Appendix B

Lopez Dam Operations Hydrologic Modeling Documentation

Lopez Water Project Habitat Conservation Plan Hydrogeologic Services

Modeling Technical Memorandum

Prepared For

San Luis Obispo County

Flood Control and Water Conservation District

By

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Water & Hydropower Consulting

August 2025

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Introduction

This memorandum provides detailed information regarding the San Luis Obispo County Flood Control & Water Conservation District (District) hydrologic modeling tool for the Lopez Reservoir watershed, primary modeling assumptions, model inputs, and methodologies. The modeling tool can be used to evaluate potential effects on mass-balance hydrology under various scenarios that will be analyzed in the Lopez Habitat Conservation Plan (HCP), and in support of the necessary regulatory requirements associated with Endangered Species Act (ESA) compliance. Implementation of the HCP could result in changes to the operations of Lopez Reservoir, flows in Arroyo Grande Creek and potentially ground water levels within the Arroyo Grande subbasin and Santa Maria Groundwater Basin.

The modeling tool will also be used to support the Water Availability Analysis (WAA) to be submitted to the State Water Resources Control Board. The modeling analysis will be based on comparisons made between computer model simulations developed to represent hydrologic, regulatory, and operational conditions for various scenarios described in this memorandum.

In concept, the model is a mass balance tracking tool. Water is routed through the system on a daily time step according to a set of operational rules and limited by physical capacities and contractual obligations of project facilities. The model uses unimpaired inflow which was developed based on historic hydrologic records. Inflow into project facilities is either routed into storage, released, bypassed, or spilled. Diversions to and from storage change daily in response to a set of programmed priorities that include:

1. Meeting all minimum release requirements;
2. Meeting consumptive water supply demands; and
3. Filling storage without spilling.

The model was developed to allow the District to test and evaluate the effects to water supply that result from changes to system variables, such as:

- Minimum instream flow requirements
- Specified flow requirements such as riparian pumping

By considering a range of historic hydrology including wet and dry years, the model introduces stakeholders to the hydrologic variability of the Arroyo Grande watershed and allows consideration of that variable hydrology in developing future operations. The model can also be easily modified by a user to incorporate potential changes to Lopez Water Project facilities or operations that may be identified during the development of the HCP.

Model Structure and Operation

The model is constructed using the OASIS platform. In the model logic, the Lopez Water Project is described by a series of arcs and nodes (Figure 1). A node is a point of interest (e.g., a reservoir, junction of two stream reaches, diversion point, etc) and an arc that connects two nodes and represents a flow of water (e.g., a stream reach, pipeline, etc).

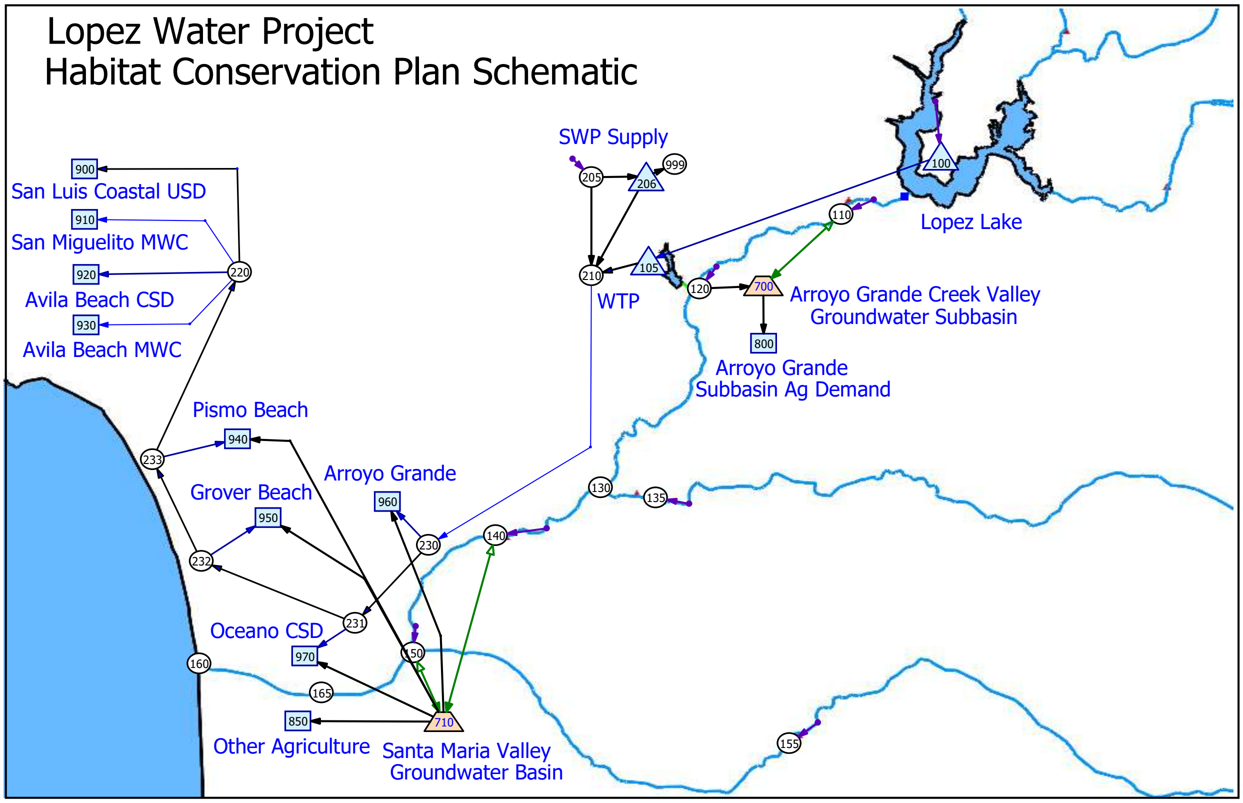


Figure 1 – San Luis Obispo Flood Control and Water Conservation District Simulation Model Schematic

The node and arc structure of the model represents the Arroyo Grande Creek watershed and the Lopez Water Project facilities (dams, diversions, pipelines, powerhouses, etc.) located in the watershed.

Operating constraints were built into the model to represent the current physical capacities of the Lopez Water Project as well as the current regulatory and contractual requirements of the project. Physical capacities built into the model include maximum reservoir storage, maximum pipeline/diversion flow, and minimum operational levels (for reservoirs and diversions). Examples of regulatory and contractual requirements include current requirements for minimum instream flows, water rights for diversions to meet consumptive demand, and District contractual water delivery requirements.

The model is designed to maximize the achievement of specific objectives given the constraints specified. When limited water is available, the model may not be able to achieve all specified objectives. The priorities of the model's objectives are specified by user-assigned "weights." The objectives specified (in order of current priority) in the model include:

- Meet consumptive and contractual water demands
- Provide instream flows to support listed species

- Provide downstream releases for AG users
- Fill Lopez Lake by the end of Spring

After the operating constraints and operating objectives are defined and the input hydrology (described later) are selected, the model simulation is run day-by-day. The model processes the constraints, objectives, and other inputs through an optimization routine using mathematical equations to best meet the objectives each day. The starting points (flows, storage, etc.) for the next day are the ending points from the previous day. Through the optimization routine, the model allocates daily releases to meet the operating constraints (requirements) and objectives like minimum flow requirements and consumptive demands. Consumptive demands can be met using required minimum instream flows. After the simulation is complete, the model summarizes the results in a series of tables and graphs.

Model Input

The following describes important Model inputs.

Hydrology: The model contains a time series database of unimpaired hydrology developed for this application. The data is based on the available hydrologic period of record, water years 1969 (completion of Lopez dam) through 2024. A water year is from October 1 through September 30. This period of record includes the driest (1977) and wettest (1983) years on record. A model simulation can be run for the entire period of record (the default), a single year, or a series of years. Please see Appendix B Arroyo Grande Watershed Hydrology Development for a detailed description of the hydrology development used in this model.

Municipal Consumptive Demands: Consumptive demand for municipalities in the model is based on the District's Master Water Report (2012). The monthly pattern for municipal consumptive demand is based on monthly delivery patterns provided by the District. Daily consumptive demand is represented by equally distributing the monthly demand for each day of the month. The monthly demand pattern is illustrated as Figure 2.

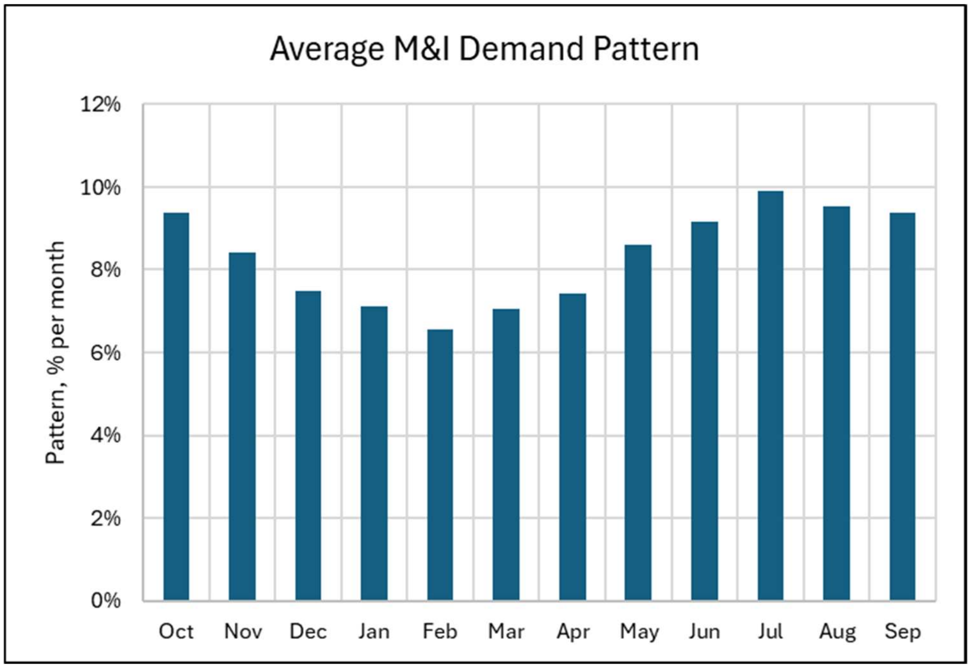


Figure 2 - M&I Demand Pattern

Agricultural Diversions: Agricultural Demand is estimated using County agricultural field acreages and estimated applied irrigation water for each crop type. These calculations are described in the Cleath-Harris Tech Memo *Arroyo Grande Valley Agricultural Water Use Survey, Lopez Hydrogeological Services Project*]. The Ag Demand Pattern is shown in Figure 3, below.

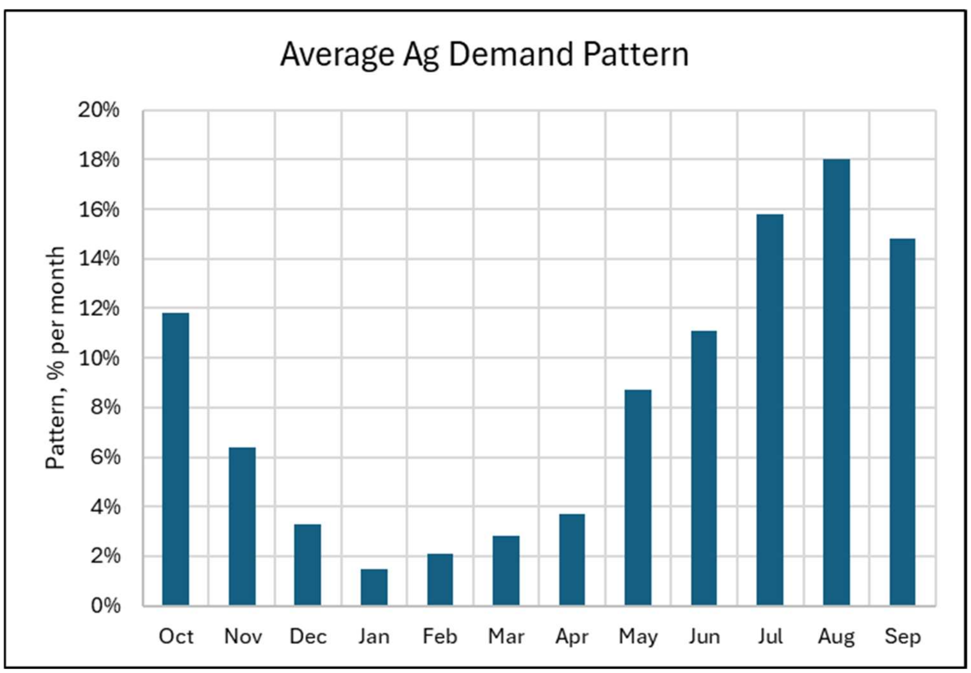


Figure 3 - Ag Demand Pattern

Pipeline Capacities: Pipeline capacities are fixed and based on known capacities established through operating the facilities. Pipeline capacities are listed in Table 2 of Appendix A Model Operating Criteria.

Water Year Types: Although operations are not currently tied to wetness, or water year type, based constraints, the model is capable of water year type based operational decision making. A water year type structure that establishes multiple water year types, such as Wet, Above Normal, Below Normal, Dry, Critically Dry, Extreme Critical, is possible. A water year type structure could be used to develop and evaluate downstream release programs.

Minimum Instream Flow Requirements: The Lopez Water Project is currently operated to maintain minimum instream flow releases at the dam of about three (3) cubic feet per second. The model user can specify different minimum instream flow requirements by time period, flow rate, and a water year type trigger.

Reservoir Storage Requirements: There are currently no minimum storage requirements at Lopez Reservoir. However, there is an option to implement the Low Reservoir Response Plan (LRRP) which was developed to preserve supplies during drought conditions. The dead pool at Lopez Reservoir is about 4,000 AF.

Pulse Flow Requirements: The model is capable of evaluated pulse flows for riparian maintenance, geomorphic processes, or other functions below Lopez Dam. The pulse flow magnitude, timing, and duration can be specified by the model user. Pulse flows from Lopez Lake can be provided through a release through the Lopez Dam outlet pipe.

Appendix A provides specific details about the assumptions used in the simulation model.

Model Output and Post Processing

After the model completes a simulation, output data are available in graphical and tabular format. Outputs include data on flows, reservoir elevation and storage, and consumptive water delivery. These data also can be exported as Data Storage System (DSS) or Microsoft Excel spreadsheet files. Standard output metrics also have been prepared that summarize the results of a model simulation. The metrics include comparisons of the following:

- Monthly and daily reservoir elevation
- Monthly and daily flow by location
- Flow exceedance plots
- Reservoir spills

Appendix C provides illustrations of some of the simulation model output.

APPENDIX A: Model Operating Criteria

Physical Characteristics

Table 1 - Reservoir Physical Characteristics

Reservoir	Storage Capacity (AF)	Dead Storage (AF)
Lopez Lake	49,388[1]	4,000
Lopez Terminal Reservoir	844	150

Table 2 - Pipeline Physical Characteristics

Pipeline / Facility	Capacity
Lopez Water Treatment Plant	6 MGD (9.3 cfs)
Lopez Dam Outlet to Stream	100 cfs

Flow Requirements

Baseline Model

The baseline model currently uses a minimum instream flow requirement of 3 cfs year-round. The compliance point for this requirement is the release from Lopez Dam.

Lopez Downstream Release Program Modeling

The Lopez Downstream Release Program (LDRP) Flow Requirements have two components: a base flow requirement at Lopez Dam, and a pulse flow requirement at Lopez Dam.

The base flow requirement at Lopez Dam is shown in Table 3 below and as Figure 1. Additional releases may be needed from Lopez Dam to maintain deliveries to agricultural users.

Table 3 - LDRP Flow Requirements

Date	Release from Lopez Dam Storage > 20,000 AF	Release from Lopez Dam Storage < 20,000 AF
Oct 1 – Dec 1	3 cfs	3 cfs
Dec 2 – Jan 1	5 cfs	4.5 cfs
Jan 2 – Mar 15	8 cfs	7.2 cfs
Mar 16 – Apr 1	7 cfs	6.3 cfs
Apr 2 – May 1	5 cfs	4.5 cfs
May 2 – Jun1	4 cfs	3.6 cfs
Jun 2 – Sep 30	3 cfs	3 cfs

[1] The storage capacity after construction of dam was estimated to be 51,777 AF. In March 2002, a bathymetric study estimated the capacity to be 49,388 AF.

