Section 2: Characterization of the Basin

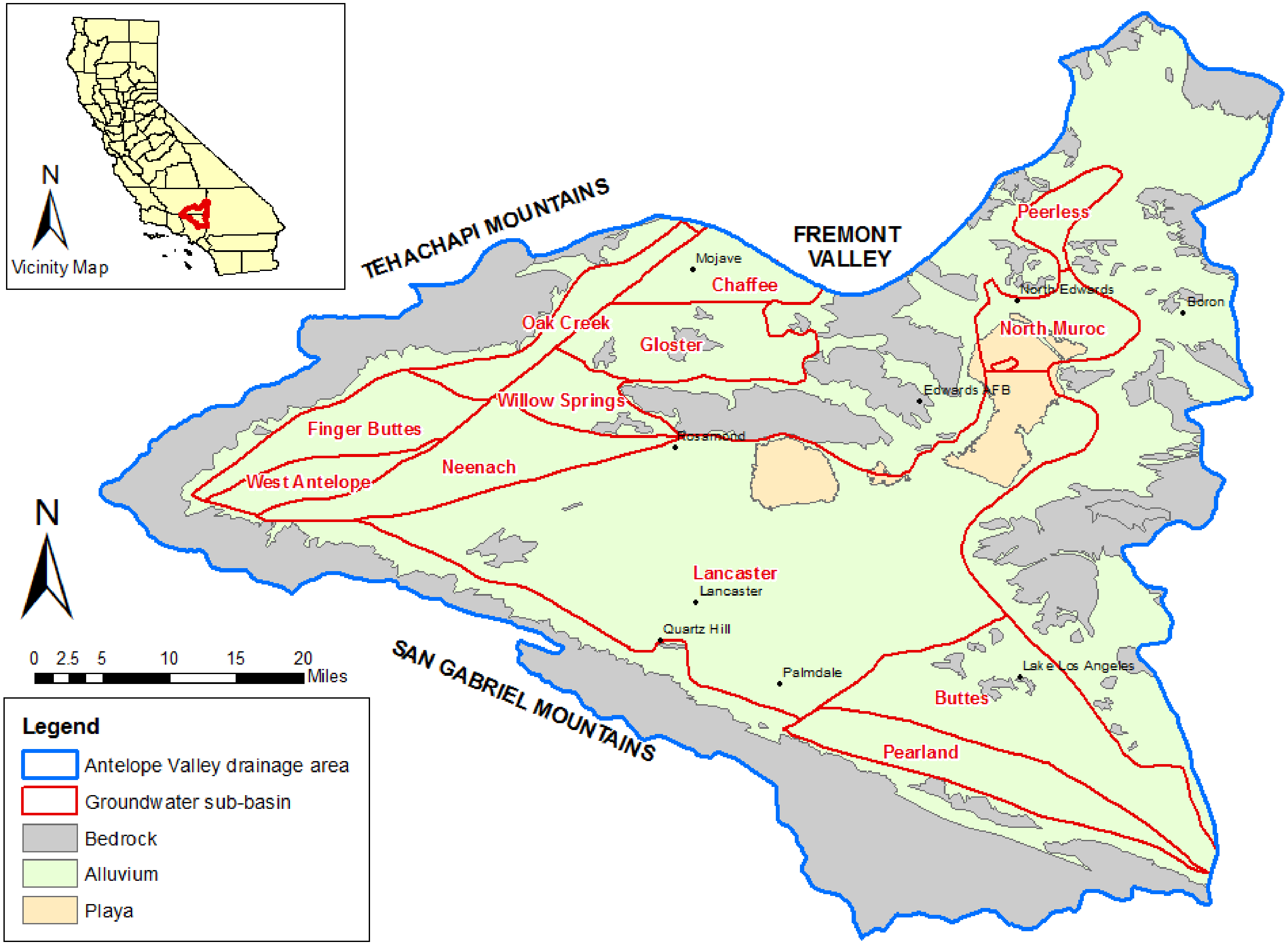
2.1 Antelope Valley Groundwater Basin

The Antelope Valley Region is located in the southwestern part of the Mojave Desert in Southern California and is approximately 40 miles north of the center of the City of Los Angeles. The Antelope Valley Groundwater Basin is bordered on the southwest by the San Gabriel Mountains, on the northwest by the Tehachapi Mountains, and on the east by a series of hills and buttes that generally follow the Los Angeles/San Bernardino County line. The basin boundaries are based on reports by the United States Geological Survey (USGS 1987) and the California Department of Water Resources (DWR 2004).

The groundwater basin is divided into twelve subbasins: Finger Buttes, West Antelope, Neenach, Willow Springs, Gloster, Chaffee, Oak Creek, Pearland, Buttes, Lancaster, North Muroc and Peerless (see Figure 2-1). Subbasin boundaries are based on faults, consolidated rocks, groundwater divides, and, in some cases, arbitrary boundaries (USGS 1998). General descriptions of the sub-basins are as follows (USGS 1987):

