BASIN SETTING

(SUBTITLE PAGE)

6. INTRODUCTION TO BASIN SETTING

§ 354.12. Introduction to Basin Setting
This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.

The following four sections describe the the physical setting and characteristics of the basin and current conditions of the Livermore Valley Groundwater Basin (Basin) (**Figure 7-1)** including the Hydrogeologic Conceptual Model (HCM, **Section 7**), the Current and Historical Groundwater Conditions (**Section 8**), the Water Budget Information (**Section 9**), and the description of the Management Areas (**Section 10**). The Basin Setting data gaps and levels of uncertainty are discussed in **Section 7.5**. These sections were prepared under direction of professional geologist Tom Rooze (PG 6039, CEG 1918) and professional engineer Ken Minn (PE 54394).

7. HYDROGEOLOGIC CONCEPTUAL MODEL

§ 354.14. Hydrogeologic Conceptual Model
(a) Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.

☑ **23 CCR § 354.14(a)**

This section presents the Hydrogeologic Conceptual Model (HCM) for the Livermore Valley Groundwater Basin (Basin). As described in the HCM Best Management Practices (BMP) document (*DWR, 2016a*), a HCM provides, through descriptive and graphical means, an understanding of the physical characteristics of an area that affect the occurrence and movement of groundwater, including geology, hydrology, land use, aquifers and aquitards, and water quality. This HCM serves as a foundation for subsequent Basin Setting analysis including Groundwater Conditions (**Section 8**), Water Budgets (**Section 9**), and the development of Sustainable Management Criteria (**Sections 11** through **13**).

7.1. General Description

§ 354.14. Hydrogeologic Conceptual Model
(b) The hydrogeologic conceptual model shall be summarized in a written description that includes the following:
- *(1) The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.*
- *(2) Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.*
- *(3) The definable bottom of the basin.*
- *(4) Principal aquifers and aquitards, including the following information:*
  - *(A) Formation names, if defined.*
  - *(B) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.*
  - *(C) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.*
  - *(D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.*
  - *(E) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.*
- *(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model*

7.1.1. Geological and Structural Setting

☑ 23 CCR § 354.14(b)(1)

The Basin is an east-west trending, inland structural basin located in northeastern Alameda County and extending slightly into southern Contra Costa County. The Basin covers 69,600 acres and includes the Livermore Valley (Valley) (41,841 acres) and the hills south of Pleasanton and Livermore (27,759 acres). The Valley has been divided into the Main Basin Management Area (Main Basin, 19,800 acres) and Fringe Management Area (Fringe Area, 22,041 acres) for purposes of groundwater management, while the surrounding hills are collectively referred to as the Upland Management Area (Upland Area).

The Valley is defined primarily by northwest-southeast trending faults and upland bedrock hills of the Diablo Range. The Valley extends approximately 14 miles in an east-west direction with a width of between three and six miles. It is separated from the San Francisco Bay by several northwesterly trending ridges of the California Coast Ranges, including the Pleasanton Ridge. Structural uplift of the Coast Range during the late middle Pliocene and Pleistocene created extensive folding and faulting of the region, which formed the Valley. The Valley is an asymmetrical syncline of Miocene-Pliocene sandstones and conglomerates generally bounded by the Calaveras Fault on the west and the Greenville Fault on the east, as shown on **Figure 7-2.**

Figure 7-2 presents a schematic geologic/tectonic map that illustrates the tectonic history and formation of the Valley. As indicated on the map, the Valley is the result of deformation between the southward movement of the Mt. Diablo thrust sheets north of the Valley and the Diablo Range uplift south of the Valley. The tectonic history of the Valley began with the uplift of the Diablo Range, which created ancestral streams (including ancestral Arroyo Mocho) that initially flowed north toward San Ramon (and continuing northwest to the Concord area). Up to 12,000 feet (ft) of Pliocene-age sediments (including the Livermore Gravels and equivalent formations) were deposited in this Proto-Livermore Basin. These sediments were down-warped with the subsequent thrusting associated with Mt. Diablo to the north (see Mt. Diablo frontal thrust zone labeled on **Figure 7-2**). This thrust zone closed the Basin on the north and re-directed surface drainage to the southwest. Additional tectonic activity along the Calaveras and Greenville fault zones continued to deform and shape the Valley.

The geologic map on **Figure 7-3** illustrates the older deformed sedimentary and bedrock units defining the Basin along with the valley-fill alluvial sediments; the Basin is outlined in black on the map. The map also contains many of the northwest-southeast trending faults that have offset the consolidated geologic units and, in some cases, shallow alluvium.

As shown on **Figure 7-3**, the Valley is partially filled with Pleistocene-Holocene age alluvium (Qu), consisting of alluvial fan, fluvial, and lake deposits that range in thickness from a few feet along the margins to more than 400 ft in the west-central Valley. The alluvium consists of unconsolidated gravel, sand, silt, and clay. The southern and southwestern alluvial deposits consist primarily of sand and gravel that were deposited by the ancestral and present Arroyo Valle and Arroyo Mocho. These deposits are rimmed by slightly older terrace deposits (Qt).

The eastern and northern Fringe Areas of the Valley are also filled with recent alluvial deposits, but these sediments were deposited from smaller streams and consist of thin, alternating layers of gravel, sand, silt, and clay that are laterally discontinuous. Consolidated units underlie the thin alluvial deposits as demonstrated by several areas in the northeast Basin where these units crop out at the surface (see **Figure 7-3**). These outcrops consist of the older consolidated units north and south of the Valley that underlie the alluvium (Pliocene-Miocene Green Valley/Tassajara group [Tgvt] units on the north and younger Pliocene-Pleistocene Livermore gravels [QTl] on the south, discussed in more detail below).

The Basin is bounded on the north by uplands of the Tassajara and Green Valley Formations (Tgvt), consolidated units of Pliocene and Miocene age. These units consist of sandstone, tuffaceous sandstone/siltstone, conglomerate, shale, and limestone deposited under both brackish and freshwater conditions. Although the Tassajara Formation is in contact laterally and underlies the alluvium of the northern Fringe Area, subsurface groundwater inflow is thought to be minor. The extreme deformation associated with the Mt. Diablo thrust sheets has created numerous bounding faults and steep geologic dip in the subsurface. In addition, the Tassajara Formation north of the Valley consists of tuffaceous-clay-rich sediments of low permeability and weather to mostly clay soils (see **Section 7.7.3**).

Geologic units in the southern portions of the Basin consist primarily of the Livermore Formation (QTl) of Pliocene-Pleistocene age. The Livermore Formation (also referred to as the Livermore Gravels) consists of beds of clayey gravels and sands, silt, and clay that are unconsolidated to semi-consolidated and estimated to be 4,000 ft thick in the southern and western portion of the Basin. The formation dips to the south and underlies the Basin. Within the Upland Area, the Livermore Formation is well-cemented with relatively low permeability and has been associated with low-yielding wells. Within the Main Basin, the upper 200-300 ft of Livermore Formation is sufficiently weathered and comprises the lower portion of the Lower Aquifer, as further described in **Sections 7.3 and 7.4**.

Additional information regarding Basin boundaries, delineation of Management Areas and subareas, and definition of Principal Aquifer units is provided in **Sections 7.2** through **7.4** below. Additionally, three novel cross-sections have been prepared for the Basin as part of the current (2021) Alternative Groundwater Sustainability Plan (Alt GSP) Update. These cross-sections are presented and described in detail in **Section 7.6.**

7.2. Lateral Basin Boundaries

☑ **23 CCR § 354.14(b)(2)**

7.2.1. Overview

As described above, the Basin's extent is delineated primarily by the recent alluvium and southern uplands of the Livermore Formation (see **Figure 7-3**). The sediments within the upper portions of the Livermore Formation and the overlying recent alluvium combine to form the aquifer system of the Basin, which has been subdivided into an Upper Aquifer and a Lower Aquifer in the Main Basin. The lower Livermore and Tassajara Formations and other upland bedrock units that crop out around the alluvium have not been found to yield significant quantities of water in wells and thus represent the effective bottom of the Basin, as described in **Section 7.3**.

For the purposes of groundwater investigations and management, the non-upland areas have been divided into the Main Basin and Fringe Areas, based on the thickness of the alluvium and changes in stratigraphy and groundwater quality. These two Management Areas have been further subdivided into subareas (previously referred to as subbasins), as shown on **Figure 7-4**. Boundaries of the Management Areas and subareas are described in more detail below and in **Section 10**.

7.2.2. Main Basin Management Area

The Main Basin covers 19,800 acres and contains the thickest alluvial deposits, the highest-yielding aquifers, and the best quality groundwater within the Basin. The Main Basin is defined by the following boundaries:

- on the west by northwesterly trending ridges of the California Coast Ranges (including Pleasanton Ridge) and the Calaveras Fault,
- on the north by stratigraphic and structural changes associated with relatively shallow bedrock and thin, clay-rich deposits sourced from the steeply-dipping bedrock of the Tassajara Uplands,
- on the east by bedrock outcrops, thin alluvial deposits, and upland areas of the Basin, and
- on the south by outcrops of the lower Livermore Formation (Upland Area).

The Main Basin has a much larger capacity to store and convey groundwater than the surrounding Management Areas. The thick and generally more permeable aquifers have been divided into Upper and Lower Aquifers, discussed in more detail in **Section 7.4**. In particular, the Lower Aquifer is tapped by most of the Basin's production wells. Since the early 1900s, the Lower Aquifer of the Main Basin has been the most significant for local groundwater supply. Accordingly, many of The Alameda County Flood Control and Water Conservation District, Zone 7's (Zone 7 Water Agency or Zone 7) management actions have focused on enhancement and protection of the Main Basin aquifers.

7.2.3. Subareas within the Main Basin

7.2.3.1. Overview

The Main Basin has been further subdivided into four Subareas to delineate areas of similar groundwater conditions and to provide a reference framework for locating wells and defining conditions of water supply. The Subarea names and boundaries are summarized below and shown on **Figure 7-4**.

7.2.3.2. Castle Subarea

The Castle Subarea is a thin strip that extends along the southwestern portion of the Main Basin. It is bounded to the south, west, and north by marine sediments of the Coastal Range and to the east by the Calaveras Fault. While usually included in the Main Basin, this subarea is not used for municipal groundwater production. This subarea functions as a westward extension of the Bernal Subarea.

7.2.3.3. Bernal Subarea

The Bernal Subarea is in the southwestern portion of the Basin and is bounded to the west by branches of the Calaveras Fault, to the east by the inferred extension of the Pleasanton Fault, to the north by the Parks Boundary, and to the south in part by contact with non-water-bearing formations and in part by contact with the Verona Fault. Both unconfined and confined aquifers exist in the subarea.

The area overlying the Bernal Subarea is the point of convergence for all major streams that drain the Valley and converge into the Arroyo de la Laguna. Like surface water, groundwater also historically converges in this subarea, which allows for the mixing of various groundwater qualities throughout the Basin.

The Recent (Holocene) and Quaternary alluvium is estimated to have a thickness of up to 400 ft in this subarea and overlies the Livermore Formation, of which another 200 ft is suitable for groundwater production. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges up to 3,500 gallons per minute (gpm), and specific capacities range from 3 to 260 gpm per foot of drawdown.

7.2.3.4. Amador Subarea

The Amador Subarea is in the west central portion of the Basin and is bounded to the west by the inferred extension of the Pleasanton Fault, to the east by the Livermore Fault, to the north by a permeability barrier of inter-fingering of alluvial deposits, and to the south by the drainage divide and contact with consolidated units of the Upland Area. This subarea contains most of the high-yielding wells and has both unconfined (Upper Aquifer) and confined (Lower Aquifer) aquifers.

The Recent (Holocene) and Quaternary alluvium has a maximum thickness in this subarea of approximately 600 ft and overlies the Livermore Formation, of which another 200-300 ft is suitable for groundwater production. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges from 42 to 2,820 gpm and specific capacities range from 1.1 to 217 gpm per foot of drawdown.

7.2.3.5. Mocho Subarea

The Mocho Subarea has been divided into two distinct areas, Mocho I (Fringe Area) and Mocho II (Main Basin), by a line of very low hills thought to be exposures of the Livermore Formation. The subareas are further distinguished by a change in groundwater chemistry.

Mocho II Subarea is located in the east central portion of the Basin and is bounded to the west by the Livermore Fault, to the east by thinning young alluvium and exposed Livermore Formation, to the north by the consolidated bedrock of the Tassajara Formation, and surrounded in the south by the Upland Area. Both unconfined and confined aquifers exist in the water-bearing sediments.

The Recent (Holocene) and Quaternary alluvium ranges in thickness from approximately 10 to 50 ft in Mocho I Subarea and up to 150 ft in Mocho II Subarea. In both subareas the alluvium overlies the Livermore Formation, both conformably and unconformably. Mocho I and Mocho II Subareas appear to be hydraulically connected only in the shallow alluvial deposits. Wells in this subarea are primarily owned and operated by California Water Company (Cal Water). Production ranges up to 950 gpm with specific capacities of 2 to 50 gpm per foot of drawdown.

7.2.4. Fringe Management Area

As shown on **Figure 7-3 and Figure 7-4**, the Fringe Area is defined by areas outside of the Main Basin that contain thinner deposits of Recent (Holocene) alluvium underlain by shallow, semi-permeable deposits of the Livermore Formation. The Fringe Area is also characterized by lower permeability aquifers overlain by clay-rich soils. Because the alluvium is generally thinner, the primary hydraulic connection between the Fringe Area and the Main Basin is through the Upper Aquifer. In general, Lower Aquifer units in the Main Basin do not extend into the Fringe Area. The most significant area of subsurface inflow from the Fringe Area into the Main Basin occurs in the Upper Aquifer along the northwestern boundary (at the Bernal and Amador subareas) of the Main Basin, estimated to be about 1,000 acre-feet per year (AFY), based on observations from transect wells.

Similar to the Main Basin, ten subareas have been defined in the Fringe Area to delineate areas of similar groundwater conditions and to provide a reference framework for locating wells. These subareas were defined in the 1970s using primarily inferred fault traces for many of the boundaries. Although the presence of some of the faults has either been re-interpreted or not confirmed, the subarea delineation provides a useful system for groundwater management and has been retained in subsequent groundwater documents. Subareas in the northwest include Bishop, Dublin, and Camp. Subareas in the northeast include Cayetano, May, Vasco, Altamont, Spring, and Mocho I.

7.2.5. Upland Management Area

The Upland Area is primarily defined by outcrops of the Livermore Formation and older bedrock units. These consolidated units are more resistant to erosion and form low rolling hills around the more-gently sloping alluvial valley. Most of the precipitation that falls on the Upland Area leaves the area as runoff and contributes to streams in the Fringe Area and the Main Basin. A small amount of deep percolation of precipitation in the Upland Area could also contribute to subsurface inflow. Subsurface inflow from the Upland Area into the Main Basin has been estimated at about 1,000 AFY. Formal subareas have not been delineated in the Upland Area because of the absence of significant groundwater pumping.

7.2.6. Neighboring Basin Boundaries

As shown on **Figure 7-1**, the Basin is bounded at the northwestern edge by the neighboring San Ramon Valley Groundwater Basin and at the southwestern edge by the neighboring Sunol Valley Groundwater Basin.

7.3. Bottom of the Basin

☑ 23 CCR § 354.14(b)(3)

7.3.1. Main Basin Management Area

The bottom of the Main Basin is defined by the base of the Lower Aquifer (see **Section 7.4**) and represents the transition zone from prolific aquifers in the upper portion of the Livermore Formation to the more consolidated units in lower portions of the Livermore Formation. Although the thickness of the productive upper Livermore Formation varies, it has been estimated to be about 200 to 300 ft thick in the southern Main Basin (representing the lower 200-300 ft of the Lower Aquifer). The elevation of the bottom of the Main Basin and adjacent Fringe Area was estimated as part of cross-section development (see **Section 7.6**) and is shown on **Figure 7-5**.

As indicated by **Figure 7-5**, the base of the Lower Aquifer in the Main Basin extends below an elevation of -450 feet above mean sea level (ft msl) in the west-central portion of the Basin. Over most of the Main Basin (and including some of the northern Fringe Area), the Basin bottom is estimated to be between -400 to -200 ft msl. In the northwestern Fringe Area and the southern portions of the Main Basin, the Basin bottom is estimated to be between -250 and 0 ft msl, with a shallower base in the southeast reaches of Arroyo Valle. In the eastern portion of the Main Basin, the Basin bottom is estimated to be between -200 and +400 ft msl, with a shallower base in the southern reaches of Arroyo Mocho. In general, this Basin geometry is consistent with previous interpretations by the California Department of Water Resources (DWR; *DWR, 1974*).

7.3.2. Fringe Management Area

The bottom of the Fringe Area is defined by the base of the Fringe Aquifer (see **Section 7.4**) and represents the transition zone from permeable deposits in the upper portion of the Livermore and/or Tassajara Formations to the more consolidated units in lower portions of the Livermore/Tassajara Formations. As described further in **Section 7.4**, the Livermore and Tassajara Formations are of lower productivity and quality within the Fringe Area, with maximum well depths ranging from 50 to 350 feet below ground surface (ft bgs) depending on location within the Fringe Area. The elevation of the bottom of the Fringe Area is shown on **Figure 7-5**.

7.3.3. Upland Management Area

As discussed further in **Section 7.4**, the Upland Area is primarily defined by outcrops of the lower Livermore Formation and older bedrock units and does not yield significant quantities of groundwater. Only a small number of wells exist within the Upland Area and thus there is insufficient information to characterize the depth to the bottom of the usable aquifer system in this portion of the Basin.

7.4. Principal Aquifers and Aquitards

☑ 23 CCR § 354.14(b)(4)

7.4.1. Overview

Although multiple aquifer units have been identified in the Main Basin, wells have been classified generally as being completed in either the Upper or Lower Aquifer. Such differentiation is not applicable to the Fringe and Upland Areas.

Observed differences in water levels and water quality with depth have been used to delineate the Upper Aquifer and Lower Aquifer within the Main Basin. The Upper Aquifer and Lower Aquifer are generally separated by a relatively continuous silty clay aquitard, which is up to 50 ft thick and occurs between 80 and 175 ft bgs. In 2004, an important local hydrostratigraphic study was conducted in the Amador Subarea of the Main Basin to examine the aquifer system in more detail (*Norfleet Consultants, 2004*). This subarea contains up to about 1,000 ft of water-bearing sediments and highly productive aquifers. The subarea is also important in that it contains gravel quarries, referred to as the quarry area or “Chain of Lakes” (COL), some of which are used currently for conjunctive use; this program will be expanded in the future as ongoing gravel mining is completed and additional quarries are available for Zone 7 use (see **Section 15**).

The 2004 hydrostratigraphic study applied sequence stratigraphy techniques to the 1,000 ft of aquifers and aquitards in the subarea. Four overall hydrostratigraphic packages, or sequences, were mapped across the subarea based on the occurrence of generalized stratigraphic facies. These sequences were labeled (shallow to deep) cyan, gray, purple, and red. A cross-section from the 2004 study showing the sequences mapped across the subarea, along with the delineation of the Upper and Lower Aquifers is shown on **Figure 7-6**. The location of the cross-section is shown on **Figure 7-7**.

As indicated on **Figure 7-6**, the Cyan sequence is correlative to the delineation of the Upper Aquifer. Stratigraphic continuity within the Lower Aquifer was examined by the mapping of the remaining three sequences (gray, purple, and red). Although it is difficult to distinguish the basal units of the recent alluvium from the upper, productive zones of the Livermore Formation, the boundary between the purple and red sequences provides a reasonable stratigraphic framework.

As part of the current Alt GSP Update, Zone 7 developed three stratigraphic cross-sections of the Basin as described in detail in **Section 7.6** and shown on **Figure 7-7** and **Figure 7-9** through **Figure 7-11**. These cross-sections further differentiate the Upper and Lower Aquifers of the Main Basin and extend into the Fringe Area and a small portion of the Upland Area. As mentioned above, there does not exist a strong differentiation between aquifer sediments, water levels, or water quality to support delineation of multiple Principal Aquifer units in the Fringe and Upland Areas. Further details regarding each Principal Aquifer unit defined within the Basin are provided below.

7.4.2. Upper Aquifer

The Upper Aquifer consists of recent (Holocene) alluvial materials, including primarily sandy gravel and clayey or silty gravels. These gravels are usually encountered underneath a confining surficial clay or silty clay layer typically 5 to 70 ft bgs in the west and exposed at the surface in the east, herein referred to as the Overburden. The thickness of the Overburden is shown on **Figure 7-12**. The base of the Upper Aquifer varies from about 70 to 190 ft bgs (*Norfleet Consultants, 2004*). A relatively thin Upper Aquifer is shown on **Figure 7-6** and **Figure 7-8**, located in the northern Main Basin (cross-section locations shown on **Figure 7-7**). On these west-to-east cross-sections, the thickness of the Upper Aquifer ranges from about 70 ft to 110 ft. These units are thicker to the south, ranging from about 70 ft thick in the west to about 190 ft thick in the southeast (see **Figure 7-10**).

In the 2004 hydrostratigraphic study, the Upper Aquifer was determined to contain several stratigraphic facies representing varying depositional environments across the central portion of the Basin. In that area, the Upper Aquifer contained fluvially-deposited gravels occurring primarily beneath aquitards of overbank and lacustrine deposits of clay and silt (**Figure 7-6**). A regional correlative lacustrine clay and silt unit underlies these deposits over much of the central and western Main Basin, herein referred to as the Aquitard.

A comparison of water levels from nested monitoring wells suggests that the Aquitard is a regional confining layer. However, the Aquitard appears to thin in the east, providing more hydraulic continuity between the two aquifers (see **Figure 7-8** and **Figure 7-9**). Groundwater in the Upper Aquifer is generally unconfined; however, when water levels are high, the zone becomes more confined in the western portion of the Main Basin where overlain by the Overburden.

7.4.3. Lower Aquifer

Hydrologic connectivity between Lower and Upper Aquifers varies by location within the Main Basin depending on the presence and extent of the Aquitard (**Figure 7-8** and **Figure 7-9**).

All productive aquifer units encountered below the Aquitard in the central and eastern Main Basin are known collectively as the Lower Aquifer. Lower Aquifer materials consist of coarse-grained, water-bearing units interbedded with relatively low permeability, fine-grained units. The 2004 hydrostratigraphic study of the central portion of the Main Basin indicated that aquifers were primarily Quaternary fluvial and deltaic sands and gravels interbedded with fluvial overbank and floodplain deposits (silts and clays).

Most of the recharge to the Lower Aquifer occurs through vertical leakage from the Upper Aquifer when piezometric heads in the Upper Aquifer are greater than those in the Lower Aquifer. Some replenishment may also come from the water-bearing members of the Livermore Formation that are in contact with the Lower Aquifer alluvium.

Within the Main Basin, the upper 200 to 300 ft of the Pliocene-Pleistocene Livermore Formation also appears to be sufficiently weathered and more permeable beneath the alluvium than in outcrops in the Upland Area. These zones comprise the lower portion of the Lower Aquifer, although sediment samples from wells are not sufficiently distinct to allow clear differentiation between these two units. Nonetheless, the lower portion of the Lower Aquifer is often characterized as having the thickest and most productive water-bearing deposits. The predominance of fluvial and deltaic sands and gravels in the lower portion of the Lower Aquifer can be seen on the western side of Norfleet 2004 Cross Section A-A' on **Figure 7-6** (labeled the Red Sequence). These lower sands are screened in many of the high-yielding production wells, especially in the western and central portions of the Main Basin.

7.4.4. Fringe Aquifer

Within the Fringe Area, a shallow (10 to 50 ft thick) sequence of recent (Holocene) alluvium directly overlies the upper portions of the Pliocene-Pleistocene Livermore and/or Tassajara Formations, depending on location. As mentioned above, there does not exist a strong differentiation between aquifer sediments, water levels, or water quality to support delineation of multiple Principal Aquifer units in the Fringe Area. As such, all water-bearing sediments encountered within the Fringe Area and associated subareas are collectively referred to as the Fringe Aquifer.

As mentioned above and discussed in greater detail in **Section 8**, the Fringe Aquifer is characterized by poorer water quality and lower well yields compared to the Principal Aquifer units encountered in the Main Basin.

7.4.5. Upland Aquifer

As mentioned above, the Upland Area is primarily defined by outcrops of the lower Livermore Formation and older bedrock units and does not yield significant quantities of groundwater. There are limited well completion reports and lithologic or geophysical information to characterize individual aquifer units or their depths and extents within the Upland Area. As such, all water-bearing sediments encountered within the Upland Area are collectively referred to as the Upland Aquifer.

7.4.6. Representation of Aquifers and Aquitards in Groundwater Model

Zone 7 maintains a numerical groundwater model of the Basin (also referred to as model in the section) for simulating the effects of proposed Basin management actions (see also **Section 8.2.2)**. The model was originally developed in 2003 and has been updated as recently as 2017. The active part of the groundwater model covers subareas in both the Main Basin (Castle, Bernal, Amador, and Mocho II Subareas) and the northwestern Fringe Area (Bishop, Dublin, and Camp Subareas). The original version of the model consisted of three layers: the Upper Aquifer (Layer 1), the Aquitard (Layer 2), and the Lower Aquifer (Layer 3). Most municipal water supply production wells in the Basin were screened in the Lower Aquifer (Layer 3). Production in the Upper Aquifer (Layer 1) was limited primarily to small private wells (Layer 1).

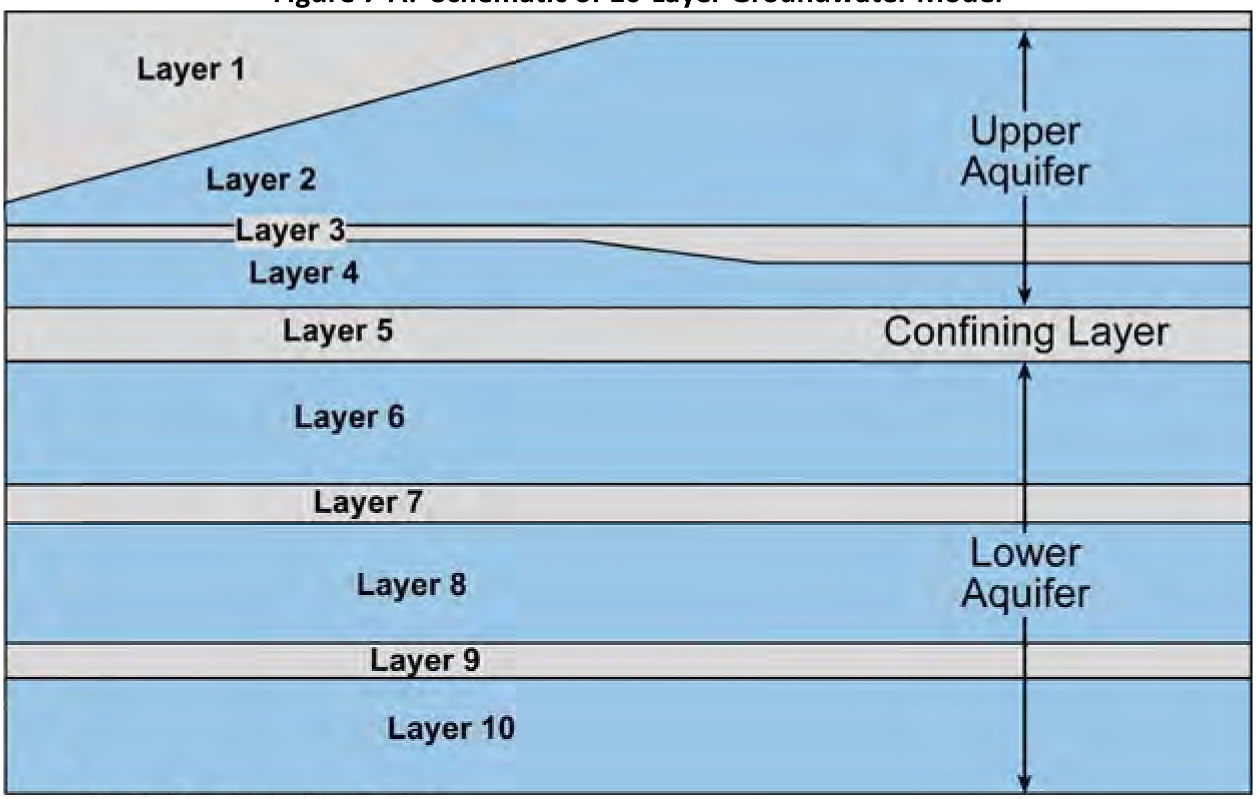
In 2017 the model was upgraded to ten layers to represent primary intervals of aquifers and aquitards as summarized and shown in **Figure 7-A** below:

- Layer 1 – shallow clay layers overlying the Upper Aquifer in the western Basin (i.e., Overburden)
- Layers 2 and 4 – primary aquifer units within the Upper Aquifer

- Layer 3 – intervening clay layers within the Upper Aquifer
- Layer 5 – confining to semi-confining layer delineating the Upper Aquifer from the Lower Aquifer
- Layers 6, 8, and 10 – primary aquifer units within the Lower Aquifer
- Layers 7 and 9 – intervening clay layers between the aquifer units in the Lower Aquifer

The base of Layer 10 is estimated to be the base of the more permeable water-bearing units and is the bottom of the Basin.

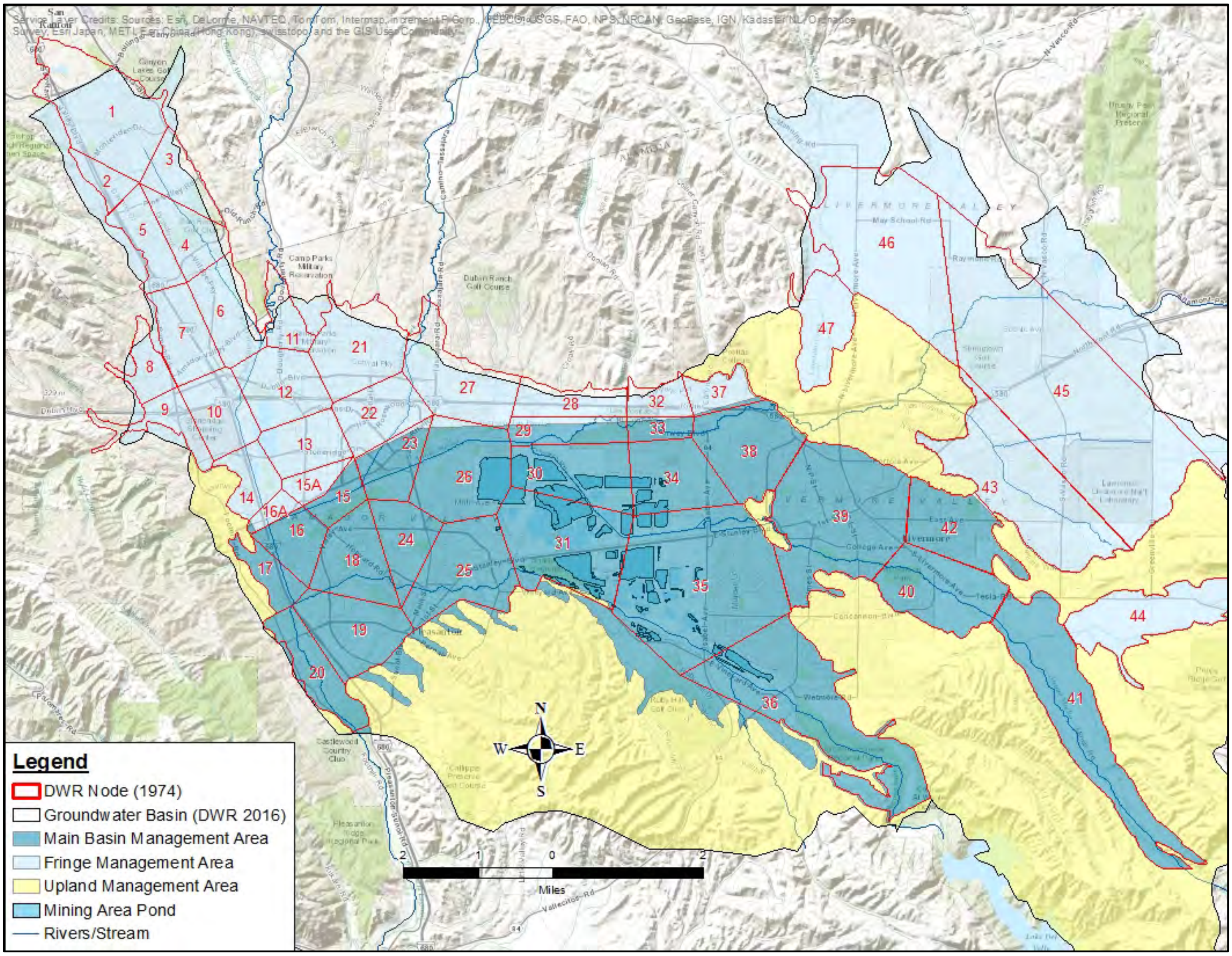
Figure 7-A: Schematic of 10-Layer Groundwater Model



Source: Modified from Hydro Metrics, 2016.

DWR originally delineated "Nodes" in their 1974 groundwater model that recognized the Upper and Lower Aquifers in the Main Basin as well as the thin alluvial Fringe Aquifer, as shown on **Figure 7-B** below. These nodes have aquifer parameters associated with them that have been confirmed over time and are used by Zone 7 for calculation of groundwater in storage, changes in storage, and groundwater quality analyses. The application of these nodes in Zone 7 groundwater management is described in more detail in the discussion of groundwater quality (**Section 8.6**) and Basin water budgets (**Section 9.2**).

Figure 7-B: DWR "Nodes" from 1974 Groundwater Model



7.5. Data Gaps and Uncertainty

☑ 23 CCR § 354.14(b)(5)

Key data gaps and uncertainties identified during development of this HCM for the Basin include:

- Uncertainty in distinguishing specific areas in the Main Basin where Upper and Lower Aquifers are hydrologically connected;
- Uncertainty in hydraulic properties within the Fringe and Upland Areas due to limited boring logs;
- Uncertainty in subarea definition in the Fringe Area;
- Uncertainty in aquifer thickness and extent in the Upland Area;
- Uncertainty in representation and extent of major fault structures within the Basin that may serve as a hydraulic barrier to groundwater flow;

- Refinement of aquifer delineations, extents, and thicknesses in other parts of Basin outside of the three stratigraphic cross-sections developed for the current Alt GSP update

Additional data gaps related to the definition of groundwater conditions and water budget estimations are discussed in their relevant sections below. Data-gap filling activities proposed as part of implementation of this Five-Year Update to the Alt GSP are presented in **Section 15.2.4**

7.6. Cross-Sections

§ 354.14. Hydrogeologic Conceptual Model
(c) The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.

☑ **23 CCR § 354.14(c)**

The three dimensional (3D) geologic modeling software platform RockWorks[11] was selected to support development of hydrogeologic cross-sections for the Basin. **Appendix I** summarizes the data sources, key assumptions, and step-wise development process that was used to build the HCM framework in RockWorks. **Appendix I** includes a detailed geologic interpretation of the cross-sections.

The cross-section trace locations are shown on **Figure 7-7.** A map of the surficial geology, major fault structures, and streams that were incorporated into the cross-sections is shown on **Figure 7-2.** A simplified schematic of the conceptual hydrostratigraphic model of the Basin and mapping between major stratigraphic facies and corresponding Principal Aquifer units is shown on **Figure 7-8.** The three cross-sections are shown on **Figure 7-9**, **Figure 7-10**, and **Figure 7-11**, respectively. The following sections document the principal geologic features, as well as the assumptions and references used to inform cross-section development.

7.6.1. Geologic Cross-Section A-A'

Cross-Section A-A' depicts a generally west-to-east trace through the Basin (see **Figure 7-9**). The trace begins just west of the southwestern Basin boundary near the Calaveras Fault deformation zone and progresses eastward through the Main Basin (including the Castle, Bernal, Amador, and Mocho II subareas), where a majority of groundwater production occurs in the Basin. The trace cuts directly through a narrow corridor of alluvium connecting the Mocho II and Mocho I subareas (an area commonly referred to as "The Gap") and continues through the southern portion of the Eastern Fringe Area (including the Mocho I and Spring subareas) before terminating in the Upland Area just west of the Greenville Fault deformation zone.

[11] RockWorks 2020 Standard Level License from RockWare was downloaded and installed on 15 October 2020: https://www.rockware.com/product/rockworks/

After crossing the main deformation zone of the Calaveras Fault and entering the Basin, Cross-Section A-A' cuts through the Castle subarea, which consists of "uplands underlain by the Livermore Formation and… adjacent valley fill material" (*DWR, 1974*). Here, the Upper Aquifer is comprised of Holocene alluvial deposits ranging from approximately 50 to 75 ft thick. Most of the wells in the Castle Subarea draw from the upper 100 to 200 ft of Plio-Pleistocene Livermore Formation, which is present "as a sequence of gravel, sand, and silt interlayered by clay" (*DWR, 1974*). This productive upper zone of the Livermore Formation (herein referred to as the "Upper Livermore Formation") comprises the Lower Aquifer in the area. "All of these materials apparently slope toward the valley at dips ranging up to ten degrees" (*DWR, 1974*).

Cross-Section A-A' subsequently passes over another presumed splay of the Calaveras Fault and enters the Bernal subarea, which acts as the point of convergence for all major streams and subsurface flows that eventually drain the Basin via the Arroyo de La Laguna. Here, a confining surficial clay unit exists reaching up to 70 ft thickness (herein referred to as the "Overburden"). Beneath the Overburden is the Upper Aquifer, which is comprised of a 50 to >100-ft sequence of unconsolidated, Holocene sandy gravel and silty/clayey gravel deposits. Beneath the Upper Aquifer is a laterally extensive lacustrine clay and silt unit of up to 50 ft thick (herein referred to as the "Aquitard"). Below the Aquitard is a thicker sequence of braided fluvial and deltaic "clean gravel" and sand deposits interbedded with fluvial overbank and floodplain clays and silts (*Norfleet Consultants, 2004*). These Quaternary (Pleistocene-Holocene) deposits are believed to represent a "structurally influenced, incised channel complex" deposited by the ancestral Arroyo Mocho stream (*Norfleet Consultants, 2004*) and are encountered up to >400 ft bgs in the area (*DWR, 1974*). Underlying the Quaternary fluvial and alluvial deposits is the Upper Livermore Formation, for which up to 200 ft is considered productive due to sufficient weathering and permeability relative to the more consolidated zones of the Lower Livermore Formation. The combined sequence of Quaternary alluvial/fluvial deposits and the Upper Livermore Formation are known collectively as the Lower Aquifer in the Main Basin. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges up to 3,500 gpm and specific capacities range from 3 to 260 gpm per foot of drawdown.

