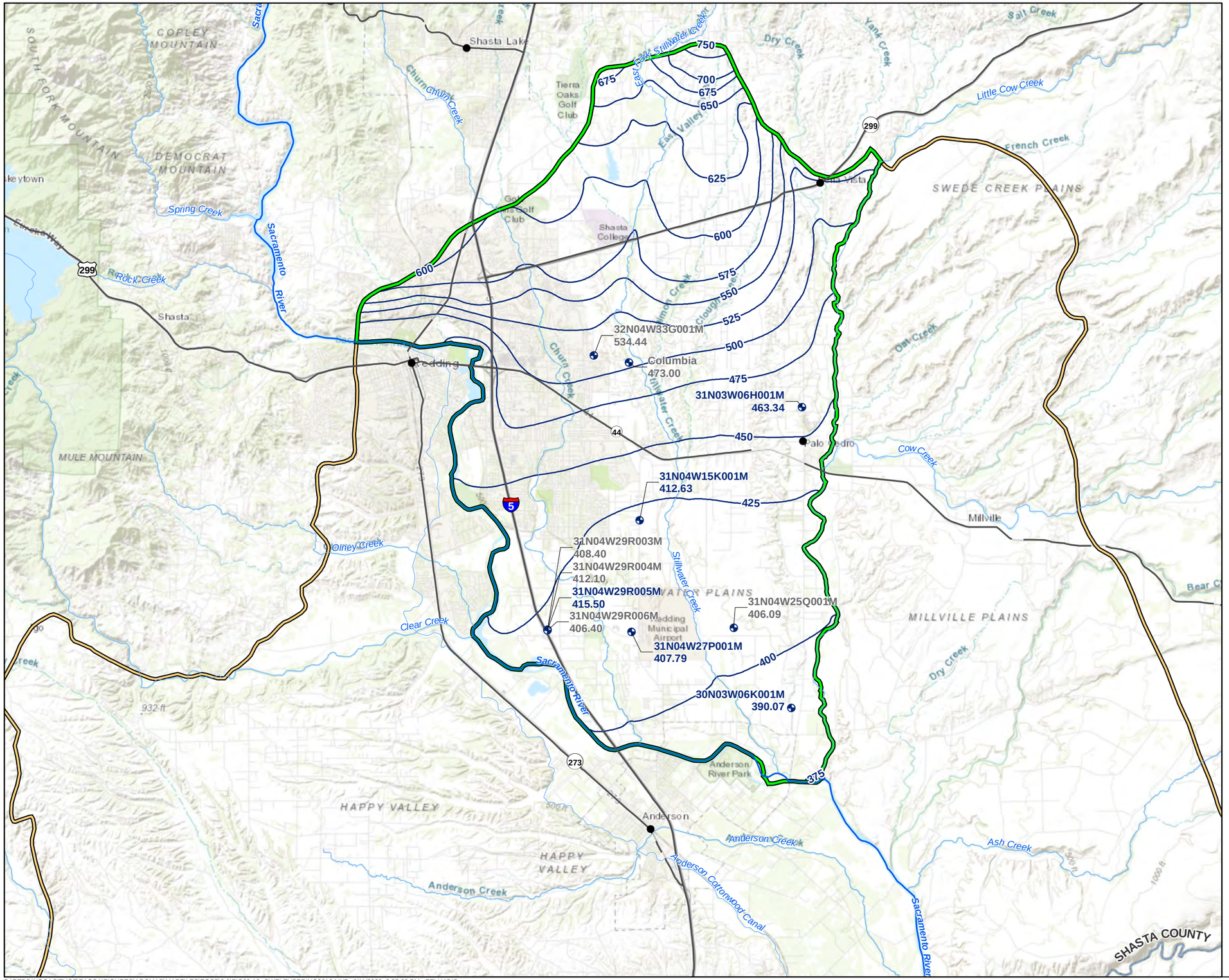

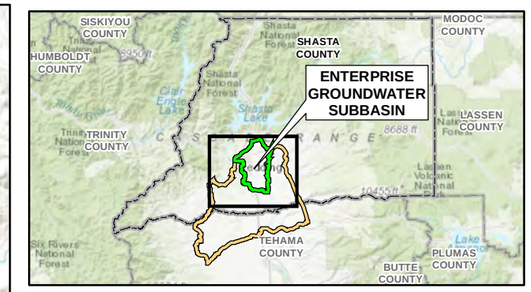

LEGEND

- GROUNDWATER ELEVATION LOCATION
- 463.34 MEASURED GROUNDWATER ELEVATION (feet NAVD88) (GRAY TEXT INDICATES ELEVATION NOT USED IN CONTOURING)
- CITY
- SPRING 2018 GROUNDWATER ELEVATION CONTOUR (feet NAVD88)
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTES:

GROUNDWATER LEVELS WERE MEASURED BETWEEN MARCH 19 AND APRIL 3, 2018 (DWR, 2019b).

WELLS SCREENED IN SHALLOW GROUNDWATER, POINT LOCATIONS ALONG SACRAMENTO RIVER WITH INTERPOLATED SURFACE WATER ELEVATIONS, AND RIVER GAGES BELOW KESWICK RESERVOIR (11370500) AND AT BEND BRIDGE IN RED BLUFF (11377100) WERE USED IN CONTOURING SHALLOW GROUNDWATER. REDFEM MODEL OUTPUTS WERE USED TO SUPPLEMENT AREAS WITHOUT CURRENT GROUNDWATER ELEVATION DATA (CH2M HILL, 2011 AND USGS, 2019a).

