HYDROGEOLOGIC
INVESTIGATION FOR "SAFE YIELD"
PINE MEADOW
RIVERSIDE COUNTY, CALIFORNIA

Prepared for:

Lake Hemet Municipal Water District
26385 Fairview Avenue
P.O. Box 5039
Hemet, CA 92544

GSi/water
520 Mission Street
South Pasadena, California 91030
(626) 441-0039

September 24, 2007

PROJECT TEAM

Mark Pratt	Data Collection, Analysis, Report and Graphics
Eric Aguilar	Data Collection, Analysis, Report and Graphics
Hector Hernandez	Graphics
Angelica Amezquita	Production

Under the Supervision of:

____
E.T. Gorman
Senior Geologist
GSi/water

____
J. H. Birman – PG 994; HG 125
President
GSi/water

CONTENTS

APPENDICES

REFERENCES USED

Bookman-Edmonston Engineering, Inc., 1970, Details of Test Well Drilling Program in the Pine Meadows Ground Water Basin.

Crippen, J.R., 1965, Natural Water Loss and Recoverable Water in Mountain Basins of Southern California, USGS Professional Paper 417-E.

Dibblee, T, 1981, Geologic Map of the Idyllwild (15 Minute) Quadrangle, California; South Coast Geological Society, Santa Anna, California.

Durbin, T.J., 1975, Ground-water Hydrology of Garner Valley, San Jacinto Mountains, California – A Mathematical Analysis of Recharge and Discharge, USGS Open-File Report 75-305.

Fetter, C.W., 1994, Applied Hydrogeology, 3rd ed.: Prentice Hall, Upper Saddle River, New Jersey.

Fraser, D.M., 1931, Geology of San Jacinto quadrangle south of San Gorgonio Pass, California, California Division of Mines, Mining in California, v. 27, no. 4, p. 494-540.

Freeze, R.A. & Cherry, J.A., 1979, Groundwater.:Prentice Hall, Englewood Cliffs, New Jersey.

GSi/water, April 2004, Ground Water Resource Evaluation, Pine Meadow, Riverside County, California: Prepared for Lake Hemet Municipal Water District.

Guay, J.R., 2002, Rainfall-Runoff Characteristics and Effects of Increased Urban Density on Streamflow and Infiltration in the Eastern Part of the San Jacinto River Basin, Riverside County, California, USGS Water-Resources Investigations Report 02-4090.

Sharp, R.V., 1967, San Jacinto Fault Zone in the Peninsular Ranges of Southern California, Geological Society of America Bulletin, v. 78, p. 705-730.

United States Geological Survey, topographic map (scale: 1:24,000): Anza, Calif.quadrangle, 1996; Butterfly Peak, Calif. quadrangle, 1996; Idyllwild, Calif. quadrangle, 1981; Palm View Peak, Calif. quadrangle, 1996.

Internet Resources:

Clackamas County Soil and Water Conservation District, 2003. www.cc-swcd.org - Pasture irrigation data.

Equine Nutrition Center, 2003. www.equinenutritioncenter.com - Equine water consumption data.

Microsoft Terraserver, 2003. www.terraserver-usa.com - Aerial photographs and digital topographic maps.

ABSTRACT

<u>Background</u>

Since 1995 the long-term trends of precipitation and the static water levels in the District's wells have been declining. This suggests that in the context of "safe yield", ground water production from Pine Meadow should not be significantly increased.

There are two specific objectives within the definition of "safe yield" as applied for this project. These are (1)pumping from an aquifer must be sustainable; and (2) the pumping must not impair the quality of the native ground water.

Sustainable means that pumping over the long term will not exceed the amount of natural recharge by withdrawing water from storage. Impairing water quality can take place by pulling in poor quality water by pumping from deep storage; from some faulting; or from some local meadow deposits.

Five wells owned by the District were available for this study, of which four are active. Of the others, one is an inactive test well, and the other is an inactive well due to sulfurous taste and smell. Drillers logs were available from the five wells.

The wells available to us are too few in number, and their distribution is such that they cannot accurately represent the quantity and quality of the ground water throughout the extent of the Pine Meadow valley floor. Accordingly the "safe yield" analysis had to be broadened to include not only the climate, the geology, well construction, pump records and test data, and downhole temperature gradient; but also analysis of the ground water recharge to and the discharge from the valley floor.

<u>Information and Available Data</u>

The aquifers from which most of the wells produce are from two porous media sedimentary formations: (1) geologically younger Quaternary alluvium, and (2) older Quaternary/Tertiary alluvium and other sedimentary deposits. The older alluvium is known as the Bautista Formation that forms prominent terrace deposits around the margins of the Valley and also underlies the younger alluvium.

In general the younger formations are the better aquifers, and all the District's wells are set in the young Quaternary formation. The wells may be deep enough to extend into the underlying Bautista Formation, but the two formations cannot be distinguished in the drillers logs.

A third potential aquifer is the bedrock that surrounds and underlies the sedimentary aquifers. Where sufficiently fractured, the bedrock can also be an aquifer. Fractured bedrock generally produces at a small fraction of the production rates of the sedimentary aquifers. However, at Pine Meadow, shattered bedrock may provide an additional source, as discussed in the report.

Test pumping the wells provides information that helps to interpret the water quantity, water quality, and sustainability. To reliably define these parameters would have demanded a longer program of testing than could be done within this project; would require long periods of shut-down and recovery

of the wells; and would likely demand removal of the pumps for videologging.

Also with enough information it is possible to know the depth, shape, and lateral "reach" of the cone of depression that forms around each well during pumping. The shapes of the cones of depression indicate how far apart the wells have to be spaced in order not to interfere with each other. To accurately define the cones of depression, there needs to be an observation well near each production well -- almost never done when a well is constructed. Unfortunately, although there are rough approaches, accurately defining the cone of depression demands an observation well near each production well, which was not within the scope of the project.

The data from the wells were useful, but not sufficient to provide an accurate assessment of "safe yield". Moreover, with a larger scope of this project using just the wells, it would still be necessary to characterize the ground water systems within the broader reach throughout the margins of the Pine Meadow valley floor away from the existing wells.

<u>*Independent Approaches*</u>

We therefore augmented the analysis for "safe yield" with two independent approaches: (1) an estimate of the amount of infiltration that may be recharging the ground water from the precipitation that falls throughout the Pine Meadow watershed; and (2) an application of Darcy's Law to assess the amount of ground water that may be flowing toward Lake Hemet out of the sedimentary formations that underlie the valley floor of Pine Meadow.

Each of these approaches is based on assumptions that we have had to make regarding the geologic conditions and the hydrologic processes of the Pine Meadow watershed and the valley floor. The accuracy of these assumptions is based on the available data, which in turn determine the accuracy of the "safe yield" as defined in this project.

From the two types of analysis and within the scope of this investigation, we derived values for the amount of ground water entering and leaving the recharge to Pine Meadow valley floor. ***The numbers and derivations that follow are approximate:***

<u>*Infiltration*</u> *1,028 acre ft per year*

This estimates the amount of recharge ***<u>to</u>*** *the ground water beneath the Pine Meadow valley floor.*

From this number it is necessary to subtract the amount of pumping from the valley floor (about 583 acre ft per year including the District pumping in 2006 and an estimate of private pumping in that year). Normally it would be necessary to remove the amount of loss from natural evapotranspiration, but that was assessed during the analysis of infiltration through the entire watershed.

We also estimated the amount of recycling from the 583 acre ft per year from pumping. The water from pumping includes losses to its own evapotranspiration and runoff, and some infiltration into the ground. For natural infiltration and evapotranspiration throughout the watershed we used 10%

of the water that falls on or runs onto the young Alluvium that covers the valley floor. For internal consistency we also use 10% for infiltration of the amount of water pumped, or 58 acre ft per year.

This leaves for the <u>*Infiltration*</u> *analysis:*

> *(1,028 recharge to the Pine Meadow valley floor) - (583 pumping) + (58 recycling from pumping) =* ***503 acre ft per year (the approximate surplus of ground water leaving the Pine Meadow watershed)****.*

<u>*Darcy's Law*</u> *137 acre ft per year*

This estimates the amount of ground water moving ***<u>out</u>*** *from beneath the Pine Meadow valley floor. Darcy's Law represents the amount of outflow after all the ground water processes that have been going on before reaching the outlet. This also represents a value for the surplus of ground water leaving the Pine Meadow watershed.*

Given the complexity of the geologic and hydrologic setting of Pine Meadow, and the assumptions that we have had to make, the two numbers for surplus are reasonably close in order of magnitude: 503 and 137 acre ft per year respectively. The difference between the two numbers may represent the error in our work: 503 - 137 = 366 acre ft per year.

There is, however another process that we have not been able to assess in this project: the likelihood that some of the ground water from the tributary catchments is being diverted out of Pine Meadow by faulting, especially along the northeastern side of the valley. If diversion is going on, some of the 229 difference in acre ft per year is being reduced by the amount of ground water diverted out of Pine Meadow. From our understanding of the geologic setting, this is not an unreasonable amount of diversion.

In summary there is little margin for long term sustainable "safe yield" in Pine Meadow without drawing out of storage or drawing-in poor quality water if the area is overpumped. However there may be potential sources of additional water as discussed in the body of the report.

BACKGROUND

The work for this report is a follow-on from our company's April 6, 2004 report: "**Ground Water Resource Evaluation, Pine Meadow**". The focus of that report was to assess the amount of ground water in storage beneath Pine Meadow. Our calculations (p.8) ".. *suggested an approximate storage capacity of 86,500 acre-ft; and stated that for many reasons excessive depletion of water in storage is not advisable*".

To prevent adverse impact on the ground water resources, we were asked to propose a study of "safe yield" for Pine Meadow and its upstream catchment area. This report describes our work, our findings, and our recommendations.

Much of our work in the present study is follow-on from our April 6, 2004 report and the information on which it was based.

"Safe Yield" as Defined for this Project

The following three paragraphs are quoted from GSi/water's letter proposal of February 2, 2007 to the District:

> "There are many different types of "safe yield", depending on different types of demands and operations that can cause undesirable results to be avoided.
>
> "According to C. W. Fetter (1994, APPLIED HYDROGEOLOGY, Third Edition, p. 518) the term was used in the early 20th Century "...as the amount of water that could be pumped regularly and permanently without dangerous depletion of storage reserve." A modern description, also from Fetter based on many ideas of many others, is: "**Safe yield is the amount of naturally occurring ground water that can be withdrawn from an aquifer on a sustained basis, economically and legally, without impairing the native ground-water quality or creating an undesirable effect such as environmental damage.**"
>
> "For this project we were asked to address only a portion of Fetter's definition. Our objective was to address the amount of naturally-occurring ground water that may be withdrawn from Pine Meadow and the upstream catchment area on a sustained basis without causing unacceptable changes in the quality of the ground water. Our work was not to address economic, legal, or environmental damage aspects. Within the scope of this project, we continue to use the term " safe yield" in quotes."

Reliability of the Results

In this complex setting the five District wells and their distribution, cannot accurately represent the subsurface geology that controls the ground water throughout all of the Pine Meadow valley floor. They do provide useful information, although not enough to accurately assess "safe yield". However, this is a small basin with good exposures of the surface geology; the District has a long history of climate and operational data from its wells, which it provided freely and also greatly supported our work in the field; and also available are the results of previous highly professional studies by others.

We tested our interpretations by applying two independent and different types of approach for assessing the amount of ground water that enters and leaves Pine Meadow. One was based on infiltration of the amount of water that falls on the total watershed. The other was based on an application of Darcy's Law for the amount of ground water that may be flowing out of the sedimentary formations that underlie Pine Meadow. Both approaches required critical information for which we had to make assumptions; The accuracy of the assumptions drives the reliability of the results.

Because of the assumptions, the results must be considered tentative. However, the numerical results of the two approaches are reasonably similar in order of magnitude; they appear to fit the geological/hydrological setting of Pine Meadow; and they support our previous work that "safe yield" is not large. Pending further studies, we think the results are reliable.

Definitions

For convenience we use the term "Sub-Basin" to distinguish the Pine Meadow watershed from the larger downstream area of Garner Valley, which this report does not address. Also for convenience, we use the term "Valley Floor" to distinguish the alluvial flat area and older terrace features within Pine Meadow from the adjacent mountainous areas.

We use the term "catchment" to describe any topographic area within which all precipitation falls. A catchment usually contains a stream and its own tributaries that drain out of the catchment. A watershed contains many individual catchments.

The term "artesian" means that ground water rises upward from below but does not emerge onto the ground surface. If it does, the term is "flowing artesian."

GENERAL MOVEMENT OF GROUND WATER WITHIN THE PINE MEADOW SUB-BASIN

Topography and Water Movement

The Pine Meadow Valley Floor trends from the southeast to the northwest. The adjacent mountainous areas are Thomas Mountain along the southwest side, and the Butterfly Peak upland along the northeast side of the Valley Floor.

The project area begins at the southeast end of the Valley Floor. No recharge enters Pine Meadow from southeast of the southeast end of the Pine Meadow watershed.

Natural ground water recharge to the Valley Floor of Pine Meadow comes from the following sources: (1) infiltration from direct precipitation onto the Valley Floor; (2) infiltration from surface runoff from the tributaries that flow onto the Valley Floor; and (3) from precipitation that falls on the hills and mountains, infiltrates downward to the underlying ground water, and adds to the ground water beneath the Valley Floor. A large part of this study was the analyses of how much water enters the Valley Floor from the tributary catchments.

Recharge source (3) may be artesian, forced by ground water mounding within the mountains and rising upward into the alluvial deposits beneath the Valley Floor.

A special condition, to which we briefly referred in our 2004 report and further supported in the present report, is that some of the water from the tributaries may be being diverted along faults to the northwest before reaching the Valley Floor.

ANALYSIS OF RECHARGE TO PINE MEADOW

The available data and information from wells were not sufficient to provide firm numbers as to the quantity, quality, and movement of the ground water in this setting. Geophysical and drilling programs were not within the scope of this part of the proposal. Therefore we considered two independent analytical approaches to help improve our interpretations: Infiltration from the watershed, and Darcy's Law. These follow from the Hydrologic Cycle.

The applications of these analyses used the information from the wells and the rest of the District's data base.

Hydrologic Cycle

This defines the fundamental processes that describe the movement of water through the atmosphere, the oceans, and the outer part of the land surface. It can be a powerful approach to help quantify the ground water. Although it could not be used independently to directly calculate infiltration, we were able to use it to a limited extent to derive surface runoff from the catchments. This done, we were able to use the runoff parameter in the Infiltration and Darcy's Law approaches that follow.
The Hydrologic Cycle is stated as: $P = ET + R + I$, where

P = Precipitation (from climate)
ET = Evapotranspiration (to the atmosphere)
R = Runoff (downslope)
I = Infiltration (to the ground water)

Precipitation is the amount of water that falls within the watershed. The other three parameters control where the water goes.

Applied to Pine Meadow, P represents the total amount of water that falls throughout the entire watershed of the Pine Meadow Sub-Basin. Of the water that falls, ET represents evaporation and transpiration (evapotranspiration) by vegetation back to the atmosphere. I represents the water that infiltrates into the ground to become the ground water.

Of these parameters, Precipitation usually provides the most accurate information. The data are available from climate publications, and in this project, the information from the District. Evapotranspiration is usually the most difficult to measure, and is usually responsible for more loss of water than from Runoff and Infiltration. With most of the water lost to Evapotranspiration, only a small percentage error can cause a large source of error in assessing the amount of ground water that is available.

If there are many stream gages, Runoff is the next-most reliable measurement. The amount of effective infiltration to the ground water can also be very difficult to measure in complex topography and a variety of formations.

For this project, we assessed all the parameters. In assessing the amount of ground water we visited all the parameters, with varying results based on the available data. We have good data for climate, and we were reasonably able to estimate Evapotranspiration, using a standard method (Crippen, 1965). The amount of Infiltration was our objective, and this left only the amount of Runoff to complete the equation. Within the scope of this project, it was not possible to measure Runoff directly.

With enough data on runoff for most of the tributary catchments, we would have made the independent calculation for the Hydrologic Cycle by subtracting all the other parameters. However without many stream gages that could have provided an accurate number for Runoff, we did not think that the value derived for the amount of infiltration to the ground water via the Hydrologic Cycle approach would be reliable.

We were, however, able to derive a value for Runoff within the Hydrologic equation by estimating ET by the method from Crippen as described in the Appendix. With the estimate of Runoff, it was then possible to apply the Infiltration Method as discussed as follows.

Infiltration Method: Infiltration from natural sources of recharge **into** the Valley Floor

This analysis requires a calculation of the rain crop for each individual catchment, and an estimate of how much of the rain crop will percolate downward to recharge the underlying aquifer(s). The estimate depends largely on the vertical hydraulic conductivity (permeability of the geologic formations with water as the fluid).

Hydraulic conductivity depends on the nature of the geologic formations. These include the Young Alluvium that covers the Valley Floor; the underlying Bautista Formation; and fractured crystalline bedrock that is exposed in the adjacent mountains and underlies the other two formations.

The catchments in the tributary areas on both sides of the Valley Floor can be defined by the USGS 7½ Minute Topographic Quadrangles: Anza, Butterfly Peak, Idyllwild, and Palm View. These maps show tributary streams that flow: (1) from Thomas Mountain northeastward down to the Valley Floor; (2) from what we call the Butterfly Peak Upland southwestward down to the Valley Floor; and (3) the Valley Floor that contains Pine Meadow and irregular deposits of terrace and Bautista Formation along the margin of the Valley Floor.

The "rain crop" is all the precipitation that falls within each catchment or within the outer boundary of all the catchments in the two tributary systems; plus the precipitation that falls directly onto the Valley Floor. Our task in this study was to interpret how much of the rain crop reaches and recharges the ground water beneath the Meadow.

Each of the two tributary systems contains individual stream networks that flow from opposite sides to the Valley Floor. Each of the individual streams has its own catchment defined by the topographic boundaries between each stream and its two adjacent neighboring streams. We used only the streams published by the USGS on their topographic maps to define the catchments. In this report the streams that are shown as solid lines within each catchment are not meant to imply whether or not the stream is intermittent or constant.

The natural processes that provide the recharge to the Valley Floor can be broken down into three components: (1) Infiltration by direct precipitation onto the Valley Floor; (2) Infiltration from surface runoff that runs onto the Valley Floor from each adjacent catchment; and (3) Infiltration from the side slopes that mounds ground water within the mountains, and which migrates as ground water flow from beneath the catchments to join the ground water beneath the Valley Floor. These components can then be added to derive an estimate of natural recharge.

This analysis utilized the following procedure. The rain crop for each catchment (plus that on the Valley Floor) were calculated using precipitation data from the Lake Hemet station. For rates of Infiltration into each catchment, we assumed 1% of the rain crop into the granitic and metamorphic bedrock; 5% of the rain crop into the Bautista Beds; and 10% of the rain crop into the young Alluvium that covers the Valley Floor. For each catchment we estimated the areas and ratios of the different geologic formations already mapped throughout the watershed.

To obtain Infiltration by surface runoff from the catchments, evapotranspiration was calculated for each catchment using a modified version of the Crippen method described in Appendix B. Surface runoff values could then be derived by subtracting evapotranspiration and the estimated infiltration percentages from the rain crop in each catchment.

The infiltration analysis, broken down into the three components are as follows.

(1) From direct precipitation onto the Valley Floor:	418 acre-ft/yr (10% Inf)
(2) From surface runoff onto the Valley Floor:	247 acre-ft/yr (10% Inf)
(3) By ground water movement from the catchments into the aquifers: (58 acre-ft/yr from Thomas Mountain + 305 acre-ft/yr from Butterfly Peak Upland)	363 acre-ft/yr (mixed% Inf)
Total	**1,028 acre-ft/yr**

<u>Darcy's Law</u>: Amount of ground water moving **out** of Pine Meadow from beneath the Valley Floor

Darcy's Law is expressed as: $Q = K * A * i$.