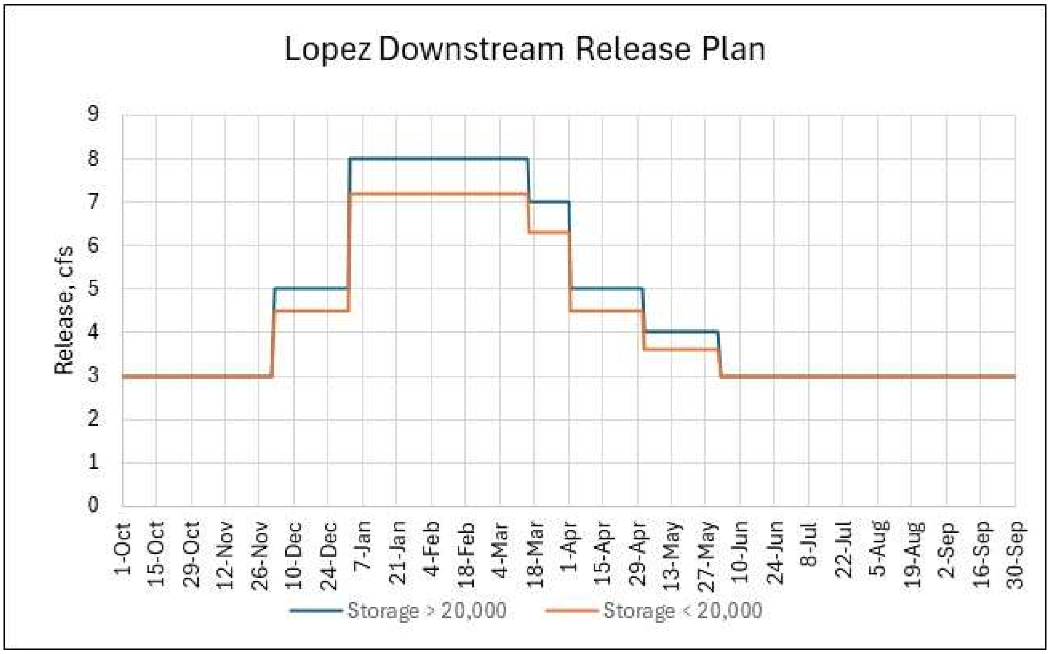


Figure 1 - Lopez Downstream Release Plan

The pulse flow requirement at Lopez Dam is triggered by flows at the Arroyo Grande Creek at Arroyo Grande stream gage and storage in Lopez Reservoir. The flow requirements are shown in Table 4. These flow requirements are triggered up to two times anytime January through May when the Arroyo Grande stream gage exceeds 25 cfs, then falls below 25 cfs. Pulse flows will not be released from the dam if Lopez Dam is spilling.

Table 4 – Lopez Downstream Release Plan Pulse Flow Requirements

Lopez Storage (Jan – May)	Release from Lopez Reservoir
Lopez Lake Storage > 20 Thousand Acre-Feet (TAF)	Day 1 : 10 cfs Day 2 : 10 cfs Day 3 : 15 cfs Day 4 : 15 cfs Day 5 : 20 cfs Day 6 : 20 cfs Day 7 : 15 cfs Day 8 : 15 cfs Day 9 : 10 cfs Day 10 : 10 cfs
Lopez Lake Storage ≤ 20 TAF	None

Figure 2 shows an example of the Pulse flow layered on the LDRP flow requirements.

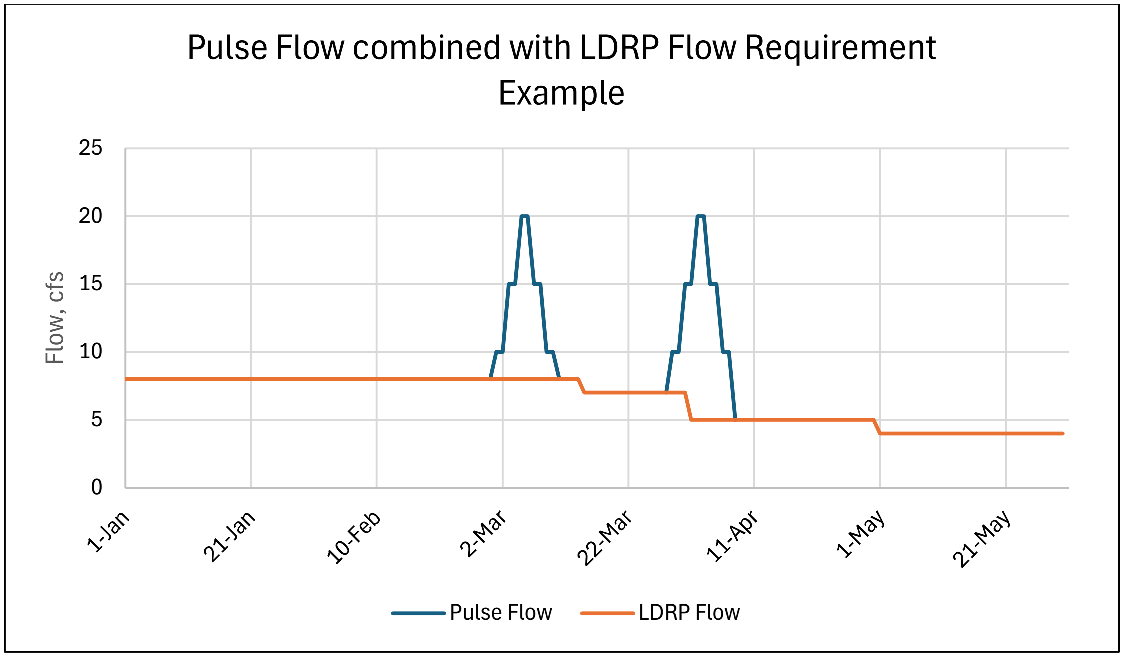


Figure 2 - Pulse Flow Example

Lake Lopez Operations

Draft Low Reservoir Response Plan for Lopez Reservoir

The Low Reservoir Response Plan limits downstream releases and municipal diversions when the storage is less than 20,000 AF. The reduced allocations shown in Table 55 below are triggered by reservoir storage levels, not by any specific dates. The LRRP is triggered by a reservoir level below 20,000 AF and a declaration of water emergency proclaimed by the District. The model assumes that a declaration of water emergency will be proclaimed any time that storage drops below 20,000 AF.

Table 5 - Low Reservoir Response Plan

Storage Conditions, AF	Downstream Release, AF	Municipal Deliveries, % allocation
>= 20,000	4,200	100%, plus Surplus Water
< 20,000	3,800	100%, no Surplus Water
< 15,000	3,800	90%
< 10,000	1,026	80%
< 5,000	300	65%
< 4,000	0	0%

Downstream releases for agricultural pumping

A total of 4,200 AF is reserved annually for downstream releases in normal years (and less when the Low Reservoir Response Plan is in effect). The current minimum flow of 3 cfs throughout the year totals 2,172 AF. An additional 2,028 AF must be released in normal years to meet the annual total of 4,200 AF. This additional release is distributed on a pattern June through November.

Groundwater

Storage Capacity

Table 6 - Groundwater Storage Capacity

Sub-Basin	Estimated Total Storage Capacity, AF[2]	Estimated Amount in Storage (1995), AF[3]
Arroyo Grande Valley	14,000	10,000
Arroyo Grande Plain	412,000	389,000

Groundwater Recharge

In addition to recharge from local creeks, the groundwater is also recharged by deep percolation of rainfall, from 0 AF in dry years to 5,000 AF in wet years[4]. DWR developed an estimate of deep percolation of rainfall for years 1975 through 1995[5]. A regression was developed between DWR's estimated deep percolation and rainfall measured at Arroyo Grande, and this regression was used in the model to estimate monthly deep percolation values. Both DWR's estimate and the developed regression average 1,600 AF per year of deep percolation of rainfall. Agricultural return flows to groundwater were estimated as 30% of applied agricultural irrigation[6].

Stream Infiltration to groundwater

DWR estimated Stream recharge of the Arroyo Grande Plain is 300-500 AF in dry years, 800 AF in normal years, and 1,600-2,200 AF in wet years[7]. In Dry years, the Arroyo Grande Plain loses around 2,000 AF of groundwater storage. DWR estimated the stream recharge of the Santa Maria Valley from the Arroyo Grande as 11,700 AF in normal years and 0 AF in dry years.

Modeled stream infiltration to groundwater is based on the hydrology developed for the project and described in Appendix B Arroyo Grande Watershed Hydrology Development. Modeled stream recharge of Arroyo Grande Plain is 1,880 AF in dry years, 2,170 AF in wet years, and 1,910 in normal years.

[2] Water Resources of the Arroyo Grande – Nipomo Mesa Area, DWR, 2002. Table 18.
[3] Water Resources of the Arroyo Grande – Nipomo Mesa Area, DWR, 2002. Table 19.
[4] 2007 Northern Cities Area Water Balance Study, Todd Engineering, Pages 7-12.
[5] Water Resources of the Arroyo Grande – Nipomo Mesa Area, DWR, 2002. Table 24.
[6] 2007 Northern Cities Area Water Balance Study, Todd Engineering, Page 19.
[7] Water Resources of the Arroyo Grande – Nipomo Mesa Area, DWR, 2002. Page 143.

Consumptive Demands and Supplies

Lopez Lake Supply

Safe yield of the reservoir is 8,730 AFY: 4,530 AFY for pipeline deliveries, and 4,200 AFY for downstream releases.[8] Allocations for pipeline deliveries are outlined in Table 77.[9]

Table 7 - Lopez Lake Treated Water Allocations

Municipal Contractor	Allocation (AFY)
Pismo Beach	892
Oceano CSD	303
Grover Beach	800
Arroyo Grande	2,290
CSA 12	245
Total	**4,530**

State Water Project Supply

Water Supply Amounts for the State Water Project contractors at the Lopez turnout are 2,392 AF, outlined in Table 88.[10]

Table 8 - State Water Project Water Supply Amount and Drought Buffers

State Water Subcontractor	Water Supply Amount	Drought Buffer	Total Reservation
Pismo Beach	1,240	1,240	2,480
Oceano CSD	750	0	750
San Miguelito MWC	275	275	550
CSA 12	127	67	194
Total	**2,392**	**1,582**	**3,974**

State Water Project delivery amounts are based on current agreements between the District and each Subcontractor. State Water Project Allocations in the model are based on DWR Calsim modeling[11] for years 1969-2003, and historical delivery allocations are used for 2004-2024.

The model accounts for additional storage of State Water in San Luis Reservoir, up to 12,500 AF per year. The amount that can be stored is outlined in the District's State Water Project contract, Article 56.

[8] SLO Master Water Report, section 2.2.8.
[9] SLO Master Water Report, section 4.3.4 and Table 4.9.
[10] SLO Master Water Report, section 4.3.1 and Table 4.5.
[11] Department of Water Resources 2011 Delivery Reliability Report, Existing Demand Levels, Calsim II study.

Groundwater Extraction Limitations

Municipal water users that are served by the Lopez Water Project and by other sources have agreements on groundwater pumping, associated with the Santa Maria groundwater adjudication. These limitations are shown in Table 99.

Table 9 - Groundwater Pumping Limitations

Water User	Maximum Groundwater Extraction from Arroyo Grande Plain (AFY)[12]
Pismo Beach	700
City of Arroyo Grande	1,314
City of Grover Beach	1,407
Oceano CSD	900

Some water agencies also have agreements on total water draw, shown in Table 10.

Table 10 - Total Water Draw Limitations

Water User	Total Water Draw (AFY)	Notes
City of Arroyo Grande	3,794[13]	From 2 groundwater basins, Lopez Reservoir, and through Oceano CSD

[12] SLO Master Water Report, section 4.6.7.2.5.

[13] SLO Master Water Report, section 4.6.7.2.5.

Table 11 provides a summary of the total supplies by Municipal contractor.

Table 11 - Summary of Supplies – Municipal Contractors

	Pismo Beach	Arroyo Grande	Grover Beach	Oceano CSD	San Miguelito MWC	CSA 12	Total
Existing Demand[14]	1,944	2,956	1,787	855	263	186	7,991
Forecast Demand[15]	2,550[16]	3,318	1,892 – 2,500	1,348	383	298	9,789
State Water Project Supply	1,240	0	0	750	275	127	2,392
Lopez Reservoir Allocation	892	2,290	800	303	0	245	4,530
GW extraction from Arroyo Grande Plain[17]	700	1,323	1,407 + 225	900	0	0	5,600 – 9,500[18]
Total Supply	2,836	3,613	2,432	1,953	393	372	11,595

[14] SLO 2012 Master Water Report, Tables 4.29 and 4.32
[15] SLOC 2014 IRWMP
[16] According to the SLOC IRWMP, Pismo Beach plans on using 1,985 - 2,020 AFY of WWTP Re-use at buildout.
[17] Arroyo Grande Plain is a sub-basin of the Santa Maria Valley Groundwater Basin. (SLOC IRWMP App L, section 17).
[18] SLOC IRWMP Appendix L, pages 23-24.

Seasonal Demand Patterns

The seasonal Municipal Demand pattern is taken from the recent (2000-2014) historical average pipeline delivery patterns, shown in Table 12.

Table 12 - Seasonal Municipal Demand Pattern

Month	Fraction of Total
Oct	0.094
Nov	0.084
Dec	0.075
Jan	0.071
Feb	0.066
Mar	0.070
Apr	0.074
May	0.086
Jun	0.092
Jul	0.099
Aug	0.095
Sep	0.094

The Seasonal Agricultural Demand pattern is taken from [Cleath-Harris Memo], shown in Table 133.

Table 13 - Seasonal Agricultural Demand Pattern

Month	Fraction of Total
Oct	0.122
Nov	0.067
Dec	0.034
Jan	0.015
Feb	0.021
Mar	0.028
Apr	0.038
May	0.082
Jun	0.106
Jul	0.155
Aug	0.178
Sep	0.153

APPENDIX B: Arroyo Grande Watershed Hydrology Development

The Arroyo Grande basin is a 153 square mile watershed in San Luis Obispo County that is tributary to the Pacific Ocean. Major drainages include Arroyo Grande, Lopez Creek, Los Berros Creek, Tar Springs Creek and Meadow Creek. The Arroyo Grande has been regulated by Lopez Reservoir since its construction in 1968, and most of Arroyo Grande below Lopez Reservoir has been channelized. This document describes the development of unimpaired hydrology of the Arroyo Grande Basin above and below Lopez Reservoir for use in a watershed operations simulation model. Figure 1 shows the model schematic made up of nodes and arcs. A node is a point of interest (e.g., a reservoir, junction of two stream reaches, diversion point, etc) and an arc that connects two nodes and represents a flow of water (e.g., a stream reach, pipeline, etc). The discussions on hydrology development refer to the associated node number in the section titles.

