GSI Water Solutions, Inc., "Technical Memorandum Regarding Potential Effects of Climate Change on Groundwater Supplies for Newhall Ranch Specific Plan, Santa Clarita Valley, California" (March 18, 2008)

Technical Memorandum

To: Susan Tebo – Impact Sciences, Inc.

From: John Porcello – GSI Water Solutions, Inc.

Date: March 18, 2008

Re: Potential Effects of Climate Change on Groundwater Supplies for the Newhall Ranch Specific Plan, Santa Clarita Valley, California

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Introduction

This technical memorandum (TM) evaluates the potential effects of future climate change on the groundwater supplies for the Newhall Ranch Specific Plan (Specific Plan) development. As discussed in the *Newhall Ranch Draft Additional Analysis* (Impact Sciences, 2001), Alluvial Aquifer groundwater wells along the Santa Clara River west of Interstate 5 (I-5) (see Figure 1) will provide 7,038 acre-feet (AF) of water to the Specific Plan development on an annual basis. This water will be provided by converting historical and present-day Alluvial Aquifer groundwater pumping (by The Newhall Land and Farming Company) from agricultural uses to urban uses. Notably, no additional groundwater pumping over historical and present amounts will occur; instead, water currently used to irrigate crops on Newhall Land's property will be treated and used to meet most of the potable water needs of the Specific Plan development's urban uses (e.g., residential; nonresidential; etc.).

GSI Water Solutions, Inc. (GSI) prepared this TM at the request of Impact Sciences, Inc., to specifically address whether future climate change may preclude the Alluvial Aquifer from providing sufficient yield to accommodate the future water demand of the Specific Plan development. The remainder of this TM discusses the following:

- The climate of the Santa Clarita Valley;
- An overview of the current understanding of future potential changes in temperature, annual rainfall, and rainfall timing and intensity (statewide and in southern California);

- The corresponding influence of rainfall and temperature changes on groundwater recharge to the Alluvial Aquifer in the Santa Clarita Valley as understood to date, including ongoing work by the local water purveyors to study this further; and
- A summary of historical data that indicate how the Alluvial Aquifer west of I-5 may be affected in the future (as gathered from records of historical fluctuations in local hydrologic and groundwater conditions).

Local Climate

The climate of the Santa Clarita Valley is discussed by CH2M HILL (2004). The valley has a semi-arid Mediterranean-type climate, characterized by long, dry summers and relatively short, wet winters. Temperatures in the valley range from a minimum of 20 to 30 degrees Fahrenheit (°F) in the winter to a maximum of approximately 100 to 110°F during the summer. Mean monthly temperatures range between approximately 48°F in the winter and 77°F in the summer.

The average rainfall since the 1880s, and also since 1950, has been approximately 18 inches per year, but varies considerably from year to year (ranging from less than 5 inches to nearly 50 inches). Additionally, rainfall is not only variable on an annual basis, but is also highly seasonal. Approximately 80 percent of the annual precipitation in the valley falls between November and March. Most of the precipitation comes from winter storms that last only a few days and are separated by relatively long periods of clear weather. Additionally, as shown in Figure 2, rainfall patterns vary considerably across the watershed because of the considerable variation in topography and the watershed's location between the coastal climates in Ventura County and the inland deserts to the east.

The major sources of natural recharge to Alluvial Aquifer groundwater include deep percolation (infiltration) of direct precipitation within the valley, and percolation of stream runoff flowing into the valley along the Santa Clara River and its tributaries. Recharge occurs primarily in the eastern portion of the valley, as conceptually shown in Figure 3. Natural groundwater discharge occurs primarily in the western portion of the valley (west of Interstate 5 [I-5]), occurring as discharge to the Santa Clara River and evapotranspiration by the riparian vegetation growing along the river corridor.

Global-Scale and Regional-Scale Predictions of Future Rainfall and Temperature Trends

Considerable research and predictive modeling work have been performed by climatologists and other scientists to understand the nature of historic and future global-scale climate changes. The largest body of this work has been conducted under the auspices of the Intergovernmental Panel on Climate Change (IPCC), which has published four comprehensive assessment reports since 1990, with the most recent reports issued in 2007 (IPCC, 2007a and 2007b).

Additionally, in 2006, the California Department of Water Resources (DWR), the California Climate Change Center (CCCC), and the California Climate Action Team (CAT; an inter-agency team managed by the California Environmental Protection Agency) published several studies evaluating the potential effects of climate change on the water resources of the State of California. These California-specific studies focus primarily on the central and northern parts of the state, where rainfall and snowfall provide water to two statewide water delivery systems (the State Water Project [SWP] and the Central Valley Project [CVP]). However, the state studies and other literature do provide some insight as to the nature of potential future climate changes in southern California. The discussion below focuses on the low-elevation mountains and valleys that are characteristic of much of the South Coast Hydrologic Region (as defined by DWR), which includes the Santa Clara River watershed.

As discussed by CCCC (2006a) and Milly (2007), global climate models (GCMs) have not been designed to support hydrologic analysis. The GCMs describe continental water fluxes and processes at very large scales. For example, two GCMs evaluated by Cayan et al. (2008) rely on a grid containing rectangular cells that are 137 to 186 miles long. The use of a discrete global grid renders the GCMs too coarse to adequately depict the complex structure of temperature and precipitation that characterizes and distinguishes each of the DWR Hydrologic Regions. Additionally, the various GCMs that have been developed by the research community and incorporated into the IPCC assessments vary in design and incorporate varied assumptions, thereby providing different results regarding the potential magnitude of future changes in rainfall and temperature in various parts of the world (including southern California).

