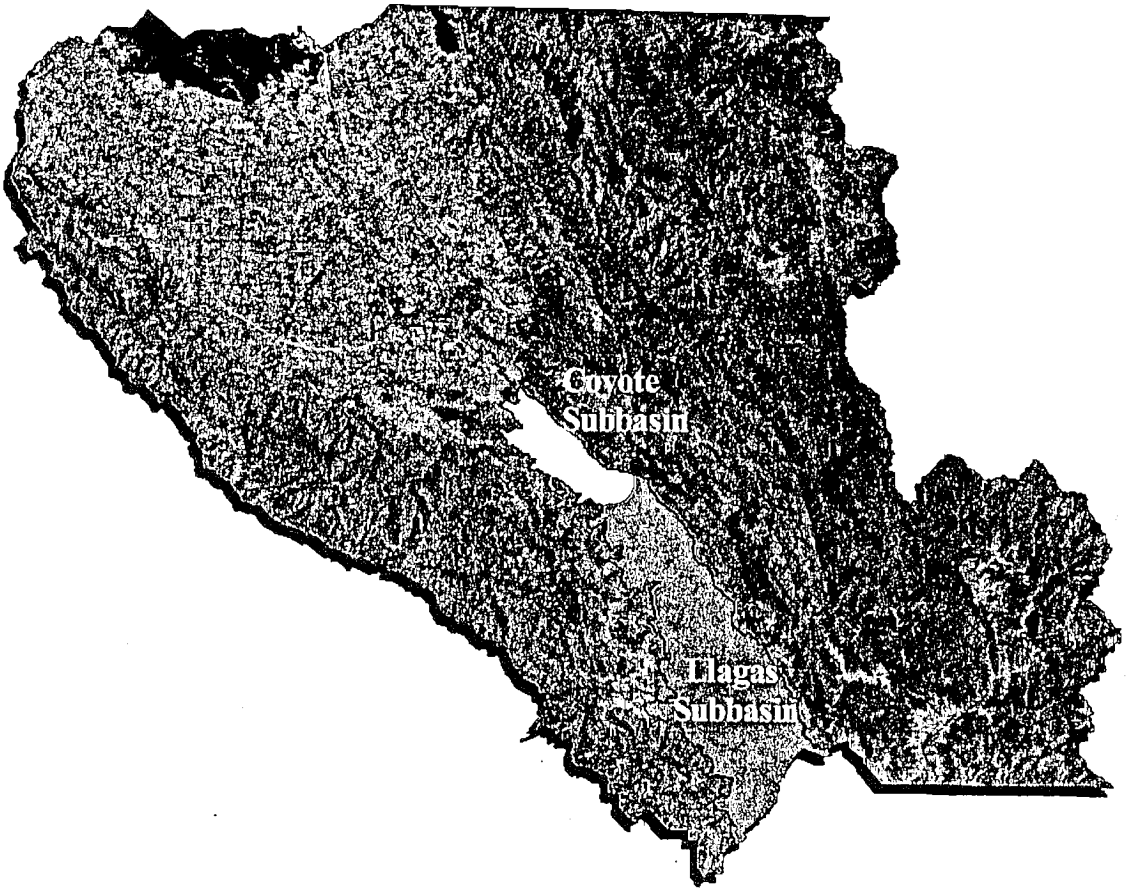
APPENDIX H – OPERATIONAL STORAGE CAPACITY OF THE COYOTE & LLAGAS GROUNDWATER SUBBASINS

Operational Storage Capacity of the Coyote and Llagas Groundwater Subbasins



April 2002

Santa Clara Valley Water District

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Operational Storage Capacity of the Coyote and Llagas Groundwater Subbasins

Prepared by
Vanessa Reymers
Assistant Engineer II
Groundwater Management Unit

Under the Direction of
Behzad Ahmadi
Unit Manager
Groundwater Management Unit

Keith Whitman
Deputy Operating Officer
Water Supply Management Division

Walter L. Wadlow
Chief Operating Officer

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EXECUTIVE SUMMARY

Background

Groundwater has been, and continues to be a critical component of water supply in Santa Clara County. Nearly all of the water supplied to the southern portion of the county comes from the groundwater subbasins. Increasing populations and competing water interests compel the Santa Clara Valley Water District (District) to do more with limited resources. Therefore, determining a reasonable range for the amount of groundwater that can be safely stored and withdrawn is critical to effective management of the groundwater subbasins and the county's water resources.

This report describes the methods used to estimate the operational storage capacity of the Coyote and Llagas Subbasins in southern Santa Clara County (South County). Operational storage capacity is defined for this report as the volume of groundwater that can be stored in a basin or subbasin as a result of District management measures. This is not the same concept as yield, which is a rate representing the amount of water a facility can produce in a particular time period. For a given subbasin, the operational storage capacity is not a constant value; it changes as demand, pumping, and recharge change.

Methods

The goal of the analysis described in this report was to estimate the operational storage capacity of the Coyote and Llagas Subbasins. In this report, operational storage capacity is calculated as the product of specific yield[1], area, and the elevation difference between high and low groundwater surfaces. Groundwater elevation data was analyzed to determine two-year periods during which a majority of wells recorded their maximum or minimum groundwater elevations in order to select the highest and lowest groundwater surfaces recorded in the subbasins (see Appendix A). This resulted in the selection of 1982-83 groundwater elevation data for the high groundwater surface and 1976-77 data for the low groundwater surface. Although these surfaces were judged to be the most reasonable, several other surfaces were fully analyzed, and these are described in Appendix B.

Discussion of Results

Due to the variability in specific yield estimates from the District and the California Department of Water Resources (DWR) and the uncertainty as to which values are more accurate, it was decided not to rely solely on one source but rather to use both sets of values to provide a range of operational storage capacity. Because of these data limitations, it is not possible to reduce the operational storage capacity estimates to single values for each subbasin. Therefore, the following ranges are assumed to represent the operational storage capacity in South County to the best accuracy possible at this time.

- Coyote Subbasin: 23,000 – 33,000 acre-feet
- Llagas Subbasin: 152,000 – 165,000 acre-feet
- Total South County: 175,000 – 198,000 acre-feet

[1] Specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table (Freeze and Cherry, 1979).

