Draft

Groundwater Sustainability Plan
Chapter 6 – Water Budget

for the

Arroyo Grande Valley Groundwater Subbasin Groundwater Sustainability Agencies

Prepared by

8/11/2021

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The grey highlighted sections in the Table of Contents (TOC) indicate that the section has been previously released (Chapters 1 through 5) or will be released in the future (Chapters 7 through 14). The complete list of the anticipated TOC is presented to give the reader context as to how Chapter 6 – Water Budget, connects with the complete Groundwater Sustainability Plan.

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LIST OF TERMS USED

Abbreviation	**Definition**
AB	Assembly Bill
ADD	Average Day Demand
AF	Acre Feet
AFY	Acre Feet per Year
AMSL	Above Mean Sea Level
Basin Plan	Water Quality Control Plan for the Central Coast Basin
Cal Poly	California Polytechnic State University
CASGEM	California State Groundwater Elevation Monitoring program
CCR	California Code of Regulations
CCRWQCB	Central Coast Regional Water Quality Control Board
CCGC	Central Coast Groundwater Coalition
CDFM	Cumulative departure from the mean
CDPH	California Department of Public Health
CIMIS	California Irrigation Management Information System
City	City of San Luis Obispo
County	County of San Luis Obispo
CPUC	California Public Utilities Commission
CPWS-52	Cal Poly Weather Station 52
CRWQCB	California Regional Water Quality Control Board
CWC	California Water Code
DDW	Division of Drinking Water
Du/ac	Dwelling Units per Acre
DWR	Department of Water Resources
EPA	Environmental Protection Agency
ERMWC	Edna Ranch Mutual Water Company
ET_0	Evapotranspiration
EVGMWC	Edna Valley Growers Ranch Mutual Water Company
°F	Degrees Fahrenheit
FAR	Floor Area Ratio
FY	Fiscal Year
GAMA	Groundwater Ambient Monitoring and Assessment program
GHG	Greenhouse Gas
GMP	Groundwater Management Plan
GPM	Gallons per Minute
GSA	Groundwater Sustainability Agency
GSC	Groundwater Sustainability Commission
GSP	Groundwater Sustainability Plan
GSWC	Golden State Water Company
IRWMP	San Luis Obispo County Integrated Regional Water Management Plan
kWh	Kilowatt-Hour
LUCE	Land Use and Circulation Element
LUFTs	Leaky Underground Fuel Tanks
MAF	Million Acre Feet
MCL	Maximum Contaminant Level

Abbreviation	**Definition**
MG	Million Gallons
MGD	Million Gallons per Day
Mg/L	Milligrams per Liter
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MWR	Master Water Report
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
RW	Recycled Water
RWQCB	Regional Water Quality Control Board
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SGMP	Sustainable Groundwater Management Planning
SGWP	Sustainable Groundwater Planning
SLO Basin	San Luis Obispo Valley Groundwater Basin
SLOFCWCD	San Luis Obispo Flood Control and Water Conservation District
SCML	Secondary Maximum Contaminant Level
SOI	Sphere of Influence
SNMP	Salt and Nutrient Management Plan
SWRCB	California State Water Resources Control Board
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
USFW	United States Fish and Wildlife Service
USTs	Underground Storage Tanks
UWMP	Urban Water Management Plan
UWMP Act	Urban Water Management Planning Act
UWMP Guidebook	Department of Water Resources 2015 Urban Water Management Plan Guidebook
VRMWC	Varian Ranch Mutual Water Company
WCS	Water Code Section
WMP	Water Master Plan
WPA	Water Planning Areas
WRF	Water Reclamation Facility
WRCC	Western Regional Climate Center
WRRF	Water Resource Recovery Facility
WSA	Water Supply Assessment
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This section to be completed after GSP is complete.

6 WATER BUDGET (§ 354.18)

The purpose of a water budget is to provide an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the Subbasin, including historical, current, and projected water budget conditions, and the change in volume stored. Both numerical and analytical methods have been used during water budget preparations for the GSP. The analytical method as used in this document refers to application of the water budget equation and the inventory method using spreadsheets, with groundwater flow estimates based on Darcy's Law and change in storage calculations based on the specific yield method.

Numerical methods refer to surface water and groundwater flow modeling, which provide a dynamic and more rigorous analysis of both surface-groundwater interactions and the impacts from pumping on groundwater in storage. The historical and current analytical groundwater budget will be used as part of the Subbasin Hydrogeologic Conceptual Model (HCM) to prepare input estimates and provide a check for the numerical model, from which the projected water budget will be produced. This chapter presents the analytical water budget for the historical and current periods and the numerical model water budget for the projected future period. Once the numerical model water budget is calibrated, the results will be presented as comparisons to the analytical water budget.

A water budget identifies and quantifies various components of the hydrologic cycle within a user-defined area, in this case the Arroyo Grande Valley groundwater Subbasin. Water circulates between the atmospheric system, land surface system, surface water bodies, and the groundwater system, as shown in Figure 6-1 (DWR, 2016). The water budget equation used for the analytical method is as follows:

INFLOW – OUTFLOW = CHANGE IN STORAGE

Inflow is the sum of all surface water and groundwater entering the Subbasin and outflow is the sum of all surface water and groundwater leaving the Subbasin. The difference between total inflow and total outflow over a selected time period is equal to the change in total storage (surface water and groundwater) within the Subbasin over the same period. Components of inflow and outflow represented in the water budget are shown in Figure 6-2. Not all of the components shown are needed for the Subbasin GSP. A key using letters to represent components in this water budget has been added to Figure 6-2 for reference with the main water budget tables. Some components have been modified and renamed from the original DWR figure to better represent this specific water budget.

The water budget equation given above is simple in concept, but it is challenging to measure and account for all the components of inflow and outflow within a Basin. Some of these components can be measured or estimated independently, while others are calculated using the water budget equation. The water budget for this GSP has been prepared for the Subbasin as a whole.

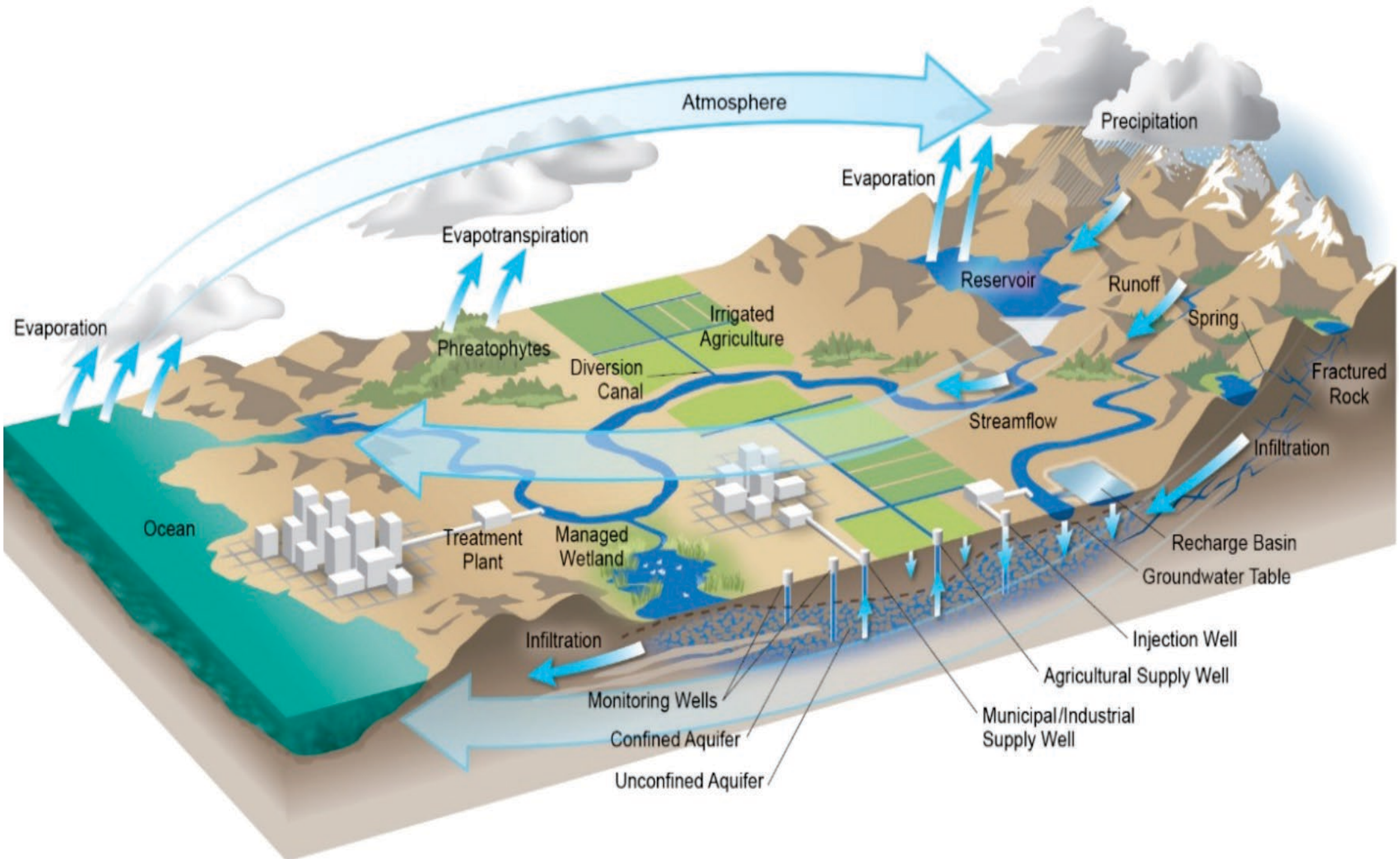


Figure 6-1: The Hydrologic Cycle.

Source: Department of Water Resources (Water Budget BMP, 2016)

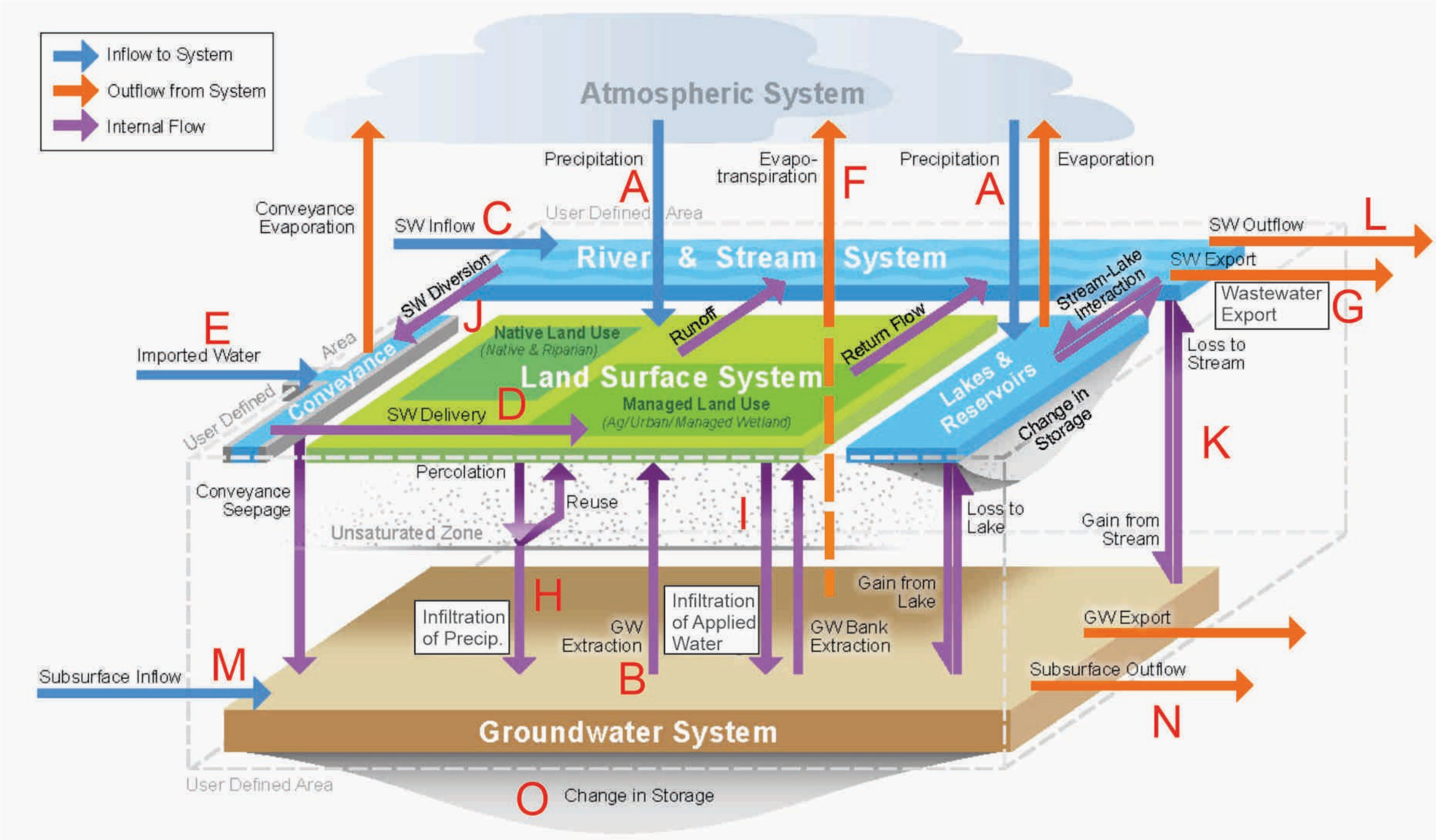


Figure 6-2: Components of the Water Budget.

Source: Modified from Department of Water Resources (Water Budget BMP, 2016)

The Subbasin is approximately 2,900 acres (4.5 square miles), and receives surface inflow from a watershed of approximately 65,800 acres (102.8 square miles) of which approximately 44,000 acres (68.8 square miles; 67%) are upstream of Lopez Dam. The largest tributary to Arroyo Grande Creek entering the Subbasin downstream of the dam is Tar Spring Creek (Figure 3-3; Chapter 3).

Table 6-1 presents the historical surface water and groundwater budgets for the Subbasin. Bar graphs for the surface water and groundwater budgets are included in Figure 6-3 and Figure 6-4. A letter key has been added to provide a visual reference between Table 6-1 and Figure 6-2.

Note that Figure 6-2 separates the water budget into four components (atmospheric system, land surface system, river & stream system, and groundwater system). The atmospheric system transfers evaporation to precipitation and overlies the other systems. The land surface system is the portion of the water budget that includes land surface and the unsaturated zone extending to the top of the groundwater system. The rivers & streams system is the portion of the water budget that includes rivers, streams, conveyance facilities and diversion ditches, and lakes and reservoirs. The atmospheric, land surface, and river & streams water budgets for this Subbasin have been combined into a single surface water budget. As a result, not all the components in Figure 6-3 have corresponding budget items listed for the Subbasin. For example, the runoff and return flow components of the land surface system into the river & stream system in Figure 6-2 are part of the surface water outflow component (Labeled “L”).

The bar graphs are graphical representations of the water budget that allow quick comparisons of the various budget quantities. Figure 6-3 illustrates the surface water budget portions of Table 6-1, while Figure 6-4 illustrates the groundwater budget portions of the table. Water budget climate, historical time period, methodology, sustainable yield, and overdraft interpretation are also presented in this chapter.

Table 6-1: Historical Water Budget – Arroyo Grande Subbasin.