- *Finger Buttes:* A large part of the subbasin is range or forest land. Water use is mainly agricultural. Recharge comes from the surrounding Tehachapi Mountains. Groundwater moves generally from the northwest to the southeast into the Neenach subbasin. Depth to water varies, but is commonly more than 300 feet.
- *West Antelope:* Water use in this area is for agricultural purposes. Groundwater flows southeasterly into the Neenach subbasin. Depth to water ranges from 250 to 300 feet.
- *Neenach:* Water use is for agricultural purposes. Groundwater flows mainly eastward into the Lancaster subbasin. Depth to water ranges from 150 to 350 feet.
- *Willow Springs:* Water use is made up of agricultural and urban land uses. Recharge comes from intermittent streams of the surrounding mountain areas. Groundwater flows southeast and ultimately enters the Lancaster subbasin, although this flow is considered negligible (USGS 2003). Depth to water ranges from 100 to 300 feet.
- *Gloster:* Water use is confined to urban and mining (quarry pits) activity. Groundwater flows mainly to the southeast and east into the Chaffee subbasin. Depth to water for the southeast area of the subbasin ranges from 50 to 100 feet; other water level data is sparse.
- *Chaffee:* Water use in this area is mainly for the town of Mojave. Groundwater moves into the Chaffee subbasin from Cache Creek, adjacent alluvial fans to the west and, in lesser amounts, from the Gloster subbasin. Groundwater moves eastward in the western part and northward in the southern part of the subbasin, generally toward the town of Mojave. Any outflow would move north to the Koehn Lake area. Depth to water ranges from 50 to 300 feet.
- *Oak Creek:* Water use in the area is nominal except for the mining activity in the central part of the subbasin. Recharge comes from the Tehachapi Mountains. Groundwater flow is generally southeastward, with some outflow moving northeasterly to the Koehn Lake area. Water depth data is not available.

Figure 2-1: Groundwater Sub-Basin Boundary Map



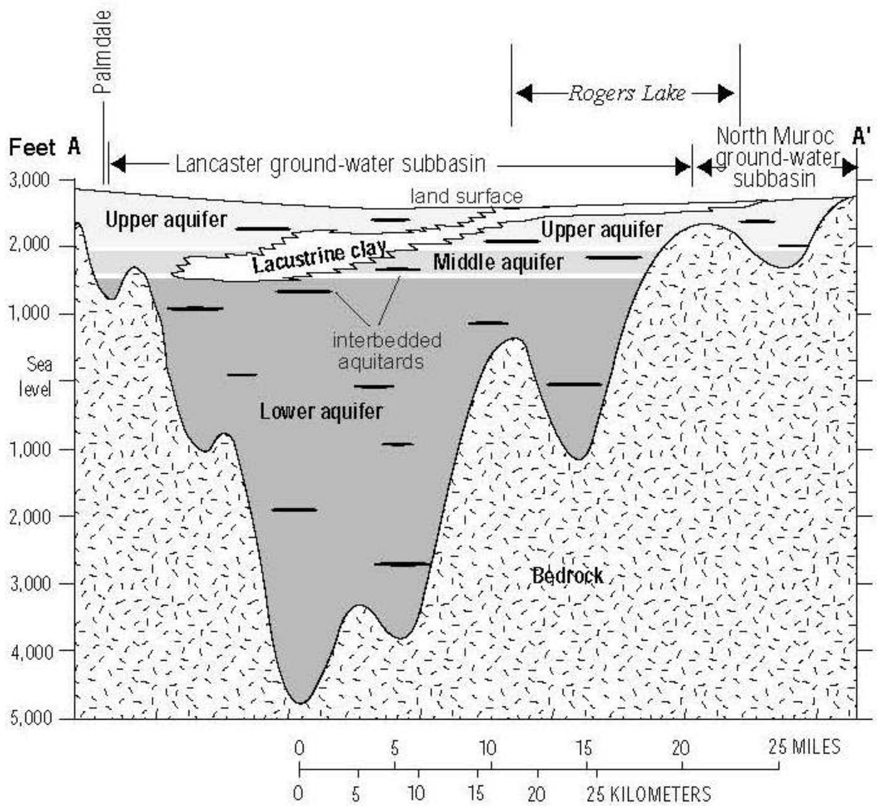
- *Pearland:* Water use is attributed to urban and irrigation activity. Substantial recharge occurs to the Pearland and Buttes subbasins from Little Rock and Big Rock Creeks. Groundwater generally flows from the southeast to the northwest, with outflows to the Lancaster subbasin. Depth to water ranges from 100 to 250 feet.
- *Buttes:* Water use includes urban and agricultural. Imported California State Water Project water became available for irrigation to the subbasin in 1972. Groundwater generally flows from the southeast to the northwest into the Lancaster subbasin. Depth to water ranges from 50 to 250 feet.
- *Lancaster:* This subbasin is the largest in both water use and size, and the most economically significant in terms of population and agriculture. Water is used for agricultural, urban and industrial applications. Groundwater flows to several pumping depressions and partially towards Rosamond and Rogers dry lakes. Due to agricultural, urban and industrial water use, depth to water varies widely, but in general is greatest in the south and west. The area includes Lancaster, Palmdale, Quartz Hill, Rosamond, Antelope Acres and other smaller communities.
- *North Muroc:* Water use is for urban and military purposes. Sewage disposal ponds are within and near this subbasin. These disposal ponds are of much less concern than similar ponds in the Antelope Valley because the soil structure allows for little percolation. The suggested monitoring networks were designed for this consideration. Groundwater flows north and west to a pumping depression located near North Edwards. North of this depression, the direction of flow is generally north into the Fremont Groundwater Basin and possibly into the Peerless subbasin.
- *Peerless:* Water is used for agricultural and municipal purposes. The general movement of groundwater is toward a pumping depression in the center of the subbasin. Little information is available on this subbasin.

