An Overview of Soils, Terrains and Climates in the Livermore Valley American Viticultural Area

For the

Livermore Valley Winegrowers Association
Livermore, California

By

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CVC

March 21, 2018

TABLE OF CONTENTS

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1.0 The Study

In 2017, the Livermore Valley Winegrowers Association commissioned a study of the Livermore Valley American Viticultural Area (AVA) to research publically available resources and compiling geologic, soil and climate information within the boundaries of the AVA. The purpose of the study was to research and identify, to the extent possible, a) differentiations in soil characteristics and climates within the AVA that are salient to viticulture, b) spatially present those areas with differences or commonalities on maps, c) to provide a narrative elaborating on, and explaining, climate and soil characteristics as they pertain to growing high quality wine grapes, and d) provide the reader of this study some details on the predominant AVA characteristics for context and reference pertaining to viticulture.

The study specifically included reviewing available climate, geologic and soil data, to identify predominant a) climate zones, b) slopes, c) certain soil characteristics, d) soil orders and e) soils series within the Livermore Valley AVA. This narrative elaborates and explains the predominant soil and climate characteristics, found in this study, and indicated on maps, and their impact to growing wine grapes. The predominant soil characteristics selected for this study included a) available soil-water holding capacities, b) total (soil) salt concentrations, c) soil pH, and d) soil textures (i.e., percentages of sand, silt and clay). These characteristics are visually presented on maps, included in this document. The data obtained by this study was reviewed analyzed by experienced, professional soils scientists, viticulturists and geographic information system (GIS) specialists, and subsequently summarized and extrapolated onto geo-referenced maps and presented in this narrative.

Information in this study is intended to provide the user broad overview of the viticulturally salient attributes that exists in the Livermore Valley AVA. Note that this study is not intended for use to evaluate the viticultural potential of a particular site or to apply site - specific vineyard management actions. However, the information in this study can provide helpful guidelines and references in selecting specific areas or sites *for further and specific investigation(s)* by parties interested in a) pursuing viticultural opportunities in the AVA and / or b) evaluating vineyard management actions.

2.0 Livermore Valley AVA Overview

The Livermore Valley AVA is located east of the San Francisco Bay, California, and west of the great Central Valley of California. Refer to the Livermore Valley AVA Vicinity Map. The AVA includes eastern portions of Alameda and Contra Costa Counties, and includes Amador, Livermore / Las Positas, San Ramon and Sunol Valleys, as well as portions of the Palomares and Eden Canyons.

The overall spatial orientation of the Livermore Valley AVA is a northwesterly to southeasterly direction. The Amador and Livermore / Las Positas Valleys (included within the AVA) are generally oriented in an east to west direction, are contiguous, are located in the near geographic center of the AVA, and occupy the majority of the area within the AVA. The east – west orientation of the Amador and Livermore / Las Positas Valleys and the Dublin Canyon typically allows cool breezes to flow from the San Francisco Bay, located west of the AVA, to enter and appreciably cool nighttime temperatures in the area. The AVA also includes the San Ramon and Sunol Valleys that are mostly oriented in a north to south direction, and are located in the westerly portions of the AVA. The Livermore Valley AVA is generally bordered by Coastal range hills and mountainous terrain that are part of the Pleasanton and Walpert Ridges, Diablo Range, Cedar and Crane Ridges, and Altamont Hills. Portions of these mountainous features are included in the AVA.

Geographically, the Livermore Valley AVA is traversed by Highway 580, which runs generally from east to west through the AVA; particularly through the Amador, Castro and Livermore / Las Positas Valleys. This feature spatially divides the AVA into northern portion and southern portions. These two portions of the AVA are similar in area. Highway 680 also geographically traverses the western portion of AVA. This feature runs in a northwest to southeast direction, mostly through the San Ramon and Sunol Valleys.

Wine grapes were first planted in the area in the 1760s, and wine making began in the 1840s. Commercial wine grape growing and wine production commenced in the Livermore Valley during the 1880s. Wines from the area won three gold medals at the Grand Prix competition at the 1889 Paris (France) Exposition. The Wente and Concannon families have continuously grown wine grapes in the area from the early 1880s, and excluding Prohibition, have also made wines in the area since that that time. Now 50+ commercial wineries exist in the area, with approximately 5,000 acres planted to wine grapes.

The Livermore Valley AVA was initially established in the early 1980s. In 2006, the AVA was amended to include other regions in the immediate, contiguous area.

The Livermore Valley AVA has, in general, a Mediterranean climate. Soils in the area vary greatly and generally range from gravelly sands to clay loams and clays. Terrain within the AVA commonly varies from mostly flat or gentle to moderate sloping (less than 20 percent) to hillsides with 40+ percent slopes.

3.0 Summary of General Soil and Terrain Characteristics

This section summarizes the prevalent terrain and soil characteristics revealed in this study. Details of the findings and interpretations are presented below, and should be read for a better understanding and use of the content of this study. Refer to Section 4.0 Findings and Discussion.

The Livermore Valley AVA offers approximately equal amounts of relatively level and elevated landscapes / mountainous terrain when considering slopes of less than 20 percent (gentle to moderate), and slopes greater than 20 percent (elevated landscapes / mountainous). The terrains, slopes and aspects in the AVA can offer a variety of micro – climates to enable a diversity of grape varietal selections and growing strategies. The relatively level or gently sloped terrain offers more flexibility for soil and vineyard management practices. The mountainous terrain offers various slope aspects ranging from northerly, easterly, southerly and westerly exposures which can offer a diversity of grape variety opportunities. Also note that mountainous terrain can pose some limitations and higher costs to vineyard development and management.

The Livermore Valley AVA has several parent materials sources from which the soils are formed. The diversity in parent materials can also provide diversity in soil types which can, in turn, offer diversity of grape growing strategies.

The predominant parent materials in the Livermore Valley AVA are Alluvium, Sandstone, and Mudstone. Alluvium is the predominant parent material in the Amador, Castro and Livermore / Las Positas and San Ramon Valleys. Generally, the alluvial soils are located mostly in flat terrain in the AVA. The majority of alluvium exists south of Highway 580. Sandstone parent materials encompass large areas of the northern and southern portions of the Livermore Valley AVA, and are located in both level and mountainous terrains. Mudstone, including some (igneous) Gabbro, parent materials is predominant in the mountainous terrain west of the Sunol Valley, and the mountainous terrain located in the northeastern portion of the AVA near Mt. Diablo. Relatively small pockets of Basalt, Greenstone, Melange and Serpentine parent materials are located mostly in the mountainous terrains in southern portion of the Livermore Valley AVA.

This study reveals that six, predominant, taxonomic soil orders exist in the Livermore Valley AVA: Alfisols, Entisols, Histisols, Inceptisols, Mollisols and Vertisols. The number and diversity of these soil orders indicate a diversity of soils in the AVA. In general, the major soil orders of the northern portions (north of Highway 580) of the AVA are Vertisols and Mollisols; dominated, in area, by Vertisols. The soil orders in the southern portion (south of Highway 580) include Alfisols, Entisols, Mollisols and Vertisols. The southern portion generally has more variety of soil orders in comparison to the northern portion of the AVA. However, Alfisols are the dominant (in area) soil order in the southern portion of the AVA. Additionally, the soil orders in the southern portion of the AVA are somewhat equal in area, whereas the Vertisols in the northern portion are notably larger in area than the other soil orders. In general, the variety of soil orders and their characteristics are reflected in soil textures and available water holding capacities, which are indicated below and in the attached maps. For more information regarding Soil Orders see Section 4.3.5 in this narrative.

The findings in the study indicate that, in general, the soils within the Livermore Valley AVA have a range of soil pH levels. However, the soil pH ranges are all within acceptable levels, indicating that soil amendments to address adverse soil pH are not likely needed.

The study reveals acceptable levels of water soluble salts (expressed as electrical conductivity) for grape growing in the Livermore Valley AVA. Acceptable levels of soluble salts indicate unlikely limitations to viticulture as grapevines are generally sensitive to even modest levels of soluble soil salts.

The study reveals a variety of soil textures (sands, silts and clays, and mixtures of sand, silt and clay) in the Livermore Valley AVA. Generally, the soil textures in the northerly portion of the Livermore Valley AVA (north of Highway 580) predominantly consist of clay loams and clays. The southerly portion of the Livermore Valley AVA (south of Highway 580) predominately consists of sandier – textured soils and loams. Note that appreciable amounts of clayey – textured soils also exist in the southern portion. Soil textures usually have an appreciable impact on selecting grapevine rootstocks, the soil's ability to store water for plant use, irrigation design, and fertilizer and erosion (soil) control strategies.

Available water holding capacities (AWCs) of the Livermore Valley AVA were parsed as part of this study. Available water holding capacities pertains to the soil's ability retain water that is accessible for plant use. Available water holding capacities have significant influences on rootstock and variety selection, irrigation and vineyard design, the need to apply supplemental water (i.e., irrigation), as well as fruit production and quality. The northern portion of the AVA generally has a predominance of soils with higher AWCs. The southern portion of the AVA has more variety of AWCs; particularly in comparison to the northern portion.

Soil textures, and related soil-water holding capacities, can have a significant impact on viticulture, particularly in consideration of rootstock selection, vineyard (fruit) goals, irrigation design and amounts of supplemental irrigation water needed. A variety of soil textures and AWCs can provide more options for rootstock selection, which, in turn, can offer more diversity and flexibility in viticultural decisions. Soils with high or low AWCs can provide advantages or disadvantages to viticulture, depending upon the goals of the viticulturist or winemaker and the need for irrigation water. Soils with higher AWCs can require less water for grapevine growth and production and can be candidates for non-irrigated ('dry') farming of wine grapes.