In general, the GCMs agree that temperatures will continue to rise globally for the next several decades and that longer-term temperature trends will depend on the magnitude of future greenhouse gas emissions. As noted by the IPCC (2007a), the GCMs also predict that precipitation increases are very likely in high latitudes, while decreases are likely in most subtropical regions. However, there is somewhat less agreement among the GCMs regarding future precipitation changes. As explained by CCCC (2006b), the variability and uncertainty in the GCMs arises in part because of uncertainties about the “feedbacks” that might amplify or lessen global warming. For example, as heat-trapping emissions cause temperatures to rise, the atmosphere can hold more water vapor, which traps heat and raises temperatures further—a positive feedback. Clouds created by this water vapor could absorb and re-radiate outgoing infrared radiation from Earth’s surface (another positive feedback) or reflect more incoming shortwave radiation from the sun before it reaches Earth’s surface (a negative feedback). Because many of these processes and their feedbacks are not yet fully understood, they are represented somewhat differently in each GCM.

The GCMs also do not account for elevation-related differences in rainfall and recharge patterns, which are important at the local scale (e.g., DWR-designated hydrologic regions and individual watersheds). To account for the importance of elevation at the local scale, researchers have taken the GCMs and "down-scaled" them to create regional models that estimate the spatial variability in future rainfall and temperature trends in California (CCCC, 2006c; DWR, 2006). The down-scaling process consists of using statistical techniques and local, physically based hydrologic models to "downscale" the GCMs to a finer spatial resolution. This procedure "distributes" the GCM predictions over the complex landscape of California. Because the distribution procedure required to acquire local-scale projections is dependent upon the simulation results from the GCMs, the individual regional models (like their GCM counterparts) also create different projections of future climate trends. Nevertheless, taken together, the GCMs and regional-scale models are useful for understanding the general magnitudes of changes in temperature and rainfall patterns that could occur in the future as a result of global warming.

In summary, the regional-scale climatologic modeling work conducted by DWR, CAT, and CCCC indicates the following:

1. On a statewide basis, the various models indicate that there will be relatively little change in annual precipitation, with a tendency toward slightly greater winter precipitation and lower spring precipitation (CAT, 2006). Dettinger (2005) summarized the primary finding from these same models as follows: "The distribution of precipitation changes includes both positive and negative changes that cluster with little change around present-day averages." CCCC (2006a) notes that the models project that (a) variability in precipitation on a year-to-year and decade-to-decade time-scale will continue, as in the past; and (b) the frequency of warm tropical events (El Niños) will remain about the same, creating anomalous precipitation patterns in California. The models, as a group, also project that summer precipitation will change only incrementally, and may even decrease, indicating that there is little evidence for a stronger summer-time monsoon influence (CCCC, 2006a).

2. For southern California, average annual precipitation during the period 2035 through 2064 is projected to decrease only slightly, probably by less than ¼-inch per year, even under the scenario involving the highest IPCC estimate of future greenhouse gas emissions (DWR, 2006). During this period, average temperatures in southern California are projected to be 1.6 to 4.2°F (0.9 to 2.3°C) higher than present-day temperatures. Although these projections were published in 2006 (DWR, 2006), they are based on GCMs (and subsequent down-scaled regional models) that were developed in support of the IPCC's most recent (fourth) assessment of global climate change (IPCC, 2007a and 2007b).

There is evidence that these projected changes are similar to trends in the recent historical record. Specifically:

1. DWR (2006) discusses an analysis of rainfall records across the state from 1890 through 2002, using data compiled by former state climatologist James Goodridge. The analysis

indicates that average annual precipitation on a statewide basis appears to be relatively flat (no increase or decrease) over the entire record. However, the report notes that an upward trend in statewide precipitation may have occurred toward the latter portion of this period. The analysis also identified a very slight decrease in annual precipitation from 1890 through 2002 for both central California and southern California (amounting to about 0.77 inch during a 100-year period).

2. A statistical analysis of water-year (October through September) and April-July flows of four rivers in central-coast and south-coast watersheds found no statistical changes in flow in any of these rivers (DWR, 2006). This analysis included two river systems in metropolitan Los Angeles – the Santa Ana River (based on data from 1901 through 2005) and the Arroyo Seco near Pasadena (based on data from 1911 through 2005). The lack of statistically identifiable changes in the flows of these rivers is consistent with the slight decrease, if any, in southern California annual rainfall that has occurred since 1890.

While the historical data and the projections from GCMs and regional-scale climate models together suggest that a slight decrease in annual rainfall could occur, the possibility that rainfall could increase slightly also cannot be ruled out completely. DWR (2006) notes that the National Weather Service's Climate Prediction Center found evidence that annual precipitation has increased in much of California, the Colorado River Basin, and the West since the mid-1960s. Additionally, some GCMs have suggested that annual average rainfall could increase slightly in southern California (Bachelet et al., 2007, using analyses by Price et al., 2004).