The Antelope Valley Basin is comprised of three primary aquifers: (1) the upper, (2) the middle and (3) the lower aquifer. The upper aquifer varies from unconfined, in the south part of the Lancaster sub-basin from Palmdale to Littlerock Wash, to confined, north of Littlerock Wash, depending on the presence and vertical position of the thick lacustrine deposits. The upper aquifer yields most of the current groundwater supplies, and therefore is the primary focus of this SNMP. Due to the overlying lacustrine deposits and interbedded aquitards, the middle aquifer is assumed to be confined. The deep aquifer is generally considered to be confined by the overlying lacustrine deposits and discontinuous interbedded aquitards (USGS 2003). A schematic geologic cross-section of the Antelope Valley is depicted in Figure 2-2.

In general, groundwater in the Antelope Valley Basin flows northeasterly from the mountain ranges to the dry lakes. The basin is principally recharged by infiltration of precipitation and runoff from the surrounding mountains and hills in ephemeral stream channels. However, precipitation over the valley floor is generally less than 10 inches per year and evapotranspiration rates, along with soil moisture requirements, are high; therefore, recharge from direct infiltration of precipitation below the root zone is deemed negligible (Snyder 1955; Durbin 1978; USGS 2003). Other sources of recharge to the basin include artificial recharge and return flows from agricultural and urban irrigation. Depending on the thickness and characteristics of the unsaturated zone of the aquifer below a particular site, these sources may or may not contribute to recharge of the groundwater.

Figure 2-2: General Geologic Cross-Section of the Antelope Valley Basin

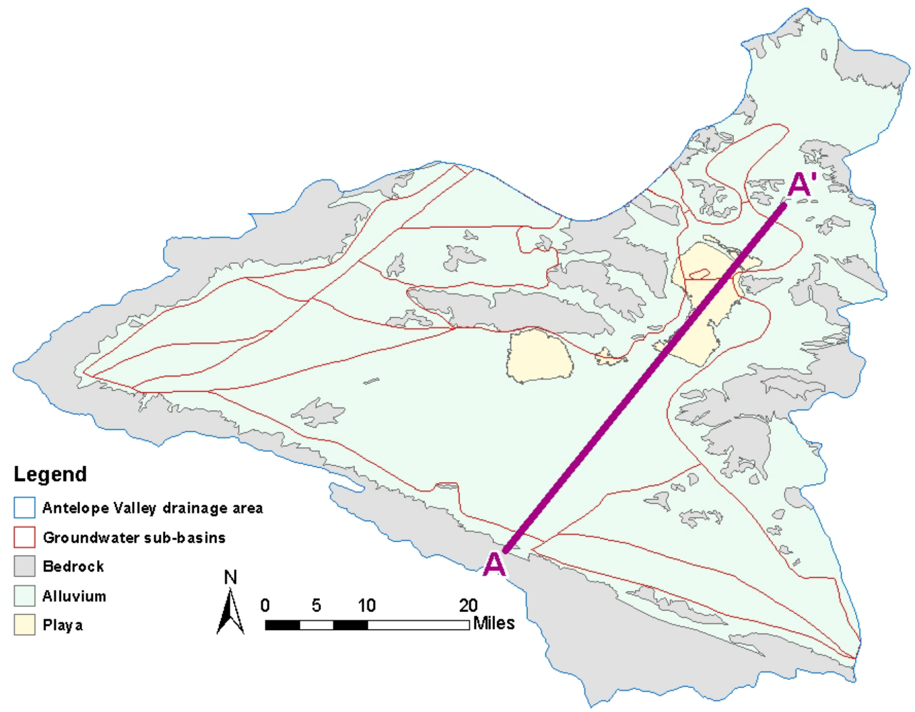
(a) Cross Section



Legend

- Bedrock
- Lacustrine clay deposits
- Continental deposits
- Older alluvium
- Younger alluvium

(b) Line of Cross-Section



Groundwater has been, and continues to be, an important resource within the Antelope Valley Region. Prior to 1972, groundwater provided more than 90 percent of the total water supply in the region; since 1972, it has provided between 50 and 90 percent (USGS 2003). Groundwater pumping in the region peaked in the 1950s and decreased in the 1960s and 1970s when agricultural pumping declined due to increased pumping costs from greater pumping lifts and higher electric power costs (USGS 2000a). The rapid increase in urban growth in the 1980s resulted in an increase in the demand for water for municipal and industrial (M&I) uses and an increase in groundwater use. Projected urban growth and limits on the available local and imported water supply are likely to continue to increase the reliance on groundwater.

The basin has historically shown large fluctuations in groundwater levels. Data from 1975 to 1998 show that groundwater level changes over this period ranged from an increase of 84 feet to a decrease of 66 feet (Carlson and Phillips 1998 as cited in DWR 2004). In general, data collected by the USGS (2003) indicate that groundwater levels appear to be falling in the southern and eastern areas and rising in the rural western and far northeastern areas of the region. This pattern of falling and rising groundwater levels correlates directly to changes in land use over the past 40 to 50 years. Falling groundwater levels are generally associated with areas that are developed and rising groundwater levels are generally associated with areas that were historically farmed but have been largely fallowed during the last 40 years. However, recent increases in agricultural production, primarily carrots, in the northeastern and western portions of the region may have reduced rising groundwater trends in these areas (LACSD 2005).

According to the USGS (2003), groundwater extractions have exceeded the estimated natural recharge of the basin since the 1920s. This overdraft has caused water levels to decline by more than 200 feet in some areas and by at least 100 feet in most of the region (USGS 2003). Extractions in excess of the groundwater recharge can cause groundwater levels to drop and associated environmental damage (e.g., land subsidence).