The study reveals a diverse variety of soil series in the Livermore Valley AVA. A soils series is a means of defining and naming a spatial area of soil with characteristics that are (mostly) unique and / or different from other groups of soils. Many factors are considered in defining and naming a soils series. For the purposes of readability and ease of display on maps, in this study soils series with generally similar characteristics were grouped together to form a soil map unit. Note that a soil map unit may include two or more soils series. Generally, the predominant soil map units in the northern portion of the AVA consist of Clear Lake soils series, Fontana – Diablo – Altamont soil series complex, and the Millsholm – Los Osos – Los Gatos – Lodo soil series complex. The Clear Lake soil series consist of soils that have mostly clays or silty-clay textures, and are located in terrain with slopes of less than 20 percent. These soils tend to have relatively high AWCs. The soil map units that include the Fontana – Diablo – Altamont soil series and the Millsholm – Los Osos – Los Gatos – Lodo soil series are mostly located on elevated landscapes and mountainous terrain with slopes greater than 20 per cent. The soil map unit comprised of the Fontana – Diablo – Altamont soil series generally have clayey and silty clay soil textures with mostly relatively high AWCs. The soil map unit comprised of the Millsholm – Los Osos – Los Gatos – Lodo soil series tend to have soil textures with more loam, and can have AWCs ranging from relatively high (Los Osos) to low (Millsholm, Los Gatos, Lodo).

The southern portion of the Livermore Valley AVA includes the soil series in the above-mentioned soil map units, as well as the soil map units that include the Positas soil series, the San Ysidro – Rincon soils series, the Vallacitos – Parrish – Los Gatos – Gaviota soils series, and the Yolo – Tehama – Pleasanton – Mocho soils series. The Positas soils generally have gravelly / cobbly, loamy textured soils. Generally, the AWCs of these soils are relatively high. The soil map units of the San Ysidro – Rincon soils series is mostly loamy-textured and have relatively high AWCs. The Vallecitos – Parrish – Los Gatos – Gaviota soils series in this map unit generally have gravelly, loamy-textured soils with relatively low AWCs. The soil map unit of Yolo – Tehama – Pleasanton – Mocho soils series is mostly loamy-textured soils. The majority of the soil series in this soil map unit have relatively high AWCs (Yolo, Tehama, Pleasanton) with Mocho having appreciably lower AWCs.

4.0 Study Findings and Discussion

4.1 Climates

Grape growing areas were classified by Dr. Albert Winkler (Professor of Viticulture, Emeritus, University of California, Davis, California) into climate Regions. Growing Degree days (GDD) and heat summation were the methods Dr. Winkler used to categorize grape growing areas using temperature data. Growing Degree Days (GDD) is the seasonal summation (April 1 through October 31 in California) of accumulated heat units in a particular area or region. The temperature data used was typically more regional in nature (not mesoclimate and microclimate data).

Climate maps prepared by Mike Bobbitt and Associates reveal that the Livermore Valley AVA is comprised primarily of a Region III climate with a smaller area mapped as Region IV. A Region III climate is well suited for growing high quality red wine grapes. Region IV can also produce good quality wine grapes although longer season or hotter climate varieties may be selected for those areas.

Growing Degree Days (GDD) units can be calculated in °F or °C; however, the resulting numbers and interpretations are very different. The table on page 6 lists the Regions or Classes of grape growing areas based upon the Winkler Index.

Winkler Index

Region	°F GDD	°C GDD	General Interpretation
Region I	< 2500	<1389	Only early ripening varieties will ripen in these areas
Region II	2500-3000	1389-1667	Suitable for early and mid-season wine varieties like Chardonnay and Pinot Noir.
Region III	3000-3500	1667-1944	Suitable for high quality red wine varietals like Merlot, Cabernet Sauvignon.
Region IV	3500-4000	1944-2222	Red wine grape varietals can be planted; however, quality may not be optimal depending upon the varietal. Hotter climate or longer season varietals like Mourvedre, Tempranillo may be better suited for these areas.
Region V	4000-4900	2222-2700	Generally not suitable for high quality wine production.

4.2 Slopes and Aspects

Sloping terrain generally increases the opportunities for soil erosion to occur, particularly soils with higher Erodibility Factors (K Factor; established by the USDA). Sloped terrains can also impact vineyard layout / design and vineyard management practices. Erodibility Factors and /or slopes can appreciably increase viticultural costs and risks by limiting the use of equipment and increasing hand labor costs. However, gently or moderately sloping terrain can allow cold air to flow and drain into adjacent lower areas thus reducing the risk of frost injury. Good air drainage can also promote faster drying of foliage, which can reduce the duration and frequency of disease infection periods. Generally, vineyard slopes less than 20 percent have insignificant impact on viticultural practices. Depending upon certain soil characteristics, vineyards on slopes greater than 30 percent can pose soil erosion and vineyard management challenges, which can increase costs and safety hazards to a point where farming these terrains is generally not practical or sustainable. Refer to the Slope Map that indicates areas with their associated slopes.

Slope aspect can have an impact on viticultural strategies and grape variety selection. Slope and aspect can offer viticultural opportunities for growing fruit with particular characteristics. The Livermore AVA has mountainous terrain that provides various aspects. These impacts of slope aspects are summarized below.

Vineyards with southern aspects generally warm earlier in the spring and the grapevines may undergo bud break earlier than vineyards with northern aspects. The early bud break is desirable in locations that do not have a danger of spring frosts that can adversely impact newly formed, tender leaves. Earlier bud break can provide earlier grape bloom and harvest times.

Sites with western-facing slopes are commonly considered for late-maturing grape varieties. Western – facing slopes can provide more sunlight and heat during the fall to promote fruit ripening.

Eastern-facing aspects receive the first of the morning sun radiation to warm vineyard canopy and soil temperatures. This can be useful during the spring season when grape buds or newly formed leaves are vulnerable to frosts.

Northern facing slopes are generally more suited for varieties that ripen earlier in the growing season. In warmer climates, some viticulturists seek northern and north-eastern aspects for the cooler temperatures to allow for more fruit 'hang time', which can enhance fruit and wine quality. Vineyards in these aspects can have more risks for frosts as vineyard soils have less opportunity to warm during daylight hours and radiate heat during morning hours.

4.3 Soils

Soil physical and chemical properties typically have a critical impact on vineyard siting, development, management and wine quality. Soil properties can be very diverse within a given area, and any one soil property can have significant impact to viticultural strategies and management, as well as wine quality.

The soil properties reflected in this study are total dissolvable salts (expressed as electrical conductivity or EC), pH, textures, and available water holding capacity (AWC) expressed in inches of water.

4.3.1 Water Soluble Soil Salts

Electrical conductivity (EC) is a measure of the amount of water soluble salts in soil. Most mineral soils have some degree of salts, either from natural sources or from the application of fertilizers or soil amendments. In general, EC refers to electrical conductivity of a water solution with salts. The greater the EC, the greater the amount of water soluble salts in a soil; the higher the EC, the more salty the soils. Elevated EC levels can adversely impact both soils and vineyards. The data obtained and reviewed revealed no soils within the AVA that had EC levels considered detrimental to soils or vineyards.

See below for more information on EC and its impact on soils and vineyards.

The concentration and types of water soluble salts (EC) in soils affects plant nutrient availability, activity of soil microorganisms, grapevine performance and, wine quality and yields. Excess salts can hinder plant growth by affecting the soil-water balance. Soil EC is generally measured or expressed in millimhos per centimeter, or mmhos/cm, or deciSiemen per meter, or dS/m. Soil salts can also be expressed in total dissolved solids or TDS. Soils that have very low levels of salts in the surface soils can have (irrigation) water penetration problems. This condition can cause irrigation water to run off, and result in wasted water and / or expose grapevines to water stresses as the water does not adequately replenish the soil for grapevine use. Soil salts generally occur naturally as minerals that are part of the soil composition, and dissolve into the soil-water solution. The addition of fertilizers and soil amendments also dissolve with water and can add salts to the soils. It is also important to note that the types of soil salts (particularly, sodium and boron) can also influence viticulture and wine quality. Depending upon the *types of soils and salts that comprise the soil salts, ECs greater than 2.5 mmhos/cm pose an increasing salinity toxicity hazard risk to grapevines.*

4.3.2 Soil pH

Soil pH indicates whether a soil is acidic (< 7.0), neutral (= 7.0) or alkaline (>7.0). Generally, vineyards will grow acceptably with a soil pH between 5.5 and 8.5 (moderately acidic to moderately alkaline). The data obtained and reviewed shows that the soils in the Livermore Valley AVA have a range of pH values, but that all have acceptable pH levels. Refer to the attached Soil pH Map that indicates ranges of soil pH in a particular area.

See below for more information on pH and its impact on soils and vineyards.

Soil pH levels below 5.5 are considered very acidic, and the availability of some nutrients (phosphorus, potassium, calcium, magnesium and sulfur) is reduced. Soil pH levels below 5.0 are considered strongly acidic, and metal (particularly, aluminum) toxicity hazards can occur. Soil pH values above 8.5 can be termed very alkaline or strongly alkaline and can indicate the presence of high sodium levels, which can adversely impact soils and grapevine growth. The availability of some nutrients (phosphate, iron, zinc, copper, and manganese) is reduced at high pH values.

The use of acidifying fertilizers or high rainfall and the application of irrigation water (leaching of bases) can lower (acidify) the soil pH over time.

4.3.3 Soil Texture

Soil texture is related to the relative proportion of sand, silt, and clay particles. Soils with approximate equal percentages of sand, silt and clays are referred to as loams or loamy. Soil textures can include modifiers such as percent gravel and cobbles, and stones. Soil textures influence soil water drainage, water holding capacity, aeration, susceptibility to erosion, cation exchange capacity (CEC), and pH / pH buffering capacity. Soil textures also influence grapevine rootstock selection, as well as irrigation design and scheduling.