Rainfall Timing and Intensity

Of equal, if not greater, importance to the question of how global climate change potentially could affect aquifer recharge is the timing and intensity of precipitation. As described by CH2M HILL (2004) and CH2M HILL and LSCE (2005), rainfall in the Santa Clarita Valley and southern California occurs predominantly during the winter months, and most groundwater recharge, therefore, occurs during that time of year. Most of the recharge to the Alluvial Aquifer occurs along the Santa Clara River corridor in the eastern part of the valley below the Lang stream gage – several miles east of the Specific Plan development (see Figures 1 and 3). During low flow events, recharge and river flow may occur only a short distance below the Lang gage, whereas during high flow events the river can recharge the groundwater as far downstream as the area between the Saugus water reclamation plant (WRP) and I-5. This recharge occurs mainly in response to heavy rainfall events that are sufficiently strong to create flow in the ephemeral reaches of the Santa Clara River (in the eastern part of the valley). This periodic river flow is an important source of recharge to the Alluvial Aquifer and occurs in some, but not all, years. The historical record shows several multi-year periods of little to no river flow (for example, 1984 through 1991 and 1999 through 2004), followed by brief periods of very high river flows and rapidly rising groundwater elevations in the eastern part of the valley where most of the recharge takes place (as occurred in 1992, 1993, 1998, and late December 2004 through January 2005).

On a global scale, the IPCC's most recent assessment (2007a) concluded that the frequency of heavy precipitation events and/or the proportion of total rainfall from heavy events has "likely" increased over most areas since 1960 and is "a very likely" trend for the 21st century. As discussed previously, CCCC (2006a) concluded that there will continue to be variability in California's precipitation on a year-to-year and decade-to-decade time-scale, as has been observed in the past. DWR (2006) concluded from a statistical analysis of the 1890-2002 historical statewide precipitation data that an increase in the variability of annual precipitation has occurred in the historical record and is a possible continued outcome of global climate change in the future. This finding by DWR was based on a 10-year moving average of mean and standard deviation values for statewide annual average precipitation, which showed end-of-period variability values about 75 percent larger than beginning-of-period values. This indicates that there tended to be more extreme wet and dry years at the end of the 20th century than occurred at the beginning of that century. DWR concluded that this trend may continue with on-going climate change.

DWR (2006) also noted that river flow records show evidence of a change in variability, as manifested by changes in flood flows (which are related to rainfall intensity). Specifically, from examination of streamflow records in another South Coast Basin watershed (the Santa Margarita River near Temecula), DWR found that the 10-year, 50-year, and 100-year flood flows have increased about 22 percent since 1955. Because this river and its watershed are in the same DWR hydrologic region as the Santa Clara River, this may be an indicator that the increasing variability and intensity of rainfall have begun creating larger high-flow events in rivers in southern California, and that this trend may continue in the future (including in the reach of the Santa Clara River that passes through the Santa Clarita Valley). The importance of river flows on groundwater recharge is discussed below.

<u>Potential Effects on Groundwater Recharge (Current Knowledge and Ongoing Studies)</u>

On a watershed scale, the amount of surface water runoff and groundwater recharge generated by individual storm event is controlled primarily by soil infiltration capacity, soil moisture levels, and evapotranspiration (ET) demands. ET consists of evaporation (vaporization) of water from soil and wet plant surfaces, and water uptake and subsequent transpiration by plants. DWR (2006) states that there are two reasons it is difficult to accurately estimate the effect of changes in global temperature on ET. First, no net change in ET will occur as long as the minimum temperature and dew point temperature continue to increase faster than the maximum temperature, as has occurred during the past five decades of global temperature rise. Second, the effect of increased air temperature on plant transpiration is at least partially offset by the increasing CO_2 concentrations that arise from increasing greenhouse gas emissions. Although these observations would suggest that ET demands could be small, it is also possible that ET demands could increase over time because of lengthening of the dry season and the corresponding decrease in the length of the rainy season.

Dettinger and Earman (2007) and Milly (2007) indicate that in general, a reduction in precipitation in the western United States would be expected to reduce runoff, which in turn potentially would decrease groundwater recharge as well. Milly (2007), citing a report by Milly et al. (2005) that discusses global-scale patterns of trends in streamflow and water availability, provides a map of the United States indicating that 90 percent of the GCMs predict decreases in annual runoff of 10 to 20 percent in California, Nevada, Utah, and western Colorado during the period 2041 to 2060, compared with runoff during the period 1900 through 1970.

Christensen and Lettenmaier (2007) down-scaled 11 GCMs to create corresponding regional-scale models for the Colorado River Basin, then used these models to project runoff trends in the basin for two future greenhouse gas emissions scenarios. They projected that on a basin-wide basis: (1) a 10 percent decrease or increase in winter-time rainfall would result in a 13 percent decrease and a 15 percent increase, respectively, in winter-time runoff; and (2) a 10 percent decrease or increase in summer-time rainfall would result in a 7 percent decrease and an 8.5 percent increase, respectively, in summer-time runoff. However, these researchers, as well as Dettinger and Earman (2007), point out that future changes in runoff could differ considerably for mountain ranges versus the alluvial fans and groundwater basins that lie below. This is because global warming would create more rain than snow, thereby reducing the amount of high-elevation snowpack available to recharge mountain groundwater supplies and instead creating unrecharged water that may run off into the fans and basins below. This potentially could increase recharge on fans and basin floors. Alternatively, if the unrecharged water is instead mostly evapotranspired from the mountain soils, then the overall recharge (mountain plus basin) may decline.