Annual groundwater extractions are reported to have increased from about 29,000 AF in 1919 to about 400,000 AF in the 1950's, when groundwater use in the Antelope Valley Region was at its highest (USGS 1995). Use of California State Water Project (SWP) water, which is imported from Northern California, has since stabilized groundwater levels in some areas of the Antelope Valley Region. In recent years, groundwater pumping has resulted in subsidence and earth fissures in the Lancaster and Edwards AFB areas, which has permanently reduced storage by 50,000 AF (DWR 2004).

Although the groundwater basin is not currently adjudicated, the adjudication process is underway. There are no existing restrictions on groundwater pumping. However, pumping may be altered or reduced as part of the adjudication process. The adjudication aims to provide clarity for the groundwater users regarding management of groundwater resources.

2.2 SNMP Area Boundaries

Figure 2-1 depicts the groundwater basin and sub-basin boundaries for the SNMP. The planning area of the SNMP is the same as that of the AVIRWMP, which was defined as the drainage area because of its use in several studies and inclusion of key agencies dealing with similar water management issues. Each sub-basin in the Antelope Valley Basin has been addressed in some manner with information and data provided in this SNMP. . Further detail and analyses for any of the sub-basins may be provided in the future, contingent on the availability of sufficient data for analysis and the presence of projects that have the potential to impact salt/nutrient concentrations in the basin.

2.3 Surface Water

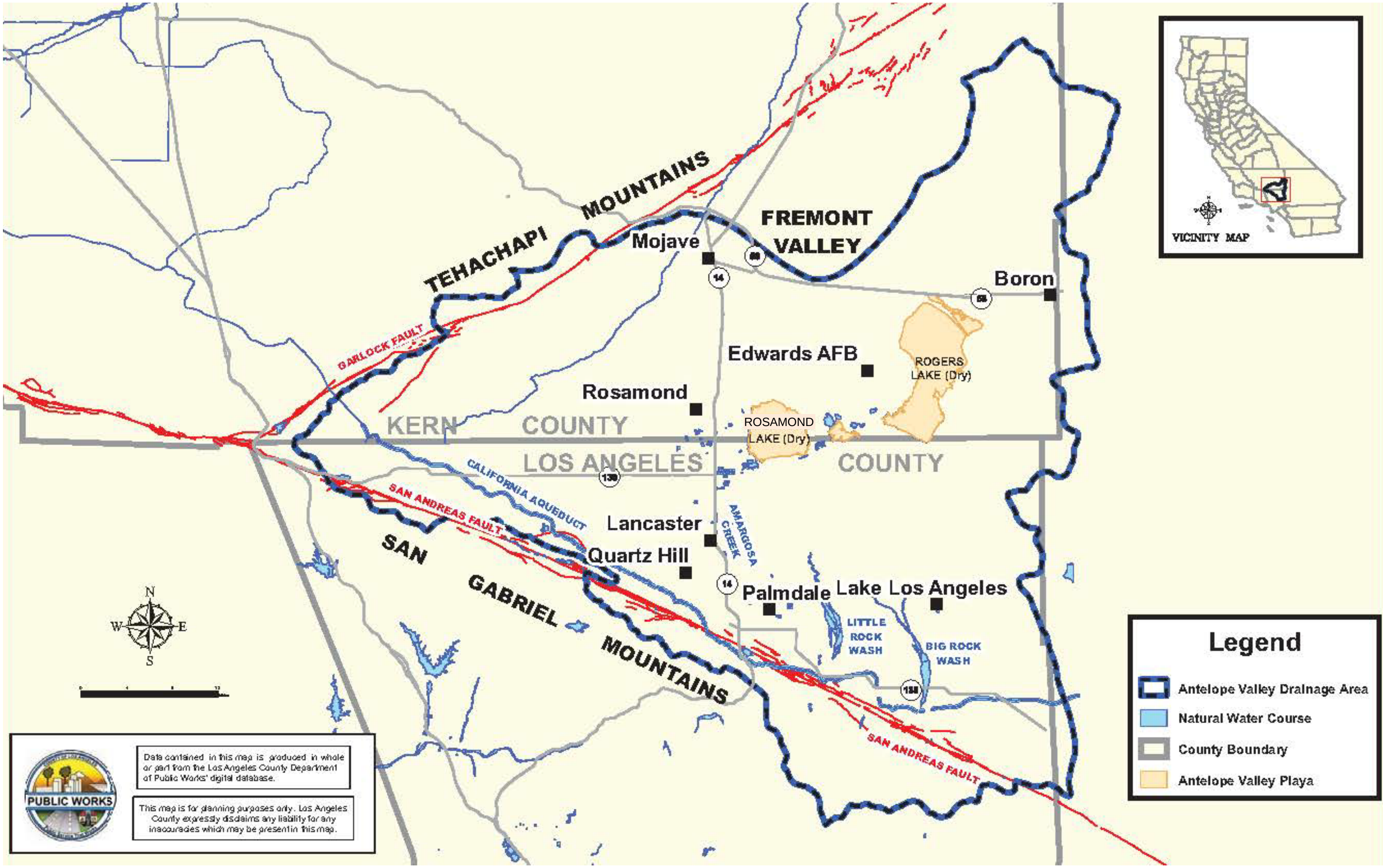
Comprising the southwestern portion of the Mojave Desert, the Antelope Valley ranges in surface elevation from approximately 2,300 feet to 3,500 feet above sea level. The Antelope Valley is a closed basin with no outlet to the ocean. Water that enters the Valley either infiltrates into the groundwater basin, evaporates, or flows toward the three dry lakes on Edwards Air Force Base—Rosamond Lake, Buckhorn Lake, and Rogers Lake. In general, water flows northeasterly from the mountain ranges to the dry lakes.