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

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FIGURE 3-12
SPRING 2018 GROUNDWATER ELEVATION CONTOURS
Enterprise Subbasin Groundwater Sustainability Plan

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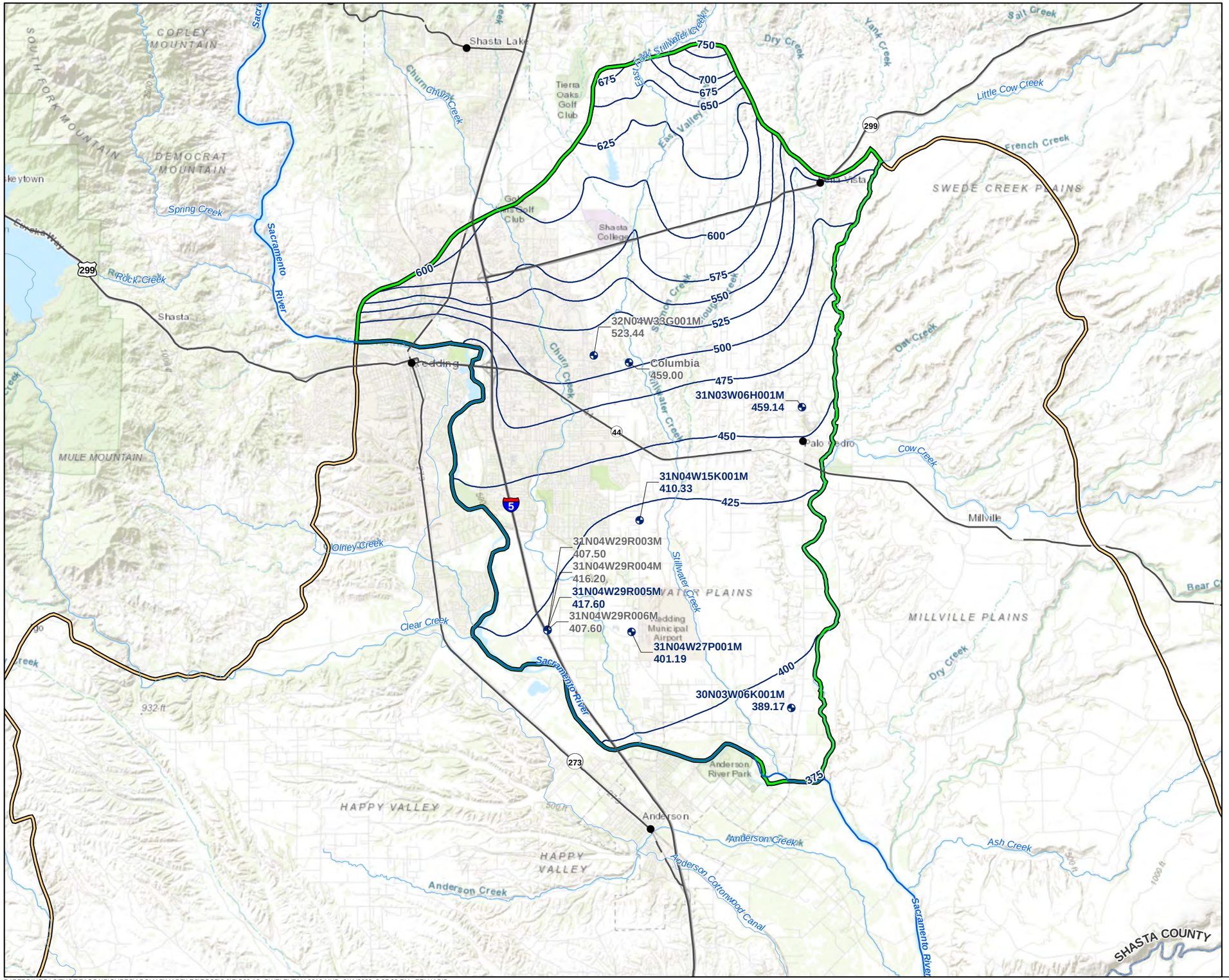
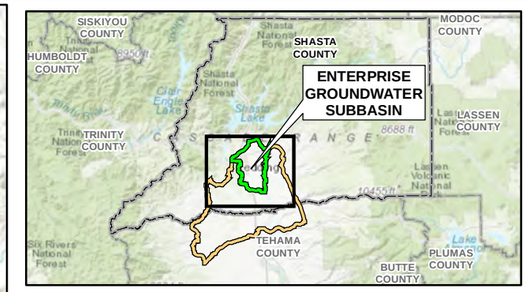




LEGEND

- GROUNDWATER ELEVATION LOCATION
- 463.34 MEASURED GROUNDWATER ELEVATION (feet NAVD88) (GRAY TEXT INDICATES ELEVATION NOT USED IN CONTOURING)
- CITY
- FALL 2018 GROUNDWATER ELEVATION CONTOUR (feet NAVD88)
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTES:

GROUNDWATER LEVELS WERE MEASURED BETWEEN OCTOBER 16 AND OCTOBER 26, 2018 (DWR, 2019b)

WELLS SCREENED IN SHALLOW GROUNDWATER, POINT LOCATIONS ALONG SACRAMENTO RIVER WITH INTERPOLATED SURFACE WATER ELEVATIONS, AND RIVER GAGES BELOW KESWICK RESERVOIR (11370500) AND AT BEND BRIDGE IN RED BLUFF (11377100) WERE USED IN CONTOURING SHALLOW GROUNDWATER. REDFEM MODEL OUTPUTS WERE USED TO SUPPLEMENT AREAS WITHOUT CURRENT GROUNDWATER ELEVATION DATA (CH2M HILL, 2011 AND USGS, 2019a)

