Los Angeles County Watershed Model Configuration and Calibration—Part I: Hydrology

Submitted to:

County of Los Angeles
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Introduction

The federal Clean Water Act (CWA) requires the Los Angeles Regional Water Quality Control Board (Regional Board) to develop water quality objectives to protect beneficial uses for each waterbody within its region. Comparing water quality data to those objectives resulted in the Regional Board identifying Ballona Creek (BC), Los Angeles River (LAR), Dominguez Channel (DC), San Gabriel River (SGR), Santa Clara River (SCR), and Santa Monica Bay and adjacent beaches (SMB) as impaired for several pollutant classes. On the basis of those impairments and a March 1999 Consent Decree (CD) between the U.S. Environmental Protection Agency (EPA) and Heal the Bay, Inc., and BayKeeper, Inc., EPA and Regional Board were compelled to develop total maximum daily loads (TMDLs) for the impaired waters within 13 years of the CD. The schedule for development and approved Basin Plan amendments for the TMDLs varies and depends on pollutants and waterbodies addressed. Typically, approved TMDLs include numeric targets for each pollutant for both dry and wet weather; an assessment of sources; the assimilative capacity of the system; the wasteload allocations (storm water and treatment plants); and a phased implementation plan. The phased implementation plans for the municipal separate storm sewer system permit mark TMDL compliance in prescribed percentages for various jurisdictional groups with a goal of total compliance with wasteload allocations to be achieved over a specified period. The Regional Board also intends to reconsider these TMDLs within specified periods on the basis of additional data obtained from special studies.

The County of Los Angeles Department of Public Works (DPW) contracted with Tetra Tech to develop a comprehensive decision support system to help select best management practices (BMPs), watershed planning, development of strategic TMDL compliance plans. The process for developing TMDL compliance plans and the expectations of the Regional Board are still evolving, with an increasing emphasis on the necessity for quantifying load reductions to show that compliance can be achieved as a result of implementing BMPs specified in the plans. Recent discussions of the Regional Board, DPW, City of Los Angeles (LA), EPA, and various researchers in the LA region have determined that watershed models can serve as a critical tool in quantification of pollutant loads and reductions achieved through BMP implementation, as well as strategic watershed planning. Such models have been developed for the LA County watersheds by EPA and the Regional Board (BC, LAR, DC, SGR, SMB) and Ventura and LA counties (SCR) to assess pollutant sources, support TMDL development, and support watershed management. Figure 1 is a map of the major LA regional watersheds that either originate in or flow through the county. The models, linked with additional BMP selection and modeling tools, serve as a powerful tool to guide watershed planning to meet TMDL load reduction requirements. The model runs can be used to support a variety of water availability and storm flow analyses. In addition, the hydrologic model will provide a platform for future modeling of changes in the watershed and its resulting influence on water quantity and quality.

Figure 1. Locations of major regional watersheds in LA County.

Scope of This Report

This report is the culmination of a number of intermediate deliverables that have outlined specific components of the model development process. The primary objective of this report is to describe model setup and configuration, hydrology calibration, and validation. It is intended to be a standalone document that incorporates relevant material contained in the earlier reports and captures relevant refinements along the way.

The first phase of modeling decision framework for county watersheds is to develop a comprehensive, uniform watershed model of county watersheds to assist in watershed planning and pollutant load reduction analysis. Various watershed models were available for each of the coastal watersheds of LA County. Through a joint effort of the Regional Board, EPA, Southern California Coastal Water Research Project (SCCWRP), and Tetra Tech, Inc., a regional modeling approach has been developed to simulate the hydrology and transport of sediment and metals. The approach was based on EPA's Hydrologic Simulation Program–FORTRAN (HSPF) and the Loading Simulation Program C++ (LSPC) (a version of HSPF, recoded into C++). It has been used to support metals TMDLs for BC, the LAR, and the SGR, and it is being applied to DC and to downstream portions of the estuary and LA and Long Beach harbors, for developing TMDLs. In addition, SCCWRP has developed an HSPF model of watersheds discharging to SMB to support TMDL development for indicator bacteria, which can be modified to provide simulation of additional pollutants. The Ventura County Watershed Protection District, the U.S. Army Corps of Engineers, and the LA County DPW are also developing an HSPF model of the SCR.

The models represented were developed over an 8-year period by the various contributors mentioned above. Table 1 lists the models by watershed, including the author, model and version used, and completion date.

Table 1. Summary of model authors and models

Model watershed	Model author	Model
Ballona Creek	SCCWRP	HSPF (version unknown)
Dominguez Channel	SCCWRP (updated by Tetra Tech)	LSPC (Original version unknown); LSPC v3.0 (dated 01/27/05); LSPC v4.01 (dated 06/20/08)
Los Angeles Harbor watersheds	Tetra Tech	LSPC v3.0 (dated 03/08/06)
Los Angeles River	Tetra Tech	LSPC v3.0 (dated 11/13/03)
Los Cerritos Channel	Tetra Tech	LSPC v3.0 (dated 03/08/06)
San Gabriel River	Tetra Tech	LSPC v3.0 (dated 09/03/03); LSPC v3.0 (dated 10/11/05)
Santa Clara River	Aqua Terra	HSPF v12.2 (dated 2005)
Santa Monica Bay watersheds	SCCWRP	HSPF (version unknown)

Those models varied with respect to assumptions and inputs for components such as average subwatershed segmentation size, segmentation basis, land use data source, and model parameterization. Table 2 shows subwatershed area, number of subwatersheds, segmentation basis, and land use source for the LA regional models.

Table 2. Summary of watershed segmentation and land use data source

Model watershed	Area (square miles [mi^2])	Number of subwatersheds	Basis of model segmentation	Land use data source
Ballona Creek	130	7	Grouped storm drain networks	Southern California Association of Governments (SCAG)
Dominguez Channel	120	78	Storm drain network	Original source unknown
Los Angeles Harbor watersheds	61.5	76	Some storm drain networks; assumed drainage areas	SCAG 2000

Model watershed	Area (square miles [mi^2])	Number of subwatersheds	Basis of model segmentation	Land use data source
Los Angeles River	819	35	Watersheds (upstream); storm drain networks (downstream)	LACDPW 1994; Multi-Resolution Land Characteristics (MRLC) 1993
Los Cerritos Channel	27.7	10	Storm drain networks	SCAG 2005
San Gabriel River	700	139	Mostly storm drain networks	SCAG 2000; MRLC 1993
Santa Clara River	1,646	209	Watersheds	SCAG 2000 (updated by LACDPW)
Santa Monica Bay watersheds	414	39	Grouped storm drain networks	LACDPW

Specific changes have been recommended to create a truly regionalized modeling approach that takes advantage of the strengths of the previous efforts, improves identified weaknesses, and builds on the collective efforts and advances of the past few years. Tetra Tech is working with LA County to implement the changes and develop a consistent regional approach.

Expected Outcomes

The baseline model resulting from this effort will serve as the driver for BMP modeling and watershed management decision support. In terms of expected outcomes, the primary objective of the watershed component of the modeling effort is to

1. Provide a uniform and consistent representation of baseline storm water hydrology for the purpose of informing predictive representation of pollutant loading (water quality is the primary objective)
2. Expand the spatial resolution of the subwatersheds for more distributed management assessment
3. Increase the spatial resolution of climate and rainfall-runoff response (to enhance spatial resolution pollutant loading potential)
4. Represent spatially variable baseline high-flow storm water peaks, flow volumes, and associated pollutant across the regional watersheds

While an earnest effort has been made to capture and reflect a variety of common watershed actions and features, such as irrigation and hydraulic modifications, it is important to note that the primary focus of this effort is rainfall-runoff hydrology and storm-related high-flow prediction of pollutant loads. It is important to recognize the most notable limitations associated with the outcomes of this effort. In summary, the model

1. Is not intended to accurately represent all non-storm-related base flow hydrologic conditions
2. Does not represent in great detail all hydraulic structures, flow modification, and unreported water management activity, though some of the most significant and impactful have been included
3. As configured, is not intended for flood or floodplain prediction; however, the high degree of rainfall spatial resolution and the focused development of the underlying hydrologic response lays the foundation for future refinement of such an application.
4. Does not represent wave-driven back-water hydraulic effects in tidally-influenced coastal watersheds and stream segments

In-stream model calibration and validation is performed as a means of assessing the aggregated representation of storm water as it is transported past historic flow monitoring gages. This document summarizes the model configuration and hydrology calibration process for the regional LA County model. The document provides a description of the selected watershed modeling platform and the information used to configure the watershed model including watershed segmentation, waterbody representation, meteorological data, land use data, and soils data. A description of the data used for hydrology calibration and the hydrology results are included as well as a discussion of the next steps in the modeling process.

Model Selection

A watershed model is necessary to address the generation of pollutant loads over the land surface and through groundwater contributions in LA County and to predict the resulting impact on stream water quality. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate land-based processes over an extended period, including hydrology and pollutant transport. Many watershed models, including the one used for this project, are also capable of simulating in-stream processes using the land-based calculations as input. Once a model has been adequately set up and calibrated, it can be used to quantify the existing loading of pollutants from subwatersheds or from land use categories and can quantify pollutant loading from ungaged tributaries and diffuse overland flow sources. It can also be used to assess the impacts of a variety of *what if* scenarios.

The EPA-approved Loading Simulation Program C++ (LSPC) was selected for LA County watershed modeling (http://www.epa.gov/athens/wwqtsc/html/lspc.html). LSPC is a watershed modeling system that includes Hydrologic Simulation Program, FORTRAN (HSPF) algorithms for simulating watershed hydrology, erosion, and water quality processes, as well as in-stream transport processes. LSPC integrates a geographical information system (GIS), comprehensive data storage and management capabilities, the original HSPF algorithms, and a data analysis/post-processing system into a convenient PC-based windows interface. LSPC’s algorithms are identical to a subset of those in the HSPF model. LSPC is currently freely distributed by EPA’s Office of Research and Development in Athens, Georgia, and is a component of EPA’s National TMDL Toolbox (http://www.epa.gov/athens/wwqtsc/index.html). A brief overview of the underlying HSPF model is provided below, and additional detailed discussion of HSPF-simulated processes and model parameters is available in the HSPF User’s Manual (Bicknell et al. 1997).

HSPF is a comprehensive watershed and receiving water quality modeling framework that was originally developed in the mid-1970s. During the past several years it has been used to develop hundreds of EPA-approved TMDLs, and it is generally considered the most advanced hydrologic and watershed loading model available. The hydrologic portion of the model is based on the Stanford Watershed Model (Crawford and Linsley 1966), which was one of the pioneering watershed models. The HSPF framework is developed modularly, with different components that can be assembled in different ways, depending on the objectives of the individual project. The model includes these major modules:

- PERLND/IMPLND for simulating watershed processes on pervious/impervious land areas
- SEDMNT/SOLIDS for simulating production and removal of sediment/solids from pervious/impervious land
- PQUAL/IQUAL for simulating prodiction and removal of pollutants from pervious/impervious land
- RCHRES for simulating flow and water quality processes in streams and vertically mixed lakes
- SEDTRN for simulating transport, deposition, and scour of sediment in modeled waterbodies
- GQUAL for simulating transport, transformations, and loss of pollutants in modeled waterbodies

All those modules include many submodules that calculate hydrologic, sediment, and water quality processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subwatersheds or subwatersheds representing the drainage areas that contribute to each of the stream reaches. The subwatersheds are then further subdivided into segments representing different land uses. For the developed areas, the land use segments are further divided into the pervious and impervious fractions. The stream network links the surface runoff and groundwater flow contributions from each of the land segments and subwatersheds and routes them through the waterbodies using storage routing techniques. The stream model includes precipitation and evaporation from the water surfaces, as well as flow contributions from the watershed, tributaries, and upstream stream reaches. Flow withdrawals can also be accommodated. The stream network is constructed to represent all the major tributary streams and different portions of stream reaches where significant changes in water quality occur.

Like the watershed components, several options are available for simulating water quality in the receiving waters. The simpler options consider transport through the waterways and represent all transformations and removal processes using simple first-order decay approaches. Decay is used to represent the net loss from processes such as settling and adsorption. The framework is flexible and allows different combinations of constituents to be modeled depending on data availability and the objectives of the study.

Advantages to choosing LSPC as the watershed model for the LA County watersheds include

- Simulates all the necessary constituents and applies to rural and urban watersheds.
- A comprehensive modeling framework using the proposed LSPC approach facilitates development of TMDLs for this project and for potential future projects to address other impairments throughout the basin.
- Allows for customization of algorithms and subroutines to accommodate the needs of LA County
- Time-variable nature of the modeling will enable a straightforward evaluation of the cause-effect relationship between source contributions and waterbody response and direct comparison to relevant water quality criteria.
- Proposed modeling tools are free and publicly available. This is advantageous for distributing the model to interested stakeholders and among government agencies.
- Approved by EPA for use in TMDLs.
- Model includes both surface runoff and baseflow (groundwater) conditions.
- Provides storage of all geographic, modeling, and point source permit data in a Microsoft Access database and text file formats to provide for efficient manipulation of data.
- Presents no inherent limitations regarding the size and number of watersheds and streams that can be modeled.
- Provides post-processing and analytical tools designed specifically to support TMDL development and reporting requirements.
- Can be linked to receiving water models.

Modeling Approach

This section of the report provides a description of the LSPC modeling approach used for LA County. Development and application of the LSPC model to address the project objectives involved the following important steps:

1. Watershed segmentation
2. Configuration of key model components (i.e., meteorological data, land use representation, soils)
3. Model calibration and validation (for hydrology, sediment, and nutrients)
4. Model simulation for existing conditions and scenarios

The first two steps are discussed in this section of the report. Step three is discussed in the Hydrology Calibration section. Note that this report only addresses hydrology calibration. Water quality calibration and Step 4, model simulation, will be completed at a later date (see the Next Steps section).

Watershed Segmentation

Watershed segmentation refers to the subdivision of the entire model area into smaller, discrete subwatersheds for modeling and analysis. This subdivision was primarily based on the drainage networks, such as engineered storm drain and stream networks, and secondarily on the locations of topography, flow, and water quality monitoring stations; the consistency of hydrologic factors; land use consistency; and existing hydrologic boundaries. In a highly urbanized area like LA, most of the segmentation was based on storm drain networks.

The LA County subwatershed GIS data layer[1] divides the county's watersheds into 2,655 subwatersheds. The sizes of the subwatersheds range between 35 and 125,000 acres, with an average of approximately 8,000 acres. To better preserve the spatial segmentation of the regional watersheds, all 2,655 subwatersheds were used for model development.

Flow Direction

In addition to the subwatershed layer, the county also provided a second GIS layer containing flow direction[2] for each subwatershed. The NHD was also used to derive flow direction for areas with more natural streams. The subwatershed routing information was carefully scrutinized for quality control to ensure that flow routing was properly represented between subwatersheds.

In the original subwatershed layer two fields, *name* and *name2*, were used to determine the hydrologic routing. The *name* attribute represents the subwatershed name, and the *name2* attribute refers to the name of the downstream subwatershed—the subwatershed to which the current subwatershed (name) is routed. However, approximately 1,000 subwatersheds do not have a name attribute. Whenever this occurred, the flow direction and NHD layers were used to complete the missing name attributes in the subwatersheds layer.

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[1] http://dpwgis.co.la.ca.us/website/oia/metadata.cfm?path=subwatershed.htm&zip=Watershed%20Sub%20Basins.zip Los Angeles County Department of Public Works. Accessed September 2008.

[2] http://dpwgis.co.la.ca.us/website/oia/metadata.cfm?path=WatershedFlowDirection.htm&zip=Watershed%20Flow%20Direction.zip. Los Angeles County Department of Public Works. Accessed September 2008.

Waterbody Representation

The 2,655 subwatersheds range in size from 35 to 125,000 acres. The desire to maintain a high resolution of spatial detail needs to be balanced with the need to preserve time of concentration along the in-stream flow network in the watershed. As previously noted, the primary objective of this model effort is to quantify water quality only (as opposed to flood prediction), which mitigates the problem of time of concentration somewhat. However, it is worth considering the effects of reach travel time on model stability and accuracy. While HSPF/LSPC is not independently applicable as a hydraulic model, the routing algorithms used are, in general, related to storage routing and kinematic wave approaches. These algorithms are most accurate when flow time of the flood wave through individual reaches approximates the simulation time step. Below is a summary of how this was handled.

First, each of the 2,655 delineated subwatersheds in the LA County LSPC watershed model was conceptually represented with a single stream assumed to be a completely mixed, one-dimensional segment with a trapezoidal cross-section. In addition to the representative reach channel dimensions, LSPC requires length, slope, and surface roughness for each representative reach to calculate reach geometry. The first step in developing the representative reaches was to spatially assign the county storm drain and U.S. Geological Survey (USGS) stream (medium resolution NHD) features to the county subwatersheds. Once assigned, the network of stream and drain features in a subwatershed provided the alternative flow paths that were used to define the representative reach. The county routing information (subwatershed downstream relationship) guided the selection of the representative reaches, while the USGS 30-meter NED was used to calculate reach slope.

The methodology used for selecting the representative reach for a subwatershed depended on the subwatershed type. Three types of subwatersheds were defined for the purposes of defining a representative reach: (1) headwater subwatershed, (2) terminal subwatershed, and (3) nested subwatershed. The headwater subwatershed represents the farthest upstream subwatershed in a hydrologically connected subwatershed network. No subwatersheds are upstream of a headwater subwatershed. The terminal subwatershed represents the farthest downstream subwatershed in a hydrological connected subwatershed network. No subwatersheds are downstream of a terminal subwatershed. The nested subwatershed represents a subwatershed positioned anywhere in between a headwater and terminal subwatershed in a hydrologically connected subwatershed network. Subwatersheds are downstream and upstream of a nested subwatershed.

Selecting a representative reach from the available flow paths assigned to a subwatershed varied by subwatershed type. For headwater subwatersheds, the representative reach length was computed as 50 percent of the longest continuous stream/drain segment that flows into the downstream representative reach, to better approximate the average time of concentration in those segments. The selected reach for nested subwatersheds was either the continuous stream/drain segment that flows from the upstream and into the downstream representative reach, or where multiple upstream subwatersheds exist, the one with the greatest aggregate drainage area was selected as the primary upstream subwatershed. The longest continuous stream/drain segment that flows from the upstream representative reach was chosen as the representative reach for the terminal subwatersheds. Once assigned to a subwatershed, a representative reach was assigned a slope using the USGS 30-meter NED and a manning's roughness coefficient depending on whether the reach was a pipe or a natural stream. Where both stream and pipe segments made up the representative reach, the longest segment type was used to characterize the reach.

After representative reaches were developed for each of the 2,655 subwatersheds, the second step was to calculate travel time at bank-full depth through each of the stream segments. The reason for calculating individual travel times is so that these segments can be grouped in such a way that the combined travel time through the composite representative reach segment is approximately equal to the 1-hour model simulation time step. Subwatersheds belonging to a composite reach segments are summed and routed together through the composite segment to preserve the cumulative travel time representation throughout the reach network. Figure 2 is a map that shows travel time by composite reach group (color coded by component subwatersheds for display purposes).

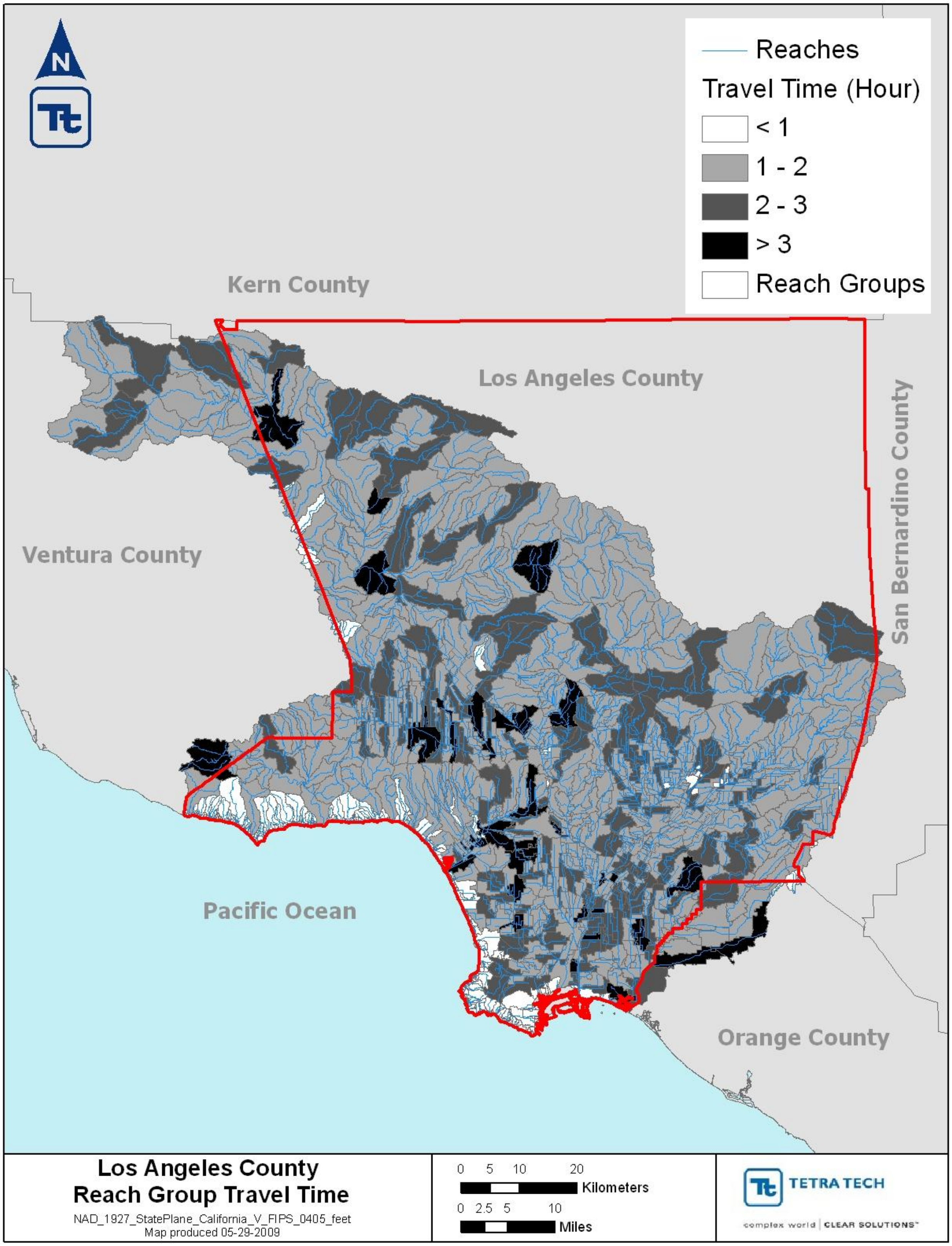

Figure 2. Estimated travel time (hours) for each composite reach group

Several small watersheds could not be grouped because they were terminal (mostly coastal), steep, or spatially isolated. Those are shown in white in Figure 2. Other reach segments did not require grouping because they had travel times that were longer than the 1-hour model simulation time. Because of the kinematic wave and storage routing algorithm in use, it is acceptable (even preferable) for watersheds to have travel times that are longer than the simulation time step.

Subwatershed and Reach Numbering Convention

This section provides a description of the process used to number each subwatershed and representative reach segment components included in the LA County watershed model. The original 2,655 subwatersheds were labeled with alphanumeric names that were relatively cryptic in nature. To better establish a more convenient scheme for organizing and reporting modeling data, a new numbering scheme was adopted. Because each subwatershed is modeled as having one representative stream segment, the assigned number applies to both the stream segment and the associated subwatershed.

The modeling subwatersheds were renumbered incrementally from downstream to upstream in groups of 1,000s for each of the major drainage basins. Numbering blocks were assigned on the basis of the basin in which a subwatershed existed. The downstream mapping was created on the basis of information provided by LA County. An example of the subwatershed numbering from upstream to downstream is shown in Figure 3 for a portion of the San Bernardino Basin. Table 3 shows the numbering blocks assigned to each of the major river watersheds. Composite reach segments were assigned the same subwatershed name as the most downstream outlet of the composite reach segment.

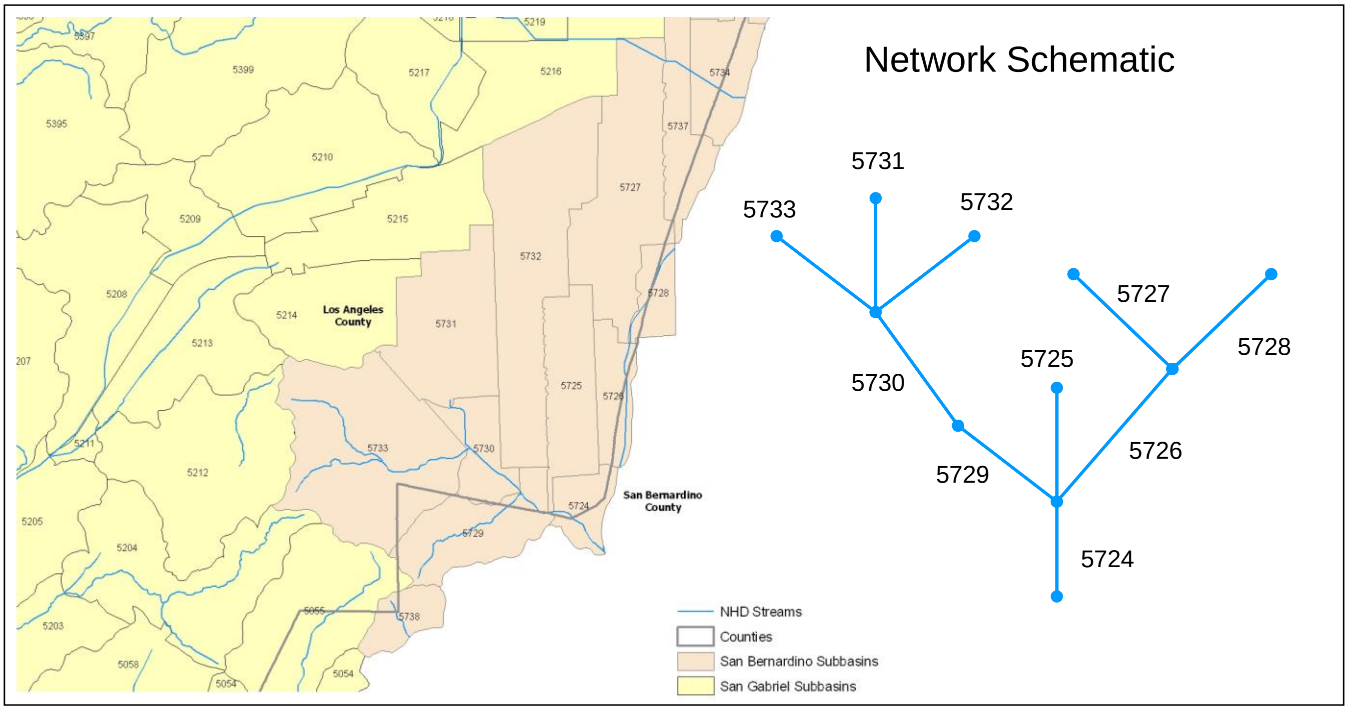

Figure 3. Example of subwatershed numbering from upstream to downstream in the San Bernardino basin.

Table 3. Numbering convention blocks for each of the major regional watersheds

Regional drainage basin	Number of subwatersheds	Number of composite reach segments	Start number	Finish number
Ballona Creek	264	168	1001	1265
Dominguez Channel	130	69	2001	2131
Malibu Creek	235	143	3001	3236
Santa Clara River	434	106	4001	4435
San Gabriel River	534	171	5001	5535
- Orange County	4	4	5601	5605
- San Bernardino	38	10	5701	5739
Los Angeles River	1,016	270	6001	7017

A comprehensive list of the subwatershed renumbering is provided in Appendix G. A comprehensive set of network schematic diagrams is provided in Appendix H.

Hydrologic Response Units Development

LSPC requires a basis for distributing hydrologic and water quality parameters. That is necessary to appropriately represent variability throughout the watershed, which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to land practices. The basis for that distribution is provided by the current land use coverage of the entire watershed.

In a watershed model, land unit representation should be sensitive to the features of the landscape that most affect hydrology and pollutant transport, including land use (including impervious assumptions), soils, and slope. In urban areas, it is important to estimate the division of land use into pervious and impervious components. In rural areas, vegetative cover is more important. Agricultural practices and crops (or crop rotations) should be well represented when present, although that component is less a factor in LA (where about one percent of the total subwatershed area is agricultural) than in other areas. Depending on the goals of the model, if soil hydrologic groups are not homogenous in a watershed, it might be important to further divide pervious land cover by soil hydrologic group so that infiltration processes are better represented. Slope might also be an important factor, especially if steep slopes are prevalent; high slopes influence runoff and moisture-storage processes. The combination of land use, soil hydrologic group, and slope were used to define the hydrologic response units (HRUs) for LA County. This section details the HRU development processes for the LA County regional watershed model.

Land Use Representation and Percent Imperviousness

For this analysis, the LA County 2005 Land Use layer[3] was originally processed and summarized to characterize land use for watersheds in the county's boundaries. The analysis was later refined to include spatial boundaries from the county's Parcel layer.[4] Although that layer contains a high degree of spatial resolution for privately owned parcels, it was not as useful for representing public parcels. Therefore, the final land use layer represents a hybrid construction that uses the best available information from a variety of spatial data sources to create composite land use and imperviousness maps.

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[3] http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/landuse_2005.zip. Los Angeles County Department of Public Works. Accessed September 2008.

[4] Los Angeles County Parcel. Los Angeles County Department of Public Works. Provided July, 2008.

The Parcel layer includes runoff factors for selected parcels, which were used as a surrogate indicator of impervious cover. When no data were available, imperviousness values from the county's Land Use layer were applied. The National Land Cover Data (NLCD 2001 Impervious Surface) from the USGS Web site[5] was used to estimate the percent imperviousness for watersheds outside the LA County boundary. The LA County Subwatershed layer[6] was used as the spatial extent to derive the average percent imperviousness of each land use category given in the 2005 Land Use layer. A zonal statistics analysis of the final composite imperviousness layer was performed by intersecting it with the composite land use layer and computing an area-weighted percent imperviousness for screening-level evaluation. The final composite land use layer was grouped into 12 major categories. Table 4 is a land area summary for the LA County watersheds. Figure 4 is a comparison of the county's Land Use layer with Parcel-based composite land use.

Table 4. Land use and average percent imperviousness distribution in LA County regional watersheds

Land use group	Original county land use area (acres)	Parcel-based composite land use area (acres)	Percent of total land use area	Percent impervious
Agriculture	17,096	20,433	1%	7%
Commercial	89,516	68,985	3%	80%
HD single-family residential	347,976	254,235	13%	36%
Industrial	97,584	93,935	5%	75%
Institutional	45,261	44,545	2%	72%
LD single-family residential	46,489	40,793	2%	5%
Multifamily residential	89,604	89,765	5%	58%
Open recreational	46,062	40,931	2%	5%
Secondary Roads	0	145,643	7%	51%
Transportation	34,590	31,797	2%	88%
Vacant	1,168,657	1,151,777	58%	1%
Water	10,882	10,882	1%	100%

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[5] http://seamless.usgs.gov/website/seamless/viewer.htm. U.S. Geological Survey. Accessed September 2008.

[6] http://dpwgis.co.la.ca.us/website/oia/metadata.cfm?path=subwatershed.htm&zip=Watershed%20Sub%20Basins.zip. Los Angeles County Department of Public Works. Accessed September 2008.

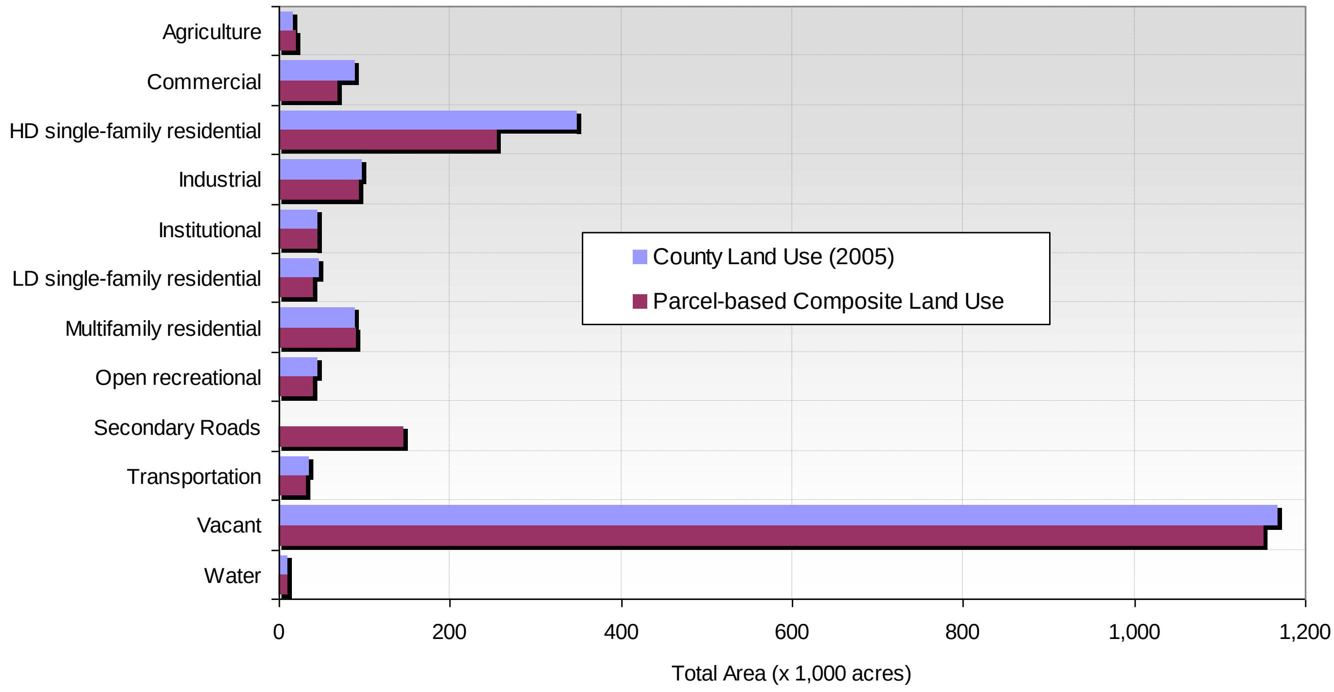

Figure 4. Comparison of County Land Use layer with Parcel-based composite land use.

The composite layer provided additional resolution for the transportation land use category. That category was further subdivided into *Transportation*, which represented the major highways and ports as represented in the County’s Land Use layer, and *Secondary Road*s. Figure 5 is a map of the transportation and secondary roads land use enhancement pratided by the Parcel layer.

Figure 6 and Figure 7 show the spatial distribution of the composite land use groups and the percent imperviousness in LA County watersheds, respectively.

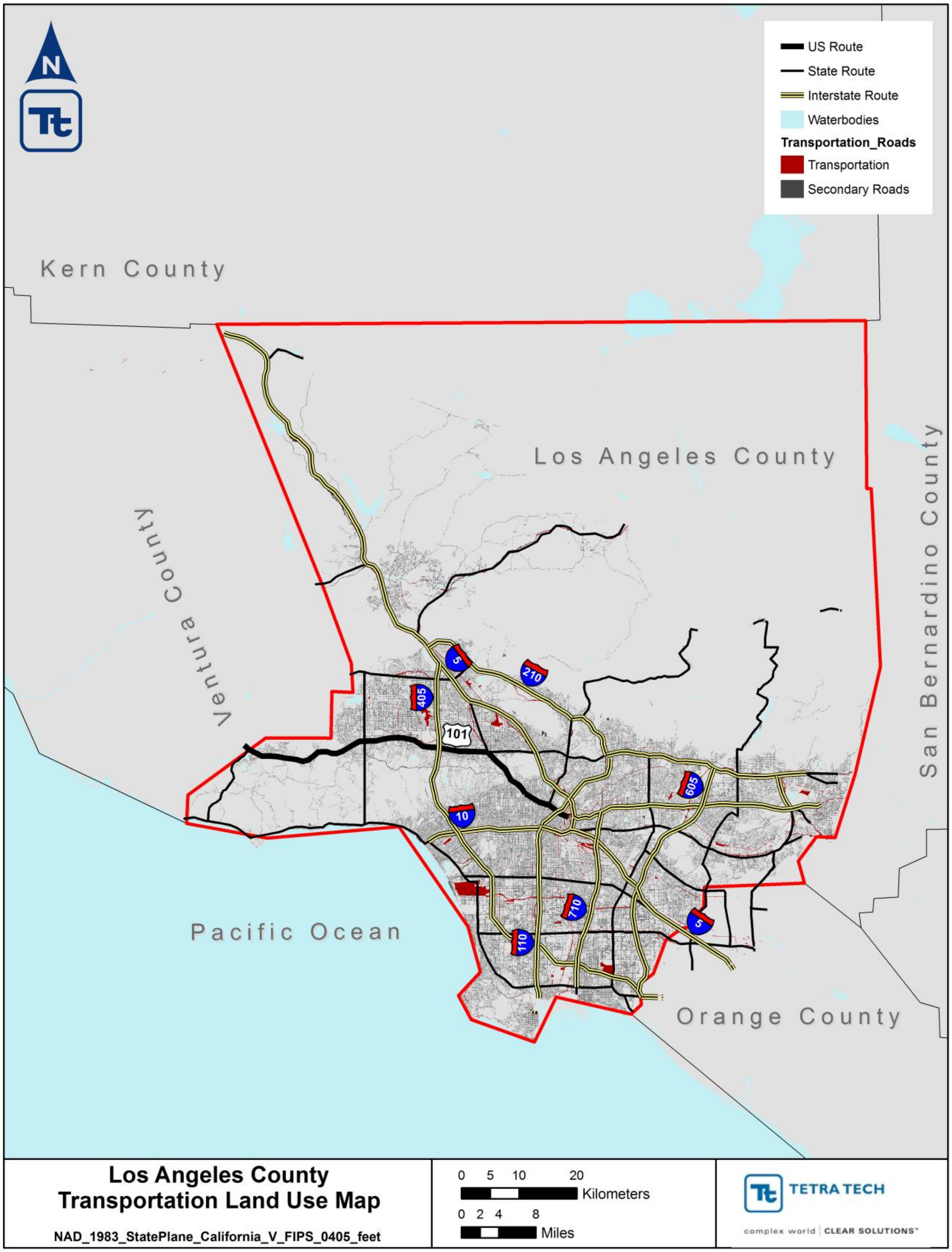

Figure 5. Transportation and secondary roads land use enhancement from the Parcel layer.

Figure 6. Land use distribution in LA County regional watersheds.

Figure 7. Percent imperviousness in LA County regional watersheds.

Developed Urban Area Refinement

In the urban areas, impervious land areas for each land use type are independently represented as their own HRU categories. For watershed modeling using LSPC, impervious land uses should be represented as directly connected impervious areas; therefore, it is important to resolve how impervious areas are handled in the model. Once total impervious area, or Mapped Impervious Area (MIA), is determined for land use polygons, it is necessary to estimate the Effective Impervious Area (EIA), which is the portion of MIA directly connected to the drainage collection system. Impervious area that is not connected to the drainage network has the opportunity to flow onto pervious surfaces, infiltrate, and become part of pervious surface overland flow; such disconnected impervious area is often represented as PERLND, which is an HSPF module that simulates pervious land surfaces. In practice, runoff from disconnected impervious surfaces often overwhelms the infiltration capacity of adjacent pervious surfaces, and the runoff can reconnect to nearby impervious surfaces. Finding the right balance between MIA and EIA can be an important part of hydrology calibration, especially in urban areas.

Sutherland (1995) describes a series of equations for MIA-to-EIA relationships spanning four levels of impervious disconnection, from *extremely disconnected basins* to *highly connected basins*. The equations take the form of

$$EIA = a(MIA)^b$$

where a and b are empirical factors; as a and b approach 1, EIA converges to MIA. Rather than choosing one of Sutherland’s relationships over another, all four can be used to describe the varying levels of impervious area in developed polygons. Instead of choosing thresholds for jumping from one relationship to the next, a regression analysis provides unique values for a and b at each increment in impervious area. Such a methodology has been used successfully in other HSPF/LSPC model applications (Clinton River, Minnesota; Ventura River, California). Exceptions are made at the low and high ends of the MIA-to-EIA relationship: EIA is assumed equal to MIA for watersheds that are 70 to 100 percent imperviousness (all impervious area connected); at the low end (1 to 15 percent imperviousness, for instance), the calculated EIA values are increased somewhat. It is expected that for most of the heavily urbanized areas in the LA County boundary, MIA will be equal to EIA; however, that relationship might come into play more for the urban fringe and suburban areas.

Pervious urban land areas are typically a combination of managed pervious land (e.g., irrigated lawns, other urban grass) and natural cover (treed areas or bare ground). Those types of managed pervious land are common to all urban land use categories, although the relative distribution within each category typically varies. For those areas, two HRU categories, *Urban Grass (irrigated)* and *Urban Grass (non-irrigated)* are selected for LA County.

Vacant Area Refinement

The *Vacant* land category represents 59 percent of the watershed area. It is recognized that physical features of vacant land are not homogeneous throughout the watershed; that is, not all vacant land responds to weather in the same way. For that reason, there is a need to further refine this land use category to better represent the physical variability and variations in hydrologic response to weather. The combination of land use, soils, and slope influence provides a sound physical basis for refining and differentiating the representation of vacant land. The details of this refinement are described in the following section.

Hydrologic Soil Group and Slope

For this analysis, the State Soil Geographic (STATSGO) and Soil Survey Geographic (SSURGO) data[7] were processed and summarized to characterize hydrologic soil groups (HSGs) in the county’s regional watersheds. The LA County subwatershed boundary was used as the spatial extent to derive the percent distribution of each HSG within each land use category given in the 2005 Land Use layer.

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[7] http://soildatamart.nrcs.usda.gov. National Resources Conservation Service. Accessed September 2008.

The four HSGs are described as follows:

> Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
>
> Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
>
> Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
>
> Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group.

A zonal statistics analysis was performed using area by land use code and associated HSGs to derive area-weighted percent HSGs throughout the county for screening-level evaluation, as presented in Table 5. In general, developed areas tend to be concentrated in areas with relatively poorly draining hydrologic soil group D soils. Nearly half of the vacant land is composed of type D soils, but the other half is almost evenly divided between types B and C soils.

Table 5. Land use and percent HSG area distribution in LA County regional watersheds

Land use group	Land use area (acres)	Percent HSG (A)	Percent HSG (B)	Percent HSG (C)	Percent HSG (D)
Agriculture	20,433	4	36	14	46
Commercial	68,985	0	13	4	82
HD single-family residential	254,235	1	13	6	81
Industrial	93,935	1	13	4	81
Institutional	44,545	1	13	3	84
LD single-family residential	40,793	3	29	8	59
Multifamily residential	89,765	1	9	2	89
Open recreational	40,931	2	14	9	76
Secondary roads	145,643	1	13	5	81
Transportation	31,797	0	11	5	84
Vacant	1,151,777	3	27	24	46
Water	10,882	n/a	n/a	n/a	n/a

In terms of slope, the developed areas are almost exclusively in areas having less than a 10 percent slope, while the more highly sloped areas are almost exclusively vacant. The low-density, single-family residential and open recreational areas have mixed slope, as shown in Table 6.

Table 6. Land use and average slope (less than or greater than 10 percent) in LA County regional watersheds

Land use group	Land use area (acres)	Average slope (0%–10%)	Average slope (> 10%)
Agriculture	20,433	60	40
Commercial	68,985	84	16
HD single-family residential	254,235	78	22
Industrial	93,935	80	20
Institutional	44,545	86	14
LD single-family residential	40,793	46	54
Multifamily residential	89,765	88	12
Open recreational	40,931	61	39
Secondary roads	145,643	83	17
Transportation	31,797	86	14
Vacant	1,151,777	8	92
Water	10,882	n/a	n/a

HSG polygons and slope severity derived from a 10-meter digital elevation model[8] (classified as less than or greater than 10 percent) are shown in Figure 8 and Figure 9, respectively.

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[8] http://seamless.usgs.gov/website/seamless/viewer.htm. U.S. Geological Survey. Accessed September 2008.

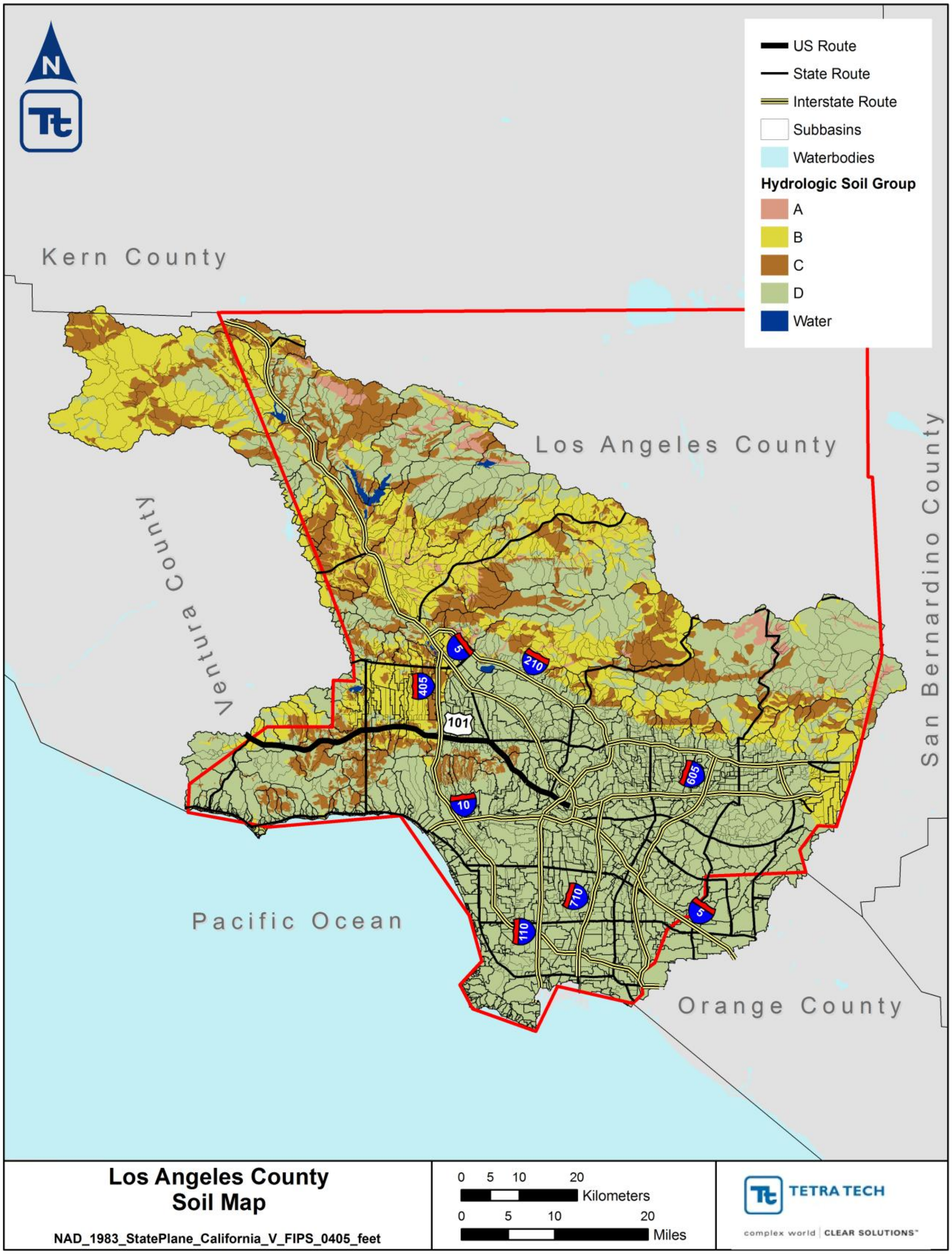


Figure 8. Hydrologic soil group polygons in LA County regional watersheds.

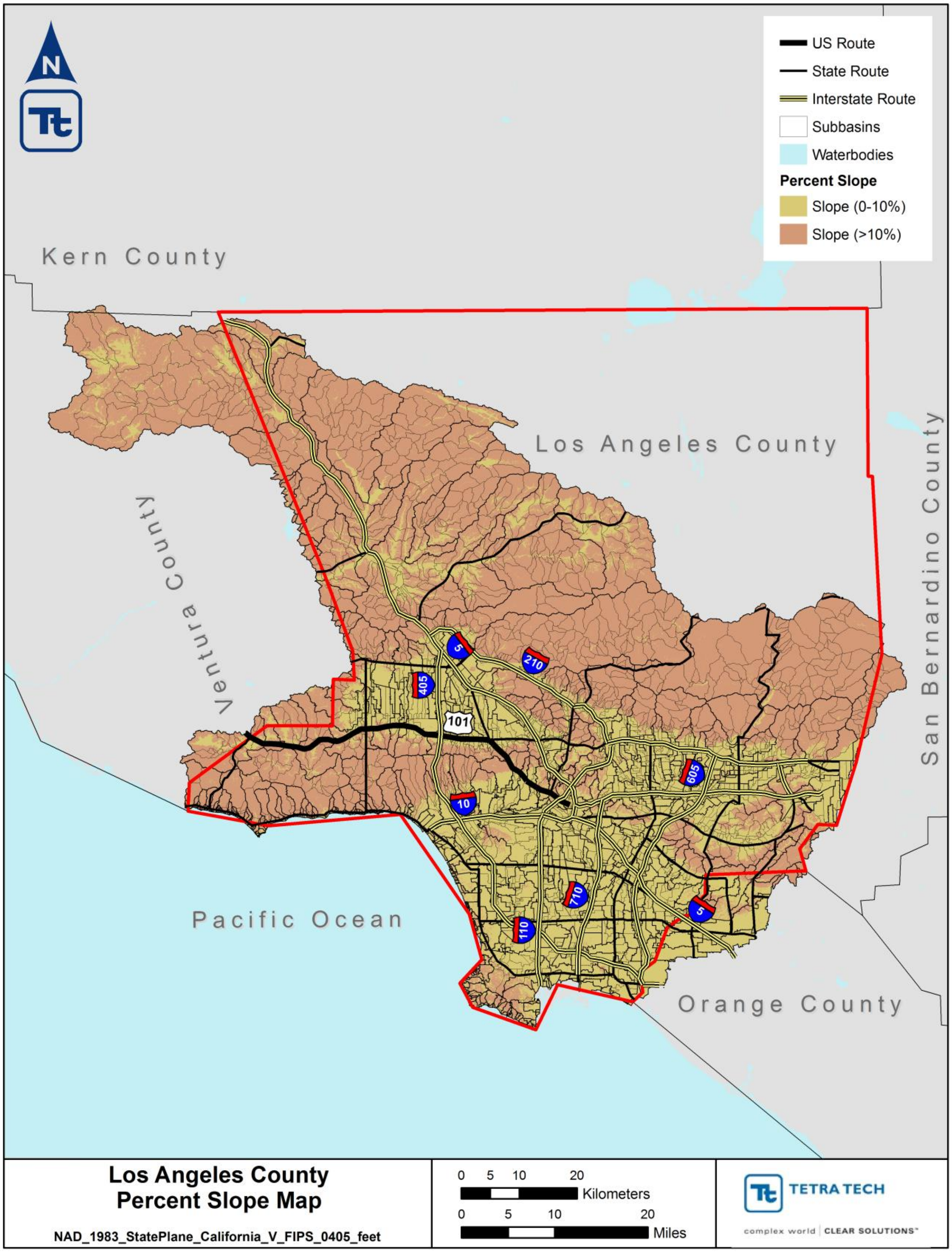


Figure 9. Percent slope (less/greater than 10 percent) in LA County subwatersheds

Given the level of detail, even with two categories, in a GIS file based on a union of land use/land cover, soil hydrologic group, and slope can create a very large number of polygons and become unmanageable. One observation is that development is almost entirely confined to areas with low slope (less than 10 percent); therefore, low/high slope designation was used exclusively in nonurban areas. To further reduce the complexity of the resulting HRU product, while providing the benefit of added resolution where most needed, the application of soil type and slope was initially confined to only the vacant land use and agricultural categories. This constraint may be revisited during model calibration if the need arises

The process of developing the HRUs proved that some of the resulting combinations were very small or negligible in terms of total area, and hence they were eliminated from the HRU list. Table 7 lists the list of HRUs that resulted from such analysis, and Table 8 summarizes the land use area for each HRU category in the county's regional watersheds. Figure 10 shows the spatial distribution of preliminary HRUs in LA County.

Table 7. Preliminary HRUs for LA County regional watersheds

HRU	Land use categories	Impervious/pervious	Slope	Soil group
Urban grass (irrigated)	Includes pervious portions of HD single-family residential, LD single-family residential, Multifamily residential, Commercial, Institutional, Industrial, Transportation, and Open recreational	Pervious portion only	0%–10%	D
Urban grass (non-irrigated)		Pervious portion only	0%–10%	D
HD single-family residential	HD single-family residential	Impervious portion only	0%–10%	n/a
LD single-family residential moderate slope	LD single-family residential and Open recreational	Impervious portion only	0%–10%	n/a
LD single-family residential steep slope			> 10%	
Multifamily residential	Multifamily residential	Impervious portion only	0%–10%	n/a
Commercial	Commercial	Impervious portion only	0%–10%	n/a
Institutional	Institutional	Impervious portion only	0%–10%	n/a
Industrial	Industrial	Impervious portion only	0%–10%	n/a
Transportation	Transportation	Impervious portion only	0%–10%	n/a
Secondary Roads	Secondary roads	Impervious portion only	0%–10%	n/a
Agriculture moderate slope B	Agriculture	Pervious	0%–10%	B
Agriculture moderate slope D			0%–10%	D
Vacant steep slope A	Vacant	Pervious	> 10%	A
Vacant moderate slope B			0%–10%	B
Vacant steep slope B			> 10%	B
Vacant steep slope C			> 10%	C
Vacant moderate slope D			0%–10%	D
Vacant steep slope D			> 10%	D
Water	Water	n/a	n/a	n/a

Table 8. HRU distribution in LA County regional watersheds

HRU	Impervious/ pervious	HRU area (acres)	Percent of total HRU area
Urban grass (irrigated)	Pervious	301,011	15.1%
Urban grass (non-irrigated)	Pervious	101,030	5.1%
HD single-family residential	Impervious	91,386	4.6%
LD single-family residential moderate slope	Impervious	2,482	0.1%
LD single-family residential steep slope	Impervious	1,701	0.1%
Multifamily residential	Impervious	51,677	2.6%
Commercial	Impervious	54,861	2.8%
Institutional	Impervious	31,832	1.6%
Industrial	Impervious	69,731	3.5%
Transportation	Impervious	28,007	1.4%
Secondary roads	Impervious	75,685	3.8%
Agriculture moderate slope B	Pervious	5,914	0.3%
Agriculture moderate slope D	Pervious	14,477	0.7%
Vacant moderate slope B	Pervious	47,592	2.4%
Vacant moderate slope D	Pervious	39,682	2.0%
Vacant steep slope A	Pervious	23,639	1.2%
Vacant steep slope B	Pervious	271,272	13.6%
Vacant steep slope C	Pervious	269,337	13.5%
Vacant steep slope D	Pervious	498,743	25.0%
Water	—	13,133	0.7%

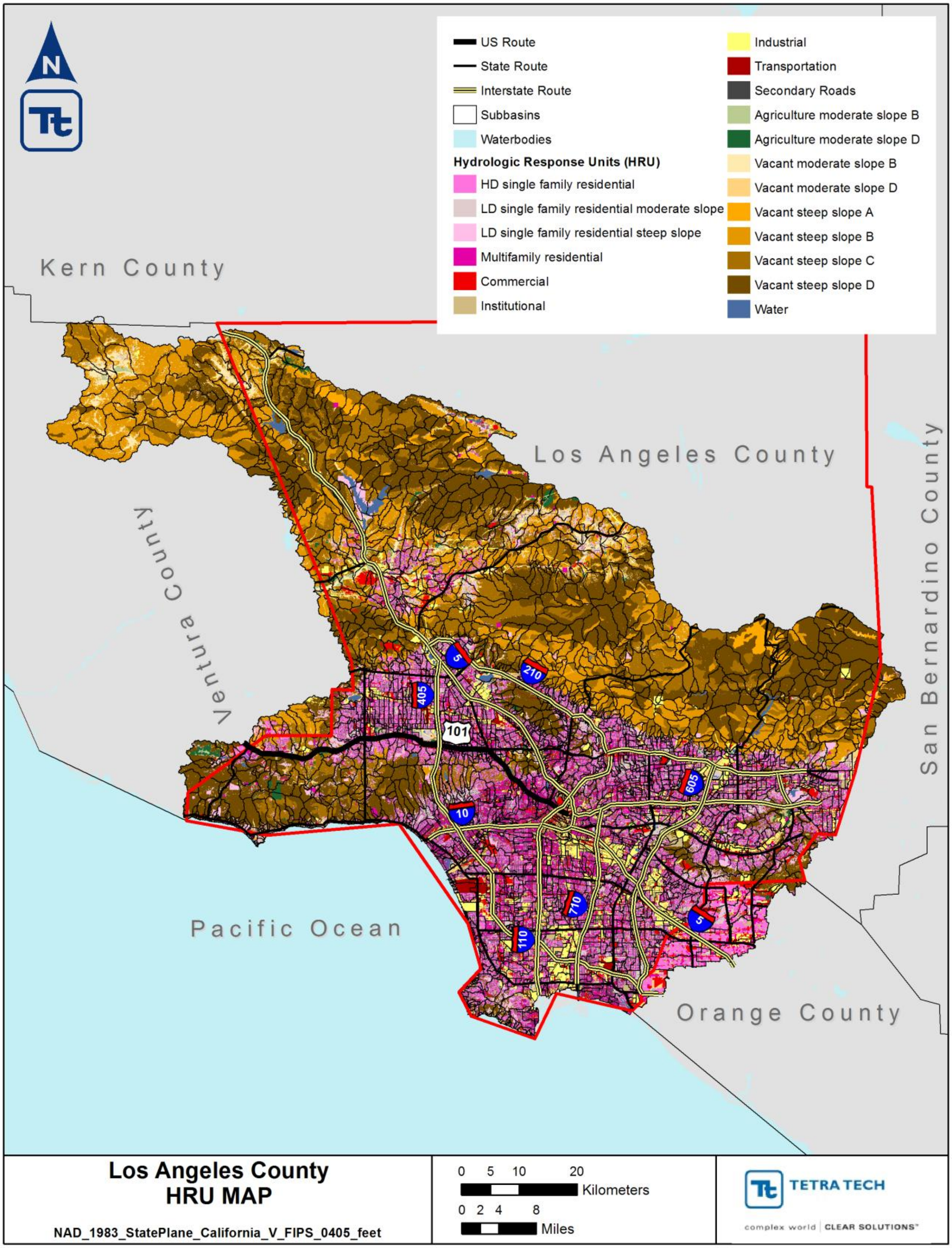


Figure 10. HRU representation in LA County regional watersheds.

Using the county's Parcel layer resulted in a significantly improved HRU layer resolution. Figure 11 is a comparison of the original versus the revised HRU representation at a smaller scale.

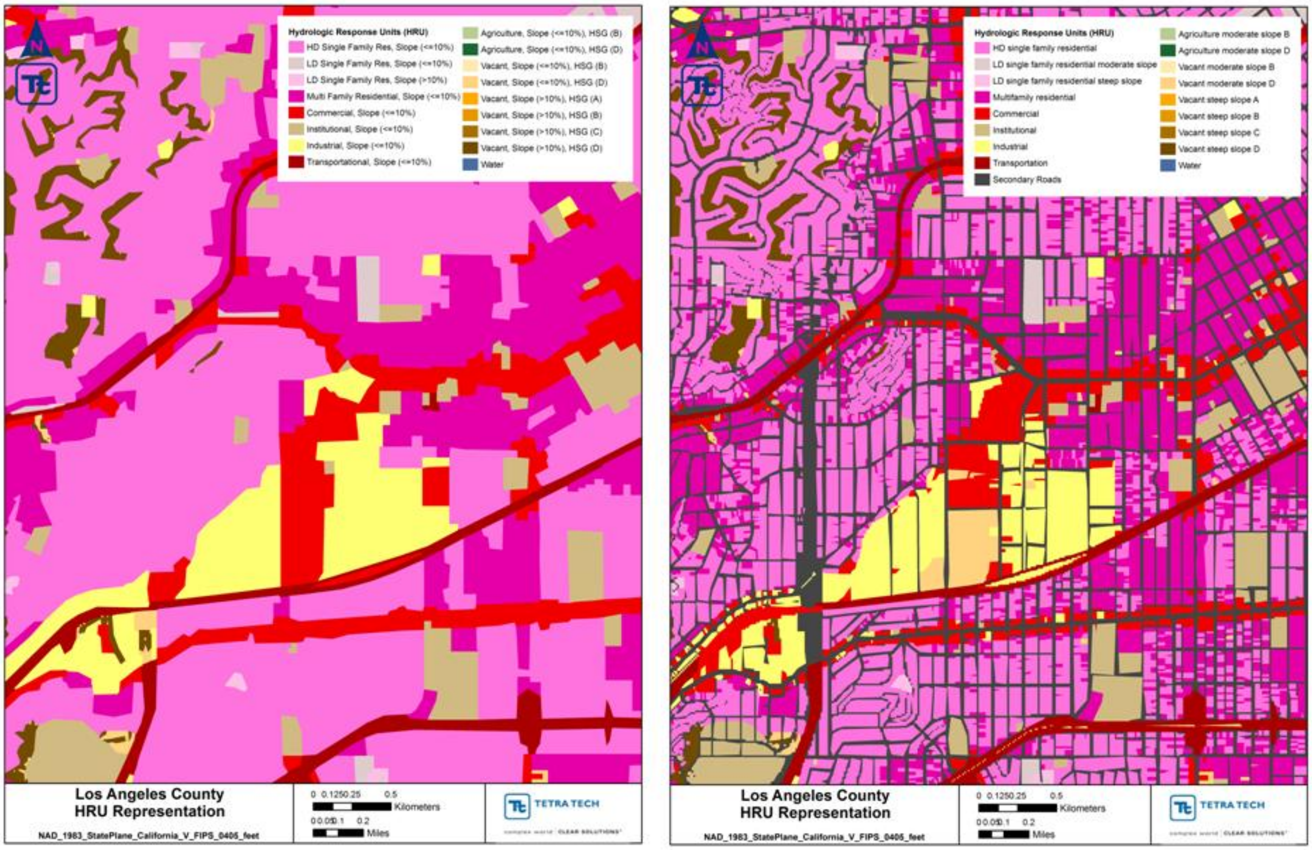


Figure 11. Comparison of original (left) versus revised (right) HRU layers for the same area.

