Chapter 3

Groundwater Basin Characteristics

3.1 Introduction

This chapter provides an overview of the hydrogeological characteristics of the Livermore-Amador Valley groundwater basin. Multiple studies of this important groundwater resource have been conducted over the last 100 years, as cited below (Section 3.2). A good overview and summary of fundamental basin characteristics was published in the 1974 DWR Bulletin 118-2 and summarized in the May 1992 Livermore-Amador Valley Water Recycling Study, appendices A and B. This chapter only briefly recounts that information (Section 3.3) and instead focuses on those aspects directly influencing salt loading impacts such as basin connectivity (Section 3.4) and Main Basin mixing and movement (Section 3.5). The approach taken to address vadose attenuation is presented in Section 3.6. Historic and on-going hydrogeological information collection is summarized in Section 3.7.

The groundwater flow and solute transport numerical model used in this SMP to evaluate the impacts of alternative salt management strategies (see Chapter 10) is described in Section 3.8. Section 3.8 also provides a detailed discussion of model calibration work conducted and a comparison of model results to actual measured groundwater elevations and TDS trends. The groundwater model provides the best current documentation of general basin characteristics.

3.2 Previous Groundwater Basin Studies

The earliest studies relating to the groundwater supply of the Livermore Valley were conducted in the early 1900s and mainly focused on the use of Livermore Valley groundwater for a drinking water supply to the City of San Francisco, California (Tibbetts, 1907; Lawson, 1912; Williams, Jr., 1912; Vickery, 1925; Smith, 1934). These early studies developed the conceptual model of a large artesian basin. The basin was recharged in the east where gravels were exposed at the surface. In the west the gravel aquifers were semi-confined under an extensive clay cap. The California Department of Water Resources (CDWR) began studying the basin in the late 1940's and published an initial study of water resources in all of Alameda County starting in July 1955. This report was revised and updated with the cooperation of Zone 7 and finally published in 1963 as Bulletin 13. Information in this report included surface water and groundwater supplies, alternate plans for surface water development, and projected water demands. DWR continued their work in conjunction with Zone 7 and focused on groundwater recharge from streams, surface and groundwater quality, groundwater inventory and groundwater movement as it related to geological features (CDWR, 1960, 1964a, 1964b, 1966, and 1974).

In January 1964, CDWR published a report on the Alameda Creek watershed that discussed the effects of wastewater discharges on surface water and groundwater in Livermore and Sunol valleys (CDWR, 1964a). In June of that same year, a report was published discussing the need for standard well construction to prevent the commingling of waters of various qualities (CDWR, 1964b). An initial report on the geology as it relates to groundwater movement in Livermore and Sunol valleys was published in August of 1966 by CDWR as Appendix A to Bulletin 118-2. Bulletin 118-2 was published in 1974 again with the cooperation of Zone 7 and included comprehensive discussions of groundwater quality, movement, local geology, and inventory of each groundwater sub-basin (CDWR, 1966, 1974). The hydrology conceptual model was modified from Appendix A following the development and calibration of a computer flow model. Two very significant developments resulted from this modeling study. One was the realization that a detailed hydrologic inventory of all supply and demand components was absolutely essential to the quantitative analysis of the groundwater basin. Zone 7's hydrologic inventory was developed out of this early modeling effort and continues to be used as an essential element of all subsequent studies and modeling analysis. The second lesson learned was the importance of good hydrologic data records and the need to actively measure and collect hydrologic data. Bulletin 118-2 specifically recommended the construction of special monitoring wells to monitor shallow aquifer areas near recharge areas and near wastewater disposal areas.

