A Water Budget For the Arroyo Seco Watershed

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December 1, 2003

In partnership with North East Trees as part of the CALFED Arroyo Seco Watershed Management Plan & Education Program

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Executive Summary

"A Water Budget for the Arroyo Seco Watershed" has been developed to provide a better understanding of how water is used in our region and what can be done to promote conservation and better management of this invaluable resource. This document, a key component of the CALFED-funded Arroyo Seco Watershed Management Plan & Education Program, evaluates the Arroyo Seco Watershed, part of the Los Angeles River system in Los Angeles County, California.

This watershed budget should not be viewed as a static analysis, but rather as a tool and a framework for determining how we can better manage local water resources. It illuminates many of the key water issues that face local residents and decision-makers:

- The need to protect our watershed and its precious environment;
- The critical importance of water quality to our region; and
- The need for comprehensive conservation and water management programs to reduce per capital consumption and water imports.

We urge policy-makers and residents of the Arroyo Seco Watershed to utilize this watershed budget as a tool to ensure that water is used wisely.

Introduction

Water has always been a vital key to the environmental health and quality of life in our region. From the first settlers who established villages on the rim of the Arroyo Seco and called our region "Hahamongna – Flowing Waters, Fruitful Valley" until today, the significance of water has not diminished.

This purpose of "A Water Budget for the Arroyo Seco Watershed" is to analyze the factors that influence water use in the Arroyo Seco Watershed in order to develop a program that will ensure wise use of local water resources and a reduction of our reliance on imported water sources such as the State Water Project and the Colorado River.

First we will examine local climatic and geographic conditions. We will summarize the relevant data and the findings of the studies that have dealt with water use, storage and conservation in the Arroyo Seco Watershed. Then we will attempt to answer some key questions, such as:

- Is there currently balance in the Arroyo Seco Watershed and the Raymond groundwater basin?
- How much potential is there for increased groundwater storage?
- How can local reliance on imported water supplies be reduced?
- What steps can be taken to augment local conservation and storage?

The essential purpose of this report is to develop a tool to use to promote more efficient management and conservation of local water resources.

CALFED

This water budget has been made possible by the Watershed Management Program of the CALFED Bay-Delta Program because the water use of residents of the Arroyo Seco Watershed affects not only our local environment but also distant regions of California and the West. CALFED is the great campaign put together by federal and state agencies to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System. CALFED's Watershed Program was established in 1998 to work at a watershed level with the communities that use or benefit from the Bay Delta ecosystem. The Watershed Program promotes the kind of education, careful planning and environmental sensitivity that will be necessary to restore the Bay-Delta system so that all those who touch or are touched by the Bay-Delta can participate in saving it.

The Hydrologic Cycle

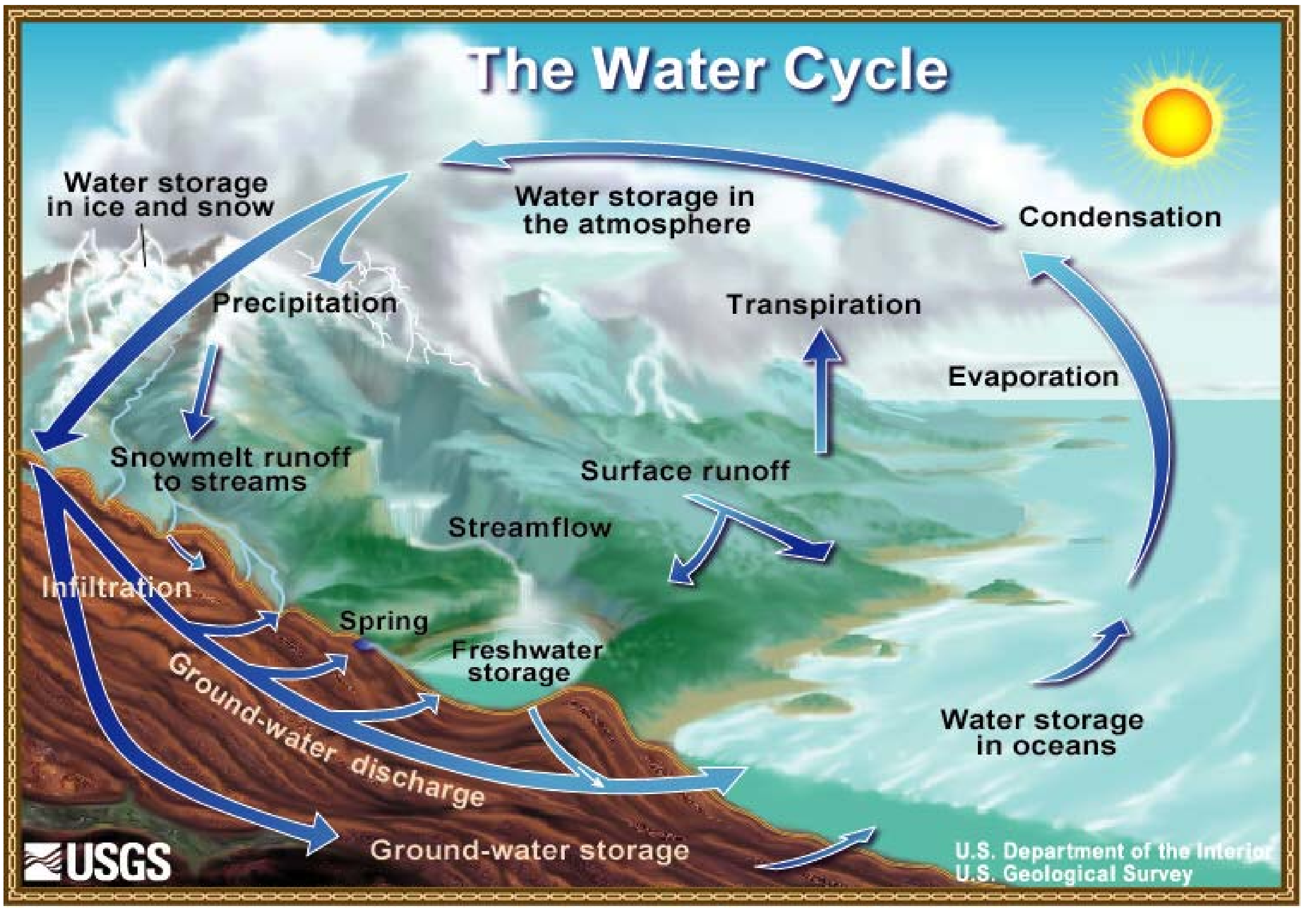

Figure 1 - The Water Cycle

A water budget measures the hydrologic cycle, or water cycle, the process through which water moves through the earth and its atmosphere.

Vapor condenses in the atmosphere until it reaches the size of drops and falls to the ground. Through infiltration some water then soaks into the soil where it increases soil moisture and can percolate down to the groundwater zone. Some rainfall will flow across the earth's surface as runoff. Through transpiration from plants and evaporation, water changes from the liquid to the gaseous state and passes into the atmosphere to complete the cycle.

Land use and vegetation affect the water cycle. Buildings, roads, paving and flood channels block infiltration and accelerate storm runoff. Trees and vegetation can facilitate infiltration and slow soil erosion and storm flow.

Types of Water Budgets

"Water Budget" is a term that can have a variety of meanings. The US Geological Survey defines a water budget as an "Estimate of the size of future water resources in an aquifer, catchment area, or geographical region, which involves an evaluation of all the sources of supply or recharge in comparison with all known discharges or extractions." This kind of water budget is sometimes referred a *water balance*.

The California Urban Water Conservation Council (CUWCC) now mandates the development of a "water budget" for all major landscape sites as part of Best Management Practice 5 -- Large Landscape Conservation Programs and Incentives. Separately metered landscapes (parks, schools, greenbelts, commercial landscapes, agricultural acreage, etc.) are allocated water based on the square footage of the site served and the actual weather conditions (Evapotranspiration - ET). Some water districts charge irrigation accounts increasingly higher rates if that site uses more water than specified by the water budget.

This water budget evaluates the Arroyo Seco Watershed, part of the Los Angeles River system in Los Angeles County. Our approach is similar to a careful study of a financial account in which we study the income and expenses so that we can see how much money is still left in the balance (storage) for future use. Using historic data and estimates, the Arroyo Seco Watershed Budget can be a valuable tool to plan for the best possible use of one of our most precious resources, water.

Related Studies

Water budgets are more precise when they are developed for specific sites or hydrologic features, such as groundwater basins. There have been a series of studies of the Raymond Basin, the groundwater basin that underlies the upper portion of the Arroyo Seco Watershed. These studies have evaluated and modeled the basin, developing complete water budgets for the aquifer. These studies include:

1. Phase I Report – Devil's Gate Multi-Use Project (1990) and Phase II Report – Devil's Gate Multi-Use Project (1991), prepared by CH2M Hill
2. Technical Memorandum on Raymond Basin Groundwater Flow Modeling, Metropolitan Water District, April 17, 1997
3. Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003

The Phase I Report on the Devil's Gate Multi-Use Project prepared by the engineering company CH2M Hill analyzed the potential for a groundwater storage program in the Raymond Basin. It evaluated impacts associated with four conjunctive use concepts, which ranged from increasing local pumping during period of high water demands to developing a regional water storage. The Phase II (1991) report concluded that there were substantial benefits to local parties and no major institutional constraints to implementing a conjunctive use program in the Raymond Basin. As part of their analysis, CH2M Hill developed a Coupled Flow, Energy Solute Transport (CFEST) model, which calculate inputs and outputs for the Raymond Basin.

In 1997 Metropolitan Water District staff prepared a "Technical Memorandum on Raymond Basin Groundwater Flow Modeling." This report updated the CFEST model and converted it to USGS Modflow, the most widely used modeling software at that time. This report included a historical water balance for the Raymond Basin and two projected water balances for two alternative storage program being considered as part of the Raymond Basin Conjunctive Use Program (RBCUP).

Geoscience Support Services currently is developing a baseline groundwater assessment of the Raymond Basin for the Raymond Basin Management Board. The study is intended to resolve key issues about the potential for groundwater storage and the water quality impacts of such a program. The study will review past groundwater models and develop a revised model to provide reliable data for better management of the basin. A preliminary report, "Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin" dated July 7, 2003, has updated water balance data and provided a revised estimate of the storage capacity of the Raymond Basin.

These studies have thoroughly evaluated the groundwater basin and its inputs and outputs to develop water budgets or balances to determine issues such as:

- The level, potential and effects of storage in the basin,
- flow characteristics, and
- water quality impacts of spreading and storage.

The Los Angeles County Department of Public Works (LACDPW) has developed a hydrologic model of the Arroyo Seco watershed that can be used to perform simulations of peak discharges for various storm events and land use conditions. This model was developed using the Watershed Modeling System (WMS), which has been adopted by LACDPW for future hydrologic analyses. WMS, which uses standard GIS software, can run hydrologic routines similar to the US Army Corps of Engineers HEC-1 program or LACDPW's modified rational method. This model, however, does not use historical data about precipitation, runoff and flow as a water budget model would.

Despite all this work, a newly released draft report from the California Department of Water Resources, "California's Groundwater -- Bulletin 118," in its description of the Raymond Basin, states: "Not enough data exist to compile a detailed groundwater budget for this basin."

While the Raymond Basin has been studied extensively, developing a water budget for the Arroyo Seco Watershed is challenging because of the geographic, governmental and hydrologic characteristics of the Watershed. The Arroyo Seco Watershed is not a closed system and has a variety of features that make precision difficult. These include:

- The Arroyo Seco Watershed overlies only part of the Raymond Basin groundwater aquifer, which is also replenished by the Rio Hondo Watershed. The Monk Hill Subbasin in the northwest corner of the basin and part of the main basin underlie the

Arroyo Seco watershed, which is bounded on the east by Millard Canyon in the foothills of the San Gabriel Mountains. Canyons further east including Rubio, Las Flores and Eaton also replenish the groundwater basin, but they are part of the Rio Hondo/San Gabriel River watershed. One third of Pasadena, for instance, physically lies within the Arroyo Seco Watershed, but virtually all of Pasadena overlies the Raymond Basin.

- Areas outside the Arroyo Seco Watershed and even outside the Raymond Basin territory receive significant amounts of water from the Raymond Basin. Arcadia, for instance, pumped 6,022 acre feet from the Raymond Basin in 2002, almost 20% of the total production of the basin.
- The portions of South Pasadena and Northeast Los Angeles that lie in the Arroyo Seco Watershed are below the Raymond Dyke and separated from the Raymond Basin. There is no significant groundwater storage in these communities, so runoff and stream flow are captured by the storm channel system or move as unmetered subsurface water flow to the Los Angeles River.
- The usage patterns of Arroyo Seco Watershed residents are not measured as distinct from other residents of Pasadena, Los Angeles or other communities.
- The total outflow of the Arroyo Seco into the Los Angeles River is not metered or measured. After the County of Los Angeles' meter just south of Devil's Gate Dam, there are no historic measurements for the remaining ten miles of the stream and flood channel as it winds through the urban portion of the Arroyo Seco.

This water budget for the Arroyo Seco Watershed will use a combination of techniques to evaluate all the sources and losses of water that constitute the hydrologic cycle in the Arroyo Seco Watershed. These methods involve data gathering, analysis and informed estimates where only incomplete data exist.

The Arroyo Seco Watershed

The Arroyo Seco Watershed Restoration Feasibility Study, completed in May, 2002, best describes the Arroyo Seco Watershed:

> "The Arroyo Seco is one of southern California's greatest natural treasures. The Arroyo Seco watershed represents an outstanding opportunity for the region to demonstrate a collaborative, multi-purpose approach to the management of vital natural resources. The 46.6 square mile Arroyo Seco watershed is tributary to the Los Angeles River and spans five jurisdictions, including, from north to south, the Angeles National Forest, the unincorporated community of Altadena, the City of La Cañada Flintridge, the City of Pasadena, the City of South Pasadena, and the City of Los Angeles."

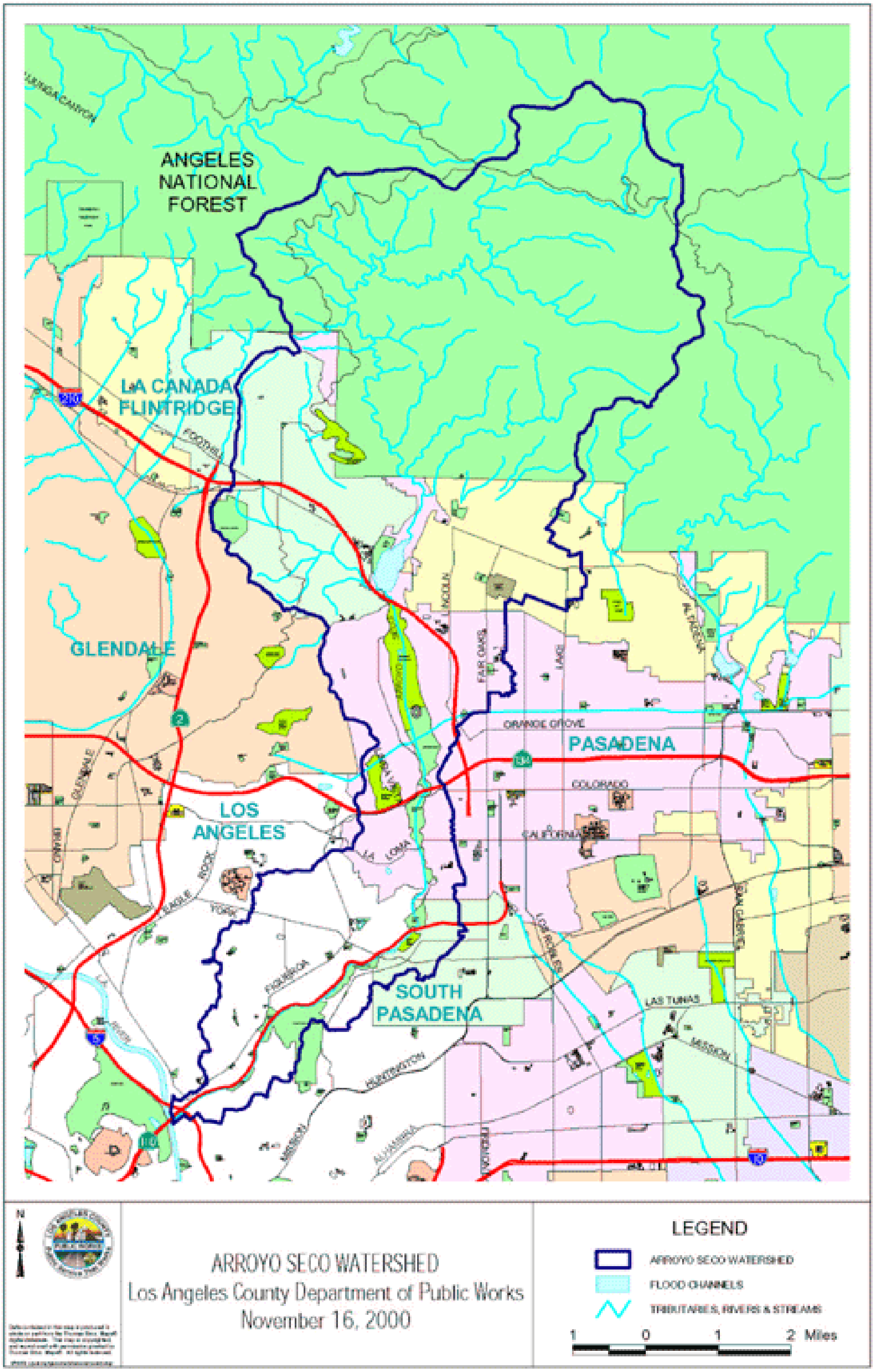

Figure 2 - The Arroyo Seco Watershed

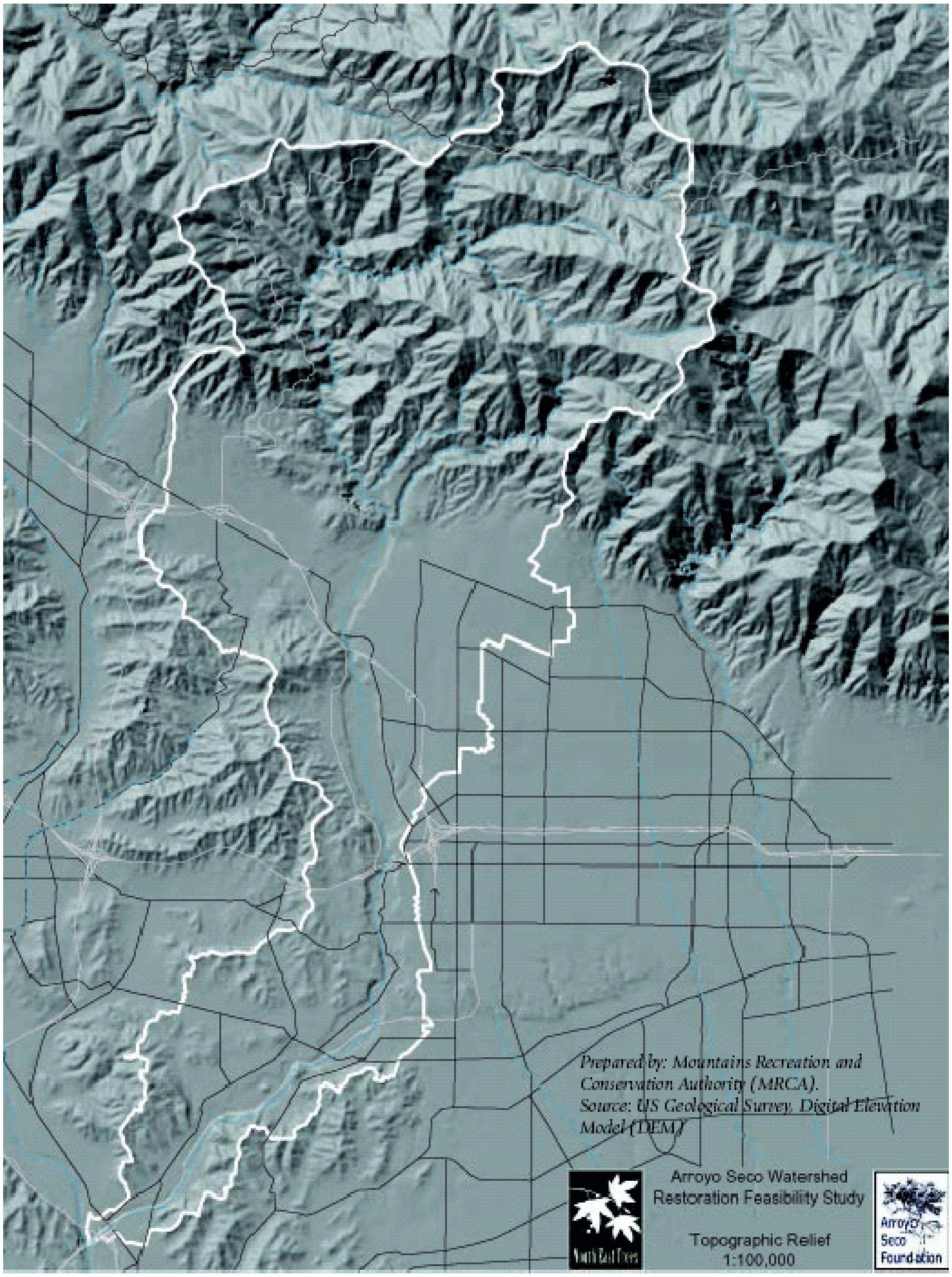

Figure 3 - Topographic Relief of the Arroyo Weco Watershed

The Watershed Budget

The Arroyo Seco watershed is a relatively small but diverse watershed, composed of mountainous upper watershed and urbanized foothills and plain. This water budget will quantify precipitation, runoff, recharge, evaporation, transpiration and human uses of water within the watershed. This will help those interested in the Arroyo Seco to understand how water arrives, flows through and leaves the watershed, and how human activities modify the natural flow of water.

Precipitation is the sole natural source of water in the Arroyo Seco. Some of the rain that falls on the terrain of the Arroyo Seco evaporates from the land or water surfaces or transpires from vegetation. These two processes are referred to as "evapotranspiration." The remainder of the rainfall either infiltrates into the aquifer beneath part of the watershed or flows off the land surfaces into storm channels that empty into the Arroyo Seco. This runoff flows to the Los Angeles River and eventually into the Pacific Ocean at Long Beach. Groundwater can become stream flow, contributing to the flow of springs or streams during both wet and dry periods, or can be pumped by local water utilities. Some groundwater also seeps over the lower boundary of the Raymond Basin and enters the Main San Gabriel Basin to the south.

More than half of the water used locally is imported from distant sources, including the Eastern Sierra Nevadas, the Colorado River and the Sacramento River, although a substantial amount of water for human consumption and use is pumped from the Raymond Basin.

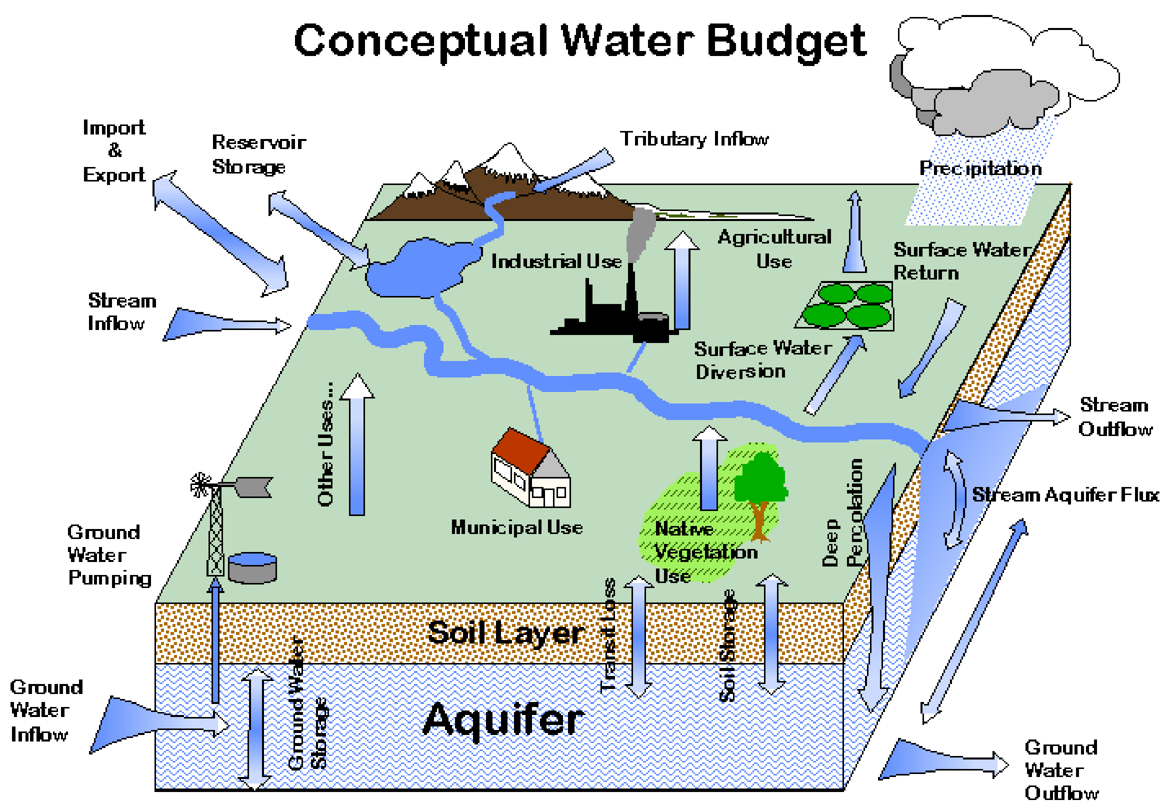

Figure 4 - Conceptual Water Budget

The water budget presented in this report is based on long-term averages. The data can best be described as general estimates. Detailed water budgets can be developed for the Arroyo Seco watershed or parts of it through use of hydrologic modeling, but such models are costly and well beyond the scope of this project.