Q represents the quantity of ground water that flows through an aquifer and discharges as outflow. K represents hydraulic conductivity of the aquifer formations (permeability with respect to water). A represents the area of the cross section through which the water is flowing. i represents the hydraulic gradient, which for the Pine Meadow application is a little shallower than the slope of the Valley Floor.

As discussed previously, the ground water beneath the Valley Floor comes from the precipitation that falls on the Valley Floor; from runoff that flows onto the Valley Floor; and from the ground water beneath the hills that adds to the ground water beneath the Valley Floor. It is not necessary to assess the amount of water provided from the individual sources. These processes are encompassed within the three variables and other processes that define Q, which is the amount of discharge at the outlet.

The unknowns that affect the results are based on subsurface conditions that cannot be accurately defined throughout the overall Valley Floor. We do not reliably know the entire thickness of the zone of aquifer contribution; or the detailed nature and distribution of the aquifer formations; or hidden structural barriers that inhibit, confine, or enhance ground water flow beneath the Valley Floor.

The subsurface information that we do have in relation to these issues comes from some geophysical data from earlier work (Durbin, 1975); the information from the District's wells including recent testing; the driller's logs for the District's wells; the District's operations including pumping and water levels; and our own observations in the field. This is enough to provide what we think is a reasonable application of Darcy's Law at this stage of progress, but with a need for more accurate information than we have at this time.

The assumptions for this application of Darcy's Law are as follows. We assumed that ground water discharges to the northwest end of the valley through two units: the Bautista Beds and the younger Valley Floor alluvium. Hydraulic conductivities of 5 and 100 gal/day/sq ft for the Bautista Beds and alluvium, respectively, were used using values for lithology from Freeze and Cherry (1979). The maximum depth of the Bautista Beds was estimated to be 370 ft, and the hydraulic gradient was taken to be 0.01. With these values, the natural discharge of the ground water out of the Pine Meadow aquifers would be on the order of **137** acre ft/yr.

HYDROBALANCE

From the Infiltration analysis, we calculate **1028 acre ft per year** to the ground water beneath the Valley Floor. From this value it is necessary to subtract the amount of extraction due to pumping by the District and by private wells. The production values by the District are accurate. The amount from private wells from our previous report is very rough because of lack of access to property and pumping information. For that study the total was **583 acre ft per year**, of which 287 acre ft per year was from the District.

Using Darcy's Law the amount of ground water discharge from the valley was **137 acre ft per year**. This would not be subtracted because it covers all the ground water activity approached from a different analysis. Another subtraction would have been evapotranspiration, but that amount had been included within the three estimated rates of 1 percent, 5 percent, and 10 percent of the rain crop into the fractured bedrock, Bautista Beds, and the young Alluvium respectively.

Therefore: (1028 - 583) acre ft per year = 445 acre ft per year.

However, not all the water from pumping leaves the valley. The water from pumping includes losses to its own evapotranspiration and runoff, but some of the pumped water infiltrates back into the ground. For the Infiltration assessment, we considered that 10% of the water that falls on the Valley Floor infiltrates into the ground water. For internal consistency we use 10% of the amount pumped, or 58 acre ft per year infiltrates beneath the Valley Floor. Adding this to the 445 acre ft per year provides **503 acre ft per year which represents an approximate value for the amount of surplus ground water that leaves the Pine Meadow watershed based on the Infiltration assessment.**

Because Darcy's Law describes the result of all the geohydrologic processes that go on beneath the Valley Floor, it is logical to consider the Darcy's Law value of **137** acre ft per year as <u>one</u> value of the District's surplus; and to consider the Infiltration value of **503** acre ft per year as <u>another</u> value of the District's surplus that represent a different approach. The difference between the two numbers, 503 -137 = **336** acre ft per year appears to represent the amount of uncertainty in our work, probably based on the assumptions used in both approaches.

However, some of the difference may be explained if there is diversion of some of the ground water that may move out of Pine Meadow before reaching the Valley Floor. If so, the District is losing water that might otherwise be captured. Stated differently, the Darcy's Law analysis suggests that water is being diverted, and the Infiltration analysis suggests that it is not.

Although all the numbers and their derivations are approximate, and because the results of the two types of analysis must be considered tentative because of the assumptions that we have had to make, it is our opinion that the results are reasonable for the climate that provides, and the geology that controls the ground water within the setting of Pine Meadow.

<u>In summary, the two numbers, 137 acre-ft per year and 503 acre-ft per yr should represent the range of values within which water may be pumped without drawing Pine Meadow into overdraft.</u>

These results indicate that there is little if any margin for "safe yield" within Pine Meadow without drawing from storage. Withdrawing from storage – as defined for this study – was to address the amount of additional ground water that may be withdrawn from Pine Meadow on a sustained basis without causing unacceptable changes in the quality of the ground water.

Poor quality water is already known within Pine Meadow. Increased pumping with more wells may draw-in more poor quality into other locations within the Valley. The hydraulic characteristics of the Bautista Formation and the fractured bedrock are not well-enough known to rely on sustainability if Pine Meadow is heavily pumped. There is much clay in the drillers logs of the District's wells, and long-term declining water levels in the District's wells also support these statements.

DISCUSSIONS OF SPECIAL PROCESSES

Types of Discharge Water from the Pine Meadow Subbasin

The processes of discharge from the hydrologic system include the following:

- Outward flow of surface water from the northwest mouth of the study area (natural)
- Outward flow of ground water from beneath the Valley Floor (natural)
- Evapotranspiration from the Valley Floor and the tributary areas (mostly natural)
- Extraction from pumping (artificial)
- Diversion of ground water laterally along faults, if occurring (natural)

Assessment of each of these processes requires different overlapping suites of information, and each differs in the reliability of its assessment. In general, evapotranspiration is the most difficult to measure, while at the same time causing the largest rates of natural water loss from precipitation. Extraction by pumping can provide the most reliable information of subsurface conditions.

Possible Diversions from the Tributaries

The ground water beneath the tributary catchments moves directly downslope toward the Valley Floor. Unless there are barriers or impediments to the ground water flow, the ground water from the catchments adds to the recharge of Pine Meadow.

Tributaries from the southwest

A large fault, the Thomas Mountain Fault, has been mapped by others along the lower slopes of Thomas Mountain. This fault can be an impediment, acting somewhat like an underground dam, to water moving to the Valley Floor. Faults however, are not impervious. There can be leakage through the fault and lateral diversion along it. In the case of the Thomas Mountain Fault, it is likely that if there is diversion, the fault detours the ground water to other downslope outlets still within the Meadow rather than diverting it completely into lower Garner Valley.

However along such faulting, the ground water is often caused to rise along the upstream side of the fault, causing springs or areas of lush vegetation that can reach the ground water. The result is evapotranspiration of ground water back to the atmosphere rather than to the Pine Meadow Sub-basin.

Tributaries from the northeast

Large-scale faulting has not been mapped by others along the lower slopes of the Butterfly Peak upland northeast of the Meadow. From our own observations for the 2004 report and the present study we think that extensive faulting does occur. This faulting may be a continuation of the Hot Springs Fault that occurs north of Hemet.

This faulting is complex, however, along the northeastern range base. There are northeast and northwest linear trends in the bedrock; and there is irregular topography along the northeastern base of the Meadow where we have observed slickensides and fault gouge in the field. The northeast trend appears to have offset the main northwestern faulting, displacing some segments to the northeast.

If lateral diversion is occurring, it may be more active than along the southwest side of the Meadow. Poor quality sulfur-bearing ground water occurs, at least locally. The poor quality water may be occurring from deep within the faulting, or from reduction of organics in shallow meadow deposits.

Trends in Water Quality Since 2004 Report

Very little change has occurred in the general parameters since our report of 2004. We find no reason to change our interpretations at this time.

In 1979 Well GV #3 reported a high value of manganese. Manganese naturally concentrates in some lake and meadow deposits. Well GV #1 also reported manganese in 1980 and a small amount of manganese was also reported in GV #4 in 1985. Iron was also reported in several of the wells in earlier years. Since then, the values of manganese and iron have greatly reduced in recent years. These observations are evidence – albeit weak – that the water quality problems in some of the wells are from shallow sources that have been flushed over time rather than from deeply rising water from the large faults. If so, this may have implications for additional production in some areas for the District.

Trends in Precipitation and Static Water Levels in District Wells

G.V. Wells #1, #2, #4, and #5 are the District's main operating wells. Data from another well, G.V. # 3, are largely unavailable. Since 1990, the long-term trendlines of precipitation and static water levels of the wells have shown consistent decline. There are long-term data for G.V. Wells #1,# 2, and #4. G.V. Well #5, was constructed in 2002.

There has been reasonable correlation of the static water levels with the precipitation. Also, there has been little delay in response of the water levels from the precipitation. However, from about 2004 to the present there has been much more variation than previously, especially for G.V. Wells # 4 and #5. The meaning of this is not clear.

G.V. Wells #4 and #5 are closer to Garner Valley Creek than are the other District wells. They are probably responding more quickly to changes in stream flow, which in turn would be expected to respond to climate. A strong rise in the static water level in G.V. Well #4 in 2006 was followed by a steep drop to the trendline in early 2007. This pattern was roughly simulated in G.V. Well #5 in opposite phase in early 2006.

An alternative explanation for the wells away from the creek may be some local impact on storage during the past several years. This appears to be supported by an increase in pumping beginning by 2003 in three of the wells and continuing to this time. Production in G.V. Well #4 has decreased since 2002.

Test Pumping

Step-drawdown and constant rate pumping were not sufficient to reach equilibrium in water levels. Because of access problems, water levels were difficult to recognize during pumping. However, recovery was quick and provided more accurate data than the pumping.

A step drawdown pumping test could be done only in G.V. Well #3 for three steps in 360 minutes. The steps ranged from about 25 gpm to about 75 gpm. Recovery was almost instantaneous to about 60 feet after the pump was shut off. From there, water levels recovered to within 14 feet of static water level after about an hour.

During drawdown, the three steps did not completely stabilize. The declines were linear, and therefore could not be extrapolated to the expected pumping levels for each rate of pumping.

Specific capacity values appear to range from less than one to about five gallons per minute per foot of drawdown. These are estimates because the drawdown did not stabilize. These wells are not large, sustainable producers.

Thermal Gradients in the Wells

Our company specializes in the use of temperature to trace the movement of ground water. For this project we did down-hole temperature logging in four of the District's wells. This was an application of opportunity, taking advantage of the existence of the District's wells to derive information on the geothermal gradient, and to see whether zones of more active ground water movement can be discerned within the depths of the wells. Access within the wells was again difficult, but this was a preliminary test that did provide some useful information.

There was a progression of temperature change from the southeastern to the northwestern wells. G.V. Well #1 was the warmest and G.V. Well #4 was the coolest through a range of about 2 Celsius degrees. The vertical gradients in all four wells were much steeper than the normal geothermal gradient; there being very little temperature change from the top to the bottom of each well. This was due probably to long-term production pumping, which has modified the thermal conditions in the surroundings of each well. Nevertheless, there was enough temperature variation to indicate differences in ground water flow within the wells and from well to well. For example, the thermal gradient in G.V. Well #1 is markedly different from that in G.V. Well #4, both of which are in different settings within the Valley.

The temperature logs will be a useful tool to help identify other well locations, and especially to compare with the thermal gradient in G.V. Well #3 to help identify the source of the poor quality water.

"Safe Depth" to the Base of the Aquifer and Implications for Pumping

For Pine Meadow, our use of the term aquifer is meant to include the three formations: Younger Alluvium; Bautista Formation; and fractured crystalline bedrock.

Based on the geologic setting; the information from the well logs; gravity information (Durbin, 1975), and the concern for water quality, the base of the Pine Meadow aquifer should not be considered to exceed about 500 feet from the surface.

The geologic setting and the well logs indicate that the subsurface is complex. The thickness of the alluvium may range from 100 to 500 feet away from the margins of the valley. The hydraulic character of the Bautista Formation is not well known, and may be hydrologically tight especially in its deeper levels. Wells in the various types of crystalline bedrock would normally produce at small rates of production.

There are not enough pumping data to reliably assess the **storativity** (not to be confused with **storage**) values in each well. With storativity data it is possible to accurately predict how far the cone of depression from each well will extend laterally and vertically; and how to avoid interference among the wells.

Concerns of over-pumping in the narrow Valley Floor of Pine Meadow include the possibility of land subsidence that can be caused by deep, interfering cones of depression if the alluvial deposits begin to be de-watered. Of special concern would be induction of the sulfurous water from the edges of (or even from within) the Valley Floor. Such processes can cause damage to the aquifer horizons, some of which may be permanent.

Before significantly increasing the numbers of wells and increases in depth, it will be necessary to set up a well-designed monitoring system to obtain additional reliable data from the existing wells.

Possible Sources of Additional Ground Water

Up-gradient of the faults

Hard bedrock is able to hold open fractures. Large faults are often characterized by zones of tight ground-up gouge bordered on either side by zones of shattered bedrock. Wells not in the gouge but along the up-slope side of the gouge zone in hard, shattered rock can provide considerable production from a line source of moving ground water rather than from a circular cone of depression.

This type of condition may occur up-slope of border faults that define the meadow. If this condition occurs north of G.V. Well #3, a fault up-slope of the fault north of the well may also provide water of good quality if the faulting is vertical or dips toward the valley rather than back beneath the mountains; and also depending on the source of the poor quality water.

Deep beneath the Meadow

Garner Valley is an anomalous topographic feature. Its straight northwestern orientation high within this part of the San Jacinto Range is probably caused by the southwest and northeastern border faults. If the faults are vertical, and the motion is also vertical, it is possible that some of the alluvium (and the Bautista Formation) may be very deep.

If the faults dip downward toward the center of the Meadow, the Valley may represent a breakaway feature as a down-dropped block between both sides being pulled apart (tension faulting). This may also support deeper aquifer conditions than we think at this time.

If the faults dip away from the center of the Meadow, and down beneath the range front, the formations would likely be tight, and drilling may penetrate the fault(s) into poor quality water.

FINDINGS AND "SAFE YIELD"

Under present conditions it is impossible to recommend a significant increase in ground water production within the context of "safe yield" as defined in the report.

Trends of precipitation and static water levels in the District's wells are continuing to decrease, and the rate of decrease has been increasing within the past few years, an impact on "safe yield." If this continues, Pine Meadow may need additional water to support increased population.

The annual surplus of ground water moving from beneath the Pine Meadow Valley Floor appears to be in the range of about 137 to 503 acre-ft/yr. These are approximate values based on the two types of analyses as described in the report. The numbers are only slightly rounded in order to help in following the analyses within the body of the report, and do not imply high accuracy.

"Safe yield" as defined in this report is likely to be within the range of the surplus values, provided that: precipitation does not continue to decrease; that water levels do not continue to lower; that over-pumping is not ongoing or increased throughout Pine Meadow; and that inducing poor quality water is not being increased by existing and new wells.

The present report adds to the results in the 2004 report, but does not require changing the statements in that report. There is, however, one important style change in the 2000 report. On page 8, we would hi-light Paragraph 1 to emphasize that it is not possible to extract all the water in storage, and that there are many detrimental reasons for not allowing excessive depletion of the water in storage to take place.

With small diameter observation wells or with access to nearby private wells, it would be possible to reliably measure storativity values (not to be confused with storage) for each well. This would tell how closely wells can be spaced to avoid interference, and in turn how much ground water can be produced on a sustainable basis.

The sources and distribution of poor quality water are not well known. Possible sources are from local meadow deposits and/or by deep rise along faults. A good understanding of the sources and distribution will help prevent impact on "safe yield" by avoiding well sites that would induce inflow of poor quality water.

The effective base of the aquifer system within Pine Meadow may be deeper than previously thought. There is some likelihood for deeper, significant production from fractured bedrock beneath the two overlying sedimentary aquifers.

If shatter zones along the up-gradient sides of the main border faults are present along or near the margins of Pine Meadow, they may provide a "line source" of additional water to Pine Meadow not presently being used.

APPENDIX A

Graphics and Detailed Explanations

INTRODUCTION

Figure 1: Project Location

This report evaluates the "Safe Yield" of the groundwater resources of Pine Meadow. It is partly an updated version of our company's April 6, 2004 report, "Groundwater Resource Evaluation, Pine Meadow". For this project, the definition of "Safe Yield" refers to the amount of naturally-occurring groundwater that may be withdrawn from Pine Meadow's aquifers on a sustained basis without adversely affecting the water's quality. Since many different definitions for "Safe Yield" exist within the literature, the term will hereafter be in quotations to remind the reader of our meaning.

Pine Meadow essentially constitutes the southern half of Garner Valley. It trends southeast-southwest, and extends approximately from the Morris Ranch Road/State Route 74 intersection (4529 ft elevation) to Santa Rosa Summit (5000 ft elevation). The meadow lies between the ridges (6200 ft elevation) near Thomas Mountain and the western shoulder of the San Jacinto Mountains, which reaches elevations as high as 7035 feet.

A literature review was conducted to incorporate information not utilized in our 2004 report. New water level, production, water quality, precipitation, and water usage data were acquired from Lake Hemet Municipal Water District (LHMWD). In addition, a field reconnaissance was conducted to collect information from the 5 wells LHMWD owns in Pine Meadow. Water level recovery was measured for Wells G.V.(Garner Valley) #1, #2, #3, #4, and #5, while down-hole temperatures were measured for Wells G.V. #1, #2, #4, and #5. Geological observations were also made to refine our interpretations from 2004. We utilized the information obtained from these sources to calculate a "Safe Yield" of Pine Meadow's groundwater resources.