Refer to the Soil Texture Map for those areas mapped with in the Livermore Valley AVA that have generally sandy, loam, clay loam, and clay soil textures.

See below for more information on soil textures and their impact on soils, yards and wine quality.

Sandy soils typically do not have high nutrient or mineral contents. Sandy soils generally have lower water holding capacities, but typically offer good internal water drainage. Clay soil can have a high nutrient / mineral contents. Clay soils can have high water holding capacities that, under certain conditions, can pose waterlogging problem that can impact rooting health. Additionally, though clays can have a high water holding capacity, but not all soil-water in clays is available for plant use. Silty soils can have high nutrient / mineral contents and moderate to high water holding capacities. Silty soils can be susceptible to erosion on sloped terrane. Loamy soils generally have similar percentage mixtures of *clay, sand and silt. Loamy soils are generally considered most desirable for agriculture as they typically have good nutrient / mineral contents, good / high water holding capacities, and good internal water drainage. Note that vineyards can be planted, and produce good fruit quality, in a wide range of soil texture types. But, astute vineyard management and additional farming inputs may be required for successful production in soil with high relative percentages of sand or clay, and / or soils with significant percentages of gravel and / or cobbles.*

4.3.4 Soil Waterholding Capacity

Total available waterholding capacity is determined primarily by soil texture, soil porosity, percent gravel or rock and effective rooting depth. Available waterholding capacity (AWC) is a measurement of how much water in a soil is mostly available for plant (vineyard) use. Research has shown that there is a relatively linear relationship between grapevine growth and available soil water (Williams et al. 2010). Therefore, available waterholding capacity (AWC) can be used to help predict the potential vigor of a vineyard (Vigor Capability). Vineyards planted on soils that have very low or very high vigor capacity can become problematic to manage and can produce undesirable fruit. It is important to note that other factors can also affect grapevine vigor (e.g. soil pests, rootstock, soil chemistry, fertilizers, climate, etc.). Soils with lowers vigor capacity can be more easily managed to attenuate vigor, but may require more supplemental water (i.e., irrigation) to enable producing a suitable crop.

Refer to the attached Available Waterholding Capacity Map that shows areas with their applicable AWC ratings.

See below for more information on Available Water Holding Capacity and its importance on wine grape viticulture.

An understanding of how soil moisture affects seasonal grapevine growth patterns is a key to using available waterholding capacity (AWC) ratings. In general, soils with high AWC ratings have more available water and potential for high grapevine vigor, whereas soils with low AWC have lower available water and likely provide lower grapevine vigor. Available waterholding capacity ratings are very important in selecting appropriate rootstocks that will perform well in a particular site and in considering overall water (irrigation) demands and irrigation design and layout for strategies to achieve good quality fruit. It is important to note that matching the fruiting varietal (scion) to site climatic conditions is also required to optimize wine quality. Available waterholding capacity ratings are influenced by various factors; soil textures, percentages of gravel or rock with the soils, and the depths roots can penetrate into the soils. Generally, soils with more percentages of sand hold less water than soils with higher percentages of silts or clays, or a relatively similar mixture of sand silt and clay (loams). Note that clays can hold relatively high percentages of water, but, due to principles in soil physics, not all the water in clay soils is available for plant use. The presence or percentages of gravels and / or rocks within a soil can limit the amount of water a soil can hold. Generally, soils with higher percentages of gravel and / or rocks have lower AWC, as these features displace soils than can hold water. Soils that have limitations to deep rooting by plants (e.g. compaction) which can have lower AWCs. Generally, soils that have conditions which limit root growth provide lesser opportunity for plants to explore the soils for water, and nutrients. This condition makes the soils a smaller water bucket. Available waterholding capacity *rating has a significant impact on rootstock selection and vineyard design. Generally, soils with high AWCs provide high vigor capability. Grapevines planted on soils with high AWCs and vigor capabilities can produce a vigorous plant that is challenging and costly to manage and can produce fruit of non-desirable characteristics. In effort to mitigate soils with high AWC / vigor capabilities, rootstocks with lower vigor are usually considered in these situations. Note that soils with high AWCs and vigor capacities can be candidates for dry farmed vineyards. Soils with low AWCs or vigor capabilities may require more irrigation, which can present more costs, or if water for irrigation is not sufficient, can cause the grapevines to develop an insufficient canopy, which can produce yield very low yields and fruit with non-desirable characteristics. In soils with low AWCs and vigor capabilities, more vigorous or drought – tolerant rootstocks are considered. Generally, these soils are not well suited for dry farmed vineyards.*

4.3.5 Soil Parent Material, Soil Taxonomy, Soil Series and Soil Map Units

Parent material is a term for the general physical, chemical, and mineralogical composition of the unconsolidated material, mineral or organic, in which soil forms. Parent materials contribute to soil variations within climatic and vegetative zones. All mineral soils initially come from rocks, a.k.a. 'parent material'. The parent material may be directly below the soil, or from great distances away if wind, water or glaciers have transported soil from another location to its existing location. The predominant parent materials within the Livermore Valley AVA consist mostly of Alluvium, Sandstone and Mudstone. The parent materials and their locations are presented on the Parent Material Map. For more details on parent materials, see below.

In addition to the nature of the soil's parent material, the formation of soil is also dependent upon other prevailing processes. The nature of the parent material and climatic conditions are important factors affecting both the physical and chemical components of soils. The nature of the parent material(s) can impart soil textures, chemistry (i.e., EC, natural mineralogy, pH, nutrient and water holding capacities, etc.) and color. Generally, two types of parent material for soils are recognized: a) unconsolidated deposits or loose sediments that have been transported by water, wind, gravity, or ice and b) weathered materials directly overlying the consolidated hard rock from which they (soils) originated.

Alluvium refers to soils or sediments that have been eroded and reshaped by moving water bodies, such as rivers and streams, and transported to another area. The texture of the deposited materials depends on the velocities the water body that transported the materials. Fast-moving water deposits coarse materials such as rocks and gravel. As water velocity decreases, finer particles (sand and silt) are deposited, while fine silt and clay particles are deposited by slower-moving water. Alluvial types of parent materials are typically associated with old, or prehistoric, streambeds, flood plains, or deltas.

Sandstone is a common sedimentary rock consists of sheets of sand, mineral particles, and a cementing material (commonly, quartz) that binds the sand grains together. Sandstone may contain a mixture of silt- or clay-size particles that exist between the spaces of the sand grains.

Mudstone is also a sedimentary rock. Mudstones typically consist of fine-grained mixtures of clay and silt-sized particles. Mudstones and shale are commonly associated. Shale is often used to describe mudstones that are hard.

To identify, understand, and manage soils, soil scientists developed a hierarchical soil classification or taxonomy system; similar to the system for the classification systems for plants and animals. The soil classification system uses several levels of detail, from the most general to the most specific. The United States Department of Agriculture (USDA), and the National Cooperative Soil Survey developed a soil taxonomy system classification of general soil types according to several parameters (such as soil profiles, textures, chemistry, physical characteristics, colors, genesis, etc.). There are 12 soil orders in the taxonomy system.

Six soil orders are in the Livermore Valley AVA, and are indicated on the Soil Taxonomy Oder Map. Four soil orders, Alfisols, Entisols, Mollisols and Vertisols, are predominant in the AVA. Each of these (four) soil orders have different soil characteristics with respect from each other, which are summarized below. Characteristics in each soil order can impact viticultural management strategies and vineyard design. For more details on the four, predominant soil orders in the AVA, see below.

Alfisols are arable soils that generally have relatively high fertile soils and can hold appreciable amounts of soil water for plant use. Alfisols generally have a clay – enriched subsurface soil layer (an accumulation of clays leached, via rainfall, from the upper soils), as well as relatively high content of available calcium, magnesium, potassium, and sodium ions. Soils in this order are commonly depleted in calcium carbonate (lime), but can have relatively higher amounts of aluminum and iron - bearing minerals compared to other soil orders. Alfisols are commonly found in Mediterranean climatic regions. Worldwide corn, wheat, and wine grapes are the principal crops grown on Alfisols.

Entisols are generally considered relatively young soils that exhibit little to no soil horizon development. These soils occur in areas of recently deposited sediments. They are common in all environments. Productivity potential of Entisols varies widely, from very productive alluvial soils found on floodplains, to low fertility/productivity soils found on steep slopes or in sandy areas.

Mollisols are highly arable and fertile soils used principally for growing grain and cereal crops. Mollisols generally have relatively high organic matter (from decaying plant debris and roots) in the surface soils, which stain the surface horizon dark brown, and contribute to the soil's relatively high fertility. These soils commonly have relatively, naturally high fertility, and are rich in chemical base ions, such as calcium and magnesium, as well as an accumulation of aluminum- and iron-bearing minerals. Mollisols are often found in semi-arid to semi-humid climates with pronounced dry seasons.

Vertisols are clay-rich soils that contain a type of "expansive" clay that shrinks and swells dramatically, and are commonly found in areas that have shale parent material. These soils therefore shrink as they dry and swell when they become wet. When dry, Vertisols form large cracks that may be more than one meter (three feet) deep and several centimeters, or inches, wide. Note that the vertical soil cracking can present vineyard management challenges. Vertisols are highly fertile and have high water holding capacities due to their high clay content; however, water tends to pool on their surfaces when they become wet. Vertisol soils can have relatively high organic matter content, and are commonly dark brown or gray in color throughout the soil profile.