The trace subsequently crosses into the Amador subarea, whereby a majority of groundwater production occurs in the Basin. The Overburden is present in the western half of the Amador subarea, extending east approximately to the COL mining area, creating semi-confined conditions in the Upper Aquifer where it is present. Beneath the Overburden are Holocene alluvial deposits of the Upper Aquifer, which reach depths of up to 190 ft bgs in the subarea (and approximately 150 ft underlying Cross-Section A-A'). Here, the Upper Aquifer is consistent with the "Cyan" stratigraphic sequence defined in the Norfleet (2004) and Zone 7 (2011) hydrostratigraphy studies. The Aquitard is present below the Upper Aquifer at a thickness of up to 50 ft under the COL area, before gradually thinning to the east. This unit is consistent with the "Grey Clay" sequence defined in the Norfleet (2004) and Zone 7 (2011) studies and serves to create semi-confined to confined conditions in the underlying Lower Aquifer. As in the Bernal Subarea, Lower Aquifer units in the western portion of the Amador subarea are comprised of up to 400 ft of interbedded, Quaternary alluvial/fluvial deposits (consistent with the "Grey" and "Purple" sequences from Norfleet (2004) and Zone 7 (2011)), underlain by 200-300 ft of productive Upper Livermore deposits (consistent with the "Red" sequence in Norfleet (2004) and Zone 7 (2011)). The Basin reaches a maximum depth of

>800 ft in the central Amador subarea near the COL mining pits. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges from 42 to 2,820 gpm and specific capacities range from 1.1 to 217 gpm per foot of drawdown.

Moving further east through the Amador Subarea, Cross-Section A-A' eventually reaches the Livermore Thrust fault zone, which presents a significant unconformity that serves to restrict groundwater flow from the Mocho II subarea to the Amador subarea. According to Norfleet (2004):

> *"The Livermore Thrust ha[s] a westward motion and dip[s] at a high angle to the east. [It] dies out rapidly to the north and do[es] not extend all the way across the current Livermore Valley. Evidence for the Livermore fault was discussed in Thomas et al. (1959) and DWR (1963, 1966, and 1974). The fault has historically been considered to be a strike-slip fault, but the data are more consistent with an east dipping, west-moving thrust fault. The Livermore thrust cut and uplifted Livermore Gravels, suggesting that the fault developed after deposition of the classical Livermore Gravels." (Norfleet, 2004)*

Several varying interpretations exist in the literature regarding the nature and extent of this fault and the degree to which it impedes groundwater flow. In their Bulletin-118 description of the Basin, DWR notes:

> *"The Livermore [Thrust] is an effective barrier to ground water inflow from the Mocho subbasin except in the vicinity of the ancestral channel of Arroyo Mocho north of Oak Knoll, where ground water moves across this fault essentially unimpeded" (DWR, 1974).*

Cross-Section A-A' traces north of Oak Knoll, within the ancestral Arroyo Mocho paleochannel. However, based on nearby water level observations collected in Fall 2019, an apparent 80-foot drop in groundwater elevation is observed in the Lower Aquifer moving westward across the fault, indicating that some degree of hydraulic restriction occurs across the fault zone in this area. Notably, this groundwater flow barrier across the fault is not observed in the Upper Aquifer.

The total depths of wells in the Mocho II subarea east of the Livermore Thrust suggest that the base of the Lower Aquifer (i.e., the bottom of the productive Upper Livermore Formation) is encountered 200-300 ft higher in this subarea than in the Amador subarea west of the fault, indicating a significant discontinuity likely exists in the Lower Aquifer formations even within the incised ancestral Arroyo Mocho channel complex resulting from uplift on the eastern side of the fault. A relatively lower proportion of "clean gravels" is also observed east of the Livermore Thrust, resulting in lower productivity of the Lower Aquifer in the Mocho II subarea (*Norfleet Consultants, 2004*). Upper Aquifer deposits progressively thin to around 50 ft thickness moving east through Mocho II subarea. The Aquitard and underlying Quaternary deposits gradually diminish as the trace moves further east outside the ancestral Arroyo Mocho paleochannel, and eventually disappear before reaching the Mocho II – Mocho I boundary such that Pleistocene-Holocene alluvial deposits are directly underlain by deposits of the Upper Livermore Formation.

Another apparent steepening of the hydraulic gradient in the Lower Aquifer is observed west of the Mocho II/Mocho I boundary as deposits of the Upper Livermore Formation continue to reduce to a total depth of approximately 330 ft bgs at well 3S2E10Q002. A short distance to the east, a narrow, roughly 50-ft thick sequence of young alluvial deposits of the Arroyo Seco channel underlain by older, interbedded sand and gravel deposits of the Upper Livermore Formation connects the Main Basin to the Eastern Fringe Area in an alluvial channel known colloquially as "The Gap". The Gap is surrounded by outcrops of the relatively impermeable Lower Livermore Formation to the north and south, also known as Livermore Uplands. These outcrops are connected by way of a buried ridge of Lower Livermore Formation within the Gap that serves to restrict the vertical cross-sectional area of connection between Upper and Lower Aquifer deposits in the Eastern Fringe Area and the Main Basin to the west (*DWR 1974, LLNL 1984*). There is considerable uncertainty to the degree which flow is restricted across The Gap, though Fall 2019 water level trends suggests this area acts as an apparent groundwater divide in both the Upper and Lower Aquifers.

As the trace of Cross-Section A-A' moves across The Gap and into the Mocho I subarea of the Fringe Area, Upper Livermore deposits again deepen to a total depth around 350 ft bgs at well 3S2E11R046 near the southwestern corner of the Lawrence Livermore National Laboratory (LLNL). A local depression in Fall 2019 groundwater elevations was observed in the Fringe Aquifer in this area, likely due to groundwater pumping. These deposits then begin to dip upward to the northeast as the trace moves into the Spring subarea, reducing to a total depth of 175 ft bgs at well 3S2E12J025 on the southeastern side of LLNL (*LLNL, 1984*). Here, the Upper Livermore deposits are described as a series of "beds of cemented gravel, sandy gravel, and sandy clay separated by beds of less-permeable clay and silty clay" (*DWR, 1974*). Overlying Pleistocene-Holocene valley-fill materials in this area "are of similar composition to the sediments of the Livermore Formation, as they are composed principally of reworked Livermore Formation detritus" (*DWR, 1974*). Both the valley fill and underlying Livermore deposits continue to dip upward to the northeast before reaching the Las Positas Fault, which likely serves to truncate the Fringe Aquifer completely. The trace then briefly crosses into the Upland Area, where the Lower Livermore Formation is the dominant outcropping unit and no significant groundwater production occurs, before ending at the southeastern Basin Boundary near the Greenville Fault zone.

7.6.2. Geologic Cross-Section B-B'

Cross-Section B-B' depicts a generally northwest-to-southeast trace through the western portion of the Basin (see **Figure 7-10**). The trace begins at the northwestern Basin boundary with the neighboring San Ramon Valley Groundwater Basin to the north. It runs southeast through the Northern Fringe Area (including the Bishop, Dublin, and Camp subareas) before entering the Main Basin. Cross-Section B-B' then passes through a large section of the west-central Main Basin (Amador subarea) and continues southeast up the Arroyo del Valle stream corridor before terminating at the contact between the Amador subarea and the Southern Upland Area near the southern Basin boundary.

The trace begins in the Bishop subarea of the Northern Fringe Area, which contains "one of the deepest developed prisms of water-bearing materials in the Basin…[with] sediments up to 800 feet in depth" (*DWR, 1974*). Surficial deposits are consistent with Holocene alluvial and fluvial sands and gravels, underlain by a thick sequence of relatively fine-grained deposits of the Pleistocene to Plio-Pleistocene

Tassajara Formation. These contain “eight to ten separate zones of sand and gravel separated by zones of silt and clay” (*DWR, 1974*). It is assumed that “the greater portion of the sediments below a depth of 100 feet are part of the Tassajara Formation” (*DWR, 1974*). The Fringe Aquifer is defined as the collective sequence of surficial Holocene alluvial deposits and the thicker underlying sequence of permeable Tassajara Formation deposits (herein referred to as the “Upper Tassajara Formation”). Groundwater production is relatively minimal in this subarea and thus few borehole lithologic and e-log data are available to more accurately delineate individual aquifer zones within the Upper Tassajara Formation.

Moving further to the southeast, Cross-Section B-B’ enters the Dublin subarea of the Northern Fringe Area. Here, deposits are very similar to those encountered in the Bishop subarea, containing an “essentially flat-lying” sequence of sediments with a “maximum depth of…about 800 feet” (*DWR, 1974*). “Valley-fill materials lap northward onto older sediments of the Tassajara Formation”, though the depth at which the Tassajara Formation meets younger Holocene alluvial deposits is not well understood in the area (*DWR, 1974*). Based on available borehole lithology and e-log data, it appears the surficial clay layer (i.e., Overburden) encountered in the Main Basin as well as a laterally extensive clay layer (i.e., Aquitard) underlying the Holocene alluvium are encountered in the southern portion of the Dublin subarea.

After passing through the Dublin subarea, the trace makes a brief east-southeasterly turn and cuts through a small portion of the Camp subarea of the Northern Fringe Area before moving southeast and entering the Main Basin (Amador subarea). The Camp subarea is similar in composition to the Dublin and Bishop subareas to the northwest, containing “beds of sandy clay and sandy gravel which overly the Tassajara Formation” (*DWR 1974*).

The Camp subarea is delineated from the Amador subarea of the Main Basin by an observed groundwater flow barrier described as the “Parks Boundary” (*Norfleet Consultants, 2004*). The Parks Boundary was originally inferred as a fault in DWR’s Bulletin-118 hydrostratigraphy summary based on significant variations in groundwater elevations between the Dublin/Camp subareas of the Northern Fringe Area and the Bernal/Amador subareas of the Main Basin (*DWR, 1974*). However, updated interpretations provided in the Norfleet (2004) hydrostratigraphy study suggest that the Parks Boundary represents a buried valley wall delineating the northern extent of the “structurally influenced, incised-channel complex” deposited by the ancestral Arroyo Mocho stream (*Norfleet Consultants, 2004*). While the Holocene alluvial deposits of the Upper Aquifer and the underlying Aquitard appear to be generally consistent across the Parks Boundary, deposits in the Lower Aquifer south of the boundary consist of a thicker sequence of braided fluvial and deltaic “clean gravel” and sand deposits interbedded with fluvial overbank and floodplain clays and silts (*Norfleet Consultants, 2004*). These are underlain by the Upper Livermore Formation, as opposed to the Tassajara Formation north of the boundary. Based on nearby water level observations collected in Fall 2019, an apparent 30 to 40-foot drop in groundwater elevation is observed in the Lower Aquifer moving south across the Parks Boundary. Lower Aquifer deposits south of the Parks Boundary are known to be more productive than those north of the boundary, thus marking the southern edge of the Northern Fringe Area and the northern edge of the Main Basin.

As Cross-Section B-B' moves southwards across the Parks Boundary and into the Main Basin, the Quaternary alluvial/fluvial deposits of the ancestral Arroyo Mocho paleochannel are encountered at depths up to 500 ft bgs. As mentioned above, these are underlain by deposits of the Upper Livermore Formation, which reach >200 ft thickness in the west-central portion of the Amador Subarea. Holocene alluvial deposits comprising the Upper Aquifer reach a maximum thickness of approximately 150 ft underlying the southern COL mining area within the subarea. Here, the Upper Aquifer is generally consistent with the "Cyan" stratigraphic sequence defined in the Norfleet (2004) and Zone 7 (2011) hydrostratigraphy studies, while the Aquitard comprises the "Grey Clay" sequence and the interbedded sequence of Quaternary alluvial/fluvial deposits comprise the "Grey" and "Purple" sequences. Deposits of the Upper Livermore Formation are generally consistent with the "Red" sequence mapped in the Norfleet (2004) and Zone 7 (2011) studies.

Moving southeast through the Amador Subarea, deposits from the incised channel-complex are found roughly up to Concannon Road, where another water level lineation has historically been observed. Norfleet (2004) interpreted this area as the southern extent of the ancestral Arroyo Mocho paleochannel, and delineated this feature as the "Concannon Boundary". South of the Concannon Boundary, deposits of the ancestral Arroyo Mocho paleochannel are not readily apparent and permeable deposits of the Upper Livermore Formation appear to directly underly the Upper Aquifer and Aquitard. Groundwater conditions range from "unconfined to confined" in this area, with unconfined groundwater occur[ing] principally near the channel of Arroyo del Valle and in the uppermost aquifer" (*DWR, 1974*).

Moving further southeast up the Arroyo del Valle stream corridor, the Upper Livermore Formation continues to dip upward to the south at an angle of one to three degrees (*DWR, 1974*). "Many of the aquifers merge near the course of Arroyo del Valle, where the combined aquifers are present as a deposit of sandy gravel up to 300 feet in thickness" (*DWR, 1974*). The Las Positas Fault, described as a "high-angle tear fault" that "cut and uplifted Livermore Gravels" south of the fault line (*Norfleet Consultants, 2004*), may act as a disconformity in the Upper Livermore Formation as maximum well depths are roughly 200 ft bgs southeast of the fault line. This may also explain the apparent confinement observed in Fall 2019 Lower Aquifer water levels in the vicinity of the fault. However, the degree to which the Las Positas Fault acts as a hydraulic barrier to groundwater flow is uncertain given the current lack of lithologic and geophysical data proximate to the fault line. Recent alluvial deposits of the Arroyo del Valle stream corridor (i.e., Upper Aquifer) continue to thin with the Upper Livermore Formation (i.e., Lower Aquifer) before pinching out at the contact between the Amador subarea and the Southern Uplands, where the relatively impermeable Lower Livermore Formation begins to outcrop. This terminus in permeable deposits marks the effective southern edge of the Basin within the Arroyo del Valle stream corridor.

7.6.3. Geologic Cross-Section C-C'

Cross-Section C-C' depicts a generally northwest-to-southeast trace through the eastern portion of the Basin (see **Figure 7-11**). The trace begins at the northeastern Basin boundary and progresses southeastward through a portion of the Northeastern Fringe Area (May and Spring subareas). The trace then makes a turn to the south and continues through the Northeastern Fringe Area (Spring and Mocho I subareas) before cutting directly through a narrow corridor of alluvium connecting the Mocho I and Mocho II subareas (an area commonly referred to as "The Gap"). The trace then progresses further south through the Main Basin (Mocho II subarea), taking another southeasterly turn and continuing up the Arroyo Mocho stream corridor. It then briefly enters the Southern Upland Area before terminating at the southern Basin boundary.

Cross-Section C-C' begins in the May subarea of the Northeastern Fringe Area, where outcrops of the relatively impermeable Lower Tassajara Formation define the northern edge of the Basin. South of the Basin boundary, "ground water occurs only in limited amounts in a relatively thin veneer of valley-fill materials which overlie a thick section of sediments belonging to the Tassajara Formation" (*DWR, 1974*). Here the Fringe Aquifer is defined as the thin veneer of recent (Holocene) alluvium deposited from smaller streams, which "does not exceed 40 ft" thickness in the May subarea (*DWR, 1974*), directly underlain by the permeable upper deposits of the Plio-Pleistocene Tassajara Formation (herein referred to as the "Upper Tassajara Formation") where a majority of groundwater production occurs in the area. The Upper Tassajara Formation is comprised of "beds of sand and gravel, clay and gravel, clay, and silty clay… which range up to 50 ft in thickness [and] dip southward at an average gradient of ten degrees." (*DWR 1974*). Based on nearby water level observations collected in Fall 2019, it appears water level conditions are semi-confined to confined in within the Upper Tassjara Formation this area.

Cross-Section C-C' further progresses southeastward into the Spring subarea of the Northeastern Fringe Area. Here, surficial deposits are very similar to those encountered in the May subarea, containing a thin veneer of recent alluvium not exceeding 50 ft thickness. Deposits underlying the recent alluvium change in composition to reflect those of the Upper Livermore Formation, though the geometry of the contact between the Tassajara and Livermore Formations is not well understood in this area. Upper Livermore deposits in the Spring subarea are described as a "wedge-shaped sequence" of permeable deposits that increase in depth moving southward (*DWR, 1974*). Upper Livermore deposits continue to deepen as the trace turns south and moves into the Mocho I subarea (LLNL, 1984). The "valley-fill portion of the Mocho I province…consists of a heterogeneous mixture of gravelly fan detritus overlying truncated beds of the Livermore Formation" (*DWR, 1974*).

The base of the Upper Livermore Formation deepens in a southerly direction along the Cross-Section C-C' trace through the Mocho I subarea to approximately 300 ft bgs while the upper surface of the formation stays within approximately 30 ft bgs (*LLNL, 1984*). Northeast of well 3S2E10Q002 the trace crosses through a narrow alluvial channel connecting the Mocho I and Mocho II subareas, known colloquially as "The Gap". The Gap is surrounded by outcrops of the relatively impermeable Lower Livermore Formation to the north and south (i.e., out of the plane of the cross-section), also known as Livermore Uplands. These outcrops are connected by way of a buried ridge of Lower Livermore Formation within The Gap that serves to restrict the vertical cross-sectional area of connection between the recent alluvium and underlying Livermore Formation deposits in the Northeastern Fringe Area and the Main Basin to the southwest (*DWR, 1974; LLNL, 1984*). There is considerable uncertainty in the degree to which flow is restricted across The

Gap, though recent water level trends suggest this area acts as an apparent groundwater divide between the Fringe Aquifer and the Upper and Lower Aquifers of the Main Basin.

After moving across The Gap, Cross-Section C-C' progresses south through the Mocho II subarea of the Main Basin. Here, "the valley-fill materials become separated into identifiable strata consisting of beds of sandy gravel and cemented gravel separated by beds of silt and clay" (*DWR, 1974*). In this area, Cross-Section C-C' encounters a thicker sequence of braided fluvial and deltaic "clean gravel" and sand deposits interbedded with fluvial overbank and floodplain clays and silts known to be deposited by the ancestral Arroyo Mocho paleochannel throughout much of the Main Basin (*Norfleet Consultants, 2004*), consistuting the upper portions of the Lower Aquifer. Based on nearby water level observations collected in Fall 2019, it appears this thicker sequence of Quaternary alluvial/fluvial deposits creates some degree of confinement in the Lower Aquifer in the area.

As the trace turns to the southeast and begins traveling up the Arroyo Mocho stream corridor, Cross-Section C-C' travels over the Las Positas Fault. The Las Positas Fault may present an unconformity in the Upper Livermore Formation, though the degree to which it acts as a hydraulic flow barrier in the Lower Aquifer is not well understood.

As Cross-Section C-C' moves further southeast up the Arroyo Mocho stream corridor, the Quaternary alluvial/fluvial deposits of the ancestral Arroyo Mocho paleochannel pinch out and disappear. Here, the recent alluvial deposits of the Arroyo Mocho are underlain directly by semi-consolidated deposits of the Upper Livermore Formation. These deposits progressively thin moving up the stream corridor until they pinch out at the contact between the Mocho II subarea and the Southern Upland Area. At this point, the relatively impermeable Lower Livermore Formation begins to outcrop, marking the effective southern edge of the Basin in the Arroyo Mocho stream corridor. Cross-Section C-C' further extends a short distance through the Southern Upland Area before reaching the southern Basin boundary.

7.7. Physical Characteristics

§ 354.14. Hydrogeologic Conceptual Model

(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:
- *(1) Topographic information derived from the U.S. Geological Survey or another reliable source.*
- *(2) Surficial geology derived from a qualified map including the locations of cross- sections required by this Section.*
- *(3) Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.*
- *(4) Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.*
- *(5) Surface water bodies that are significant to the management of the basin.*
- *(6) The source and point of delivery for imported water supplies.*

7.7.1. Topographic Information

☑ 23 CCR § 354.14(d)(1)

Ground surface within the Main Basin and Fringe Area slopes gently west and southwest from an elevation of approximately 700 ft msl in the east to approximately 300 ft msl in the southwestern corner, which is the location of the Basin's surface and subsurface outflow. The highest elevations in the Basin are in the east-southeastern Upland Area where the ground surface is above 2,000 ft msl. In the southern Upland Area, ground surface elevations are above 1,100 ft msl. The highest elevations in the Main Basin are also in the southeast, along the upper reach of Arroyo Mocho, where elevations are around 1,000 ft msl. Ground surface elevations across the central Main Basin average about 400 ft msl. The overall topography across the Basin is shown on **Figure 7-13** as represented from a digital elevation model (± 3 meters) covering Alameda and Contra Costa Counties.

7.7.2. Surficial Geology

☑ 23 CCR § 354.14(d)(2)

The geologic map on **Figure 7-3** illustrates the older deformed sedimentary and bedrock units defining the Basin along with the valley-fill alluvial sediments; the Basin is outlined in black on the map. The map also contains many of the northwest-southeast trending faults that have offset the consolidated geologic units and, in some cases, shallow alluvium.

As shown on **Figure 7-3**, the Valley is partially filled with Pleistocene-Holocene age alluvium (Qu), consisting of alluvial fan, fluvial, and lake deposits that range in thickness from a few feet along the margins to more than 400 ft in the west-central Valley. The alluvium consists of unconsolidated gravel, sand, silt, and clay. The southern and southwestern alluvial deposits consist primarily of sand and gravel that were deposited by the ancestral and present Arroyo Valle and Arroyo Mocho. These deposits are rimmed by slightly older terrace deposits (Qt).

The eastern and northern Fringe Areas of the Valley are also filled with recent alluvial deposits, but these sediments were deposited from smaller streams and consist of thin, alternating layers of gravel, sand, silt, and clay that are laterally discontinuous. Consolidated units underlie the thin alluvial deposits as demonstrated by several areas in the northeast Basin where these units crop out at the surface (see **Figure 7-3**). These outcrops consist of the older consolidated units north and south of the Valley that underlie the alluvium (Pliocene-Miocene Green Valley/Tassajara group [Tgvt] units on the north and younger Pliocene-Pleistocene Livermore gravels [QTl] on the south, discussed in more detail below).

7.7.3. Soil Characteristics

☑ 23 CCR § 354.14(d)(3)

Figure 7-14 shows the soil types throughout the Basin as mapped by the National Resource Conservation Service (NRCS). In general, the soils reflect the lithology of the upland source rocks. The predominant soils in the northern Fringe Area are low-permeability clay (Cl) and clay loams (ClL), associated with the

Tassajara Uplands. Soils in the southern Basin consist of more permeable soils including gravelly loams (GrL) associated with the Livermore Uplands. Across the Main Basin, soils are also more permeable than northern soils and include gravelly coarse sandy loams (GrSaL), extremely gravelly sand (GrSa), sand (Sa), silt loam (SiL) and loam (L). The lower permeability soils in the Main Basin occur along the northern and western portions.

The low permeability soils along the northern and western areas of the Main Basin are also underlain by shallow clay deposits that overlie the Upper Aquifer. These shallow clay layers have been mapped by Zone 7 to identify areas where shallow clays may be impeding surface recharge (see **Figure 7-15**).

7.7.4. Recharge and Discharge Areas

☑ **23 CCR § 354.14(d)(4)**

7.7.4.1. Recharge Areas and Sources

Groundwater inflows to the Basin include percolation of artificial recharged surface water, percolation of applied irrigation water, percolation of streamflow from surrounding watersheds, percolation of canal leakage, percolation of precipitation, and percolation of municipal and industrial (M&I) effluent. **Figure 7-16** shows the recharge areas of the Main Basin from streams, mining area ponds, and surficial geology. Some of the mining area ponds in the central portion of the Basin (Amador Subarea) are in communication with the groundwater basin; and are currently or will be used in the future for conjunctive use (see **Sections 5.2.3**, **7.7.5**, and **15.2.1.3**).

Zone 7 has been importing and recharging State Water Project (SWP) water (artificial recharge) since the 1960s to replenish what has been pumped from the Basin. Zone 7 actively embraces a conjunctive use approach to Basin management by integrating management of local and imported surface water supplies with the management of local conveyance, storage and groundwater recharge features, including local Arroyos (which are also used as flood protection facilities during wet seasons).

Both the Arroyo Valle and the Arroyo Mocho serve vital roles in Zone 7's groundwater recharge program, as does the Arroyo Las Positas but to a lesser extent. The upper portions of these arroyos are underlain by coarse soils and readily act as losing streams (**Figure 7-16**). At Zone 7's request, DWR releases water into these Arroyos to supplement the natural recharge of the Main Basin, while providing secondary aesthetic and environmental benefits. In addition to the managed (artificial) stream recharge conducted in these Arroyos, the stream channels also serve to recharge the Basin with natural rainfall and runoff. Basin recharge varies from less than 5,000 AF per year to more than 20,000 AFY depending on local hydrologic conditions and availability of SWP water. Historical natural (both from streams and rainfall) and artificial recharge (from streams) volumes are discussed in detail in **Section 9.3.2** with averages from 1974 to 2020 presented in **Table 7-A** below.

Table 7-A: Average Recharge Volumes from 1974 to 2020 (in acre feet)

Recharge From	Average Volume
Rainfall	4,700
Natural Flow in Streams	5,700
Artificial Flow in Streams	5,300

7.7.4.2. Discharge Area and Sources

Groundwater outflows from the Basin include groundwater pumping for agricultural, domestic and M&I uses, evaporation from mining area ponds, and discharges to streams within the Basin. The coarse-grained alluvium in the center of the Main Basin has been mined for aggregate since the 19th century, resulting in several mining area ponds between Pleasanton and Livermore. Continued mining has impacts on the local groundwater budget, levels, and flow. Most notably, many of the quarry pits have been dug deep into the Upper Aquifer and some are proposed to mine into the Lower Aquifer. This mining activity has removed aquifer material, created "windows" into the Basin, and exposed groundwater to large evaporative losses. Groundwater is also pumped from some of the pits and transferred to others or discharged to the Arroyos to facilitate gravel extraction; the latter can result in loss of water from the Basin. In addition, interruption of groundwater movement can result from the mining of aggregate resources and occasional placement of less permeable material in former pits.

Accordingly, Zone 7 has worked and is working closely with the mining companies and Alameda County Community Development Agency (the administrative representative of the State for mining operations and reclamation) to develop a reclamation plan whereby ownership of ten quarry lakes (COLs A through I and Cope Lake) is to be transferred to Zone 7 for water resources management purposes (**Section 15**). Two of the lakes have already been transferred to Zone 7 (Lake I and Cope Lake) and are currently operated and maintained by Zone 7 for storage and groundwater replenishment.

Numerous saline springs have been observed on the eastern Basin associated with upwelling along faults, especially those in the Greenville Fault zone. One such seasonal spring, Springtown Alkali Sink **(Section 7.7.5)**, has been documented and monitored in the northeastern Fringe Area of the Basin. Springtown Alkali Sink is located along Altamont Creek in the vicinity of Springtown golf course and is close to stream gauges on Altamont Creek monitored by Zone 7. When groundwater levels are sufficiently high, groundwater discharges to Altamont Creek, exiting the Springtown Alkali Sink as surface water. Much of this discharge is lost to evapotranspiration.

7.7.5. Surface Water Bodies

☑ 23 CCR § 354.14(d)(5)

As shown on **Figure 7-3**, six major streams flow into and/or through the Basin and merge in the southwest where Arroyo de la Laguna flows out of the Basin. The other Arroyos and major surface water bodies include the Arroyo Valle, Arroyo Mocho, Arroyo Las Positas, Alamo Creek, Altamont Creek, South San Ramon Creek, Tassajara Creek, COLs, and Springtown Alkali Sink.

Both the Arroyo Valle and Arroyo Mocho originate in the woodland forests of the Burnt Hills region in Santa Clara County, in the sub-watershed above Lake Del Valle. The two streams and their tributaries cover the largest drainage areas within the Zone 7 service area. The Arroyo Valle flows into Lake Del Valle above Lang Canyon, and then continues below the Del Valle Dam, flowing westerly through a regional park on the southern border of Livermore before reaching Pleasanton. Flowing southwesterly through the historic downtown area of Pleasanton, the Arroyo Valle ultimately joins the Arroyo de la Laguna at the southwestern outflow from the Basin. Arroyo de la Laguna is a tributary to Alameda Creek.

The Arroyo Mocho remains a natural waterway as it flows southwest through the oak woodlands east of Livermore, then continues through the southern portion of Livermore. Northwest from Livermore, the Arroyo Mocho has a graded and engineered channel, which proceeds through the gravel mining area and merges with the Arroyo Las Positas in northwest Livermore. The Arroyo Las Positas mainly flows westerly along Interstate 580 and is fed by the Arroyo Seco, Altamont Creek, Cayetano Creek, Collier Canyon Creek, and Cottonwood Creek. At its confluence with the Arroyo Mocho in Livermore, the streambed becomes a wide, trapezoidal-shaped flood control channel. The Arroyo Mocho then flows into the Arroyo de la Laguna at the surface and subsurface outflow from the Basin.

Although minor springs contribute to the upper reaches of the Arroyo Mocho and Arroyo Valle above Lang Canyon, none of these springs contribute sufficient runoff to the Arroyos to cause continuous flow in the streams. Most are isolated and are subject to tectonic shifts and climatic conditions that impact the amount of flow emanating.

Figure 7-17 shows the COL, a series of gravel quarries in the central portion of the Basin (Amador Subarea). Some of COLs are used currently for conjunctive use, which will be expanded in the future as ongoing gravel mining is completed and additional quarries are available for Zone 7 use for flood control and managed aquifer recharge. Full implementation of the COLs by Zone 7 is not expected before 2058 when the mining operations are projected to be completed. The Arroyo Valle channel is located along the southern perimeter of the mining area, while the Arroyo Mocho channel has been directed through the middle of the mining area.

The Springtown Alkali Sink, as shown on **Figure 7-11**, is characterized by gently sloping lowland underlain by alluvium and confined in part by shallow bedrock. Historical springs within the Springtown Alkali Sink were caused by high groundwater levels. Development occurred in the area in the late 1960s when Altamont Creek was deepened (up to 15 ft bgs). The deepening of the creek is thought to have created a local drain for shallow groundwater and significant springs no longer occur in the Springtown Alkali Sink. As a result, groundwater elevations are lower than they once were, causing the wetlands to be more seasonal. Currently, less-prominent springs occur in various areas of the sink only during wet periods when the water table is high.

The Springtown Alkali Sink is considered a Groundwater Dependent Ecosystem (GDE) for the purposes of Sustainable Groundwater Management Act (SGMA), as discussed in **Section 8.8**. The Springtown Alkali Sink supports an alkali-saline wetland habitat with seasonal surface ponding and shallow, seasonal high-salinity groundwater. The Springtown Alkali Sink has a mound and swale topography allowing alkali scalds to form in surface water ponds where groundwater is shallow. These scalds support salt-tolerant plants. In areas with better drainage, water accumulates in pools supporting vernal pool biota. The Springtown Alkali Sink also contains several protected species including the Palmate-Bracted Bird's Beak, burrowing owl, tiger salamander, and the fairy shrimp (**Section 8.8**).

7.7.6. Source and Point of Delivery for Imported Water Supplies

☑ **23 CCR § 354.14(d)(6)**

Zone 7 ensures that local water supplies (e.g., groundwater) are not depleted by importing approximately 80% of the Basin's water supply from SWP (delivered to Zone 7's retailers and agricultural customers) and recharging the Main Basin with surplus surface water when available (artificial recharge). **Figure 7-18** shows the point of delivery for imported water supplies.

Zone 7's surplus surface water supplies, which are accounted for by calendar year, come from the following sources:

- **State Water Project (SWP deliveries via the South Bay Aqueduct [SBA])** – As a SWP contractor, Zone 7 imports supplies from the SWP through the SBA. As of 1998, Zone 7 has had an annual maximum SWP contract amount of 80,619 AFY referred to as the "Table A Contract Amount." However, actual SWP deliveries are usually allocated in any given year by the DWR at a lower level based on numerous factors, including hydrologic conditions. Currently, the long-term reliable yield of the SWP is approximately 60% of the Table A amount (48,370 AFY).

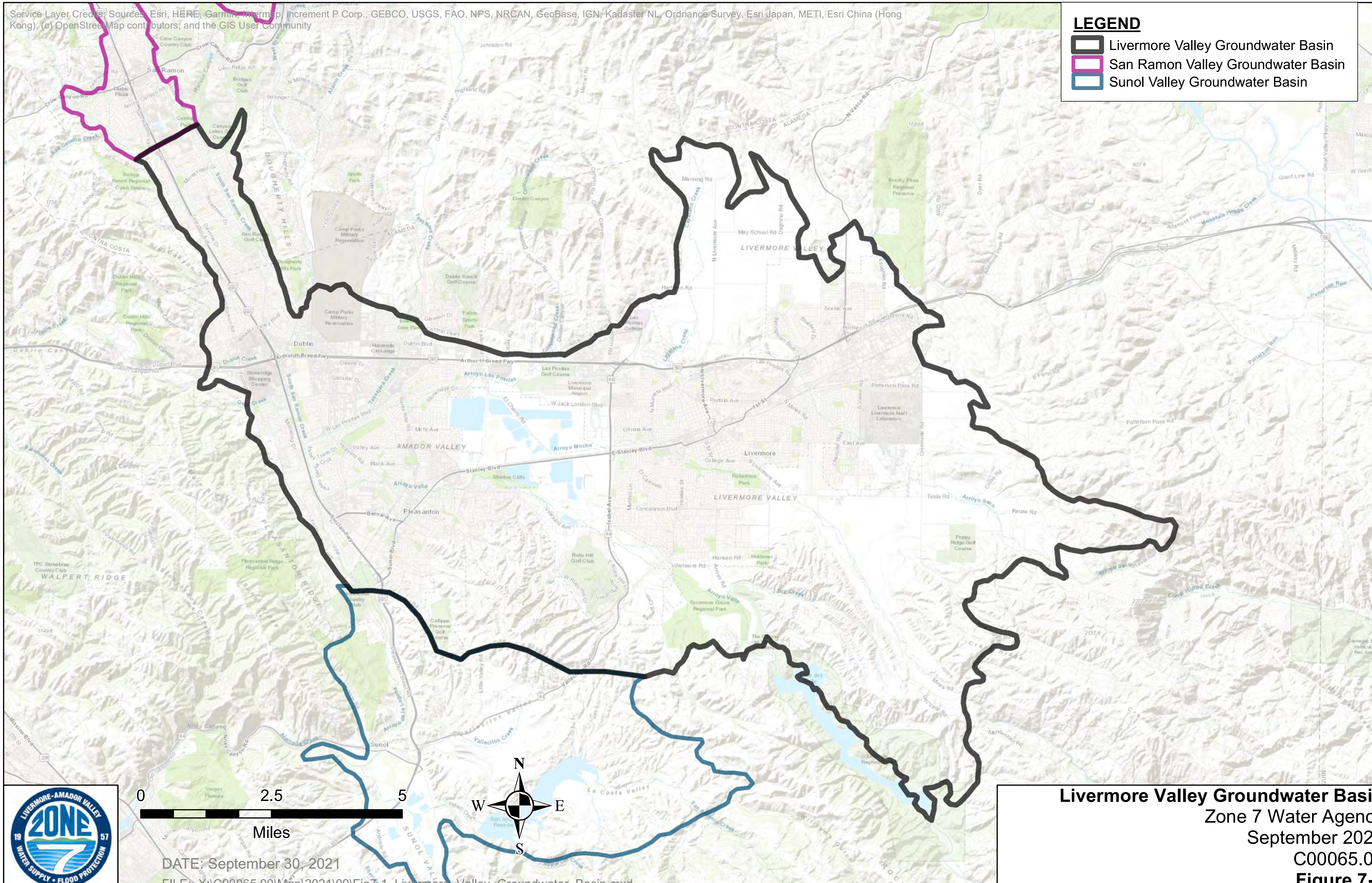
- **Arroyo Valle Water Rights (Lake Del Valle)** – Zone 7 has temporary water rights for a portion of the natural flows into Lake Del Valle. Accordingly, Zone 7 coordinates releases from the reservoir into the Arroyo Valle to maintain downstream flows and streambed recharge at the levels that would have occurred had the reservoir not been constructed. Additional releases of Arroyo Valle water can be made from the lake when such water is available for Zone 7. Maintaining minimum flows is a condition of Zone 7's water rights permit for the Arroyo Valle water. Zone 7 can also use other portions of Arroyo Valle water for supply to its treatment plants and for supplemental aquifer recharge. Zone 7 is currently pursuing the permanent rights to this surface water source.

- **Kern County Subbasin (storage rights only)** – Zone 7 has purchased water storage rights in the Semitropic Water Storage District (78,000 AF) and in the Cawelo Water District (120,000 AF) in Kern County. These rights give Zone 7 the ability to remotely store surplus SWP water when available. When Zone 7 is ready to use the water locally; it can import that quantity of SWP water through an exchange procedure within the SWP system.

- **Lower Yuba River Accord (Yuba Accord)** – In 2008, Zone 7 entered a contract with DWR to purchase additional water under the Yuba Accord. The contract was amended in 2020 to extend through 2025. There are four different Components (types) of water available; Zone 7 has the option to purchase Component 2 and Component 3 water during drought conditions, and

Component 4 water when Yuba County Water Agency has determined that it has water supply available to sell. Zone 7 estimates the average yield from the Yuba Accord to be 850 AFY.

- **Dry Year Transfer Program** – The State Water Contractors, an organization composed of contractors of the SWP, facilitates the purchase of water from the Feather River Watershed for transfer to SWP contractors during dry years. This is an optional program that Zone 7 has utilized on an as-needed basis.
- **Other Transfers** – As part of Zone 7's long-term reliability program, Zone 7 actively seeks out transfers from other agencies or districts that have water available.