A more detailed hydrologic model would be beneficial for conservation planning, such as for evaluating the feasibility of water percolation enhancements or best management practices for the retention of rainwater. For the purposes of this project, a generalized spreadsheet model was developed, using estimates of precipitation, infiltration and runoff based on readily available information. This report draws heavily from water supply studies and plans of the US Geological Survey, the County of Los Angeles Department of Public Works, the Raymond Basin Management Board, the City of Pasadena Water & Power Department, the Los Angeles Department of Water and Power and the Metropolitan Water District of Southern California.

Impact of Development

Development in the last two hundred years has altered the natural water cycle throughout the Arroyo Seco watershed. The most significant change is that there is no longer a balance in the water budget. Water users in the Arroyo Seco watershed now depend on a mix of surface water from the Arroyo Seco stream, groundwater and imported supplies for local use.

The first imported water used to supplement local sources occurred in the Los Angeles section of the Arroyo Seco, when that city began distributing water from the Owens Valley in the Eastern Sierra Nevada Mountains in 1913. In the northern regions of the Arroyo Seco, imported water from the Colorado River first arrived in Pasadena in 1941. Then in the early 1970s the Metropolitan Water District of Southern California began supplying water from the State Water Project to its member agencies, including Los Angeles, Pasadena, Upper San Gabriel Valley Municipal Water District (South Pasadena) and Foothill Municipal Water District (La Cañada Flintridge and Altadena).

Today the neighborhoods of Los Angeles that lie within the Arroyo Seco are totally dependent on imported water sources. The Los Angeles Department of Water Power supplies water to these communities from the San Fernando Valley Basin, the Owens Valley in the Eastern Sierra Nevadas, the Colorado River and the Sacramento/San Joaquin Rivers in Northern California.

As the table below shows, local water agencies in the upper portion of the Arroyo Seco watershed are now dependent on imported supplies for more than half their supplies.

Table 1 - Raymond Basin Agencies Water Use in 2001-2002

Agency	Groundwater	Diversions	MWD	Total Water Use	Imported
La Cañada Irrigation	130.3	73.0	2,873.5	3,076.8	93.4%
Lincoln Avenue	833.0	32.2	1,978.4	2,843.6	69.6%
Pasadena	14,628.8	-	23,032.4	37,917.2	60.7%
Valley Water	1,375.4	17.4	3,263.9	4,639.3	70.4%
Total	16,967.5	122.6	31,148.2	48,476.9	64.3%

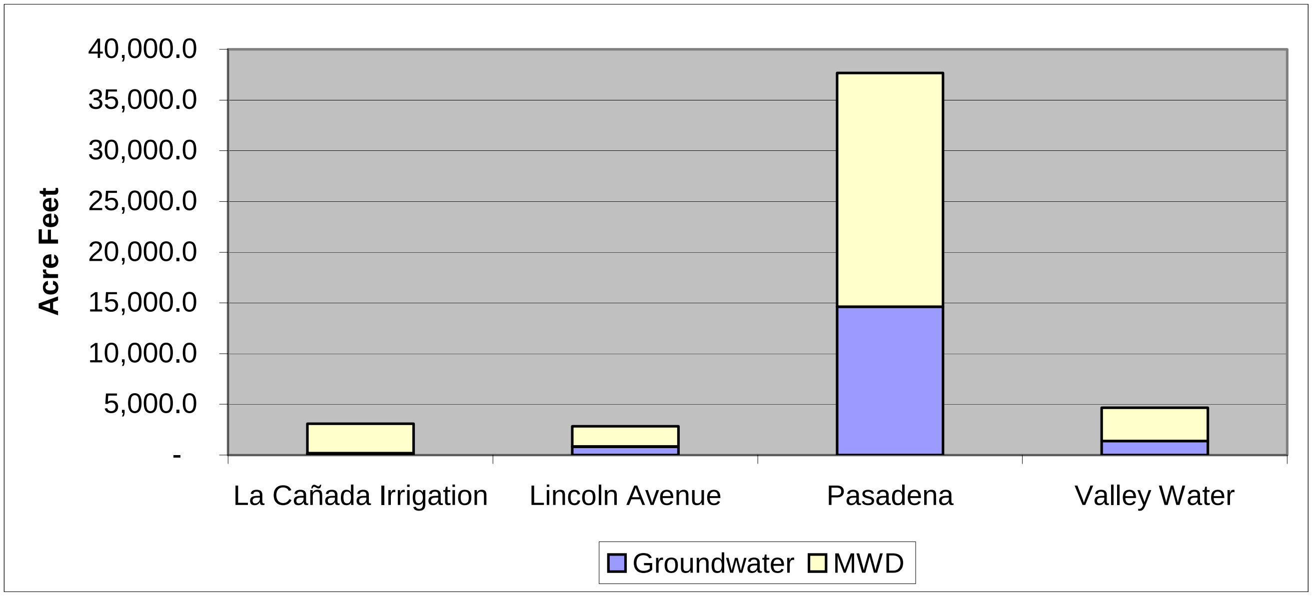

Figure 5 - Raymond Basin Agencies Water Use - 2002

This chart shows the relative use of groundwater pumping and imported water by Raymond Basin agencies for the last thirty-six years. It demonstrates the decline of the direct use of surface water during that period as well as a clear pattern of increasing reliance by Raymond Basin agencies on imported water.

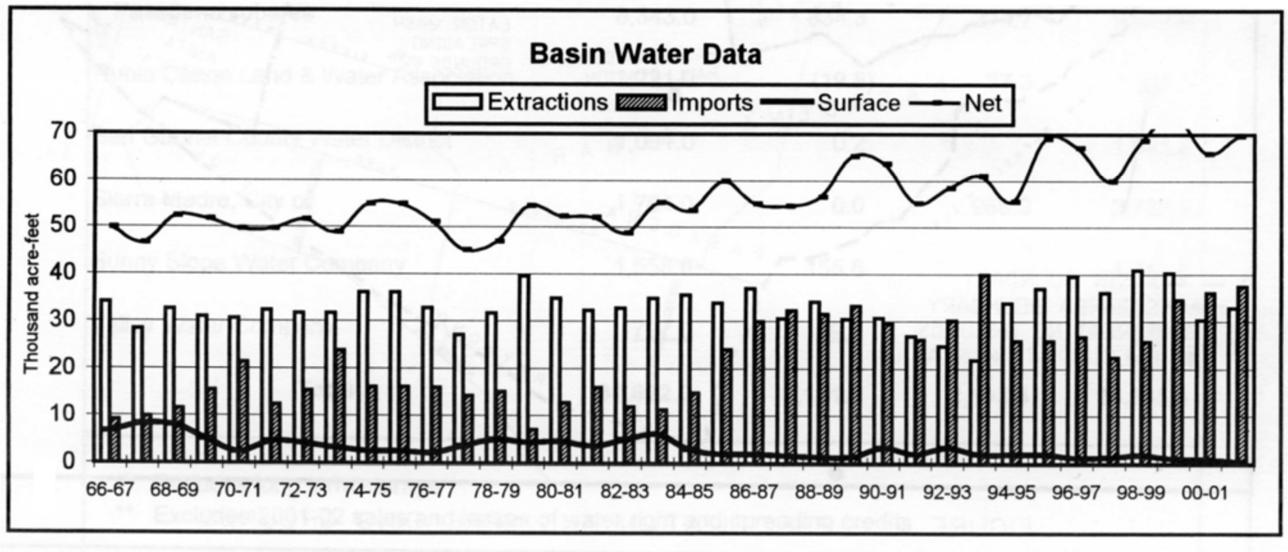

Figure 6 - Raymond Basin Water Use Historic Pattern

Groundwater Recharge

Natural ground water recharge to Arroyo Seco watershed occurs through infiltration and percolation of rainfall and surface runoff as well as subsurface inflow from the San Gabriel Mountains. Average annual precipitation across the watershed ranges from approximately 18 to 24 inches (see Figure 13). Direct percolation of precipitation principally occurs through the watershed's intermittent streams: Arroyo Seco, Millard Canyon and Flint Canyon Wash. Some of the stream flow is diverted to spreading grounds or is retained behind debris structures, thereby enhancing percolation.

Spreading basins in the Hahamongna area at the mouth of the Arroyo Seco as it emerges from the San Gabriel Mountains are used to enhance groundwater recharge by allowing diverted stream flow and storm runoff to percolate in the aquifer beneath. Injection wells are also used to replenish the groundwater basin. (cf. Appendix 6: Spreading Operations In the Arroyo Seco). Since 1977 almost one hundred thousand acre-feet have percolated into the groundwater basin through the spreading programs.

The Raymond Basin

The Raymond Basin is the groundwater aquifer that underlies the cities of Pasadena, Sierra Madre, Arcadia, Altadena, San Marino, and La Cañada-Flintridge. Bound by the San Gabriel Mountains to the north, the San Rafael Hills to the west and the Raymond Fault on the south and the east, the forty square mile basin supplies about 40% of the water supply in these communities. The basin slopes to the south, with elevations from 1,500 feet above sea level at the toe of the San Gabriel Mountains to 500 to 700 feet at the Raymond Fault. Local rainfall, the Arroyo Seco, Eaton Canyon and the foothills of the San Gabriel Mountains feed the Raymond Basin. Groundwater is stored in thick alluvial deposits that have washed down from the mountains to cover the irregular bedrock topography. The Raymond Basin is much like a bowl of sand and gravel filled with water. The bowl tilts to the southeast where some water spills into the Main San Gabriel Basin. Groundwater levels on the north side of Raymond Fault are 200 to 300 feet higher than on the south side of the fault.

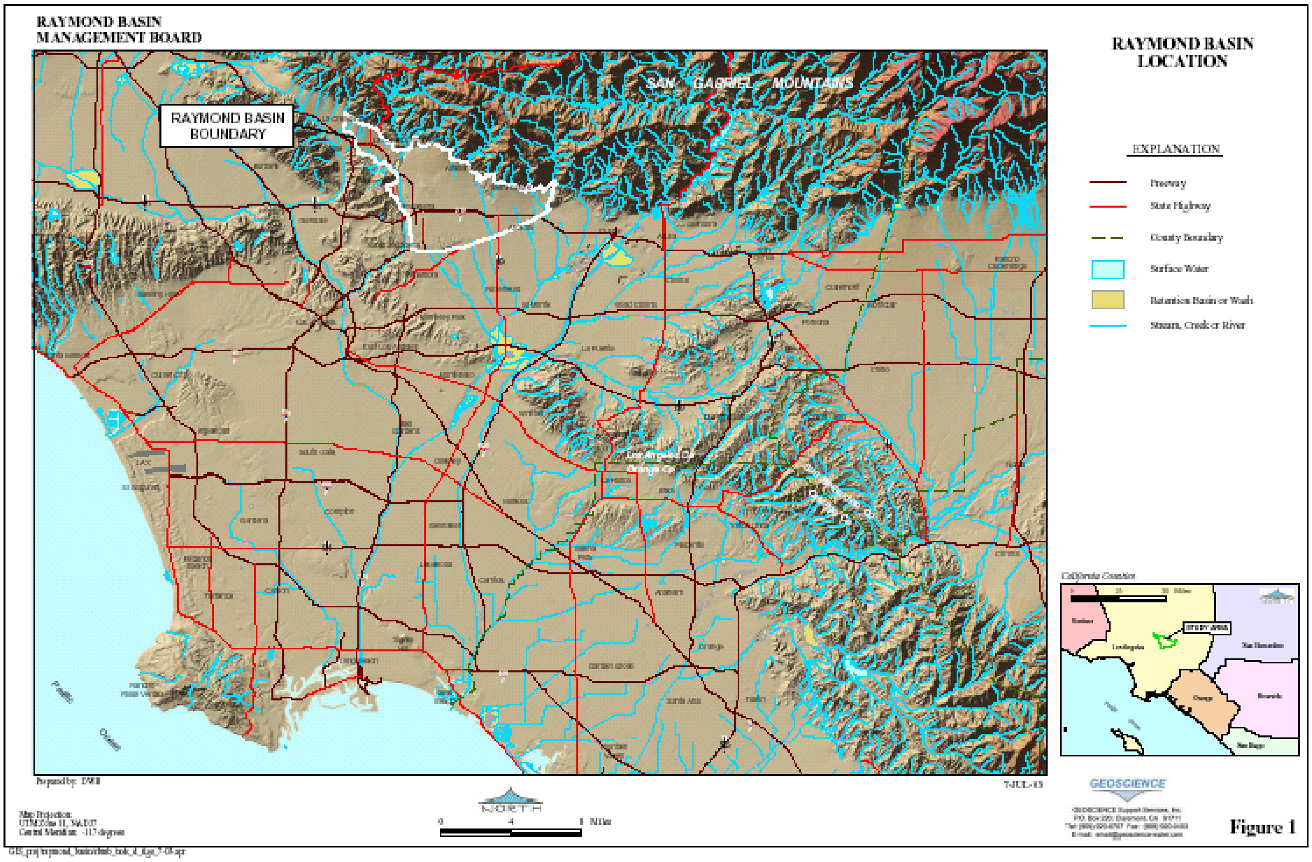

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Figure 7 - Raymond Basin Location Map

The Raymond Basin is divided into three sub-areas. The northwest of the basin is the Monk Hill Subarea which includes La Cañada-Flintridge, Altadena and northwest Pasadena down to Monk Hill (just north of Washington Boulevard). The main basin is the Pasadena Subarea, found beneath Pasadena. The Santa Anita Subarea makes up the northeastern corner of the basin and includes portions of Arcadia and Sierra Madre.

The water budget for a groundwater basin is balanced if the amount of water entering the aquifer matches the amount of water extracted. When outputs exceed inputs, the aquifer is overdrawn. The Raymond Basin has been overdrawn for more than one hundred years. The addition of imported water has relieved the draw down. Even with imports, though, the Raymond Basin today is still suffering a significant annual overdraft.

Inputs or recharge sources to the water budget for the Raymond Basin include boundary inflow from the mountain watershed and surface flow. There are five components of surface flow: natural recharge from precipitation, stream flow, recharge from applied water such as landscaping, recharge from septic flows, and percolation from spreading operations.

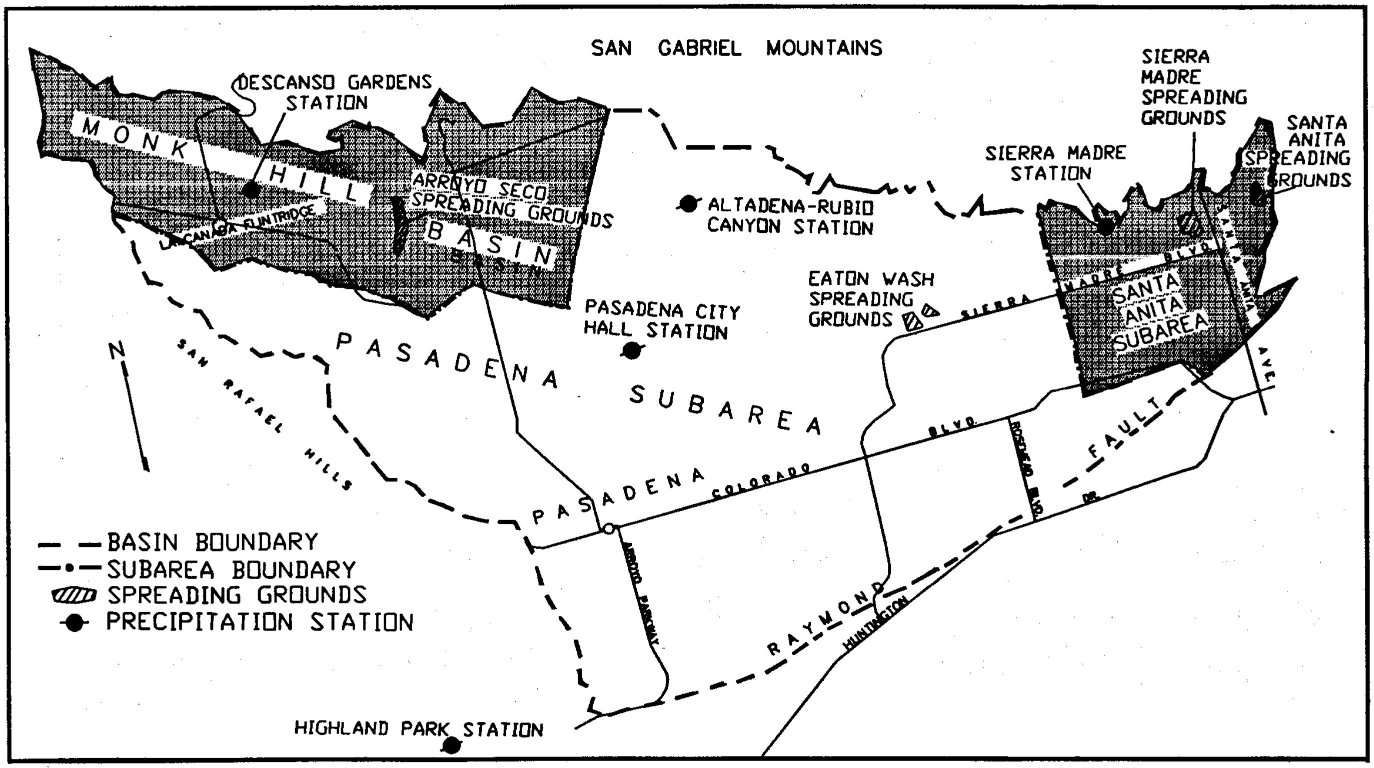


Figure 8 - Location of Precipitation Stations and Spreading Grounds

Outputs include surface diversions and groundwater extractions for urban and industrial use, transpiration by riparian vegetation, and subsurface seepage from the Raymond Basin to the Man San Gabriel Basin, the aquifer below the Raymond Fault. The California Department of Water Resources estimated the subsurface outflow across the Raymond Fault in 1969 to be 6,360 acre-ft per year. CH2M Hill in 1992 estimated that in some years the flow is as much as 10,564 acre-ft.

In the 1940s the Raymond Basin was the subject of adjudication, a legal agreement or decision that defines the rights of water pumpers in a basin. The intent of the Raymond Basin adjudication and subsequent management efforts has been to develop a sustained yield program that would balance extractions from the basin with natural replenishment supplemented by imported supplies.

The recent Geoscience technical report found that the management program is not reaching its goal. "Despite increases in spreading, the volume of ground water in storage within the Raymond Ground Water Basin has decreased by 112,600 acre-ft from 1983 to 2002, although the decrease was less pronounced during the period from 1991 to 2002. Between 1991 and 2002, the volume of ground water in storage decreased by approximately 46,100 acre-ft while it decreased by approximately 66,500 acre-ft from 1983 to 1991." This overdraft of about 5,600 acre feet per year, in a basin with a capacity of 1.45 million acre feet, has occurred during the same period of time as local water agencies have established storage accounts in the basin.

Overdrafting of groundwater can cause environmental problems, including land subsidence, habitat reduction, and adverse groundwater quality impacts. It also leads inevitably to further reliance on imported supplies.

Water Budget Factors

Climatic Conditions – Precipitation and Temperature

The climate of the Arroyo Seco Watershed is subtropical to semiarid with hot dry summers and mild, moist winters occasionally punctuated by intense storm events. The watershed begins in the San Gabriel Mountains, part of the Transverse Range of Southern California, where the rainfall is significant higher than at lower elevations. In the report "Climate of California," the Western Regional Climate Center states: "The maximum intensity of precipitation for periods of 12 hours or longer which might be expected at intervals of 10 to 100 years is greater in portions of the San Gabriel and San Bernardino Mountains in southern California than anywhere else in the continental United States." The upper watershed of the Arroyo Seco is one of those fierce portions. More than 11 inches of rain has fallen in a twenty-four period in the upper watershed, while the maximum in the lower reaches was 7.7 inches recorded on March 2, 1938.

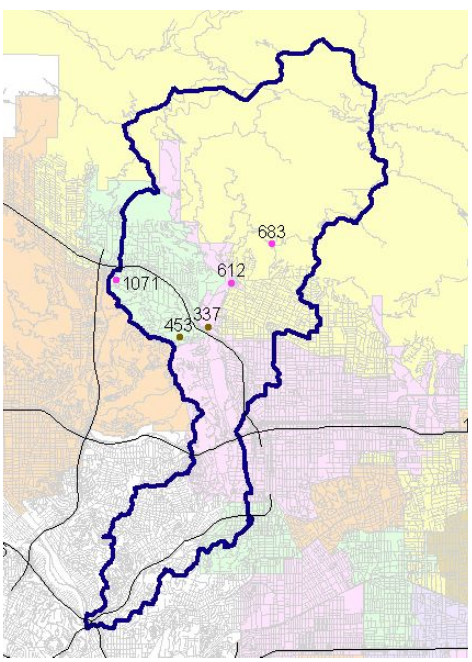


Figure 9 – Los Angeles County Rainfall Gages in the Arroyo Seco

Rainfall generally declines as elevation falls in the watershed. At Mount Wilson, just outside the upper limit of the watershed, the mean annual rainfall is 35.47 inches. The average at Oakwilde five miles into the mountains is 28.19 inches. At County Weather Station 683, a few miles south, the mean rainfall for the period from 1981 to 2003 was 23.5 inches, while at the Pasadena City Hall weather station, average annual precipitation from 1931 to 2002 was 20.24 inches. In Highland Park the historic mean rainfall has been 18.56 inches. The average precipitation at Los Angeles Civic Center, 2 miles south of the lower limits of the Arroyo Seco watershed is 14.73 inches. The highest annual rainfall occurred in 1983 at 48.47; the lowest year was 1947 in which there were only 5.37 inches.

Table - 2 - Precipitation in the Arroyo Seco

Station	Station Type		Period of Record in Years	Precipitation			
	Valley	Mountain		1999-00	2000-01		50-year* Mean
Altadena-Rubio Canyon	x		103	9.04	18.58		23.08
Highland Park	x		105	14.29	9.53	##	18.56
Descanso Gardens	x		88	18.12	21.66		23.18
Chilao**		x	65	8.59	6.32	#	36.40
Oakwilde**		x	56	---	---		28.19
Big Tujunga Dam**		x	83	11.07	21.43	##	41.19
Pasadena City Hall	x			17.18	18.22		n/a
Sierra Madre Dam	x	x	105	17.62	19.97		25.01
Upper Haines Canyon**		x	65	---	---		30.06
Clear Creek City School**		x	73	17.89	23.53		27.72
Pasadena Chlorine Station		x	76	---	---		23.40
Arithmetic Mean (Valley)				15.32	17.56		22.46
Arithmetic Mean (Mountain)				27.66	19.20		30.28

* 1896-97 to 1945-46
** Outside basin
-- Record no longer maintained

\# Malfunctioned March and April 2001
\## Unprocessed June 2001

Local Rainfall Pattern

Most of the precipitation in the Arroyo Seco watershed occurs during the winter months of December through March, following the pattern of monthly precipitation recorded at the Pasadena weather station.

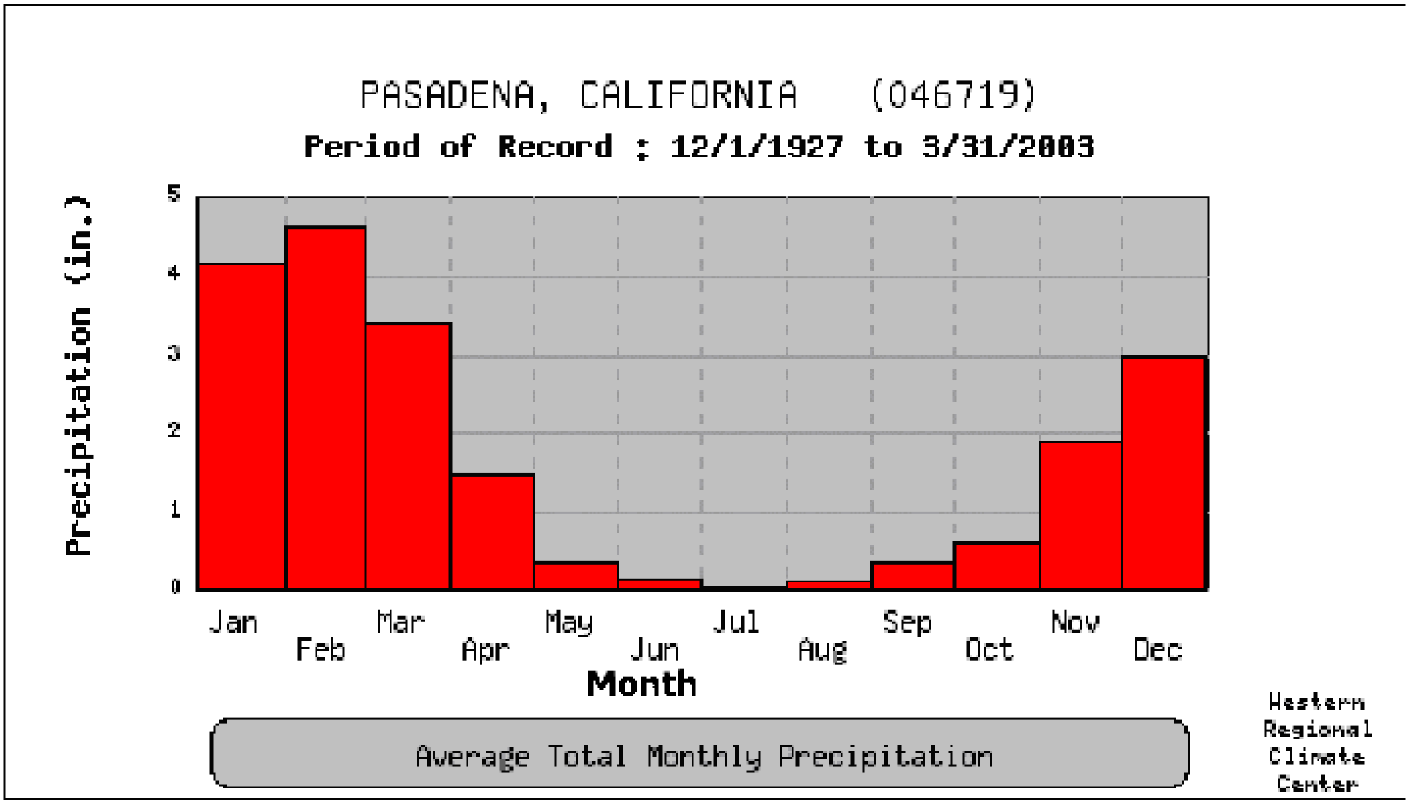


Figure 10 - Pasadena Monthly Precipitation

These charts illustrate the rainfall and precipitation patterns of the Arroyo Seco.