Historical Water Budget - Arroyo Grande Subbasin

Water Year	SURFACE WATER INFLOW (AF)							SURFACE WATER OUTFLOW (AF)												GROUNDWATER INFLOW (AF)						GROUNDWATER OUTFLOW (AF)				Change in GW Storage (AF)
	Precipitation	GW extractions (Urban)	GW extractions (Ag)	Stream Inflow	Surface Water Delivery	Local Imported Supplies	TOTAL IN	ET of Precipitation	ET of Applied Water (Urban)	ET of Applied Water (Ag)	Riparian ET	Wastewater export	Infiltration of Precipitation	Infilt. of Applied Water (Urban)	Infilt. of Applied Water (Ag)	Surface Water Diversion	GW-SW interaction	Stream outflow	TOTAL OUT	Infiltration of Precipitation	Infilt. of Applied Water (Urban)	Infilt. of Applied Water (Ag)	GW-SW interaction	Subsurface Inflow	TOTAL IN	GW Extractions (Urban)	GW Extractions (Ag)	Subsurface Outflow	TOTAL OUT	
KEY	A	B	B	C	D	E		F	F	F	F	G	H	I	I	J	K	L		H	I	I	K	M		B	B	N		O
1988	2,380	120	2,810	3,950	450	440	10,150	2,260	480	2,170	230	180	100	70	640	450	1,350	2,220	10,150	100	70	640	1,350	170	2,330	120	2,810	480	3,410	-1,080
1989	3,050	110	2,410	4,310	450	410	10,740	2,710	450	1,850	230	160	280	70	560	450	1,470	2,510	10,740	280	70	560	1,470	170	2,550	110	2,410	480	3,000	-450
1990	1,920	110	2,810	4,150	450	390	9,830	1,900	430	2,170	230	150	20	70	640	450	1,420	2,360	9,840	20	70	640	1,420	170	2,320	110	2,810	480	3,400	-1,080
1991	3,920	110	2,590	4,110	450	380	11,560	3,020	430	1,990	230	150	740	70	590	450	1,410	2,490	11,570	740	70	590	1,410	170	2,980	110	2,590	480	3,180	-200
1992	4,150	110	2,530	5,040	450	390	12,670	3,080	430	1,940	230	150	880	70	580	450	1,730	3,130	12,670	880	70	580	1,730	170	3,430	110	2,530	480	3,120	310
1993	5,820	110	2,400	7,590	450	380	16,750	3,150	420	1,840	230	150	2,210	70	550	450	820	6,840	16,730	2,210	70	550	820	170	3,820	110	2,400	480	2,990	830
1994	3,080	110	2,150	3,700	450	360	9,850	2,740	400	1,640	230	140	290	60	510	450	1,260	2,120	9,840	290	60	510	1,260	170	2,290	110	2,150	480	2,740	-450
1995	7,600	110	2,340	11,900	450	380	22,780	3,160	420	1,800	230	150	3,400	70	540	450	1,290	11,270	22,780	3,400	70	540	1,290	170	5,470	110	2,340	480	2,930	2,540
1996	4,610	110	2,320	19,490	450	420	27,400	3,170	460	1,780	230	170	1,190	70	540	450	1,110	18,240	27,410	1,190	70	540	1,110	170	3,080	110	2,320	480	2,910	170
1997	6,010	120	2,730	55,830	450	370	65,510	3,180	420	2,110	230	150	2,350	70	620	450	950	54,990	65,520	2,350	70	620	950	170	4,160	120	2,730	480	3,330	830
1998	9,070	110	2,060	80,040	450	420	92,150	3,180	460	1,570	230	170	1,310	70	490	450	1,370	82,860	92,160	1,310	70	490	1,370	170	3,410	110	2,060	480	2,650	760
1999	3,670	120	2,820	17,350	450	450	24,860	2,990	490	2,190	230	180	560	80	640	450	990	16,080	24,880	560	80	640	990	170	2,440	120	2,820	480	3,420	-980
2000	4,520	110	2,020	9,070	450	430	16,600	3,190	470	1,540	230	170	1,080	70	480	450	520	8,400	16,600	1,080	70	480	520	170	2,320	110	2,020	480	2,610	-290
2001	4,830	110	2,100	10,420	450	450	18,360	3,190	490	1,610	230	180	1,340	70	490	450	590	9,710	18,350	1,340	70	490	590	170	2,660	110	2,100	480	2,690	-30
2002	2,970	120	2,400	6,530	450	450	12,920	2,700	490	1,850	230	180	230	80	550	450	1,340	4,830	12,930	230	80	550	1,340	170	2,370	120	2,400	480	3,000	-630
2003	4,070	120	1,960	8,350	450	460	15,410	3,100	490	1,490	230	180	790	80	470	450	900	7,210	15,390	790	80	470	900	170	2,410	120	1,960	480	2,560	-150
2004	3,060	120	2,110	7,200	450	430	13,370	2,740	480	1,610	230	170	260	80	490	450	780	6,080	13,370	260	80	490	780	170	1,780	120	2,110	480	2,710	-930
2005	3,850	120	2,020	11,060	450	420	17,920	3,030	470	1,550	230	170	670	80	480	450	2,270	8,540	17,940	670	80	480	2,270	170	3,670	120	2,020	480	2,620	1,050
2006	5,950	130	2,030	8,990	450	450	18,000	3,190	500	1,550	230	180	2,280	80	480	450	510	8,550	18,000	2,280	80	480	510	170	3,520	130	2,030	480	2,640	880
2007	1,790	160	2,670	5,780	450	430	11,280	1,790	500	2,070	230	170	0	80	600	450	630	4,760	11,280	0	80	600	630	170	1,480	160	2,670	480	3,310	-1,830
2008	4,810	160	2,660	7,500	450	400	15,980	3,190	480	2,060	230	160	1,320	80	600	450	430	6,980	15,980	1,320	80	600	430	170	2,600	160	2,660	480	3,300	-700
2009	2,710	150	2,410	5,450	340	370	11,430	2,550	440	1,880	230	150	140	80	530	340	1,120	3,980	11,440	140	80	530	1,120	170	2,040	150	2,410	480	3,040	-1,000
2010	5,340	150	1,770	6,310	580	360	14,510	3,200	430	1,320	230	150	1,760	80	450	580	1,290	5,020	14,510	1,760	80	450	1,290	170	3,750	150	1,770	480	2,400	1,350
2011	6,950	150	2,020	8,740	490	380	18,730	3,200	450	1,540	230	150	3,110	80	490	490	1,790	7,210	18,740	3,110	80	490	1,790	170	5,640	150	2,020	480	2,650	2,990
2012	2,830	160	2,130	5,160	600	370	11,250	2,630	450	1,600	230	150	170	80	530	600	1,060	3,760	11,260	170	80	530	1,060	170	2,010	160	2,130	480	2,770	-760
2013	3,030	170	2,840	5,380	510	360	12,290	2,730	450	2,190	230	150	250	80	640	510	1,100	3,950	12,280	250	80	640	1,100	170	2,240	170	2,840	480	3,490	-1,250
2014	1,420	170	2,500	4,220	420	360	9,090	1,420	450	1,940	230	140	0	80	560	420	1,440	2,410	9,090	0	80	560	1,440	170	2,250	170	2,500	480	3,150	-900
2015	2,130	170	2,650	3,620	420	350	9,340	2,070	440	2,060	230	140	50	80	590	420	1,240	2,030	9,350	50	80	590	1,240	170	2,130	170	2,650	480	3,300	-1,170
2016	3,870	170	2,100	4,700	420	340	11,600	3,090	430	1,620	230	140	640	80	480	420	1,610	2,870	11,610	640	80	480	1,610	170	2,980	170	2,100	480	2,750	230
2017	6,860	180	2,500	7,990	400	340	18,270	3,260	430	1,940	230	130	3,000	90	560	400	2,730	5,500	18,270	3,000	90	560	2,730	170	6,550	180	2,500	480	3,160	3,390
2018	2,170	190	2,230	4,770	420	330	10,110	2,120	430	1,730	230	130	50	90	500	420	820	3,600	10,120	50	90	500	820	170	1,630	190	2,230	480	2,900	-1,270
2019	4,920	180	1,940	7,560	310	320	15,230	3,320	420	1,520	230	130	1,310	90	420	310	1,290	6,200	15,240	1,310	90	420	1,290	170	3,280	180	1,940	480	2,600	680
2020	3,020	200	2,340	3,890	450	330	10,230	2,760	440	1,810	230	130	210	90	530	450	800	2,780	10,230	210	90	530	800	170	1,800	200	2,340	480	3,020	-1,220

Type Year: Dry / Below Normal / Above Normal / Wet

AF = Acre-Feet; KEY = Reference Components on Figure 6-2

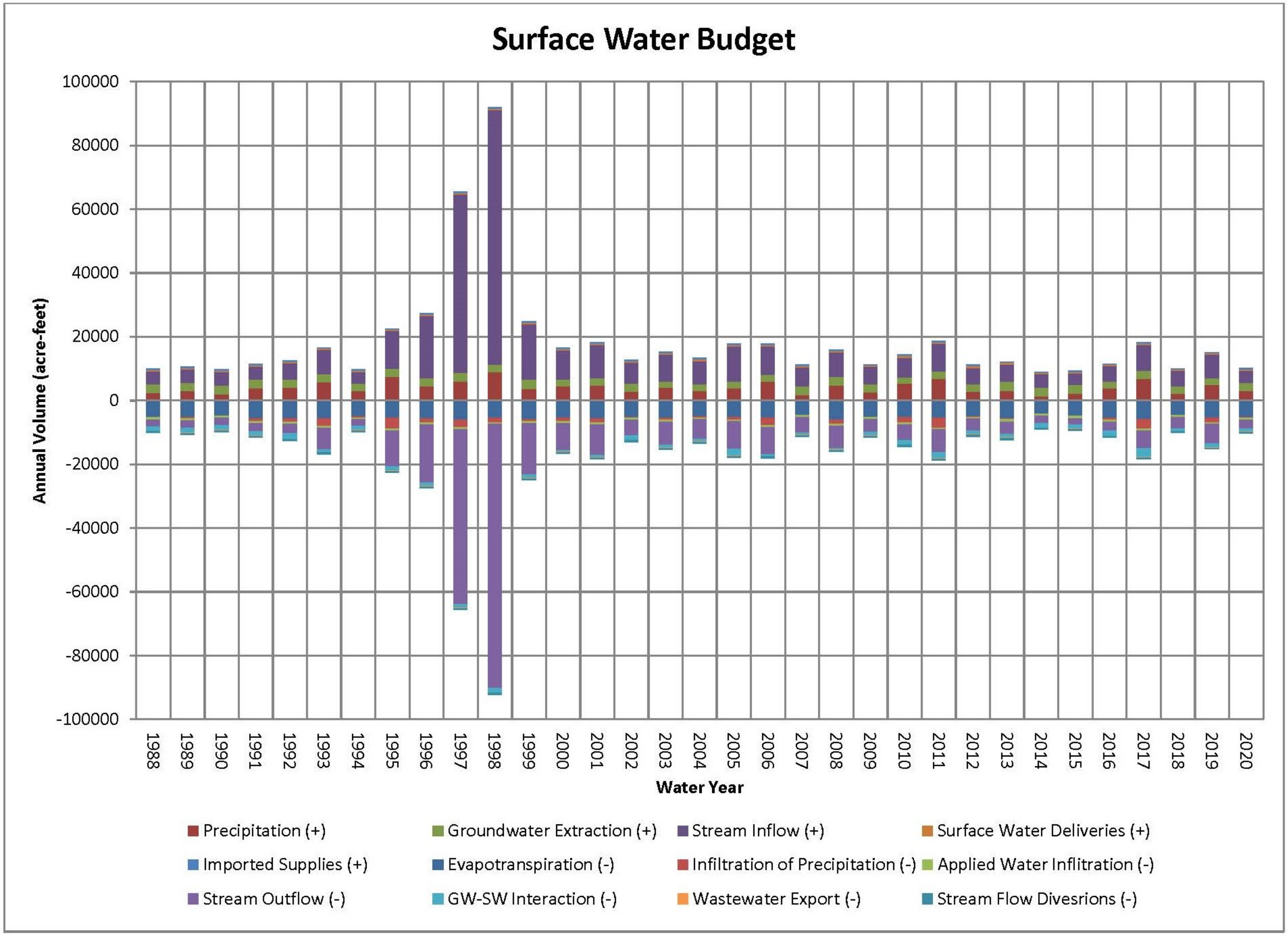


Figure 6-3: Surface Water Budget.

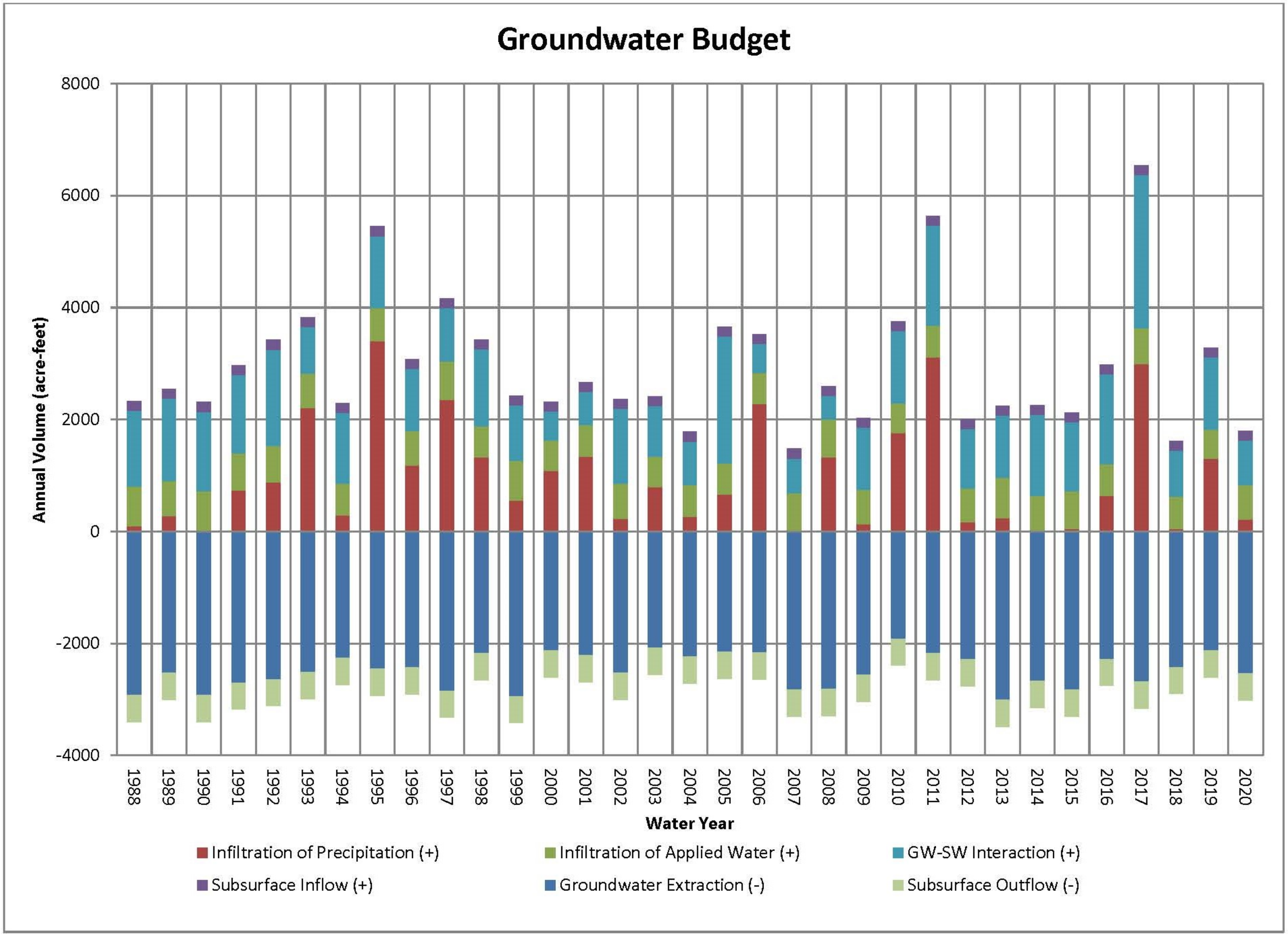


Figure 6-4: Groundwater Budget.

6.1 CLIMATE

Climate is one of the principal measures of water supply conditions and is used for hydrologic base period definition and for developing evapotranspiration estimates. The main component of climate monitoring in the Subbasin is rainfall, with records at Lopez Dam (Station 737; formerly Station 178.1) beginning in the 1968-69 rainfall year (July 1st – June 30th). Rainfall is used in the water budget for establishing the hydrologic base period needed for representing long-term water supply conditions.

Another climate parameter used in the water budget is evapotranspiration. Evapotranspiration is calculated from a combination of monitored parameters, such as air temperature, wind speed, solar radiation, vapor pressure, and relative humidity. These parameters, along with precipitation, have been monitored at CIMIS Station #52 (San Luis Obispo – Cal Poly) since 1986. The water budget uses crop evapotranspiration for estimating the applied irrigation requirements for crops (see Section 6.3.4.2). Cal Poly is within DWR reference evapotranspiration Zone 6 (Upland Central Coast), which is one of 18 climate zones in California based on long-term monthly average reference evapotranspiration (CIMIS, 1999). Approximately one third of the Subbasin is within Climate Zone 6, with the remaining two thirds in Climate Zone 3 (Coastal Valleys). CIMIS Station #202 (Nipomo) is within Climate Zone 3, with a record that begins in 2006. A correlation between evapotranspiration at CIMIS Stations #52 and #202 was performed to extend a record representative of Climate Zone 3 to the beginning of the historical base period, as discussed below.