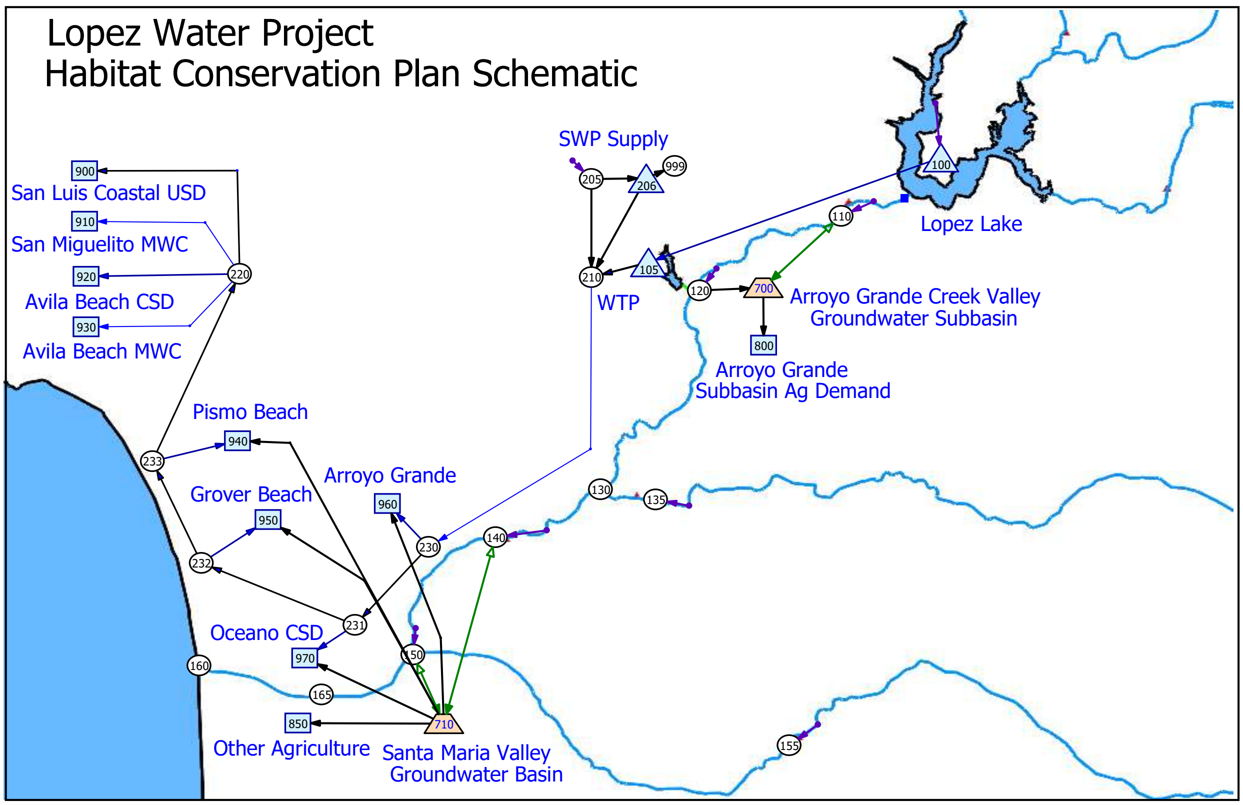


Figure 1 - Arroyo Grande Creek Model Schematic

Lopez Lake inflow (Inflow to node 100)

Inflow to Lopez Reservoir consists of two main tributaries, Arroyo Grande and Lopez Creek. Arroyo Grande above Lopez Reservoir is impaired by agricultural diversions and runoff, while Lopez Creek is largely unimpaired.

Monthly operations data was supplied by San Luis Obispo County Flood Control and Water Conservation District (District) for the period May 1968 through June 1998, and daily operations data was supplied by San Luis Obispo Water Conservation and Flood Control District (District) for the period December 1993 through March 2025. This operations data included reservoir storage, releases, measured pan evaporation, and precipitation. Using this data, an inflow to the reservoir was calculated on a mass balance, using Figure 2 and Equation 1.

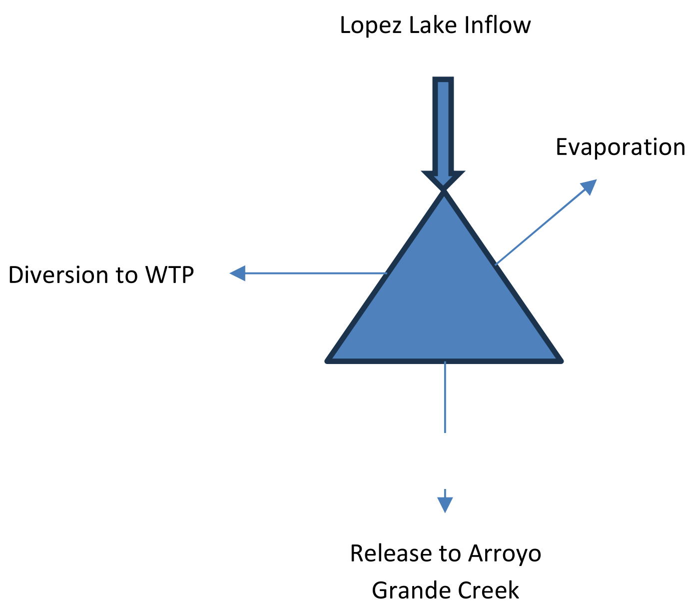


Figure 2 - Lopez Lake Inflow Diagram

On April 1, 2003 the new Lopez Reservoir Storage-Area-Elevation Curve was implemented, causing the reported storage capacity to decrease by 2,000 AF during a time when the gaged releases and gaged inflow were fairly steady. On this day the mass balance calculated value was discarded and the inflow was estimated as the average of the two surrounding days, which is consistent with the upstream gage.

Equation 1

$$Inflow = Change\ in\ Storage + Releases\ to\ Arroy\ Grande\ Creek + Diversions\ the\ Water\ Treatment\ Plant + Evaporation$$

The daily inflows calculated by mass balance are noisy, oscillating by 5-10 cfs throughout the summer. These daily inflows were smoothed using the Lopez Creek stream gage as a pattern, as shown in Equation 2.

Equation 2

$$\text{Smoothed Daily Inflow} = \text{Lopez Creek Daily Streamgage Reading} * \frac{\text{Annual Lopez Lake Inflow}}{\text{Annual Lopez Creek Streamgage Volume}}$$

The monthly inflows calculated by mass balance need to be disaggregated into daily inflow values. This is done in the same manner as the daily inflows, using Equation 2. The final inflow set consists of smoothed monthly mass balance calculations for October 1968 through December 1993, and smoothed daily mass balance calculations for January 1994 through December 2024.

Because of the fluctuations in any storage record, smoothing techniques were applied to make a more realistic daily inflow record. The Lopez Lake records have been verified by running the resulting inflow hydrology through the model and comparing modeled storage results to the historic storage records. The 1978 through 1994 period was chosen because that period wasn't influenced by the dam retrofit project during which the reservoir levels were drawn down lower than normal to protect and repair the dam. See Figure 3. The calculated inflow records result in a modeled storage record that very closely agree with the historic record. Therefore, we conclude that the calculated inflow record closely aligns with the actual inflow.

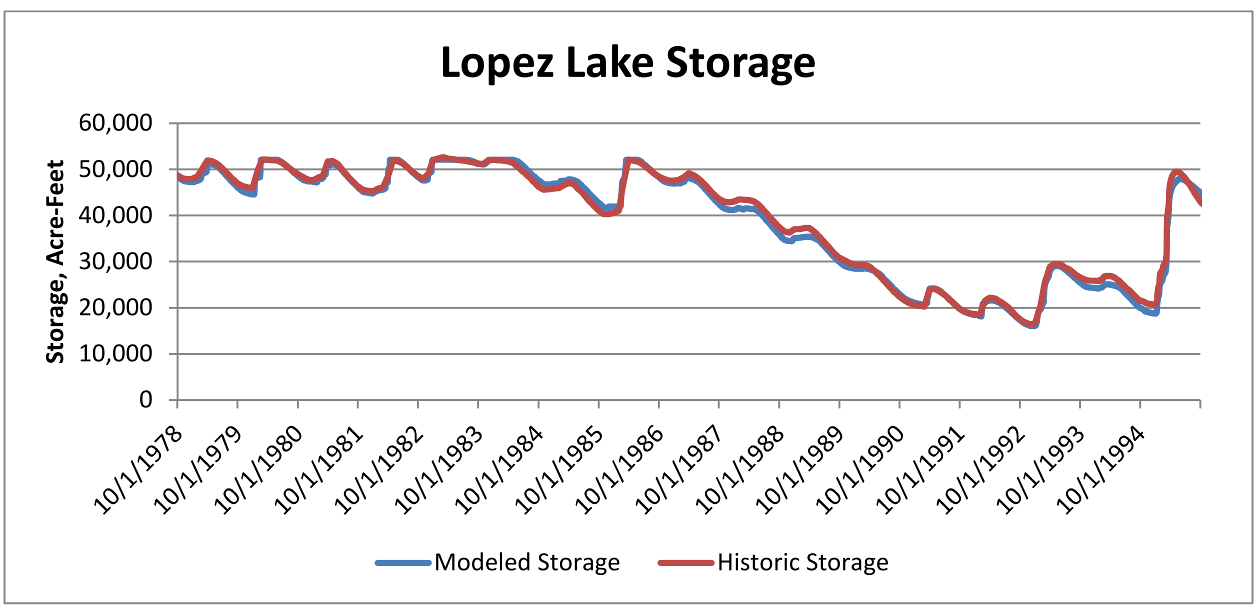


Figure 3 - Modeled storage vs Historic Storage

Tar Springs Creek (Inflow 135)

Tar Springs Creek was directly gaged by USGS from October 1967 through September 1979, and the record needs to be extended through 2024. This was done using a regression with a reference basin. Correlations with multiple local creeks were investigated, and the correlation with Lopez Creek was found to be the strongest with an $R^2 = 0.85$. For Water Years 1980 through 2024, Tar Springs Creek was estimated using Equation 3. When the calculation in Equation 3 resulted in negative values for Tar Springs Creek, the flow in Tar Springs Creek was estimated to be zero.

Equation 3

$$Tar\ Springs\ Creek\ (cfs) = Lopez\ Creek(cfs) * 0.5047 - 1.965$$

Los Berros Creek (Inflow 155)

Los Berros Creek was directly gaged by USGS from 1968 through 2001. Los Berros was also gaged when the District took over the stream gage in 2009. When records are available the direct streamgage data is used, and from June 2001 through February 2009 Los Berros Creek is estimated using Equation 4, which was developed using a daily regression with Lopez Creek R^2=0.84.

Equation 4

$$Los\ Berros\ Creek\ (cfs) = Lopez\ Creek\ (cfs) * 0.2371 - 0.4054$$

Arroyo Grande below Lopez Reservoir

Arroyo Grande below Lopez Reservoir was directly gaged by USGS from 1937 through 1986. The District took over the gaging and has directly gaged Arroyo Grande at this location up through the present, with the exception of a two year gap of 2003-2004 during which there are no records. The District added several stream gages along Arroyo Grande during the 2000s, and a graphic depicting the period of record for stream gages along the Arroyo Grande is shown in Figure 4. Monthly releases to Arroyo Grande from Lopez Reservoir are available beginning May 1968, and daily releases are available beginning December 1993. Accretions and Depletions along Arroyo Grande from Lopez Reservoir to the Arroyo Grande streamgage at Arroyo Grande can be directly calculated for the entire study period, except for the two years for which there is no Arroyo Grande streamgage data. Accretions and Depletions along Arroyo Grande from the Arroyo Grande streamgage to the 22nd Street Bridge streamgage can be directly calculated from beginning in 2009 and need to be estimated prior to 2009.

Figure 4 - Arroyo Grande Stream gages Data Availability

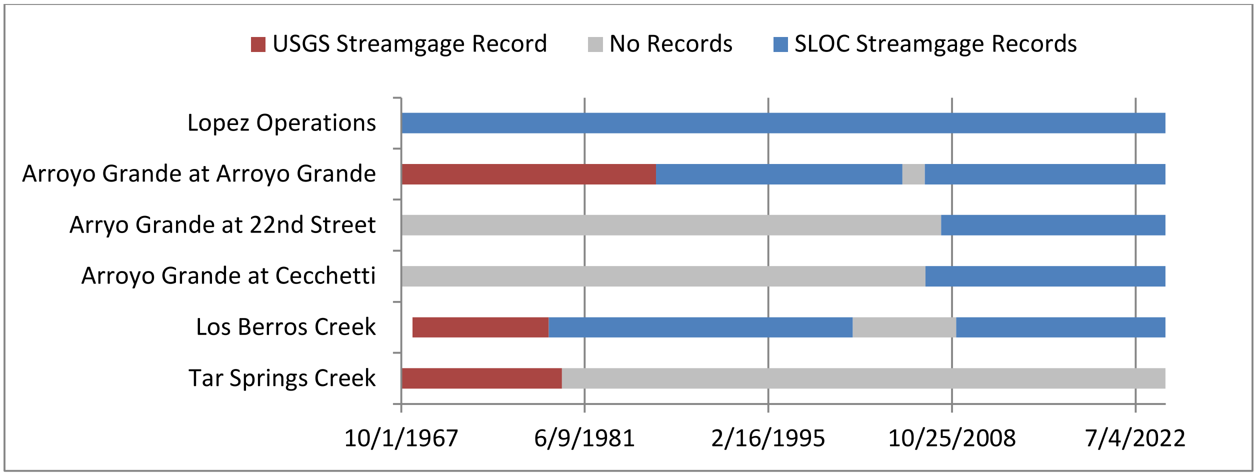


Table 1 shows the documented stage changes or shifts applied to the stage readings at the Arroyo Grande Creek at Arroyo Grande. The stage changes are used with the rating curve to determine the flow. The rating curve has not changed since the District took over the operations of the gage in 1986.

Table 14 – Documented Shift Changes & Datum Changes

Date	Shift	Notes
10/16/2006	-0.17	
2/22/2007	-0.27	
6/28/2007	-0.17	
4/13/2009	-0.37	
4/16/2009	-0.17	
7/2/2009	-0.37	
7/7/2009	-0.17	
11/7/2010	-0.34	
3/22/2011	-0.57	
7/2/2011	-0.52	
8/31/2011	-0.47	
11/9/2011	-0.22	
12/8/2011	-100.45	Datum change to NAVD29
1/12/2012	-99.44	
9/10/2012	-99.64	
1/11/2013	-100.55	
2/28/2013	-100.65	
3/10/2013	-100.55	
3/25/2013	-100.45	
10/19/2013	-100.55	
1/28/2015	-99.825	Datum Change to NGVD88 0.0' on old staff gage = 99.825'
Fall 2024		Modification Project changed the channel.

Because the Arroyo Grande Creek gage has been rebuilt as shown in Figures 5 and 6, it needs to be re-rated. This will take at least a year or two. The stage data can be collected while the rating is being developed.

Figure 5 - Arroyo Grande Creek Gage at Arroyo Grande – Before

Figure 6 - Arroyo Grande Creek Gage at Arroyo Grande - After

Accretions and Depletions from Lopez Reservoir to Arroyo Grande Stream gage (Flow 120.700)

Accretions between Lopez Reservoir and the Arroyo Grande stream gage are often seen during and immediately following rain events. Generally, there are depletions between Lopez and the Arroyo Grande Stream gage in the months of April through November other than during rain events. When the calculated historical accretions are positive in these dry months, the accretions are presumed to be the result of rainfall. When the calculated historical accretions are negative, historical regressions are used each month to estimate depletions. The results of historical depletion regressions are shown in figures 7 through 18 and summarized in Table 15. The regressions were developed in the Lower Arroyo Grande Hydrology 2.7.xlsm spreadsheet on the Arroyo Grande Lopez to AG Gage worksheet. In these figures, the black dots represent the entire historical dataset, while only the orange dots were used in determining the flow relationships. Dots that are not colored orange were not included due to rainfall, which masks the depletion relationships.