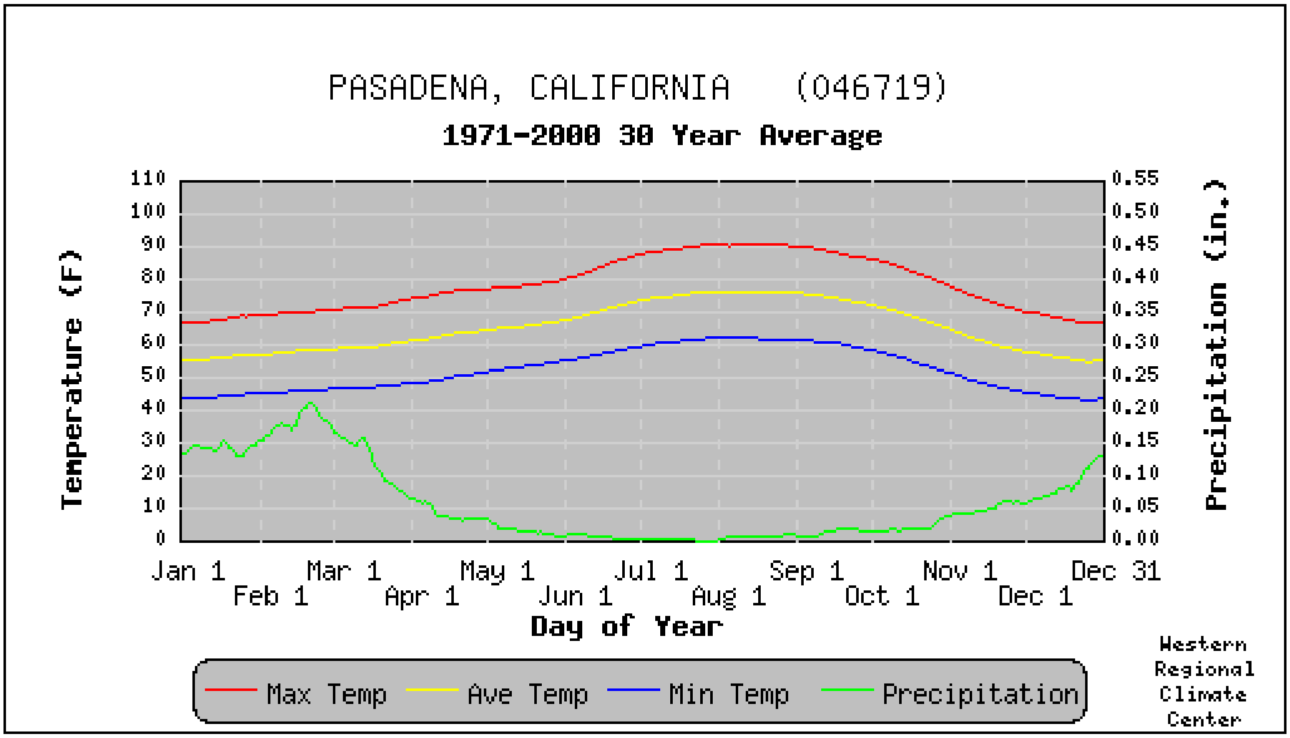


Figure 11 - Pasadena Climate

- Max. Temp. is the average of all daily maximum temperatures recorded for the day of the year between the years 1971 and 2000.
- Ave. Temp. is the average of all daily average temperatures recorded for the day of the year between the years 1971 and 2000.
- Min. Temp. is the average of all daily minimum temperatures recorded for the day of the year between the years 1971 and 2000.
- Precipitation is the average of all daily total precipitation recorded for the day of the year between the years 1971 and 2000.

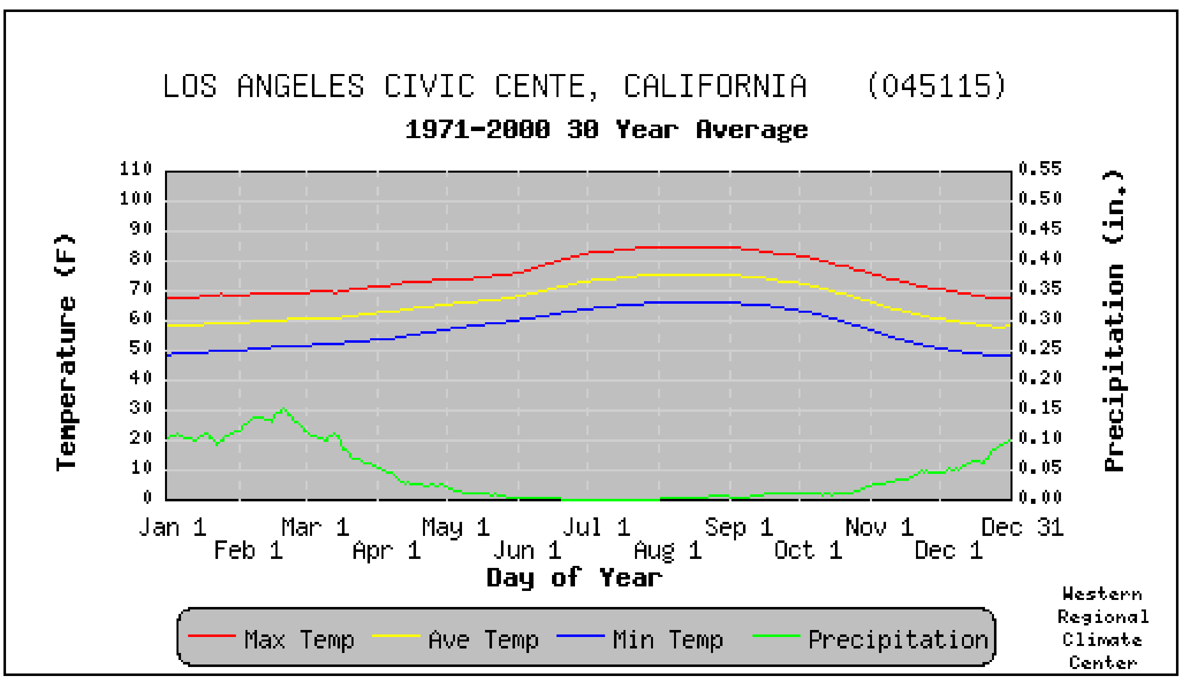


Figure 12- Los Angeles Climate

- Max. Temp. is the average of all daily maximum temperatures recorded for the day of the year between the years 1971 and 2000.
- Ave. Temp. is the average of all daily average temperatures recorded for the day of the year between the years 1971 and 2000.

- Min. Temp. is the average of all daily minimum temperatures recorded for the day of the year between the years 1971 and 2000.
- Precipitation is the average of all daily total precipitation recorded for the day of the year between the years 1971 and 2000.

Table 3 - Temperature in the Arroyo Seco Watershed

Month	High Temp	Average Temp	Low Temp	CDD*	HDD*	Rain (Inches)
January	**67.8**	**56.1**	**44.3**	**0.3**	**28.1**	**4.5**
February	**70.3**	**58.1**	**45.9**	**1.1**	**20.5**	**5.0**
March	**71.3**	**59.3**	**47.2**	**2.2**	**20.0**	**4.4**
April	**76.0**	**63.0**	**50.0**	**6.9**	**12.9**	**1.2**
May	**78.2**	**65.9**	**53.5**	**10.6**	**8.0**	**0.5**
June	**84.0**	**70.7**	**57.4**	**19.1**	**2.0**	**0.2**
July	**89.4**	**75.3**	**61.1**	**31.8**	**0.0**	**0.1**
August	**90.6**	**76.3**	**62.0**	**35.2**	**0.2**	**0.2**
September	**88.5**	**74.6**	**60.6**	**29.4**	**0.8**	**0.5**
October	**82.5**	**68.9**	**55.2**	**15.3**	**3.4**	**0.7**
November	**73.8**	**61.0**	**48.1**	**3.3**	**15.6**	**1.5**
December	**68.0**	**56.1**	**44.1**	**0.6**	**28.3**	**2.5**

Heating Degree Days relate a day's temperatures to the demand for fuel to heat a building. When the temperature is above 65 degrees, there are no heating degree days. If the temperature is less than 65, subtract it from 65 to find the number of heating degree days.

Cooling Degree Days are also based on the temperature minus 65. It relates the temperature to the energy demands of air conditioning.

Heating and cooling degree days can be used to estimate how much is spent on heating or air conditioning in a particular region.

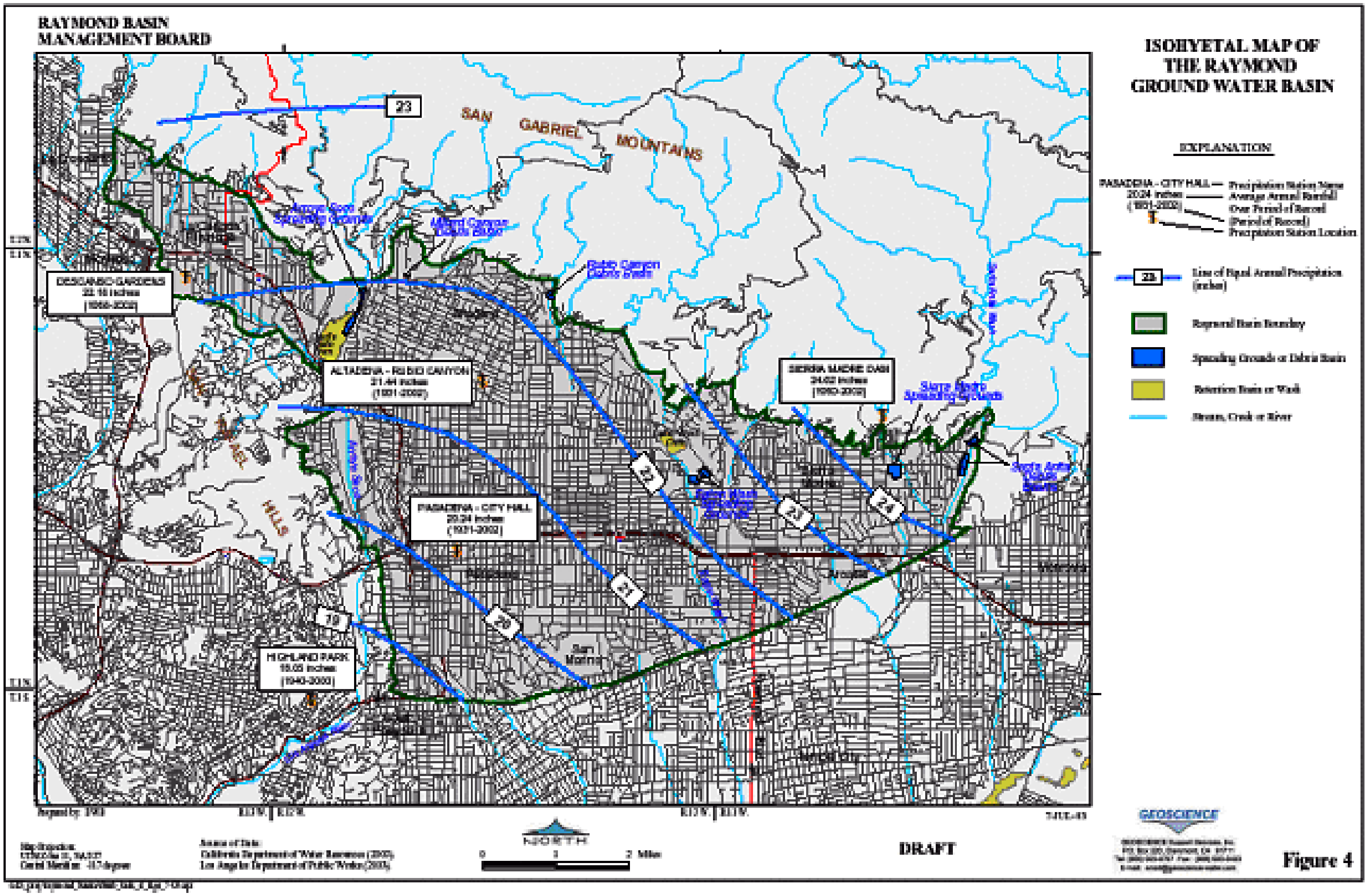


Figure 13 - Isohyetal Map of the Raymond Basin

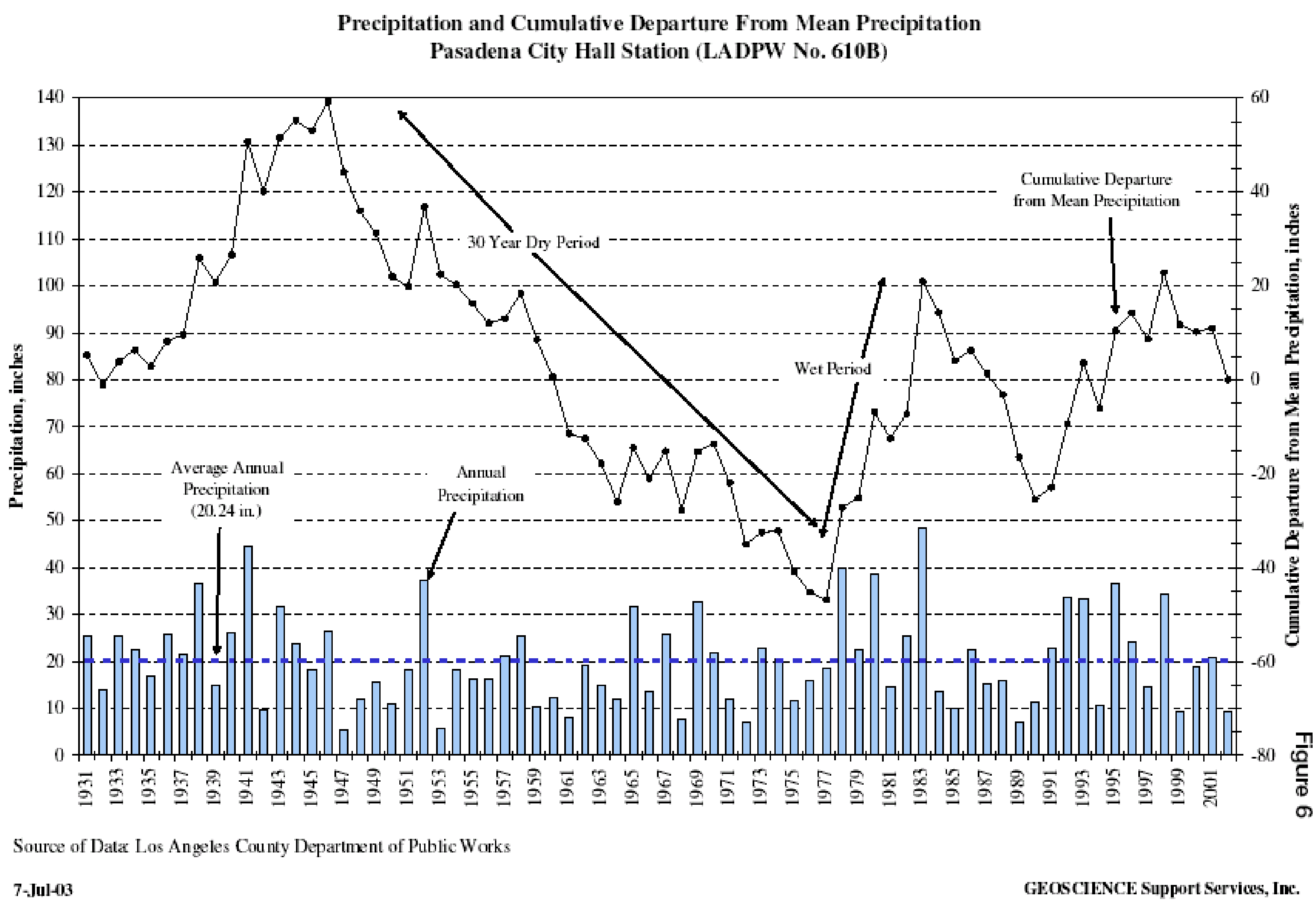


Figure 14 - Pasadena Precipitation

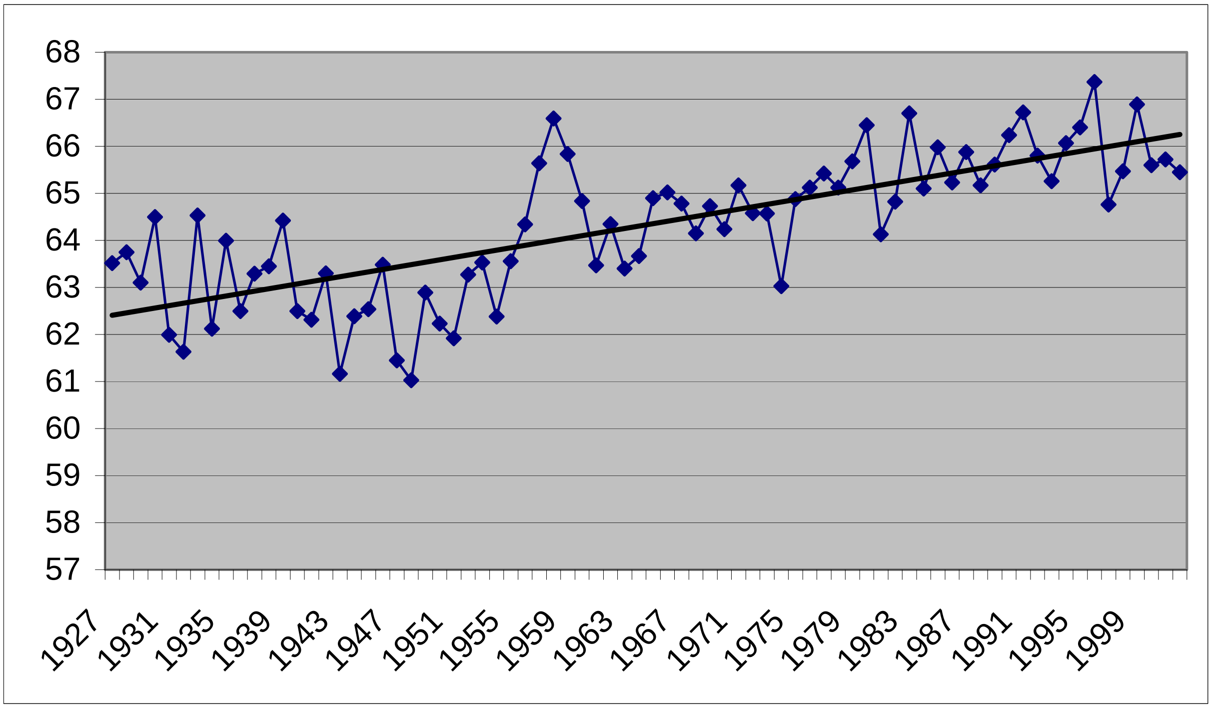


Figure 15 - Pasadena Average Temperature

The mean annual temperature in Pasadena is 65.9 degrees Fahrenheit, 2.7 degrees higher than the same measure seventy years ago. At the Los Angeles Civic Center, the mean temperate, now 66.0 degrees, has climbed 3.1 degrees since 1914.

Streamflow

Figure 16 - Location of USGS Stream Gage

The County of Los Angeles Department of Public Works and the United States Geologic Survey monitor streamflow in the Arroyo Seco Watershed.

The USGS gage station (USGS Gage #11098000) is located about 0.7 miles east of the Angeles Crest Highway and 5.5 miles northwest of Pasadena. The USGS gage provides continuous data going back to December 1, 1910. It can be viewed in real-time at: http://waterdata.usgs.gov/ca/nwis/discharge?site_no=11098000.

Figure 17 indicates the sharp variation in daily mean streamflow in the Arroyo Seco. Figure 18 portrays the peak stream flow in cubic feet per second since 1914.

Complete data and documentation can be found at the USGS website.

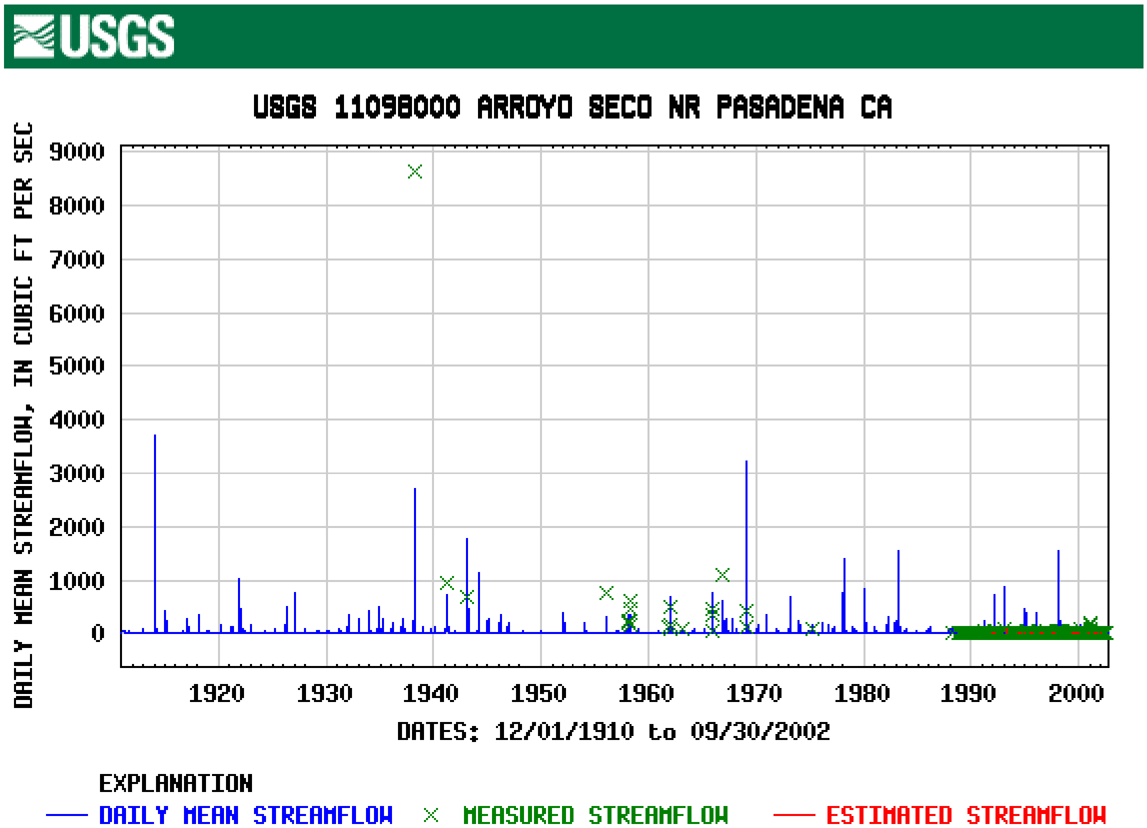


Figure 167 - Arroyo Seco Daily Mean Streamflow - 1910-2002

Daily mean streamflow for the 92 years of record on the USGS gage is 9.997 cubic feet per second per day. The mean streamflow past this point is 7238 acre-feet per year. This measurement records the stream flow in the 16.0 square miles of the upper mountain watershed above the gage.

The peak streamflow was recorded on Mar. 02, 1938 at 8,620 cubic feet per second (cfs). The flood of 1969 trailed closely with a flow of 8,540 cfs on Jan. 25, 1969. The flood of 1914, which was so destructive in the Los Angeles section of the Arroyo Seco, had a peak of 5,800. The largest streamflow in the last 25 years occurred on February 23, 1998 with a flow of 4,380 cfs.