Irrigation

In the climate of LA County, lawns and agricultural irrigation is necessary to sustain viable plants. To improve the simulation of selected low-flow hydrology components, this additional supply of water must be considered. Because application rates across the watershed are rarely known, estimates of irrigation are required. In California, those estimates are typically based on the reference evapotranspiration (ET) rates measured at a nearby California Irrigation Management Information System (CIMIS) station, along with daily rainfall data and crop or grass coefficients specific to each land use. That method typically results in simulating some baseflows during the summer. While the objective of the watershed modeling is focused on storm water representation, accounting for irrigation and its effect on groundwater and baseflow will help to provide at least an estimate for load contributions associated with urban irrigation flows during the summer months. That is why irrigated urban pervious surfaces are categorized as an independent HRU.

For the existing Calleguas Creek and SCR HSPF model, Aqua Terra (2005, 2008) developed a detailed approach for simulating irrigation applications. It consists of two components: (1) calculating potential irrigation demand on the basis of cropping data, cover coefficients, reference ET, and irrigation efficiency and (2) calculating daily irrigation applications after accounting for rainfall contributions to crop and lawn demands. For this model, irrigation will be modeled as a function of model input potential ET associated with each subwatershed. Developing that data set is described in the meteorological data section. Because LSPC has an option to computing irrigation demand as a function of input potential ET, this method is preferred because it self-adjusts the actual irrigation volume according to the actual estimated demand for each day of the simulation. As shown in

Figure 12, a plot of monthly average variation in model input potential ET versus CIMIS reference ET confirms that the model input potential ET is within the range expected reference ET; therefore, using the potential ET time series option in LSPC is both reasonable and preferable.

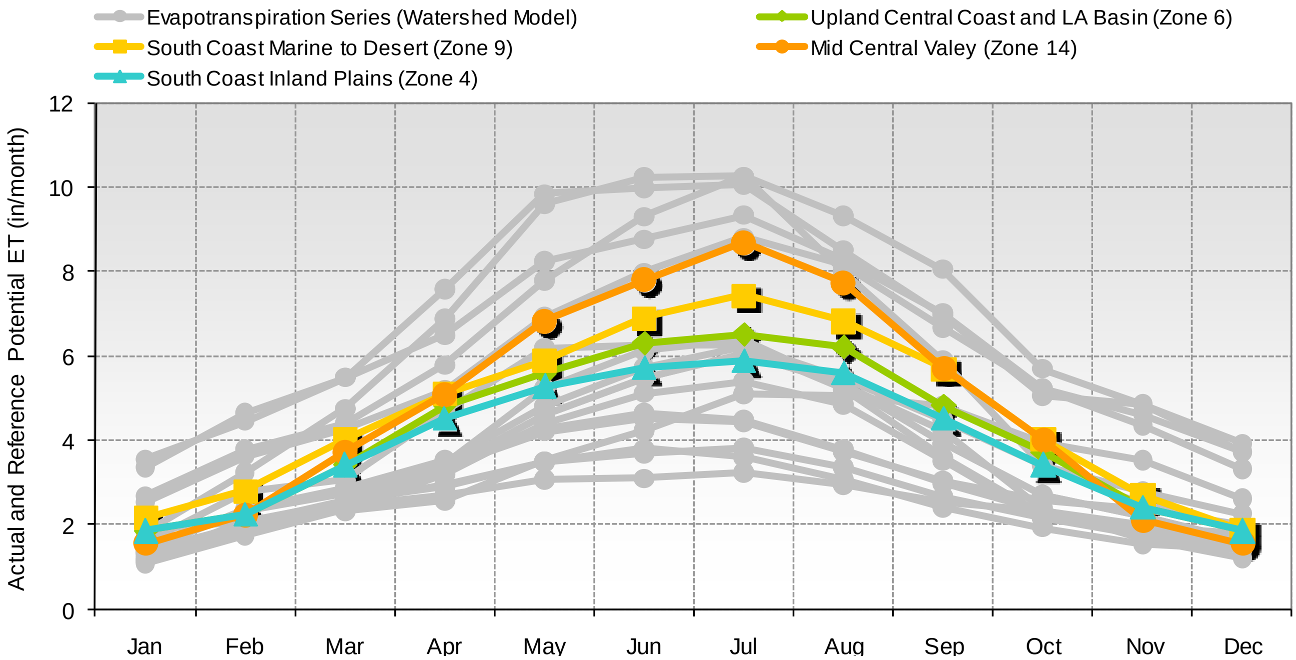


Figure 12. Model input versus CIMIS reference potential ET in LA County

To calculate the irrigation demand, potential ET must be adjusted according to crop or cover type and irrigation efficiency. Table 9. shows how the model coefficient is computed using (1) the crop/cover coefficient and (2) average irrigation efficiency values for both irrigated urban grass and agricultural land segments in the model.

Table 9. Effective irrigation coefficients for use in the model

HRU	Crop/cover coefficient (K_c)	Irrigation efficiency (IE)	Model coefficient ($ET_c = K_c / IE$)
Irrigated Urban Grass	0.60	0.85	0.71
Agriculture (all slopes and soils)	0.75	0.75	1.00

Finally, the total land area that is irrigation was determined during the HRU development process. To calculate the total amount of urban grass, the percent irrigation values for LA watersheds were derived from these sources. They are 50 percent for low-density residential, 70 percent for medium-density residential, 80 percent for high-density residential, and 85 percent for commercial or industrial or transportation land use category.

Meteorological Data

Meteorological data are a critical component of the watershed model. Models require appropriate representation of precipitation and potential ET. In general, hourly precipitation (or finer resolution) data are recommended for nonpoint source modeling and therefore are preferred. Rainfall-runoff processes for each subwatershed were driven by precipitation data from the most representative station. Those data provide necessary input to LSPC algorithms for hydrologic and water quality representation.

Successful hydrologic modeling depends on an accurate representation of the overall water balance. The two largest terms in the water balance are typically precipitation input and ET output. Precipitation is specified as a direct external forcing to the model, while actual ET is either derived as a function of observed pan-evaporation, or computed as a function of other weather data such as wind speed, air temperature, dew point temperature, and solar radiation. Together, those constitute the external meteorological time series needed to drive the model. This section focuses on the precipitation and evaporation/ET data, which were rigorously evaluated and processed for modeling purposes.

The accuracy of a hydrologic model is limited by the accuracy of the meteorological time series. In most cases, precipitation and evaporation data are the most hydrologically sensitive and spatially variable data sets used in watershed modeling; therefore, having a complete quality-controlled continuous set of the data benefits the modeling effort. A major and crucial early effort for model development is, thus, assembly and processing of meteorology. That presents often several challenges. First, precipitation data are typically available as point-in-space measurements, rather than integrated totals over subwatershed areas. Second, precipitation, temperature, and other meteorological series typically show strong spatial gradients in response to elevation (orographic effects) and aspect. An initial evaluation of meteorological data for the LA County watersheds is provided below.

Rainfall data from multiple sources was available at several locations in and around the LA County region (Figure 13). There were four primary data sources of locally observed weather data that were evaluated and processed for modeling: (1) the National Climatic Data Center (NCDC) hourly precipitation (21 gages), (2) NCDC Summary of Day precipitation stations (48 total, of which 36 gages were selected on the basis of screening level quality and quantity assessment), (3) the LA County DPW daily rainfall gages (9 gages), and (4) the Los Angels County Flood Control District (LACFCD) daily rainfall gages (155 gages). There were some additional privately owned gages for which the county provided data. Finally, there was another set of recent 5-minute interval rainfall gages (most beginning around the year 2000) maintained by the DPW that were processed and archived. Of the 64 5-minute stations, 62 of them represent locations that are also among the daily LACFCD and DPW gages. Altogether, there were 512 unique rainfall data sets reporting at daily, hourly, and 5-minute intervals, at 448 unique locations. Data quality and quantity were evaluated at each of these locations, resulting in the selection of 148 data sets. The following section describes the weather data quality control procedure that was applied for intervals of missing data.

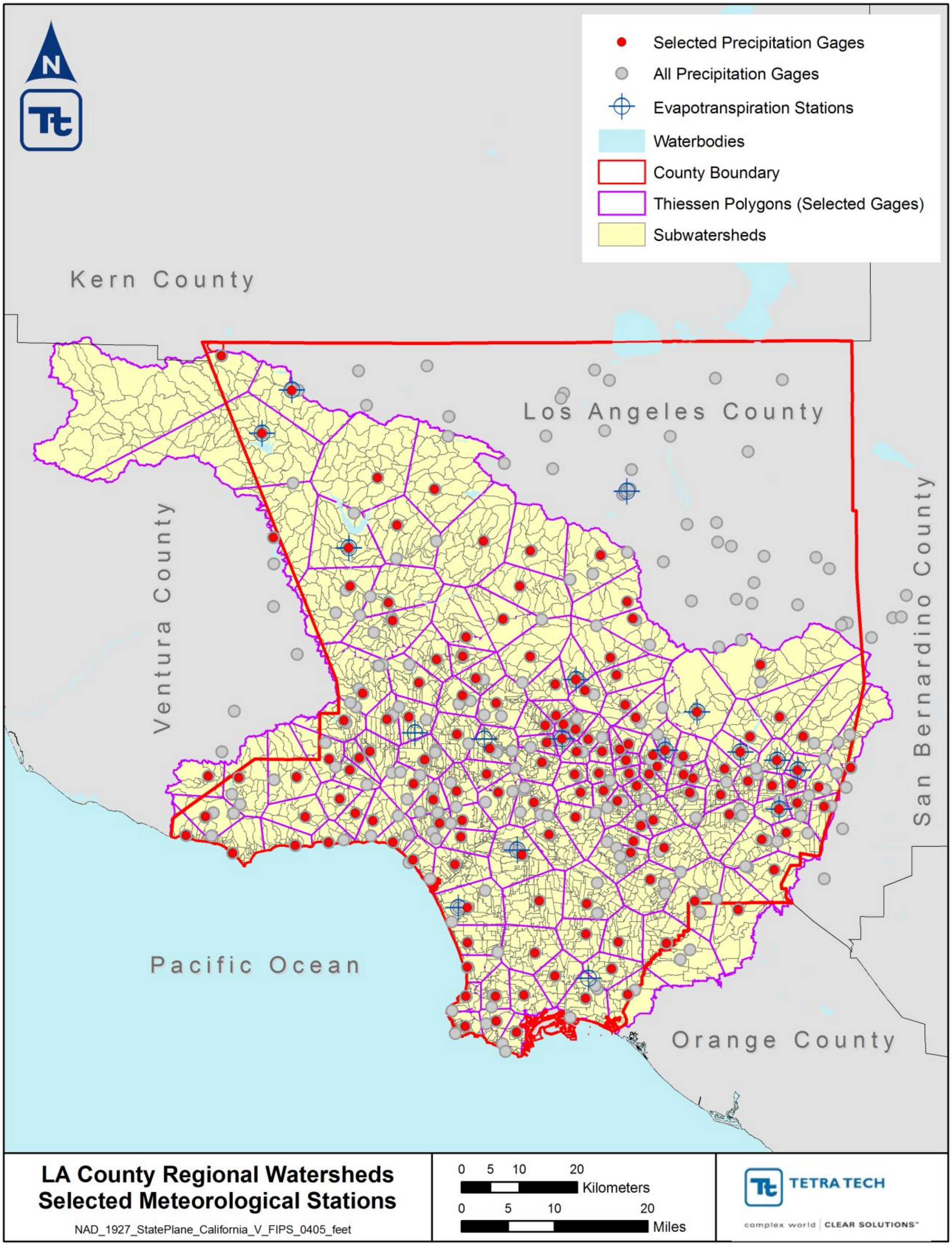


Figure 13. Location of measured precipitation gages for the LA County regional watersheds

Weather data quality control

The precipitation and evaporation data sets sometimes contained intervals of missing data. Periods before and after the data-collection period were also considered *missing* for this analysis. For watershed modeling, a continuous record is required to adequately represent continuous hydrology and water quality conditions. Sometimes, the missing intervals can be estimated using weather data at nearby stations with unimpaired data. Missing precipitation and evaporation data were estimated using the normal-ratio method, which estimates a missing value with a weighted average from surrounding index stations with similar precipitation or evaporation patterns according to the relationship:

$$P_A = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{N_A}{N_i} P_i\right)$$

where P_A is the estimate for the impaired value at station A, n is the number of surrounding index stations with unimpaired data at the same specific point in time, N_A is the long-term average value at station A, N_i is the long term average value at nearby index station i, and P_i is the observed value at nearby index station i. For each impaired daily value at station A, n consists of only the surrounding index stations with unimpaired data; therefore, for each record, n varies from 1 to the maximum number of surrounding stations. In the case of precipitation, when no precipitation is available at the surrounding stations, zero precipitation is assumed at station A. The U.S. Weather Bureau has a long established practice of using the long-term average rainfall as the precipitation normal (Dunn and Leopold 1978). Since normalization is the underlying principle, this method is adaptable to regions where there is large orographic variation in weather.

All 512 unique data sets were considered during the patching process. The first step in the process was to compute the percent missing on a monthly basis for each of the stations in the modeling period of interest (1/1/1986 through 12/31/2006). Second, for each station with missing data within the time period of interest, nearby index stations were selected according to (1) shortest straight-line distance from the station, and (2) availability of unimpaired data for periods of impaired data at the station. A minimum of three nearby daily stations were used for patching impaired data; however, more nearby stations were added as needed to ensure that for each station, at least one index station was included that had complete data for each month with impaired data. Patching of missing intervals was performed at a daily time step.

All daily data—and any accumulated intervals in the record—were then disaggregated to an hourly time step. Similar to how daily index stations were selected for repairing missing intervals, hourly index stations were included in the mix to ensure that each month in the modeling period was covered by at least one unimpaired set of hourly data. For each day (24-hour accumulated interval) or any other accumulated interval in the patched data record, the one hourly distribution with the closest daily total over that same interval was chosen from among the available set of nearby hourly index stations to disaggregate the accumulated total to hourly.

The local data provided by LACDPW provided a significantly denser spatial and quality of data coverage than what was previously available in previous modeling efforts in the region. The isohyetal map shown in Figure 14 was derived following the rainfall data quality control process. This map further highlights the importance of increasing the spatial coverage of rainfall gages in the LA County regional watersheds. A more detailed temporal summary of results from the (a) precipitation and (b) evaporation quality control process and results are presented in Appendices A and B, respectively.

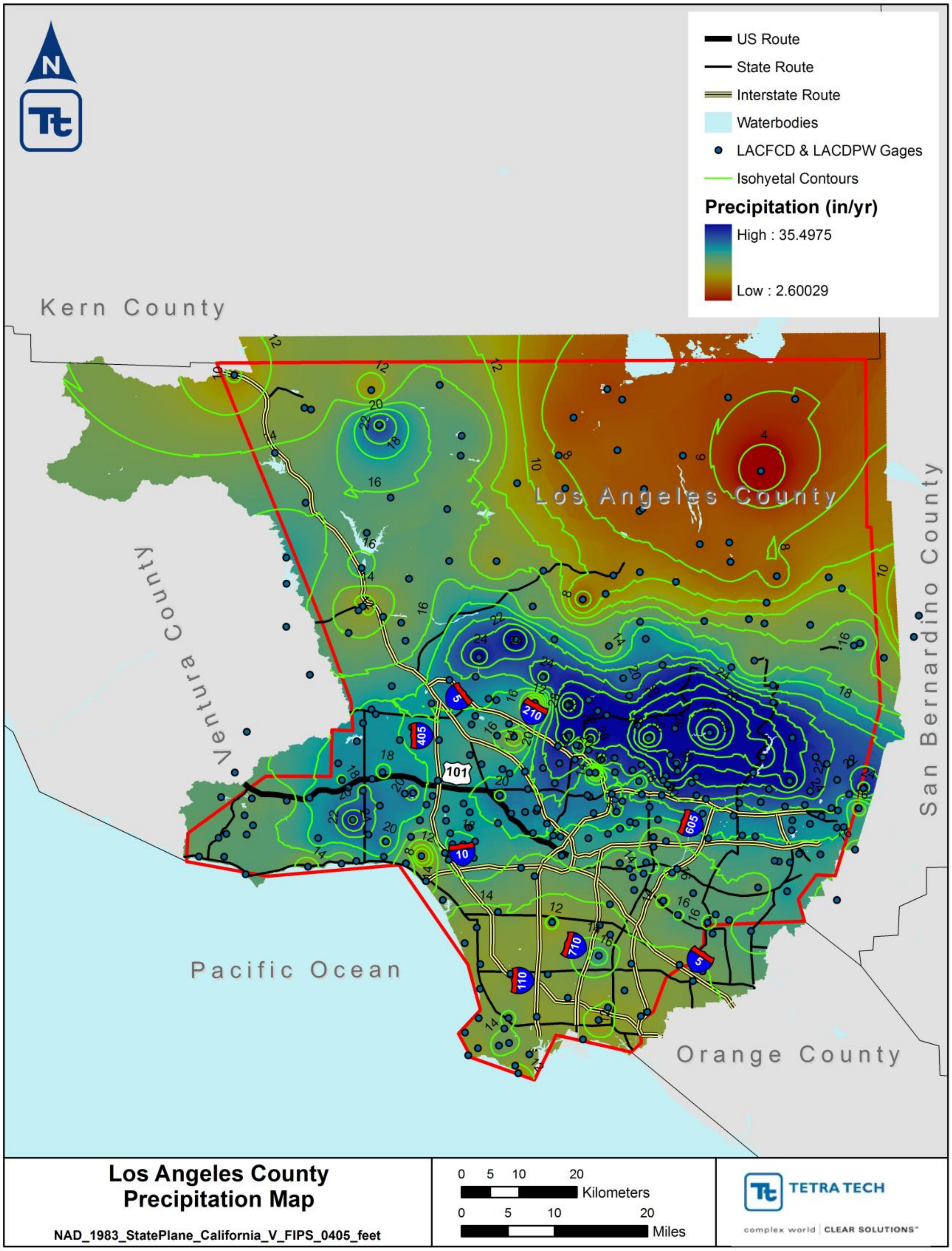


Figure 14. Average annual precipitation (Processed: 1/1/1987–12/31/2006) for the LA County regional watersheds

Data Inventory for Selected Precipitation Gages

The data from NCDC weather gages provided quality controlled daily and hourly precipitation observations, while the county-provided data included both daily and 5-minute observations. The various data sets were well documented and organized with quality control flags. The flags were summarized into two major categories: (1) missing data where no data records were available or there was a gap in the data set and (2) accumulated data over a known period where only the total volume was verified, but the distribution was unknown. As previously described, following a careful review and preprocessing of the various data sets, a data quality control procedure was implemented to repair missing, deleted, and accumulated intervals using complete data from nearby stations. Tables C-1 through C-6 in Appendix C are inventories of the selected rainfall data sets by contributing agency, including LA County DPW, the LACFCD, the NCDC, observer gages, private sources, and other reporting entities, respectively.

Figure 15 is a graph of average annual precipitation totals sorted by gage elevation for the 148 selected gages. On average, precipitation totals increase with increasing elevation. Among the gages at or near the same elevation in the watershed, the major factor influencing differences in precipitation total appears to be the slope aspect. There is also a dramatic difference between the elevation trends of gages outside (particularly those to the east), though none of them were plotted in Figure 15.

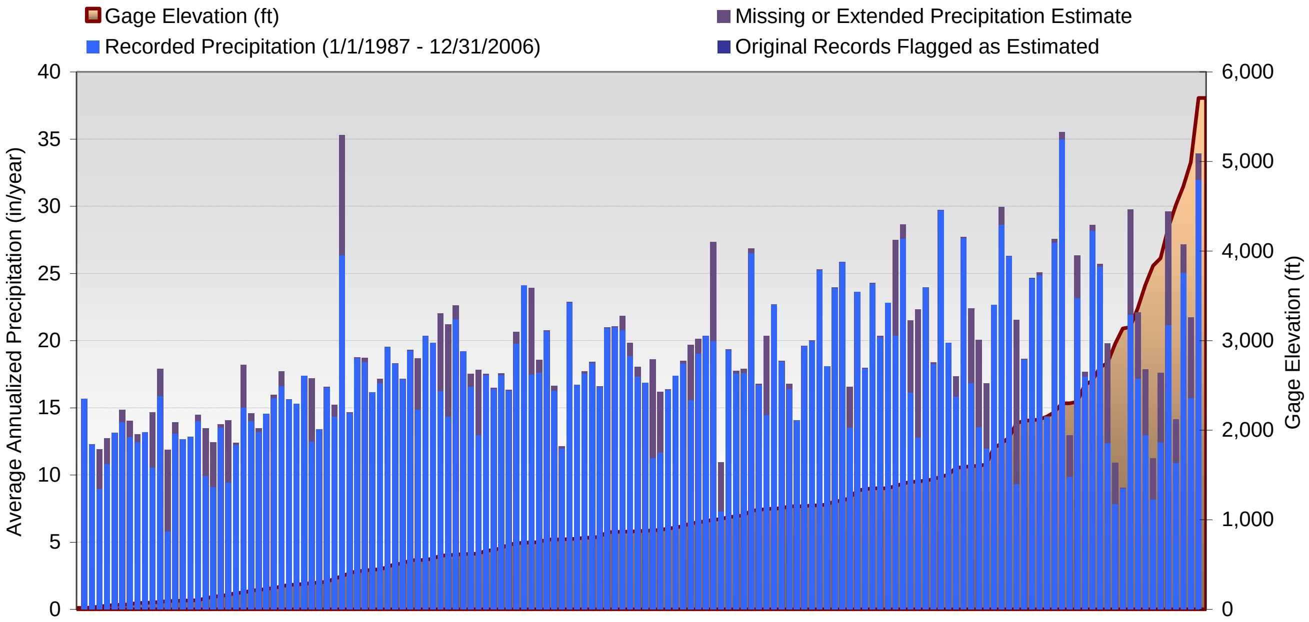


Figure 15. Average precipitation versus elevation for selected gages.

Data Inventory for Selected Evaporation Stations

Along with precipitation, observed pan evaporation measurements at fifteen locations in the county were also provided. These data varied in terms of quantity and quality. Evaporation also contained periods of missing data. As previously described, these missing intervals were processed using a similar methodology as was used for precipitation. Table 10 and Figure 16 are an inventory and graphical summary of all reported pan evaporation data in the county.

Table 10. Inventory of reported pan evaporation data in LA County (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Evaporation *	
			Start	End		Measured	Processed
Pacoima Dam	D33	1,500	10/02/87	05/31/08	93.1%	6.2	94.6
Big Tujunga Dam	D46	2,315	10/01/91	05/31/08	37.7%	60.8	95.6
Santa Anita Dam	D63	1,400	10/08/91	02/02/07	37.7%	32.9	51.9
San Dimas Dam	D89	1,350	10/02/87	02/02/07	22.2%	41.6	51.4
Puddingstone Dam	D96	1,030	10/02/87	02/02/07	17.6%	43.3	52.0
Big Dalton Dam	D223	1,587	10/02/87	02/02/07	17.6%	43.3	52.0
Castaic Dam	D252	1,150	10/01/91	02/02/07	44.5%	54.2	96.3
San Gabriel Dam Number	D334	2,300	10/02/87	02/02/07	24.6%	41.4	52.4
Morris Dam	D390	1,210	10/02/87	02/02/07	20.8%	67.4	85.0
Pyramid Reservoir	D409	2,505	10/01/91	02/02/07	47.1%	55.1	102.7
San Gabriel Dam	D425	1,481	10/02/87	01/31/07	35.6%	47.9	72.7
Neenach	D598	3,062	07/01/02	02/02/07	89.4%	15.0	156.9
Palmdale	D1058	2,595	10/01/91	02/02/07	34.2%	59.2	88.4
Descanso Gardens	D1071	1,325	10/02/87	02/02/07	22.4%	38.3	47.5
Pearblossom Cal. D.W.R. Booster Sta	D1240	3,050	07/01/02	02/02/07	88.8%	14.2	132.1

* Measured and processed evaporation totals represent average annual values between 1987 and 2006

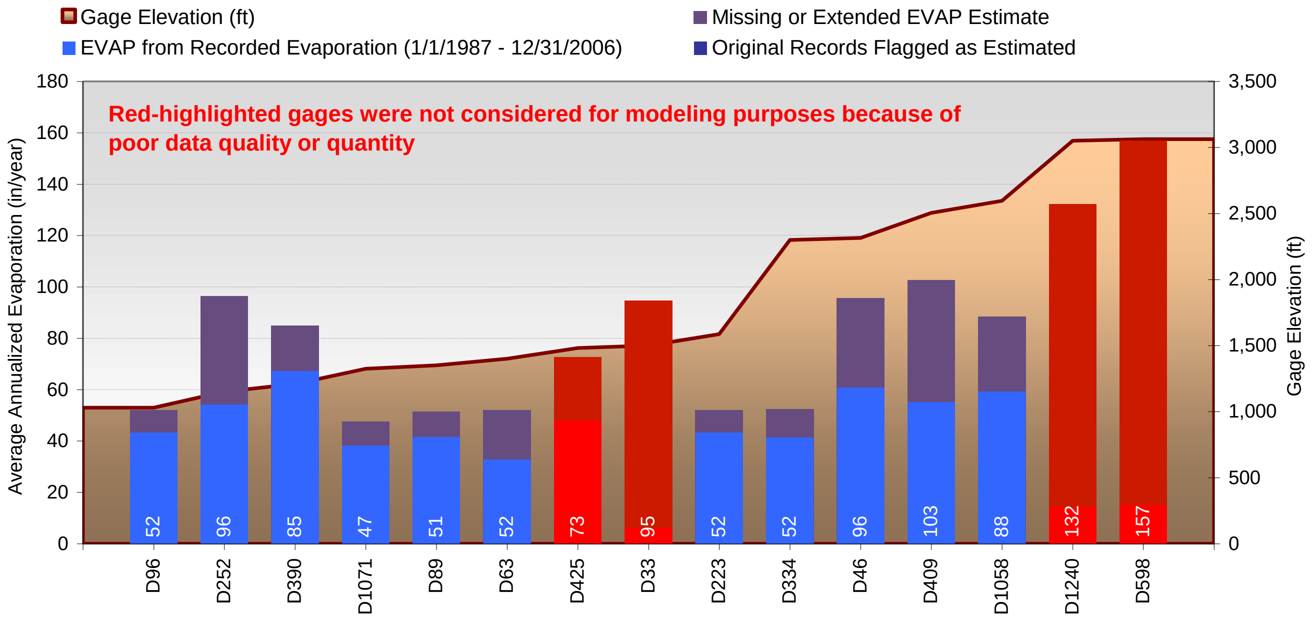


Figure 16. Average pan evaporation versus elevation for all observed stations in LA County.

The pan evaporation stations were generally adjacent to dams or reservoirs in relatively higher altitude areas of the watershed. For that reason, much of the lower-lying elevations are not properly represented by observed evaporation. The data seem to show somewhat of an increasing trend in ET with increasing elevation; however, because temperature generally decreases with increasing elevation, this regional trend could be more indicative of a stronger relationship of increasing ET with increasing wind activity.

Without observed data, pan evaporation can be computed using methods such as the Penman method, which estimates evaporation as a function of temperature, wind speed, dew point temperature or relative humidity, and solar radiation (Penman 1948). In previous modeling efforts in the region, the Hamon method (1963) alone was used to estimate ET. That method is convenient because it is a function of temperature only, which is widely monitored; however, in areas of contrasting orographic relief, experience has shown that the method tends to under predict potential ET. For the lower elevations, long-term continuous data at six of the NCDC weather gages were found to be long enough to sufficiently calculate Penman pan evaporation. Whenever the data records were shortened or incomplete, the computed pan evaporation data were extended using nearby estimated or computed records, as previously described.

Other recent regional studies have shown that the biggest difference in evaporation occurs between the flatter, lower-lying coastal areas and the higher more inland areas (Tetra Tech 2009). For example, the El Rio-UWCD Spreading Grounds pan (239), in Ventura County a few miles from the coast, showed a seasonal trend that was distinctly different from other inland, higher elevation observation pans. Observations from field visits have also suggested that coastal fog has an influence on evaporation behavior. Both of those points are supported by an analysis of CIMIS data. CIMIS has interpreted 18 unique reference ET zones in California, four of which are present in the LA County regional watersheds. Two zones run parallel to the coastline (going inland 6 to 7 miles) and have descriptions reflecting greater and lesser fog influence, while the three interior zone descriptions reflect drier conditions. The default Penman method by itself tends to overpredict coastal evaporation. A scaling multiplier of 0.5 was applied to the Penman estimates to bring them in line with expected coastal evaporation levels. Table 11 is an inventory of the computed pan evaporation totals at six NCDC weather gages.

Table 11. Inventory of computed pan evaporation data in LA County (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Extraction Period		Percent missing	Evaporation *	
			Start	End		Available	Extended
Long Beach Airport	23129	10	01/01/86	12/31/06	0.0%	39.3	39.3
Van Nuys Airport	23130	260	01/01/86	12/31/06	56.3%	20.3	46.4
Burbank-Glendale-Pasadena	23152	240	01/01/86	12/31/06	57.0%	19.8	45.9
LA Intl Airport	23174	37	01/01/86	12/31/06	0.0%	37	37
Sanburg	23187	1,480	01/01/86	12/31/06	47.5%	32.6	62.2
Downtown LA/USC Campus	93134	60	01/01/86	12/31/06	62.5%	14.2	37.8

* Available and extended pan evaporation estimates represent average annual values between 1987 and 2006

Finally, pan evaporation data (both observed and computed) must be transformed into potential ET using an appropriate pan coefficient. For the original SCR watershed, LACDPW previously provided Aqua Terra monthly pan coefficients for their stations (Aqua Terra 2008).

Table 12 shows monthly pan coefficients for the LA County evaporation stations.

Table 12. Monthly pan coefficients for LA County evaporation stations

Spring and summer		Fall and winter	
Month	**ET coefficient**	**Month**	**ET coefficient**
January	0.82	July	0.74
February	0.63	August	0.78
March	0.68	September	0.87
April	0.66	October	0.93
May	0.68	November	0.97
June	0.77	December	0.95

The ET coefficients were applied to both the observed and computed evaporation time series on a monthly basis to derive potential ET. Figure 17 shows estimated potential ET versus elevation for selected modeling stations.

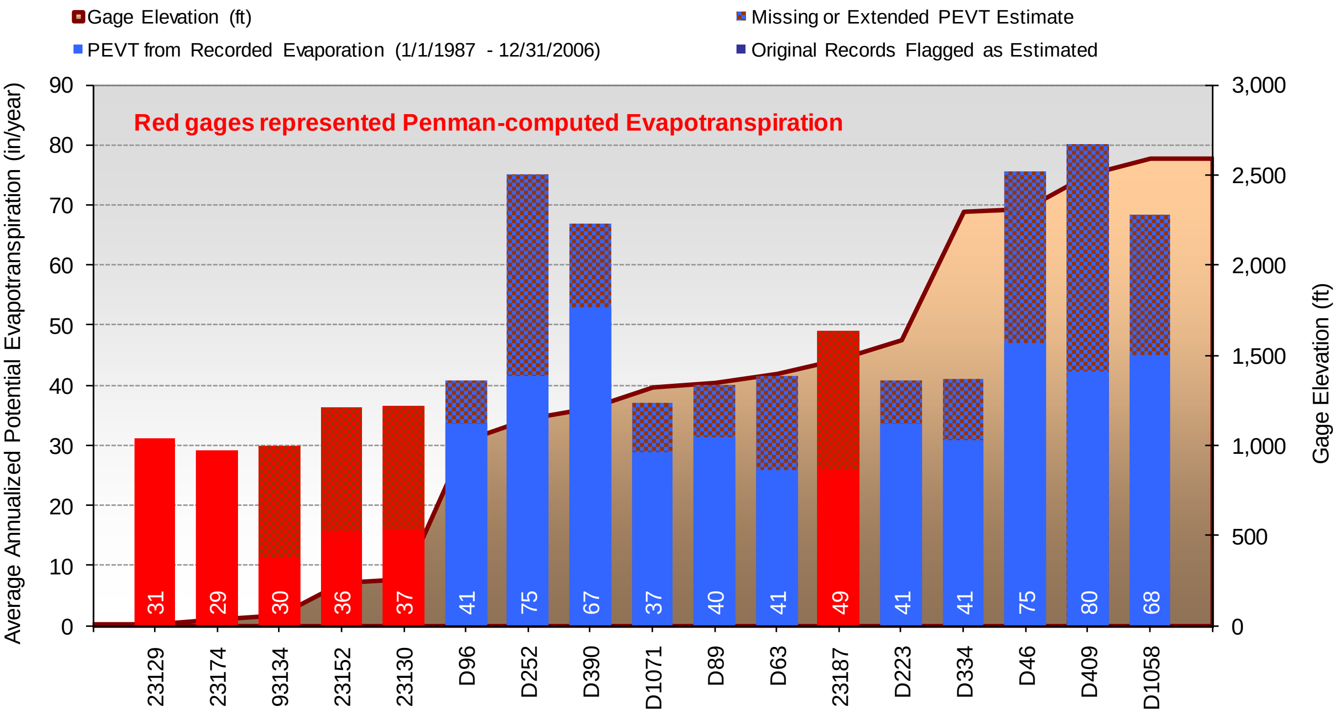


Figure 17. Estimated potential ET versus elevation for selected modeling stations.

The final step involved disaggregating the daily potential ET estimates to hourly. Disaggregation was performed by fitting a sine curve distribution over the computed daylight hours. For each station, daylight hours (from sunrise and sunset) were uniquely derived as a function of latitude and the average curvature of the earth.

Assigning weather data to modeling segments

The previous inventories and analyses have focused on the selected stations. This section describes how the stations were selected, and ultimately, how data were spatially assigned to modeling subwatersheds. After patching the missing intervals for the precipitation and evaporation data sets, maps of long-term average data summaries were created and evaluated to help identify outliers from expected spatial trends. The percent coverage (computed as 100 percent of time missing) was also plotted for (1) the 20-year period between 1987 and 2006 (Figure 18), and (2) the most recent available 10- year period 1997–2006 (Figure 19). However, data quality for the most recent 10-year period was given greater consideration because other supporting watershed data (such as land use) represent conditions for the period. The selected gages previously shown in Figure 13 were selected so that where a cluster of gages with similar long-term average totals were in close proximity, the ones with the highest percent coverage (or having the least amount of missing data) were preferentially retained, while the more impaired or processed gages were rejected.

Notice that for the 1987–2006 time frame shown in Figure 18, two stations with relatively low percent coverage (56 and 68 percent) were retained among the selected stations. Those stations began reporting data around the mid 1990s. Recall that although the stations show low percent coverage of observed measurements, the earlier impaired years in the modeling records would still contain *estimated* data derived using the Normal Ratio Method. The two stations were retained to better capture spatially under-represented areas in the watershed. Also note that for the 1997 to 2006 period (Figure 19), the same stations are among the highest quality stations among the selected set. Figure 20 shows a color gradient of increasing annual average precipitation totals assigned for each of the 2,655 modeling subwatersheds in the model. One selected precipitation record was assigned per subwatershed according to the highest percentage of an intersecting Thiessen polygon with the subwatershed.

Finally, ET data were assigned to the subwatersheds using a similar Thiessen polygon methodology that was used for assigning precipitation stations. Each subwatershed needs one precipitation and one ET time series for LSPC. There are 148 unique rainfall locations. In an effort to manage the number of unique combinations of ET and precipitation, ET data were first assigned per precipitation Thiessen polygon according to the highest percentage of intersecting evaporation and precipitation Thiessen polygons. Therefore, even after associating ET, the number of unique weather combinations remains at 148. Figure 21 shows annual average ET throughout the LA regional watersheds area and station assignments by precipitation Thiessen polygon.

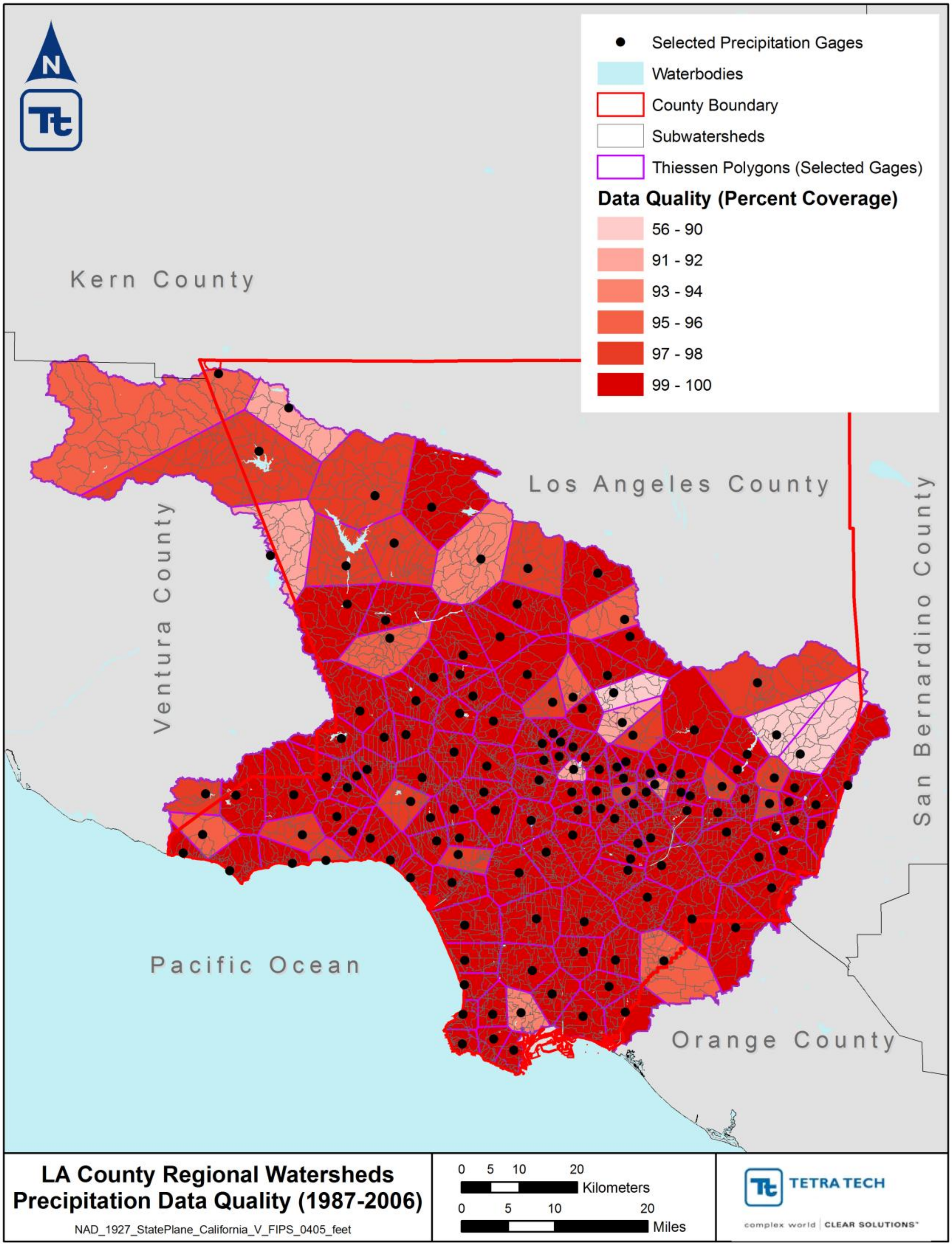


Figure 18. Data quality of selected precipitation gages summarized for 1987–2006.

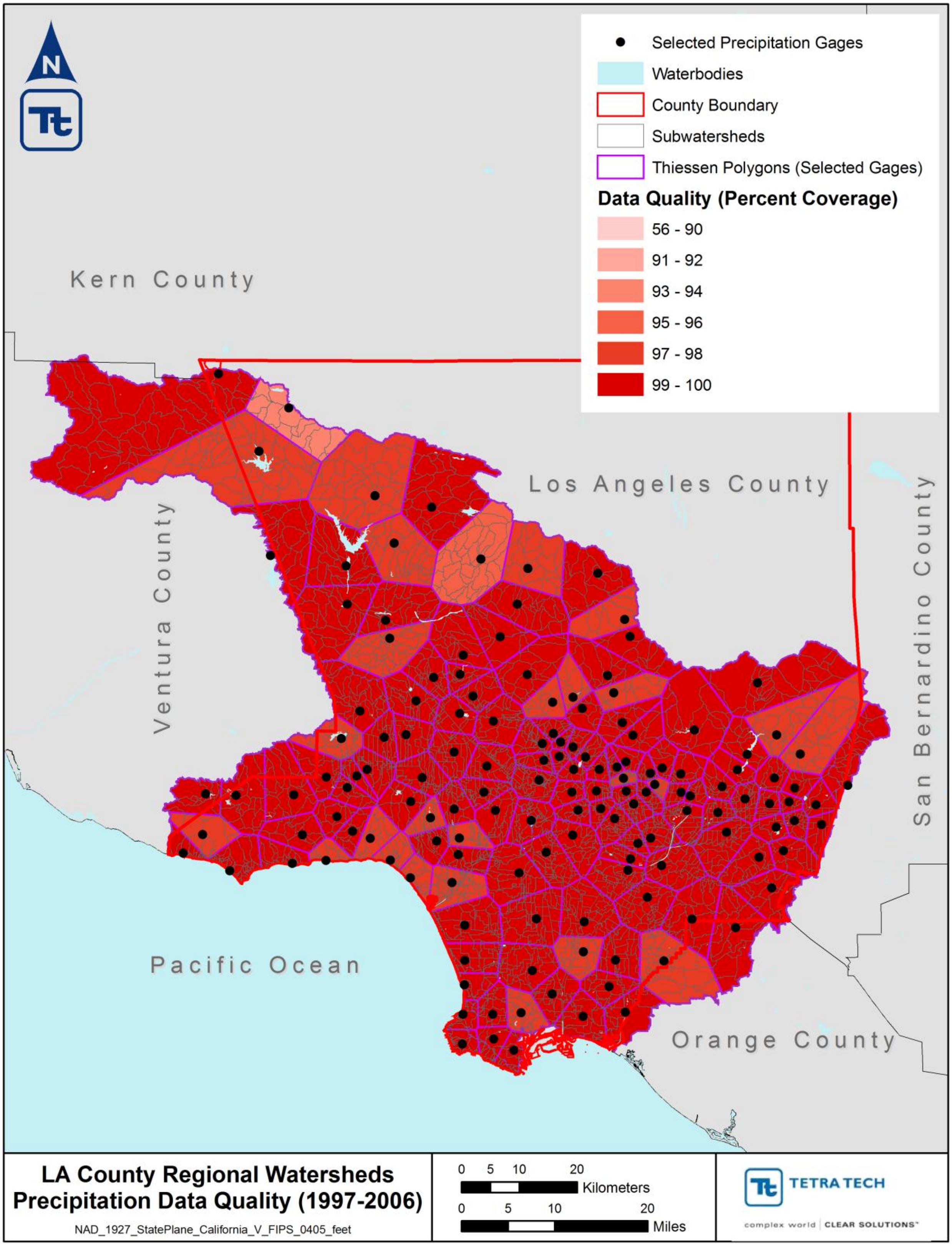


Figure 19. Data quality of selected precipitation gages summarized for 1997–2006

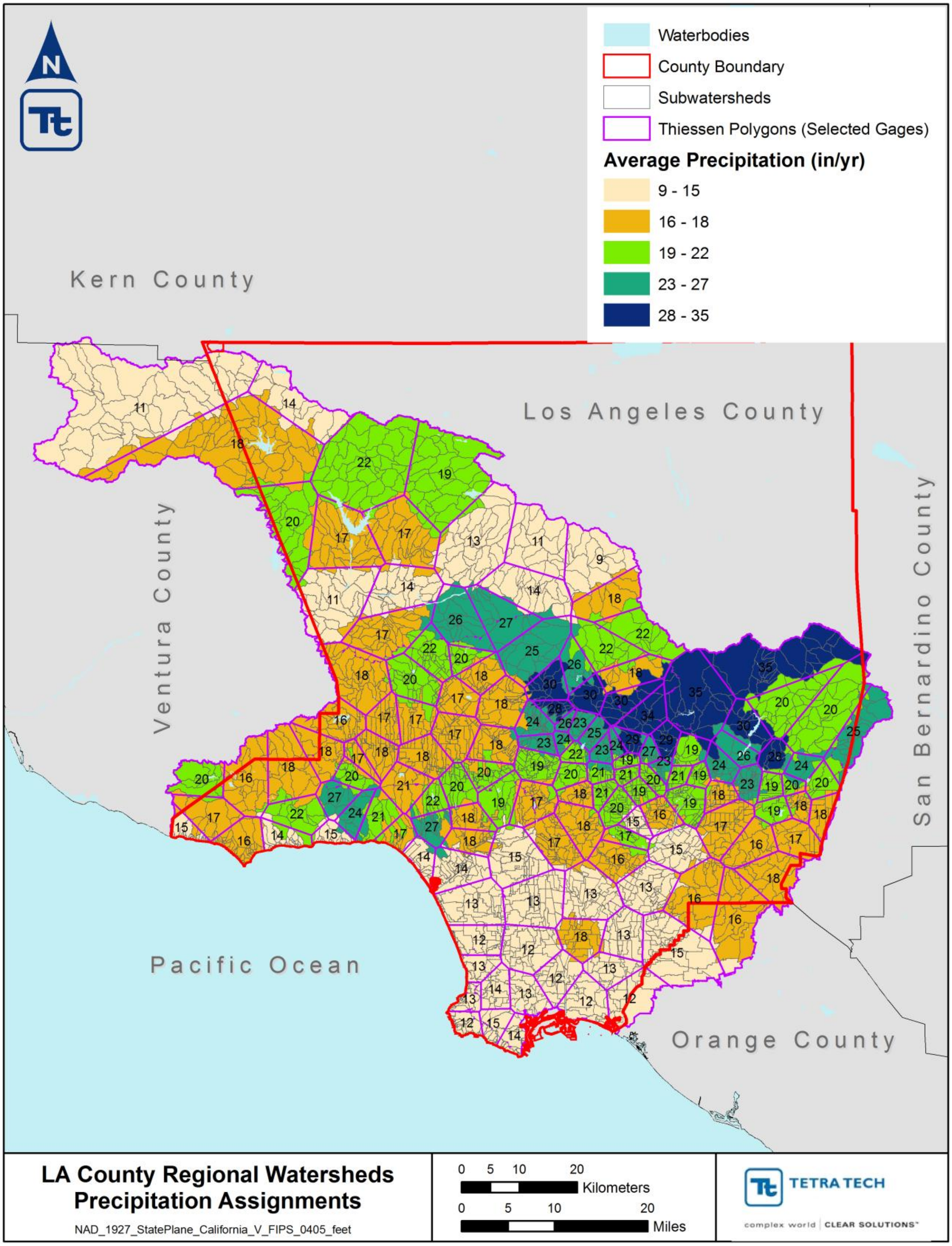


Figure 20. Average annual precipitation (1987–2006) by subwatershed for assigned modeling subwatersheds

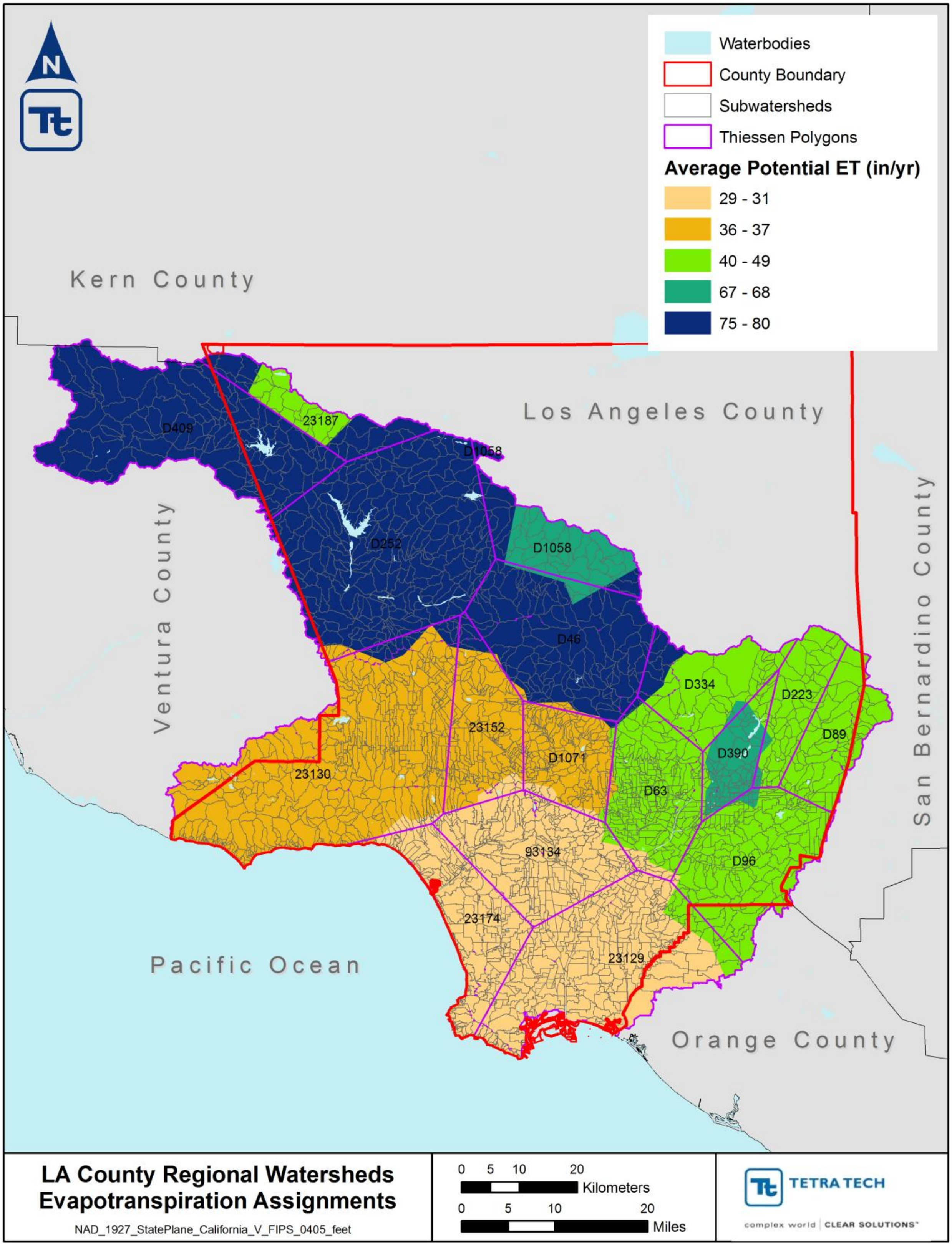


Figure 21. Average annual potential ET (1987–2006) for assigned modeling subwatersheds

Hydrologic Modifications

The LA regional watershed area includes some important hydrologic modifications that were considered during model development. These include an extensive network of spreading grounds, where stormwater is diverted during extremely wet events. There are also several reservoirs located throughout the higher altitude areas of the study area. In addition to these known hydrologic modifications, there is thought to be a number of centralized BMPs that could potentially have an impact on the way hydrology is represented in the watershed. These will be further evaluated for consideration and/or inclusion in Phase II of this modeling effort. This section describes the representation of spreading grounds and reservoirs in the model.

Spreading Grounds

As previously described, the LSPC model has two main components for hydrology: (1) a land module for generating runoff and baseflow contributions, and (2) a stream routing module. Both of these modules are used together to represent both the baseline condition. Spreading grounds were modeled as intermediate storage compartments within the stream/reach routing network. Figure 22 is a map showing the location, drainage area, and aerial footprints of existing spreading grounds within the Los Angeles Regional watersheds. As shown on this map, many of the spreading grounds are nested within areas served by larger spreading grounds, as part of the larger stream network. This map also characterizes the degree to which the different spreading grounds are nested within the larger network. Level 1 represents areas draining to a single spreadhing ground, Level 2 reprsents areas with at least one Level 1 region nested within its drainage area. This nested area naming convention continues through Level 6. Figure 22 shows that about 50% of the study area is affected one way or another by a spreading ground. For this reason, spreading grounds were represented within the model as part of the baseline simulation and calibration run. The Figure 23 highlights one particular location of interest, the Santa Anita spreading ground (with neighboring Sierra Madre spreading ground), located in the Los Angeles River watershed.

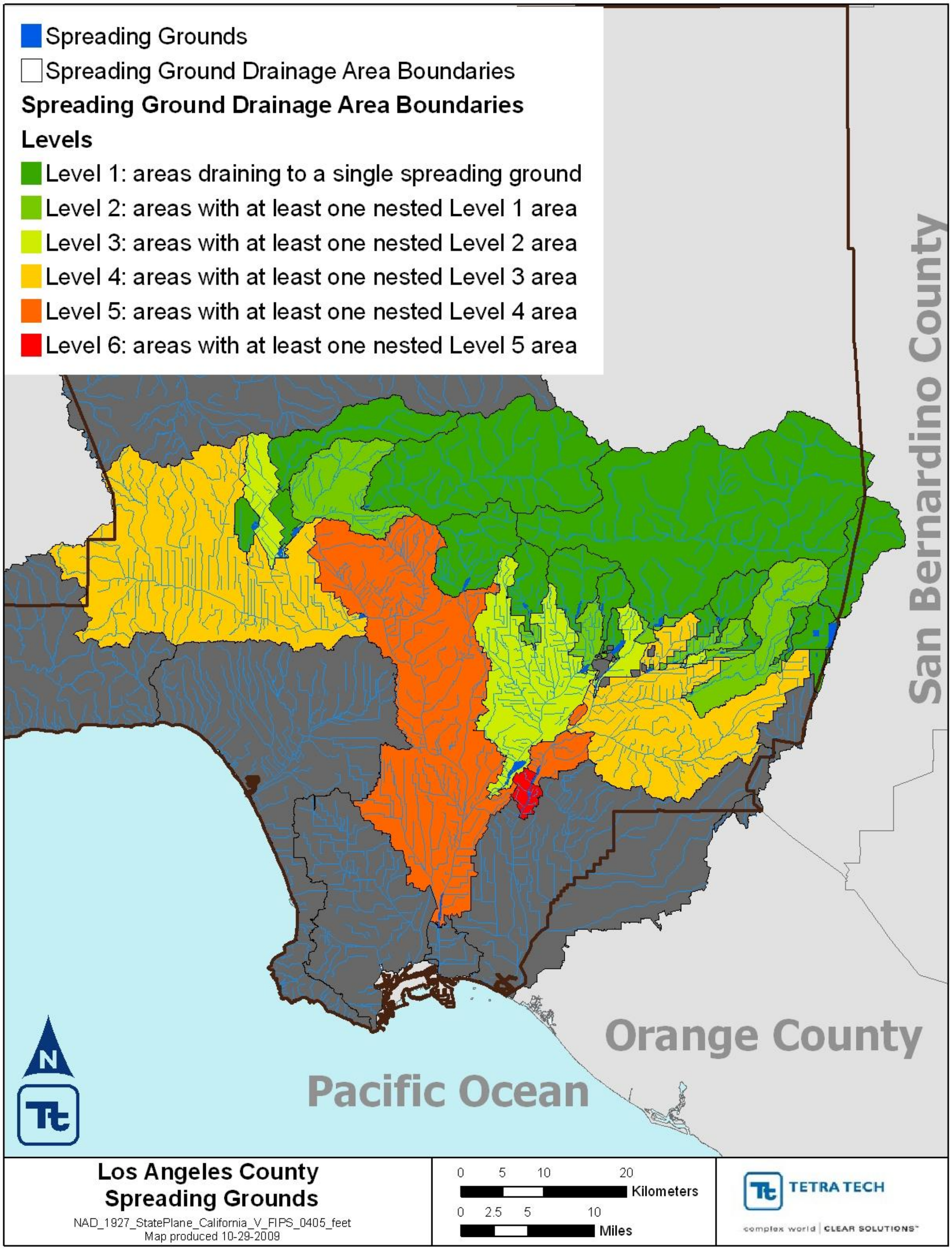


Figure 22. Locations, drainage areas, and aerial foot prints of spreading grounds

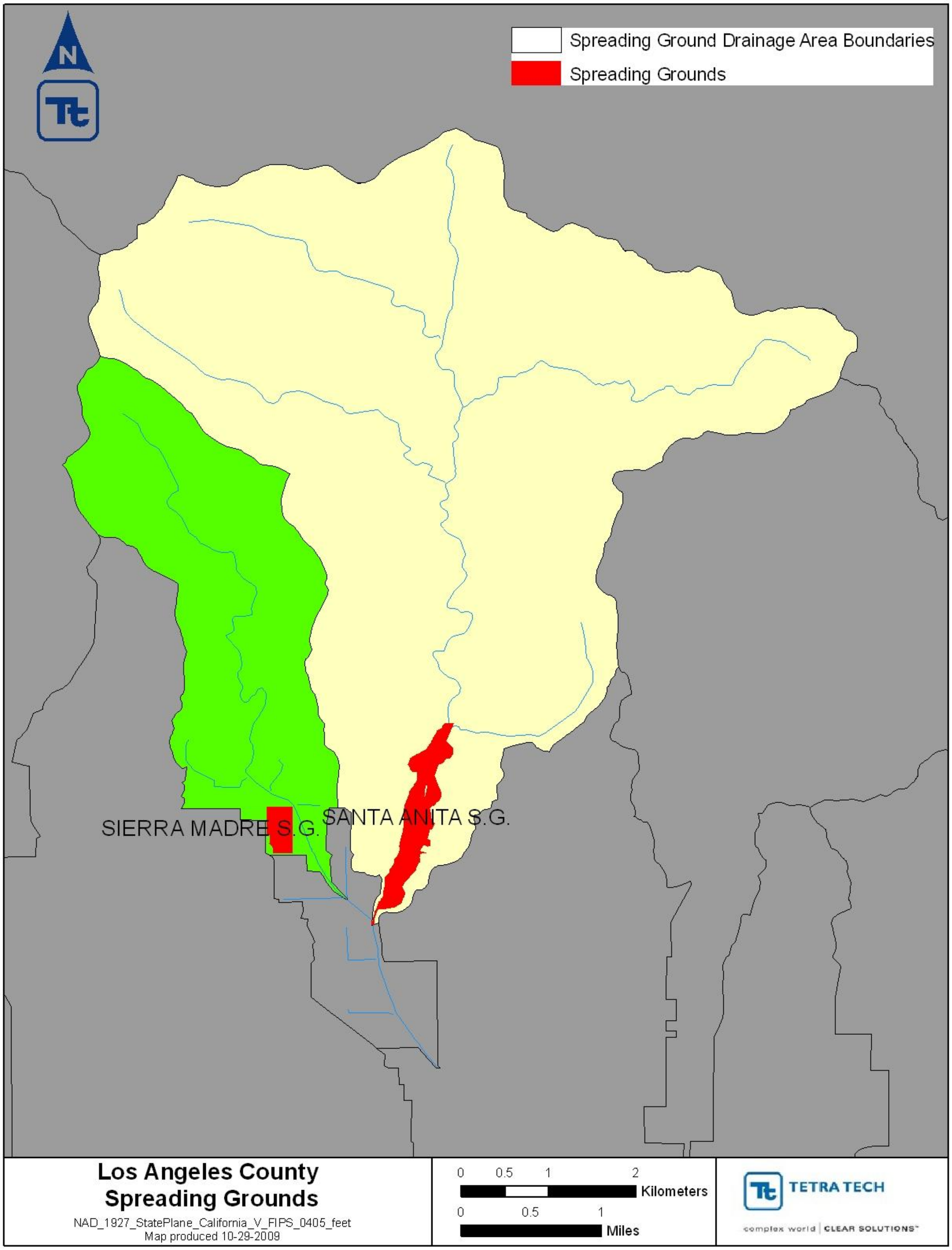


Figure 23. Locations, drainage areas, and aerial foot prints for the Santa Anita & Sierra Madre spreading grounds

LSPC model uses a hydraulic function table (F-table) to represent the geometry and hydraulic properties of water bodies such as streams, lakes, or other hydrologic structures. The F-table is a piece-wise linear constructed table that relates four the variables of depth, surface area, volume, and outflow discharge(s). Because spreading grounds have both storage capacities and serve to recharge groundwater, volume, outflow, and recharge rates were all used to represent their physical size and hydraulic performance. Figure 24 is a schematic showing the storage, volume, inflows and outflows of a conceptual spreading ground in LSPC. The same conceptual representation was also used for the reservoirs, with the exception of a groundwater outflow term.