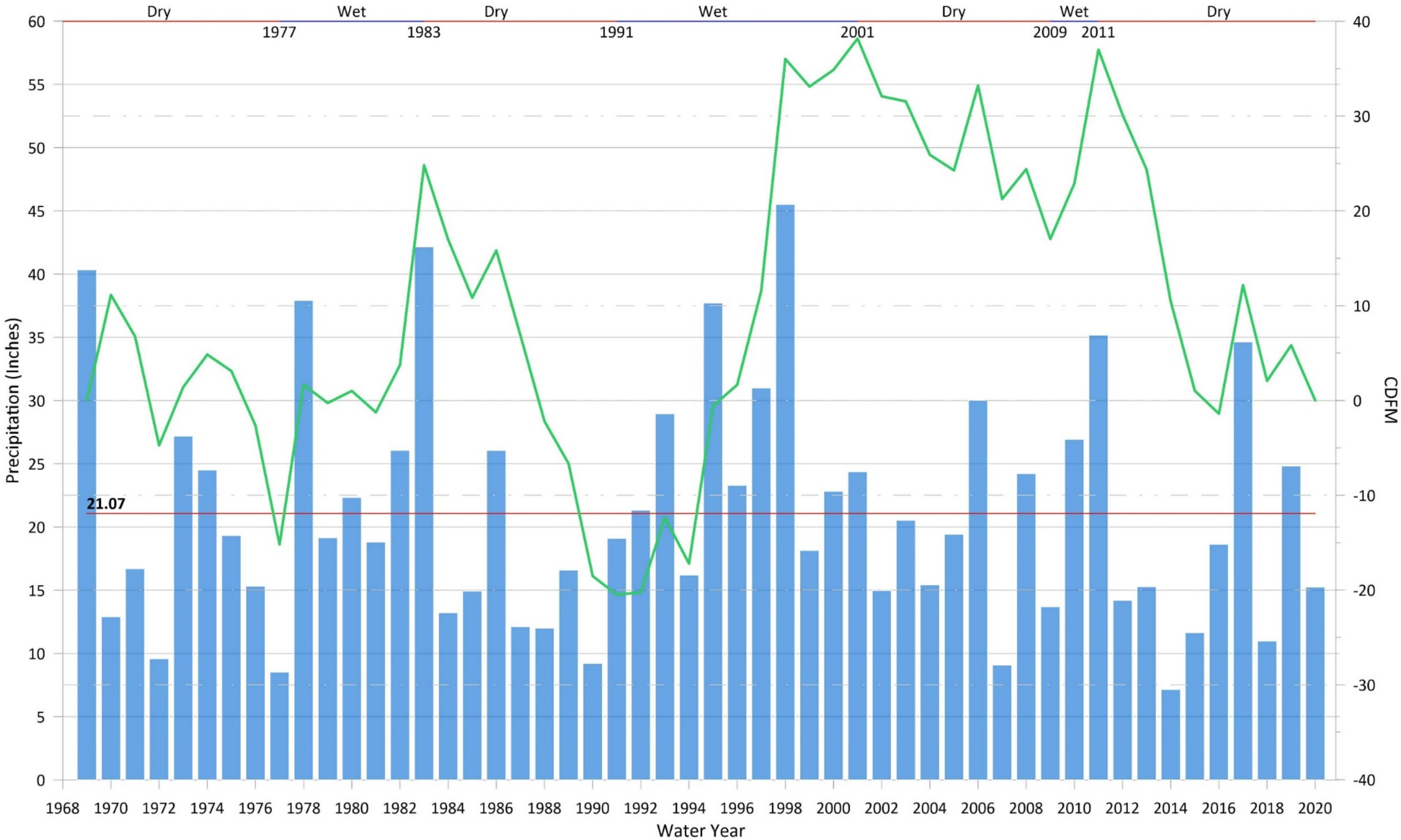
6.1.1 Historical Climate/Base Period

The historical rainfall record at Lopez Dam has been used to define a period of years, referred to as a base period, which represents long-term hydrologic conditions. As described by DWR (2002):

> *The base period should be representative of long-term hydrologic conditions, encompassing dry, wet, and average years of precipitation. It must be contained in the historical record and should include recent cultural conditions to assist in determining projected Basin operations. To minimize the amount of water in transit in the zone of aeration, the beginning and end of the base period should be preceded by comparatively similar rainfall quantities.*

The historical rainfall record for the Lopez Dam Station was presented in Figure 3-10; Chapter 3. The SLOCFCWCD reports rainfall data on a water year basis running from July 1 through June 30 (also referred to as rainfall year), while stream flow data is reported from October 1 through September 30 (San Luis Obispo County, 2005). The DWR reports hydrologic data on a water year basis from October 1 through September 30. These conventions are maintained for the water budget, and the DWR water year is used for all water budget components of inflow and outflow. Water years are referenced herein based on the ending year.

The hydrologic base period selected to represent historical climatic conditions for the Subbasin encompasses the years 1988 through 2020 (33 years). Average precipitation at Lopez Dam over this base period was 20.9 inches, compared to the long-term average of 21.07 inches, and included wet, average, and dry periods (Figure 6-5). These periods are visually defined by the movement of the cumulative departure from mean precipitation curve, which declines over dry periods, is flat through average periods, and rises over wet periods.



Arroyo Grande Historical Annual Precipitation and CDFM

Figure 3-10

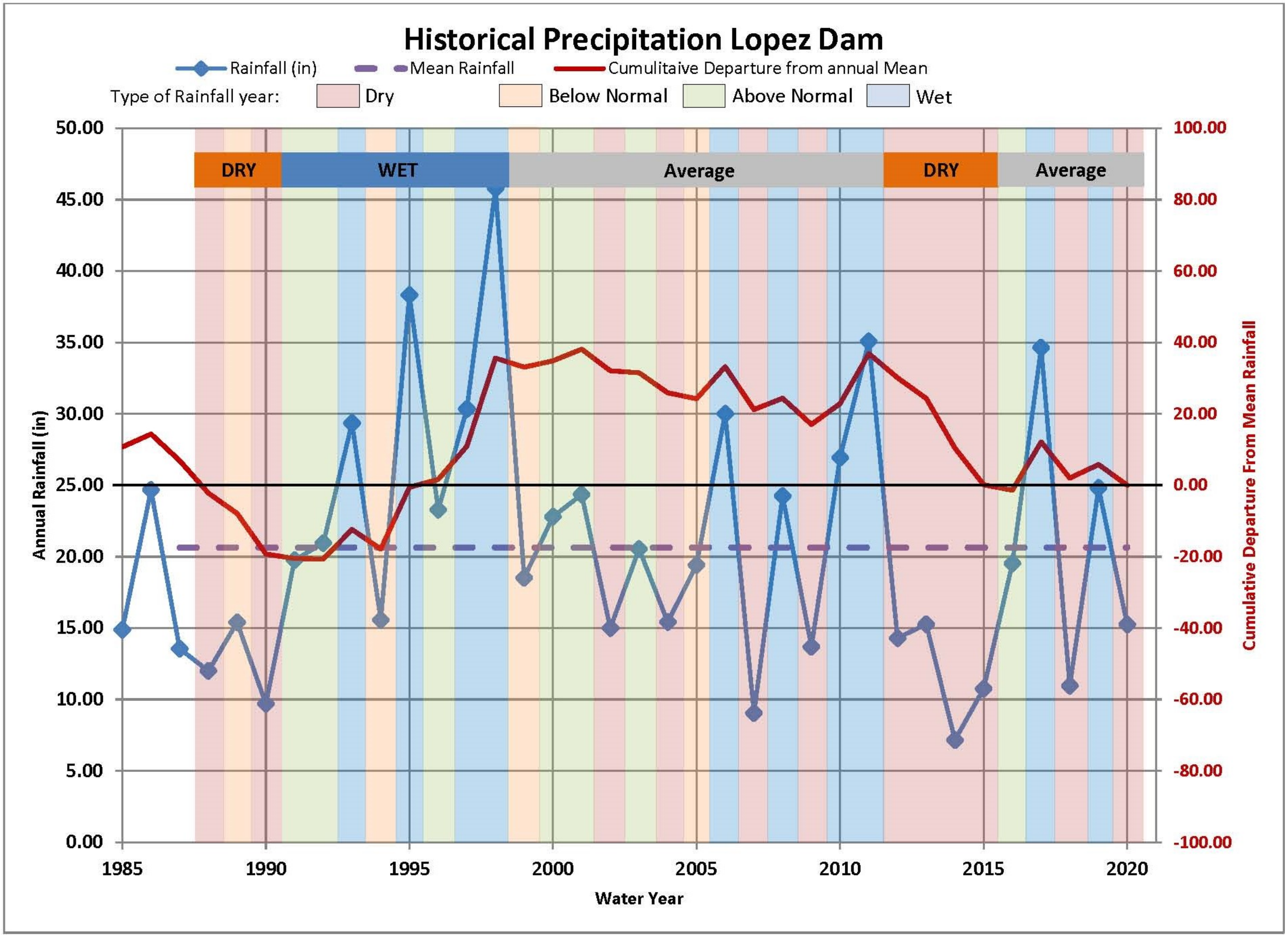


Figure 6-5: 1988-2020 Historical Base Period Climate.

Water year types for this water budget have been developed and classified based on annual precipitation as a percentage of the previous 30-year average precipitation. Each July 1 through June 30 rainfall year of the historical base period was given a ranking of 1 (wettest) through 30 (driest) based on a comparison to a 30-year (rolling) data set. The minimum precipitation threshold for wet type years was assigned based on the average for the 10th ranked year (23.75 inches). The maximum precipitation threshold for dry type years was assigned based on the average for the 21st ranked year (15.05 inches). Below normal (from 15.05 to less than 19.66 inches) represents the 16th through 20th ranked years, while above normal (from 19.65 to 23.75 inches) represents the 10th through 15th ranked years. Note that the division between below normal and above normal rainfall (19.66 inches) is less than the average over the base period (20.9 inches) because there are more below average rainfall years than above average years. The water year types were developed from Lopez Dam rainfall records. The rainfall thresholds for water year types are summarized in Table 62.

Table 6-2: Rainfall Thresholds for Water Year Types.

Water Year Type	Rainfall Threshold (in.)*
Dry	<15.05
Below Normal	15.05 - <19.66
Above Normal	19.66 – 23.75
Wet	>23.75

*As measured at Lopez Dam

The base period includes recent cultural conditions (i.e. water supply, water demand, and land use) as recommended. Differences between water in transit in the vadose zone (deep percolation of precipitation and stream seepage) are minimal, based on comparing the two rainfall years leading up to the beginning and ending of the base period. The 1986 and 1987 rainfall years leading into the base period have 24.68 inches and 13.56 inches, respectively, compared to 24.82 and 15.25 inches of rainfall at the end of the base period in 2019 and 2020 (Figure 6-5).

An isohyetal map of average annual rainfall is shown in Figure 4-3 (Chapter 4). The average annual precipitation across the Subbasin between 1981 and 2010 ranged from 15.5 inches to 20 inches, and averaged approximately 17 inches.

The water budget uses the Lopez Dam rain gauge (Station 737) to identify the historical base period and water year types due to the extensive period of record. Annual rainfall used in the surface water budget calculations that involve precipitation volumes, however, are adjusted to account for the difference between rainfall at the dam and average rainfall across the Subbasin.

Table 6-3 presents the annual rainfall at Lopez Dam over the historical base period. Water years are listed as dry, below normal, above normal, and wet in accordance with the thresholds described above. Average annual rainfall over the historical base period at the dam is estimated to be 20.9 inches.

Table 6-3: Historical Base Period Rainfall.

Year	Type	Lopez Dam Rainfall (in.)
1988	Dry	12.00
1989	Below Normal	15.40
1990	Dry	9.70
1991	Above Normal	19.77
1992	Above Normal	20.96
1993	Wet	29.36
1994	Below Normal	15.57
1995	Wet	38.34
1996	Above Normal	23.29
1997	Wet	30.34
1998	Wet	45.80
1999	Below Normal	18.53
2000	Above Normal	22.80
2001	Wet	24.36
2002	Dry	15.00
2003	Above Normal	20.55
2004	Below Normal	15.43
2005	Below Normal	19.43
2006	Wet	30.02
2007	Dry	9.05
2008	Wet	24.26
2009	Dry	13.70
2010	Wet	26.93
2011	Wet	35.08
2012	Dry	14.30
2013	Below Normal	15.28
2014	Dry	7.16
2015	Dry	10.76
2016	Below Normal	19.53
2017	Wet	34.64
2018	Dry	10.97
2019	Wet	24.82
2020	Below Normal	15.25
Average		20.9

6.2 WATER BUDGET DATA SOURCES

The following sources and types of data have been used for the water budget:

- Hydrogeologic and geologic studies and maps
- County stream flow gages
- County and NOAA precipitation Stations
- PRISM 30-year normal dataset (1981-2010)
- CIMIS weather station data
- Aerial Imagery
- County water level monitoring program
- City of Arroyo Grande, County, and DWR land use data and planning documentation
- County Ag Commissioner's Office data sets
- County Water Master Plan
- Stakeholder supplied information
- Water rights filings

6.3 HISTORICAL WATER BUDGET

In accordance with GSP regulations, the historical water budget shall quantify the following, either through direct measurement or estimates based on data (reference to location of data in Chapter 6 also listed):

(1) Total surface water entering and leaving a Basin by water source type (Table 6-1).
(2) Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs, and conveyance systems (Table 6-1).
(3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow (Table 6-1).
(4) The change in annual volume of groundwater in storage between seasonal high conditions (Table 6-1).
(5) If overdraft occurs, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions (Section 6.3.8).
(6) The water year type associated with the annual supply, demand, and change in groundwater stored (Table 6-1).
(7) An estimate of sustainable yield for the Basin (Section 6.3.7).

6.3.1 Historical Time Period

The time period over which the historical water budget is estimated is the hydrologic base period from 1988-2020 (33 years). Groundwater storage calculations using the specific yield method were performed for Spring 1987, 1990, 1996, 2002, 2009, 2011, 2015, 2017, and 2020. These years include the beginning (Spring 1987) and ending (Spring 2020) storage in the base period, with multiple interspersed years to characterize change in storage trends through the base period.