In 1972, Brown and Caldwell Consulting Engineers completed a water quality management plan for the watershed of Alameda Creek above Niles Canyon for Zone 7 Alameda County Flood Control and Water Conservation District, City of Livermore, City of Pleasanton, and Valley Community Services District (now Dublin San Ramon Services District). The report discussed various plans for the management of surface water, groundwater, and wastewater treatment and disposal. Numerous other wastewater management studies were subsequently conducted in the 1970's leading to construction of the LAVWMA export pipeline in 1980. These studies and later ones were summarized in the report "Wastewater Disposal and Reuse Alternatives for the Livermore-Amador Valley 1960-1995" (EOA, July 1995).

In 1982, a wastewater management plan was prepared for Zone 7 that included wastewater and recycled water management policies for the unsewered, unincorporated area of the Alameda Creek watershed above Niles. It also addressed salt and nitrate loading impacts from septic tanks in these rural areas (Camp Dresser & McKee, 1982). The U.S. Geological Survey, working cooperatively with Zone 7, conducted three investigations of surface and groundwater quality and the impacts thereon of wastewater discharges in the late 1970's and early 1980's (USGS Water Resources Investigations Reports 81-46, 82-4100, 84-4352). During this decade, following 118-2, the USGS supervised the construction of new monitoring wells and the establishment of a groundwater and surface water monitoring network. Zone 7 staff working with the USGS staff developed techniques for the collection of good monitoring data on the quality and quantity of surface and groundwater within the watershed and groundwater basin.

As noted above, the May 1992 Livermore-Amador Valley Water Recycling Study contains a comprehensive summary of the local hydrogeology based on many of the above reports, particularly USGS Bulletin 118-2.

The concept of a central basin or a Main Basin was developed in the 1980's by Zone 7 and others to signify the area of the groundwater basin that contained the majority of usable groundwater storage.

Groundwater flow from the fringe basins was calculated as subsurface inflow to the Main Basin utilizing aquifer properties and groundwater gradients developed from the cooperative studies by DWR and the USGS. The Zone 7 Water Resources section calculates the annual quantity of subsurface inflow to the main groundwater basin for each water year. In 1995, Zone 7 produced an internal memorandum detailing this calculation process for the water years 1974 through 1994. Because it was determined that the majority of the subsurface inflow comes from the Dublin and western Camp sub-basins, the memo focuses on these areas. It was found that the average subsurface inflow in this region of the basin is approximately 1,000 acre/feet per year.

Zone 7 has been monitoring the salt balance of the basin since the mid-1970s and the impacts of recycled water irrigation since the early 1980s. In the early 1980's Zone 7 expanded the hydrologic inventory to include a water quality inventory of the Main Basin. This quantitative inventory of water quality is called the salt balance. The latest annual Zone 7 salt balance report (August 1999) includes salt balance calculations for the basin from 1974-1998 (see Chapter 5).

In 1998, Zone 7 and CH2MHill developed a calibrated groundwater flow and solute transport model for the Livermore Valley Groundwater Basin. A summary report documented the calibration parameters and demonstrated the model's usefulness in evaluating basin-wide trends in TDS through time (CH2MHill, 1998). This model utilized the entire historic hydrologic inventory and salt balance inventory records 1974-98 for calibration. In January 1999, CH2MHill and Zone 7 produced an additional memorandum documenting results from using the model to examine 14 salt management strategies for the groundwater basin (see Section 3.8 and Chapter 10).

In 2004, Norfleet Consultants prepared the "Preliminary Stratigraphic Evaluation, West Side of the Main Basin." This study developed updated cross sections in a portion of the Main Basin using sequence stratigraphy, a method of relating the depositional environment of sediments to the stratigraphic framework in which they were deposited. The evaluation included:

- A data quality review of selected Zone 7 existing data,
- A standard presentation format for graphic logs representing lithologic and geophysical data,
- Two cross sections through the study area,
- Sequence stratigraphic analyses to correlate the cross sections, and
- A detailed stratigraphic description to assess the geologic controls on groundwater movement in the Chain of Lakes basin recharge area.