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), (c) OpenStreetMap contributors, and the GIS User Community
LEGEND
Livermore Valley Groundwater Basin
San Ramon Valley Groundwater Basin
Sunol Valley Groundwater Basin
Dublin
Pleasanton
Livermore
San Ramon
Sunol
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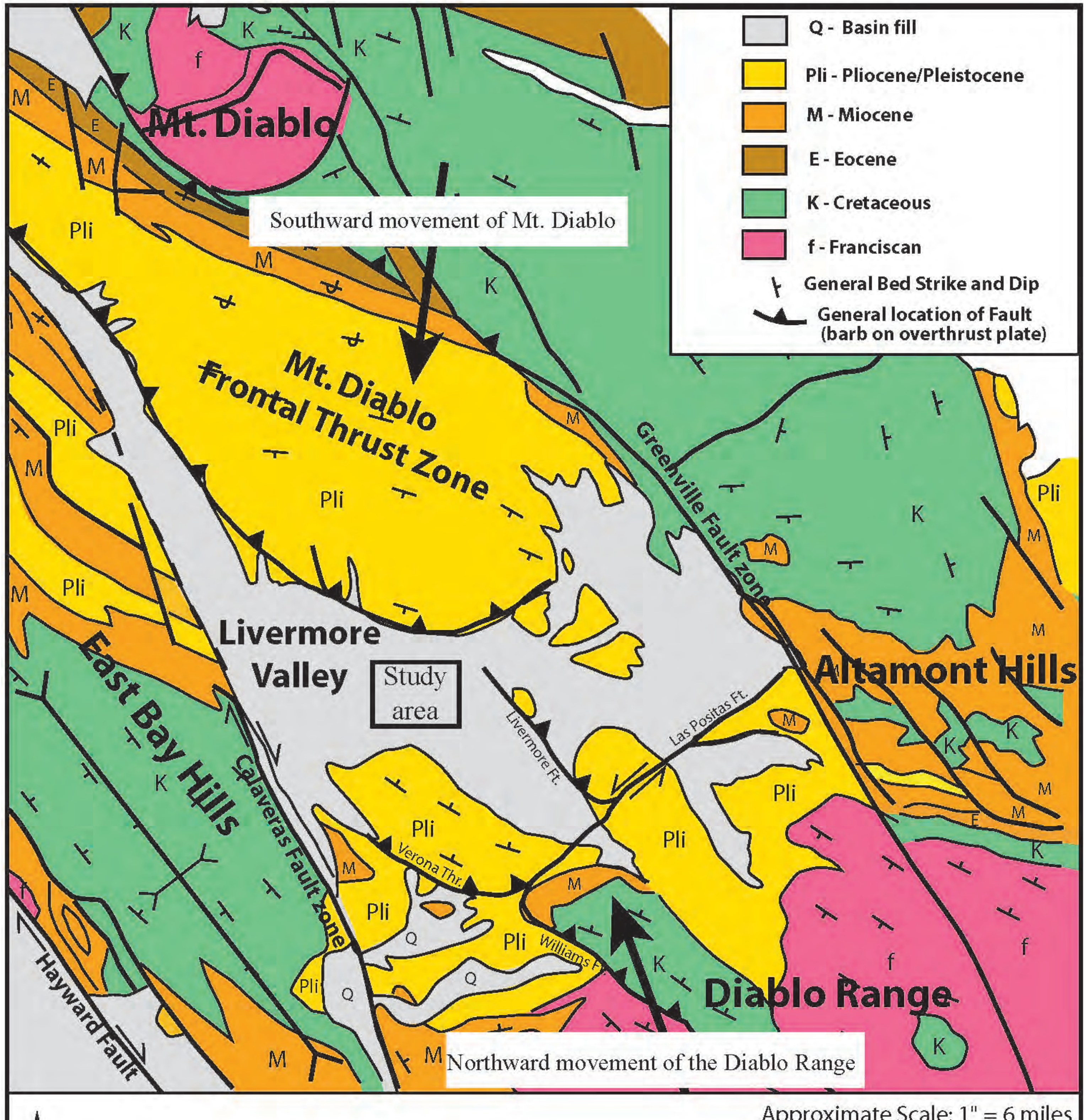
Livermore Valley Groundwater Basin
Zone 7 Water Agency
September 2021
C00065.00
Figure 7-1



A generalized geologic/ tectonic map of the greater Livermore Valley area. The current Livermore Valley is the result of the deformation of the Proto-Livermore Basin between the southward movement of the Mt. Diablo thrusts and the northward component of movement of the Diablo Range, south of the valley. There has been minor deformation of the Valley adjacent to the Calaveras and Greenville fault zones.

Source: Norfleet Consultants, 2004. *Preliminary Stratigraphic Evaluation, West Side of the Main Basin, Livermore-Amador Groundwater Basin.* Figure 3-1

Figure 7-2
Generalized Geologic/Tectonic Map of the Livermore Valley

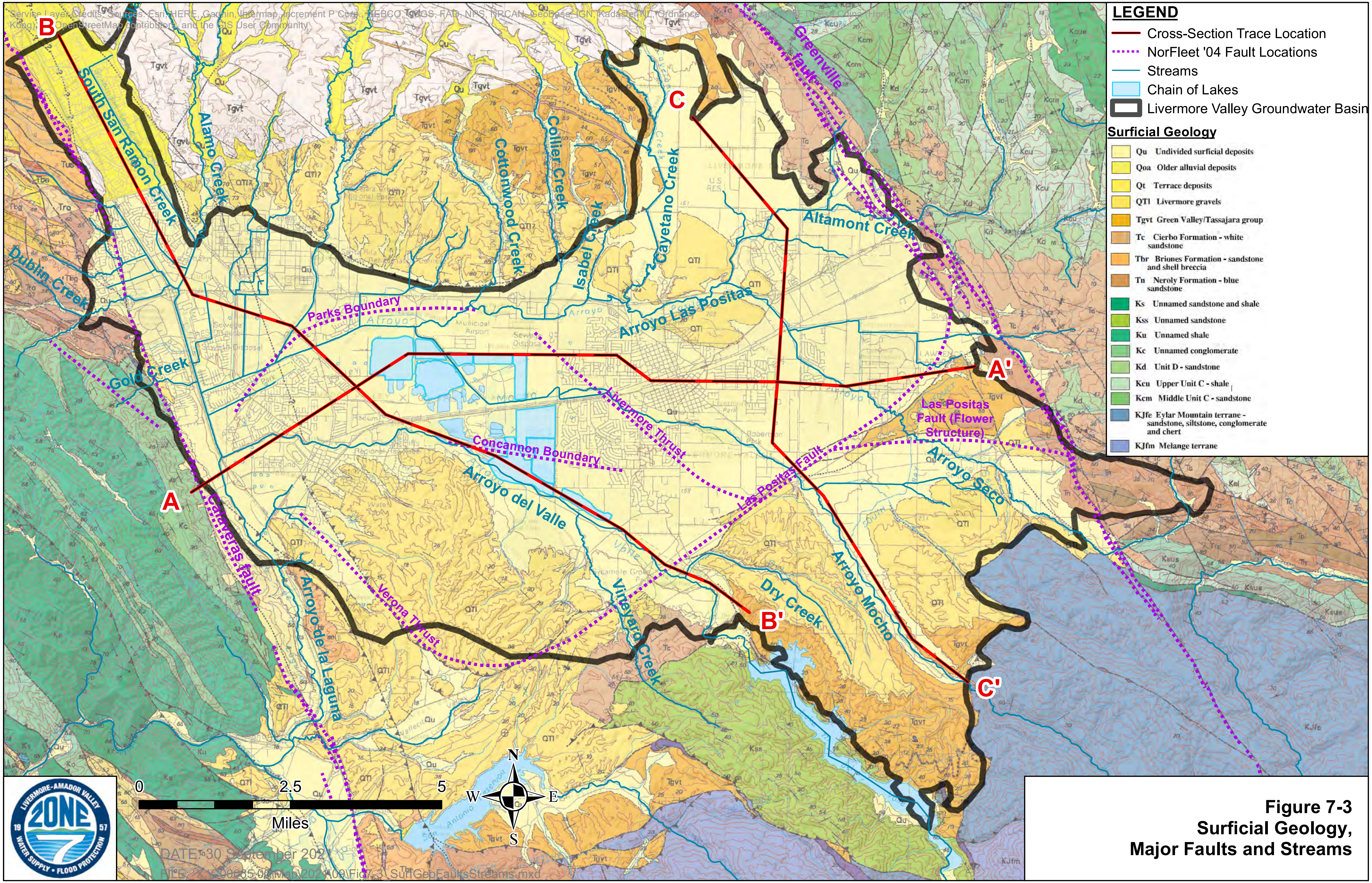
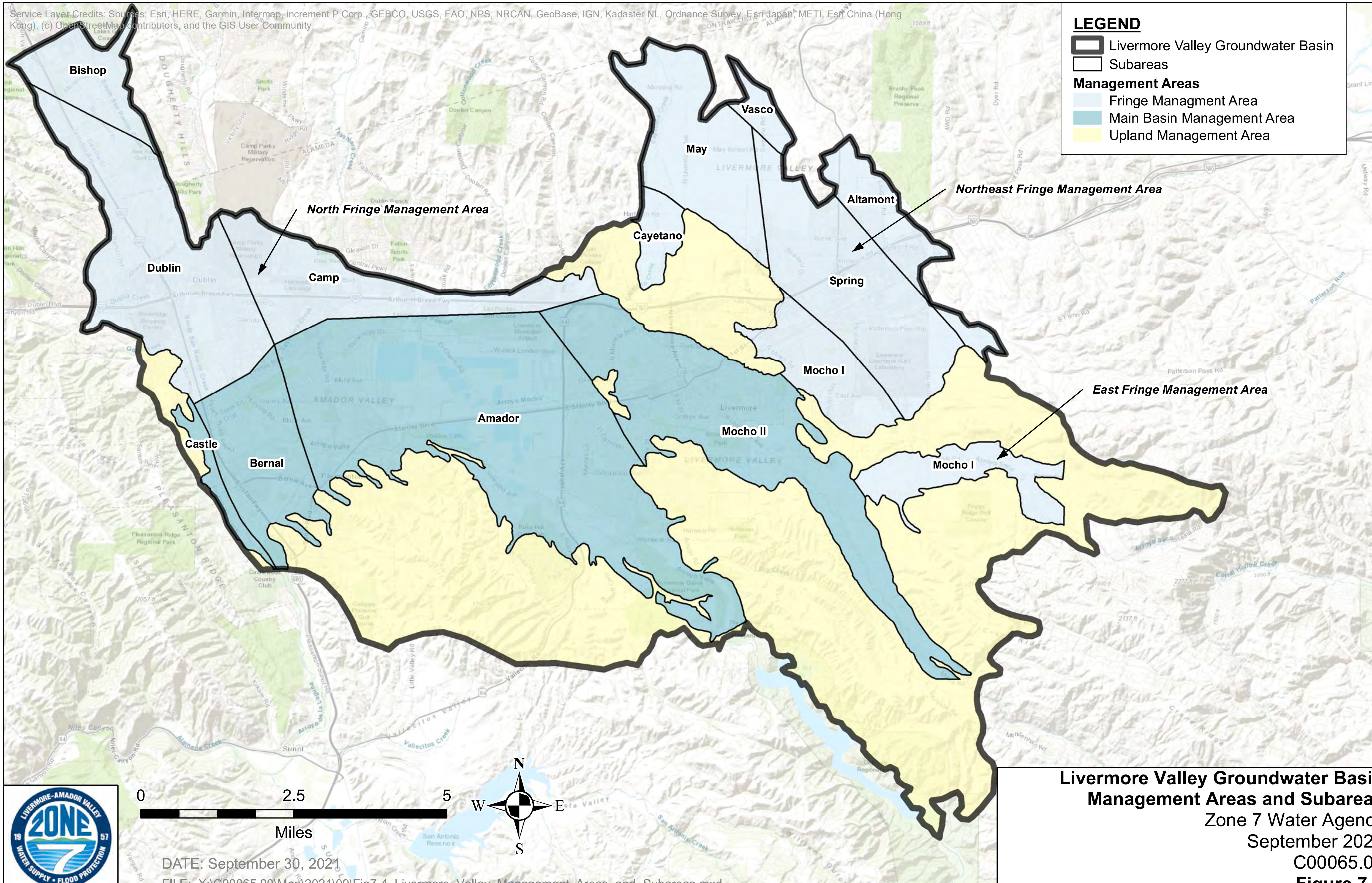
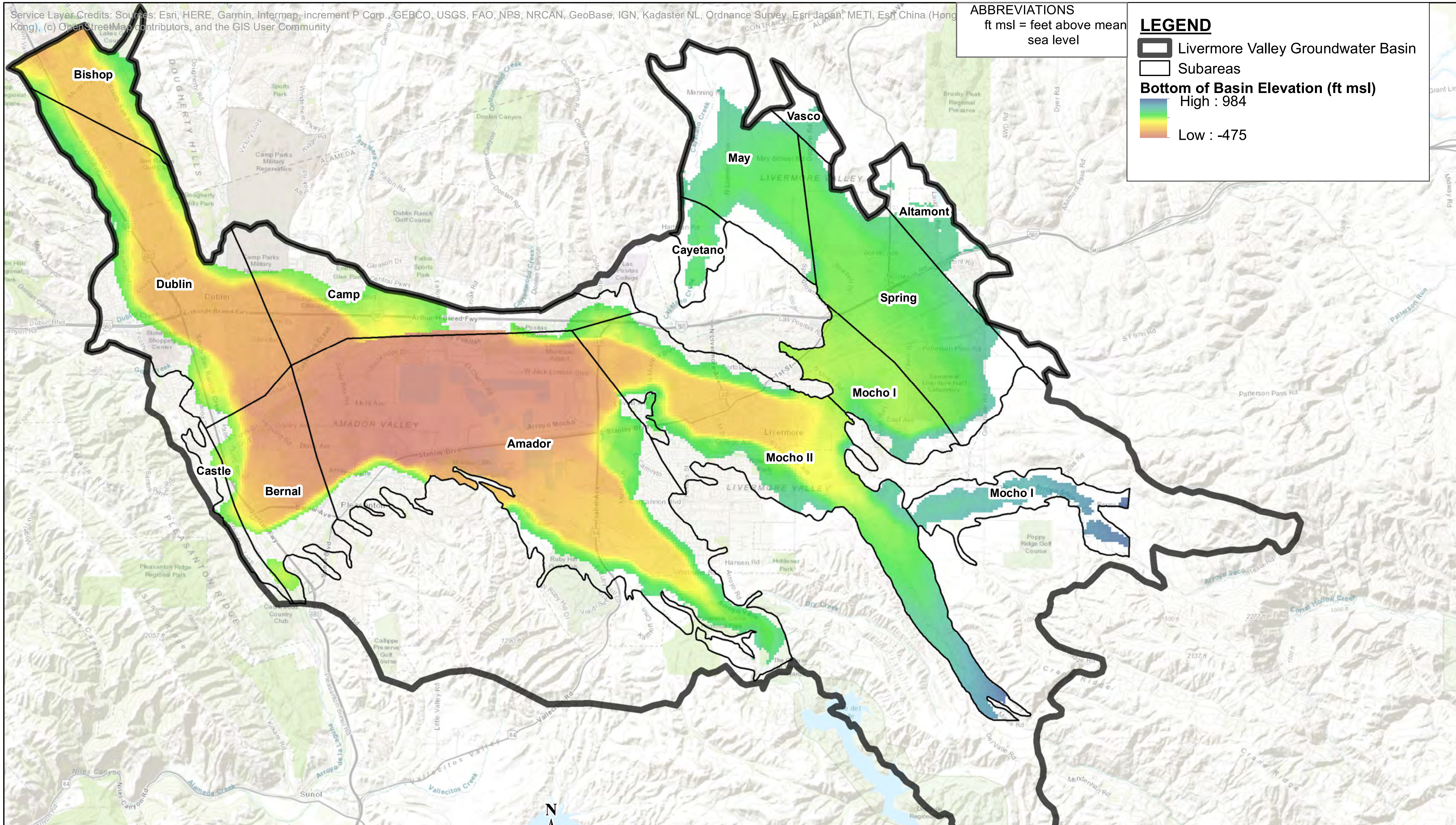


Figure 7-3
Surficial Geology,
Major Faults and Streams



Livermore Valley Groundwater Basin Management Areas and Subareas
Zone 7 Water Agency
September 2021
C00065.00
Figure 7-4



0 2.5 5
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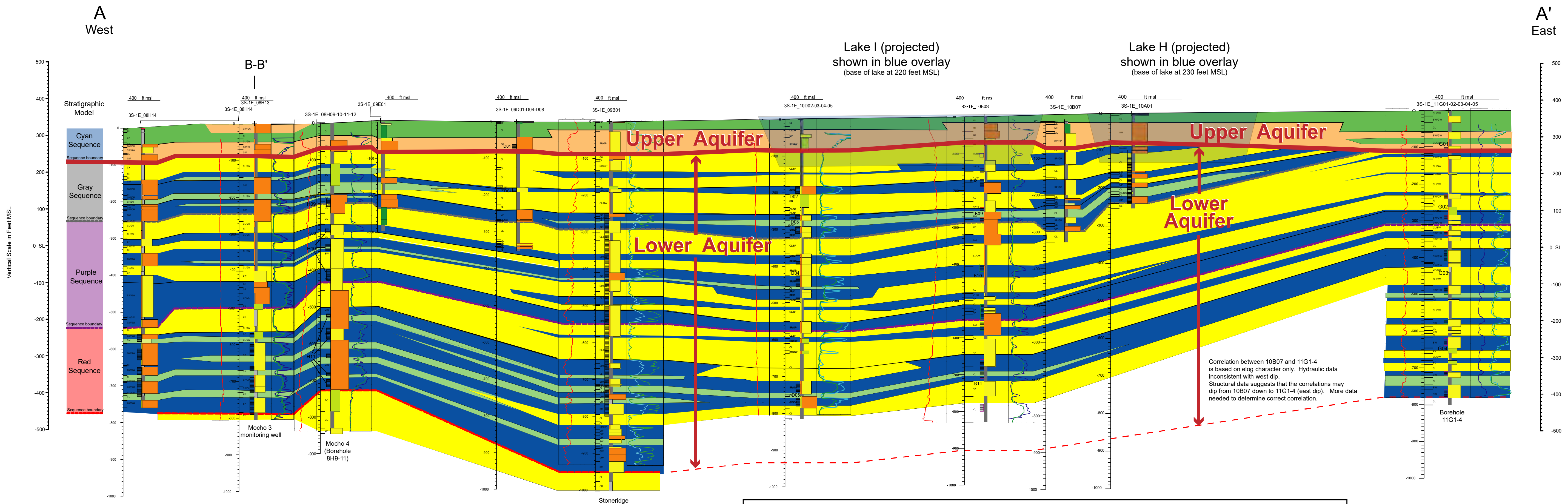
Elevation of Bottom of Basin
Zone 7 Water Agency
September 2021
C00065.00
Figure 7-5



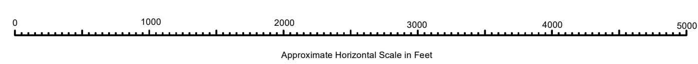
Source: Plate 3.
Cross Section A-A' Chain-of-Lakes Area
Livermore Valley

Zone 7 Water Agency

Stratigraphic Interpretation by
Kenn Ehman and Rick Blake
December 2003

Assistance from
Tom Rooze, Zone 7 Water Agency
David Lunn, Zone 7 Water Agency
Ken Stevens, CIS Solutions
Rick Cramer, Groundworks Environmental, Inc.
Sands Figuers, Norfleet Consultants

Skyline Ridge, Inc.



5:1 Vertical Exaggeration

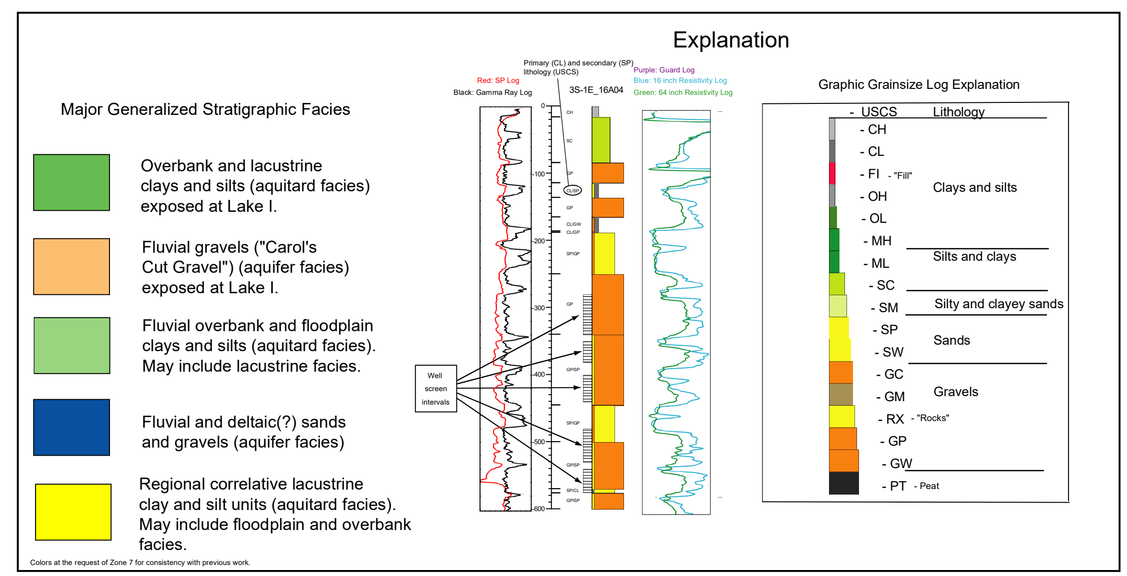


Figure 7-6
Norfleet 2004 Cross-Section A-A'

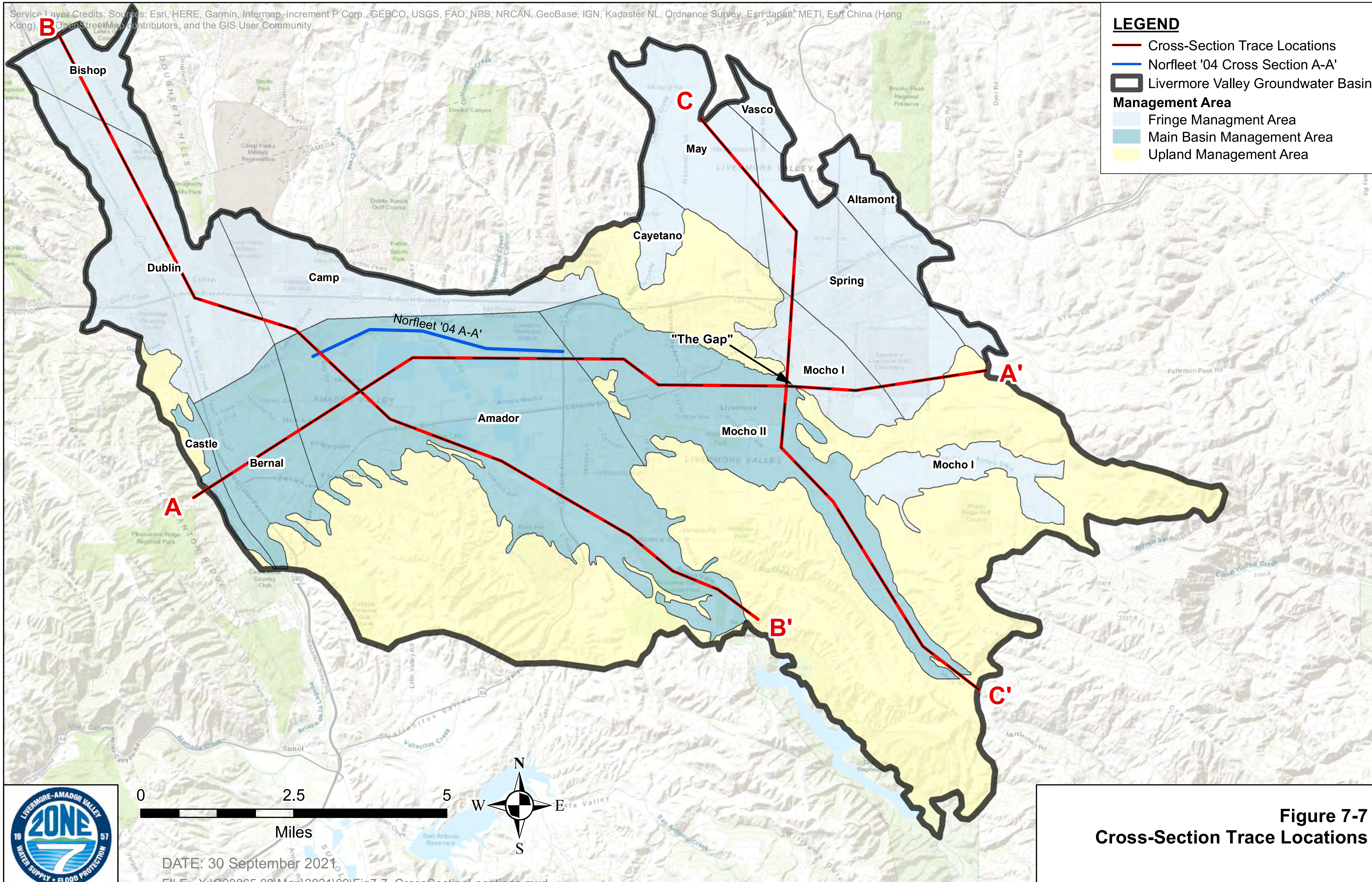
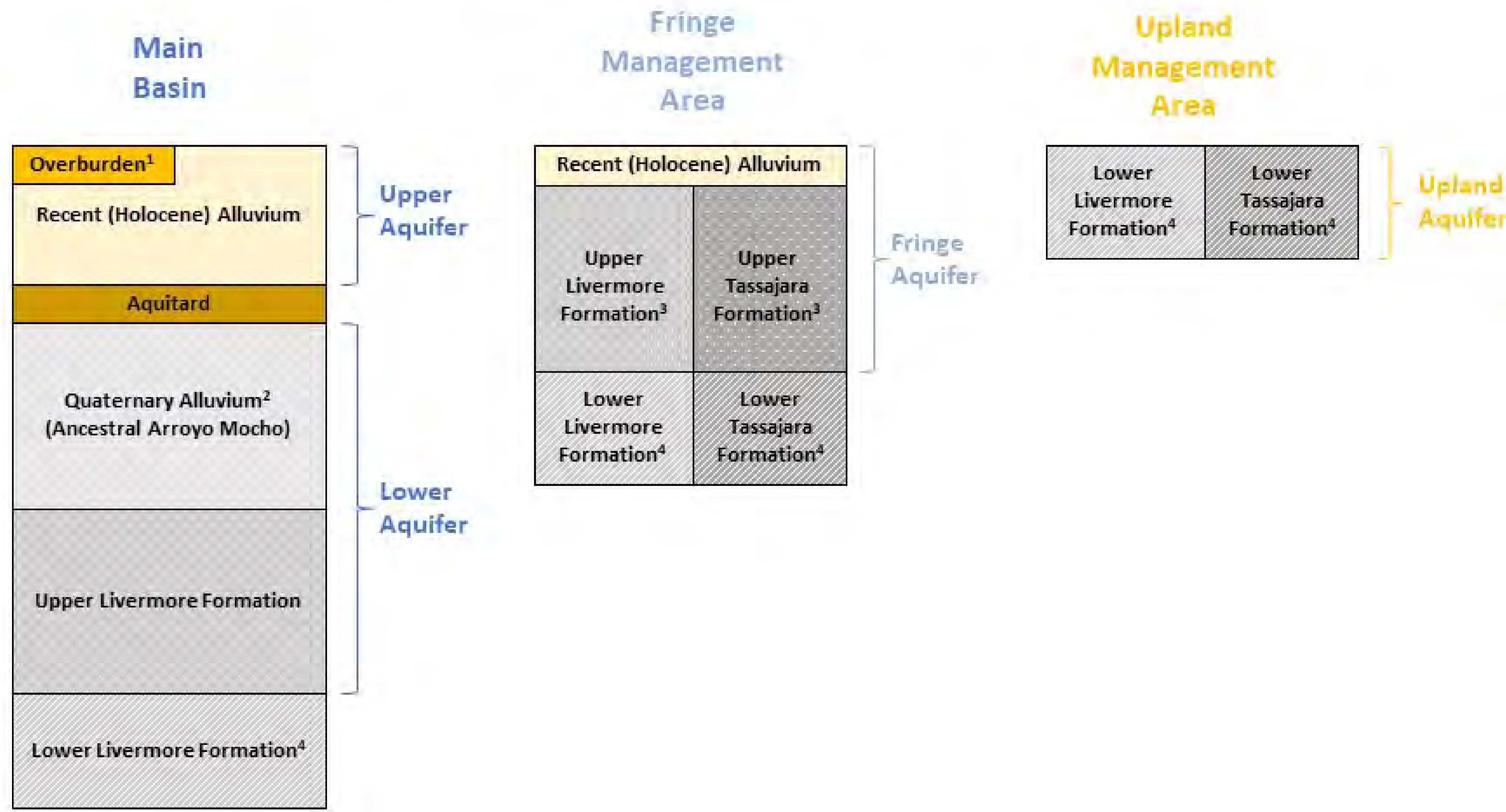


Figure 7-7
Cross-Section Trace Locations

Livermore Valley Groundwater Basin
Conceptual Hydrostratigraphy Model



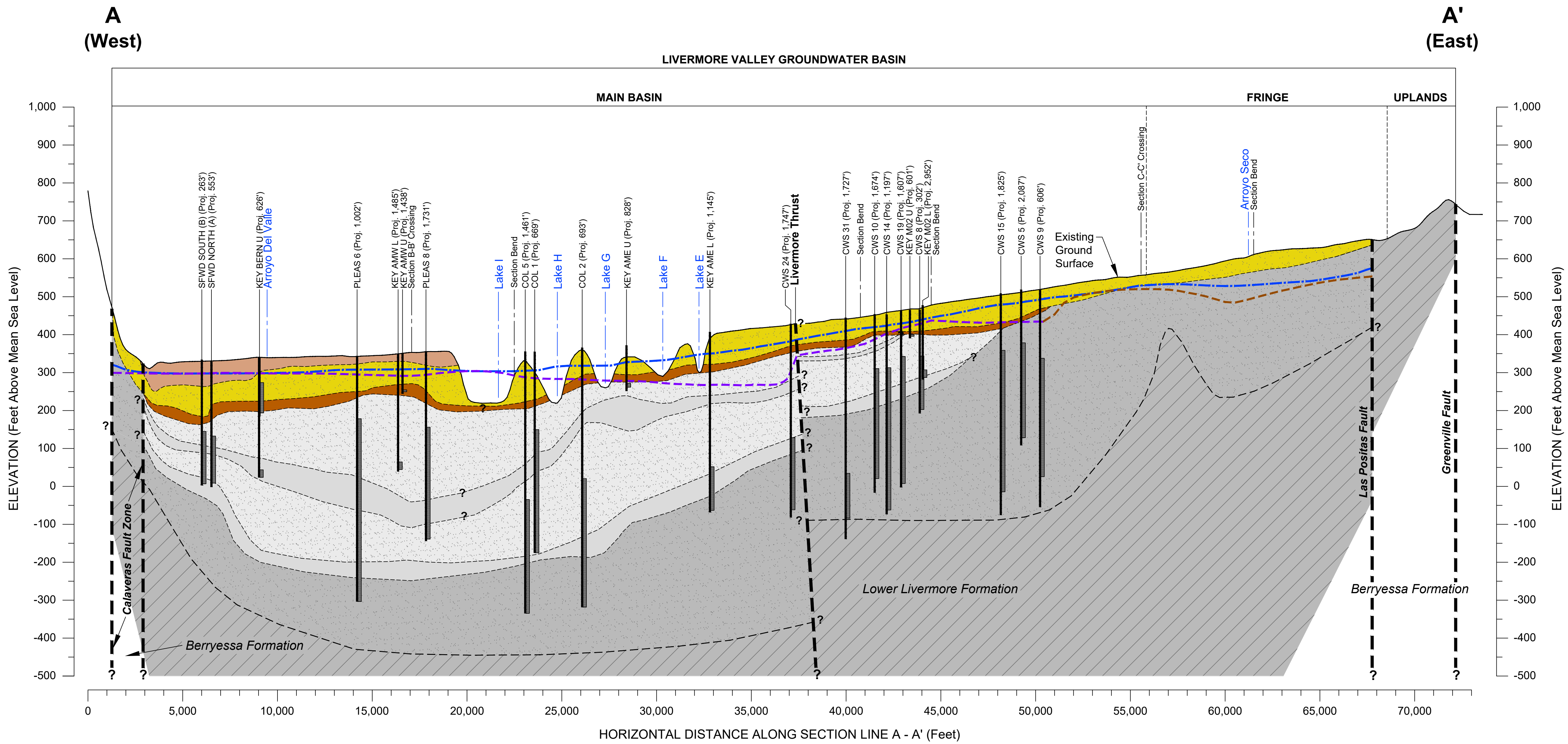
Notes:

1 Only encountered in western portion of Main Basin (Bernal, Amador subareas)
2 Only encountered where Ancestral Arroyo Mocho incised valley complex exists (see Norfleet 2004, Figure 3-5)
3 Tassajara Formation encountered in northwestern (Bishop, Dublin, Camp subareas) and northeastern (May, Cayetano subareas) portion of Fringe Management Area; Livermore Formation encountered in all other Fringe subareas
4 Considered generally impermeable and below the bottom of the usable groundwater basin
5 Drawings not to scale; for discussion purposes only

Conceptual Hydrostratigraphy Model

Zone 7 2022 Alternative GSP
Livermore, CA
October 2021
EKI C00065.00

Figure 7-8



Cross-Section A - A'

Legend:

Stratigraphy

- Surficial Clay (Overburden)
- Holocene Alluvium
- Lacustrine Clay (Aquitard)
- Quaternary Alluvium (Gravels/Sands)
- Quaternary Alluvium (Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore (Fall 2019)

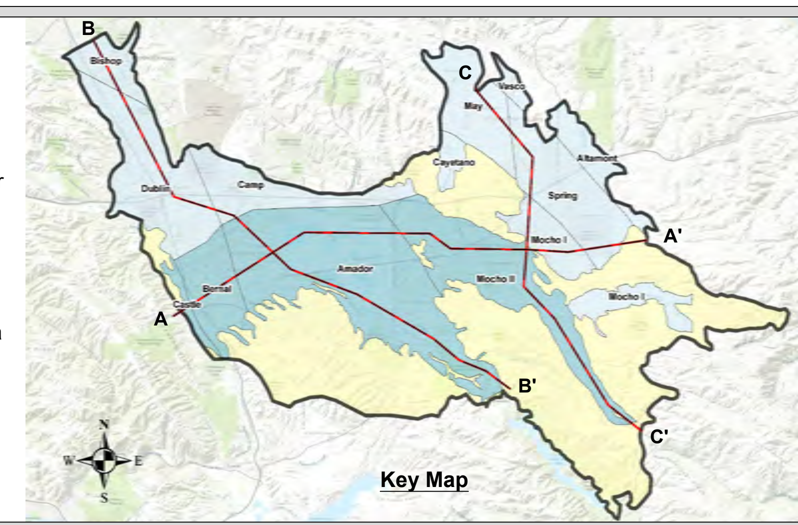
- Well Log
- Screen Interval

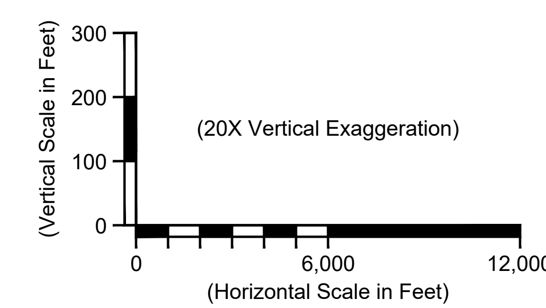
Map Elements

- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



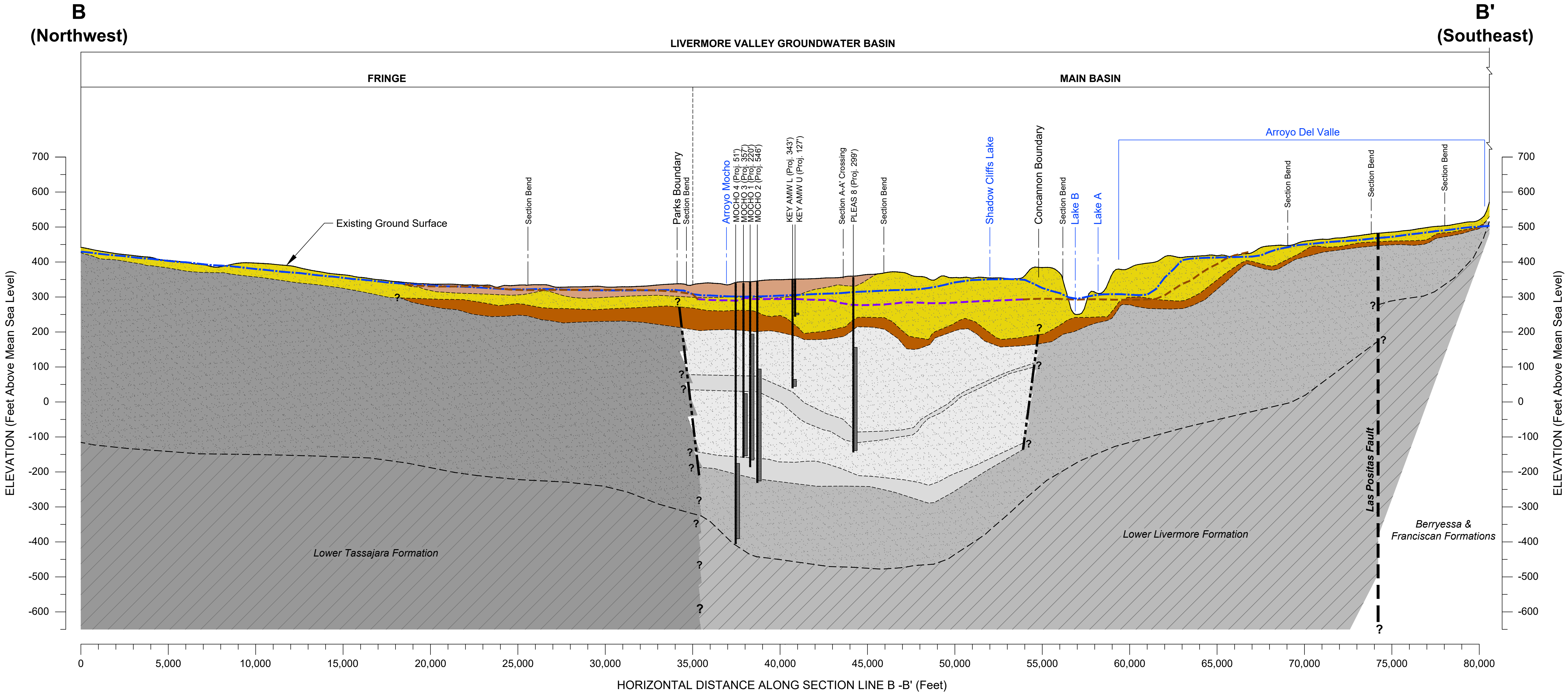


Geologic Cross-Section A - A'