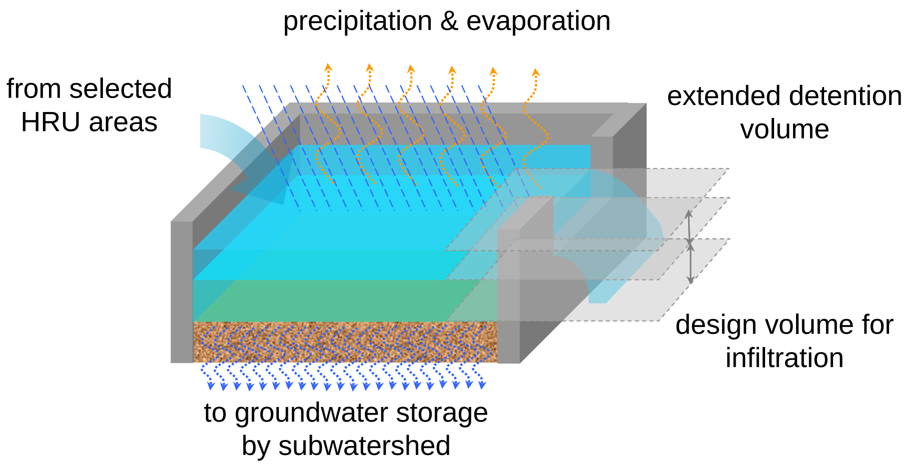


Figure 24. Conceptual modeling segment schematic showing storage volume, inflows, and outflows

Notice that the structure illustrated in Figure 24 has four boundaries defined. Because these structures are located within the stream network, inflow to the spreading grounds include instream outflow from the reach segment that drains all upstream HRU areas. Because the element is modeled as a stream segment, it is also possible to allow direct precipitation and evaporation to occur as a function of the exposed surface area. For each time step, runoff is allowed to flow into the segment, updating the total volume of water stored in the segment. Using step-wise linear interpolation, the corresponding depth, surface area, discharge volume (if the depth is above the overflow weir, representing the storage capacity), and net infiltration volume are computed using the F-table. The advection methodology used to solve the F-table is applied to the condition at both the beginning and at the end of the time step, resulting in an averaged set of values for each time step.

Consider the Santa Anita spreading ground, previously shown in Figure 23. This spreading ground is owned and managed by the Los Angeles County Department of Public Works. According to the attribute information, it is a shallow basin with a storage capacity of 25 acre-ft and a ground percolation rate of 5 cfs. The overflow weir height is 3.13 ft. The discharge rate was computed assuming a broad-crested weir of 60 feet width for volumes exceeding the 25 acre-ft capacity. The percolation rate is assumed to be infiltrated and lost to deep ground water (i.e. it will not be recharged to downstream reach segments in the model). The corresponding F-table for the Santa Anita spreading ground is presented in Table 13.

Table 13. Unit-area FTABLE for the Santa Anita Spreading Ground

Reach ID	Depth (feet)	Surface Area (acres)	Volume (acre-ft)	Overflow Rate (cfs)	Percolation Rate (cfs)
7909	0	8	0	0	5
7909	0.625	8	5	0	5
7909	1.25	8	10	0	5
7909	1.875	8	15	0	5
7909	2.5	8	20	0	5
7909	3.125	8	25	0	5
7909	3.1251	8	25.0008	0	5
7909	3.126	8	25.008	0.006	5
7909	3.135	8	25.08	0.2	5
7909	3.225	8	25.8	6.318	5
7909	3.325	8	26.6	17.871	5
7909	3.425	8	27.4	32.83	5
7909	3.625	8	29	70.64	5
7909	3.875	8	31	129.774	5
7909	4.125	8	33	199.8	5
7909	5.125	8	41	565.12	5
7909	6.125	8	49	1038.191	5
7909	8.125	8	65	2233.832	5
7909	10.625	8	85	4103.811	5
7909	13.125	8	105	6318.231	5
7909	23.125	8	185	17870.655	5
7909	33.125	8	265	32830.49	5
7909	53.125	8	425	70639.967	5

The F-table approach is convenient and efficient for large-scale BMP simulation because while the layers are derived according to the geometric and hydraulic properties of the BMP, all of that information does not have to be considered during model simulation. The limitation of this approach is that water is assumed to flow only in one direction – in through the inlet and out through the outlet of the BMP. This method and solution technique cannot be used for flood conditions where backwater flow might occur.

Reservoirs

Of the original available watershed models, only the SCR HSPF models included derived F-tables for its two reservoirs. These were directly used in the LSPC translation. Between the LAR and SGR watersheds, there are 14 other reservoirs that had adequate information available for inclusion in the model. Figure 25 is a map showing the approximate locations of the fourteen reservoirs within their respective watersheds.

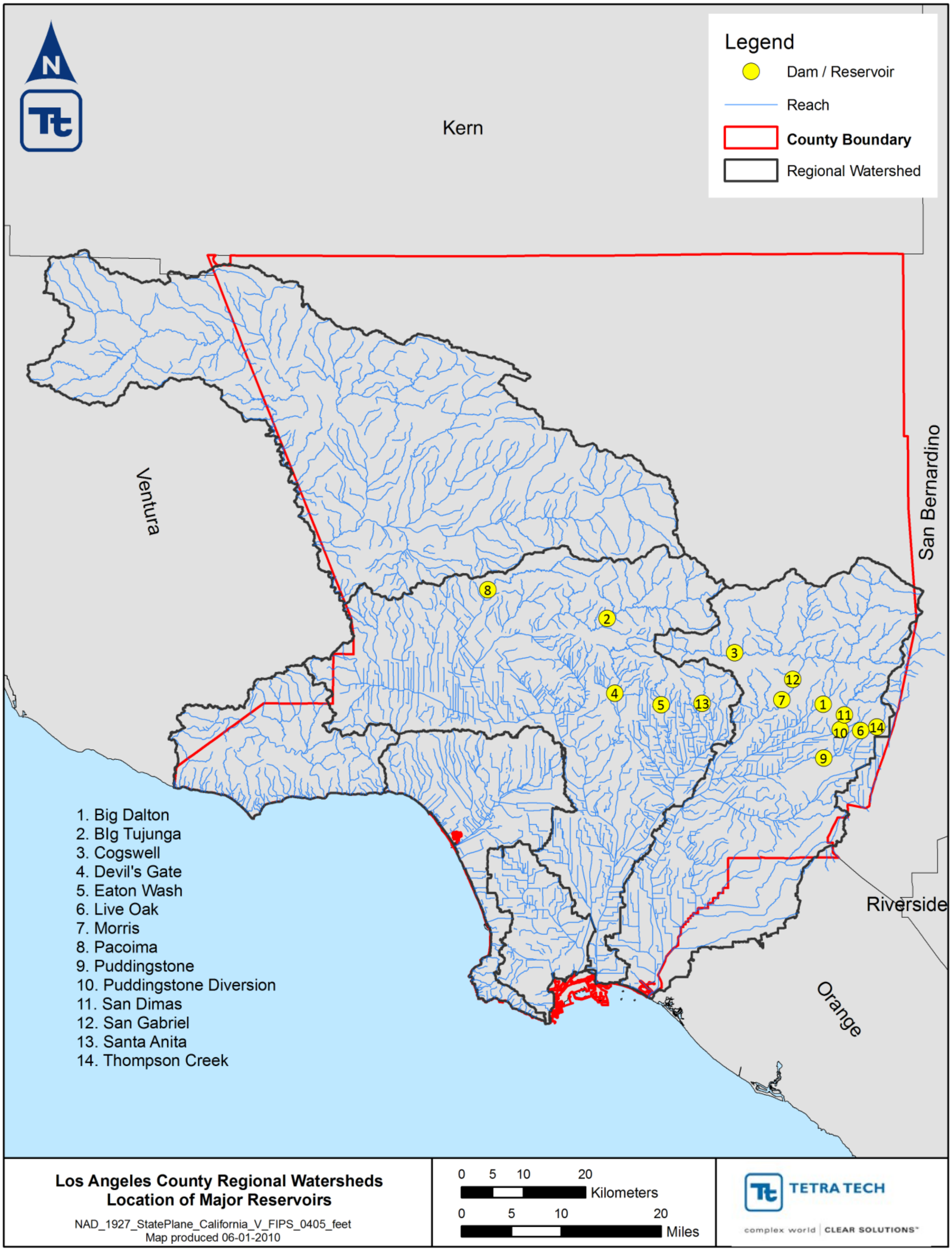
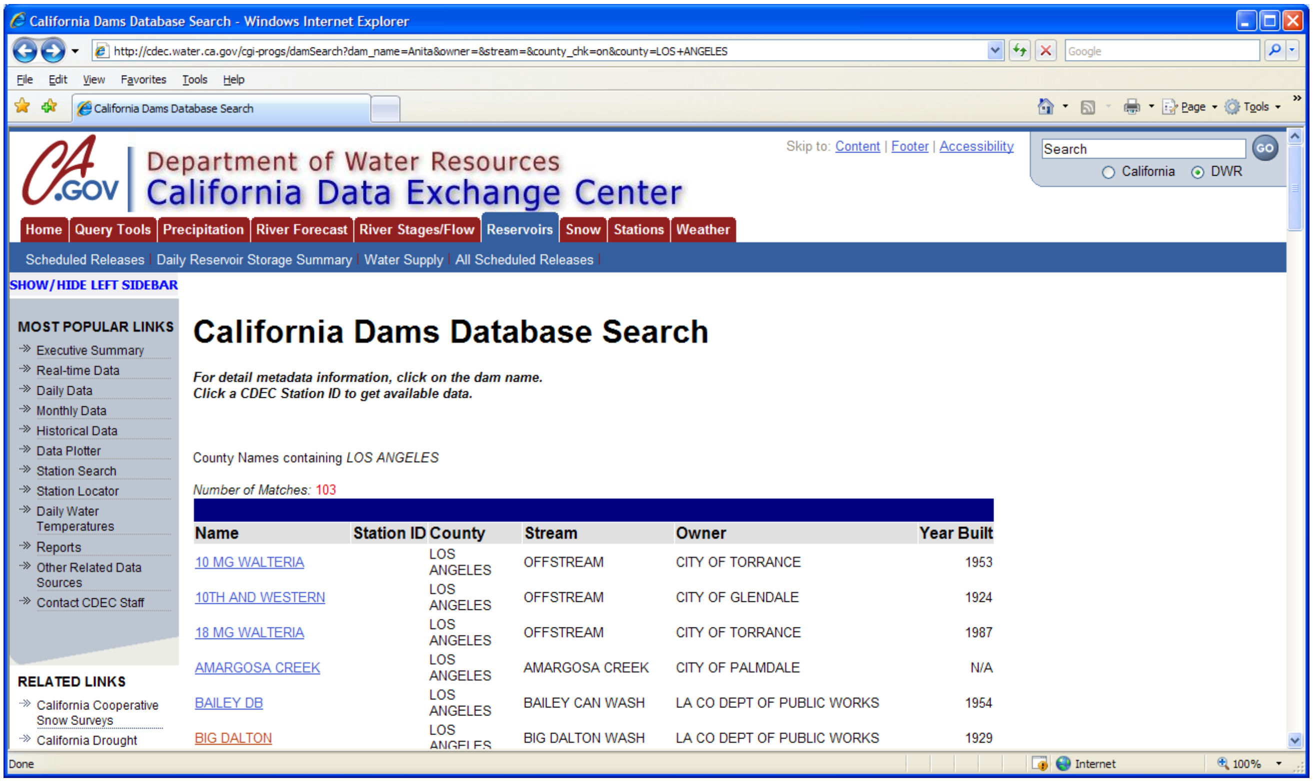


Figure 25. Locations of major reservoirs within Los Angeles County.

General Statistics and Reservoir Geometry

The LACDPW provided general information and operation schedules for fourteen dams located within Los Angeles County, which included dimensional statistics about the dam (length, crest height, etc.) and the corresponding drainage area. The amount of detail included in the operating schedules varied from one reservoir to the next. Additional information was compiled from the California Department of Water Resources California Data Exchange Center website (shown in Figure 26). Available information included crest elevation (from sea level) and estimates of maximum reservoir storage capacity and surface area. These parameters were used as benchmarks when reviewing the operations dataset and the estimated values of reservoir surface area.



California Dams Database Search

For detail metadata information, click on the dam name.
Click a CDEC Station ID to get available data.

County Names containing *LOS ANGELES*

Number of Matches: 103

Name	Station ID	County	Stream	Owner	Year Built
10 MG WALTERIA		LOS ANGELES	OFFSTREAM	CITY OF TORRANCE	1953
10TH AND WESTERN		LOS ANGELES	OFFSTREAM	CITY OF GLENDALE	1924
18 MG WALTERIA		LOS ANGELES	OFFSTREAM	CITY OF TORRANCE	1987
AMARGOSA CREEK		LOS ANGELES	AMARGOSA CREEK	CITY OF PALMDALE	N/A
BAILEY DB		LOS ANGELES	BAILEY CAN WASH	LA CO DEPT OF PUBLIC WORKS	1954
BIG DALTON		LOS ANGELES	BIG DALTON WASH	LA CO DEPT OF PUBLIC WORKS	1929

Figure 26. California Department of Water Resources listing of Dams within LA County

Data from the LACDPW and California Department of Water Resources was compiled and used as a basis for deriving starge-discharge relationships for the reservoirs. A summary of the compiled datasets for the reservoirs studied is presented below as Table 14 and Table 15.

Table 14. Summary of major reservoirs within the Los Angeles River watershed.

	Dam Crest Elevation (ft.)	Streambed Elevation (ft.)	Freeboard (ft.)	Estimated Depth (ft.)
Big Tujunga	2,308	2,108	18	182
Devils Gate	1,075	975	16	84
Eaton Wash	902	840	15	47
Pacoima	2,016	1,651	65	300
Thompson Creek	1,648	1,582	14	52

Table 15. Summary of major reservoirs within the San Gabriel River watershed

	Dam Crest Elevation (ft.)	Streambed Elevation (ft.)	Freeboard (ft.)	Estimated Depth (ft.)
Big Dalton	1,714	1,568	8	138
Cogswell	2,412	2,147	27	238
Live Oak	1,506	1,436	9	61
Morris	1,175	930	23	222
Puddingstone	982	835	12	135
Puddingstone Diversion	1,168	834	11	323
San Dimas	1,481	1,364	19	98
San Gabriel	1,481	1,171	28	282
Santa Anita	1,328	1,103	12	213

Reservoir Operations Datasets

Operations data were made available for all fourteen dams covering the period from October 1, 1998 through November 9, 2008. This data included daily records of water surface elevation, storage, average inflow, and average outflow. Additional notes were available documenting any unique weather or operating conditions. A summary of the elevation and storage capacity boundary conditions for each of the fourteen reservoirs is presented below as Table 16.

Table 16. Summary of data from the reservoir operation logs (WY 1998 through WY 2009).

	Minimum Water Surface Elevation (ft)	Maximum Water Surface Elevation (ft)	Minimum Storage Volume (ac-ft)	Maximum Storage Volume (ac-ft)
Big Dalton Dam	1,608.9	1,706.3	14.6	945.1
Big Tujunga Dam	2,203.1	2,296.2	1,148.4	6,496.1
Cogswell Dam	2,175.0	2,389.2	6.1	11,716.3
Devils Gate	994.8	1,045.4	1.3	1973.4
Eaton Wash	847.2	889.0	0.1	863.4
Live Oak Dam	1,449.0	1,490.9	0.1	188.1
Morris Dam	992.3	1,168.1	39.6	27,992.8
Pacoima Dam	1,788.3	1,965.9	3.5	4549.1
Puddingstone Dam	936.4	953.8	5,195.2	9,930.6
Puddingstone Diversion	1,133.7	1,154.4	0.7	239.6
San Dimas	1,385.2	1,467.3	5.6	1,794.6
San Gabriel	1,297.8	1,458.4	602.3	48,833.6
Santa Anita	1,236.0	1,321.2	84.1	905.7
Thompson Creek	1,609.0	1,626.9	90.6	393.5

The operations datasets also serve as a time series of scheduled releases from the reservoirs over the time period described above. These discharges were incorporated into the model as point source withdraws from the reservoir segments, which where then immediately discharged into the next segment downstream, in order to capture the effect of these man-made releases. It would otherwise have been impossible to characterize these occurrences within the stream network, since they are caused by human judgment instead of purely hydrologic influence.

Methodology for Generating Reservoir F-tables

The reservoir operations data log was the most comprehensive long-term dataset available for characterizing the relationships between storage, depth, and surface area for each reservoir. The datasets appear to have been compiled manually, and as such were subject to a certain degree of inconsistency. The most common inconsistency found in the entries was a single water surface elevation with multiple storage volumes. There were also periodic periods of missing data that were logged as either having no data (EMPTY) or a broken gage board (BGB).

Inconsistencies were evaluated and corrected using the following methodology:

1. Operation records for each of the fourteen reservoirs were sorted in descending order by water surface elevation. The datasets were then compared against the known dam crest elevation to ensure that the water surface elevation records were within reasonable bounds.
2. When sorted by water surface elevation, storage volume should also appear sorted. Corresponding storage volumes were verified to also be in descending order to check that a lower water surface elevation did not result in greater storage volume. Any record not meeting this standard was flagged as suspect and removed from the dataset.
3. Records marked in the log as BGB or EMPTY were also removed from the dataset.

F-Tables for each of the fourteen reservoirs were then developed using the following methodology:

1. Using the sorted operations record dataset, a maximum and minimum water surface elevation was obtained and assumed to represent the upper and lower bounds in order to calculate a maximum depth. For reservoirs where the minimum water surface elevation did not correspond to a near-zero storage volume, the minimum water surface elevation was assumed to be the elevation of the original streambed as shown in Table 14. Reservoir storage capacity between this and the lowest recorded water surface elevation was assumed to be linear.
2. A corresponding storage capacity for each water surface elevation was copied from the operations record dataset. When multiple entries for the same water surface elevation were encountered, the average was used. When no exact matching water surface elevation was available, an average of the three lower bounding and three upper bounding storage capacity values was used.
3. The maximum water surface area for Table 14 for each reservoir was assumed to correspond to the maximum depth in the F-Table. Surface area was scaled proportionally to storage capacity for all other depths.

Modeled Influence of Hydrologic Modification

The period of record for which reservoir operations data were available only slightly overlapped with the period of record for which instream observed flow was available for downstream LAR and SGR gages. In order to better illustrate the effects of hydrologic modification on watershed hydrology, modeled results from the segments immediately downstream of the reservoirs were evaluated with and without the reservoirs. Of the fourteen reservoirs included in the model, two were represented by reaches immediately downstream of another reservoir. These two were the Puddingstone Dam and San Dimas Reservoir. Because the discharge from these reservoirs would look exactly like the managed release, comparisons are not presented. Figure 27 through Figure 38 show modeled flows with and without the reservoirs for the twelve, between the common comparison periods of 10/1/1988 (the start of the reservoir operations datasets) and 12/31/2006 (the end of the modeling time period). The yellow arrows on the graphs highlight special periods of time where there is notable human influence on the flow as a result of hydrologic modifications.

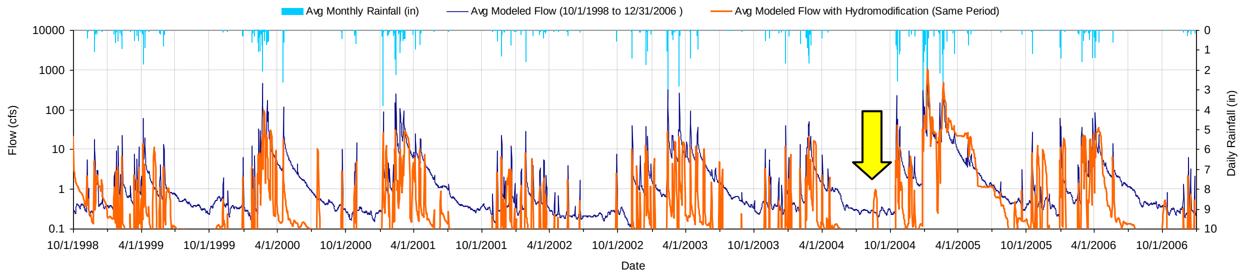


Figure 27. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 6253 (Eaton Wash)

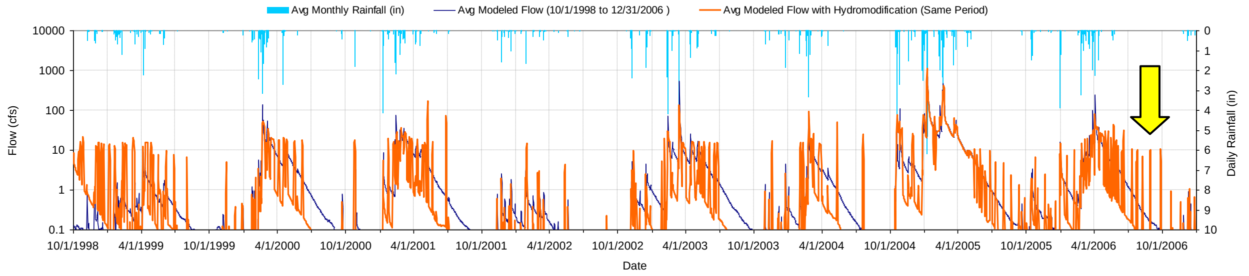


Figure 28. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 6341 (Big Santa Anita)

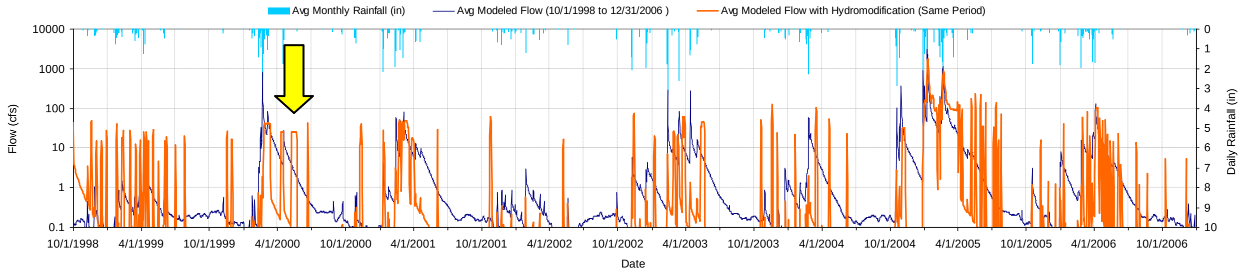


Figure 29. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 6719 (Pacioma Dam)

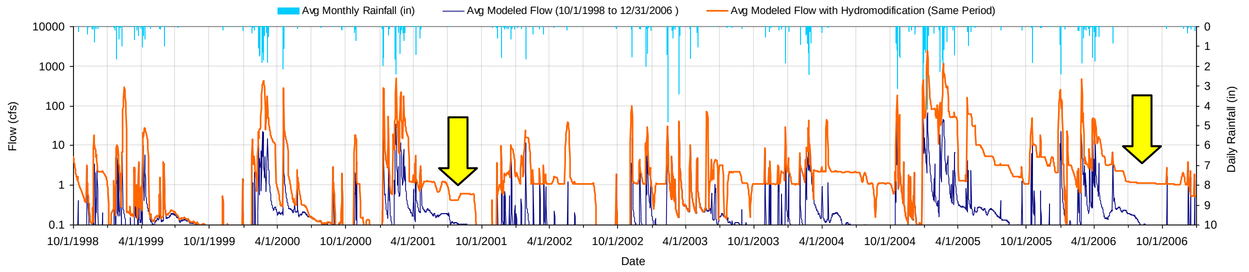


Figure 30. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 6427 (Devil's Gate)

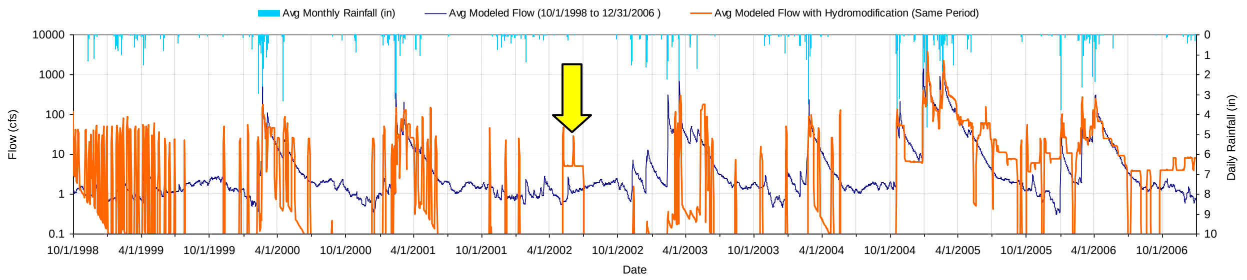


Figure 31. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 6790 (Big Tujunga Dam)

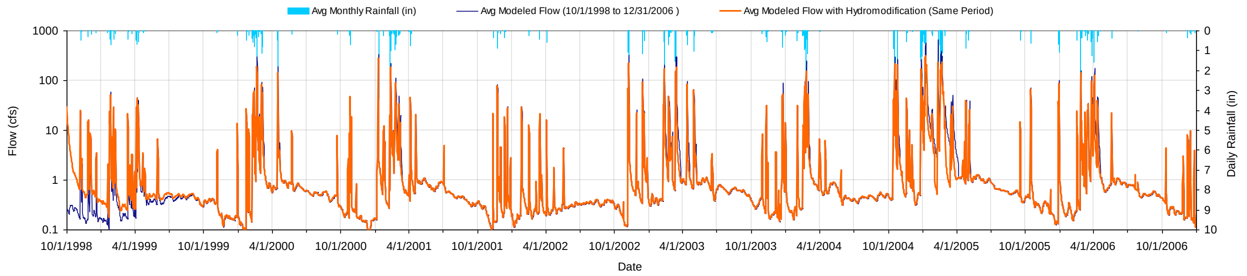


Figure 32. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5271 (San Gabriel Dam)

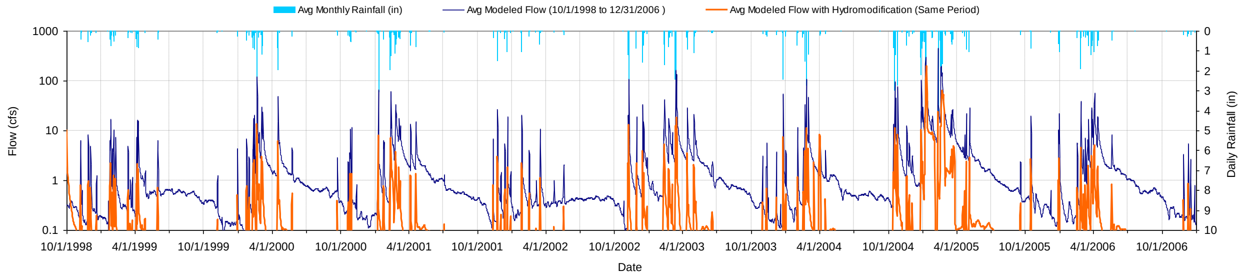


Figure 33. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5223 (Thompson Creek Dam)

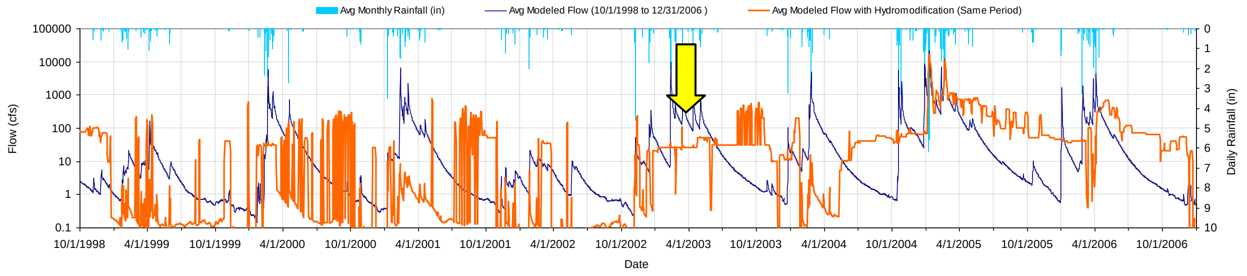


Figure 34. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5269 (Morris Dam)

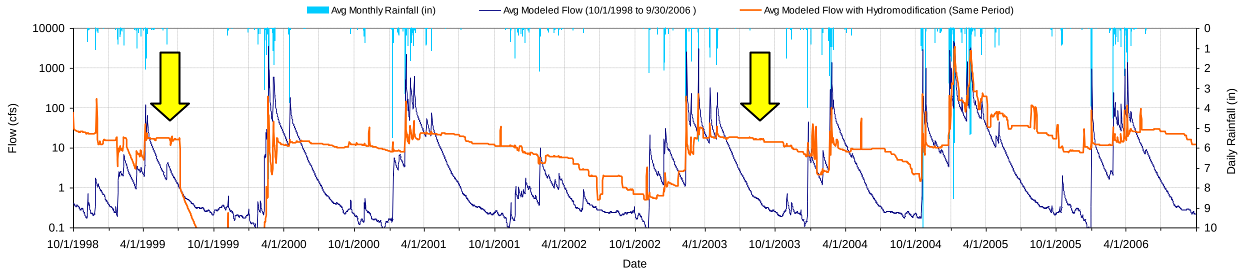


Figure 35. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5305 (Cogswell Dam)

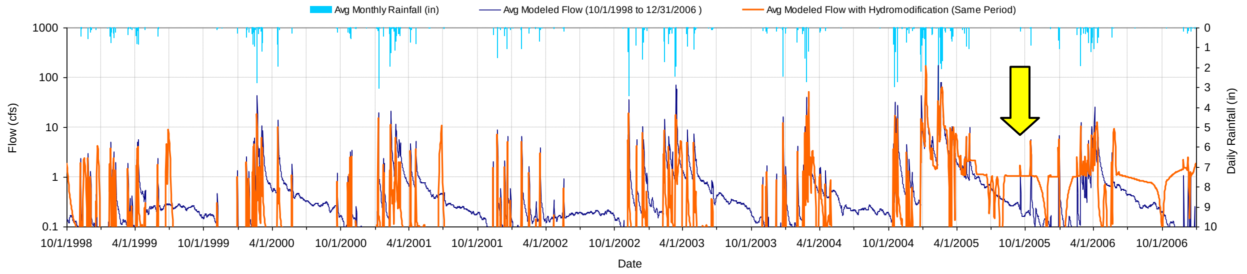


Figure 36. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5408 (Live Oak Dam)

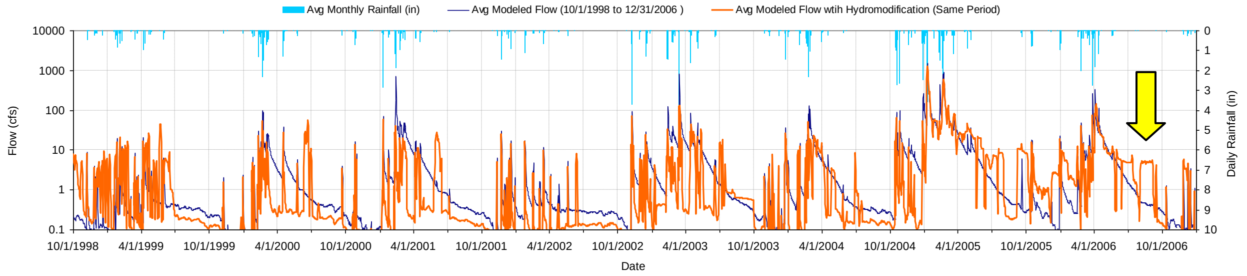


Figure 37. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5410 (Puddingstone Diversion)

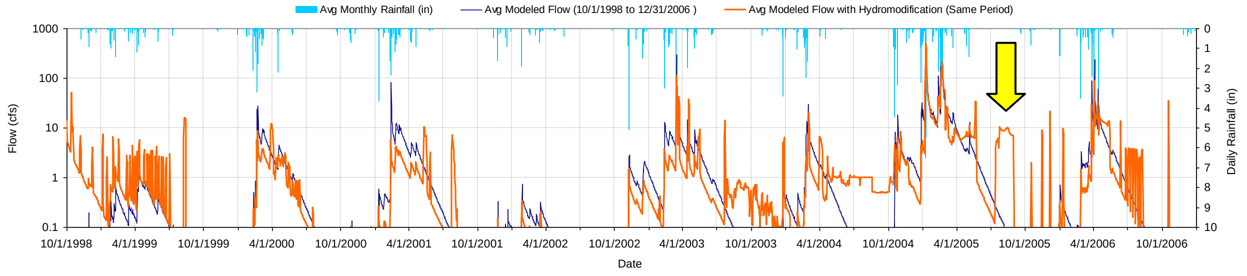


Figure 38. Modeled Flow vs. Modeled Flow with Hydromodification for Reach 5489 (Big Dalton)

Point Sources

There are 17 point sources that are considered in the modeling. Because water is a limited resource in the county, many of the facilities are designed as water reclamation facilities that treat the water to levels safe enough to be used for irrigation and reuse. Some of the water reclamation facilities actually reuse 100 percent of all water that passes through. The reclaimed water is accounted for in the model as supply water for irrigation to designated pervious land areas, rather than as traditional point source discharges to streams. Two groups of plants belong to two different networks: (1) the JWPCP network, which is managed by the LA County Sanitation Districts, and (2) Hyperion Treatment Plant network, which is managed by the City of LA. Sewage that cannot be reclaimed or that is not discharged to the streams is routed to the two central facilities for additional treatment. The treated wastewater from the plants is discharged 2 to 5 miles offshore into the Pacific Ocean. Table 17 is a summary of major point source facilities in the LA regional watersheds, showing average treatment capacity and effluent discharge distribution. Table 18 summarizes the total number of acres per major regional watershed that are irrigated by reclaimed waste water. Figure 39 is a map showing a sewer schematic for water reclamation facilities managed by the LA County Sanitation Districts. Figure 40 is a map showing permitted facility locations, water reuse sites, and subwatersheds irrigated by reclaimed water. The data review for point source discharges is summarized in Appendix D.

Table 17. Inventory of major point source discharges and effluent distribution

Facility name	Operating start date	Model outfall reach	Average treatment capacity (mgd)	Effluent distribution (percentage)		
				Reclaimed	Diverted	Discharged
Tapia Water Reclamation Plant (WRP)	1965	3008	9.5	60%	0%	40%
Burbank WRP	1966	6602	9	44%	0%	56%
Malibu Mesa WRP	unknown	3209	0.2	unknown	0%	variable
West Basin Municipal Water District	unknown	2055	unknown	unknown	0%	unknown
JWPCP Network	unknown	n/a	300	unknown	0%	To Ocean
• La Cañada WRP	1962	n/a	0.2	100%	0%	0%
• Long Beach WRP	1973	n/a	25	20%	80%	0%
• Los Coyotes WRP	1970	n/a	37	14%	86%	0%
• Pomona WRP	1966	n/a	13	100%	0%	0%
• San Jose WRP	1971	n/a	100	35%	65%	0%
• Whittier Narrows WRP	1962	n/a	15	100%	0%	0%
Saugus WRP	1962	4117	7	0	0%	100%
Valencia WRP	1967	4091	21.6	variable	0%	variable
Hyperion Treatment Plant Network	1950	n/a	350	unknown	0%	To Ocean
• Terminal Island WRP	1935	n/a	4.5	unknown	0%	External
• Donald C. Tillman WRP	1985	6870	80	33%	3%	63%
• LA-Glendale WRP	1976	6506	20	23%	3%	65%

Table 18. Total reclaimed water discharge area by major watershed

Major regional watershed	Total reclaimed water discharge area (acres)
Dominguez Channel	2
Los Angeles River	815.5
San Gabriel River	7,279.2
Santa Clara	95

Source: http://www.lacsd.org/about/wastewater_facilities/default.asp

Figure 39. Sewer routing schematic for water reclamation facilities in LA County.

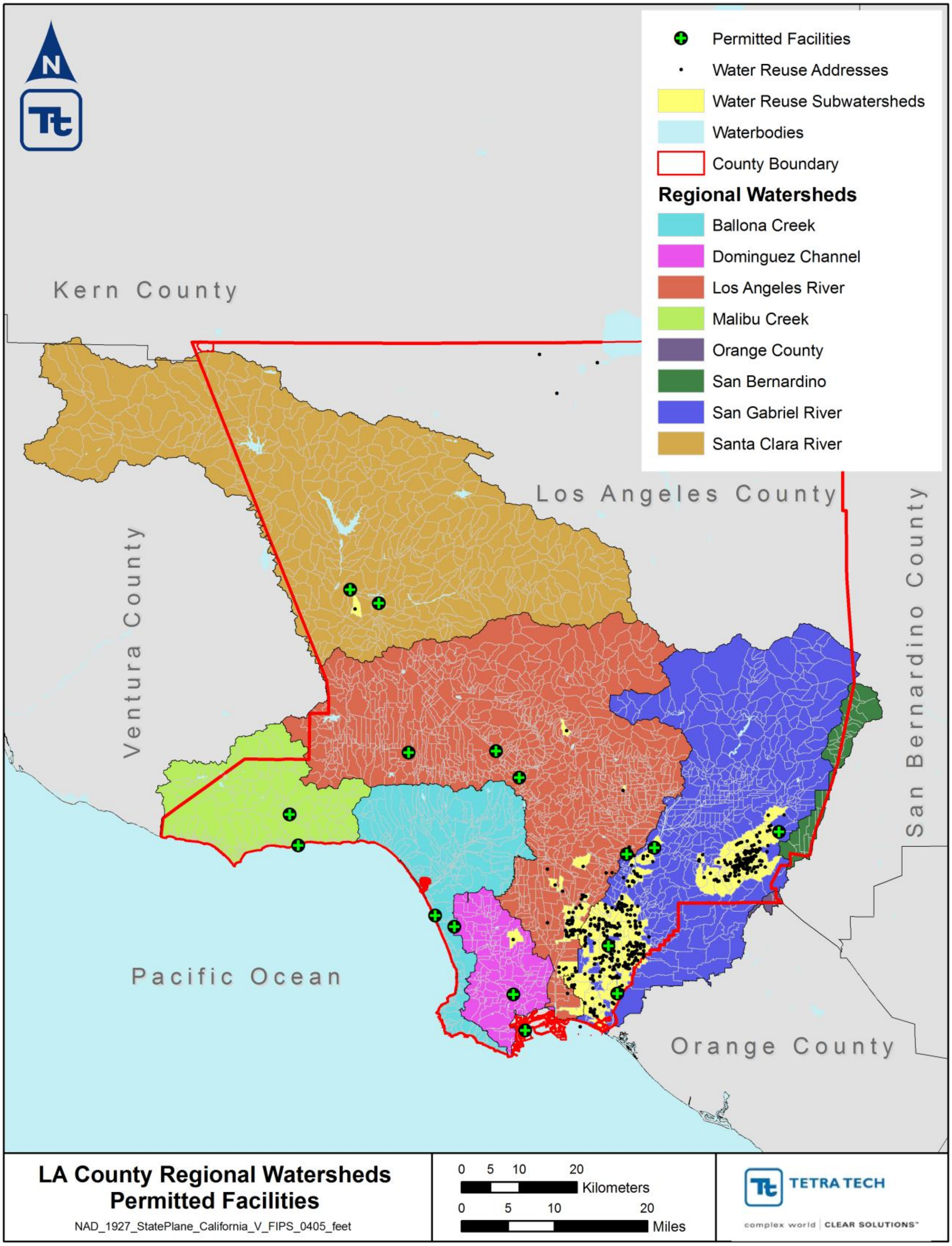


Figure 40. Permitted facility locations, water reuse sites, and subwatersheds irrigated by reclaimed water.

Hydrology Data Review

This section provides a summary of the hydrological data that were reviewed and used for evaluating the LA County regional watershed models. Hydrology monitoring stations were first georeferenced with both the subwatershed boundary and reach layer to identify the associated model outflow points for comparison. Upstream drainage area characteristics, such as contributing land use distribution, were also summarized for each flow gage. All hydrology data for the entire regional watershed area were compiled in a Microsoft Access database. Of the available flow gages, 30 were selected for model calibration.

Note that 40 hydrological stations were not considered because they were lacking sufficient georeferencing information (i.e., latitude/longitude coordinates). Using descriptions fields, other GIS data sources, and additional literature searches, these stations could be added to the query if it is deemed necessary; however, the selected stations are deemed sufficient to obtain a meaningful calibration according to the expected outcomes of this modeling process. Additional data summaries are provided below for each of the regional watersheds.

Figure 41 shows the 30 selected in-stream hydrology calibration stations in the LA County watershed and the gages to be featured in the main document for hydrology calibration. Table 19 lists all hydrology stations having recent data that is deemed to be most useful for calibration. Table D-1 in Appendix D presents a data summary of selected USGS gages and Table D-2 in Appendix D presents a summary of all hydrology stations and model subwatershed assignments.

Figure 41. In-stream hydrology calibration and validation stations in the LA County regional watersheds.

Table 19. Subwatershed and flow monitoring station pairs with the most recent data (after 2003)

	Subwatershed and flow monitoring station pairs			
Station name	**Subwatershed**	**Station ID**	**Subwatershed**	**Station ID**
Ballona Creek	1007	ME05	1124	LU03
Dominguez Channel	2042	ME08	2056	LU02
Los Angeles River	6006	11103000*	6473	F57C
	6007	ME03	6513	F252
	6013	F319	6599	E285
	6044	F37B	6609	11097260
	6104	F45B	6655	F300
	6129	11102300	6726	11097000
	6173	11101250	6868	11092450
	6453	11098000	6953	LU14
Malibu Creek	3001	11105510	3103	ME07
San Gabriel River	5001	F354	5158	SG03
	5002	SG02	5244	11085000
	5033	11089500	5255	F190
	5050	11088500	5267	U8
	5102	SG01	5367	F304
	5103	LU25	5369	SG04
	5104	F42B	5397	F40
	5124	F262C	5412	F303
	5156	11087020	5426	F274B
	5157	F312B	5504	F279C
Santa Clara River	4030	11108135*	4160	F377
	4030	11108134	4170	11107860*
	4036	11108130*	4201	11107770
	4061	11108095*	4201	F328
	4062	11108092	4236	11107745
	4063	11108090*	4236	F93B
	4065	11108080*	4314	11109525
	4075	11108075*	4314	11109550
	4091	11108000	4315	11109398
	4091	F92C	4327	11109395*
	4160	11107870	4418	11109600

* These stations contain data older than 2003 that were still useful for model calibration

Ballona Creek Summary

There are six hydrology stations in the BC watershed (Table D-2). Two of those stations have samples taken after 12/31/2003 (Table 13). Only one station has a significant number of samples and a longer period of record (2,835 samples from 2001 to 2004). That station is ME05 and it is in subwatershed 1007.

Dominguez Channel Summary

There are four hydrology stations in the DC watershed (Table D-2). Two of those stations have samples taken after 12/31/2003 (Table 13). None of the stations has a significant number of samples or a longer period of record. The station with the most records is ME08 (1,362 records from 2002 to 2004) and it is in subwatershed 2042.

Los Angeles River Summary

There are 46 hydrology stations in the LAR watershed (Table D-2). Of those stations, 15 have samples taken after 12/31/2003 (Table 13). The station with the most records is F252 (133,246 records from 1992 to 2008) and it is in subwatershed 6513. In addition to that station, stations F300 (subwatershed 6655), F57C (subwatershed 6473), E285 (subwatershed 6599), F319 (subwatershed 6013), F37B (subwatershed 6044), and station F45B (subwatershed 6104) all have a good period of record and a significant number of samples (> 40,000). Four USGS gages in the watershed have more than 10,000 samples and their period of record continues past 2007 [11101250 (subwatershed 6173), 11098000 (subwatershed 6453), 11097000 (subwatershed 6726), and 11102300 (subwatershed 6129)].

Malibu Creek Summary

There are seven hydrology stations in the Malibu Creek watershed (Table D-2). Two stations have samples taken after 12/31/2003 (Table 13). Station ME07 in subwatershed 3103 has the most samples (6,482) and a period of record from 2003 to 2005.

San Gabriel River Summary

There are 34 hydrology stations in the SGR watershed (Table D-2). Twenty stations have samples taken after 12/31/2003 (Table 13). The station with the most samples is F279C in subwatershed 5504 with a period of record from 2001 to 2008. Table D-1 summarizes data for all the SGR watershed stations.

Santa Clara River Summary

There are 24 hydrology stations in the SCR watershed (Table D-2). Fourteen stations have samples taken after 12/31/2003 (Table 13). The station with the most samples in the SCR watershed is F92C in subwatershed 4091. The station was sampled more than 60,000 times from 2000 through 2008. Table D-1 summarizes data for all the SCR watershed stations.

Hydrology Calibration

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations on the basis of field monitoring data. This section describes the modeling and calibration of the hydrology components of the watershed model. Simulation of hydrologic processes is an integral part of developing an effective watershed model for LA County. The goal of the calibration was to obtain physically realistic model predictions by selecting parameter values that reflect the unique characteristics of the watersheds represented. Spatial and temporal aspects were evaluated through the calibration process.

Hydrologic calibration was performed after configuring the LSPC model. For LSPC, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, physical, and chemical characteristics of the watershed and compounds of interest. Hydrology calibration was based on several years of simulation to evaluate parameters under a variety of climatic conditions. The calibration procedure resulted in parameter values that produce the best overall agreement between simulated and observed stream flow values throughout the calibration period. Calibration included a time series comparison of daily, monthly, seasonal, and annual values, and individual storm events. Composite comparisons (e.g., average monthly stream flow values over the period of record) were also made. All those comparisons must be evaluated for a proper calibration of hydrologic parameters.

High-resolution meteorological variability, together with the establishment of HRUs both contributed to creating an efficient and streamlined hydrology calibration process for this modeling effort. For impervious land segments, representing rainfall-runoff response is largely a function of how good the rainfall data reflects the area of concern. For that reason, the model only has two primary calibration parameters associated with runoff from impervious land: interception storage (CEPSC), and surface roughness (NSUR). Of course, physical properties of the land such as slope of the land surface (SLSUR) and length of overland flow (LSUR) also have an influence on the rate of runoff delivery, but even SLSUR was somewhat already reflected in the HRU development process. For pervious land segments, calibration involves more parameters such as infiltration index (INFILT), surface interception and subsurface soil storage parameters (CEPSC, UZSN, LZSN), interflow inflow and recession rates (INTFW, IRC), baseflow percolation and recession rates (AGWRC), and parameters associated with ET (PETMIN/PETMAX, DEEPFR, BASETP, AGWETP). From one HRU to another, these parameters tend to vary systematically. For example, well-drained soils will tend to exhibit higher infiltration and percolation rates, higher subsurface losses or recharge to groundwater, and more efficient and enhanced baseflow contribution in streams, whereas poorly drained soils will tend to have lower infiltration, percolation, and subsurface losses in comparison.

Because most of the impervious land areas are downstream in the watershed, the first order of business was to address HRU calibration for pervious headwater regions. The cumulative upstream drainage areas of all the available calibration stations was evaluated to (1) determine a list of stations that could be used to calibrate specific HRUs, and (2) to prioritize the order of operations for the calibration so that process of elimination can be used to set one HRU group while adjusting another. selected reach segments were summarized to determine the calibration priority order. Table 20 shows the example calibration sequence for selected reaches in the LA Regional watersheds that will be presented in this section.

Table 20. Calibration sequence for selected reaches in the LA Regional watersheds

Order	Flow gage ID	Reach outlet (subwatershed ID)	MODEL adjustment focus
1	11108090	4063	HRU: Vacant Steep Slope D
2	11108080	4065	HRU: Vacant Steep Slope C
3	11108075	4075	HRU: Vacant Steep Slope A & B
4	11101250	6173	HRU: Urban Grass (Irrigation)
5	11102300	6129	Hydromodification (Whittier Dam)
6	11103000	6006	Model Validation (and Point Source Influence)

Location 1: Elderberry Canyon above Castaic Creek (Vacant Steep Slope D)

Figure 42 shows drainage area HRU distribution upstream of USGS 11108090, Elderberry Canyon Creek above Castaic Creek near Castaic, California. Figure 43 shows the HRU distribution in and around subwatershed 4063. This watershed was selected first from among the featured set because it has the largest area of a single HRU category. Therefore, the calibration focus for this watershed was Vacant Steep Slope D. For this area, INFILT was set at a value of 0.1, and the AGWRC was set at 0.94. Both of those are relatively low among the recommended ranges for each of those parameters. The values were required to adequately capture total volumes and unique signature of storm recessions observed in this watershed. Figure 44 through Figure 50 show daily, monthly, seasonal, exceedance frequency, and flow accumulation plots of modeled versus observed flow, while Table 21 and Table 22 summarize seasonal and multi-variable calibration statistics, respectively.

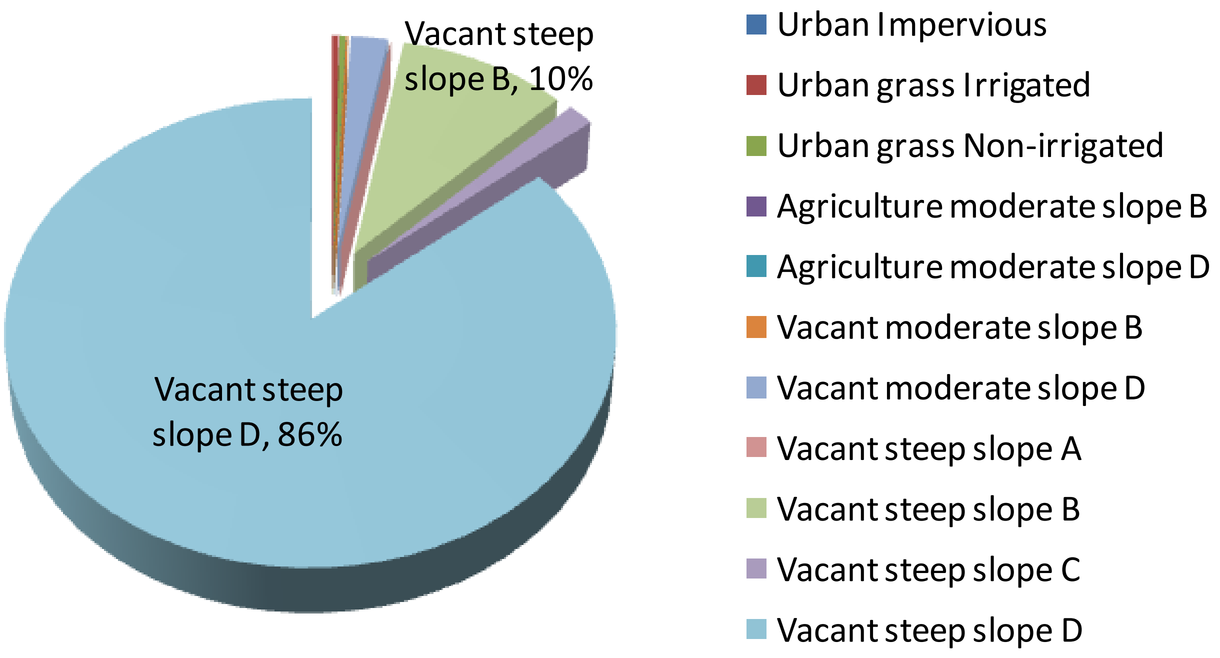


Figure 42. Catchment area to USGS 11108090 Elderberry Canyon Creek above Castaic Creek near Castaic, CA (model outlet 4063).

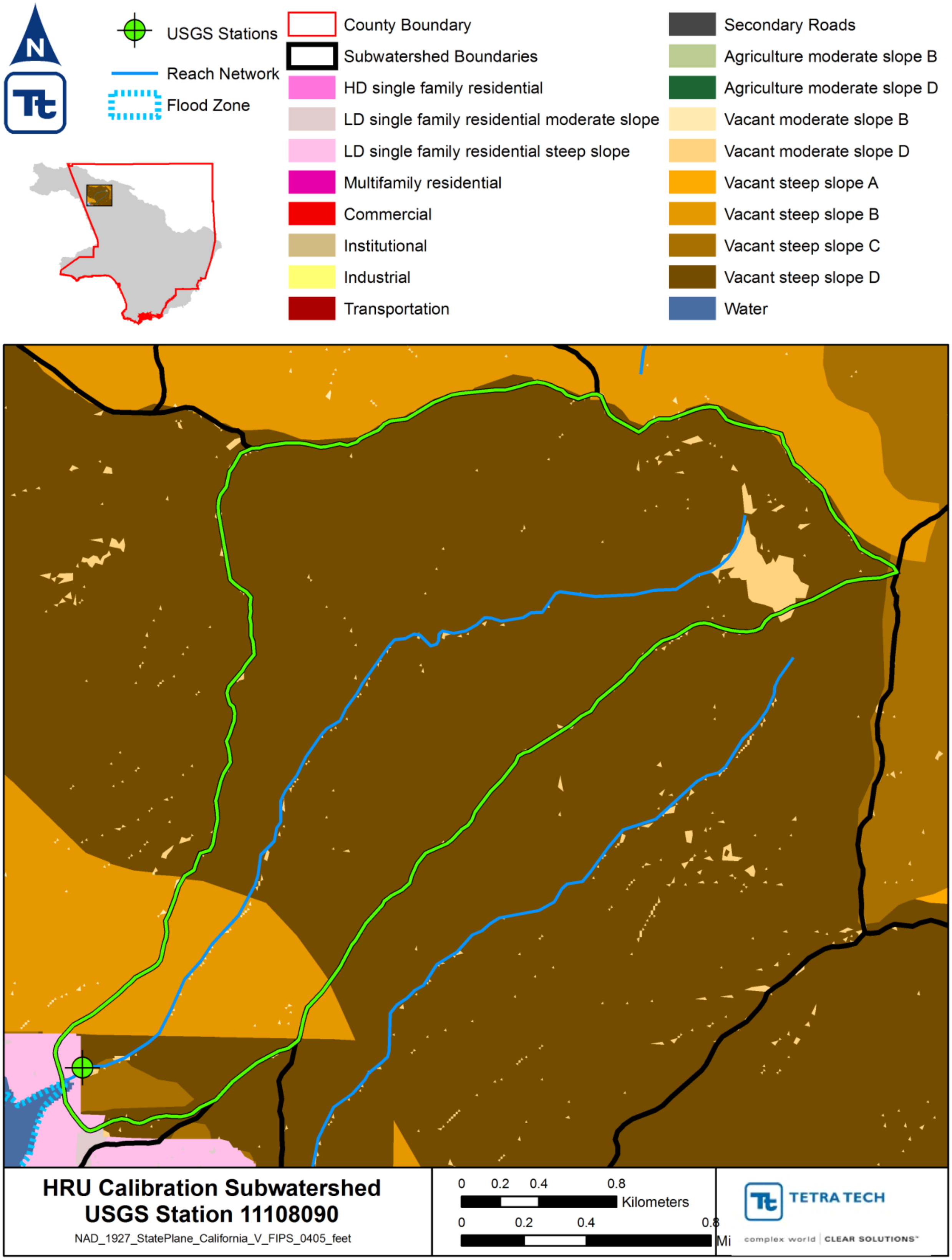


Figure 43. HRU Map: USGS 11108090 Elderberry Canyon Creek above Castaic Creek near Castaic, CA (model outlet 4063).