Figure 7 - January Accretions Lopez to Arroyo Grande

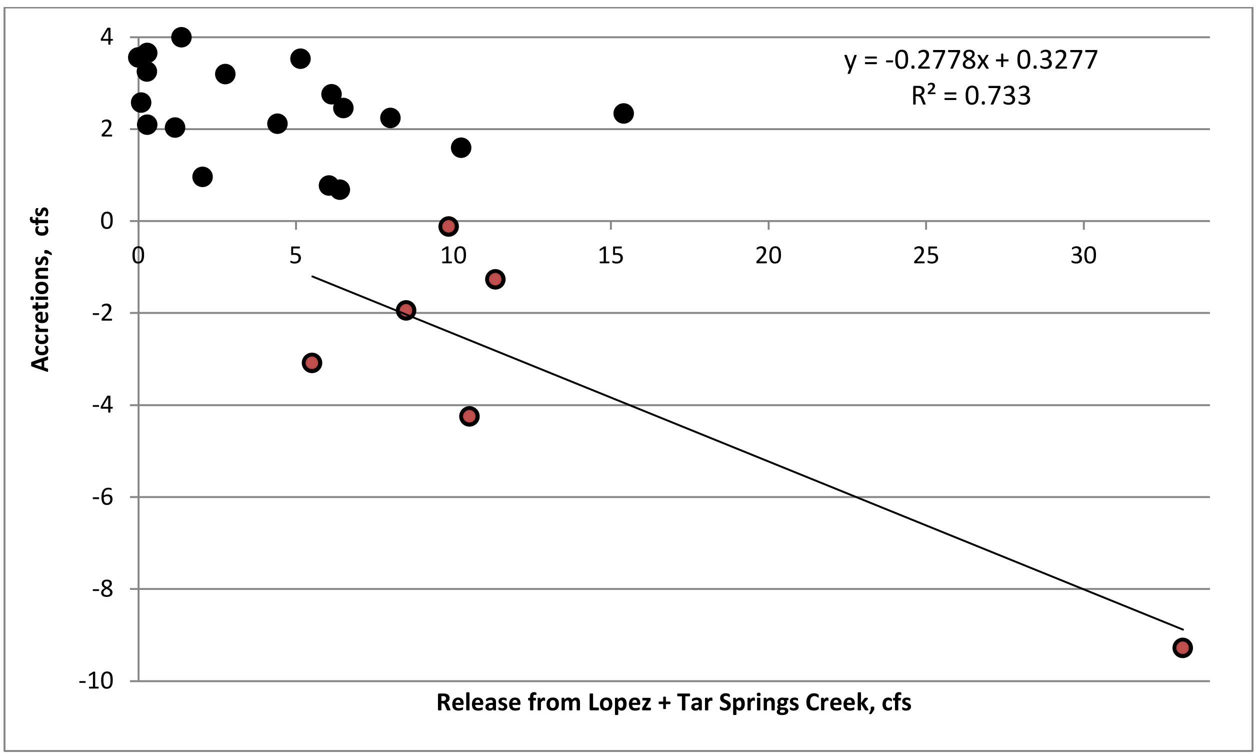


Figure 8 - February Accretions Lopez to Arroyo Grande

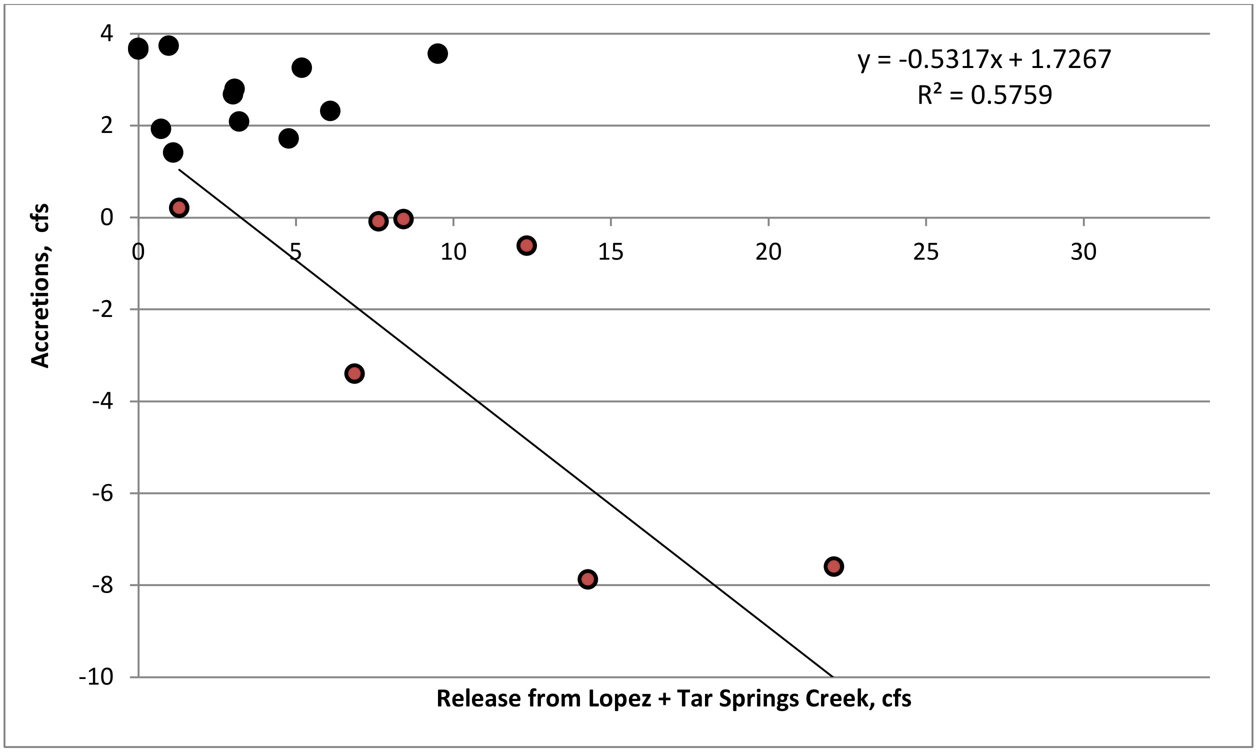


Figure 9 - March Accretions Lopez to Arroyo Grande

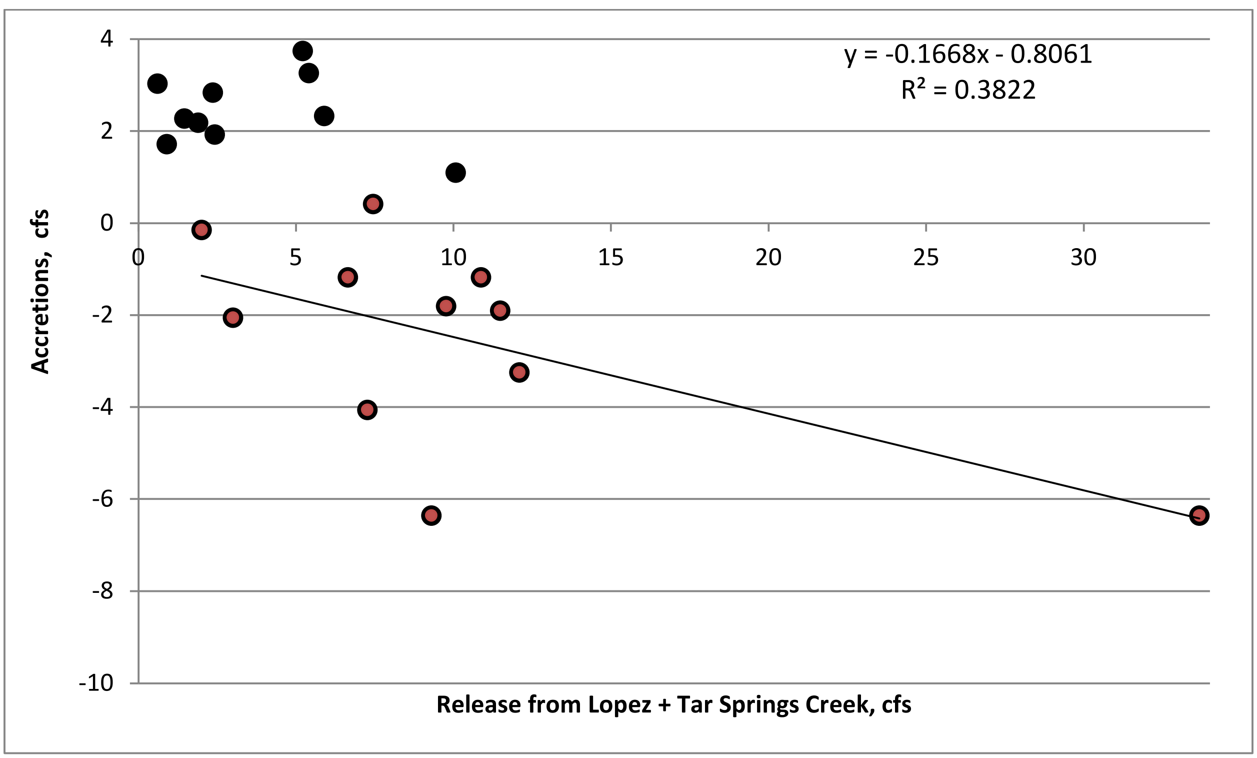


Figure 40 - April Accretions Lopez to Arroyo Grande

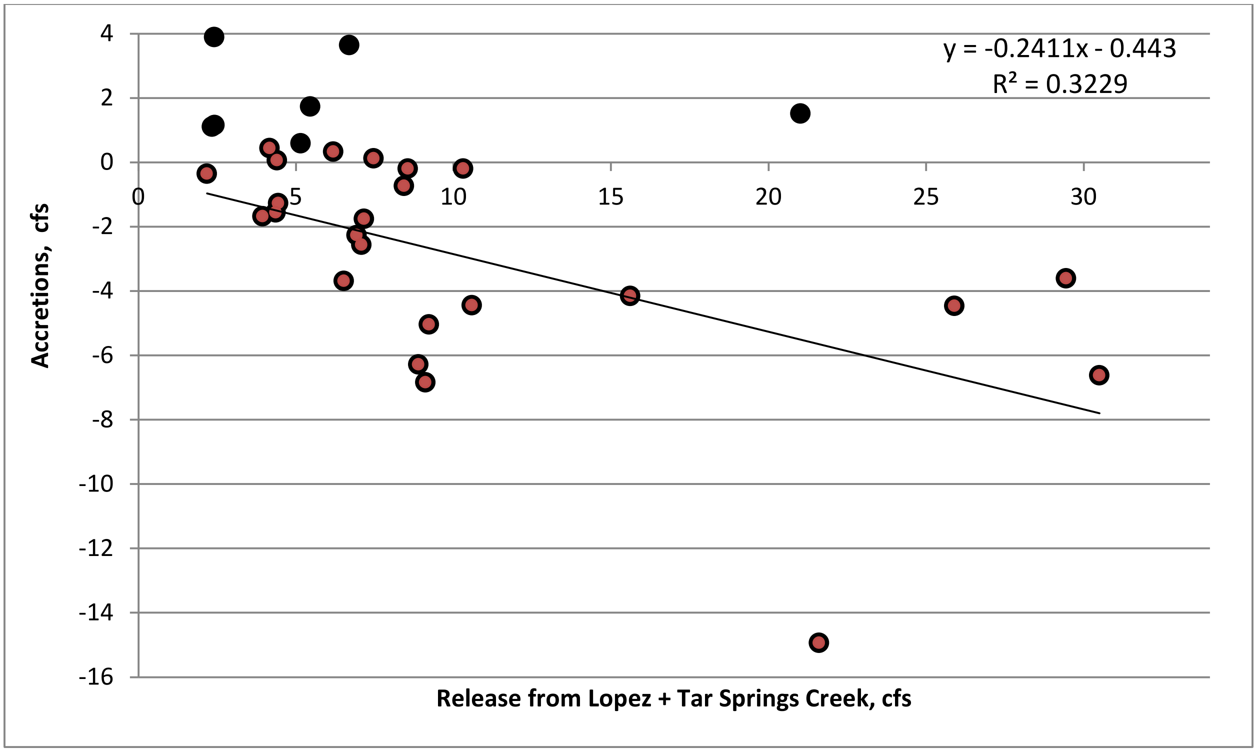


Figure 51 - May Accretions Lopez to Arroyo Grande

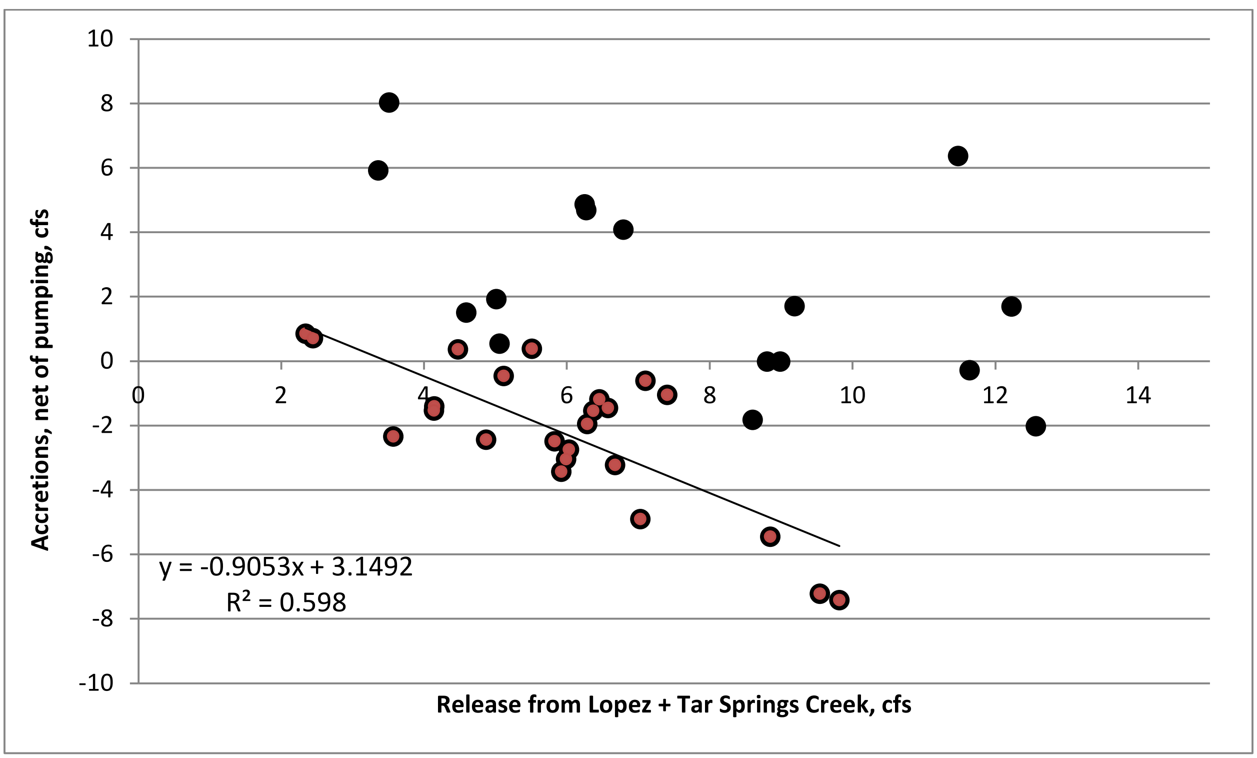


Figure 62 - June Accretions Lopez to Arroyo Grande

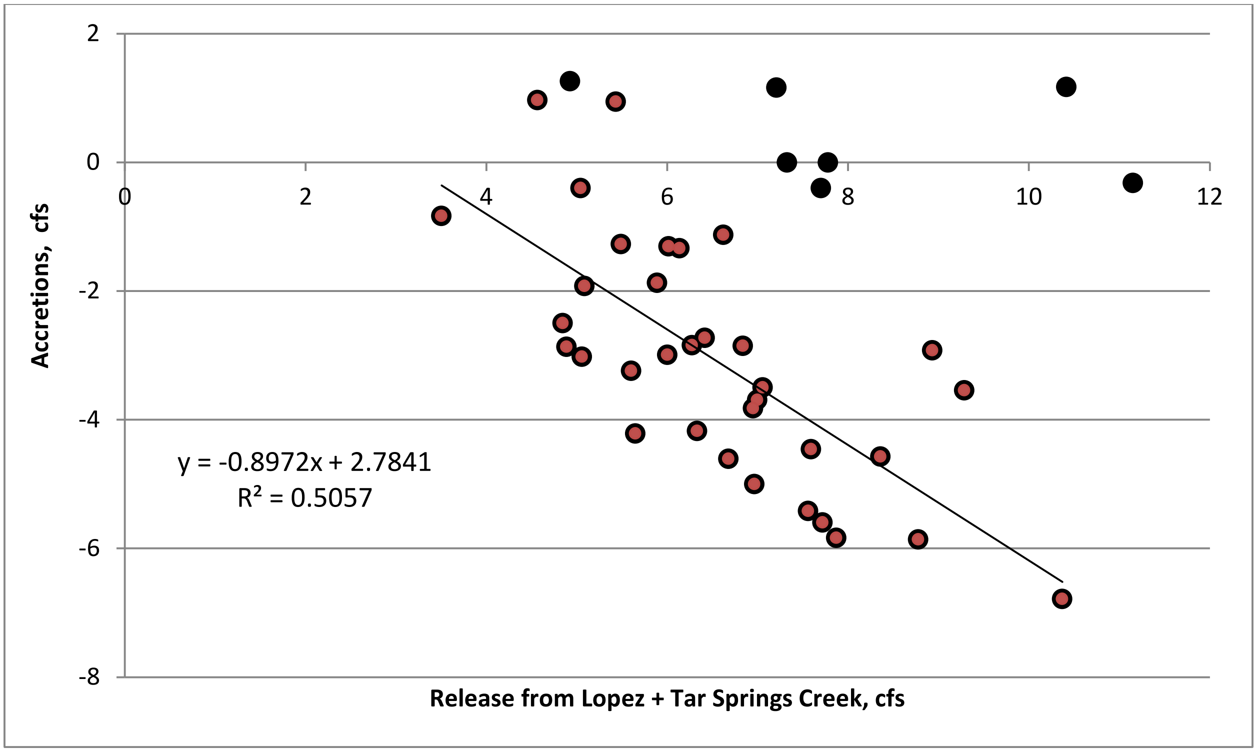


Figure 73 - July Accretions Lopez to Arroyo Grande

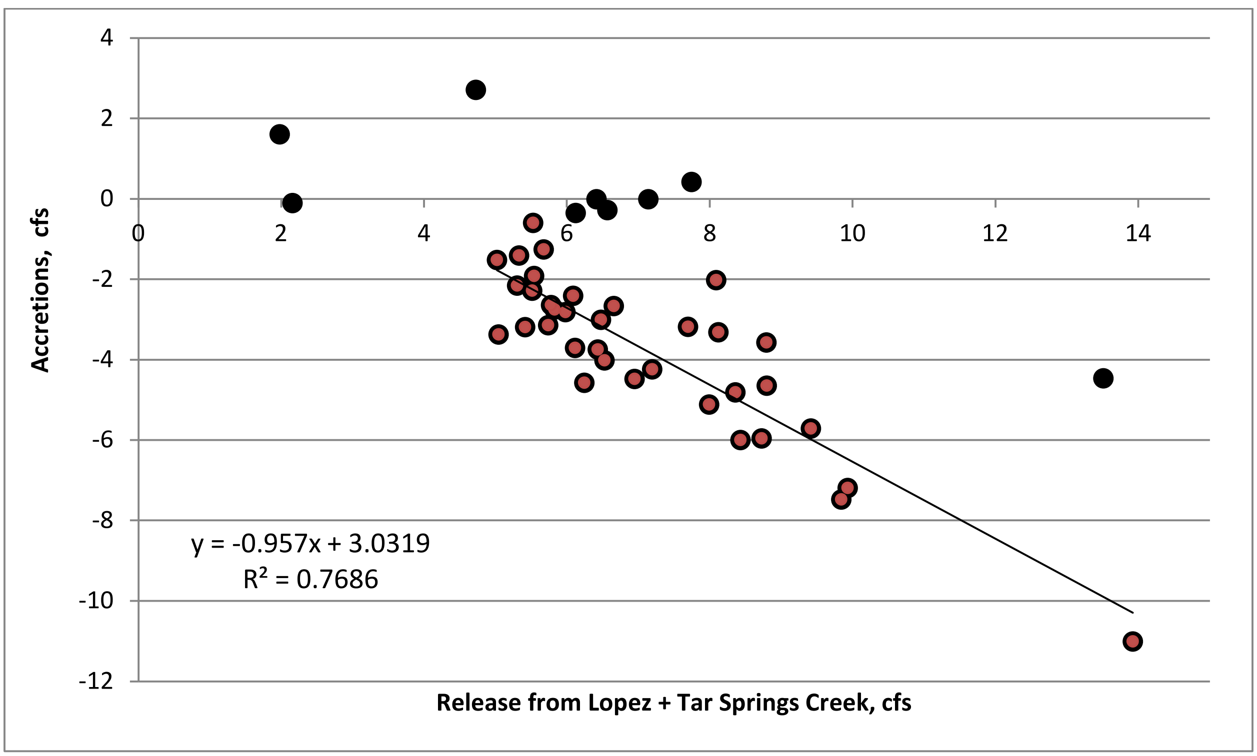


Figure 84 - August Accretions Lopez to Arroyo Grande

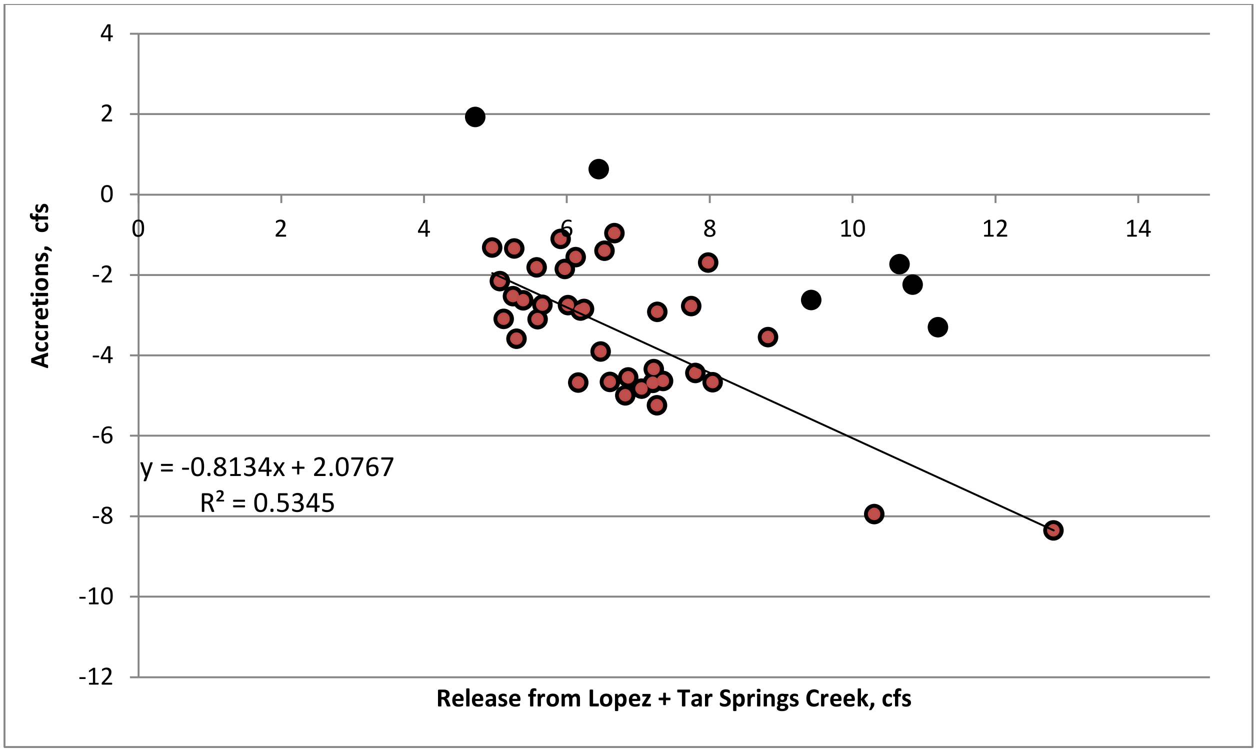


Figure 95 - September Accretions Lopez to Arroyo Grande

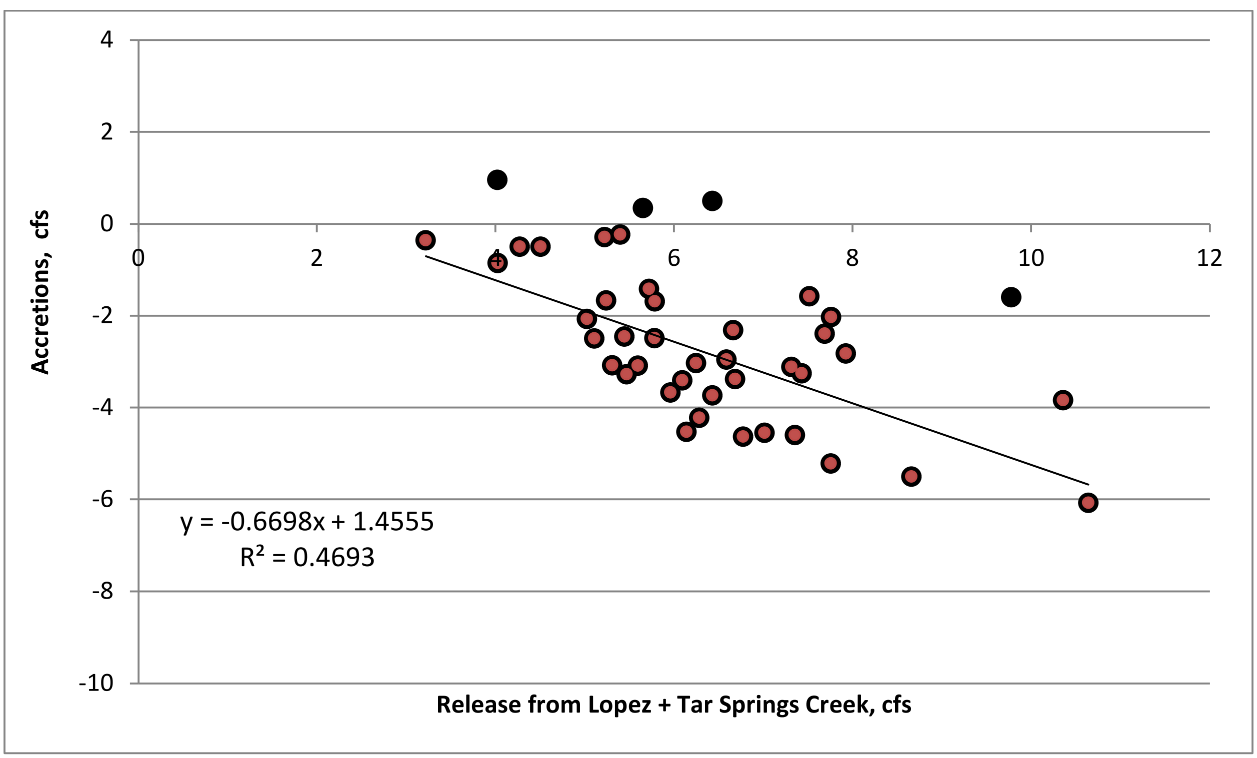


Figure 16 - October Accretions Lopez to Arroyo Grande

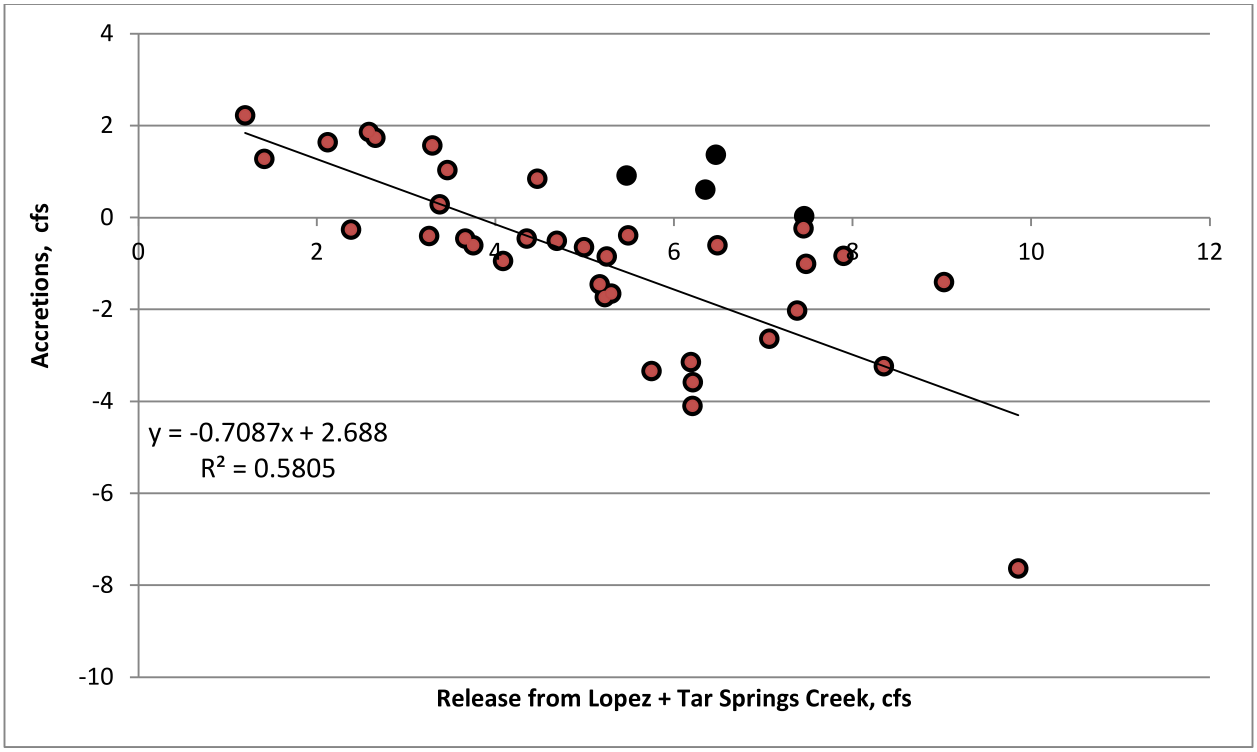


Figure 107 - November Accretions Lopez to Arroyo Grande

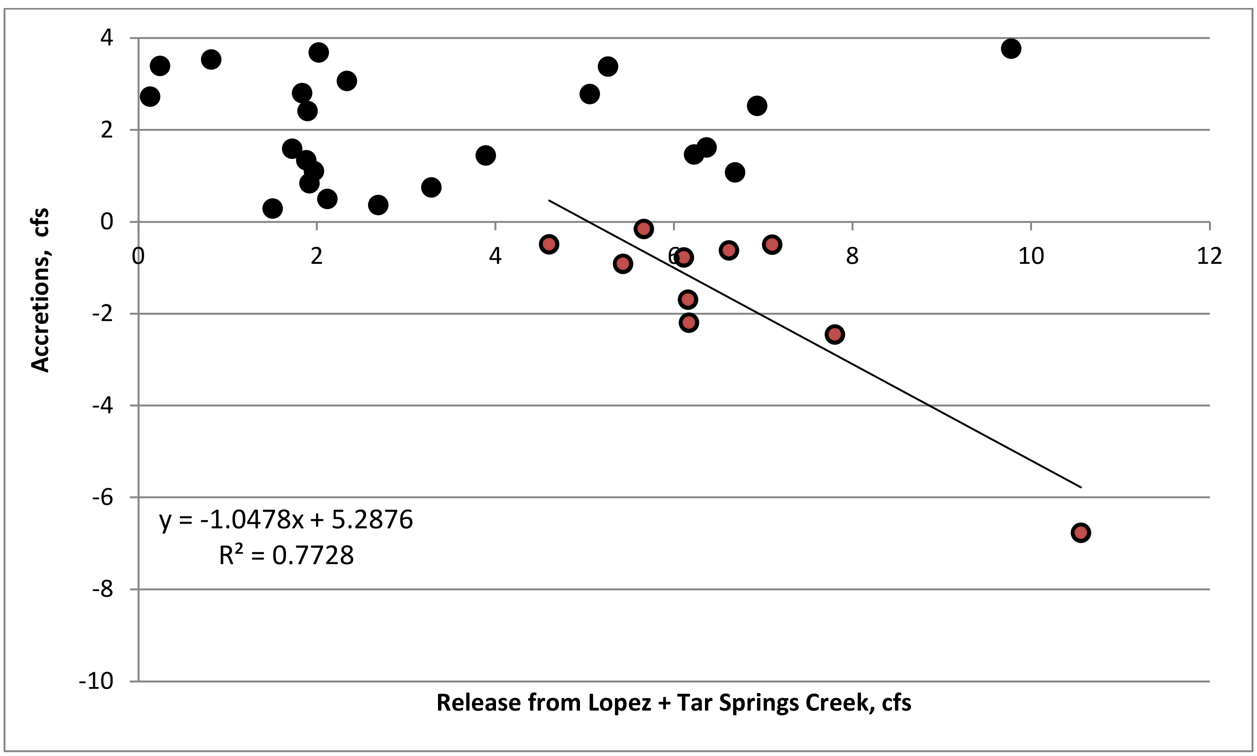


Figure 118 - December Accretions Lopez to Arroyo Grande

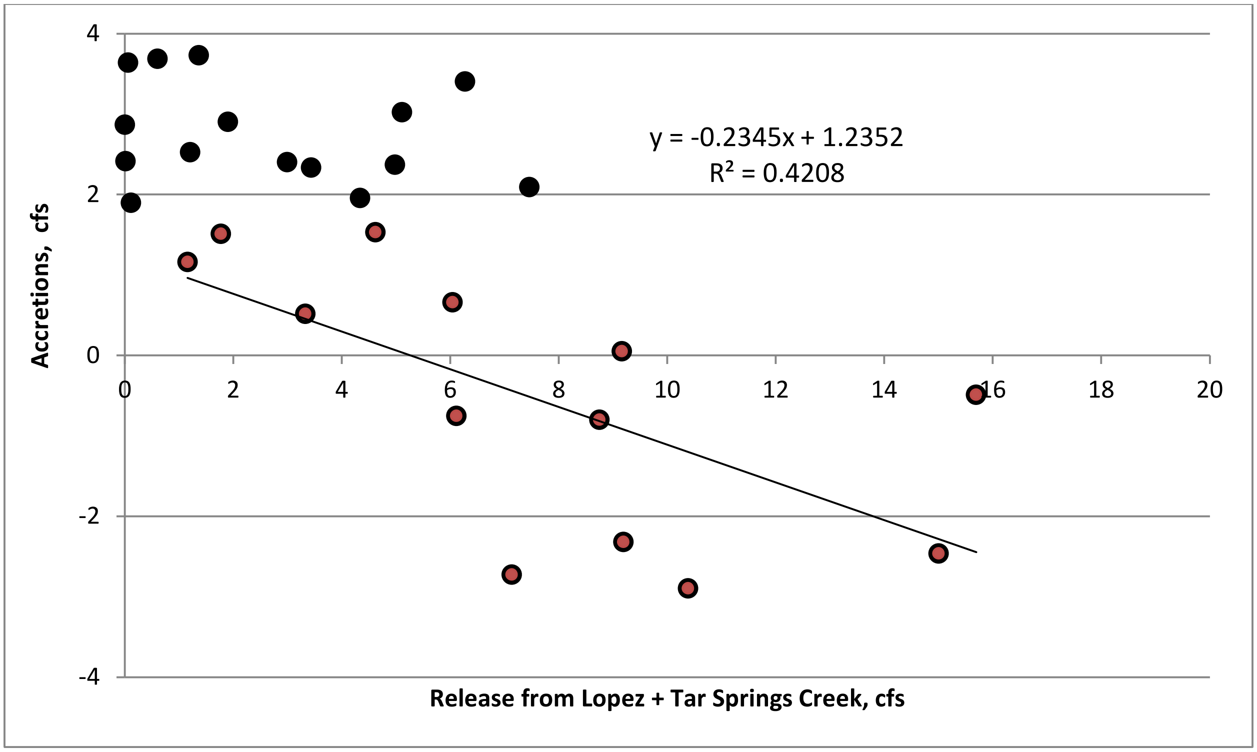


Table 15 - Lopez to Arroyo Grande Accretions Factors Summary

Month	Accretions multiplier	Accretions Intercept
January	-0.2778	0.3277
February	-0.5317	1.7267
March	-0.1668	-0.8061
April	-0.2411	-0.443
May	-0.9053	3.1492
June	-0.8972	2.7841
July	-0.9570	3.0319
August	-0.8134	2.0767
September	-0.6698	1.4555
October	-0.7087	2.6880
November	-1.0478	5.2876
December	-0.2345	1.2352

Deep Percolation of Precipitation (Flow 110.700)

The Arroyo Grande Creek has very dynamic connectivity to the groundwater basin. The hydrology for the OASIS model attempts to mimic that connectivity by including deep percolation of precipitation. The relationship between precipitation and deep percolation comes from a 2002 report from the

California Department of Water Resources[19] which provides the factors shown in Table 3. Using these factors and the corresponding annual precipitation total at Arroyo Grande, a correlation was developed to estimate Deep percolation. The correlation was then used with precipitation to develop the Deep Percolation for the period of the study.

Table 16 - Tri Cities Mesa - Arroyo Grande Deep Perc