Zone 7 2022 Alternative GSP
Livermore, CA
October 2021
EKI C00065.00

eki environment & water

Figure 7-9



Cross-Section B - B'

Legend:

Stratigraphy

- Surficial Clay (Overburden)
- Holocene Alluvium
- Lacustrine Clay (Aquitard)
- Quaternary Alluvium (Gravels/Sands)
- Quaternary Alluvium (Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Upper Tassajara Formation
- Lower Tassajara Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore/Tassajara Formation (Fall 2019)

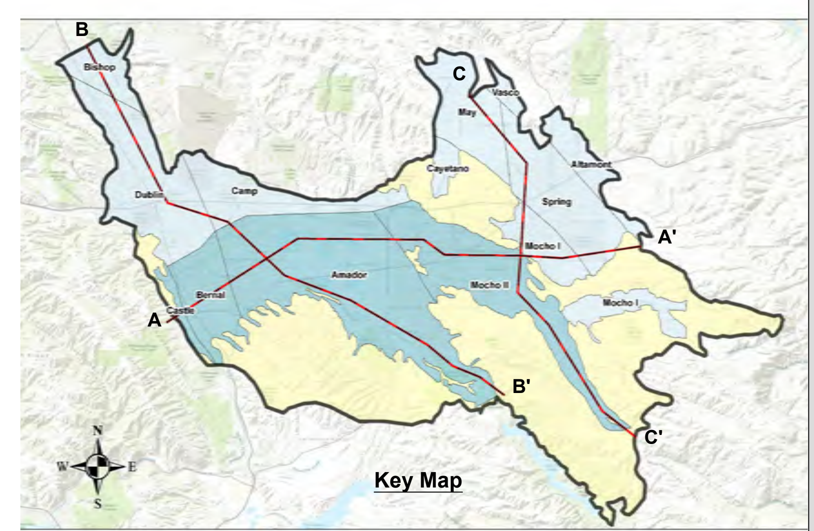
- Well Log
- Screen Interval

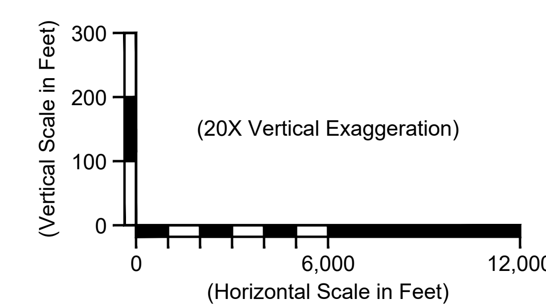
Map Elements

- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area





Geologic Cross-Section B - B'

Zone 7 2022 Alternative GSP
Livermore, CA
October 2021
EKI C00065.00

Figure 7-10

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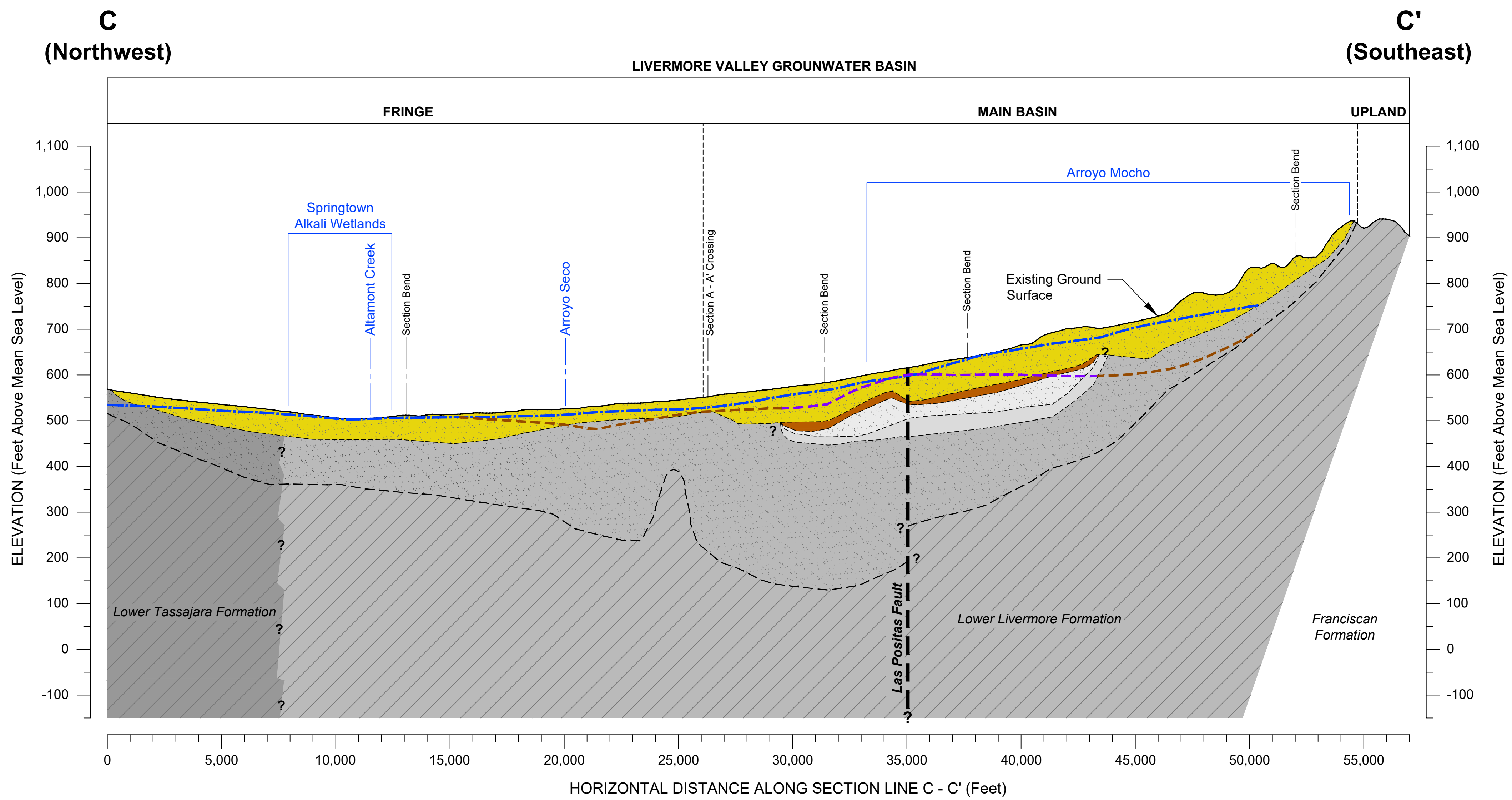
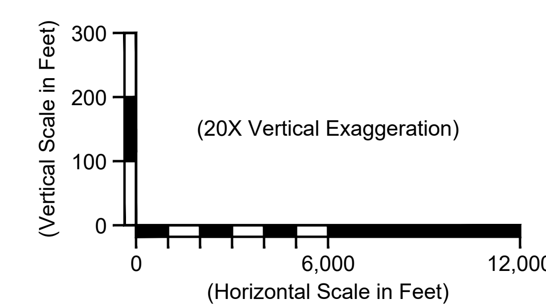


Cross-Section C - C'



Legend:

Stratigraphy

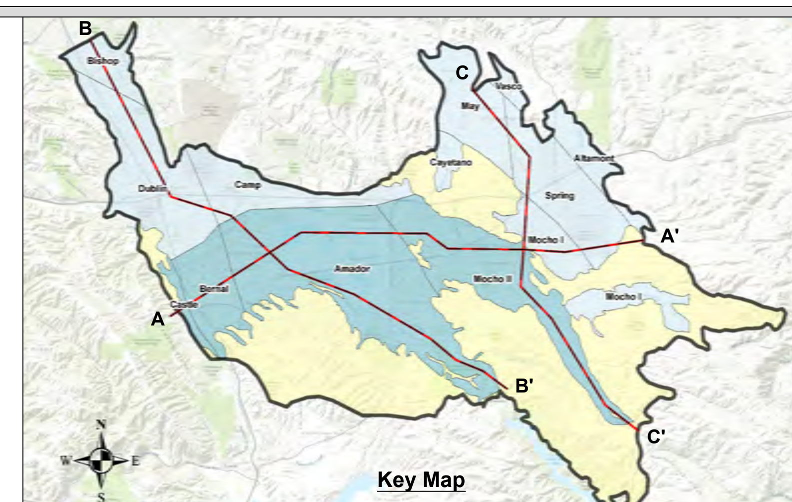
- Holocene Alluvium
- Lacustrine Clay (Aquitard)
- Quaternary Alluvium (Gravels/Sands)
- Quaternary Alluvium (Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Upper Tassajara Formation
- Lower Tassajara Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore/Tassajara Formation (Fall 2019)

Map Elements

- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



Geologic Cross-Section C - C'

Zone 7 2022 Alternative GSP
Livermore, CA
October 2021
EKI C00065.00

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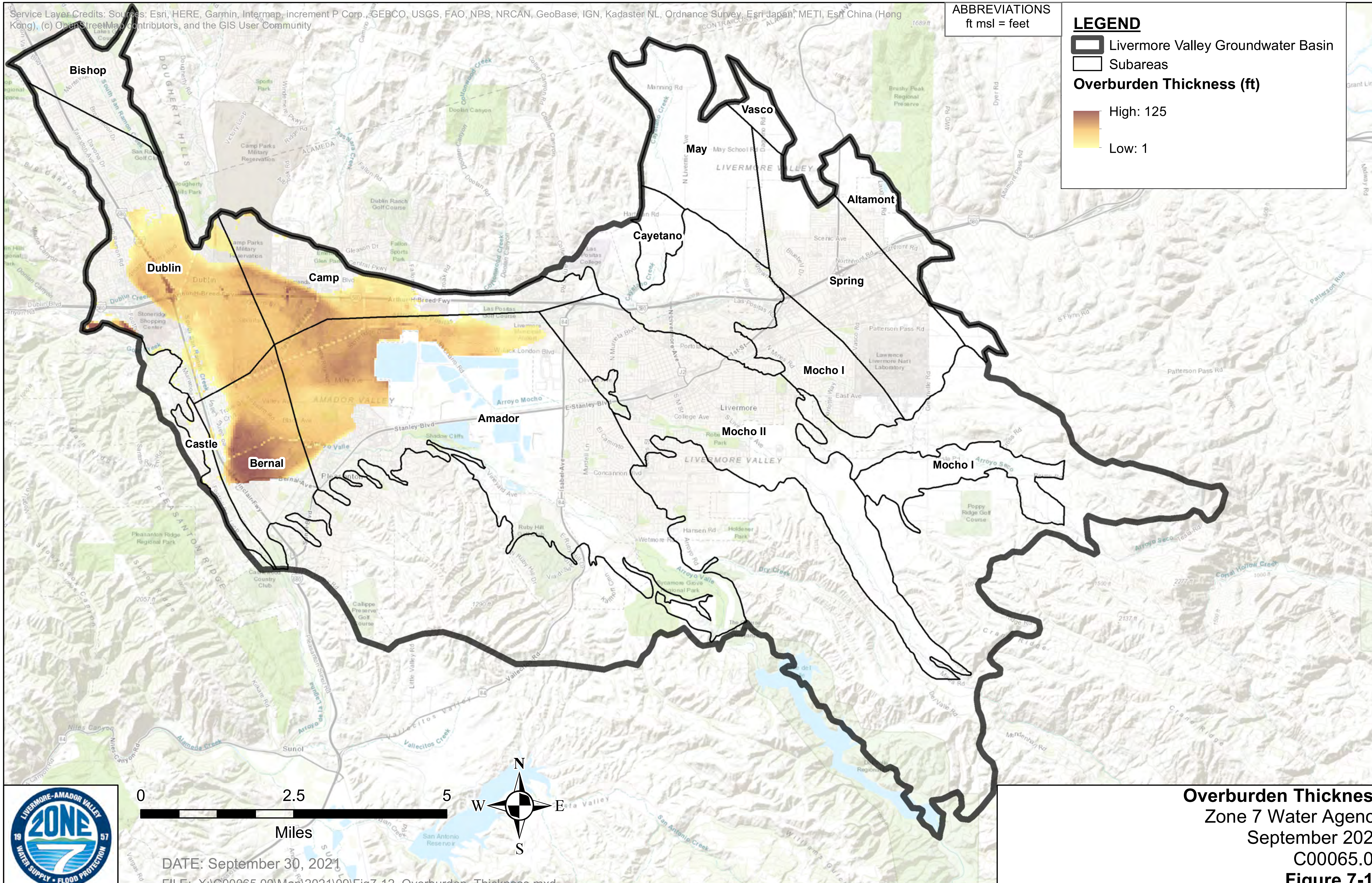
Figure 7-11

20210603.085444 G:\C00065.00\2021-06_Cross Section C-C.dwg Section C-C'



Overburden Thickness
Zone 7 Water Agency
September 2021
C00065.00
Figure 7-12

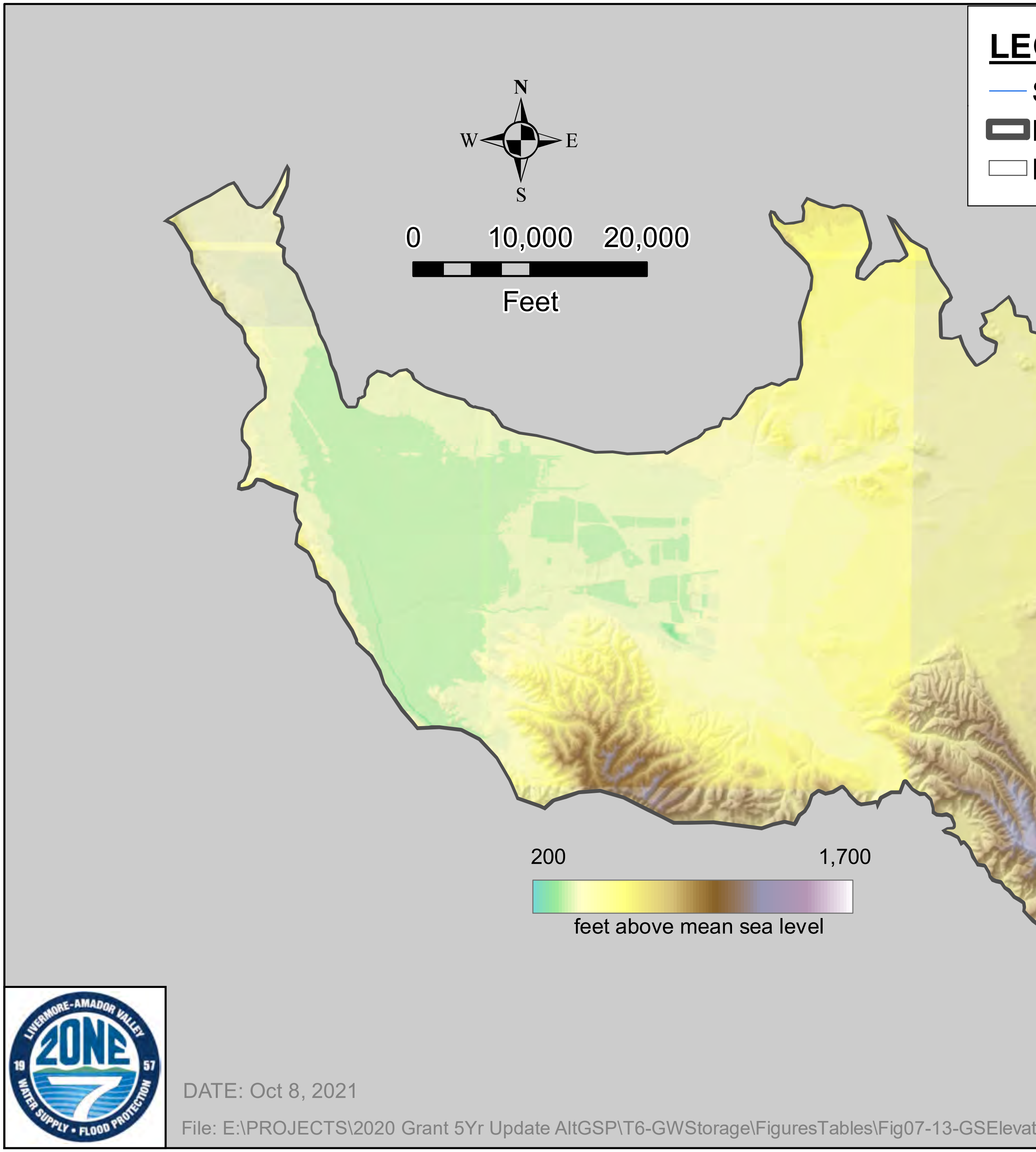


Figure 7-13
Ground Surface Elevations
Livermore Valley Groundwtaer Basin

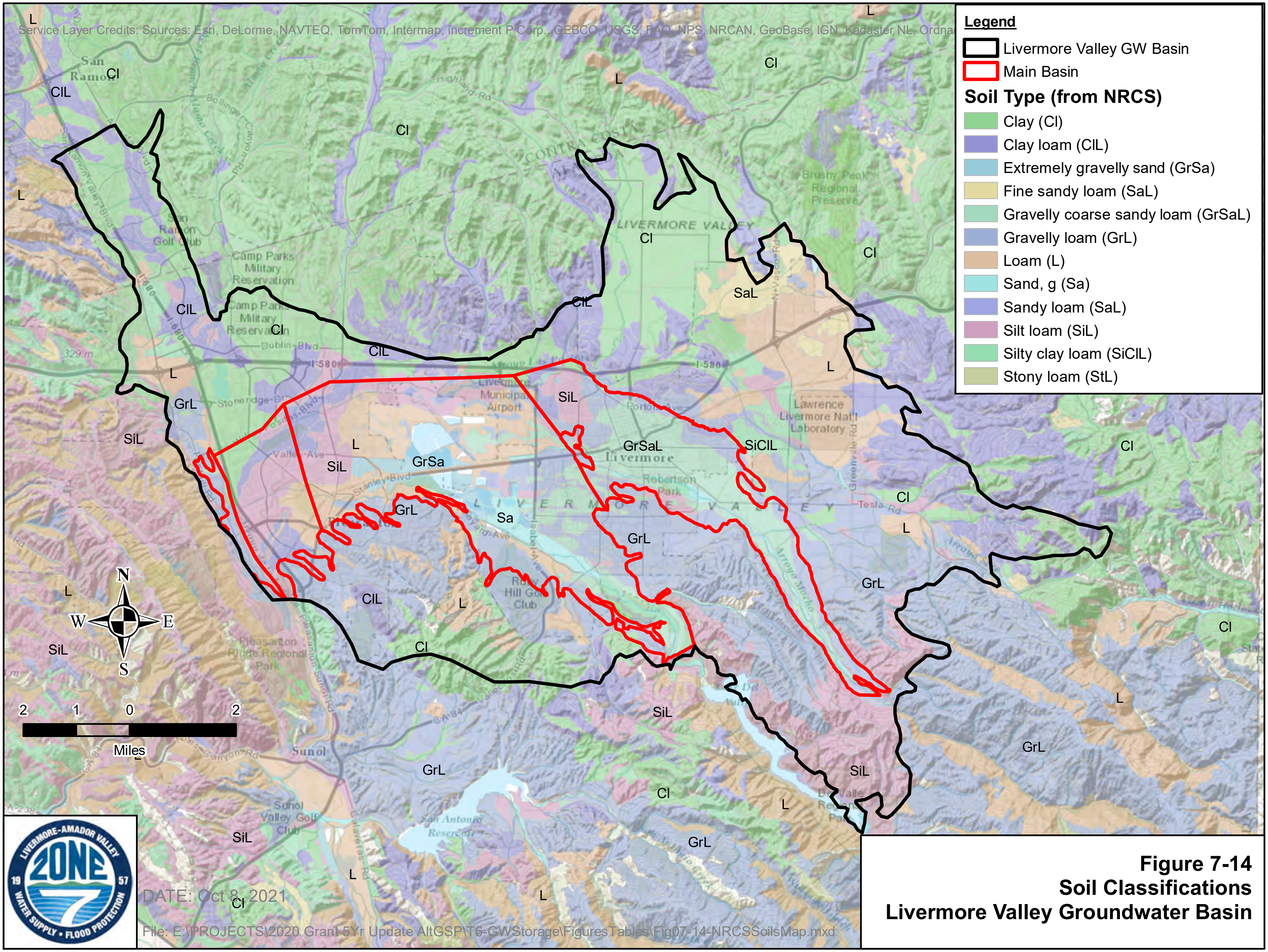


Figure 7-14
Soil Classifications
Livermore Valley Groundwater Basin

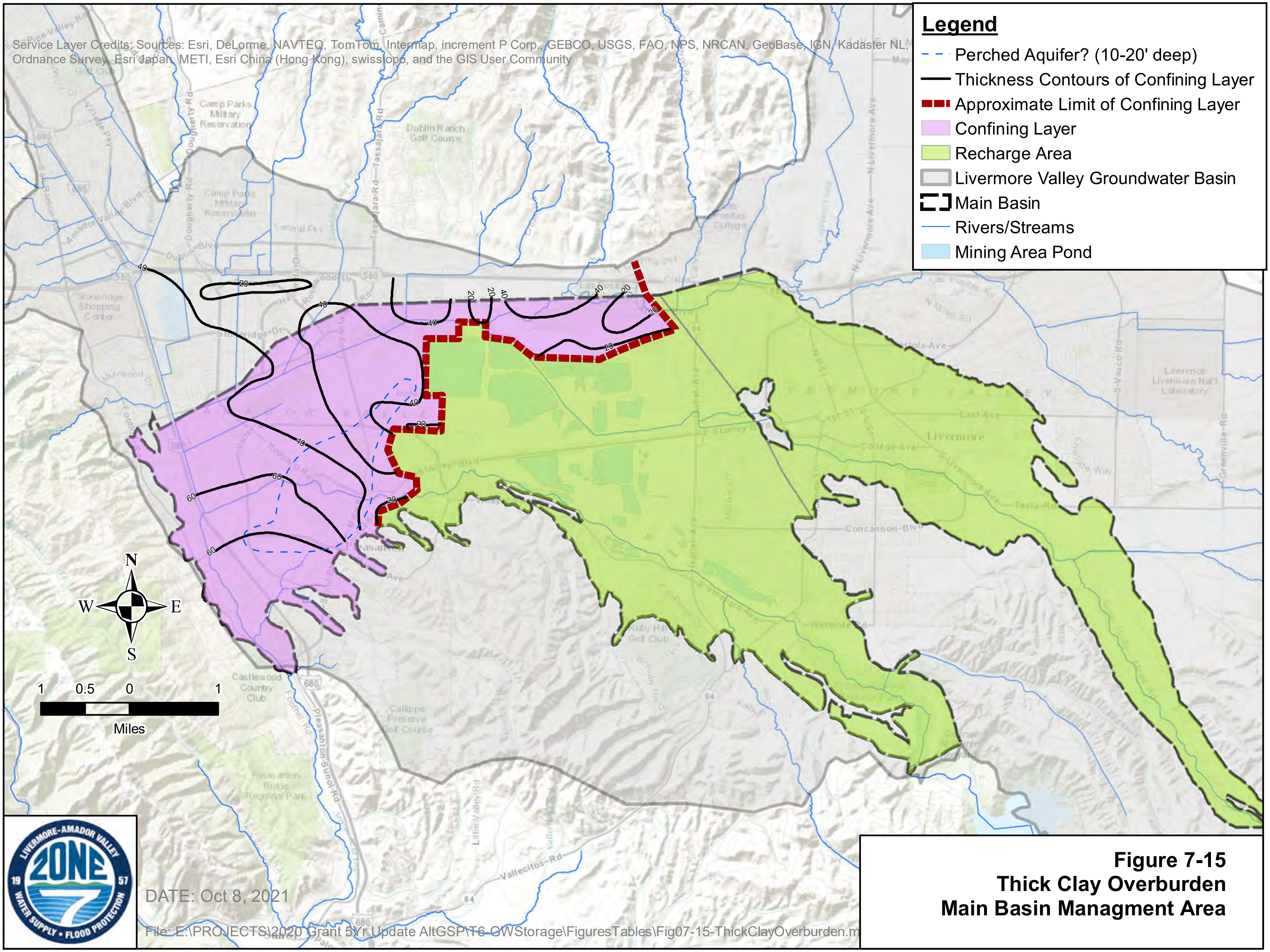


Figure 7-15
Thick Clay Overburden
Main Basin Managment Area

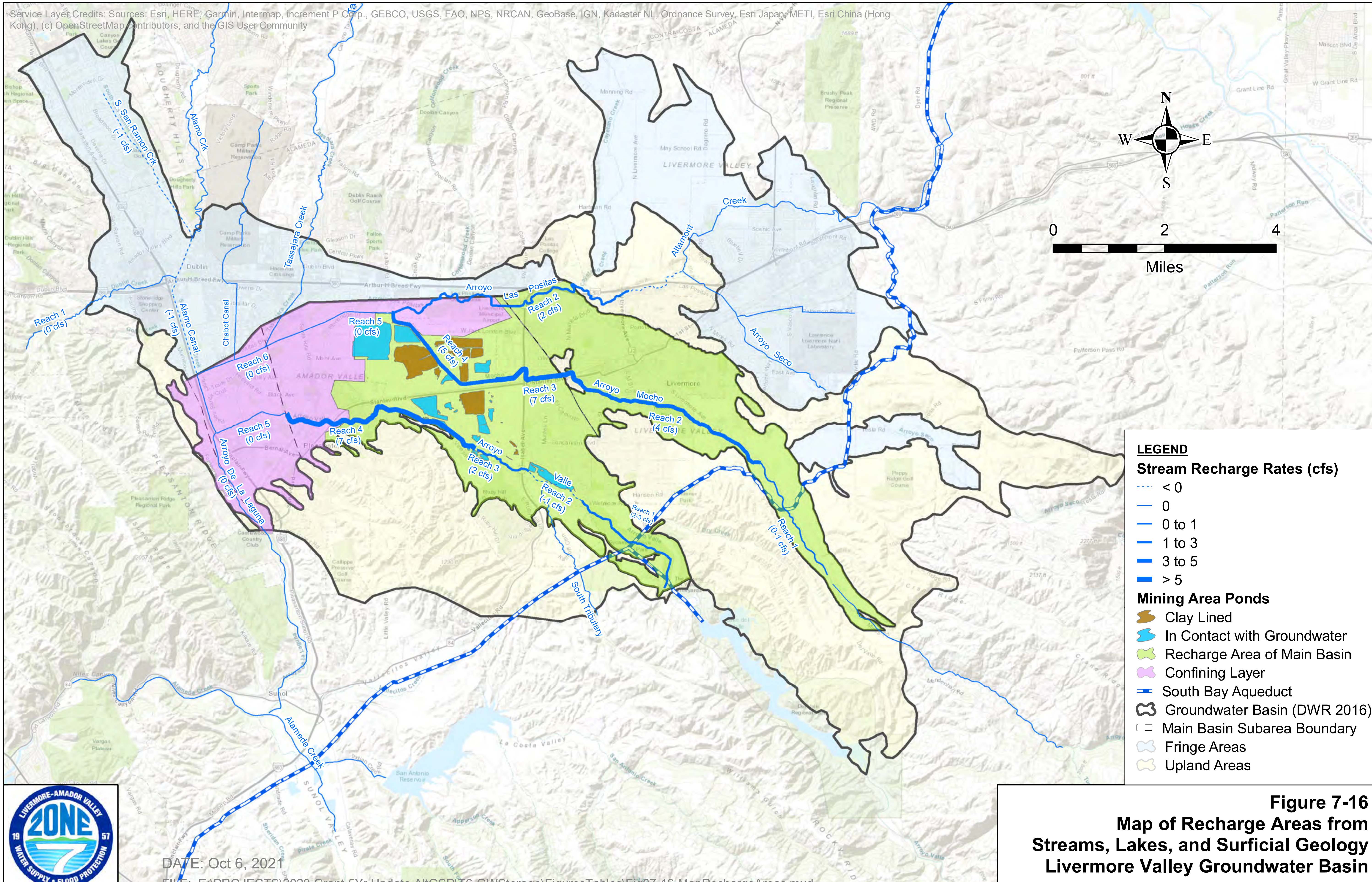


Figure 7-16
Map of Recharge Areas from Streams, Lakes, and Surficial Geology Livermore Valley Groundwater Basin

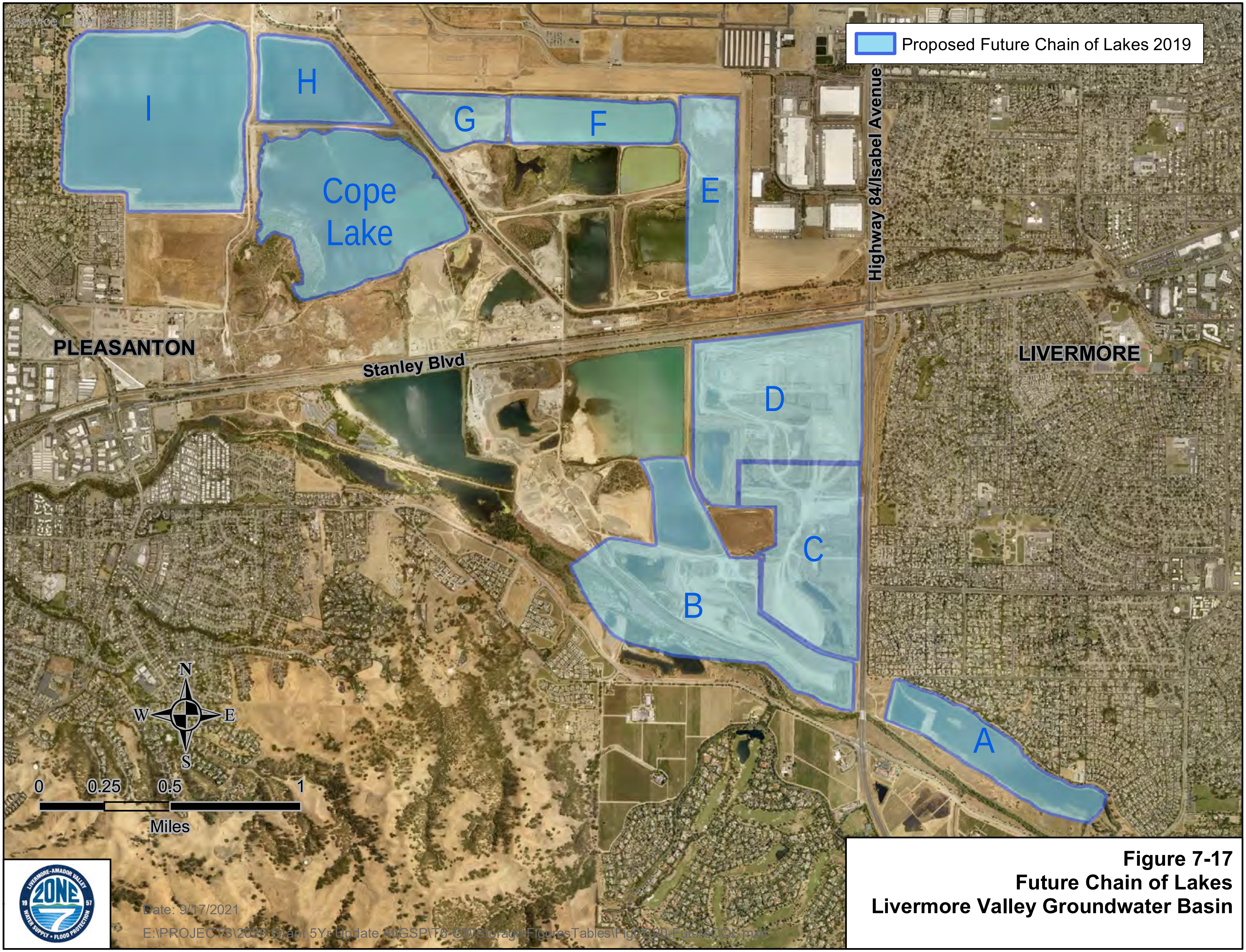


Figure 7-17
Future Chain of Lakes
Livermore Valley Groundwater Basin

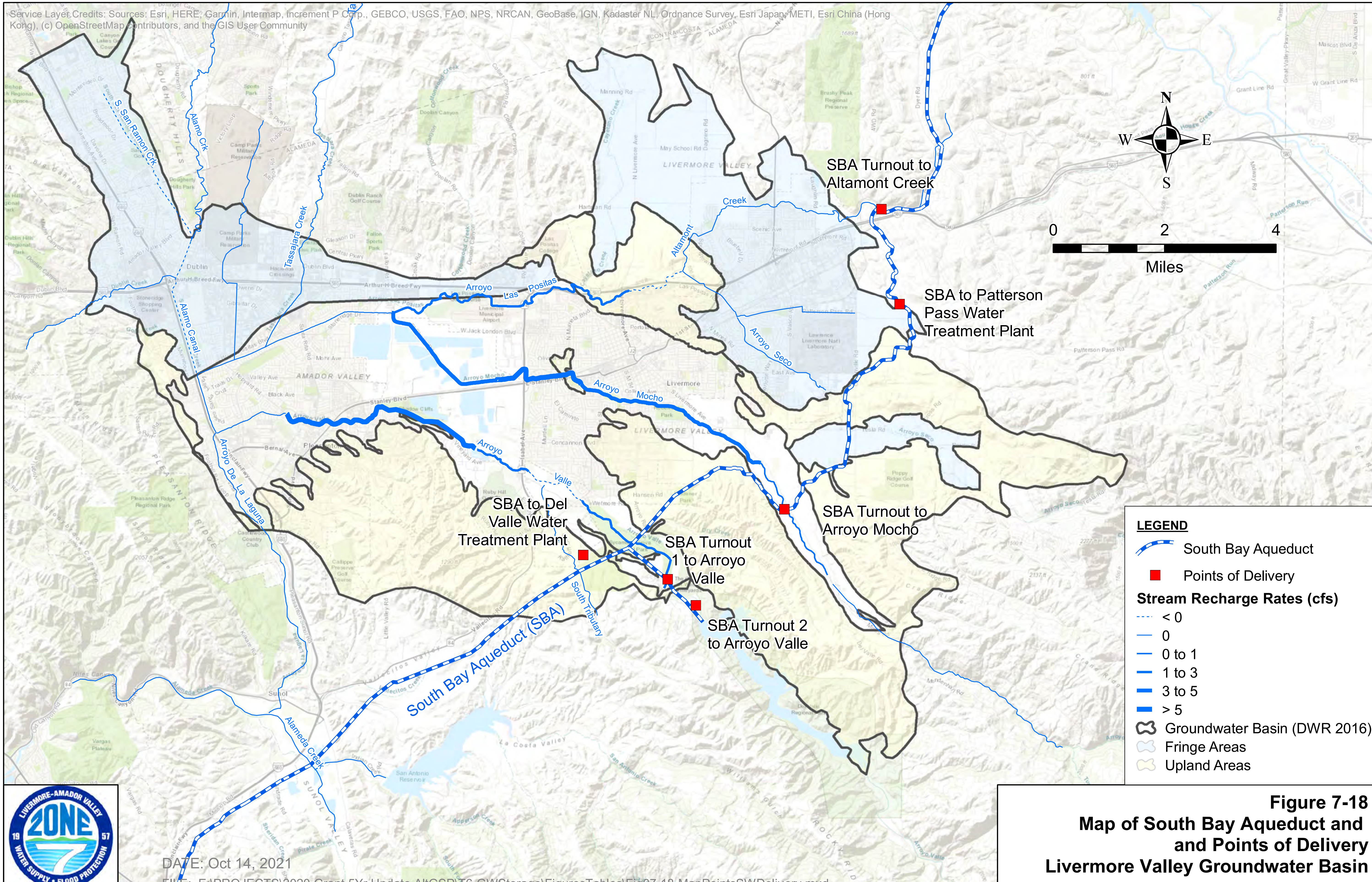


Figure 7-18
Map of South Bay Aqueduct and and Points of Delivery
Livermore Valley Groundwater Basin

8. CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

8.1. Introduction

§ 354.16. Groundwater Conditions
Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:

☑ **23 CCR § 354.16**

§ 356.4 Periodic Evaluation by Agency
Each Agency shall evaluate its Plan at least every five years and whenever the Plan is amended, and provide a written assessment to the Department. The assessment shall describe whether the Plan implementation, including implementation of projects and management actions, are meeting the sustainability goal in the basin, and shall include the following:
(a) A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.
...
(c) Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.
(d) An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency's evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.

☑ **23 CCR § 356.4 (a)**
☑ **23 CCR § 356.4 (c)**
☑ **23 CCR § 356.4 (d)**

This section characterizes current and historical groundwater conditions in the Livermore Valley Groundwater Basin (Basin). Best available data are used to characterize current conditions, 2020 Water Year (WY) conditions, and historical conditions (i.e., the period from 1974 WY to 2020 WY). Subsections below address data sources and compilation (**Section 8.2**), groundwater elevations and flow (**Section 8.3**), groundwater in storage (**Section 8.4**), seawater intrusion (**Section 8.5**), groundwater quality (**Section 8.6**), land subsidence (**Section 8.7**), Groundwater Dependent Ecosystems (GDEs; **Section 8.8**), and Interconnected Surface Water systems (ICSW; **Section 8.9**).

As demonstrated herein, consistent with the approved 2016 Alternative Groundwater Sustainability Plan (Alt GSP) and the requirements of California Water Code (CWC) § 10733.6 (a)(3) and California Code of Regulations Title 23 (23 CCR) § 356.4, Zone 7 has continued to sustainably manage the Basin to avoid Undesirable Results (URs) (as defined in **Section 13**) for at least 10 years. In fact, most of the datasets discussed in this Alt GSP date back to 1974 allowing for a comprehensive, long-term assessment of Zone 7's sustainable Basin management, including over three major droughts.