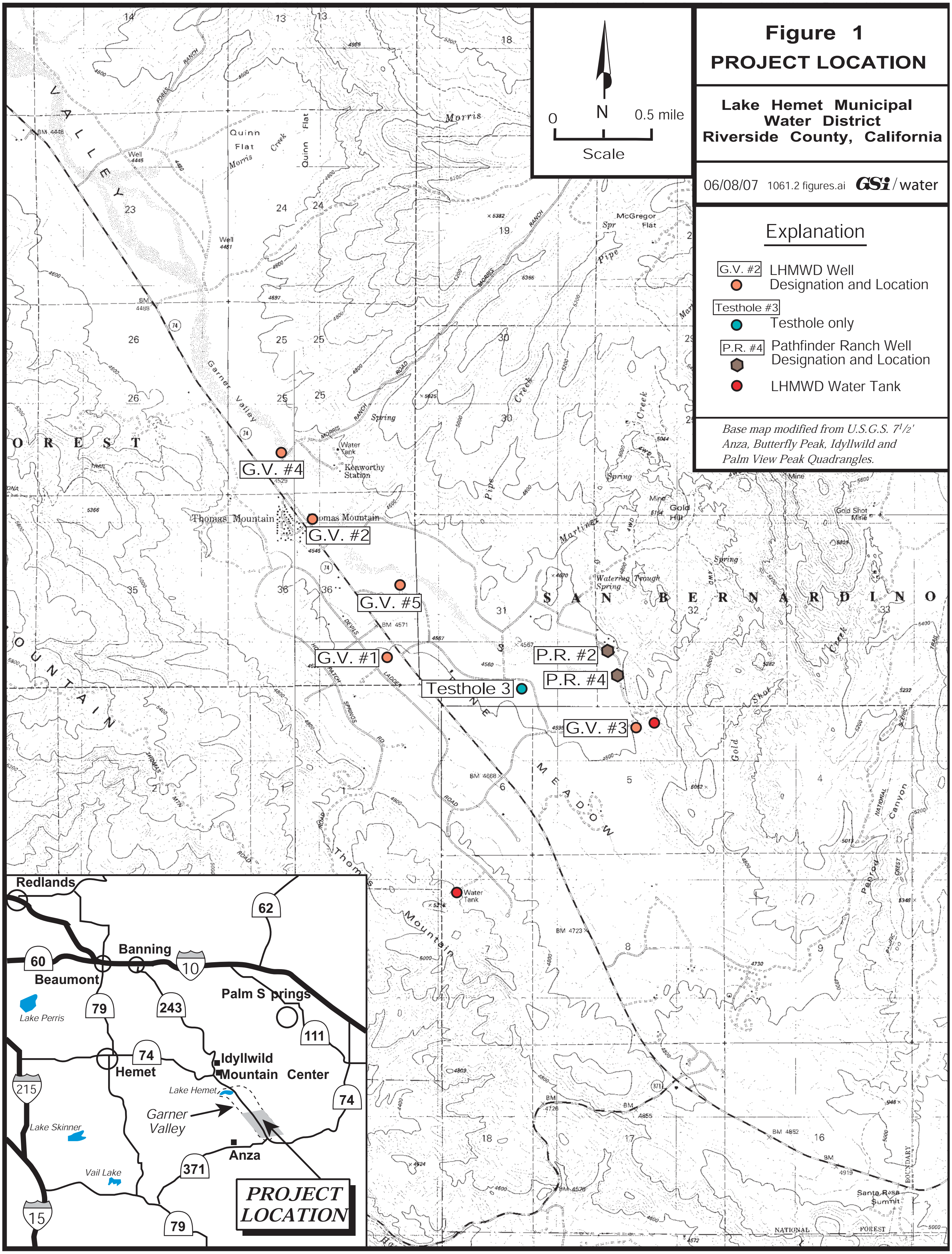


Figure 1
PROJECT LOCATION
Lake Hemet Municipal Water District
Riverside County, California
06/08/07 1061.2 figures.ai GSi/water
N
0 0.5 mile
Scale
Explanation
G.V. #2 LHMWD Well Designation and Location
Testhole #3 Testhole only
P.R. #4 Pathfinder Ranch Well Designation and Location
LHMWD Water Tank
Base map modified from U.S.G.S. 7 1/2' Anza, Butterfly Peak, Idyllwild and Palm View Peak Quadrangles.
G.V. #4
G.V. #2
G.V. #5
G.V. #1
G.V. #3
Testhole 3
P.R. #2
P.R. #4
Thomas Mountain
Water Tank
Kenworthy Station
Garner Valley
McGregor Flat
Quinn Flat
Morris Creek
S A N B E R N A R D I N O
M E A D O W
Gold Hill
Waterng Trough Spring
Santa Rosa Summit
PROJECT LOCATION
Redlands
Banning
Beaumont
Palm Springs
Lake Perris
Hemet
Idyllwild
Mountain Center
Lake Hemet
Garner Valley
Lake Skinner
Vail Lake
Anza
60
10
62
79
243
111
74
215
371
15

EXISTING WELLS

Figure 2a: Static Water Levels and Precipitation vs. Time
Figure 2b: Annual Precipitation and Production vs. Time

Lake Hemet Municipal Water District (LHMWD) currently owns five wells in the Pine Meadow area. Well G.V.#1 was drilled in 1969 to a depth of 477 ft. G.V. #2 was drilled in 1969 to a depth of 350 ft. G.V. #3 was drilled in 1979 to a depth of 217 ft, but it has been mostly inactive since 1984 due to water quality issues. G.V. #4 was drilled to a depth of 323 ft in 1985, whereas G.V. #5 was drilled to a depth of 465 ft in 2002.

Static water levels in G.V. #1, #2, #4, and #5 continue to exhibit trends similar to those observed in 2004. Namely, static water levels have been declining at rates ranging from 1.9 to 2.9 ft/yr since 1990 (Figure 2a). Average yearly precipitation has declined at a rate of about 0.58 inches/yr since 1990.

G.V. #1 and #5 continue to have relatively low static water levels with high variability, while G.V. #2 and #4 have high static water levels with low variability. This may mean that each pair of wells draws groundwater from a separate aquifer. Alternatively, each pair may draw from the same aquifer, but the recharge rate may be greater near G.V. #2 and #4 due to nearby streams.

G.V. #4 continues to be the highest-producing well in Pine Meadow, with total production reaching 123.22 acre ft in 2006 (Figure 2b). G.V. #5 is the next highest producer with a total of 64.59 acre ft in 2006, followed by G.V. #2 with 64.5 acre ft and G.V. #1 with 34.39 acre ft. Total production for all 4 wells in 2006 was 286.7 acre ft.

Figure 2a: Static Water Levels and Precipitation vs. Time

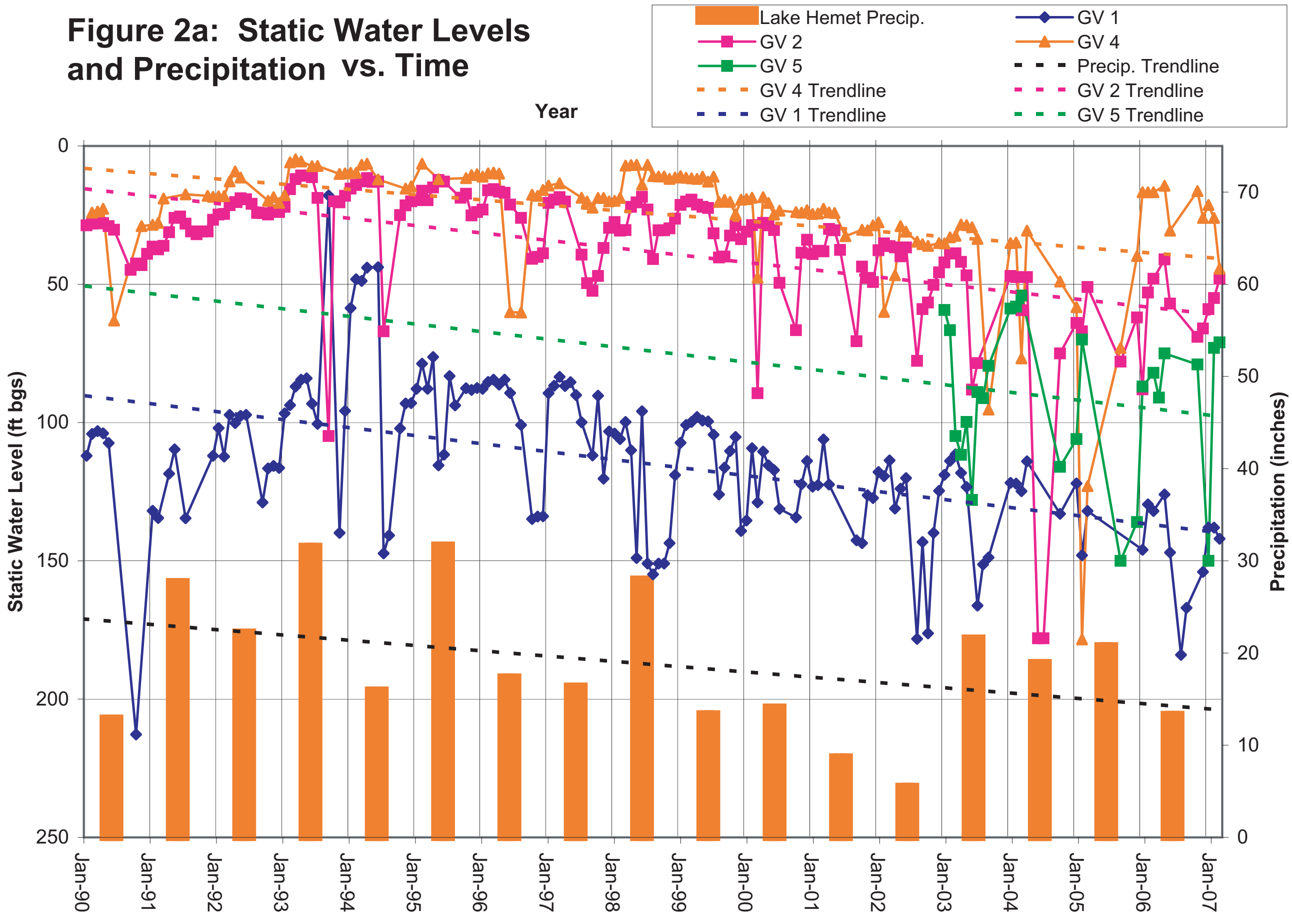
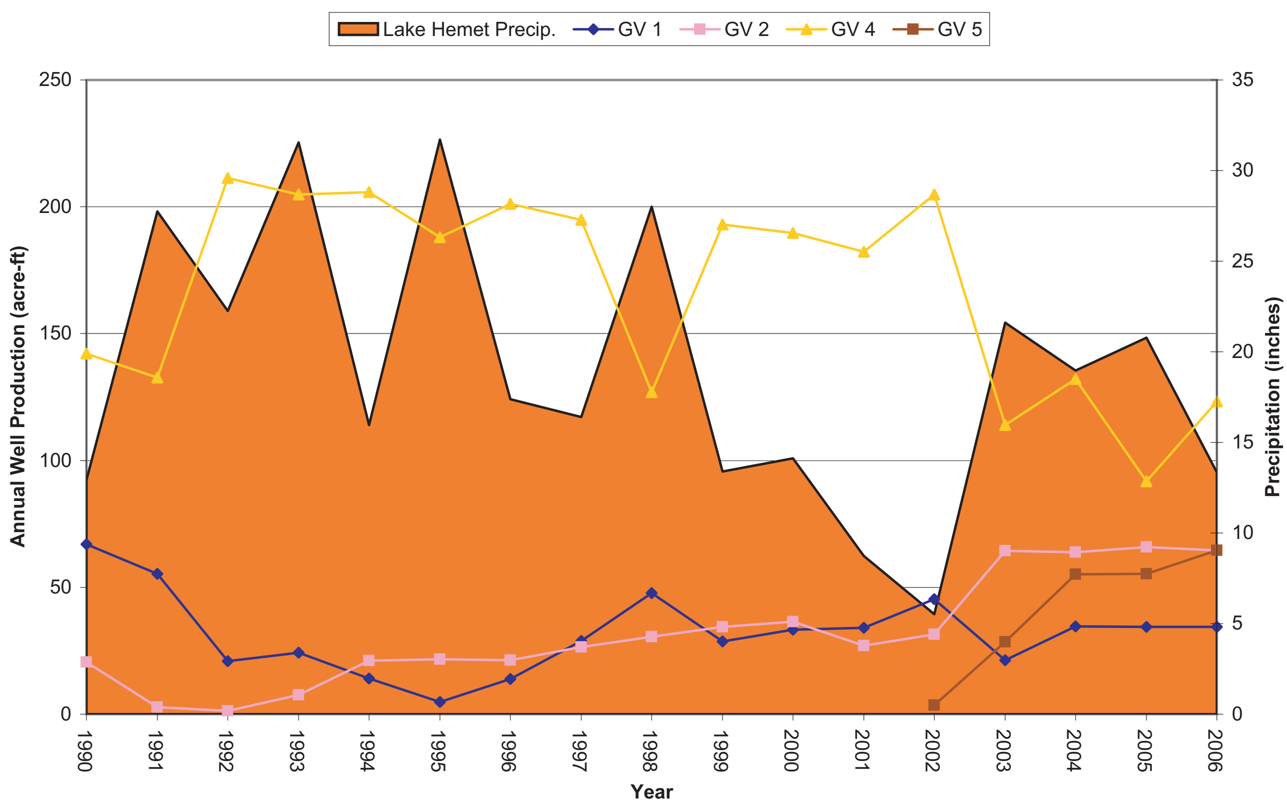


Figure 2b: Annual Precipitation and Production vs. Time



RESULTS OF TEST PUMPING

Figure 3a: Garner Valley Well #3 Step-Drawdown Test 4/2/2007
Figure 3b: Garner Valley Well #1 Test Pumping and Recovery 4/18/2007
Figure 3c: Garner Valley Well #2 Test Pumping and Recovery 4/19/2007
Figure 3d: Garner Valley Well #4 Test Pumping and Recovery 4/18/2007
Figure 3e: Garner Valley Well #5 Test Pumping and Recovery 4/19/2007

A seven hour step-drawdown test was conducted for Well G.V. #3 on April 2, 2007 to test its production potential. Static water level was measured at 70.15 ft below ground surface. Water levels were then measured at three different pumping rates (25, 50, and 65-75 gallons per minute) for two hours each. After the three steps were completed, water levels were measured for one hour to test the well's recovery.

Figure 3a shows G.V. #3's water levels during the test plotted against cumulative time after the pump was turned on. The resulting estimates of specific capacity are 1.07 gpm/ft of drawdown at about 25 gpm, 0.81 gpm/ft of drawdown at about 50 gpm, and 0.69 gpm/ft of drawdown at about 70 gpm. Water level recovered to within 14 ft of static water level one hour after the pump was shut off.

Shorter pumping tests were performed on LHMWD's other wells, G.V. #1, #2, #4, and #5. Pumping water levels and subsequent recovery water levels were measured for one hour at each well. The resulting measurements were plotted against cumulative time after the pump was turned on (see Figures 3b through 3e). Results from these measurements are tentative. Due to the automated nature of LHMWD's water system, the exact time when each pump was turned on had to be estimated. Static water levels were provided by the well operator. Cascading water affected the accuracy of water level measurements in every well, especially G.V. #1 and #5.

At about 37 gpm, G.V. #1 had a temporary specific capacity of approximately 0.35 gpm/ft of drawdown. Water level recovered to within 12 ft of static water level 46 minutes after the pump was turned off. At about 79 gpm, G.V. #2 had a temporary specific capacity of approximately 0.53 gpm/ft of drawdown. Water level recovered to within 43 ft of static water level 30 minutes after the pump was turned off. G.V. #4 had a temporary specific capacity of 5.65 gpm/ft of drawdown at 185 gpm. Its water level recovered to within 0.8 ft of static water level 30 minutes after pump stoppage. G.V. #5 had a temporary specific capacity of 0.60 gpm/ft of drawdown at 75 gpm. Water level recovered to within 54 ft of static water level 323 minutes after pumping ceased. The long interval between recovery data points was necessary at G.V. #5 because of measurement reliability issues.