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

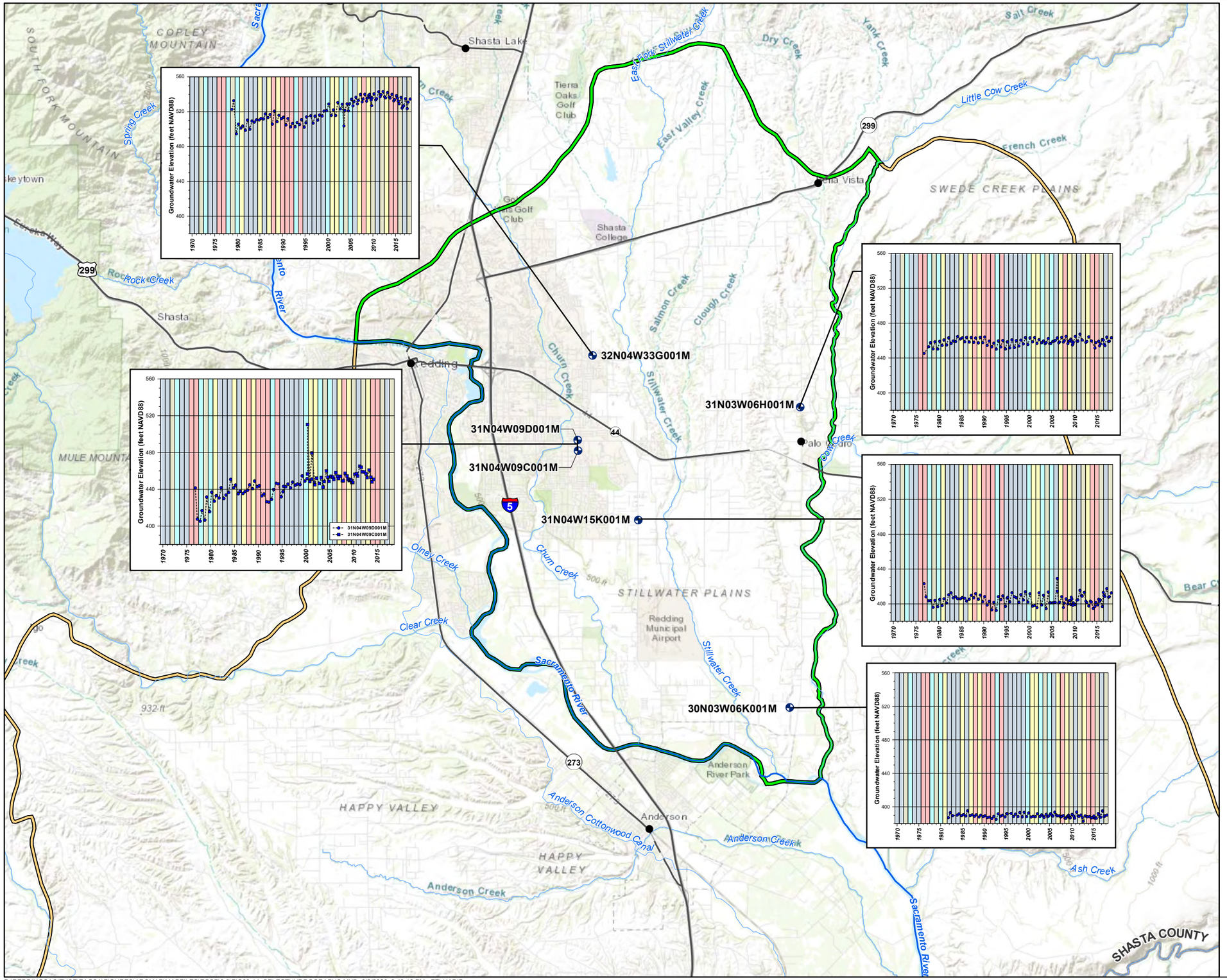
0 2 4 Miles

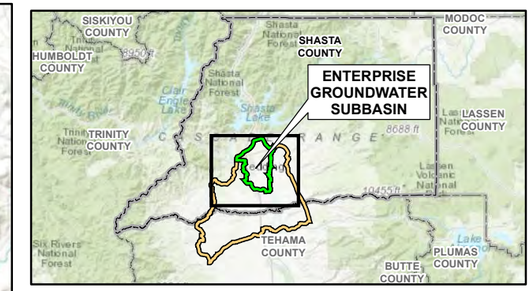
N

FIGURE 3-13
FALL 2018 GROUNDWATER ELEVATION CONTOURS
Enterprise Subbasin Groundwater Sustainability Plan

JACOBS

D:\REDDINGCACITYOF\EAGSA\FIGURES\ARCMAP\MAPFILES\EGSP\3.0\FIG03-13_GWELEVFALL2018.MXD 6/11/2020 3:37:23 PM FELHADID





MAP LEGEND

- GROUNDWATER ELEVATION LOCATION
- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

GRAPH LEGEND

- GROUNDWATER ELEVATION (feet NAVD88)

SACRAMENTO VALLEY HYDROLOGIC REGION UNIMPAIRED RUNOFF (5 MILLION ACRE-FEET)

- WET YEAR
- ABOVE NORMAL YEAR
- BELOW NORMAL YEAR
- DRY YEAR
- CRITICAL YEAR

NOTES:

DATA SOURCES: DWR, 2019b

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

FIGURE 3-14
SELECT HYDROGRAPHS
Enterprise Subbasin Groundwater Sustainability Plan