Because the boundaries of the Santa Clara River watershed lie in low-elevation mountains, rainfall is a far more significant contributor to the flow of this river than snowfall. Consequently, rainfall runoff from these mountains and from within the Santa Clarita Valley and other valleys can be expected to continue to be the predominant source of flow to the river, and therefore the predominant source of groundwater recharge. Additionally, future groundwater recharge potentially may increase because most recharge occurs during high-rainfall storm events, and climate change may intensify these events. However, the magnitude of potential increases or decreases in recharge is difficult to project.

Dettinger and Earman (2007) conclude that, in general, it is unknown whether groundwater recharge will increase, decrease, or stay the same “at any scale” in the western United States; and, while groundwater supplies may fare well, they also may fare poorly. They conclude that, in general, the tools and data are currently unavailable to allow for confident detection or prediction of groundwater responses to changes in climate. While this may be true in some locations, the water purveyors in the Santa Clarita Valley have a considerable “head start” on this process. Specifically:

- The agricultural and urban water purveyors in the valley have monitored groundwater levels and pumping volumes for many years. This monitoring began in the1940s, when groundwater was pumped exclusively for agricultural purposes, mainly in the western portion of the valley, and mainly from the Alluvial Aquifer. The historical record illustrates how the aquifer systems in the valley have responded over time as groundwater pumping has expanded to include urban uses, with the urban pumping extending into other portions of the valley, as well as into a deeper aquifer system (in the Saugus Formation).

- Rainfall and streamflow records are available in the valley, dating back to the early 1900s. These records have provided important information that the local water purveyors have used to understand the relationship between rainfall, streamflow, and groundwater recharge.

- In 2004, the local water purveyors completed the calibration of a detailed numerical model of the valley's groundwater systems, using the historical data for 1980 through 1999 to calibrate the model. The calibration process, described by CH2M HILL (2004), consisted of adjusting model parameters until the model was able to replicate the time-varying nature of groundwater elevations and streamflows across the valley. A later update (check) of the model's calibration identified that the model also was capable of simulating the hydrologic conditions that were observed from 2000 through 2004 (CH2M HILL, 2005).

The process of calibrating the groundwater model resulted in the derivation of a rainfall-runoff relationship for the Santa Clarita Valley. This relationship, shown in Figure 4, was developed for annual rainfall and runoff, and is based on a relationship derived by Turner (1986) for a large number of watersheds in California. Through the model calibration process, the empirical parameters contained in this relationship were adjusted to improve the model's simulation of recharge patterns and historic groundwater elevations and river flows. As shown in Figure 4, according to the final relationship that was established from this model calibration process, little recharge occurs when annual rainfall is less than 15 inches per year; recharge for the average rainfall of 18 inches per year is only about 2 inches per year; and years with rainfall of 32 inches or more can produce 10 inches per year or more of recharge (for example, as much as 20 inches per year of recharge can occur when rainfall is 45 inches).

During 2008, the local water purveyors will use this model to further evaluate how to manage pumping from the local groundwater system while maintaining its sustainability and will address in more detail the effect of global climate change on rainfall and recharge in the Santa Clarita Valley. Meanwhile, the historical record of rainfall, streamflows, and groundwater elevations in the Santa Clarita Valley provides evidence of how the Alluvial Aquifer has responded to other changes in the hydrologic system in the past. This evidence, which is discussed below, provides insight as to how the portion of the Alluvial Aquifer along the Santa Clara River corridor west of I-5 may respond to future changes in rainfall and recharge.

Evidence from Historical Fluctuations in Local Hydrology and Groundwater Conditions

Before 1970, agriculture was the predominant land use in the Santa Clarita Valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during the 1950s and early 1960s ranged from 35,000 to 44,000 AF per year (AF/yr). Pumping from the Alluvial Aquifer dropped gradually from 40,000 AF/yr in 1967 to less than 30,000 AF/yr by 1983, and did not rise above 30,000 AF/yr again until 1993. Since then, pumping has ranged between about 33,000 and 43,000 AF/yr, and has averaged slightly less than 38,000 AF/yr.

Figure 5 shows trends in groundwater elevations since 1950 in two Alluvial Aquifer wells (NLF-C5 and NLF-C7) located near the western end of the basin (just west of I-5) and two Alluvial Aquifer wells (VWC-N and NLF-S) located 2 to 3 miles east of I-5. The charts in Figure 5 show how Alluvial Aquifer groundwater levels have varied in comparison with fluctuations in Alluvial Aquifer pumping, rainfall, municipal WRP discharges to the Santa Clara River, and seasonal low flows in the river. The charts show the following:

- In the area west of I-5, including the locations of Alluvial Aquifer wells that will provide water to the Specific Plan development, groundwater in the Alluvial Aquifer discharges to the river and is consumed by riparian vegetation located along the river corridor. Additionally, deeper Saugus Formation groundwater discharges to the overlying Alluvial Aquifer. Because this area is a regional groundwater discharge zone for the Saugus Formation (as illustrated in Figure 3), Alluvial Aquifer groundwater levels in this area have been relatively stable over time with only modest seasonal fluctuations, as shown by the hydrographs for wells NLF-C5 and NLF-C7. This stability has occurred despite annual variations in rainfall, increased WRP discharges to the river, and the corresponding increases in the river baseflow (which is displayed in Figure 5 as the flow during the lowest-flow month of each year).