Figure 3a: Garner Valley Well #3 Step-Drawdown Test 4/2/2007

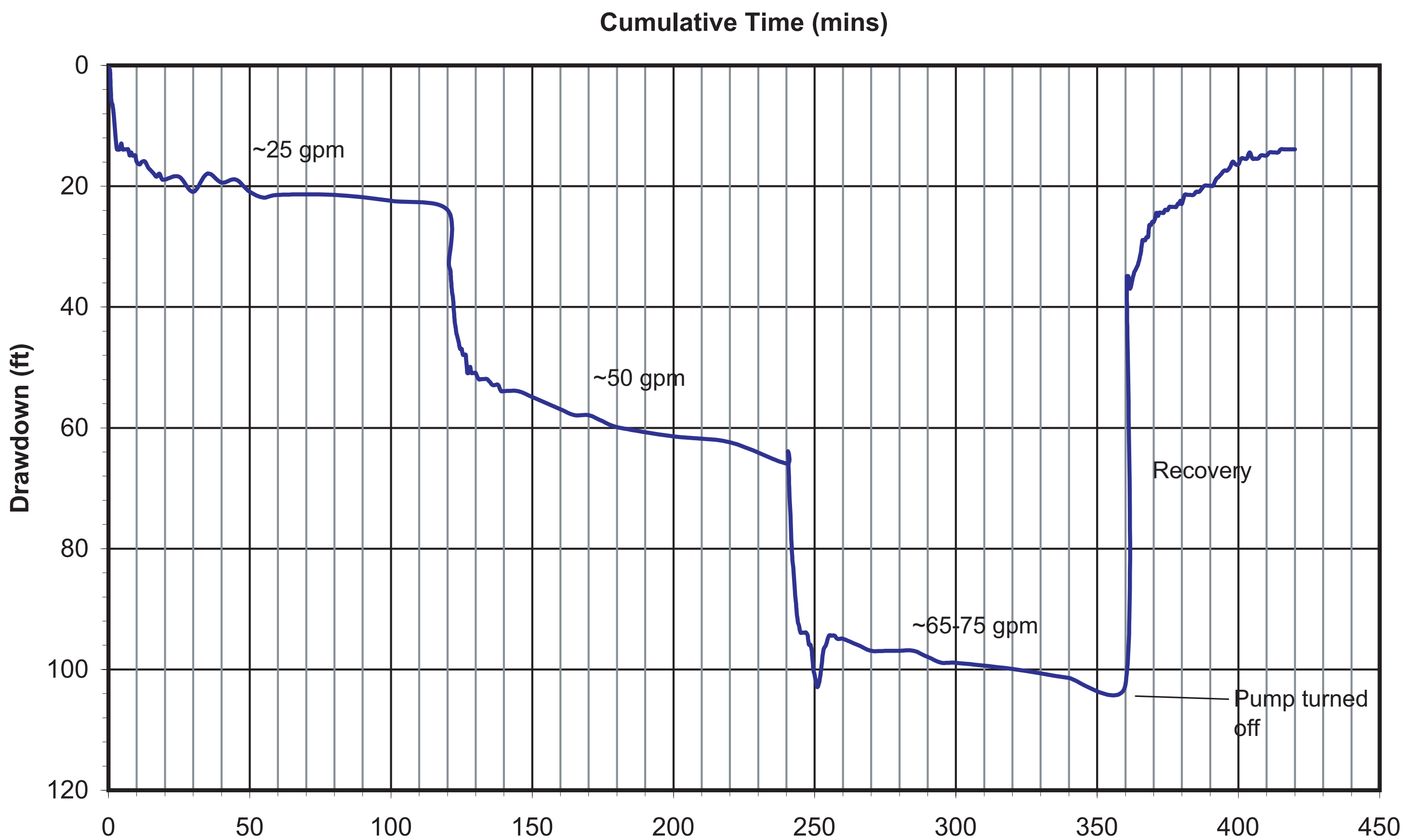


Figure 3b: Garner Valley Well #1 Test Pumping and Recovery 4/18/2007

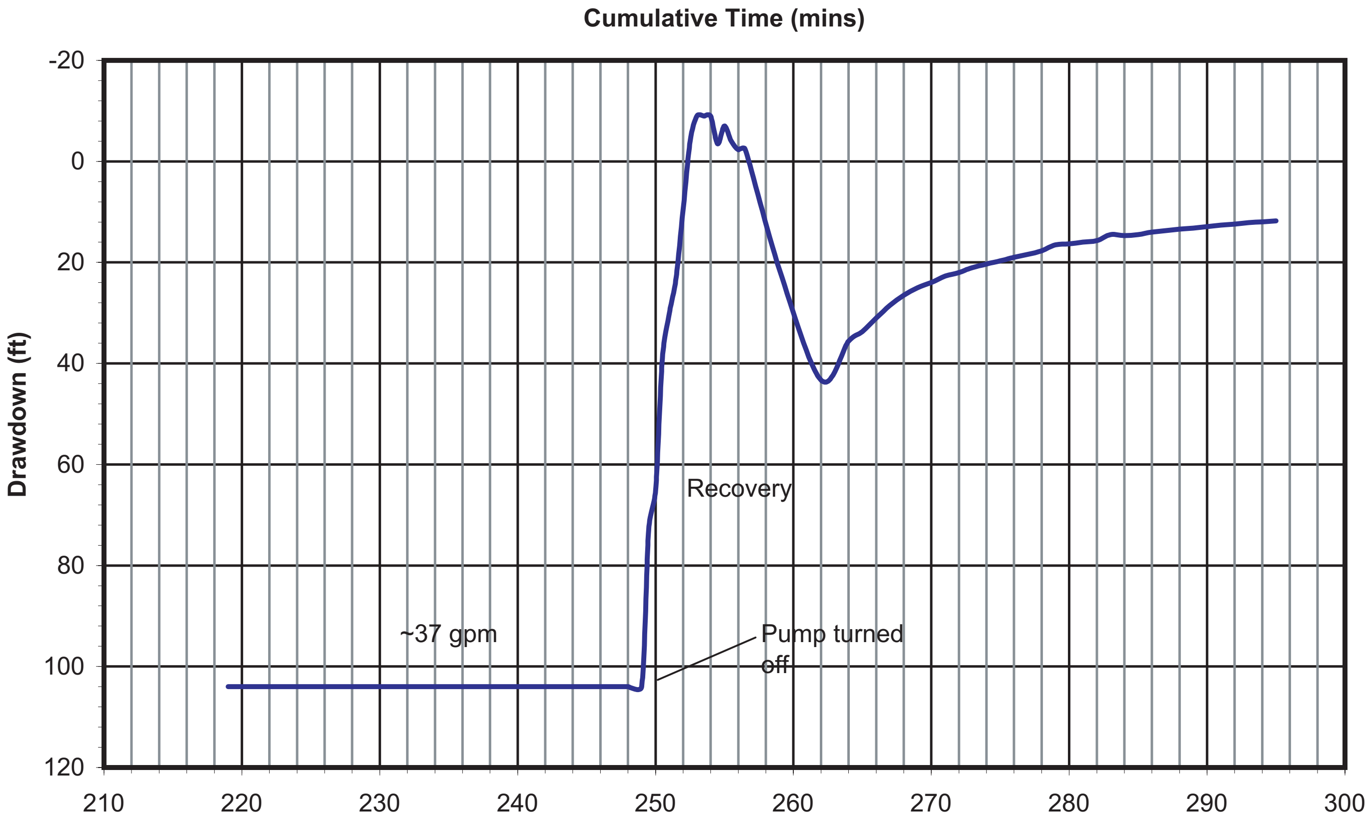


Figure 3c: Garner Valley Well #2 Test Pumping and Recovery 4/19/2007

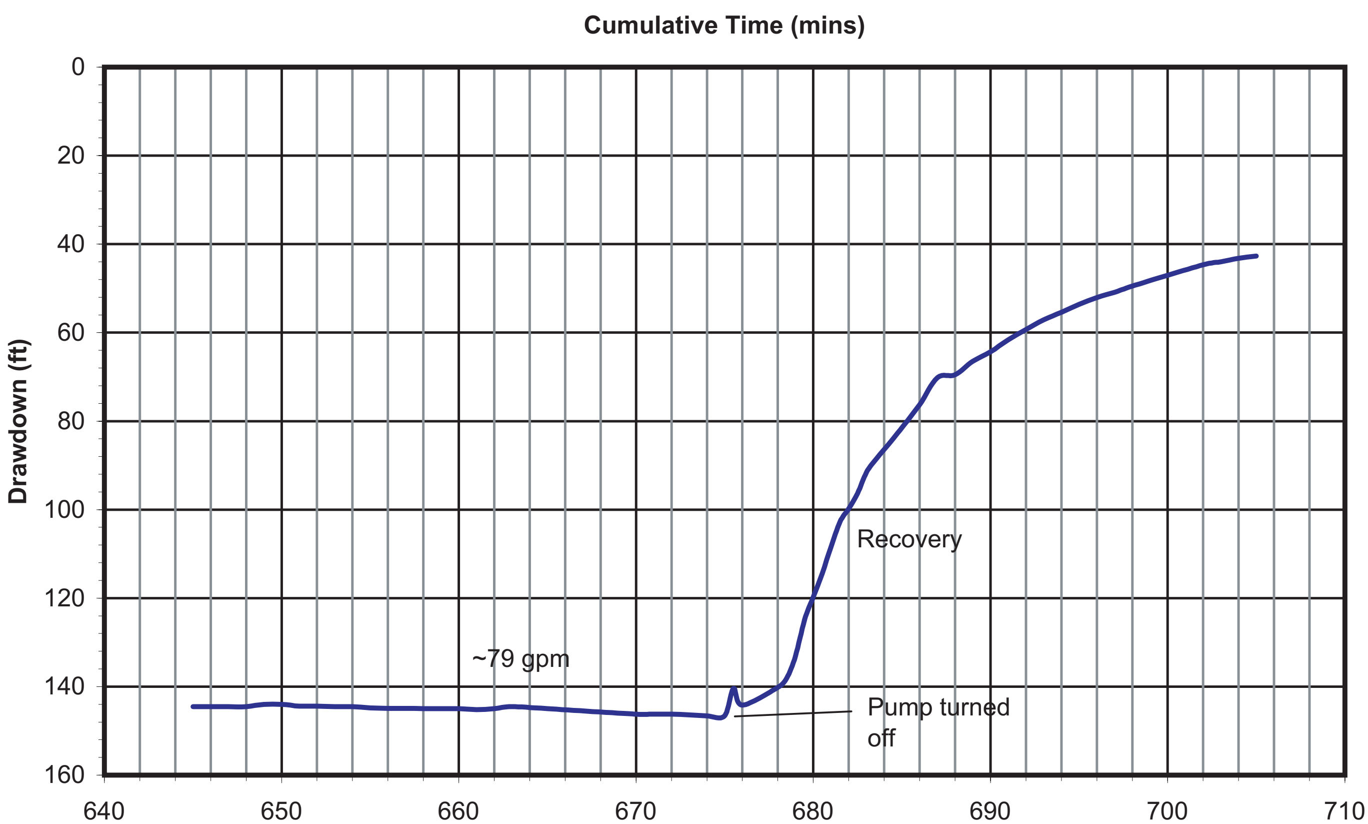


Figure 3d: Garner Valley Well #4 Test Pumping and Recovery 4/18/2007

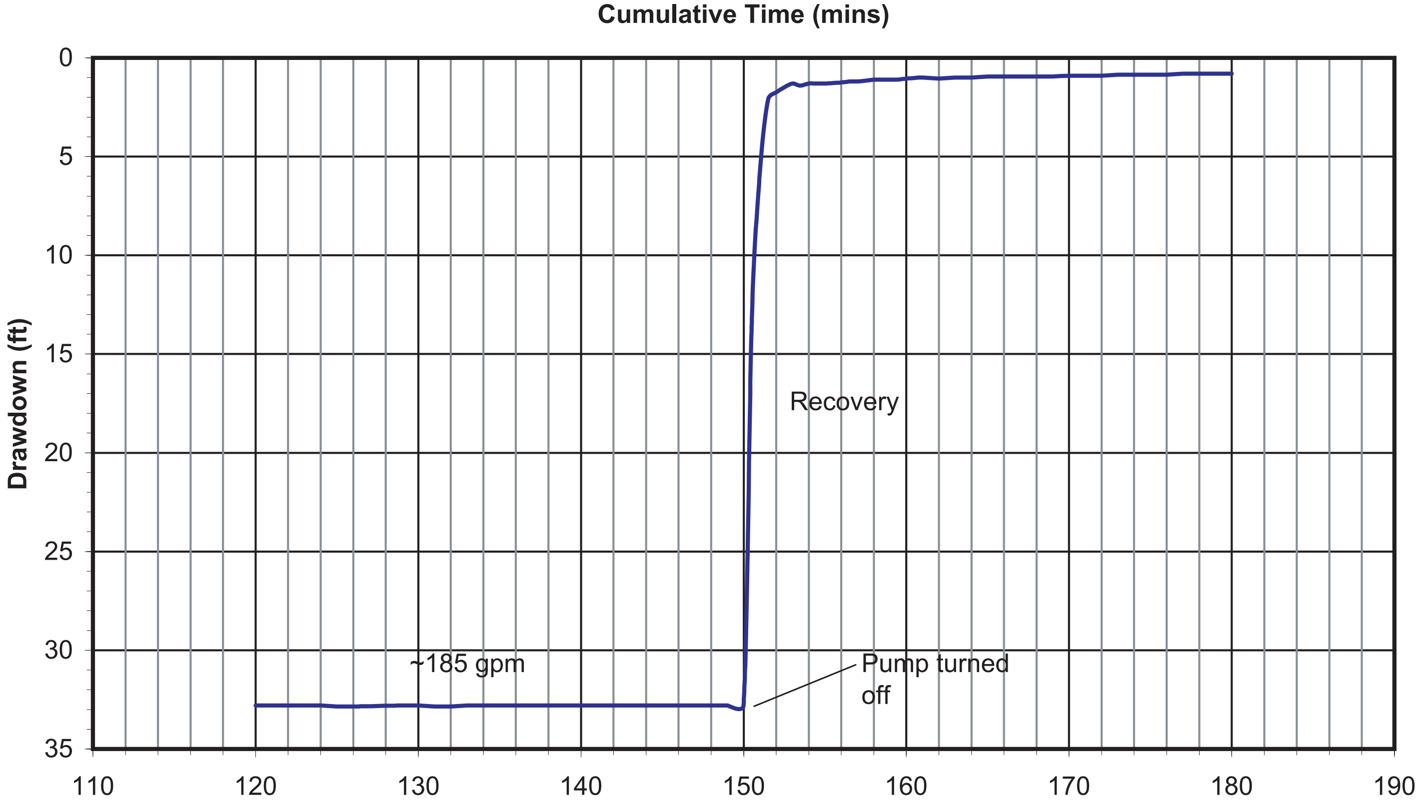
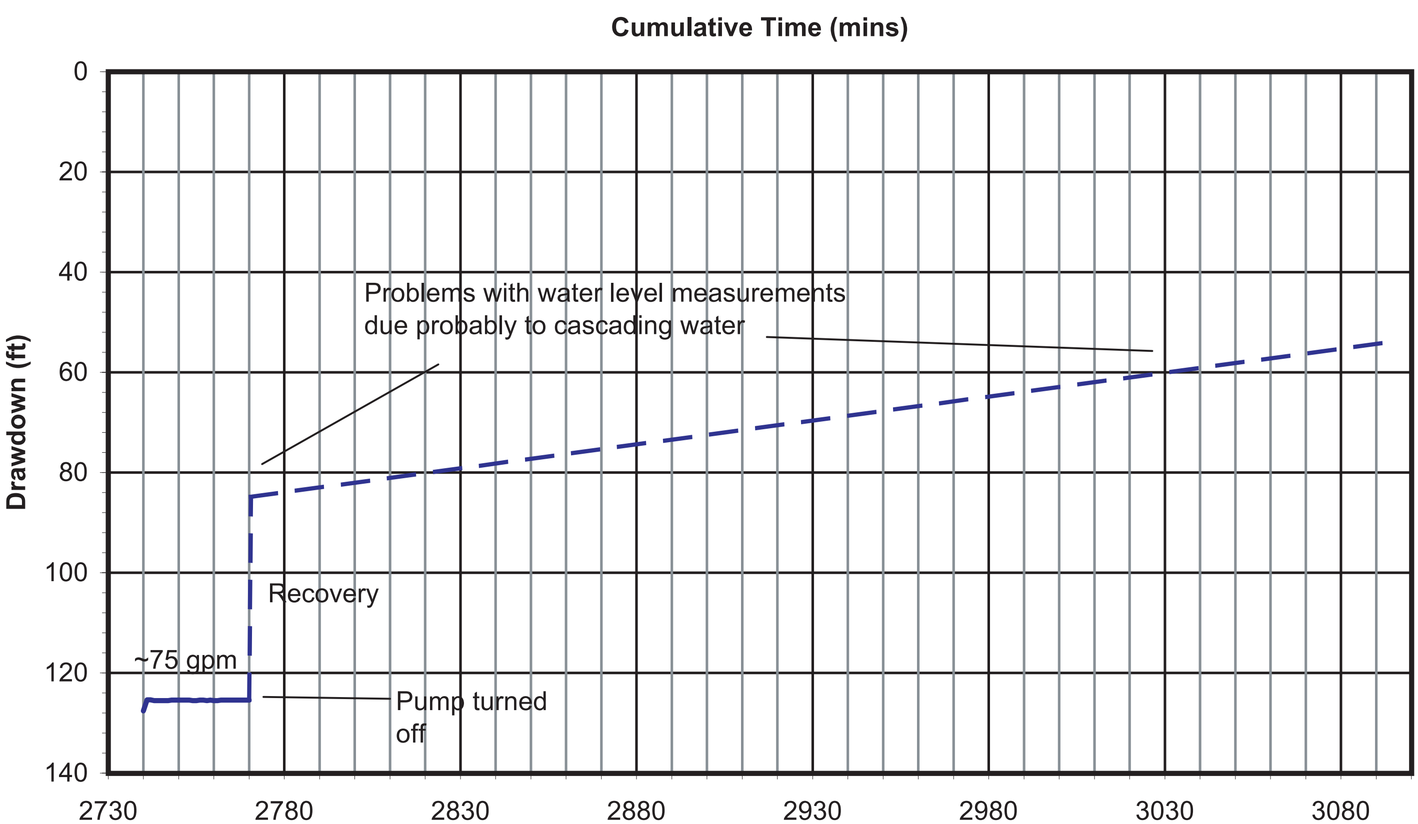


Figure 3e: Garner Valley Well #5 Test Pumping and Recovery 4/19/2007



RESULTS OF TEMPERATURE LOGGING

Down-hole temperature logs were performed in G.V. #1, G.V. #2, G.V. #4, and G.V. #5 to investigate the nature of the aquifer(s) intercepted by each well. The results are depicted as temperature vs. depth profiles in Figures 4a - 4e.

The term used for aquifers is relative. They refer to zones of more active ground water flow within the well.

Figure 4a depicts the down-hole temperature profiles for all four wells, adjusted for elevation. Definitive correlations between wells are difficult to discern, which indicates that the aquifers in this area are not homogeneous. Overall, subsurface temperatures become cooler from southeast to northwest. The trends of cooling and higher elevations of the static water levels toward the northwest conform with higher production rates in that direction. This may indicate the presence of fractures and/or faulting in the southeastern portion of Pine Meadow.

The temperature measurements in G.V. #1 had the highest reliability among the four wells. Consequently, more inferences could be made about the aquifer(s) intercepted by this well. The temperature profile seems to follow the groundwater-absent geothermal gradient until about 230 ft bgs. At this depth, temperatures cool abruptly, suggesting that G.V. #1's main aquifer is intercepted at this depth. This aquifer probably extends down to about 330 ft bgs (below ground surface), where the temperatures appear to resume following the groundwater-absent geothermal gradient. Beginning at about 365 ft bgs, another aquifer may be intercepted. The temperature log concluded at about 380 ft bgs to avoid interfering with the well's submersible pump.

Temperature measurements for G.V. #2 may not have reached thermal equilibrium, since the pump was not shut off until about 18 hours prior to logging. Measurements may also have been affected by the numerous obstructions encountered in the well. Nevertheless, the profile suggests that two aquifers are intercepted by this well, one between approximately 125 and 155 ft bgs, and another between approximately 170 and 210 ft bgs. Alternatively, groundwater may be moving in the vertical direction beneath about 125 ft bgs. Measurement reliability began to decrease significantly at about 200 ft bgs due to numerous obstructions. Logging concluded at about 240 ft bgs due to blockages.

The temperature profile for G.V. #4 indicates that the well intercepts an aquifer at about 55 ft bgs. This aquifer appears to extend down to about 175 ft bgs. However, obstructions probably began affecting measurements at about 160 ft bgs. The log concluded at approximately 175 ft bgs due to these blockages.

Temperature measurements for G.V. #5 may have been affected by water mixing, since the well's pump was shut off only about 19 hours prior to logging. The well seems to intercept an aquifer which extends from about 153 ft bgs to at least 228 ft bgs. At approximately 230 ft bgs, the log was again concluded because of obstructions.