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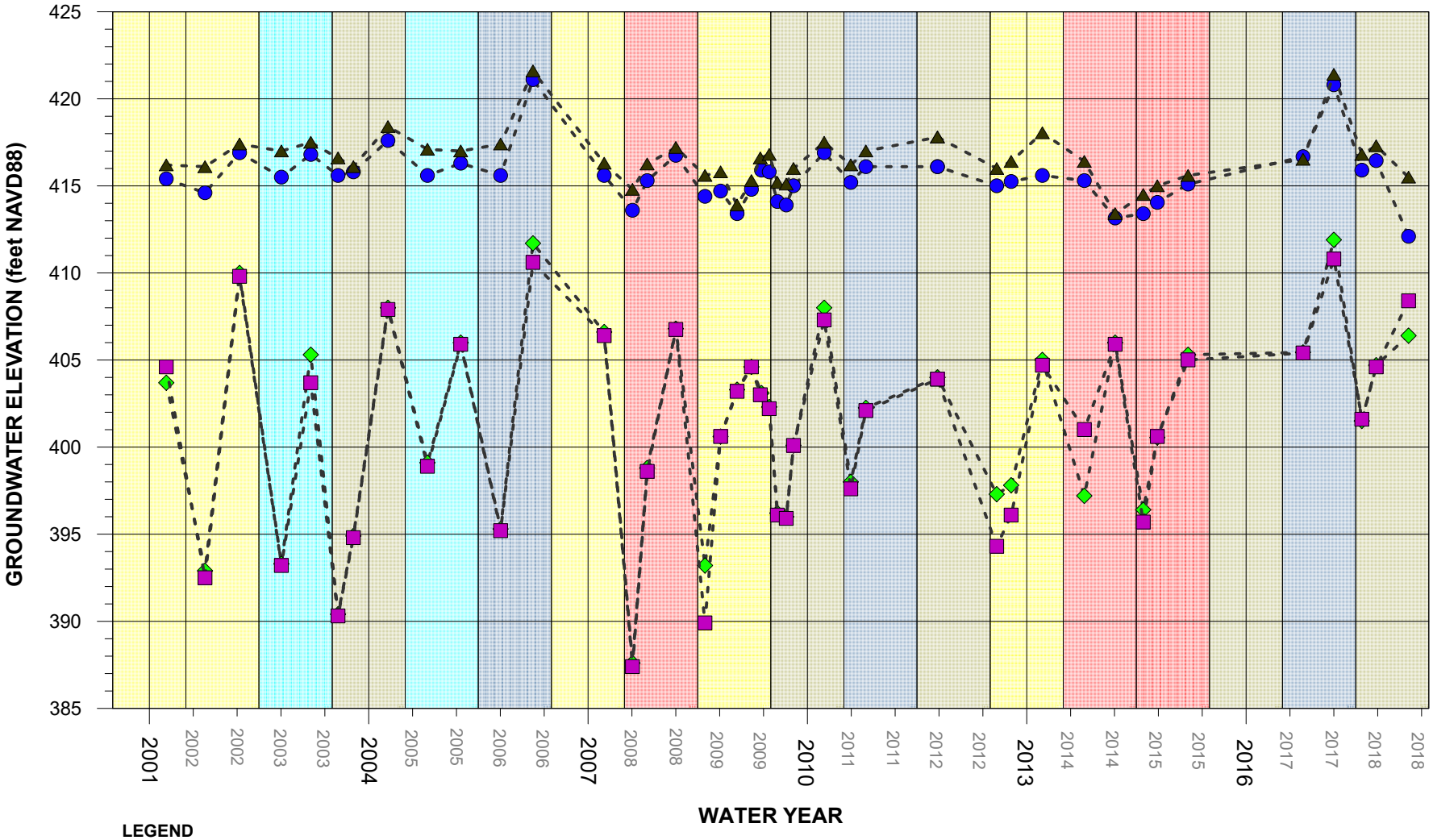


LEGEND

- 31N04W29R003M (200.6 to 119.6)
- 31N04W29R004M (275.6 to 235.6)
- 31N04W29R005M (330.6 to 320.6)
- 31N04W29R006M (199.6 to 119.6)

- WET YEAR
- ABOVE NORMAL YEAR
- BELOW NORMAL YEAR
- DRY YEAR
- CRITICAL YEAR

NOTES:

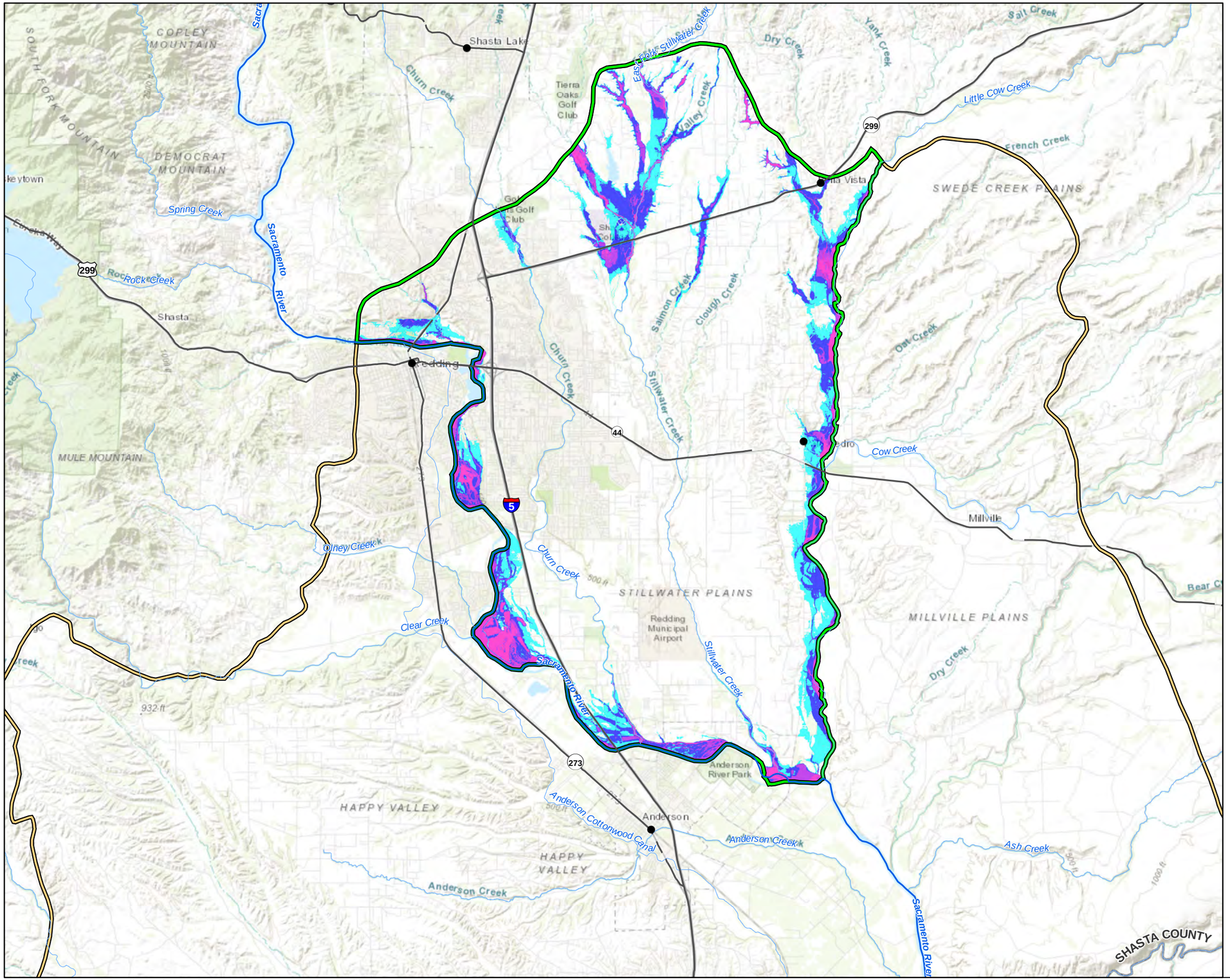
(200.6 to 119.6) = WELL SCREEN ELEVATION (feet NAVD88)