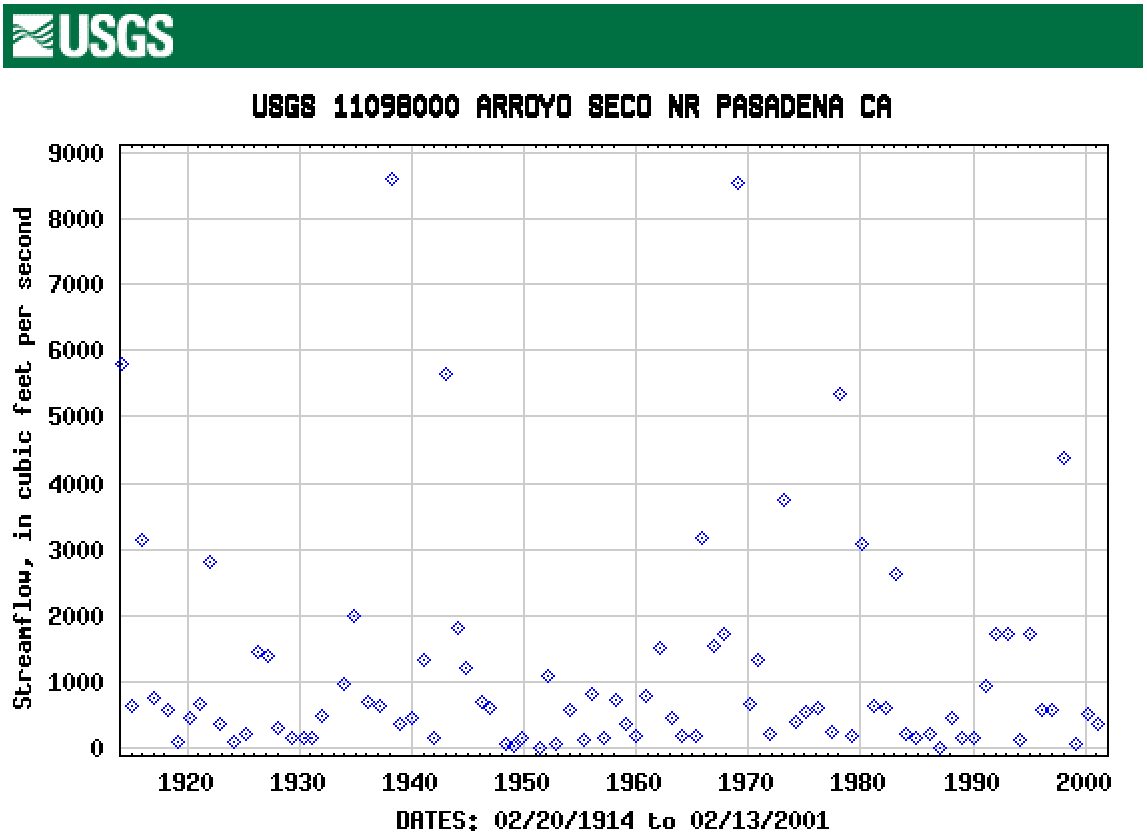


Figure 18 - Peak Streamflow in the Arroyo Seco - 1914-2001

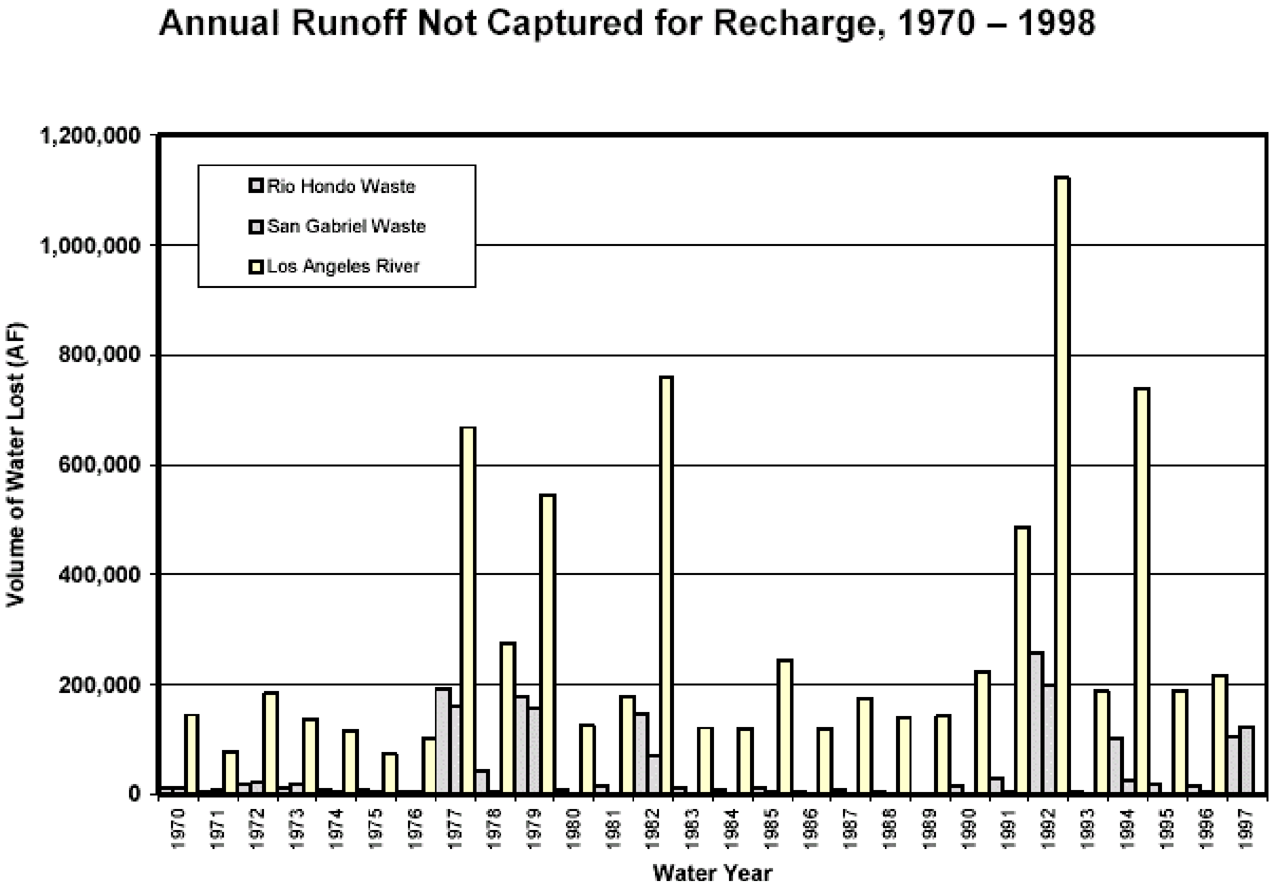
Table 4 – LA County Stream Gage 477					
LA County Department of Public Works Streamflow Gage 477 Arroyo Seco Below Devil's Gate Dam Water Years 1990-2002					
Water Year	**Total**	**Mean**	**Max**	**Min**	**Acre-Ft**
1990	70	0.19	12	0	139
1991	2552	7.07	572	0	5070
1992	16321	44.60	3530	0	32390
1993	1620	8.85	403	1.3	3200
1994	836	2.29	21	0.12	1670
1995	12381	33.90	505	0	24590
1996	1738	4.75	408	0	3450
1997	847	2.32	77	0	1680
1998	1079	6.00	352	0	2140

2000	1557	4.26	325	0	3080
2001	5927	16.20	620	0	11740
2002	611	2.87	188	0	1210
Total	45768				90810
Average		10.30			6985

These figures record the streamflow from the upper mountain watershed of the Arroyo Seco. The LA County gage, below Devil's Gate Dam, records the mountain watershed as well as the flow from La Cañada and from Millard Canyon, a total of 32 square miles. There is no gage on the Arroyo Seco for the ten miles of the stream and flood channel below Devils Gate Dam, so there is no accurate historic measure of the runoff from the 15 square miles of the urbanized watershed. Based on modeling and calculations contained in the Technical Report On Hydrology, Hydraulics And Geomorphology prepared by Montgomery Watson Harza for the Arroyo Seco Watershed Restoration Feasibility Study, the average annual flow of the Arroyo Seco into the Los Angeles River is about 10,620 acre feet.

The amount of runoff in the lower urbanized section of the watershed, averaging approximately 3300 acre feet per year, is critical to determine the potential savings that can be achieved by local rainfall retention programs. Because 75% of all rainfall in the watershed occur in storms of ¾ inch or less, the amount of runoff have a significant water supply impact in the Arroyo Seco Watershed.

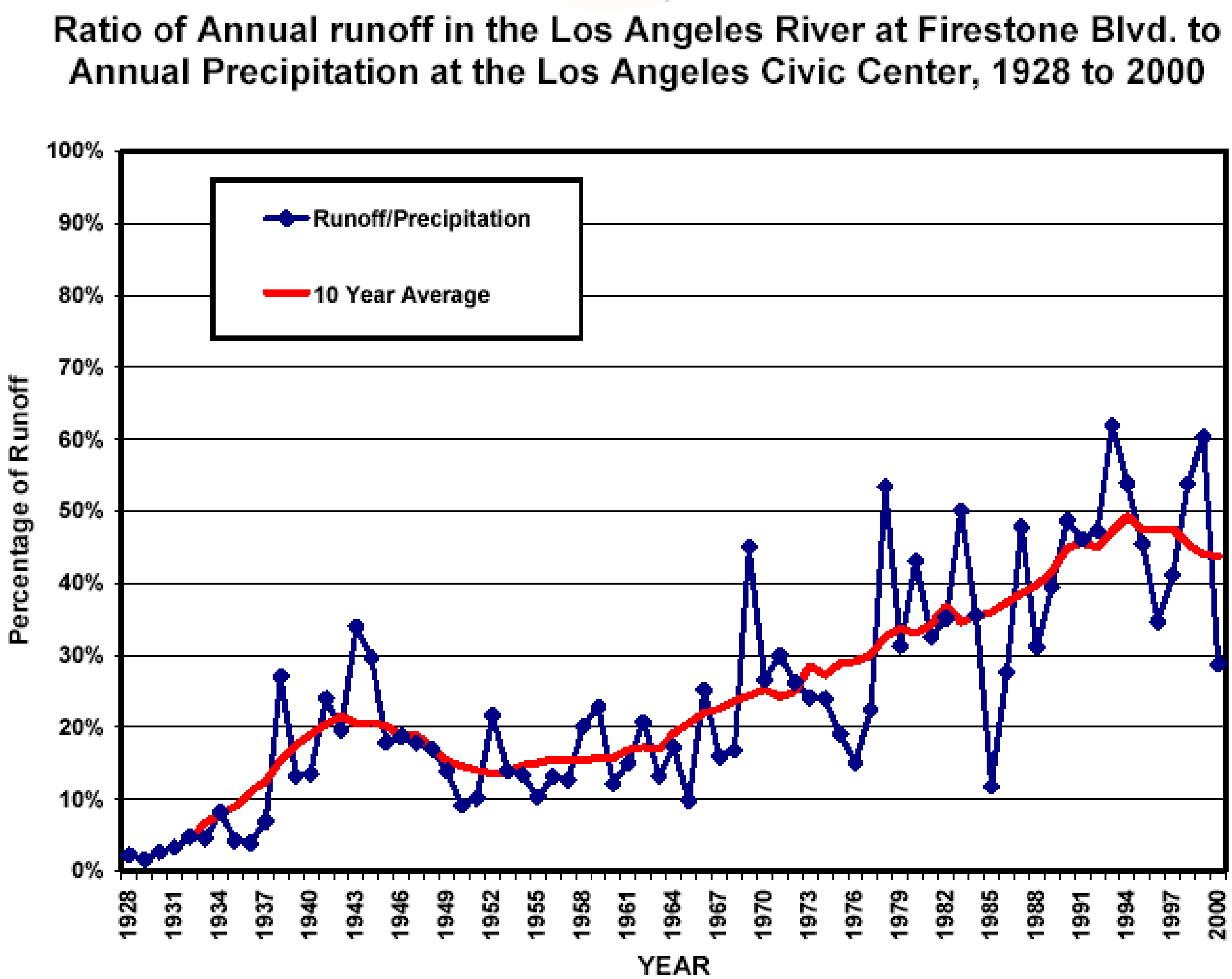
Figure ?? demonstrates the large amount of runoff from the major rivers of Los Angeles County that now reaches the ocean, sometimes more than 400,000 acre feet per year. Runoff from the Arroyo Seco, a tributary of the Los Angeles River, contributes to this flow.



Source: LACDPW Water Resources Division
Note: in the years 1970-1998, records indicate that significant spreading did occur, but runoff exceeded the spreading capacity.

Figure 19 - Annual Runoff Not Captured for Recharge, 1970 - 1998

Land use changes in the last one hundred and twenty fives years have had a profound impact on natural hydrologic processes in the Arroyo Seco. First agriculture and then urbanization altered the stream courses, water storage, pollutant levels, evapotranspiration, infiltration, and surface runoff in the watershed. The amount of rainfall converted to runoff has significant increased with urbanization. The same forces of urbanization that have occurred in the Arroyo Seco Watershed have transformed the Los Angeles River. Figure ??, taken from the Water Augmentation Study Pilot Program Report, prepared by the Los Angeles and San Gabriel Rivers Watershed Council, illustrates the ratio of annual runoff in the Los Angeles River to annual precipitation from 1928 to 1998. Before the late 1930s, less than 10 percent of Los Angeles basin rainfall was converted to runoff and entered the Los Angeles River. The rest either evaporated or infiltrated into the ground. Now 40-50% of rainfall becomes runoff (Figure 20).



Source: Los Angeles County Department of Public Works and Western Regional Climate Data Center

Figure 20 - Ratio of Annual Runoff - Los Angeles River

Urban development has also altered the timing and extent of flooding, the sediment yield of rivers, and the suitability and viability of aquatic habitats. Roads, buildings, parking lots, and other impermeable surfaces, have replaced the natural terrain of the Arroyo Seco, preventing rainfall from infiltrating into the ground. In the 1930s and 1940s, a concrete-lined flood control channel, designed to efficiently convey water out of the area during storms, replaced the natural Arroyo Seco stream. Pipes and culverts captured the other streams in the watershed, funneling their flow directly into the flood channel system and eventually to the Pacific Ocean.

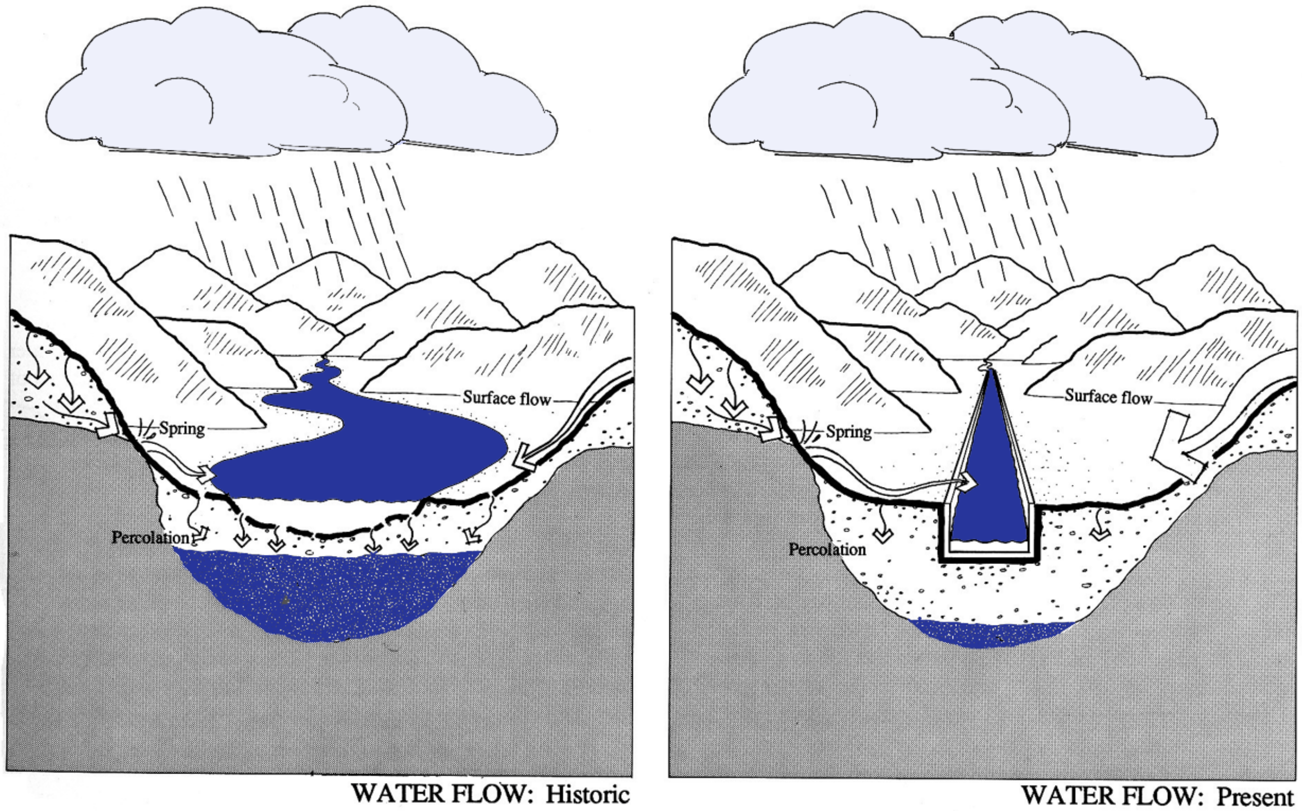
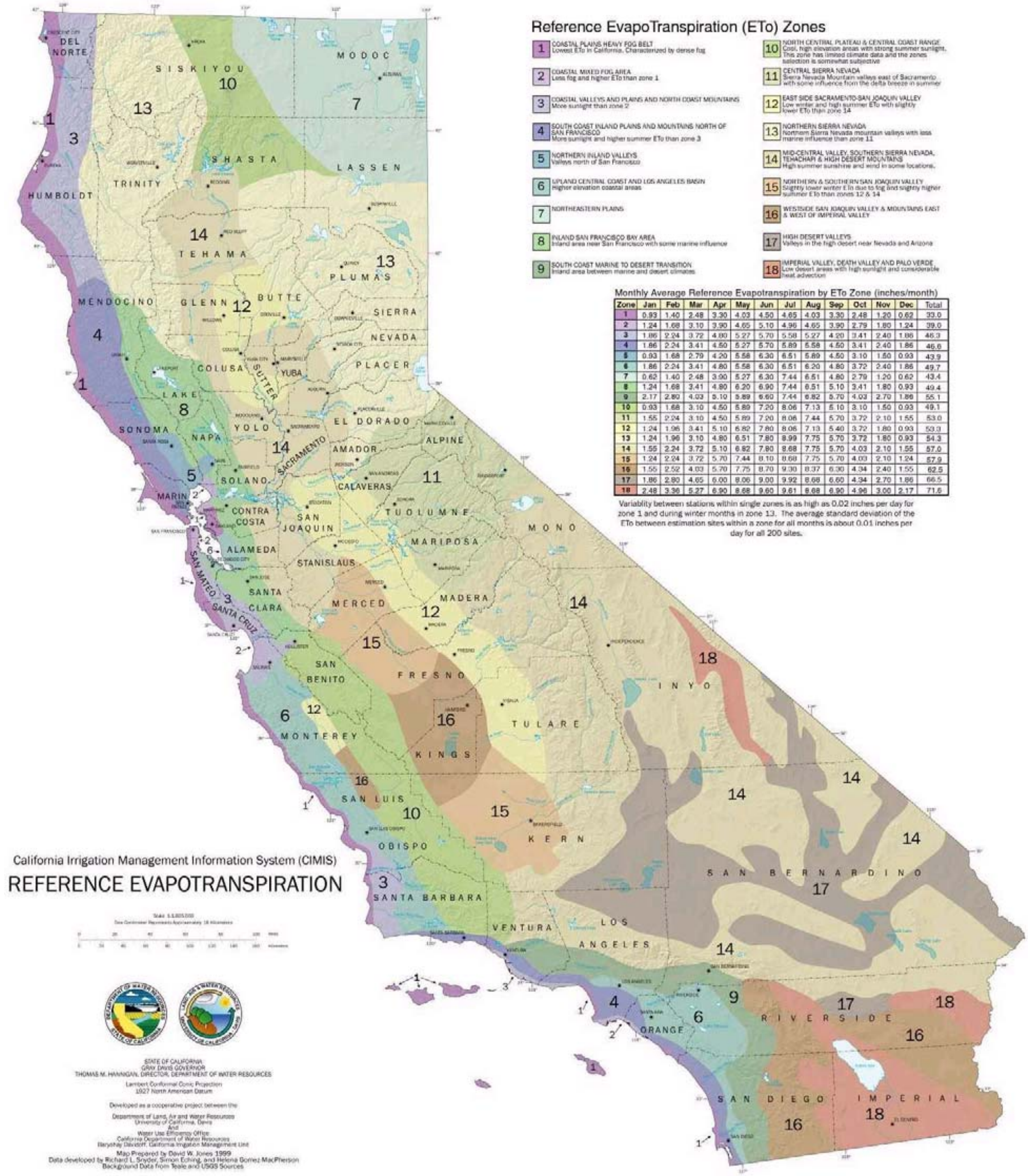


Figure 21 - The Effect of Channelization on Infilitration

Evapotranspiration in the Arroyo Seco Watershed



Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Figure 22- California Irrigation Management Information System (CIMIS) Evapotranspiration Map

Evapotranspiration (ET) is the combination of soil evaporation and plant transpiration. These two processes represent the water loss from the plant-soil system due to evaporative demand of the atmosphere.

The ET rate (Eto) is a reference number which represents an estimate of evapotranspiration from an extended surface of 3 to 6 inch tall green grass cover of uniform height, actively growing, completely shading the ground, and not short on water. Throughout the state of California, a series of weather stations that form the California Irrigation Management Information System (CIMIS) are located within a small grass field that is optimally irrigated. Instruments attached to the weather station datalogger measure weather parameters that would directly affect ETo estimates such as solar radiation, air temperature, humidity, wind and rain. This data is incorporated within the weather station's database and calculates a reference evapotranspiration (ETo) number every hour.

CIMIS helps agricultural growers and turf managers administering parks, golf courses and other landscapes to develop water budgets for determining when to irrigate and how much water to apply, but it also supplies a key factor for our water budget calculation of the Arroyo Seco Watershed.

The two closest CIMIS weather stations to the Arroyo Seco Watershed are in Glendale and Monrovia. ETo data for those weather stations for the last year can be found in Appendix 7.

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

Figure 23 - Evapotranspiration Rate Zones

Reference Evapotranspiration Rates for Selected Cities*

Daily Average Reference Evapotranspiration by ET_o Zone (inches per day)

ET_o Zone	City	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	Santa Monica	0.03	0.05	0.08	0.11	0.13	0.15	0.15	0.13	0.11	0.08	0.04	0.02
2	Santa Cruz	0.04	0.06	0.10	0.13	0.15	0.17	0.16	0.15	0.13	0.09	0.06	0.04
3	Monterey/Salinas	0.06	0.08	0.12	0.16	0.17	0.19	0.18	0.17	0.14	0.11	0.08	0.06
4	San Diego	0.06	0.08	0.11	0.15	0.17	0.19	0.19	0.18	0.15	0.11	0.08	0.06
5	Santa Rosa	0.03	0.06	0.09	0.14	0.18	0.21	0.21	0.19	0.15	0.10	0.05	0.03
6	Los Angeles	0.06	0.08	0.11	0.16	0.18	0.21	0.21	0.20	0.16	0.12	0.08	0.06
7	Alturas	0.02	0.05	0.08	0.13	0.17	0.21	0.24	0.21	0.16	0.09	0.04	0.02
8	San Jose	0.04	0.06	0.11	0.16	0.20	0.23	0.24	0.21	0.17	0.11	0.06	0.03
9	San Bernardino Pasadena	0.07	0.10	0.13	0.17	0.19	0.22	0.24	0.22	0.19	0.13	0.09	0.06
10	Paicines	0.03	0.06	0.10	0.15	0.19	0.24	0.26	0.23	0.17	0.10	0.05	0.03
11	Sonora	0.05	0.08	0.10	0.15	0.19	0.24	0.26	0.24	0.19	0.12	0.07	0.05
12	Fresno	0.04	0.07	0.11	0.17	0.22	0.26	0.26	0.23	0.18	0.12	0.06	0.03
13	Quincy	0.04	0.07	0.10	0.16	0.21	0.26	0.29	0.25	0.19	0.12	0.06	0.03
14	Sacramento	0.05	0.08	0.12	0.17	0.22	0.26	0.28	0.25	0.19	0.13	0.07	0.05
15	Bakersfield	0.04	0.08	0.12	0.19	0.24	0.27	0.28	0.25	0.19	0.13	0.07	0.04
16	Hanford	0.05	0.09	0.13	0.19	0.25	0.29	0.30	0.27	0.21	0.14	0.08	0.05
17	Needles	0.06	0.10	0.15	0.20	0.26	0.30	0.32	0.28	0.22	0.14	0.09	0.06
18	Palm Springs	0.08	0.12	0.17	0.23	0.28	0.32	0.31	0.28	0.23	0.16	0.10	0.07

* For comprehensive descriptions of each zone and to locate your region in a zone, see the California Irrigation Management Information System (CIMIS) color map

Figure 24 - Reference Evapotranspiration

Water Balance

A helpful way of looking at local weather conditions compares precipitation to potential evapotranspiration. This chart, sometimes referred to as a water budget, is a direct comparison of supply of water and the natural demand for water. It illustrates the months when there is plenty of precipitation and when there is very little or none. Here are some useful terms.

- **Potential Evapotranspiration (PE)**: This is a measure of the ability of the atmosphere to remove water from the surface through the processes of **evaporation** and **transpiration** assuming no control on water supply.
- **Actual evapotranspiration** (**AE)** is the quantity of water that is actually removed from a surface due to the processes of **evaporation** and **transpiration**.
- **Precipitation (P)**: All moisture from the atmosphere, rain, snow, hail and sleet.
- **Surplus**: Water above what is lost naturally from the soil (when P is greater than PE)
- **Deficit**: Water that would be lost above what is in the soil if it were present (when P is less than PE)

Another interesting way to look at climate factors demonstrates how they interact to affect water consumption. The chart below shows the water balance for the Arroyo Seco watershed based on average monthly rainfall rates and evapotranspiration patterns. The seasonal variability in evapotranspiration is similar to the seasonal trend in air temperature. In this watershed measurable evapotranspiration occurs all year long but reaches a maximum in July and decreases in October. This pattern can be a handy water conservation tool for landscape irrigators who often fail to adjust automatic sprinkler systems according to ET conditions. Irrigation rates should be set to meet but not exceed evapotranspiration.