This is the first in-depth analysis of the operational storage capacity for South County conducted by the District. The District's 1997 Integrated Water Resources Plan (IWRP) assumed 150,000 acre-feet operational storage capacity in the Llagas Subbasin and no year-to-year operational storage volume in the Coyote Subbasin. This study estimates a range between 152,000 and 165,000 acre-feet in the Llagas Subbasin and 23,000 and 33,000 acre-feet in the Coyote Subbasin. This increase in the estimated operational storage capacity could have important implications for water supply planning and management decisions, in terms of additional local storage or recharge capacity. The 2002 IWRP update is currently being developed, and the operational storage capacity values estimated in this study will be considered in that analysis.

Although the values from this analysis represent a reasonable range for the operational storage capacity of the South County subbasins, it should be noted that the estimates are limited by the fact that they were obtained using a static analysis. A static analysis is one that does not represent changes in time, so it does not account for changes in groundwater elevations with time. Therefore, different demand scenarios or hydrological conditions, or changes in pumping and artificial recharge can not be simulated using a static analysis. A three-dimensional groundwater flow model would allow dynamic simulation of groundwater conditions under different pumping, recharge, and demand scenarios, and would account for the heterogeneity of the groundwater subbasins. A model would also allow the District to evaluate the effect of various groundwater management alternatives on the South County operational storage capacity. A groundwater model is used to analyze operational storage capacity in the North County, enabling District staff to refine estimates according to changing demand, recharge, or hydrologic conditions.

Recommendations

This analysis produced a reasonable range of estimates of the operational storage capacity for the Coyote and Llagas Subbasins. However, in addition to the limitations inherent to a static analysis, this study was limited by significant variations in specific yield values obtained from the District and DWR. The relatively small number of groundwater elevation monitoring wells in the South County also limited this analysis.

Estimates of the operational storage capacity of a groundwater subbasin directly relate to the amount of water that can be withdrawn without adverse impacts. As such, it is important that these estimates be refined to more accurately reflect conditions in the groundwater subbasins and to ensure groundwater supplies are sustained, as directed by Board Ends Policy. Therefore, the following activities are recommended to further improve the District's estimate of the South County operational storage capacity:

1) **Expand current groundwater elevation monitoring network in South County to ensure adequate lateral, vertical (depth), and temporal coverage.**

   As both a static analysis (such as this one) and a groundwater model for dynamic analysis require adequate spatial and depth-specific groundwater elevation data, the District should strive to improve the current groundwater elevation monitoring network to incorporate additional wells that can provide this type of data. Also, groundwater elevation data must be available in time intervals that are of an adequate frequency to be useful in capturing important fluctuations in groundwater elevation due to changing demand or recharge conditions.

2) **Develop and calibrate a three-dimensional groundwater flow model for South County in order to evaluate groundwater conditions under different pumping, recharge, and demand scenarios and to periodically update operational storage capacity estimates.**

It is unrealistic to represent the operational storage capacity of a groundwater subbasin with a single, fixed value, as it is highly dependent on how the subbasin is managed. A static analysis cannot represent dynamic groundwater conditions; therefore, different demand scenarios or recharge conditions can not be simulated. As the groundwater surfaces change in response to hydrological conditions or management of the subbasin, so does the volume of groundwater available in storage.

A groundwater model allows great flexibility in that the inputs (i.e., rainfall and artificial recharge, pumping) can be updated or changed fairly easily, and the model can be re-run to estimate operational storage capacity under the desired groundwater management scenario. A calibrated groundwater flow model will allow District staff to evaluate the amount of water that can be withdrawn without adverse impacts under various groundwater management alternatives.

3) **Refine specific yield estimates through the model calibration process.**

The origin of most specific yield values currently used is unknown or unverified. As significant differences in specific yield values resulted in a large range of estimates for operational storage capacity, it is important that these be refined to a single set of numbers of which the District can be confident. This can be achieved through the model calibration process, which fits simulated groundwater data to measured data. Using the model calibration process, the District can minimize the amount of field work necessary to refine specific yield values.

INTRODUCTION

Background

The mission of the Santa Clara Valley Water District (District, or SCVWD) is "a healthy, safe, and enhanced quality of living in Santa Clara County through the comprehensive management of water resources in a practical, cost-effective, and environmentally-sensitive manner." The District Board of Directors has identified the conjunctive management of the groundwater basins to maximize water supply reliability as an integral part of the District's comprehensive water management program. In addition, the Board has adopted specific Ends Policies that direct the Chief Executive Officer (CEO) to achieve certain results or outcomes. Management of groundwater supplies can be directly linked to the following Board Ends Policies:

- The water supply is reliable to meet current demands.
- The water supply is reliable to meet future demands as identified in the District's Integrated Water Resource Plan (IWRP) process.
- Groundwater supplies are sustained.

The District ensures that groundwater supplies are sustained through the conjunctive management of surface water and groundwater supplies; water is stored in wet years in reservoirs and aquifers, to be withdrawn in drier times. To most effectively meet demand during times of shortage, it is necessary to have an accurate estimate of the operational storage capacity of the groundwater subbasins. Operational storage capacity is defined for this report as the volume of groundwater that can be stored in the basin or subbasin as a result of District management. This is not the same concept as yield, which is the amount of water a facility can produce in a particular time period. For a given subbasin, the operational storage capacity is not a constant value as it changes as demand, pumping, and recharge change.

Increasing populations and competing water interests compel the District to do more with limited resources. The operational storage capacity of the groundwater subbasins is an important factor in determining the most effective way to manage the water resources of Santa Clara County.