Surface water from the surrounding hills and from the Antelope Valley floor flows primarily toward the three dry lakes. Except during the largest rainfall events of a season, surface water flows toward the Antelope Valley from the surrounding mountains, quickly percolates into the stream beds, and recharges the groundwater basin. Due to the relatively impervious nature of the dry lake soil and high evaporation rates, water that collects on the dry lakes eventually evaporates rather than infiltrating into the groundwater (LACSD 2005). It appears that little percolation occurs in the Antelope Valley other than near the base of the surrounding mountains due to low permeability soils overlying the groundwater basin.

Surface water flows are carried by ephemeral streams. The most hydrologically significant streams begin in the San Gabriel Mountains on the southwestern edge of the Antelope Valley and include Big Rock Creek, Littlerock Creek and Amargosa Creek. Oak Creek begins in the Tehachapi Mountains. The hydrologic features are shown on Figure 2-3.

Littlerock Creek is the only developed surface water supply in the Antelope Valley. The Littlerock Reservoir collects runoff from the San Gabriel Mountains and is jointly owned by Palmdale Water District (PWD) and Littlerock Creek Irrigation District (LCID). Historically, water stored in the Littlerock Reservoir has been used directly for agricultural uses within LCID's service area and for M&I uses within PWD's service area following treatment at PWD's water purification plant.

Figure 2-3: Antelope Valley Hydrologic Features



Source: 2007 Antelope Valley Integrated Regional Water Management Plan

2.4 Water Resources

Two major sources contributing to the Antelope Valley Region water supply are imported water via the SWP (or California Aqueduct) and natural recharge (precipitation). These sources may eventually become another water source for the region, such as infiltrated groundwater (including return flows from water use activities), recycled water from wastewater treatment, and surface water flow from precipitation, run-off, and subsurface flow.

Potable water supply in the Antelope Valley comes from three primary sources. Historically, the main water source in the region has been groundwater from well extraction (i.e., pumping). However, the groundwater in the Antelope Valley is not currently managed and is susceptible to overdraft, which could cause land subsidence and thereby decrease the region's groundwater storage capacity. Most Antelope Valley residents are familiar with the SWP, a surface water source beginning in Northern California at Oroville Reservoir with water flowing into the Sacramento River Delta and pumped south to serve, amongst others, the urban and agricultural centers in Southern California. Water from the SWP may be used directly for agricultural use or treated at one of the region's water treatment plants for potable supply. The availability of SWP supply is known to be variable and fluctuates from year to year depending on precipitation, regulatory and legislative restrictions, and operational conditions, and is particularly unreliable during dry years. The third source of potable water is surface water supplied by Littlerock Reservoir, which is fed by natural run-off from snow packs in the local San Gabriel Mountains and from precipitation. Further stress to the Antelope Valley's water supply management is due to recent lower than average precipitation levels and mountain snowpack.

Recycled water is a supplemental source of water used for non-potable applications such as landscape and agricultural irrigation, construction activities, and commercial and industrial processes. Recycled water can also be used for indirect potable uses through groundwater replenishment. Recycled water is assumed to be 100 percent reliable and practically drought-resistant since it is derived from consistent water use. Maximizing recycled water use helps increase the region's water reliability by augmenting local supplies and reducing dependence on imported surface water, which has varying and recently decreasing reliability. By 2035, the Los Angeles County Sanitation District's (LACSD) Lancaster and Palmdale Water Reclamation Plants are projected to produce 36,000 acre-feet per year of tertiary treated water. The regional goal is to fully utilize the recycled water for beneficial uses.

Development demands on water supply, coupled with the potential curtailments of SWP deliveries due to environmental constraints and prolonged drought periods, have intensified the competition for available water resources. Consequently, the Antelope Valley Integrated Regional Water Management Plan (AVIRWMP) was developed by stakeholders as a strategy to sustainably manage water resources and address the needs of the M&I purveyors to reliably provide the quantity and quality of water necessary to serve the expanding Antelope Valley Region, while concurrently addressing the need of agricultural users and small pumpers to have adequate supplies of reasonably-priced water.

2.5 Geology and Soils

The Antelope Valley represents a large topographic and groundwater basin in the western part of the Mojave Desert in southern California. It is a prime example of a single, undrained, closed basin. The Antelope Valley Region occupies part of a structural depression that has been downfaulted between the Garlock, Cottonwood-Rosamond, and San Andreas Fault Zones. The Antelope Valley Region is bounded on the southwest by the San Andreas Fault and San Gabriel Mountains, the Garlock Fault and Tehachapi Mountains to the northwest, and San Bernardino County to the east. Consolidated rocks that yield virtually no water underlie the basin and crop out in the highlands that surround the basin. They consist of igneous and metamorphic rocks of pre-Tertiary age that are overlain by indurated continental rocks of Tertiary age interbedded with lava flows (USGS 1995).