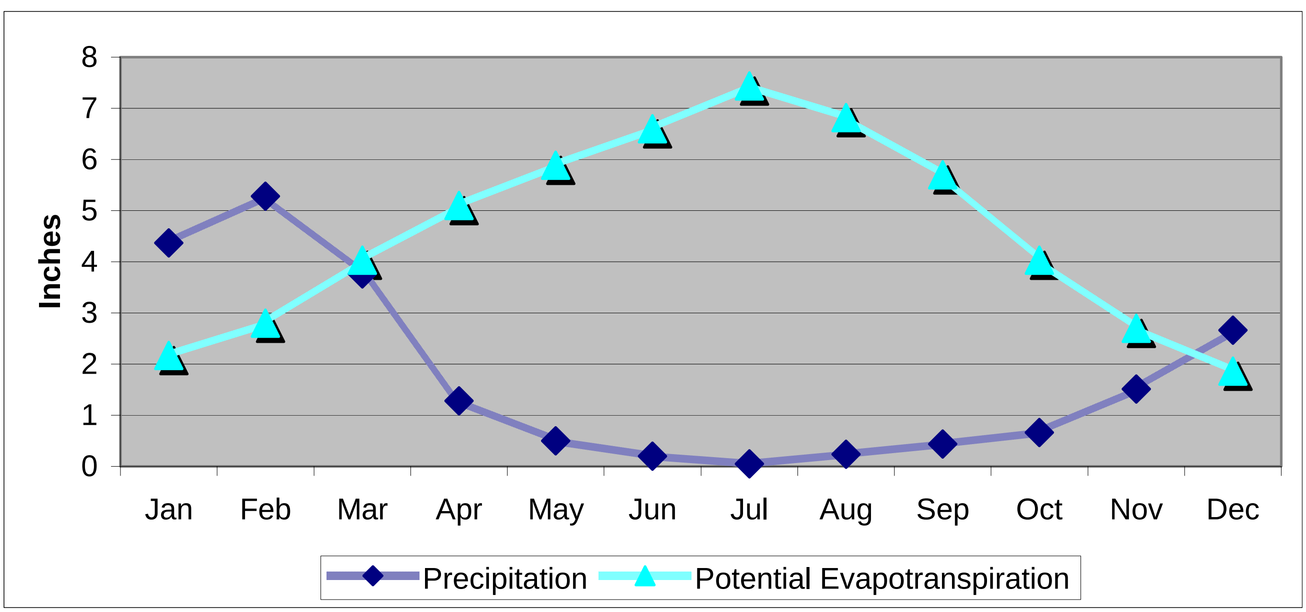


Figure 24 - Water Balance

Water Use in the Arroyo Seco Watershed

Supply

The communities of the Arroyo Seco rely heavily on imported water to supply local needs. Almost 80% of the water used in the Arroyo Seco is imported from sources outside of the watershed. The remainder comes from groundwater pumping from the Raymond Basin in the upper part of the watershed and a small amount of surface water. In this tabulation, we include only those portions of the communities that lie within the Arroyo Seco Watershed.

Table 5 – Local Water Usage

City	Population	Sales	Imports	% Imports
NE Los Angeles	78,598	8,547	8,547	100%
South Pasadena	8,089	2,456	2,456	100%
La Cañada	14,131	5,363	4,265	79.5%
Pasadena	44,839	11,348	7,447	65.6%
Altadena	21,305	3,671	1,944	53.0%
Total/Average	166,962	31,385	24,659	78.6%

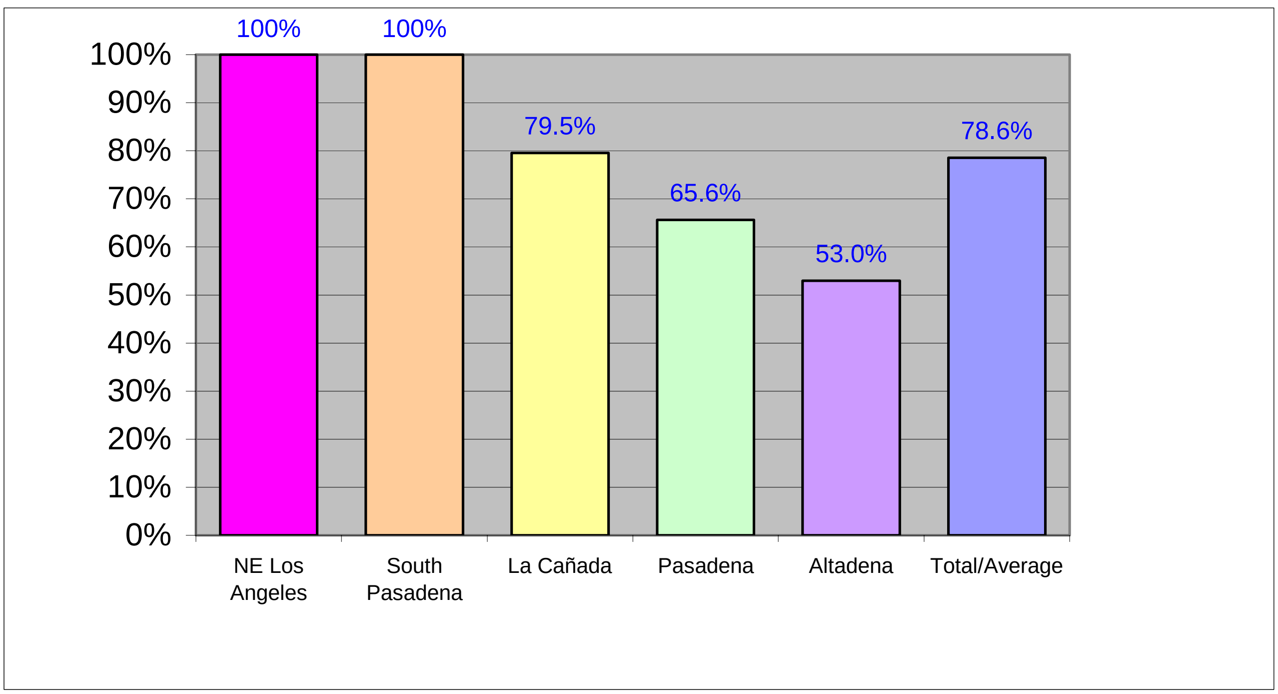


Figure 26 - Reliance on Imported Water

Los Angeles

Northeast Los Angeles is entirely dependent on imported water. The Los Angeles Department of Water and Power provides supplies from the San Fernando groundwater basin and the Owens Valley, as well as water from the State Water Project and the Colorado River that it obtains from the Metropolitan Water

District.

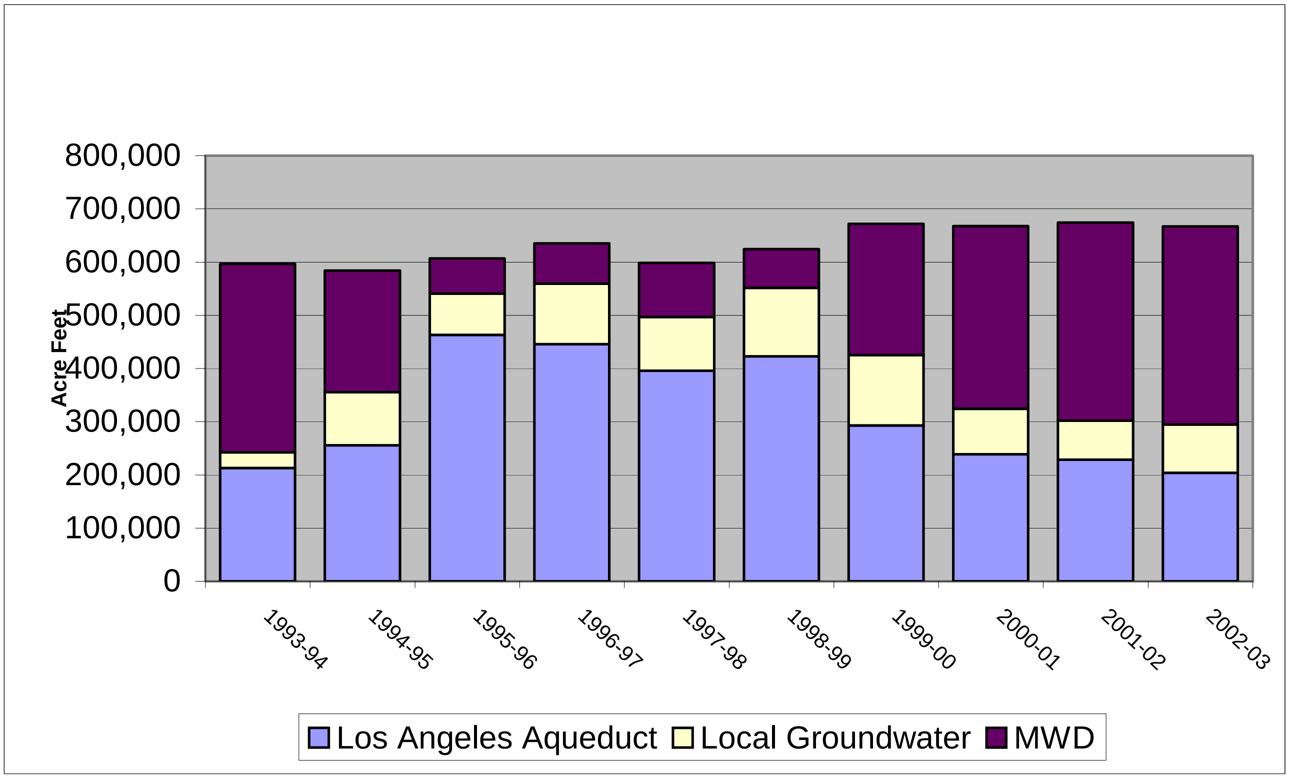


Figure 27 - Los Angeles Sources of Supply

In recent years Los Angeles has come to increasingly rely on water imported from the Metropolitan Water District due to court-imposed limits on exports from the Owens Valley. MWD receives water from the and the State Water Project and from the Colorado River

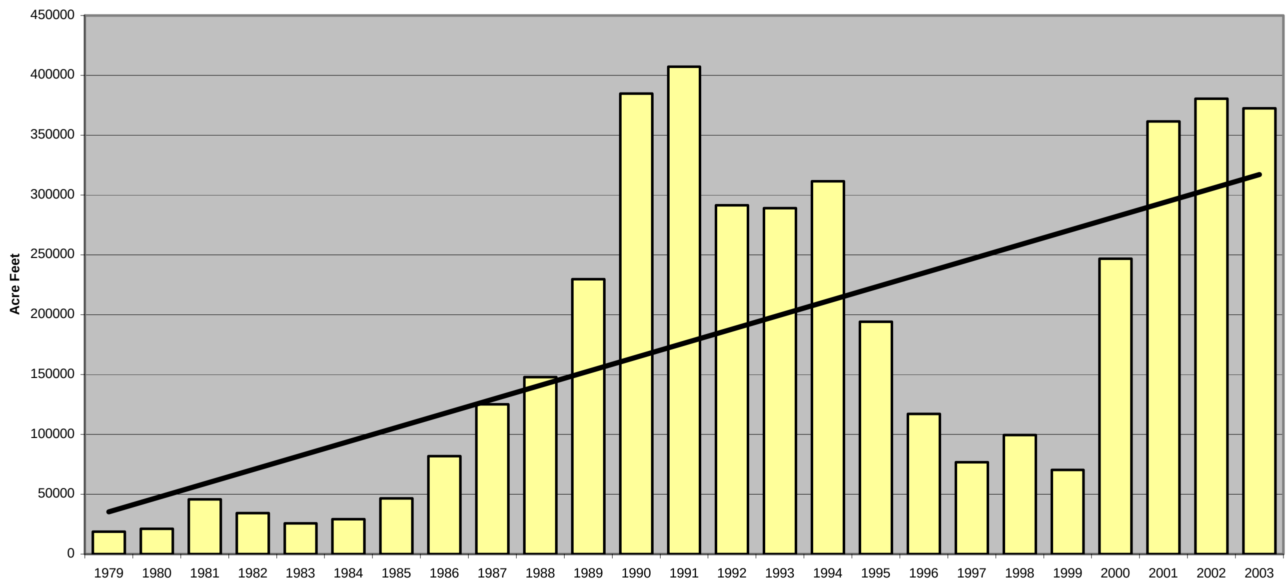


Figure 28 - Los Angeless Purchases from MWD

South Pasadena

There are no local sources of supply in South Pasadena. That community receives water from groundwater pumping in the nearby Main San Gabriel Basin as well as from the State Water Project and the Colorado River, supplied by Upper San Gabriel Municipal Water District, an MWD member agency.

La Cañada Flintridge

The City of La Cañada Flintridge is supplied primarily (+/- 80%) by imported water delivered by Foothill Municipal Water District, a member agency of the Metropolitan Water District of Southern California. Local groundwater is pumped by La Cañada Irrigation District. Foothill MWD estimates that of the water served 90% is used for residential purposes, 5% goes to light commercial, and 5% government.

In the last ten years, water consumption has grown significantly in La Cañada Flintridge. Figure 28 illustrates a 40% growth in per capita consumption in the last ten years. Figure 29 shows a 30% rise in sales for the other major water company serving La Cañada, Valley Water Company. These increases are all the more alarming because La Cañada Flintridge experienced an 11% decline in population during the 1990s.

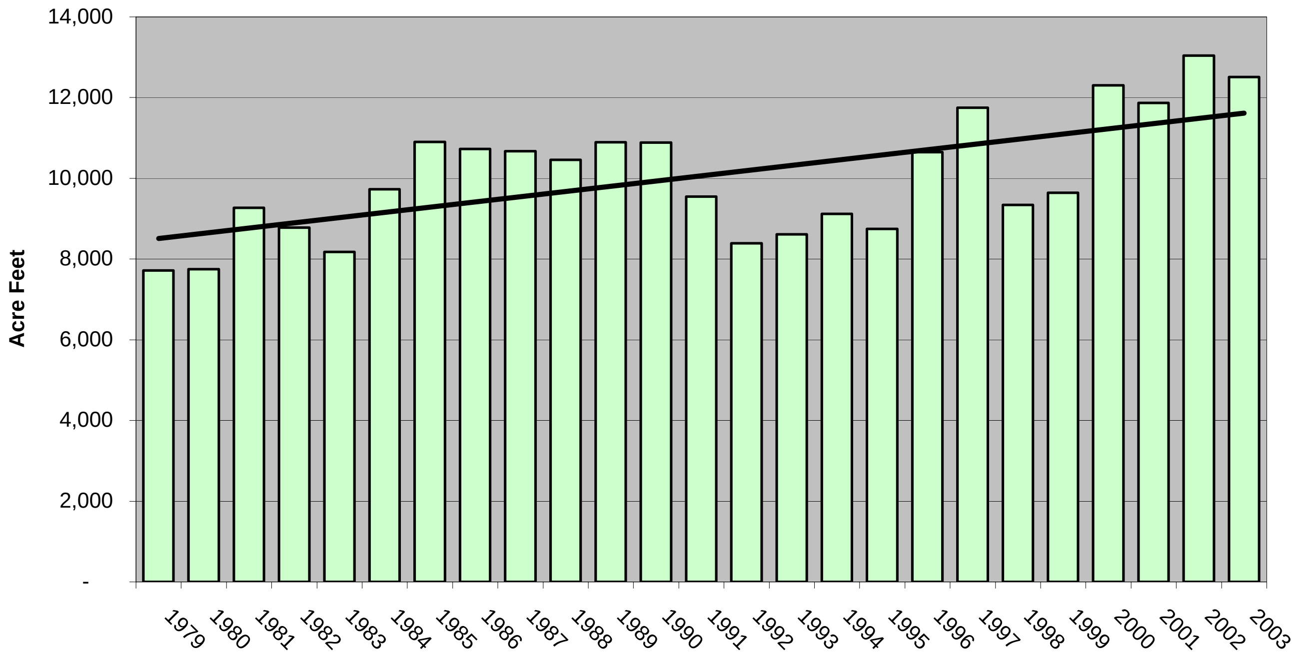


Figure 29 – Foothill Municipal Water District Purchases from MWD

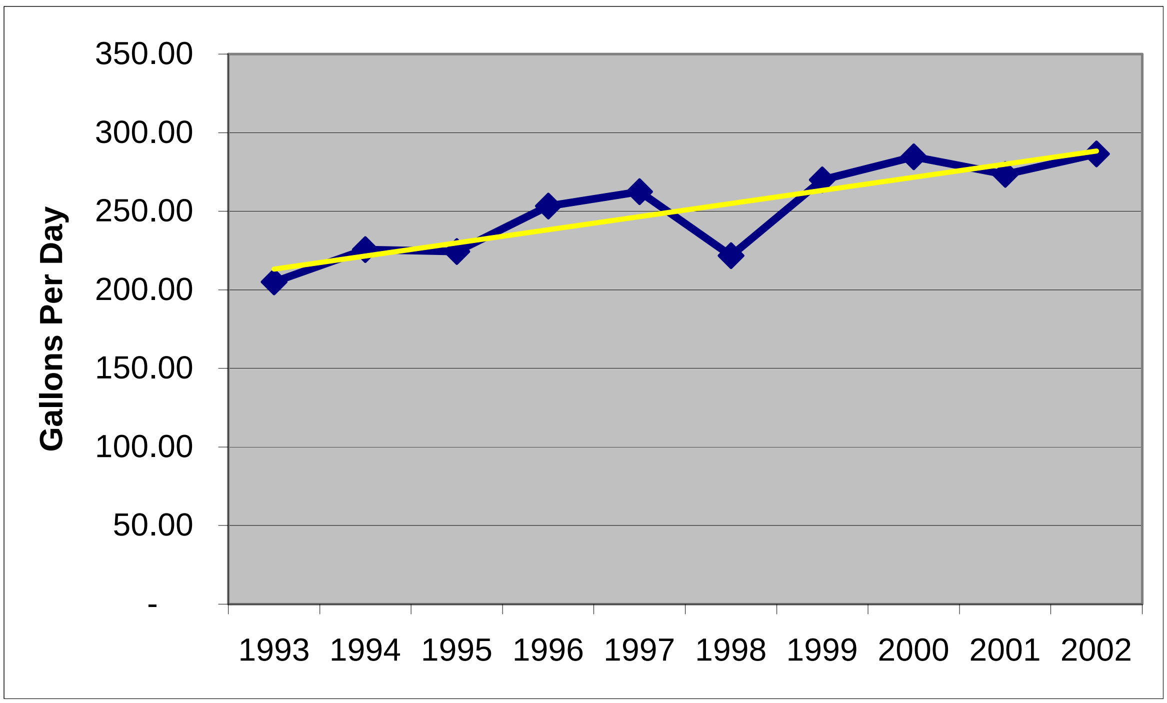


Figure 30 - La Cañada Irrigation District Per Capita Consumption

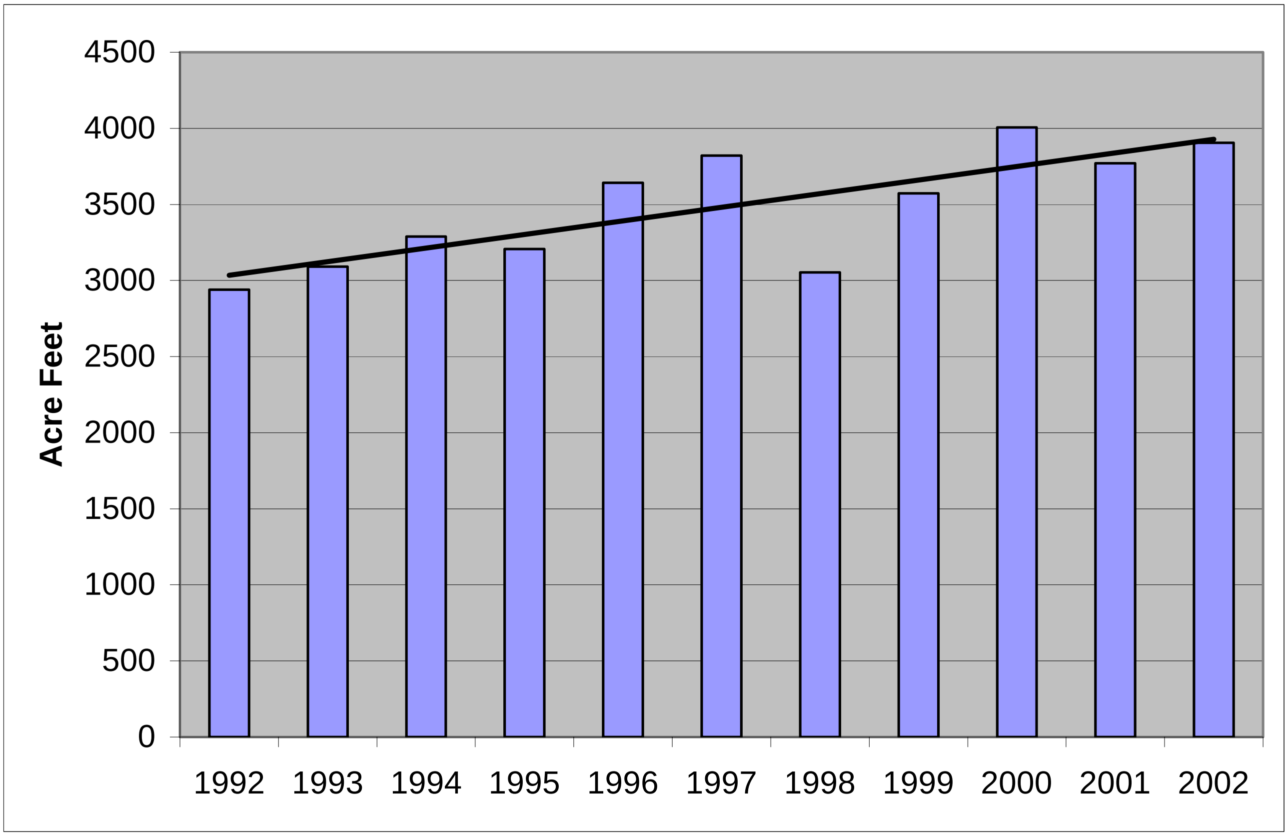


Figure 31 - Valley Water Company Sales

Pasadena

Pasadena receives about 62.8% of its water from the Metropolitan Water District's State Water Project and Colorado River supplies. Pasadena also has the right to pump 41% of the supplies of the Raymond Basin. In the last few years Pasadena has had to close nine of its wells due to perchlorate contamination, forcing that city to rely more heavily on imported water supplies.

In 1993 Pasadena discontinued its use of the Behmer Treatment Plant at the mouth of the Arroyo Seco to treat surface water from the Arroyo Seco due to new water quality requirements.

Figure 27 shows imported water purchases for the Foothill Municipal Water District and Figure 30 shows the totals for Pasadena from 1979 through June 2003. The purchase data mirrors weather patterns slowing or declining during wet periods, but there is a clear growth trend that significantly exceeds population growth. In Pasadena the growth amounts to 42%, while population growth during the period has only been 13%. In the Foothill MWD territory, which includes Altadena, La Cañada and La Crescenta, the growth in imported water purchases has been 63% during that period.