Soil series are a level of classification (of soils) in the USDA Soil Taxonomy classification system (discussed above) hierarchy. The USDA and the National Cooperative Soil Survey established this classification system. Soil series describe, delineate and group, in more detail than the soil order /

taxonomy system, and indicate more details on soil characteristics, such as soil color, soil texture, soil structure, soil pH, consistence, mineral and chemical composition, arrangement of soils in the soil profile. In some circumstances, the classification and details may include water holding capacities and / or the amount of water the soils hold for plant use. Soils with same and / or very similar characteristics, as previously indicated, are grouped into a soils series, and designated with a name. A soil series map unit roughly outlines / delineates the boundaries of a particular soil series, and graphically outlines (to the extent possible) the boundaries of a soil series on a map. A soil series map unit may include a complex (two or more) of different soil series. Soil series map units are the basic geographic unit of the Soil Survey Geographic Database (SSURGO) dataset produced by the National Resources Conservation Service (NRCS).

The Soil Series units are grouped together in geographic areas in the STATSGO2 database. The following STATSGO2 database definition taken from the USDA, NRCS website, "*The Digital General Soil Map of the United States or STATSGO2 is a broad-based inventory of soils and non-soil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped of 1:250,000 in the continental U.S., Hawaii, Puerto Rico, and the Virgin Islands and 1:1,000,000 in Alaska. The level of mapping is designed for broad planning and management uses covering state, regional, and multi-state areas."*

The STATSGO2 database reveals the presence of seven, major, soil units within the Livermore Valley AVA. Those STATSGO2 Major Soil Units are: 1) Clear Lake, 2) Fontana-Diablo-Altamont, 3) Millsholm-Los Osos-Los Gatos-Lodo, 4) Positas, 5) San Ysidro-Rincon, 6) Vallecitos-Parrish-Los Gatos-Gaviota and 7)Yolo-Tehama-Pleasanton-Mocho. The (seven) STATSGO2 major soil units and their locations are presented on the Major Soil Unit Map. Summarizations for each Major Soil Unit characteristics are below.

The Clear Lake STATSGO2 Soil Unit consists of the Clear Lake and other soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized below.

> The Clear Lake soil series is found in terrain basins and in swales of drainage ways, and consist mostly consist of clays or silty clay soil textures. The upper soil horizon is commonly moderately acidic to moderately alkaline pH, with the lower soil horizons with mostly slightly to moderately alkaline pH. These soils are poorly drained with slow to very slow permeability. Water tables can be found at 4 to 10 feet below surface grade. Generally, Clear Lake soils are underlain by sandstone which can occur at 60 inches below grade. The Clear Lake soil series is associated with the Vertisol soil order, and its parent material is alluvium. Clear Lake soils generally have high available waterholding capacities (AWC).

The Fontana-Diablo-Altamont STATSGO2 Soil map unit includes the Fontana, Diablo and Altamont and other soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized in the ensuing pages.

The Fontana series has soils that are mostly clay loam textures, with either slightly acid or mildly alkaline pH in the upper soil strata. The lower soil strata typically have shaly clay loam textures that have moderately alkaline pH. These soils are typically well drained with moderately slow permeability. Generally, Fontana soils overly mudstone and / or shale parent materials that generally exist at a depth of 28 to 60 inches below surface grade. The Fontana soil series is associated with the Mollisol soil order, though this soil series can exhibit some Vertisol characteristics (i.e., vertical cracking of surface soils). These soils can have generally high AWCs.

Typically, Diablo soils are silty clay textures and neutral to mildly alkaline pH in the upper soil strata. The lower soil strata typically have silty clay textures and moderately alkaline pH. These soils are generally well drained and have slow permeability. These soils typically overlay mudstone and / or shale parent materials that typically exist at 50 to 60 inches below surface grade. Diablo soil series are generally associated with the Vertisol soil order. This soil series typically has high AWCs.

The Altamont series typically has clay loam, silty clay or clay soil textures. Soils in the upper strata commonly have slightly acidic pH, and the lower strata have slightly to moderately alkaline pH. Some soil within this series can have gravel in the lower strata. These soils are typically well drained with slow permeability. These soils typically overlay mudstone and / or shale parent materials at 50 to 65 inches below surface grade. These are soils are associated with the Vertisol soil order, and have moderate AWCs.

Millsholm-Los Osos-Los Gatos-Lodo STATSGO2 soil map unit includes the Millsholm-Los Osos-Los Gatos-Lodo soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized below.

Millsholm soils can consist of clay loam, silty clay loam, silt loam, loam, gravelly clay loam or gravelly sandy clay loam textures and may have up to 35 percent rock fragments. The soils have moderately acid to slightly alkaline pH, and are typically well drained with moderate permeability. Fractured shale and fine-grained sandstone are the parent materials that typically exist at 16 to 20 inches below surface grade. These soils are generally associated with the Alfisol soil order, and typically have low AWCs.

Los Osos soils consist of loam, silt loam, clay loam, or silty clay loam textures with medium acid to neutral pH in the upper soil strata, clay loam, clay, or silty clay textures with moderately acid to neutral pH in the mid soil lower soil strata and sandy loam, loam, or clay loam textures with neutral pH in the lower soil stratum. These soils are well drained with slow permeability. The sandstone parent material typically exists at 20 to 40 inches below surface grade. These soils are generally associated with the Mollisol soil order, and typically have high AWCs.

Los Gatos soils consist of fine sandy loam, loam or clay loam textures in the upper soil strata and gravelly clay loam textures in the lower soil strata. Soils in the upper strata have slightly acidic pH, and the soils in the lower strata have moderately acid pH. These soils are well drained with moderate permeability. The sandstone parent material typically exists at 24 to 40 inches below surface grade. Los Gatos soils are typically associated with the Alfisol soil order, and commonly have low AWCs.

Lodo soils consist of shaly clay loam textures with slightly to moderately acid pH. These soils are somewhat excessively drained with moderate permeability. The sandstone parent material typically exists at 4 to 20 inches below surface grade. These soils are typically associated with the Mollisol soil order, and commonly have low AWCs.

The Positas STATSGO2 Soil Unit consists of the Positas and other soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized below.

Positas consists of sandy loam, fine sandy loam, silt loam, loam or clay loam textures and can have up to 35 percent pebbles, gravel or cobblestones, with strongly acid to neutral pH in the upper soil strata. The mid soil strata have clay, silty clay or gravelly clay textures with strongly acid to moderately alkaline pH. The lower soil strata have textures that range from silt loam to gravelly and very gravelly sandy loam or sandy clay loam, with moderately alkaline to neutral pH. These soils are very deep (60+ inches), moderately well drained and have slow to very slow permeability. These soils have alluvium parent materials, and are associated with the Alfisol soil order. Positas soils typically have high AWCs.

The San Ysidro – Rincon STATSGO2 soil map unit includes the San Ysidro – Rincon and other soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized below.

San Ysidro soils in the upper strata consist of fine sandy loam textures with slight to moderate acid pH. The mid soil strata consists of sandy clay loam and clay loam textures with slightly neutral to acid pH. The lower soil strata have sandy loam to silty clay loam to clay loam textures, with moderately alkaline to neutral pH. These soils are very deep (60+ inches), moderately well drained and have very slow permeability. These soils have alluvium parent materials, and are generally associated with the Alfisol soil order. San Ysidro soils typically have high AWCs.

Rincon soils in the upper strata consist of silty clay loam textures with slightly acid pH. The mid soil strata consist of sandy clay to sandy clay loam textures with slight to moderately alkaline pH. The lower soil strata have sandy clay loam and sandy loam textures, with moderately alkaline pH. These soils are deep (40+ inches), moderately well drained and have slow permeability. These soils have alluvium parent materials and are generally associated with the Alfisol soil order. Rincon soils typically have high AWCs.

The Vallecitos - Parrish – Los Gatos – Gaviota STATSGO2 soil map unit includes the Vallecitos - Parrish – Los Gatos – Gaviota and other soil series. Characteristics of the predominant soil series that comprise this mapped unit are summarized below.

Vallecitos soils in the upper strata typically consist of gravely loam textures with up to 25 percent gravel. Soil pH is slightly to moderately acid. The lower soil strata commonly have clay loam, clay, gravelly clay loam or gravelly clay textures, with up to 30 percent gravel. Soil pH is typically neutral in the lower strata. Vallecitos soils are shallow with sandstone or shale parent materials at 16 to 20 inches below surface grade. These soils are also well drained and have slow permeability. Vallecitos soils are generally associated with the Alfisol soil order, and typically have low AWCs.

Parrish soils typically consist of gravelly loam to gravelly clay loam textures with slightly acid soil pH in the upper strata. The lower soil strata generally have gravelly clay textures, with a soil pH from medium to strongly acid. These soils are shallow with metamorphosed sandstone typically existing at depths of about 26 inches below surface grade. The soils can have various parent materials consisting of mudstone and / or sandstone. These soils are also well drained and have moderately slow to slow permeability. These soils are generally associated with the Alfisol soil order. Parrish soils can have moderate AWCs.

Los Gatos soils consist of fine sandy loam, loam or clay loam textures in the upper soil strata and gravelly clay loam textures in the lower soil strata. Soils in the upper strata have slightly acidic pH, and the soils in the lower strata have moderately acid pH. These soils are well drained with moderate permeability. The sandstone parent material typically exists at 24 to 40 inches below surface grade. These soils are typically associated with the Alfisol soil order, and commonly have low AWCs.

Gaviota soils consist of sandy loam, fine sandy loam, loam, gravelly sandy loam, gravelly fine sandy loam, and gravelly loam textures with moderately acid to neutral soil pH. These soils are very shallow with the sandstone parent material existing at depths of about 10 to 17 inches below surface grade. These soils are also well and excessively drained with moderately rapid permeability. The Entisol soil order is associated with these soils. Gaviota soils typically have low AWCs.