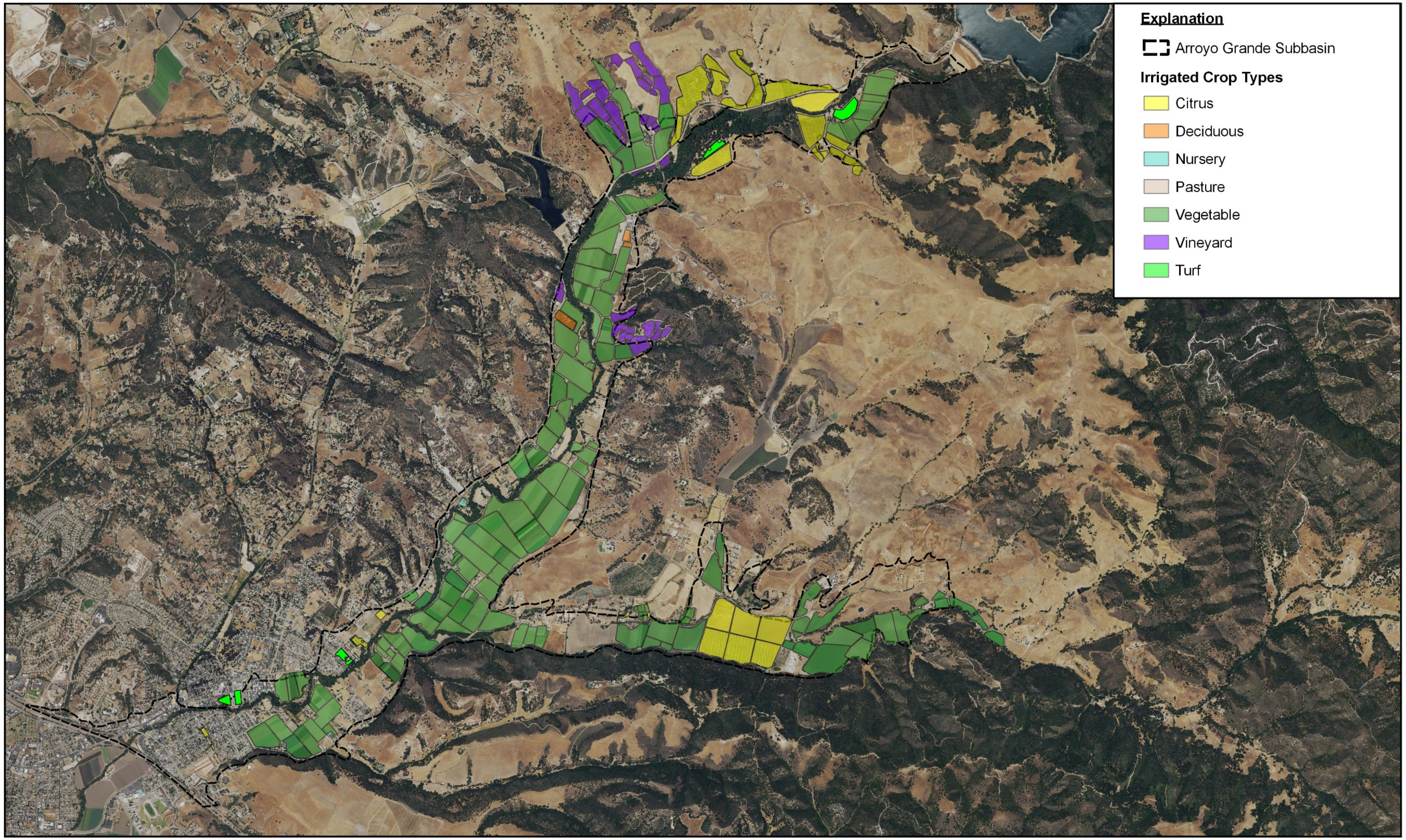
6.3.2 Historical Land Use

Land use is one of the primary data sets used in developing a water budget. Several types of land use/land cover in the basin have been used to estimate components of the water budget. For example, the acreages of various crops are multiplied by their respective water use factors to estimate agricultural groundwater extractions (Section 6.3.4.2), and acreages of various land covers are multiplied by empirical correlations to estimate their respective evapotranspiration and percolation of precipitation (Section 6.3.4.1). The land uses/land covers including the following:

- Irrigated Agriculture
    - Citrus
    - Deciduous
    - Pasture
    - Vegetable
    - Vineyard
- Native Vegetation
    - Brush, trees, native grasses
    - Wetlands/open water (Riparian)
- Urban/Suburban
    - Developed (City, subdivisions)
    - Open space (parks, empty lots)
    - Turf (play fields)

Irrigated Agriculture

Irrigated crop acreage was estimated from aerial imagery of the Subbasin for the following years: 1989, 1994, 1999, 2003, 2005, 2007, and 2011. San Luis Obispo County land use data was used for crop acreage from 2013 to 2020. The DWR land use survey for 1985 was also used. Figure 6-6 shows an example of the County irrigated crop data set for 2018.



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Author: TK
Date: 08/10/2021

ARROYO GRANDE SUBBASIN GSP

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0 0.25 0.5 0.75 mi
0 0.5 1 km

References:

1. Coordinate System: State Plane California V FIPS 0405 Feet
2. Projection: Lambert Conformal Conic
3. Horizontal Datum: NAD 83
4. Vertical Datum: NAVD 88
5. Basemap: NAIP 2018 Imagery

Notes:

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Arroyo Grande Subbasin Irrigated Crops 2018

Figure 6-6

Irrigated acreage for years in the historical base period without aerial imagery, surveys, or County data were estimated from the nearest available year with data. Acreages for irrigated crops, estimated from aerial imagery and County datasets used to characterize the historical base period are shown in Table 6-4.

Table 6-4: Irrigated Agriculture Acreages.

Crop Type	1985	1989	1994	1999	2003	2005	2007	2011	2013	2014	2015	2016	2017	2018	2019
	San Luis Valley Subarea (acres)														
Citrus	26	99	132	130	152	152	156	156	156	176	176	192	192	245	262
Deciduous	5	5	5	10	10	10	27	27	30	22	22	1	10	8	18
Pasture	36	15	1	3	3	3	3	3	3	3	3	3	2	2	0
Vegetable	1,508	1,462	1,414	1,356	1,312	1,328	1,309	1,294	1,307	1,238	1,275	1,063	1,130	1,099	1,018
Vineyard	80	64	93	96	127	127	133	128	128	121	124	127	135	111	111
Subtotal	1,654	1,645	1,646	1,594	1,603	1,619	1,628	1,609	1,625	1,561	1,601	1,386	1,469	1,465	1,410

Native Vegetation and Urban Areas

Native vegetation acreages were compiled using data sets from the National Land Cover Database (NLCD), which is derived primarily from satellite imagery. The years for which NLCD coverage is available are 2001, 2004, 2006, 2008, 2011, 2013, 2016, and 2019. Adjustments to the acreages in the NLCD data were performed to reconcile with the agricultural acreages and urban turf areas compiled using the aerial imagery and crop survey data set. Where the NLCD data sets showed less agricultural acreage than the aerial imagery, the native vegetation (brush, trees, grassland) acreage and urban open space was reduced or increased so the total basin acreage remained constant. The estimated acreages for native vegetation and urban areas, along with irrigated agriculture interpolated from Table 6-4, are presented in Table 6-5 below.

Table 6-5: Land Cover Acreages.

Land cover	2001	2004	2006	2008	2011	2013	2016	2019
	Arroyo Grande Subbasin (acres)							
Native - brush, trees, grassland	513	517	505	491	493	484	542	582
Native - Riparian*	281	281	281	282	283	282	282	285
Urban - Developed	394	396	399	400	401	404	408	404
Urban - Open Space	102	84	79	86	97	79	134	181
Urban - Turf	10	10	14	17	17	17	17	17
Irrigated Agriculture	1,599	1,611	1,621	1,623	1,609	1,632	1,516	1,429
Subbasin Total	2,899	2,899	2,899	2,899	2,899	2,899	2,899	2,899

*riparian corridors mapped as wetlands/open water in NLCD imagery

6.3.3 Historical Surface Water Budget

The surface water system is represented by water at the land surface within the boundaries of the Subbasin. As previously mentioned, surface water systems for the water budget include the atmospheric system, lakes & streams system, and the land surface system (Figure 6-2).

6.3.3.1 Components of Surface Water Inflow

The surface water budget includes the following sources of inflow:

- Local Supplies
    - Precipitation
    - Groundwater extractions

  - Stream inflow at Basin boundary
  - Surface Water Deliveries
  - Groundwater-Surface Water Interactions
- Local Imported Supplies
  - Lopez Reservoir Water
  - Groundwater from outside the Subbasin

Precipitation

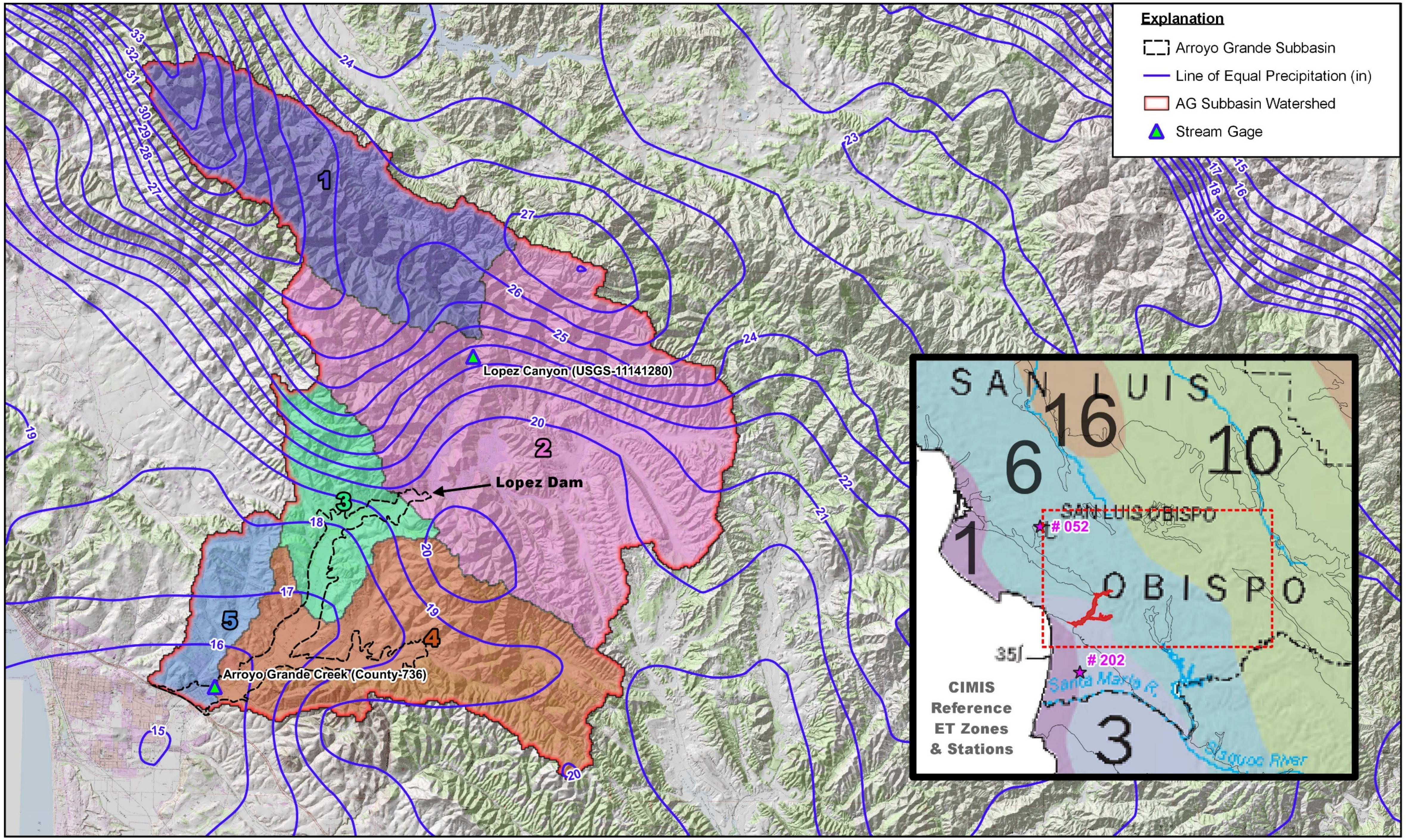
Precipitation occurs as rainfall. The annual volume of rainfall within the Subbasin has been estimated as 80 percent of the rainfall year totals for Lopez Dam, multiplied by the Subbasin area. As previously mentioned, the average rainfall over the subbasin is lower than the average at the Lopez Dam rain station. Rainfall volumes falling within the subbasin boundary are shown as precipitation in the surface water inflow budget of Table 6-1.

Groundwater Extractions

Groundwater extractions are included in the surface water budget as inflow because after extraction groundwater is distributed and applied at land surface. These extractions are then divided into Urban and Agricultural water use sectors and match the groundwater extraction outflow values from the groundwater budget. Details on data collection and groundwater pumping estimates are provided in the Historical Groundwater Budget section (Section 6.3.3).

Stream Inflow at Basin Boundary

Inflow along stream channels at the Subbasin boundary has been estimated based on paired watershed methodology. The total watershed area drained by the Subbasin was divided into 5 sub-watershed areas, one of which is the subarea drained by Lopez Canyon (sub-watershed 1, Figure 6-7). Annual (water year) flows from 1988 through 2020 at the Lopez Canyon stream gage was then processed using a watershed area factor and an isohyetal factor to estimate annual flows for each of the other subareas. The watershed area factor was the ratio of the watershed area for which flow was being estimated to the Lopez Canyon gage watershed area. The isohyetal factor addressed differences between the average annual rainfall across each of the sub-watersheds being compared, and consisted of the ratio of average annual precipitation above 13.5 inches between sub-watersheds.



Prepared For:

ARROYO GRANDE SUBBASIN GSP

Author: TK
Date: 08/10/2021

References:
1. Coordinate System: State Plane California V FIPS 0405 Feet
2. Projection: Lambert Conformal Conic
3. Horizontal Datum: NAD 83
4. Vertical Datum: NAVD 88
5. Basemap: USGS 7.5' Topographic Map

Notes:
1.
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Subbasin Watershed Areas and Isohyetals

Figure 6-7

Surface Water Deliveries

Surface water deliveries represent the movement of water generated by surface water diversion between the streams & lakes system to the land surface system (Figure 6-2). In the surface water budget, in-stream diversions are represented as outflow, and the delivery of this water for irrigation is inflow. They are offsetting values, and further discussed under surface water diversions (Section 6.3.3.2).

Groundwater-Surface Water Interaction (Net)

Groundwater-surface water interactions take place primarily along stream channels. When groundwater is rising into streams (gaining reaches of a stream), the interaction is a surface water budget inflow and a groundwater budget outflow. Conversely, when stream flow is percolating to groundwater (losing reaches of a stream), the interaction is a surface water budget outflow and groundwater budget inflow. This water budget has combined the gaining and losing stream reaches into single (net) term, the result of which are net losing streams in the Subbasin, which is an outflow component of the surface water budget and inflow component of the groundwater budget. Net groundwater-surface water interaction was estimated by adjusting the percent of stream inflow that recharges groundwater while optimizing the water balance. The optimization consisted of minimizing the sum of squares of the residual error between the calculated change in storage and measured change in storage (Section 6.3.4.1).

Local Imported Supplies

The City of Arroyo Grande imports water from Lopez Reservoir and also uses groundwater from outside the Subbasin. A portion of the local imported supplies are delivered to customers overlying the subbasin. In order to estimate the volumes of local imported supplies delivered to City residents overlying the Subbasin, the acreages of various City land use classifications (such as Village Core, Single Family Residential Medium Density, and Mixed Use) were multiplied by water use factors for each land use type reported in the Arroyo Grande Urban Water Management Plan (2012, Updated 2015). Local imported supplies are presented in the surface water budget of Table 6-1.

6.3.3.2 Components of Surface Water Outflow

The surface water budget includes the following sources of outflow:

- Evapotranspiration of Precipitation
- Evapotranspiration of Applied Water
- Riparian Corridor ET
- Infiltration of Precipitation
- Infiltration of Applied Water
- Wastewater Export
- Surface Water Diversions
- Groundwater-Surface Water Interaction
- Stream outflow (runoff)

Evapotranspiration of Precipitation

The fate of precipitation that falls within the Subbasin boundaries can be divided into three components: evapotranspiration, infiltration, and runoff. Of these three, infiltration has the greatest influence on the groundwater budget and ultimately, Subbasin sustainable yield. Therefore, the approach to estimating the fate of precipitation uses a methodology focused primarily on infiltration, but from which the other two components may also be estimated. This methodology is based on work by Blaney (1933, 1963), and which has been used for other analytical water budgets in major studies of central coast Basins (DWR, 2002; Fugro, 2002).

Evapotranspiration is the evaporation of water from surfaces and the transpiration of water by plants. The first seasonal rains falling on the Subbasin are mostly evaporated directly from surfaces (vegetative canopy, soil, urban area hardscapes) and used to replenish soil moisture deficits that accumulate during the dry season. For the Arroyo Grande – Nipomo Mesa area of the Santa Maria Groundwater Basin, DWR (2002) assumed that precipitation could begin to infiltrate to groundwater (deep percolate) only after 11 inches of annual precipitation had fallen in urban and agricultural irrigation areas, and when 17 inches of rainfall had fallen in areas of native vegetation. In the Paso Robles groundwater Basin, an estimated 12 inches of annual rainfall was needed for infiltration below agricultural lands, while 18 inches of rainfall was needed for infiltration beneath native ground cover and urban/suburban areas (Fugro, 2002).

These threshold values for minimum annual rainfall prior to infiltration are assumed to approximate the annual evapotranspiration of precipitation. Once these thresholds are exceeded, infiltration to groundwater and runoff would become dominant. It is recognized that a portion of the initial annual rainfall may result in runoff, depending on rain intensity, but this is assumed to be offset by the portion of the late season rainfall that is evapotranspired. Since infiltration is the critical component of precipitation with respect to Subbasin sustainable yield, offsetting of early wet season runoff with late wet season evapotranspiration in the water budget is considered a reasonable approach.

The specific thresholds for annual rainfall that are estimated to evapotranspire prior to infiltration and runoff have been developed from Blaney's field studies. Evapotranspiration of precipitation has been estimated by multiplying land use/land cover acreages by the infiltration threshold values. Results of these estimates are shown in the surface water budget of Table 6-1. Additional details of the methodology are provided in section 6.3.4.1 (Components of Groundwater Inflow).