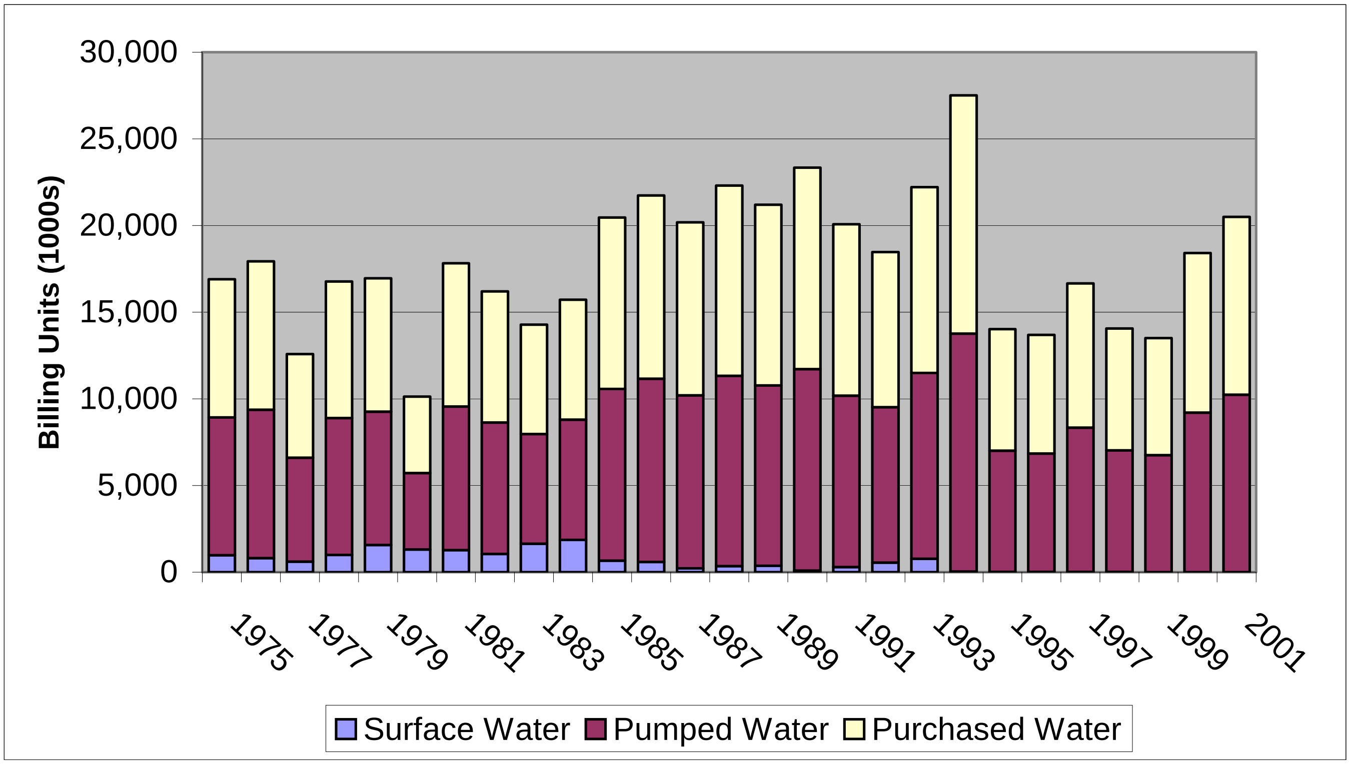


Figure 32 - Pasadena Water Sources

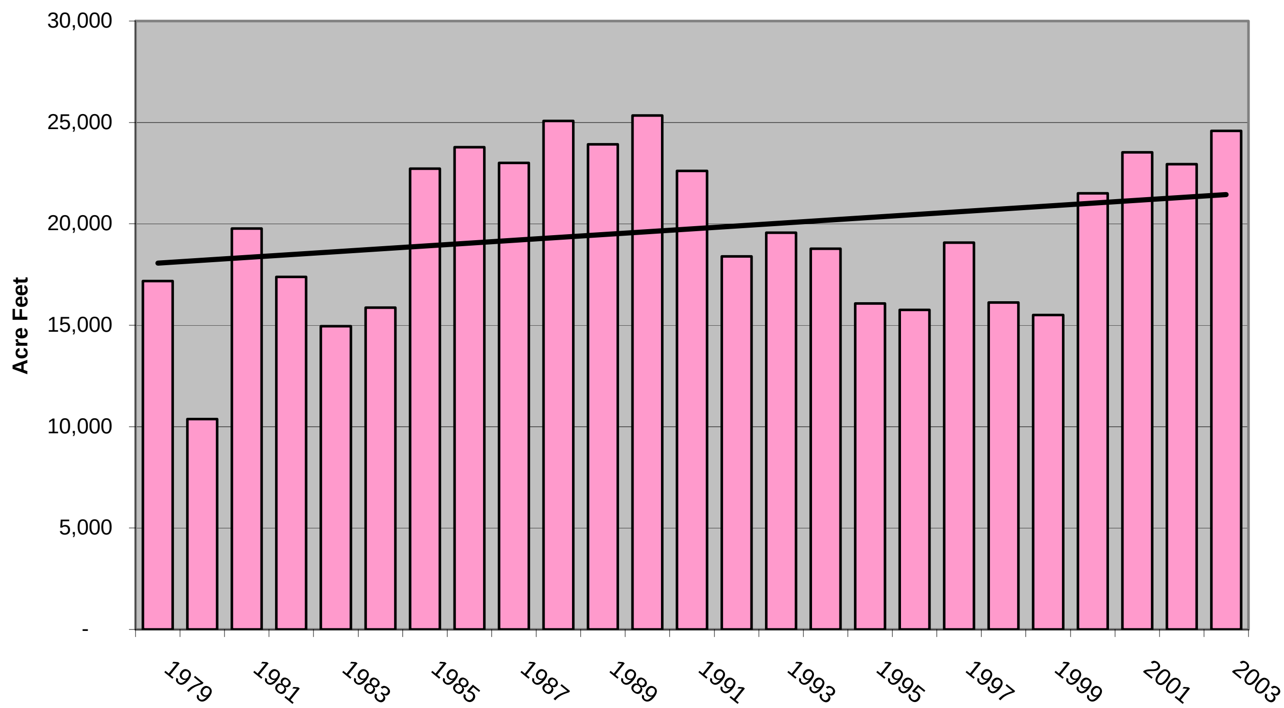


Figure 33 - Pasadena Water Purchases from MWD

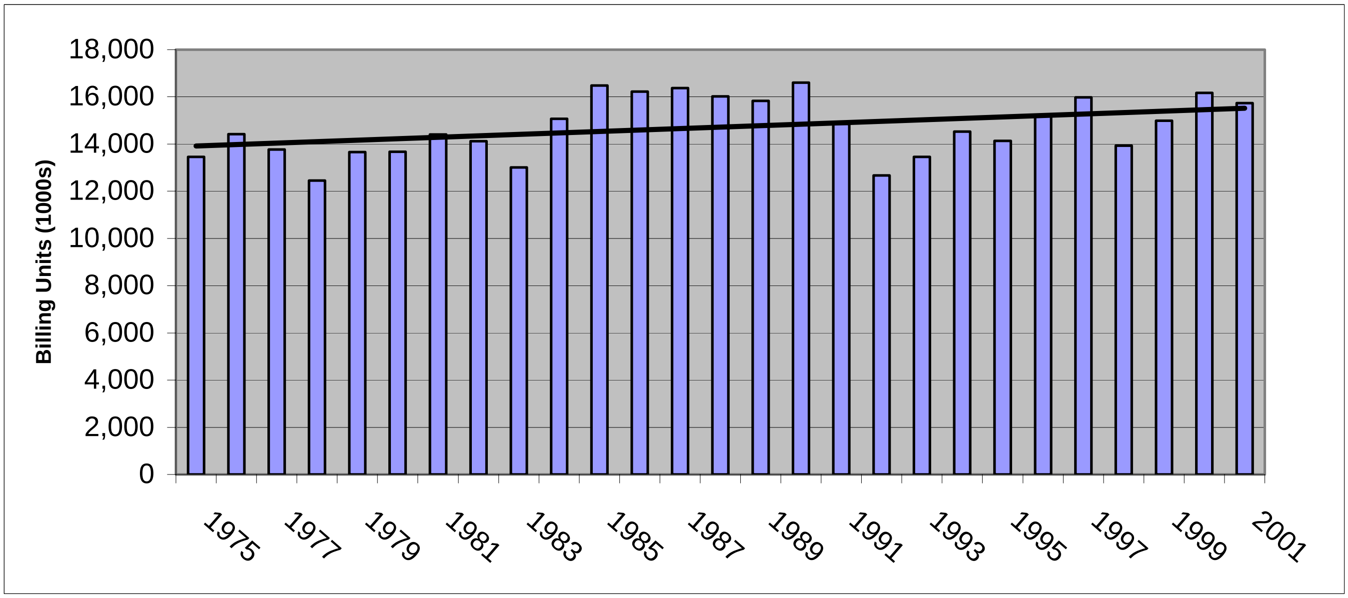


Figure 34 - Pasadena Water Sales

Altadena

The community of Altadena receives most of its water (53%) from imported sources delivered by Foothill Municipal Water District. Lincoln Avenue Water Company, Las Flores Water Company and Rubio Cañon Land and Water Association all supply local water as well to the residents of western Altadena.

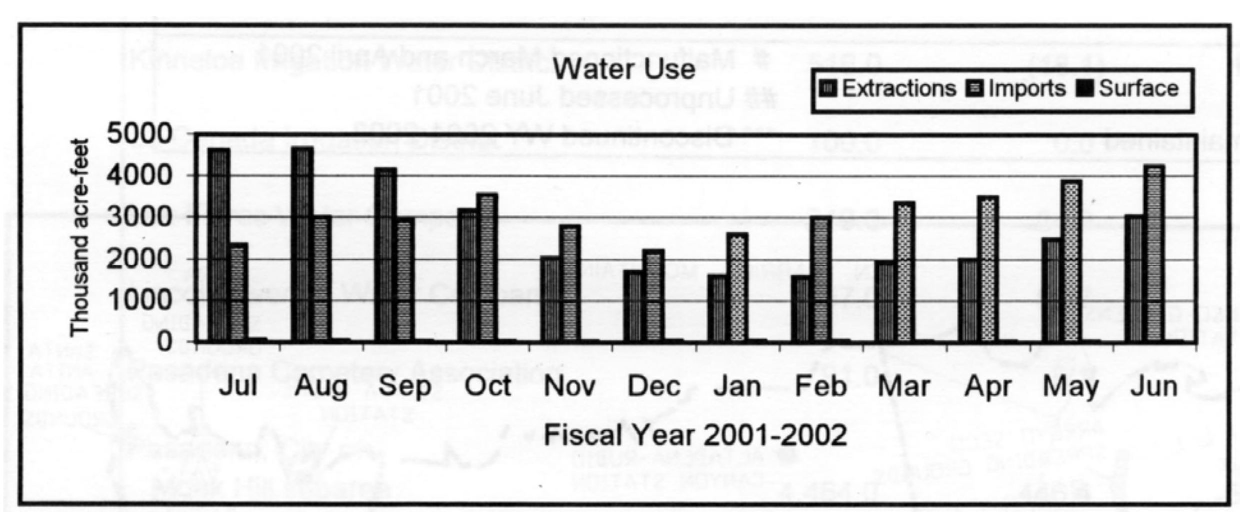


Figure 35 - Water Use by Month - Raymond Basin Agencies

Water Consumption

Water consumption in the Arroyo Seco Watershed varies dramatically. It ranges from a low of 97 gallons per day per capita in Northeast Los Angeles to a high of 339 gallons per day in La Cañada. Factors that contribute to the disparity include density, lot size and economic status.

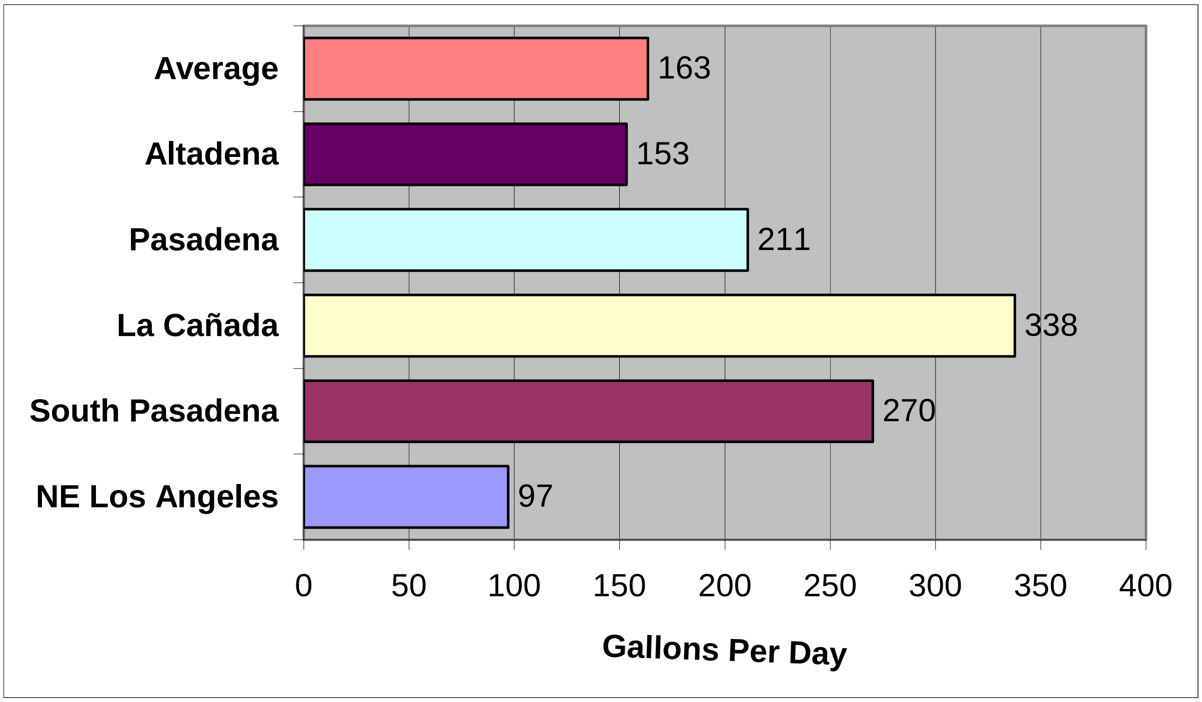


Figure 36 - Per Capita Consumption

Water users in Northeast Los Angeles not only set the conservation standard for the Arroyo Seco Watershed but also for the City of Los Angeles as well, consuming only 67% of the amount per capita as other residents of Los Angeles. Factors that contribute to this remarkably low level of usage include density, lot size, the amount of outside irrigation and income levels.

Table 6 – North East Los Angeles Water Consumption

City of Los Angeles - Dept. of Water and Power

Comparison of Approximate Water Uses for N.E. Los Angeles and All Areas Served

Geographic Area	Metered Consumption All Uses Gallons per Capita per Day	Metered Consumption Residential Uses Gallons per Capita per day	Total Annual Metered Consumption (HCF)	Annual Residential Metered Consumption (HCF)	Population (2000 Census)
All Areas	145	104	260,734,505	186,742,157	3,694,820
North East Los Angeles*	97	74	10,688,789	8,109,822	225,565
All Areas Excluding N. E. L. A.*	148	106	250,045,716	178,632,335	3,469,255

* N. E. Los Angeles includes ZIP Codes 90031, 90032, 90041, 90042 and 90065

Note: Data is based on 2002-2003 meter readings

Note: Irrigation water uses is estimated to be in the range of 25-30% of total use with no apparent difference in the amount of such uses in the North East Los Angeles area compared with "all areas excluding North East Los Angeles".

September 4, 2003

The Water Budget

Now we will examine the inputs and outputs of the Arroyo Seco Watershed to complete the water budget.

Inputs

Rainfall in various forms is the key local input into the watershed budget. Average annual precipitation for the Arroyo Seco Watershed amounts to 54,400 acre-feet. Some of this rainfall recharges the Raymond Basin directly or through boundary inflow from the San Gabriel Mountains. Water agencies also divert some of the surface flow that results from the precipitation into spreading basins where it percolates into the aquifer beneath the communities of La Cañada, Pasadena and Altadena.

Some water also replenishes the Raymond Basin from septic systems primarily in the La Cañada Flintridge area and from imported water used for landscaping. Most of the septic tank input will be eliminated in the next few years as sewer systems are extended throughout La Cañada Flintridge.

Imported water is brought into the watershed from a variety of sources:

- The State Water Project and the Bay Delta ecosystem (MWD and its member agencies)
- The Colorado River (MWD and its member agencies)
- The Eastern Sierra Nevadas (Los Angeles)
- The Upper Los Angeles River Area (San Fernando Basin – Los Angeles)
- Central Basin (Los Angeles)
- Main San Gabriel Basin (South Pasadena)

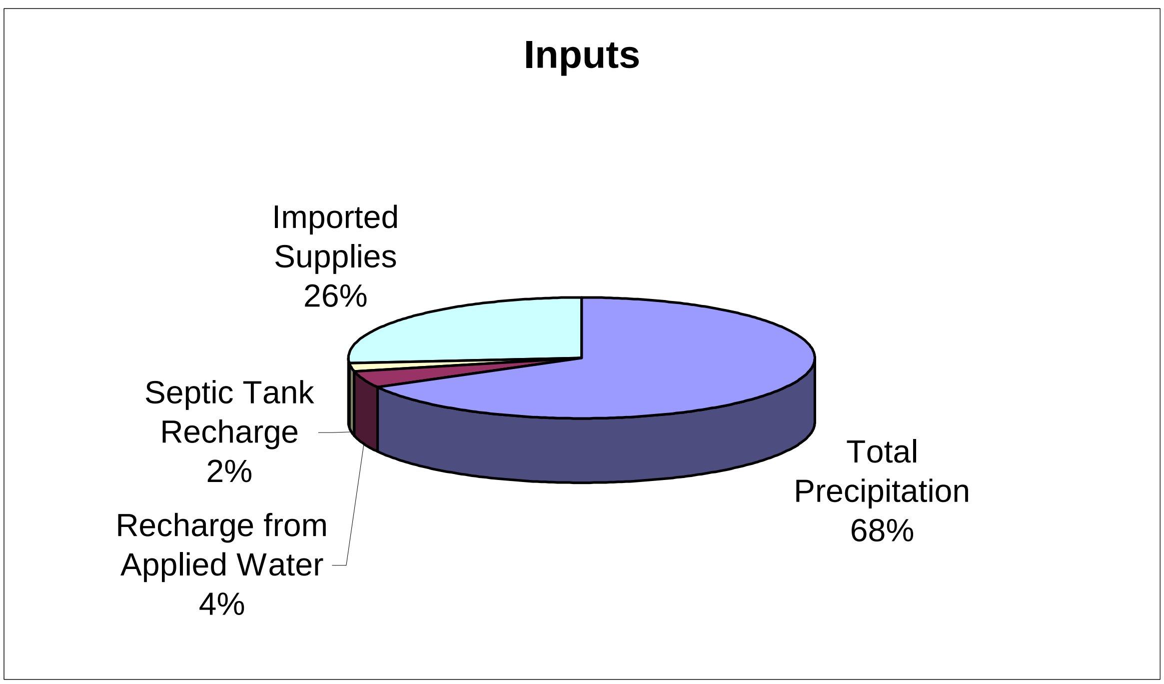


Figure 37 - Inputs to the Water Budget

Outputs

A large part of the water that enters the Arroyo Seco Watershed naturally is consumed by evaporation and transpiration of plants. A small amount is exported outside of the watershed. Approximately 7,000 acre-feet per year seeps over the Raymond Fault into the Main San Gabriel Basin to the south. In an average year just over 10,000 acre-feet of water runs off the surface and is discharged into the Los Angeles River. The main consumptive use (+/- 27,000 acre feet annually) is for water production and sales to local water users, primarily residential users.

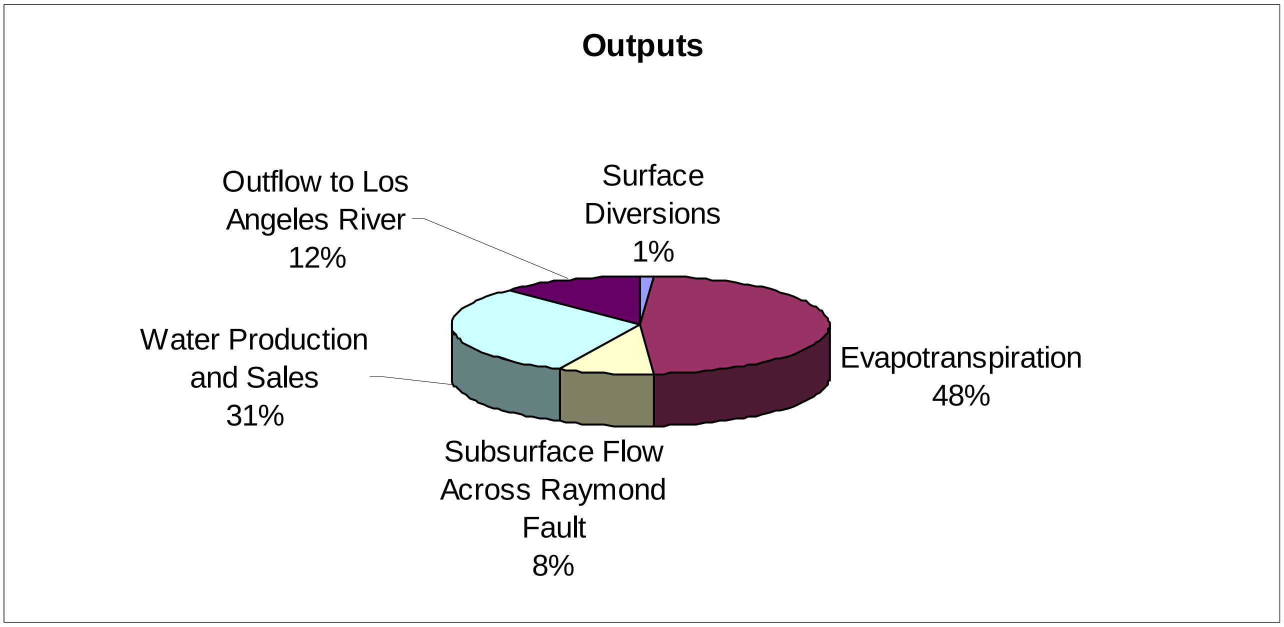


Figure 38 - Outputs from the Water Budget

Table 7 - Arroyo Seco Watershed Budget			
Inputs			
	Total Precipitation	54,400	
	Precipitation Recharge		8,160
	Boundary Inflow		7,900
	Stream Flow (Spreading)		3,770
	Recharge from Applied Water	3,623	
	Septic Tank Recharge	2,000	
	Imported Supplies	21,378	
	TOTAL INPUTS	81,401	
Outputs			
	Surface Diversions	1,007	
	Evapotranspiration	41,555	
	Subsurface Flow Across Raymond Fault	7,000	
	Water Production & Sales	26,837	
	Outflow to Los Angeles River	10,602	
	TOTAL OUTPUTS	87,001	
Changes in Storage		(5,600)	

Ways to Improve the Water Budget

People impact the Arroyo Seco Watershed and its water budget in both negative and positive ways. Here are some examples:

- Removing ground water (e.g. pumping for domestic or commercial use)
- Adding ground water (e.g. septic systems, irrigation, replenishment)
- Removing surface water (e.g. for municipal and industrial use)
- Adding surface water (e.g. treated wastewater, drains)
- Changing vegetation types (e.g. landscaping)
- Building impervious surfaces (e.g. parking lots, buildings, roads)

Once the water budget is properly understood, the communities of the Arroyo Seco can construct a comprehensive program to protect our watershed and to maximize the value of local water resources.

Problems of Imported Water

In additional to hydrologic variability, the water supply for Southern California and the Arroyo Seco Watershed is linked to critical environmental and political issues that affect not only our region but also most of California and the West. Imported water, once thought to be the solution to future water needs, has not proven to be reliable as early planners thought. Each of the major sources of imported supply is plagued by persistent problems:

- **The State Water Project –** The SWP cannot deliver enough water to satisfy the contracts that were signed with agencies like MWD in the 1960s. Continuing challenges related to fish and wildlife, water supply reliability, natural disasters, and water quality have beset the project. The CALFED Bay-Delta Program has been initiated to bring together federal and state agencies to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System.
- **The Colorado River** -- Southern California has been relying on surplus deliveries of Colorado River water to meet the needs of agricultural and the coastal communities, but that surplus is no longer available. Water agencies that rely on the Colorado River, such as MWD, have to cut their usage of this supply from the recent average of 5.2 million acre feet per year to 4.4 million acre feet per year.
- **The Owens Valley –** Los Angeles developed this supply of water from the Eastern Sierra Nevadas in 1913 and relied on it for many years, but in the last two decades a series of legal actions and a new environmental stewardship ethic have limited the amount of water that Los Angeles can import from the Owens Valley.

It is clear that the economic and environmental health of our region requires us to decrease our reliance on imported water sources. The solution lies in conservation and better utilization of local water resources. The water budget can be a useful tool to accomplish this goal.

Since precipitation and imports are the only ways to increase the supply or input side of the water budget, there is not much that can be done there to improve the water budget. The areas where substantial progress can be made are in reducing the demand or outputs and in managing local resources more efficiently.

Some Practical Steps

Stream Restoration

The availability of imported water and the threat of floods in our semi-arid region led planners to undervalue the rainfall that falls upon our watershed. Instead of husbanding precious water resources, streams are treated as nuisances or threats. More than ten thousand acre-feet a year of runoff that should replenish the ground is efficiently diverted into pipes, culverts, and storm drains where it is whisked away to the ocean. The main Arroyo Seco stream, which transports an average of 7,000 acre feet per year from the upper mountain watershed and an additional 3,000 acre feet of runoff, has been transformed into a three-sided concrete box with only limited interaction with the water table.

Rainwater Retention

Runoff in the lower urbanized section of the watershed amounts to an average of 3300 acre feet per year. Local rainfall retention programs, such as the Standard Urban Stormwater Mitigation Plan (SUSMP) program mandated by the Los Angeles Regional Water Quality Control Board, can recover a significant amount of this water. The SUSMP program requires that new developments retain or treat the first ¾-inch of a 24-hour rainfall event in order to reduce pollutants transported to the Pacific Ocean. The SUSMP standards have been developed to improve water quality, but they can also have a significant water supply impact in the Arroyo Seco Watershed because 75% of all rainfall in the watershed occurs in storms of ¾-inch or less.

Cleaning Up Contamination

A large number of wells in the Arroyo Seco Watershed have been closed due to contamination, particularly in the critical percolation zone at Hahamongna as the streams descends from the San Gabriel Mountains and enters the urbanized plain of the Arroyo Seco. Volatile organic chemicals, nitrates and perchlorate have knocked the wells out, forcing Pasadena and Lincoln Avenue Water Company to increase their purchase of imported water at considerable expense. Cleaning up this contamination should be the first priority of local water agencies to protect public health and water reliability.

Native Landscaping

Landscape irrigation is the major factor that contributes to the wide divergence of per capita water consumption in the Arroyo Seco Watershed. Typically more than half the consumption in a single-family detached house in our region will be for outdoor irrigation, primarily for lawns and exotic plants better suited to other climatic regions. The native plants that once predominated in our region have learned to adapt to the natural cycle of wet and dry years, thriving in the heat and dry weather like camels in the desert. They are perfectly suited to our climate, and can be beautiful additions to local landscapes while significantly reducing outdoor water use.

Recycled Water

Reclaimed wastewater is now being used extensively throughout Southern California primarily for landscape irrigation and industrial applications, but not yet in the Arroyo Seco Watershed.

Wastewater from the upper Arroyo Seco Watershed goes to the facilities of the Los Angeles County Sanitation District near Whittier Narrows where it is treated. Some of it replenishes Central Basin, a groundwater aquifer in southern Los Angeles County. In the Northeast Los Angeles portion of the watershed, wastewater is shipped to the Los Angeles Glendale Water Reclamation Plant near the intersection of the 5 and 135 Freeways.

Pasadena made arrangements ten years ago to hook up to recycled water from the LA/Glendale plant, and a pipeline now brings the water as far as Scholl Canyon at the western boundary of Pasadena. The pipes and facilities needed to distribute the water to Brookside Golf Course and other large irrigation users in Pasadena, however, have not been completed. Even a modest reclamation program can increase Pasadena's water supplies by 3%.

Conjunctive Use

The next major step in the historical development of water resources in our region is the Raymond Basin Conjunctive Use Program (RBCUP). Conjunctive use, the coordinated use of surface supplies and groundwater resources with imported water, is a water resources management methodology that can optimize water resources while reducing the environmental stress often associated with water importation. The RBCUP, now being developed by local water agencies and the Metropolitan Water District, will provide MWD with storage capacity of up to 75,000 acre-feet in the Raymond Basin to improve regional water reliability. MWD will replenish the Raymond Basin with the water to be stored. In most years MWD will leave the water in storage, but in dry years it will pump up to 25,000 acre-feet from the aquifer. The Raymond Basin Management Board and the MWD are now evaluating the environmental impacts of the project.

Consumer Education

For many decades the residents of our region have taken water for granted, but we now face a mounting water crisis. A growing population is met with diminished imported supplies, contaminated local water sources and an expanding per capita consumption that significantly exceeds most of Southern California. Local water agencies need to step up their water conservation programs by educating the public about the water situation and offering the public incentives and motivation to use water more wisely.