8.2. Data Sources and Compilation

§ 352.6. Data Management System
Each Agency shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin.

☑ **23 CCR § 352.6**

8.2.1. Databases and Software

Per the 23 CCR § 352.6, each Groundwater Sustainability Agency (GSA) "shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin." In support of the Alt GSP development (i.e., the Hydrogeologic Conceptual Model [HCM] development, analysis of groundwater conditions, water budget development, and Plan Area definition), a substantial number of data sources were compiled, organized, processed, and stored within the data management system described below.

The Alameda County Flood Control and Water Conservation District, Zone 7 (Zone 7 Water Agency or Zone 7) stores its hydrologic data (e.g., groundwater levels, water quality, geology, well construction) into HydroGeoAnalyst (HGA), a proprietary environmental database management system designed for storing chemistry, hydrology, and geologic information. The program includes a detailed Quality Assurance/Quality Control (QA/QC) checking module that confirms data integrity during import. Once imported into the database, Zone 7 uses the reporting and mapping tools within HGA to view and report the datasets. Zone 7 also exports datasets from HGA for use in other programs such as Microsoft Excel, Microsoft Access, and ArcGIS to generate tables and figures in reports and other work products.

Zone 7 uses a proprietary program called Aquarius Time-Series (Aquarius) for managing time series datasets for:

- Surface water stage and flow,
- Groundwater elevation,
- Diversion flow,
- Precipitation, and
- Evaporation.

The program also allows Zone 7 to build rating curves, apply corrections, create comparison graphs, derive statistics, and report datasets.

Other datasets that are not appropriate for HGA or Aquarius (e.g., land surface elevations, wastewater volumes, land use) are entered into Microsoft Access databases and/or ArcGIS feature classes.

8.2.2. Groundwater Model

Zone 7 maintains a numerical groundwater model (based on of the Basin for predicting the consequences of proposed Basin management actions. The groundwater model is run using Groundwater Vistas with USGS's Modular Finite-Difference Flow Model (MODFLOW) packages (e.g., NWT, MT3D) to perform the modeling calculations. In 2016, Zone 7 and HydroMetrics WRI (HydroMetrics) reevaluated, recalibrated, and revised the groundwater model as described in the Annual Report for the Groundwater Management Program – 2005 WY (*Zone 7, 2006)*.

The active part of the groundwater model encompasses the Amador, Bernal, Bishop, Camp, Castle, Dublin, and Mocho II Subareas of the Basin. The groundwater model has been used for water supply well siting and planning (*Zone 7, 2003*). More recently, the groundwater model was used for the following analyses:

- Identify the maximum amount of groundwater Zone 7 could pump using existing wells during a six-year drought without going below historic lows;
- Predict the impacts that Zone's planned groundwater pumping would have on groundwater levels if the drought continued for two additional years;
- Evaluate and simulate salt loading impacts and the siting effects of a second Zone 7 groundwater demineralization plant planned for construction in the future; and Assist with the Tri-Valley water agencies' Joint Tri-Valley Potable Reuse Technical Feasibility Study (*Carrolo, 2018*).

8.3. Groundwater Elevations and Flow Directions

§ 354.16. Groundwater Conditions
(a) Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:
(1) Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.
(2) Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.

☑ **23 CCR § 354.16(a)**
☑ **23 CCR § 354.16(a)(1)**
☑ **23 CCR § 354.16(a)(2)**

8.3.1. General Setting and Gradients

The geologic setting of the Basin comprises a complex stratigraphy of fluvial channels, floodplain deposits, and regionally extensive lacustrine deposits. As described in **Section 7,** for management purposes, in the Main Basin Management Area (Main Basin) these have been organized into an "Upper Aquifer" consisting primarily of sandy gravels underlain by a relatively continuous, silty clay aquitard and a "Lower Aquifer" that includes aquifers below the aquitard. Groundwater is generally unconfined in the Upper Aquifer and semi-confined to confined in the Lower Aquifer (see **Figure 7-4**). The Fringe Management Area (Fringe

Area) is represented as an unconfined aquifer (the Fringe Aquifer) that consists of thin sequence of recent (Holocene) alluvium underlain directly by the Upper Livermore Formation. The Upland Management Area (Upland Area) is represented as one unconfined aquifer (the Upland Aquifer) that consists of the Lower Livermore Formation, as discussed in **Section 7.4**.

Zone 7 has a long-standing and extensive program of groundwater level monitoring throughout the Basin. Currently there are about 240 wells in the program (see **Section 14.1** for a description of the monitoring network). Groundwater elevations from these wells indicate that groundwater flow in the Fringe Aquifer and Upland Aquifer is generally from their respective Management Areas toward the Main Basin and associated aquifers. Most of the subsurface inflow occurs across the northern boundaries of the Main Basin—in particular the Dublin and western Camp Subareas—and flows in a southerly direction. Within the Main Basin, groundwater in both aquifers generally follows a westerly flow pattern, mirroring the surface water streams, along the structural central axis of the valley and toward the municipal pumping centers.

8.3.2. Current Groundwater Levels

As demonstrated herein (consistent with the approved 2016 Alt GSP) and the requirements of CWC §10733.6 (a)(3) and 23 CCR §356.4, Zone 7 has continued to sustainably manage water levels in the Basin to avoid Undesirable Results (URs; as defined in **Section 13.1.1**) for decades, including over three major droughts.

8.3.2.1. Main Basin Upper Aquifer and Fringe Aquifer

Figure 8-1 and **Figure 8-2** show groundwater elevation contours in the Upper Aquifer for the Spring and Fall 2020 WY, representing the highest and lowest groundwater elevations observed during the water year, respectively. **Figure 8-3** shows the depth to water to the Upper Aquifer groundwater table in the Spring 2021 WY. The groundwater gradient in the Upper Aquifer was generally from east to west and ranged from 0.005 to 0.025 feet per feet (ft/ft). Quarry dewatering operations in the eastern Amador Subarea create groundwater depressions in pits where water is pumped and mounds in pits that are not clay-lined and where excess water is stored. The water from the dewatering of Lakes B (P42 on the figures) and J (P46) was discharged into other adjacent clay-lined mining pits; while the water from Lakes D and E was eventually discharged into Cope Lake, after which it was conveyed into Lake I and was recharged back into the groundwater basin.

During the first half of the 2020 WY, water levels in wells in the southwestern portion of the Main Basin near the Arroyo de la Laguna (as indicated primarily by the Bernal Upper Key Well, 3S1E20C007 and Well 3S1E29M004) were slightly above the upper threshold elevation at which basin overflow occurs. Consequently, approximately 146 acre-feet (AF) (**Section 9.2.3.4**) of water overflowed from the Upper Aquifer into the Arroyo de la Laguna during the 2020 WY and exited the valley.

Areas of shallow groundwater overlie the Fringe Aquifer where alluvial sediments are relatively thin and groundwater use is limited. Groundwater levels in the Fringe Aquifer and Upland Aquifer typically stay relatively constant, generally varying by less than 5.0 feet (ft). The groundwater gradients in the northwestern Fringe Area (Bishop, Dublin, and Camp Subareas) ranged from 0.002 to 0.02 ft/ft generally southward towards the Main Basin. The groundwater gradients in the Fringe Area - Northeast ranged from 0.001 to 0.004 ft/ft generally westward towards the Main Basin or gaining streams in the northwestern portion of the Basin (Altamont Creek and Cayetano Creek). The groundwater gradient in the Fringe Area - East was about 0.006 ft/ft westward towards the Main Basin.

8.3.2.2. Lower Aquifer

Figure 8-4 and **Figure 8-5** show groundwater elevation contours in the Lower Aquifer for the Spring high and Fall low of the 2020 WY, respectively. In general, the groundwater gradient runs toward the center of the Basin where there are piezometric depressions created around several municipal wellfields and three mining pits (Lakes B, D, and E) that appear to extend into the Lower Aquifer. The lowest groundwater elevation in the Lower Aquifer corresponded to the pond in mining excavation for Lake D (R28 at 168 ft above msl). The westernmost California Water Service (CWS) municipal supply wells (CWS 20 and CWS 24) also pull groundwater from this portion of the Basin.

There appears to be a mound in the Lower Aquifer of about 10 feet underneath Lake I. This mound suggests that the diversion of excess mined water into Lake I (via Cope Lake) since 2014 is impacting the Lower Aquifer.

As is usually the case, groundwater elevations in the Mocho II Subarea during the 2020 WY were about 60 to 90 ft higher than those to the west, across the Livermore Fault in the Amador Subarea. Deep groundwater elevations in the Fringe Subarea - North were 15 to 30 ft higher than those across the Main Basin boundary to the south.

8.3.2.3. Upland Aquifer

Prior to this update, there was only one Upland Aquifer well in Zone 7’s groundwater monitoring program. Groundwater levels in the well (3S2E32E007), which is used to monitor groundwater downgradient of Zone 7’s Del Valle Water Treatment Plant, have been relatively steady at about 17 to 20 feet below ground surface. For this update Zone 7 added five additional wells in the Upland Aquifer (see **Section 14.5**). Results from these additional wells will be included in the 2021 Annual Report.

8.3.3. Historical Groundwater Levels

8.3.3.1. General Historical Trends

Figure 8-6 shows historical groundwater levels at the Bernal Upper Key Well (a.k.a., Fairgrounds Key Well) in the westernmost portion of the Main Basin from 1900 to present and demonstrates the long-term sustainable management of the Basin. Prior to groundwater development, much of the Main Basin experienced artesian conditions, as indicated by groundwater levels above the ground surface. In the late 1800s, the pre-development groundwater levels and hydraulic gradients caused groundwater to flow from east to west across the Basin and naturally exit the Basin as surface outflow (baseflow) into the Arroyo de la Laguna. In the early and mid-1900s, groundwater began to be extracted in appreciable quantities, causing groundwater levels to drop throughout the Basin. As a result, groundwater levels dropped below the point (about 295 feet above mean sea level [ft msl]) where groundwater would naturally flow into the Arroyo de la Laguna and continued to drop significantly during the 1940s and 1950s.

Zone 7 was established in 1957 partially to address the Basin overdraft conditions. The downward trend in groundwater elevation began to reverse in 1962 when Zone 7 began importing water from the State Water Project (SWP) and later in the 1960s when Zone 7 began capturing and storing local runoff in Lake Del Valle. The first imports were diverted to an off-stream recharge facility called Las Positas Pit. This facility was operated from 1962 until the late 1970s and again, briefly, in the 1980s. Thus, after experiencing historical groundwater lows in the 1960s, Main Basin water levels stabilized in the late 1960s and started to rise in the early 1970s with the advent of regional groundwater management programs.

Following a 'very critical dry' year in 1977, groundwater levels continued to recover and peaked in 1983, which is the modern maximum ("basin full") limit. Since 1983, water levels have been drawn down three separate times in response to times of limited water importation from the SWP but have not reached previous historic low levels. As shown on the hydrograph, groundwater levels subsequently recovered following the dry cycles in the early 1990s and the early 2000s because of Zone 7's managed aquifer recharge operations and a corresponding reduction in groundwater production. The recent severe drought cycle of 2012-2015 resulted in a lowering of Basin-wide water levels, but levels remained above those observed during the drought cycle of the early 1990s and significantly above historic lows (**Section 8.3.3.3**). These water level data are consistent with sustainable groundwater management practices since at least the early 1970s.

Hydrographs of the Amador West Key Wells (**Figure 8-7**) show that overall trends and fluctuations are quite similar in both the Upper Aquifer and Lower Aquifer. In general, seasonal fluctuations are slightly larger in the Lower Aquifer where most of the pumping occurs. Water levels in the Lower Aquifer can fall as much as 10 to 20 ft lower than levels in the Upper Aquifer during the high demand summer pumping season (e.g., 1973, 1976, 1991, 2001, and 2013). Water levels are higher during winter seasons and overall wet periods (e.g., 1978-1986). Data typically indicate a downward vertical gradient, although water levels in the Lower Aquifer rose higher than those in the Upper Aquifer during the wet seasons of the mid- to late-1990s, corresponding to a time of lower amounts of pumping.

Figure 8-8 shows hydrographs for the period 1974 to present from selected wells from the Main Basin, Fringe, and Upland Areas; an inset map shows the well locations. Along the top of the figure, seven wells represent groundwater level trends in the Northern and Northeastern Fringe Areas: Dublin, Bishop, Camp, May, Cayetano, and Spring Subareas. In addition, at right, one well represents conditions in the East Fringe Area (a.k.a., Mocho I subarea). At lower left, one well shows groundwater levels for the Castle Subarea. All of these represent conditions in the Upper Aquifer (given that the Lower Aquifer generally is not present in these subareas). Except for a slight decrease in the May Subarea well, groundwater levels in these wells generally are steady and groundwater variations (both seasonal and long-term) are less than 20 ft. This generally reflects the relatively thin aquifer sediments in the Fringe Area and lack of groundwater use. Seasonal peaks in the Castle subarea well may reflect seasonal pumping variations in the Main Basin.

The hydrographs along the bottom in **Figure 8-8** are from the eight Key Wells that represent groundwater level trends in each of the Main Basin subareas, including Mocho II, Amador (split into East and West on either side of the mining area), and Bernal subareas. These hydrographs show clear seasonal variations, typically less than 20 ft. The two easternmost key wells (Mocho II) show seasonal variations (more pronounced in the Lower Aquifer) and response to drought (for example between about 1986 and 1992). Nonetheless, the overall trend is steady. Hydrographs for wells in the central and western portions of the Main Basin also indicate more pronounced seasonal variations in Lower Aquifer relative to the Upper Aquifer. Most significantly, these hydrographs show longer-term variations spanning 60 to even 100 vertical feet and extending over decades with troughs generally occurring about 1992, 2002, and 2014. These broad groundwater level changes reflect active management of groundwater storage in the Basin, whereby available surface water is stored during wet periods and then utilized during drought.

8.3.3.2. Historic Low Water Levels

Zone 7 has prepared contour maps representing historic low groundwater elevations in the Upper and Fringe Aquifers (**Figure 8-9**) and the Lower Aquifer (**Figure 8-10**). These historic low contour maps represent a compilation of historic recorded low groundwater elevations in various wells in the Basin. Zone 7 uses static water levels from local monitoring wells rather than pumping level data to evaluate the height above the historic lows. Data used to create the composite contours are typically from the 1960s, 1977, 1987-1992, or 2012-2015 drought periods. The historic low values are a function of both data availability and some variability in water levels during drought cycles. Although the 1960s generally represented the lowest water levels across the Basin, wells added to the monitoring program after the 1960s were used to provide more detailed information in areas of limited data or areas with a lack of historical pumping. By including historic lows for numerous generations of wells in the region, the historic low contour maps represent a more conservative benchmark and provide for adaptive management in the future.

The historic low contour map for the Lower Aquifer was first created in 2005 for the Zone 7 Well Master Plan (WMP) Environmental Impact Report (EIR; Zone 7, 2005b) to help define possible mitigation measures for the potential risk for groundwater pumping-induced subsidence. The historic low surface for the Lower Aquifer used in the Zone 7 WMP EIR was revised in 2009 and converted to a surface grid (i.e., ArcGIS raster image) for comparison with end-of-water-year groundwater elevations and for spatial analyses. The surface was modified again slightly in January 2014 and October 2015, as additional information became available and is presented herein as **Figure 8-10**. Similarly, an updated historic low map for the Upper Aquifer and Fringe Aquifer was created in 2021 as part of this update (**Figure 8-9**).

These historic low contour maps represent a groundwater management tool used by Zone 7 to guide management actions in the Basin. Zone 7 compares low water levels in each year to these values (see **Figure 8-11** and **Section 8.3.3.3** below) to ensure that the Basin is being operated in a sustainable manner and to identify areas to focus management actions. For example, as described in **Section 15**, such actions have included redistribution of pumping among wells, and focused conjunctive use, among others.

8.3.3.3. Comparison to Historic Low Water Levels

Figure 8-11 compares groundwater levels at the end of the 2020 WY and the historic lows for the Lower Aquifer. Groundwater levels in the vicinity of the Bernal subarea were up to about 110 ft above the historic lows. In the Amador subarea, levels were generally 25–90 ft above the historic lows except in the immediate vicinity of two mining excavations that were being dewatered during the 2020 WY; the water levels in Lake B (P42) were 2.0 ft below the historic lows, while water levels in Lake D (R28) were about 45 ft below the historic lows. These mining area excavations below the historic lows are expected to occur only while there is active mining and are closely monitored by Zone to ensure there are no undesirable results to the Basin. Over the central portion of the Mocho II Subarea where there is municipal pumping, the end-of-year groundwater levels were 50–135 ft above historic lows. Other portions of the Mocho II Subarea, not affected by the municipal pumping, remained relatively stable at or slightly above historic lows.

8.4. Groundwater Storage

§ 354.16. Groundwater Conditions
(b) A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.

☑ **23 CCR § 354.16(b)**

As demonstrated herein (consistent with the approved 2016 Alt GSP) and the requirements of CWC §10733.6 (a)(3) and 23 CCR §356.4, Zone 7 has continued to sustainably manage groundwater storage in the Basin to avoid URs (as defined in **Section 13.2.1**) for decades, including over three major droughts.

8.4.1. Methodology for Calculating Storage

Zone 7 used three methods to calculate groundwater storage in the Basin: (1) the Groundwater Elevation (GWE) Nodal method, (2) the GWE Rockworks method, and (3) the Hydrologic Inventory (HI) method.

The GWE Nodal method uses groundwater level data and storage coefficients to estimate the total volume of water in the Basin. To calculate the GWE storage in the Main Basin from the 1974 to 2020 WYs, Zone 7 uses polygonal areas (referred to as nodes) created for the 1974 California Department of Water Resources (DWR) study (*DWR, 1974*). Each node has its own set of hydrogeologic parameters, such as storage coefficient, nodal thickness, and nodal area. The saturated thickness of each node was calculated using the nodal thickness, average groundwater elevations from the fall semiannual measuring event, and storage coefficient. The groundwater storage of each node is then calculated by multiplying the saturated thickness by the total area of the node. The total Main Basin groundwater storage is equal to the sum of all the nodal storage values for the 22 nodes in the Main Basin. GWE storage calculations before 1992 were calculated assuming a constant storage coefficient for all the nodes (i.e., without differentiating between aquifers). However, starting in 2007, average groundwater elevations for each of the nodes and aquifers were calculated using *ArcGIS Spatial Analyst.*

The GWE Rockworks method uses the same approach as the GWE Nodal method for calculating storage, except in this case the saturated thickness of each Principal Aquifer unit is informed by aquifer volumetrics produced from the three-dimensional (3D) geologic model of the Basin created using the Rockworks (2020) software platform as part of the current five-year update to the Alt GSP (see **Appendix I** and **Appendix C**). The GWE Rockworks method currently uses the same storage coefficients as employed in the GWE Nodal method for the Upper Aquifer and Lower Aquifer (see **Appendix E).** While the GWE Nodal method is limited to calculating groundwater storage volumes in the Upper Aquifer and the first ~150-300 feet of the Lower Aquifer in the Main Basin (i.e., the "grey" and "purple" sequences described in **Section 7.4)**, the GWE Rockworks method also provides for a calculation of groundwater storage within the underlying Upper Livermore Formation (i.e., the "red" sequence) of the Lower Aquifer within the Main Basin, resulting in higher estimates of total storage. For the Upper Livermore Formation and Fringe Aquifer, the GWE Rockworks method employs a range of storage coefficients based on the best available information regarding aquifer lithologies and grain size distributions and applicable methodologies.

The HI method, also known as the Water Budget (see **Section 9**), involved an accounting of all inflows and outflows and derivation of the change in storage as the residual of the water budget equation. The groundwater inflow and outflow components of the HI are summarized in **Table 8-A** below and discussed in more detail in **Section 9**. Each component was derived independently, either directly from the monitoring program results or calculated using the results of a monitoring program. Total storage in the HI method was originally estimated from the GWE Nodal method and is subsequently updated each year based on the results of the HI mass balance equation.

Table 8-A Groundwater Inflow and Outflow

INFLOWS	OUTFLOWS
Rainfall Recharge	Municipal Pumping
Stream Recharge	• Zone 7
Applied Water Recharge	• By Others
Subsurface Groundwater Inflow	Agricultural Pumping
Pipe Leakage	Mining Use
	Groundwater Basin Overflow

For the Main Basin, results of the three two methods have been compared to each other, leading to periodic re-examination and refinement of each method, and then averaged to quantify the total storage, as described below.

8.4.2. Main Basin Management Area

8.4.2.1. Current Storage

Most of the groundwater storage is contained in the Main Basin, which is characterized by the largest saturated thickness. **Table 8-B** below shows the groundwater storage for the Main Basin. The GWE Nodal method yielded a total storage of 231.6 thousand acre-feet (TAF) for end of the 2020 WY, which is 16.8 TAF less than the total storage calculated for the 2019 WY. **Figure 8-12** shows the Upper and Lower Aquifer groundwater storage volumes for each node from the GWE Nodal method for the 2020 WY. The HI method produced a total storage value of 247.2 TAF for end of the 2020 WY, which is about 7.9 TAF less than the total storage calculated for the 2019 WY. The results of the HI method for the 2020 WY are discussed in more detail in **Section 9.**

Table 8-B: Groundwater Storage Summary, 2020 WY (in Thousand AF)

Storage Calculation Method	End of 2019 WY	End of 2020 WY	Change in Storage
GWE Nodal method	248.5	231.7	-16.8
Hydrologic Inventory (HI)	255.2	247.2	-8.0
TOTAL STORAGE (Average of GWE Nodal and HI)	**251.8**	**239.5**	**-12.3**
GWE Rockworks (includes Upper Livermore Formation)	286.0	276.0	-10.0

The total storage, which is calculated by averaging the storage from the GWE Nodal and HI methods, was 239.5 TAF. By comparison, the GWE Rockworks method yielded a total storage of 276.0 TAF[12] at the end of 2020 WY, which about 36 TAF greater than the total storage calculated using the average of the GWE Nodal and HI methods.

For the past few years, the differences of total storage calculated by the GWE Nodal and HI methods have been within approximately 6.0 TAF (**Figure 8-13**). However, total storage calculated by the GWE Nodal and HI methods dropped significantly (16.8 TAF and 8.0 TAF respectively) during the 2020 WY, with a cumulative difference of 15.5 TAF between the two storage values as of 2020 WY. While there have been significant differences between the two methods in the past that converged a few years later (e.g., 1992 and 2008/2009). The reason for this divergence is unclear but is mirrored using the GWE Rockworks method (see **Appendix E**).

[12] Based on the lower-range storage coefficient for the Upper Livermore Formation (0.025).

8.4.2.2. Operational Storage

To avoid significant depletion of groundwater storage, Zone 7 operates the Basin such that groundwater in storage remains between a full basin volume (254 thousand acre-feet [TAF]) and the historic low storage of 128 TAF, or about one half of total storage volume. This 126 TAF (254 TAF – 128 TAF) is considered the Operational Storage (**Table 8-C**). Groundwater below this minimum threshold is regarded as Reserve Storage that is intended for use only during emergency conditions.

Table 8-C: Operational Storage, 2020 WY (in Thousand AF)

Storage Volumes	End of 2020 WY
Total Storage (Average of GWE Nodal and HI)	**239.5**
Reserve Storage (below Historic Lows)	128
Operational Storage (above Historic Lows)	111.5

8.4.2.3. Historical Change in Storage

As illustrated on **Figure 8-6**, the Main Basin was full in early 1900 and full again in 1983 (as measured by rising water levels in gravel quarries in the central Main Basin). Groundwater storages were drawn down to historic low levels in 1962 and 1966. Beginning in 1974, Zone 7 began calculating the basin storage by using the HI and GWE Nodal methods **Figure 8-13** shows the historical change in storage from 1974 to 2020 from both the HI and GWE Nodal methods and the resulting average between the two.

To avoid significant depletion of groundwater storage, Zone 7 has operated the Basin such that groundwater storage remains between the full basin volume of 254 TAF (based on the GWE Nodal method) and the historic low storage of 128 TAF, or about one half of total storage volume. This 126 TAF of storage (i.e., between 254 TAF and 128 TAF) is considered to be the “Operational Storage”. The significant amount of additional storage below 128 TAF is considered “Reserve Storage” that is available during emergency (e.g., drought) conditions. A schematic diagram showing the Operational Storage and changes in storage from the 1974 through 2020 WY is shown on **Figure 8-14**.

Figure 8-15 graphs the annual and cumulative change in groundwater storage, along with the annual groundwater use and water year type. **Table 8-1** shows the historical annual groundwater storage volumes for each Subarea of the Main Basin from the 1974 through 2020 WY.

As mentioned in **Section 8.4.1**, the recently introduced GWE Rockworks method estimates a greater volume of total storage for the Main Basin than the GWE Nodal method due to its inclusion of the Upper Livermore Formation (i.e., the “red” sequence) of the Lower Aquifer. As such, the Operational and Reserve

Storage volumes presented above are likely conservative and will be revisited in consideration of all three storage calculation methodologies as part of the next five-year update to the Alt GSP.

8.4.3. Fringe and Upland Management Areas

As further described in **Section 9.3.1.2.** the Fringe Area is not used for municipal supply or managed groundwater storage primarily because of low aquifer transmissivity. Groundwater quality is also typically poor in the Fringe Area (see **Section 8.6**) due to natural elevated total dissolved solids (TDS) and boron concentrations. However, the Fringe Area does provide limited supply for domestic and agricultural users. For display and database purposes, the Fringe Area is considered to only consist of the Fringe Aquifer (**Section 7.4.4**). **Figure 8-12** shows the groundwater storage volumes for each node from the GWE Nodal method for the 2020 WY. **Table 8-D** below shows that the total groundwater storage for the Fringe Area estimated from three different methods:

- GIS Method- the area-weighted average thickness of the saturated area of each region was multiplied by the estimated Specific Yield (assume 0.05).
- Nodal Method - was calculated using nodal depth-of-alluvium estimates from DWR 1974.
- Rockworks Method (ranged low to high) – estimated storage using the Rockworks method (**Appendix E**), which was calculated a range (shown below as Low and High).

Table 8-D Estimated Fringe Subarea Storage (AF)

Fringe Region	GIS	Nodal	Rockworks Low	Rockworks High	Average
North	38,348	25,070	74,000	133,000	67,604
Northeast	61,656	45,002	23,000	46,000	43,914
East	1,630	1,153	300	600	921
Total	**95,509**	**71,224**	**97,300**	**179,600**	**112,439**

The total groundwater storage of the Upland Area is unknown because it consists of semi-consolidated bedrock of highly variable specific yields and of unknown thickness. The Upland Area provides only very limited groundwater supply for domestic and agricultural uses.

8.5. Seawater Intrusion

§ 354.16. Groundwater Conditions
(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.

☑ **23 CCR § 354.16(c)**

The Basin is not a coastal basin subject to seawater intrusion, and therefore this sustainability indicator is not applicable and has not been included herein.

8.6. Groundwater Quality

> *§ 354.16. Groundwater Conditions*
> *(d) Groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.*

☑ 23 CCR § 354.16(d)

As demonstrated herein (consistent with the approved 2016 Alt GSP) and the requirements of CWC §10733.6 (a)(3) and 23 CCR §356.4, Zone 7 has continued to sustainably manage groundwater quality in the Basin to avoid URs (as defined in **Section 13.4.1**) for decades, and is implementing multiple groundwater quality monitoring and management programs to that end.

8.6.1. General Water Chemistry and Constituents of Concern

8.6.1.1. Introduction

Zone 7 conducts annual sampling and analysis for inorganic constituents for meeting the Basin groundwater quality objectives (WQOs; see **Section 13** for Sustainable Management Criteria [SMC]). Zone 7's understanding of groundwater quality throughout the Basin has improved over time as additional monitoring points have been added to the monitoring network and additional analyses have been conducted when areas of concern (AOCs) have been identified. Consistent with adaptive management principles, Zone 7 has actively and pro-actively responded to numerous groundwater quality issues over time. This section provides a characterization of groundwater quality and changes in quality in space and time since 1974, a period of sustainable management. Although numerous groundwater quality challenges have arisen during this time, Zone 7 has been able to address each issue, preventing significant and unreasonable degradation of groundwater quality. **Section 13.4.1** defines significant and unreasonable URs with respect to groundwater quality and establishes Minimum Thresholds in compliance with Sustainable Groundwater Management Act (SGMA). Details on the Zone 7 water quality monitoring program are provided in **Section 14.2.4**.

In general, groundwater quality is highest in the Main Basin where it is suitable for most urban and agriculture uses with some minor localized water quality degradation. Primary constituents of concern in the Main Basin are locally high TDS (**Section 8.6.2**), nitrate (**Section 8.6.3**), boron (**Section 8.6.4**), and chromium (**Section 8.6.5**). Some of these elevated concentrations are naturally occurring in many areas of the Basin and are not caused or being exacerbated by groundwater extractions.

Zone 7 analyzes these constituents of concern through numerous maps and statistical analyses. For this Alt GSP, basin-wide maps and chemographs are presented to characterize both current and historical conditions of groundwater quality and provide a broad view of Zone 7 management of groundwater quality. Zone 7 also prepares contour maps on an annual basis for each constituent of concern, which are presented in the sections below by constituent of concern and aquifer.

In general, groundwater is of lower quality in the Fringe Area, which is characterized by relatively high TDS and locally elevated boron. TDS and boron concentrations are particularly elevated in the shallow Fringe Aquifer and in the northeast, reflecting recharge from marine sediments adjacent to the Basin. High boron levels and lower yields can limit the use of some Fringe Area for extensive agricultural irrigation.

Per- and polyfluoroalkyl substances (PFAS, **Section 8.6.6**) are a large group of human-made substances that do not occur naturally in the environment. PFAS are classified by the Environmental Protection Agency (EPA) as "contaminants of emerging concern" (CECs). These substances have been used extensively in the United States since the 1940s, particularly in surface coating and protectant formulations due to their ability to repel oil, grease, and water. There is limited research to date, but some studies show that they may cause adverse health effects. Additional research is needed to determine the full scope of PFAS impacts on human health. Zone 7 started sampling for PFAS in the 2019 WY and is continuing to evaluate the extent and impact of PFAS on the Basin.

Releases of fuel hydrocarbons from leaking underground storage tanks and spills of organic solvents at industrial sites have caused minor-to-significant groundwater impacts locally throughout the Basin, although there is no impact on municipal wells to date. Zone 7 participated in the development of the Groundwater Ambient Monitoring and Assessment (GAMA) project, and except for methyl tertiary-butyl ether (MTBE), no fuel hydrocarbons were detected in any of the municipal wells. Proactive cooperation with regulatory agencies on site cleanup is helping to protect the Basin from fuel hydrocarbon contamination.

Zone 7 also reviews results from site cleanup projects made available through GeoTracker and from cleanup reports routinely sent to Zone 7 for review. Results of these programs are documented annually in Zone 7 reports. Chlorinated organic solvent releases to soil and groundwater are an issue, primarily in the Upper Aquifer in portions of the Fringe Area. Cleanup programs at Lawrence Livermore National Laboratory (LLNL) are in place to remediate this large superfund site from a 50-year-old plume associated with World War II activities. Zone 7 assisted LLNL during the initial year of cleanup and has been working cooperatively with them ever since. During the past decade, LLNL has been providing valuable assistance to Zone 7 in the monitoring and analysis of groundwater conditions within the Basin.

Zone 7's current groundwater quality monitoring network, which includes approximately 240 wells, is discussed in detail in **Section 14.2.4**. Groundwater quality issues that may affect the supply and beneficial uses of groundwater are discussed below, including a description and map of the location of known groundwater contamination sites and plumes.

8.6.1.2. Municipal Wastewater and Recycled Water

The two largest wastewater collection and treatment plants are operated by the City of Livermore and Dublin San Ramon Services District (DSRSD), which treat over 99% of the wastewater in the Livermore-Amador Valley (Valley). Both of the publicly-owned treatment works produce secondary-treated effluent, which is exported from the Valley through the Livermore-Amador Valley Water Management Agency

(LAVWMA) export pipeline, and tertiary-treated recycled water, which is used primarily for urban landscape irrigation. Currently, none of the recycled water is used for groundwater replenishment.

As summarized in **Table 8-E** below, approximately 7,176 AF of the 17,676 AF of the wastewater produced in the Valley was recycled and used for landscape irrigation in the 2020 WY. This use of recycled water represents conservation of groundwater storage, assuming that the irrigation demand would otherwise have been met with groundwater.

Table 8-E: Recycled Water Volumes (AF) for the 2020 WY

Water Type	LWRP	DSRSD	Total
Wastewater Influent	6,141	11,535	17,676
Treated Effluent Exported via LAVWMA	4,590	6,039	10,629
Total Volume Recycled	2,426	4,740	7,176
Recycled Volume-Main Basin**	609	427	1,036

* Does not include Zone 7 Demin Plant discharge to LAVWMA via DSRSD

** Only the portion of recycled water which was applied over Main Basin landscapes.

The recycled water from both wastewater plants meets the Title 22 water quality standards for irrigation uses. While salt and nutrients are the primary constituents-of-concern for wastewater and recycled water applications over the Main Basin, other COCs/CECs would need to be considered if recycled water was used in aquifer recharge projects.

A small amount of untreated wastewater is also discharged to the Main Basin as leachate from the Veterans Administration (VA) Hospital wastewater treatment ponds located in southern Livermore, from other domestic onsite wastewater treatment systems (OWTS, also known as septic systems), and from leaking wastewater and recycled water pipelines that run throughout the Basin. Estimated volumes for the 2020 WY are presented in **Table 8-F** below.

Table 8-F: Wastewater Volumes (AF) for the 2020 WY

	VA Hospital*	OWTS (Main Basin)*	Pipe Leakage**	Total
Wastewater Leachate	50	80	400	530

* OWTS = Onsite Wastewater Treatment Systems. Total is estimated

** Calculated. Includes leakage from sanitary sewer and recycled water pipes

The contribution to the Main Basin groundwater supply (530 AF) was estimated using "typical" wastewater flows from domestic septic systems, an estimate for the VA Hospital ponds, and the pipe leakage. No significant changes have occurred in land uses or OWTS densities over the Main Basin that would change the estimated water volumes from these sources in recent years. **Section 8.6.3.7** evaluates the effect of Zone 7's Nutrient Management Plan (NMP) recommendations on the nitrate mass that leaches into the groundwater from OWTS.

8.6.2. Salt (as TDS)

8.6.2.1. Introduction

Every year, Zone 7 uses well and mining pit sampling data to contour salt (measured as TDS) concentrations in the Main Basin (Upper and Lower Aquifers) and Fringe Area (Fringe Aquifer) (**Sections 8.6.2.2** and **8.6.2.3**). Zone 7 then calculates average TDS concentrations in the Main Basin and Fringe Area (**Section 8.6.2.4**). Historical TDS concentrations are presented in **Section 8.6.2.5**. Zone 7 has sampled or estimated concentrations and volumes of all inflows into and outflows from the Basin from 1974 to 2020 to estimate the trends in overall TDS over time (**Section 8.6.2.6**). Zone 7 also uses a similar approach to estimate future projected salt concentrations (**Section 8.6.2.7**).

8.6.2.2. TDS in the Upper/Fringe Aquifer

Figure 8-16 shows TDS concentrations in the Upper/Fringe Aquifer in the 2020 WY. TDS concentrations in groundwater were lowest in the areas adjacent to the Arroyo Valle and the Arroyo Mocho, where they were generally less than 500 milligrams per liter (mg/L). There continues to be two main areas of the groundwater basin where TDS concentrations exceed 1,000 mg/L in the Upper Aquifer:

- In the western portion of the Fringe Area and extending south into the northwestern portion of the Main Basin. This high TDS area is most likely due to the combination of the concentrating effects of urban irrigation, leaching of buried lacustrine and marine sediments, recharge of poorer quality water from Arroyo Las Positas, and legacy wastewater and sludge disposal practices in the Pleasanton and Livermore areas.
- In the northeastern portion of the Fringe Area. This high-TDS area is likely due to poorer quality water that runs off marine sediments on the east and north of the Basin and recharges the Basin along the hill-fronts.

8.6.2.3. TDS in the Lower Aquifer

Figure 8-17 shows TDS concentrations in the Lower Aquifer in the 2020 WY. Water from the Lower Aquifer is generally of good drinking water quality (i.e., below 500 mg/L). Around the margins of the Main Basin, TDS concentrations are slightly higher, generally ranging from 500 mg/L to 900 mg/L in the 2020 WY. The distribution of TDS concentrations is likely caused by deep percolation of low-TDS surface waters in the central portion of the Basin and municipal pumping in the western Basin that pulls high-TDS groundwater laterally and downward from the north Fringe Area and the Upper Aquifer.

Many of the municipal supply wells in the Pleasanton area produced water with TDS concentrations greater than 500 mg/L (the Minimum Threshold for the Main Basin, see **Section 13**) during the 2020 WY. The highest concentrations were detected as follows:

- The Mocho wellfield in the Amador Subarea had one well with TDS above 800 mg/L (854 mg/L in Mocho 4).
- One of the San Francisco Public Utilities Commission (SFPUC) wells in the Bernal Subarea (SF-A) detected TDS at 932 mg/L.

- A monitoring well (3S1E17B004) in the Amador Subarea located central to four active wellfields (Mocho, Hopyard, Bernal, and Busch Valley) had TDS at 902 mg/L.

The source of these high TDS concentrations is believed to be the Upper Aquifer, which has had TDS concentrations as high as 2,000 mg/L in the same area directly above the Mocho well screened intervals. When the Mocho wells are pumped, a very large vertical gradient is created between the Upper and Lower Aquifers, inducing flow between the two zones. Zone 7 can strip and export much of the salts from the water produced by the Mocho wells with its onsite groundwater demineralization facility. See **Section 8.6.2.5.** for details on the Mocho Groundwater Demineralization Plant's (MGDP). Other planned corrective actions and strategies are described in **Section 15**.

8.6.2.4. Average TDS Concentrations

Average TDS concentrations in the Main Basin, Fringe, and Upland Areas using 2020 WY data are shown on **Figure 8-18**. For the Main Basin, the average volume-weighted TDS concentrations for the Upper and Lower Aquifers are 623 and 524 mg/L, respectively, with the overall volume-weighted concentration averaging 578 mg/L. The average concentrations for each of the Fringe Area subareas range from 884 to 1,301 mg/L. The average concentrations across the entire Upland Area are approximately 673 mg/L.