Water Year	Deep Percolation of Precipitation (TAF)
1975	1.3
1976	0.6
1977	0.0
1978	4.2
1979	1.4
1980	1.5
1981	1.3
1982	2.7
1983	4.9
1984	0.6
1985	0.6
1986	2.7
1987	0.6
1988	0.7
1989	0.6
1990	0.0
1991	1.3
1992	1.5
1993	2.9
1994	0.6
1995	4.1
2010	1.1
2020	1.1

This development of the Deep Percolation is done in a spreadsheet called Precipitation Data – All Stations.xlsx.

[19] Department of Water Resources, Southern District, Water Resources of the Arroyo Grande – Nipomo Mesa Area, 2002. Table 25, Chapter VII Water Budget.

Arroyo Grande Valley Groundwater to Arroyo Grande Plain Groundwater Subsurface Flows

To account for the Groundwater subsurface flow from the Arroyo Grande Valley to the Arroyo Grande Plain, the model includes a term based on DWR's estimate[20]. As groundwater storage increases in the Arroyo Grande Valley, subsurface flow also increases to the Arroyo Grande Plain. Generally, groundwater storage ranges from 8,000 AF to 12,000 AF in the Arroyo Grande Valley. Likewise, subsurface flow will increase from 380 AF to 3,800 AF, annually.

Arroyo Grande Creek Accretions at Cecchetti (Inflow 120)

Once the accretions (positive values) from Lopez Dam to the Arroyo Grande gage (Arroyo Grande Accretion), are determined, they are split between Cecchetti and Arroyo Grande Gage by factors determined by annual ratio of Arroyo Grande Creek at Cecchetti Accretions to the Arroyo Grande Accretion. This was determined when gage data was available from 2012 to 2014. For the Cecchetti accretions a factor of 40% is applied to the Arroyo Gande Accretion.

Arroyo Grande Creek Accretions at Arroyo Grande Gage (Inflow 140)

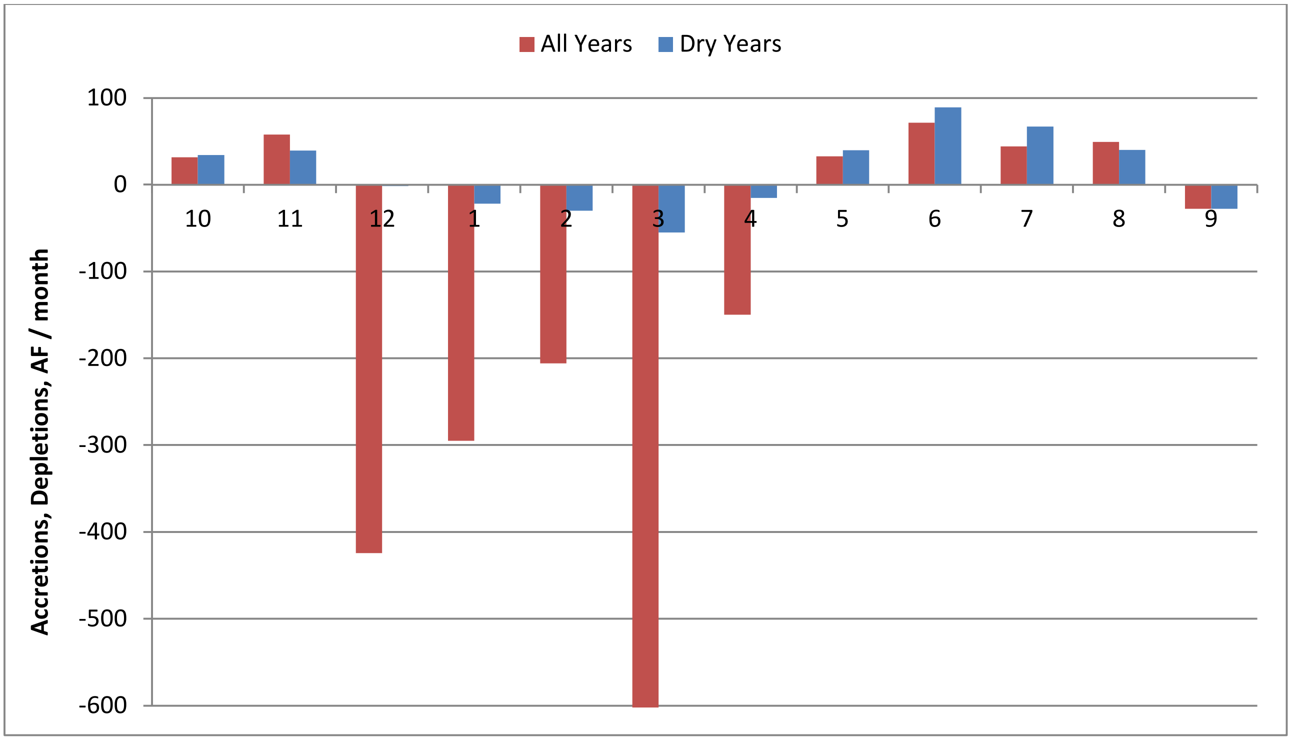
Once the accretions (positive values) from Lopez Dam to the Arroyo Grande gage (Arroyo Grande Accretion), are determined, they are split between Cecchetti and Arroyo Grande Gage by factors determined by annual ratio of Arroyo Grande Creek at Cecchetti Accretions to the Arroyo Grande Accretion. This was determined with gage data from 2012 to 2014. For the Cecchetti accretions a factor of 60% is applied to the Arroyo Gande Accretion.

Accretions and Depletions from Arroyo Grande Streamgage to 22nd Street Bridge Streamgage (Inflow 150)