The Yolo - Tehama – Pleasanton – Mocho STATSGO2 soil map unit includes the Yolo - Tehama – Pleasanton – Mocho and other soil series. Characteristics of the soil series that comprise this complex are summarized below.

Yolo soils in the upper strata consist of loam or silt loam to silty clay loam and / or sandy loam textures with slightly acid to neutral soil pH. The lower soil strata have silt loam or silty clay loam textures, with slightly acid to mildly alkaline pH. These soils are very deep (60+ inches), well drained and have moderate permeability. Also, these soils are typically associated with the Entisol soil order, and have alluvium parent materials. Yolo soils commonly have high AWCs.

Tehama soils consist of loam or silt loam to sandy loam textures with strongly to slightly acid soil pH in the upper strata. The lower soil strata have silty clay loam, clay loam or loam textures, with slightly acid to neutral soil pH. These soils are deep (50+ inches), well drained or moderately well drained with slow permeability. Also, these soils are associated with the Alfisol soil order and have alluvium parent materials. Tehama soils typically have high AWCs.

Pleasanton soils consist of gravelly fine sandy loam textures with moderately acid to neutral soil pH in the upper strata. The mid soil strata have loam, sandy clay loam or clay loam textures, with the occurrence of gravel or cobbles. The soil pH ranges from slightly acid to slightly alkaline. The lower soil strata have gravelly, fine sandy loam or loam textures, with neutral or mildly alkaline soil pH. These soils are deep (50+ inches), well-drained with moderately slow permeability. Also, these soils are typically associated with the Alfisol soil order and have alluvium parent materials. Pleasanton soils typically have high AWCs.

Mocho soils consist of loam textures with moderately alkaline soil pH in the upper strata. The lower soil strata have fine sandy loam or loam textures, with moderately alkaline soil pH. These soils are very deep (60+ inches), well-drained with moderately slow permeability. Also, these soils are associated with the Mollisol soil order and mostly have alluvium parent materials. Mocho soils commonly have lower AWCs.

5.0 Maps Produced in this Study

Below is a list of maps produced and included in this study and document. The list below indicates the order the maps are discussed in the narrative. Maps 2 through 8 (listed below) graphically display data that is discussed above in this narrative. For readers' reference and orientation, some major features (i.e., roadways and cities) within the Livermore Valley AVA and study area are included on the maps.

1) Livermore Valley AVA Vicinity Map
2) Percent Slope Map
3) Soil pH Map
4) Soil Texture Map
5) Available Water Holding Capacity Map
6) Parent Material Map
7) Soil Taxonomy Map
8) Major Soil Unit Map

6.0 About Coastal Viticultural Consultants

Below is a summary of the credentials of Coastal Viticultural Consultants and key personnel.

Coastal Viticultural Consultants, Inc. (CVC) is a professional agricultural consultancy, established in 1998. CVC employs a multidisciplinary staff of technical and highly experienced professionals that are proficient and current in their respective disciplines that include soils science, viticulture, agronomy and environmental sciences, and geographic information systems. CVC offers professional technical services to efficiently manage vineyards, orchards and other agricultural crops to improve yields and / or product quality, with emphasis in sustainable agriculture. CVC serves California, and also has clientele in other Western States, and internationally. Visit www.coastalvit.com for additional information on CVC, its services and staff.

Bryan L. Rahn, CPAg/SS, CCA, President

Mr. Rahn is a Certified, Professional Soil Scientist and Agronomist, and has been a consulting soil scientist and viticulturist since 1982. Bryan's soil science and agricultural consulting career spans a wide range of crops as well as designing soil reclamation plans for major mining projects. Mr. Rahn has designed, developed and manages his own world class vineyards in the Napa Valley and in the San Francisco Bay area. He has provided agricultural/ vineyard consulting throughout California, Oregon and internationally. Mr. Rahn is an industry leader in soil mapping, grape and wine quality enhancement, vineyard irrigation, winegrape nutrition and vineyard design. Mr. Rahn lectures at professional agriculture organization meetings and at industry symposia. Mr. Rahn has published technical articles in respected, peer reviewed trade journals.

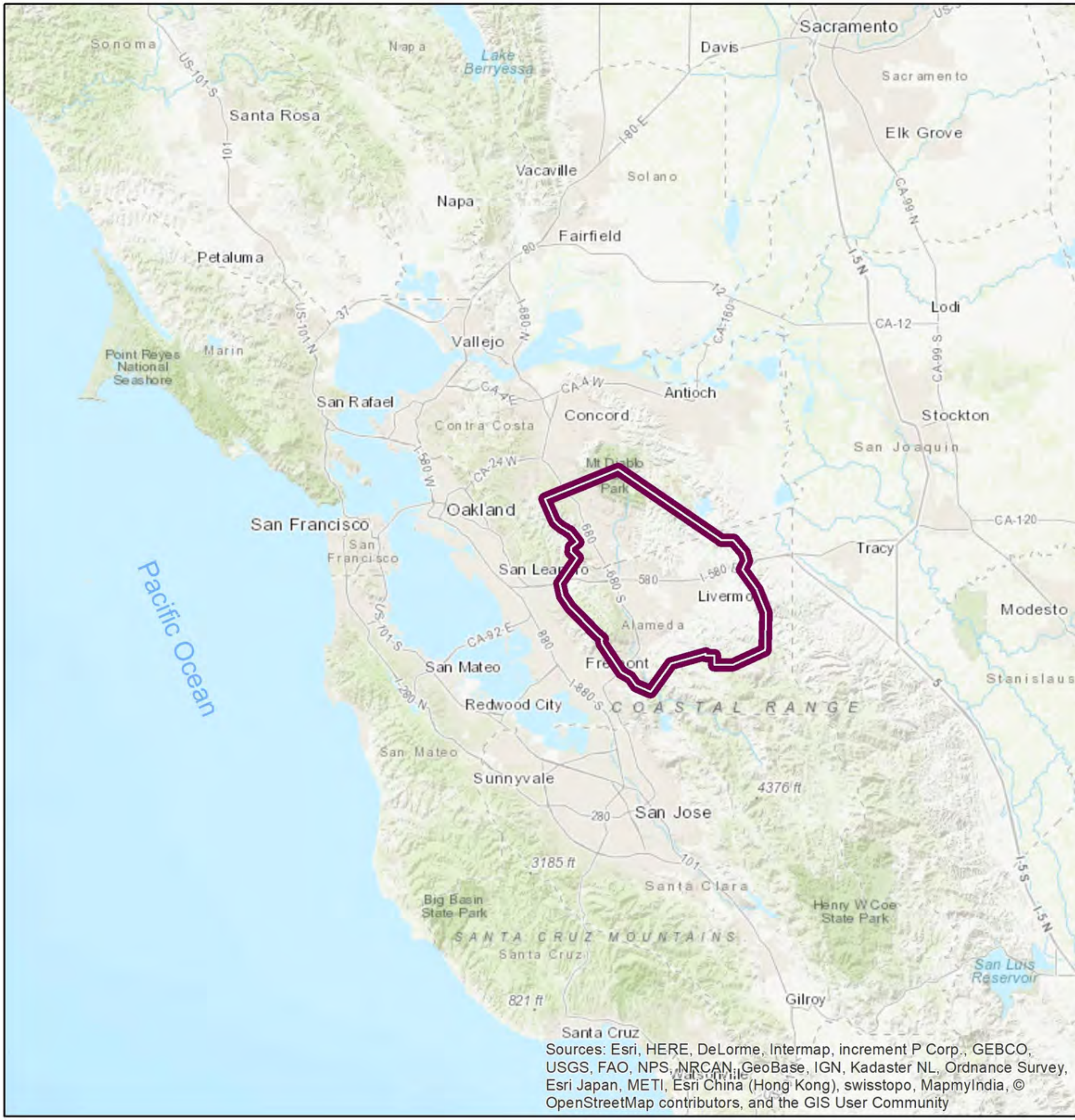
Certifications:

Certified Professional Agronomist # 3100, 30 years
Certified Professional Soil Scientist # 3100, 30 years
Certified Crop Advisor

Michael Princevalle, Senior Soil Scientist

Mr. Princevale is a senior consulting soil scientist and viticulturist for CVC. Mr. Princevalle was employed as a Soil Scientist and Project Engineer at various agricultural and environmental engineering consultancy firms since the early 1980s, and has been a Soils Scientist and Viticulturist for Coastal Viticultural Consultants since 1998.

Mr. Princevalle has been a Board Member on land conservancy and agricultural advocacy non-profit organizations, and has been a wine judge for various competitions. Mr. Princevalle has given technical talks at industry events and a guest lecturer at UC Davis and Las Positas College, and has authored articles on soils science and viticulture topics for use in trade publications.