A key component of an effective consumer education program is to let the residents of the Arroyo Seco Watershed know how their water use affects the local environment as well as distant parts of California and the West. It is important that the residents of our region know of the environmental challenges that face the Sacramento and San Joaquin Rivers and San Francisco Bay because a significant part of our water supplies and that of 20 million other Californians flows through that hub. It is a powerful motivation for local residents to know about the work of the CALFED Bay Delta Program to restore the ecological health of those rivers and our state.

Water waste and inefficient use can no longer be tolerated. The residents of the Arroyo Seco must join with their fellow Californian to develop a new ethic and practice of stewardship of water and our precious environmental resources.

Other Steps

The Water Resources technical report of the Arroyo Seco Watershed Restoration Feasibility Study includes these recommendations for augmenting or supplementing local water supply:

- Protect and preserve foothill lands to enhance percolation into the groundwater basin and to prevent aggravated runoff.
- Promote comprehensive conservation and implement best management practices throughout the watershed to improve water quality and reduce consumption.
- Expand water conservation and recycling programs through the watershed.
- Create conjunctive use of groundwater basin for enhanced storage during wet periods and for use during dry periods.
- Develop upper watershed reforestation and revegetation programs to reduce sediment flow and improve local retention.
- Naturalize the stream in Hahamongna for greater percolation and habitat benefits and reconsider the use and expansion of the spreading basins.
- Complete a sediment management study for Devil's Gate Dam basin.
- Review the functionality and effects of the upper basin flood control structures such as debris basins and check dams.

These and other approaches should be carefully evaluated and implemented if feasible to enhance and better manage local water supplies.

Conclusion

The Arroyo Seco Watershed Budget is a tool to promote a better understanding of local water use and better management of the water resources of the Arroyo Seco. The approach used here is a relatively simple, straightforward evaluation of all the components of the hydrologic cycle and human interaction with it. More detailed and sophisticated techniques can be used to refine this budget to help the public and planners understand the effects of future management options.

The water budget highlights many of the key water issues that face local decision-makers:

- The need to protect our watershed and its precious environment
- The critical importance of water quality to our region
- The need for comprehensive conservation and water management programs to reduce per capital consumption and water imports.

More sophisticated watershed modeling tools, which include surface water, groundwater and water quality elements, can serve as decision-making tools for watershed management programs involving habitat restoration, water conservation/supply and water quality. These tools can be used to refine, test and assess specific watershed management alternatives. In this way, the water budget and refined models can provide the context for an informed, prescriptive approach to planning and the development of local codes and ordinances to help "balance the budget". Planners and policy makers can determine the relative benefits of conservation standards and programs and even derive an estimate of their economic benefits. Local agencies such as planning departments and water service providers could use these forecasts and estimates to develop incentive programs for voluntary "site improvements" such as removing impermeable surface.

The Arroyo Seco Foundation and North East Trees, the two partners in the CALFED Arroyo Seco Management Program and Education Program, urge the residents of the Arroyo Seco and our governmental leaders to redouble their efforts to use water wisely and to restore the natural functioning of the Arroyo Seco, our region's greatest natural treasure.

Appendix 1 – Water Budget Terminology

Evaporation. The process by which water is changed from the liquid or the solid state into the vapor state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.

Gaging station. A particular site on a stream, canal, lake, or reservoir where systematic observations of *gage height* or *discharge* are obtained.

Ground water. Water in the ground that is in the *zone of saturation*, from which wells, springs, and *ground-water runoff* are supplied.

Ground-water outflow. That part of the discharge from a drainage basin that occurs through the ground water. The term "underflow" is often used to describe the ground-water outflow that takes place in valley alluvium (instead of the surface *channel)* and thus is not measured at a *gaging station.*

Ground-water runoff. That part of the runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

Hydrologic budget. An accounting of the inflow to, outflow from, and storage in, a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project.

Hydrologic cycle. A convenient term to denote the circulation of water from the sea, through the atmosphere, to the land; and thence, with many delays, back to the sea by overland and subterranean routes, and in part by way of the atmosphere; also the many short circuits of the water that is returned to the atmosphere without reaching the sea. (After Meinzer, 1949, p. 1.)

Hydrology. The science encompassing the behavior of water as it occurs in the atmosphere, on the surface of the ground, and underground. (Am. Soc. Civil Engineers, 1949, p. 1.)

Infiltration. The flow of a fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word *percolation*, which connotes flow through a porous substance.

Percolation. The movement, under hydrostatic pressure, of water through the interstices of a rock or soil, except the movement through large openings such as caves.

Runoff. That part of the precipitation that appears in surface streams. It is the same as *streamflow* unaffected by *artificial diversions*, *storage*, or other works of man in or on the stream channels.

Streamflow. The discharge that occurs in a natural *channel.* Although the term *discharge* can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than *runoff*, as streamflow may be applied to discharge whether or not it is affected by *diversion* or *regulation*.

Surface water. Water on the surface of the earth.

Transpiration. The quantity of water absorbed and transpired and used directly in the building of plant tissue, in a specified time. It does not include soil evaporation.

(Source - Manual of Hydrology: Part 1. General Surface-Water Techniques, GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1541-A, *Methods and practices of the Geological Survey* http://water.usgs.gov/wsc/glossary.html)

Appendix 2 – Monthly Total Precipitation – Pasadena CA

Pasadena, CA
Monthly Total Precipitation in Inches
Station 46719

File last updated on Aug 1, 2003
*** Note *** Provisional Data *** After Year/Month 200303
a = 1 day missing, b = 2 days missing, c = 3 days, ..etc..,
z = 26 or more days missing, A = Accumulations present
Long-term means based on columns; thus, the monthly row may not
sum (or average) to the long-term annual value.
MAXIMUM ALLOWABLE NUMBER OF MISSING DAYS: 5
Individual Years not used for annual statistics if any month in that year has more than 5 days missing.
Individual Months not used for annual or monthly statistics if more than 5 days are missing.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1927	0z	0z	0z	0z	0z	0z	0z	0z	0z	0z	0z	3.52	3.52
1928	0.09	3.35	2.22	0.7	0.5	0.2	0	0	0	0.7	1.93	3.01	12.8
1929	1.53	1.93	2.99	3.6	0	0.2	0	0	0.5	0	0a	0	10.8
1930	6.25	0.59	5.85	0.6	2.4	0	0	0	0	0.2	2.37	0	18.3
1931	4.37	5.47	0.02	4	0.9	0.1	0	0.1	0.2	0.5	3.22	6.63	25.5
1932	2.36	8.23	0.24	0.6	0.1	0.3	0	0	0.3	0.1	0	1.77	13.9
1933	12.5	0.05	0.12d	0.8	0.3	0.3	0	0	0	0.5b	0.2	10.3	25.2
1934	6.42	3.18	0.03	0.1	0	0.4	0	0	0.3	4	2.29	5.94	22.6
1935	4.39	2.64	3.01	4.4	0.1	0	0.2	0.1	0	0.3	0.93	0.78	16.7
1936	0.39	9.84	2.45	0.9	0	0.1	0	0	0	2.3	0.06	9.6	25.7
1937	2.97	8.04	5.22	0.3	0.3	0	0	0	0	0	0	4.75	21.6
1938	1.89	11.2	12.6	0.8	0.1	0.1	0	0	0	0.1	0.01	9.95	36.7
1939	4.48	1.33	1.38	0.4	0.2	0	0	0	5.9	0.5	0.15a	0.69	15
1940	5.76	6.05h	1.5	2.1	0	0	0	0	0	2	0.62	7.72	19.7
1941	2.66	16.8	11.4	5.1	0.1	0	0	0.1	0	1.7	0.16	6.42	44.4
1942	0.45	1.12	1.69a	3	0	0	0	0.5	0	1.1	0.41	1.26	9.63
1943	16.4	5.51	6.76	1.2	0	0.1	0	0	0	0.4	0.05	7.9	38.4
1944	0.9	10.9	3.72	1.3	0j	0.3	0	0	0	0	5.47	1.18	23.8
1945	0.06	5.09	4.04	0.4	0	0.2	0	0.5	0	0.7	0.24	7.02	18.1
1946	0.24	2.27	5.28	0.7	0.1	0	0	0i	0	1.5	10.3	5.79f	20.3
1947	0.46	0.63	0.96d	0.3	0.5	0.1	0	0.1	0.2	0.2	0.27	1.81	5.37
1948	0.01	2.08	3.63	2.1	0	0.5	0	0	0	0.6	0	3.04	11.9
1949	3.52b	1.68c	1.71	0.1	1.2	0	0	0f	0	0.1	2.55	4.27	15.1
1950	3.18	2.42	1.29	0.7	0.1	0.1	0.1	0	0.8	0.5	1.72	0.03	11
1951	3.74	1.32	1.02	2.4	0.2	0	0	0.2	0	0.7	1.93	6.74	18.2
1952	15	0.66	8.53	3.1	0	0	0	0	0.1	0	5.15	4.57	37.1
1953	1.53	0.3	0.99	1.2	0	0.1	0	0	0	0	1.36	0.34	5.83
1954	6.67	3.17	4.4	0.3	0.1	0.2	0	0	0	0	2.16	1.17	18.1
1955	5.75	1.29	1.51	1.6	2.4	0.1	0	0.1	0	0	1.81	1.65	16.2
1956	9.05	1.21	0	4	0.9	0	0	0	0	0.6	0	0.31	16.1
1957	6	3.12	1.89	2.1	1.4	0.2	0	0	0	2	0.69	3.76	21.1
1958	2.56	10.1	5.93	5.6	0	0	0	0.2c	0.1	1	0.12	0	25.6
1959	2.84b	5.3a	0f	0.7	0	0	0	0	0	0	0.05	1.63	10.5

1960	3.03g	2.25	0.56	1.8	0	0f	0	0	0	0.1	4.07	0.16	8.95
1961	1.51	0	0.88	0.5	0	0	0	0.1	0	0	1.12d	2.66	6.72
1962	3.42	13.1	1.69	0	0.7	0	0	0	0	0.2	0	0.05	19.3
1963	0.48	4.84	2.35	1.9	0	0.4	0	0	1.5	1	2.44	0.02	14.9
1964	2.7	0.04	2.43	1.6	0	0.3	0	0	0	0.5	2.75	1.82	12.1
1965	0.86	0.48	1.47	6.8	0.2	0.1	0.1	0.1	1.2	0	13.7	6.75	31.8
1966	0.92	1.42	0.65	0	0.3	0	0	0	0.4	0.1	3.76	6.25	13.8
1967	6.59	0.12	3.66	5	0.2	0.1	0	0	0.3	0	8.43	1.51	25.9
1968	1.01	0.97	3.33	0.6	0.1	0.1	0	0	0	0.4	0.43	0.91	7.82
1969	16.7	11.3	1.82	0.8	0.1	0.2	0	0	0	0	1.41	0.11	32.6
1970	1.77	4.52	3.51	0.1	0	0.1	0	0	0	0	6.54	5.48	22
1971	1.39	1.1	0.78	0.5	0.5	0.1	0	0	0	0.2	0.35	7.05	11.9
1972	0.01	0.05	0	0.2	0	0.4	0	0.4	0	0.3	3.53	2.25	7.16
1973	4.09	11.2	4.34	0	0.1	0.1	0	0	0	0.3	0z	0.66	20.7
1974	10.5	0.1	4.61	0.4	0.1	0	0	0	0	0.9	0.02	3.99	20.6
1975	0.1	2.62	5.97	1.7	0.2	0	0	0	0	0.4	0.11	0.53	11.6
1976	0	4.8	2.33	1.2	0.1	0.2	0	0.2	3.9	1.4	0.83	0.75	15.8
1977	4.46	0.24	1.96	0	3.7	0	0	2.3	0	0	0.13	5.85	18.6
1978	8.99	9.37	12.9	0z	0.1	0	0	0	0.8	0.2	2.19	1.99	36.5
1979	7.74	4.26	0z	0	0	0.1	0	0	0	0.9	0.3	0.88	14.2
1980	11.1	19.7	5.62	0.6	0.5	0	0	0	0	0	0	1	38.5
1981	3.23	1.42	5.26	0.7	0	0	0	0	0.1	0.7	2.49	0.77	14.7
1982	3.4	0.77	6.73	3	0.4	0.2	0	0	2	0.5	6.8	1.59	25.4
1983	8.86	6.19	12.6	7.8	0.3	0.1	0	1.9	2.2	1.3	2.89	4.42	48.5
1984	0.2	0	0.49	0.5	0	0.2	0	0.6	0.7	0.1	3.14	7.74	13.7
1985	0.96	1.89	1.43	0	0.3	0	0	0	0.2	0.8	4.28	0.22	9.99
1986	3.59	5.77	6.91	0.7	0	0	0.1	0	2	1.6	1.33	0.48	22.4
1987	2.22	1.91	1.54	0.4	0.1	0.1	0.2	0.1	0.2	3.3	2.5	2.79	15.3
1988	2.61	2.17	0.95	3.2	0.1	0	0	0.1	0.1	0	1.76	4.91	15.8
1989	1.05	2.45	1.19	0.1	0.2	0.1	0	0	1	0.6	0.44	0	6.93
1990	2.83	4.35	0.34	1.2	1.5	0	0	0.2a	0.1	0	0.74	0.09	11.2
1991	2.02	5.3	10	0.1	0	0	0.2	0.1	0.2	1.2	0.05	3.68	22.8
1992	2.73	12.5	9.14	0.3	0.1	0	0.8	0	0	1.7	0	6.45	33.8
1993	16	9.19	4.11	0	0	1.3	0	0	0	0.2	1.17	1.35	33.3
1994	0.4	4.25	2.19	1	0.4	0.1	0	0	0	0.7	0.63	1	10.6
1995	18.5	2.18	9.89	1.5	0.2	1.9	0	0	0	0	0.07	2.48	36.7
1996	3.2	8.38	2.97	0.7a	0	0	0	0	0	1.2	2.42	5.86	24.7
1997	6.99	0.25	0	0	0	0.1	0	0	0.7	0	2.84	3.74	14.7
1998	4.07	16.9	4.06	2.1a	4.4	0.4	0	0.5	0	0	1.52	0.53	34.4
1999	2.26	1.02	1.48	2.9	0.2	1.2	0	0	0	0	0.43	0.35	9.79
2000	1.08	9.7a	3.42	2.7	0.2	0	0a	0	0.4	1.3a	0	0	18.8
2001	5.06	8.43	1.31	2.1a	0	0	0.1a	0	0	0.1	2.6a	1.26	20.9
2002	1.88	0.41	0.43	0.2	0.3	0.1	0	0	0.6	0	2.5e	2.92	9.32
2003	0	7.04	4.03	1.3	1	0.5a	0a	0z	0z	0z	0z	0z	13.9
Period of Record Statistics													
MEAN	4.16	4.47	3.43	1.5	0.4	0.2	0	0.1	0.4	0.6	1.88	2.95	19.8
S.D.	4.38	4.53	3.23	1.7	0.8	0.3	0.1	0.4	0.9	0.8	2.49	2.81	10
SKEW	1.63	1.3	1.37	1.7	3.5	3.9	6.6	4.8	4.1	2.1	2.43	0.86	0.85

MAX	18.5	19.7	12.9	7.8	4.4	1.9	0.8	2.3	5.9	4	13.7	10.3	48.5
MIN	0	0	0	0	0	0	0	0	0	0	0	0	5.37
NO YRS	75	75	74	75	75	75	76	73	75	75	74	75	66

Source – Western Regional Climate Center: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?capasa

Appendix 3 – Los Angeles Temperature

LOS ANGELES CIVIC CENTER, CALIFORNIA

Monthly Average Temperature (Degrees Fahrenheit)

Station 4511544

File last updated on Aug 1, 2003

*** Note *** Provisional Data *** After Year/Month 200303

a = 1 day missing, b = 2 days missing, c = 3 days, ..etc..,

z = 26 or more days missing, A = Accumulations present

Long-term means based on columns; thus, the monthly row may not sum (or average) to the long-term annual value.

MAXIMUM ALLOWABLE NUMBER OF MISSING DAYS : 5

Individual Months not used for annual or monthly statistics if more than 5 days are missing.

Individual Years not used for annual statistics if any month in that year has more than 5 days missing.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1914	56.82	59.36	63.05	62.8	60.3	64.9	66.8	68.1	67.9	68.56	66.9	53.5	63.25
1915	55.92	54.71	61.45	60.4	61.5	66.7	70.1	72.5	68	65.02	61.7	57.3	62.94
1916	50.79	58.71	62	62.3	61.3	63.6	66.8	68.7	65.2	59.69	59.4	52.6	60.92
1917	51.18	55.34	56.71	57.9	58.7	68.6	72.3	70	70.9	68.18	63.7	62.9	63.02
1918	55.6	56.04	59.11	61.7	61.3	69.7	69.9	71.7	72.2	71.05	60.8	-----z	64.46
1919	60.23	53.7	55.65	60.9	61.6	68.7	71	70.3	68.3	63.82	61.5	58.9	62.88
1920	56.6	57.55	56.73	58.8	62.1	65.8	71.3	72.4	68.4	63.21	60.1	55.7	62.38
1921	54.1	57.45	59.35	59.1	58.8	65.7	71.7	70.7	69.3	66.71	63.2	60.2	63.02
1922	53.37	53.98	55.56	57.6	62.6	67.7	69.5	73.3	73.1	65.4	59.8	58.3	62.52
1923	58.1	56.66	60.94	58.4	64.6	63.6	70	69.6	70.5	66.85	66.5	58.7	63.7
1924	58.52	62.59	56.37	60.4	64.8	68.2	69.3	69.1	70	62.6	64.1	55.5	63.45
1925	57.6	57.68	58.87	60	62.9	67.4	72.3	69.9	69.2	65.06	62.4	63.3	63.87
1926	59.39	61.25	63.08	63.4	65.4	67.3	69.9	72.6	68	67.44	67	56.1	65.05
1927	57.23	56.55	57.4	59.5	63.9	65	72.1	70.3	68.4	67.42	65.8	56.3	63.32
1928	61.44	60.07	60.6	62.3	64.2	65.4	69.3	70.1	71	63.69	63.2	58.9	64.17
1929	55.23	54.43	57.24	57.4	65	68.5	72.2	75.8	70.2	70.13	65.9	63.7	64.64
1930	55.95	59.41	60.79	63.6	61.8	67.6	72.8	74	67.9	68.68	66.2	60.1	64.9
1931	60.23	60.73	66.03	65.9	67.5	70.5	77.2	76.1	71.5	68.74	58.7	54.9	66.5
1932	53.29	56.47	62.15	62.7	63.6	66.2	69.1	69.6	68.4	67.27	68.9	55.2	63.57
1933	54.35	56.05	59.68	59.1	60.2	65	69.4	70.2	64.6	66.69	66.5	57.4	62.42
1934	60.39	59.5	65.47	64.6	67.5	65.3	72.3	71.1	72.7	67.53	62.7	60.7	65.82
1935	57	60.04	55.26	60.7	61.9	66.4	70.7	74	69.9	66.94	60.8	59.4	63.59
1936	59.37	56.5	59.03	60.6	65.6	68.9	74.1	73.4	70.5	67.4	67.7	58.6	65.15
1937	47.74	55.32	58.52	62.3	64	67.8	71.3	71.6	72.4	67.58	61.7	61.9	63.51
1938	61.21	56.73	57.71	61.6	63.3	65.4	69.6	73.9	74.1	66.71	62.7	62.3	64.59
1939	57.05	54.07	56.77	63.1	63.7	66.9	70.7	73	76.7	-----z	67.1	64.2	64.83
1940	59.79	59.38	61.23	62.8	66	66	70.7	70.5	69.7	68.29	63.4	61.3	64.91
1941	57.61	58.84	60.52	59.1	67.9	66	70.7	71.1	68	65.95	65.3	57.2	64.01
1942	58.58	55.7	58.79	59.4	62.8	65.9	71.7	71	67.8	67.65	63.5	58.8	63.48
1943	57.68	60.07	58.79	61.4	65.5	66.4	70.7	71.3	70.7	66.6	64.9	56.8	64.23
1944	57.19	53.67	59.65	58.9	62.4	63.4	66.6	71.3	69.3	64.79	59	60	62.18
1945	56.63	56.62	54.56	59.4	61.9	64.6	70.9	73.3	73.2	67.24	61.7	57.2	63.1
1946	57.94	54.75	57.44	62	61.1	68.7	71.8	72.3	73.1	64.53	58.8	56.4	63.24

1947	55.73	59.79	60.4	62.5	64.1	67.5	73	71.3	72.3	66.32	59	57.2	64.09
1948	58.65	54.66	55.19	60.5	63.9	66.9	70.9	71.2	71.5	66.31	62.1	53.4	62.94
1949	46.85	52.66	56.05	63.3	64.3	69.7	71.8	73.7	72.9	66.11	67.2	55.7	63.35
1950	50.42	56.64	58.71	62.7	62.2	66.5	73.3	70.9	68.8	69.48	63.7	62.1	63.78
1951	55.68	56.38	60.18	60.4	63.1	66.7	72.8	71.3	71	68.82	61.9	54.3	63.54
1952	52.79	58.76	55.31	61.1	66.7	65.7	72.3	74	74.3	67	59.1	56.1	63.59
1953	60.63	58.84	58.92	58.7	63.9	66.8	74.9	70.6	70.2	69.08	63.6	59.1	64.6
1954	55.55	64.04	56.97	60.9	63.8	67.5	76.6	73.1	72.4	65.69	64.3	58.1	64.91
1955	53.65	56.96	61.21	61.3	63	66.7	70.5	75.2	74.5	64.16	61.1	55.6b	63.65
1956	56	53.05	60.47	58.7	64.5a	69.8	71.7	71.9	76.4	66.47	67a	60.5	64.7
1957	54.21	60.66	61.55	61.7	64.2	72.5	76	76.2	72.2	67.08	60.7	61.7	65.72
1958	59.55	60.27	56.87	65.4	68	71	72.8	75.2	75.8	73.98	63.3	62	67.01
1959	60.02	56.27	64.69	66.2	65	71.5	77.8	75.5	73.4	70.15	66.6	60.6	67.31
1960	54.58	56.97	61.95	65.3	67.7	70.1	75.5	73.1	75.5	67.97	60.3	58.7	65.63
1961	61.94	60.98	60.11	64	63.3	68.8	74.2	74.3	70.9	67.89	60.1	56.9	65.28
1962	57.5	53.79	55.18	64.3	62.9	66.3	70.1	74	70.8	65.66	60.6	57.4	63.21
1963	55.58	62.68	58.26	59.6	64.1	66.3	72.1	73.7	77.2	69.11	62.2	60.6	65.12
1964	56.68	59	58.6	60.5	61.7	64.8	72	73.3	70.1	70.48	59.8	56.4	63.62
1965	58.21	57.93	58.97	61.7	63.4	64.1	70.1	75.6	69.6	73.06	62	56.9	64.29
1966	55.68	56.2	61.29	64.3	64.5	70.2	74.3	76.6	73.4	71.19	63.6	60.6	65.98
1967	59.11	62.86	60.92	56.1	67.3	66.2	75.7	79.2	75.2	72.45	66.6	55.5	66.42
1968	58.42	63.76	62.82	64	65.5	69.2	74.7	74.1	73.4	69.15	63.3	56.2	66.2
1969	58.29	54.86	59.68	63.8	66.6	67.2	73.7	77	71.7	67.27	65.2	59.2	65.36
1970	57.58	61.38	61.15	60.9	67.4	70	75.3	76.2	74.3	68.32	63.3	57.2	66.07
1971	58.76	59.18	60.34	62	63.9	68.7	74.2	78.9	74.6	67.39	60.2	52.8	65.07
1972	55.45	60.28	63.71	63.8	67.6	72.2	78	77.4	72.3	67.16	62.2	58.1	66.5
1973	56.39	59.93	57.85	63.1	65.8	72	72.3	73.6	70	68.79	60	59.9	64.96
1974	55.13	59.16	59.55	64.7	65.6	72.2	74.1	72.3	73.2	67.56	64	56.2	65.3
1975	57.6	55.73	55.66	56	62.7	65.7	72.5	71.8	73.9	66.4	61.2	57	63.02
1976	59.34	56.38	58.4	57.8	64.2	71.1	72.6	71.5	72.5	70.69	66.8	60.4	65.15
1977	58.06	63.05	56.89	63.6	61.8	69.2	74.2	75.6	71.7	69.02	66.3	60.8	65.85
1978	58.1	58.88	63.19	60.7	68.6	71.8	73.4	73.7	76	70.24	58.4	53.2	65.51
1979	53.23	54.93	57.89	62.7	65.4	71.5	72.1	72.9	77.4	68.73	64.5	63.2	65.37
1980	60.9	64.59	60.94	64.8	63.2	71.7	77.1	76.3	72.6	71.44	65.3	63.7	67.71
1981	61.82	64.25	62	66	68.9	77.4	77.2	78.3	75	68.44	65	62.1	68.87
1982	57.06	63.98	59.27	62.2	64.4	65.3	74	75.1	73.9	70.94	61.7	58.1	65.49
1983	61.87	62.98	63.84	63.2	70.7	70.6	75.9	80.8	79.1	74.16	63.5	59.8	68.86
1984	61.18	61.83	65.58	65.2	72.4	72.2	78.7	76.4	81.3	68.52	60.9	57.2	68.44
1985	57.5	60.41	59.32	66.8	66.2	73.6	79.2	75.7	71.8	71.32	60.4	61.7	66.99
1986	65.85	62.32	64.5	66.4	68.1	71.2	73.2	76	68.8	69.39	66.4	60.1	67.68
1987	57.13	60.34	61.18	67.7	68.1	69.7	70.8	73	75.2	71.84	62.9	54.4	66.02
1988	58.29	62.88	64.89	64.1	67.2	67.9	74.3	72.9	72.2	69.65	61.9	57.1	66.11
1989	56.29	56.38	62.37	67.9	66.2	69.7	75.1	72.8	74.5	69.16	66.7	62.7	66.64
1990	59.44	57.95	61.69	65.7	66.9	74.3	77.3	74	76	73.19	65.6	57.7	67.47
1991	59.13	63.45	56.76	64.2	63.9	67.1	71	73.1	73.6	72.02	66.2	59.6	65.82
1992	60.21	62.33	60.79	69.6	69	70.4	75.8	78.9	76.6	70.35	65.1	56.5	67.95
1993	57.26	58.29	64.44	67	68.9	72.3	72.9	74.4	74.3	71.23	64.5	60.8	67.19
1994	62.21	59.3	64.71	64.3	65.1	74.3	73.6	80.5	76.5	70.4	59.9	59.8	67.54
1995	58.37	65.29	62.61	64.8	64	69	75.7	77.5	77	71.48	67.1	60.9	67.81
1996	60.85	61.34	62.95	68.7	69	71.9	75.1	77.2	73.5	66.95	64.3	59.6	67.61