Study Area

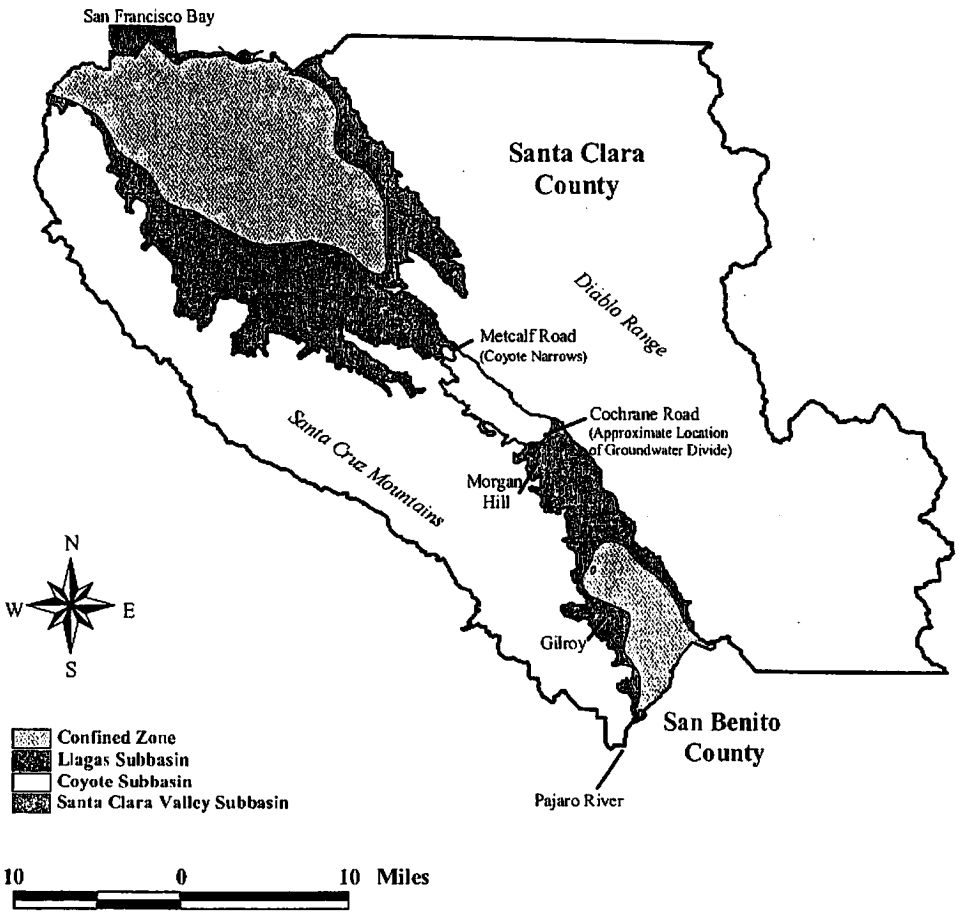
This report focuses on the southern portion of Santa Clara County (South County), which extends from the Coyote Narrows near Metcalf Road to the Pajaro River at the county's southern border, and includes the cities of Morgan Hill and Gilroy (Figure 1). In South County, groundwater is the sole source for drinking water; groundwater also supplies nearly all of the water used for agricultural uses. South County contains the Coyote and Llagas Groundwater Subbasins, which are bordered by the Diablo Range to the east and the Santa Cruz Mountains to the west.

The Coyote Subbasin is approximately 2 miles wide and 7 miles long, with a surface area of about 15 square miles. In general, the subbasin is unconfined and is composed primarily of unconsolidated alluvium. The subbasin extends from Metcalf Road south to Cochrane Road near Morgan Hill. The foothills of the Diablo and Santa Cruz ranges nearly merge at the Coyote Narrows near Metcalf Road, reducing the subbasin width to about half a mile and constricting groundwater flow. The southern boundary of the subbasin is a prescribed boundary at Cochrane Road; this boundary generally coincides with a hydrogeological boundary in the form of a

groundwater divide[2] near Morgan Hill. There is some evidence from historical groundwater elevation data that the divide may shift up to a mile north or south of the prescribed Cochrane Road boundary depending on local groundwater levels. In the case that the divide shifts to the north of the established boundary, there is some component of flow south to the Llagas Subbasin. According to the State Water Resources Board Bulletin 7, average flow from the Coyote Subbasin to the Llagas Subbasin is 2,400 acre-feet per year. However, the great majority of flow from the Coyote Subbasin is north into the Santa Clara Valley Subbasin.

The Llagas Subbasin extends south from Cochrane Road to the Pajaro River, which marks the border between Santa Clara and San Benito Counties. The subbasin is hydraulically connected to the Bolsa Subbasin in San Benito County (U.S. Geological Survey, 1981). Therefore, the southern boundary of the Llagas Subbasin is based on the location of the Pajaro River. The Llagas Subbasin is approximately 15 miles long, 3 to 6 miles wide, and has a surface area of approximately 74 square miles. The presence of a laterally extensive low permeability zone in the southern portion of the subbasin separates the Llagas into confined and unconfined zones (Figure 1). The land surface overlying the Llagas Subbasin slopes to the south, and groundwater within the subbasin generally mimics the topography and flows toward the south.

Figure 1 – Santa Clara County Groundwater Subbasins



[2] A vertical imaginary boundary, across which there is no flow of groundwater (Freeze and Cherry, 1979). Similar to a river system divide, a groundwater divide separates groundwater systems flowing in opposite directions.

Previous Work

Several estimates of storage capacity for the South County groundwater subbasins exist, although there is little description of how the estimates were obtained. Previous estimates for both the Coyote and Llagas Subbasins are summarized in Tables 1 and 2. Many of the references do not describe exactly what is meant by "storage capacity" so it is uncertain if these values can be directly compared to estimates from this analysis. Because many of these values cannot be directly compared to operational storage capacity estimates from this report, they have been reported here simply to document previous estimates of subbasin capacity. The language used in the "Description" column matches that of the original documents as closely as possible.

In most of these estimates, the storage capacity is a calculation of the volume of groundwater between two specific elevations, which are completely independent of groundwater elevations measured in wells. It should be noted that the 1997 IWRP defines operational storage capacity using subsidence thresholds (see "Description" column, Tables 1 and 2). Significant land subsidence[3] has occurred historically in the Santa Clara Valley Subbasin, and subsidence thresholds, or groundwater elevations below which significant subsidence will occur, are used as the lower threshold for acceptable groundwater elevations in that subbasin. However, there is no evidence of subsidence in the Coyote or Llagas Subbasins, and no subsidence thresholds have been established for South County.