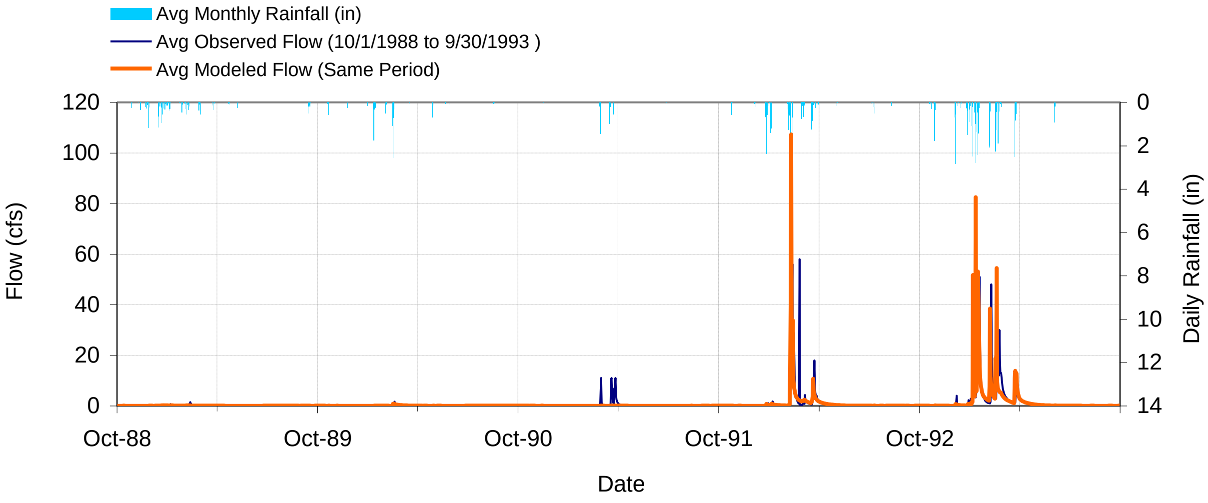


Figure 44. Mean daily flow: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

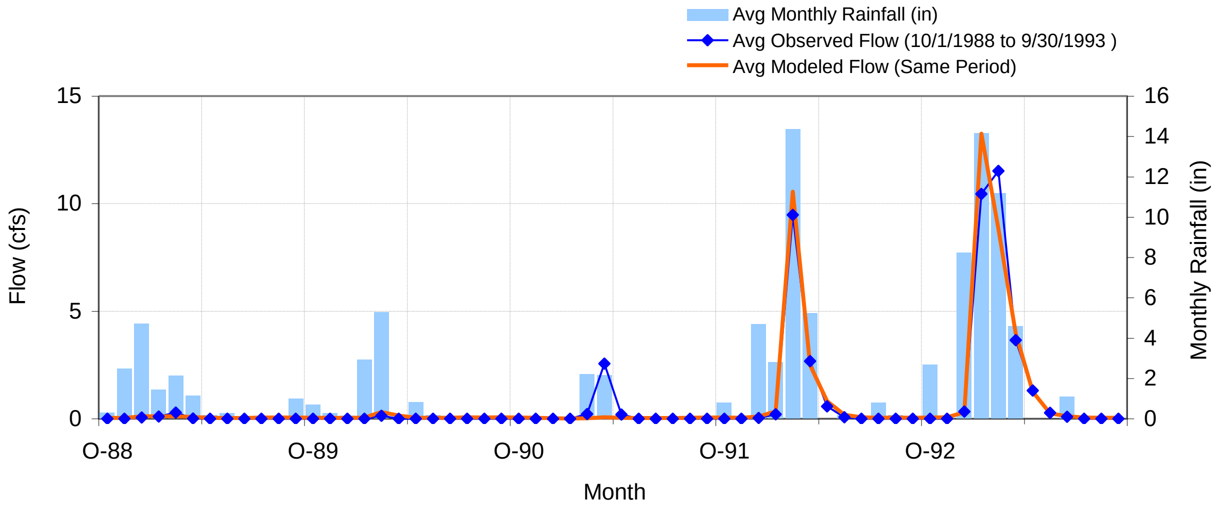


Figure 45. Mean monthly flow: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

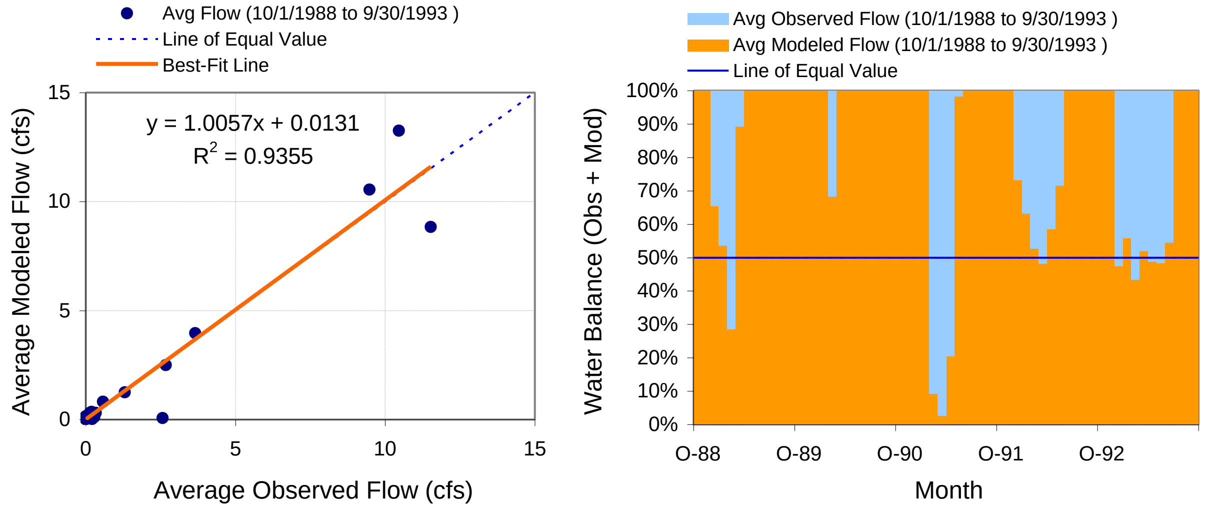


Figure 46. Monthly flow regression and temporal variation: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

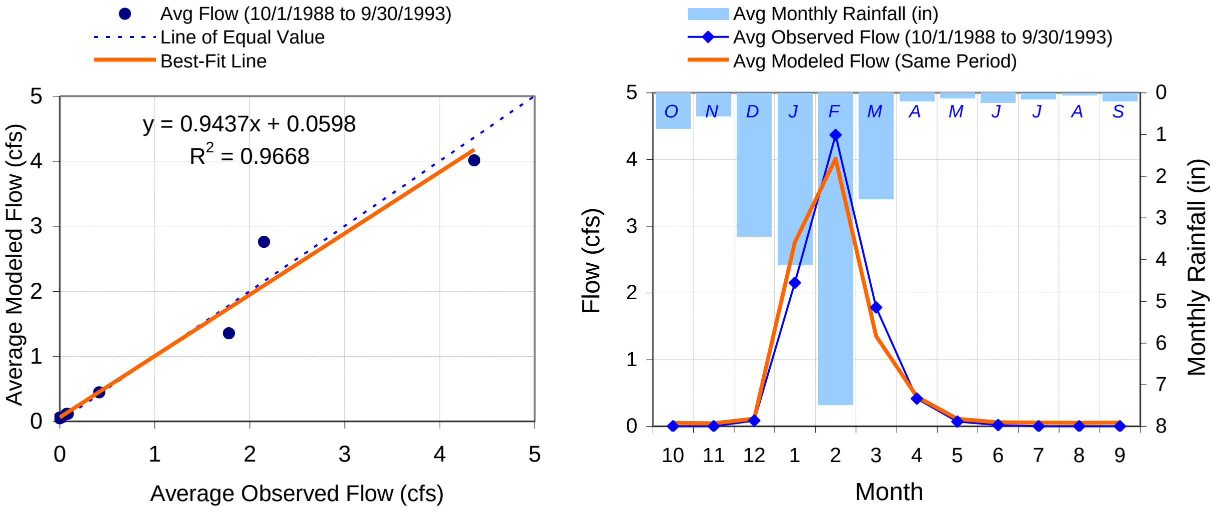


Figure 47. Seasonal regression and temporal aggregate: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

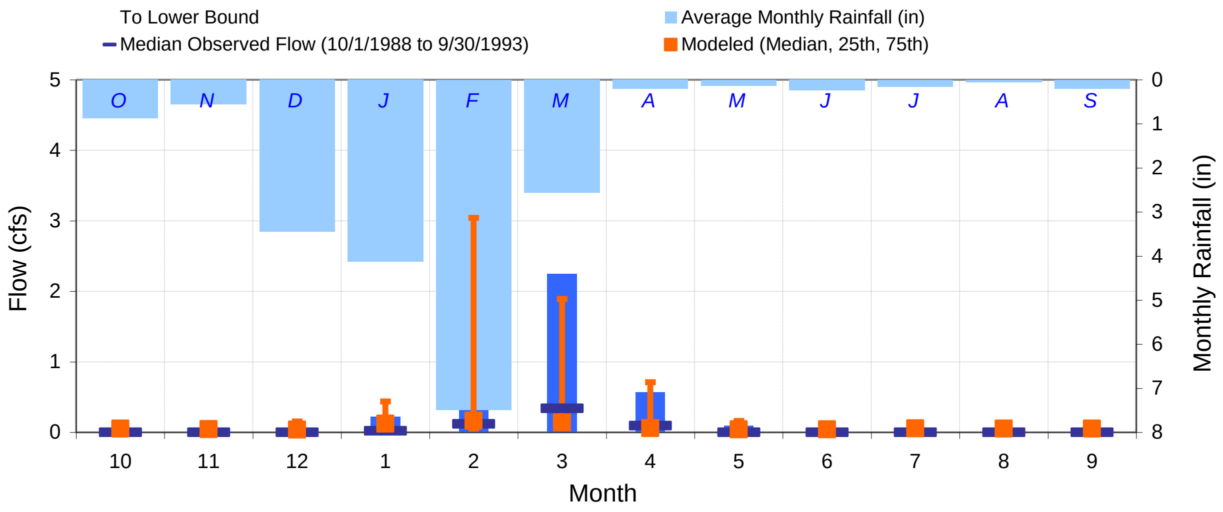


Figure 48. Seasonal medians and ranges: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

Table 21. Seasonal summary: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	0.00	0.00	0.00	0.00	0.05	0.05	0.04	0.06
Nov	0.00	0.00	0.00	0.00	0.04	0.04	0.03	0.05
Dec	0.09	0.00	0.00	0.00	0.12	0.04	0.03	0.15
Jan	2.15	0.02	0.00	0.23	2.76	0.12	0.02	0.44
Feb	4.37	0.12	0.00	1.90	4.01	0.16	0.05	3.04
Mar	1.78	0.34	0.00	2.25	1.35	0.14	0.08	1.89
Apr	0.42	0.10	0.00	0.57	0.44	0.06	0.05	0.71
May	0.07	0.00	0.00	0.10	0.11	0.04	0.04	0.16
Jun	0.02	0.00	0.00	0.00	0.06	0.04	0.04	0.07
Jul	0.00	0.00	0.00	0.00	0.05	0.06	0.04	0.06
Aug	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.06
Sep	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.06

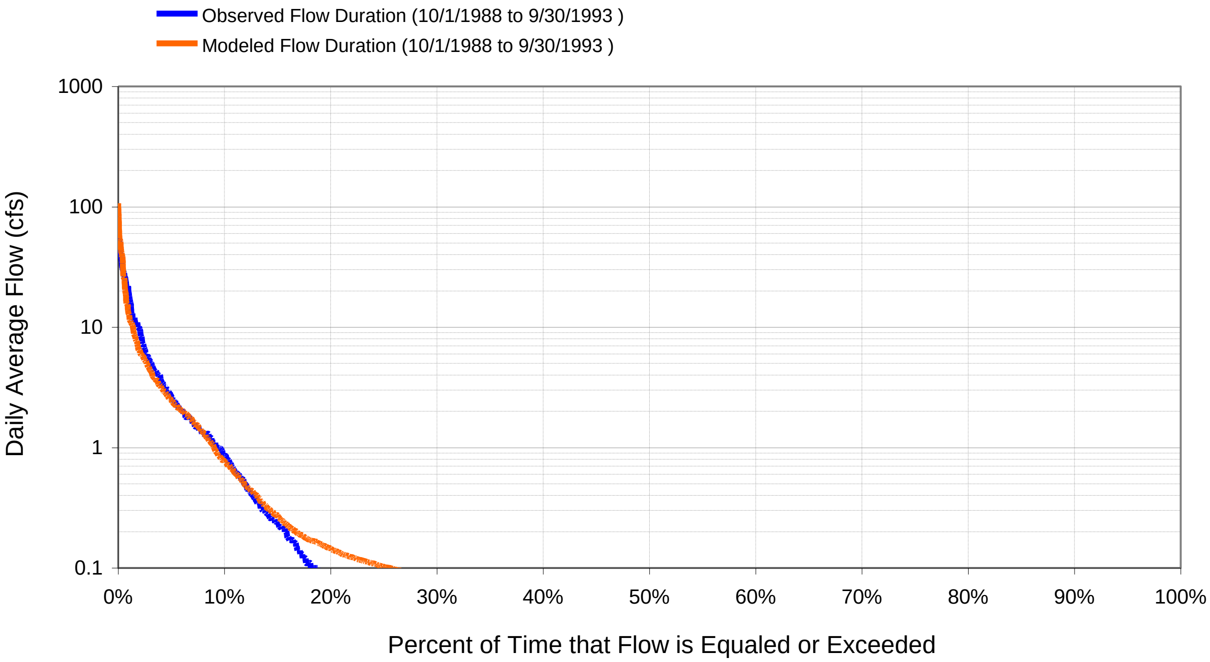


Figure 49. Flow exceedance: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

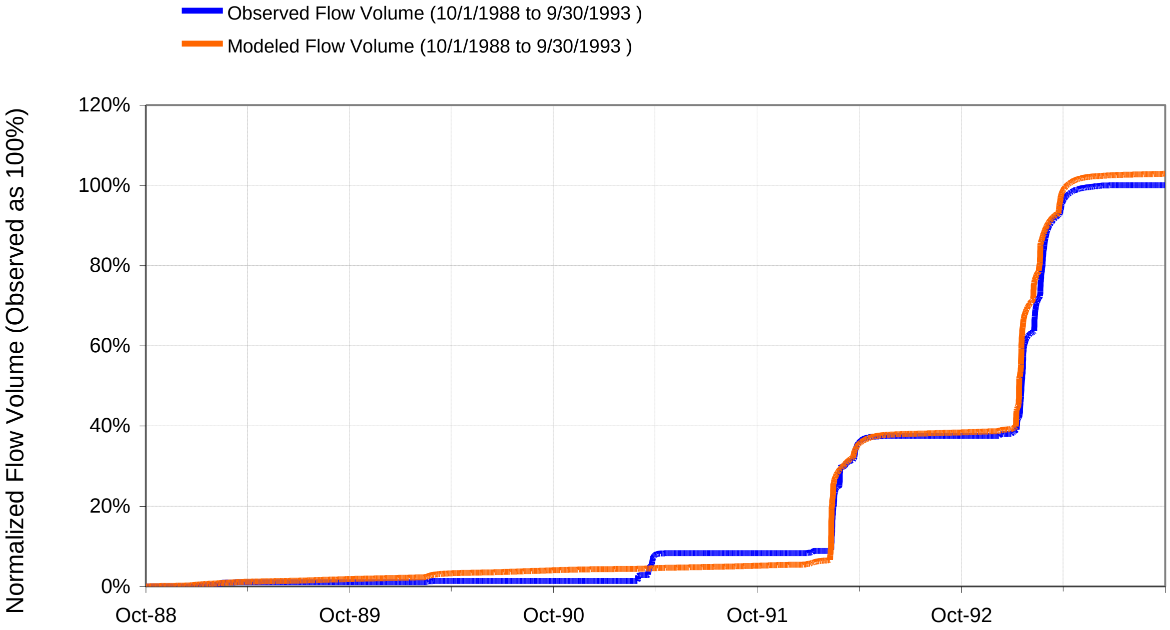


Figure 50. Flow accumulation: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

Table 22. Summary statistics: Model Outlet 4063 vs. USGS 11108090 Elderberry Cyn C Ab Castaic C near Castaic, CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 4063 5-Year Analysis Period: 10/1/1988 - 9/30/1993 Flow volumes are (inches/year) for upstream drainage area		**USGS 11108090 ELDERBERRY CYN C AB CASTAIC C NR CASTAIC CA** Hydrologic Unit Code: 18070102 Latitude: 34.5722118 Longitude: -118.6253655 Drainage Area (sq-mi): 2.5	
Total Simulated In-stream Flow:	**4.02**	Total Observed In-stream Flow:	**3.91**
Total of simulated highest 10% flows:	**3.62**	Total of Observed highest 10% flows:	**3.74**
Total of Simulated lowest 50% flows:	**0.11**	Total of Observed Lowest 50% flows:	**0.00**
Simulated Summer Flow Volume (months 7-9):	**0.07**	Observed Summer Flow Volume (7-9):	**0.00**
Simulated Fall Flow Volume (months 10-12):	**0.10**	Observed Fall Flow Volume (10-12):	**0.04**
Simulated Winter Flow Volume (months 1-3):	**3.58**	Observed Winter Flow Volume (1-3):	**3.65**
Simulated Spring Flow Volume (months 4-6):	**0.27**	Observed Spring Flow Volume (4-6):	**0.23**
Total Simulated Storm Volume:	**1.26**	Total Observed Storm Volume:	**1.22**
Simulated Summer Storm Volume (7-9):	**0.00**	Observed Summer Storm Volume (7-9):	**0.00**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	2.88	10		
Error in 50% lowest flows:	-	10		
Error in 10% highest flows:	-3.22	15		
Seasonal volume error - Summer:	-	30		
Seasonal volume error - Fall:	144.44	30		
Seasonal volume error - Winter:	-1.83	30		
Seasonal volume error - Spring:	21.51	30		
Error in storm volumes:	3.15	20		
Error in summer storm volumes:	-	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	-0.210	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.467	as E or E' approaches 1.0		

Location 2: Fish Creek above Castaic Creek (Vacant Steep Slope C)

After hydrology parameters were established at location 1, the parameters were not adjusted again during calibration at location 2. Figure 51 shows drainage area HRU distribution upstream of USGS 11108080, Fish Creek above Castaic Creek near Castaic, California. Figure 52 shows the HRU distribution in and around subwatershed 4065. This watershed was selected second from among the featured set because it has the second largest area of a single HRU category, and includes some area of Vacant Steep Slope D, which was previously calibrated at location 1. The calibration focus for this watershed was Vacant Steep Slope C. For this area, INFILT was set at a value of 0.2, and the AGWRC was set at 0.95. Both of those are relatively low among the recommended ranges for each of the parameters, but higher than the previously calibrated parameters at location 1. Those values were needed to adequately capture total volumes and unique signature of storm recessions observed in this watershed. Figure 53 through Figure 59 show daily, monthly, seasonal, exceedance frequency, and flow accumulation plots of modeled versus observed flow, while Table 23 and Table 24 summarize seasonal and multi-variable calibration statistics, respectively.

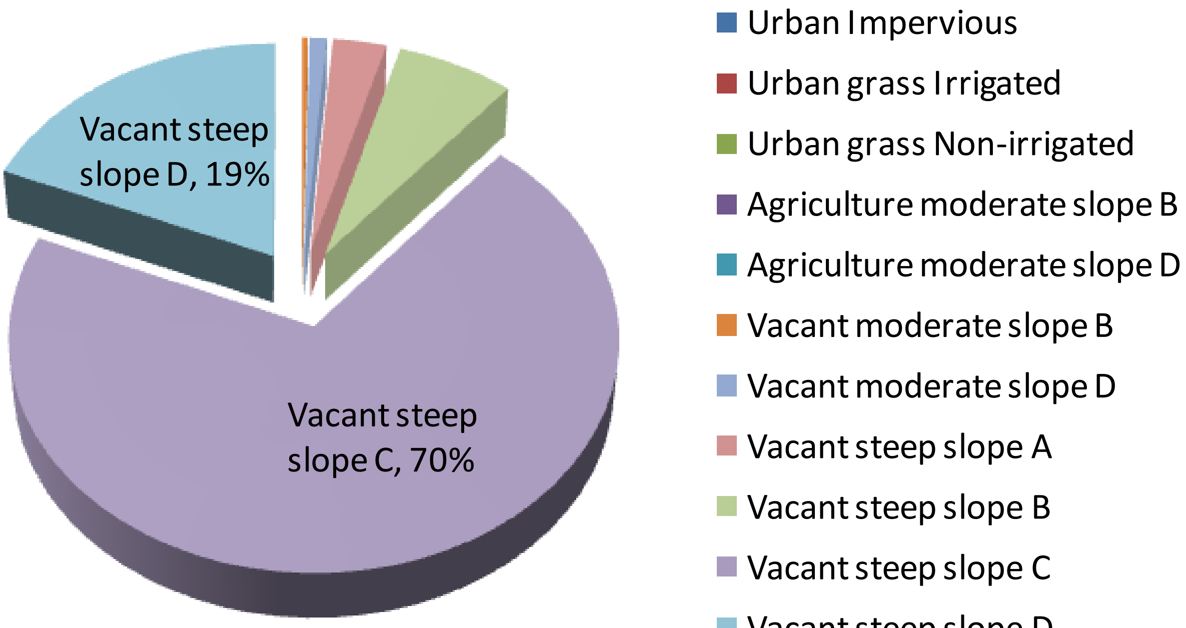


Figure 51. Catchment area distribution at USGS 11108080 Fish C Ab Castaic C near Castaic, CA (Model Outlet 4065)

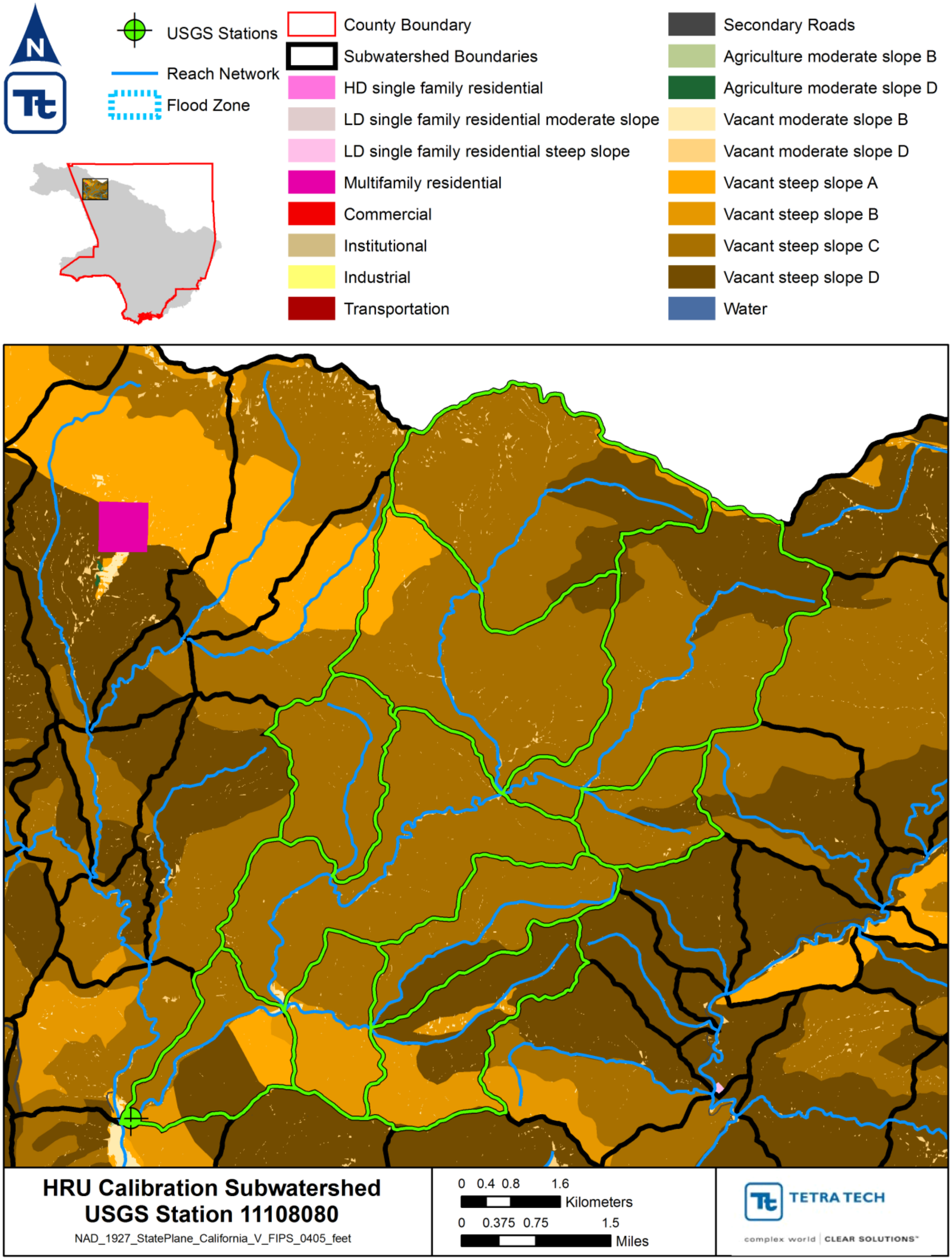


Figure 52. HRU Map: USGS 11108080 Fish C Ab Castaic C near Castaic, CA (Model Outlet 4065)

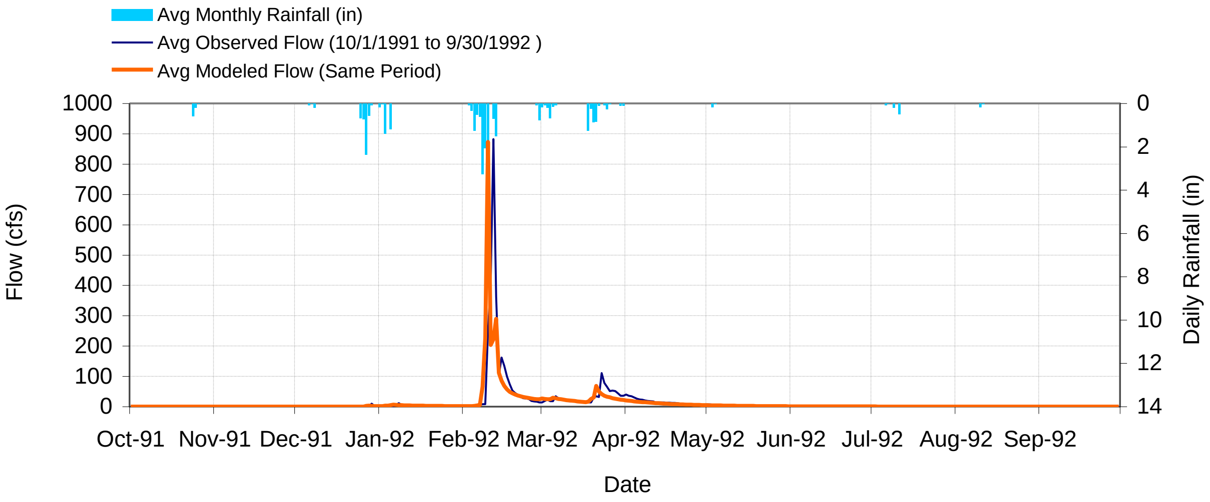


Figure 53. Mean daily flow: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

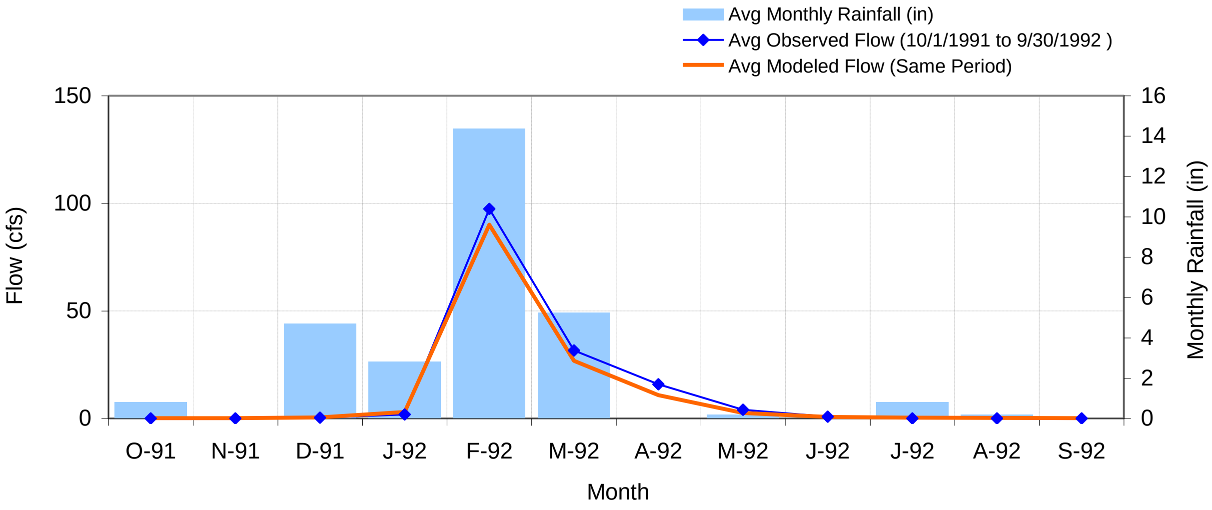


Figure 54. Mean monthly flow: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

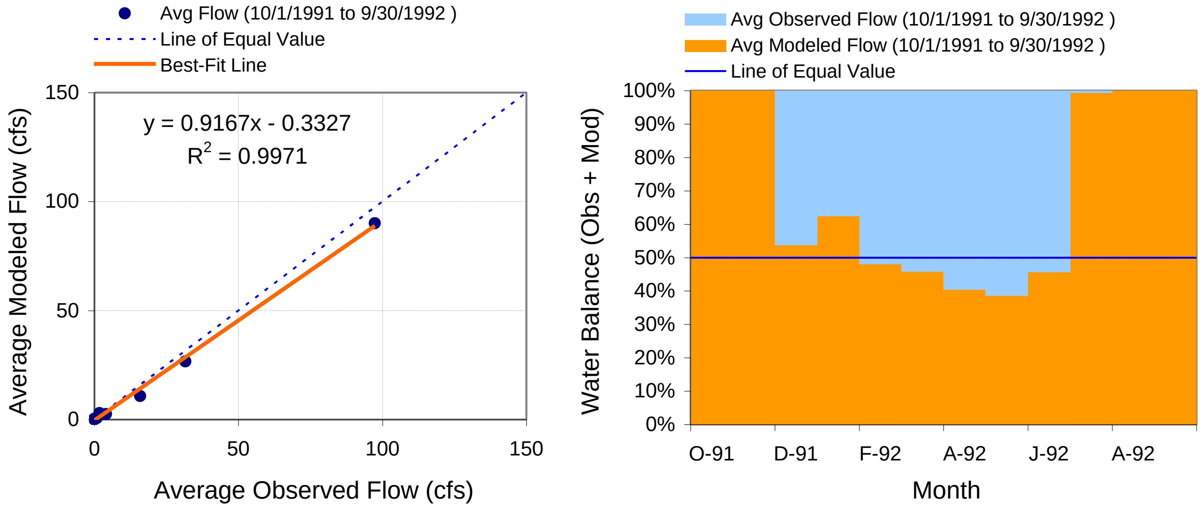


Figure 55. Monthly flow regression and temporal variation: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

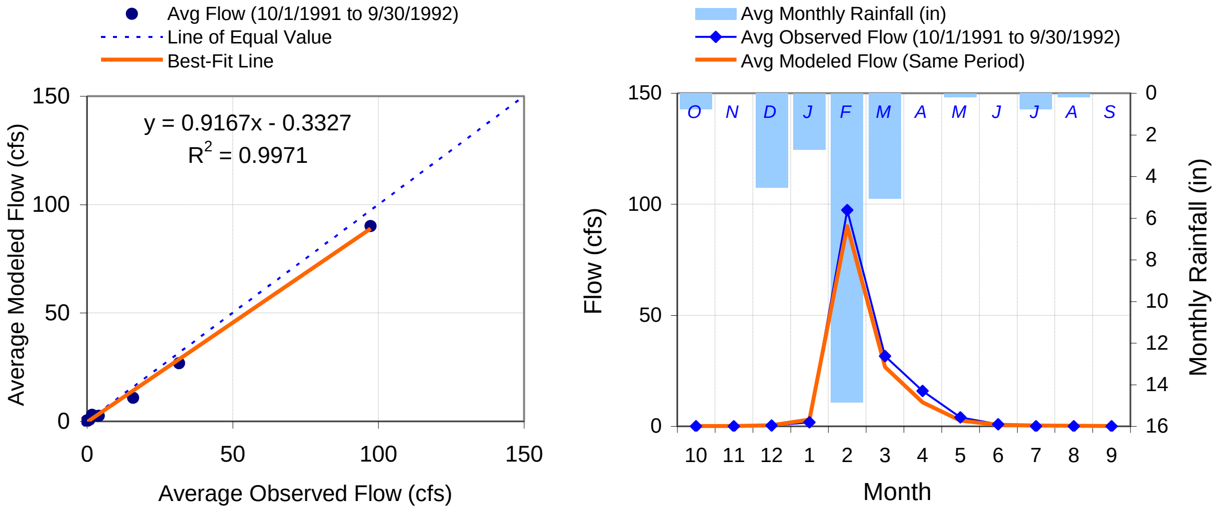


Figure 56. Seasonal regression and temporal aggregate: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

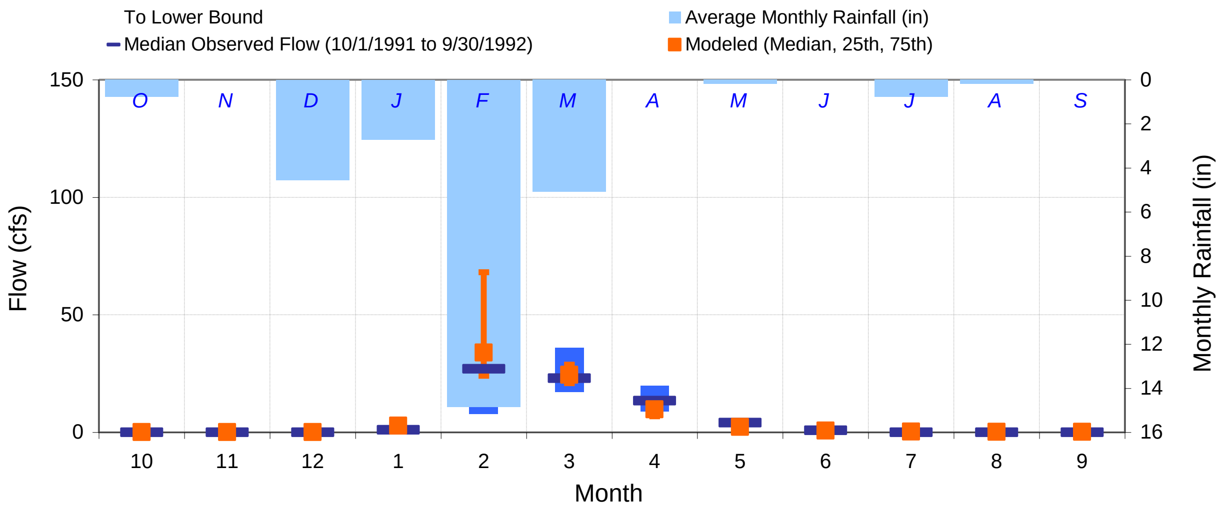


Figure 57. Seasonal medians and ranges: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

Table 23. Seasonal summary: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	0.00	0.00	0.00	0.00	0.15	0.15	0.14	0.16
Nov	0.00	0.00	0.00	0.00	0.11	0.11	0.10	0.13
Dec	0.37	0.00	0.00	0.00	0.44	0.08	0.07	0.09
Jan	1.81	1.10	0.90	1.55	3.01	2.79	1.91	3.72
Feb	97.37	27.00	7.80	99.00	90.10	33.96	24.08	68.08
Mar	31.61	23.00	17.00	36.00	26.74	24.46	20.94	28.75
Apr	15.87	13.50	8.85	19.75	10.79	9.82	6.82	14.08
May	4.05	4.10	2.60	4.65	2.55	2.33	1.68	3.34
Jun	0.86	0.79	0.23	1.45	0.72	0.68	0.54	0.86
Jul	0.00	0.00	0.00	0.00	0.31	0.29	0.27	0.35
Aug	0.00	0.00	0.00	0.00	0.22	0.21	0.21	0.22
Sep	0.00	0.00	0.00	0.00	0.16	0.16	0.15	0.17

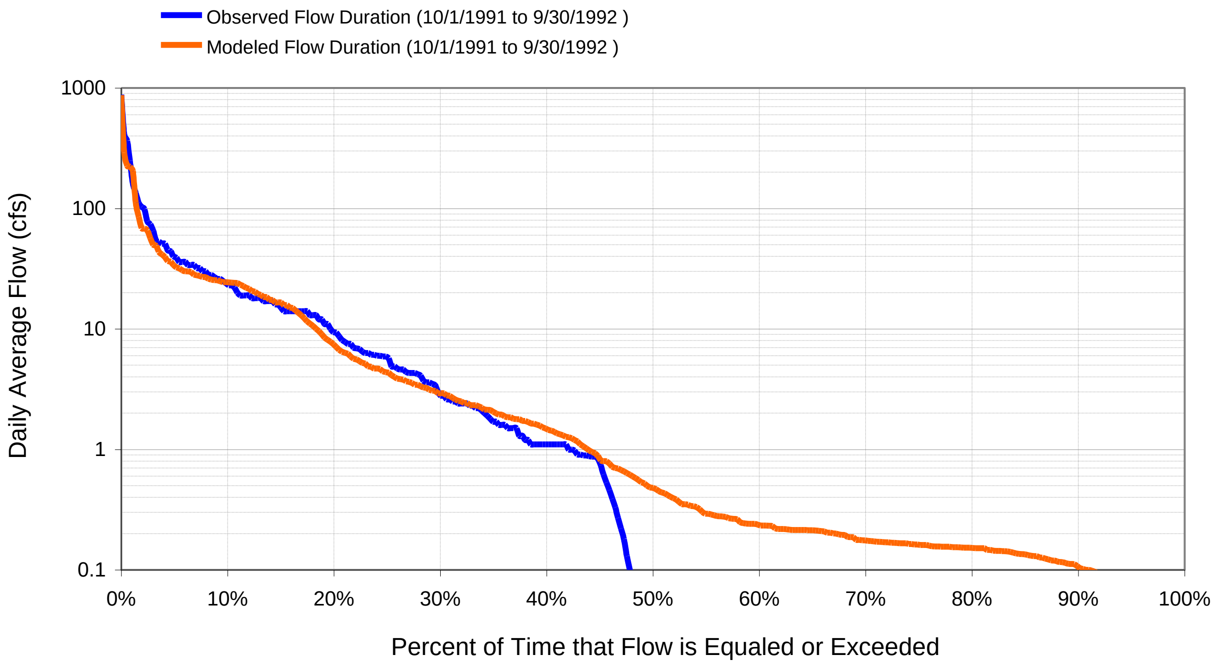


Figure 58. Flow exceedance: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

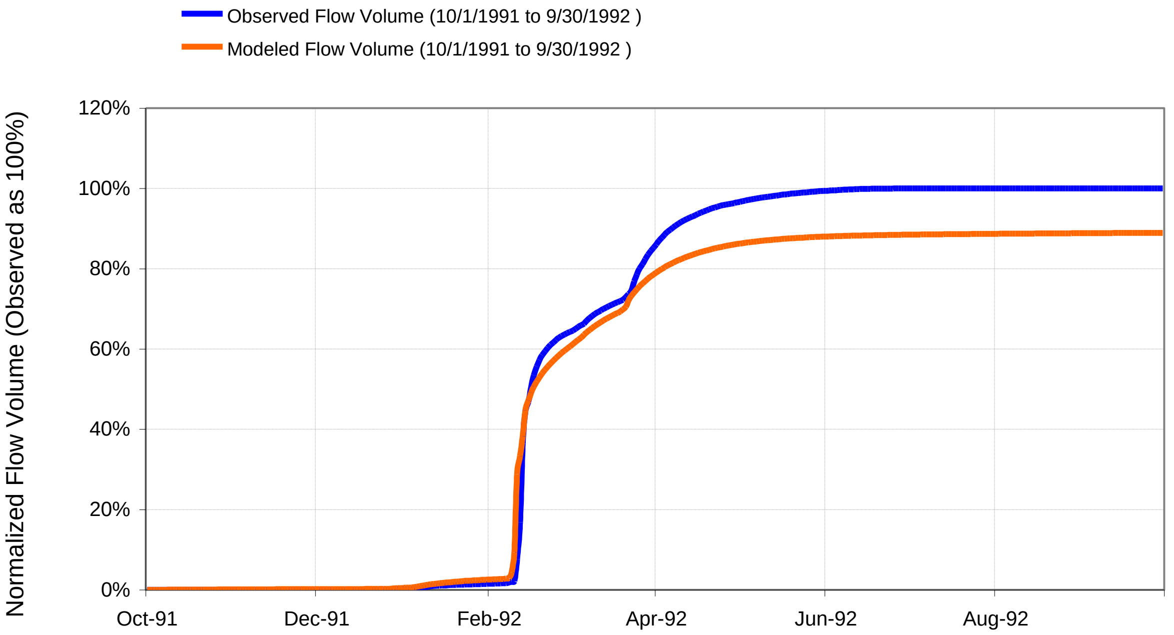


Figure 59. Flow accumulation: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

Table 24. Summary statistics: Model Outlet 4065 vs. USGS 11108080 Fish C Ab Castaic C near Castaic, CA

LSPC Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM SUBBASIN 4065 1-Year Analysis Period: 10/1/1991 - 9/30/1992 Flow volumes are (inches/year) for upstream drainage area		**USGS 11108080 FISH C AB CASTAIC C NR CASTAIC CA** Hydrologic Unit Code: 18070102 Latitude: 34.60248818 Longitude: -118.6628665 Drainage Area (sq-mi): 27.2		
Total Simulated In-stream Flow:	**5.46**	Total Observed In-stream Flow:		**6.14**
Total of simulated highest 10% flows:	**4.26**	Total of Observed highest 10% flows:		**4.98**
Total of Simulated lowest 50% flows:	**0.05**	Total of Observed Lowest 50% flows:		**0.00**
Simulated Summer Flow Volume (months 7-9):	**0.03**	Observed Summer Flow Volume (7-9):		**0.00**
Simulated Fall Flow Volume (months 10-12):	**0.03**	Observed Fall Flow Volume (10-12):		**0.02**
Simulated Winter Flow Volume (months 1-3):	**4.82**	Observed Winter Flow Volume (1-3):		**5.27**
Simulated Spring Flow Volume (months 4-6):	**0.58**	Observed Spring Flow Volume (4-6):		**0.86**
Total Simulated Storm Volume:	**1.40**	Total Observed Storm Volume:		**1.49**
Simulated Summer Storm Volume (7-9):	**0.00**	Observed Summer Storm Volume (7-9):		**0.00**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-11.04	10		
Error in 50% lowest flows:	-	10		
Error in 10% highest flows:	-14.39	15		
Seasonal volume error - Summer:	-	30		
Seasonal volume error - Fall:	-	30		
Seasonal volume error - Winter:	-8.42	30		
Seasonal volume error - Spring:	-32.37	30		
Error in storm volumes:	-6.15	20		
Error in summer storm volumes:	-	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.221	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	0.571			

Location 3: Castaic Creek above Fish Creek (Vacant Steep Slope A & B)

After hydrology parameters were established at both locations 1 and 2, those parameters were not adjusted again during calibration at location 3. Figure 60 shows drainage area HRU distribution upstream of USGS 11108075, Castaic Creek above Fish Creek near Castaic, California. This watershed was selected third from among the featured set because following Vacant Steep Slope C and D, it has the next highest distribution of an HRU soil types A and B in a Vacant category, which not previously been calibrated. The dual-HRU calibration focus for this watershed was Vacant Steep Slope A and B. For this area, INFILT was set at a final value of 1.0 for soil type A and 0.4 for soil type B. The AGWRC was given a final value of 0.98 for A and 0.96 for B. Both of those are in the mid to high levels among the recommended ranges for each of these parameters, and higher than the previously calibrated parameters at locations 1 and location 2. Those values were needed to adequately capture total volumes and unique signature of storm recessions observed in this watershed. Figure 61 through Figure 67 show daily, monthly, seasonal, exceedance frequency, and flow accumulation plots of modeled versus observed flow, while Table 25 and Table 26 summarize seasonal and multi-variable calibration statistics, respectively.

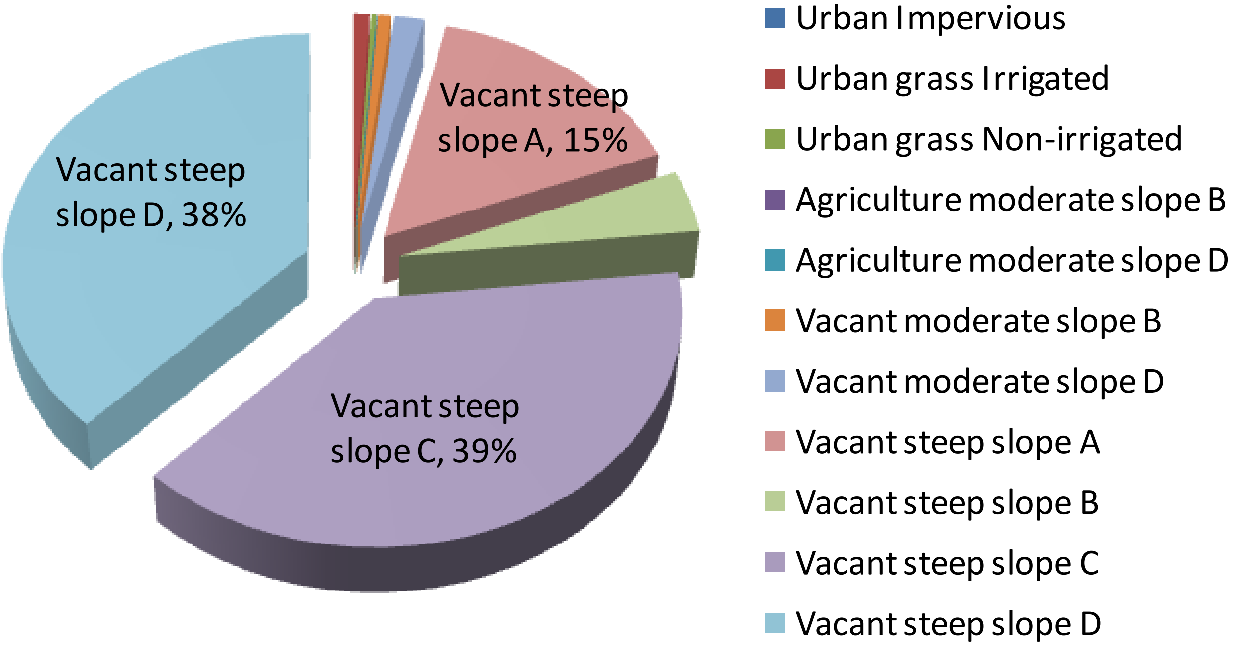


Figure 60. Catchment area distribution at Castaic Creek above Fish Creek (Model outlet 4075)

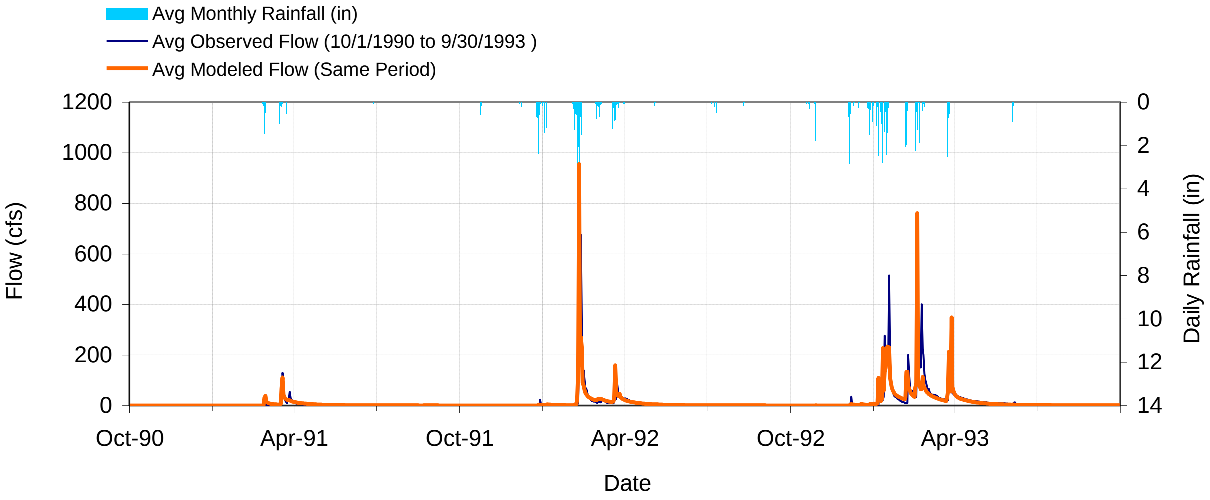


Figure 61. Mean daily flow: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

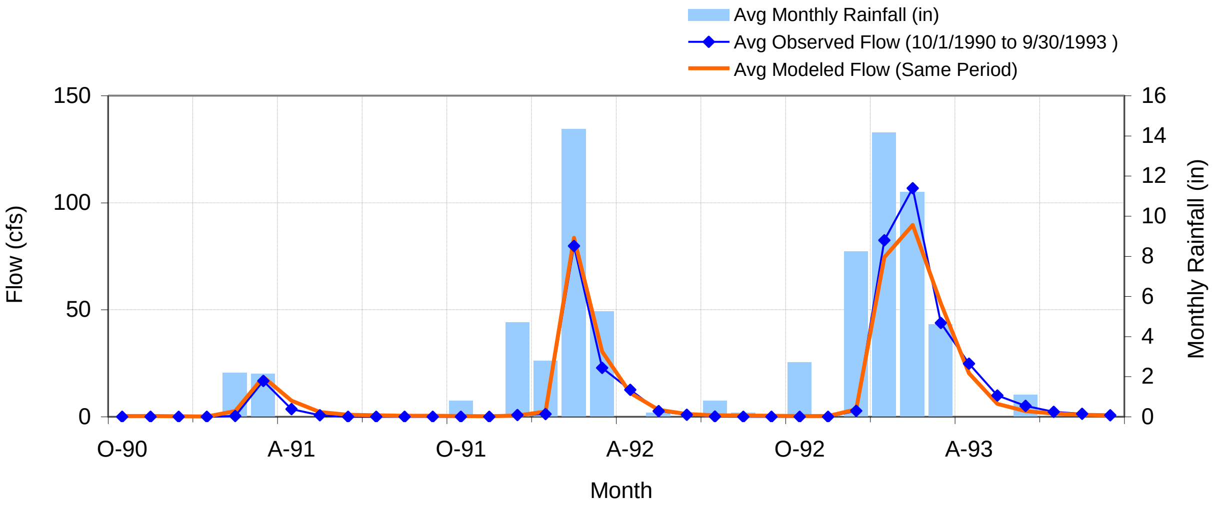


Figure 62. Mean monthly flow: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

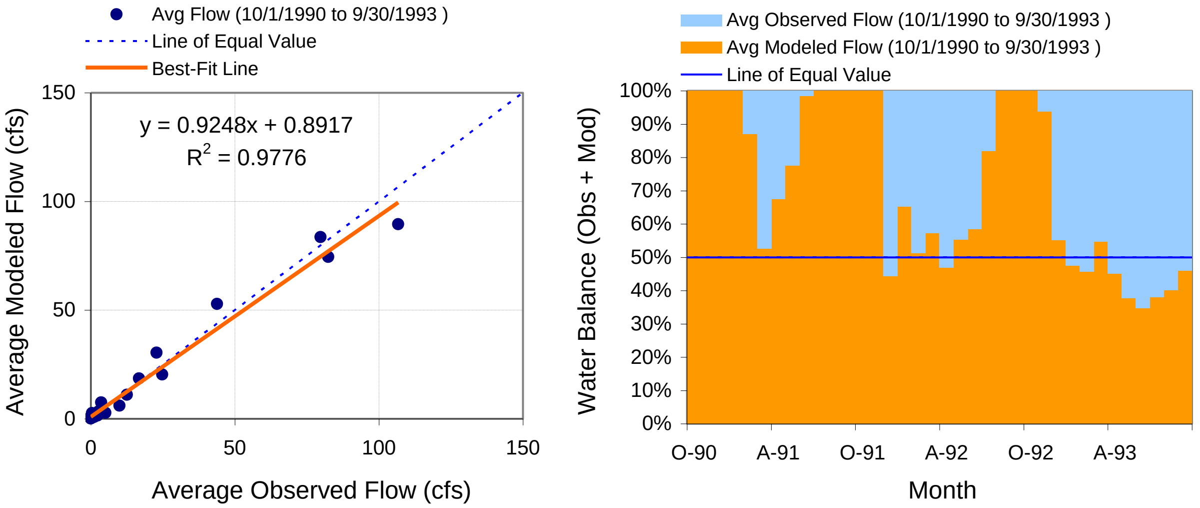


Figure 63. Monthly flow regression and temporal variation: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

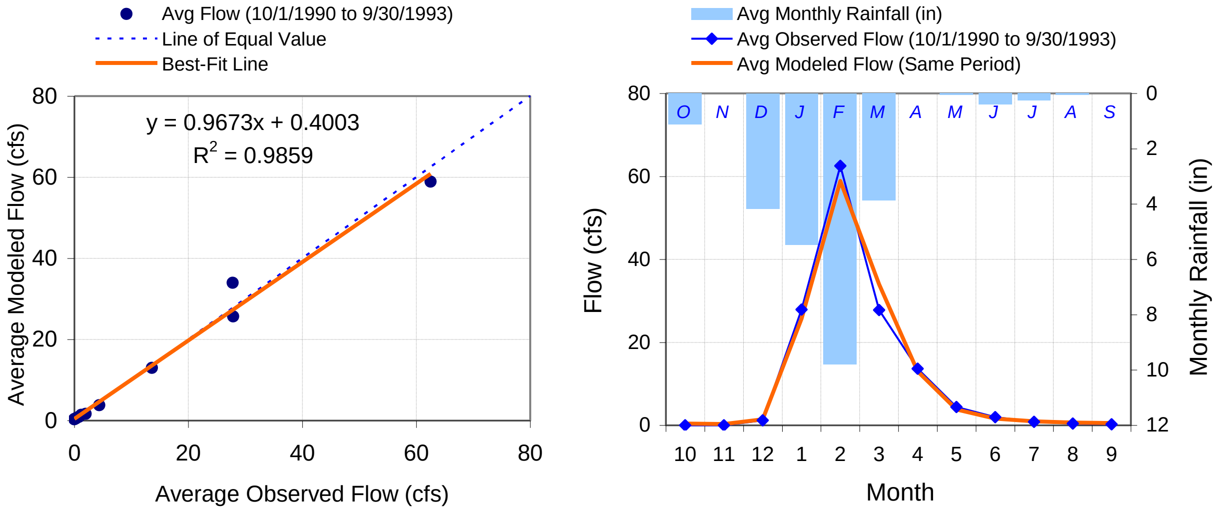


Figure 64. Seasonal regression and temporal aggregate: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

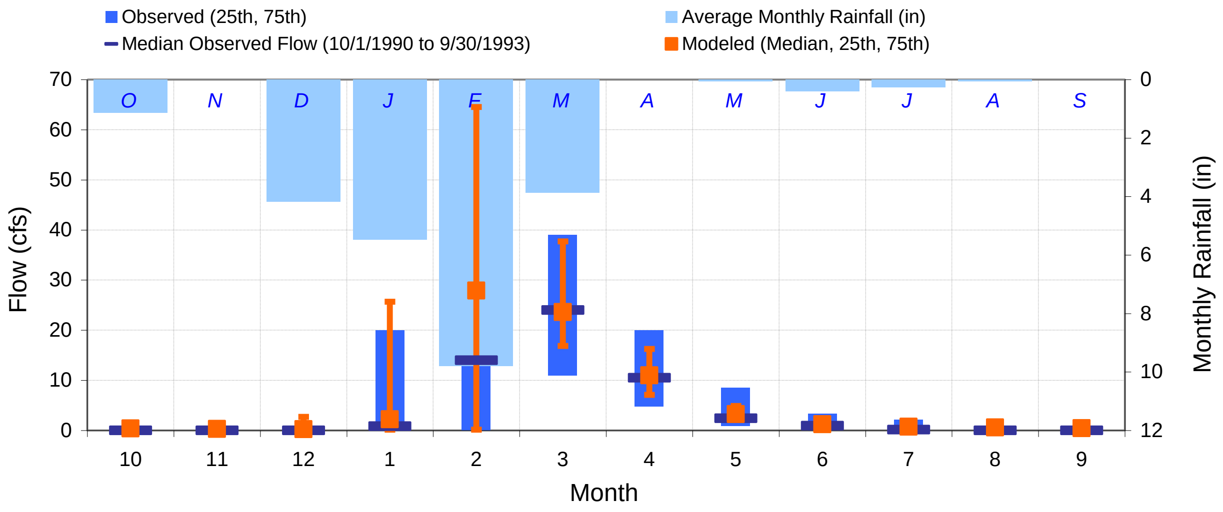


Figure 65. Seasonal medians and ranges: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

Table 25. Seasonal summary: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	0.00	0.00	0.00	0.00	0.39	0.39	0.36	0.43
Nov	0.01	0.00	0.00	0.00	0.29	0.29	0.26	0.33
Dec	1.20	0.00	0.00	1.00	1.42	0.24	0.20	2.72
Jan	27.90	0.84	0.00	20.00	25.67	2.22	0.16	25.68
Feb	62.51	14.00	0.00	66.00	58.88	27.91	0.16	64.51
Mar	27.79	24.00	11.00	39.00	33.98	23.61	16.85	37.70
Apr	13.63	10.50	4.78	20.00	12.97	11.01	7.10	16.26
May	4.40	2.40	0.90	8.50	3.81	3.27	2.23	4.87
Jun	1.98	0.92	0.02	3.35	1.63	1.21	1.03	2.18
Jul	0.84	0.17	0.00	2.10	0.94	0.73	0.62	1.22
Aug	0.44	0.00	0.00	1.00	0.67	0.60	0.54	0.76
Sep	0.25	0.00	0.00	0.70	0.51	0.46	0.43	0.57

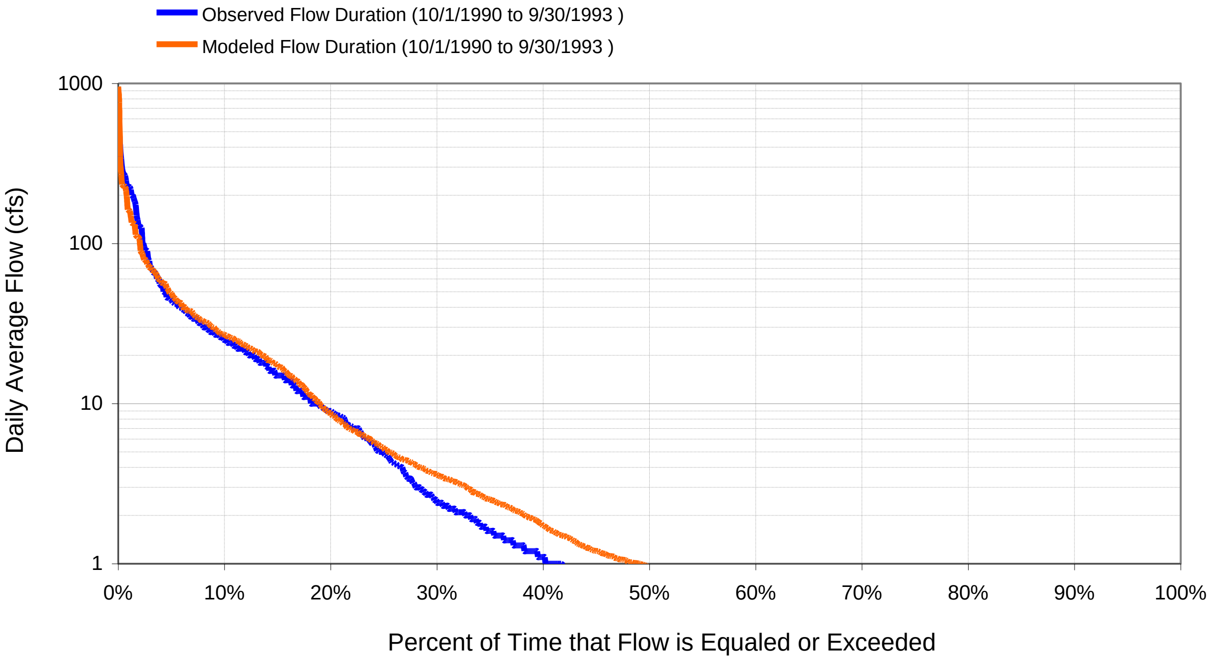


Figure 66. Flow exceedance: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

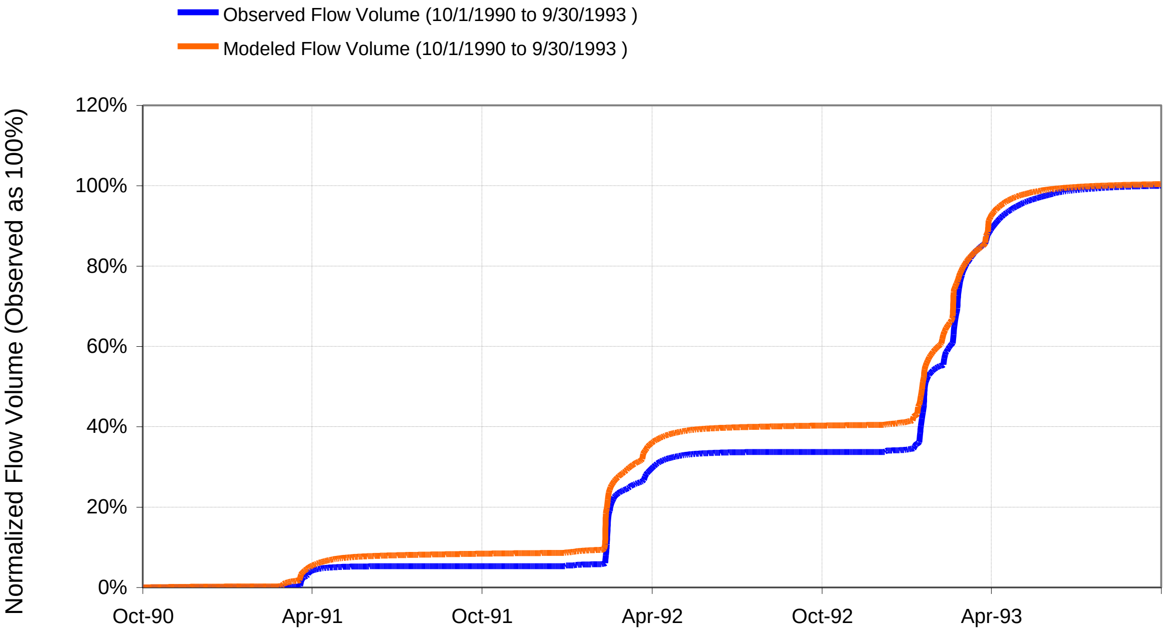


Figure 67. Flow accumulation: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

Table 26. Summary statistics: Model Outlet 4075 vs. USGS 11108075 Castaic C Ab Fish C near Castaic, CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 4075 3-Year Analysis Period: 10/1/1990 - 9/30/1993 Flow volumes are (inches/year) for upstream drainage area		**USGS 11108075 CASTAIC C AB FISH C NR CASTAIC CA** Hydrologic Unit Code: 18070102 Latitude: 34.60637689 Longitude: -118.6650888 Drainage Area (sq-mi): 37	
Total Simulated In-stream Flow:	**4.22**	Total Observed In-stream Flow:	**4.21**
Total of simulated highest 10% flows:	**3.17**	Total of Observed highest 10% flows:	**3.35**
Total of Simulated lowest 50% flows:	**0.08**	Total of Observed Lowest 50% flows:	**0.00**
Simulated Summer Flow Volume (months 7-9):	**0.07**	Observed Summer Flow Volume (7-9):	**0.05**
Simulated Fall Flow Volume (months 10-12):	**0.07**	Observed Fall Flow Volume (10-12):	**0.04**
Simulated Winter Flow Volume (months 1-3):	**3.53**	Observed Winter Flow Volume (1-3):	**3.51**
Simulated Spring Flow Volume (months 4-6):	**0.56**	Observed Spring Flow Volume (4-6):	**0.61**
Total Simulated Storm Volume:	**1.59**	Total Observed Storm Volume:	**1.61**
Simulated Summer Storm Volume (7-9):	**0.00**	Observed Summer Storm Volume (7-9):	**0.00**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	0.39	10		
Error in 50% lowest flows:	-	10		
Error in 10% highest flows:	-5.23	15		
Seasonal volume error - Summer:	37.78	30		
Seasonal volume error - Fall:	73.50	30		
Seasonal volume error - Winter:	0.57	30		
Seasonal volume error - Spring:	-8.10	30		
Error in storm volumes:	-1.19	20		
Error in summer storm volumes:	-	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.222	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.579	as E or E' approaches 1.0		

Locations 4 and 5: Whittier Narrows Dam (Irrigation and Hydromodification)

After hydrology parameters were established at both locations 1 through 3, those parameters were not adjusted again during calibration at locations 4 and 5. Figure 68 shows drainage area HRU distribution upstream of USGS 11101250, Rio Hondo above Whittier Narrows Dam, California. Figure 69 shows the HRU distribution in and around the Whittier Narrows Dam. This watershed was selected for calibration because (1) the upstream gage includes a large percentage of urban pervious land that was relatively uninfluenced by other man-made hydromodifications, and (2) the downstream gage provides a flow record that could be used to estimate dam regulation for areas further downstream of this point. As a third benefit, the watershed was relatively high in terms of percentage of Vacant Steep Slope B area. Calibrating the upstream gage for irrigation influence could also serve a secondary purpose of providing additional validation for the fixed parameters established at locations 1 through 3. Recall that Urban impervious area needs no adjustment in terms of calibration. Urban development in the watershed tends to be concentrated in areas that are generally flat. The soils are a mix of well-drained and poorly drained soils; however spatial averaging suggests that the predominant soil type in urban areas is poorly drained soils. For that reason, this land use was assigned an INFILT value of 0.1. AGWRC was set at 0.8 because it was found that irrigation does not generally result in steep recessions, but in long, sustained and steady water release back to the streams. Figure 70 through Figure 76 show daily, monthly, seasonal, exceedance frequency, and flow accumulation plots of modeled versus observed flow, while Table 27 and Table 28 summarize seasonal and multi-variable calibration statistics, respectively.