- In the area just east of I-5, Alluvial Aquifer groundwater levels are more variable on a seasonal basis as shown in Figure 5 by the hydrographs for two Alluvial Aquifer wells (VWC-N and NLF-S) that are located in this area. Additionally, groundwater elevations in these wells rose as pumping decreased from the mid-1960s through the 1980s, then were relatively stable during the 1990s despite increased pumping from the Alluvial Aquifer.

The historical hydrographs for these four wells provide insight as to the potential future effects on the aquifer system of climate change-induced variations in groundwater recharge. Specifically, the figures show the historical effect on the Alluvial Aquifer of marked changes in groundwater pumping and surface water flows that began during the 1960s and continue to this day. The hydrographs show that Alluvial Aquifer groundwater levels west of I-5 have shown little variation over time despite the following changes to the hydrologic system in the valley:

1. Decreased pumping upstream east of I-5 in the 1970s and 1980s, followed by increased pumping in this reach during the 1990s;

2. Fluctuations in annual rainfall;

3. Introduction of treated water discharges to the Santa Clara River during the 1960s and the steady increase in these flows since that time; and

4. Resulting increases in river flows, including summer-time (seasonal low) flows, since the 1960s.

In summary, Alluvial Aquifer groundwater levels along the Santa Clara River corridor west of I-5 are controlled less by pumping than by the discharge of Saugus Formation groundwater into the Alluvial Aquifer. This, in turn, indicates that groundwater levels in this portion of the groundwater system are relatively insensitive to changes in recharge compared with other portions of the valley. As discussed by CH2M HILL (2004), even the remainder of the valley historically has not shown long-term water level declines. Specifically, hydrographs in these areas indicate that after an extended drought and high rates of pumping, Alluvial Aquifer groundwater elevations recover very quickly when normal or above normal rainfall patterns return. Because the western part of the Alluvial Aquifer system (where some of the historical pumping would be converted from agricultural to urban water supplies for the Specific Plan development) occupies the regional groundwater discharge zone in the valley, it is unlikely that significant changes will occur to the aquifer system in this area, especially given that the climate projections indicate a continuance of the periodic large storm events that recharge the groundwater system in the valley.

Conclusions

The historical hydrograph records indicate that the groundwater resources in the western portion of the Santa Clarita Valley are relatively unaffected by local fluctuations in rainfall. Instead, as discussed in detail by CH2M HILL (2004) and CH2M HILL and LSCE (2005), the available data and groundwater modeling simulations indicate that rainfall fluctuations primarily affect groundwater levels and groundwater availability in the easternmost portion of the valley, where most of the recharge occurs to the Alluvial Aquifer. Consequently, if rainfall and groundwater recharge rates were to decline in the future because of climate change, these changes are likely to be fairly small as indicated by the various climatologic studies (discussed previously in this TM) that have been conducted by the various California state agencies involved in water resources management and planning. For this reason, and also because of the well-developed understanding to date of the valley's hydrology and its shallow and deep aquifer systems, it is anticipated that only minor fluctuations in groundwater levels will occur in the Alluvial Aquifer west of I-5, and that these fluctuations will not reduce the availability or sustainability of Alluvial Aquifer groundwater in this area.

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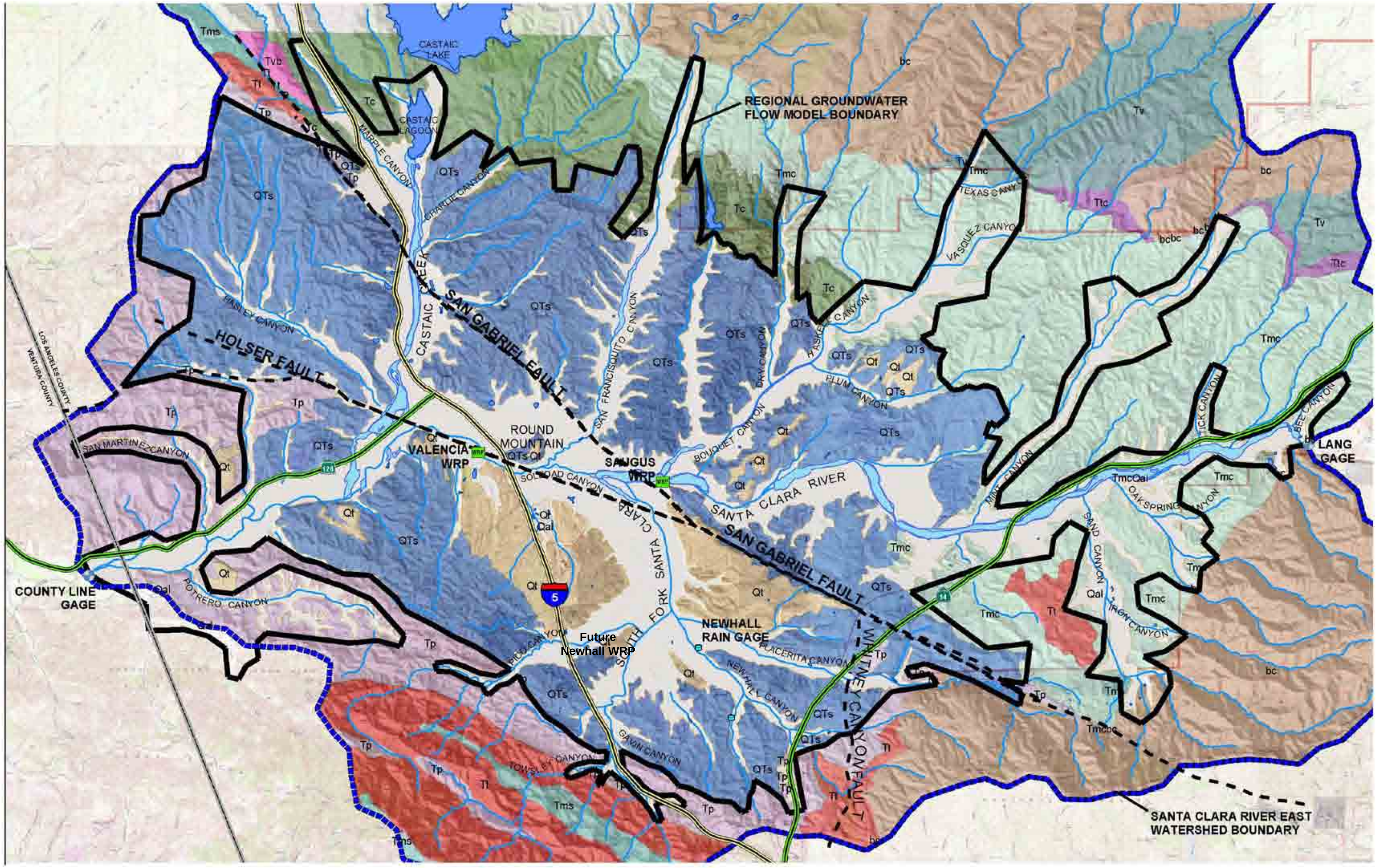