1997	58.65	60.93	65.06	65.7	72.6	71	73.2	77.6	79.8	71.1	65.2	58.9	68.3
1998	58.76	57	61.9	62.2	64.2	68.8	76.2	79.8	73.6	69	62.4	59.1	66.08
1999	60.76	59.84	56.85	59.4	63.3	66.8	71.8	71.3	69.2	71.27a	61.8	58.1	64.19
2000	58.53	57.53	59.52	64	67.7	71.2	72.2	74.7	72.7	65.1	58.9	58.8	65.08
2001	54.39	54.68	60.37	59.9	67.3	70.8	70.9	72	71.4	68.15	62	56.4	64.02
2002	56.71	60.68	59.77	61.2	64.4	68.7	72.3	71.4	72.1	64.66	64.4	56.6	64.41
2003	63.35	58.86	61.89	60.7	64.7a	67.1a	75.6	-----z	-----z	-----z	-----z	-----z	64.6

Period of Record Statistics

MEAN	57.4	58.6	59.98	62.3	64.8	68.4	72.8	73.6	72.3	68.14	63.2	58.5	64.99
S.D.	3.15	3.08	2.82	2.84	2.7	2.79	2.65	2.81	3.13	2.65	2.62	2.72	1.73
SKEW	-0.65	0.15	0.13	0.17	0.44	0.49	0.17	0.51	0.25	-0.16	0.03	0	0.32
MAX	65.85	65.29	66.03	69.6	72.6	77.4	79.2	80.8	81.3	74.16	68.9	64.2	68.87
MIN	46.85	52.66	54.56	56	58.7	63.4	66.6	68.1	64.6	59.69	58.4	52.6	60.92
NO YRS	90	90	90	90	90	90	90	89	89	88	89	88	87

Source: Western Regional Climate Center: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?calacc

Appendix 4 – Daily Mean Streamflow – USGS Arroyo Seco Station

Day of month	Mean of daily mean values for this day for 92 years of record[1], in ft^3/s											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12.2	14	49.7	21.3	9.46	4.77	2.3	1.21	0.82	1.46	1.58	3.11
2	10.7	17.6	79.3	18	8.67	4.68	2.22	1.19	0.87	1.46	1.27	3.92
3	9.13	22.2	43	19	8.36	4.56	2.2	1.17	0.84	1.14	1.24	6.13
4	8.22	18.7	52.9	18.6	8.48	4.49	2.15	1.15	0.83	1.04	1.21	4.04
5	9.8	14	43	20.3	10.1	4.65	2.09	1.11	0.83	1.1	1.81	4.77
6	9.83	16.9	36.1	18.3	8.95	4.3	2.06	1.08	0.86	1.08	2.15	10.1
7	14.9	16.2	31.3	19.5	8.03	4.14	2	1.08	0.8	1.06	2.04	6.36
8	12.2	22.1	28.5	22.7	8.13	4.08	1.97	1.05	0.78	1.01	1.5	4.39
9	9.12	35.9	23.3	17	8.88	3.99	1.9	1.05	0.77	0.97	1.86	3.64
10	13.1	34.4	24.3	15.2	7.5	3.91	1.83	1.05	1.4	1	2.32	4.37
11	12.2	46.7	28.9	14.8	7.15	3.89	1.77	1.02	2.33	1	4.58	4.59
12	8.53	28.6	28.2	13.5	7.98	3.8	1.78	1	0.85	0.97	3.79	3.84
13	14.2	24.5	29.8	12.7	8.74	3.66	1.73	0.99	0.81	0.94	3.54	10.1
14	12.1	30.3	24.9	12.1	7.95	3.53	1.68	1	0.82	0.93	2.61	9.04
15	14.6	29	24.5	12.6	7.36	3.44	1.65	1	0.8	0.93	2.13	5.76
16	17.2	36.8	25	11.9	7.02	3.47	1.61	0.97	0.79	0.93	2.29	6.48
17	19.2	24.6	24.7	11.3	6.62	3.32	1.58	0.99	0.79	1.79	5.79	5.57
18	24.8	30.2	20.8	12	6.4	3.17	1.53	1.03	0.8	1.48	4.36	6.29
19	16.9	43.7	19.5	11.2	6.37	3.03	1.49	1.1	0.81	1.03	5.79	17.7
20	14.2	81.9	19.1	12.5	6.04	2.97	1.44	0.98	0.8	1.14	5.14	14.7
21	16.5	56.8	20.3	12.3	7.32	2.9	1.44	0.97	0.81	1.01	3.85	13.4
22	24.4	54.9	20.7	11.2	6.7	2.81	1.42	0.94	0.79	1.13	10.8	13.4
23	29.6	56.4	21.2	10.2	6.15	2.75	1.39	0.9	0.79	1.3	5.54	10.3
24	18.7	40.8	19.1	10	5.86	2.68	1.39	1.15	1.1	1.05	6.37	10.7
25	55.7	46.6	18.2	9.56	5.76	2.62	1.37	0.89	1.87	1.03	5.7	9.06
26	59.3	26.4	18.2	10.2	5.58	2.57	1.37	0.86	1.45	1.03	4.39	9.37
27	22	23.6	18	9.67	5.37	2.54	1.36	0.84	1.05	1.02	3.72	11
28	15.5	30.8	16.9	9.28	5.32	2.47	1.32	0.83	1.01	1.04	3.35	13.5
29	23	15.7	16.4	9.97	5.14	2.41	1.28	0.81	1.67	1.08	6.79	17.9
30	16.4		19.4	10.6	4.97	2.33	1.25	0.8	1.81	1.62	5.63	11.4
31	14.5		17.3		4.94		1.22	0.81		1.73		10.6
Average	18.0	32.4	27.8	13.9	7.1	3.5	1.7	1.0	1.0	1.1	3.8	8.6

Appendix 5 – Arroyo Seco Peak Stream Flow Per Year

Los Angeles County, California	Hydrologic Unit Code 18070105
Latitude 34°13'20", Longitude 118°10'36" NAD27	Drainage area 16.0 square miles
Gage datum 1,397.88 feet above sea level NGVD29	

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)		Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1914	Feb. 20, 1914	12.5	5,800		1958	Apr. 03, 1958	4.23	715
1915	Feb. 03, 1915	5.6	634		1959	Feb. 16, 1959	3.54	351
1916	Jan. 17, 1916	9.3	3,150		1960	Jan. 12, 1960	2.88	170
1917	Dec. 24, 1916	4.79	760		1961	Nov. 06, 1960	4.3	769
1918	Mar. 10, 1918	4.1	570		1962	Feb. 11, 1962	5.06	1,500
1919	Feb. 11, 1919	2.72	92		1963	Feb. 09, 1963	3.75	464
1920	Mar. 02, 1920	3.74	450		1964	Jan. 21, 1964	2.94	182
1921	Mar. 13, 1921	4.3	650		1965	Apr. 09, 1965	3	194
1922	Dec. 19, 1921	7.75	2,800		1966	Nov. 22, 1965	6.33	3,160
1923	Dec. 13, 1922	3.5	370		1967	Dec. 06, 1966	4.8	1,530
1924	Mar. 26, 1924	2.35	81		1968	Nov. 19, 1967	4.99	1,720
1925	Apr. 04, 1925	2.95	210		1969	Jan. 25, 1969	9.37	8,540
1926	Apr. 07, 1926	5.95	1,450		1970	Feb. 28, 1970	3.78	668
1927	Feb. 16, 1927	5.9	1,400		1971	Nov. 29, 1970	4.6	1,330
1928	Feb. 04, 1928	3.45	298		1972	Dec. 24, 1971	2.84	222
1929	Apr. 04, 1929	2.78	155		1973	Feb. 11, 1973	6.43	3,740
1930	3-May-30	2.65	143		1974	Mar. 08, 1974	3.22	390
1931	Feb. 03, 1931	2.7	151		1975	Mar. 06, 1975	3.58	535
1932	Dec. 28, 1931	4.8	480		1976	Feb. 09, 1976	3.64	590
1933	Jan. 19, 1933	4.85			1977	9-May-77	2.88	230
1934	Jan. 01, 1934	6.38	950		1978	Mar. 04, 1978	7.57	5,360
1935	Oct. 17, 1934	8.6	2,000		1979	Feb. 21, 1979	2.82	193
1936	Feb. 12, 1936	5.2	706		1980	Feb. 16, 1980	6.06	3,080
1937	Feb. 06, 1937	4.2	640		1981	Jan. 29, 1981	3.76	627
1938	Mar. 02, 1938		8,620		1982	Mar. 17, 1982	3.74	615
1939	Dec. 18, 1938	7.7	375		1983	Mar. 02, 1983	6.09	2,640
1940	Jan. 08, 1940	7.92	452		1984	Dec. 25, 1983	3.06	217
1941	Feb. 20, 1941	8.57	1,340		1985	Dec. 16, 1984	2.79	139
1942	Dec. 10, 1941	6.57	146		1986	Jan. 30, 1986	3.05	213
1943	Jan. 23, 1943	11.86	5,660		1987	Jan. 05, 1987	1.58	13
1944	Feb. 22, 1944	9	1,800		1988	Feb. 29, 1988	3.57	457[D]
1945	Nov. 11, 1944	8.38	1,210		1989	Dec. 16, 1988	2.83	155
1946	Mar. 30, 1946	4.17	680		1990	Feb. 17, 1990	2.86	163
1947	Dec. 25, 1946	4.05	600		1991	Mar. 01, 1991	4.3	921
1948	Apr. 29, 1948	1.84	45		1992	Feb. 11, 1992	5.25	1,710
1949	Jan. 20, 1949	1.6	35		1993	Jan. 17, 1993	5.25	1,710
1950	Nov. 10, 1949	2.76	150		1994	Feb. 07, 1994	2.69	129
1951	Apr. 29, 1951	1.7	12		1995	Jan. 10, 1995	5.27	1,730
1952	Jan. 16, 1952	4.75	1,090		1996	Feb. 21, 1996	3.83	584
1953	Dec. 02, 1952	1.8	49		1997	Dec. 22, 1996	3.81	569
1954	Jan. 24, 1954	4	571		1998	Feb. 23, 1998	7.34	4,380
1955	Apr. 30, 1955	2.39	107		1999	Feb. 09, 1999	2.34	62
1956	Jan. 26, 1956	4.3	815		2000	Feb. 20, 2000	3.66	509
1957	Feb. 23, 1957	2.84	158		2001	Feb. 13, 2001	3.37	348

Appendix 6 - Spreading Operations in the Arroyo Seco Watershed 1977-2002
(in acre feet)

	Arroyo Seco			Millard Cyn	Total
Agency	**Pasadena**	**LADPW**	**Lincoln**	**Pasadena**	
1977	33.65	431.90	355.31	0.00	820.86
1978	ND	ND	ND	ND	0.00
1979	1268.01	2096.20	718.01	291.76	4373.98
1980	ND	ND	ND	ND	0.00
1981	276.87	477.90	278.92	365.01	1398.70
1982	511.89	1354.80	290.88	290.59	2448.16
1983	1672.10	6131.40	302.35	262.12	8367.97
1984	629.70	625.30	306.83	1059.55	2621.38
1985	741.65	913.40	141.26	374.72	2171.03
1986	1584.68	2248.00	186.68	613.31	4632.67
1987	435.17	454.00	261.03	149.38	1299.58
1988	441.00	1573.00	220.00	623.00	2857.00
1989	462.00	647.00	204.00	289.00	1602.00
1990	188.93	174.00	205.59	77.79	646.31
1991	343.39	917.00	213.69	116.20	1590.28
1992	1290.30	2695.00	219.81	709.99	4915.10
1993	4592.32	3854.00	405.37	1915.47	10767.16
1994	2646.58	1923.70	381.01	626.83	5578.12
1995	5351.80	5609.70	323.50	1625.20	12910.20
1996	3010.60	2201.00	462.70	1470.00	7144.30
1997	3131.40	2919.00	339.70	1064.40	7454.50
1998	3727.10	0.00	656.50	1854.80	6238.40
1999	1748.80	1524.20	119.40	171.00	3563.40
2000	1023.70	651.80	161.30	138.20	1975.00
2001	1188.20	997.60	134.10	0.00	2319.90
2002	178.90	101.70	44.60	2.90	328.10
Average	**1519.90**	**1688.40**	**288.90**	**587.10**	**3770.16**
				Total	**98024.10**

Appendix 7: ET Data from Nearby CIMIS Weather Stations

Glendale - Station Los Angeles Basin - 133

Year Month	Tot. ETo (in)	Tot. Precip (in)	Avg Sol. Rad. (Ly/dy)	Avg Vap. Pres. (mBars)	Avg Max Air Temp (°F)	Avg Min Air Temp (°F)	Avg Avg Air Temp (°F)	Avg Max Rel. Hum. (%)	Avg Min Rel. Hum. (%)	Avg Rel. Hum. Avg (%)	Avg Wind Speed (mph)	Avg Soil Temp (°F)
2002 08	5.64	0.00	543	16.1	81.0	57.0	68.0	89	48	70	2.7	72.0
2002 09	4.78	0.00	460	14.4	84.0	59.0	70.0	82	40	59	2.6	71.0
2002 10	2.46	0.00	309	12.9	70.0	50.0	60.0	91	56	76	2.3	65.0
2002 11	2.57	0.76	255	8.5	73.0	48.0	60.0	72	32	50	2.6	60.0
2002 12	1.65	7.53	196	8.6	63.0	42.0	52.0	88	42	66	3.0	54.0
2003 01	2.72	0.10	249	8.1	73.0	48.0	59.0	68	30	50	3.2	54.0
2003 02	2.07	5.65	266	9.0	63.0	44.0	53.0	86	42	64	3.1	55.0
2003 03	3.95	1.79	418	9.3	69.0	46.0	57.0	82	41	61	3.6	57.0
2003 04	3.83	2.04	450	9.7	65.0	44.0	54.0	91	48	68	3.5	59.0
2003 05	4.65	1.25	494	13.6	72.0	50.0	61.0	94	55	74	3.4	64.0
2003 06	3.92	0.56	447	16.6	72.0	56.0	63.0	98	68	85	3.2	69.0
2003 07	5.71	0.37	523	19.7	84.0	62.0	72.0	94	52	73	3.3	74.0
Totals/Avgs	43.97	20.04	386	12.2	73.0	51.0	61.0	86	46	66	3.0	63.0

Monrovia - Station Los Angeles Basin - 159

Year Month	Tot. ETo (in)	Tot. Precip (in)	Avg Sol. Rad. (Ly/dy)	Avg Vap. Pres. (mBars)	Avg Max Air Temp (°F)	Avg Min Air Temp (°F)	Avg Avg Air Temp (°F)	Avg Max Rel. Hum. (%)	Avg Min Rel. Hum. (%)	Avg Rel. Hum. Avg (%)	Avg Wind Speed (mph)	Avg Soil Temp (°F)
2002 08	6.35	0.00	579	16.1	86.0	59.0	71.0	85	40	62	3.4	73.0
2002 09	5.38	0.11	498	14.7	87.0	60.0	72.0	79	34	55	3.1	70.0
2002 10	2.90	0.00	301	12.6	73.0	53.0	62.0	83	47	67	3.0	64.0
2002 11	2.84	3.88	274	9.1	76.0	51.0	62.0	73	30	51	3.3	60.0
2002 12	1.94	2.52	240	8.8	65.0	43.0	53.0	84	39	63	2.9	55.0
2003 01	2.42	0.02	219	8.6	76.0	49.0	61.0	71	29	50	3.2	57.0
2003 02	1.96	6.06	235	9.2	66.0	47.0	56.0	81	39	61	3.4	58.0
2003 03	4.20	3.68	430	9.7	72.0	47.0	59.0	81	36	57	3.6	61.0
2003 04	4.32	1.42	469	9.7	68.0	47.0	57.0	83	40	61	3.7	63.0
2003 05	5.17	1.32	503	13.2	76.0	53.0	64.0	86	46	65	3.6	68.0
2003 06	4.21	0.38	427	15.8	76.0	58.0	66.0	88	56	73	3.5	71.0
2003 07	7.05	0.03	603	18.7	90.0	65.0	76.0	84	41	62	3.7	76.0
Totals/Avgs	48.75	19.42	399	12.2	76.0	53.0	63.0	82	40	61	3.4	65.0

Monthly Average ETo Report

133 - Glendale - Los Angeles Basin

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2.20	2.45	3.64	4.74	5.31	6.06	6.75	6.66	5.01	3.95	2.73	2.31	51.81

Appendix 8 - Raymond Basin Agencies Water Use 2002

TABLE 10. WATER USE IN 2001-02
in acre feet

Party	(1) Ground Water Extractions	(2) Water Diversions To System*	(3) Imported MWD Water	(4) Water Exported from Basin	(5) Water Imported (Exported) within Basin	(6) Total Water Use Within Basin (1)+(2)+(3)+(4)+(5)
Alhambra, City of	3.7		3,429.0			3,432.7
Arcadia, City of	5,595.9					5,595.9
California-American Water Company	2,871.1		602.7			3,473.8
East Pasadena Water Company	437.1		480.6 **			917.7
H.E. Huntington Library & Art Gallery	400.9					400.9
Kinneloa Irrigation District	718.0	198.1			(87.3)	828.8
La Canada Irrigation District	130.3	73.0	2,873.5			3,076.8
Las Flores Water Company	248.9		774.8			1,023.7
Lincoln Avenue Water Company	833.0	32.2	1,978.4			2,843.6
Pasadena Cemetery Association	70.6					70.6
Pasadena, City of	14,628.8		23,032.4 ***	168.7	87.3	37,917.2
Rubio Canon Land & Water Association	1,491.6	17.4	1,136.0			2,645.0
San Gabriel County Water District	0.0					0.0
Sierra Madre, City of	2,969.3	191.6				3,160.9
Sunny Slope Water Company	1,141.5			(1,025.6)		115.9
Valley Water Company	1,375.4		3,263.9			4,639.3
Total	**32,916.1**	**512.3**	**37,571.3**	**(856.9)**	**0.0**	**70,142.8**

* Does not include surface water diversions for spreading credit
** San Gabriel basin water
*** Includes small quantity of MWD water delivered to San Rafael Hills

Appendix 9 –Table and Figures

Tables

Figures

Appendix 10 - Credits

Page	Title	Source
4	Figure 1 - The Water Cycle	United States Geological Survey (USGS), Illustration by John M. Evans USGS, Colorado District, http://ga.water.usgs.gov/edu/watercyclegraphichi.html
4	Definition of Water Budget	USGS [Adapted from Dic. of Earth Sciences, Oxford University Press, 1999]
6	California DWR, Bulletin 118	California Department of Water Resources, 2003. California' s Ground Water, Bulletin 118. Draft Individual Basin Descriptions. Raymond Groundwater Basin. Accessed online 3/26/03 at http://www.waterplan.water.ca.gov/groundwater/draftmain2.htm
8	Figure 2 – Arroyo Seco Watershed	Los Angeles County Department of Public Works
9	Figure 3 – Topographic Map	Arroyo Seco Watershed Restoration Feasibility Study, North East Trees and the Arroyo Seco Foundation
10	Figure 4 - Conceptual Water Budget	Colorado Division of Water Resources, Office of the State Engineer
12	Table 1 – Raymond Basin Water Use and Figure 5	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board
13	Figure 17 - Raymond Basin Water Use Historic Pattern	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board
14	Figure 18 - Raymond Basin Location Map	Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003
16	Figure 19 - Location of Precipitation Stations and Spreading Grounds	Watermaster Service in the Raymond Basin, July 1, 2000 – June 30, 2001, Raymond Basin Management Board
16	Figure 20 – Los Angeles County Rainfall Gages in the Arroyo Seco	County of Los Angeles Department of Public Works, Watershed Management Division, August 5, 2003
17	Table - 2 - Precipitation in the Arroyo Seco	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board
18	Figure 21 - Pasadena Monthly Precipitation	Western Regional Climate Council
19	Figure 11 – Pasadena Climate	Western Regional Climate Council
19	Figure 12 – Los Angeles Climate	Western Regional Climate Council
20	Table 3 - Temperature in the Arroyo Seco Watershed	Climate Average by Zip Code, Melissa Data – www.melissadata.com
21	Figure 13 – Isohyetal Map of the Raymond Basin	Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003
22	Figure 14 – Pasadena Precipitation	Draft Technical Memorandum on Evaluation of the Effects of the Current Long Term Storage Program for the Raymond Ground Water Basin, prepared for the Raymond Basin Management Board by Geoscience Support Services, July 7, 2003
23	Figure 22 - Pasadena Average Temperature	Western Regional Climate Council
24	Figure 16 - Location of USGS Stream Gage	United States Geologic Survey Site Map11098000 Arroyo Seco Nr Pasadena Ca
25	Figure 17 – Arroyo Seco Daily	USGS Water Resources Data 11098000 Arroyo Seco Nr Pasadena Ca

	Mean Streamflow	
26	Figure 18 - Peak Streamflow in the Arroyo Seco	USGS Water Resources Data 11098000 Arroyo Seco Nr Pasadena Ca
26	LA County Rainfall Gages in the Arroyo Seco	County of Los Angeles Department of Public Works, Watershed Management Division, August 5, 2003
26	LA County DPW Streamflow Gage 477	County of Los Angeles Department of Public Works, Watershed Management Division, August 5, 2003
28	Figure 19 - Annual Runoff Not Captured for Recharge, 1970 - 1998	Water Augmentation Study, Pilot Program Report, June 2002, prepared by Montgomery Watson Harza for the Los Angeles San Gabriel Rivers Watershed Council
29	Figure 20 - Ratio of Annual Runoff - Los Angeles River	Water Augmentation Study, Pilot Program Report, June 2002, prepared by Montgomery Watson Harza for the Los Angeles San Gabriel Rivers Watershed Council
30	Figure 21 - The Effect of Channelization on Infiltration	Lower Arroyo Master Plan, a project of the California Polytechnic University at Pomona 606 Studio, 1988
31	Figure 22 – CIMIS Evapotranspiration Map	California Irrigation Management Information System
33	Figure 23 - Evapotranspiration Rate Zones	California Irrigation Management Information System
33	Figure 24 – ET Reference Zones	California Irrigation Management Information System
34	Figure 25 – Water Balance Data	California Irrigation Management Information System
	Monthly Average ETo Report	California Irrigation Management Information System
35	Table 5 – Water Use	Data provided by Raymond Basin Management Board, City of Los Angeles Department of Water & Power, City of Pasadena Water & Power Department
36	Figure 27 - Los Angeles Sources of Supply	Data provided by City of Los Angeles Department of Water & Power
37	Figure 28 - Los Angeless Purchases from MWD	Metropolitan Water District Operations Data
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38	Figure 30 – La Canada Irrigation District Per Capita Consumption	La Canada Irrigation District, September 16, 2003
39	Figure 31 – Valley Water Company Sales	Valley Water Company, September 17, 2003
39	Figure 32 - Pasadena Water Sources	Pasadena Water & Power Department Annual Reports
40	Figure 33 - Pasadena Water Purchases from MWD 1979-2003	Metropolitan Water District Operations Data
41	Figure 34 - Pasadena Water Sales	Pasadena Water & Power Department Annual Reports
42	Figure 35 - Water Use by Month - Raymond Basin Agencies	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board
42	Figure 36 - Per Capita Consumption	Data provided by Raymond Basin Management Board, City of Los Angeles Department of Water & Power, City of Pasadena Water & Power Department
43	Table 6 – North East Los Angeles Water Consumption	Los Angeles Department of Water & Power
45	Table 7 - Arroyo Seco Watershed Budget	Data provided by Raymond Basin Management Board, City of Los Angeles Department of Water & Power, City of Pasadena Water & Power Department, County of Los Angeles Department of Public Works, US Geologic Survey, Geoscience Draft Technical Memorandum, MWD's, Technical Memorandum on Raymond Basin Groundwater Flow Modeling,

		CIMIS, and Western Regional Climate Center
50	Appendix 1 – Water Budget Terminology	Manual of Hydrology: Part 1. General Surface-Water Techniques, GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1541-A, *Methods and practices of the Geological Survey* http://water.usgs.gov/wsc/glossary.html)
51	Appendix 2 - Monthly Total Precipitation – Pasadena CA	Western Regional Climate Council
54	Appendix 3 – Los Angeles Temperature	Western Regional Climate Council
57	Appendix 4 - Daily Mean Streamflow by Day of Month	USGS Water Resources Data 11098000 Arroyo Seco Nr Pasadena Ca
58	Appendix 5 – Arroyo Seco Peak Stream Flow Per Year	USGS Water Resources Data 11098000 Arroyo Seco Nr Pasadena Ca
60	Appendix 6 - Spreading Operations in the Arroyo Seco Watershed	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board
61	Appendix 7: ET Data from Nearby CIMIS Weather Stations	California Irrigation Management Information System
62	Appendix 8 - Raymond Basin Agencies Water Use 2002	Watermaster Service in the Raymond Basin, July 1, 2001 – June 30, 2002, Raymond Basin Management Board