Figure 4a: Down-hole Temperature Profiles

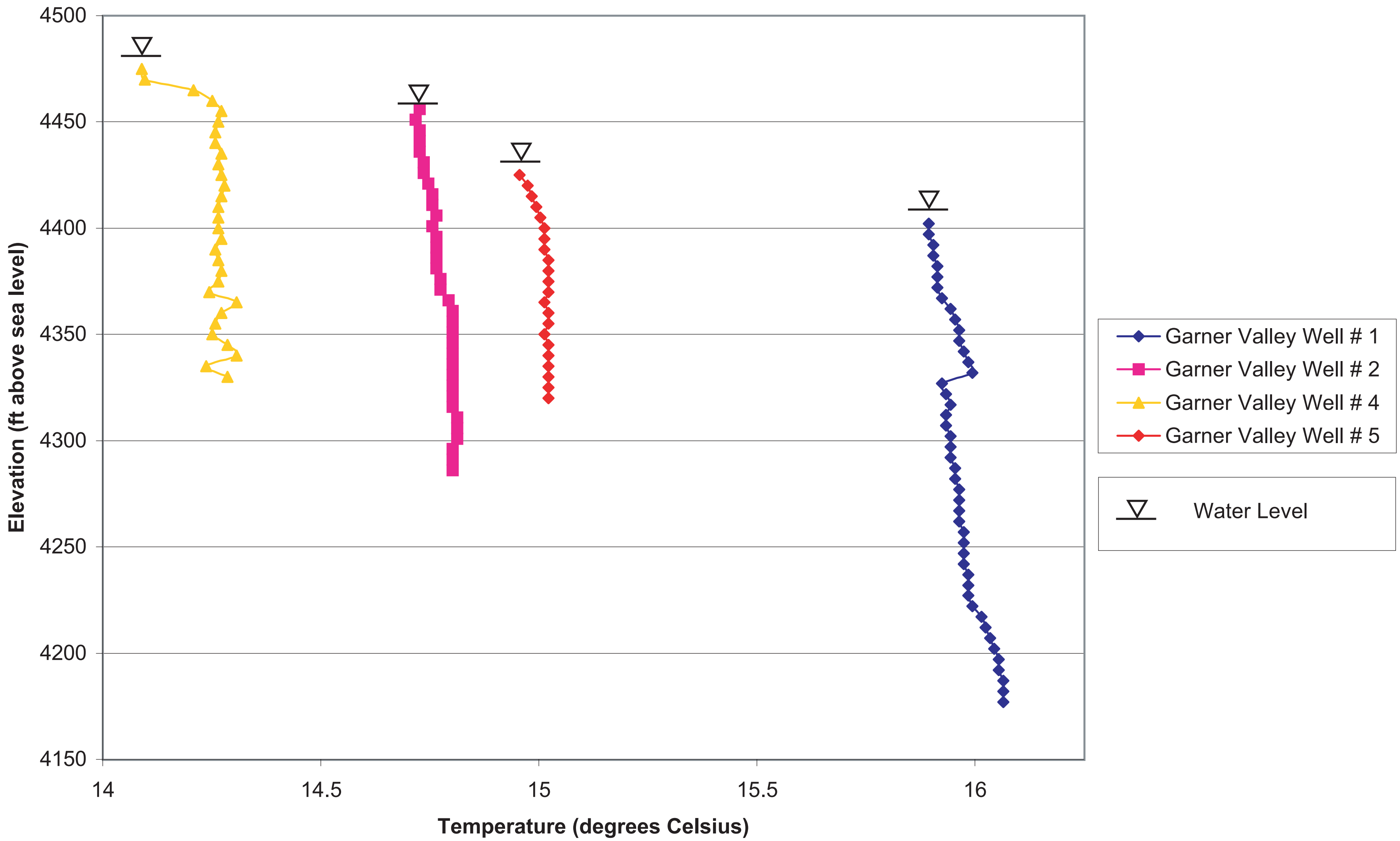


Figure 4b: Garner Valley Well #1 T-log

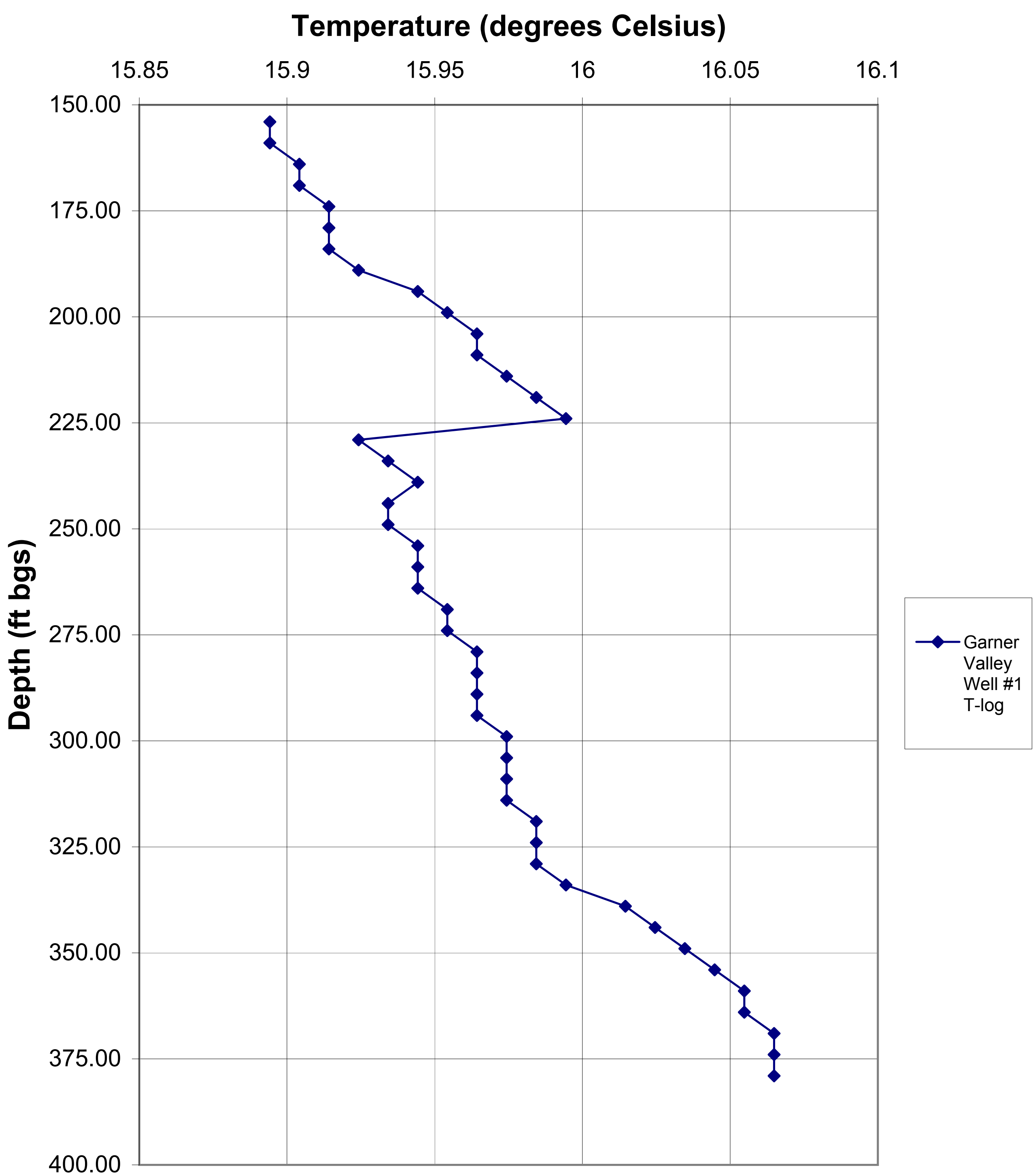


Figure 4c: Garner Valley Well # 2 T-log

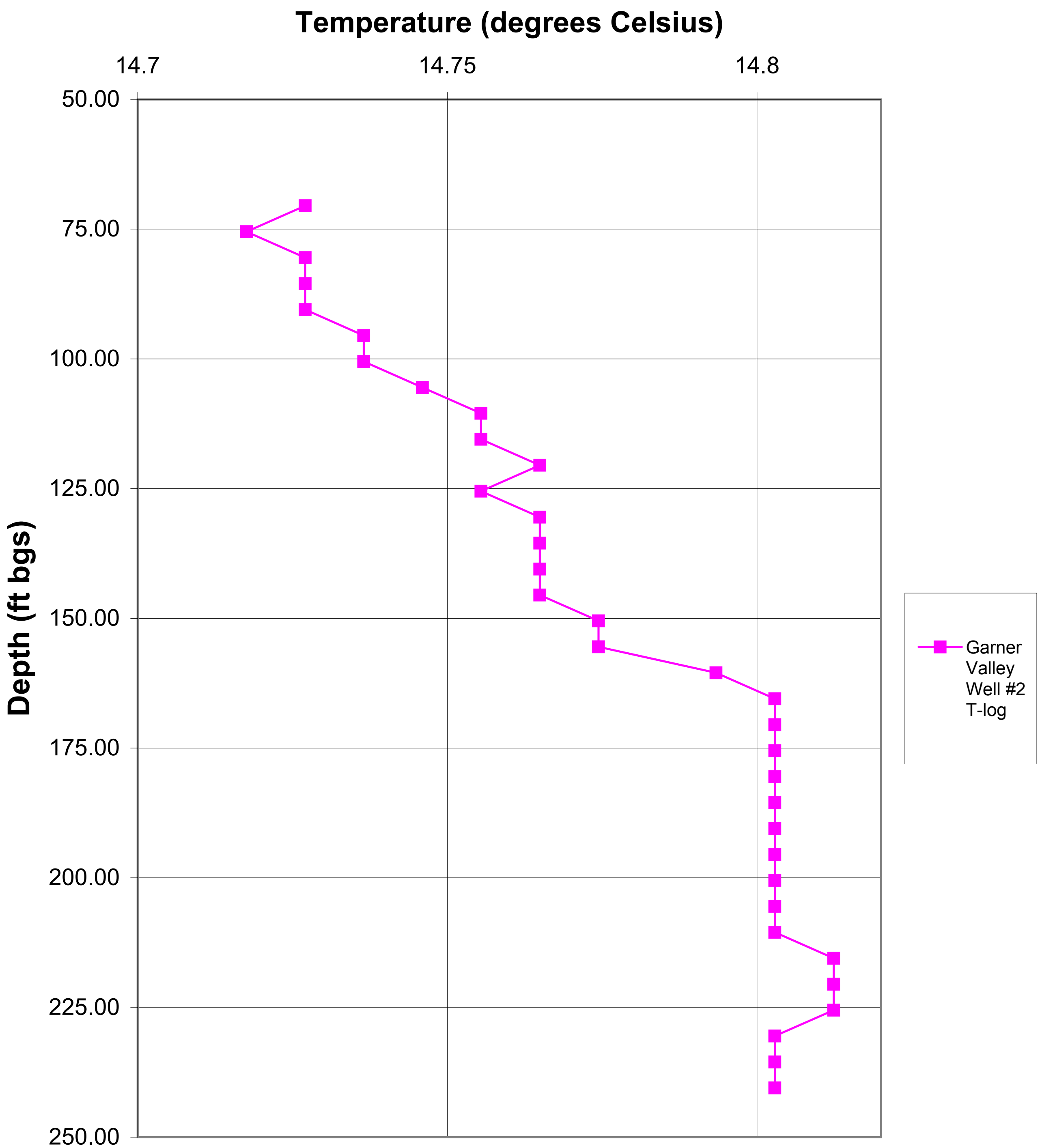


Figure 4d: Garner Valley Well #4 T-log

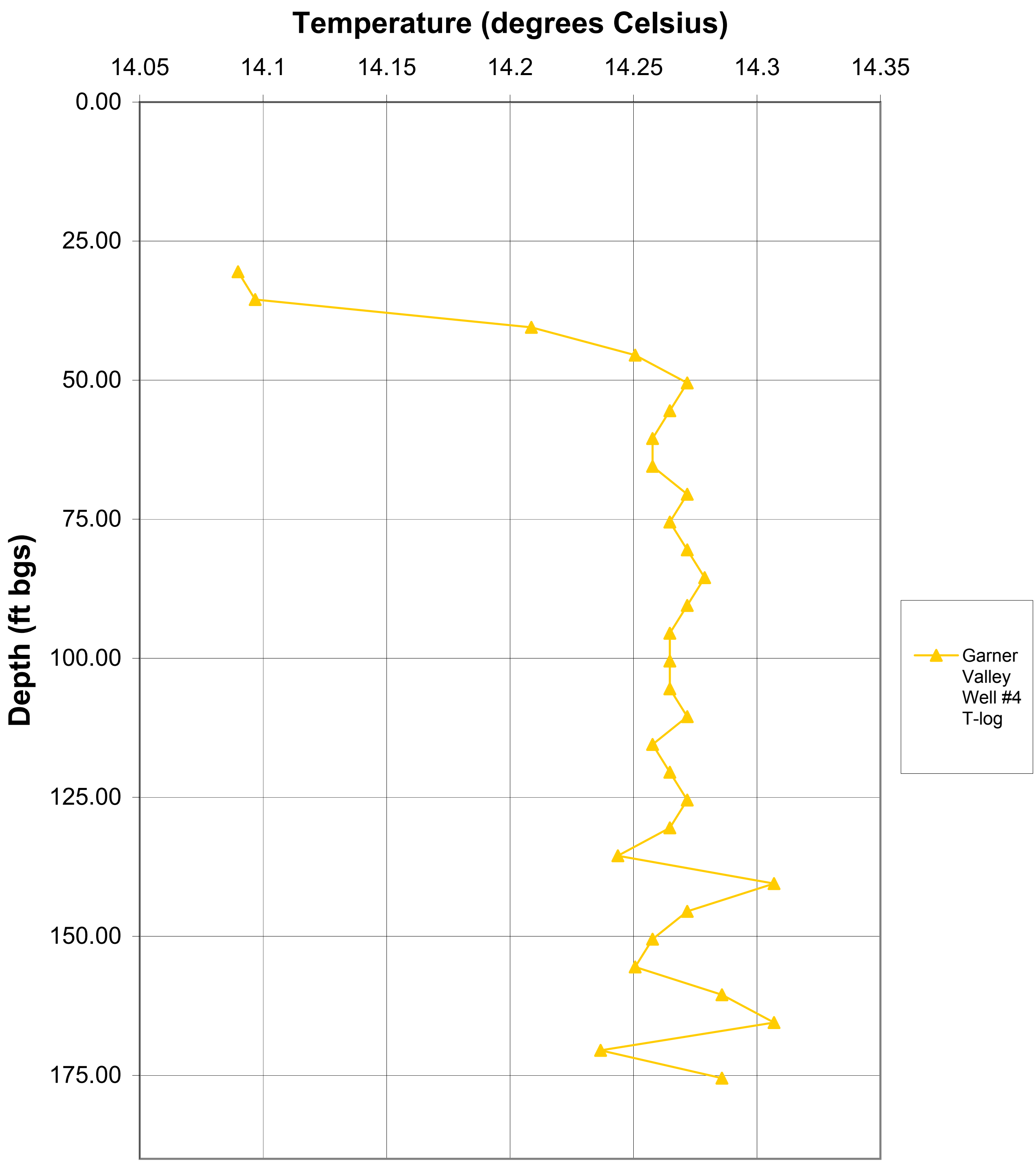
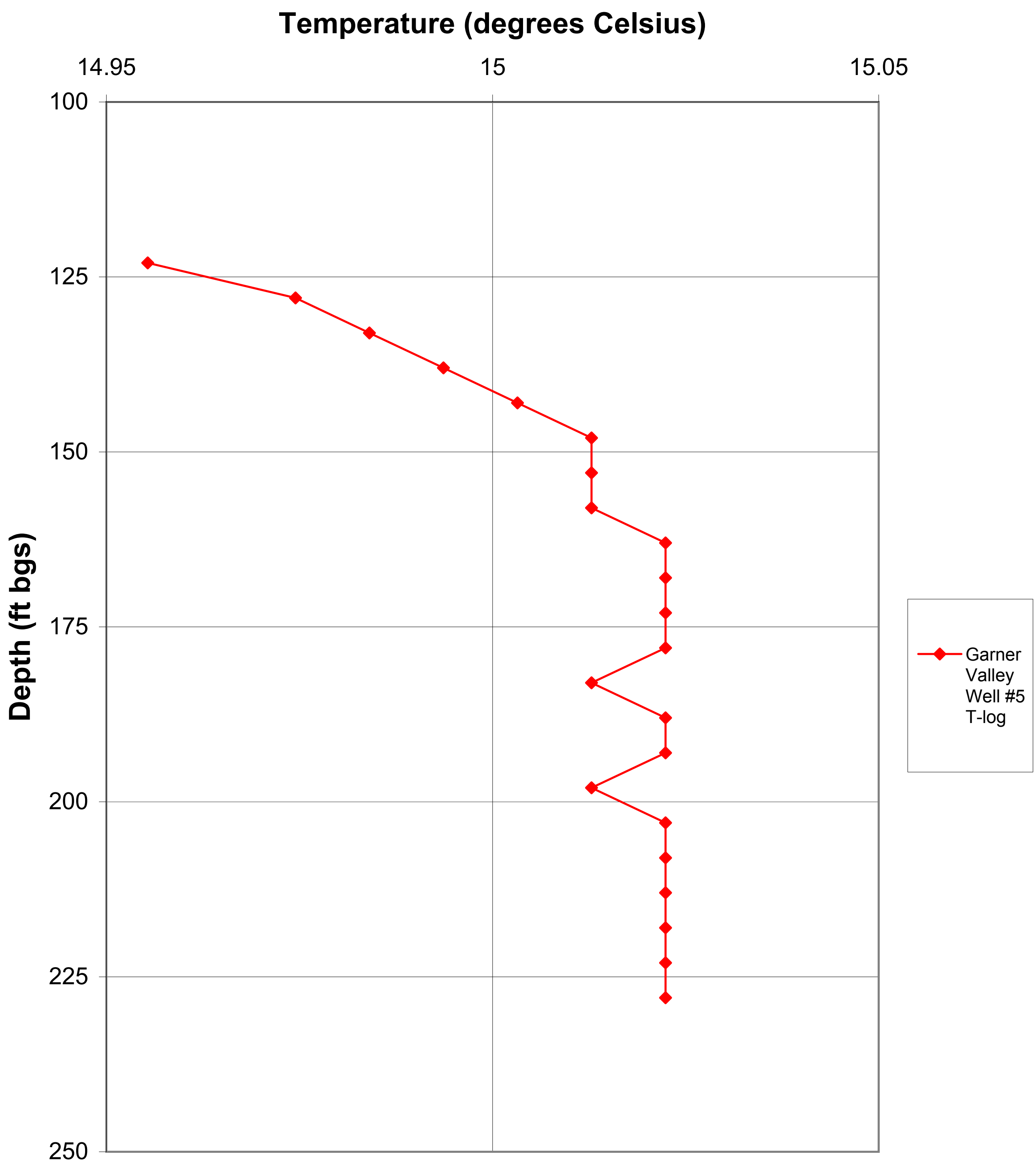


Figure 4e: Garner Valley Well # 5 T-log



WATER QUALITY

Figure 5: Water Quality in Pine Meadow Wells

Using data provided by LHMWD, water quality in G.V. #1, #2, #3, #4, and #5 was analyzed. Our objective was to update our records and make observations about how water quality has varied through time. We analyzed only a small number of the chemicals and properties that have been tested for – organic and radiological results were not considered. It should also be noted that we only analyzed samples in which results for all or most of the general physical and inorganic constituents were tested. Finally, since we do not have a complete water quality record, this analysis probably does not include all of the samples for which all or most of the general physical and organic constituents were tested. For these reasons, only general interpretations can be made.

Figure 5 shows stiff diagrams for each well in Pine Meadow, which are based on the most recent data in our records (Appendix D). Only the diagrams for G.V. #3 and #4 have been updated since our 2004 report with samples taken on 4/2/07 and 2/12/07, respectively. The water from G.V. #3 is still of sodium-bicarbonate type, although its sodium concentration has increased significantly. The water from G.V. #4 has increased slightly in bicarbonate concentration, but is still of calcium-bicarbonate type.

The stiff diagrams suggest that the northerly (G.V. #2 and #4) and southerly (G.V. #1, #3, and #5) wells draw from different aquifers. These aquifers could be separated by a vertical barrier, possibly a fault, between the two well groups. More likely, the aquifers may be separated by horizontal barriers, possibly tight clay lenses, which occur below the bottoms of G.V. #2 and #4 and pinch out to the southeast.

In Appendix D, graphs are given illustrating water quality trends through time. Values for 32 arbitrarily-chosen chemical parameters were plotted for the purpose of comparing samples taken at various times. For G.V. #1, overall values have risen and fallen from 1980 to 2002. From 1987 to 2002, most values appear to have increased. For G.V. #2, barium concentration increased and copper concentration decreased from 1987 to 2002. For G.V. #3 from 1984 to 2007, bicarbonate and sodium increased in concentration, while total hardness decreased. Most values for G.V. #4 appear to have increased slightly through time, except for iron and manganese, which have decreased. There are not enough data to describe general trends through time for G.V. #5.

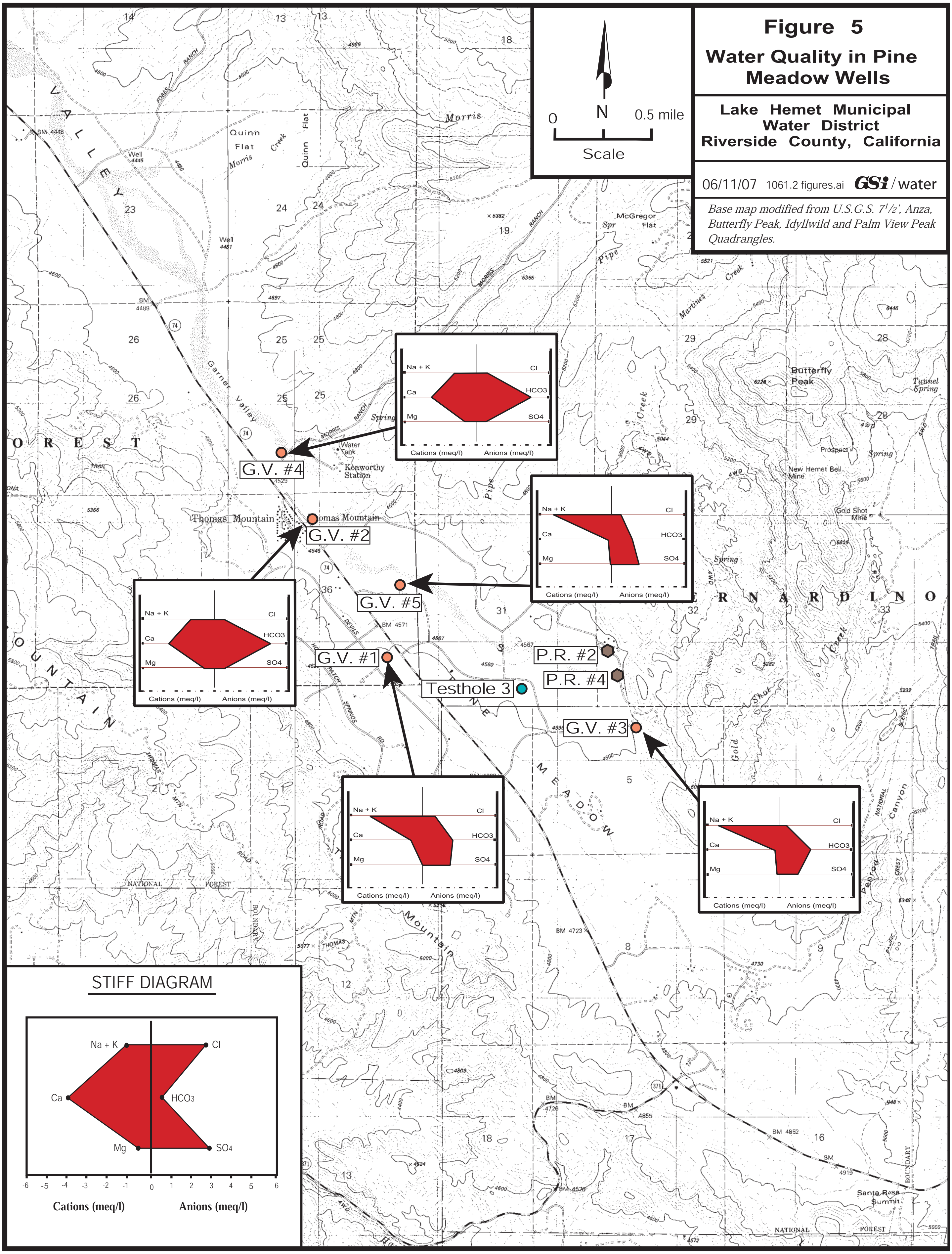


Figure 5
Water Quality in Pine Meadow Wells
Lake Hemet Municipal Water District
Riverside County, California
06/11/07 1061.2 figures.ai GSi/water
Base map modified from U.S.G.S. 7[1]/2', Anza, Butterfly Peak, Idyllwild and Palm View Peak Quadrangles.
N
0
0.5 mile
Scale
G.V. #4
G.V. #2
G.V. #5
G.V. #1
G.V. #3
P.R. #2
P.R. #4
Testhole 3
Na + K
Ca
Mg
Cl
HCO3
SO4
Cations (meq/l)
Anions (meq/l)
STIFF DIAGRAM
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6

“SAFE YIELD” GENERAL ANALYSIS

Figure 6: Pine Meadow Catchments

Figure 6 shows the Valley Floor, defined by the Pine Meadow alluvium, along with the various bedrock catchments and their streams.