Newhall Ranch

Santa Clarita

Ventura County

Los Angeles County

LEGEND

NEWHALL RANCH

VALENCIA WATER COMPANY MUNICIPAL WELLS FOR NEWHALL RANCH

GEOLOGY

UNDIFFERENTIATED ALLUVIUM (Qal)

TERRACE DEPOSITS (Qt)

SAUGUS FORMATION (QTs)

PICO FORMATION (Tp)

TOWSLEY FORMATION (Tt)

MODELO FORMATION (Tms)

CASTAIC FORMATION (Tc)

VIOLIN BRECCIA (Tvb)

MINT CANYON FORMATION (Tmc)

TICK CANYON FORMATION (Ttc)

VASQUEZ FORMATION (Tv)

UNDIFFERENTIATED BASEMENT COMPLEX (bc)

HYDROGRAPHY

LAKE

STREAM

STREAM GAGE

MAJOR ROAD

INTERSTATE

STATE HIGHWAY

0 9,000 18,000 27,000 feet

N

Figure 1

Santa Clarita Valley Geologic Map

Newhall Land and Farming Company

GSI Water Solutions, Inc.

Prepared From Map By
CH2M HILL (2004)

March 2008

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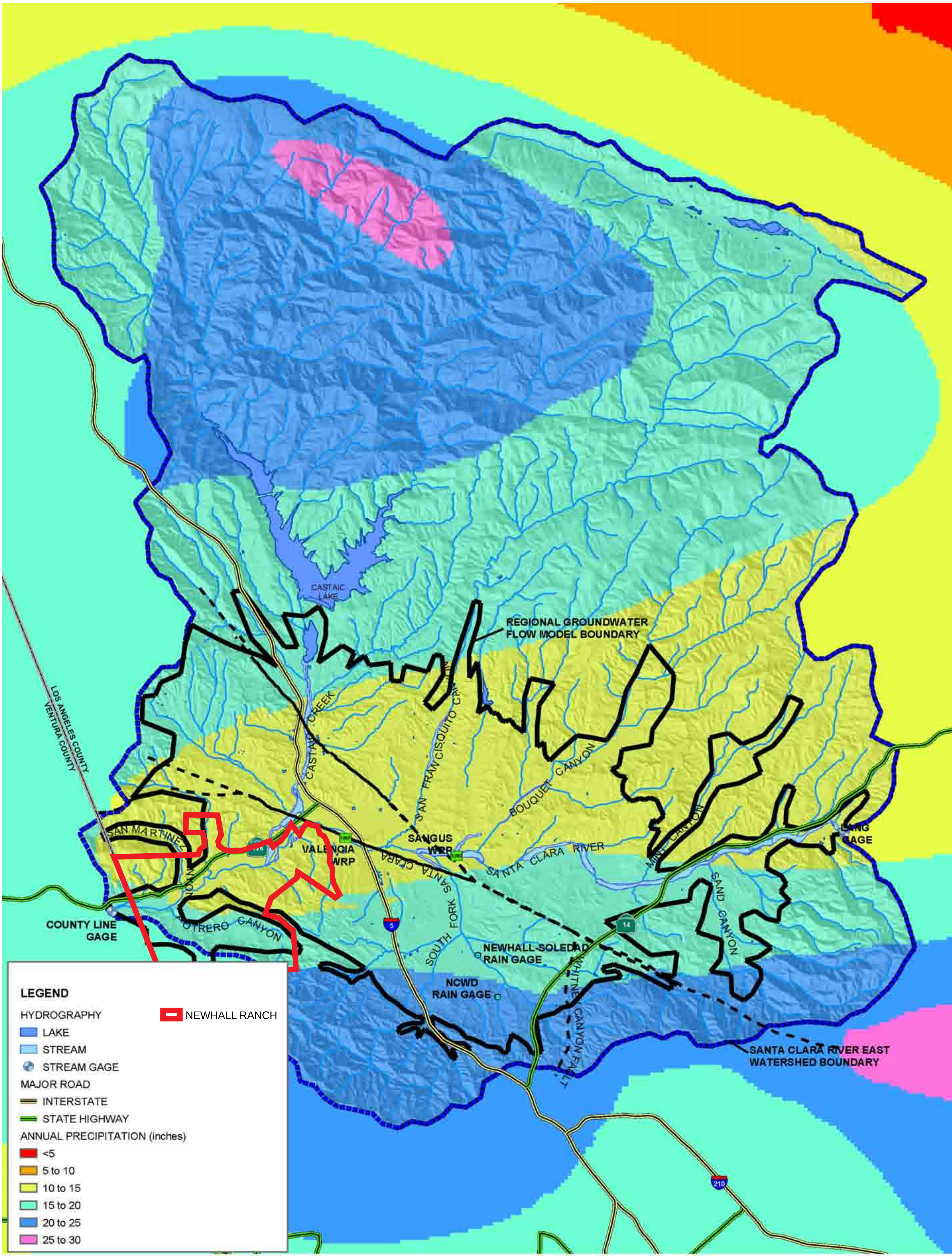