Accretions and depletions from the Arroyo Grande Streamgage to the 22nd Street Bridge Stream gage can be directly calculated from 2009 through 2014 by subtracting the flow at the Arroyo Grande Creek at Arroyo Grande gage and the Los Berros Creek flow from the flow at the 22nd Street bridge. The general pattern of accretions and depletions in this reach is shown in Figure 7. Large depletions are seen during times of rainfall, while much lower depletions are seen during times of no rainfall. The late spring to early fall season (May through November) do not show depletions historically, although large flows due to large rainfall events would probably see some depletion to groundwater. The exception to this is September, which shows small losses in most years. Instead, these months gain a small amount of flow, likely due to agricultural runoff from the agricultural fields south of the Arroyo Grande along this reach. These agricultural gains typically measure 0.5 to 1.4 cfs. Historical depletion relationships for months in which there are depletions are shown in Figures 19 through 25 and are the source of the depletion factors.

[20] Department of Water Resources, Southern District, Water Resources of the Arroyo Grande – Nipomo Mesa Area, 2002. Tables 19 & 21, Chapter V Hydrogeology.

Figure 19 - Accretion and Depletion Patterns, Arroyo Grande to 22nd Street Bridge



The accretions shown in Figure 19 (values greater than 0) are expressed as local inflows to node 150. The depletions shown in Figure 19 (values less than 0) are expressed as losses to the groundwater basin at Node 710.

Depletions to GW Basin (Node 710)

The following factors are applied to the accretions below the Arroyo Grande Gage and are assumed to recharge the groundwater basin.

Table 17 - Lower Arroyo Grande Creek Depletion Factors

Condition	Depletion Factor
Jan Arroyo Grande Flow at Arroyo Grande >= 15 cfs	0.5
Jan Arroyo Grande Flow at Arroyo Grande < 15 cfs	0.1
Feb Arroyo Grande Flow at Arroyo Grande >= 10 cfs	0.5
Feb Arroyo Grande Flow at Arroyo Grande < 10 cfs	0.15
Mar Arroyo Grande Flow at Arroyo Grande >= 10 cfs	0.55
Mar Arroyo Grande Flow at Arroyo Grande < 10 cfs	0.1
Apr Arroyo Grande Flow at Arroyo Grande >= 10 cfs	0.5
Apr Arroyo Grande Flow at Arroyo Grande < 10 cfs	0.02
May through Aug	0
Sep	0.1
Oct & Nov	0
Dec Arroyo Grande Flow at Arroyo Grande > 10 cfs	0.5