In our 2004 report, an infiltration rate method, based on the lithology of Pine Meadow and its surrounding rainfall catchment, was used to calculate the rate of recharge within the Pine Meadow aquifers. This rate was calculated to be 1389 acre ft per year. Subtracting the extraction by wells, the estimated amount of surplus water was 850 acre ft per year. With a projected increase from 217 to 307 residences, this surplus would reduce to 749 acre ft per year.

In this report, we used an infiltration method to calculate the rate of recharge within the Pine Meadow aquifers (i.e. the “Safe Yield”). The total recharge, or Q (in), can be broken down into four terms: (1) Infiltration from direct precipitation onto the Valley Floor; (2) Infiltration from surface runoff from the surrounding catchments; (3) Infiltration from groundwater movement from the catchments into the aquifers; and (4) Infiltration from irrigation and septic tank leaching. These terms can then be added to estimate recharge (the methods for determining these terms are described in Appendix B).

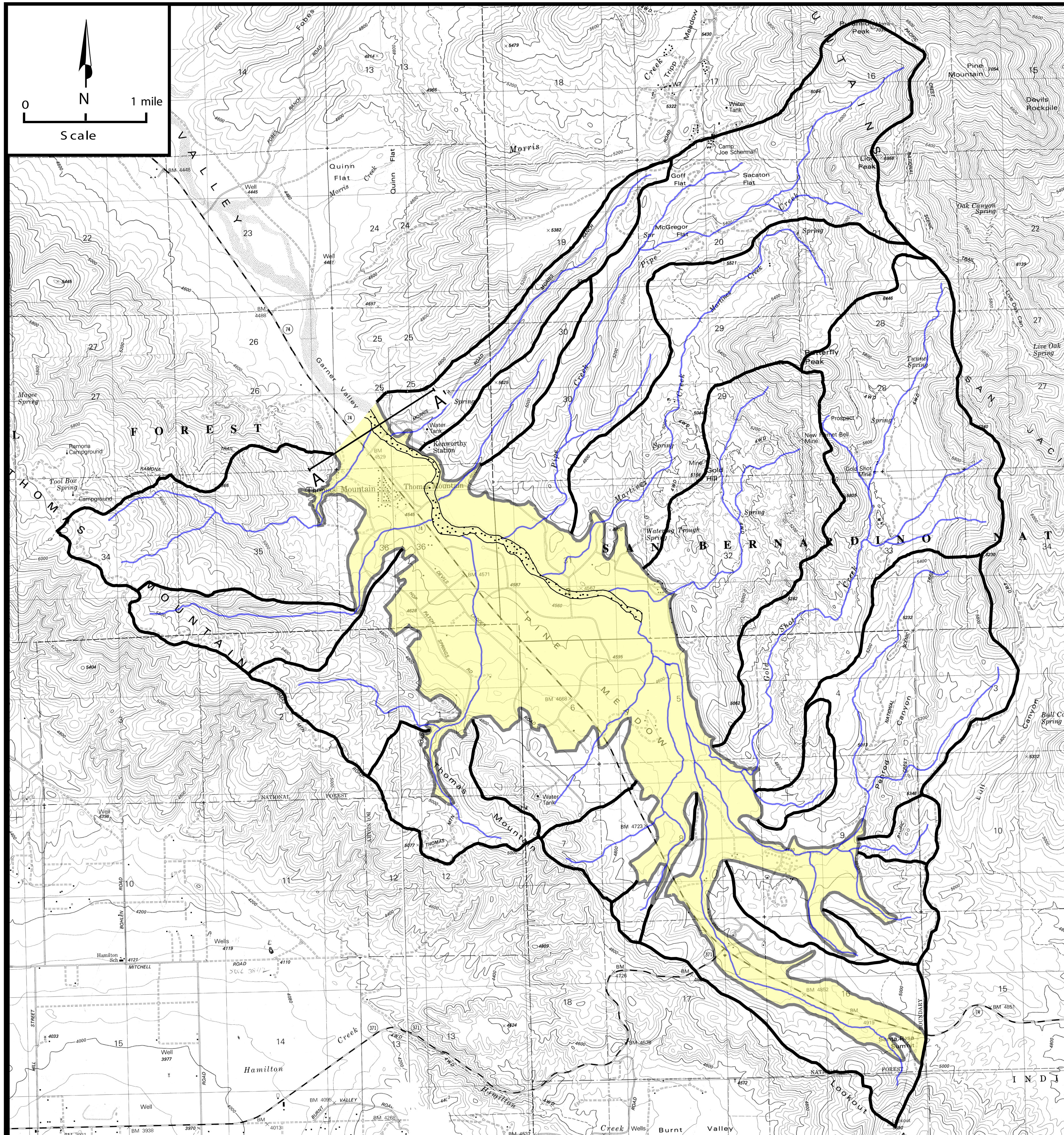
Using the infiltration method, we arrived at an estimated recharge (1028 natural and 58 artificial acre ft per year) of 1086 acre ft per year. This is 303 acre ft per year lower than our 2004 estimate based on infiltration rates. However in 2004, the lack of evapotranspiration and stream gauge data to constrain parameters, the discrepancy is to be expected. Also, our 2004 estimate considered infiltration from irrigation and septic tank leaching to be negligible, whereas in this report it was taken to be 58 acre ft per year.

As another comparison, Durbin (1975) calculated a total natural recharge of 2200 acre ft per year for all of Garner Valley, which is approximately three times the area of Pine Meadow. Thus, one could make a very rough estimate of 730 acre ft per year for natural recharge in Pine Meadow. Again, there is a discrepancy between this estimate and our value of 1086 acre ft per year. However, this may be due to Durbin’s assumption that no recharge occurs in areas with chaparral. Also, Durbin’s calculation does not consider infiltration from septic tank leaching and irrigation.

Total recharge is not the total amount of water in the aquifers. Well extraction reduces this amount. A description of the method used for calculating well extraction is given in Appendix B. Water is extracted from the aquifers by two groups of wells: those owned by LHMWD and those owned by private landowners. The total yearly well extraction, by adding total LHMWD well production in 2006 plus a water requirement estimation for other wells, is about 583 acre ft per year. From the Infiltration approach, the Pine Meadow aquifers may be providing a surplus of 503 acre ft per year. (1086 - 583 = 503 acre ft per year).

The current population served by the Pine Meadow wells is 823 people. If the ratio of total well production to total population served remains constant, then the District’s Pine Meadow wells will have to produce 446 acre ft per year to accommodate the projected population of 1279. This will still leave about 360 acre ft per year of surplus ground water that may be available.

As an independent check on our water balance estimate, we used Darcy’s Law to calculate the amount of groundwater discharging the Pine Meadow aquifers. Our estimate from Darcy’s Law is 137 acre ft per year. Details are explained in Appendix B.



Explanation

Valley Floor Alluvium

Streams (continuous or intermittent)

Catchment Area Boundary

A A' Cross Section Line

Figure 6

"Safe Yield" General Analysis

Pine Meadow Catchments

Lake Hemet Municipal Water District
Riverside County, California

06/12/07 1061.2 fig6.ai GSi/water

Base map modified from U.S.G.S. 7½', Anza, Butterfly Peak, Idyllwild and Palm View Peak Quadrangles.

*All numbers are estimates

	Average Precipitation Year (acre-feet/year)
Current Recharge to Pine Meadow Aquifers	
Natural:	1028
Artificial (Septic tank leaching and irrigation):	58
Total Recharge:	1086
Current Well Extraction	
LHMWD 2006 Production:	287
Other Users:	296
Currently Surplus (Infiltration Method)	
Total Recharge - Extraction:	503
Projected Recharge to Pine Meadow Aquifers	
Natural:	1028
Artificial (Septic tank leaching and irrigation):	74
Total Recharge:	1102
Projected Well Extraction	
LHMWD:	446
Other Users:	296
Projected Surplus (Infiltration Method)	
Total Recharge - Outflow - Extraction:	360
Current Surplus (Darcy's Law)	
Subsurface Outflow:	137

APPENDIX B

<u>“Safe Yield” Detailed Methods</u>

Method Used for "Safe Yield" Calculations for Recharge (Infiltration Method)

The following expression for recharge into the Pine Meadow aquifers beneath the Valley Floor was used:

Recharge = Q (in) = Infiltration from direct precipitation onto Valley Floor + Infiltration from surface runoff from the surrounding catchments + Infiltration by ground water movement from the catchments into the alluvial Valley Floor aquifers + Infiltration by irrigation and septic tank leaching (artificial recharge)

Recharge:

The rain crop for each catchment (including the Valley Floor) was calculated using data from the Lake Hemet precipitation station. To calculate Infiltration by direct precipitation on the Valley Floor, 10% of its rain crop was used. To obtain the Infiltration by ground water movement from the bedrock ("bedrock" in this case means non-alluvium) catchments into the aquifers, 1% (for mainly granitic catchments) or 5% (for catchments covered mainly by the Bautista Beds) of each bedrock catchment's rain crop was taken. Each catchment's contribution was then added to derive the total. Infiltration by irrigation and septic tank leaching was deemed to be 10% of the well extraction by LHMWD and other users in the Pine Meadow area.

To obtain Infiltration by surface runoff from the bedrock catchments, evapotranspiration was calculated for each catchment using a modified version of the method described by Crippen in 1965 (see References). This involved estimating an estimated "average" elevation for each catchment, assuming that precipitation would be roughly constant throughout the basin; and using an empirical curve from Crippen to estimate potential evapotranspiration for each catchment. The amount of recoverable water could then be found using the empirical relation between the ratios of Precipitation/Potential Evapotranspiration and Recoverable Water/Potential Evapotranspiration. After adjusting for lithologic effects with a retentivity factor (from Crippen), Recoverable Water was subtracted from Precipitation to obtain Actual Evapotranspiration. Surface runoff values could then be derived by subtracting evapotranspiration and estimated infiltration from each rain crop. 10% of the total surface runoff volume was estimated to infiltrate the Pine Meadow aquifers.

This infiltration method assumes that our estimated infiltration rates are reasonably accurate. It also assumes that the method we used to calculate evapotranspiration, as well as our modifications of that method, are valid. Additionally, this method assumes that all infiltrated ground water and surface runoff from the bedrock catchments flows into the Pine Meadow aquifers.

Method Used for “Safe Yield” Calculations for Well Extraction and Groundwater Outflow

Ground Water Outflow (Darcy’s Law):

If ground water flows northwest through the alluvial aquifers and out of Pine Meadow, the outflow can be calculated using Darcy’s Law: $Q = K * A * i$, where Q is discharge, K is hydraulic conductivity, i is the hydraulic gradient, and A is the cross-sectional area.

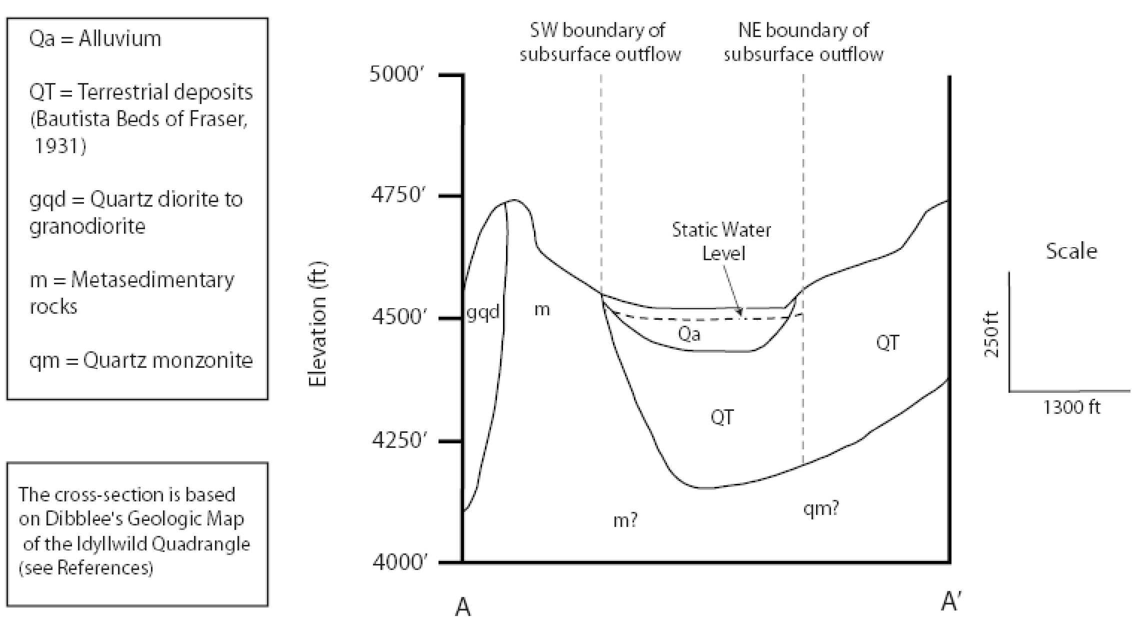
A cross-section (A -- A’ in Figure 6) was drawn across Pine Meadow’s northwest boundary chosen from the data from Durbin’s gravity study, well logs, water levels, and geological information. Cross-sectional areas were calculated using this cross-section. The hydraulic gradient, 0.01, was reduced from the slope of the valley (which was approximately 0.14). A hydraulic conductivity value of 100 gpd/ft^2 was used for alluvium, and 5 gpd/ft^2 was used for the older Bautista beds (Freeze and Cherry, 1979).

This method assumes that our cross-section reasonably represents the subsurface, and that ground water flows only through the area defined by the Quaternary units between the edges of the valley.

Well Extraction:

To obtain LHMWD’s well extraction, the total 2006 production for G.V. #1, #2, #4, and #5 was used. For the Estimated extraction for other wells in Pine Meadow, our estimate from 2004 (based on a very liberal average amount of water required to maintain livestock, pastureland, and residences) was used.

The estimated extraction for other wells in Pine Meadow is very rough, due to a lack of available information from private sources.



APPENDIX C

Pine Meadow Static Water Levels and Production Records

Pine Meadow Static Water Levels (Feet Below Ground Surface)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983												
GV #1						92	99.5		100	83	79	84.5
GV #2						5				17.5	24	22
1984												
GV #1	76.5		140	140		139			113	132.6	120.5	147
GV #2	30		32	22		22				26		22
1985												
GV #1	108.5				147.6							
GV #2	18.5	19.1	19	17.5						41	33.5	114.8
1986												
GV #1		111		103.6								
GV #2	26.7	39.5	23.6	26	25.9			30.1	30		27.8	24.5
GV #4					7	8.5	9				11	11.4
1987												
GV #1	121.2			117		103.1	109	110				224.5
GV #2	22.4	21.1	22	22.3					32.3	32.5	30.4	28.8
GV #4	11	11.2	11.9	9.5		10		15		16.3	15.8	15
1988												
GV #1	107.7	107.5	97.7	101	97.9				132.4			115.4
GV #2	25.3	25	22	24.3	22.4	24.8	25.4		28.2		28.2	27
GV #4	15.9	15.1	15.2		15.7	16.9	16.5		10.4			
1989												
GV #1	104.6	99.4	132.2	103.8	105.3	101.3				116.8		112.5
GV #2	25		24.2	24.3	25.6	26.8				32.9		29.8
GV #4		18.8	18.2									25.9

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990												
GV #1	112	104.1	103.1	103.9	107.4					212.8		
GV #2	28.7	28.1	28	27.9	29	30.3			44.8	42.5	43.1	39
GV #4		24.1	23.7	22.7		63.1					29	
1991												
GV #1	131.9	134.5		118.5	109.7		134.6					112
GV #2	36.4	37.4	36.1	31.2	26	25.5	28.1	30.9	31.9	30.9	30.9	26.7
GV #4	28.5	27.8	19				17.5				18	18.4
1992												
GV #1	102	112..3	97.2	100.2	97.6	97.2			128.9	116.6	115.7	116.4
GV #2	24.8	24.6	21.4	20.3	18.9	19.3	20.9	24.2	24.3	24.8	23.3	23.9
GV #4	18.2	18.1	12.8	9.2	11.4					19.8	18.5	20.6
1993												
GV #1	96.7	93.7	87	84.5	84	93.2	100.5		17.9		139.9	95.8
GV #2	22	15.6	12	10.7	10.8	11.3	18.8		104.9	20	20.4	18
GV #4	17.8	5.9	4.8	5.6		7.3	7.2				10.1	9.9
1994												
GV #1	58.6	48.2	48.8	44		43.8	147.3	140.8		102.1	93.1	93
GV #2	15.4	14.1	12.8	11.6	13	12.9	67			25	21.5	20
GV #4	9.7	9.7	6.8	6.4		12.1					15.4	14.6
1995												
GV #1	87.8	78.7	87.8	76.3	115.5	111.6	83.2	93.8		87.6	88.2	87.5
GV #2	19.6	16.2	19.6	15	12.3	12.9			18.7	17.3	25.1	23.9
GV #4		6.4			12					11.6	10.5	10.2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996												
GV #1	87.8	85.3	84.5	86.3	84.5	89.3		100.9		134.9	134	133.9
GV #2	23	16	15.6	16.5	16.9	21.2		26		40.8	40.1	38.8
GV #4	11.1	9.9	9.6	10		60.1		60.2		17.6	18	15.9
1997												
GV #1	89.4	86.7	83.5	86.8	85.4	90.1	99.9		111.9	90.3	120.3	103.2
GV #2	20.6	19.4	18.5	20.1			39.3	49.6	52.4	47	36.9	29.6
GV #4	14.3		13.5				18.7	20.1	22.3	18.8	18.8	20
1998												
GV #1	104	106	99.8	110	149	95.9	151	154.9	151	151	143.6	119
GV #2	27.5	30.6	30.4	22	20.4	18.4	23	40.9	30.5	30.5	29.8	26.3
GV #4	19.8	18.8	7.1	6.9	6.8	14	6.8	10.9	11	11	11.9	11.4
1999												
GV #1	107.3	100.9	99.8	98	99.3	99.6	104.4	126	116.3	110.3	105.2	139.2
GV #2	21.3	20.1	19.4	21.2	22	22.4	31.6	40.3	40	32.4	28.6	33.7
GV #4	10.9	11.5	11.7	11.9	11.1	12.9	11.1	20.2	19.5	20.2	24.7	19.4
2000												
GV #1	135.4	109.3	128.9	110.5	115.5	117.2	131.2			134.3	122.3	113.9
GV #2	31	28.6	89.4	27.8	28.7	30.4	49.5			66.6	38.6	33.9
GV #4	19.2	18.7	47.6	18.5	20.6	24.8	23.4			23.9	24.1	23.2
2001												
GV #1	123.2	122.6	106.1	122.4					142.6	143.6	126.3	127.3
GV #2	39.1	37.9	38.1	30	30.5	37.6			70.6	43.6	47.7	49.2
GV #4	24.6	24.4	22.7	24	24.2		32.6			30.3	30.5	28.7