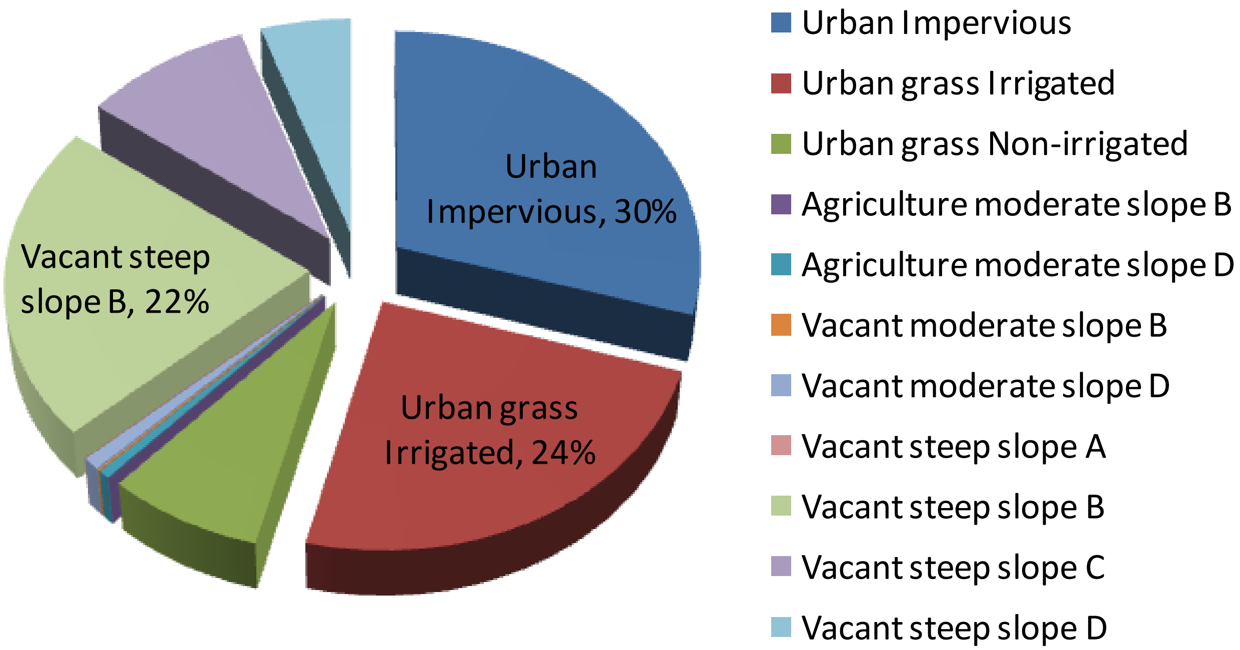


Figure 68. Catchment area distribution at Rio Hondo above Whittier Narrows Dam, CA (Model Outlet 6173)

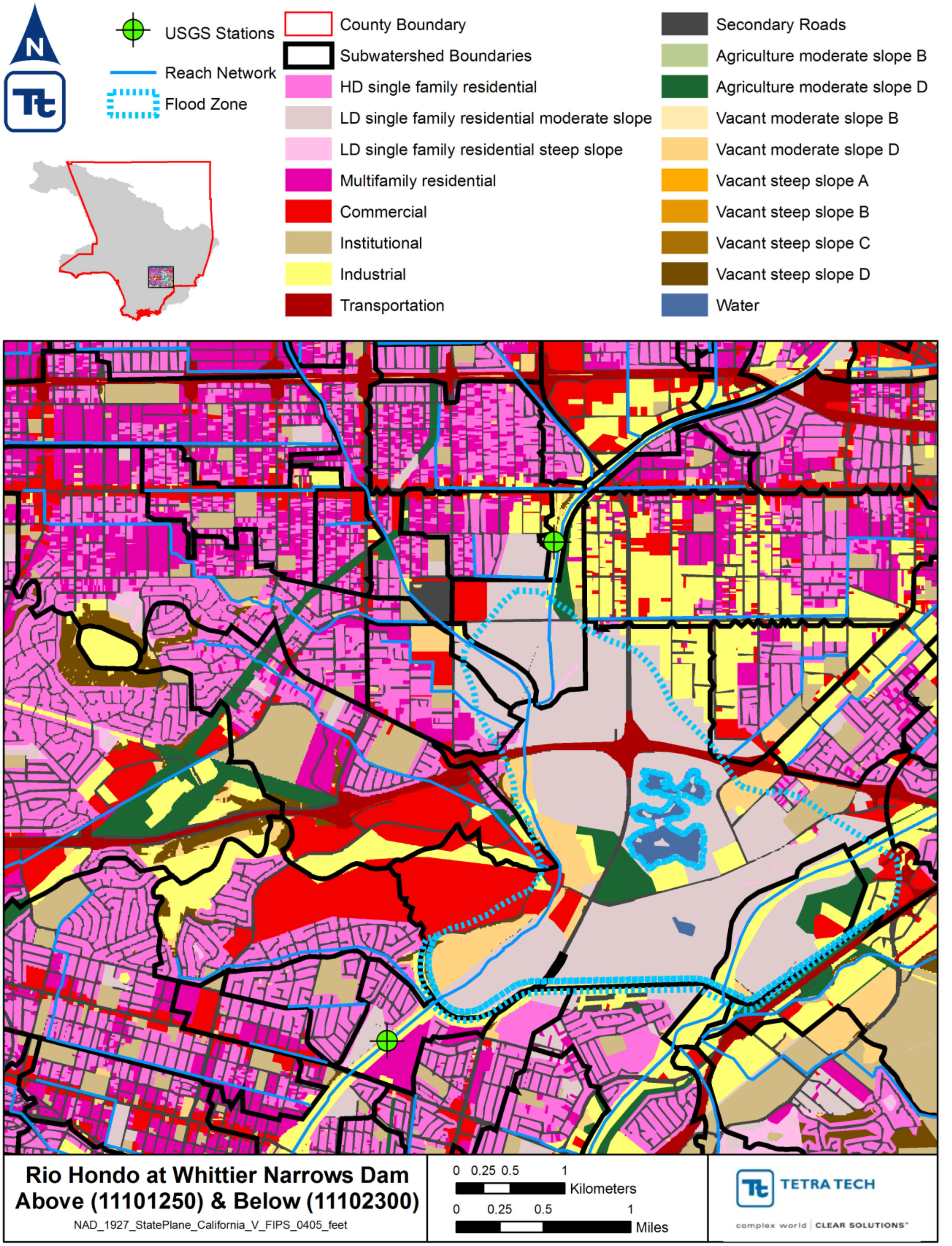


Figure 69. Hydromodification at Rio Hondo above and below Whittier Narrows Dam, CA (Model outlets 6173 and 6129)

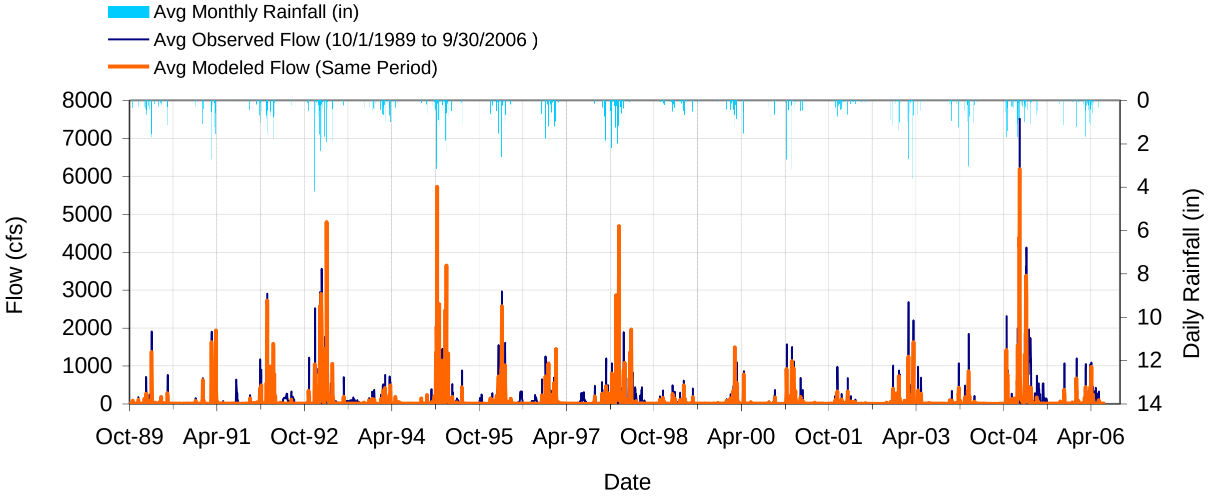


Figure 70. Mean daily flow: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

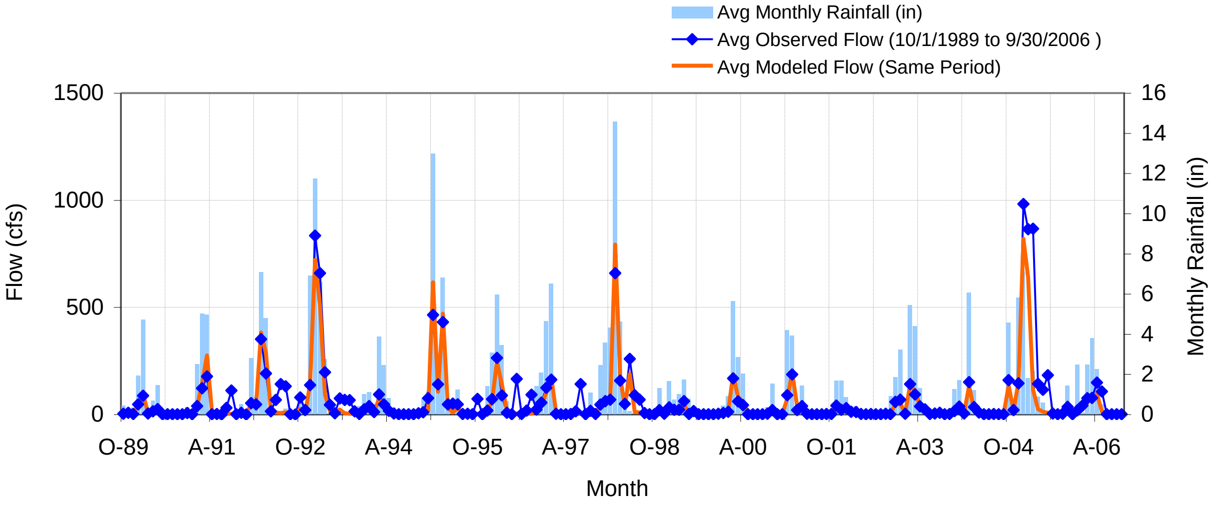


Figure 71. Mean monthly flow: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

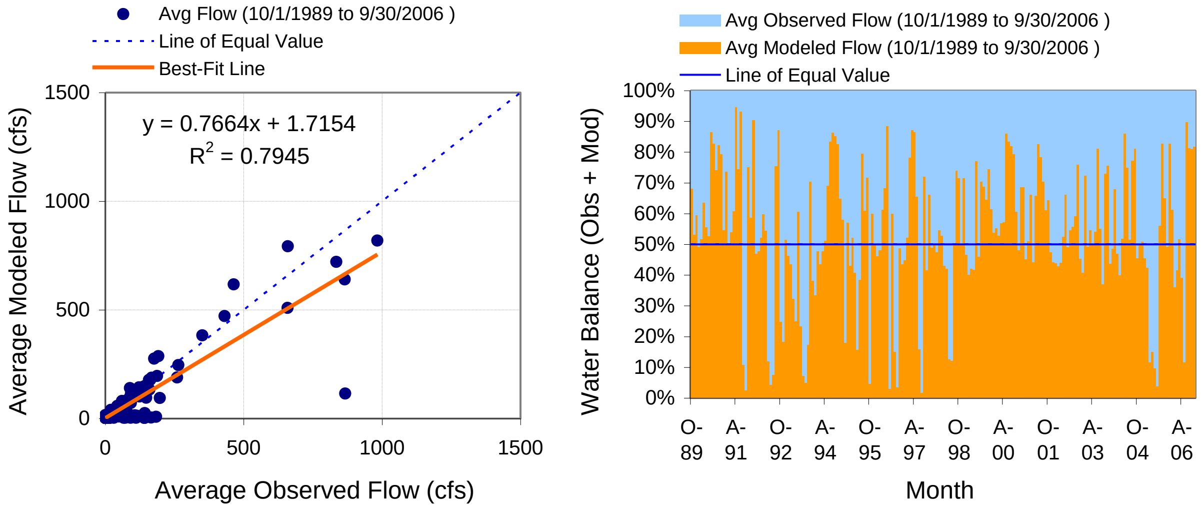


Figure 72. Monthly flow regression and temporal variation: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

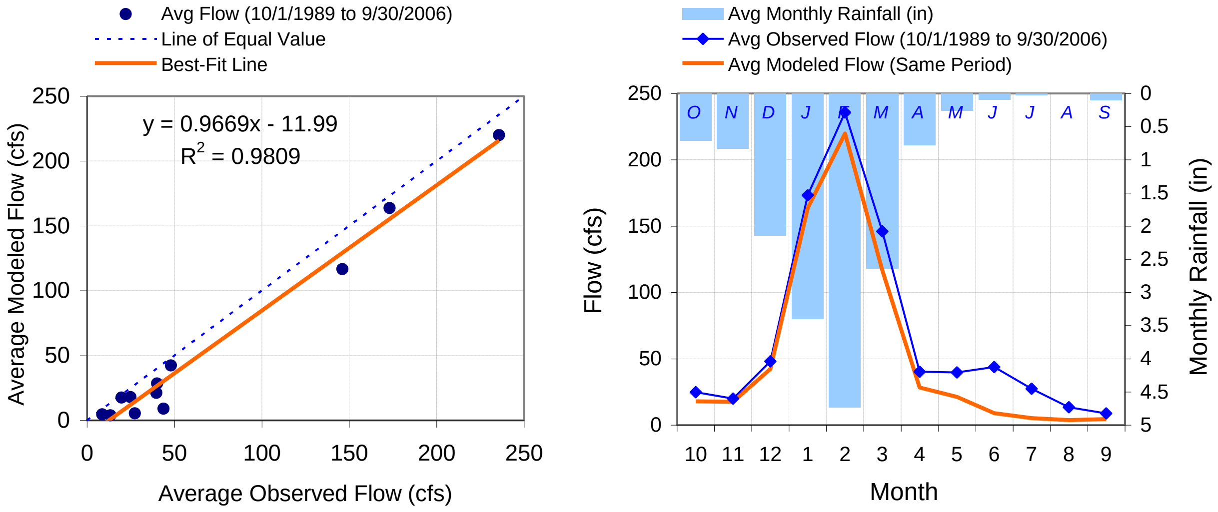


Figure 73. Seasonal regression and temporal aggregate: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

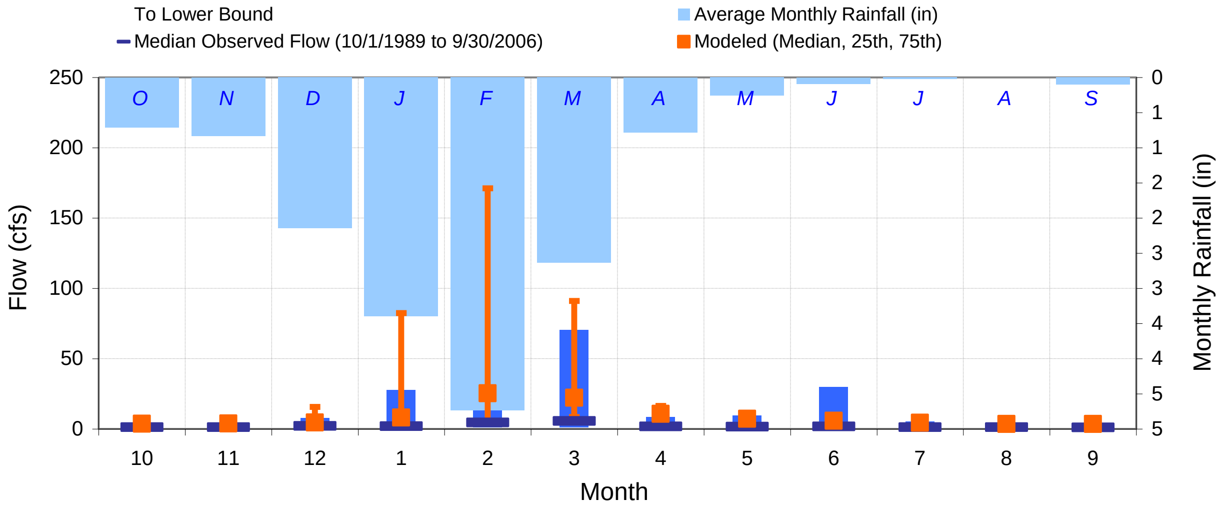


Figure 74. Seasonal medians and ranges: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

Table 27. Seasonal summary: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	24.87	1.20	0.91	2.00	17.93	3.62	2.86	4.57
Nov	19.84	1.25	0.76	2.80	17.60	3.95	3.17	5.96
Dec	48.10	2.10	0.85	8.00	42.22	4.65	3.06	15.64
Jan	173.18	2.00	1.00	27.50	163.61	8.18	3.49	82.39
Feb	235.68	4.50	1.20	85.75	219.87	25.40	5.47	171.13
Mar	146.08	5.60	1.20	70.50	116.65	22.15	8.48	91.07
Apr	40.15	1.70	0.91	8.45	28.38	10.80	6.60	16.34
May	39.74	1.50	0.88	9.45	21.22	7.21	4.85	9.32
Jun	43.80	1.70	0.88	29.75	8.91	5.86	4.50	7.81
Jul	27.48	1.30	0.89	5.20	5.30	4.34	3.49	6.08
Aug	13.39	1.20	0.80	2.40	3.81	3.58	3.01	4.22
Sep	8.75	1.10	0.76	1.60	4.51	3.46	3.01	4.02

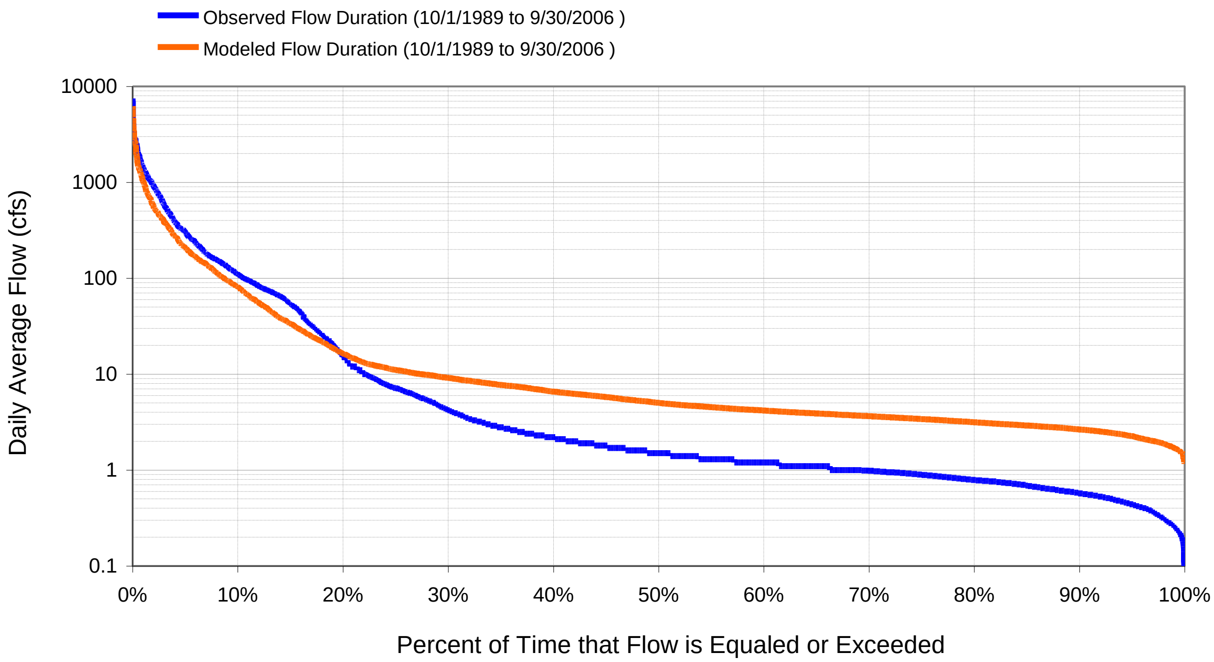


Figure 75. Flow exceedance: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

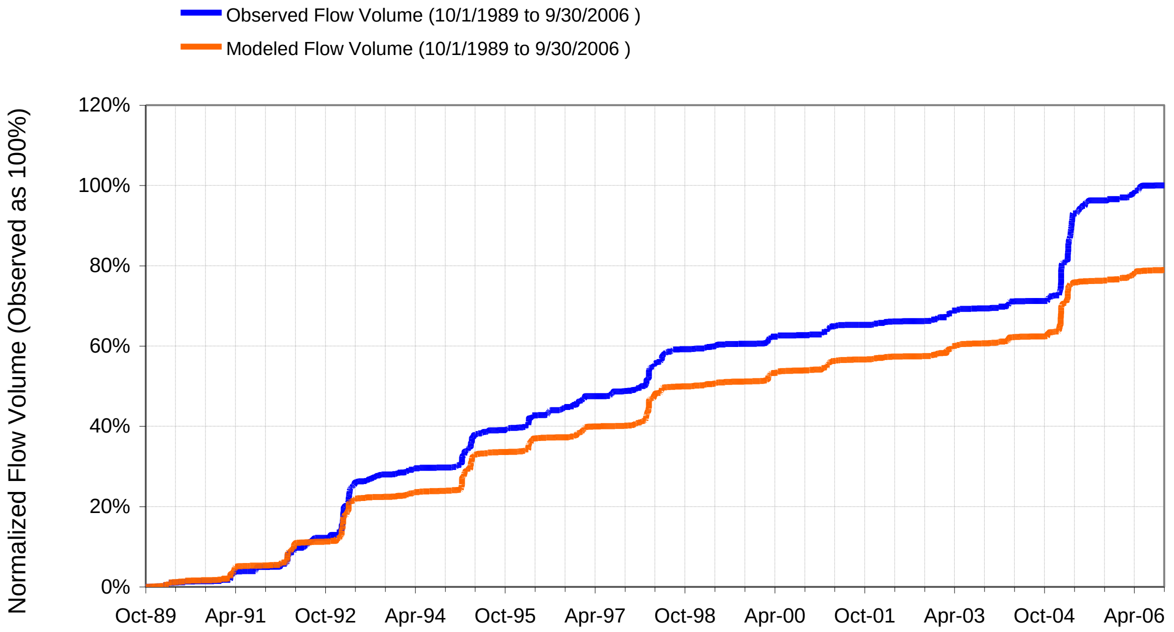


Figure 76. Flow accumulation: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

Table 28. Summary statistics: Model Outlet 6173 vs. USGS 11101250 Rio Hondo Ab Whittier Narrows Dam, CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 6173 17-Year Analysis Period: 10/1/1989 - 9/30/2006 Flow volumes are (inches/year) for upstream drainage area		**USGS 11101250 RIO HONDO AB WHITTIER NARROWS DAM CA** Hydrologic Unit Code: 18070105 Latitude: 34.05834368 Longitude: -118.0717348 Drainage Area (sq-mi): 91.2	
Total Simulated In-stream Flow:	**7.95**	Total Observed In-stream Flow:	**10.07**
Total of simulated highest 10% flows:	**6.75**	Total of Observed highest 10% flows:	**8.99**
Total of Simulated lowest 50% flows:	**0.25**	Total of Observed Lowest 50% flows:	**0.07**
Simulated Summer Flow Volume (months 7-9):	**0.17**	Observed Summer Flow Volume (7-9):	**0.62**
Simulated Fall Flow Volume (months 10-12):	**0.98**	Observed Fall Flow Volume (10-12):	**1.17**
Simulated Winter Flow Volume (months 1-3):	**6.07**	Observed Winter Flow Volume (1-3):	**6.75**
Simulated Spring Flow Volume (months 4-6):	**0.72**	Observed Spring Flow Volume (4-6):	**1.53**
Total Simulated Storm Volume:	**5.26**	Total Observed Storm Volume:	**6.98**
Simulated Summer Storm Volume (7-9):	**0.02**	Observed Summer Storm Volume (7-9):	**0.22**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-21.09	10		
Error in 50% lowest flows:	285.44	10		
Error in 10% highest flows:	-24.92	15		
Seasonal volume error - Summer:	-72.68	30		
Seasonal volume error - Fall:	-16.26	30		
Seasonal volume error - Winter:	-10.00	30		
Seasonal volume error - Spring:	-52.63	30		
Error in storm volumes:	-24.67	20		
Error in summer storm volumes:	-89.41	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.474	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.441	as E or E' approaches 1.0		

Locations 6: Los Angeles River above Long Beach, California, (Validation and Point Source Influence)

After all components of the model have been adequately calibrated using best available information, the next step in the model testing process is validation. Model validation involves running the watershed model with all calibrated components and parameters in place, but not making any changes to the existing parameter values. Validation can either be performed for an independent period or for an independent location. The selected validation example shown here is a gage near the mouth of the LAR. Figure 77 shows the HRU distribution upstream of the gage (USGS 11103000). That watershed was selected for validation because (1) the upstream gage included some of the HRU components that had been previously calibrated, and (2) the land use distribution and drainage area characteristics were typical most of the regional watersheds. A third added benefit to validating to this gage is that it contains point source contributions (major discharges such as Burbank, Glendale, and Tillman). While the focus of this modeling approach is not on baseflow hydrology, a meaningful representation of these conditions lends greater credibility to the superimposed storm responses. The validation run showed agreeable comparisons between modeled and observed flows near the outlet of the LAR. Figure 78 through Figure 84 show daily, monthly, seasonal, exceedance frequency, and flow accumulation plots of modeled versus observed flow, while Table 29 and Table 30 summarize seasonal and multi-variable calibration statistics, respectively.

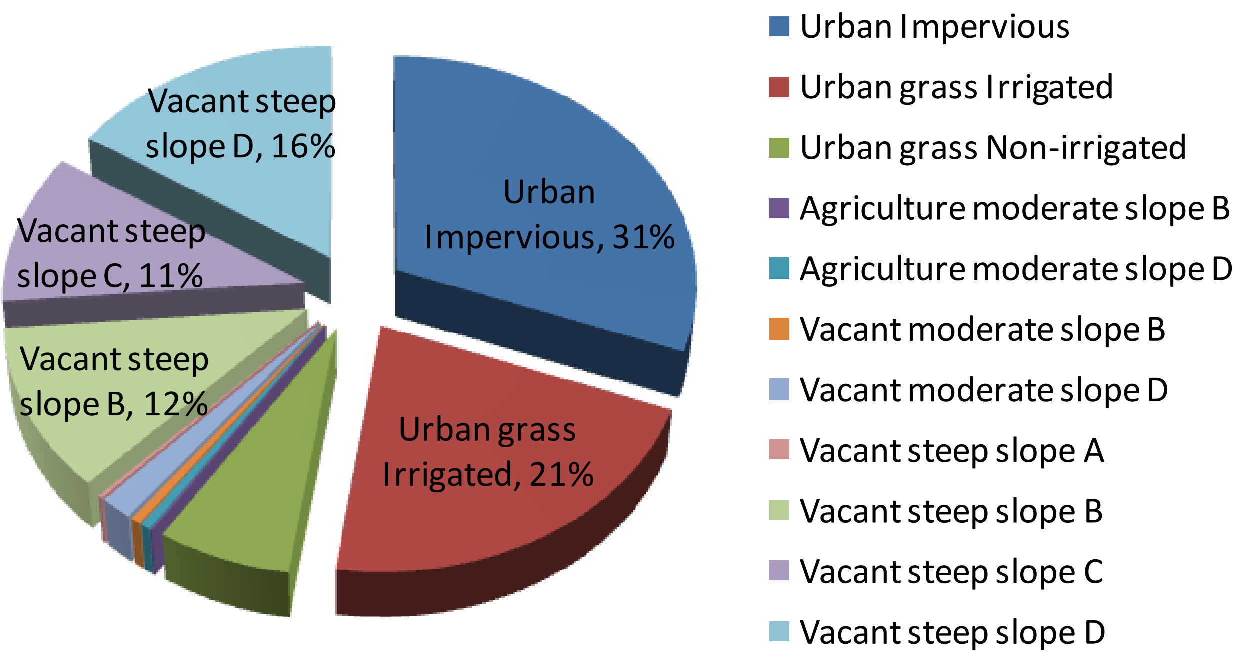


Figure 77. Catchment area distribution at LAR above Long Beach, CA (Model Outlet 6006)

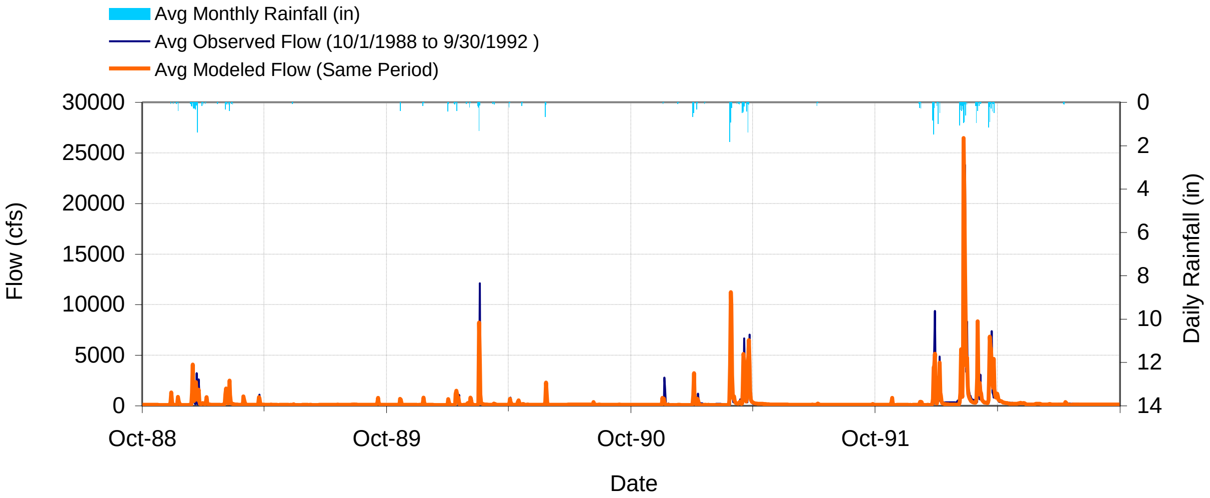


Figure 78. Mean daily flow: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

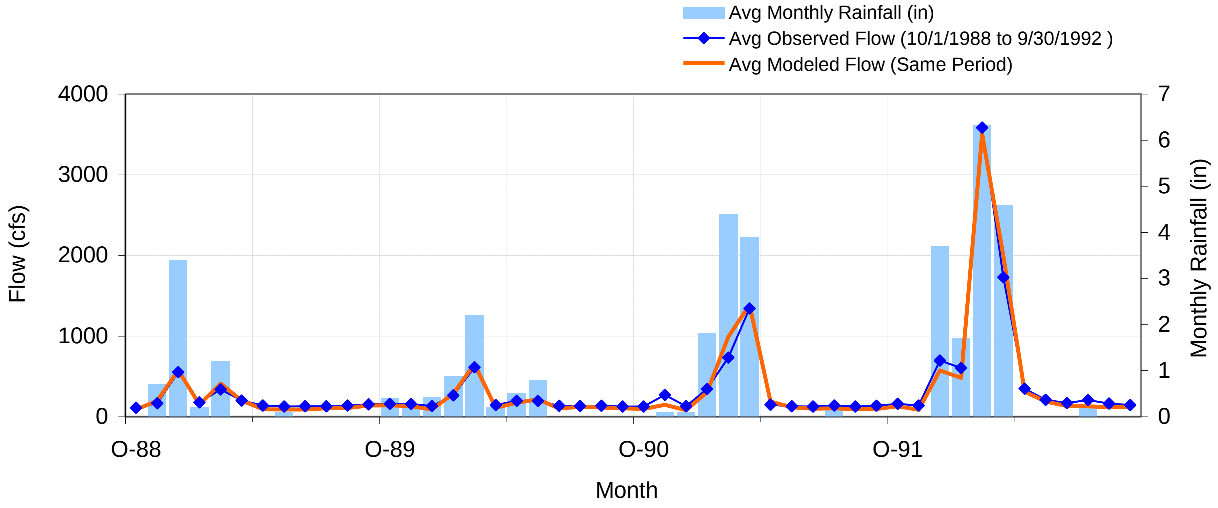


Figure 79. Mean monthly flow: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

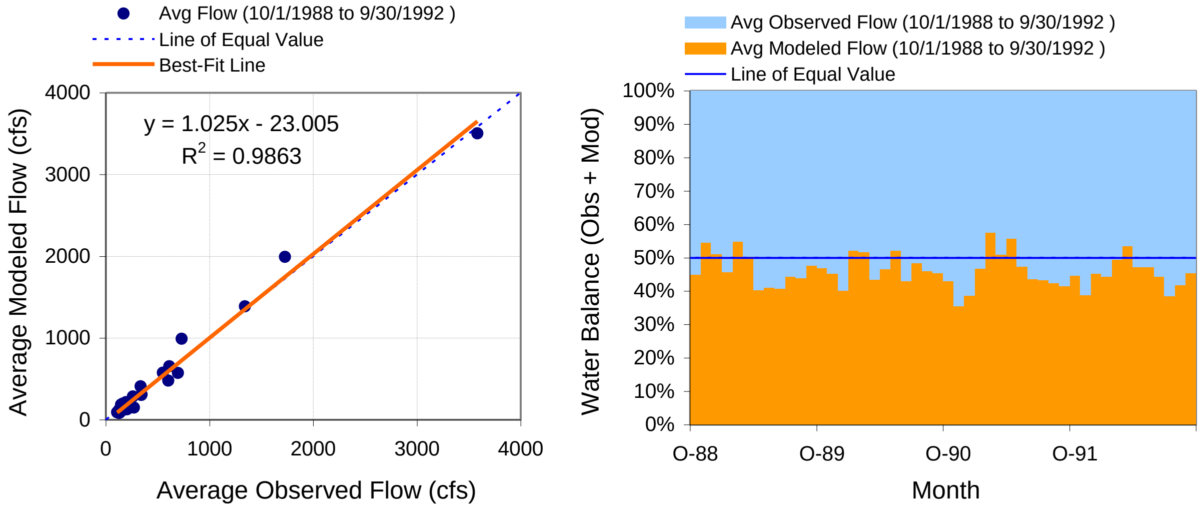


Figure 80. Monthly flow regression and temporal variation: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

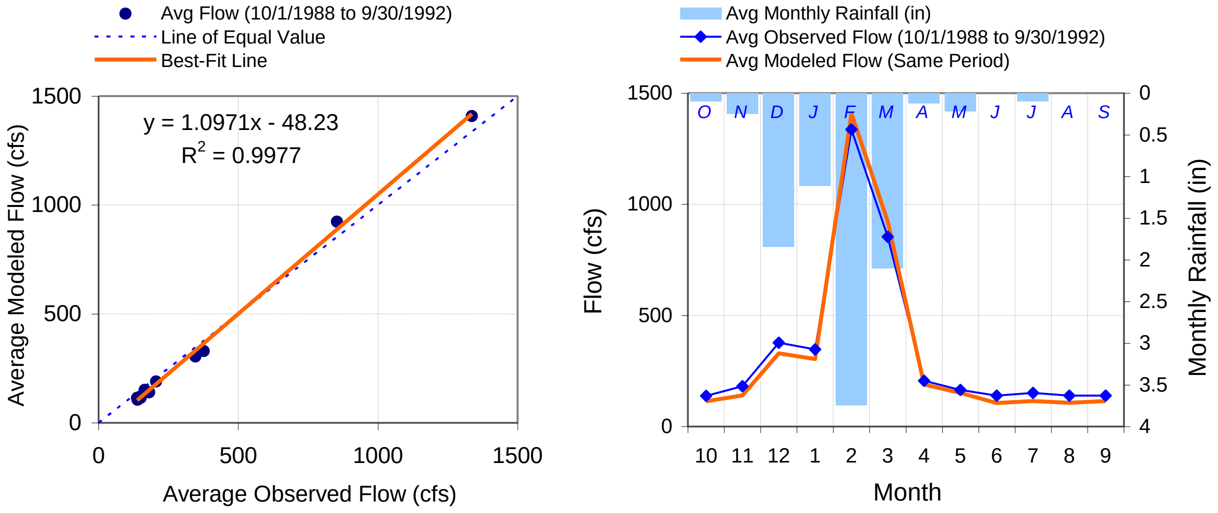


Figure 81. Seasonal regression and temporal aggregate: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

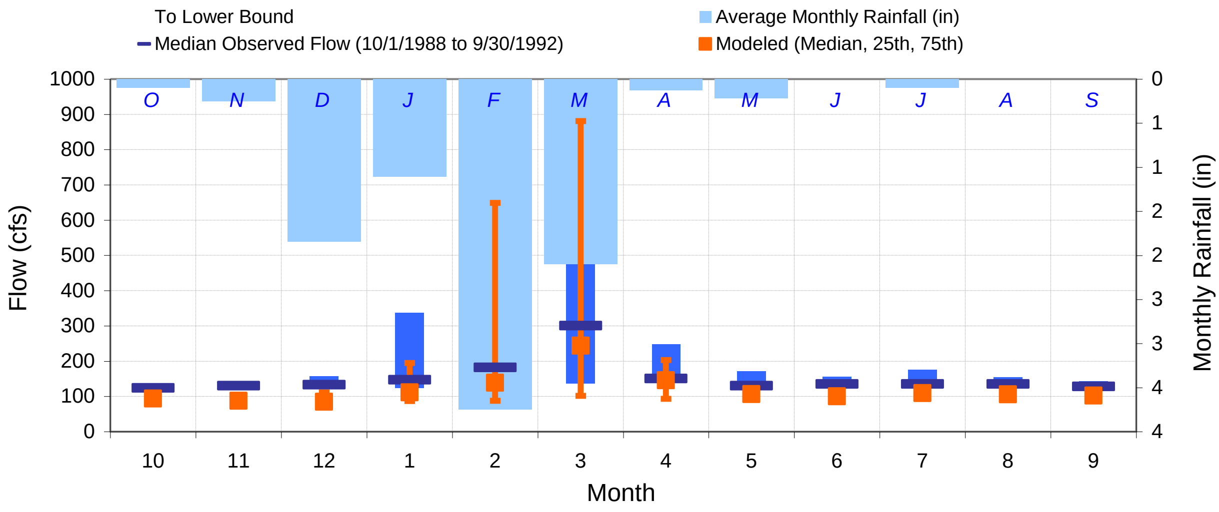


Figure 82. Seasonal medians and ranges: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

Table 29. Seasonal summary: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	138.31	124.00	113.00	133.00	113.25	93.73	90.27	97.11
Nov	181.66	130.00	122.00	138.25	139.77	87.94	85.36	91.87
Dec	376.74	133.00	126.75	158.00	329.50	84.86	82.01	111.51
Jan	347.05	147.50	124.00	338.00	304.28	111.16	87.12	195.01
Feb	1336.30	182.00	130.00	569.00	1408.37	139.01	87.65	648.68
Mar	853.48	300.50	136.75	567.00	923.03	244.04	101.81	881.04
Apr	206.13	151.00	141.00	248.00	189.18	146.00	93.34	202.88
May	165.00	130.00	124.00	171.75	151.17	106.26	92.79	128.85
Jun	139.33	135.00	126.00	156.25	105.22	100.30	93.48	113.85
Jul	151.36	135.00	130.00	176.00	114.95	109.08	99.92	120.58
Aug	139.53	135.00	126.00	154.00	107.27	105.63	94.56	113.64
Sep	138.82	128.00	124.00	143.00	114.23	102.52	96.84	117.59

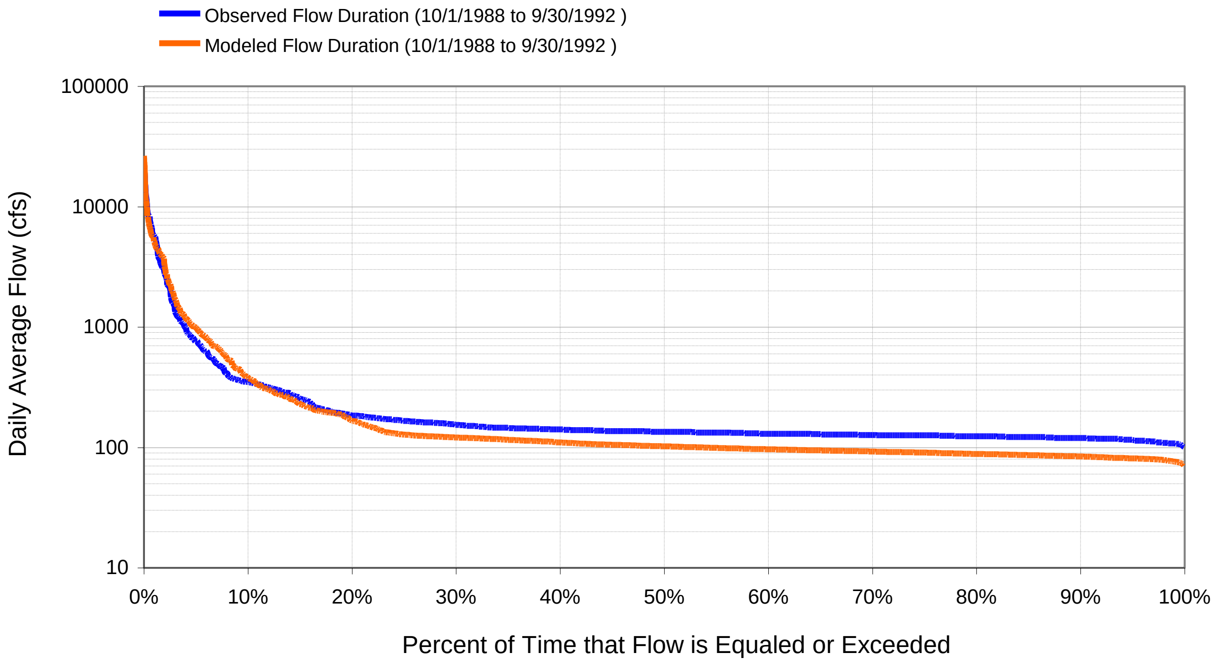


Figure 83. Flow exceedance: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

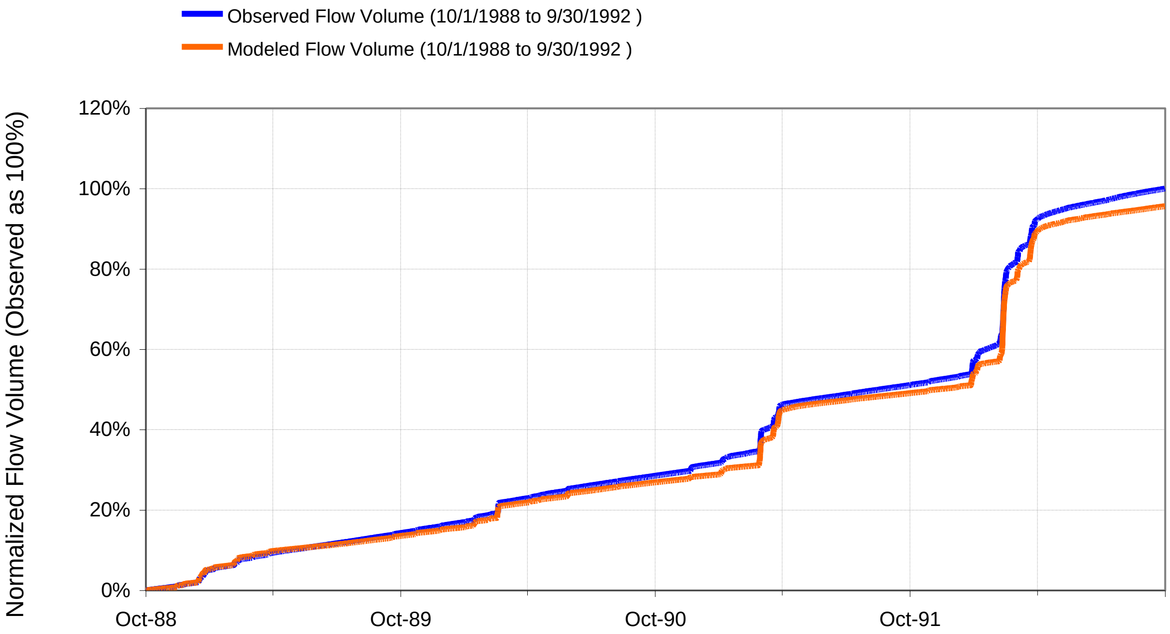


Figure 84. Flow accumulation: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

Table 30. Summary statistics: Model Outlet 6006 vs. USGS 11103000 at LAR above Long Beach, CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 6006		**USGS 11103000 LOS ANGELES R A LONG BEACH CA**	
4-Year Analysis Period: 10/1/1988 - 9/30/1992 Flow volumes are (inches/year) for upstream drainage area		Hydrologic Unit Code: 18070105 Latitude: 33.81723937 Longitude: -118.2064584 Drainage Area (sq-mi): 827	
Total Simulated In-stream Flow:	**5.38**	Total Observed In-stream Flow:	**5.62**
Total of simulated highest 10% flows:	**3.65**	Total of Observed highest 10% flows:	**3.44**
Total of Simulated lowest 50% flows:	**0.74**	Total of Observed Lowest 50% flows:	**1.02**
Simulated Summer Flow Volume (months 7-9):	**0.46**	Observed Summer Flow Volume (7-9):	**0.59**
Simulated Fall Flow Volume (months 10-12):	**0.81**	Observed Fall Flow Volume (10-12):	**0.96**
Simulated Winter Flow Volume (months 1-3):	**3.50**	Observed Winter Flow Volume (1-3):	**3.37**
Simulated Spring Flow Volume (months 4-6):	**0.61**	Observed Spring Flow Volume (4-6):	**0.70**
Total Simulated Storm Volume:	**3.12**	Total Observed Storm Volume:	**2.90**
Simulated Summer Storm Volume (7-9):	**0.04**	Observed Summer Storm Volume (7-9):	**0.04**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-4.37	10		
Error in 50% lowest flows:	-27.61	10		
Error in 10% highest flows:	6.26	15		
Seasonal volume error - Summer:	-21.75	30		
Seasonal volume error - Fall:	-16.33	30		
Seasonal volume error - Winter:	3.82	30		
Seasonal volume error - Spring:	-12.67	30		
Error in storm volumes:	7.55	20		
Error in summer storm volumes:	-7.33	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.639	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.488	as E or E' approaches 1.0		

Summary of the Hydrology Calibration and Validation Process

The calibration approach presented here relies heavily on two key considerations: (1) a high-resolution spatial representation of meteorological patterns throughout the watershed, and (2) a robust, physically based, and systematically consistent characterization of HRUs throughout the watershed. Because those two considerations are adequately established at the onset before model calibration, the ensuing calibration process follows a top-down methodical process of elimination, whereby homogeneous headwater reaches of predominantly one type of land unit are identified, calibrated, and frozen. The process then continues by selecting watershed that are more and more heterogeneous, progressively adding one new type of land unit to the mix, calibrating, and freezing the parameters. Finally, once all land units have been calibrated, the moment of truth is when the calibrated parameters are validated at a downstream location, which encompasses the full heterogeneity of the watershed. Table 31 through Table 34 represent the final set of calibration parameters. In the tables, boxes that have dash-marks indicate impervious HRUs for which the designated parameter is not relevant or available.

Table 31. Calibrated values: LSPC hydrology parameter Group 1

ID	HRU name	LZSN	INFILT	KVARY	AGWRC
1	HD_SF_Residential	-	-	-	-
2	LD_SF_Res_Moderate	-	-	-	-
3	LD_SF_Res_Steep	-	-	-	-
4	MF_Res	-	-	-	-
5	Commercial	-	-	-	-
6	Institutional	-	-	-	-
7	Industrial	-	-	-	-
8	Transportation	-	-	-	-
9	Secondary_Roads	-	-	-	-
10	Urban_Grass_Irrigated	7	0.1	0	0.8
11	Urban_Grass_NonIrrigated	7	0.1	0	0.8
12	Agriculture_Moderate_B	7	0.4	0	0.8
13	Agriculture_Moderate_D	7	0.1	0	0.8
14	Vacant_Moderate_B	7	0.4	0	0.8
15	Vacant_Moderate_D	7	0.1	0	0.8
16	Vacant_Steep_A	7	1.0	0	0.98
17	Vacant_Steep_B	7	0.4	0	0.96
18	Vacant_Steep_C	7	0.2	0	0.95
19	Vacant_Steep_D	7	0.1	0	0.94
20	Water	-	-	-	-
21	Water_Reuse	7	0.1	0	0.8

Table 32. Calibrated values: LSPC hydrology parameter Group 2

ID	HRU name	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1	HD_SF_Residential	45	35	-	-	-	-	-
2	LD_SF_Res_Moderate	45	35	-	-	-	-	-
3	LD_SF_Res_Steep	45	35	-	-	-	-	-
4	MF_Res	45	35	-	-	-	-	-
5	Commercial	45	35	-	-	-	-	-
6	Institutional	45	35	-	-	-	-	-
7	Industrial	45	35	-	-	-	-	-
8	Transportation	45	35	-	-	-	-	-
9	Secondary_Roads	45	35	-	-	-	-	-
10	Urban_Grass_Irrigated	45	35	2	2	0.5	0	0
11	Urban_Grass_NonIrrigated	45	35	2	2	0.5	0	0
12	Agriculture_Moderate_B	45	35	2	2	0.5	0	0
13	Agriculture_Moderate_D	45	35	2	2	0.5	0	0
14	Vacant_Moderate_B	45	35	2	2	0.5	0	0
15	Vacant_Moderate_D	45	35	2	2	0.5	0	0
16	Vacant_Steep_A	45	35	2	2	0.5	0	0
17	Vacant_Steep_B	45	35	2	2	0.5	0	0
18	Vacant_Steep_C	45	35	2	2	0.5	0	0
19	Vacant_Steep_D	45	35	2	2	0.5	0	0
20	Water	45	35	-	-	-	-	-
21	Water_Reuse	45	35	2	2	0.5	0	0

Table 33. Calibrated values: LSPC hydrology parameter Group 3

ID	HRU name	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	HD_SF_Residential	0.05	-	0.011	-	-	-
2	LD_SF_Res_Moderate	0.05	-	0.011	-	-	-
3	LD_SF_Res_Steep	0.05	-	0.011	-	-	-
4	MF_Res	0.05	-	0.011	-	-	-
5	Commercial	0.05	-	0.011	-	-	-
6	Institutional	0.05	-	0.011	-	-	-
7	Industrial	0.05	-	0.011	-	-	-
8	Transportation	0.05	-	0.011	-	-	-
9	Secondary_Roads	0.05	-	0.011	-	-	-
10	Urban_Grass_Irrigated	0.1	0.5	0.2	1	0.6	0.7
11	Urban_Grass_NonIrrigated	0.1	0.5	0.2	1	0.6	0.7
12	Agriculture_Moderate_B	0.1	0.5	0.2	1	0.6	0.7
13	Agriculture_Moderate_D	0.1	0.5	0.2	1	0.6	0.7
14	Vacant_Moderate_B	0.15	0.5	0.2	1	0.6	0.7
15	Vacant_Moderate_D	0.15	0.5	0.2	1	0.6	0.7
16	Vacant_Steep_A	0.2	0.5	0.2	1	0.6	0.7
17	Vacant_Steep_B	0.2	0.5	0.2	1	0.6	0.7
18	Vacant_Steep_C	0.2	0.5	0.2	1	0.6	0.7
19	Vacant_Steep_D	0.2	0.5	0.2	1	0.6	0.7
20	Water	0	-	0.011	-	-	-
21	Water_Reuse	0.1	0.5	0.2	1	0.6	0.7

Table 34. Calibrated values: LSPC irrigation module parameters

ID	HRU name	STARTMONTH	ENDMONTH	FRACTION2	ETCOEFF	ETDAYS
1	HD_SF_Residential	-	-	-	-	-
2	LD_SF_Res_Moderate	-	-	-	-	-
3	LD_SF_Res_Steep	-	-	-	-	-
4	MF_Res	-	-	-	-	-
5	Commercial	-	-	-	-	-
6	Institutional	-	-	-	-	-
7	Industrial	-	-	-	-	-
8	Transportation	-	-	-	-	-
9	Secondary_Roads	-	-	-	-	-
10	Urban_Grass_Irrigated	1	12	1	0.706	1
11	Urban_Grass_NonIrrigated	1	12	0	0	1
12	Agriculture_Moderate_B	1	12	1	1	1
13	Agriculture_Moderate_D	1	12	1	1	1
14	Vacant_Moderate_B	1	12	0	0	1
15	Vacant_Moderate_D	1	12	0	0	1
16	Vacant_Steep_A	1	12	0	0	1
17	Vacant_Steep_B	1	12	0	0	1
18	Vacant_Steep_C	1	12	0	0	1
19	Vacant_Steep_D	1	12	0	0	1
20	Water	-	-	-	-	-
21	Water_Reuse	1	12	1	0.706	1

Because much of the spatial variability has been captured during in the model setup and configuration components, the actual number of calibration parameters is relatively small and concise. Notice that in the above tables, a new HRU has been added to represent areas that are subjected to irrigation from water reclamation facilities. On the basis of a GIS overlay of water-reuse addresses and associated property areas, the actual *Water_Reuse* area within each subwatershed was subtracted from *Urban_Grass* (HRUs 10 and 11) and reconstituted as HRU 21.

Next Steps

The next report in the series, *Los Angeles County Watershed Model Configuration and Calibration—Part II* will focus on the water quality aspects of the model calibration.

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Appendix A – Quality Control Process Summary for Precipitation Data

There were four primary sources of precipitation data used for this analysis. The NCDC hourly precipitation gages, NCDC Summary of Day totals, the Los Angeles County DPW daily rainfall gages, and the LACFCD daily rainfall gages. Hourly precipitation data were evaluated for missing, deleted, and accumulated intervals, and patched using nearby gages. Daily precipitation stations were also evaluated and patched and then disaggregated to an hourly time step using observed distributions at nearby hourly gages. A graphical summary of the patching results is presented for 221 unique rainfall gages.