Table 1. Previous Estimates of Storage Capacity for the Coyote Subbasin

Source	Description	Notes	Storage Capacity (acre-feet)
SCVWD Draft of South County Planning Study (1970)	Storage capacity from ground surface to bedrock.	Bedrock elevation, origin of specific yield values unknown.	85,000
SCVWD Master Plan (1975) / Tom Iwamura (1983)	Storage volume for depths between 25 and 300 feet below ground surface. Specific yield values from State Water Resources Bulletin 7 (1955).	Value could not be confirmed using Bulletin 7 values.	76,000
SCVWD Overview Study (1994)	Estimated operational storage volume.	Origin of specific yield values unknown.	55,000
SCVWD Integrated Water Resources Plan (1997)	Volume of groundwater storage between subsidence threshold and operational maximum groundwater level.	No year-to-year operational storage volume assumed.	0

[3] Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. One cause of subsidence is the mining of groundwater, which causes a reduction of fluid pressure in the pores and cracks of aquifer systems, resulting in deformation of the aquifer system through the compression or consolidation of aquitards (USGS, 1999).

Table 2. Previous Estimates of Storage Capacity for the Llagas Subbasin

Source	Description	Notes	Storage Capacity (acre-feet)
State Water Resources Board Bulletin 7 (1955)	Groundwater storage capacity for the zone from 0 to 300 feet below ground surface.	Bulletin 7 specific yield values used.	513,000
State Water Resources Board Bulletin 7 (1955)	Groundwater storage capacity in the usable storage zone between 25 and 200 feet below ground surface.	Bulletin 7 specific yield values used.	300,000
SCVWD Master Plan (1975)	Storage volume for depths between 25 and 300 feet below ground surface.	Calculation not described.	475,000
SCVWD Overview Study (1994)	Estimated operational storage capacity.	Origin of specific yield values unknown.	150,000
SCVWD Integrated Water Resources Plan (1997)	Volume of groundwater storage between subsidence threshold and operational maximum groundwater level.	District staff estimate.	150,000

OPERATIONAL STORAGE CAPACITY ANALYSIS

The goal of this analysis is to estimate the operational storage capacity of the Coyote and Llagas Subbasins. The operational storage capacity is estimated by calculating the volume of groundwater stored between high and low groundwater surfaces. The difference in elevation between the two groundwater surfaces, the area, and the specific yield are multiplied to estimate the operational storage capacity according to the following equation:

$$V = S_y * A * \Delta h$$

where

V = volume of groundwater available from storage (operational storage capacity)

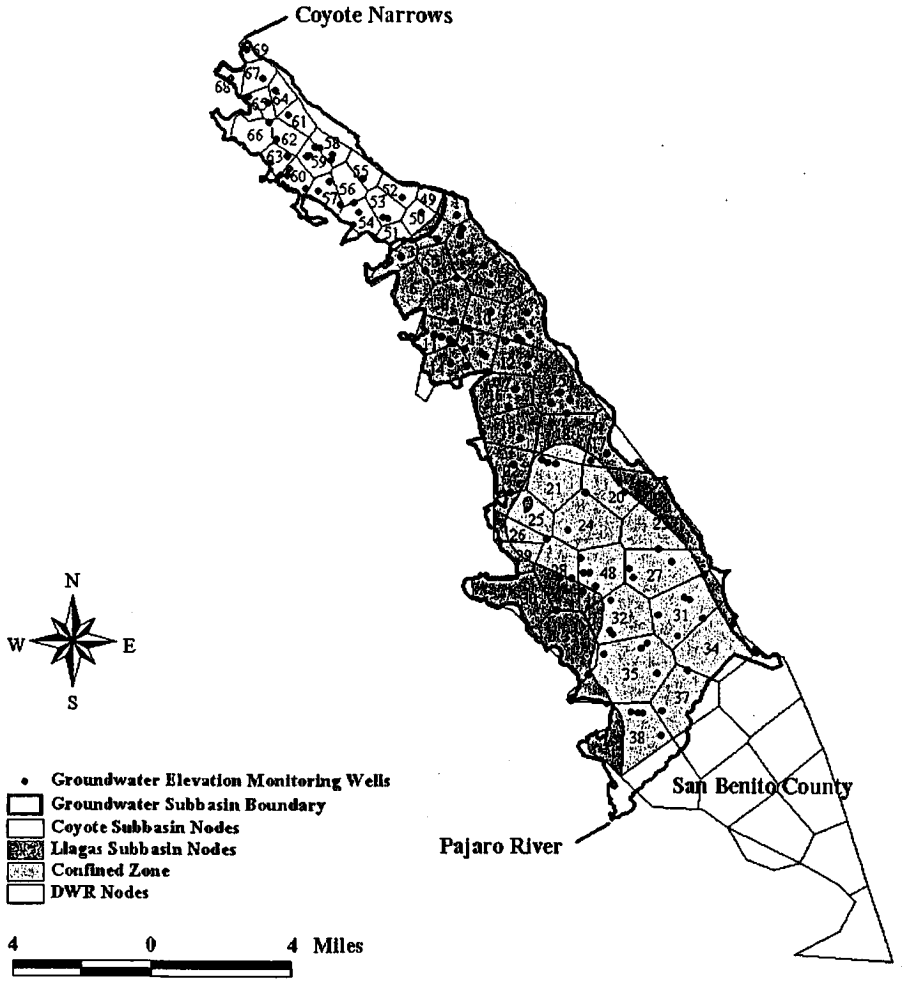
S_y = specific yield (volume of water an unconfined aquifer releases from storage per unit surface area per unit decline in the water table)

A = area

Δh = difference in elevation between high and low groundwater surfaces

DWR developed a groundwater model for South County that did not calibrate well; the model is described in Bulletin 118-1, Volume IV (1981). Bulletin 118 provides areas and specific yields for model nodes within South County. This analysis also used nodes as a convenient way to evaluate the subbasins using smaller areas (Figure 2). The nodes used in this analysis are based on the DWR nodes, but account only for those areas within the groundwater subbasin boundaries.

Figure 2 – Nodes and Groundwater Elevation Monitoring Wells Used to Evaluate Operational Storage Capacity



High and Low Groundwater Surfaces

Estimates of operational storage capacity are highly dependent on the high and low groundwater surfaces used in the calculation, and there are many options for these surfaces. Estimates of operational storage capacity in northern Santa Clara County have generally used land subsidence thresholds as the low groundwater surface. However, there is no evidence that significant subsidence has occurred in South County so subsidence thresholds have not been established. For this reason, the low groundwater surface used in this analysis is not dependent on a subsidence threshold, but rather on historical low groundwater elevations.