8.6.2.5. Historical TDS Concentrations

Over the last 40 years there has been a general upward trend in TDS concentrations, principally in the western portion of the Main Basin. Concentrations in the eastern and central portions of the Valley have stayed relatively low, especially during times of significant stream recharge. The local Regional Water Quality Control Board (RWQCB) Water Quality Control Plan (Basin Plan) has set the water quality objective (WQO) at 500 mg/L (or ambient, whichever is lower) for the Main Basin and at 1,000 mg/L (or ambient, whichever is lower) for the Fringe Area.

Figure 8-19 shows TDS chemographs for the period 1975 to 2020. Most TDS concentrations are presented on the vertical axis from 0 to 1,600 mg/L, but two extend higher to include all concentrations: 3S1E06F003 to 3,800 mg/L and 3S2E01F002 to 2,200 mg/L. The graphs also include the minimum thresholds (dashed lines, blue for upper aquifer and red for lower aquifer) and measurable objectives (the WQO, in solid green line) for the representative monitoring sites as discussed in **Sections 13.4** and **14.4.** The inset map shows TDS concentrations in the upper aquifer in 2020 WY.

The top portion of shows eight chemographs of TDS concentrations in the Fringe Area. All eight graphs show trends that generally are steady over the long term, although a slight increase is discernible in the May Subarea well. Most wells have TDS concentrations less than the WQO 1,000 mg/L except for those in the Spring Subarea (3S2E01F002) and in the Northeast Fringe Area (3S1E06F003):

- Spring subarea (3S2E01F002) - generally has concentrations between 1,200 and 2,000 mg/L; this reflects recharge from local streams with high TDS and watersheds characterized by marine sediments and deep saline water associated with the numerous bounding faults in the area.

- Northeast Fringe Area (3S1E06F003) – concentrations are between about 1,200 mg/L and 1,700 mg/L in the late 1970s and early 1980s. In the late 1980s, concentrations rose significantly to around 3,000 mg/L and have been relatively steady since that time. The cause of the rise in TDS is unknown. Naturally occurring, low permeability clays and historic lake beds have been documented in the area and some elevated TDS concentrations could be naturally occurring. Localized point sources, such as historical wastewater and sludge disposal practices are also potential causes.

The bottom portion of **Figure 8-19** shows several chemographs from both the Upper (in blue) and Lower (in red) aquifers of the Main Basin, discussed below from west to east:

- Castle subarea well (3S1W13J001) - Although Zone 7 considers Castle Subarea to be a part of the Main Basin, the Basin Plan WQO is the same as in the Fringe Area, recognizing the local, higher-salinity groundwater. The chemograph indicates that TDS concentrations in the Upper Aquifer are generally between 200 and 700 mg/L with a steady trend since about 1994.

- Bernal subarea Key Wells - concentrations in both the Upper and Lower Aquifer were observed to increase in the late 1990s and early 2000s, but have stabilized since then at about 400 to 600 mg/L.

- Amador West subarea Key Wells - Upper Aquifer concentrations are significantly higher (above 1,000 mg/L prior to 2009), but have recently declined and are now below the 500 mg/L WQO. Concentrations in the Lower Aquifer have been consistently around 450 mg/L.

- Amador East subarea Key Wells - TDS concentrations in the Upper Aquifer varied considerably and were relatively high (between 500 and 1,000 mg/L) between 1975 and 1995, but have stabilized at about 600 to 800 mg/L in the last two decades. TDS concentrations in the Lower Aquifer, with concentrations between about 350 mg/L and 500 mg/L have been generally constant since 1976.

- Mocho II Key Wells - show relatively steady TDS trends with concentrations generally between 500 and 600 mg/L.

Because high-TDS groundwater from the Fringe Aquifer provides some subsurface inflow to the Upper Aquifer of the Main Basin, these concentrations are being carefully monitored for any additional increasing trends. Starting with Zone 7's Salt Management Plan (SMP; *Zone 7, 2004*), Zone 7 has been proactively addressing TDS concentrations (**Section 15.2)**, including demineralization projects, both ongoing (Mocho Wellfield demineralization) and planned (Tri-Valley Recycled Water Project).

TDS increases in the Basin, particularly in some Lower Aquifer wells such as the Bernal subarea Key Well, triggered aggressive development and implementation of the SMP by Zone 7 beginning in 2004. By 2010, Zone 7 had developed a groundwater demineralization program, providing reverse-osmosis treatment and export of brine out of the Basin. Also, note that the Bernal subarea Key Wells show that TDS concentrations in the Upper Aquifer are actually lower than in the Lower Aquifer in this area. This is thought to be due, in part, to the recharge of low TDS water along Arroyo Valle as part of the Zone 7 conjunctive use program. These ongoing projects, along with other SMP actions, are discussed in **Section**

15 of this Alt GSP. Additional data and analyses conducted by Zone 7 for the examination of current and historical average TDS concentrations are discussed below.

8.6.2.6. Main Basin Salt Loading Calculations

Zone 7's Main Basin salt loading spreadsheet (**Table 8-2)** calculates the addition and removal of minerals in the Main Basin by tracking or estimating the salt mass associated with the recharge and discharge components of the Basin Hydrologic Inventory. These calculations include all salts, including those applied at the ground surface and those that may exist in the Overburden and interbedded aquitards. Therefore, the calculated concentrations are theoretical and differ from the average basin-wide salt concentrations described above, which are based on measurement of TDS concentrations in groundwater. This approach to calculating salt loads is a conservative or "worst case" analysis. Actual, measured TDS concentrations are shown in **Figure 8-16** to **Figure 8-19**. In general, salts are added to or removed from the Main Basin by the mechanisms listed in **Table 8-G.**

Table 8-G: Main Basin Salt Loading Calculation Components

SALT ADDITION	SALT REMOVAL

• Natural stream recharge
• Natural areal recharge
• Artificial stream recharge
• Subsurface groundwater inflow
• Pipe leakage
• Applied water (irrigation) recharge
  o Municipal
  o Groundwater
  o Recycled water
	• Municipal pumping, including brine export from the MGDP
	• Agricultural pumping
	• Mining area discharges and wet gravel export
	• Basin outflow

By assigning a TDS value for each inventory component, the net theoretical salt load is then calculated for each water year. Zone 7 calculates a theoretical average TDS concentration of the entire Main Basin by assuming a starting average concentration of 450 mg/L in 1973 (*DWR, 1974*), and calculating the net theoretical salt load and change in storage for every year since then. A negative value for the net theoretical salt mass from the Basin may not result in a lowering of the theoretical average TDS concentration if it is associated with a loss of storage.

Groundwater pumping removes salts from the Main Basin as solute in the produced groundwater. Some of this salt mass is then exported from the Main Basin in the municipal wastewater, brine from the MGDP, mining area discharges, and deliveries of groundwater to areas outside of the Main Basin. Other portions of the salt mass removed by Main Basin pumping are reapplied to the Main Basin as recharge from irrigation, pipe leakage, subsurface groundwater inflow, and to a lesser degree, onsite wastewater discharges.

The calculations account for evapotranspiration and evaporation of groundwater in the mining area ponds, which have the effect of concentrating salts in the Main Basin. Similarly, the salt-concentrating effects of water applications for irrigation are calculated. In contrast, rainfall recharge dilutes the salt concentrations as it adds essentially salt-free water to the system. Artificial recharge with low salinity SWP water also tends to dilute the Main Basin salt concentrations but does add some salt mass to the system. The amount of added salt accounts for the salinity of the water being recharged, which varies seasonally and annually, and the amount recharging the aquifers.

While theoretical, the calculations provide insights into the processes of salt addition and removal both geographically and temporally. **Figure 8-20** illustrates the results from 1974 to 2020 of the theoretical salt loading calculations in terms of annual salt loading and TDS concentrations. The graphs indicate considerable variability in salt loading from year to year. It should be noted that the salt loading is presented as mass (tons) entering or leaving the basin. The theoretical TDS concentration curve (Graph 3) is expressed as a concentration which accounts not only for the mass of salt (Graph 2, red line), but also the volume of groundwater in storage (Graph 2, blue line). Hence, an apparent increase in concentration can be associated with negative salt loading (i.e., decrease of salt mass) if the volume of groundwater is decreased with lower groundwater levels. Therefore, the theoretical TDS concentration generally increases during drought conditions, primarily due to a corresponding decrease in the volume of groundwater in storage. Such an increase is noted during the drought of the late 1980s and early 1990s. Predicted theoretical concentrations have been relatively stable between drought cycles.

8.6.2.7. Projected Salt Loading Calculations

Zone 7's salt management program uses an adaptive management approach to select the combination of salt management strategies to be implemented each year. The available strategies include salt removal by groundwater pumping, salt export through the operation of Zone 7's MGDP, and reduction of groundwater salinity by artificially recharging lower salinity imported water. In 2013, Zone 7 generated graphs that estimated future Main Basin salt concentrations (as TDS) from 2011 to 2050. These graphs were used to evaluate and develop long term plans (e.g., installing a second demineralization plant) for managing salt in the Main Basin.

For this update, Zone 7 updated these graphs using long-term supply and demand estimates developed for Zone 7's 2020 Urban Water Management Plan (UWMP, see **Section 9.4**). **Figure 8-21** shows three graphs with projections from 2020 to 2081:

- **Graph 1**: estimated net annual salt loading (tons) and net annual Basin storage change (AF);
- **Graph 2**: total salt in the Basin (tons) and total Basin storage (including all imported water added to the Chain of Lakes for recharge, in AF); and
- **Graph 3**: average Basin TDS concentrations (total salt/total storage, in mg/L).

The following milestones influence salt loading and TDS concentrations:

- Initially Zone 7 is expected to continue to rely on the Basin for municipal supply, which will both decrease Basin storage and increase salt removal. During this period TDS concentrations in the Basin are expected to stay relatively constant.
- In 2025, the Chain of Lakes (COL) Pipeline is expected to come online which will allow Zone 7 to recharge surface water into the COL. The bump in storage will cause TDS concentrations to drop slightly.
- In 2030 the Sites Reservoir and potable reuse projects are expected to come online, so Zone 7's reliance on the Basin will slowly decrease. In the beginning total salt will increase, but storage increases significantly, which will result in a decrease in Basin TDS concentrations. Eventually, storage will level off, but salt will continue to be imported into the Basin, resulting in a gradual increase in TDS concentrations.
- In 2060 mining will cease, and Zone 7 gets ownership of the remaining COL. The increased recharge capacity enables Zone 7 to install a second demineralization plant and increase pumping. This will result in an increase in salt removal increases and TDS concentrations will decline significantly.

TDS concentrations in the Fringe Area are generally not affected by Zone 7's conjunctive use and therefore are expected to continue trending as shown on the historical chemographs on **Figure 8-19**. Most of those chemographs show relatively constant TDS concentrations except for those in the Camp and May subareas.

8.6.3. Nitrate

8.6.3.1. Introduction

The Zone 7 groundwater quality monitoring program addresses nitrate as one of the inorganic constituents of concern; accordingly, Zone 7 conducts numerous analyses for nitrate in the Basin similar to those presented above for TDS. Every year, Zone 7 uses well and mining pit sampling data to contour nitrate (as nitrate-nitrogen, NO_3-N) concentrations in the Main Basin (Upper and Lower Aquifers) and Fringe Areas (**Sections 8.6.3.2** and **8.6.3.3**). Zone 7 then calculates average nitrate (as N) concentrations in the Main Basin and Fringe Areas (**Section 8.6.3.4**). **Section 8.6.3.5** presents historical nitrate concentrations from 1974 to 1980. Zone 7 also calculates the net nitrate loading (**Section 8.6.3.6**) to estimate trends for each of the Management Areas. For this update, Zone 7 also evaluated the change in nitrate concentrations and loading since 2015 when Zone 7's NMP was published (**Section 8.6.3.7**).

8.6.3.2. Nitrate in the Upper Aquifer

The NMP identified ten local AOCs in the Upper Aquifer where nitrate (as N) has been detected at concentrations above the Maximum Contaminant Level (MCL) of 10 mg/L. These hot spots are shown in **Figure 8-22**. The descriptions below characterize each hot spot and identify potential sources of nitrate, current concentrations are also included:

- **Happy Valley** – This unincorporated, unsewered area has been subdivided into 1- to 5-acre lots and developed with rural residences relying on domestic wells for water supply. There are currently about 100 septic tanks or OWTS in use in Happy Valley. Very little additional development has been planned for Happy Valley because Alameda County has placed a moratorium on new OWTS construction in the area due to high nitrate detections in some of the domestic wells. There are no dedicated monitoring wells in the area; however, many of the domestic wells have been tested for nitrate since 1973. In 2013, Zone 7 and Alameda County Department of Environmental Health (ACEH) conducted voluntary testing of water samples from domestic wells in Happy Valley. Seven of the 31 wells had nitrate concentrations that exceeded the MCL. Most of the high nitrate occurrences were detected in the central portion of this enclosed subarea, which consists of only one aquifer (the Upland Aquifer). Nitrate concentrations were not monitored in this Upland Area AOC in the 2020 WY; however, when studied in the 2013 WY by Zone 7 and ACEH, the nitrate occurrences were found to be stable.

- **Staples Ranch** – This elongated AOC runs from west to east in the southern portion of the Camp Subarea and in the eastern portions of Dublin and Pleasanton. This area was heavily farmed in the past, and then left largely as undeveloped open space until recently. It is now planned for low- to medium-density residential and commercial development with connections to the municipal sewer, water, and recycled water. In the 2020 WY, the nitrate concentration was detected above the MCL threshold after dropping below in the 2019 WY (12.5 mg/L in the 2020 WY). A second area of elevated concentrations in this AOC existed historically to the west near Tassajara Creek; however, for the past few years, nitrate concentrations in this portion of the AOC have dropped below the MCL (9.3 mg/L in the 2020 WY in 3S1E05K006). The high nitrate levels are likely a remnant of past agricultural operations that included row crops, alfalfa cultivation, small dairy operations, and OWTS clusters. There is still some dry farming of hay in the area and a golf driving range in the eastern part with approximately 16 acres of irrigated turf. The future planned commercial development may effectively cap any potential buried nutrient sources from the historical agricultural land use, minimizing their leaching during rainfall events.
- **Bernal** – This AOC is based on nitrate concentrations from one well (3S1E22D002) in the southern portion of the Upper Aquifer of the Amador West subarea. The long-term trend of concentrations in this well has been slowly declining. In the 2020 WY, the concentration was just below the MCL of 10 mg/L at 9.58 mg/L. This area is primarily sewered and developed as medium-density residential (about 2 to 8 dwellings per acre) with no future additional development planned. The source of high nitrate and the reason for the fluctuating concentrations has not been identified, but it is speculated that the nitrate may have been entering the Main Basin as hill-front recharge and/or subsurface inflow from the neighboring Upland Area to the south. These sources are likely diminishing as urban development and associated sewering spreads into the Upland Area.
- **Jack London** – This AOC extends from the eastern portion of the Mocho II subarea to the northeastern portion of the Amador subarea. The eastern portion is primarily sewered medium-density residential while the western portion is sewered commercial (including the Livermore airport) with little future development currently planned. A horse boarding facility operates in the most western part. Portions of this nitrate plume date back to at least the 1960s. Several wells in the Upper Aquifer have consistently had nitrate concentrations above the MCL. The highest nitrate concentration detected in this AOC during the 2020 WY was 13.2 mg/L in 3S1E12D002. The most significant nutrient contributor is believed to have been the historical municipal

wastewater disposal that was practiced at several locations in this AOC before the LAVWMA wastewater export pipeline was constructed. Historical and current agricultural practices, and current recycled water use are other potential nutrient loading sources for this area, although considered to be less significant.

- **Constitution** – This AOC exists near the boundary of the Mocho II, Camp, and Amador subareas and is up-gradient from the Las Positas Golf Course in Livermore. This area is primarily sewered commercial with little future land use development. Nitrate concentrations were detected above the MCL in 3S1E01H003, at 15.7 mg/L during the 2020 WY. The source of the nitrate is unconfirmed but may be from historical OWTS use and agricultural practices, and current landscape fertilizer application and/or recycled water use.
- **May School** – The highest nitrate concentration detected in the groundwater basin is in a well (2S2E28D002) near May School Road in the Upper Aquifer of the May subarea. For the 2020 WY, only 2S2E28D002 was sampled and had a concentration of 42 mg/L. The source of high nitrate has not been identified; however, it likely comes from agricultural land use in that area. Also, this unsewered area has a concentration of rural residences on Bel Roma Road that are served by OWTS. There are no known future development plans for the area.
- **Charlotte Way** – This AOC exists in the western portion of the Mocho I subarea and may commingle with the Buena Vista AOC in the eastern portion of the Mocho II subarea. The area is primarily sewered and developed as medium-density residential. There is no future development planned for the area. Elevated nitrate concentrations have been typically detected in three monitoring wells in this AOC. However, in the 2020 WY, only one of the three wells sampled exceeded the MCL; 13.8 mg/L in 3S2E03K003. Nitrate concentrations were detected just below the MCL in two other monitoring wells at 9.83 mg/L in 3S2E14A003 and at 9.35 mg/L in 3S2E10F003.The cause is believed to be historical OWTS, fertilizer applications, and other agricultural land uses that no longer exist in the area, but continue to have impacts on groundwater quality.
- **Buena Vista** – This nitrate plume is defined by several wells in the central and eastern portion of the Mocho II Subarea in both the Upper and Lower Aquifers. This area is primarily unsewered low- to medium-density residential, vineyard and winery land uses with some future vineyard and winery development planned. The concentration in 3S2E22B001, near the proximal end of the plume, fluctuates above and below the MCL. During the 2020 WY, the highest concentration was detected in the northeastern portion of the plume at 15.2 mg/L in 3S2E10Q001. The potential sources of the nitrate are existing OWTS and historical agricultural practices, livestock manure, and composting vegetation. There are over 100 OWTS still in use near the proximal end of the plume, documented historical poultry farming, and crop and floral farming along Buena Vista Avenue.
- **Greenville** – This east Fringe Area AOC, located near the corner of Greenville Road and Tesla Road, is primarily developed as unsewered low-density residential, vineyard, and wineries. Additional vineyard and winery uses are planned for this AOC in the South Livermore Valley Specific Plan. The highest concentration of nitrate recorded in this area was 37 mg/L in 2001 WY. In the 2020 WY, 3S2E24A001 had a concentration of 24.5 mg/L. The source of nitrate in this area is

unconfirmed, but believed to be from historical poultry farming, and other agricultural land uses located up-gradient. There is concern for the potential increase in onsite wastewater disposal from the future commercial development planned for this area.

- **Mines Road** – This AOC is represented by a single well; 3S2E26J002, located in the southern portion of the Main Basin Upper Aquifer along Mines Road. Nitrate concentrations in this well have fluctuated widely, ranging from non-detect to a maximum of 21.4 mg/L in October 2011. For the 2020 WY, the nitrate concentration was below the MCL at 1.37 mg/L. The reasons for the fluctuations are unknown but may be related to agriculture and changes in precipitation. This area is primarily unsewered low-density residential with little future development planned.

8.6.3.3. Nitrate in the Lower Aquifer

In the Lower Aquifer, nitrate was detected above the MCL in only three areas (**Figure 8-23**):

- **Jack London** – While smaller in extent than the AOC for the Upper Aquifer, the general location of this AOC also underlies the shallow nitrate plume, suggesting communication between the Upper Aquifer and the Lower Aquifer. Nitrate was not detected above the MCL in any of the wells in this AOC during the 2020 WY.
- **Buena Vista** – The general location of this AOC underlies the Buena Vista nitrate plume in the Upper Aquifer, also suggesting that nitrate from the Upper Aquifer has migrated into the Lower Aquifer. This plume also appears to have migrated towards, and possibly co-mingled with, the Jack London plume. In the 2020 WY, nitrate concentrations exceeded the MCL in two monitoring wells (11.2 mg/L in 3S2E8H003 and 10.8 mg/L in 3S2E16A003). Four other wells, including two municipal supply wells located in the same AOC had nitrate concentrations that approached the MCL (8.7 mg/L in CWS 10, 8.04 mg/L in CWS 9, 9.6 mg/L in 3S2E15E002, and 9.35 mg/L in 3S2E05N001). Overall, this Lower Aquifer nitrate plume has been relatively stable over the last five years.
- **Southern Portion of Amador Subarea** – Historically, nitrate was detected in one well above the MCL (3S1E19D009 at 11.5 mg/L) in this area. There is no corresponding concentration of nitrate above the MCL in the Upper Aquifer; however, nitrate was detected at a slightly elevated concentration in a shallower well in the same nested set (6.12 mg/L in 3S1E19D007). The source of this nitrate is unknown but may come from historical agricultural land use in the vicinity. Nitrate was not detected above the MCL in any of the wells in this AOC during the 2020 WY.

8.6.3.4. Average Nitrate Concentrations

Each year, Zone 7 calculates the average nitrate concentrations for several areas in the Fringe Area and for the Main Basin (both Upper and Lower Aquifers) using groundwater quality contours based on actual measured monitoring data. The 2020 WY results are shown in **Figure 8-24**. In the Main Basin, the total average nitrate (as N) concentration for 2020 is 3.2 mg/L for both the Upper and Lower Aquifers. In the each of the Fringe Areas, average concentrations range from 2.9 to 8.3 mg/L. The average concentrations across the entire Upland Area is approximately 3.7 mg/L. All concentrations are below the MCL; however, there are certain localized areas ("Nitrate Areas of Concern" on **Figure 8-22**) where the nitrate concentration exceeds the MCL.

8.6.3.5. Historical Nitrate Concentrations

Figure 8-25 shows chemographs of nitrate (as N) for the period 1975 to 2020. All nitrate concentrations are presented with a vertical axis from 0 to 50 mg/L. The graphs also include the minimum thresholds (dashed lines, blue for upper aquifer and red for lower aquifer) and measurable objectives (i.e., the Basin MCL of 10 mg/L, solid green line) for the representative monitoring sites as discussed in **Sections 13.4** and **14.4.** The inset map shows the areas where nitrate concentrations were above the MCL in the upper aquifer in 2015 WY (as black dashed lines) and, for comparison, in 2020 WY (as orange regions).

The top portion of **Figure 8-25** shows eight nitrate chemographs from 1975 to 2020 along the subareas of the North Fringe Area (Dublin, Bishop, Camp, May, Cayetano, Spring). For all chemographs except May Subarea, concentrations are below 10 mg/L and trends area generally steady over the long term. The graph for the May Subarea shows a significant increase in nitrate with concentrations varying in recent years between about 25 and 45 mg/L. As discussed below, this area has been identified in the NMP as one of ten local AOCs. Similarly, the nitrate graph for the East Fringe Area at the right also shows nitrate above the Basin Plan WQO; this area, too, has been identified as an AOC.

The bottom portion of **Figure 8-25** shows nitrate chemographs from the Upper (in blue) and Lower (in red) Aquifers of the Main Basin. These chemographs show that nitrate trends have been relatively steady over time, most of which have remained below the 10 mg/L WQO. The Amador East Upper Key well indicates nitrate concentrations in the Upper Aquifer have generally ranged between 10 to 25 mg/L with a few outliers. The two easternmost Key Wells (Mocho II Upper and Lower) show relatively steady nitrate trends with concentrations generally around 10 mg/L for both the Upper Aquifer and Lower Aquifer.

Only one nitrate concentration (below the detection limit) from 1987 was available from the 3S2E21K009 in the Upland Area.

8.6.3.6. Nutrient Loading Calculations and Trends

The nitrate loading and assimilative capacity of the Basin was studied as part of the NMP. Groundwater nitrate concentrations are good indicators of nutrient contamination, and graphing concentrations versus time can indicate whether nitrate conditions are changing or stable. Given the variability of nitrate in the environment, Zone 7 uses estimates of nitrogen loading to evaluate long-term nitrate trends. The primary nitrogen sources and losses assumed in the NMP are shown in **Table 8-H** below.

Table 8-H: Sources and Losses of Nitrogen in Groundwater

NITROGEN SOURCES	NITROGEN LOSSES
Stream Recharge	Soil Processes
Rainfall Recharge	• Denitrification
Pipe Leakage	• Soil texture (absorption)
Subsurface Inflow	• Plant Uptake
Horse Boarding (manure)	Groundwater Pumping Mining Export Subsurface Outflow
Rural (OWTS and livestock manure)	Mining Export
Winery (OWTS and process water)	Subsurface Outflow
Applied water (well water & recycled) water)	
Fertilizers (agriculture and turf)	

For this update, Zone 7 updated the estimated the future annual nitrogen loading and removal from all these components for average hydrologic conditions (**Table 8-3** for the Main Basin, **Table 8-4** for the Fringe and Upland Areas. Annual nitrogen loading from each known source was estimated and summed to predict future nitrate trends for each Management Area. The model results predict that average nitrate concentrations will decrease over time in the Main Basin and East Fringe Area, and will increase in the North and Northeast Fringe Areas and Upland Area.

8.6.3.7. Effectiveness of NMP Strategies

To minimize nitrate loading to the Basin, the 2015 NMP recommended implementing OWTS loading limits in AOCs with existing OWTS. These "OWTS Special Permit Areas" (SPAs) are shown on **Figure 8-25 to Figure 8-27**. **Figure 8-25** also shows nitrate concentrations above the 10 mg/L MCL for the 2013 (when the NMP was first released) and 2020 WYs. **Figure 8-26 and Figure 8-27** include nitrate concentrations contours above the 10 mg/L MCL for the 2015 (just before the NMP recommendations were implemented) and 2020 WYs in the Upper and Lower Aquifers, respectively. These figures show that the contoured areas decreased for the Jack London, Staples Ranch and Bernal AOCs. The Buena Vista AOC appears to have increased slightly and has migrated down-gradient towards the California Water Company (Cal Water) municipal wells. The Greenville, May School, and Happy Valley AOCs show little change; however, all three have been represented by limited data, so the actual extent of those contoured areas is unknown. The graphs on **Figure 8-25** shows that the concentrations of 2S2E28D002 in the May School AOC and 3S2E24A001 in the Greenville AOC have both been increasing over time, suggesting that the plumes are either increasing or migrating down-gradient.

For this update, Zone 7 was able to obtain some OWTS data from the ACEH. **Figure 8-28** shows parcels with OWTS and locations with OWTS permits given by ACEH since 2015. **Table 8-5** shows the change in nitrogen loading from OWTS in the Basin and the SPAs and also estimates the change in loading attributable to the NMP recommendations (e.g., installing an advanced OWTS system with nitrogen reduction instead of a standard OWTS). The table shows that the NMP OWTS recommendations have reduced nitrogen loading by about 70 pounds (lbs) of nitrogen per year, primarily in the Buena Vista and Greenville SPAs.

8.6.4. Boron

8.6.4.1. Boron in the Upper Aquifer

Boron is a naturally-occurring element typically found at very low concentrations in groundwater from the Basin. While there is no MCL for boron, the EPA has identified a Health Reference Level (HRL) of 1,400 micrograms per liter [µg/L] (1.4 mg/L). Boron also becomes a problem for irrigated crops when present at levels above 1,000 or 2,000 µg/L, depending on the crop sensitivity.

Boron exists at elevated concentrations in the Upper Aquifer in the following areas of the Basin (**Figure 8-29**):

- There is a plume of elevated boron concentrations that extends along the boundary between the North Fringe Area and the Main Basin. This localized concentration of boron has been relatively stable for many years. The highest concentration measured in the 2020 WY (12,000 micrograms per liter [µg/L]) was found near the center of this area in monitoring well 3S1E04J005.
- Elevated boron concentrations were also detected in parts of the Northeast and East Fringe Areas. The highest concentration detected in these areas in the 2020 WY was detected at 29,000 µg/L in monitoring well 2S2E27P002.

The source of boron is likely from natural alkali/marine sediments in the east, but this is unconfirmed. It should be noted that the boron detected in the western portion of the Basin primarily occurs along the Arroyo Las Positas and lower Arroyo Mocho. This occurrence of elevated boron may be from high-boron groundwater discharging into the Arroyo Las Positas in the eastern portion of the Valley and flowing downstream to the Arroyo Mocho, recharging groundwater along the way. The eastern portion of the Arroyo Las Positas has been a gaining stream and continuously flowing into the Arroyo Mocho since the 1981 WY.

8.6.4.2. Boron in the Lower Aquifer

In general, boron concentrations are relatively low in the Lower Aquifer; detections are typically less than 1,000 µg/L. In the 2020 WY, boron was detected above 1,000 µg/L in the Lower Aquifer in the following areas of the Basin (**Figure 8-30**, note that concentrations are shown on the figure in µg/L):

- In municipal supply well Mocho 3, in Zone 7's Mocho Wellfield, at 1,000 µg/L .
- In monitoring well 3S2E23E002, in the southeastern portion of the Mocho II Subarea, at 2,600 µg/L.

The source of boron is unconfirmed but may originate in localized natural alkali/marine sediments or vertical migration through the leaky aquitard from the Upper Aquifer.

8.6.4.3. Historical Boron Concentrations

Figure 8-31 shows chemographs of boron (in µg/L) for the period 1975 to 2020. The boron concentrations are presented on the vertical axis from 0 to 5,000 µg/L (except for the graph for 3S2E01F002, which extends to 11,000 µg/L). The graphs also include the minimum thresholds (dashed lines, blue for upper aquifer and red for lower aquifer) and measurable objectives (i.e., the Basin Objective of 1,400 µg/L, solid green line) for the representative monitoring sites as discussed in **Sections 13.4** and **14.4**. The inset map shows the areas where boron concentrations were above the basin objective (1,400 µg/L) in the upper aquifer for the 2020 WY.

8.6.5. Chromium

8.6.5.1. Chromium in the Upper Aquifer

Chromium (Cr) is typically found at very low concentrations in groundwater in the Basin. It can be a naturally occurring element found in the Basin and is generally derived from the Franciscan Assemblage, which contains Serpentinite that tends to be rich in magnesium, chromium and nickel. Chromium can also be the result of an anthropogenic impact. Prior to August 2017, the Basin WQO and the Minimum Threshold in the Alt GSP had been set at the MCL for hexavalent chromium (CrVI), which was 10 µg/L. In August 2017, under orders of the Superior Court, the State Water Resources Control Board (SWRCB) withdrew the CrVI regulation from the California Code of Regulations. Until the SWRCB establishes a new MCL for CrVI, they have returned to use the more general total Cr MCL of 50 µg/L to ensure public water systems are safe. Since all the Minimum Thresholds in the Alt GSP have been set based on the State's drinking water standards, Zone 7 adjusted the Minimum Threshold for Cr to match the State's Cr MCL that is in effect; currently 50 µg/L (see **Section 13**). Chromium concentrations exceeded the 50 µg/L threshold in two Upper Aquifer monitoring wells during the 2020 WY sampling effort. Concentrations are presented on **Figure 8-32**:

- Cr was detected at 94 µg/L in monitoring well 3S2E12C004 which is located on the LLNL site in the East Fringe Area.
- Cr was detected at 108 µg/L in monitoring well 3S1E07G007 located in the North Fringe Area just north of the Main Basin.

8.6.5.2. Chromium in the Lower Aquifer

Cr was not detected above the MCL in any of the monitored Lower Aquifer wells. However, Cr was detected in several monitoring and production wells at greater than the former Minimum Threshold of 10 µg/L as shown on **Figure 8-33** (note that concentrations are shown on the figure in µg/L).

Because the locations of the slightly elevated Cr concentrations in the Lower Aquifer do not coincide with those in the Upper Aquifer, it is likely that the Cr in the Lower Aquifer is not a result of vertical migration from the Upper Aquifer. It may be the result of localized leaching of naturally occurring chromium-rich minerals in those portions of the Lower Aquifer.

8.6.5.3. Historical Chromium Concentrations

Figure 8-34 shows chemographs of chromium (in µg/L) for the period 2000 to 2020 (no chromium results are available before the 2020 WY). The chromium concentrations are presented on the vertical axis from 0 to 80 µg/L. The graphs also include the minimum thresholds (dashed lines, blue for upper aquifer and red for lower aquifer) and measurable objectives (i.e., the Basin Objective of 50 µg/L, solid green line) for the representative monitoring sites as discussed in **Sections 13.4** and **14.4**. The inset map shows the areas where chromium concentrations were above the basin objective (50 µg/L) in the upper aquifer for the 2020 WY.

8.6.6. PFAS

8.6.6.1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are a large group of human-made substances that do not occur naturally in the environment. PFAS are classified by the EPA as CEC. These substances have been used extensively in the United States since the 1940's, particularly in surface coating and protectant formulations due to their ability to repel oil, grease, and water. There is limited research to date, but some studies show that they may cause adverse health effects. Additional research is needed to determine the full scope of PFAS impacts on human health.

Zone 7 began sampling for PFAS compounds in the 2019 WY. Based on the detections in some of the supply wells and the limited set of monitoring wells sampled, Zone 7 hired Jacobs Engineering, Inc. to conduct a PFAS Potential Source Investigation (*Jacobs, 2020*). The investigation, which concluded in December 2020, included recommendations for additional sampling of existing monitoring wells. Those wells will be incorporated into the 2021 WY sampling program. Jacob's PFAS Potential Source Investigation Report and other information on PFAS are located on the Zone 7 website: http://www.zone7water.com/pfas-information.

Of those PFAS compounds detected, only perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), and perfluorobutanesulfonic acid (PFBS) have any regulatory limits (see **Table 8-I**), and of those three compounds, PFOS had the highest concentrations relative to regulatory limits. **Figure 8-35** and **Figure 8-36** show PFOS concentrations (in part per trillion [ppt]) for the Upper and Lower Aquifers.

Table 8-I: Regulatory Limits for PFAS Compounds (in ppt)

Agency	Type of Limit	PFOS	PFOA	PFBS**
US EPA	Screening Level	40*	40*	-
	Preliminary Remediation Goal (PRG)	70*	70*	-
State Water Resources Control Board (SWRCB) - Division of Drinking Water (DDW)	Notification Level (NL)	6.1	5.1	500
	Response Level (RL)	40	10	5,000

* Either individually or combined.
** Pending

8.6.6.2. PFAS in the Upper Aquifer

Monitoring wells previously sampled and presented in the 2019 WY Annual Report were not resampled in the 2020 WY; however, additional wells were sampled to help determine the extent of PFOS in the Basin. The results from both water years are presented on **Figure 8-35**.

- While most of the wells sampled in the 2019 WY had PFOS detections, those concentrations that were above the EPA's 40 ppt screening level and above the DDW's 70 ppt response level (RL) appear to be northeast of the mining area in the vicinity of the Jack London Boulevard. The highest concentration detected in the Upper Aquifer remains 450 ppt in well 3S1E10A002 sampled in the 2019 WY, which is just southeast of the airport.
- Two wells sampled in the 2020 WY (3S2E19D007 and 3S2E19N003) that were east of Isabel Avenue and south of Stanley Boulevard were both non-detect for PFOS.
- In the 2020 WY five wells were sampled north and east of the highest concentration area. These wells ranged from non-detect to 40 ppt (in well 3S1E04J005). The PFOS detected in 3S1E04J005 does not appear to be connected to the plume southeast of the airport and may come from a separate source.

8.6.6.3. PFAS in the Lower Aquifer

Figure 8-36 shows PFOS concentrations in the Lower Aquifer wells that were sampled in either the 2019 or 2020 WYs. For wells that were sampled more than once, the map shows the highest PFOS concentrations detected. In nested well sets, the map shows the Lower Aquifer well with the highest PFOS concentration. The 2019 WY samples are labeled black with gray highlights in the map.

- Wells with concentrations above the EPA's 40 ppt screening level are within a roughly-triangular area that stretched from the southwestern edge of the airport (north of the mining area) to the

City of Pleasanton's Wellfield (west of the mining area) and to Zone 7's Mocho Wellfield (northwest of the mining area).

- There were two areas where PFOS concentrations exceeded the DDW's RL (70 ppt):
  - The first extended west from the airport to Zone 7's Mocho Wellfield. This area included 3S1E10B008, which had the highest concentration detected in the Basin, at 1,400 ppt in the 2020 WY. Zone 7's Mocho 1 municipal well was the only municipal well in this area with PFOS concentrations above the RL at 110 ppt in the 2020 WY.
  - The second was at Pleasanton's Well 8 (Pleas 8 or P8), which had a maximum concentration of PFOS at 110 ppt in the 2020 WY. During the 2019 WY the PFOS concentrations ranged from 68 to 120 ppt. This area of elevated PFOS concentration appears to be relatively isolated as evidenced by several wells with concentrations below the RL both north (roughly up-gradient) and west (down-gradient) of Pleas 8.
- Eight of Zone 7's municipal wells have tested above the NL for PFOS (6.5 ppt) in the 2020 WY, but only one of the municipal wells, Mocho 1 (i.e., 3S1E09M002), had PFOS concentrations (110 ppt) that exceeded DDW's recommended RL of 70 ppt. Four of Zone 7's wells also tested above the NL for PFOA (5.1 ppt). Although additional PFAS compounds were also detected in Zone 7's water supplies, at present there are no regulatory guidelines for these contaminants.
- PFOS was detected in five of six CWS wells sampled in the 2020 WY. None of the wells had concentrations above the RL (70ppt).

8.6.6.4. Other PFAS Monitoring/Studies

Zone 7 continues to monitor and characterize PFAS in the Basin and is working with the San Francisco Region Water Board to identify potential sources. In preparation for a MCL setting for PFAS at the end of 2023 and compliance by Spring 2024, Zone 7 is undertaking design of a PFAS treatment facility project to ensure that water quality from the COL wells would be in compliance with the MCL and available for use. The project scope includes design and construction of a PFAS treatment facility located at the COL 1 well site. COL 1 has the chemical treatment facilities for all three existing wells (COL 1, 2, and 5) and future wells and shares a common manifold to the Zone 7 distribution system.

Zone 7 is also performing a Desktop Groundwater Contaminant Mobilization Study (Project) that will develop a model that can be used to simultaneously analyze flows, chemical transport, and geochemical interactions and evaluate the potential for chemical constituents or contaminants to mobilize under a variety of conditions. The Project will help Zone 7 better understand how existing and future groundwater pumping operations affect contaminants in the Basin. Model simulations could inform Zone 7's and retailers' pumping operations, and construction of new wells. Although this Project and other studies were originally identified as next steps in the Potable Reuse Feasibility Study completed in May 2018, the list of studies and their focus have transitioned to broader water supply and water quality efforts that will benefit overall water supply reliability and groundwater quality and management, including PFAS-related issues.