On the cross sections, four stratigraphic sequences were identified: cyan, gray, purple and red (youngest to oldest). Each sequence was marked by a sequence boundary at the base and series of fining upward braided fluvial channels containing sand and gravel with interstratified flood plain and lacustrine clays and silts. The results of the study showed that in the study area, the base of the youngest stratigraphic sequence appears to provide a pathway for groundwater to flow between the recharge basins and the underlying shallow aquifers (<250 feet below ground surface). However, no direct pathway was observed between the recharge basins and the deeper aquifer units in the study area.

3.3 Groundwater Basin Overview

The Livermore-Amador Valley Groundwater Basin is contained in the Livermore/Amador/Dublin Valley area (herein called the Livermore Valley, but also sometimes known as the Tri-Valley).

3.3.1 Physiographic Description

The Livermore Valley, an inland structural basin, is located in northeastern Alameda County (Figure 3.1). It is surrounded primarily by north-south trending faults and hills of the Diablo Range. The valley extends approximately 14 miles in an east-west direction and varies from three to six miles in width. It is separated from San Francisco Bay by several northwesterly trending ridges of the California Coast Ranges including the Pleasanton Ridge. The valley floor slopes gently west and southwest from an elevation of approximately 700 feet above sea level in the east to approximately 320 feet above sea level in the southwest.

Six principal streams flow into and/or through the valley, and join in the southeast where the Arroyo de la Laguna flows out of the valley. The other five arroyos are essentially tributaries to the Arroyo de la Laguna:

- Arroyo Valle,
- Arroyo Mocho,
- Arroyo Las Positas,
- South San Ramon Creek?
- Tassajara Creek, and
- Alamo Creek.

Average precipitation rates range from 16 inches per year at the valley floor to over 20 inches per year in the southeast and northwest portions of the valley.

3.3.2 Geologic Description

Structural uplift of the entire Coast Ranges occurred during the late middle Pliocene & Pleistocene causing extensive folding and faulting of the region. The Livermore Valley, a structural valley formed by a faulted, asymmetric syncline, was created as a result of downwarping of the Miocene-Pliocene sandstones and conglomerates between the western bordering Calaveras Fault and the eastern bordering Greenville Fault. Continued deposition, uplift, and faulting have led to the current Livermore Valley stratigraphy (DWR, 1964b, 1974; Crane, 1988; Hall, 1958). The majority of the valley consists of the following three types of geologic units (presented from youngest to oldest).

Valley Fill/Quaternary Alluvium - The valley is partially filled with Pleistocene-Holocene age (recent alluvium) alluvial fan, stream and lake deposits, which range in thickness from a few feet along the margins to nearly 400 (and possibly 800) feet in the west-central portion. The alluvium consists of unconsolidated gravel, sand, silt, and clay. This alluvium, most likely consisting of reworked Livermore Formation, was deposited and heavily influenced by the alluvial deposition of ancestral and recent streams, including Alamo Creek, Arroyo del Valle, Arroyo Las Positas, Arroyo Mocho, South San Ramon Creek, and Tassajara Creek.

The southern region of the Livermore Valley is the most important groundwater recharge area and consists of mainly sand and gravel that was deposited by the ancestral and present Arroyo del Valle and Arroyo Mocho. The eastern and northern regions of the valley contain thinner deposits and consist of alternating layers of gravel, sand, silt, and clay that are laterally discontinuous and resulted from the deposition of smaller streams. The western region of the valley has extensive gravel layers alternating with thick clay beds totaling approximately 400 feet in thickness. The alternation of sand/gravel layers and silt/clay layers form the basic aquifers for the area (CDWR, 1966, 1974).

Livermore Formation - The Livermore Formation consists of beds of clayey gravels and sands, silt, and clay that are unconsolidated to semi-consolidated and estimated to be 4,000 feet thick in the southern and western portion of the basin (DWR, 1964b). These sediments are exposed along the south flanks of the valley in the uplands, and exhibit bed dips 5 to 25 degrees toward the northeast in the Livermore Uplands. In between, the geologic contact between the recent alluvium and the underlying Livermore Formation is not discernable from drill cuttings in the central part of the valley because the formation materials are similar. Groundwater from this formation is sodium bicarbonate in nature and of moderately good quality.