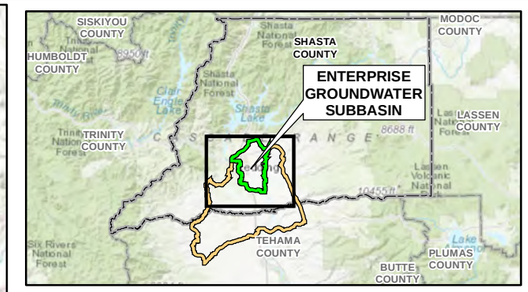
DATA SOURCES: DWR, 2019a and 2020a

NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988

FIGURE 3-15
ENTERPRISE SUBBASIN WELL CLUSTER HYDROGRAPHS
Enterprise Subbasin Groundwater Sustainability Plan

JACOBS





LEGEND

- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

GROUNDWATER LEVELS WITHIN 20 FEET OF GROUND SURFACE (feet BGS)

- ABOVE GROUND SURFACE TO 5 FEET
- 5 to 10
- 10 to 15
- 15 to 20

NOTES:

BGS = BELOW GROUND SURFACE

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

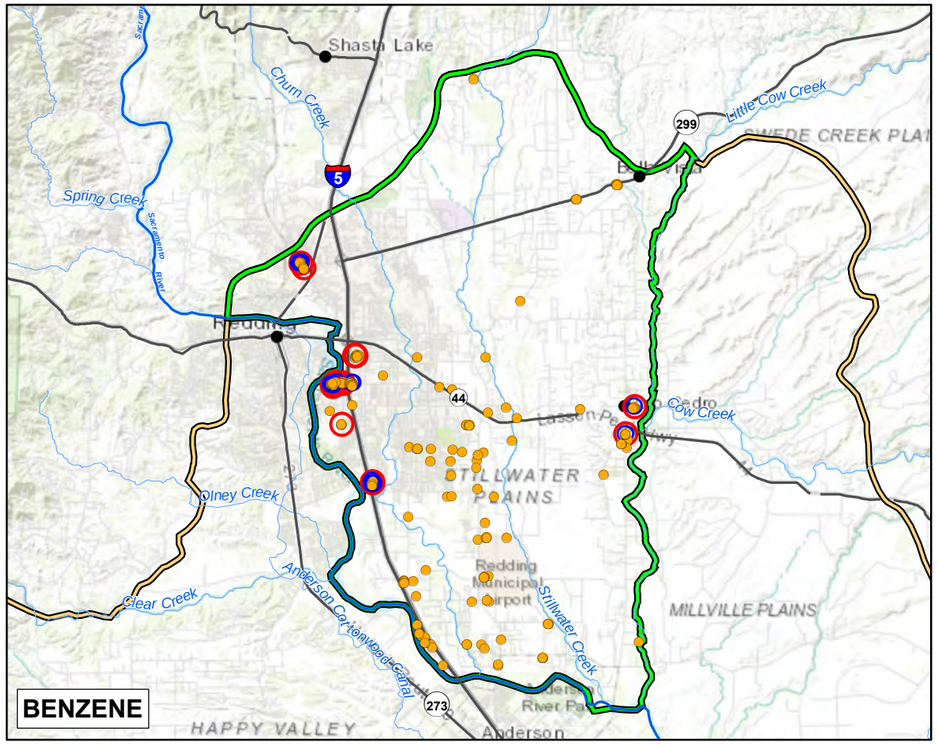
N

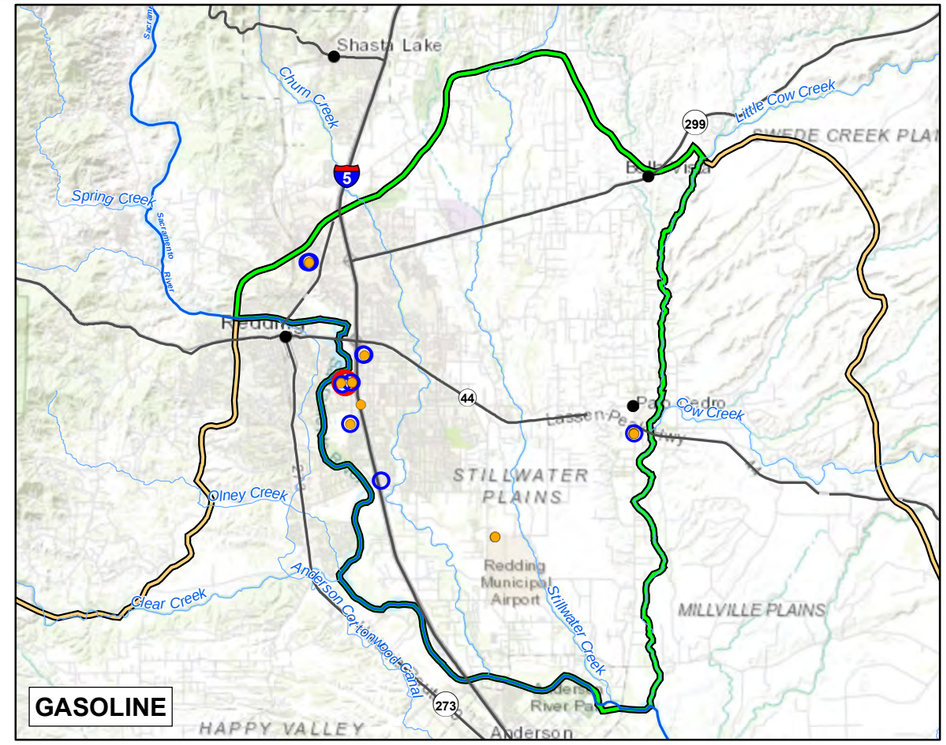
FIGURE 3-16
GROUNDWATER WITHIN 20 FEET OF LAND SURFACE
Enterprise Subbasin Groundwater Sustainability Plan