Livermore Valley AVA Vicinity Map

AVA Boundary

(From Livermore Valley Winegrowers Association)

0 5 10 20

Miles

N

All data provided by USGS and USDA-NRCS.
9/1/2017

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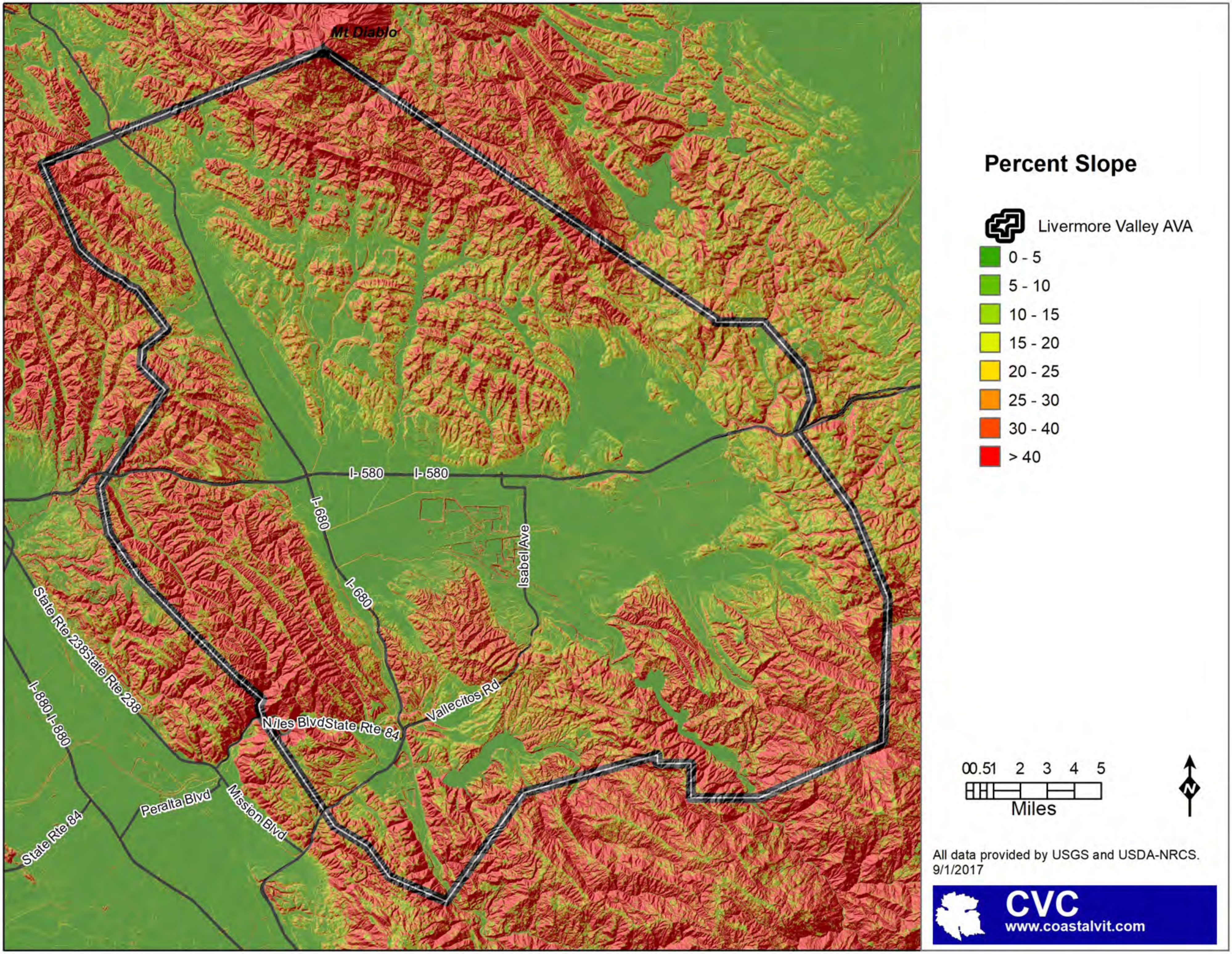
Mt Diablo
I-580
I-580
I-680
I-680
Isabel Ave
State Rte 238State Rte 238
I-880 I-880
Niles BlvdState Rte 84
Vallecitos Rd
Peralta Blvd
Mission Blvd
State Rte 84
Percent Slope
Livermore Valley AVA
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 40
> 40
00.51 2 3 4 5
Miles
N
All data provided by USGS and USDA-NRCS.
9/1/2017
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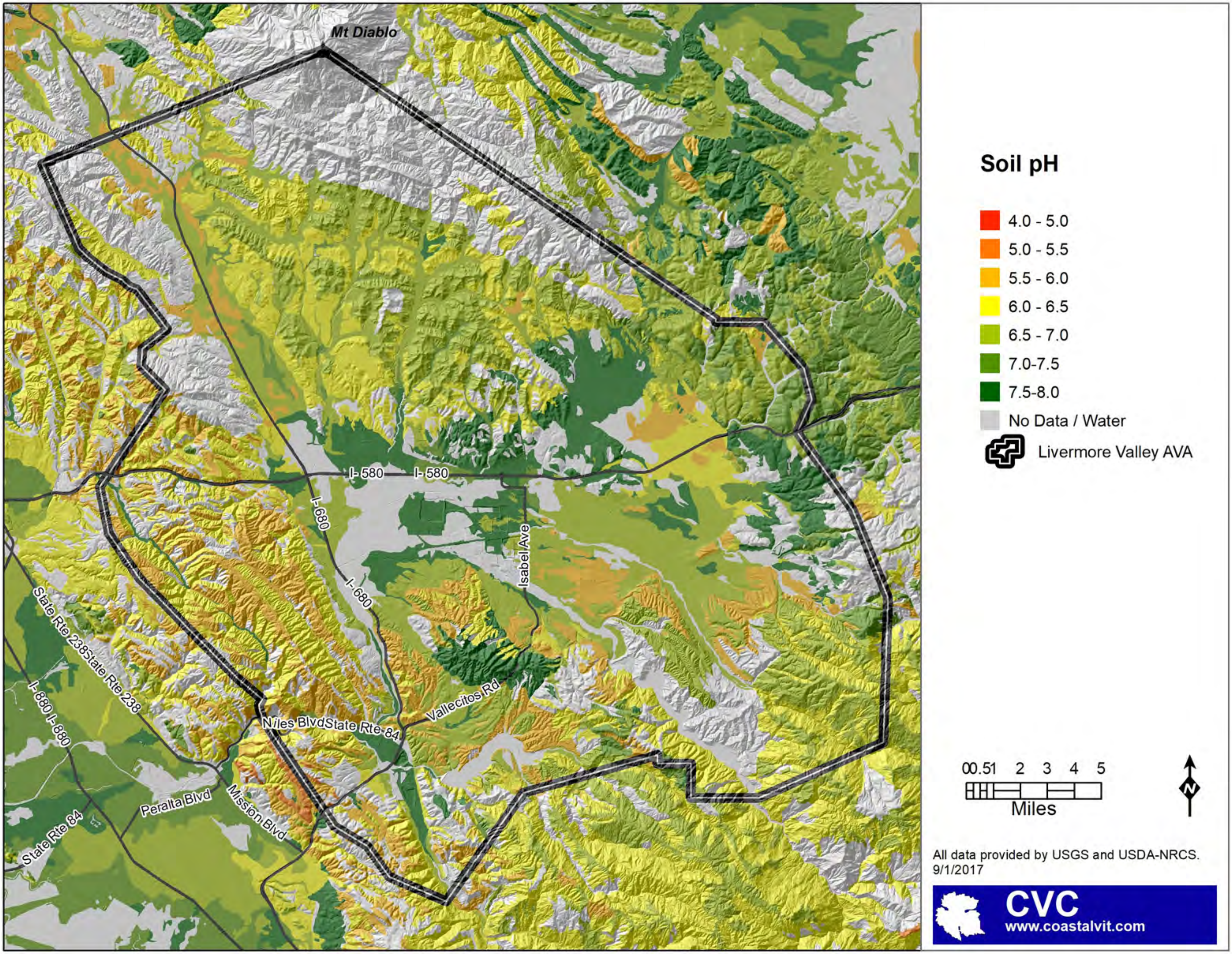

All data provided by USGS and USDA-NRCS.
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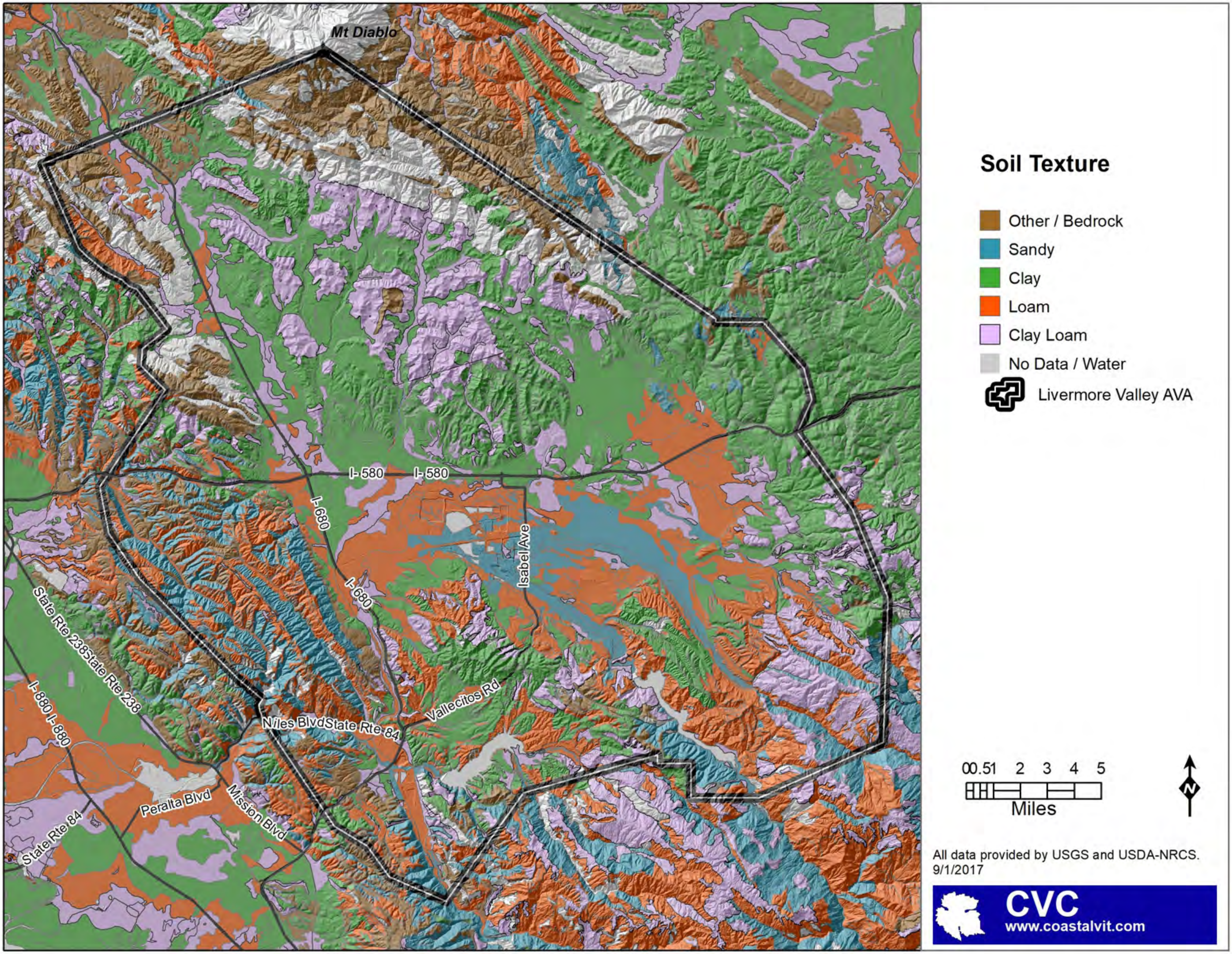