Alluvium and interbedded lacustrine deposits of Quaternary age are the important aquifers within the closed basin and have accumulated to a thickness of as much as 1,600 feet. The alluvium is unconsolidated to moderately consolidated, poorly sorted gravel, sand, silt, and clay. Older units of the alluvium are somewhat coarser grained, and are more compact and consolidated, weathered, and poorly sorted than the younger units. The rate at which water moves through the alluvium, also known as the hydraulic conductivity of the alluvium, decreases with increasing depth. Groundwater sub-basins are often divided by faulted bedrock that influences groundwater flow between the basins.

During the depositional history of the Antelope Valley, a large intermittent lake occupied the central part of the basin and was the site of accumulation of fine-grained material. The rates of deposition varied with the rates of precipitation. During periods of relatively heavy precipitation, massive beds of blue clay formed in a deep perennial lake. During periods of light precipitation, thin beds of clay and evaporative salt deposits formed in playas or in shallow intermittent lakes. Individual beds of the massive blue clay can be as much as 100 feet thick and are interbedded with lenses of coarser material as much as 20 feet thick. The clay yields virtually no water to wells, but the interbedded, coarser material can yield considerable volumes of water.

Soils within the area are derived from downslope migration of loess and alluvial materials, mainly from granitic rock sources originating along the eastern slopes of the Tehachapi and San Gabriel Mountains. Figure 2-4 depicts a soil map of the Antelope Valley Region.

2.6 Land Use

Figure 2-5 depicts the major existing land use categories within the Antelope Valley Region that are characterized and grouped together according to broad water use sectors. The map was created with City of Lancaster, City of Palmdale, Los Angeles County, and Kern County Geographic Information System (GIS) parcel level data. Table 2-1 depicts the colors used to indicate each land use category. Each major land use category is identified below, including the types of “like water uses” assigned to each category. Additional descriptions for the land use categories provided by the agencies are detailed in Appendix C.

- *Residential:* Residential uses include a mix of housing developed at varying densities and types. Residential uses in the Antelope Valley Region include single-family, multiple-family, condominium, mobile home, low density “ranchettes,” and senior housing.
- *Commercial/Office:* This category includes commercial uses that offer goods for sale to the public (retail) and service and professional businesses housed in offices (doctors, accountants, architects, etc.). Retail and commercial businesses include those that serve local needs, such as restaurants, neighborhood markets and dry cleaners, and those that serve community or regional needs, such as entertainment complexes, auto dealers, and furniture stores. Also included in this category are government offices that have similar water duty requirements as a typical commercial/office use.

- *Industrial:* The industrial category includes heavy manufacturing and light industrial uses found in business, research, and development parks. Light industrial activities include some types of assembly work, utility infrastructure and work yards, wholesaling, and warehousing.
- *Public and Semi-Public Facilities:* Libraries, schools, and other public institutions are found in this category. Uses in this category support the civic, cultural, and educational needs of residents.
- *Resources:* This category encompasses land used for private and public recreational open spaces, and local and regional parks. Recreational use areas also include golf courses, cemeteries, water bodies and water storage. Also included in this category are mineral extraction sites.
- *Agriculture:* Agricultural lands are those in current crop, orchard or greenhouse production, as well as any fallow lands that continue to be maintained in agricultural designations or participating in tax incentive agricultural programs.
- *Vacant:* Vacant lands are undeveloped lands that are not preserved in perpetuity as open space or for other public purposes.