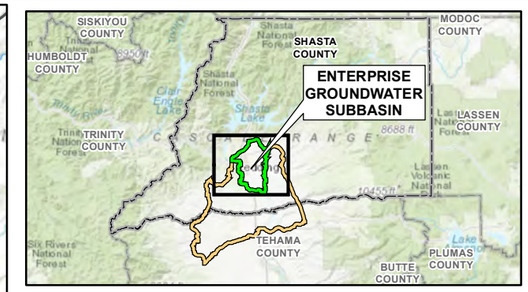
JACOBS

D:\REDDINGCACITYOF\EAGSA\FIGURES\ARCMAP\MAPFILES\EGSP\3.0\FIG03-16_GW_LANDSURFACE.MXD 6/8/2020 3:55:11 PM FELHADID

Figure 3-17
-PENDING-

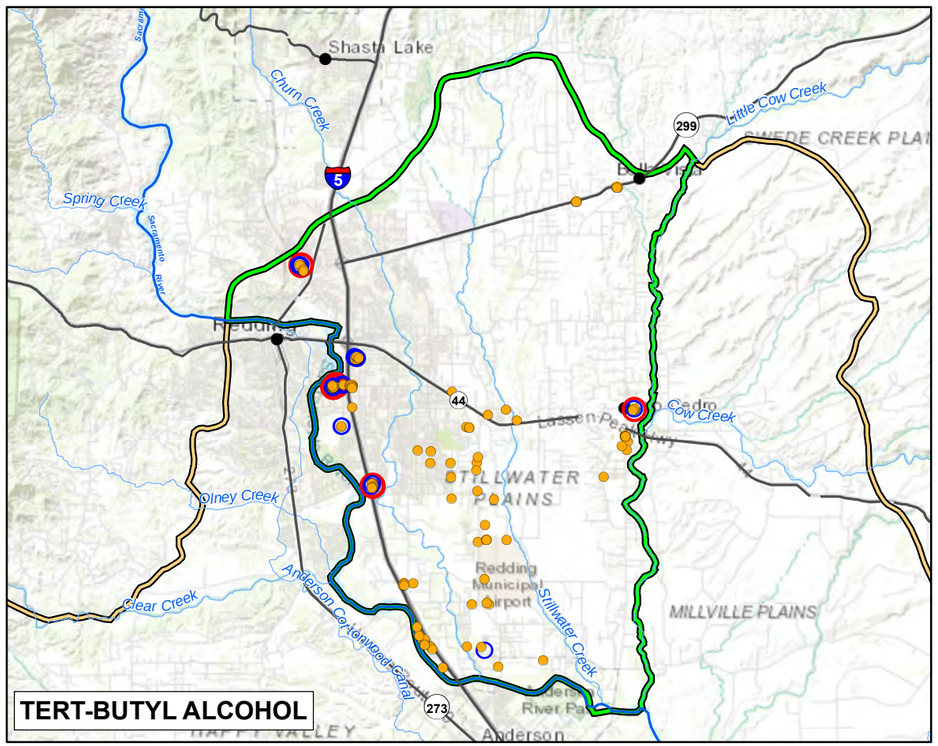


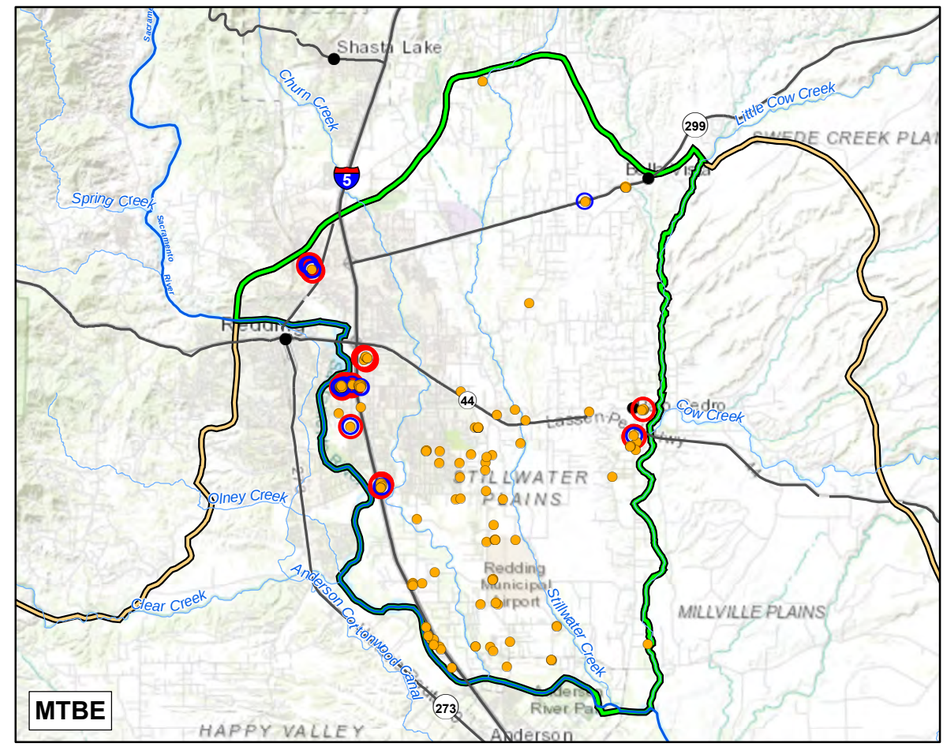




LEGEND

- SAMPLING LOCATION (NO EXCEEDANCES)
- SAMPLING LOCATION (1 to 5 EXCEEDANCES)
- SAMPLING LOCATION (> 5 EXCEEDANCES)
- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN





NOTES:

DATA USED TO ASSESS AREAS OF AFFECTED GROUNDWATER ARE FROM 2000 THROUGH 2019 (SWRCB, 2019a).

BENZENE CA EPA MAXIMUM CONTAMINANT LEVEL = 1 µg/L