8.6.7. Toxic Sites

Zone 7 documents and tracks sites where groundwater has been impacted from anthropogenic sources and identifies those that pose a potential threat to drinking water. Zone 7 also coordinates closely with lead agencies to ensure protection of beneficial uses. Information is gathered from state, county, and local agencies, as well as from Zone 7's well permitting program and the SWRCB's GeoTracker website, and compiled in a geographic information systems (GIS) database. This tracking program is designated the Toxic Sites Surveillance (TSS) Program and is described in the Zone 7 Annual Reports.

Each site in Zone 7's TSS Program has been assigned a Zone 7 number, which corresponds to a file number containing reports or other information about the site. In addition, all sites are reviewed and given a priority designation (high, moderate, or low) based on the threat they pose to groundwater. For example, a site is designated as high priority if contamination at the site is present in groundwater at concentrations greater than the MCL and a water supply well is within 2,000 ft down-gradient of the site, or it is shown that drinking water or surface water will likely be impacted by the contamination at the site. High Priority sites are typically located in the Main Basin where Zone 7 and their retailers' wells are located. However, if another type of supply well (domestic, industrial, agricultural, etc.) located outside of the Main Basin is impacted or threatened the same criteria would apply.

In general, the TSS Program has found two types of contamination threatening groundwater in the Basin:

- **Petroleum-based fuel products** - including total petroleum hydrocarbon as gasoline (TPHg), TPH as diesel (TPHd), benzene, toluene, ethylbenzene, xylene (collectively known as BTEX), and fuel oxygenates, such as Methyl tert-butyl ether (MTBE) and tertiary-butyl alcohol (TBA). California has assigned clean-up standards (*Title 22, California Code of Regulations*) for the BTEX compounds and fuel oxygenates. However, a clean-up standard for total petroleum (TPHg or TPHd) has not officially been established.
- **Industrial chemical contaminants** – including the chlorinated solvents tetrachlorethylene (PCE), trichloroethylene (TCE), and their degradation by-products, such as vinyl chloride (VC) and dichloroethene (DCE). PCE is common in the dry cleaning business, and TCE is commonly used as a degreaser for electronics and automotive industries. Both PCE and TCE have an established MCL of 5 µg/L (*CCR, Title 17, Section 64444*).

In the 2020 WY, Zone 7 tracked the progress of 56 active sites where contamination has been detected in groundwater or is threatening groundwater. Eleven of these active sites have a contaminant plume that is within 2,000 ft of a water supply well or a surface water source and are therefore classified as "High Priority" cases due to their impact or threat of impact on potable groundwater supplies. Zone 7's database also contains 283 other contamination cases that have been either "Closed" or classified as "No Action Required" because they have been sufficiently cleaned up and/or pose minimal threat to drinking water supplies.

The locations of all the toxic sites, and their proximity to the Valley's municipal water wells, are shown on the accompanying individual area maps (**Figure 8-37** through **Figure 8-39**, Livermore, Pleasanton/Sunol, and Dublin subareas, respectively). Zone 7 also maintains a database for all the toxic sites that includes the case status, its priority, and which agency is responsible for providing oversight for the case. It also identifies the contaminants of concern for each case and provides brief notes regarding the cases. Zone 7's Annual Reports include tables that summarize the results for the year. In addition, copies of plans, reports, directive letters, and background data on the cases can be found at the SWRCB's GeoTracker website: http://geotracker.waterboards.ca.gov/.

8.7. Land Subsidence

§ 354.16. Groundwater Conditions
(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

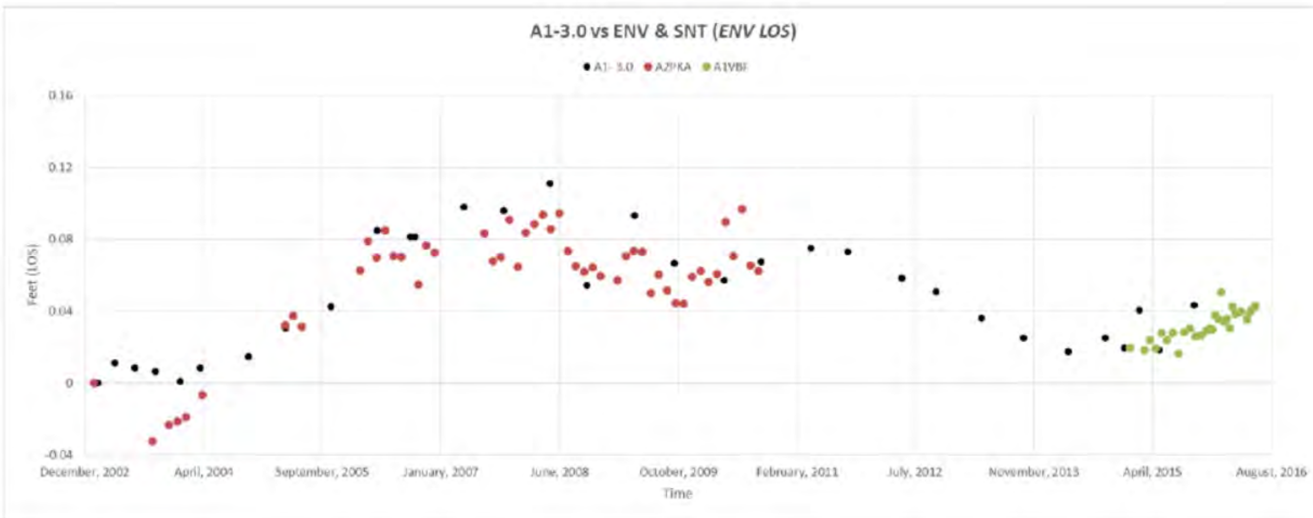
☑ 23 CCR § 354.16(e)

As demonstrated herein (consistent with the approved 2016 Alt GSP) and the requirements of CWC § 10733.6 (a)(3) and 23 CCR § 356.4, Zone 7 has continued to sustainably manage land subsidence in the Basin to avoid URs (as defined in **Section 13.5.1**) for decades, including over three major droughts.

Land surface elevations have been monitored in the Basin for over 60 years, with no evidence of inelastic land subsidence occurring; however, the data collected have revealed small seasonal fluctuations as well as larger cycles of elevation gains and losses that correlate with groundwater elevation trends. Up until the 2018 WY, land surface elevations in the Main Basin were monitored using benchmark surveys; several level survey circuits were run between 1947 and 1980, and more recently, semi-annual spirit-level surveys were conducted as part of the Land Surface Elevation Monitoring Program starting in 2002.

In the 2016 WY, Zone 7 contracted with TRE Altamira (TRE) to evaluate Interferometric Synthetic Aperture Radar (InSAR) as an alternative to land surveying for subsidence monitoring. The study results correlated well with topographic surface measurements taken by land surveys within the same period (see **Figure 8-A** below, taken from Attachment I of Zone 7's 2016 Alt GSP) and provided a basis to justify InSAR as an alternative method to monitor subsidence.

Figure 8-A: Comparison of Land Survey Point (A1-3.0) to InSAR Data

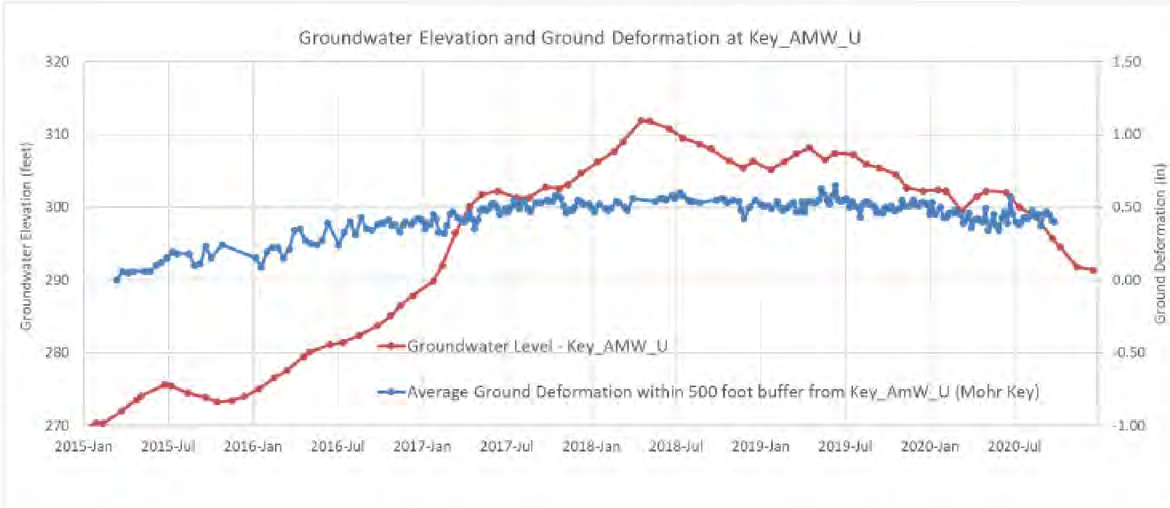


Starting in the 2019 WY, instead of continuing the land surveying program, Zone 7 used InSAR for monitoring land subsidence. For that year's study, TRE expanded the coverage area to include all the Basin, including the entire Main Basin, Fringe, and Upland Areas. For the 2020 WY, Zone 7 contracted again with TRE to perform an analysis of satellite data for the Valley collected since the 2016 WY. **Figure 8-40** shows the extent of the InSAR study performed this year, the locations of the selected InSAR points, and the total land surface deformation from March 2015 to September 2020. The figure shows that the overall change in ground surface elevations are very small (from between -0.04 to +0.02 feet, represented by yellow and green dots) or have actually have generally risen (about 0.02 to 0.06 feet, represented by green and blue dots). These land surface elevation changes (i.e., within +/- 0.04 feet) are within the range Zone 7 considers to be "elastic deformation" (i.e., rebounds to the original elevation when groundwater levels return to previous levels). In fact, the general land surface increase since 2015 likely represents an "elastic" response to groundwater elevation increases following the drought in the early 2010s. The following items summarize other findings from the InSAR analysis:

- Several areas in the mining area appear to have dropped more than 0.10 feet (indicated by red dots in **Figure 8-40**). These are likely due to elevation changes from mining excavation and additional grading activities, and not from land subsidence.
- In the vicinity of Zone 7's wellfields, fluctuations in ground surface elevation have generally trended with changes in groundwater elevations and appear to be indicative of elastic land ground-surface deformations.

The TRE report (**Appendix J**) includes the following additional figures and tables: Figures 10 and 11 (pages 16 and 17) show the cumulative land surface elevation change from the 2019 to 2020 WYs. Figures 13 through 15 (pages 19 to 21, a portion of Figure 14 is reproduced in **Figure 8-B** below) show graphs of ground surface elevation and groundwater elevation.

Figure 8-B: Groundwater Elevation vs Ground Displacement at the Amador West Key Well



The ground deformation graphs in **Figure 8-A** and **Figure 8-B** show that no inelastic subsidence has been observed since the beginning of the land surveys in 2002.

In 2021, rather than contracting directly with TRE, Zone 7 will obtain TRE's InSAR dataset from DWR that is published as part of DWR's SGMA technical assistance to provide "important SGMA-relevant data to GSAs for GSP development and implementation". For more information about the TRE InSAR Subsidence Data for DWR, visit this website: https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence.

8.8. Groundwater Dependent Ecosystems

§ 354.16. Groundwater Conditions
(f) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

☑ **23 CCR § 354.16(g)**

The following sections describes the process used to identify likely GDEs within the Basin. A summary of the work effort is presented below and in **Appendix F**.

8.8.1. Preliminary Screening

Preliminary identification of likely GDEs within the Basin is performed based on the available data and tools, field and aerial photo surveys, and analysis conducted in general accordance with the process laid out in The Nature Conservancy (TNC) guidance (*Rohde et al., 2018*).

8.8.1.1. Data Source

Primary data sources that were incorporated into the screening analyses or otherwise supported the GDE field investigation and identification include the following:

- GDE information from the DWR's Natural Communities Commonly Associated with Groundwater (NCCAG) dataset and TNC guidance documents (*Rohde et al., 2018; Klausmeyer et al. 2019; TNC, 2019*);
- GDE health indices from the TNC GDE Pulse tool[13], including the Normalized Derived Moisture Index (NDMI) and the Normalized Derived Vegetation Index (NDVI), which indicate the vegetation moisture and vegetation greenness, respectively;
- Additional resources regarding the presence of GDEs in the Basin, including GDE geospatial data and Sycamore alluvial woodland data;
- United States Geological Survey (USGS) ground surface elevation data;
- Well information, including locations and well construction details; and
- Groundwater elevation and depth to water data.

8.8.1.2. Depth to Groundwater Analysis

The NCCAG dataset identifies land areas by vegetation or wetland categories that potentially indicate the presence of GDEs, as shown on **Figure 8-41**. The NCCAG dataset also assigns the potential GDEs a polygon number. An additional GDE area (i.e., the Springtown Alkali Sink[14]) was not identified in the NCCAG dataset, but was included in this analysis and on **Figure 8-41** for completeness.

Based on review of the NCCAG dataset, the maximum rooting depth of various plant species associated with potential GDEs within the Basin is approximately 30 feet below ground surface (ft bgs).[15] As such, if the minimum depth to groundwater between 2015 and 2020 in the vicinity of the mapped potential GDEs was greater than 30 ft bgs,[16] it is unlikely that the mapped vegetation or wetland areas in the NCCAG dataset were accessing the principal aquifer[17] as their source of supply. Rather, these mapped vegetative communities are likely supplied by a surface water, perched groundwater, or other source (e.g., runoff or a man-made water feature) and are therefore not GDEs in the context of SGMA.

To further clarify whether the mapped vegetative communities from the NCCAG are likely GDEs that are dependent on the principal aquifer, the depth to groundwater for each potential GDE polygon (and the

[13] https://gde.codefornature.org/#/methodology; The GDE Pulse interactive map developed by TNC provides users easy access to satellite data to view long term temporal trends of vegetation metrics. These vegetation metrics serve as an indicator of vegetation health for GDEs. In addition, the GDE Pulse web app provides long-term temporal trends of groundwater depth and regional precipitation data. This provides users with a platform to infer relationships between groundwater levels, precipitation, and GDE vegetation metrics to monitor and sustainably manage groundwater and GDEs.
[14] The 2016 Alt GSP identified the Springtown Alkali Sink as a GDE in Section 2.1.4.
[15] https://groundwaterresourcehub.org/sgma-tools/gde-rooting-depths-database-for-gdes/
[16] Since the Plan is not required to address URs that occurred before, and have not been corrected by January 1, 2015 (Water Code Section 10727.2 (b)(4)), 2015 is selected as the start of the analysis timeframe.
[17] Per § 351.(aa), "Principal aquifers" refer to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. The Main Basin includes a single principal aquifer that includes two hydraulically connect zones with varying degrees of connectivity: the Upper Aquifer and Lower Aquifer.

area of the Springtown Alkali Sink) was estimated by comparing the potential max GDE rooting depth (30 ft bgs) to the measured depth to groundwater from nearby Upper Aquifer wells within the Basin. Upper Aquifer wells within a one kilometer (km) radius of the mapped potential GDEs were assumed to be representative of groundwater conditions within those areas (*Klausmeyer et al. 2019*). The locations of Upper Aquifer wells within the Basin that were used to evaluate shallow groundwater conditions are shown on **Figure 8-42**. If multiple wells were within one km of a GDE polygon, the minimum depth to groundwater between 2015 and 2020 from these wells was calculated.

If the minimum depth to water between 2015 and 2020 was greater than 30 ft bgs, then that respective GDE polygon was determined to likely not be a GDE that was dependent on the principal aquifer and was "removed" from further consideration. If the minimum depth to groundwater between 2015 and 2020 was less than 30 ft bgs or if no proximate groundwater data were available, the potential GDE polygon was preliminarily "retained" for further review. The retained and removed GDE polygons are shown on **Figure 8-42**.

8.8.1.3. Application of the TNC GDE Pulse Tool Methodology

The TNC GDE Pulse tool provides time series data for two remote sensing indices that are used to monitor a vegetation's health: (1) the NDMI, and (2) the NDVI, which indicate the vegetation moisture and vegetation greenness, respectively. Higher NDMI and NDVI values are associated with "healthier" vegetation. In the TNC GDE Pulse tool the NDMI and NDVI data are indexed to the same GDE polygon numbers included in the NCCAG dataset[18].

The premise of the TNC GDE Pulse tool is that, since the NDMI and NDVI indices can quantify changes in the rates and patterns of vegetation growth and moisture levels in plants over time, the relationship between these two indices and the depth to shallow groundwater can be evaluated to examine whether these measures of GDE "health" have a relationship to shallow groundwater conditions. Since limited depth to groundwater data are provided in the TNC GDE Pulse tool, depth to groundwater data collected within the Basin were used to supplement this analysis.

Time series data of these two indices and the nearby (i.e., within one km) depth to groundwater data were plotted for each retained GDE polygon, as shown on **Figure 8-43** and **Appendix F**. A linear correlation between the two indices and the local depth to groundwater data was then evaluated for each polygon. A negative correlation would mean that, when the depths to groundwater increase, the NDMI and NDVI indices decrease, indicating that the GDEs are less healthy when conditions are such that local groundwater elevations decrease, and vice versa.

Among the preliminarily retained GDEs (i.e., those GDE polygons where the minimum depth to groundwater in the Upper Aquifer between 2015 and 2020 was less than 30 ft bgs), 84% exhibited a negative correlation between NDMI and depth to groundwater, and 71% exhibited a negative correlation

[18] There are no TNC GDE Pulse data for Springtown Alkali Sink, so the analysis of groundwater level trends and the NDMI and NDVI indices could not be conducted for this GDE.

between NDVI and depth to groundwater. For the purpose of this analysis, correlation with a p-value that is less or equal to 0.05 is considered to be significant. Among the potential GDEs that have negative correlations, 46% of them have a significant correlation between NDMI and depth to groundwater, and 38% of them have a significant correlation between NDVI and depth to groundwater. The potential GDE areas that exhibited negative correlations for both NDMI and NDVI are shown on **Figure 8-44**. These data indicate that one factor impacting vegetative health in the retained GDE area could be the depth to groundwater.

It should be noted, however, that correlation is not the same as causation and a negative correlation does not necessarily confirm the presence of a GDE that would be impacted by changes in Upper Aquifer groundwater levels. Rather, what this analysis confirms is that GDEs are objectively less healthy when conditions are such that local groundwater elevations decrease, and vice versa. However, significant uncertainties remain. For example, the Overburden layer extent in the Fringe Area is uncertain, and therefore while vegetation along the Tassajara Creek and near Dublin (northeastern portion of the Basin) are retained as potential GDEs, they may be disconnected from the underlying Upper Aquifer and any apparent correlation would be meaningless.

8.8.2. Field Investigation & Verification

Field investigation and verification of likely GDE is conducted by a subconsultant, Stillwater Sciences (Stillwater). As described in **Appendix F,** Stillwater integrated the aforementioned screening analysis and other available local data to conduct a refined mapping of the potential GDEs within the Basin, including: the Classification and Assessment with Landsat of Visible Ecology Groupings (CalVeg) dataset; Urban Creeks Council (UCC) 2014 CalVeg update for third-order and higher channels; Aerial Information Systems (AIS) Springtown Alkali Sink Preserve Wetlands Mapping; and Sycamore Alluvial Woodland Tree Survey in Arroyo Mocho and Arroyo Valley. Man-made open water areas (e.g., the COL and golf course ponds) were removed from the refined vegetation map. As part of the ecological inventory, special-status species and sensitive natural communities that are potentially associated with GDEs in the Basin were also identified using regional and local databases.[19]

On 31 March 2021, Stillwater conducted field studies and surveyed aerial photography to verify the presence of GDEs at 12 unique sites throughout the Basin (Sites A through L as shown on **Figure 8-45**). These sites included areas where there were: (1) apparent "gaps" in the potential GDE map shown on **Figure 8-41** (i.e., where vegetation similar to GDEs occurred immediately upstream and downstream of the mapped site but was not identified as a GDE); (2) where the riparian vegetation was mapped along stream channels (i.e., where the mapped GDEs are potentially supported by surface water, not groundwater); and (3) where the mapped GDEs are underlain by thick clay layers (i.e., where perched groundwater, not the principal aquifer, could be the source). Additionally, Stillwater scientists assessed

[19] Databases used by Stillwater to identify special-status species include: (1) California Natural Diversity Database, (2) California Native Plant Society (CNPS) Manual of California Vegetation, (3) eBird, and (4) TNC freshwater species lists generated from the California Freshwater Species Database (CAFSD).

potential GDEs at sites where groundwater data are sparse (e.g., near Sycamore Park and Springtown). Likely groundwater dependence of these sites was determined by assessing various local water sources and the width of the riparian zone. Where riparian zones were narrow and relatively sparse, other water sources likely support the vegetation. Where existing vegetation and wetland areas extend beyond a narrow strip along the channel, groundwater dependence was considered likely (*Stillwater, 2021*).

Based on the totality of the above analysis, a final determination was made on the presence of likely GDEs within the Basin. The primary differences in GDE mapping relative to the initial NCCAG map of potential GDEs are summarized below and shown on **Figure 8-45**:

- Additional GDEs were identified in the northeast portion of the Basin where the AIS mapping occurred (Site H, **Figure 8-45**).
- Potential GDEs mapped in the NCCAG dataset that occur adjacent to man-made open water features along COLs (in the Arroyo Valle corridor) and near the City of Dublin were removed.
- Some further changes in GDE mapping reflect differences between the UCC update to the CalVeg map along Arroyo Mocho and Arroyo Valle. In particular, the width of the riparian vegetation along both streams increased in places, as seen in **Figure 8-45**.
- The reclassification of vegetation near Lake Boris on Arroyo Valle (downstream of Site I, **Figure 8-45**) reduced the extent of GDEs downstream of the lake.
- The vegetation was removed along Arroyo de la Laguna and west of Pleasanton (Sites B, C, and D, **Figure 8-45**) after conducting field investigations. These sites occur above a thick clay layer (known colloquially as the Overburden layer) that precludes connection to the principal aquifer. Observations during the field visit suggested that the riparian vegetation at Sites B, C, and D was likely dependent on surface water rather than groundwater due to the relatively narrow riparian zone.
- The potential GDE community near Site L was also removed since the very sparse riparian vegetation suggested the area was not connected to groundwater.
- Wetlands mapped within man-made lakes and ponds (e.g., Frick Lake in the eastern part of the basin) were also removed (*Stillwater, 2021*).

The final likely GDE map is presented on **Figure 8-46**. Likely GDEs are grouped and named based on their location and major vegetation types, as shown on **Figure 8-46** and in **Table 8-J.** However, significant uncertainties remain. For example, the Overburden layer extent in the Fringe Area is uncertain, and therefore while vegetation along the Tassajara Creek and near Dublin (northeastern portion of the Basin) are retained as potential GDEs, they may be disconnected from the Upper Aquifer. Other areas retained as potential GDEs include areas of non-native vegetation (such as Eucalyptus trees) or that are adjacent to shallow bedrock outcrops in the center of the Basin (e.g., the “Oak Knoll” area). These GDE areas have been preliminarily retained, but will be further evaluated through monitoring and periodic visual inspections as discussed in **Section 14** below.

Table 8-J. GDE Region and Major Vegetative Composition

Management Area	Likely GDE Name	Acreages
Main Basin	Arroyo Valle – Riparian Mixed Hardwood	137
	Arroyo Valle – Sycamore Grove	343
	Arroyo Mocho – Riparian Mixed Hardwood & Sycamore	94
	Arroyo Mocho – Valley Oak	178
Fringe Area	Springtown Alkali Sink	173
	Arroyo Las Positas – Mixed Vegetation	56
Upland Area	Upland – Riparian Mixed Hardwood	35
Basin-Wide	Potential GDEs to be Further Evaluated	37
	Total Acreages	1,052

In total, the Basin includes approximately 1,052 acres of likely GDEs, approximately 2% of the total Basin area. The Main Basin contains approximately 69% of the total likely GDE area, the Fringe Area contains approximately 20%, and the Upland Area contains the remaining 11% of the likely GDEs. The most prevalent vegetation communities across all likely GDE units are the riparian mixed hardwood alliance and California sycamore alliance, which respectively comprise 40% and 30% of the likely GDE areas in the Basin and are located almost entirely in the Main Basin. The Alkaline mixed grasses and forbs alliance comprises 10% of total likely GDE area and is located almost entirely in the Fringe Area (*Stillwater, 2021*).

The Basin includes United States Fish and Wildlife Service (USFWS) designated critical habitat for four federally listed species: the Alameda whipsnake, California red-legged frog, California tiger salamander, and vernal pool fairy shrimp. As described in **Appendix F**, of the designated critical habitat, most of the habitat for the vernal pool fairy shrimp is co-located with mapped GDEs, but this species relies on vernal pools, which are dependent on rainfall, rather than groundwater and is therefore unlikely to be groundwater dependent. Most of the critical habitat for California red-legged frogs and Alameda whipsnake occurs outside of the defined GDEs, with approximately two acres of their critical habitat overlapping with a riparian GDE at the upstream end of Arroyo Mocho (*Stillwater, 2021*). Zone 7 adheres to the East Alameda County Conservation Strategy (EACCS) that was developed to preserve endangered species by developing a shared vision for long term habitat protection.[20]

As described in **Appendix F**, 22 special-status plants occur within the Basin, including Alkali milk-vetch, Heartscale, Brittlescale, Livermore tarplant, and Jepson's coyote-thistle. Of these, 12 plant types were

[20] EACCS website, http://eastalco-conservation.org/about.html.

likely dependent upon groundwater, four were possibly dependent on groundwater, one was unlikely to be groundwater dependent, and five were not groundwater dependent. All 12 special-status plants likely Upland Area. The likely groundwater dependent special-status plants in the Fringe Area mostly were observed in or around the Springtown Alkali Sink (*Stillwater, 2021*).

Thirty-one special-status terrestrial and aquatic wildlife species were identified as having the potential to occur within the Basin, including the Crotch bumble bee, Southwestern pond turtle, and American peregrine falcon. Of these, 14 were potentially groundwater dependent species: two amphibian species, two reptile species, seven bird species, and three mammal species. Additional information on these groundwater dependent species, including regulatory status and habitat associations, is provided in **Appendix F**. Ten of the groundwater dependent special status species are likely to occur in the Main Basin, eight of the groundwater-dependent special status species are likely to occur in the Fringe Area, and 13 of the groundwater-dependent special status species are likely to occur in the Upland Area (*Stillwater, 2021*).

8.8.3. Likely Groundwater Dependent Ecosystems

Based on the above analyses and field investigation, the Basin includes approximately 1,062 acres of likely GDEs, which encompass approximately 2% of the total Basin area. The most prevalent vegetation communities across all likely GDE units are the riparian mixed hardwood alliance, California sycamore alliance, and the Alkaline mixed grasses and forbs alliance. Most of the likely GDEs are located along the Arroyo Valle and Arroyo Mocho creeks in the Main Basin and around Altamont Creek in the Fringe Area.

8.8.4. Groundwater Dependent Ecosystem Demands

Quantifying groundwater consumptive use from GDEs can be estimated using a soil moisture balance model discussed in **Section 9**. Evapotranspiration (ET) uptake from groundwater occurs when the saturated groundwater table is accessible by the root zone of a GDE or is within a small enough depth below the root zone such that groundwater can be accessed via capillary rise. As part of this work effort, DWR’s Integrated Water Flow Model Demand Calculator (IDC) soil moisture balance model is utilized to provide initial estimates of ET uptake from groundwater for the GDE communities identified in the above analyses. The IDC employs the “Root Water Uptake” package to simulate shallow groundwater uptake by GDE communities to meet ET demands (*DWR, 2020a*). In its current form, the Zone 7 IDC model explicitly simulates shallow groundwater uptake from the five largest and most contiguous GDE communities identified in the Basin, including:

- Arroyo Valle - Riparian Mixed Hardwood
- Arroyo Valle - Sycamore Grove
- Arroyo Mocho - Riparian Mixed Hardwood & Sycamore
- Arroyo Mocho - Valley Oak
- Springtown Alkali Sink

These GDE communities collectively comprise approximately 925 acres, or roughly 90% of the total mapped GDE areas within the Basin.

Based on IDC model outputs for DWR 2011 – 2020 WYs, approximately 2,900 acre-feet per year (AFY) of shallow groundwater are consumed by GDE communities to help meet ET demands, equating to approximately 3.0 acre-feet per acre (AF/acre). This represents roughly 70% of the total potential ET demand estimated for GDEs within the Basin (~4.3 AFY/acre) [21]. Given the considerable uncertainties in soil properties, shallow groundwater availability, and plant-specific groundwater uptake rates embedded in this calculation, a more reasonable range of average GDE groundwater demands within the Basin is likely somewhere between 2,000 AFY (~2 AFY/acre) and 4,000 AFY (~4 AFY/acre).

8.9. Interconnected Surface Water Systems

§ 354.16. Groundwater Conditions
(g) Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

☑ 23 CCR § 354.16(f)

As demonstrated herein (consistent with the approved 2016 Alt GSP) and the requirements of CWC § 10733.6 (a)(3) and 23 CCR § 356.4, Zone 7 has continued to sustainably manage ICSW depletion in the Basin to avoid URs (as defined in **Section 13.6.1**) for decades, including over three major droughts.

Locations of surface water bodies (e.g., streams) within the Basin are shown on **Figure 7-3**. In general, bottoms of the surface water channels are above the water table and provide recharge to the groundwater system where sufficiently permeable sediments occur beneath the arroyos. Wet reaches of the arroyos are correlated to discharge of surface water to the channel from mining operations or for conjunctive use. Surface water remains in several reaches of surface streams in the Basin where surficial clay deposits impede groundwater recharge. Nonetheless, groundwater does not generally contribute to baseflow along surface water reaches in the Basin. Statistical and geospatial analyses discussed in detail below are performed to identify stream reaches that are likely interconnected to shallow groundwater. A summary of the work effort is presented below and in **Appendix F**.

8.9.1. Preliminary Screening

8.9.1.1. Data Source

A preliminary screening of potential ICSW locations was conducted using the following primary data sources:

[21] Based on local CIMIS station reference evapotranspiration (ETo) data and monthly riparian/native vegetation ET coefficients provided by DWR's Cal-SIMETAW model for the Livermore study area.

- Locations of surface water bodies;
- Stream daily flow data and gauge height between 2015 and 2020;
- Stream recharge rates shapefile provided by Zone 7 based on synoptic surveys;
- Groundwater elevation and depth to water data;
- Stream cross sections; and
- Guidance document from Environmental Defense Fund (EDF) (*EDF, 2018*), USGS (*Winter et al., 1998*), and UC Berkeley (*Cantor et al., 2018*).

8.9.1.2. Physical and Operational Exemptions

Artificial stream sections (i.e., those that have been channelized and lined with concrete) were excluded from the depth to groundwater analysis discussed below that was used to identify potential ICSW. Similarly, stream sections that overlie the Overburden layer were excluded. The Overburden layer consists of a thick, continuous surficial lens of clay reaching up to 70 feet thickness that precludes connection to the Upper Aquifer, and mainly exists in the Main Basin and extends from the north central portion of the Basin to the western edge of the Basin.

COL is also excluded from ICSW consideration. Ongoing mining and reclamation are changing to some degree the connection between upper and lower aquifers and surface water, as some areas are capped or filled (thus reducing connection), and as excavation of wet pits effectively creates surface water ponds. However, no GDEs exist in the mining area and the surface water pits are not identified for specific beneficial uses in the Regional Water Quality Control Board-San Francisco Bay Region (RWQCB) Water Quality Control Plan (Basin Plan). Releases of water for recharge along the arroyos have resulted in dry season flows in the arroyos; however, these are flows are relatively warm and not equivalent to cool pre-mining flows that could support some native species.

8.9.1.3. Depth to Groundwater Analysis

The relationship between groundwater and surface water largely depends upon the depth to groundwater relative to the streambed depth. For groundwater to be interconnected with a stream channel, the depth to groundwater in the vicinity of the stream must be less than the streambed depth. Conversely, for surface water to seep to groundwater, which indicates disconnectivity between surface water and groundwater, the depth to groundwater in the vicinity of the stream must be deeper than the streambed depth.

The maximum streambed depth of the streams within the Basin is approximately 30 feet. As such, if the minimum depth to groundwater between 2015 and 2020 in the vicinity of the stream sections is more than 30 ft bgs, it is unlikely that the mapped stream sections are interconnected with groundwater.22

[22] Since the Plan is not required to address URs that occurred before and have not been corrected by January 1, 2015 (Water Code Section 10727.2 (b)(4)), 2015 is selected as the start of the analysis timeframe.

Conversely, if the depth to groundwater is less than 30 ft bgs along the stream sections, the groundwater and stream sections are likely to be interconnected. Depth to groundwater estimates in the vicinity of the mapped streams were made at 500 foot intervals along the length of the mapped streams from the 2015-2020 depth to groundwater rasters. Additionally, synoptic surveys have been performed by Zone 7, as shown on **Figure 7-16**, to identify the reaches of major streams in the Basin, whether they are gaining or losing, and what the respective rates are.

Based on the above data and analysis, locations of potential ICSW locations are shown on **Figure 8-47**.

8.9.1.4. Correlation Analysis

SGMA requires that the sustainability criteria of the ICSW Sustainability Indicator be developed based on the "…rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water..."[23] Alternatively, groundwater levels can be used as a proxy.[24]

Based on the above, the potential correlation between Upper Aquifer groundwater elevation and streamflow data between 2015 and 2020, including gauge height and flow rate, were evaluated to examine whether the portions of the streams that were identified as likely ICSW have a quantifiable relationship to the principal aquifer. Stream gauging stations along potential ICSW sections and near likely GDEs (discussed in **Section 8.8**) were selected for the correlation analysis, as shown on **Figure 8-48**.

Upper Aquifer wells within a one km radius of the selected stream gauging stations were assumed to be representative of groundwater conditions in vicinity of the stations. If multiple wells were associated with (i.e., within one km of) a stream gauging station, average groundwater elevations from these wells were calculated. The Upper Aquifer wells within the one km buffer of each selected stream gauging station are shown on **Figure 8-48**. Since most of the groundwater elevations were measured monthly, monthly average flow data and gauge height were calculated.

Time series data of the gauge height and flow rate were plotted for each stream gauging station, as shown on **Figure 8-49** and in **Appendix F**. A linear correlation between the stream flow data (gauge height and flow rate) and the local groundwater elevation was then evaluated for each station. A positive correlation would mean that, when the gauge height or flow rate increases, the groundwater elevation also increases, indicating that there is potential interconnectivity between the stream and groundwater, and vice versa.

Zone 7 imports surface water from the SWP through the South Bay Aqueduct (SBA) for treatment, storage, and groundwater recharge as part of the active management of the Basin. Since the streams within the Basin are also used for artificial recharge, correlation between low flow, which better represents the natural streamflow conditions, and Upper Aquifer groundwater elevation was also performed. Low flow

[23] § 354.28(b)(6)

[24] § 354.28(d) An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence

data for each stream gauging station were obtained by removing the gauge height and flow rate data that fell outside of the 90th percentile[25]. The low flow correlation result for each stream gauging station is also shown on **Figure 8-49** and in **Appendix F**.

Among the selected stream gauging stations (i.e., stations located along potential ICSW and near likely GDEs), only the AVNL station exhibited statistically significant positive correlations between streamflow data (gauge height and flow rate) and groundwater elevation data.[26] The ADVP station also showed a low but statistically significant positive correlation for low flow conditions only. Groundwater elevation measurements from the wells located close to the other stream gauging stations are generally collected biannually, and thus there is insufficient groundwater elevation data to support statistically significant correlation between groundwater levels and monthly average stream flow data. This data gap is addressed further under **Section 14**.

For the AVNL station, the correlation using all stream flow data has a larger correlation coefficient and smaller p-value than those for the correlation using low flow data only (i.e., for all stream flow data, correlation coefficients and p-values are 0.88 and 2.1e-22 for gauge height, 0.87 and 9.8e-22 for flow rate; for low flow data, the correlation coefficients and p-values are 0.35 and 0.006 for gauge height, 0.40 and 0.002 for flow rate). The AVNL station is located along Arroyo Valle and near the location where imported SWP water is released into the stream. Nearby likely GDEs (Sycamore Grove located in the southeastern portion of the Basin as discussed in **Section 8.8**) have been documented to rely on the released imported water for artificial recharge (*Zone 7, 2009*), which is also reflected in the higher correlation for all flow data (i.e., during active Zone 7 recharge operations).

Additionally, cross-correlation was performed for the AVNL station data to examine whether a time lag exists between the stream flow data and shallow groundwater elevations.[27] The cross-correlation result shows that maximum correlation is reached when time lag equals zero months and the correlation is significant, which indicates that limited time lag exists between the stream flow data and groundwater elevations for the AVNL station.

8.9.2. Potential Interconnected Surface Water

Based on the above analyses, likely ICSW sections have been identified along several reaches of the major surface water features within the Basin, including Arroyo Valle, Arroyo Mocho, Arroyo Las Positas, and Altamont Creek. Unsurprisingly, most of the areas where potential ICSW sections occur also support likely GDEs as discussed in **Section 8.8**, as these stream corridors consistently encounter some of the shallowest groundwater elevations observed within the Basin, see **Figure 8-47**.

[25] Ratio of high flow events to low flow events is approximately 1:9 in most of the stream stations, and therefore 90th percentile is used as a threshold to retain low flow data.
[26] For the purpose of this analysis, correlation with a p-value that is less or equal to 0.05 is considered to be significant.
[27] Cross-correlation is a measurement that tracks the movements of two or more sets of time series data relative to one another.

Where sufficient data and ICSW conditions exist, groundwater levels in the Upper Aquifer can be correlated to ICSW conditions and GDE locations. As such, Upper Aquifer wells and the selected stream gauging stations can serve as the representative monitoring sites for purposes of SGMA implementation, as discussed in **Section 14.2.6**, and sustainability criteria that are protective of both GDEs and ICSW can be developed using groundwater levels as a proxy, as discussed in **Section 13.6**.