NCDC Hourly Precipitation Gages

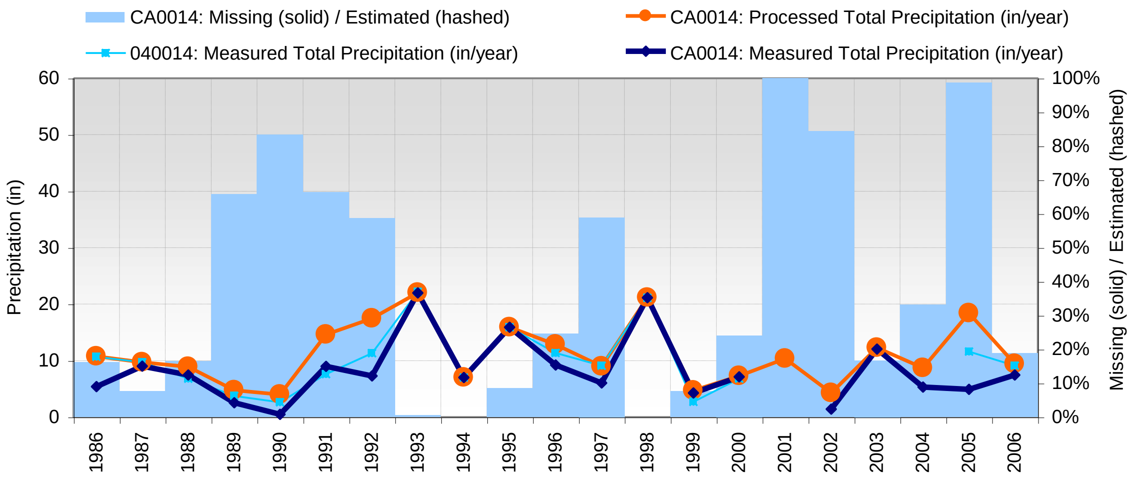


Figure A-1. Total precipitation at Acton Escondido FC261 (CA0014)

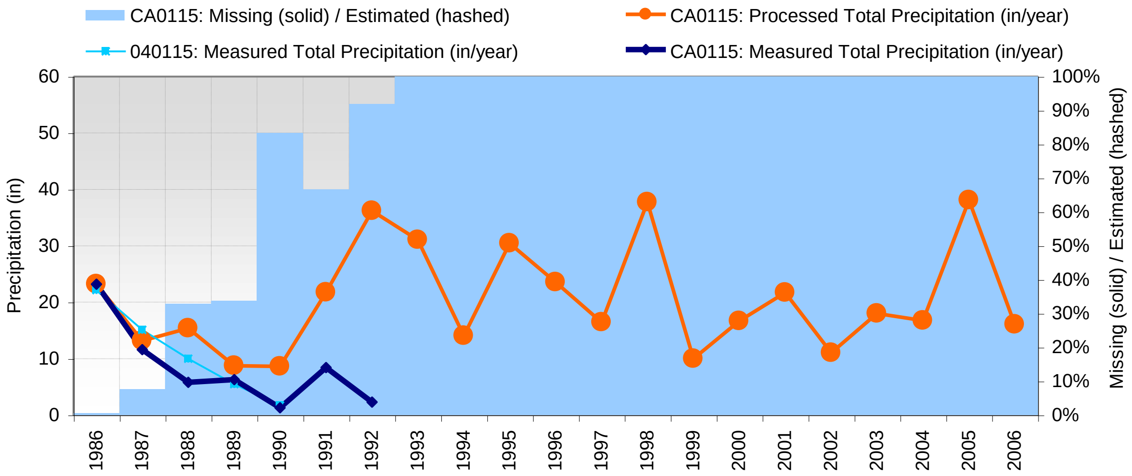


Figure A-2. Total precipitation at Aliso Canyon Oat Mtn FC (CA0115)

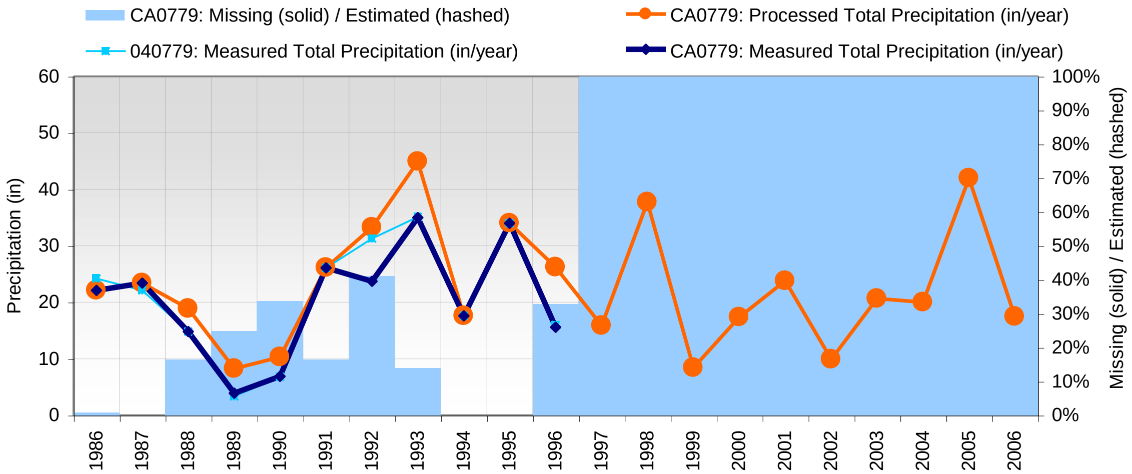


Figure A-3. Total precipitation at Big Pines Park FC83B (CA0779)

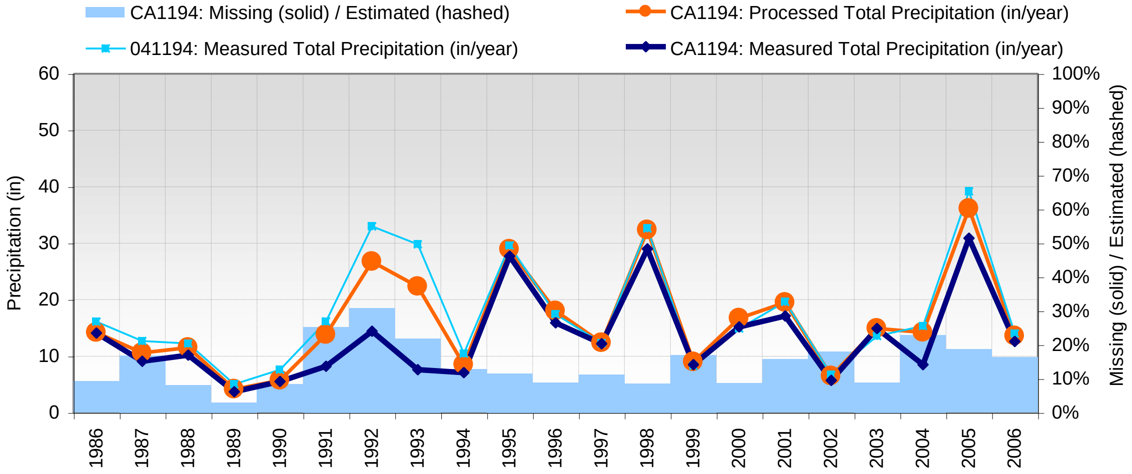


Figure A-4. Total precipitation at Burbank Valley Pump Pla (CA1194)

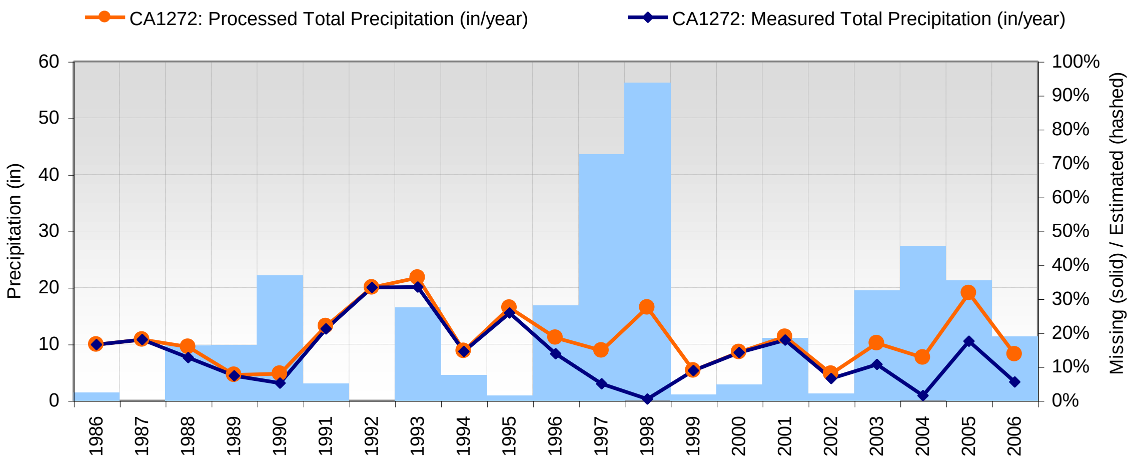


Figure A-5. Total precipitation at Cajon West Summit (CA1272)

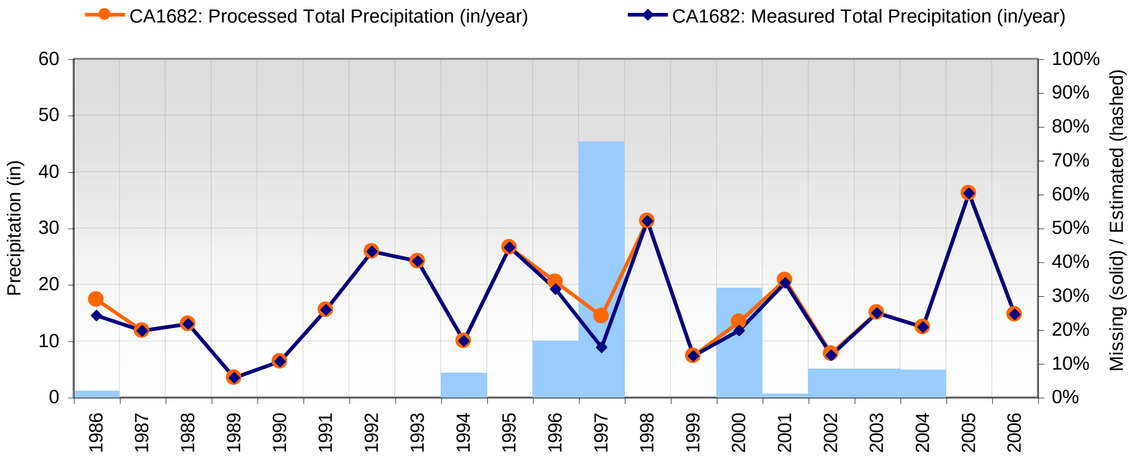


Figure A-6. Total precipitation at Chatsworth Reservoir (CA1682)

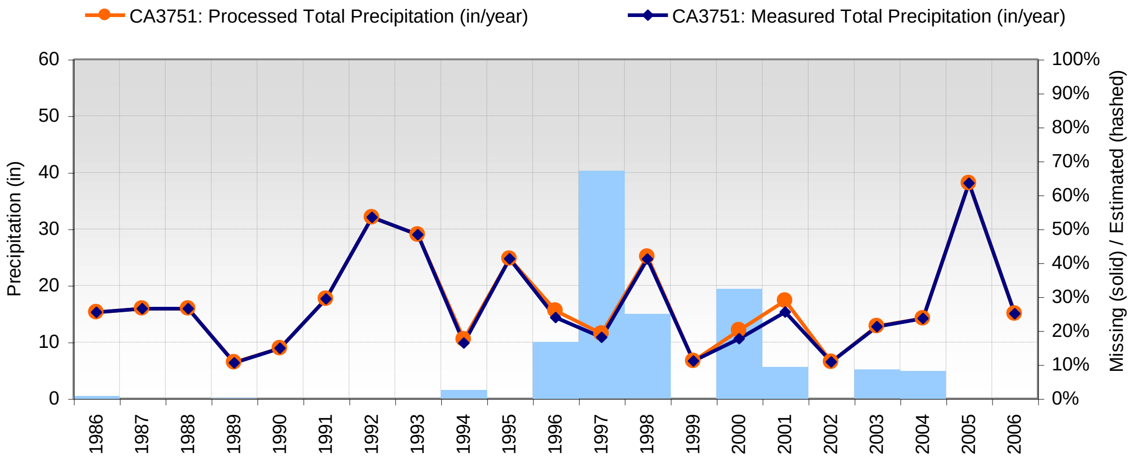


Figure A-7. Total precipitation at Hansen Dam (CA3751)

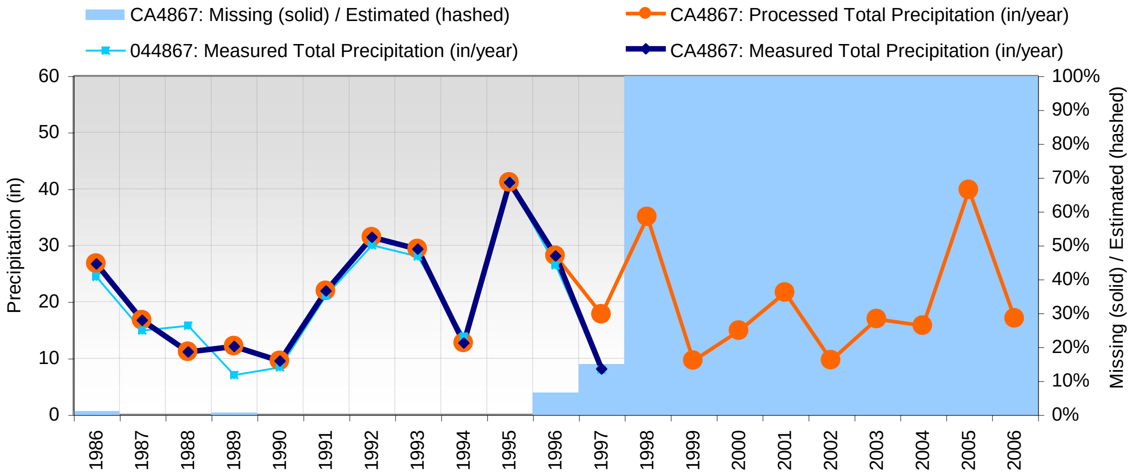


Figure A-8. Total precipitation at Lechuza Ptrl ST FC352B (CA4867)

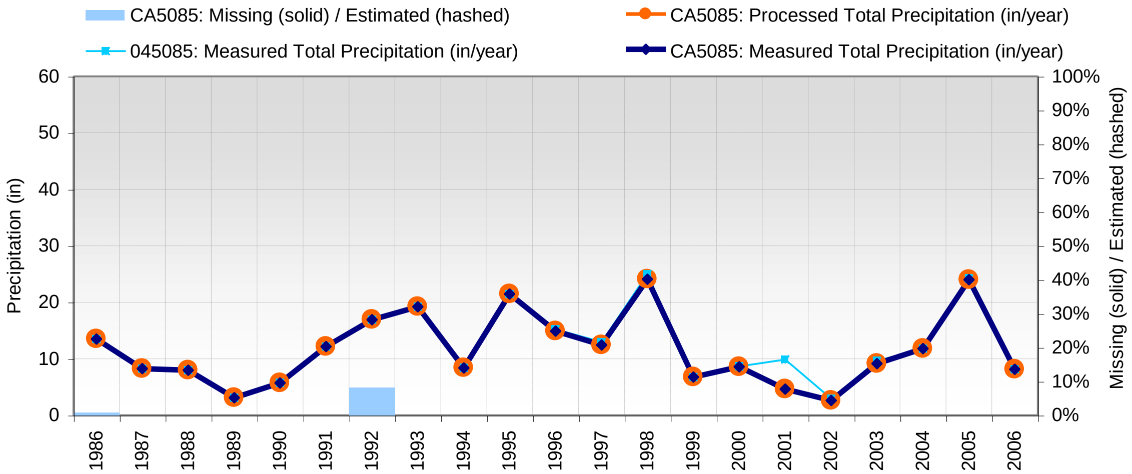


Figure A-9. Total precipitation at Long Beach AP (CA5085)

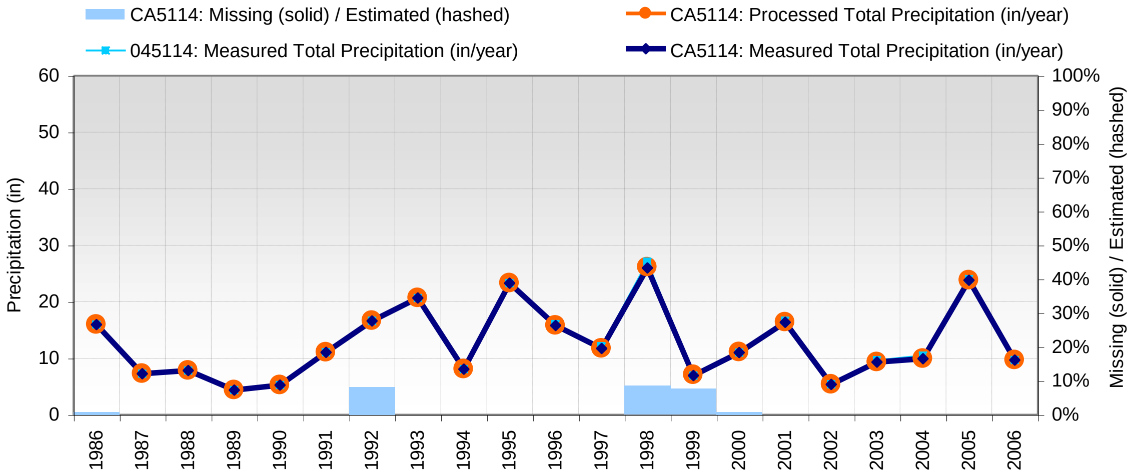


Figure A-10. Total precipitation at Los Angeles WSO Arpt (CA5114)

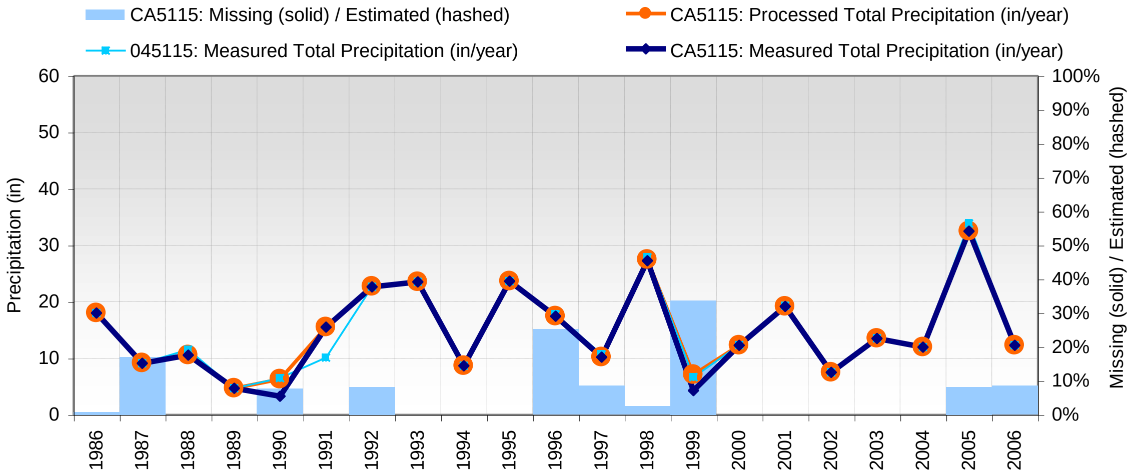


Figure A-11. Total precipitation at Los Angeles Downtown (CA5115)

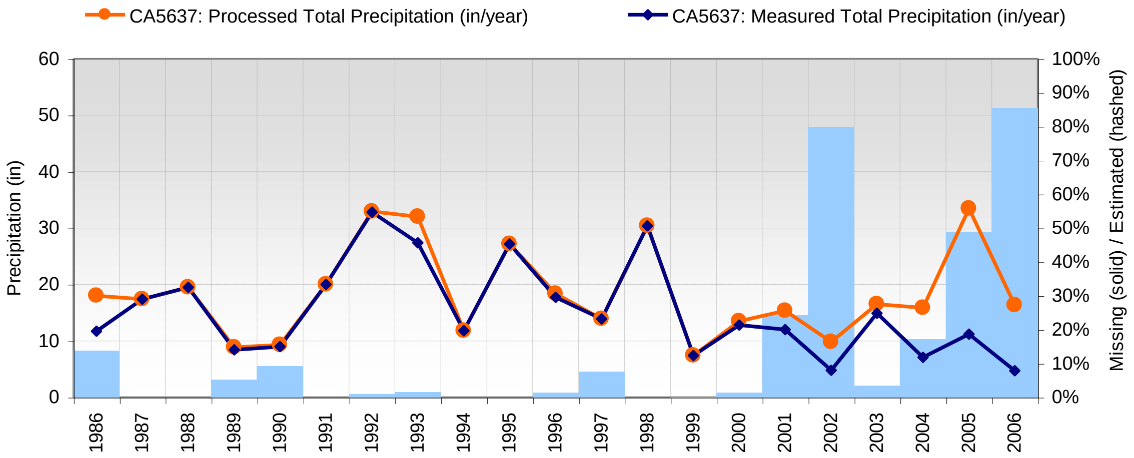


Figure A-12. Total precipitation at Mill Creek Summit R S (CA5637)

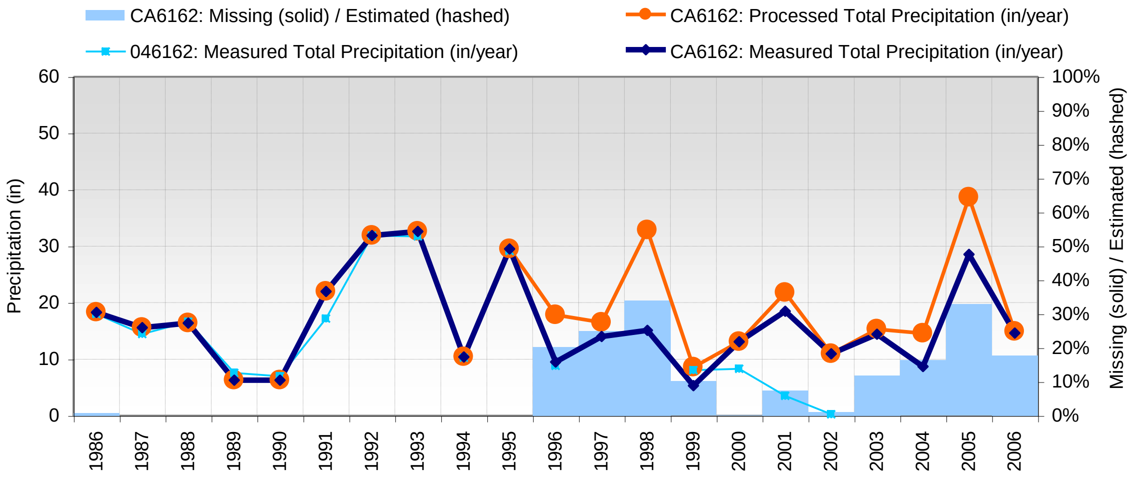


Figure A-13. Total precipitation at Newhall S FC32CE (CA6162)

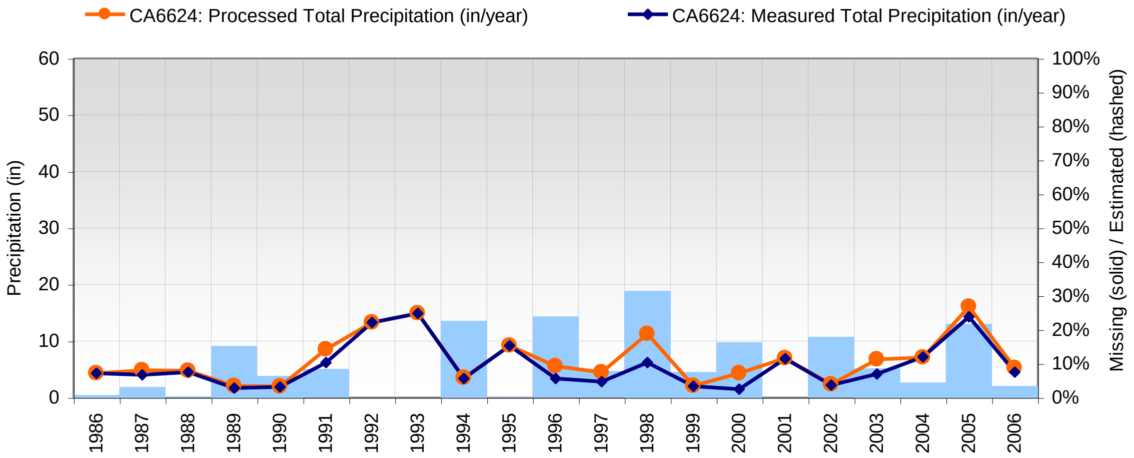


Figure A-14. Total precipitation at Palmdale (CA6624)

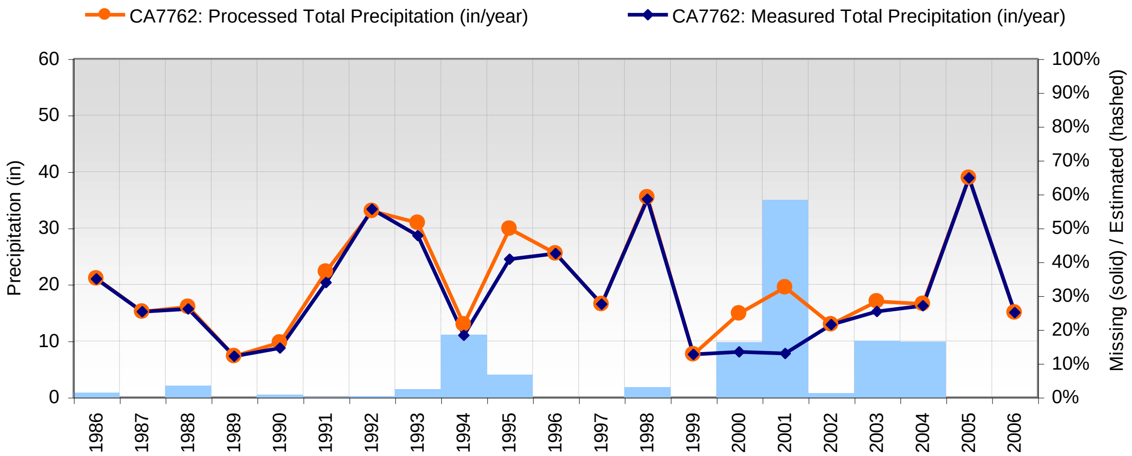


Figure A-15. Total precipitation at San Fernando PH 3 (CA7762)

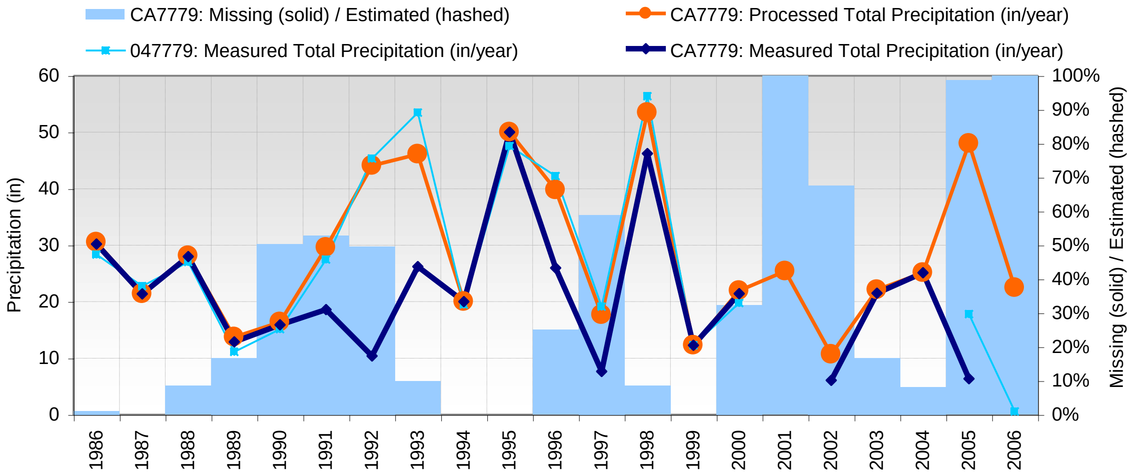


Figure A-16. Total precipitation at San Gabriel Dam FC425B (CA7779)

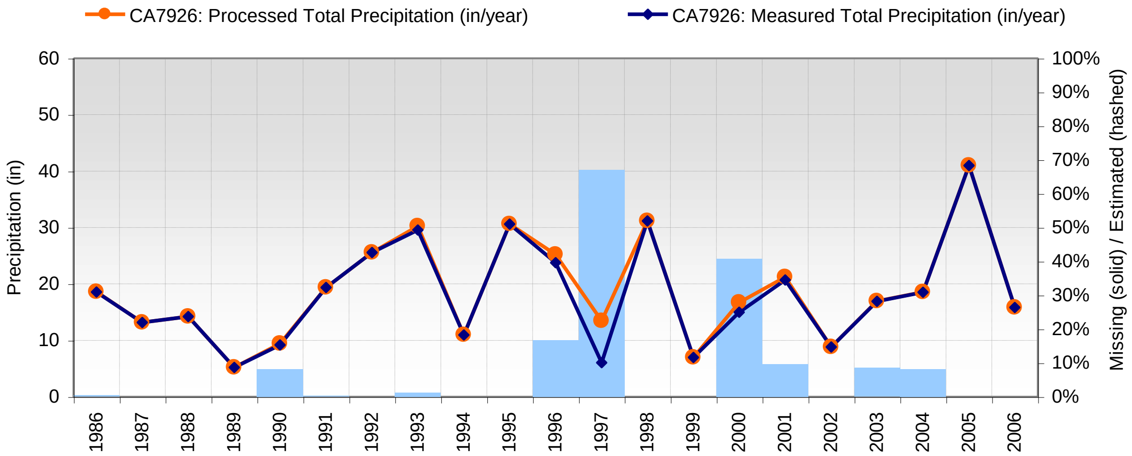


Figure A-17. Total precipitation at Santa Fe Dam (CA7926)

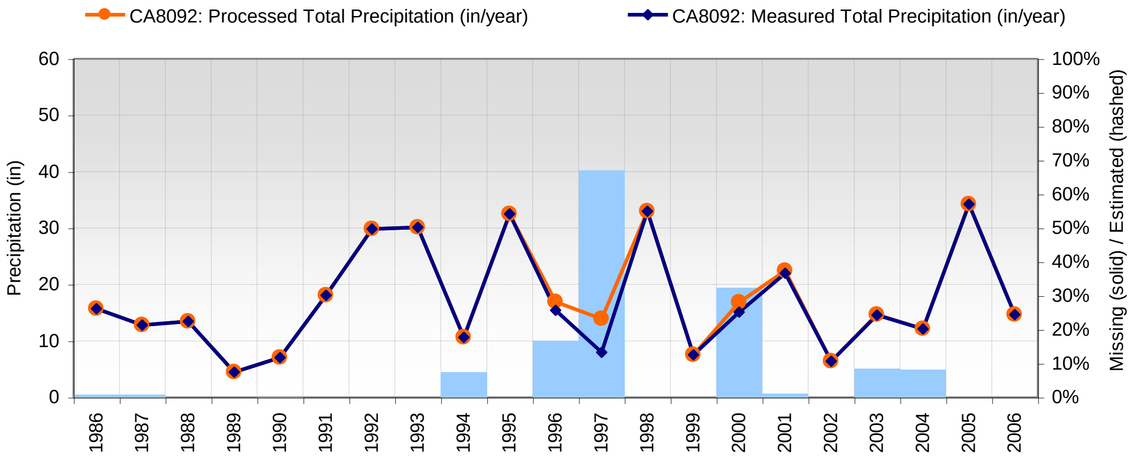


Figure A-18. Total precipitation at Sepulveda Dam (CA8092)

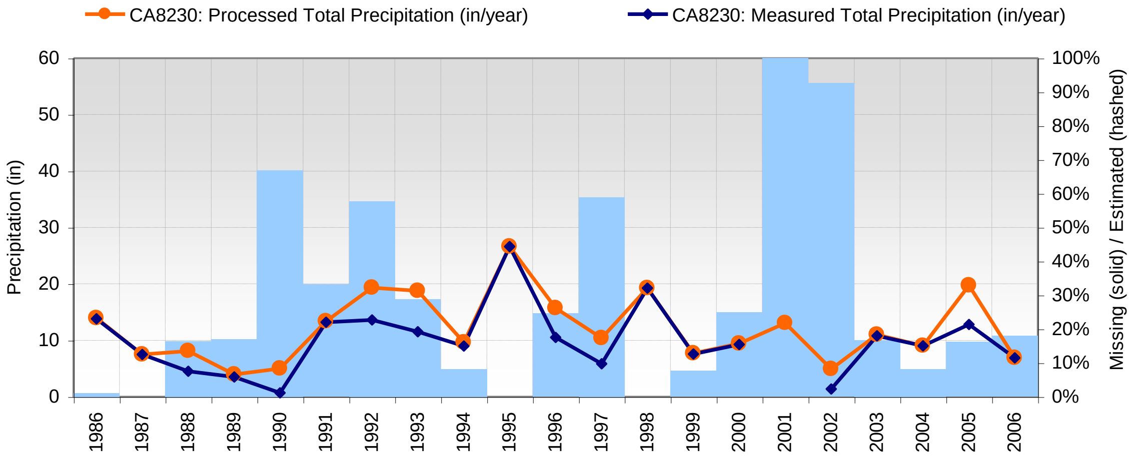


Figure A-19. Total precipitation at Signal Hill FC 415 (CA8230)

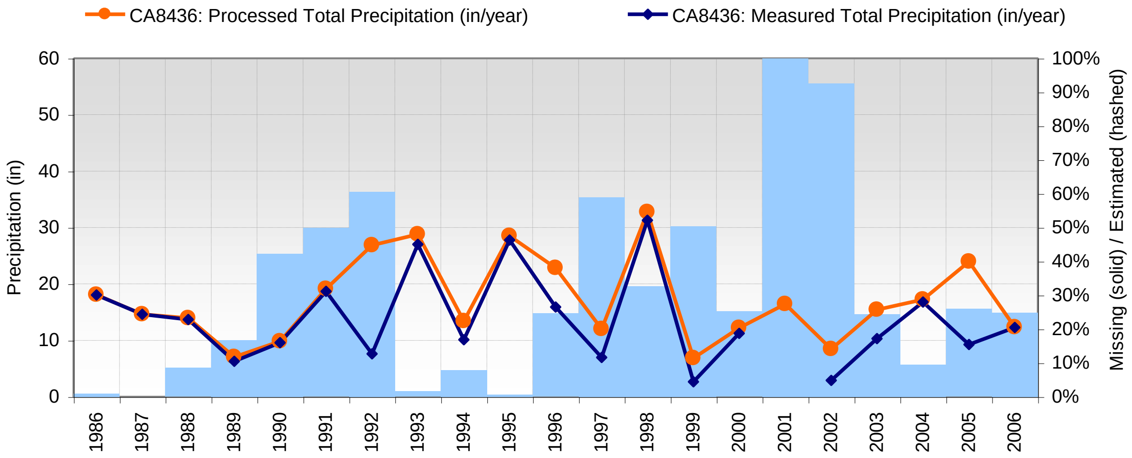


Figure A-20. Total precipitation at Spadra Lanterman Hosp (CA8436)

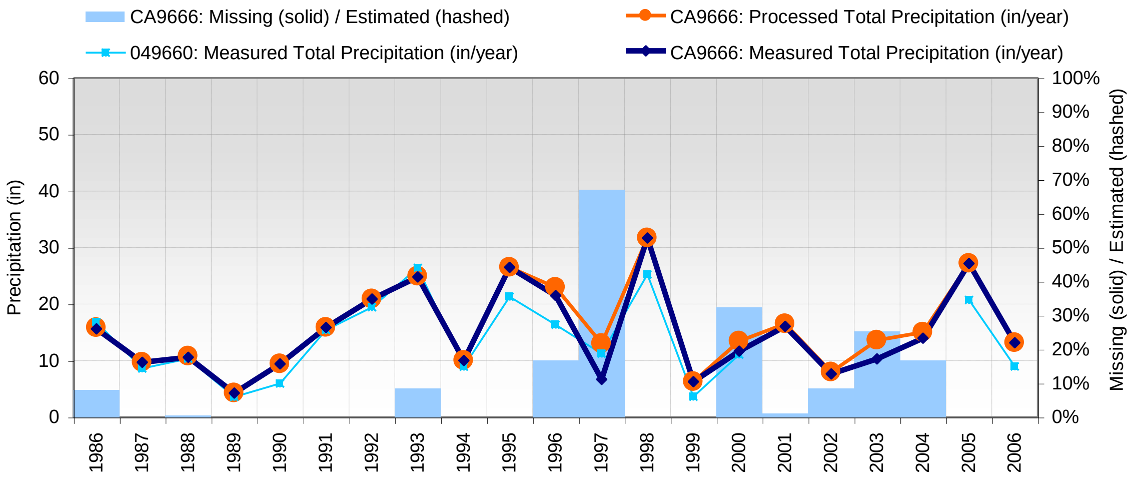


Figure A-21. Total precipitation at Whittier Narrows Dam (CA9666)

NCDC Summary of the Day Precipitation Gages

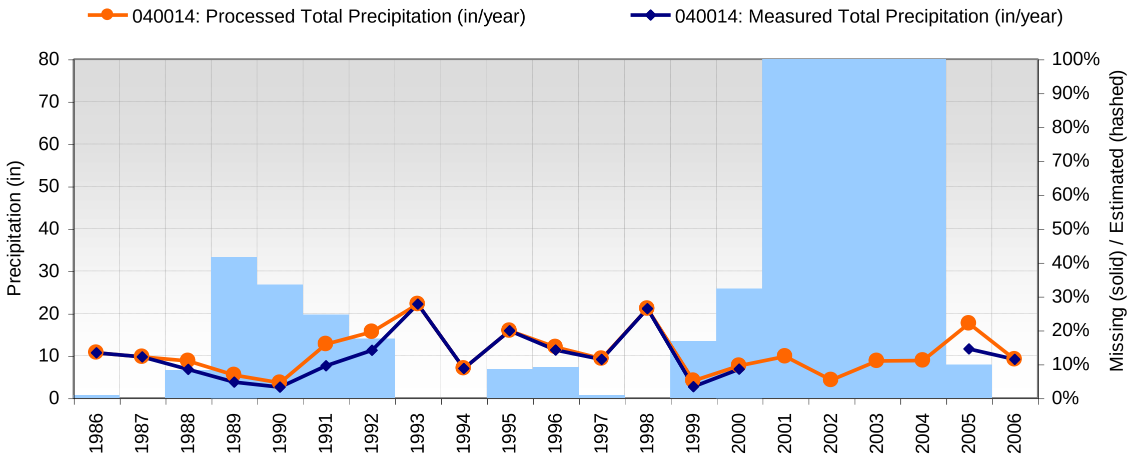


Figure A-22. Total precipitation at Acton Escondido FC261 (040014)

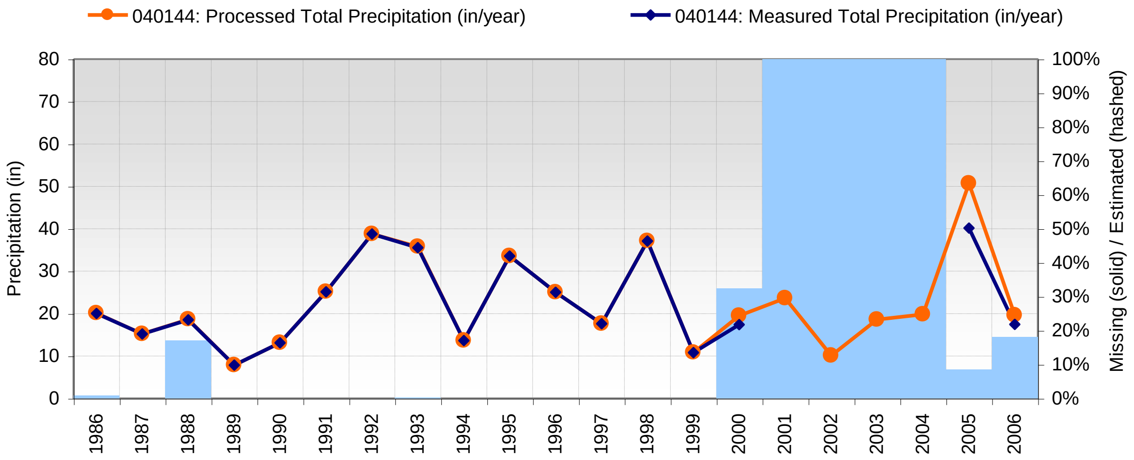


Figure A-23. Total precipitation at Altadena (040144)

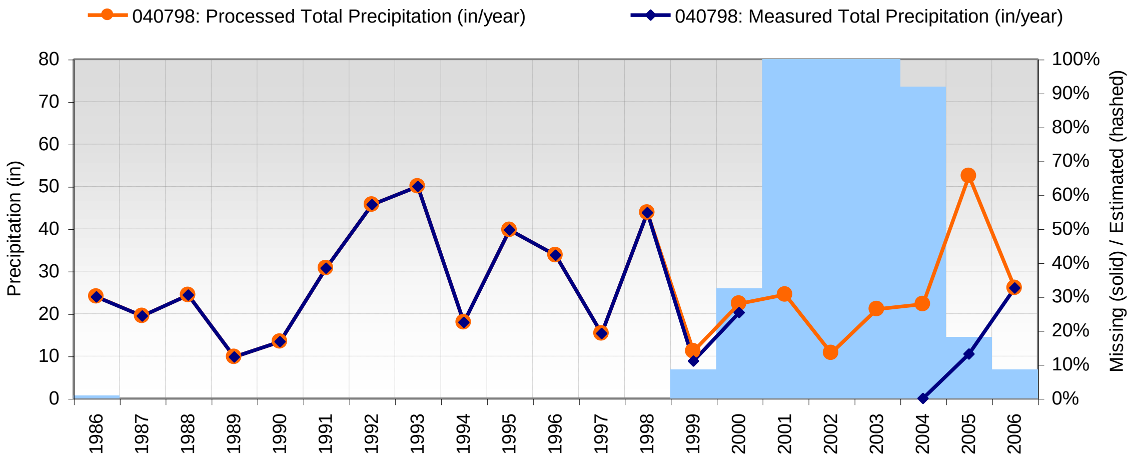


Figure A-24. Total precipitation at Big Tujunga Dam FC46DE (040798)

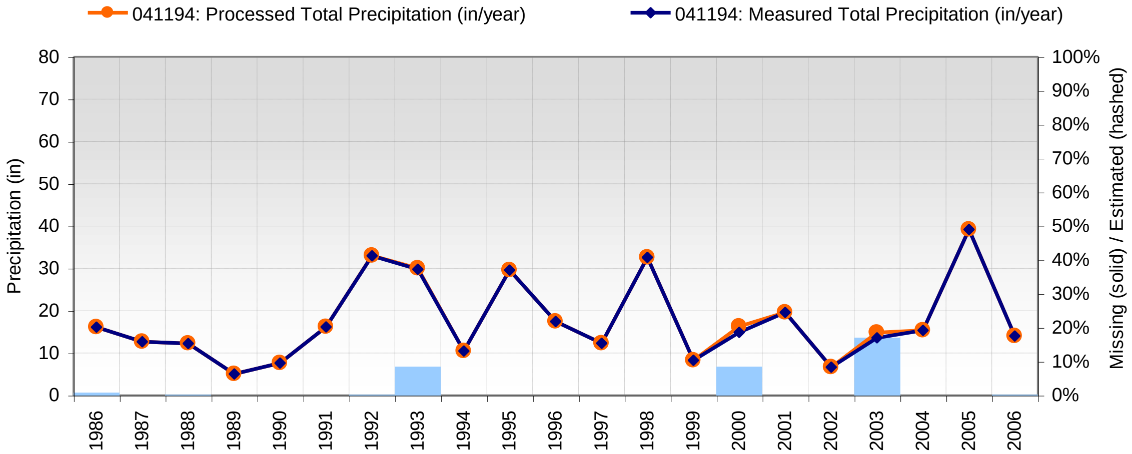


Figure A-25. Total precipitation at Burbank Valley Pump Pla (041194)

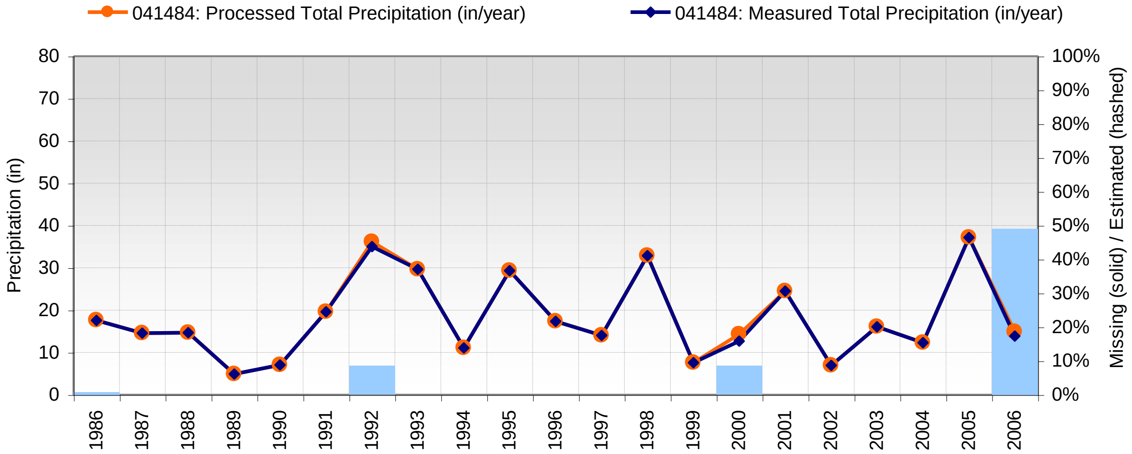


Figure A-26. Total precipitation at Canoga Park Pierce Coll (041484)

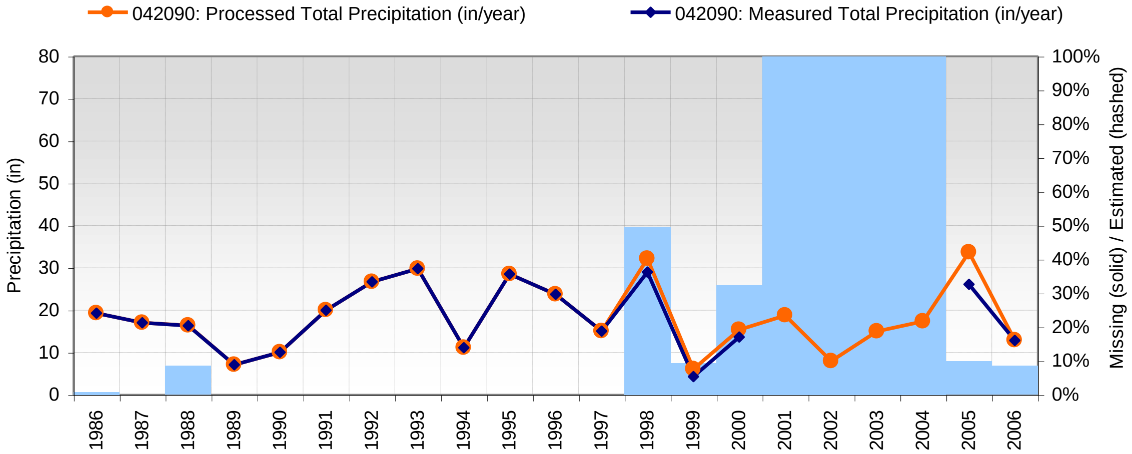


Figure A-27. Total precipitation at Covina City Yrd FC387B (042090)

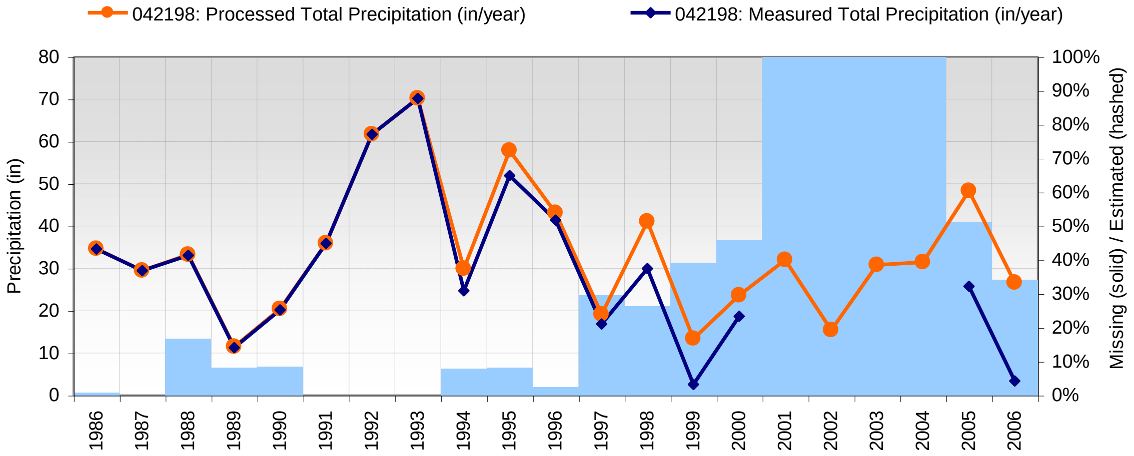


Figure A-28. Total precipitation at Crystal Lake FC238C (042198)

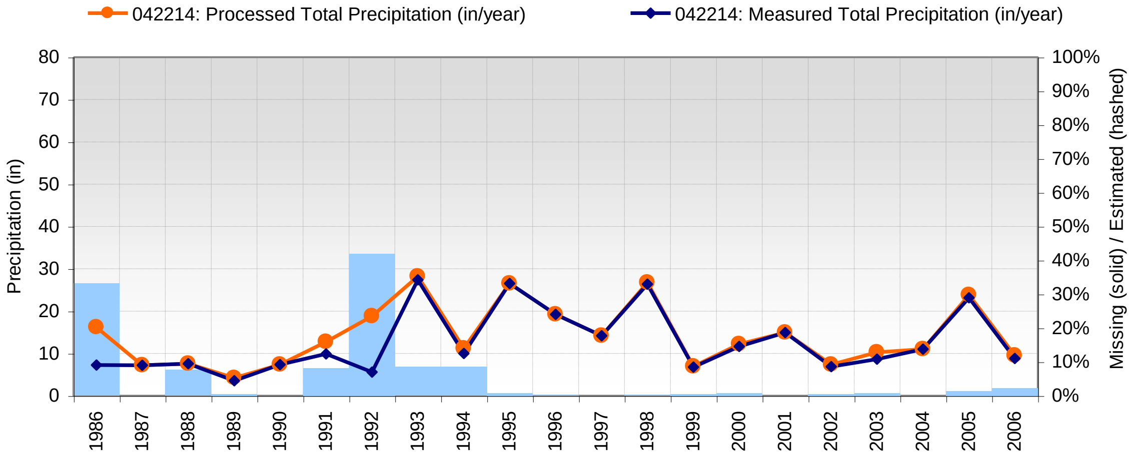


Figure A-29. Total precipitation at Culver City (042214)

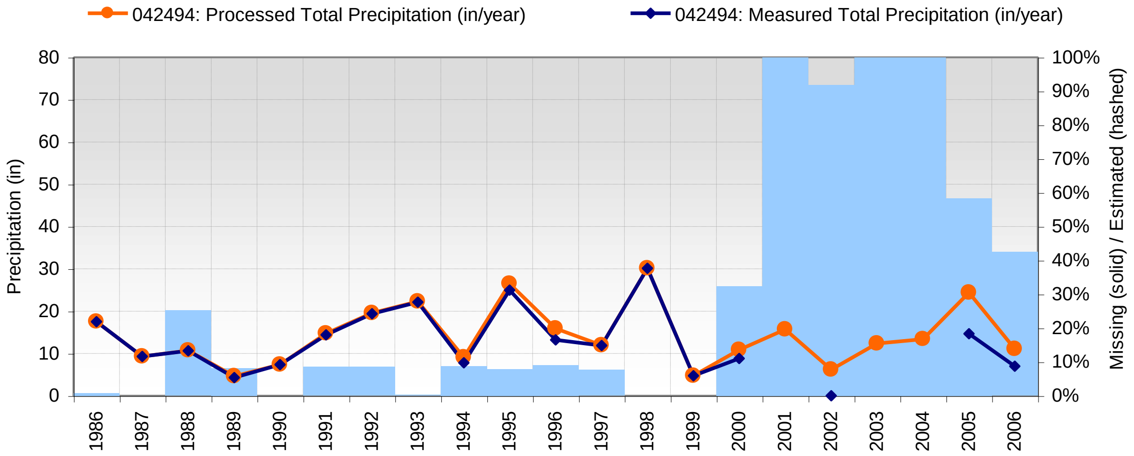


Figure A-30. Total precipitation at Downey FirE Stn FC107C (042494)

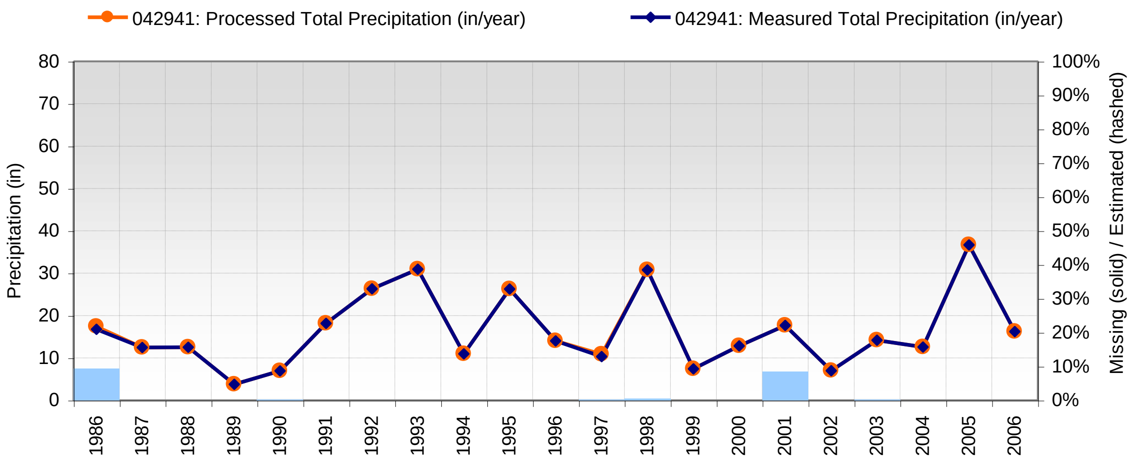


Figure A-31. Total precipitation at Fairmont (042941)

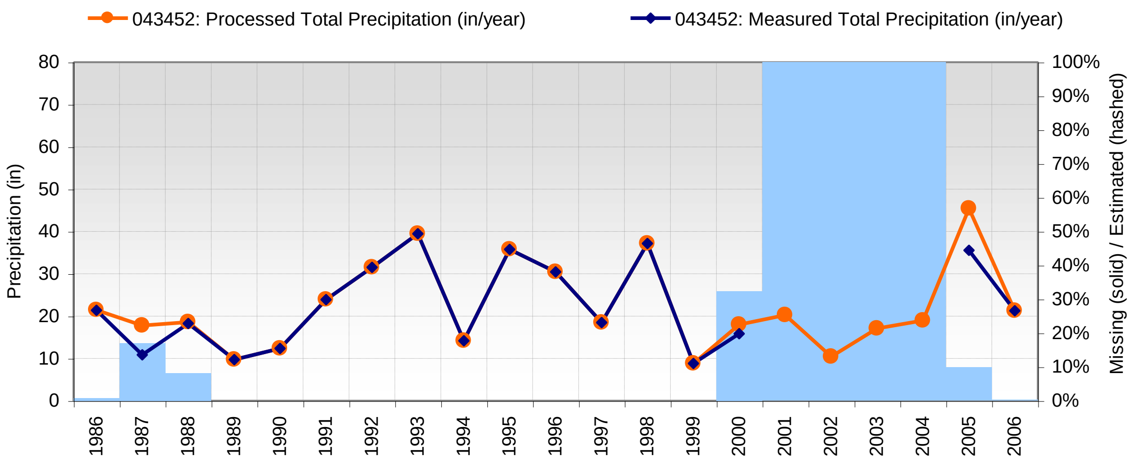


Figure A-32. Total precipitation at Glendora FC 287B (043452)

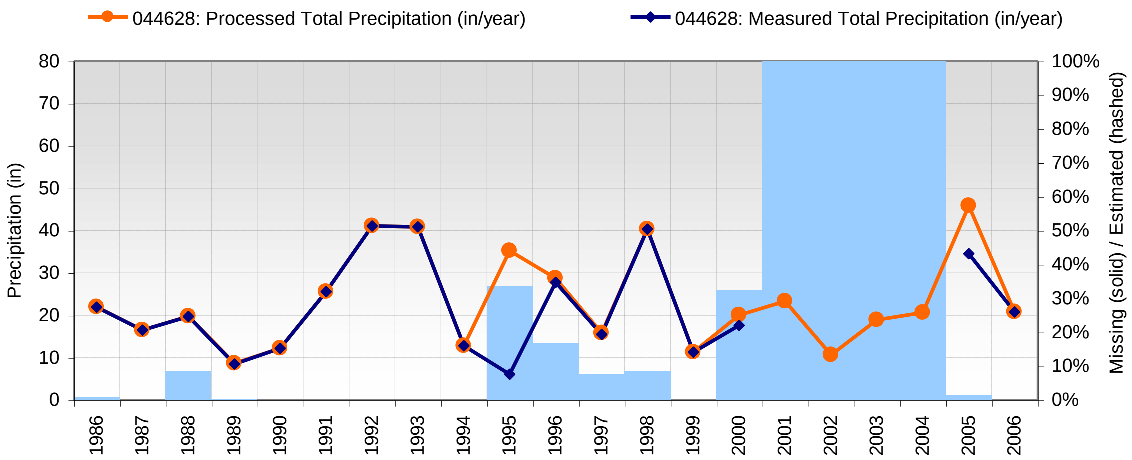


Figure A-33. Total precipitation at La Crescenta FC 251C (044628)

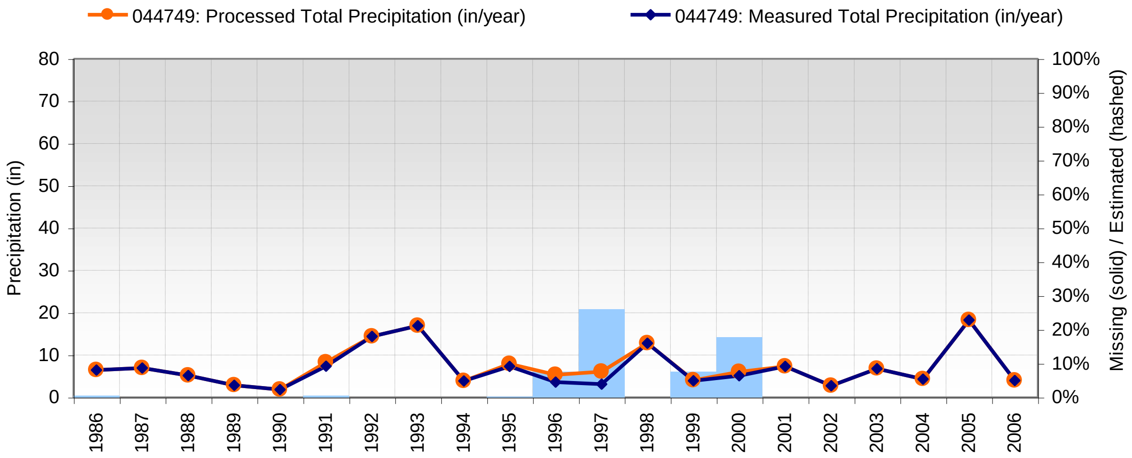


Figure A-34. Total precipitation at Lancaster ATC (044749)

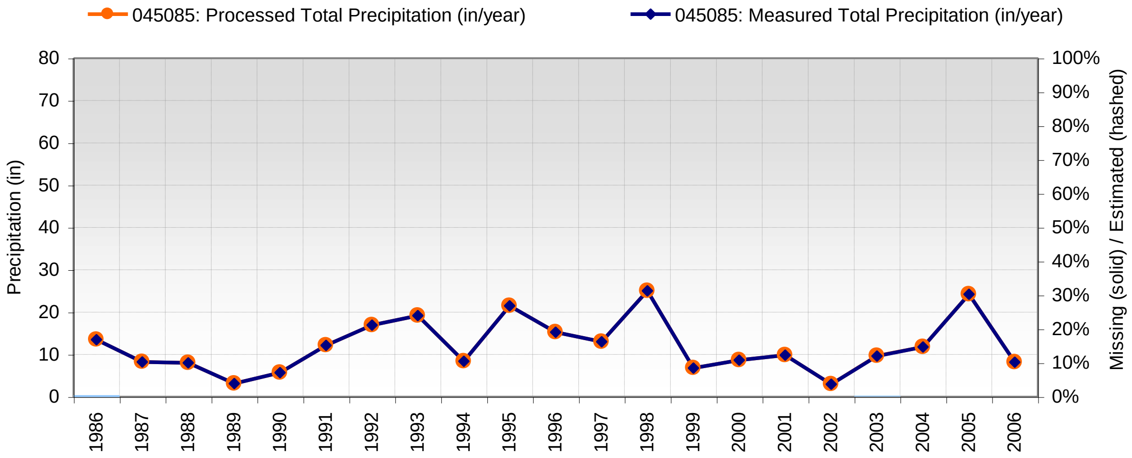


Figure A-35. Total precipitation at Long Beach AP (045085)

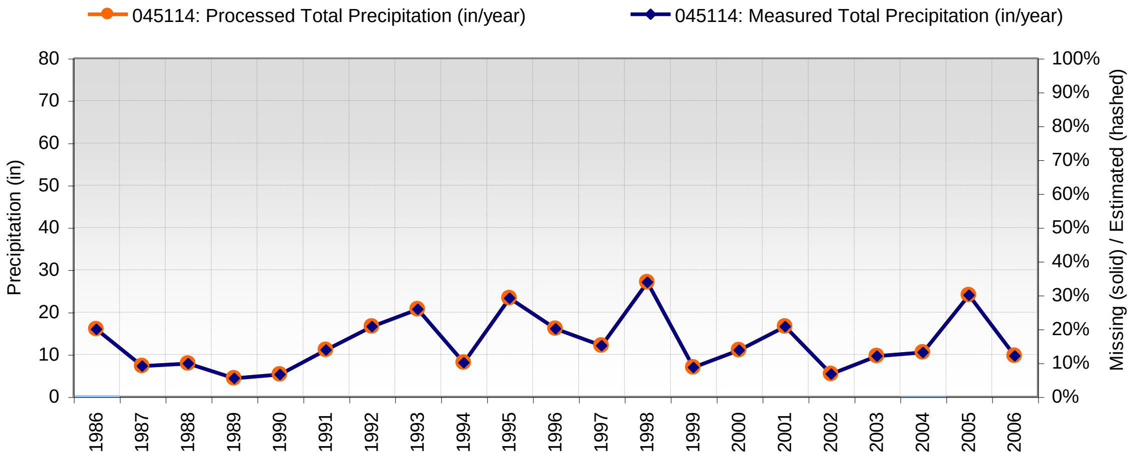


Figure A-36. Total precipitation at Los Angeles Intl Ap (045114)

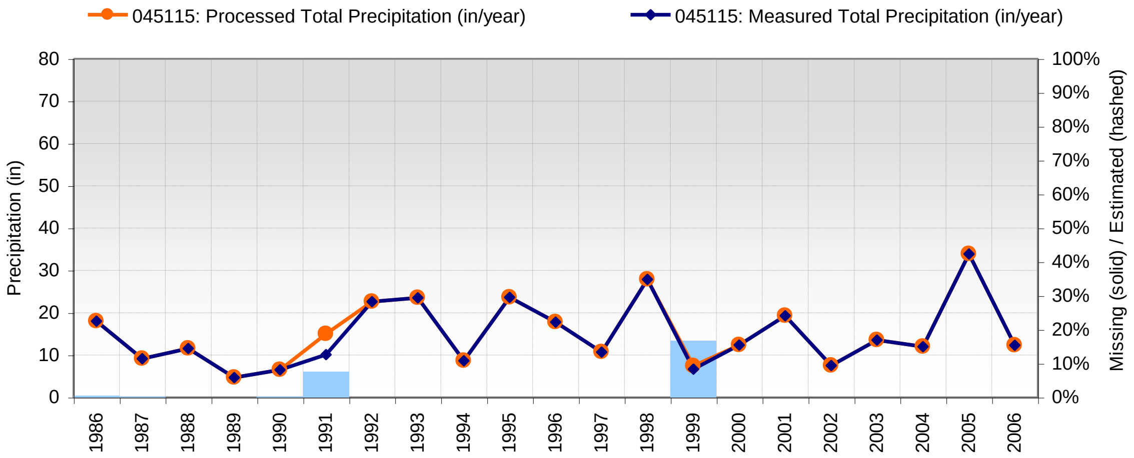


Figure A-37. Total precipitation at Los Angeles Downtown (045115)