Mt Diablo
I- 580
I- 580
I- 680
I- 680
Isabel Ave
State Rte 238State Rte 238
I- 880 I- 880
Niles BlvdState Rte 84
Vallecitos Rd
Peralta Blvd
Mission Blvd
State Rte 84
Soil Texture
Other / Bedrock
Sandy
Clay
Loam
Clay Loam
No Data / Water
Livermore Valley AVA
0 0.5 1 2 3 4 5
Miles
N
All data provided by USGS and USDA-NRCS.
9/1/2017
CVC
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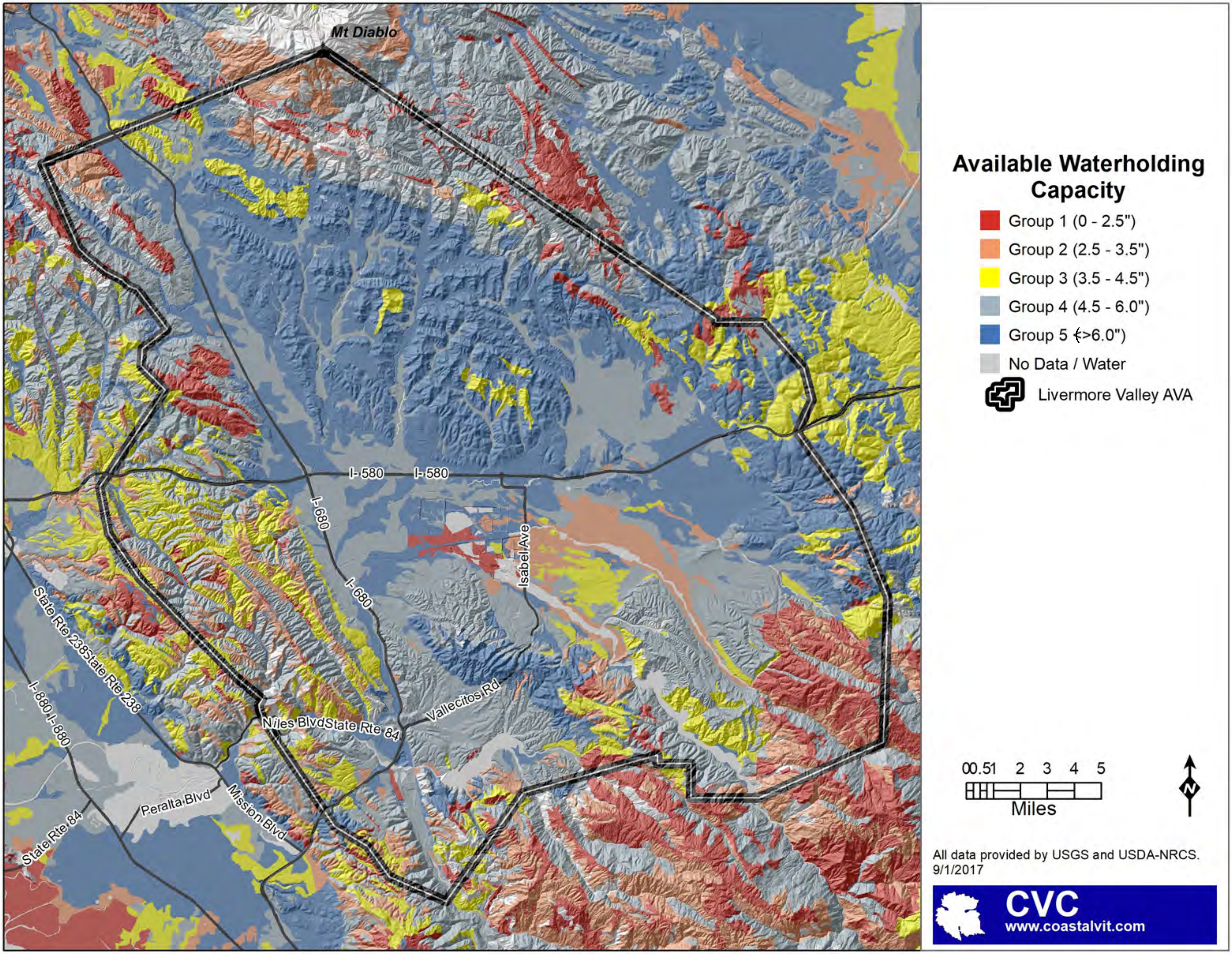
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Isabel Ave
Vallecitos Rd
Niles Blvd
State Rte 84
State Rte 238
State Rte 238
I-880
I-880
Peralta Blvd
Mission Blvd
State Rte 84
Available Waterholding Capacity
Group 1 (0 - 2.5")
Group 2 (2.5 - 3.5")
Group 3 (3.5 - 4.5")
Group 4 (4.5 - 6.0")
Group 5 (>6.0")
No Data / Water
Livermore Valley AVA
0 0.5 1 2 3 4 5
Miles
N
All data provided by USGS and USDA-NRCS.
9/1/2017
CVC
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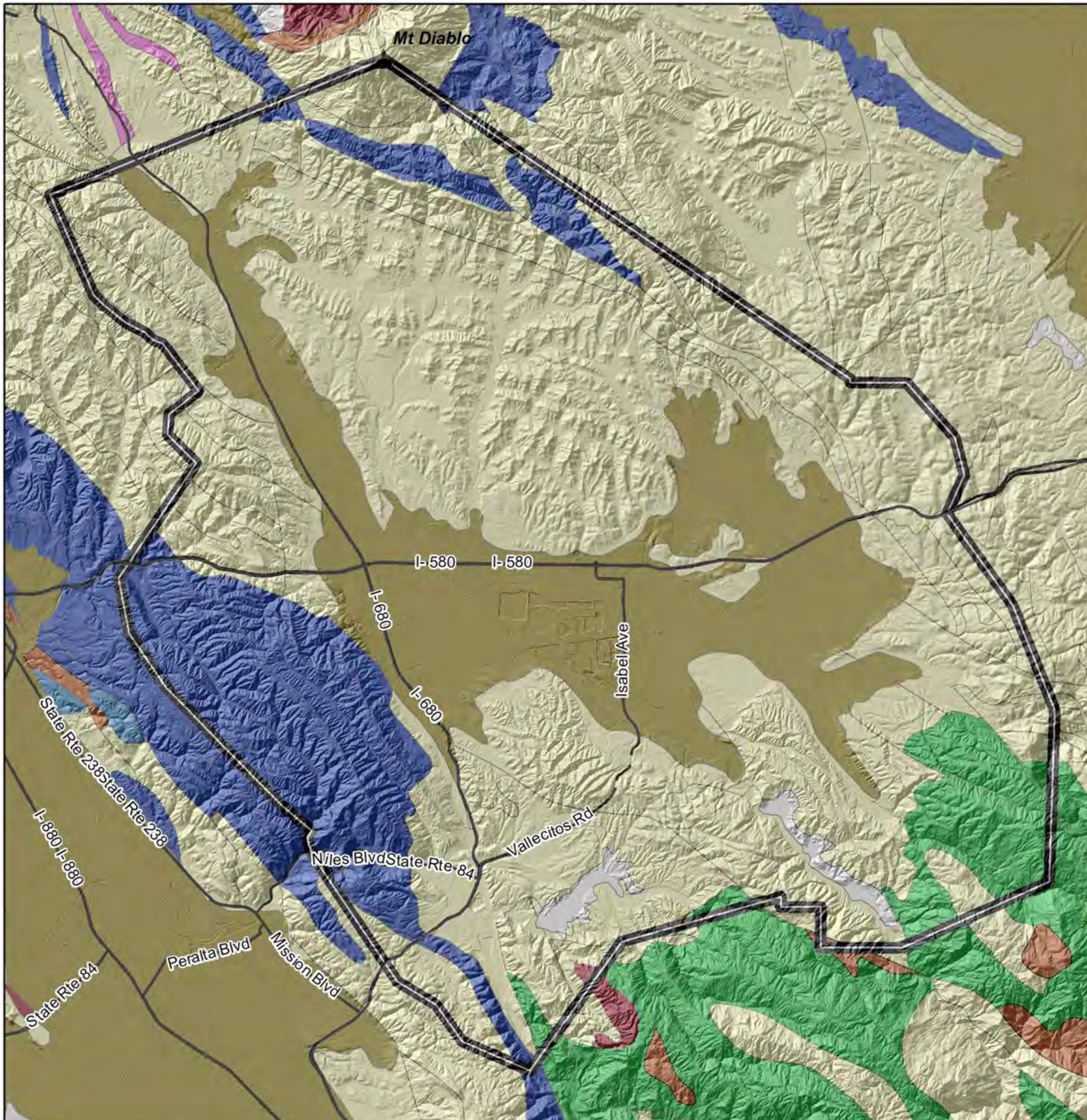