Evapotranspiration of Applied Water

The evapotranspiration of applied irrigation water has been divided into urban and agricultural sectors. Urban applied water includes residential outdoor irrigation and park/play field irrigation. Most of the urban applied water is from imported local supplies by the City of Arroyo Grande. Other water purveyors within the Subbasin are relatively small (typically less than 30 connections) and are considered rural residential. Estimation of applied water for agricultural irrigation involves a soil-moisture balance approach discussed in section 6.3.4.1 (Components of Groundwater Outflow).

Most water applied for irrigation is taken up by plants and transpired. Some water, however, is lost to evaporation or infiltrates to groundwater as return flow. The evapotranspiration of applied irrigation water has been calculated by subtracting the estimated return flow from the applied water estimates. Both applied water and return flow estimates are presented under the historical groundwater budget section. Results of the calculations of evapotranspiration of applied water are shown in the surface water budget of Table 6-1.

Riparian Corridor Evapotranspiration

Riparian plant communities present along the creeks can access surface flows and creek underflow. An estimated 282 acres of riparian areas are included within the Subbasin (Table 6-5) based on the interpreted NLCD satellite imagery, which maps the riparian corridors as mostly woody wetlands and emergent herbaceous wetlands, with a few acres of open water. Given that the riparian corridor is directly connected to adjacent surface flows, and stream flow is present throughout of the year, water use for the riparian corridor is included in the surface water budget. Riparian vegetation water use is the evapotranspiration of precipitation estimated for the native brush, trees, and grasses land cover, with an additional 0.8 acre-feet per acre of consumptive water use (Fugro, 2002; Robinson, 1958). Riparian evapotranspiration is included in Table 6-1.

Infiltration of Precipitation and Applied Water

Infiltration of precipitation and applied water are both outflow components from the surface water budget and inflow components to the groundwater budget. Discussion of these components is provided in Section 6.3.4.1 (Components of Groundwater Inflow).

Wastewater Export

When imported surface water is brought into the Subbasin from local supplies (Lopez Reservoir), it is counted as surface water inflow. This imported water is then provided to customers through deliveries from the City of Arroyo Grande. After residential and business use, most of the delivered water that was used indoors is conveyed by sewer out of the Subbasin to a wastewater treatment plant (South San Luis County Sanitation District) for treatment and discharge. Since the wastewater does not return to the Subbasin, it is effectively exported. Similar to the estimated for Local Imported Supplies, the acreages of various City land use classifications (such as Village Core, Single Family Residential Medium Density, and Mixed Use) were multiplied by sewer flow factors for each land use type reported in the Arroyo Grande Wastewater Master Plan (City of Arroyo Grande, 2012) and shown in the surface water budget of Table 6-1.

Stream Flow Diversions

Stream flow on Arroyo Grande Creek is subject to permitted diversion by in-stream pumping. Reported annual stream flow diversions were compiled from available records, which were considered representative beginning in 2009 (more complete reporting). The reported creek flow diversions ranged from 340 acre-feet in 2009 to 600 acre-feet in 2012, with an annual average diversion of 450 acre-feet per year between 2009 and 2019. The resulting estimated stream inflow estimates for the historical base period are shown in the surface water budget of Table 6-1.

Groundwater-Surface Water Interaction (Net)

Groundwater-surface water interaction involves both surface water and groundwater budgets. The net interaction is an outflow component for the surface water budget and an inflow component for the groundwater budget (losing streams). Details of the methodology used to develop the groundwater-surface water interaction are presented in the Sections 6.3.4.1 and 6.3.6.

Stream Outflow from Basin

Stream outflow was estimated using the water balance method and compared to available flow records. No significant changes to surface water in storage are assumed in the water budget from year to year. Storm water runoff exits the Subbasin annually, and creek storage fluctuations are considered minor compared to the total surface water budget. Lopez Reservoir and Lopez Terminal Reservoir are outside of the Subbasin boundary.

Using the water budget equation, stream outflow is estimated as the difference between total surface water inflow and all other components of surface water outflow. Results of stream outflow calculations are presented in Table 6-1. The stream gage on Arroyo Grande Creek at the City of Arroyo Grande (Station 736) is the closest gage to the south Subbasin boundary, and captures runoff from approximately 95 percent of the watershed drained by the subbasin (roughly 65,500 acres gaged out of 68,700 acres of watershed (including watershed area above Lopez Dam).

A comparison of gaged stream flow at Station 736 with the estimated stream flow leaving the basin from the surface water budget is presented in Figure 6-8. The comparison shows that the surface water budget produces stream outflow estimates that are reasonably close to the measured flows at Station 736.

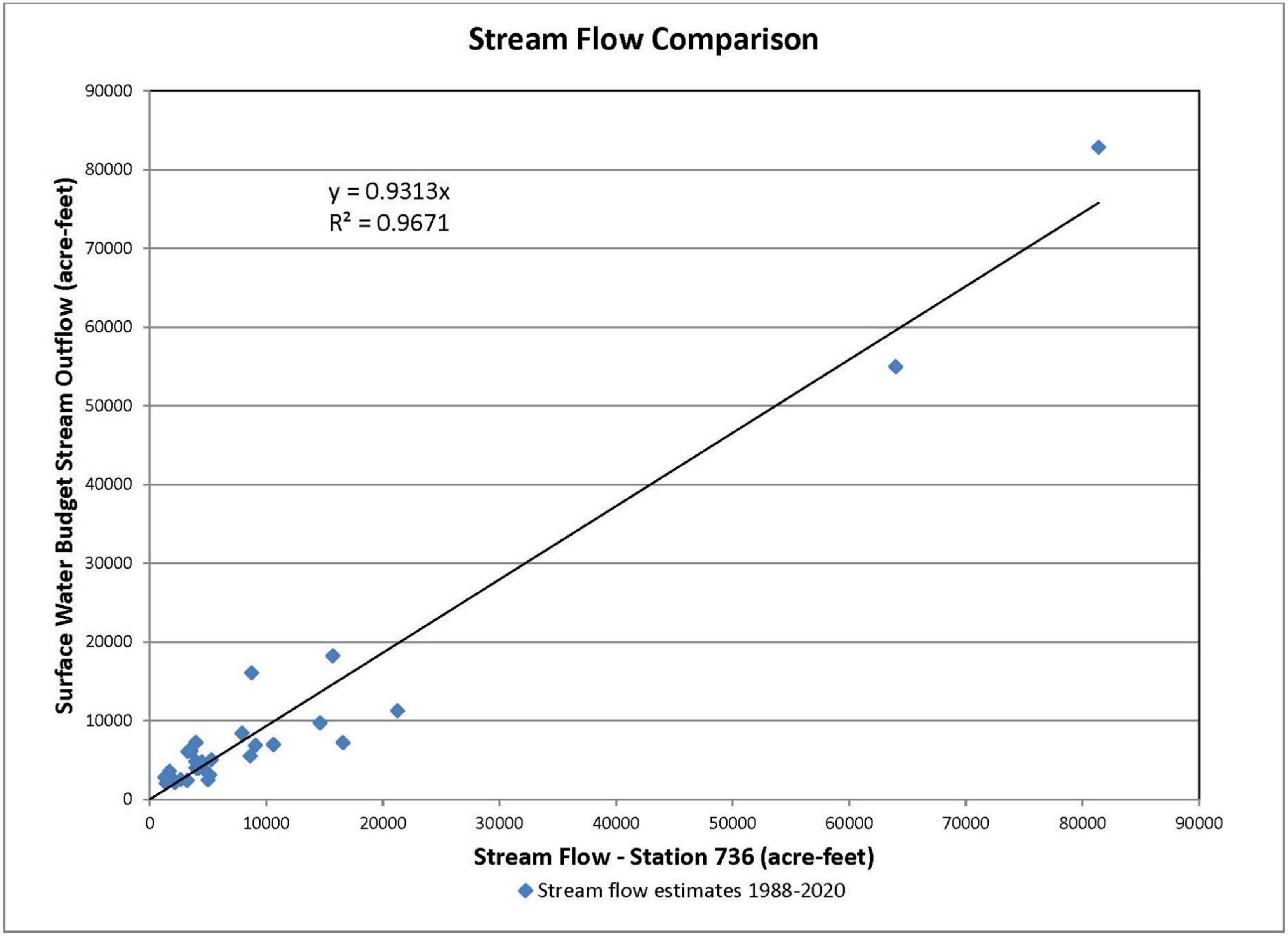


Figure 6-8: 1988-2020 Stream Flow Comparison.

6.3.4 Historical Groundwater Budget

The groundwater budget includes the following sources of inflow:

- Infiltration of Precipitation
- Groundwater-Surface Water Interaction
- Subsurface Inflow
- Infiltration of Applied Water (Return Flow)

The groundwater budget includes the following sources of outflow:

- Groundwater Extractions
- Subsurface Outflow
- Groundwater-Surface Water Interaction

6.3.4.1 Components of Groundwater Inflow

Infiltration of Precipitation

Infiltration of precipitation refers to the amount of rainfall that directly recharges groundwater after moving through the soil and unsaturated zone (Figure 6-2). Direct measurement of infiltration has not been performed in the Subbasin, and estimates have been prepared based on prior work by Blaney (1933) in Ventura County basins and Blaney et al. (1963) in the Lompoc Area. These studies involved soil moisture measurements at rainfall penetration test plots with various types of land cover, and the resulting deep percolation versus rainfall correlations have been considered applicable to central coast Basins (DWR, 2002; Fugro, 2002). The work by Blaney is several decades old, however, modeling efforts have shown the generalizations are relatively accurate for semi-arid climates (Rosenberg, 2001). The main advantage of Blaney's approach is that it is based on direct measurements of infiltration of precipitation.

Criteria based on Blaney et al. (1963) were used for analytical water budgets in the Santa Maria Valley and Tri-Cities Mesa areas, where it was assumed that precipitation could infiltrate only in urban and agricultural areas when 11 inches of precipitation had fallen annually, and on areas of native vegetation when 17 inches of precipitation had fallen annually. Any amount of rainfall above 30 inches annually was not considered to contribute to deep percolation of precipitation, regardless of the land use classification (DWR, 2002). Correlations between infiltration and annual rainfall based on Blaney (1933) were also used historically for the 2002 Paso Robles Groundwater Basin analytical water budget (Fugro, 2002).

Estimates for infiltration of precipitation for the Arroyo Grande Subbasin have been developed by applying Blaney correlations that restrict deep percolation to precipitation in agricultural areas that occurs after 11-12 inches of rainfall, and in native vegetation areas after approximately 18 inches of rainfall. Native vegetation was the most restrictive land cover for infiltration when tested by Blaney due to high initial soil moisture deficiencies.

Urban areas were not part of the original studies by Blaney. The low permeability of hardscape (buildings and paving) limits infiltration and increases surface evaporation, compared to other types of land cover, but hardscape also increases runoff, which can lead to greater infiltration in adjacent areas receiving the runoff. Therefore, the infiltration threshold was set higher than irrigated agricultural land, but not as high as native grasslands. The Blaney correlation that produces infiltration between irrigated agriculture and native grassland is the curve for non-irrigated grain, with an infiltration threshold of approximately 14 inches of rainfall. Figure 6- plots the data collected by Blaney (1933).

As with prior work by the DWR in northern Santa Barbara and southern San Luis Obispo Counties, rainfall above 30 inches was not considered to contribute to deep percolation in the Basin (DWR, 2002). The rainfall values used for the Blaney Correlations in the Subbasin were 80 percent of the rainfall totals at Lopez Dam. Infiltration of precipitation results are shown in Table 6-1.

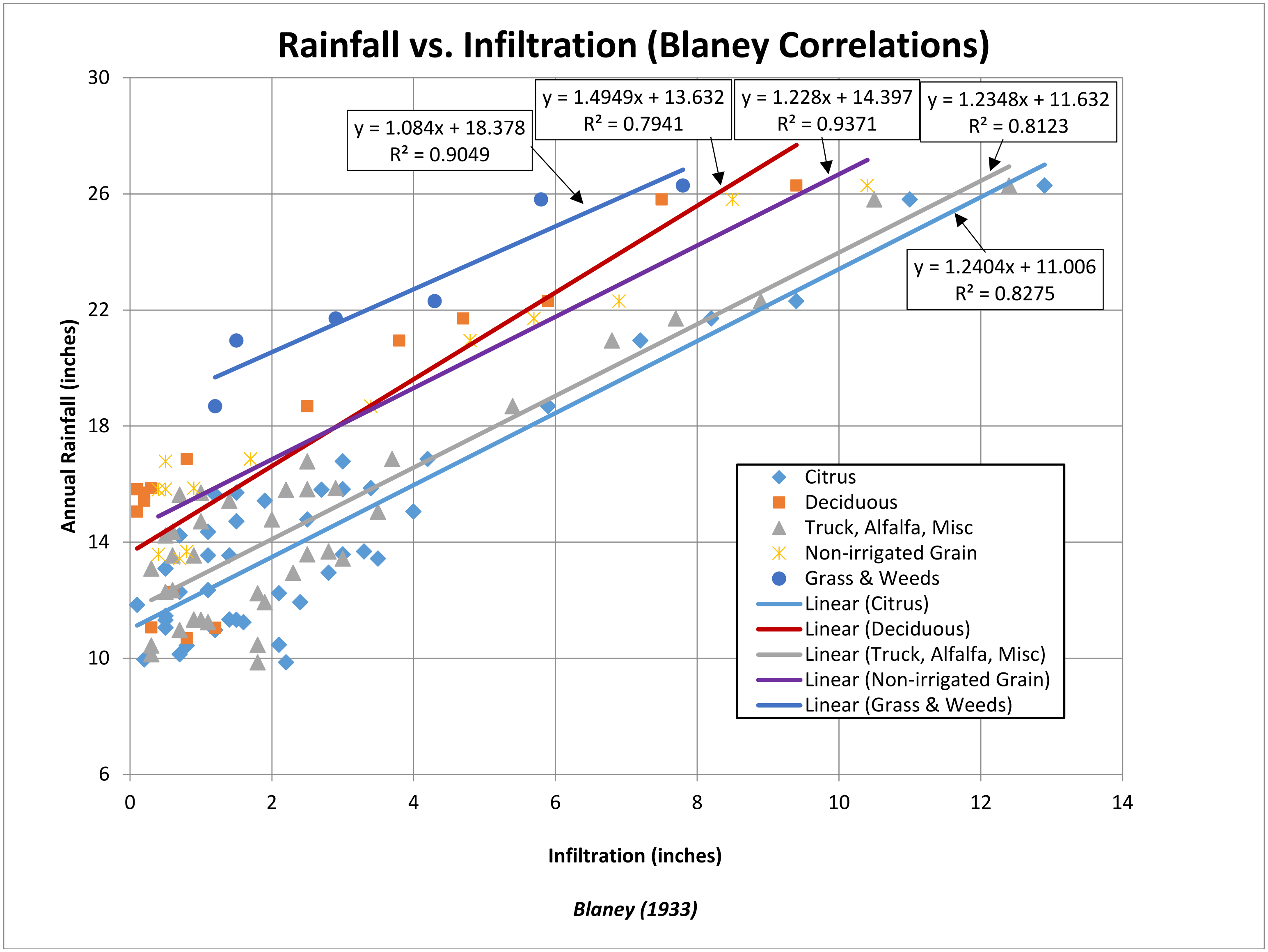


Figure 6-9: Rainfall vs Infiltration.

The land use classifications for which infiltration thresholds have been developed for this GSP include citrus, deciduous, pasture, vegetable, vineyard, native brush/grassland (includes riparian corridors), urban developed/open space, and urban turf. The minimum rainfall needed before infiltration of precipitation can occur for various land uses and covers are summarized in Table 6-6.

Table 6-6: Minimum Rainfall for Infiltration.

Land Use/Cover	Infiltration Threshold (in.)
Citrus	11.0
Deciduous	13.6
Pasture	11.6
Vegetable	11.6
Vineyard	13.6
Native brush/grassland	18.4
Urban developed/open space	14.4
Urban turf	11.6

Groundwater-Surface Water Interaction (Net)

As previously mentioned, groundwater-surface water Interaction involves both components of the surface water and groundwater budgets. The net interaction is an outflow component of the surface water budget and inflow component of the groundwater budget (losing streams).

The groundwater-surface water interaction component is estimated using a mass balance approach for the Subbasin by adjusting the percent of stream inflow that percolates to groundwater (as recharge) while minimizing the sum of squares of the residual error between the calculated change in storage and the measured change in storage (specific yield method) for multiple years. It became apparent during water budget calibration that a variable percentage was needed depending on the type of year (a greater percentage of stream flow percolation during drought years) and reservoir operation (lowest percent of stream flow seepage during reservoir spill years).