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002												
GV #1	117.9	119.4	113.7	131.1	123.9	120.1		178.2	143.2	176.2	139.9	124.7
GV #2	37.7	35.2	36.2	36.7	39.9	36.7		77.7	59	56.6	50.2	45.7
GV #4	27.6	60		46.7	29	31		34.6	35.5	36.1		35.1
2003												
GV #1	118.9	113.9	111.5	118.2	123.3		166.2	151.3	148.8			
GV #2	42.1	38.9	38.8	41.9	46.8	88.1	78.5					
GV #4	35.2	33	32.5	28.4	28.6	29.4	33.6		95.3			
GV #5	59.3	66.6	104.9	111.7	99.8	128	89	91.2	79.5			
2004												
GV #1	121.8	122.1	124.8	114						133		
GV #2	47	47.4	59.4	47.4		178	178			75		
GV #4	35.1	34.9	76.8	30.6						49		
GV #5	58.8	58.1	54.1							116		
2005												
GV #1	122	148	132									
GV #2	64	67	51						78			62
GV #4	58.3	178.4	123						73			39.8
GV #5	106	70							150			136
2006												
GV #1	146	129.6	132		126	147		184	167			154
GV #2	88	53	48		41	57					69	66
GV #4	16.7	16.7	16.7		14.4	30.6					16.3	26
GV #5	87		82	91	75						79	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007												
GV #1	138	138	142									
GV #2	59	55	48									
GV #4	21.3	26	44.4									
GV #5	150	73	71									

Pine Meadow Well Production (acre-ft)

Year	GV # 1	GV # 2	GV # 4	GV # 5	Total
1987	8.44	0.64	10.71		19.79
1988	42.80	12.21	172.07		227.08
1989	22.71	15.71	205.06		243.48
1990	67.01	20.62	142.18		229.81
1991	55.31	2.69	132.60		190.60
1992	20.91	1.22	211.28		233.41
1993	24.16	7.66	204.82		236.64
1994	14.13	21.09	205.74		240.96
1995	4.89	21.73	188.00		214.62
1996	13.95	21.34	201.06		236.35
1997	28.94	26.44	194.94		250.32
1998	47.74	30.57	126.97		205.28
1999	28.73	34.35	192.95		256.03
2000	33.30	36.50	189.68		259.48
2001	34.08	27.04	182.26		243.38
2002	45.36	31.52	204.88	3.54	285.30
2003	21.28	64.39	113.97	28.50	228.12
2004	34.58	63.85	132.03	55.20	285.67
2005	34.41	65.88	91.84	55.35	247.47
2006	34.39	64.50	123.22	64.59	286.70
Average (1988 - 2006)	32.04	29.96	169.24	41.43	242.14

APPENDIX D

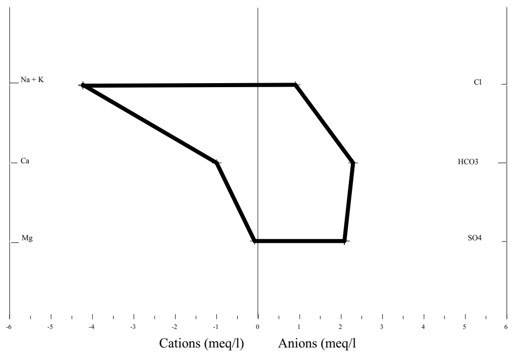
Stiff Diagrams and Water Quality Trends

G.V. #1

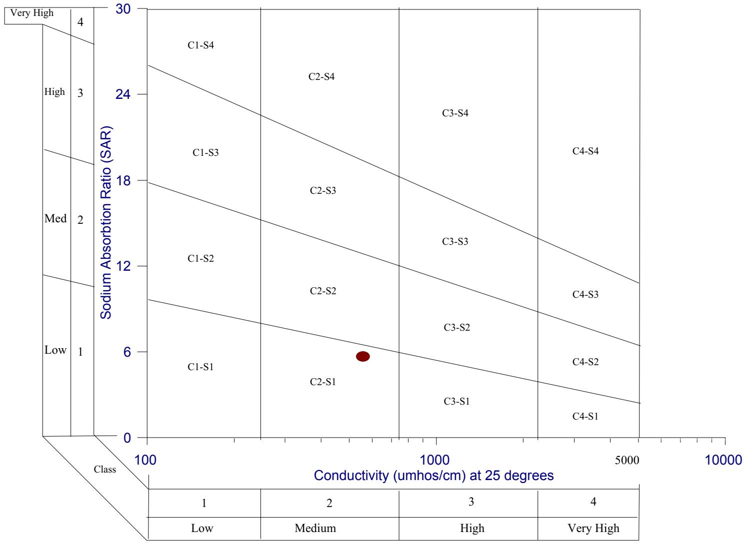
Sample collected 03/13/2002

Water Classification

Stiff Diagram



Irrigation Water Classification



Chloride (Cl)	32	mg/l	0.9	meq/l
Sulfate (SO4)	100	mg/l	2.1	meq/l
Bicarbonate (HCO3)	140	mg/l	2.3	meq/l
Potassium (K)	2	mg/l	0.1	meq/l
Sodium (Na)	96	mg/l	4.2	meq/l
Calcium (Ca)	20	mg/l	1.0	meq/l
Calcium hardness	52	mg/l		
Magnesium (Mg)	1	mg/l	0.1	meq/l
Total filterable residue as CaCO3	330	mg/l		
Temperature	15	deg C		
pH	8.30	pH Units		
Total Alkalinity as CaCO3	110	mg/l		
Total Dissolved Solids	330	mg/l		
Electrical Conductivity	560	umhos/cm		

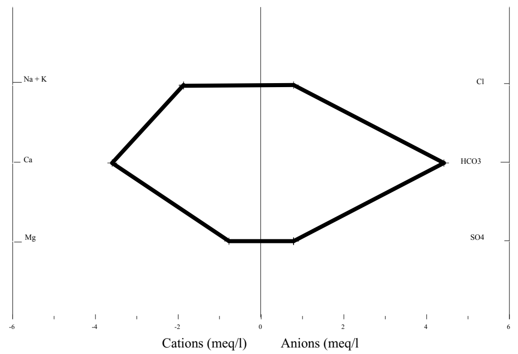
Langlier Index	-0.43
Will the water form carbonate scale?	NO
Ryzner Index	8.20
Is the water corrosive?	YES
SAR	5.68

G.V. #2

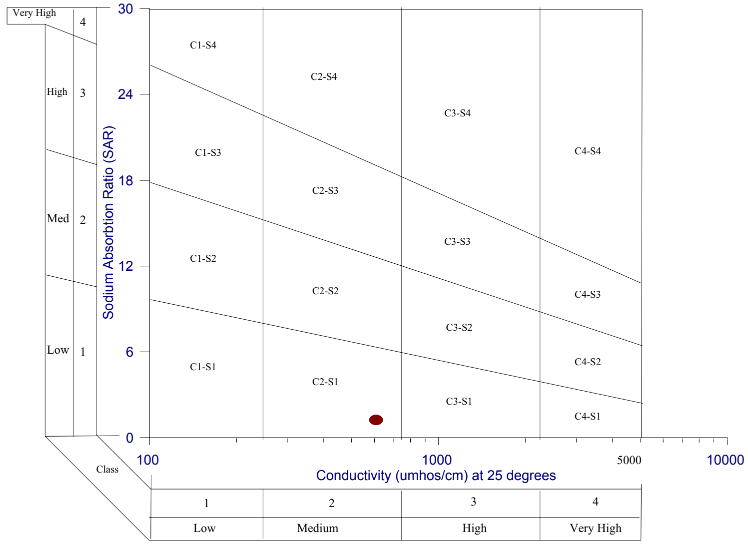
Sample collected 03/13/2002

Water Classification

Stiff Diagram



Irrigation Water Classification



Chloride (Cl)	28	mg/l	0.8	meq/l
Sulfate (SO4)	38	mg/l	0.8	meq/l
Bicarbonate (HCO3)	270	mg/l	4.4	meq/l
Potassium (K)	2	mg/l	0.0	meq/l
Sodium (Na)	42	mg/l	1.8	meq/l
Calcium (Ca)	72	mg/l	3.6	meq/l
Calcium hardness	220	mg/l		
Magnesium (Mg)	9	mg/l	0.8	meq/l
Total filterable residue as CaCO3	380	mg/l		
Temperature	15	deg C		
pH	7.40	pH Units		
Total Alkalinity as CaCO3	220	mg/l		
Total Dissolved Solids	380	mg/l		
Electrical Conductivity	610	umhos/cm		

Langlier Index	-0.48
Will the water form carbonate scale?	NO

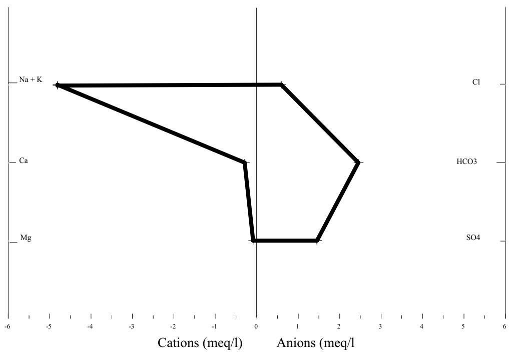
Ryzner Index	7.32
Is the water corrosive?	YES

SAR	1.24

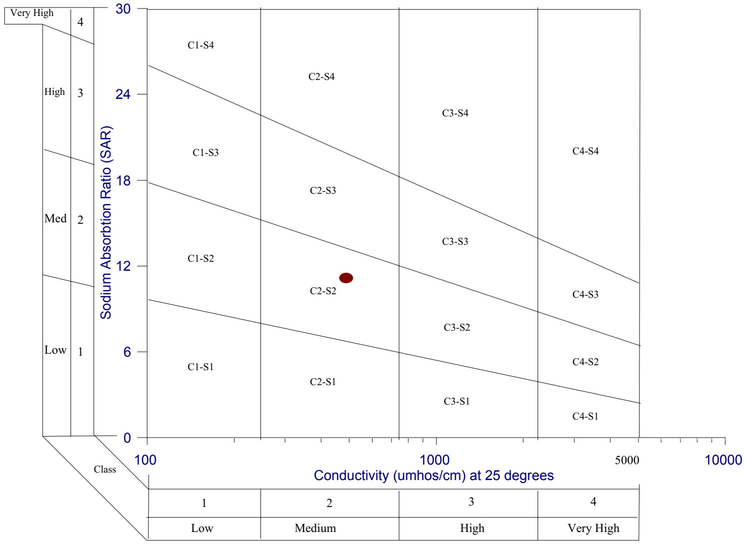
G.V. #3
Sample collected 04/02/2007

Water Classification

Stiff Diagram



Irrigation Water Classification



Chloride (Cl)	21	mg/l	0.6	meq/l
Sulfate (SO4)	70	mg/l	1.5	meq/l
Bicarbonate (HCO3)	150	mg/l	2.5	meq/l
Potassium (K)	1	mg/l	0.0	meq/l
Sodium (Na)	110	mg/l	4.8	meq/l
Calcium (Ca)	6	mg/l	0.3	meq/l
Calcium hardness	15	mg/l		
Magnesium (Mg)	1	mg/l	0.1	meq/l
Total filterable residue as CaCO3	290	mg/l		
Temperature	15	deg C		
pH	8.70	pH Units		
Total Alkalinity as CaCO3	120	mg/l		
Total Dissolved Solids	290	mg/l		
Electrical Conductivity	490	umhos/cm		

Langlier Index	-0.53
Will the water form carbonate scale?	NO

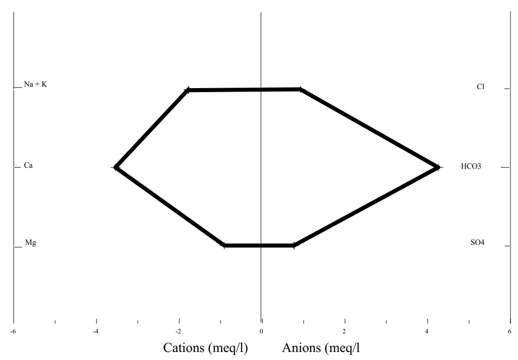
Ryzner Index	8.79
Is the water corrosive?	YES

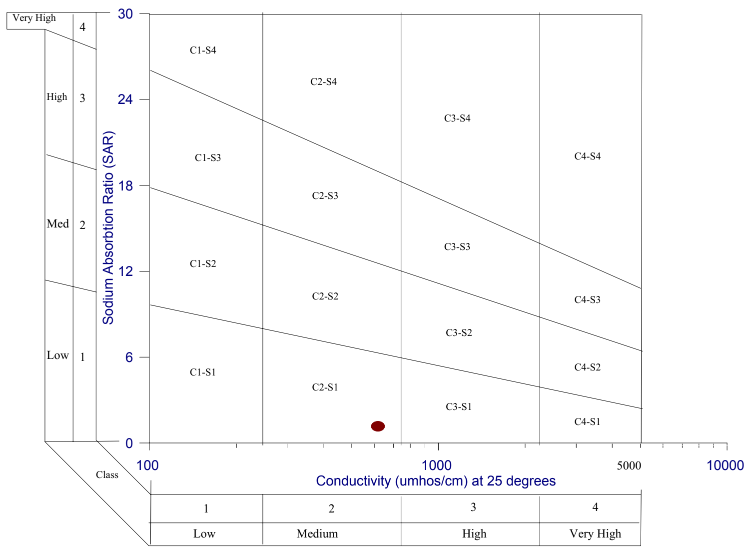
SAR	11.17

G.V. #4

Sample collected 02/12/2007

Water Classification





Chloride (Cl)	33	mg/l	0.9	meq/l
Sulfate (SO4)	37	mg/l	0.8	meq/l
Bicarbonate (HCO3)	260	mg/l	4.3	meq/l
Potassium (K)	1	mg/l	0.0	meq/l
Sodium (Na)	40	mg/l	1.7	meq/l
Calcium (Ca)	71	mg/l	3.5	meq/l
Calcium hardness	220	mg/l		
Magnesium (Mg)	11	mg/l	0.9	meq/l
Total filterable residue as CaCO3	360	mg/l		
Temperature	15	deg C		
pH	7.20	pH Units		
Total Alkalinity as CaCO3	210	mg/l		
Total Dissolved Solids	360	mg/l		
Electrical Conductivity	620	umhos/cm		

Langlier Index	-0.71
Will the water form carbonate scale?	NO

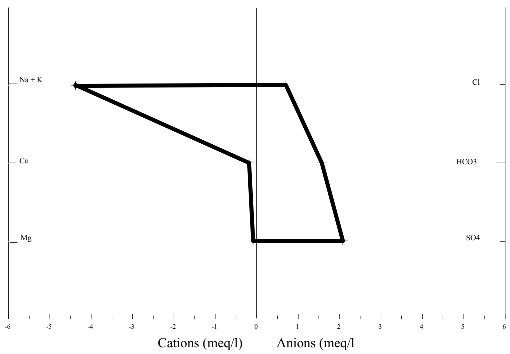
Ryzner Index	7.51
Is the water corrosive?	YES

SAR	1.17

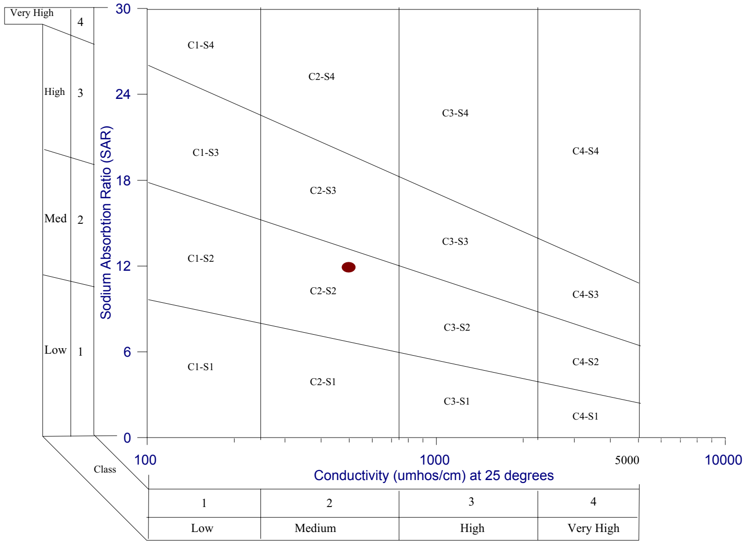
G.V. #5
Sample collected 08/28/2002

Water Classification

Stiff Diagram



Irrigation Water Classification

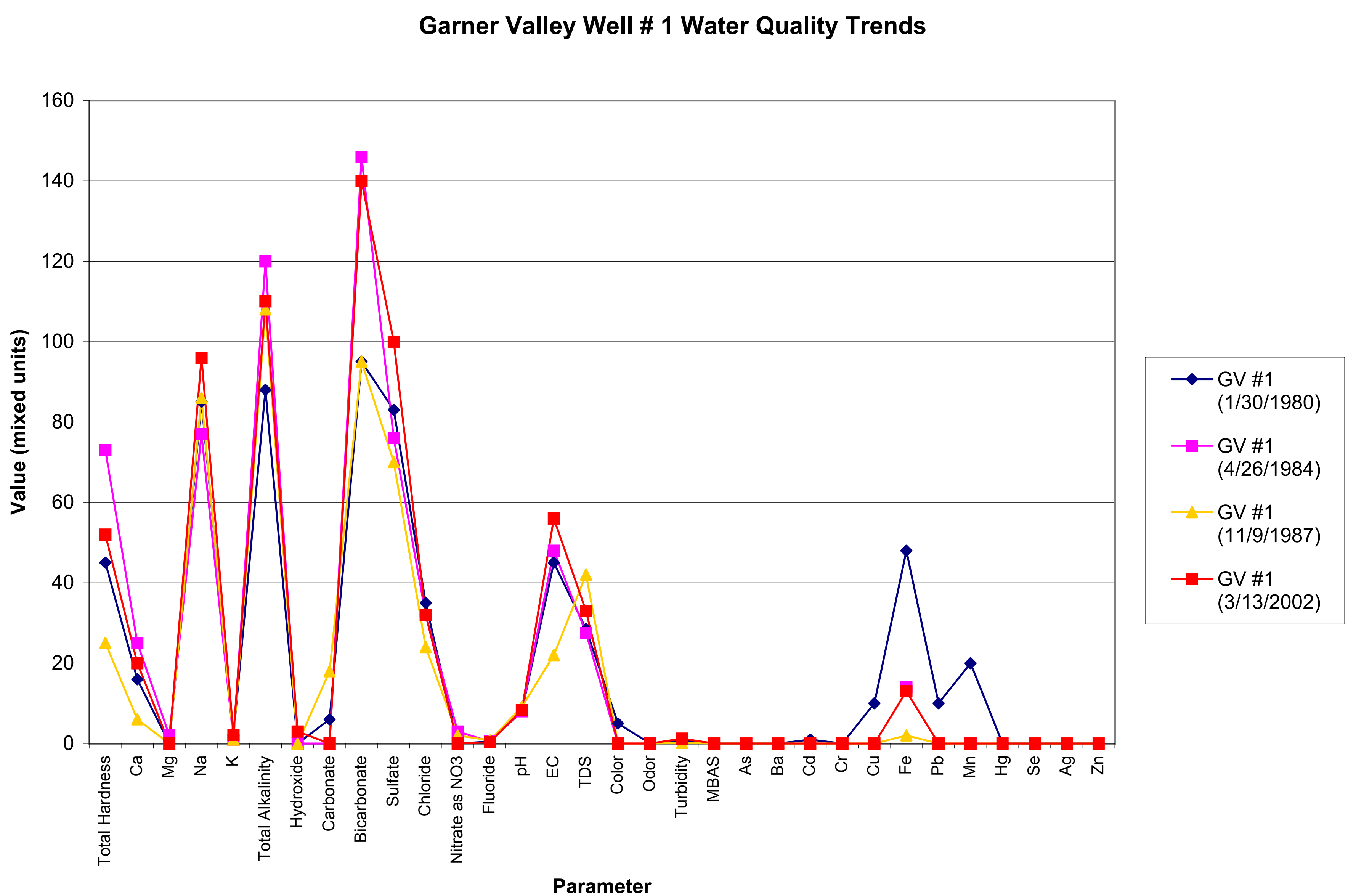


Chloride (Cl)	25	mg/l	0.7	meq/l
Sulfate (SO4)	100	mg/l	2.1	meq/l
Bicarbonate (HCO3)	96	mg/l	1.6	meq/l
Potassium (K)	1	mg/l	0.0	meq/l
Sodium (Na)	100	mg/l	4.3	meq/l
Calcium (Ca)	4	mg/l	0.2	meq/l
Calcium hardness	10	mg/l		
Magnesium (Mg)	1	mg/l	0.1	meq/l
Total filterable residue as CaCO3	270	mg/l		
Temperature	15	deg C		
pH	9.00	pH Units		
Total Alkalinity as CaCO3	85	mg/l		
Total Dissolved Solids	270	mg/l		
Electrical Conductivity	500	umhos/cm		