GASOLINE US FEDERAL HEALTH ADVISORY LEVEL = 5 µg/L

TERT-BUTYL ALCOHOL FEDERAL NOTIFICATION LEVEL = 12 µg/L

METHYL-TERT-BUTYL ETHER (MTBE) CA EPA MAXIMUM CONTAMINANT LEVEL = 13 µg/L

µg/L = MICROGRAMS PER LITER

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 3.5 7 Miles

N

FIGURE 3-18
GROUNDWATER SAMPLING LOCATIONS – ORGANICS
Enterprise Subbasin Groundwater Sustainability Plan

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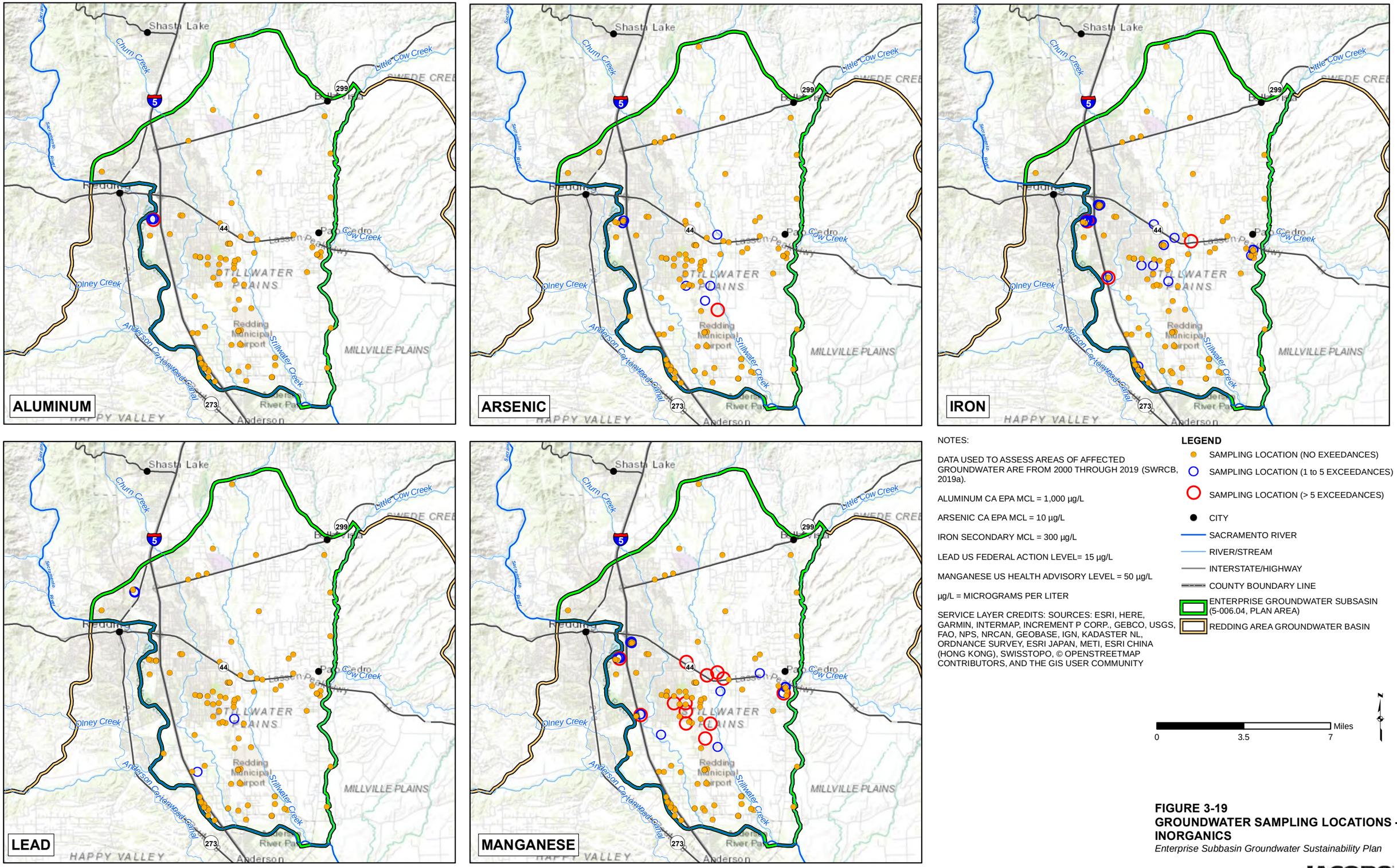

NOTES:

DATA USED TO ASSESS AREAS OF AFFECTED GROUNDWATER ARE FROM 2000 THROUGH 2019 (SWRCB, 2019a).