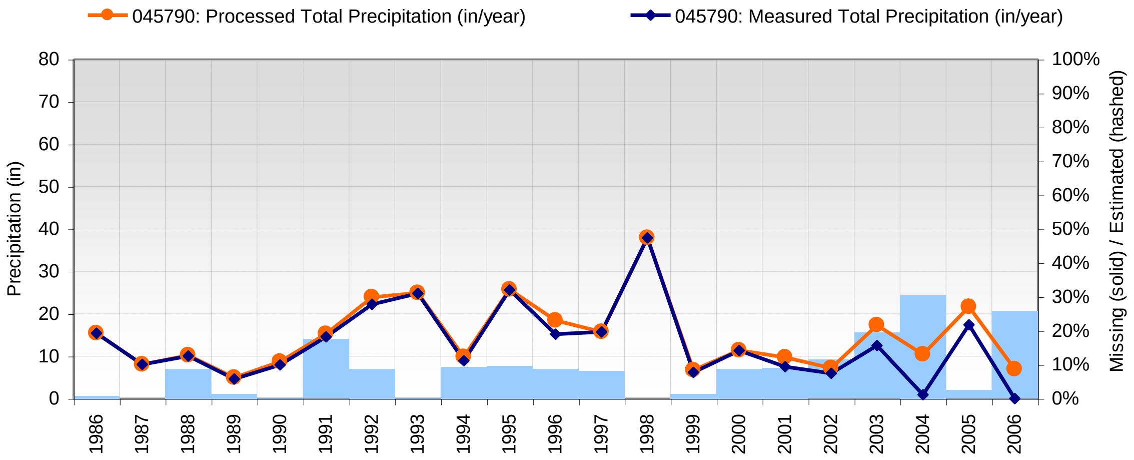


Figure A-38. Total precipitation at Montebello (045790)

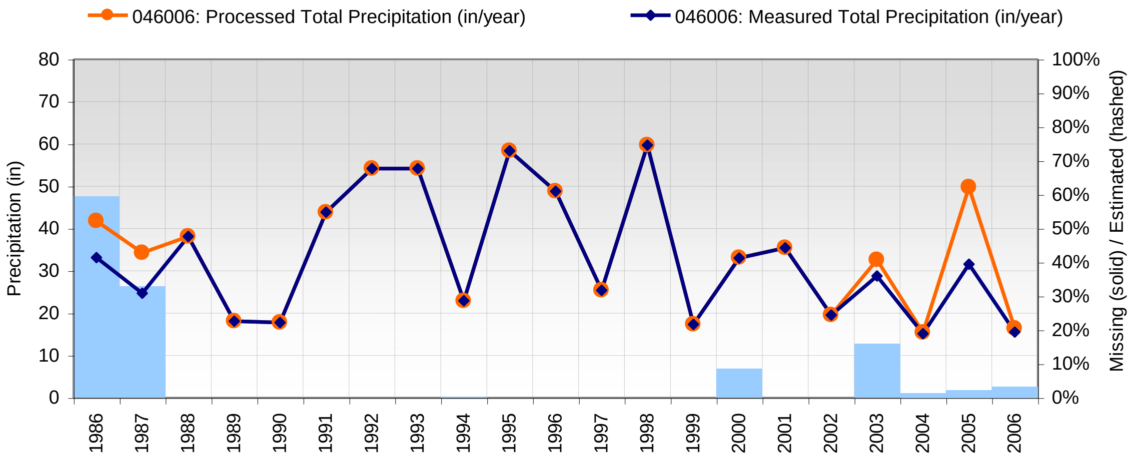


Figure A-39. Total precipitation at Mt Wilson No 2 (046006)

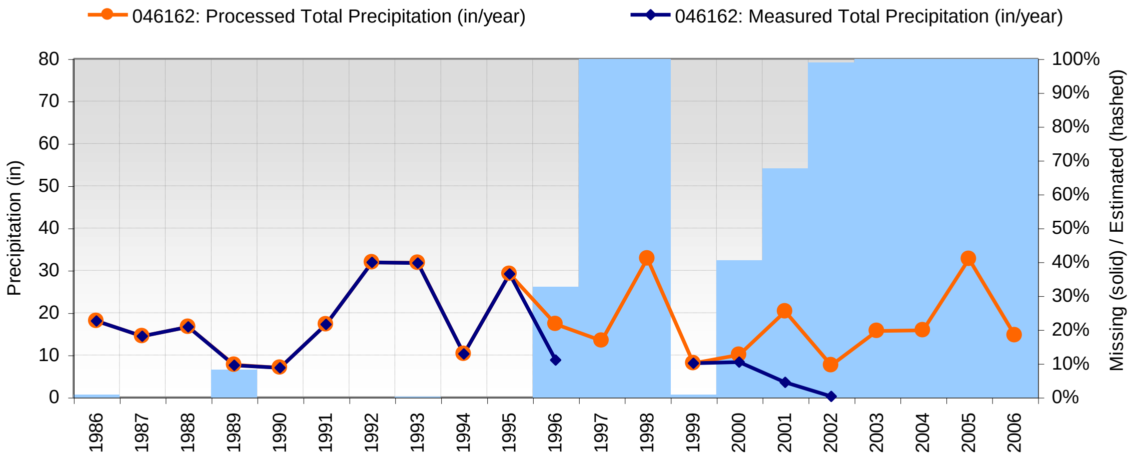


Figure A-40. Total precipitation at Newhall S FC32CE (046162)

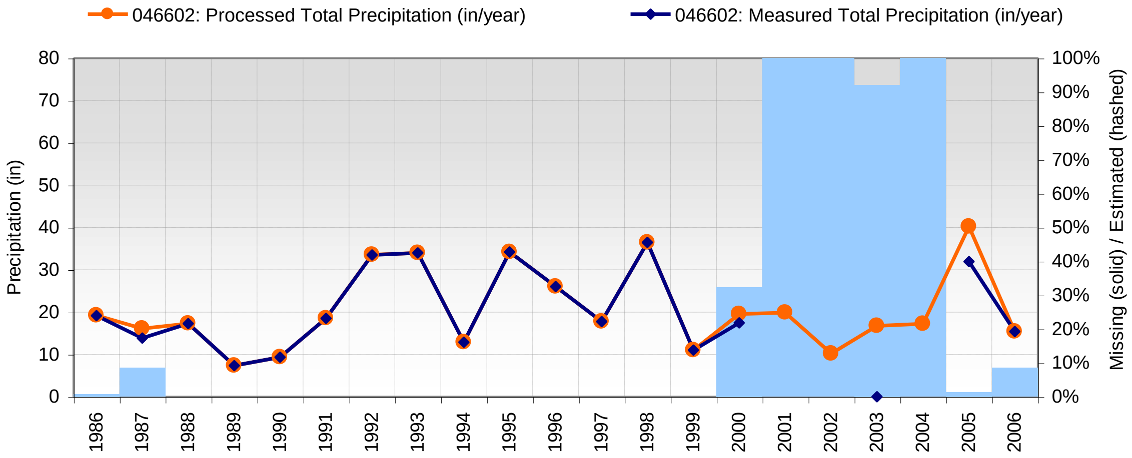


Figure A-41. Total precipitation at Pacoima Dam FC 33 A-E (046602)

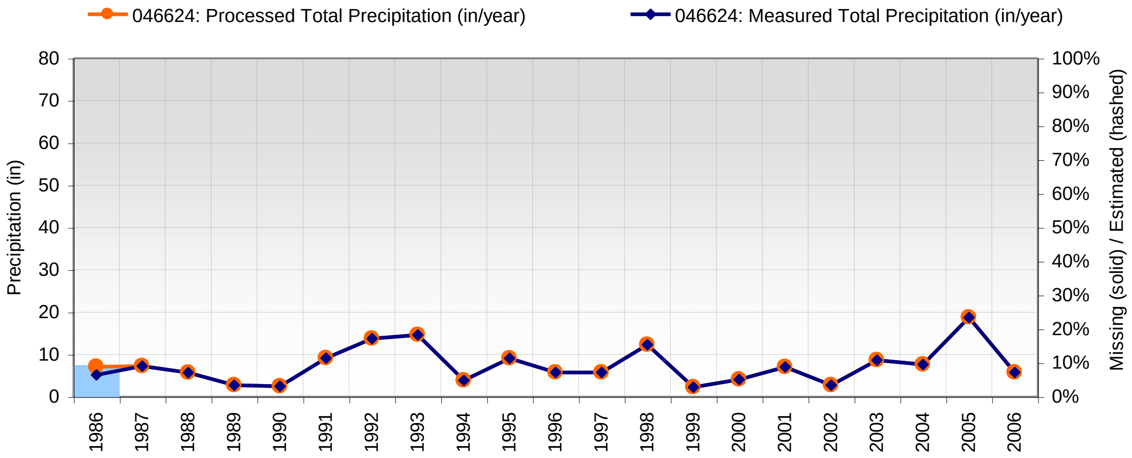


Figure A-42. Total precipitation at Palmdale (046624)

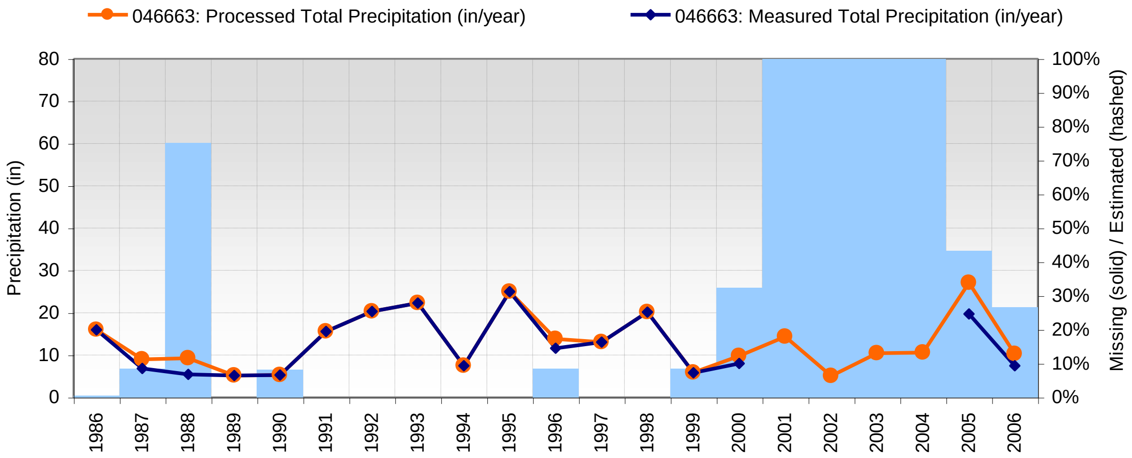


Figure A-43. Total precipitation at Palos Verdes Est FC43D (046663)

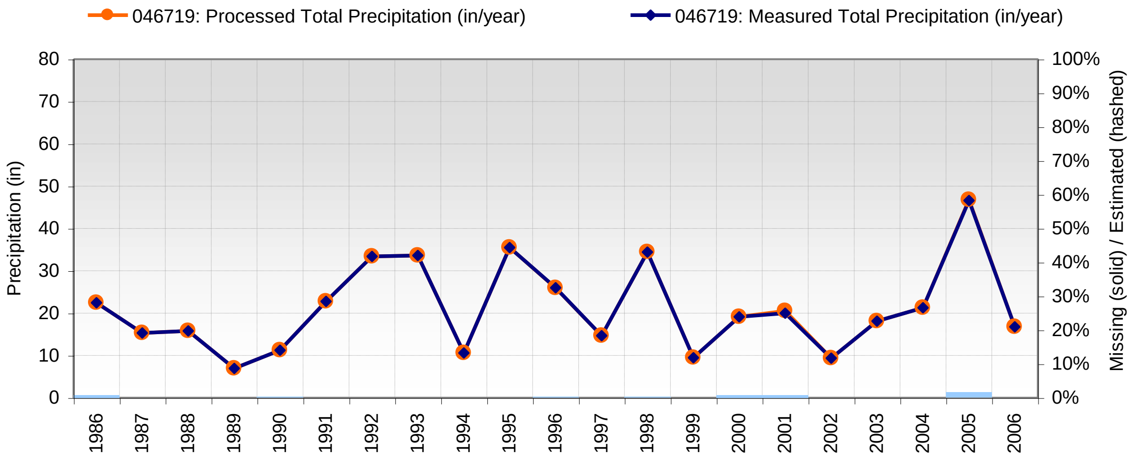


Figure A-44. Total precipitation at Pasadena (046719)

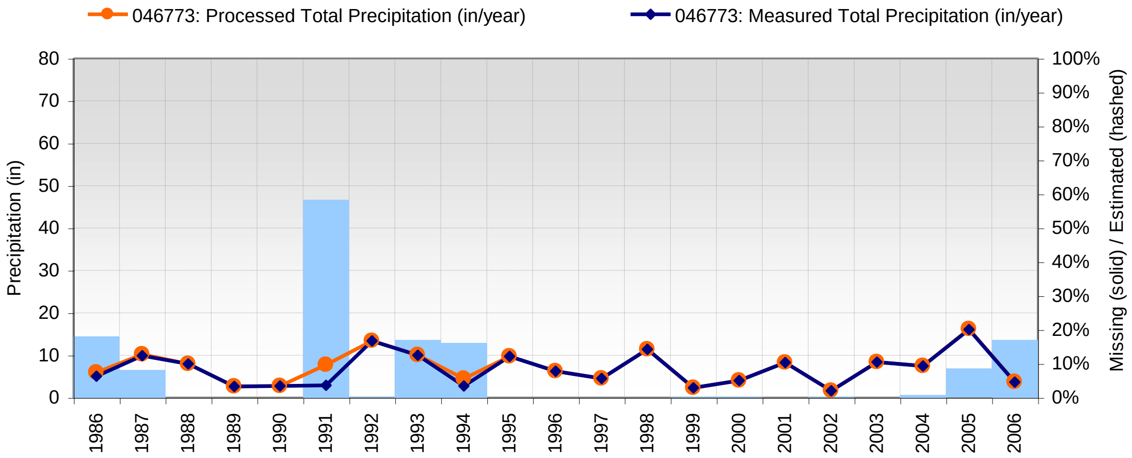


Figure A-45. Total precipitation at Pearblossom (046773)

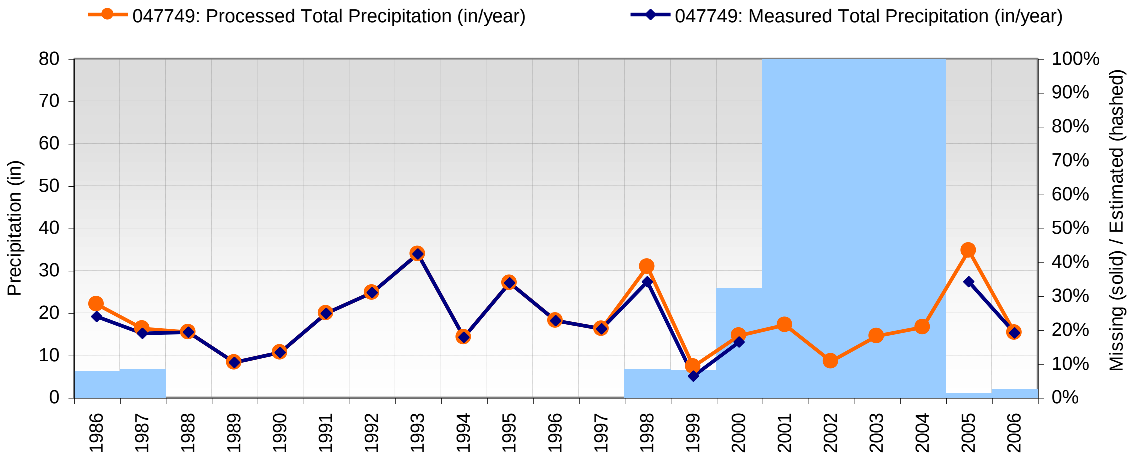


Figure A-46. Total precipitation at San Dimas Fire FC95 (047749)

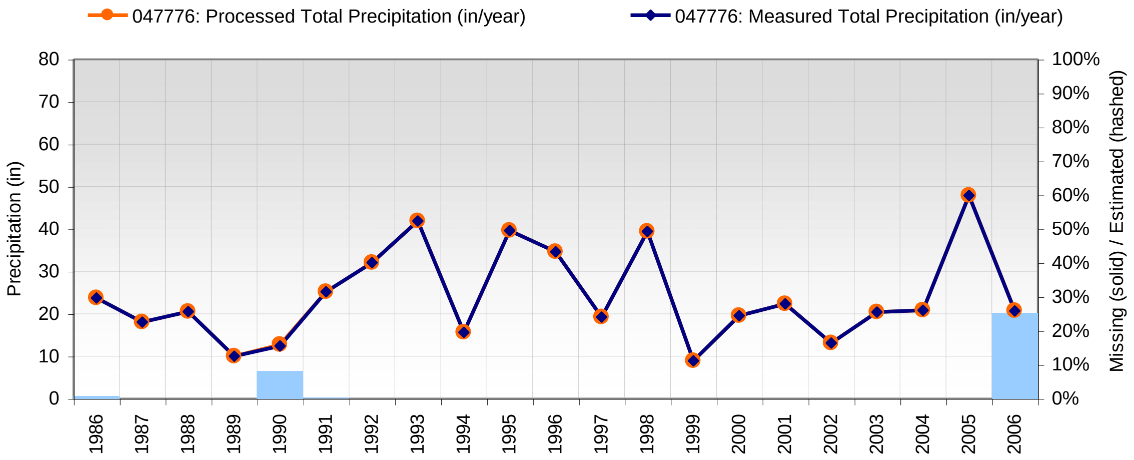


Figure A-47. Total precipitation at San Gabriel Canyon P H (047776)

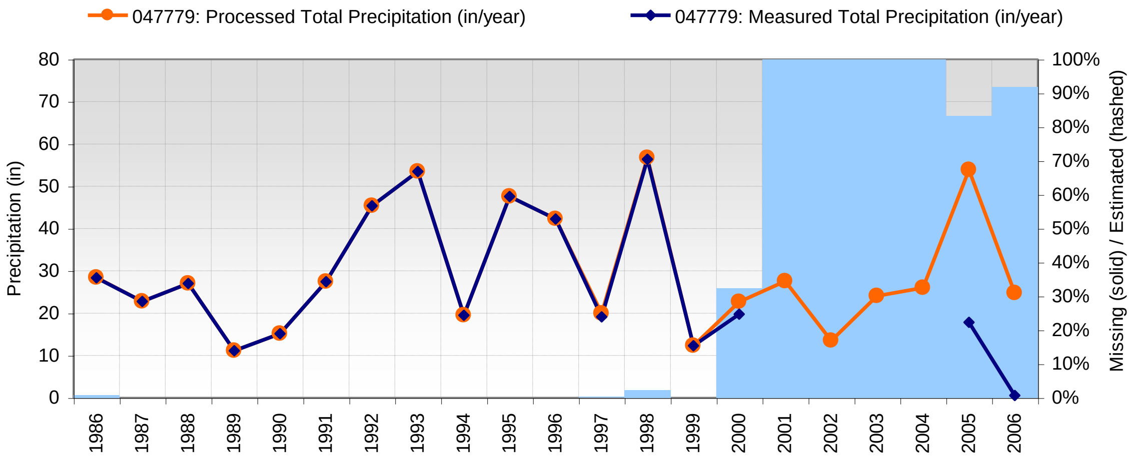


Figure A-48. Total precipitation at San Gabriel Dam FC425B (047779)

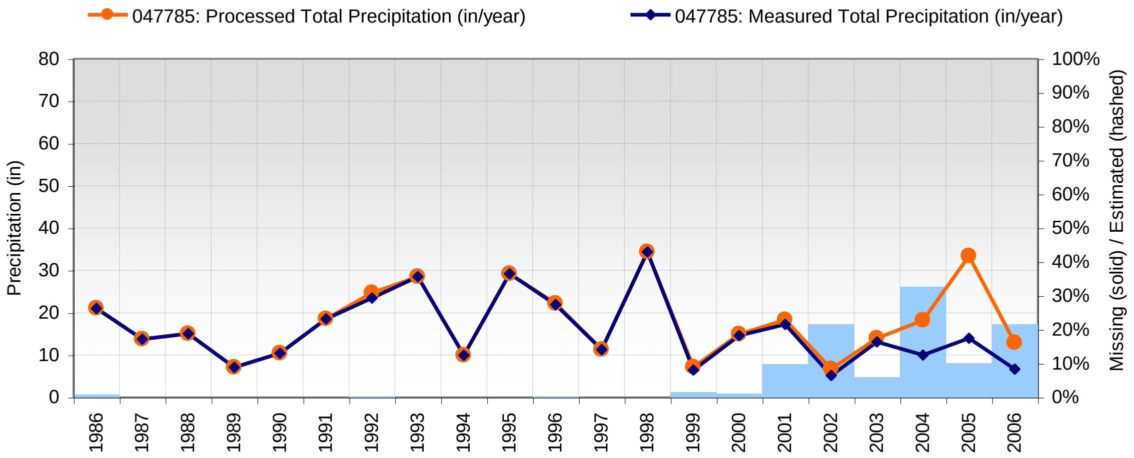


Figure A-49. Total precipitation at San Gabriel Fire Dept (047785)

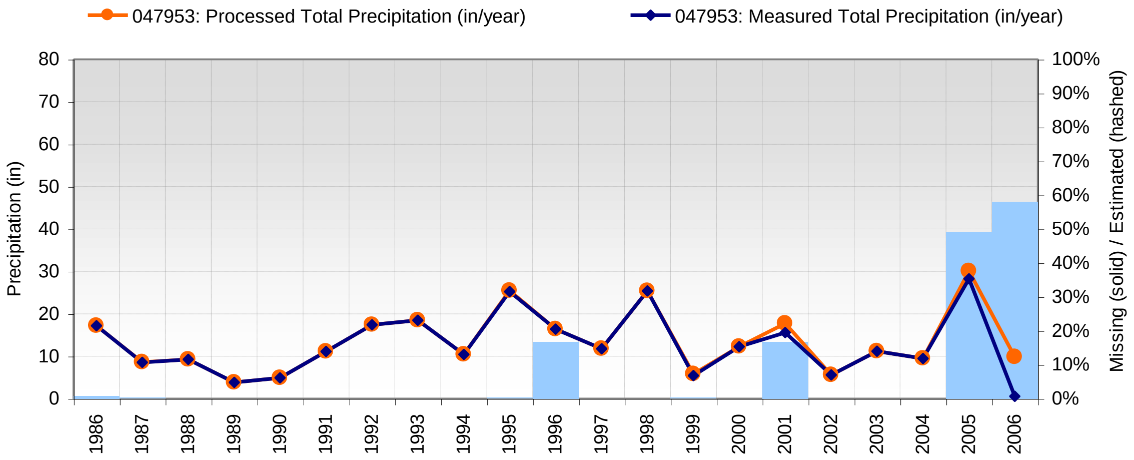


Figure A-50. Total precipitation at Santa Monica Pier (047953)

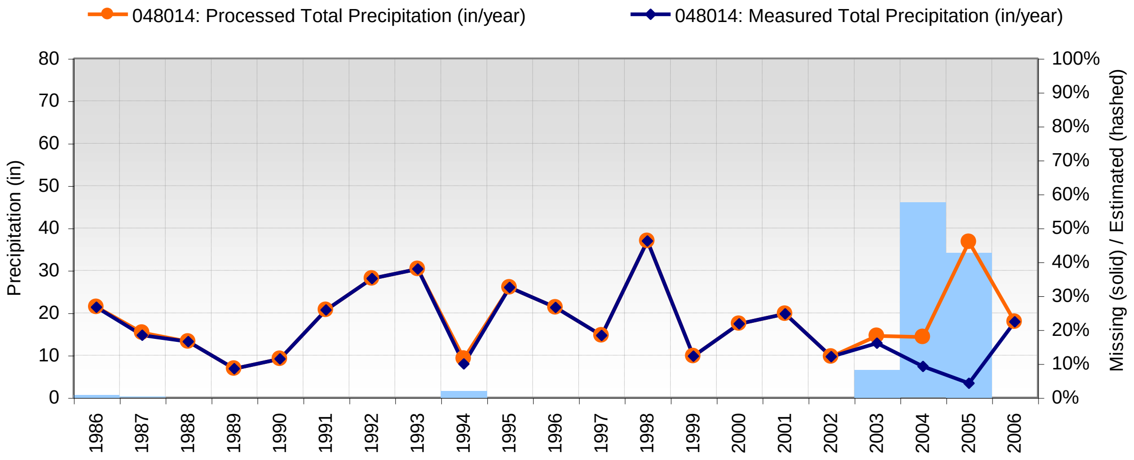


Figure A-51. Total precipitation at Saugus Power Plant 1 (048014)

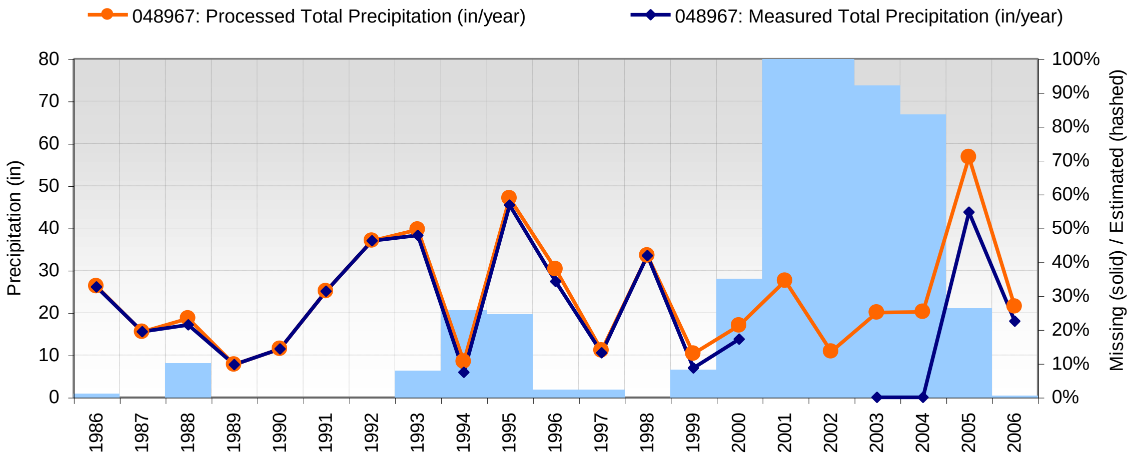


Figure A-52. Total precipitation at Topanga Patrol Stn FC6 (048967)

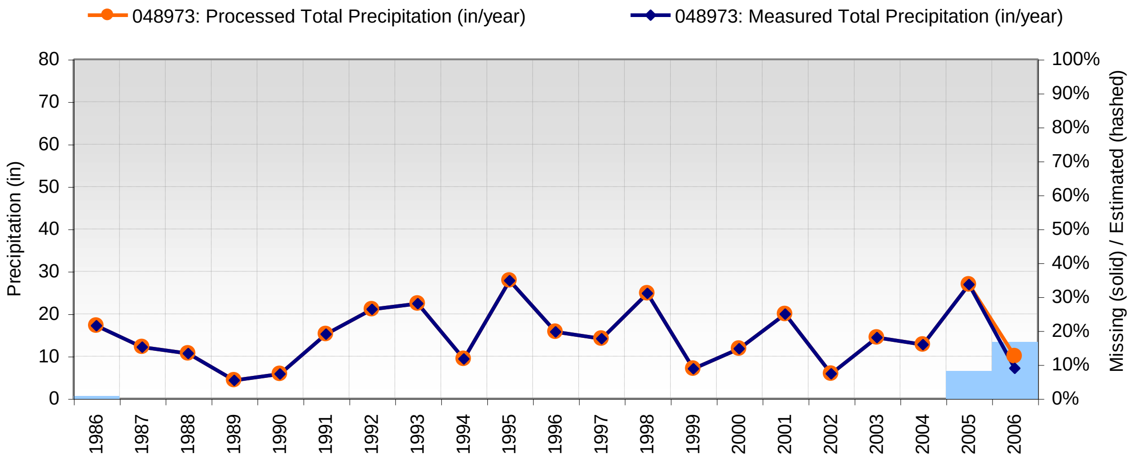


Figure A-53. Total precipitation at Torrance (048973)

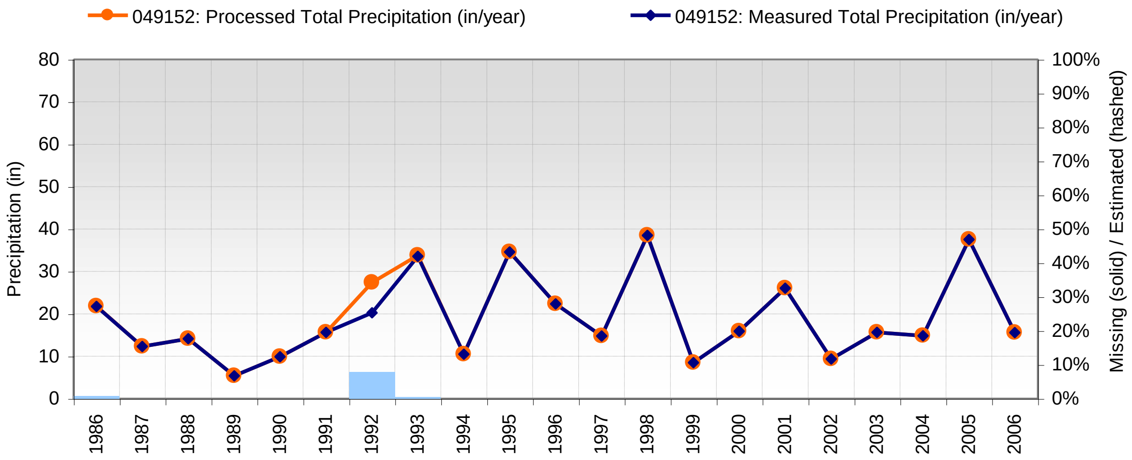


Figure A-54. Total precipitation at UCLA (049152)

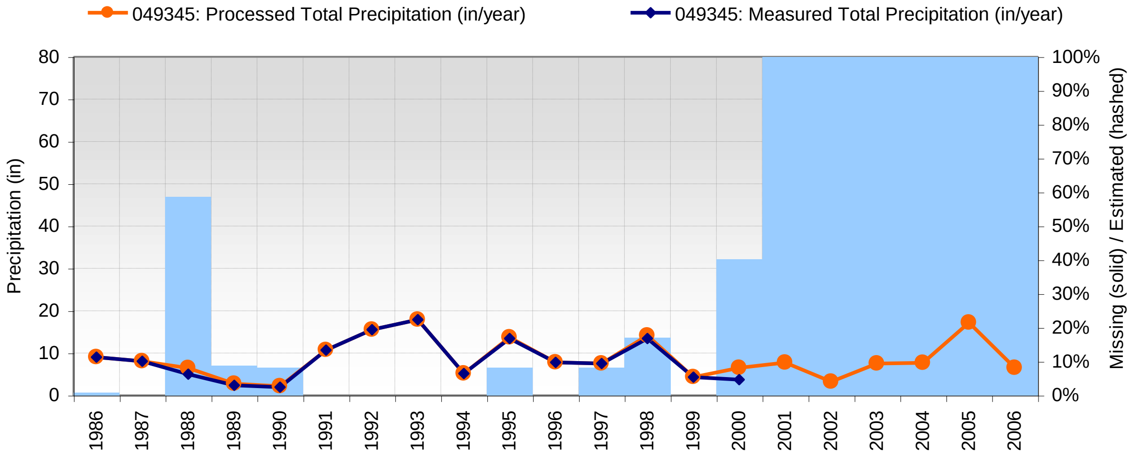


Figure A-55. Total precipitation at Vincent FS FC 120 (049345)

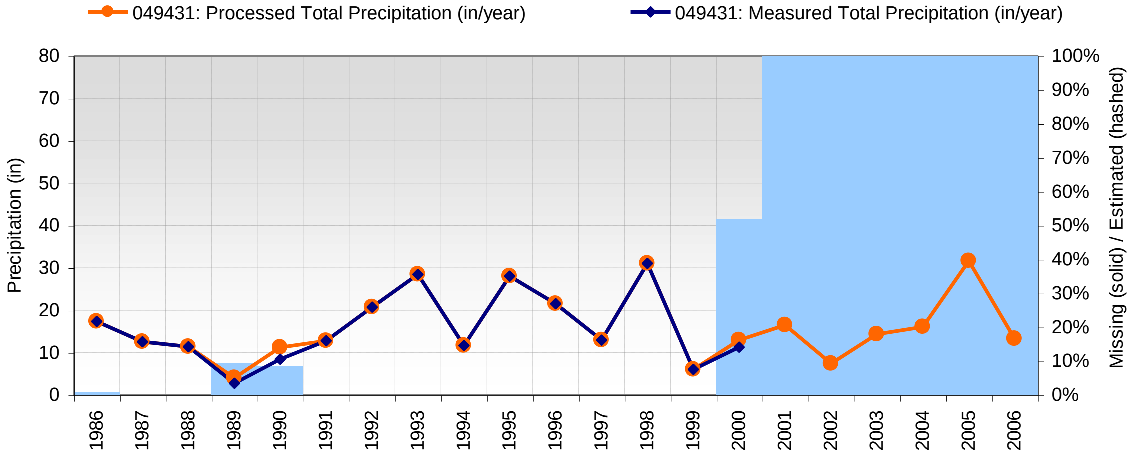


Figure A-56. Total precipitation at Walnut NI FC102C (049431)

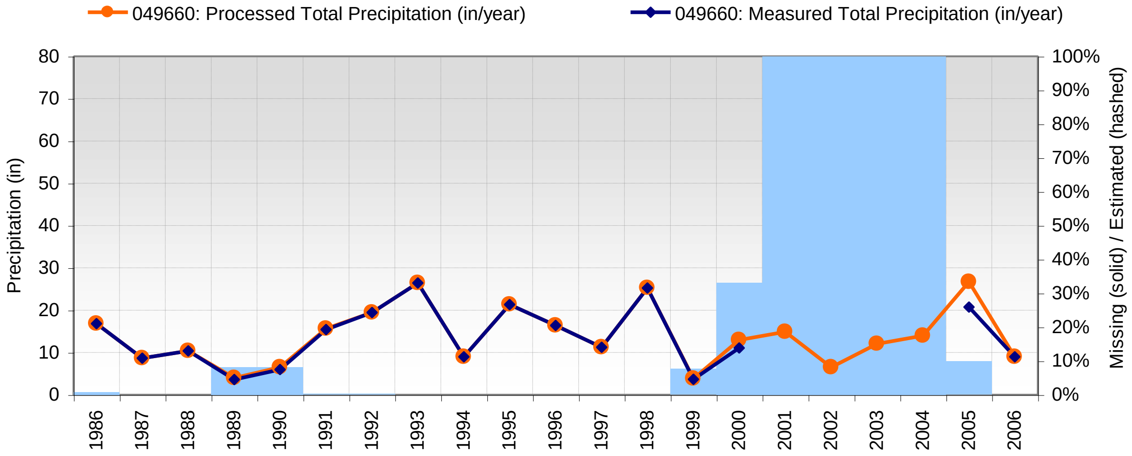


Figure A-57. Total precipitation at Whittier City YD FC106C (049660)

LACDPW Daily Precipitation Gages

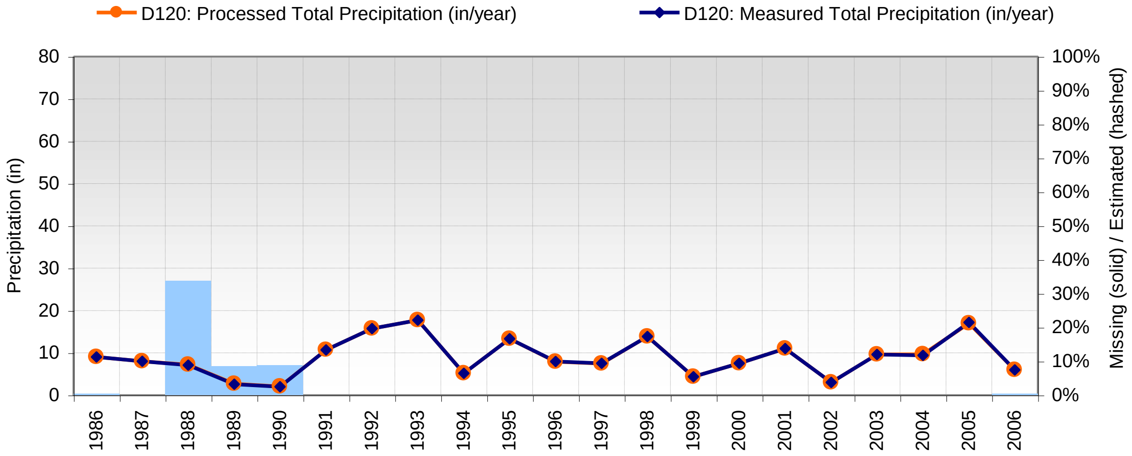


Figure A-58. Total precipitation at Vincent Patrol Station (D120)

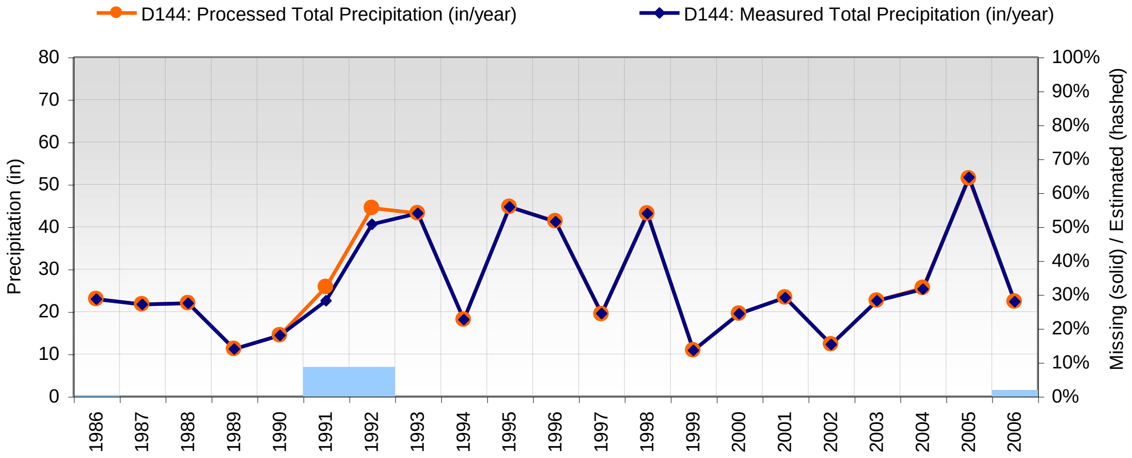


Figure A-59. Total precipitation at Sierra Madre Dam (D144)

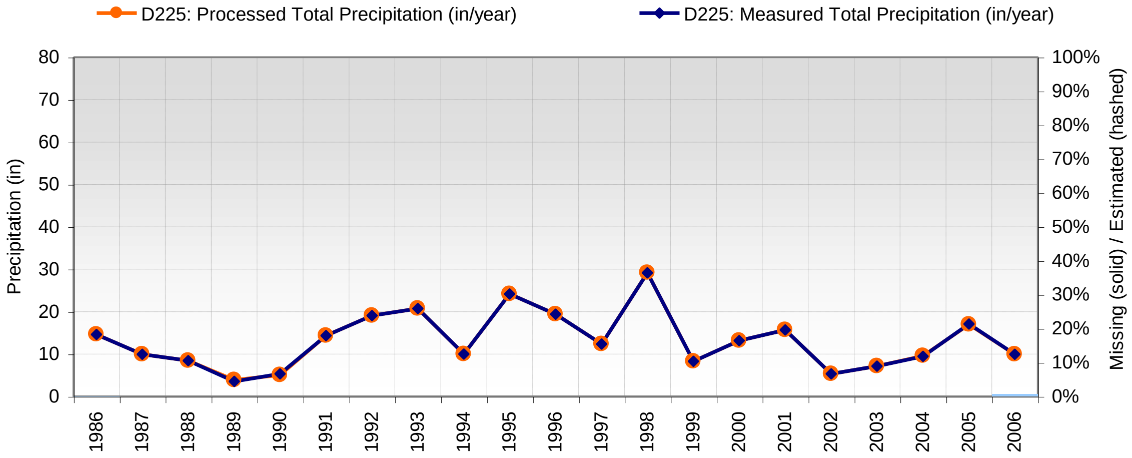


Figure A-60. Total precipitation at Wheeler Canyon (D225)

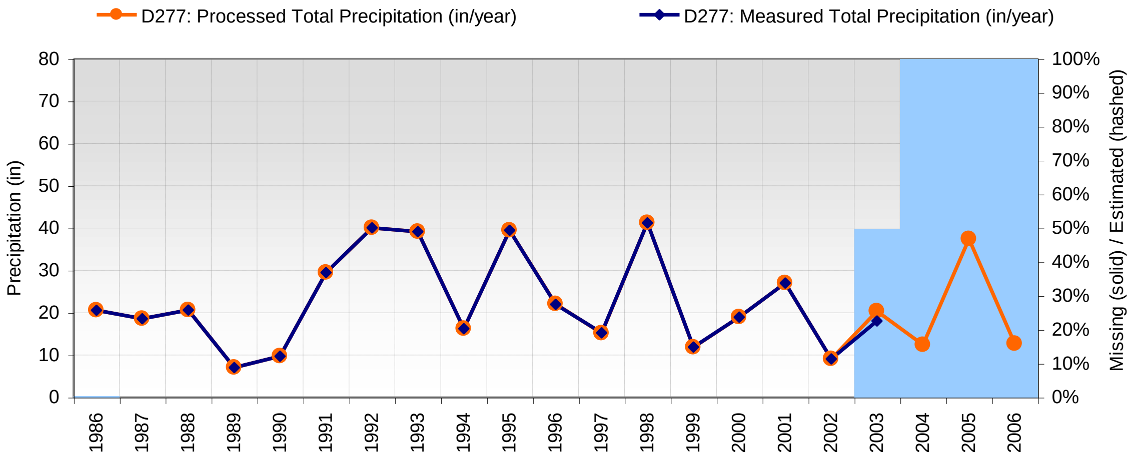


Figure A-61. Total precipitation at Sawmill Mountain (D277)

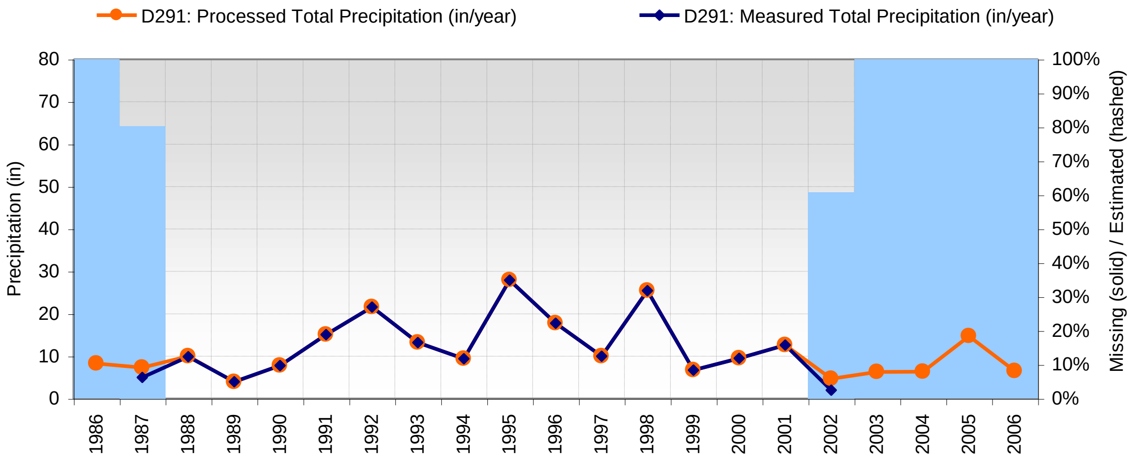


Figure A-62. Total precipitation at Los Angeles 96th and Central (D291)

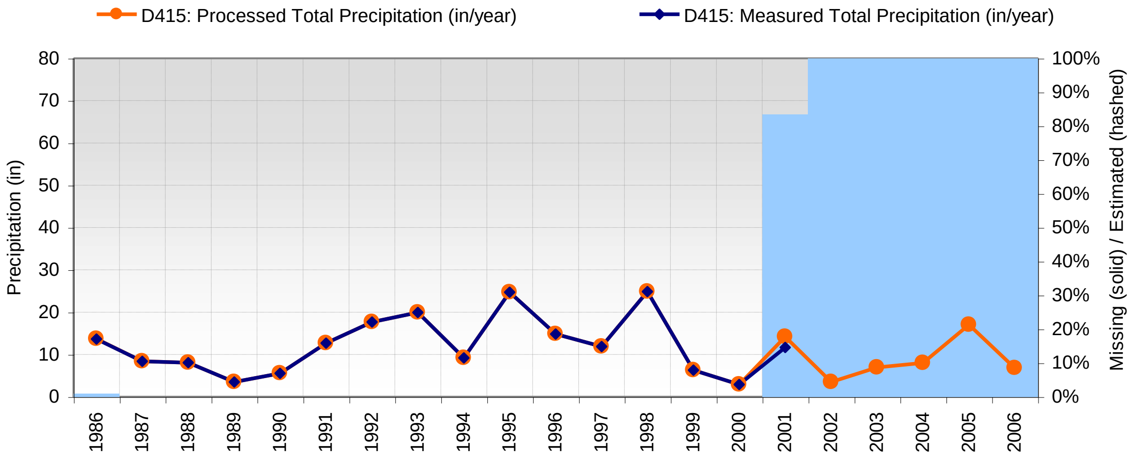


Figure A-63. Total precipitation at Signal Hill City Hall (D415)

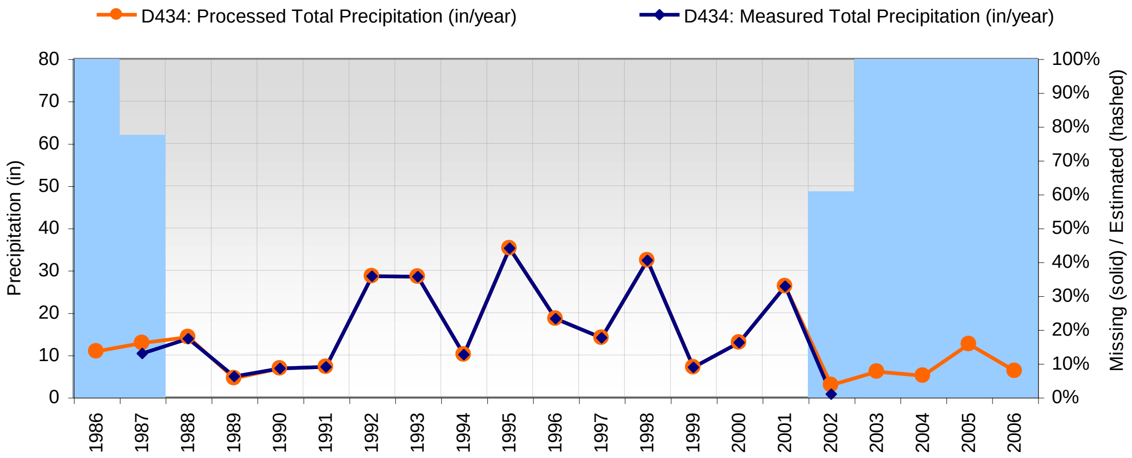


Figure A-64. Total precipitation at Agoura (D434)

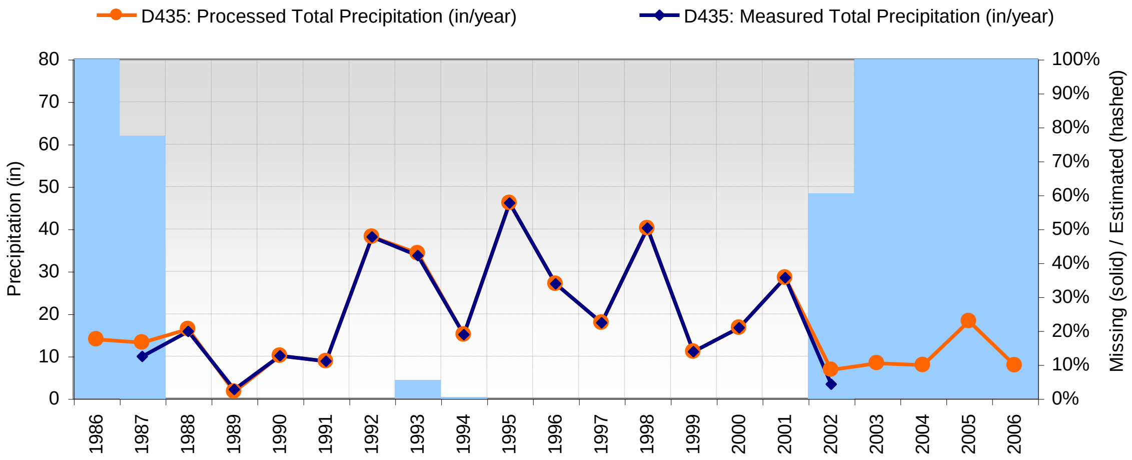


Figure A-65. Total precipitation at Monte Nido (D435)

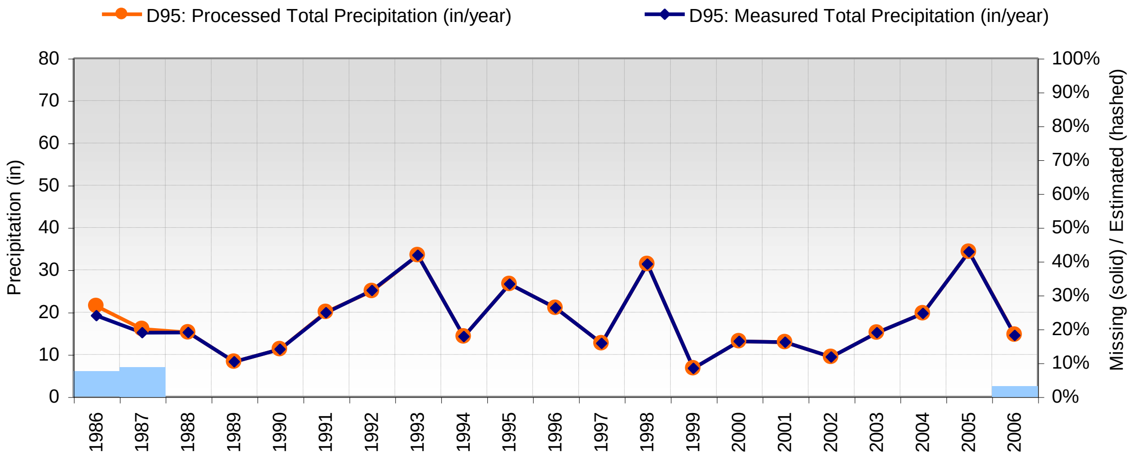


Figure A-66. Total precipitation at San Dimas Fire Warden (D95)

LACFCD Daily Precipitation Gages

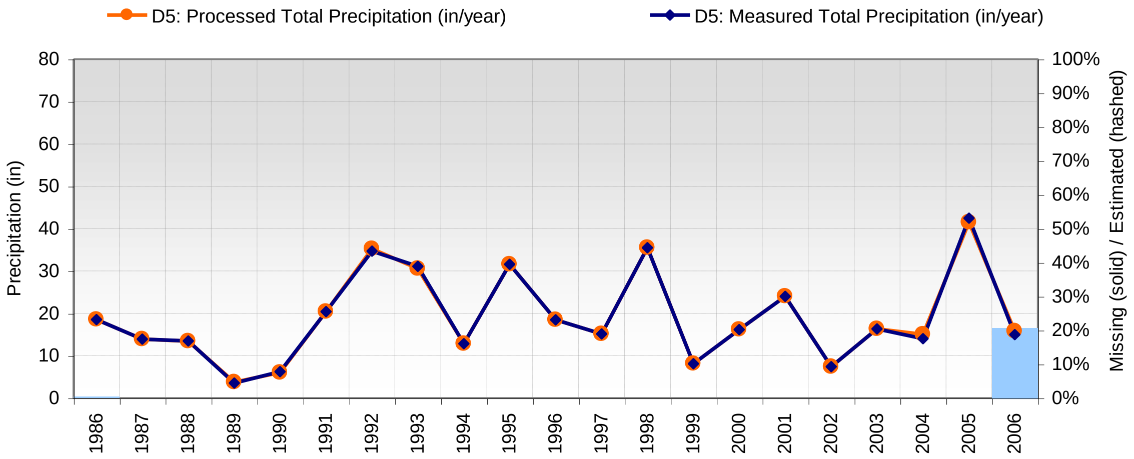


Figure A-67. Total precipitation at Calabasas (D5)

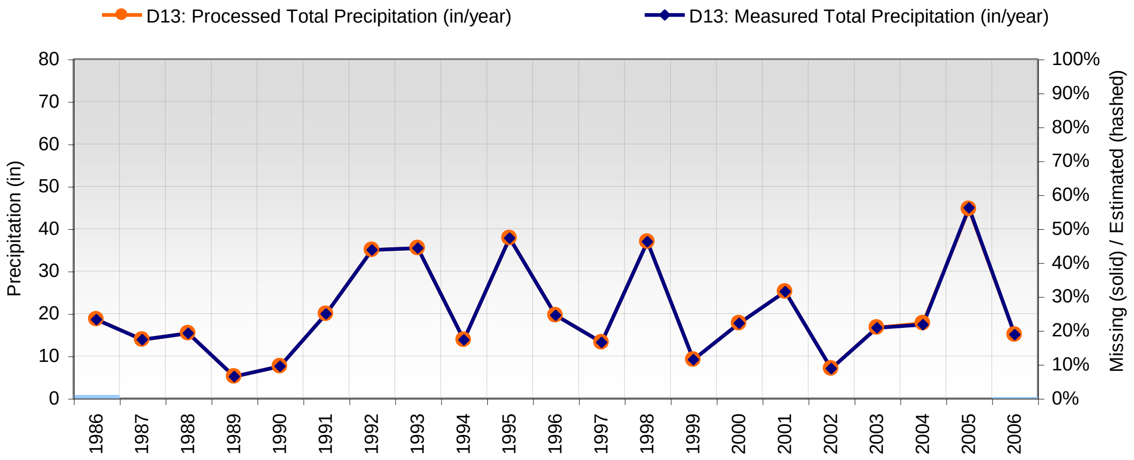


Figure A-68. Total precipitation at North Hollywood Lakeside (D13)

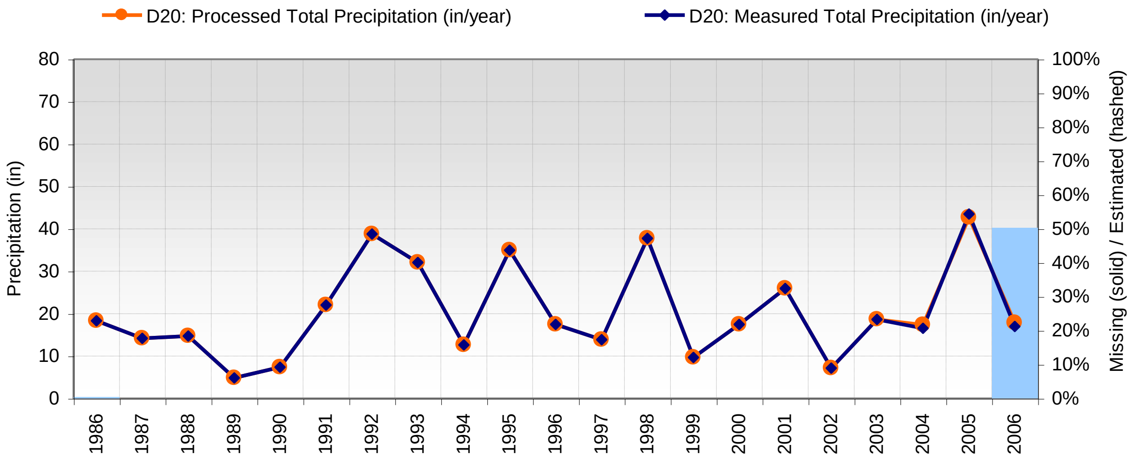


Figure A-69. Total precipitation at Girard Reservoir (D20)

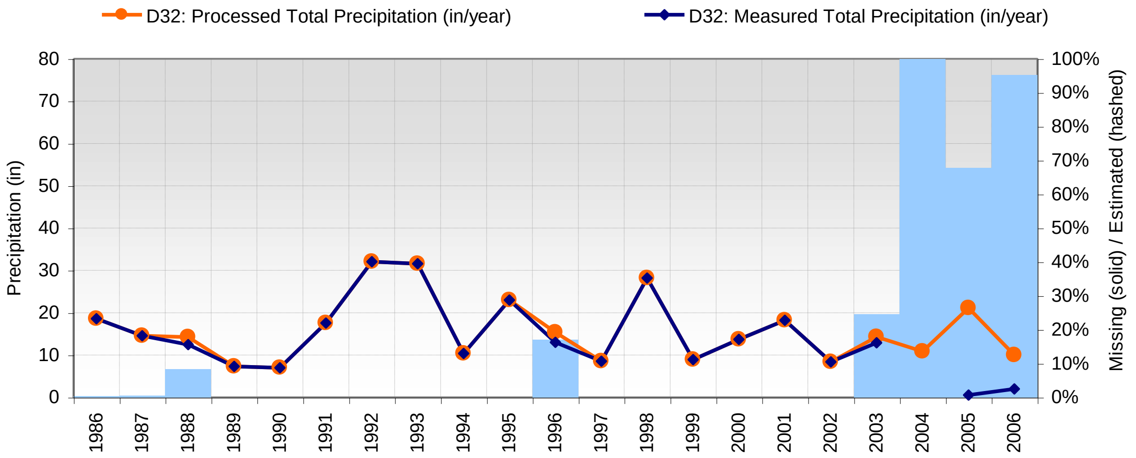


Figure A-70. Total precipitation at Newhall Soledad (D32)

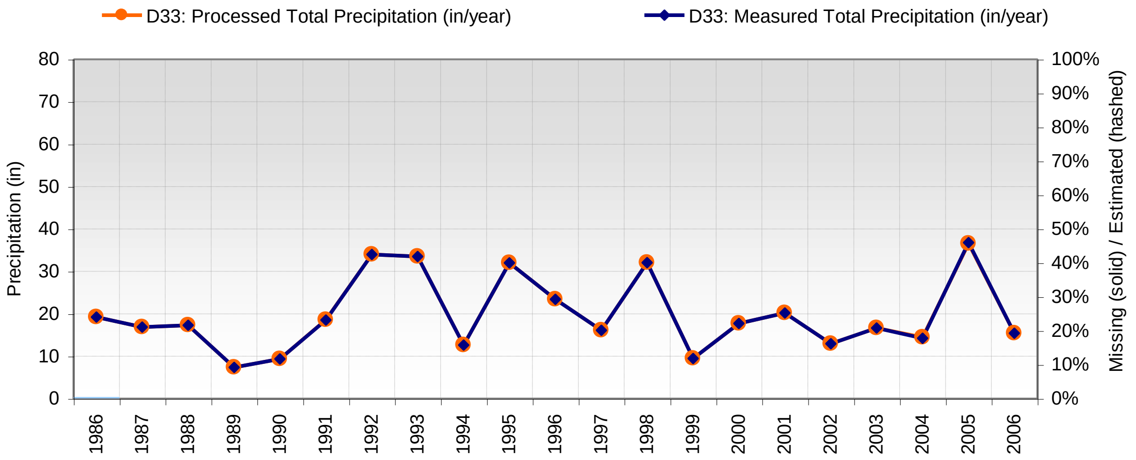


Figure A-71. Total precipitation at Pacoima Dam (D33)

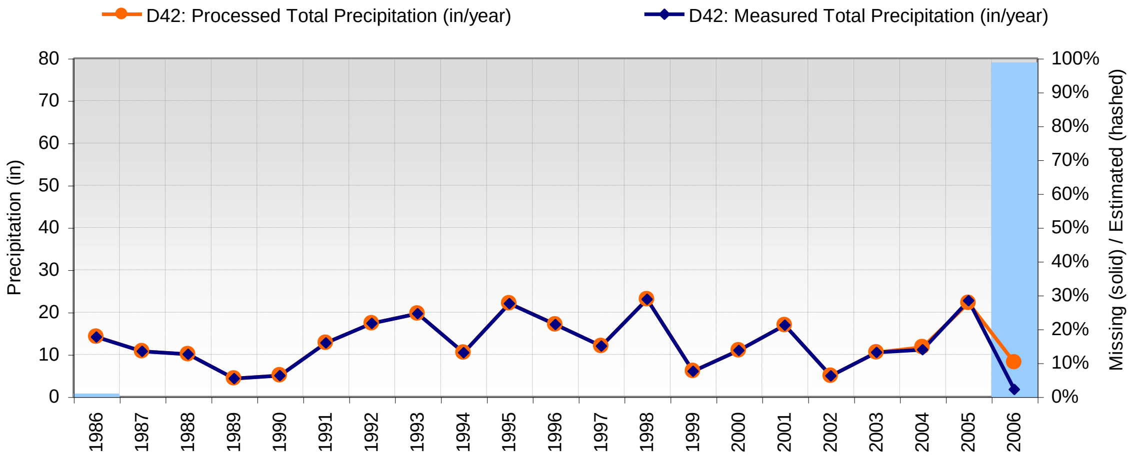


Figure A-72. Total precipitation at Redondo Beach City Hall (D42)