Figure 2-4: Antelope Valley Soils

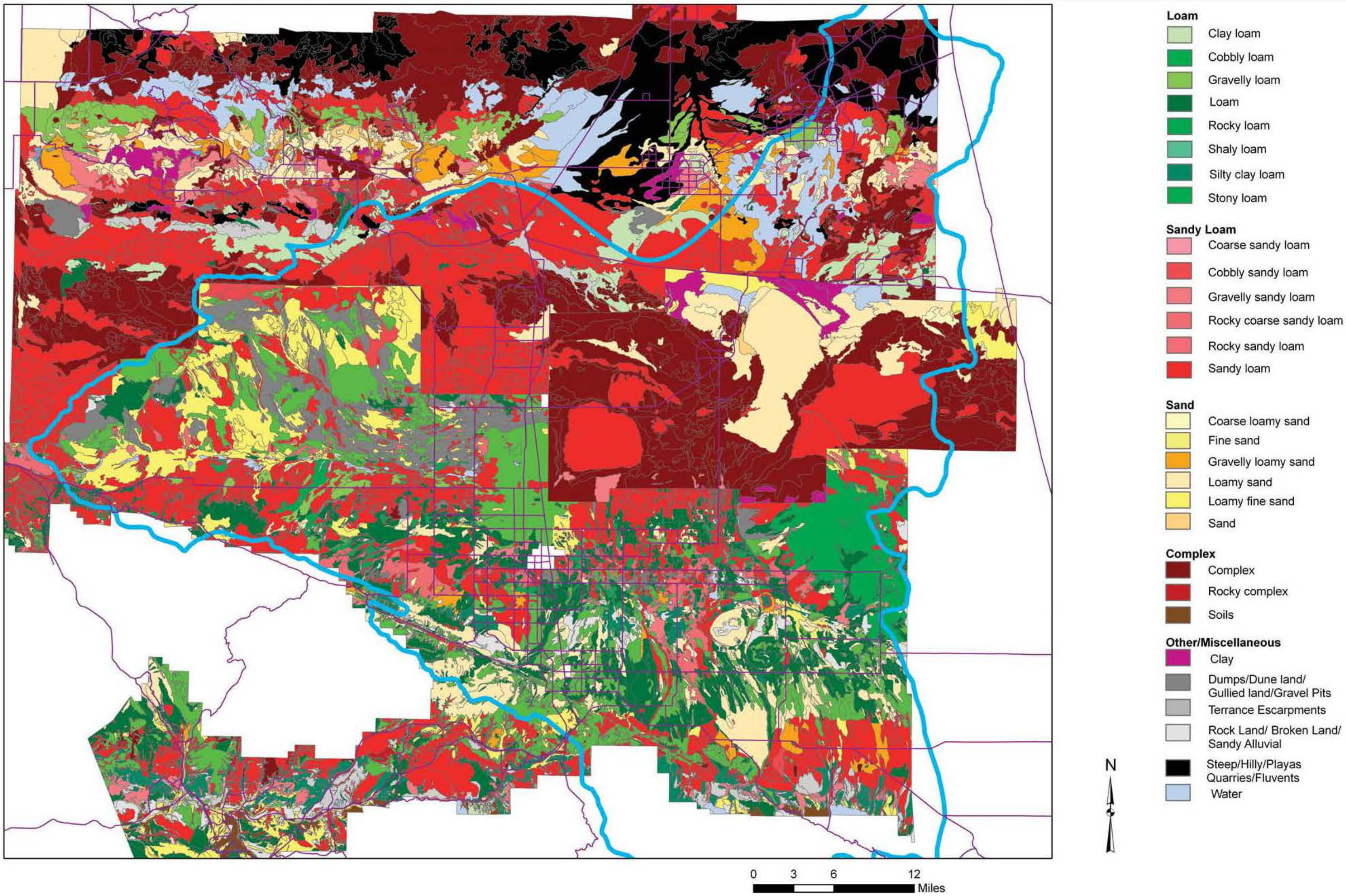
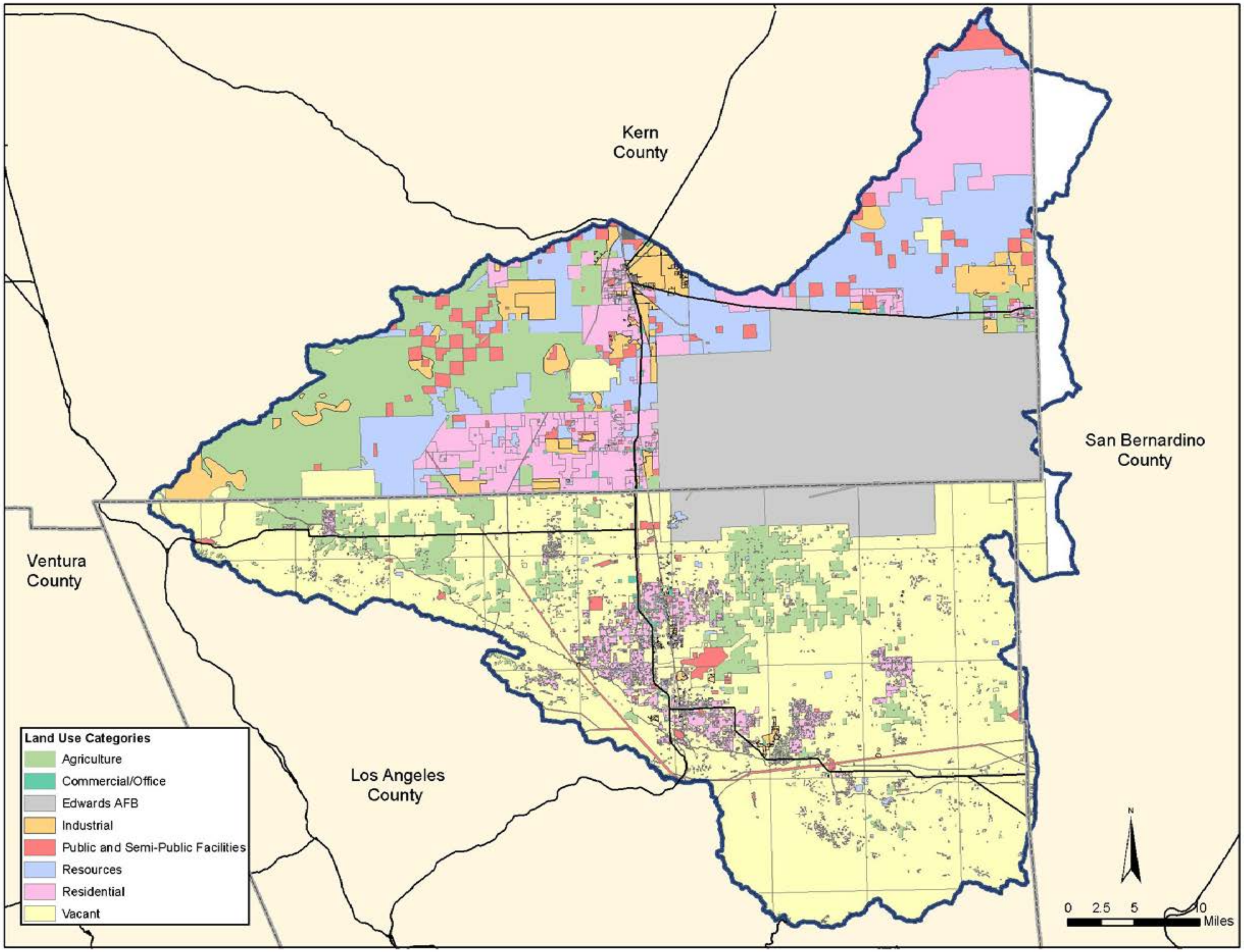