In order to choose the high and low groundwater surfaces for this analysis, groundwater elevation data for monitoring wells in South County were retrieved from a District database. This yielded 106 groundwater elevation monitoring wells within the boundary of the South County subbasins (Figure 2). Groundwater elevation information from 1936 to 1999 was analyzed to determine two-year periods in which a majority of wells recorded their maximum or minimum groundwater elevations (see Appendix A for details of the frequency analysis). Choosing the highest and the

lowest surfaces occurring throughout the subbasins as a result of District management provides the largest range for the estimate of operational storage capacity.

Through the analysis of historical groundwater elevation data, the years 1982 and 1983 were identified as wet years, when groundwater elevations were generally quite high throughout the groundwater subbasins and many wells recorded historical maximum groundwater elevations. In 1976 and 1977, the region experienced a short-lived but fairly severe drought, and groundwater elevations were quite low. These high and low surfaces were selected to represent conditions that occurred in the subbasins during a discrete and short period of time as a result of District management of the subbasins. The high and low surfaces were created using 1982-83 groundwater elevations and 1976-77 groundwater elevations, respectively. For each node, the maximum groundwater elevation from 1982-83 and the minimum groundwater elevation from 1976-77 were used. In some cases, no wells within the node had recorded data during one or both of those periods. In these situations, values were obtained from groundwater elevation contour maps from the appropriate period.

During the course of this study, several other high and low groundwater surfaces were fully analyzed to estimate operational storage capacity. However, due to the nature of the limitations of these alternatives, it was determined that none could provide a representation as likely or reasonable as the one using the 1982-83 and 1976-77 groundwater surfaces. The additional alternatives evaluated are presented in Appendix B to document the full analysis conducted for this study.

Specific Yield

In addition to high and low groundwater surfaces, the calculation of operational storage capacity also requires values for specific yield. The specific yield of an unconfined aquifer is the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the water table (Freeze and Cherry, 1979). Specific yield values for each node in both the Coyote and Llagas Subbasins were obtained from previous estimates from the District and from DWR Bulletin 118. A more complete description of the specific yield values and their origin can be found in Appendix C.

This analysis assumes that the specific yield estimates are constant for the entire vertical column within each node. This assumption does not account for aquifer heterogeneity; specific yield depends upon the aquifer material, which is generally not assumed to be homogeneous with depth. However, no additional depth-specific values are available.

Area

Only areas within the unconfined zone are considered in this analysis, as the storativity[4] in the confined zone is generally orders of magnitude smaller than the specific yield of the unconfined zone. Typical values for specific yield of the unconfined zone range from 0.01 to 0.30, while the storativity of confined aquifers is generally between 0.005 and 0.00005. Releases from storage in the unconfined zone result from actual dewatering of soil pores. Releases from storage in the confined zone represent the secondary effects of water expansion and aquifer compaction (Freeze and Cherry, 1979). Although there is a relationship between storage in the unconfined zone and

[4] Storativity is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to the specific yield (Fetter, 1994).

the pressure in the confined zone, the confined zone has no significant contribution in terms of aquifer storage. Therefore, this analysis focuses on areas within the unconfined zone.

The DWR nodes from Bulletin 118 were digitized into a Geographic Information System (GIS), which has excellent area calculating capabilities. There was a median error of approximately two percent between the node areas given in the DWR report and those calculated from the GIS. This discrepancy is probably due to digitizing error, differing precision of area calculation, or a combination of the two factors. As the digitized GIS nodes simply represent the nodes from Bulletin 118, the areas were adjusted to consider only those areas within the South County groundwater subbasins and the unconfined zone for the purposes of this analysis (see Figure 2).

RESULTS

Estimates of operational storage capacity for the Coyote and Llagas Subbasins are shown in Table 3 below, along with the specific yield source used to obtain the estimates.

Table 3. Operational Storage Capacity Estimates

Specific Yield Source	Coyote Subbasin (acre-feet)	Llagas Subbasin (acre-feet)	Total South County (acre-feet)
District	23,000	152,000	175,000
DWR	33,000	165,000	198,000

As can be seen from Table 3, the total South County operational storage capacity estimates range from 175,000 to 198,000 acre-feet. The estimate calculated using DWR specific yield values is approximately thirteen percent higher than the estimate obtained using District values. The estimates of the operational storage capacity of the Llagas Subbasin range from 152,000 to 165,000 acre-feet. For the Llagas Subbasin, the estimate calculated using the DWR specific yield values is nearly ten percent higher than that calculated using District specific yields. Estimates for the Coyote Subbasin range from 23,000 to 33,000 acre-feet. Again, the estimate calculated using the DWR specific yield values is higher than that obtained using District values, although in this case the difference is over forty percent.

DISCUSSION

Due to the variability in specific yield estimates from the District and DWR and the uncertainty as to which values are more accurate, it was decided not to rely solely on one source. Because of these data limitations, it is not possible to reduce the operational storage capacity estimates to single values for each subbasin. Therefore, the following ranges are assumed to represent the operational storage capacity in South County to the best accuracy possible at this time.

- Coyote Subbasin: 23,000 – 33,000 acre-feet
- Llagas Subbasin: 152,000 – 165,000 acre-feet
- Total South County: 175,000 – 198,000 acre-feet

The District's 1997 Integrated Water Resources Plan (IWRP) assumed 150,000 acre-feet operational storage capacity in the Llagas Subbasin and no year-to-year operational storage volume in the Coyote Subbasin. This study estimates a range between 152,000 and 165,000 acre-

feet in the Llagas and 23,000 and 33,000 acre-feet in the Coyote Subbasin. This increase in the estimate of operational storage capacity could have important implications for water supply planning and management decisions, in terms of additional local storage or recharge capacity. The 2002 IWRP update is currently being developed, and the values estimated in this study will be considered in that analysis.

Although the estimates calculated in this analysis represent a reasonable range for the operational storage capacity of the South County groundwater subbasins, there are limitations to this analysis. This analysis does not account for the shape of the subbasins, but treats the subbasins as a "box", where the operational storage capacity is calculated using nodes, which are small divisions of the box. This analysis assumes that the specific yield value of each node is valid for the entire volume between the high and low surfaces. This assumption does not account for the heterogeneous nature of the groundwater subbasins. The difference in specific yield estimates between District and DWR values also leads to significant variation in the operational storage capacity results, most notably in the Coyote Subbasin.