8.10. Other Programs and Conditions

8.10.1. Land Use

Zone 7 monitors land use changes in the Valley as part of the long-range groundwater basin management program. The emphasis is on changes in pervious areas and quantity and quality of irrigation water that could affect the volume or quality of water recharging the Main Basin. The information is used by Zone 7 to quantify areal recharge (i.e., "rainfall recharge" and "applied water recharge").Wastewater and Recycled Water Use.

Land use data are derived from aerial photography, well permit applications, field observations, and City and County planning documents. Zone 7 staff also review new development plans and associated California Environmental Quality Act (CEQA) documentation to evaluate potential impacts to groundwater supply and quality.

For the purpose of Zone 7's Groundwater Management Program, primary land uses are mapped as polygons having one of the following designations:

- Residential (rural)
- Residential (low density)
- Residential (medium density)
- Residential (high density)
- Commercial and Business
- Public
- Public (Irrigated Park)
- Agriculture (vineyard)
- Agriculture (non-vineyard)
- Mining Area – Pit
- Water Body (including COL)
- Golf Course
- Open Space

Each individual land use polygon is also assigned one of the following sources of irrigation water based on Zone 7's understanding of the primary irrigation water source used for that particular area:

- Delivered (municipal) water
- Groundwater (non-municipal supply wells)
- Recycled water

- None

Land use categories and source water type are then assigned spatially to the groundwater model cells (500 feet by 500 feet), which are also the spatial units used for the areal recharge calculations. **Figure 8-50** and **Table 8-6** show the results of the Land Use program for the 2020 WY.

8.10.2. Wastewater and Recycled Water Use

Zone 7 monitors the quality and quantities of wastewater and recycled water as they apply to the Basin (recharge supply and quality). Assessments of wastewater quality and the contribution to the water budget are discussed in **Section 8.6.1.2** and **Section 9**, respectively, in this update.

The City of Livermore and DSRSD are currently responsible for treating and either discharging or recycling (see **Figure 8-50**) the vast majority of wastewater produced in the Valley. Both of these publicly-owned treatment works (POTWs) produce secondary-treated and tertiary-treated effluent, which is disinfected and either reclaimed and used for landscape irrigation or exported from the Valley through the Livermore-Amador Valley Water Management Agency (LAVWMA) export pipeline. Applications of recycled water are mostly conducted for landscape irrigation projects; however, a minor amount is used for dust suppression, grading projects, and crop irrigation.

Elsewhere in the Basin, a minor amount of untreated or partially-treated wastewater may reach the groundwater supply as percolate. The program assumes that there are small, but quantifiable amounts (estimated) of untreated wastewater that percolate in the Main Basin from onsite wastewater treatment systems (OWTS). The quantity of leachate is based on the estimated number of individual OWTS that overlie the Main Basin. The quality of the leachate is estimated from published technical literature. Zone 7 also receives monthly monitoring reports from the Department of Veteran Affairs for the VA Medical Center's sewage treatment system located in southern Livermore. Zone 7 also estimates contributions from leaking wastewater and recycled water pipelines that run throughout the Groundwater Basin. The quantity is based on the length and age of buried pipes (**Section 9.2.2.4**). The quality is based on sample data received from DSRSD and the City of Livermore.

8.10.3. Climatological

Zone 7's Climatological Monitoring Program tracks rainfall and evaporation in the Valley, employing a network of climatological stations. The primary objective of this monitoring network is to provide high quality basin-wide data for long-term studies, basin recharge calculations, and water management decisions. Specifically, the calculations of basin recharge are used in the annual water budget, change in groundwater storage, and the defined objectives of operational storage (**see Section 9**). Data are collected to provide short-term, seasonal, and long-term trends in local hydrologic conditions. Water year type is being incorporated into the analysis using DWR calculations for the Sacramento Valley. This hydrology is more consistent with the availability of imported supplies and generally approximates local rainfall patterns in the groundwater basin.

The Zone 7 Climatological Monitoring Program network consists of several rainfall stations, two pan evaporation stations, and one California Irrigation Management Information System (CIMIS) station (including rainfall and evaporation) located within the Alameda Creek Watershed.

There are two basic types of rainfall stations used in Zone 7's Climatological Monitoring Program: daily record stations and recorder stations (see **Section 14.2.7.1** for details of the monitoring metwork). A daily record station consists of a rain gauge at which, once-a-day, the observer measures and records the depth of rain that has fallen during the preceding 24 hours (see **Appendix G** for Monitoring Protocols). A recorder station, which provides rainfall intensity for periods of less than 24 hours as well as daily totals, consists of a computerized-tipping-bucket rain gauge and a data recorder. These semi-continuous-reading rain gauges generally provide rainfall totals on a 15-minute frequency.

Zone 7's Climatological Monitoring Program also contains both reference ETo and pan evaporation stations to determine water transfer to the atmosphere. Station 191 (CIMIS) is a reference ETo station, which estimates the ETo value of the water used by a well-watered, full-cover grass surface, whereas the pan evaporation stations at Lake Del Valle (LDV) and Livermore Water Reclamation Plant (LWRP) measure evaporation directly. LDV and LWRP pan evaporation data is converted to ETo using a conversion factor (ETo=Pan Evap x 0.6402). Zone 7 uses ETo to calculate evaporation from the gravel quarry ponds as well as in its applied water recharge model. The CIMIS Station's ETo is also used as part of Zone 7's Water Conservation Program to help regulate weather-based irrigation ("SMART") controllers.

8.10.4. Surface Water

Zone 7 monitors streamflow in the arroyos that run though the Basin, surface area and water levels of active and inactive gravel quarry ponds located in the central part of the Basin, and water transfers from arroyos and quarry ponds to those former quarry pits that are being used for aquifer recharge. In addition, Zone 7 tracks flow from the upper Arroyo Valle watershed into Lake Del Valle and the portion of Lake Del Valle storage for which Zone 7 has water rights. The objectives of Zone 7's Surface Water Monitoring Program are:

- **Surface Water Level and Flow Monitoring** – Quantify inflow and outflow of surface water to/from the groundwater basin. These data are used to quantify aquifer recharge resulting from streamflow (natural and artificial) and capture of gravel quarry discharges and as input for the evaporative losses determinations. They are also used in hydraulic modeling of the watershed for flood control management purposes;

- **Surface Water Quality Monitoring** - Provide a record of water quality for the basin's recharge and discharge waters with which the groundwater basin's annual salt (TDS) loading is calculated; and

- **Del Valle Water Rights** - Satisfy the requirements of Zone 7's and Alameda County Water District's (ACWD) provisional water rights on the Arroyo Valle. This involves continuous flow monitoring and quarterly sampling at two surface water stations.

The program focuses on the four main gaining and losing streams that affect the Basin (Arroyo Valle, Arroyo Mocho, Arroyo Las Positas, and Arroyo de la Laguna) and the diversions, releases, and natural runoff that affect the flows into and out of each of them. The program utilizes a network of main recorder stream gauge stations and flow meters (see **Section 14.2.7.2** for details of the monitoring network) to compute the quantity of water flowing past each station, and both, semi-continuous and periodic water level measurements to track change in surface water storage. Several of the gauges are owned and maintained by the USGS under Department of Interior 'Cooperative Agreements" with Zone 7 and others. Several other auxiliary surface water monitoring stations have been established as high flow and/or stream temperature monitoring stations to augment the data collected at the main stations for various ongoing flood management and habitat studies. Water samples are collected from the main recorder sites and significant quarry ponds at least once per year, and submitted to Zone 7's laboratory for analysis of metals, minerals and general properties (the same parameters that are routinely analyzed in the Groundwater Quality Monitoring Program).

Stream stage is converted to streamflow using calibrated stage-to-flow rating curves. Stream discharge measurements are periodically conducted at each station to recalibrate the rating curve, if necessary, to maintain its accuracy. **Appendix G** contains a description of Zone 7's discharge measurement procedure. Records from all gauge stations, including records of the rating curve corrections are stored in the Zone 7 maintained AQUARIUS Time-Series® database (**Section 8.2.1**), however, certain data can be viewed by the public in virtually "real-time" on the HydroSphere website[28].

Zone 7 calculates the basin groundwater budget (storage) using data from the gauge stations on the recharging streams (Arroyos Valle, Mocho, and Las Positas) and data from turnout flow meters that record the South Bay Aqueduct (SBA) releases made to these arroyos. The other gauges do not have significance for aquifer recharge, salt loading or basin outflow, and are maintained primarily for flood control study and management purposes.

In general, surface waters flowing past gauges AMNL, ALPL and AVNL, or through the SBA/Arroyo Mocho turnout, represent surface water entering the Basin that has potential for groundwater replenishment. The gravelly middle reaches of Arroyo Valle and Arroyo Mocho, and to a lesser extent, Arroyo Las Positas, offer aquifer recharge potential; whereas, downstream of gauges ALP_ELCH, AM_KB, AMP and ADVP the channels are mostly incised in clayey overburden and therefore do not do not offer much recharge potential. Consequently, water flowing past these lower gauges will mostly flow out of the Valley, past ADLLV, and into Alameda Creek. For the water budget calculation, the differences between the amount of surface water entering the Basin upstream of the recharge reaches and that flowing past the gauges at the end of each respective recharge reach equates to the stream recharge components.

[28] https://cloud.xylem.com/hydrosphere/public-sites/OWA_1245EDE7887A4C7D888D3671A060A8E1

TABLE 8-1
TOTAL MAIN BASIN STORAGE BY SUBAREA (AF)
GROUNDWATER ELEVATION METHOD
1974 TO 2020 WATER YEARS

Water Year	Bernal	Amador: Amador West	Amador: Amador East	Mocho II	Total
1974	49,651	52,916	80,671	29,821	213,060
1975	51,149	54,220	80,840	28,872	215,080
1976	54,180	56,319	86,194	29,012	225,705
1977	51,970	53,968	81,889	27,954	215,782
1978	50,272	52,077	79,541	27,751	209,641
1979	52,863	56,739	89,122	29,210	227,933
1980	55,952	60,000	94,014	29,500	239,466
1981	57,910	61,890	95,688	30,224	245,712
1982	57,623	61,228	93,235	29,156	241,242
1983	58,654	63,488	100,642	31,492	254,277
1984	59,021	64,418	102,569	31,626	257,635
1985	58,487	64,024	95,703	31,568	249,782
1986	56,723	60,837	95,019	27,719	240,298
1987	55,723	58,635	91,170	25,147	230,675
1988	54,486	53,217	83,377	25,672	216,752
1989	52,754	51,260	82,836	27,433	214,282
1990	50,712	50,879	80,834	27,321	209,746
1991	44,627	49,348	76,543	24,631	195,148
1992	29,663	35,438	74,616	44,036	183,753
1993	29,749	38,787	83,714	58,498	210,748
1994	30,941	39,437	88,451	56,713	215,542
1995	32,193	43,156	89,301	60,834	225,484
1996	32,217	42,917	87,193	60,865	223,193
1997	32,240	41,992	88,828	59,157	222,217
1998	32,292	43,411	88,140	61,336	225,179
1999	32,065	43,310	86,508	60,595	222,479
2000	31,894	42,591	87,585	59,947	222,018
2001	30,720	40,853	73,393	58,231	203,198
2002	30,685	37,537	84,147	59,655	212,025
2003	30,597	41,563	87,510	60,749	220,419
2004	30,518	43,784	79,441	59,614	213,357
2005	31,969	48,734	93,670	61,720	236,093
2006	32,382	53,465	91,847	60,685	238,379
2007	32,401	54,368	90,478	54,733	231,980
2008	32,365	54,160	91,898	56,097	234,520
2009	32,350	51,088	91,755	57,605	232,798
2010	32,350	50,282	92,080	59,167	233,879
2011	32,353	50,631	92,729	59,214	234,927
2012	31,772	47,442	90,475	58,154	227,844
2013	30,892	44,226	87,086	58,684	220,889
2014	30,313	42,806	82,627	53,961	209,707
2015	31,411	46,734	81,465	55,215	214,826
2016	32,205	53,885	83,016	57,583	226,689
2017	32,391	67,540	86,119	59,564	245,614
2018	32,409	71,452	85,792	56,347	246,000
2019	32,410	70,196	85,031	60,942	248,579
2020	32,361	61,215	81,447	56,701	231,725

Calculated as one aquifer (1974–1991, blue shading)

Sum of Upper and Lower Aquifers (1992–2020, tan shading)

TABLE 8-2
HISTORICAL SALT LOADING (in tons)
1974 TO 2020 WATER YEARS

SALT INFLOW COMPONENTS	1974	1975	1976	1977	1978	1979	1980
NATURAL STREAM RECHARGE	**3,210**	**3,464**	**874**	**581**	**4,638**	**1,723**	**2,706**
Total Arroyo Valle	**1,018**	**1,041**	**391**	**315**	**957**	**707**	**777**
Flood releases recharge	100	344	0	0	216	0	128
Non Flood Natural Inflow	918	697	391	315	741	707	649
Arroyo Mocho	**1,717**	**2,043**	**293**	**76**	**3,206**	**636**	**1,358**
Arroyo Las Positas	**475**	**380**	**190**	**190**	**475**	**380**	**571**
AV PRIOR RIGHTS	**361**	**418**	**31**	**0**	**494**	**267**	**386**
ARTIFICIAL STREAM RECHARGE	**986**	**2,201**	**1,914**	**2,289**	**3,286**	**3,699**	**2,897**
Arroyo Valle	293	1,174	509	883	1,427	1,599	1,234
Arroyo Mocho	340	497	875	876	1,350	1,570	1,432
Arroyo Las Positas	353	530	530	530	509	530	231
INJECTION WELL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
RAINFALL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lake Recharge	*0*	*0*	*0*	*0*	*0*	*0*	*0*
LEAKAGE	**21**	**25**	**30**	**35**	**41**	**48**	**56**
APPLIED WATER RECHARGE	**7,670**	**7,218**	**9,123**	**10,675**	**8,352**	**8,304**	**7,175**
SUBSURFACE BASIN INFLOW	**2,038**	**2,038**	**2,058**	**3,648**	**2,506**	**2,017**	**1,325**
NET INFLOW	**14,286**	**15,364**	**14,030**	**17,228**	**19,317**	**16,058**	**14,545**

OUTFLOW COMPONENTS	1974	1975	1976	1977	1978	1979	1980
MUNICIPAL PUMPAGE	**-7,217**	**-6,577**	**-5,074**	**-4,382**	**-4,579**	**-5,351**	**-4,458**
Zone 7 Wells - Hop, Stone, COL	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Zone 7 Wells - Mocho	**-3,303**	**-2,057**	**-842**	**-201**	**-506**	**-532**	**-26**
Demin Salts Exported from Valley	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Other Pumpage	**-3,914**	**-4,520**	**-4,232**	**-4,181**	**-4,073**	**-4,819**	**-4,432**
AGRICULTURAL PUMPAGE	**-2,289**	**-1,476**	**-2,997**	**-3,241**	**-2,081**	**-2,420**	**-1,678**
MINING USE	**-1,126**	**-1,725**	**-802**	**-668**	**-869**	**-1,603**	**-2,508**
Stream Export	-745	-1,345	-422	-287	-489	-1,223	-2,127
Evaporation	0	0	0	0	0	0	0
Processing Losses	-380	-380	-380	-380	-380	-380	-380
GROUNDWATER BASIN OVERFLOW	**0**	**0**	**0**	**0**	**0**	**-173**	**-612**
NET OUTFLOW	**-10,632**	**-9,778**	**-8,873**	**-8,291**	**-7,529**	**-9,547**	**-9,256**

NET SALT INFLOW (Tons)	3,654	5,586	5,157	8,937	11,788	6,511	5,289
CUMULATIVE SALT INFLOW (Tons)*	3,654	9,240	14,397	23,334	35,122	41,633	46,922

TDS Concentration Calculations	1974	1975	1976	1977	1978	1979	1980
Net Basin Recharge (AF)	-478	5,508	-4,311	-5,953	11,942	6,394	8,103
Basin Storage (HI Method)(AF)	211,522	217,030	212,719	206,766	218,708	225,102	233,205
Total Salt in Main Basin (tons)	133,252	138,838	143,995	152,932	164,720	171,231	176,520
Main Basin TDS Concentration (mg/L)	**464**	**471**	**498**	**544**	**554**	**560**	**557**
Cumulative Increase in TDS Conc (mg/L)**	**14**	**21**	**48**	**94**	**104**	**110**	**107**

* Basinwide salt buildup since 1973

** Basinwide TDS concentration increase relative to 1973 value of 450 mg/L

TABLE 8-2
HISTORICAL SALT LOADING (in tons)
1974 TO 2020 WATER YEARS

SALT INFLOW COMPONENTS	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NATURAL STREAM RECHARGE	**1,513**	**4,803**	**7,657**	**5,286**	**3,058**	**4,941**	**2,852**	**2,610**	**2,782**	**2,480**
Total Arroyo Valle	**579**	**1,048**	**1,433**	**936**	**375**	**779**	**232**	**372**	**187**	**206**
Flood releases recharge	0	271	624	20	0	415	0	0	0	0
Non Flood Natural Inflow	579	777	809	916	375	364	232	372	187	206
Arroyo Mocho	**478**	**2,614**	**4,626**	**2,508**	**932**	**2,269**	**458**	**490**	**440**	**233**
Arroyo Las Positas	**456**	**1,141**	**1,598**	**1,842**	**1,751**	**1,893**	**2,162**	**1,748**	**2,155**	**2,041**
AV PRIOR RIGHTS	**251**	**502**	**381**	**236**	**328**	**286**	**283**	**325**	**356**	**125**
ARTIFICIAL STREAM RECHARGE	**3,238**	**1,617**	**184**	**0**	**0**	**0**	**0**	**525**	**1,585**	**1,809**
Arroyo Valle	1,719	663	0	0	0	0	0	0	51	132
Arroyo Mocho	1,394	894	184	0	0	0	0	525	1,534	1,677
Arroyo Las Positas	125	60	0	0	0	0	0	0	0	0
INJECTION WELL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
RAINFALL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lake Recharge	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
LEAKAGE	**65**	**74**	**84**	**94**	**105**	**115**	**125**	**136**	**147**	**158**
APPLIED WATER RECHARGE	**5,507**	**4,709**	**4,723**	**5,046**	**5,938**	**6,632**	**5,558**	**6,834**	**6,015**	**6,541**
SUBSURFACE BASIN INFLOW	**1,284**	**1,284**	**876**	**1,325**	**1,528**	**1,508**	**1,569**	**1,875**	**2,364**	**2,568**
NET INFLOW	**11,858**	**12,989**	**13,905**	**11,987**	**10,957**	**13,482**	**10,387**	**12,305**	**13,249**	**13,681**

OUTFLOW COMPONENTS	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
MUNICIPAL PUMPAGE	**-4,700**	**-4,748**	**-5,410**	**-5,525**	**-5,752**	**-6,465**	**-5,537**	**-6,662**	**-6,915**	**-7,185**
Zone 7 Wells - Hop, Stone, COL	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-54**	**-441**
Zone 7 Wells - Mocho	**0**	**0**	**-17**	**-227**	**-863**	**-869**	**-326**	**-1,425**	**-2,082**	**-1,683**
Demin Salts Exported from Valley	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Other Pumpage	**-4,700**	**-4,748**	**-5,393**	**-5,298**	**-4,889**	**-5,595**	**-5,211**	**-5,237**	**-4,779**	**-5,062**
AGRICULTURAL PUMPAGE	**-1,553**	**-844**	**-912**	**-1,015**	**-1,378**	**-1,428**	**-998**	**-1,043**	**-776**	**-944**
MINING USE	**-4,372**	**-4,161**	**-7,834**	**-2,857**	**-2,814**	**-6,011**	**-839**	**-2,301**	**-1,728**	**-918**
Stream Export	-3,992	-3,781	-7,454	-2,476	-2,433	-5,535	-364	-1,825	-1,253	-443
Evaporation	0	0	0	0	0	0	0	0	0	0
Processing Losses	-380	-380	-380	-380	-380	-475	-475	-475	-475	-475
GROUNDWATER BASIN OVERFLOW	**-635**	**-2,494**	**-3,418**	**-2,587**	**-1,386**	**-693**	**-693**	**-462**	**-122**	**0**
NET OUTFLOW	**-11,260**	**-12,247**	**-17,574**	**-11,984**	**-11,330**	**-14,597**	**-8,067**	**-10,468**	**-9,541**	**-9,047**

NET SALT INFLOW (Tons)	**598**	**742**	**-3,669**	**3**	**-373**	**-1,115**	**2,320**	**1,837**	**3,708**	**4,634**
CUMULATIVE SALT INFLOW (Tons)*	**47,520**	**48,262**	**44,593**	**44,596**	**44,223**	**43,108**	**45,428**	**47,265**	**50,973**	**55,607**

TDS Concentration Calculations	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Net Basin Recharge (AF)	-528	11,593	9,192	-4,203	-9,722	-1,684	-7,906	-9,106	-4,973	-5,692
Basin Storage (HI Method)(AF)	232,677	244,270	253,462	249,259	239,537	237,853	229,947	220,841	215,868	210,176
Total Salt in Main Basin (tons)	177,118	177,860	174,191	174,194	173,821	172,706	175,026	176,863	180,571	185,205
Main Basin TDS Concentration (mg/L)	**560**	**536**	**506**	**514**	**534**	**535**	**560**	**590**	**616**	**649**
Cumulative Increase in TDS Conc (mg/L)**	**110**	**86**	**56**	**64**	**84**	**85**	**110**	**140**	**166**	**199**

* Basinwide salt buildup since 1973

** Basinwide TDS concentration increase relative to 1973 value of 450 mg/L

TABLE 8-2
HISTORICAL SALT LOADING (in tons)
1974 TO 2020 WATER YEARS

SALT INFLOW COMPONENTS	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NATURAL STREAM RECHARGE	**3,356**	**3,665**	**5,743**	**2,544**	**4,376**	**4,331**	**4,639**	**5,704**	**3,727**	**3,409**
Total Arroyo Valle	**575**	**743**	**1,083**	**300**	**1,034**	**400**	**1,450**	**1,661**	**1,361**	**956**
Flood releases recharge	98	0	528	0	472	336	183	524	0	55
Non Flood Natural Inflow	477	743	555	300	562	64	1,267	1,137	1,361	901
Arroyo Mocho	**1,023**	**814**	**2,174**	**995**	**1,580**	**2,627**	**1,741**	**2,292**	**996**	**857**
Arroyo Las Positas	**1,758**	**2,108**	**2,486**	**1,249**	**1,762**	**1,304**	**1,448**	**1,751**	**1,370**	**1,596**
AV PRIOR RIGHTS	**290**	**151**	**276**	**321**	**306**	**87**	**93**	**188**	**149**	**175**
ARTIFICIAL STREAM RECHARGE	**1,590**	**410**	**1,953**	**2,795**	**1,026**	**491**	**1,325**	**500**	**1,352**	**2,276**
Arroyo Valle	36	185	385	293	49	31	472	107	321	242
Arroyo Mocho	1,554	225	1,568	2,502	977	460	853	393	1,031	2,034
Arroyo Las Positas	0	0	0	0	0	0	0	0	0	0
INJECTION WELL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**204**	**497**	**498**
RAINFALL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lake Recharge	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
LEAKAGE	**169**	**181**	**193**	**206**	**220**	**234**	**248**	**263**	**279**	**294**
APPLIED WATER RECHARGE	**6,918**	**5,793**	**5,109**	**4,989**	**3,323**	**4,071**	**4,887**	**4,367**	**3,479**	**4,314**
SUBSURFACE BASIN INFLOW	**3,423**	**3,199**	**2,710**	**2,221**	**2,017**	**1,875**	**1,386**	**1,651**	**1,528**	**1,846**
NET INFLOW	**15,746**	**13,399**	**15,984**	**13,076**	**11,268**	**11,089**	**12,578**	**12,877**	**11,011**	**12,812**

OUTFLOW COMPONENTS	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
MUNICIPAL PUMPAGE	**-11,014**	**-8,752**	**-6,072**	**-3,867**	**-2,681**	**-3,874**	**-5,192**	**-6,468**	**-6,101**	**-8,560**
Zone 7 Wells - Hop, Stone, COL	**-1,679**	**-1,185**	**-859**	**-85**	**-87**	**-754**	**-270**	**-475**	**-2,362**	**-2,553**
Zone 7 Wells - Mocho	**-3,313**	**-2,111**	**-609**	**-24**	**-125**	**-767**	**-682**	**-397**	**-167**	**-783**
Demin Salts Exported from Valley	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Other Pumpage	**-6,023**	**-5,455**	**-4,604**	**-3,757**	**-2,469**	**-2,353**	**-4,240**	**-5,596**	**-3,572**	**-5,224**
AGRICULTURAL PUMPAGE	**-249**	**-236**	**-142**	**-130**	**-88**	**-130**	**-155**	**-47**	**-46**	**-188**
MINING USE	**-970**	**-1,007**	**-2,134**	**-4,928**	**-6,883**	**-7,507**	**-9,983**	**-9,588**	**-8,642**	**-5,792**
Stream Export	-495	-532	-1,658	-4,453	-6,408	-7,041	-9,460	-9,084	-8,081	-5,316
Evaporation	0	0	0	0	0	0	0	0	0	0
Processing Losses	-475	-475	-475	-475	-475	-466	-523	-504	-561	-475
GROUNDWATER BASIN OVERFLOW	**0**	**0**	**0**	**0**	**-226**	**-968**	**-960**	**-998**	**-482**	**-175**
NET OUTFLOW	**-12,233**	**-9,995**	**-8,348**	**-8,925**	**-9,878**	**-12,479**	**-16,290**	**-17,101**	**-15,271**	**-14,715**

NET SALT INFLOW (Tons)	**3,513**	**3,404**	**7,636**	**4,151**	**1,390**	**-1,390**	**-3,712**	**-4,224**	**-4,260**	**-1,903**
CUMULATIVE SALT INFLOW (Tons)*	**59,120**	**62,524**	**70,160**	**74,311**	**75,701**	**74,311**	**70,599**	**66,375**	**62,115**	**60,212**

TDS Concentration Calculations	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Net Basin Recharge (AF)	-8,389	-6,628	14,974	592	13,031	1,873	-1,390	2,511	-4,911	-3,674
Basin Storage (HI Method)(AF)	201,787	195,159	210,133	210,725	223,756	225,629	224,239	226,750	221,839	218,165
Total Salt in Main Basin (tons)	188,718	192,122	199,758	203,909	205,299	203,909	200,197	195,973	191,713	189,810
Main Basin TDS Concentration (mg/L)	**688**	**725**	**700**	**712**	**675**	**665**	**657**	**636**	**636**	**640**
Cumulative Increase in TDS Conc (mg/L)**	**238**	**275**	**250**	**262**	**225**	**215**	**207**	**186**	**186**	**190**

* Basinwide salt buildup since 1973

** Basinwide TDS concentration increase relative to 1973 value of 450 mg/L

TABLE 8-2
HISTORICAL SALT LOADING (in tons)
1974 TO 2020 WATER YEARS

SALT INFLOW COMPONENTS	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NATURAL STREAM RECHARGE	**3,666**	**3,267**	**7,097**	**3,105**	**5,796**	**4,962**	**3,260**	**4,078**	**4,367**	**5,080**
Total Arroyo Valle	**1,823**	**1,399**	**2,833**	**1,081**	**3,652**	**2,274**	**1,450**	**2,691**	**2,554**	**2,974**
Flood releases recharge	0	193	302	0	731	0	0	327	0	1,383
Non Flood Natural Inflow	1,823	1,206	2,531	1,081	2,921	2,274	1,450	2,364	2,554	1,591
Arroyo Mocho	**575**	**886**	**2,996**	**838**	**1,241**	**1,813**	**839**	**380**	**540**	**1,211**
Arroyo Las Positas	**1,268**	**982**	**1,268**	**1,186**	**903**	**875**	**971**	**1,007**	**1,273**	**895**
AV PRIOR RIGHTS	**224**	**399**	**416**	**383**	**80**	**524**	**219**	**100**	**407**	**0**
ARTIFICIAL STREAM RECHARGE	**1,351**	**3,503**	**2,811**	**2,480**	**1,949**	**1,266**	**1,359**	**727**	**1,248**	**1,690**
Arroyo Valle	501	647	399	476	619	330	782	727	686	635
Arroyo Mocho	839	2,855	2,412	2,004	1,300	914	577	0	562	1,055
Arroyo Las Positas	11	1	0	0	30	22	0	0	0	0
INJECTION WELL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
RAINFALL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lake Recharge	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
LEAKAGE	**313**	**333**	**352**	**372**	**393**	**414**	**436**	**458**	**481**	**504**
APPLIED WATER RECHARGE	**5,074**	**5,606**	**4,618**	**5,090**	**4,824**	**3,223**	**5,157**	**6,258**	**6,152**	**5,079**
SUBSURFACE BASIN INFLOW	**1,970**	**1,970**	**1,970**	**1,970**	**2,513**	**2,309**	**2,174**	**2,214**	**2,106**	**1,997**
NET INFLOW	**12,598**	**15,078**	**17,264**	**13,400**	**15,555**	**12,698**	**12,605**	**13,835**	**14,761**	**14,350**

OUTFLOW COMPONENTS	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
MUNICIPAL PUMPAGE	**-10,467**	**-12,061**	**-11,096**	**-12,419**	**-10,057**	**-5,557**	**-8,423**	**-9,271**	**-14,577**	**-12,609**
Zone 7 Wells - Hop, Stone, COL	**-3,867**	**-3,690**	**-3,360**	**-4,198**	**-1,858**	**-1,382**	**-1,340**	**-3,217**	**-3,920**	**-1,290**
Zone 7 Wells - Mocho	**-1,745**	**-3,322**	**-2,271**	**-3,762**	**-3,003**	**-1,170**	**-1,976**	**-1,402**	**-5,448**	**-6,563**
Demin Salts Exported from Valley	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*-798*	*2,759*
Other Pumpage	**-4,855**	**-5,049**	**-5,465**	**-4,459**	**-5,196**	**-3,005**	**-5,107**	**-4,651**	**-5,208**	**-4,756**
AGRICULTURAL PUMPAGE	**-182**	**-94**	**-73**	**-79**	**-80**	**-46**	**-43**	**-68**	**-68**	**-73**
MINING USE	**-4,520**	**-475**	**-276**	**-438**	**-454**	**-658**	**-584**	**-714**	**-1,341**	**-1,428**
Stream Export	-4,006	-111	0	-84	-94	-218	-274	-305	-913	-1,057
Evaporation	0	0	0	0	0	0	0	0	0	0
Processing Losses	-514	-364	-276	-354	-360	-440	-310	-409	-428	-371
GROUNDWATER BASIN OVERFLOW	**0**	**0**	**0**	**0**	**0**	**0**	**-738**	**-1,080**	**-171**	**0**
NET OUTFLOW	**-15,169**	**-12,630**	**-11,445**	**-12,936**	**-10,591**	**-6,261**	**-9,788**	**-11,133**	**-16,157**	**-14,110**

NET SALT INFLOW (Tons)	**-2,571**	**2,448**	**5,819**	**464**	**4,964**	**6,437**	**2,817**	**2,702**	**-1,396**	**240**
CUMULATIVE SALT INFLOW (Tons)*	**57,641**	**60,089**	**65,908**	**66,372**	**71,336**	**77,773**	**80,590**	**83,292**	**81,896**	**82,136**

TDS Concentration Calculations	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Net Basin Recharge (AF)	-11,666	62	8,309	-4,560	13,193	8,790	-3,639	-3,011	-4,997	4,290
Basin Storage (HI Method)(AF)	206,499	206,561	214,870	210,310	223,503	232,293	228,654	225,643	220,646	224,936
Total Salt in Main Basin (tons)	187,239	189,687	195,506	195,970	200,934	207,371	210,188	212,890	211,494	211,734
Main Basin TDS Concentration (mg/L)	**667**	**676**	**670**	**686**	**662**	**657**	**677**	**695**	**706**	**693**
Cumulative Increase in TDS Conc (mg/L)**	**217**	**226**	**220**	**236**	**212**	**207**	**227**	**245**	**256**	**243**

* Basinwide salt buildup since 1973

** Basinwide TDS concentration increase relative to 1973 value of 450 mg/L

TABLE 8-2
HISTORICAL SALT LOADING (in tons)
1974 TO 2020 WATER YEARS

SALT INFLOW COMPONENTS	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	AVG	TOTAL
NATURAL STREAM RECHARGE	**5,459**	**2,026**	**2,242**	**1,820**	**3,735**	**3,366**	**4,948**	**1,315**	**3,531**	**1,952**	**3,654**	**171,744**
Total Arroyo Valle	**3,039**	**553**	**963**	**356**	**1,664**	**1,620**	**2,392**	**249**	**1,185**	**285**	**1,190**	**55,953**
Flood releases recharge	150	0	0	0	0	0	404	0	-53	0	165	7,751
Non Flood Natural Inflow	2,889	553	963	356	1,664	1,620	1,988	249	1,238	285	1,026	48,202
Arroyo Mocho	**2,056**	**949**	**751**	**973**	**1,472**	**945**	**1,882**	**430**	**1,648**	**834**	**1,335**	**62,735**
Arroyo Las Positas	**364**	**524**	**528**	**491**	**599**	**801**	**674**	**636**	**698**	**833**	**1,129**	**53,056**
AV PRIOR RIGHTS	**384**	**196**	**409**	**3**	**395**	**288**	**91**	**208**	**249**	**249**	**261**	**12,290**
ARTIFICIAL STREAM RECHARGE	**882**	**2,851**	**2,519**	**1,483**	**1,689**	**2,571**	**2,046**	**1,494**	**558**	**675**	**1,598**	**75,100**
Arroyo Valle	167	1,178	573	339	1,667	1,299	667	924	442	556	541	25,419
Arroyo Mocho	698	1,649	1,943	1,120	0	1,272	1,379	570	116	119	981	46,129
Arroyo Las Positas	17	24	3	24	22	0	0	0	0	0	76	3,552
INJECTION WELL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**26**	**1,199**
RAINFALL RECHARGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lake Recharge	*0*	*0*	*0*	*1,603*	*2,736*	*3,641*	*6,743*	*8,295*	*6,864*	*3,979*	*720*	*33,861*
LEAKAGE	**527**	**551**	**403**	**600**	**625**	**651**	**677**	**703**	**778**	**821**	**299**	**14,038**
APPLIED WATER RECHARGE	**4,295**	**6,074**	**8,158**	**5,654**	**6,505**	**5,251**	**4,421**	**5,707**	**5,625**	**6,588**	**5,801**	**272,629**
SUBSURFACE BASIN INFLOW	**2,024**	**2,092**	**448**	**1,834**	**2,051**	**2,078**	**2,106**	**2,078**	**2,187**	**2,201**	**1,999**	**93,959**
NET INFLOW	**13,571**	**13,790**	**14,179**	**11,394**	**15,000**	**14,205**	**14,289**	**11,505**	**12,928**	**12,486**	**13,637**	**640,959**

OUTFLOW COMPONENTS	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	AVERAGE	TOTAL
MUNICIPAL PUMPAGE	**-9,873**	**-16,765**	**-12,781**	**-11,831**	**-6,080**	**-6,194**	**-7,635**	**-8,700**	**-10,427**	**-12,388**	**-10,163**	**-339,102**
Zone 7 Wells - Hop, Stone, COL	**-1,197**	**-2,785**	**-3,595**	**-2,639**	**-870**	**-750**	**-1,107**	**-1,938**	**-1,982**	**-4,441**	**-2,470**	**-54,340**
Zone 7 Wells - Mocho	**-4,040**	**-8,204**	**-3,997**	**-3,713**	**-1,080**	**-666**	**-2,200**	**-2,642**	**-4,895**	**-4,890**	**-3,072**	**-67,576**
Demin Salts Exported from Valley	*2,006*	*4,064*	*2,479*	*1,047*	*76*	*183*	*949*	*1,168*	*1,869*	*1,231*	*362*	*17,033*
Other Pumpage	**-4,625**	**-5,766**	**-5,179**	**-5,583**	**-4,128**	**-4,779**	**-4,326**	**-4,120**	**-3,549**	**-3,057**	**-4,621**	**-217,186**
AGRICULTURAL PUMPAGE	**-68**	**-77**	**-393**	**-515**	**-490**	**-92**	**-84**	**-87**	**-101**	**-97**	**-666**	**-31,295**
MINING USE	**-2,756**	**-3,064**	**-3,042**	**-502**	**-417**	**-378**	**-364**	**-388**	**-368**	**-363**	**-3,412**	**-160,375**
Stream Export	-2,368	-2,665	-2,655	-442	0	0	0	0	0	0	-2,211	-103,914
Evaporation	0	0	0	0	0	0	0	0	0	0	0	0
Processing Losses	-388	-399	-387	-364	-417	-378	-364	-388	-372	-363	-415	-19,485
GROUNDWATER BASIN OVERFLOW	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-506**	**-758**	**-113**	**-435**	**-20,450**
NET OUTFLOW	**-12,697**	**-19,906**	**-16,216**	**-12,848**	**-6,987**	**-6,664**	**-8,083**	**-9,681**	**-11,654**	**-12,961**	**-11,557**	**-543,173**

NET SALT INFLOW (Tons)	**874**	**-6,116**	**-2,037**	**-1,454**	**8,013**	**7,541**	**6,206**	**1,824**	**1,274**	**-475**	**2,081**	**97,786**
CUMULATIVE SALT INFLOW (Tons)*	**83,010**	**76,894**	**74,857**	**73,403**	**81,416**	**88,957**	**95,163**	**96,987**	**98,261**	**97,786**		

TDS Concentration Calculations	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Net Basin Recharge (AF)	6,893	-10,438	-5,542	-12,153	6,037	15,405	25,259	285	4,482	-7,932
Basin Storage (HI Method)(AF)	231,829	221,391	215,849	203,696	209,733	225,138	250,397	250,682	255,164	247,232
Total Salt in Main Basin (tons)	212,608	206,492	204,455	203,001	211,014	218,555	224,761	226,585	227,859	227,384
Main Basin TDS Concentration (mg/L)	**675**	**687**	**697**	**734**	**741**	**715**	**661**	**665**	**657**	**677**
Cumulative Increase in TDS Conc (mg/L)**	**225**	**237**	**247**	**284**	**291**	**265**	**211**	**215**	**207**	**227**

* Basinwide salt buildup since 1973

** Basinwide TDS concentration increase relative to 1973 value of 450 mg/L