N

0 2.5 5 miles

Figure 2

Isohyetal Map Showing Average Annual Precipitation Pattern From 1900 to 1960

Newhall Land and Farming Company

GSI Water Solutions, Inc.

Prepared From Map By CH2M HILL (2004)

March 2008

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Newhall Ranch Specific Plan

Figure 3

Schematic Cross-Section Showing
Santa Clarita Valley Hydrology

Newhall Land and Farming Company

GSI Water Solutions, Inc.

Prepared From Figure
By CH2M HILL (2004)

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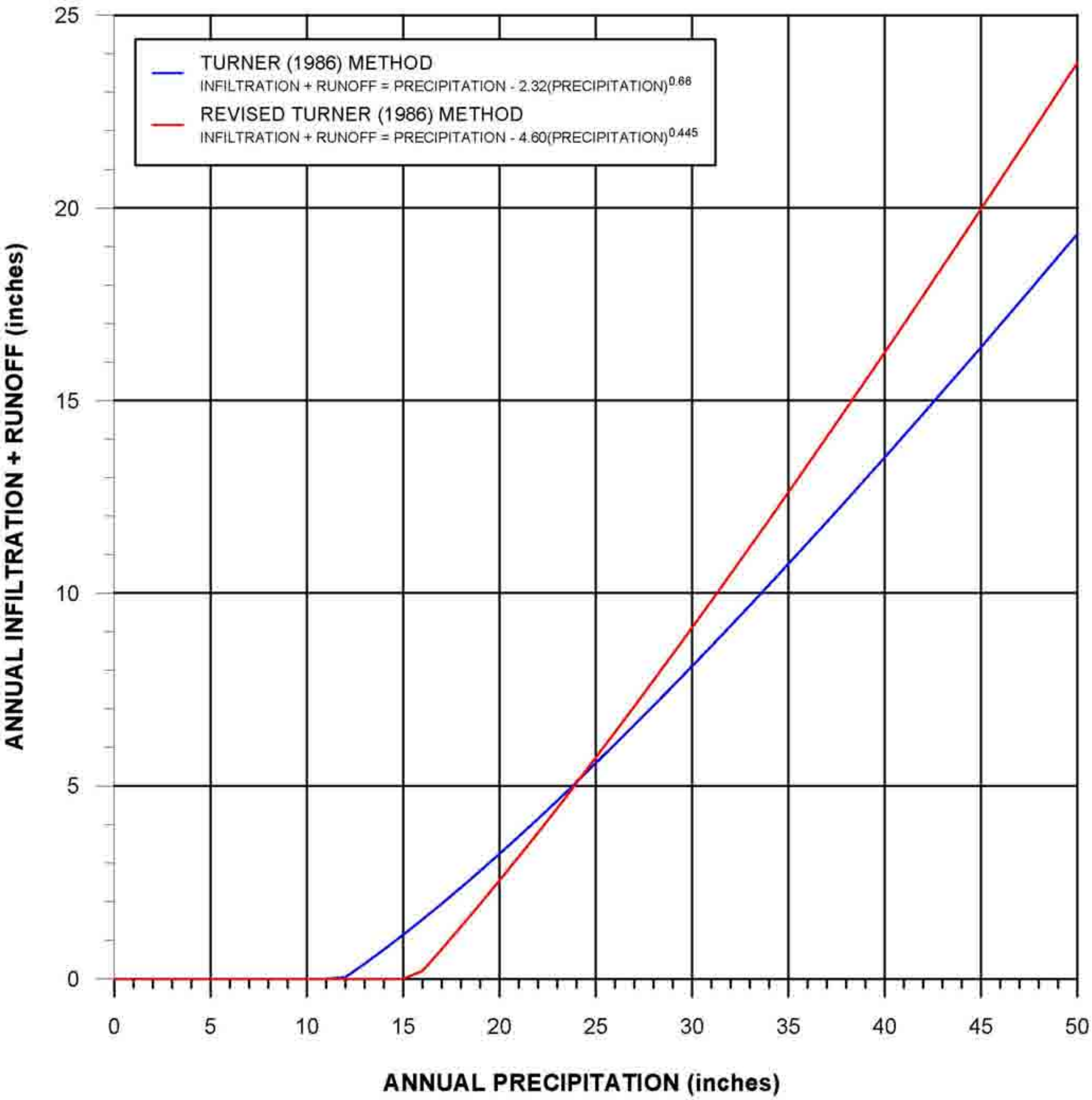