The maximum amount of groundwater storage in Subbasin is assumed to be 15,200 acre-feet, based on the specific yield method. In 1998, inflow to the groundwater budget exceeded the maximum storage capacity, and some of the inflow (percolation of precipitation) was transferred to the surface water budget as stream outflow for that year. The groundwater-surface water interaction estimates are in Table 6-1. Additional details of the calibration methodology used to minimize the residual error are presented in Change in Storage (Section 6.3.6).

Subsurface inflow

Subsurface inflow from bedrock were estimated using Darcy's Law, which is an empirical formula describing the flow of fluid though a porous material, and expressed as:

$$Q = -K\frac{dh}{dl}A$$

Where:

Q = groundwater discharge rate through a cross-sectional area of the porous material
K = hydraulic conductivity of the material
$\frac{dh}{dl}$ = hydraulic gradient at the cross-section
A = cross-sectional area

The negative sign denotes that flow is in the direction of decreasing pressure. Since groundwater pressures are greater within the bedrock hills surrounding the Subbasin than beneath the alluvial valleys, there is subsurface inflow to the Subbasin from bedrock. The application of Darcy's Law to estimate subsurface inflow from bedrock involves simplification and assumptions of uniformity in the subsurface.

Cross-sectional areas for boundary flows were based on the approximate length of the Subbasin boundary (126,500 feet divided into 12 straight-line segments), multiplied by the estimated saturated thickness of Subbasin sediments adjacent to each segment (the weighted average was 70 feet thick). Hydraulic gradients for each segment were developed by averaging topographic slopes between a line along the Subbasin boundary and a line drawn at a 2,500-foot setback from the boundary, and assuming the average hydraulic gradient was approximately three-quarters of these slopes (0.75 ft/ft). The hydraulic conductivity of bedrock was estimated at a nominal 0.03 feet per day. The resulting average annual subsurface inflow from bedrock is 170 acre-feet per year.

Infiltration of Applied Water (Return Flows)

Estimates for infiltration of applied water include urban return flow and agricultural return flow. Urban return flow comes from water delivered for domestic or commercial/industrial uses that infiltrates to groundwater, mainly through landscape/turf irrigation and septic system discharges (includes suburban/rural residential return flow). Urban return flow does not include City wastewater that is collected and exported from the Subbasin, which is accounted for in the surface water budget. Agricultural return flows come from applied irrigation water to crops, originating from both groundwater wells and in-stream diversions.

The first step in estimating urban return flows was to separate delivered water (from local imported supplies and suburban groundwater) into indoor and outdoor use. An estimated 5 percent of indoor use is assumed to be consumptive use (95 percent return flow; EPA, 2008), while 85 percent of outdoor use is consumed (15 percent return flow) based on the typical range of estimates for other local Basins (DWR, 2002; Fugro, 2002). Almost all Indoor water use drains to septic systems or sewer systems. Outdoor water use is generally for irrigation, most of which evapotranspires into the atmosphere.

The distribution of indoor to outdoor water use will vary based on the user. For example, City customers in single-family homes (medium density) are estimated in the Water and Wastewater Master Plans (2015, 2012) to use approximately 700 gallons per day of water and produce 310 gallons per day of wastewater, for an average 44 percent indoor use and 56 percent outdoor use. The indoor and outdoor water use and associated return flows were estimated from water use by the City, suburban/rural residences, and a few commercial operations. Infiltration of Applied Water estimates for urban and agricultural sectors are presented in the historical water budget Table 6-1.

6.3.4.2 Components of Groundwater Outflow

Urban Groundwater Extractions

Groundwater extraction from wells is the primary component of outflow in the groundwater budget. Estimates for historical pumping were derived primarily from land use data and water duty factors, and from the daily soil-moisture budgets. There are no City groundwater extractions from the Subbasin.

Rural residential groundwater use was estimated based on the number of residences identified on aerial images within the Subbasin but outside of the City water service area. Each rural residence was assigned a water use of 0.8 AFY, consistent with the San Luis Obispo County Master Water Plan (Carollo, 2012) and with stakeholder-provided information. In addition to rural residences overlying the Subbasin, residences in two subdivisions with homes outside of the Subbasin but supplied by alluvial wells in the Subbasin were added to the total count.

Aerial images for multiple years were reviewed for rural residential development. The estimated number of residences outside of the City service area was compiled, and resulting computed rural residential water use for these years is presented in Table 6-7.

Table 6-7: Rural Residential Water Use.

Year	Arroyo Grande Subbasin	
	Estimated Number of Residences[1]	Estimated Water Use (AFY)[2]
1989	91	73
1994	93	74
1999	94	75
2002	98	78
2003	101	81
2007	117	94
2011	127	102
2014	136	109
2019	164	131

[1] outside City limits
[2] based on 0.8 AFY per residence

In addition to the above rural residential water use, there are three commercial operations in the Subbasin that were evaluated separately for water use: Talley Vineyard and Talley Farms in the upper Arroyo Grande Valley, and the Mushroom Farm in Tar Spring Canyon. Square footages of the various buildings were estimated from aerial imagery and multiplied by a nominal water duty factor of 0.06 acre-feet per year per 1,000 square feet, which is considered representative of warehouse, commercial service, and manufacturing (City of San Luis Obispo, 2000). The resulting combined water use for the three commercial operations was 10 acre-feet per year.

Agricultural Groundwater Extractions

Groundwater use for agricultural irrigation has been estimated using the DWR Consumptive Use Program Plus (CUP+; DWR, 2015) which is a crop water use estimator that uses a daily soil moisture balance. CUP+ was developed as part of the 2013 California Water Plan Update to help growers and agencies estimate the net irrigation water needed to produce a crop.

Daily climate data from CIMIS Station #52 (San Luis Obispo) from 1988 to 2020 were used in the CUP+ program, along with estimates for various crop and soil parameters. The climate data is used to determine local reference evapotranspiration (ETo) on a daily basis. Crop coefficients are then estimated for up to four growth stages (initial, rapid, mid-season, late-season) which determine the crop evapotranspiration (ETc) values. Lastly, the CUP+ program uses variables related to the soil and crop type to determine the estimated applied water demand (ETaw), which is equivalent to the net irrigation requirement. Figure 6-10 shows the annual ETaw for various crops during the historical base period, along with ETo and rainfall at CIMIS Station #52.

As noted in Section 6.1, the CIMIS Station at Cal Poly is within DWR reference evapotranspiration Climate Zone 6 (Upland Central Coast; average ETo of 49.7 inches), which is one of 18 climate zones in California based on long-term monthly average reference evapotranspiration (CIMIS, 1999). As shown in the inset in Figure 6-7, most of the Subbasin is within Climate Zone 3 (Coastal Valleys; average ETo of 46.3 inches). Therefore, the reference ETo at Cal Poly would be expected to be greater than in the Subbasin. As previously mentioned in Section 6.1, Nipomo CIMIS Station #202 is within Climate Zone 3, with a historical record going back to 2006 (Figure 6-7 inset). A correlation between the two CIMIS stations shows that the ETo at Station #202 is approximately 83 percent of the ETo at Station #52. Therefore, results of the 1988-2020 soil moisture budget using Station #52 were reduced by 17 percent to better represent the Arroyo Grande Subbasin.

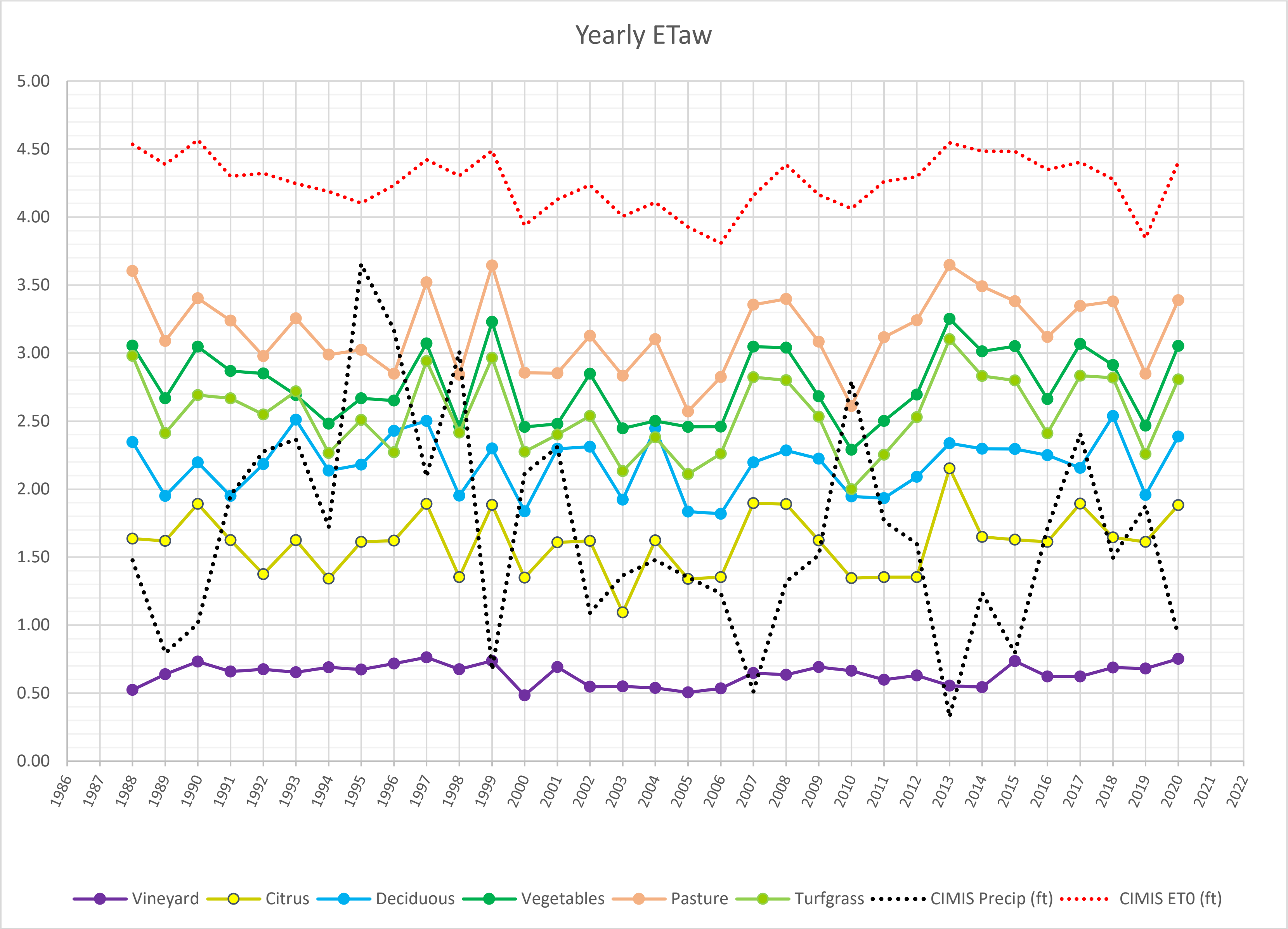


Figure 6-10: Consumptive Use of Applied Water.

Crop types were grouped according to the classification used by County Agricultural Commissioner's Office for crops overlying the Basin. These crop types included citrus, deciduous (non-vineyard), pasture, vegetable, and vineyard. A turf grass classification was added for estimating Urban sector water demand served by groundwater. The CUP+ program provides monthly water demand for each crop type during the hydrologic base period (1988-2020). Low, medium, and high consumptive use of applied irrigation water estimates are presented in Table 6-8. Low and high consumptive use are the respective annual minimum and maximum estimates over the base period, while medium consumptive use is the average. The CUP+ applied water requirement for vegetables was reduced by 40 percent to account for fallow acreage, which is not in production at any given time, based historical aerial image review and discussion with a local grower.

Table 6-8: Consumptive Use of Applied Water.

Crop Type	Acre-feet per acre per year		
	Low	Med	High
Citrus	0.9	1.3	1.8
Deciduous	1.5	1.8	2.1
Pasture	2.1	2.6	3.0
Vegetables*	1.1	1.4	1.6
Vineyard	0.4	0.5	0.6
Turfgrass	1.7	2.1	2.6

*60 percent of ETaw to account for fallow fields

As previously discussed in section 6.3.2 (Historical Land Use), the distribution of crop acreage was determined by a review and correlation of DWR and County crop surveys with aerial imagery. Crop acreages were interpolated between the years with data.

Applied water demand volumes were calculated by multiplying the annual acreage for each crop by the average annual applied water demand during each year. The final applied water estimates used for the water budget were adjusted to include efficiency (with system leakage) factors of 80 percent for drip/micro emitter and high-efficiency sprinkler irrigation (citrus, deciduous, vineyard, and turfgrass) and 75 percent for mostly sprinkler with some drip irrigation (pasture and vegetables), based on information from the County Water Master Plan (Carollo, 2012). The estimated groundwater extractions for agricultural water use are shown in the main water budget Table 6-1.

Subsurface Outflow

Subsurface outflow from Subbasin sediments occurs as underflow through the alluvial deposits of Arroyo Grande Creek. Outflow volumes were estimated using Darcy's Law (see Subsurface Inflow in Section 6.3.4.2). Table 6-9 presents the parameters used for subsurface outflow estimates.

Table 6-9: Subsurface Outflow Estimates.

Cross-sectional Area*	Hydraulic gradient	Hydraulic conductivity	Outflow
ft^2	ft/ft	ft/day	AFY
170,000	0.01	34	480

Cross sectional areas for outflow were based on the estimated saturated cross-sectional area of alluvial deposits in the vicinity of where the creek exits the groundwater Subbasin. Hydraulic gradients are the approximate grade of the stream channel, and the hydraulic conductivities are based on pumping tests

(Chapter 5). The outflow estimate is within the range of prior estimates by DWR (2002), but lower than the previous estimate of 2,000 AFY (GSI, 2018), mainly due to a lower hydraulic conductivity based on available pumping tests.

6.3.5 Total Groundwater in Storage

Groundwater is stored within the pore space of Subbasin sediments. The Specific yield is a ratio of the volume of pore water that will drain under the influence of gravity to the total volume of saturated sediments. The specific yield method for estimating groundwater in storage is the product of total saturated Subbasin volume and average specific yield. Calculation of total groundwater in storage for selected years was performed based on the specific yield method.

Estimates of specific yield for Subbasin sediments were obtained based on a review of 19 representative well logs. The lithology for each well log was correlated with specific yield values reported for sediment types in San Luis Obispo County (Johnson, 1967), and were weighted based on the thicknesses of individual sediment types in each log. A summary of the correlations is shown in Table 6-11. Locations of well logs used for the specific yield correlations are shown in the referenced cross-sections from Chapter 4. The average specific yield for the alluvial deposits is estimated at 14.7 percent, compared to 12 percent previously estimated by DWR (2002).