It should also be noted that it is unrealistic to represent the operational storage capacity of a groundwater subbasin with a single, fixed value, as it is highly dependent on how the subbasin is managed. A static analysis, such as this one, cannot represent dynamic groundwater conditions as it cannot represent changes in pumping or recharge, nor can it simulate different demand scenarios. This analysis provides a "snapshot" view of the subbasins by estimating the volume between two constant surfaces. In reality, groundwater surfaces throughout the subbasins are dynamic and respond to changes in pumping and recharge. As the groundwater surfaces change, so does the volume of groundwater available in storage.

The operational storage capacity of the Santa Clara Valley Subbasin in North County was determined using a groundwater model, which can simulate subbasin dynamics (SCVWD, 1999). There is currently no groundwater model for South County, so this analysis relied on available groundwater elevation data and a static approach. A calibrated three-dimensional groundwater flow model for South County would allow for dynamic simulation of groundwater conditions under different pumping, recharge, and demand scenarios, and would allow the District to more effectively evaluate the effect of various groundwater management alternatives on the operational storage capacity.

RECOMMENDATIONS

This analysis determined a reasonable range of estimates of the operational storage capacity for the Coyote and Llagas Subbasins. However, there are limitations to this analysis, and the estimates should be refined further. In addition to the limitations inherent to a static analysis, this study was limited by significant variations in specific yield values obtained from the District and DWR. This led to substantially different estimates of operational storage capacity, particularly in the Coyote Subbasin, that could not be resolved in this analysis. The relatively small number of groundwater elevation monitoring wells in the South County also limited this analysis. As both a static analysis (such as this one) and a groundwater model for dynamic analysis rely on groundwater elevation data, adequate spatial, vertical, and temporal information is critical.

Estimates of the operational storage capacity of a groundwater subbasin directly relate to the amount of water that can be withdrawn without adverse impacts. As such, it is important that these estimates be refined to more accurately reflect conditions in the groundwater subbasins and to ensure groundwater supplies are sustained, as directed by Ends Policy 1.2.2.3. Therefore, the

following activities are recommended to further improve the District's estimate of the South County operational storage capacity:

1) **Expand current groundwater elevation monitoring network in South County to ensure adequate lateral, vertical (depth), and temporal coverage.**

   As both a static analysis (such as this one) and a groundwater model for dynamic analysis require adequate spatial and depth-specific groundwater elevation data, the District should strive to improve the current groundwater elevation monitoring network to incorporate additional wells that can provide this type of data. Also, groundwater elevation data must be available in time intervals that are of an adequate frequency to be useful in capturing important fluctuations in groundwater elevation due to changing demand or recharge conditions.

2) **Develop and calibrate a three-dimensional groundwater flow model for South County in order to evaluate groundwater conditions under different pumping, recharge, and demand scenarios and to periodically update operational storage capacity estimates.**

   It is unrealistic to represent the operational storage capacity of a groundwater subbasin with a single, fixed value, as it is highly dependent on how the subbasin is managed. A static analysis cannot represent dynamic groundwater conditions; therefore, different demand scenarios or recharge conditions can not be simulated. As the groundwater surfaces change in response to hydrological conditions or management of the subbasin, so does the volume of groundwater available in storage.

   A groundwater model allows great flexibility in that the inputs (i.e., rainfall and artificial recharge, pumping) can be updated or changed fairly easily, and the model can be re-run to estimate operational storage capacity under the desired groundwater management scenario. A calibrated groundwater flow model will allow District staff to evaluate the amount of water that can be withdrawn without adverse impacts under various groundwater management alternatives.

3) **Refine specific yield estimates through the model calibration process.**

   The origin of most specific yield values currently used is unknown or unverified. As significant differences in specific yield values resulted in a large range of estimates for operational storage capacity, it is important that these be refined to a single set of numbers of which the District can be confident. This can be achieved through the model calibration process, which fits simulated groundwater data to measured data. Using the model calibration process, the District can minimize the amount of field work necessary to refine specific yield values.

APPENDIX A – GROUNDWATER ELEVATION DATA FREQUENCY ANALYSIS

Groundwater elevation data from 1936 to 1999 was analyzed to identify two-year periods when a significant number of wells recorded historical high or low groundwater elevations. Of the 106 groundwater elevation monitoring wells identified in South County (see Figure 2), 55 recorded historical high groundwater elevations in 1982-83 and 40 wells recorded historical low groundwater elevations in 1976-77 (see Figures A-1 and A-2 below). Therefore, these two periods were selected as being representative of the highest and lowest surfaces occurring historically throughout a significant portion of the South County subbasins.

Figure A-1 Number of Wells Recording Historical Maximum Groundwater Elevation for Given Two-Year Periods