Tassajara and Green Valley Formations - The Tassajara and Green Valley Formations, located uplands north of the valley, are roughly Pliocene in age and were deposited under both brackish and freshwater conditions. They basically consist of sandstone, tuffaceous sandstone/siltstone, conglomerate, shale, and limestone. Beds typically dip 60 to 80 degrees toward the south or north in the Tassajara Uplands. These formations are bordered on the northeast by Marine sediments and are overlain to the south by the Livermore Formation. Because of low groundwater yields, the use of these formations is limited to residential or basic agricultural uses.

3.3.3 Hydrologic Inventory

It is a common misconception that the Livermore Valley Groundwater Basin is a "closed" basin. In the late 1800s, the pre-development groundwater levels in the basin created a gradient causing groundwater to flow from east to west and naturally exit the basin as surface flow in the Arroyo de la Laguna. In the early to mid-1900s, groundwater began to be extracted in appreciable amounts causing groundwater levels to drop throughout the basin. At that time, groundwater levels dropped below the point where groundwater would naturally rise into the Arroyo de la Laguna and exit the basin through stream flow. This was the closest the Main Basin came to being, by definition, totally enclosed. Surface application of extracted groundwater through irrigation and septic systems reintroduced the groundwater to the system with minimal outflow at the Arroyo de la Laguna.

Since that time, additional development has required increased import of surface water and use of groundwater. The groundwater basin cannot be considered "totally enclosed" since water is exported from and recharged into the basin through various means. These include:

- Dewatering and export of mining water from the gravel pits,
- Export of irrigation runoff by streams to the Arroyo de la Laguna, and
- Municipal pumpage plus export of resultant treated wastewater to the bay through the LAVMA pipeline.

The total outflow of water from the basin is on average 20,000 acre-feet per year (this is about 8% of the total groundwater storage: 240,000 acre-feet). Approximately 20,000 acre-feet per year recharges (i.e., inflow) the groundwater basin through percolation of irrigation and stream flow.

The ratio of inflow to outflow will vary depending on precipitation. During drought years outflow increases due to increased pumping. During wet years more imported water is available and used to artificially recharge the basin. Land use also plays an important role total inflow and outflow from the groundwater basin.

As evidenced by the increase in "gaining stream" reaches during seasonal highs, observed groundwater levels have appeared to rise in various parts of the basin. Primarily, these gaining reaches are in the northeastern and western portions of the groundwater basin (Figure 3.3). Reasons for these increases may in part be attributed to urban development, which uses more imported water than groundwater from localized wells. Urban development also increases applied water recharge due to landscape irrigation.

3.4 Occurrence and Movement of Groundwater

3.4.1 Definitions

For the purposes of this report, geologic formations will be grouped into one of three categories:

Water Bearing Formations - Water bearing strata represent geologic deposition of quaternary alluvium and portions of the Livermore Formation that are believed to extend beneath the alluvium.

Low Yielding Formations - The Tassajara Formation, Green Valley Formation, and upland areas of the Livermore Formation display lower yields. Groundwater from these formations is sodium bicarbonate in nature and of moderately good quality.

Non-water Bearing Formations - Totally non-water bearing strata consist of Cretaceous to mid-Tertiary marine sediments that do not readily absorb, transmit, or yield water to wells in appreciable amounts. Often, the groundwater that is extracted is of a poor quality sodium bicarbonate-chloride or sodium chloride nature with dissolved solids ranging from 700 to 2150 parts per million (CDWR, 1964b).

Several types of groundwater boundaries are present either along the edges of the basin or within the basin. These boundaries can be categorized into four types:

Barrier - A boundary where there is no hydraulic connectivity between the adjacent aquifer unit. Examples of this boundary may represent movement along a