Figure 120 - January Depletions Arroyo Grande to 22nd Street Bridge

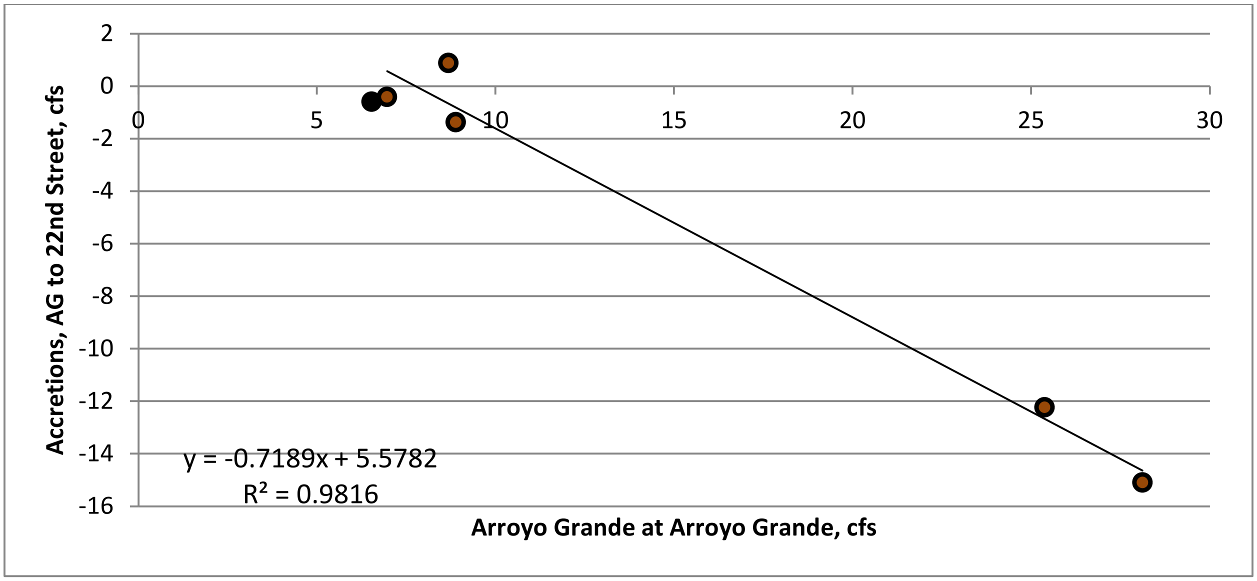


Figure 131 - February Depletions Arroyo Grande to 22nd Street Bridge

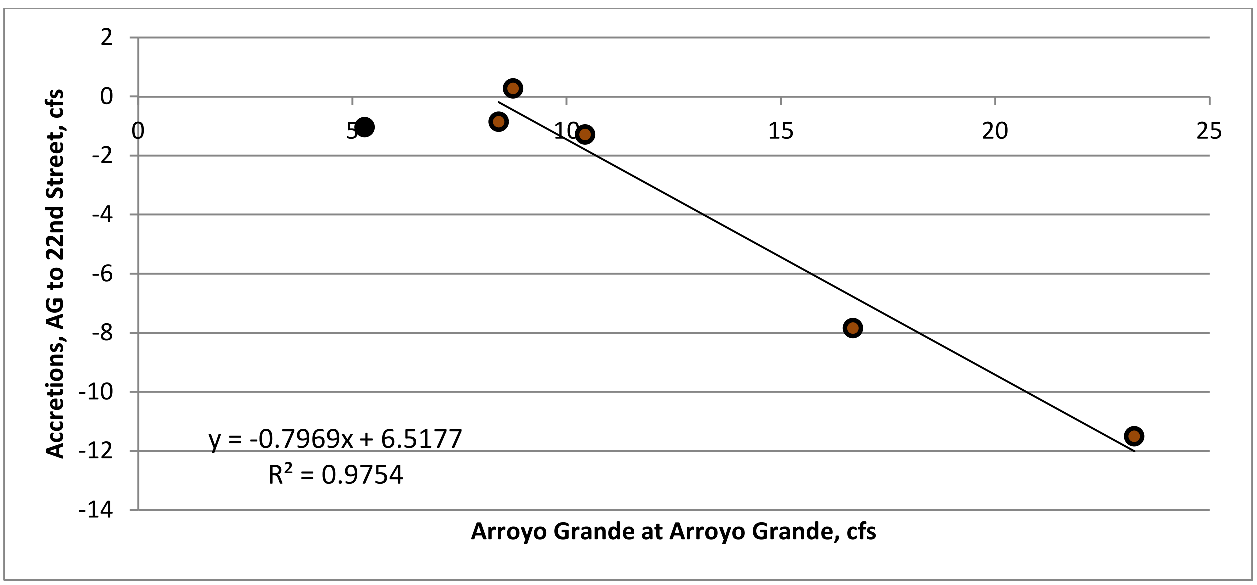


Figure 142 - March Depletions Arroyo Grande to 22nd Street Bridge

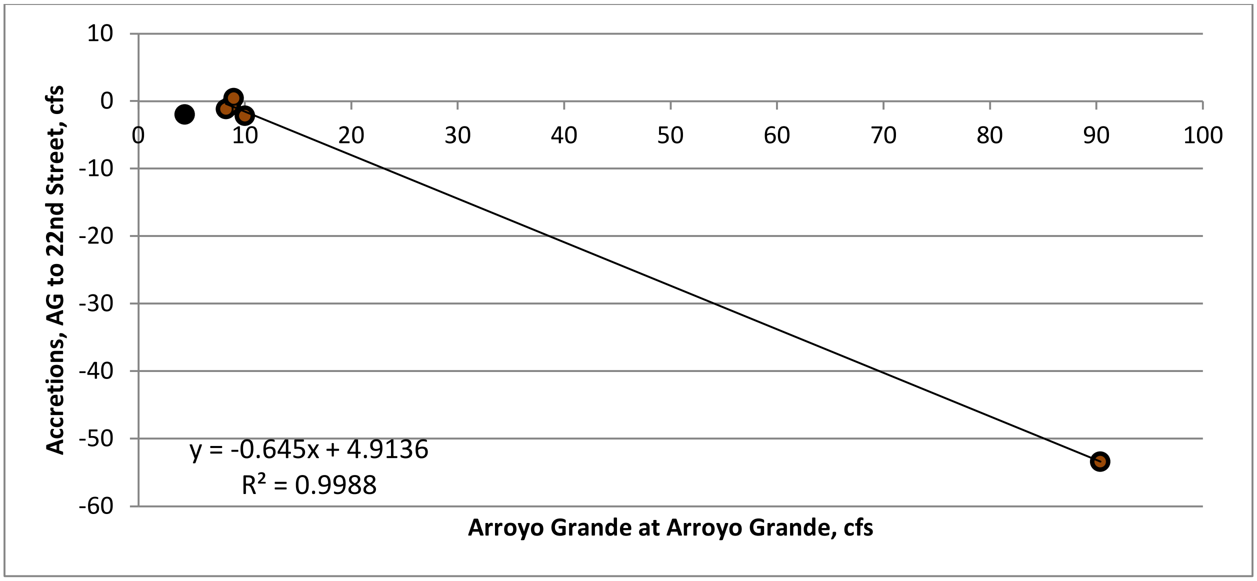


Figure 153 - April Depletions Arroyo Grande to 22nd Street Bridge

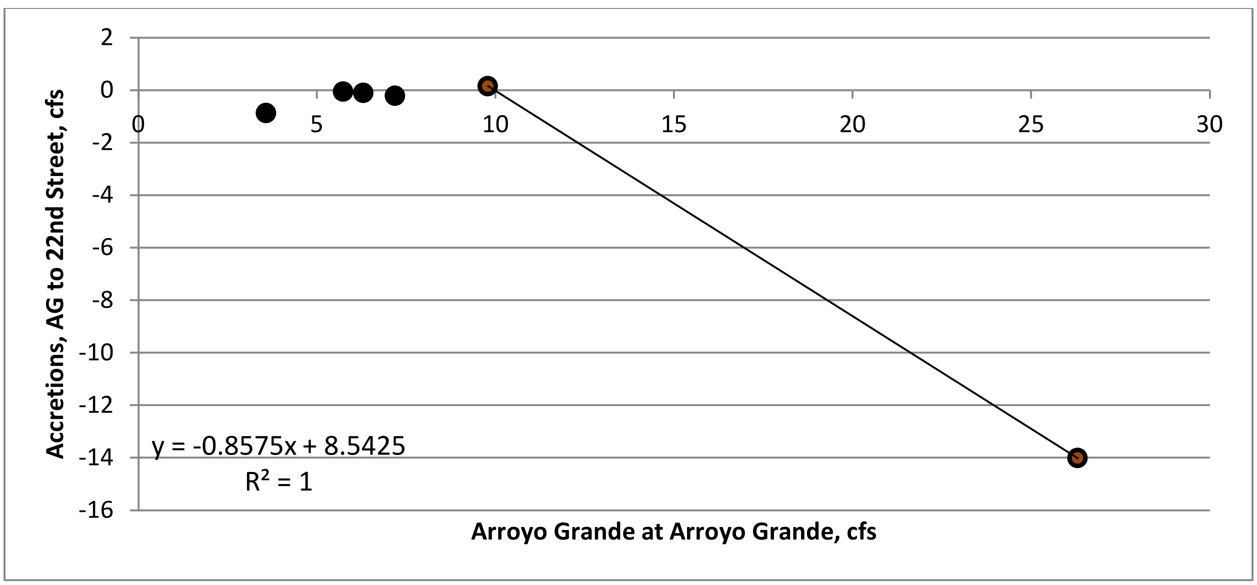


Figure 164 - September Depletions Arroyo Grande to 22nd Street Bridge

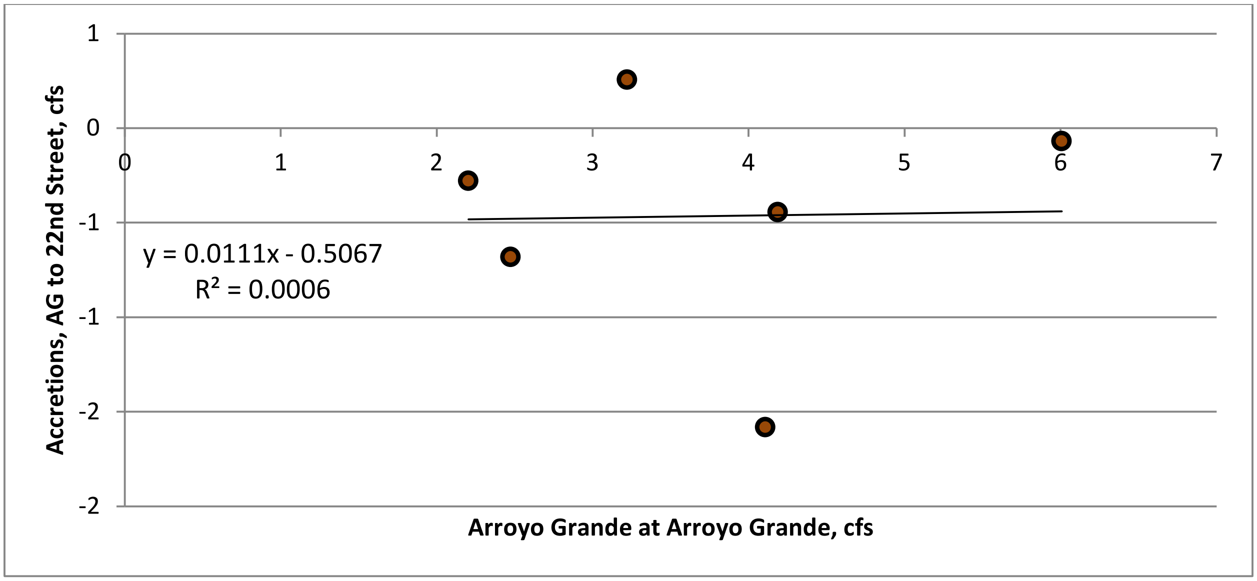
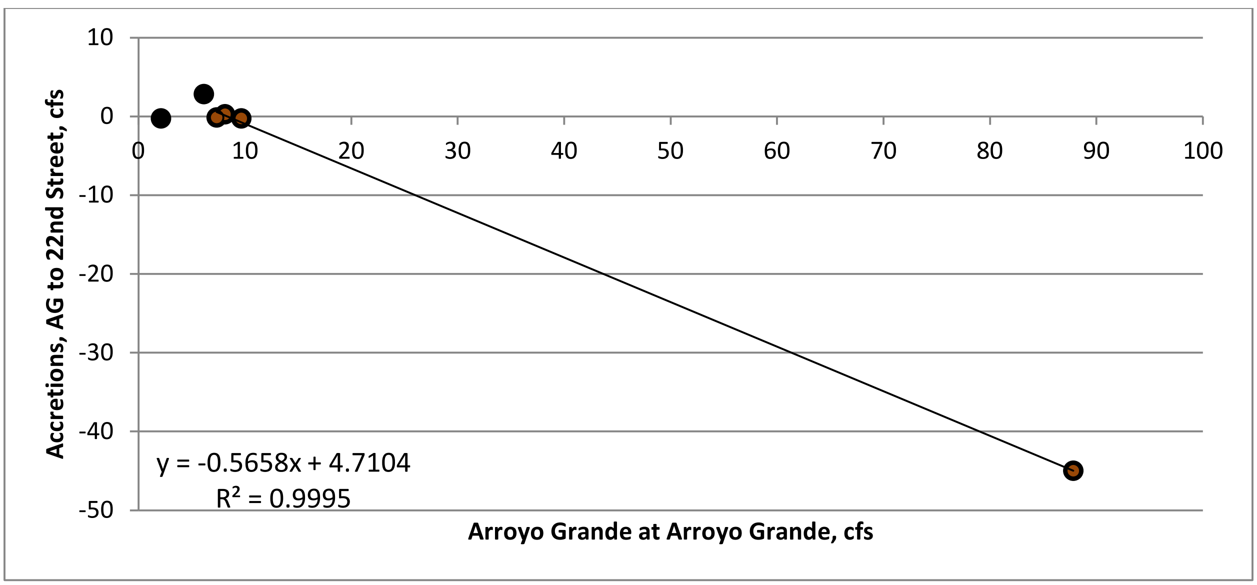


Figure 175 - December Depletions Arroyo Grande to 22nd Street Bridge



APPENDIX C: Simulation Model Sample Output

Output Plots

The OASIS software package is capable of generating output plots like the following or can generate output tables suitable for use with Microsoft Excel. Figure 1, below, shows water supply demand and corresponding water sources that make up the delivery. In this example the entire demand is met with a combination of State Water Project supplies, Lopez Lake supplies, and groundwater pumping.

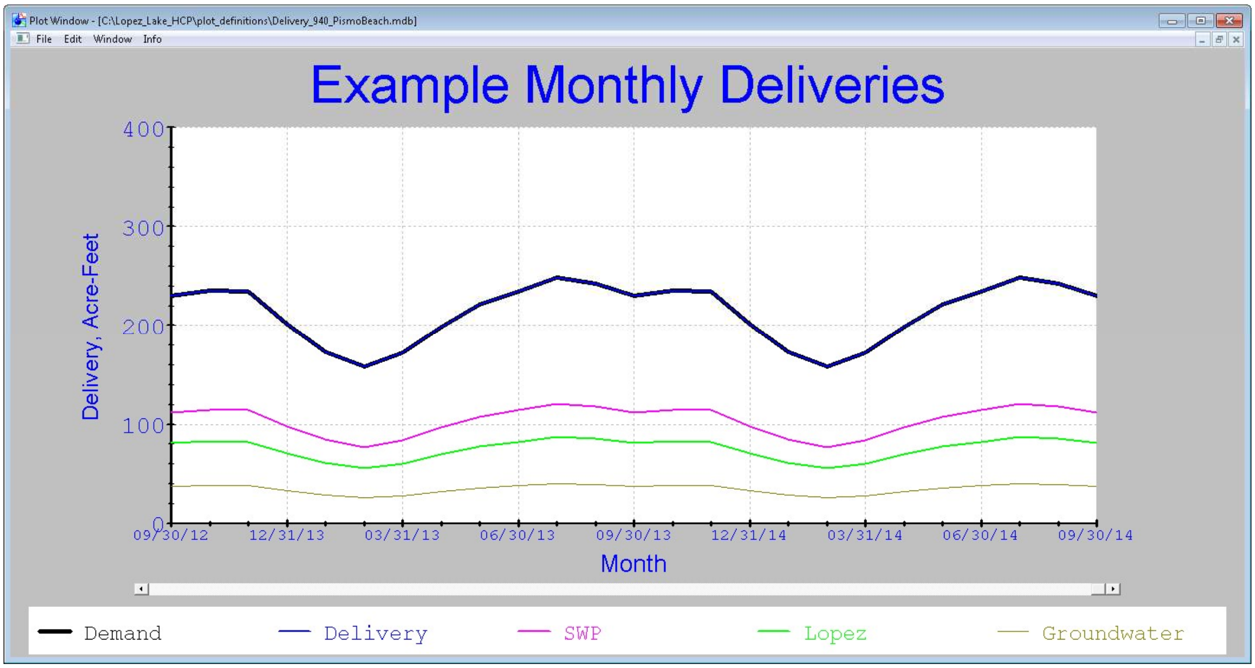


Figure 1 - Sample Agency Deliveries

Figure 2 shows hypothetical deliveries to an agency that has no access to State Water. In this case, deliveries are made up of groundwater and from Lopez Lake supplies.

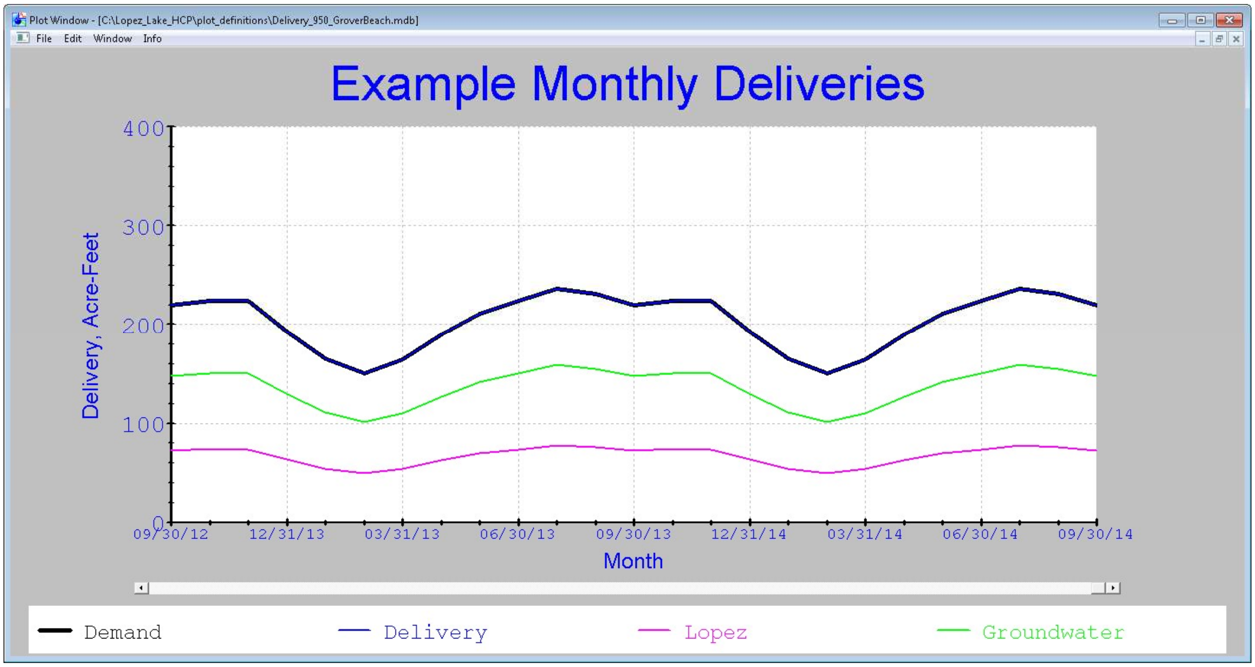
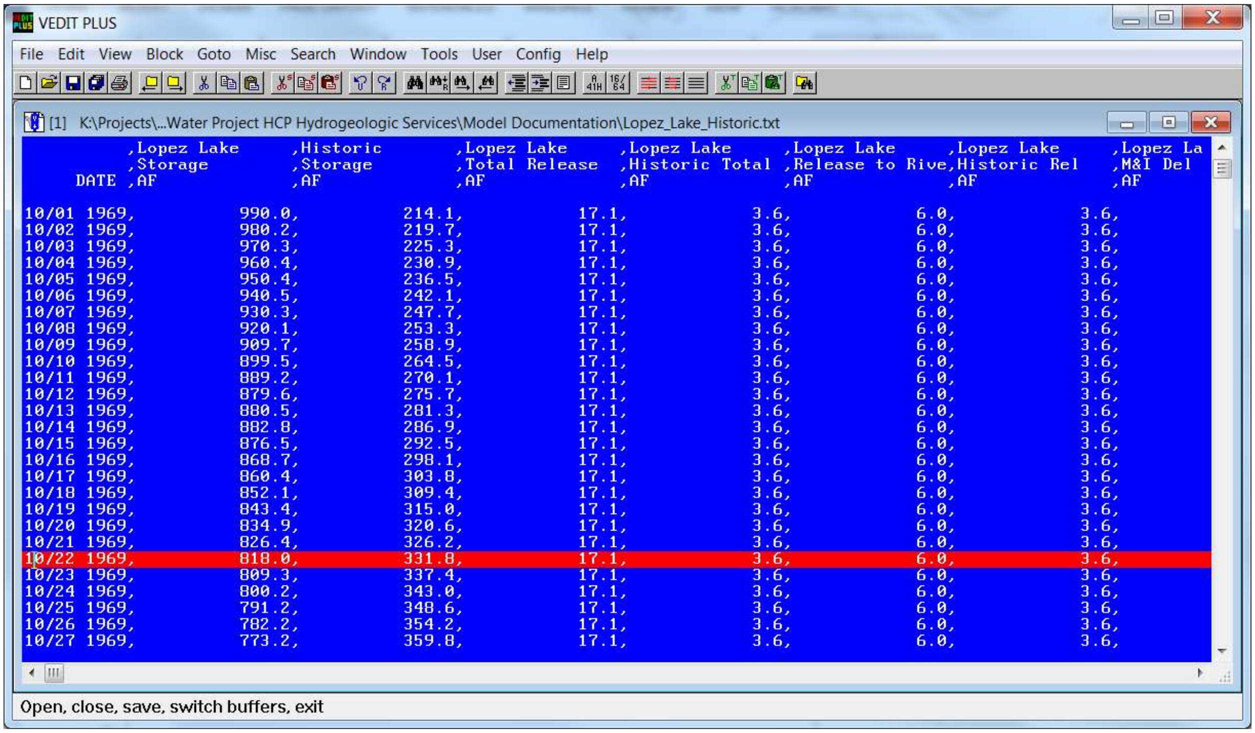