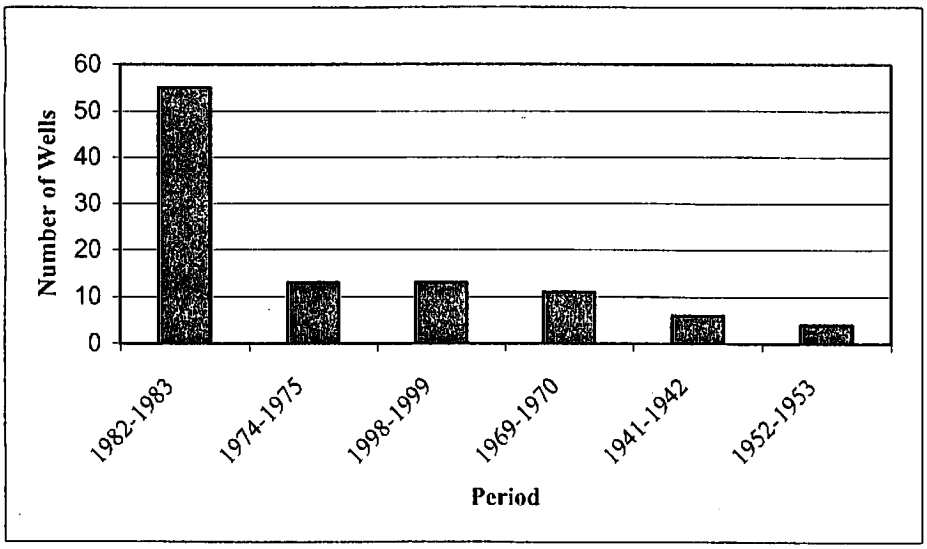
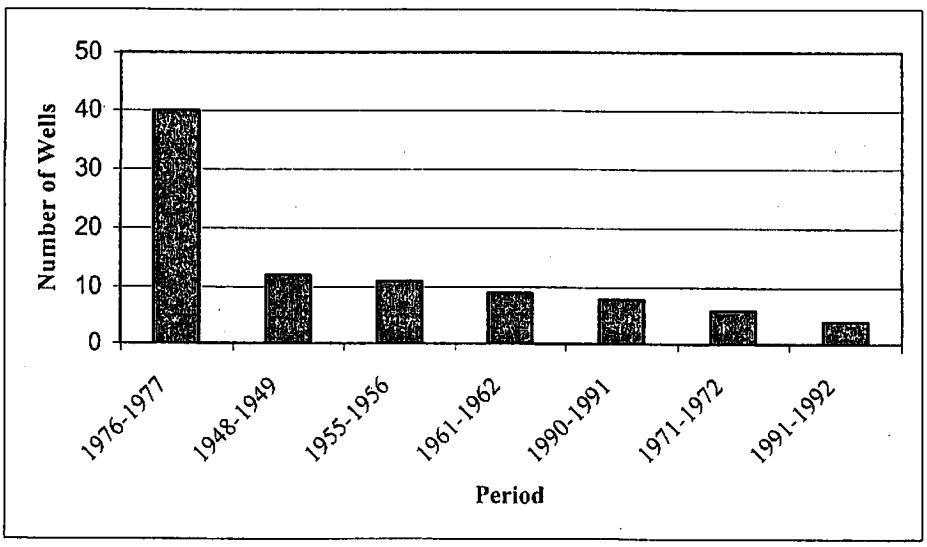


Figure A-2 Number of Wells Recording Historical Minimum Groundwater Elevation for Given Two-Year Periods



APPENDIX B – OPERATIONAL STORAGE CAPACITY ALTERNATIVES EVALUATED

This section describes four additional combinations of high and low groundwater surfaces that were fully analyzed to estimate South County operational storage capacity that are not described in the body of the report. Due to the nature of the limitations for each alternative described here (see Table B-1), it was determined that none could provide a representation as likely or reasonable as the one presented in the body of the report. They are presented here to document the analysis conducted for this study.

The alternatives described below were analyzed in the same manner as the alternative described in the body of the report in that the operational storage capacity is calculated as the product of the specific yield, the area of each node, and the difference in elevation between the groundwater surfaces.

Due to the data constraints described in this paragraph, the storage capacity for several nodes had to be analyzed differently than the rest of the nodes for each surface that was based on groundwater elevation data. As only the unconfined zone was considered in this analysis (see discussion on page 8), nodes 24 and 37 were not analyzed as they are completely within the confined zone. Several nodes contained wells within both the confined and unconfined zones (see Figure 2); only data from wells within the unconfined zone was used. For nodes without groundwater elevation monitoring wells or nodes in which all wells were within the confined zone, groundwater elevation contour maps were used to determine groundwater elevations. The value for each node lacking data was determined using maps from 1982 and 1983 (used for the high) and 1976 and 1977 (used for the low) by averaging the values from the two years.

Estimates of the operational storage capacity in the Coyote and Llagas Subbasins for the alternatives described below are given in Table B-2.

Description of Alternatives

High Surface at 30' Below Ground Surface, Historical Low

The high groundwater elevation is that which will avoid the saturation of root zones and the interception of groundwater by septic systems. According to the Santa Clara County ordinance on septic systems, trenches are not to be more than 8 feet deep and, depending on the percolation rate, there must be 10 or 20 feet between the trench bottom and the groundwater. The high groundwater elevation used in this alternative is 30 feet below ground surface.

Several nodes near the Coyote Narrows had to be treated differently, as groundwater is known to be very shallow in that area. Historically, the District has maintained groundwater levels to a maximum elevation of 5 feet below ground surface, and that elevation is used in this analysis for five nodes at the Narrows. The lowest groundwater elevation ever recorded at each node is used as the low.

Setting the high groundwater elevation at 30 feet below ground surface (or 5 feet at the Narrows) accounts for operational constraints, such as the avoidance of septic systems and root zones. However, there are some limitations to this analysis. First, as the high surface is not based on groundwater elevations that have occurred in the subbasins, it may not be possible to achieve and/or maintain the groundwater surface 30 feet below the ground surface. Depending on local pumping and hydrogeology, some areas may require significant recharge to achieve this, resulting in considerable expense and use of recharge water. The low groundwater elevations are based on

actual groundwater elevation data and are representative of the lowest groundwater elevations recorded at wells throughout the subbasins. However, the surface is created using the historical low groundwater elevations at each node, regardless of the time at which they occurred. This creates a theoretical groundwater surface, which is not based in physical reality at one particular period in time.

Historical High and Low Groundwater Surfaces

In this scenario, the difference in elevation at each node is calculated using the historical low and high groundwater elevations. If multiple wells are present within a single node, the highest and lowest historical values are used, regardless of the well at which they occur. The historical highs or lows often occur at different times for different wells; two neighboring nodes may have recorded their respective maximum (or minimum) groundwater elevations in different decades. However, this analysis assumes that all wells can be brought to their respective high and low values concurrently to create the high and low groundwater surfaces. Although this analysis uses actual groundwater elevation data, the fact that the absolute high and low values for each node are used, regardless of where or when they occur leads to the creation of a theoretical groundwater surface that is not physically representative of conditions throughout the subbasins during one period in time.

Averaged High and Low Groundwater Elevations

In this approach, the historical high and low groundwater elevations at each individual well are identified. The high values for wells are then grouped by node, and the average of those values is determined. A similar process is performed to evaluate the average of the low groundwater elevations at each node. This is done to try to obtain high and low values that better represent the historical high and low groundwater conditions at all wells within each node. In effect, the historical groundwater elevation data is normalized for each node. Although this alternative represents all wells within a given area instead of just those where the absolute high or low occur, the high and low values are used without regard to the time at which they occur, again creating a theoretical and perhaps hydrologically infeasible surface.