ALUMINUM CA EPA MCL = 1,000 µg/L

ARSENIC CA EPA MCL = 10 µg/L

IRON SECONDARY MCL = 300 µg/L

LEAD US FEDERAL ACTION LEVEL= 15 µg/L

MANGANESE US HEALTH ADVISORY LEVEL = 50 µg/L

µg/L = MICROGRAMS PER LITER

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

LEGEND

- SAMPLING LOCATION (NO EXEEDANCES)
- SAMPLING LOCATION (1 to 5 EXCEEDANCES)
- SAMPLING LOCATION (> 5 EXCEEDANCES)
- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

0 3.5 7 Miles

N

FIGURE 3-19
GROUNDWATER SAMPLING LOCATIONS – INORGANICS
Enterprise Subbasin Groundwater Sustainability Plan

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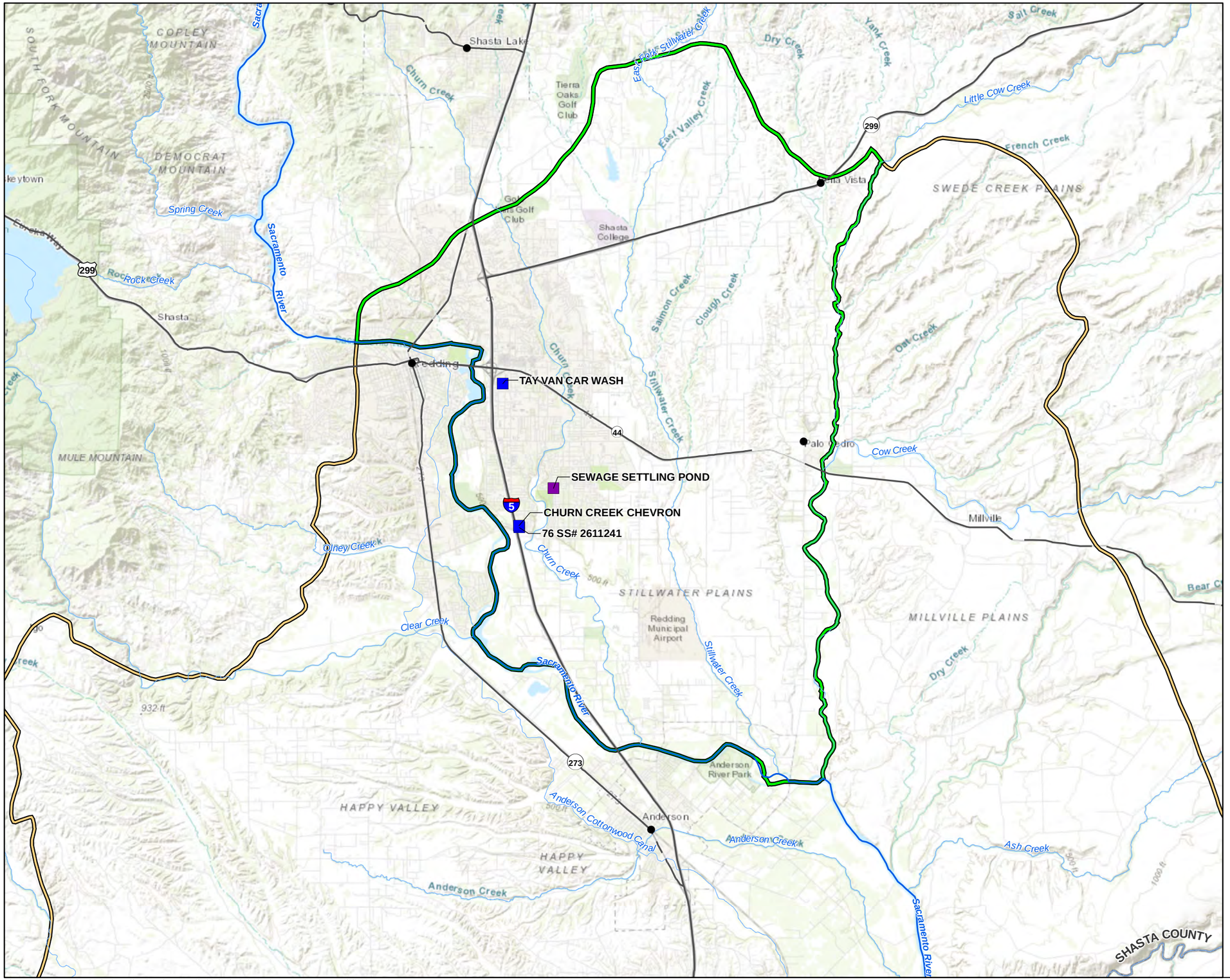

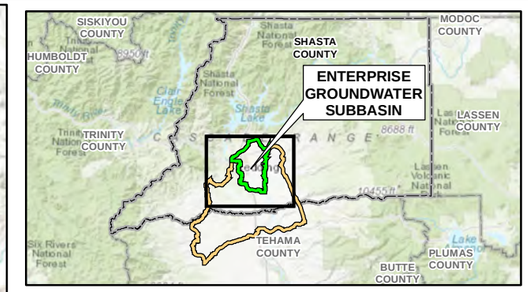

LEGEND

ACTIVE REMEDIATION SITE

- CALIFORNIA STATE DEPARTMENT OF TOXIC SUBSTANCES CONTROL
- STATE WATER RESOURCES CONTROL BOARD
- CITY
- SACRAMENTO RIVER
- RIVER/STREAM
- INTERSTATE/HIGHWAY
- COUNTY BOUNDARY LINE
- ENTERPRISE GROUNDWATER SUBSASIN (5-006.04, PLAN AREA)
- REDDING AREA GROUNDWATER BASIN

NOTES:

DATA SOURCES: DTSC, 2019 AND SWRCB, 2019b

SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

0 2 4 Miles

FIGURE 3-20
ACTIVE REMEDIATION SITES
Enterprise Subbasin Groundwater Sustainability Plan

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