Figure 2 - Sample Agency Deliveries

Comma Delimited Output Tables

Figure 3 is an example of a comma delimited output table that can be exported to Microsoft Excel. These output tables are fully customizable to any variable included in the simulation model. Figure 3 output is specific to Lopez Lake operations.


VEDIT PLUS

File Edit View Block Goto Misc Search Window Tools User Config Help

[1] K:\Projects\...Water Project HCP Hydrogeologic Services\Model Documentation\Lopez_Lake_Historic.txt

DATE	,Lopez Lake ,Storage ,AF	,Historic ,Storage ,AF	,Lopez Lake ,Total Release ,AF	,Lopez Lake ,Historic Total ,AF	,Lopez Lake ,Release to Rive ,AF	,Lopez Lake ,Historic Rel ,AF	,Lopez La ,M&I Del ,AF
10/01 1969,	990.0,	214.1,	17.1,	3.6,	6.0,	3.6,	
10/02 1969,	980.2,	219.7,	17.1,	3.6,	6.0,	3.6,	
10/03 1969,	970.3,	225.3,	17.1,	3.6,	6.0,	3.6,	
10/04 1969,	960.4,	230.9,	17.1,	3.6,	6.0,	3.6,	
10/05 1969,	950.4,	236.5,	17.1,	3.6,	6.0,	3.6,	
10/06 1969,	940.5,	242.1,	17.1,	3.6,	6.0,	3.6,	
10/07 1969,	930.3,	247.7,	17.1,	3.6,	6.0,	3.6,	
10/08 1969,	920.1,	253.3,	17.1,	3.6,	6.0,	3.6,	
10/09 1969,	909.7,	258.9,	17.1,	3.6,	6.0,	3.6,	
10/10 1969,	899.5,	264.5,	17.1,	3.6,	6.0,	3.6,	
10/11 1969,	889.2,	270.1,	17.1,	3.6,	6.0,	3.6,	
10/12 1969,	879.6,	275.7,	17.1,	3.6,	6.0,	3.6,	
10/13 1969,	880.5,	281.3,	17.1,	3.6,	6.0,	3.6,	
10/14 1969,	882.8,	286.9,	17.1,	3.6,	6.0,	3.6,	
10/15 1969,	876.5,	292.5,	17.1,	3.6,	6.0,	3.6,	
10/16 1969,	868.7,	298.1,	17.1,	3.6,	6.0,	3.6,	
10/17 1969,	860.4,	303.8,	17.1,	3.6,	6.0,	3.6,	
10/18 1969,	852.1,	309.4,	17.1,	3.6,	6.0,	3.6,	
10/19 1969,	843.4,	315.0,	17.1,	3.6,	6.0,	3.6,	
10/20 1969,	834.9,	320.6,	17.1,	3.6,	6.0,	3.6,	
10/21 1969,	826.4,	326.2,	17.1,	3.6,	6.0,	3.6,	
10/22 1969,	818.0,	331.8,	17.1,	3.6,	6.0,	3.6,	
10/23 1969,	809.3,	337.4,	17.1,	3.6,	6.0,	3.6,	
10/24 1969,	800.2,	343.0,	17.1,	3.6,	6.0,	3.6,	
10/25 1969,	791.2,	348.6,	17.1,	3.6,	6.0,	3.6,	
10/26 1969,	782.2,	354.2,	17.1,	3.6,	6.0,	3.6,	
10/27 1969,	773.2,	359.8,	17.1,	3.6,	6.0,	3.6,	

Open, close, save, switch buffers, exit

Figure 3 - Sample of Comma Delimited Output Table

Figure 4 is an example illustration of the Baseline study compared to the historic operation. This graphic was developed with Microsoft Excel using the comma delimited file illustrated in Figure 4. This type of information is used to quickly compare alternative modeling scenarios.

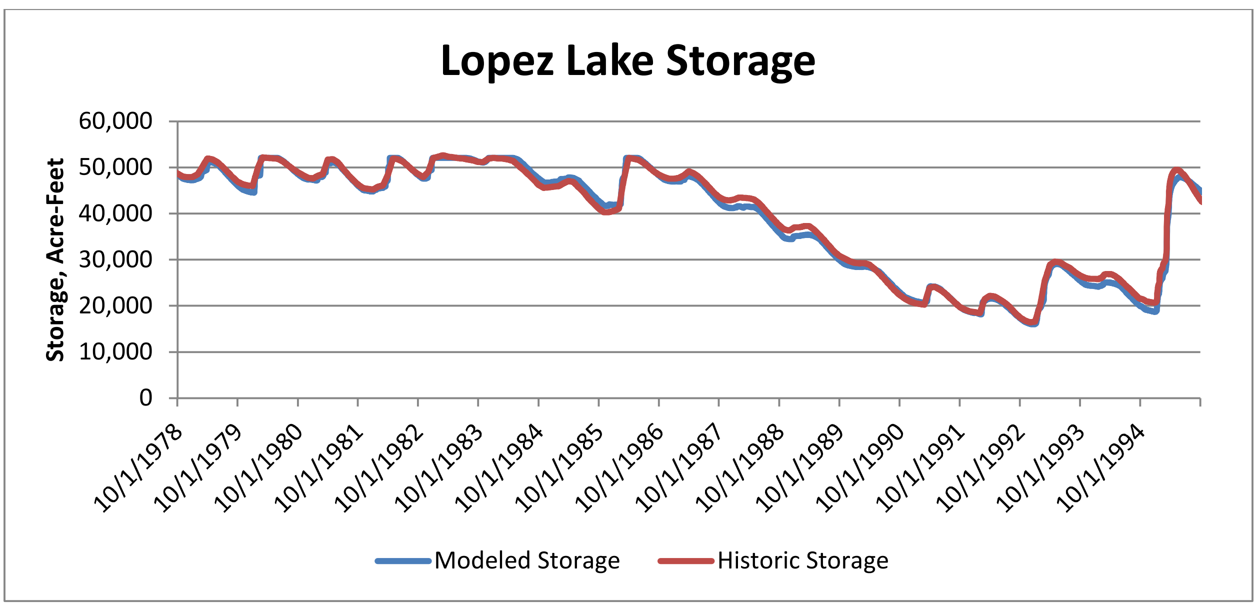
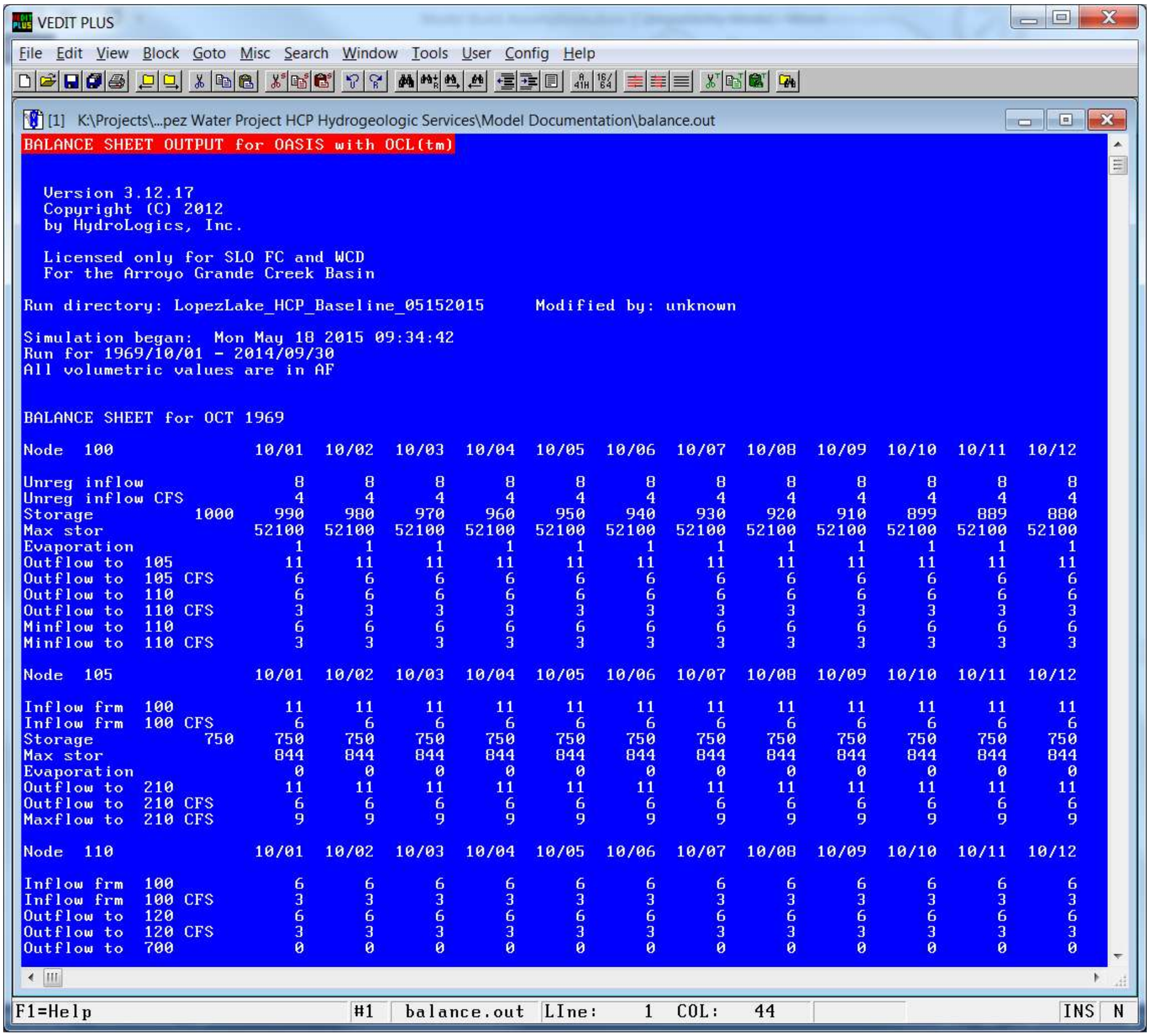


Figure 4 - Sample of Lopez Lake Storage Analysis

Balance Sheet

Figure 5 is an example of a diagnostic output table called a Balance Sheet that provides information about all inputs and releases at each node in the system for each time step in the simulation. Using the modeling schematic, the user can identify each node, to check how the model is routing the water. In this example, Node 100 represents Lopez Lake and has a starting storage is 1,000 AF. The unimpaired inflow is 8 AF, and the releases to the creek (6 AF) and to meet the Municipal demand (11 AF) and evaporation (1 AF) cause the reservoir to drop by 10 AF in the first day. This utility can be used to help the user understand how the water is routed.



```
BALANCE SHEET OUTPUT for OASIS with OCL(tm)

  Version 3.12.17
  Copyright (C) 2012
  by HydroLogics, Inc.

  Licensed only for SLO FC and WCD
  For the Arroyo Grande Creek Basin

Run directory: LopezLake_HCP_Baseline_05152015     Modified by: unknown

Simulation began:  Mon May 18 2015 09:34:42
Run for 1969/10/01 - 2014/09/30
All volumetric values are in AF


BALANCE SHEET for OCT 1969

Node  100                 10/01  10/02  10/03  10/04  10/05  10/06  10/07  10/08  10/09  10/10  10/11  10/12

Unreg inflow                  8      8      8      8      8      8      8      8      8      8      8      8
Unreg inflow CFS              4      4      4      4      4      4      4      4      4      4      4      4
Storage            1000     990    980    970    960    950    940    930    920    910    899    889    880
Max stor                  52100  52100  52100  52100  52100  52100  52100  52100  52100  52100  52100  52100
Evaporation                   1      1      1      1      1      1      1      1      1      1      1      1
Outflow to  105              11     11     11     11     11     11     11     11     11     11     11     11
Outflow to  105 CFS           6      6      6      6      6      6      6      6      6      6      6      6
Outflow to  110               6      6      6      6      6      6      6      6      6      6      6      6
Outflow to  110 CFS           3      3      3      3      3      3      3      3      3      3      3      3
Minflow to  110               6      6      6      6      6      6      6      6      6      6      6      6
Minflow to  110 CFS           3      3      3      3      3      3      3      3      3      3      3      3

Node  105                 10/01  10/02  10/03  10/04  10/05  10/06  10/07  10/08  10/09  10/10  10/11  10/12

Inflow frm  100              11     11     11     11     11     11     11     11     11     11     11     11
Inflow frm  100 CFS           6      6      6      6      6      6      6      6      6      6      6      6
Storage             750     750    750    750    750    750    750    750    750    750    750    750    750
Max stor                    844    844    844    844    844    844    844    844    844    844    844    844
Evaporation                   0      0      0      0      0      0      0      0      0      0      0      0
Outflow to  210              11     11     11     11     11     11     11     11     11     11     11     11
Outflow to  210 CFS           6      6      6      6      6      6      6      6      6      6      6      6
Maxflow to  210 CFS           9      9      9      9      9      9      9      9      9      9      9      9

Node  110                 10/01  10/02  10/03  10/04  10/05  10/06  10/07  10/08  10/09  10/10  10/11  10/12

Inflow frm  100               6      6      6      6      6      6      6      6      6      6      6      6
Inflow frm  100 CFS           3      3      3      3      3      3      3      3      3      3      3      3
Outflow to  120               6      6      6      6      6      6      6      6      6      6      6      6
Outflow to  120 CFS           3      3      3      3      3      3      3      3      3      3      3      3
Outflow to  700               0      0      0      0      0      0      0      0      0      0      0      0
```

Figure 5 - Sample of Diagnostic Output File: Balance Sheet