Additional Alternatives

There are many more combinations of the surfaces discussed that may be used to estimate the operational storage capacity. Some combinations evaluated are not discussed because it was determined that one of the four alternatives reasonably represented a similar idea or because the combinations produced results similar to the alternatives discussed. The limitations of other combinations were determined to be too restrictive to warrant a full analysis. Ultimately, the alternative presented in the body of the report, which uses groundwater elevations from years where the most highs and low occurred, is believed to provide the most reasonable range for the operational storage capacity of the South County Subbasins. The results for all the alternatives evaluated are presented in the Table B-2.

Table B-1 Surfaces Evaluated to Estimate Operational Storage Capacity

High Surfaces Evaluated	Limitations
• 1982-83 groundwater elevations	- Could produce high groundwater nuisance conditions.
• Groundwater surface fixed at elevation 30 feet below ground surface	- May not be possible to achieve groundwater surface at 30 feet below ground surface throughout the subbasins. - Some areas may require significant recharge to maintain surface, resulting in considerable expense and use of recharge water.
• Historical high groundwater elevations	- Surface based on historical high at any well within the node, regardless of when it occurred. This creates a theoretical surface with has no basis in physical reality at a particular point in time.
• Averaged high groundwater elevations	- Surface based on average of historical highs of all wells within each node. Again, this creates a theoretical surface that may not be hydrologically feasible.
Low Surfaces Evaluated	
• 1976-77 groundwater elevations	- None recognized.
• Historical low groundwater elevations	- Surface based on historical low at any well within the node, regardless of when it occurred. This creates a theoretical surface with has no basis in physical reality at a particular point in time.
• Averaged low groundwater elevations	- Surface based on average of historical lows of all wells within each node. Again, this creates a theoretical surface that may not be hydrologically feasible.

Table B-2 Estimates of Operational Storage Capacity for Each Alternative

Groundwater High/Low Surfaces Evaluated		Specific Yield Value Source	Total South County Operational Storage Capacity (acre-ft)	Coyote Subbasin Operational Storage Capacity (acre-ft)	Llagas Subbasin Operational Storage Capacity (acre-ft)
1	1982-83 groundwater elevations (high), 1976-77 groundwater elevations (low)	SCVWD	175,000	23,000	152,000
		DWR	198,000	33,000	165,000
2	High 30' below ground surface, historical low groundwater elevations	SCVWD	181,000	26,000	154,000
		DWR	204,000	36,000	168,000
3	Historical high and low groundwater elevations	SCVWD	212,000	37,000	174,000
		DWR	241,000	51,000	190,000
4	Averaged high and low groundwater elevations	SCVWD	178,000	33,000	145,000
		DWR	202,000	46,000	157,000

APPENDIX C – DESCRIPTION OF SPECIFIC YIELD VALUES USED

Specific Yield

Specific yield values for both the Coyote and Llagas Subbasins were obtained from previous estimates from the District and DWR (Table C-1). The SCVWD specific yield estimates, although frequently used, are of unknown and unverified origin. Values for the Llagas Subbasin range from 0.04 to 0.129, while the entire Coyote Subbasin is assigned a specific yield of 0.072. It is unclear why a single and constant value of 0.072 is assigned to the entire Coyote Subbasin.

The origin of the DWR estimates reported in Bulletin 118 is summarized below. Specific yield values for the Llagas Subbasin were obtained using GEOLOG, which computes values from data in the water well log files. Bulletin 118 reports that average values for the Coyote Subbasin were obtained from a SCVWD Coyote ground water model. Although documentation on the District's early and unsuccessful Coyote model was located, there was no clear description on how the specific yield estimates were obtained nor was there any table with the specific yield values by node. The DWR specific yield values used in Bulletin 118 range from 0.03 to 0.179 for the Llagas Subbasin, and from 0.07 to 0.12 for the Coyote Subbasin.

Due to the fact that District staff were unable to verify the origin of the SCVWD specific yield estimates, at this time it cannot be determined whether the District values or the DWR values better characterize the specific yield of the subbasins.

Table C-1 – Specific Yield Estimates by Node
(Nodes 1-48 in Llagas Subbasin, 49-69 in Coyote Subbasin)

Node	DWR Specific Yield (%)	SCVWD Specific Yield (%)
1	5.0	5.0
2	9.0	6.7
3	5.5	7.7
4	7.0	7.7
5	6.3	7.7
6	4.5	5.0
7	9.0	7.8
8	15.0	5.4
9	3.6	6.3
10	3.0	5.5
11	7.8	4.2
12	10.2	7.3
13	5.5	7.3
14	10.0	4.7
15	6.5	6.2
16	6.1	7.5
17	5.0	6.0
18	10.0	6.7
19	8.8	8.0
20	17.5	8.0
21	4.1	12.9
22	7.3	9.4
23	7.9	6.5
24	6.0	*
25	6.4	7.7
26	7.0	7.6
27	5.8	4.9
28	8.0	11.0
29	7.7	8.2
30	7.8	6.8
31	5.0	4.7
32	6.7	10.3
33	6.4	5.8
34	6.8	6.3
35	6.2	7.3
36	4.0	*
37	8.5	*
38	6.2	4.0
39	6.5	*
40	6.0	*
41	5.0	*
42	5.6	*
43	15.0	*
44	8.0	*
45	5.0	*
46	10.0	*
47	6.5	*
48	11.0	12.8

Node	DWR Specific Yield (%)	SCVWD Specific Yield (%)
49	9.9	7.2
50	11.8	7.2
51	9.5	7.2
52	9.5	7.2
53	11.8	7.2
54	11.8	7.2
55	11.8	7.2
56	9.6	7.2
57	9.6	7.2
58	9.3	7.2
59	9.7	7.2
60	9.0	7.2
61	9.9	7.2
62	12.0	7.2
63	8.9	7.2
64	7.0	7.2
65	7.0	7.2
66	7.0	7.2
67	7.0	7.2
68	7.0	7.2
69	9.9	7.2

* Nodes in original DWR report south of Pajaro River (San Benito County)

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