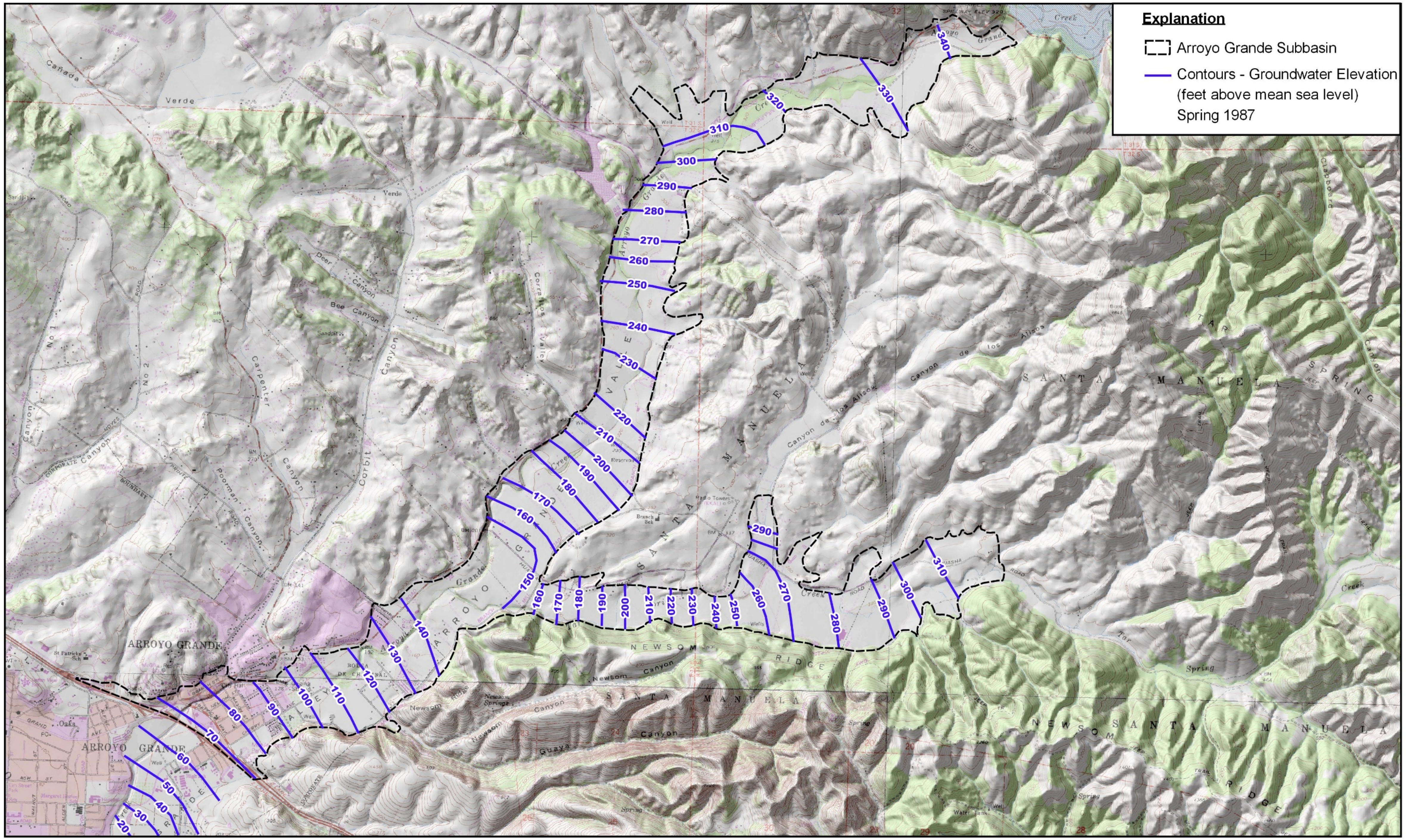
Table 6-10: Specific Yield of Alluvial Deposits.

Well ID	Cross-Section	Specific Yield (%)
961610	*A'-A"*	21.0
1981-003	*A'-A"*	21.2
E0074069	*A'-A"*	18.9
WCR2018-06066	*A'-A"*	17.8
906318	*A'-A"*	15.8
E0047973	*A'-A"*	12.6
E0111409	*A'-A"*	11.8
E0074480	A-A'	15.7
0962373	A-A'	12.6
003929	A-A'	15.4
E0063597	A-A'	11.6
00792659	*B-B'*	9.7
00335753	*B-B'*	15.0
00802727	*B-B'*	16.0
00152206	*B-B'*	13.9
00738180	*B-B'*	11.9
00906244	*B-B'*	14.9
EHS 78-147	A-A' & A'-A"	11.3
EHS 82-51	A-A'	12.9
Average		*14.7*

Notes: Cross-sections in Chapter 4 (Figures 4-9, 4-10, 4-11)

Groundwater in storage calculations were performed for the Spring conditions of 1987, 1990, 1996, 2002, 2009, 2011, 2015, 2017, and 2020 using the specific yield method. Water level contours for each year were prepared based on available water level data from various sources, including the County water level monitoring program, well logs, and Stakeholder provided information. Water level contour maps for Spring 1996, 2015, and 2020 were shown previously in Chapter 5. Water level contours for Spring 1987 (the start of the historical base period), along with a change in groundwater elevation map from Spring 1987 to Spring 2020 (the end of the historical base period) is shown in Figure 6-11 and Figure 6-12.

The water level contours for storage calculations extend to the Subbasin boundaries. Groundwater levels in the Subbasin in Spring 1987 show a pattern similar to the other contour maps in Chapter 5, including the flattening of the hydraulic gradient in the middle of the Subbasin, where Tar Spring Creek valley enters the Arroyo Grande valley (Figure 6-11). The change in water level elevation map shows relatively minor differences between 1987 and 2020, with fluctuations ranging from five feet of water level decline to 10 feet of water level increase over the base period (Figure 6-12).



Prepared For:

Author: TK
Date: 08/10/2021

ARROYO GRANDE SUBBASIN GSP

N

0 0.25 0.5 0.75 mi
0 0.5 1 km

References:
1. Coordinate System: State Plane California V FIPS 0405 Feet
2. Projection: Lambert Conformal Conic
3. Horizontal Datum: NAD 83
4. Vertical Datum: NAVD 88
5. Basemap: USGS 7.5' Topographic Map

Notes:
1.
2.
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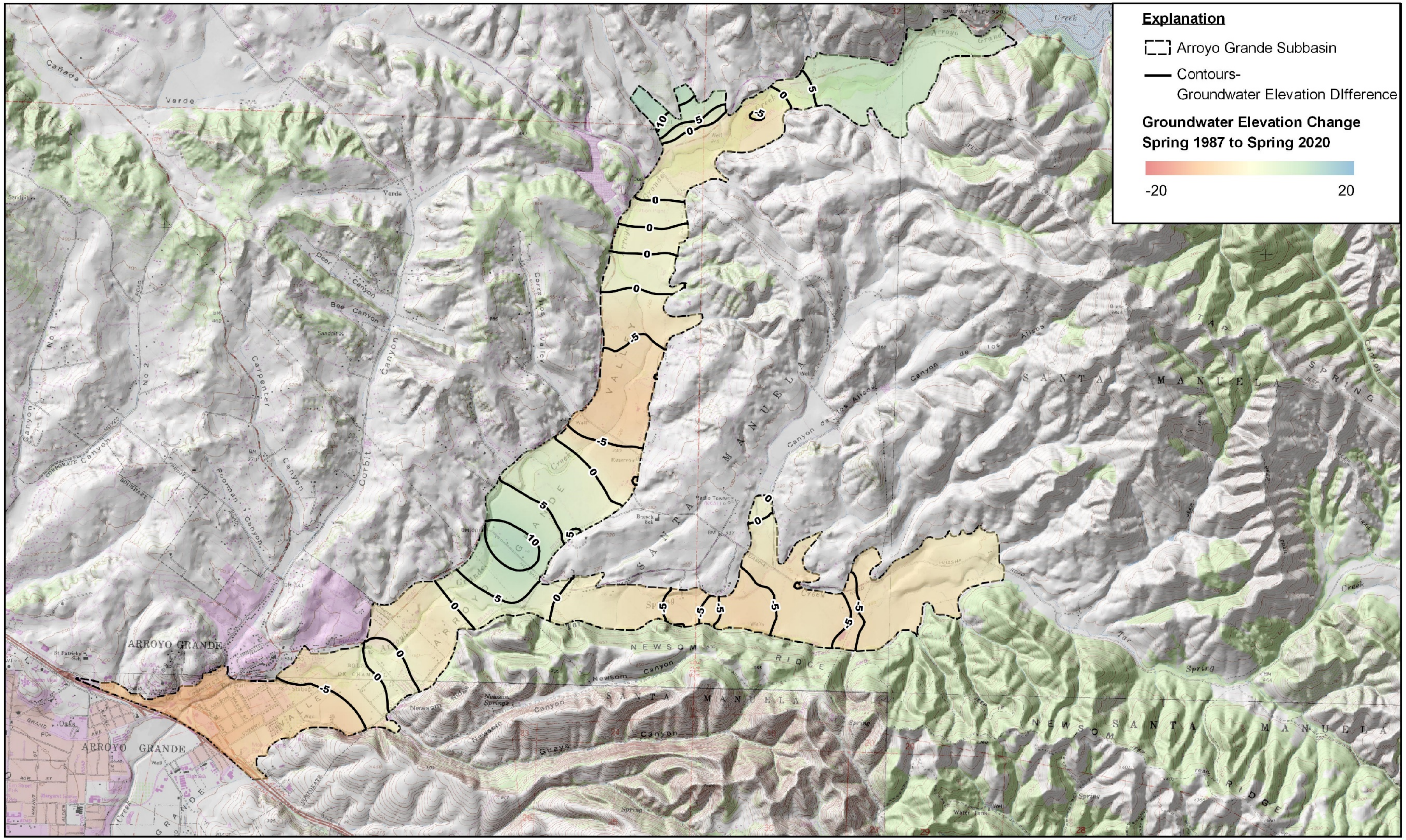
Groundwater Elevation Surface
Spring 1987

Figure 6-11



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ARROYO GRANDE SUBBASIN GSP

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Notes:
1.
2.
3.

Groundwater Elevation Change
Spring 1987 to Spring 2020

Figure 6-12

The water level contour maps and the base of permeable sediments were processed for volume calculation using Surfer, a grid-based mapping and graphic program. The methodology consisted of gridding and trimming surfaces to the Basin subarea boundaries, followed by volume calculation between surfaces. The gross volumes obtained were then multiplied by the representative specific yield. An example of the methodology showing gridded surfaces for Spring 2020 water levels and the base of permeable sediments is presented in Figure 6-13. Estimated total storage volumes for selected years using the specific yield method are listed in Table 6-11.

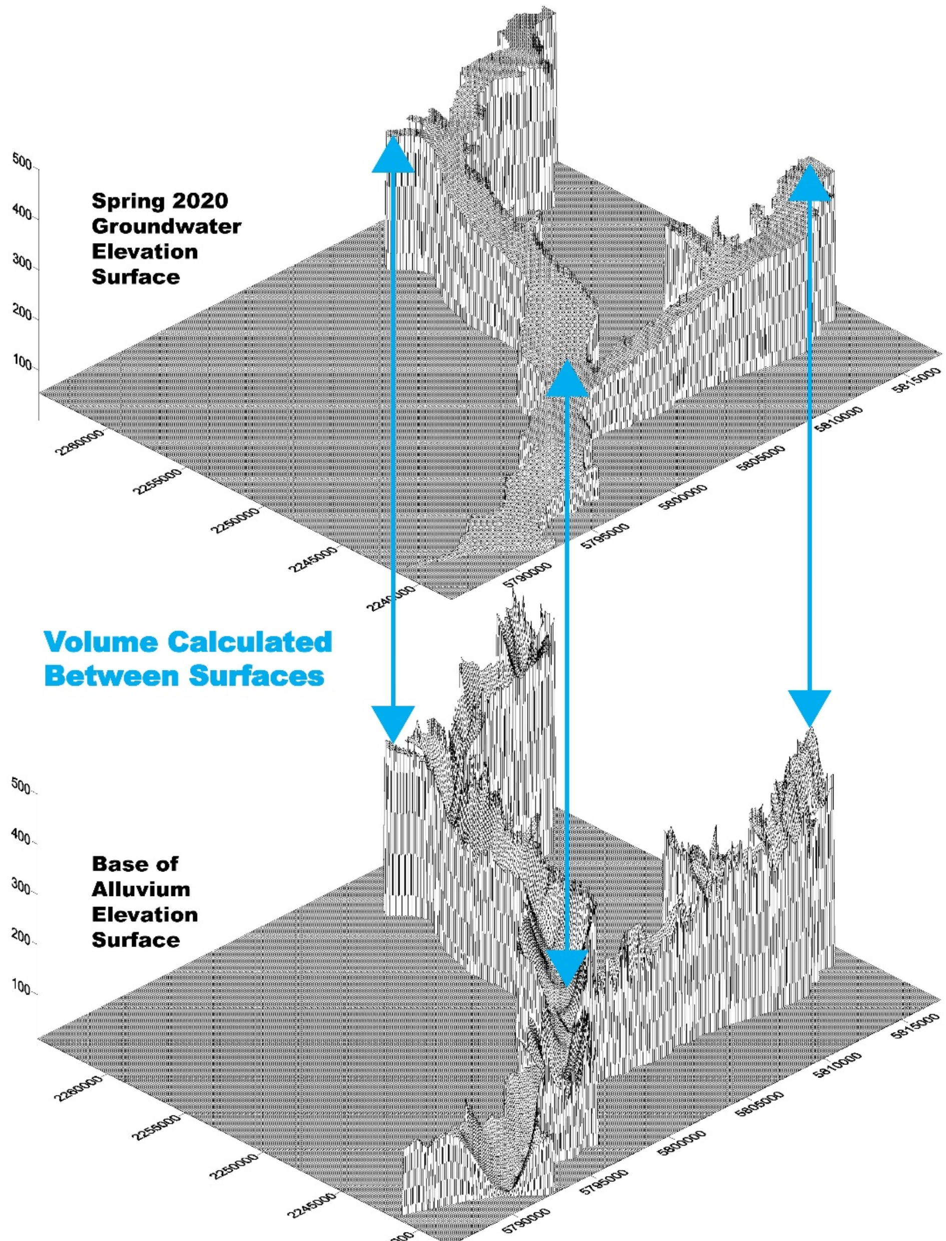

Figure 6-13: Storage Volume Grids.

Table 6-11: Spring Groundwater Storage Estimates.

Year	Groundwater Storage
	Acre-Feet
1987	13,000
1990	10,300
1996	13,700
2002	13,300
2009	10,400
2011	15,200
2015	10,700
2017	14,700
2020	12,800

The groundwater storage estimates are comparable to previously reported estimate of 14,000 acre-feet total storage capacity for the Arroyo Grande Valley (DWR, 2002). The DWR total storage capacity represented the total volume that could theoretically be held in underground storage. The maximum storage estimated herein by the specific yield method is 15,200 acre-feet (Spring 2011).

6.3.6 Change in Storage

Balancing the water budget final step in water budget development. As previously mentioned, the water budget equation is as follows:

INFLOW – OUTFLOW = CHANGE IN STORAGE

The annual change in storage for the surface water budget is assumed to be zero, as surface flow moves quickly through the basin and any differences in storage are minor compared to the total budget. Therefore, the surface water balance equation can be simplified as INFLOW = OUTFLOW, and was used to estimate the stream outflow component of the surface water budget.

For the groundwater budget, groundwater-surface water interaction (as stream flow seepage) was adjusted to approximate the change in storage calculated using the specific yield method discussed above. The difference between the estimated change in storage shown in the water budget and the measured change in storage using the specific yield method is the mass balance error. Change in storage is reported between seasonal high (Spring) conditions per GSP regulations. Change in storage and mass balance error for the groundwater budget is shown in Table 6-12. Figure 6-14 compares storage estimates using the water budget and the specific yield method.

Table 6-12: Change in Storage Comparison – Historical Base Period 1988 – 2020.

Groundwater Budget	Specific Yield Method	Mass Balance Error		
Change in Storage (acre-feet)		acre-feet	AFY	Percent*
-300	-200	100	3	0

*Percent of total subarea water budget

The difference in change in storage estimates between the water budget and the specific yield method is approximately 100 AFY for the Subbasin over the historical base. The water budget estimates a 300 acre-foot decline in storage, compared to a 200 acre-foot decline in storage using the specific yield method. The difference in change in storage estimates between the water budget and the specific yield method is less than 5 AFY over the historical base period.