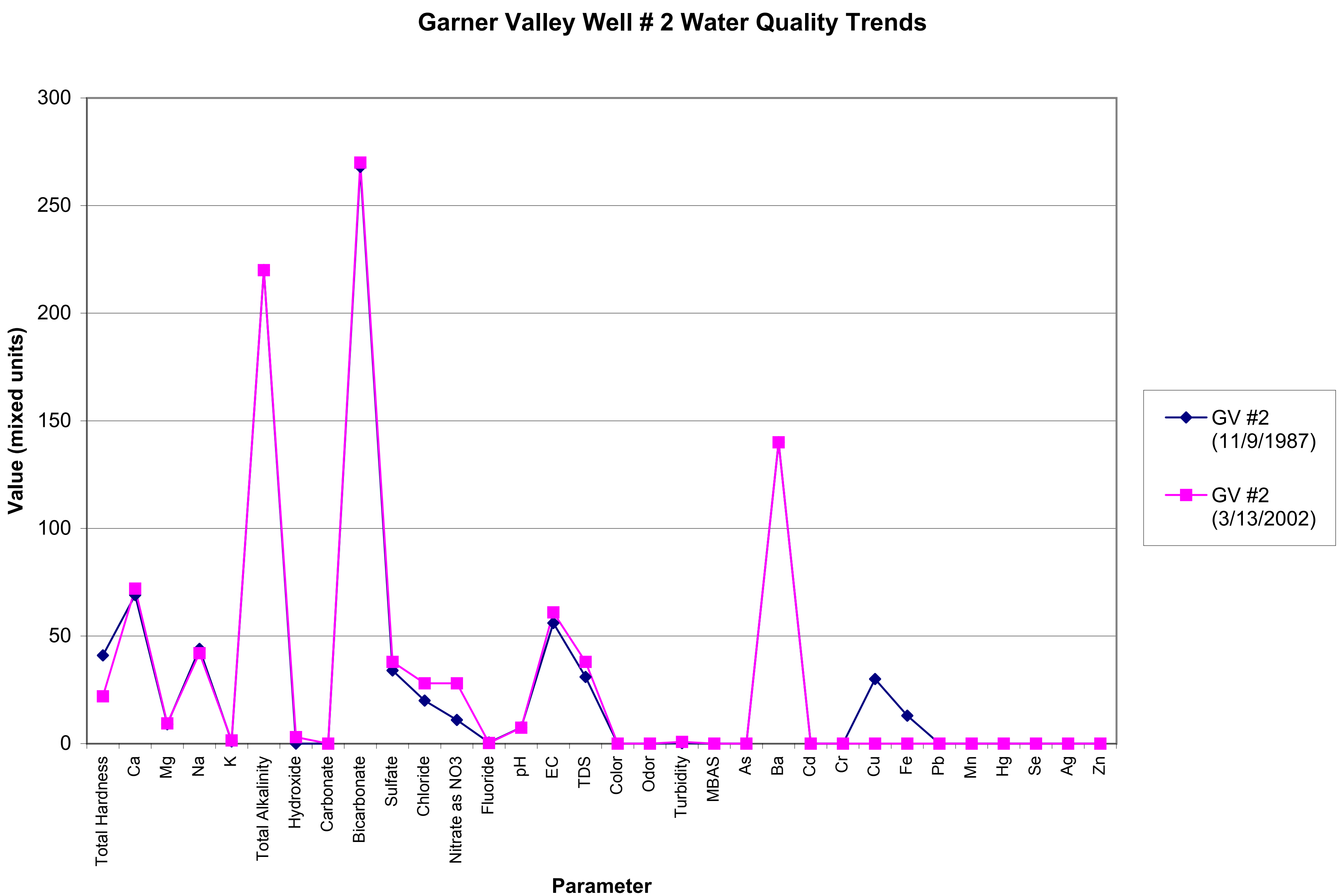
Langlier Index	-0.57
Will the water form carbonate scale?	NO

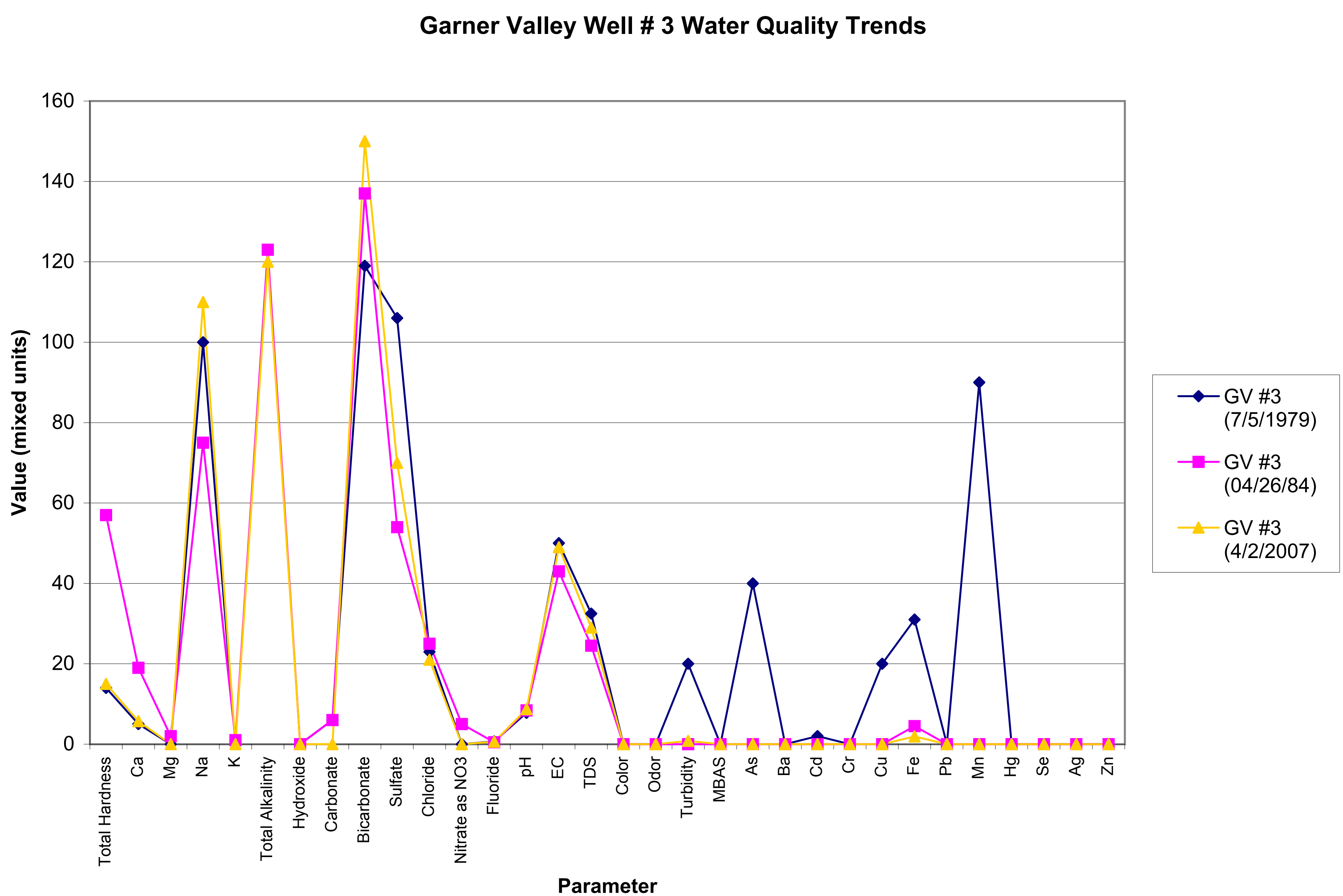
Ryzner Index	9.09
Is the water corrosive?	YES

SAR	11.91

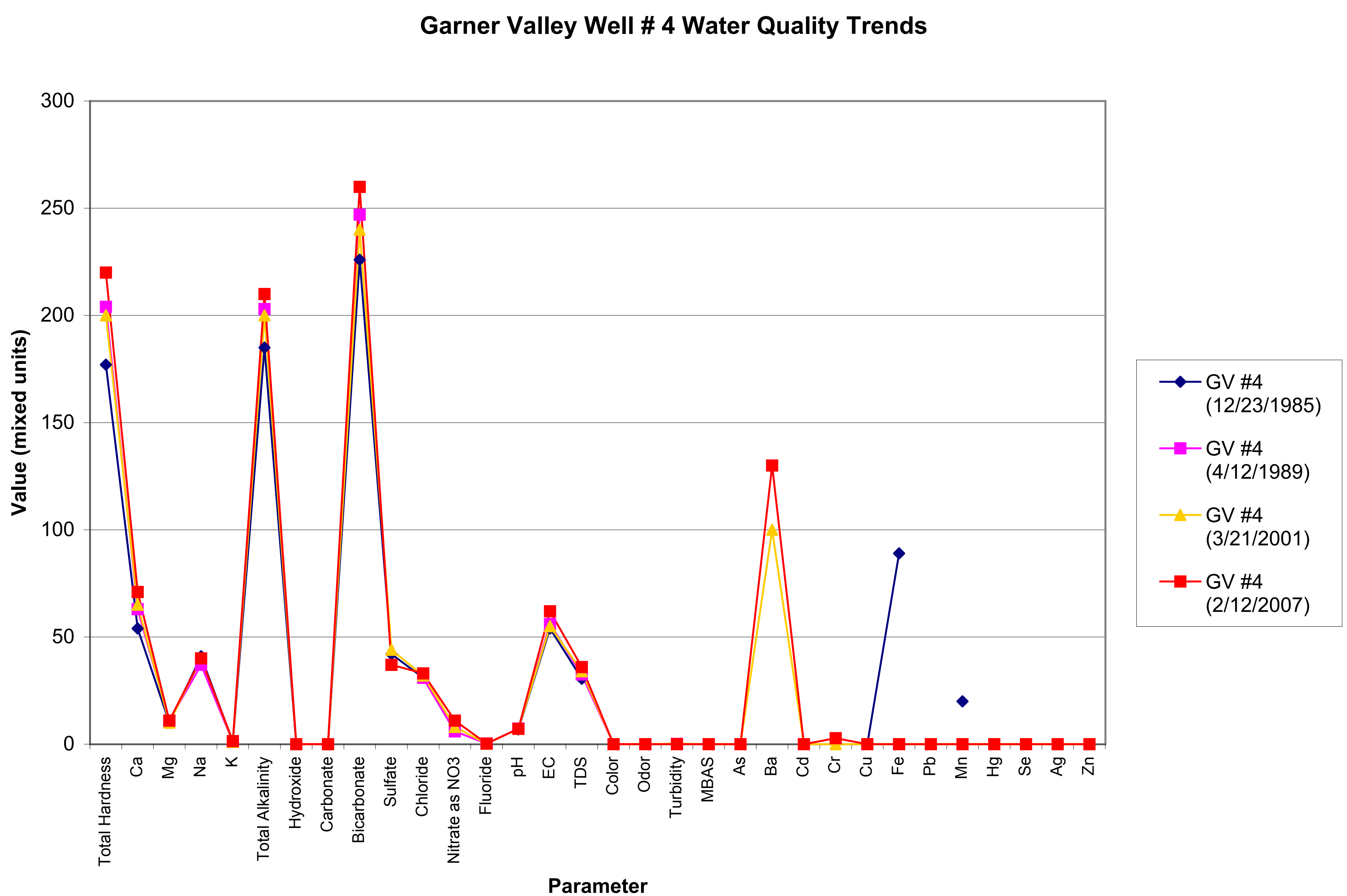


Garner Valley Well # 1 Water Quality Trends
Value (mixed units)
160
140
120
100
80
60
40
20
0
Total Hardness
Ca
Mg
Na
K
Total Alkalinity
Hydroxide
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate as NO3
Fluoride
pH
EC
TDS
Color
Odor
Turbidity
MBAS
As
Ba
Cd
Cr
Cu
Fe
Pb
Mn
Hg
Se
Ag
Zn
Parameter
GV #1 (1/30/1980)
GV #1 (4/26/1984)
GV #1 (11/9/1987)
GV #1 (3/13/2002)

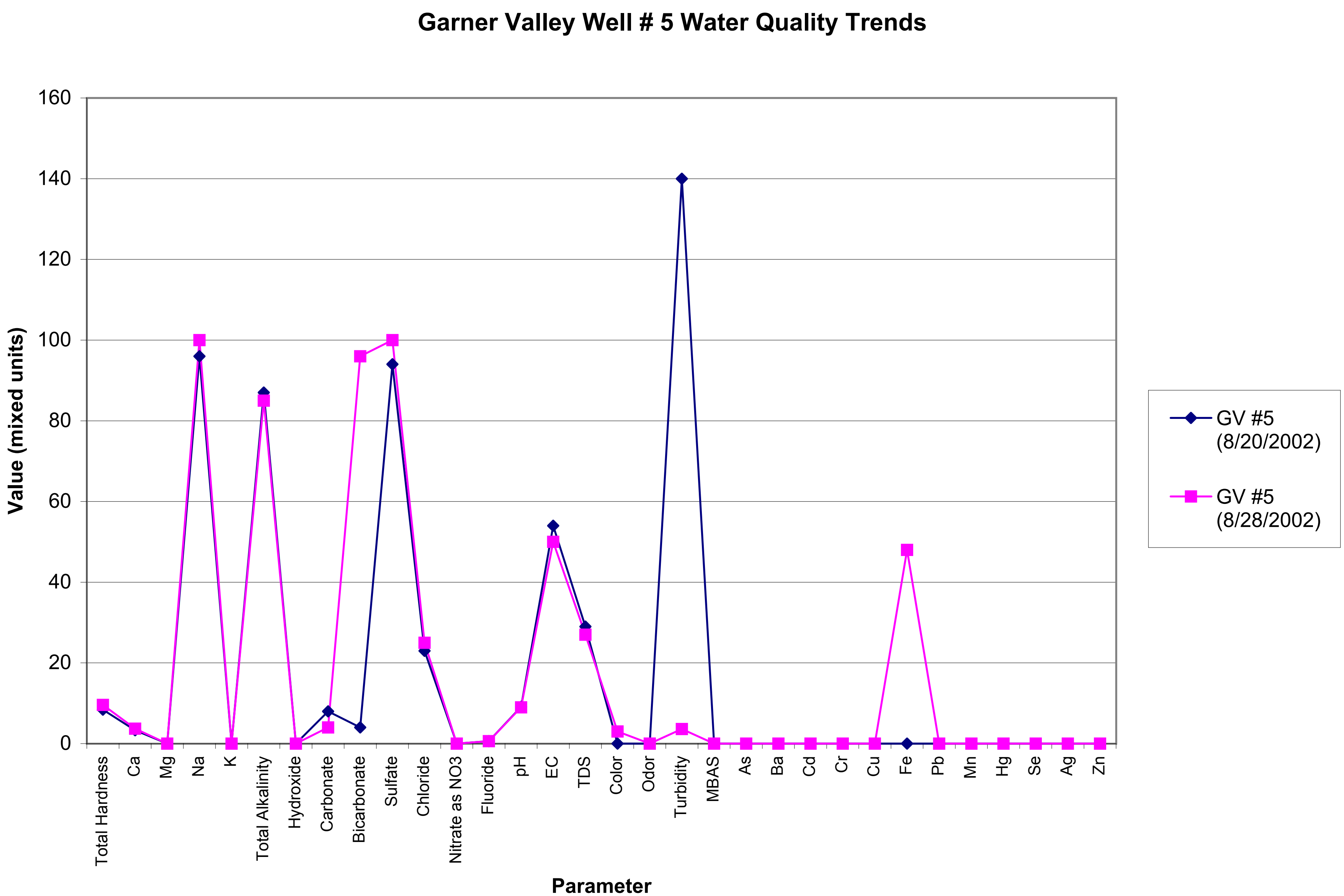

Garner Valley Well # 2 Water Quality Trends
Value (mixed units)
300
250
200
150
100
50
0
Total Hardness
Ca
Mg
Na
K
Total Alkalinity
Hydroxide
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate as NO3
Fluoride
pH
EC
TDS
Color
Odor
Turbidity
MBAS
As
Ba
Cd
Cr
Cu
Fe
Pb
Mn
Hg
Se
Ag
Zn
Parameter
GV #2 (11/9/1987)
GV #2 (3/13/2002)



Garner Valley Well # 3 Water Quality Trends
Value (mixed units)
160
140
120
100
80
60
40
20
0
Total Hardness
Ca
Mg
Na
K
Total Alkalinity
Hydroxide
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate as NO3
Fluoride
pH
EC
TDS
Color
Odor
Turbidity
MBAS
As
Ba
Cd
Cr
Cu
Fe
Pb
Mn
Hg
Se
Ag
Zn
Parameter
GV #3 (7/5/1979)
GV #3 (04/26/84)
GV #3 (4/2/2007)



Garner Valley Well # 4 Water Quality Trends
Value (mixed units)
300
250
200
150
100
50
0
Total Hardness
Ca
Mg
Na
K
Total Alkalinity
Hydroxide
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate as NO3
Fluoride
pH
EC
TDS
Color
Odor
Turbidity
MBAS
As
Ba
Cd
Cr
Cu
Fe
Pb
Mn
Hg
Se
Ag
Zn
Parameter
GV #4 (12/23/1985)
GV #4 (4/12/1989)
GV #4 (3/21/2001)
GV #4 (2/12/2007)


Garner Valley Well # 5 Water Quality Trends
Value (mixed units)
160
140
120
100
80
60
40
20
0
Total Hardness
Ca
Mg
Na
K
Total Alkalinity
Hydroxide
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate as NO3
Fluoride
pH
EC
TDS
Color
Odor
Turbidity
MBAS
As
Ba
Cd
Cr
Cu
Fe
Pb
Mn
Hg
Se
Ag
Zn
Parameter
GV #5 (8/20/2002)
GV #5 (8/28/2002)

APPENDIX E

Precipitation Records

Annual Precipitation Lake Hemet Station	
Year	Total Precip. (inches)
1970	23.35
1971	15.02
1972	12.24
1973	18.38
1974	14.27
1975	15.6
1976	19.28
1977	17.82
1978	36.97
1979	21.54
1980	37.92
1981	14.48
1982	34.1
1983	37.48
1984	17.68
1985	16.65
1986	17.33
1987	18
1988	15.75
1989	7.47
1990	12.93
1991	27.74
1992	22.26
1993	31.56
1994	15.97
1995	31.7
1996	17.39
1997	16.4
1998	28.01
1999	13.39
2000	14.13
2001	8.72
2002	5.53
2003	21.61
2004	18.96
2005	20.78
2006	13.33
Yearly Average	19.78