Figure 2-5: Antelope Valley Land Uses



2.7 Groundwater Quality

Groundwater quality is excellent within the upper or "principal" aquifer but degrades toward the northern portion of the dry lake areas. Considered to be generally suitable for domestic, agricultural, and industrial uses, the water in the principal aquifer has a total dissolved solids (TDS) concentration ranging from 200 to 800 milligrams per liter (mg/L). The deeper aquifers typically have higher TDS levels. Hardness levels range from 50 to 200 mg/L and high fluoride, boron, and nitrate concentrations have been measured in some areas of the basin. Arsenic is a concern in parts of the region and has been observed in some water supply wells. Research conducted by Waterworks and USGS has shown the problem to reside primarily in the deep aquifer. It is not anticipated that the existing arsenic concentrations will lead to future loss of groundwater as a water supply resource for the region. Portions of the basin have experienced nitrate levels above the maximum contaminant level (MCL) of 10 mg/L as N.

Most, if not all, water supply wells in the Antelope Valley draw groundwater from the principal aquifer. The SNMP and future monitoring plan will focus on the groundwater quality in the principal aquifer. The basin's groundwater quality is discussed further in Section 3 and 4.

2.8 Water Quality Control

The primary responsibility for ensuring the highest reasonable quality for waters of the State has been assigned by the California legislature to the State Water Resources Control Board (State Board) and the nine Regional Water Quality Control Boards. The mission of the Regional Boards is to develop and enforce water quality objectives and implementation plans that will best protect the beneficial uses of the State's waters, recognizing local differences in climate, topography, geology and hydrology.

The Antelope Valley Region falls within the jurisdiction of the Lahontan Regional Water Quality Control Board (Regional Board), the regulatory agency whose primary responsibility is to protect water quality within the Lahontan Region. The Regional Board adopted and implemented the "*Water Quality Control Plan for the Lahontan Region*" (Basin Plan; Regional Board 1995), which, among other functions, sets forth water quality standards for the surface and groundwater within the Regional Board's jurisdiction. The Basin Plan includes the designated uses of water and the narrative and numerical objectives which must be maintained or attained to protect those uses. The Regional Board has not established water quality objectives specific to the Antelope Valley Region. However, water quality objectives have been established that apply to all groundwaters in the Lahontan Region. These objectives are aimed to be protective of the beneficial uses assigned to the groundwater basins. Further discussion on the water quality objectives examined in this SNMP is included in Section 4.

2.9 Antelope Valley Regulatory Groundwater Cleanup Sites

The State Board's Site Cleanup Program regulates and oversees the investigation and cleanup of non-federally owned sites where recent or historical unauthorized releases of pollutants to the environment, including soil, groundwater, surface water, and sediment, have occurred. Sites in the program include, but are not limited to, pesticide and fertilizer facilities, rail yards, ports, equipment supply facilities, metals facilities, industrial manufacturing and maintenance sites, dry cleaners, bulk transfer facilities, and refineries. The types of pollutants encountered at the sites are numerous and diverse and may include substance such as solvents, pesticides, heavy metals, and fuel constituents.

GeoTracker is the State Board's data management system for managing sites that impact groundwater, especially those that require groundwater cleanup as well as permitted facilities such as land disposal sites. Information relating to the groundwater cleanup sites is available on the GeoTracker website [1].

At the request of the Regional Board, a discussion of the Antelope Valley cleanup sites is included in the SNMP. The list of cleanup sites was obtained with Regional Board assistance. The list can be downloaded using the following steps and search parameters:

1. Website: http://geotracker.waterboards.ca.gov/
2. Use the "advanced search" link.
3. County: Los Angeles, Kern (separate runs are needed for both)
4. Site/Facility Type: Uncheck the "Leaking Underground Storage Tank (LUST) Cleanup Sites"
5. Regional Board: Lahontan
6. Use latitude and longitude coordinates to determine which sites are within the basin

According to GeoTracker, there are currently 548 cleanup sites on Edwards Air Force Base, 36 cleanup sites on Air Force Plant 42 and 30 non-military cleanup sites in the Antelope Valley. All but 29 of the Edwards Air Force Base and Air Force Plant 42 sites are open cases. 22 of the 30 non-military sites are open cases. Of the 614 total cases, 9 are cleanup program sites, 21 are land disposal sites and 584 are military cleanup sites. The cleanup sites are listed in Appendix D and depicted in Figure 2-6.

For the sites that have a listed potential contaminant(s) of concern, the majority of the contaminants are gasoline and diesel from gas stations. Only one site, the eSolar Sierra SunTower Power Plant, has listed potential contaminants in GeoTracker that are relevant to the SNMP. The potential contaminants are listed as "Nitrate, other inorganic / salt, arsenic, chromium, other metal." This site is listed as a land disposal site; however, it is a power generating location using solar power. The cleanup case is also listed as inactive, meaning that it is a site that has ceased accepting waste but has not been formally closed or is still within the post closure monitoring period, and the site is not considered a significant threat to water quality.

This SNMP includes a monitoring plan, as discussed later in Section 5. If in the future, the SNMP monitoring network detects a high concentration of a monitored constituent, the stakeholders may use this map or updated information from GeoTracker to see if there are any known cleanup sites in the vicinity of the well that may be contributing to the high concentration.

[1] http://geotracker.waterboards.ca.gov/

Figure 2-6: GeoTracker Groundwater Cleanup Sites