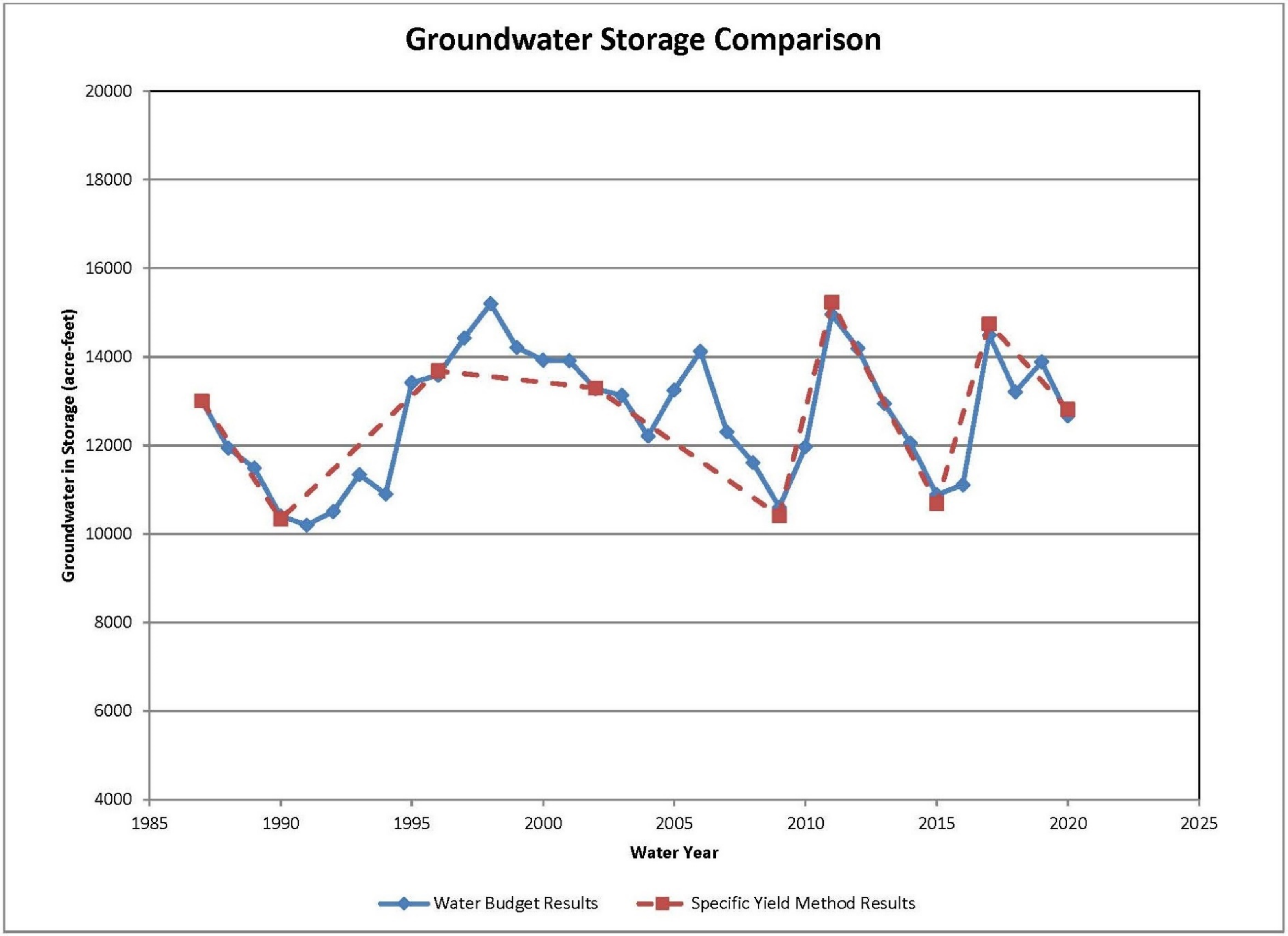

Figure 6-14: Groundwater Storage Estimate Comparison.

6.3.7 Preliminary Sustainable Yield Estimate

The sustainable yield is the maximum quantity of water, calculated over a base period representative of long-term conditions in the Subbasin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result. Temporary surplus is the amount of water that may be pumped from an aquifer to make room to store future water that would otherwise be unavailable for use. Undesirable results will be defined for six sustainable management criteria in Chapter 7. Examples of potential undesirable results are related to long-term declines in water levels and associated loss of groundwater in storage.

Estimating sustainable yield includes evaluating historical, current, and projected water budget conditions. The analytical water budget method utilized in this analysis evaluates historical and current conditions, and provides a preliminary estimate for the Subbasin sustainable yield. The projected water budget will be evaluated using the Subbasin numerical model presented later in the projected water budget section of the chapter, at which time the minimum thresholds for the sustainable management criteria can be incorporated and the final sustainable yield will be determined. The preliminary sustainability estimate can be used for planning potential projects and management action scenarios for the Subbasin numerical model.

The Arroyo Grande Subbasin has not experienced cumulative and persistent storage declines. The estimated net decline in groundwater storage of less than 10 acre-feet per year over the 33-year historical base period is less than one percent of the annual groundwater budget.

The preliminary sustainable yield of the Arroyo Grande Subbasin is estimated at 2,500 AFY, based on the long-term average recharge of 3,000 AFY minus 500 AFY subsurface outflow (rounded to nearest 100 acre-feet). This preliminary sustainable yield assumes continued operation of Lopez Reservoir in accordance with historical practices. Table 6-13 summarizes the preliminary sustainable yield estimates.

Table 6-13: Preliminary Sustainable Yield Estimate (AFY).

Long-term recharge	3,000
Subsurface outflow	-500
Sustainable Yield	2,500

There are no prior estimates of the Subbasin sustainable yield for comparison. DWR (2002) estimated sustainable yield for portions of the main (downstream) groundwater basin areas. Absent of cumulative and persistent storage declines or other identified undesirable results, the existing level of groundwater basin development may be considered sustainable. It is not a coincidence that Subbasin pumping over the base period for urban and agricultural uses averaged 2,500 AFY, equal to the preliminary sustainable yield.

6.3.8 Quantification of Overdraft

Overdraft is the condition of a groundwater basin or subbasin where the amount of water withdrawn by pumping exceeds the amount of water that recharges a basin or subbasin over a period of years, during which the water supply conditions approximate average conditions.

The Arroyo Grande Subbasin is not in overdraft. There have been no significant cumulative and persistent storage declines over the 33-year historical base period. As with the preliminary sustainable yield estimate given above, the absence of overdraft assumes continued operation of Lopez Reservoir in accordance with historical practices.

6.4 CURRENT WATER BUDGET

The current water budget quantifies inflows and outflows for the Subbasin based on the last five years of the historical water budget, from 2016 to 2020. These years provide the most recent population, land use, and hydrologic conditions. Recent Subbasin conditions have been characterized by average rainfall (with wet and dry years), along with a slight increase in urban extractions associated with development projects. There has also been a slight decline in total agricultural acreage and associated groundwater extractions over the last 5 years in the Subbasin, compared to the 33-year base period.

Comparisons of the current water budget to the 1988-2020 historical water budget are shown in Table 6-14, and graphs are shown in Figure 6-15 and Figure 6-16. The average annual surface water budget inflows and outflows are lower for current conditions (averaging 13,090 AFY) compared to the historical base period average of 18,360 AFY. The main reason for the lower total surface water budget for the current condition, despite average rainfall, is a decrease in stream inflow, which was due to the extreme drought that preceded the current condition. Lopez Reservoir was only about 24 percent capacity at the start of the 2016 water year (October 2015), with capacity subsequently doubling by the end of water year 2020. Downstream releases from the reservoir over the current condition were half of the historical average.

The average annual groundwater budget outflows are similar for current conditions (averaging 2,890 AFY) compared to the historical base period average of 2,960 AFY. The groundwater budget inflows, however, are slightly greater for the current condition (3,240 AFY), compared to the historical average of 2,950 AFY. The main reason for the increased inflow is also a response to the preceding drought period. Close to 35 inches of rain fell at Lopez Reservoir in 2017, which replenished soil moisture deficits from the drought and resulted in 3,000 acre-feet of deep percolation across the Subbasin, one of the highest estimated values on record (Table 6-1). Overall groundwater in storage increased an estimated 3,390 acre-feet in 2017. Storage has been generally decreasing since 2017, although there was a net gain over the current condition (2016 through 2020).

Table 6-14: Current Water Budget.

SURFACE WATER BUDGET	Historical Average (1988-2020)	Current (2016-2020)
Inflow	**AFY**	
Precipitation	4,130	4,170
Groundwater extractions (Urban)	140	180
Groundwater extractions (Ag)	2,340	2,220
Stream Inflow at Basin Boundaries	10,910	5,780
Surface Water Deliveries	450	400
Local Imported Supplies	390	340
TOTAL IN	18,360	13,090
Outflow		
ET of precipitation	2,820	2,910
ET of Applied Water (Urban)	450	430
ET of Applied Water (Ag)	1,800	1,720
Riparian ET	230	230
Wastewater Export	160	130
Stream Flow Diversions	450	400
Infiltration of Precipitation	970	1,040
Infiltration of Applied Water (Urban)	80	90
Infiltration of Applied Water (ag)	540	500
GW-SW interaction (net)	1,200	1,450
Stream outflow at basin boundary	9,680	4,190
TOTAL OUT	18,360	13,090
GROUNDWATER BUDGET	**Historical Average (1988-2020)**	**Current (2016-2020)**
Inflow	**AFY**	
Infiltration of precipitation	970	1,040
Urban water return flow	80	90
Agricultural return flow	540	500
GW-SW interaction (net)	1,200	1,450
Subsurface from bedrock	170	170
TOTAL IN	2,950	3,240
Outflow		
Groundwater extractions (Urban)	140	180
Groundwater extractions (Ag)	2,340	2,220
Subsurface outflow	480	480
TOTAL OUT	2,960	2,890

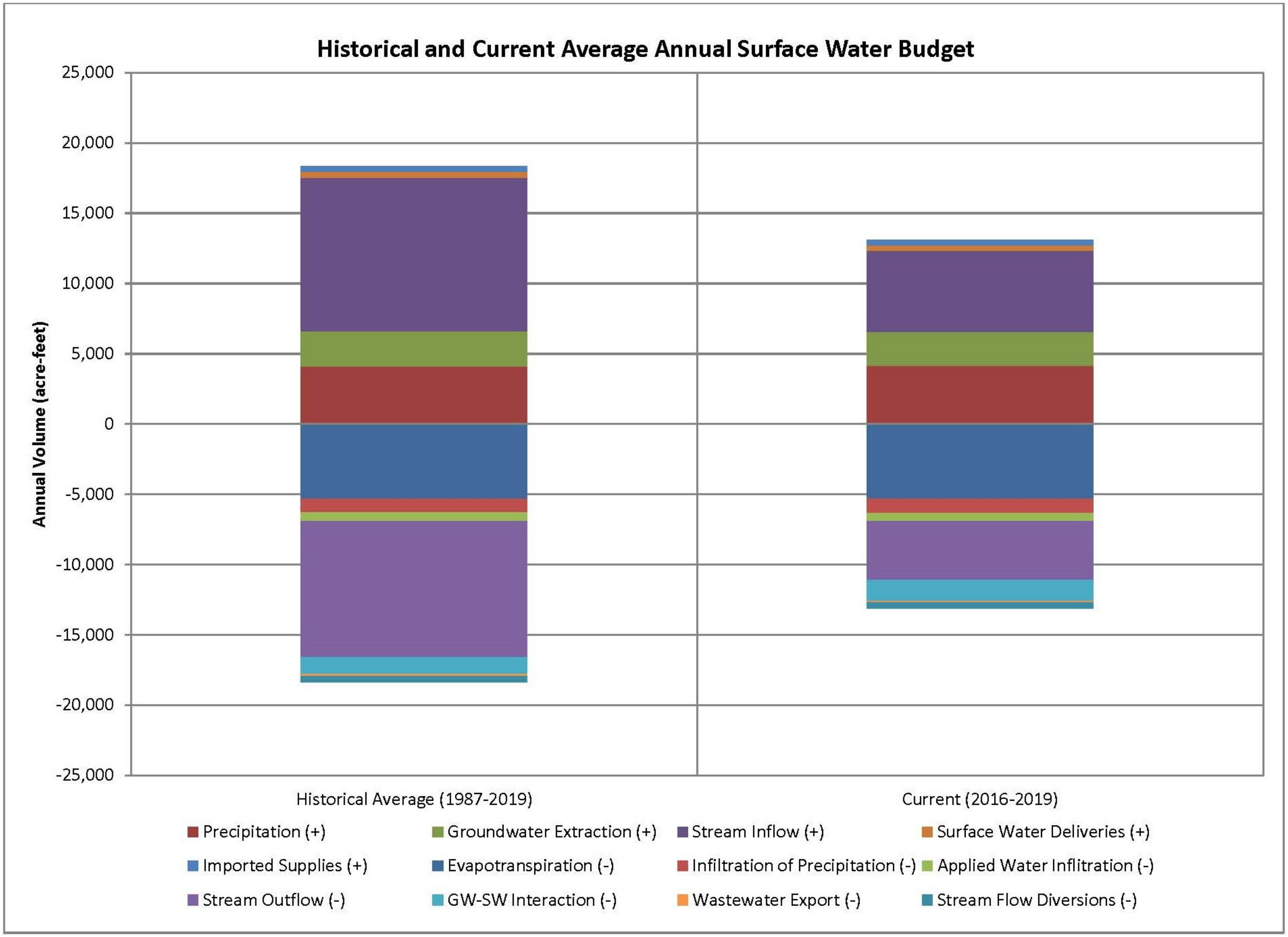

Figure 6-85: Historical and Current Average Annual Surface Water Budget – Arroyo Grande Subbasin

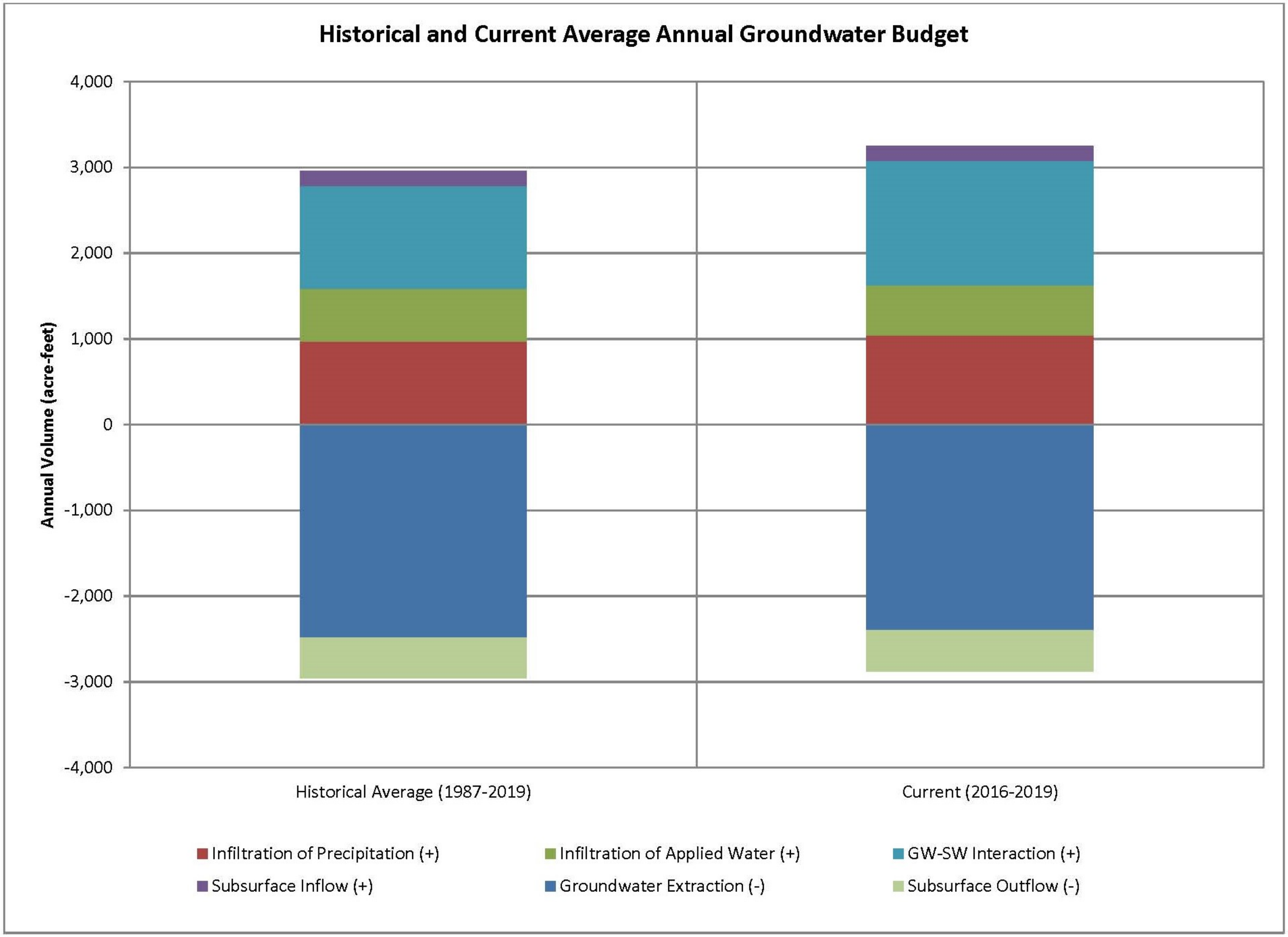

Figure 6-96: Historical and Current Average Annual Groundwater Budget – Arroyo Grande Subbasin.

The graphs in Figures 6-16 and 6-17 provide a visual comparison of the magnitude of components of inflow and outflow listed in Table 6-14. The surface water budget (Figure 6-16) is balanced (total inflow equals total outflow), while the groundwater budget (Figure 6-17) depicts a relatively balanced historical period with a net increase of inflow compared to outflow for current conditions

6.5 FUTURE WATER BUDGET

6.5.1 Assumptions

6.5.2 Inflows

6.5.3 Outflows

6.5.4 Change In Storage

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