Figure 4

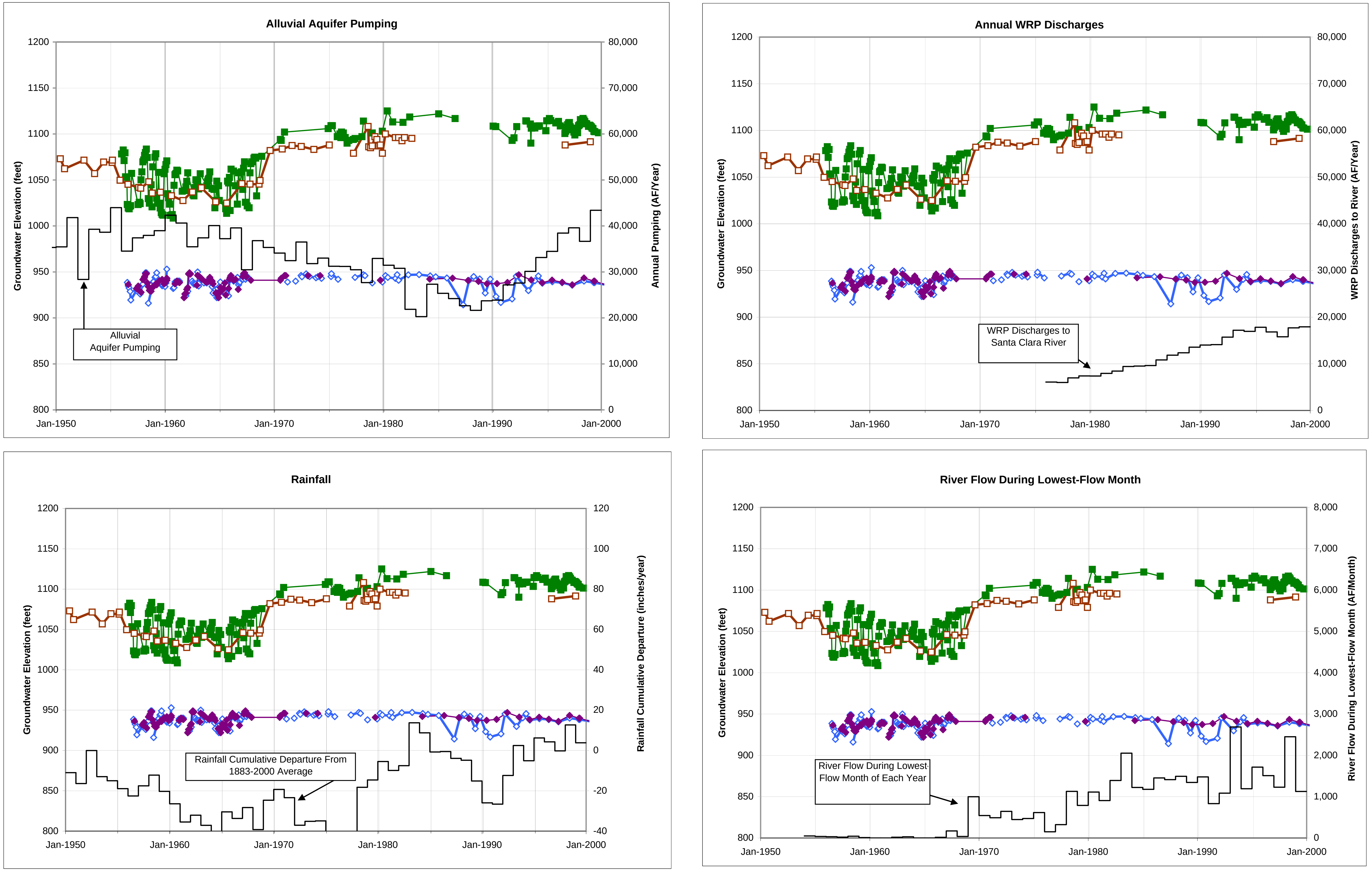
Infiltration and Runoff as a Function of
Precipitation in the Santa Clarita Valley

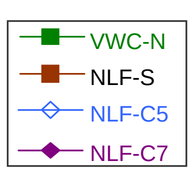
Newhall Land and Farming Company

GSI Water Solutions, Inc.

Prepared From Figure
By CH2M HILL (2004)

March 2008





NOTE: Wells VWC-N and NLF-S are Just east of I-5, near the mouth of the South Fork Santa Clara River. Wells NLF-C5 and NLF-C7 are west of I-5 and east of the Log Angeles/Ventura County line. WRP = water reclamation plant.

Figure 5

Alluvial Groundwater Elevations versus Groundwater Recharge and Discharge Mechanisms (1950-2000)

Prepared from figures by CH2M HILL (2004).