Parent Material

- Alluvium
- Basalt
- Gabbro
- Greenstone
- Melange
- Mudstone
- Sandstone
- Serpentinite
- No Data / Water
- Livermore Valley AVA

0 0.5 1 2 3 4 5
Miles

All data provided by USGS and USDA-NRCS.
9/1/2017

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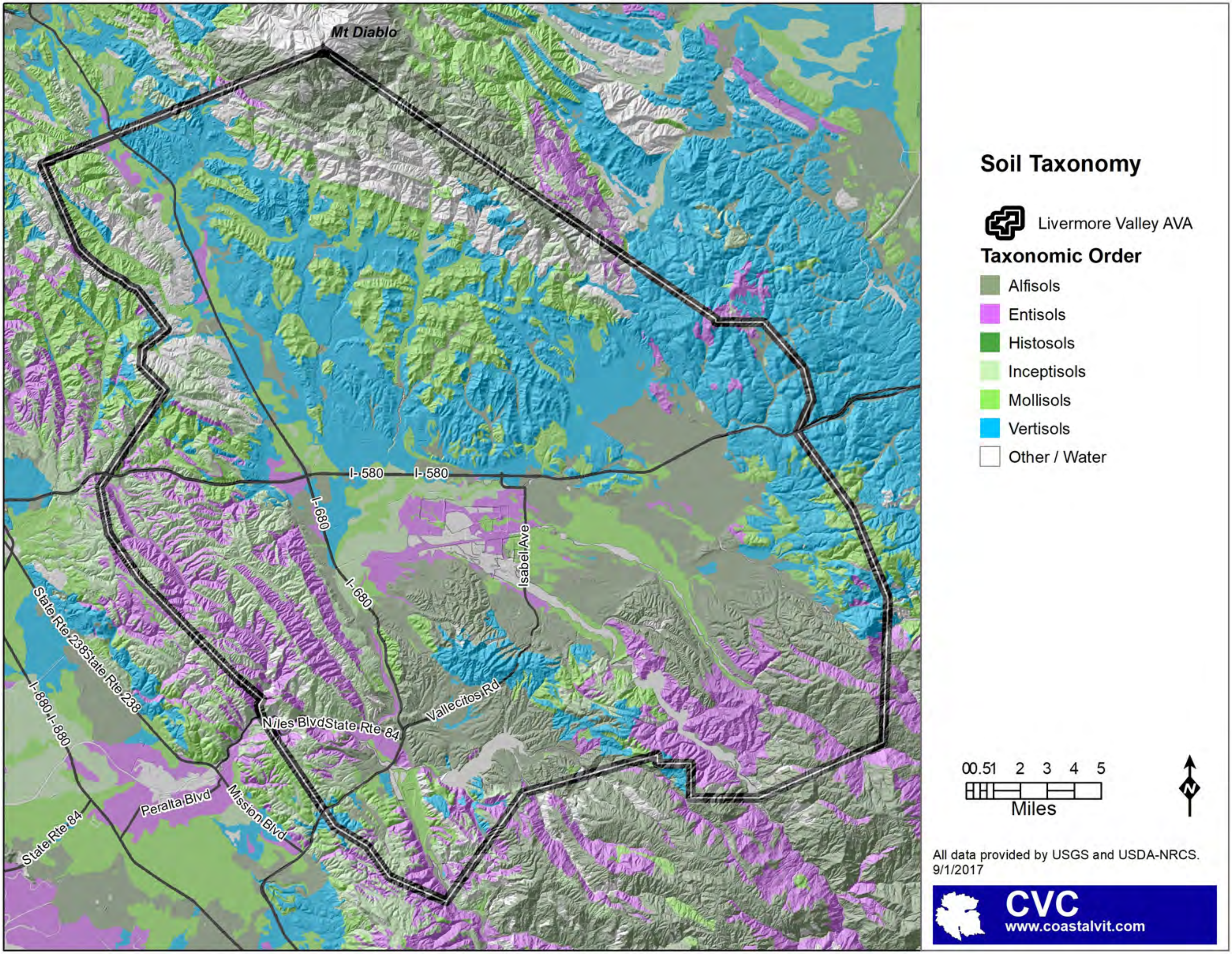
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Isabel Ave
Vallecitos Rd
State Rte 238
State Rte 238
I-880
I-880
Niles Blvd
State Rte 84
Peralta Blvd
Mission Blvd
State Rte 84
Soil Taxonomy
Livermore Valley AVA
Taxonomic Order
Alfisols
Entisols
Histosols
Inceptisols
Mollisols
Vertisols
Other / Water
0 0.5 1 2 3 4 5
Miles
N
All data provided by USGS and USDA-NRCS.
9/1/2017
CVC
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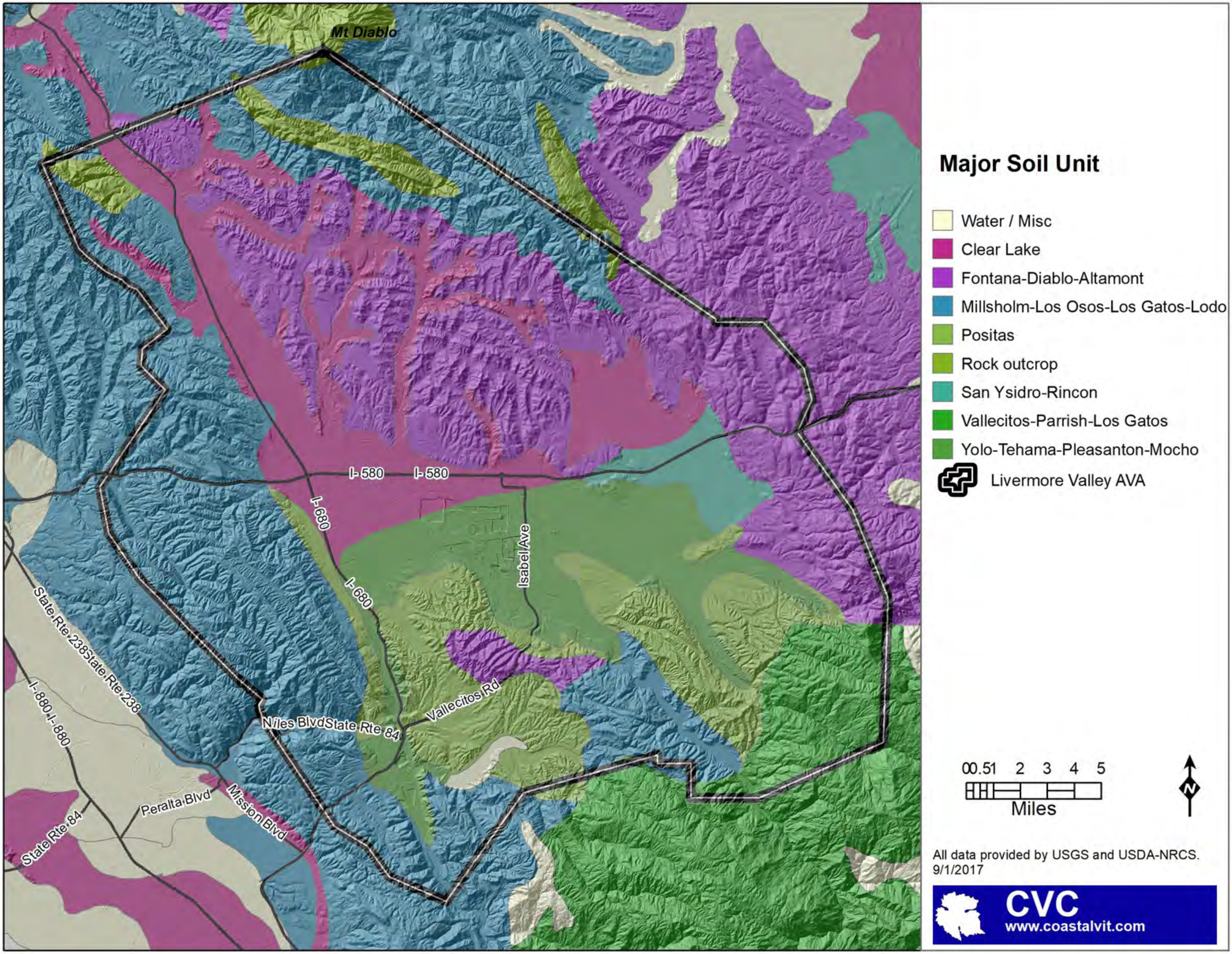
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State Rte 238State Rte 238
I-880 I-880
Niles BlvdState Rte 84
Vallecitos Rd
Peralta Blvd
Mission Blvd
State Rte 84
Major Soil Unit
Water / Misc
Clear Lake
Fontana-Diablo-Altamont
Millsholm-Los Osos-Los Gatos-Lodo
Positas
Rock outcrop
San Ysidro-Rincon
Vallecitos-Parrish-Los Gatos
Yolo-Tehama-Pleasanton-Mocho
Livermore Valley AVA
00.51 2 3 4 5
Miles
N
All data provided by USGS and USDA-NRCS.
9/1/2017
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