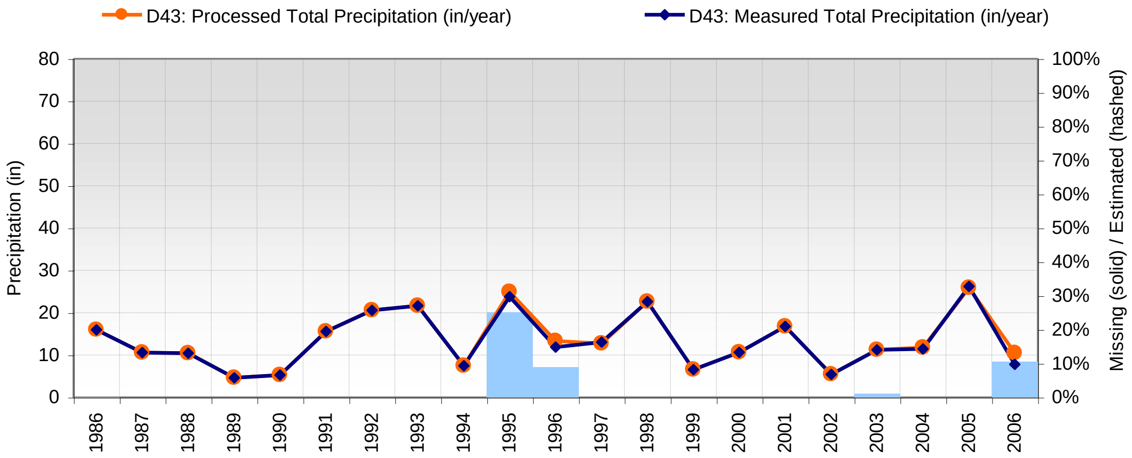


Figure A-73. Total precipitation at Palos Verdes Estates (D43)

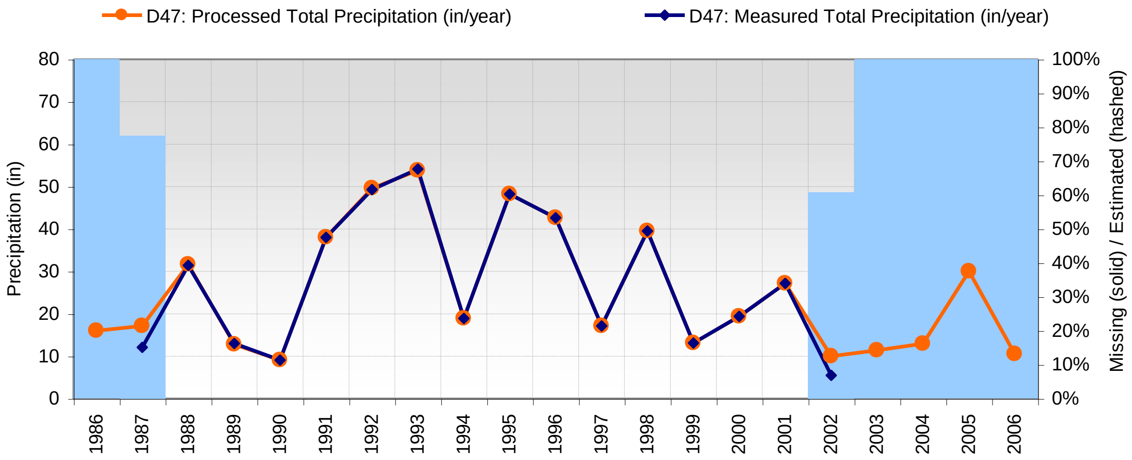


Figure A-74. Total precipitation at Clear Creek City School Daily Automatic (D47)

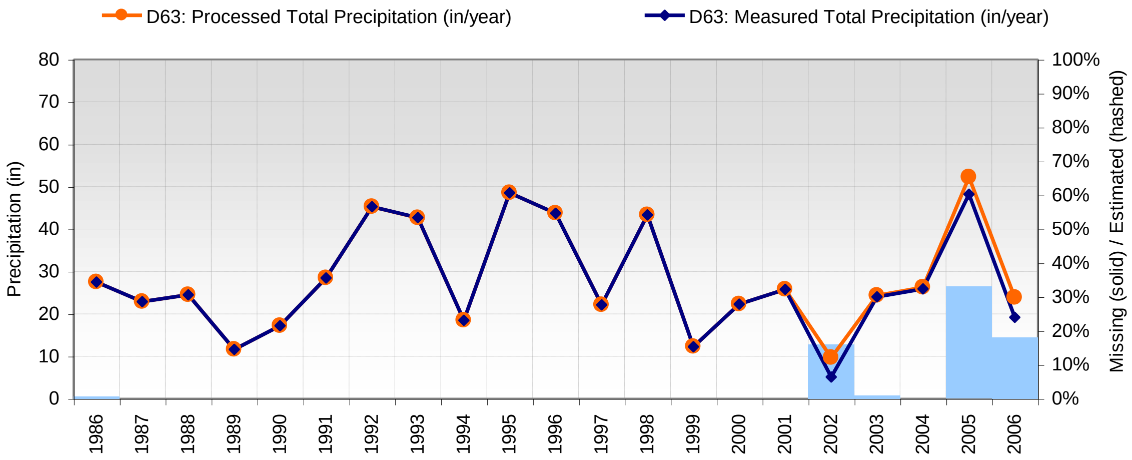


Figure A-75. Total precipitation at Santa Anita Dam (D63)

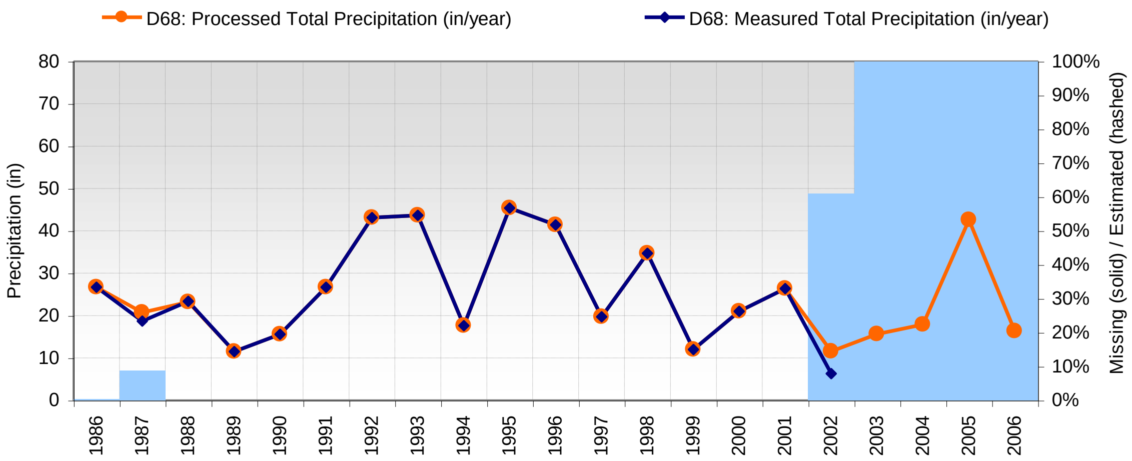


Figure A-76. Total precipitation at Sawpit Dam (D68)

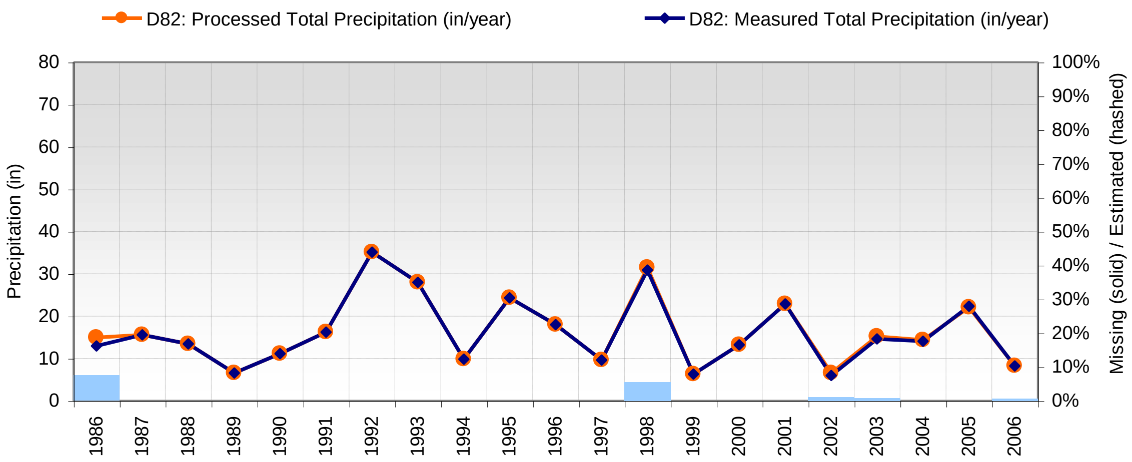


Figure A-77. Total precipitation at Table Mountain (D82)

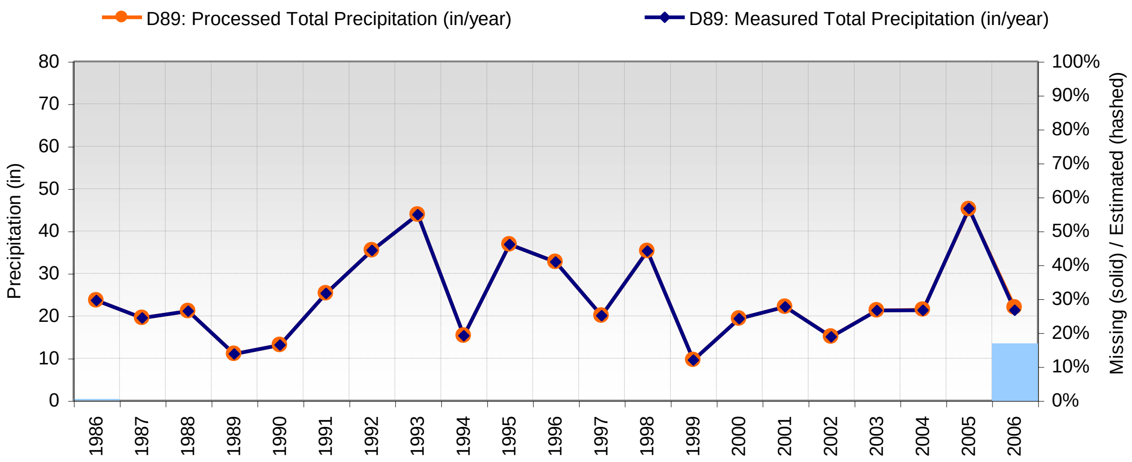


Figure A-78. Total precipitation at San Dimas Dam (D89)

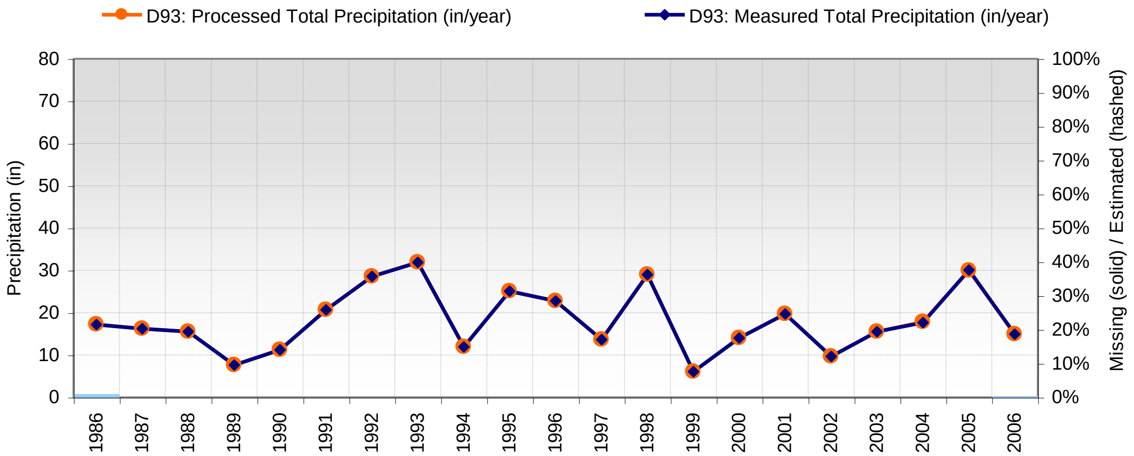


Figure A-79. Total precipitation at Claremont Police Station (D93)

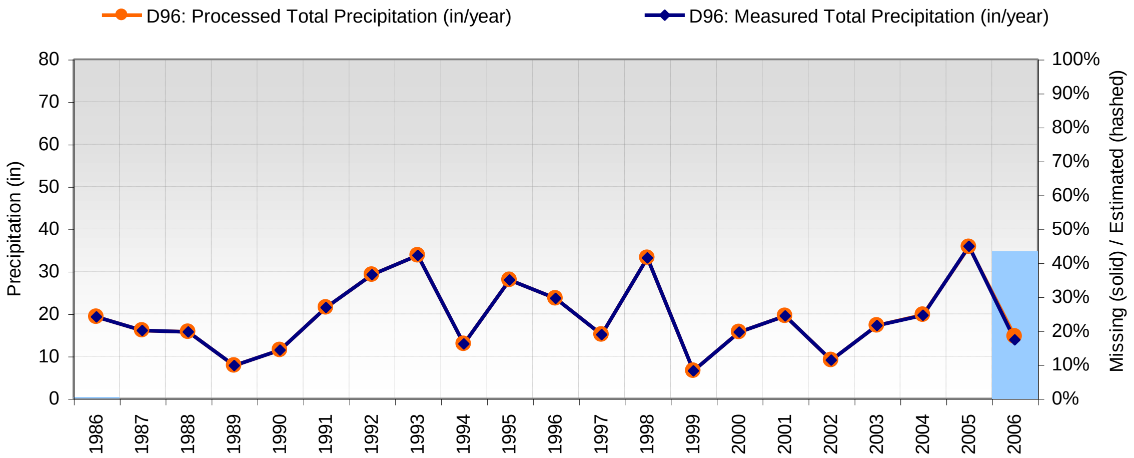


Figure A-80. Total precipitation at Puddingstone Dam (D96)

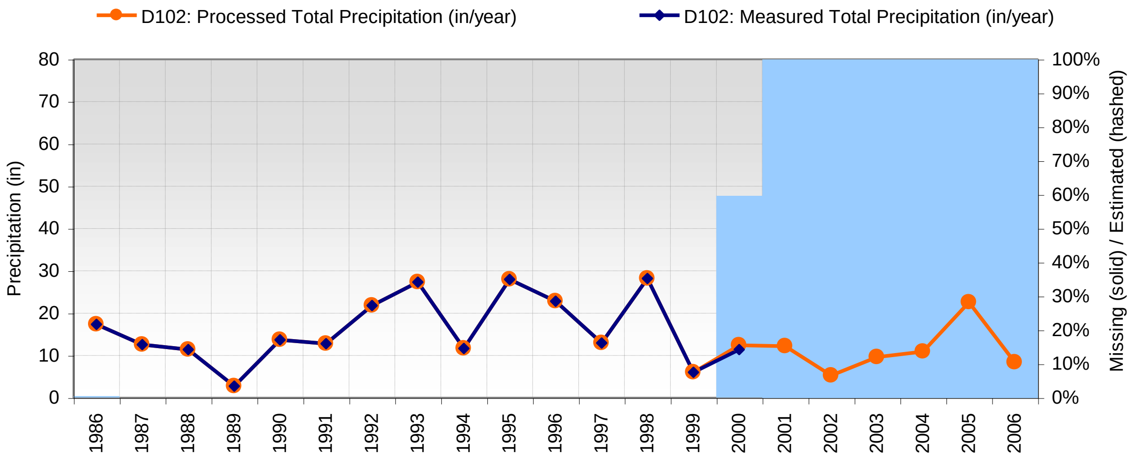


Figure A-81. Total precipitation at Walnut N.T. Industries (D102)

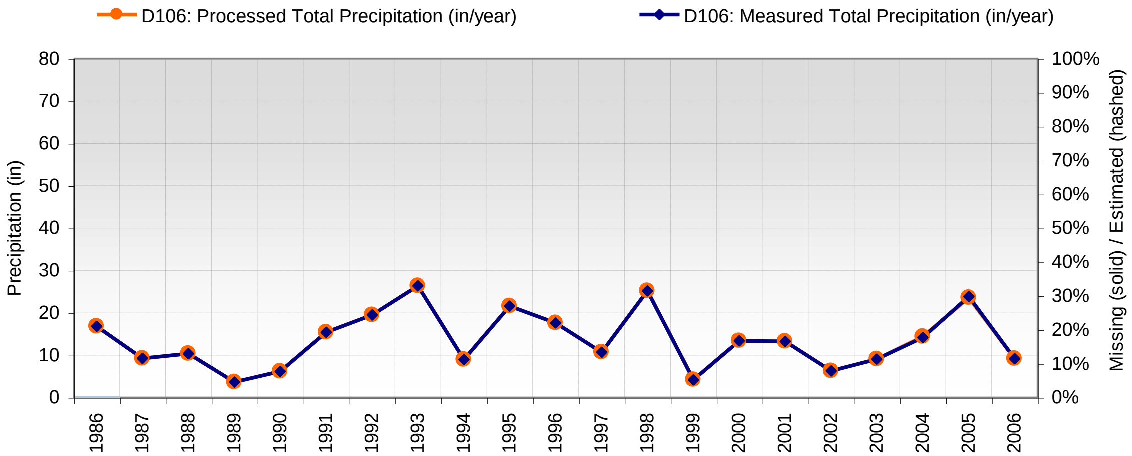


Figure A-82. Total precipitation at Whittier City Yard (D106)

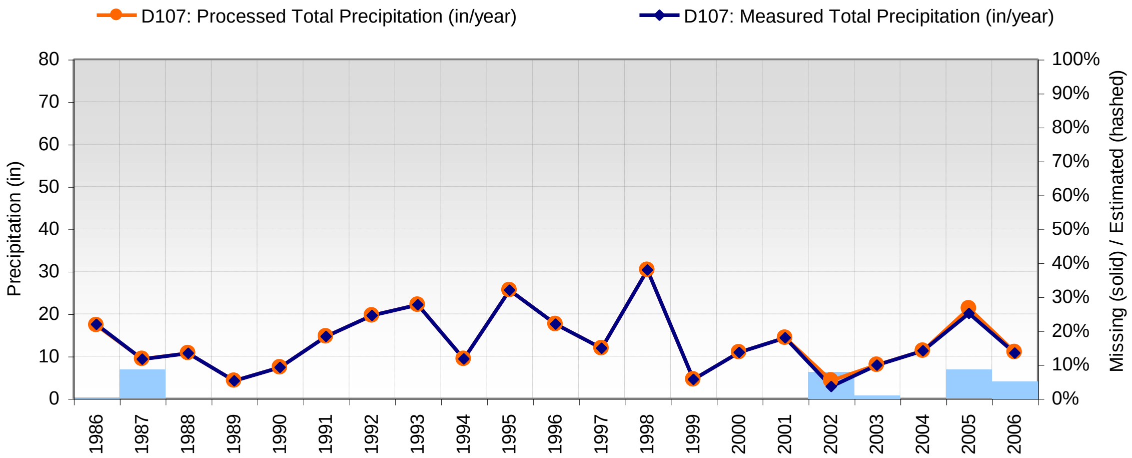


Figure A-83. Total precipitation at Sheldon Ranch-Matilija Canyon (D107)

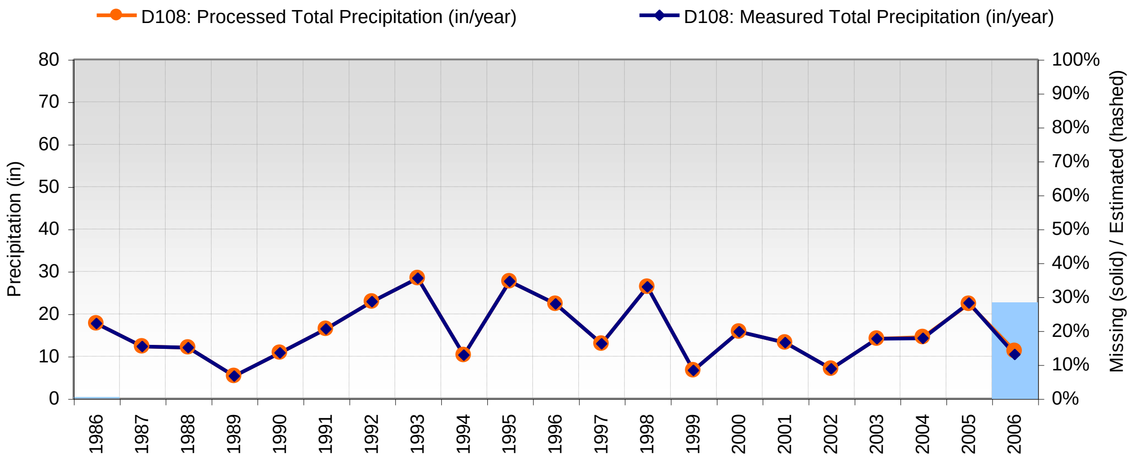


Figure A-84. Total precipitation at El Monte Fire Station (D108)

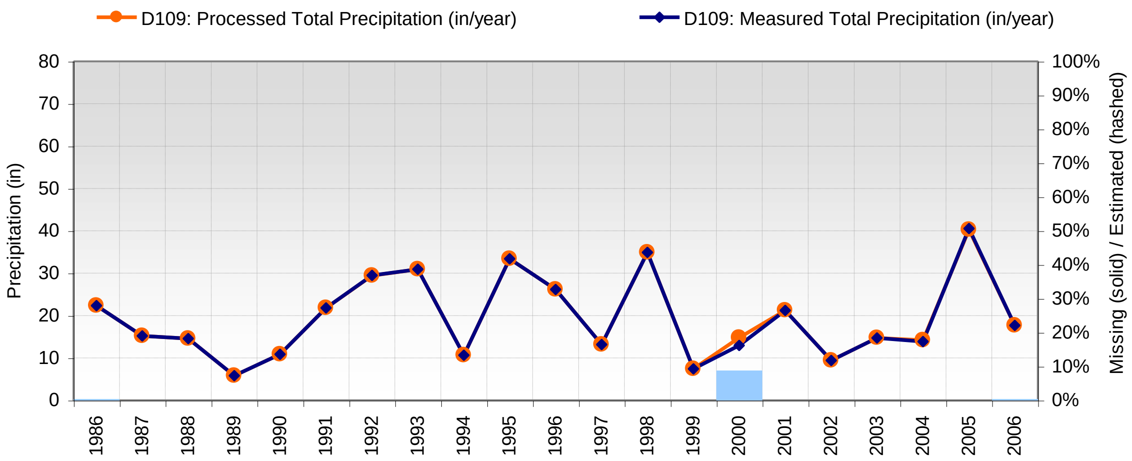


Figure A-85. Total precipitation at West Arcadia (D109)

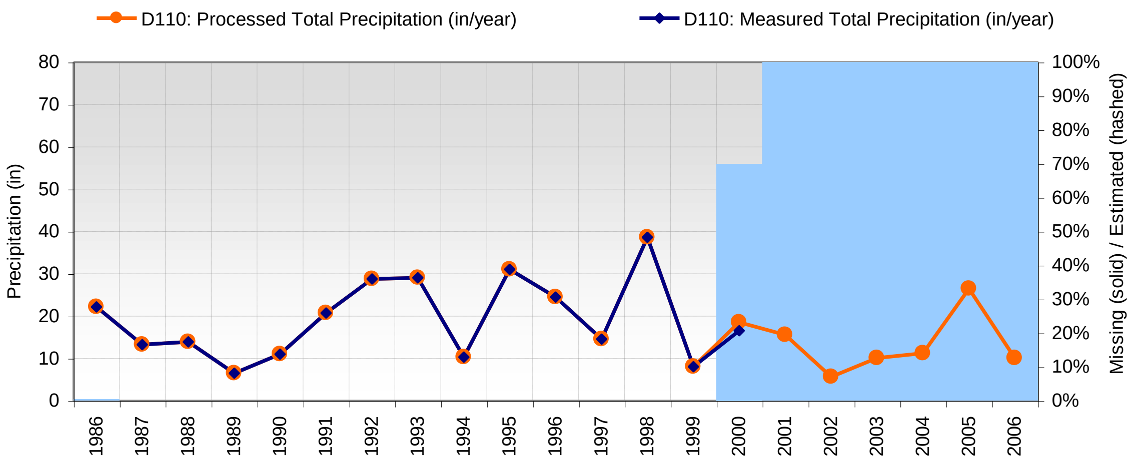


Figure A-86. Total precipitation at Alhambra (D110)

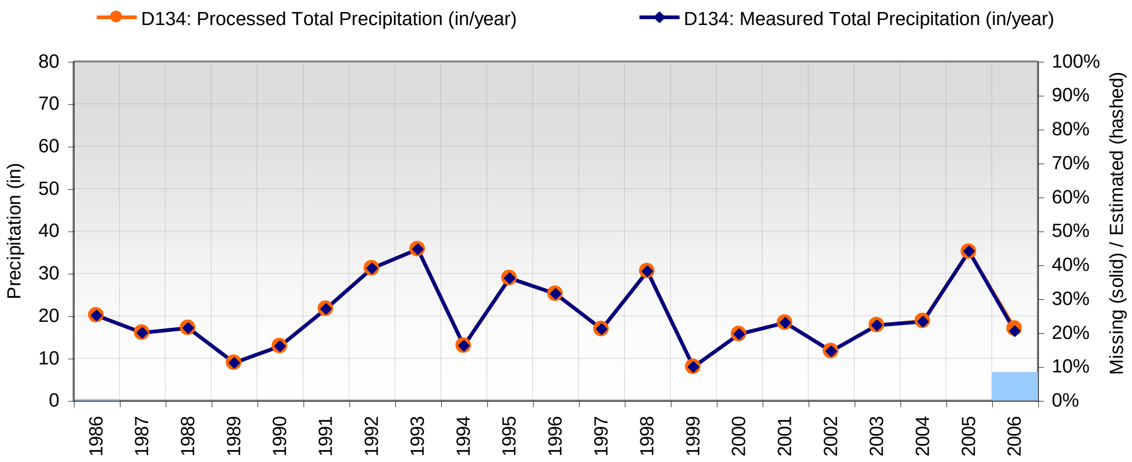


Figure A-87. Total precipitation at Matilija Dam (D134)

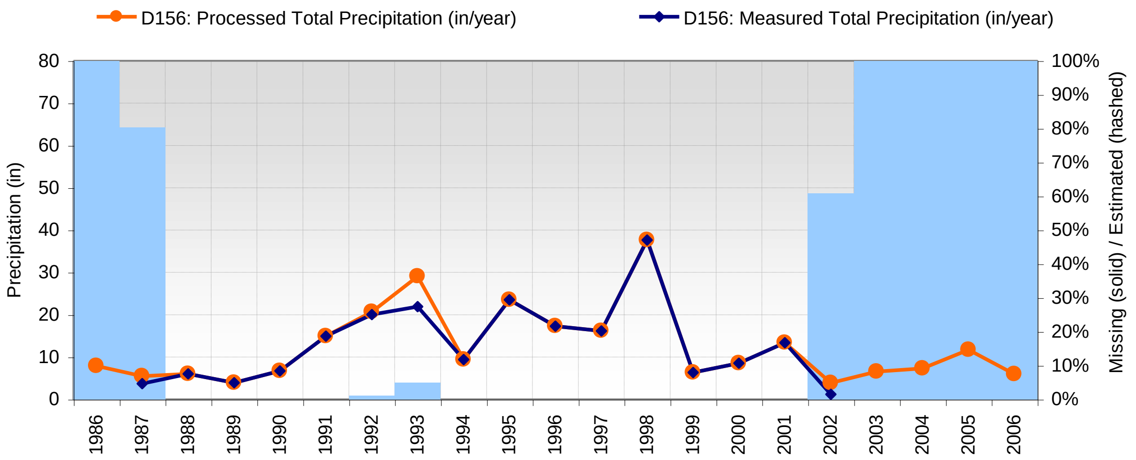


Figure A-88. Total precipitation at La Mirada Standard Oil Company (D156)

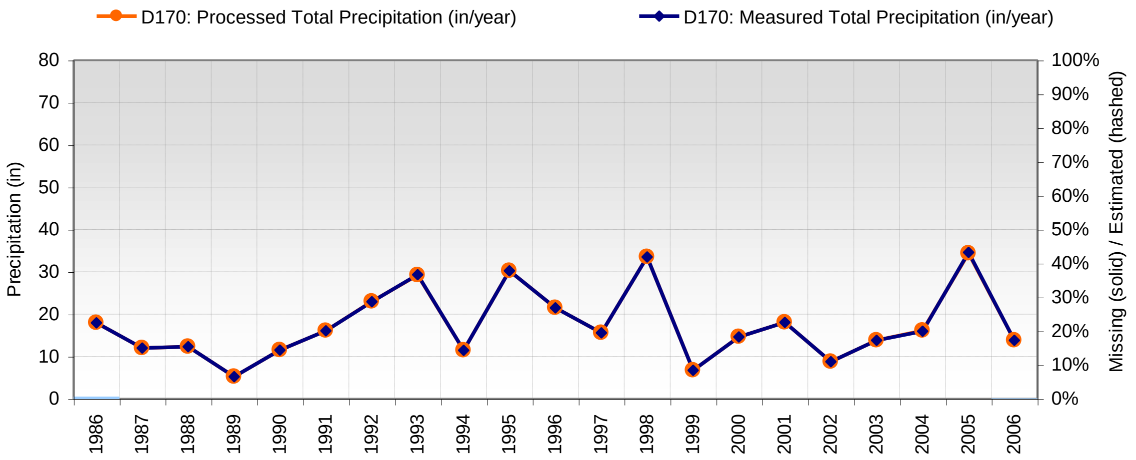


Figure A-89. Total precipitation at Potrero Heights (D170)

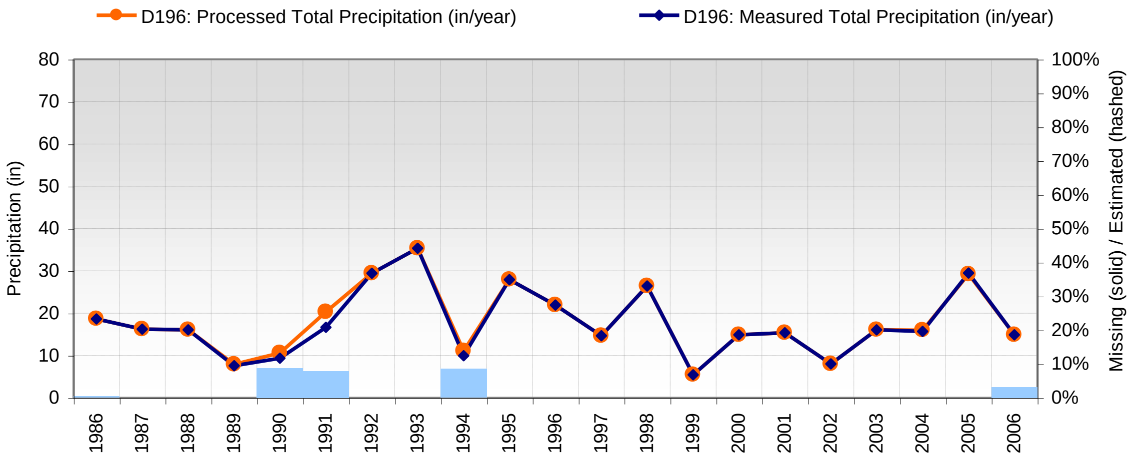


Figure A-90. Total precipitation at La Verne Leader (D196)

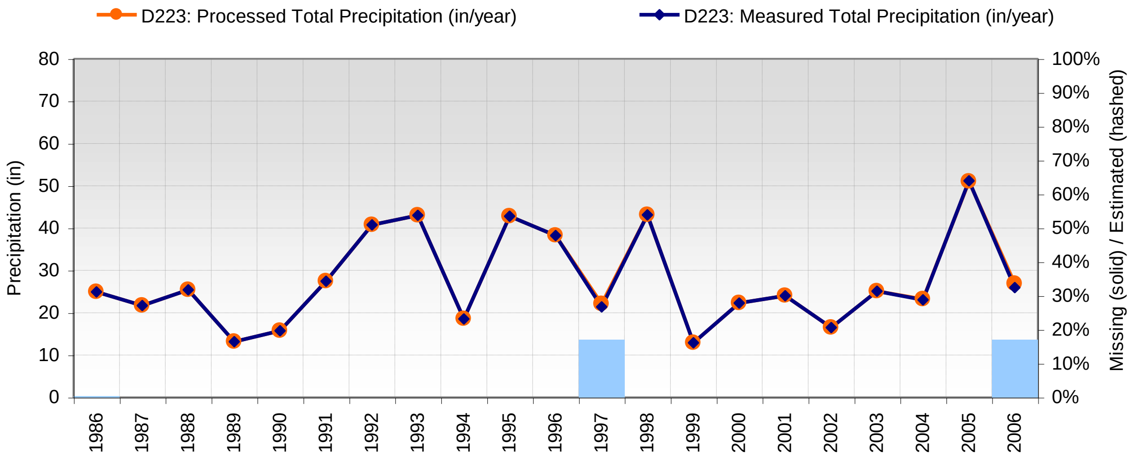


Figure A-91. Total precipitation at Big Dalton Dam (D223)

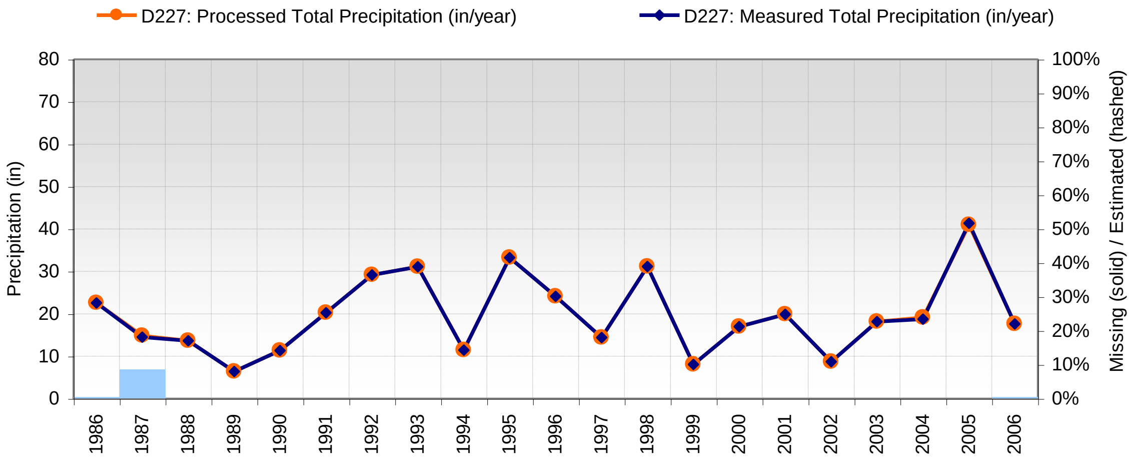


Figure A-92. Total precipitation at San Gabriel Bruington (D227)

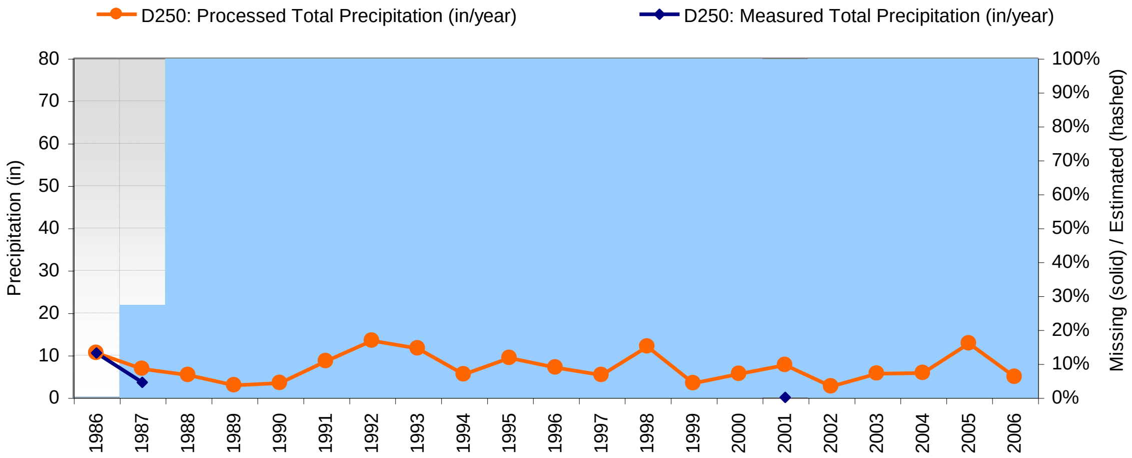


Figure A-93. Total precipitation at Acton Camp (D250)

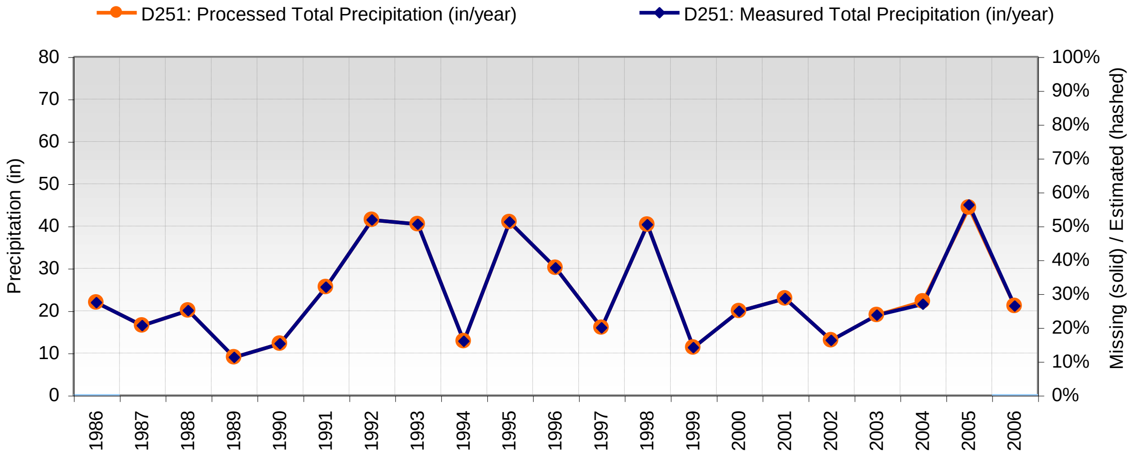


Figure A-94. Total precipitation at La Crescenta (D251)

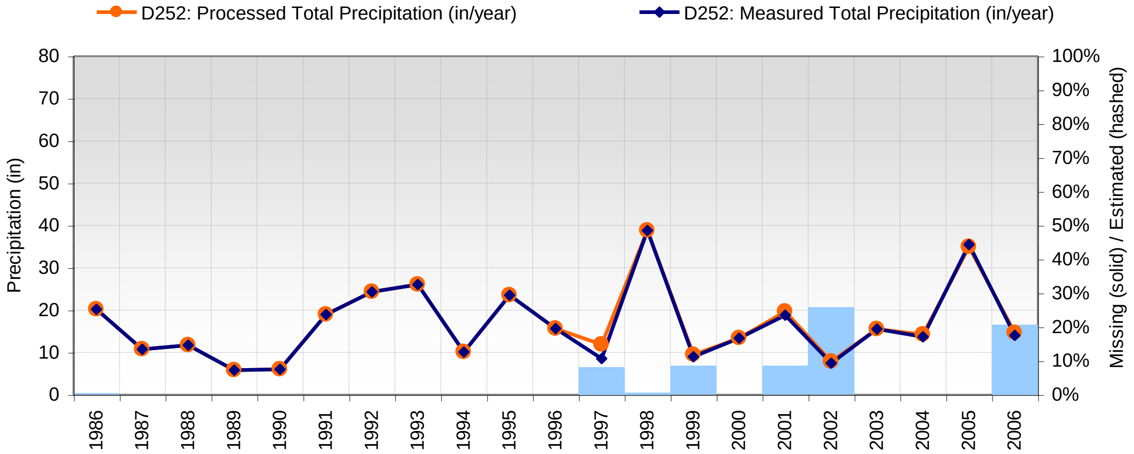


Figure A-95. Total precipitation at Castaic Dam (D252)

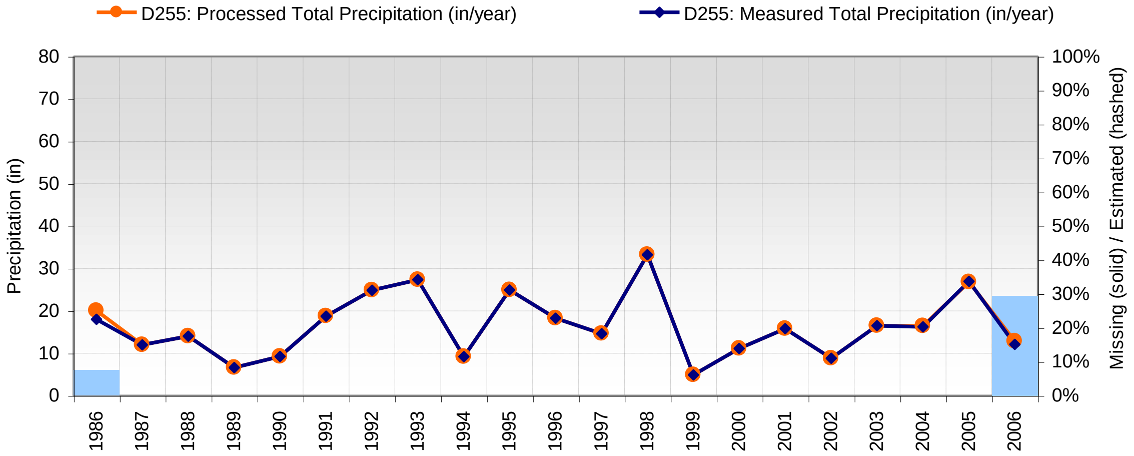


Figure A-96. Total precipitation at Mount San Antonio College (D255)

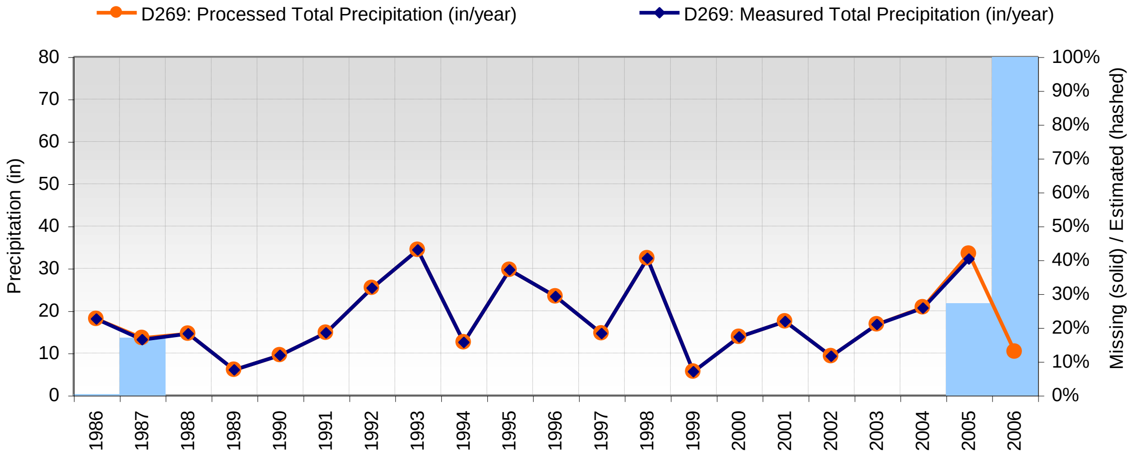


Figure A-97. Total precipitation at Diamond Bar Fire Station (D269)

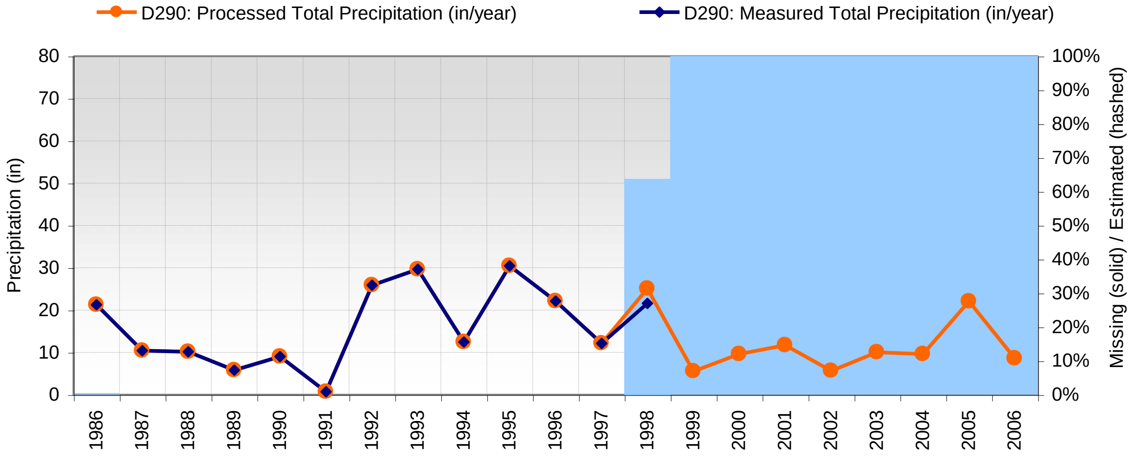


Figure A-98. Total precipitation at Monterey Park Fire Station (D290)

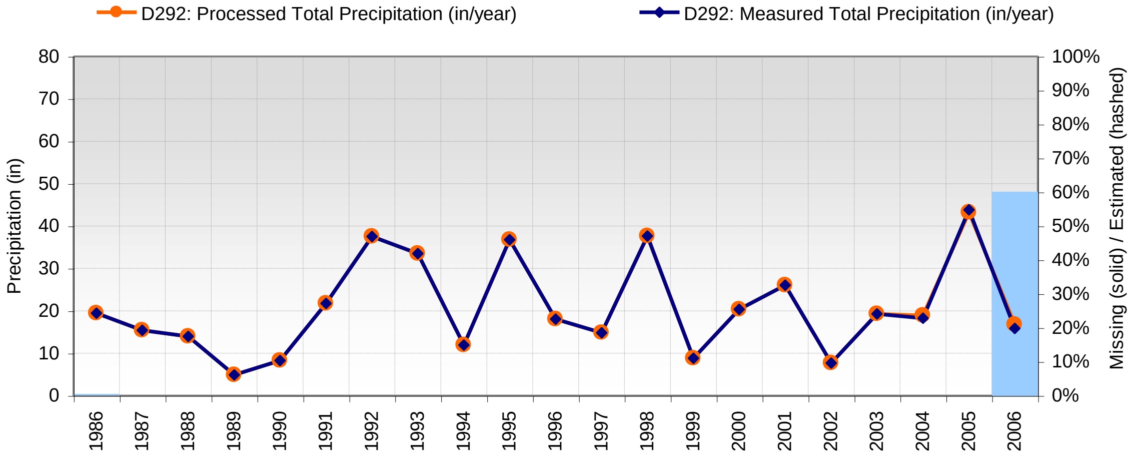


Figure A-99. Total precipitation at Encino Reservoir (D292)

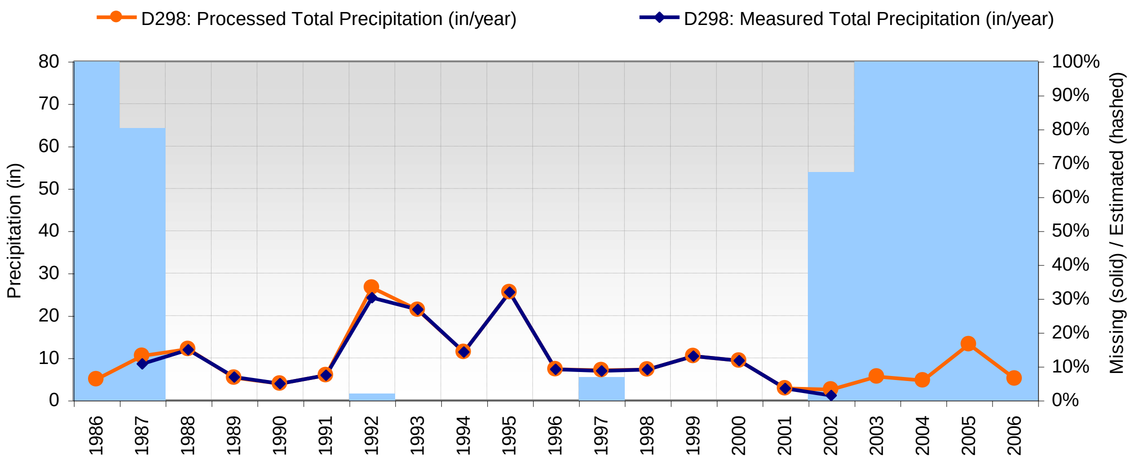


Figure A-100. Total precipitation at Gorman Sheriff (D298)

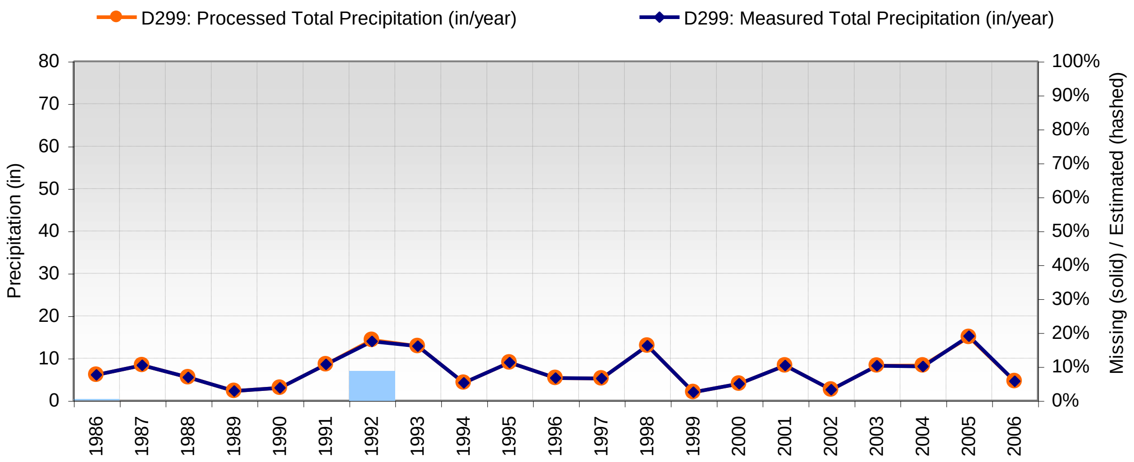


Figure A-101. Total precipitation at Little Rock Schwab (D299)

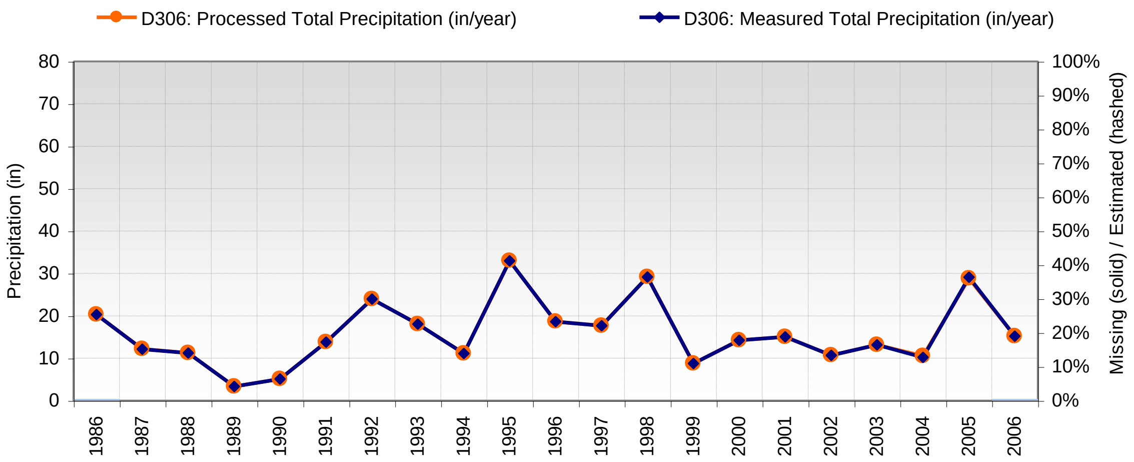


Figure A-102. Total precipitation at Zuma Beach (D306)

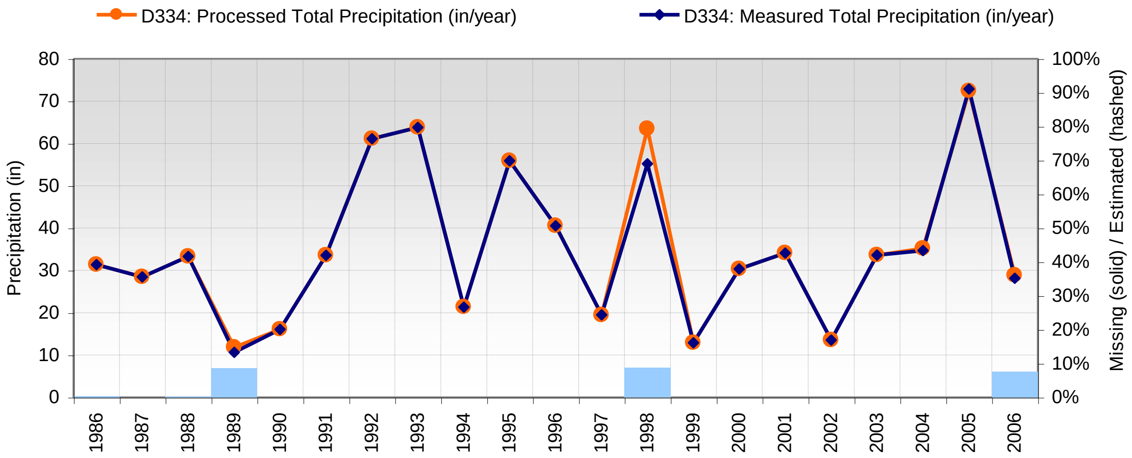


Figure A-103. Total precipitation at San Gabriel Dam Number (D334)

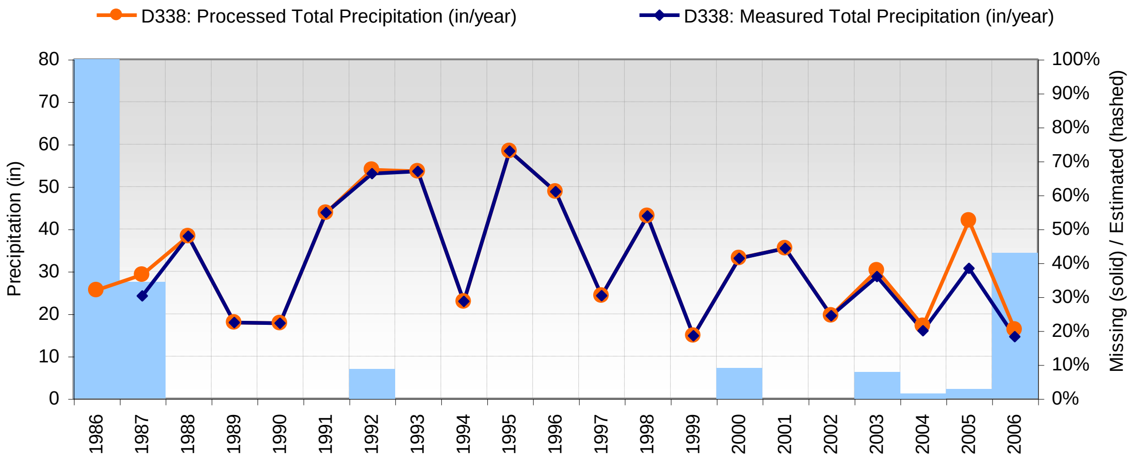


Figure A-104. Total precipitation at Mt. Wilson Observatory (D338)

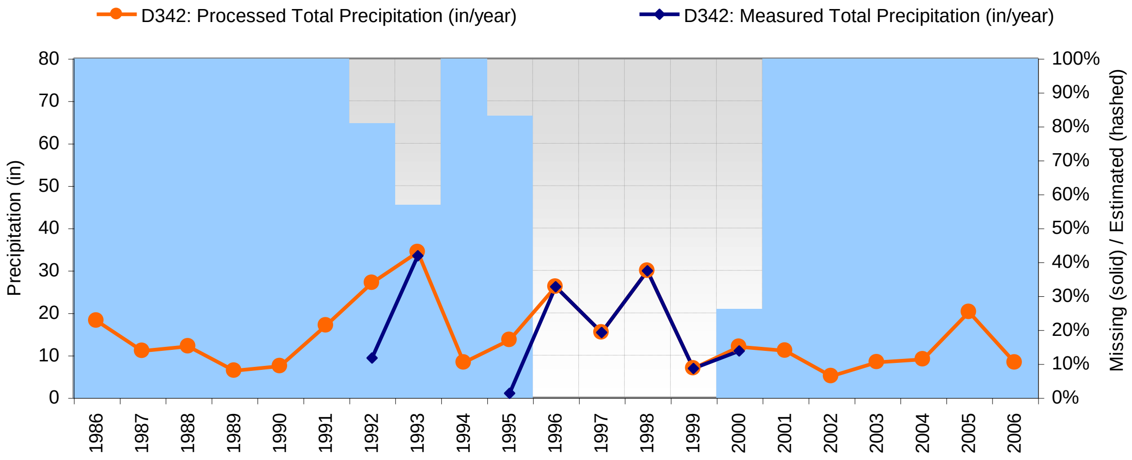


Figure A-105. Total precipitation at Upland Chappel (D342)

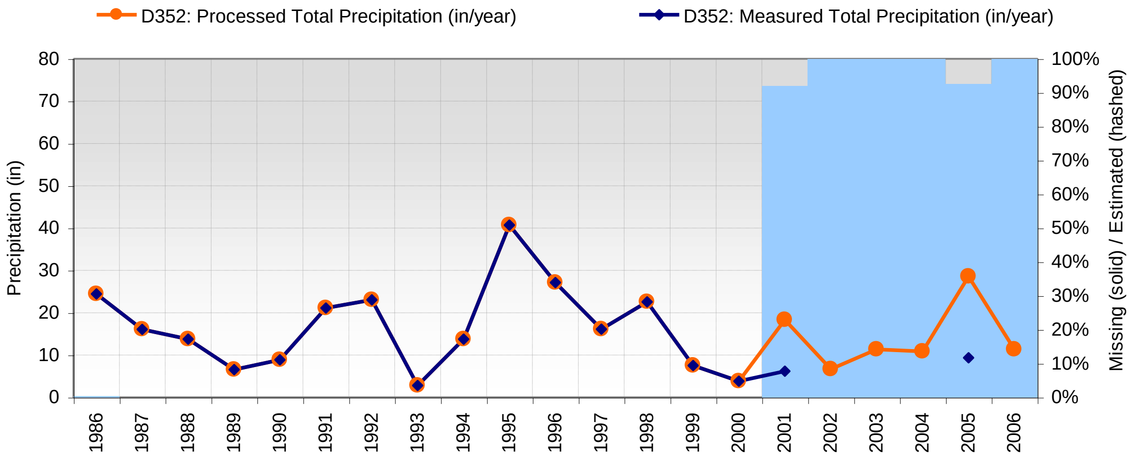


Figure A-106. Total precipitation at Lechuaza Patrol Station (D352)

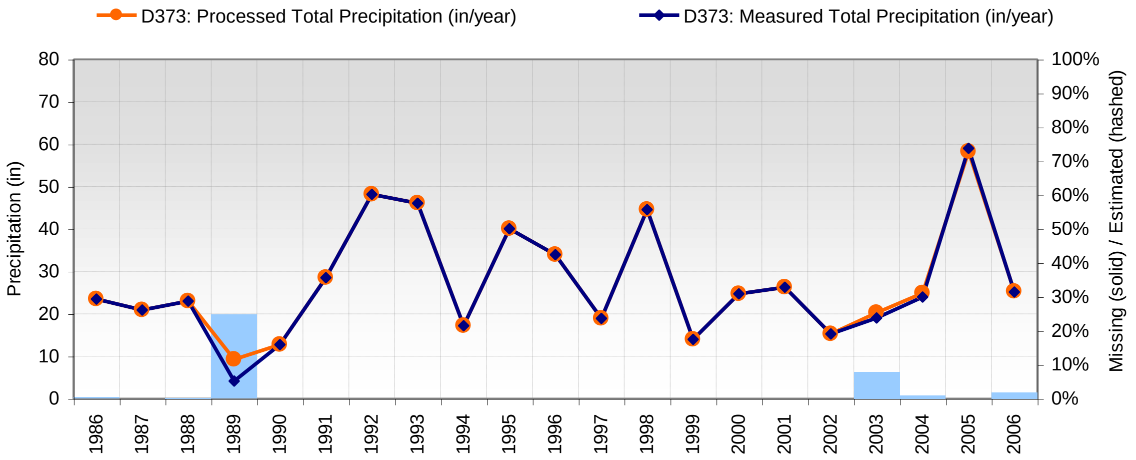


Figure A-107. Total precipitation at Briggs Terrace (D373)

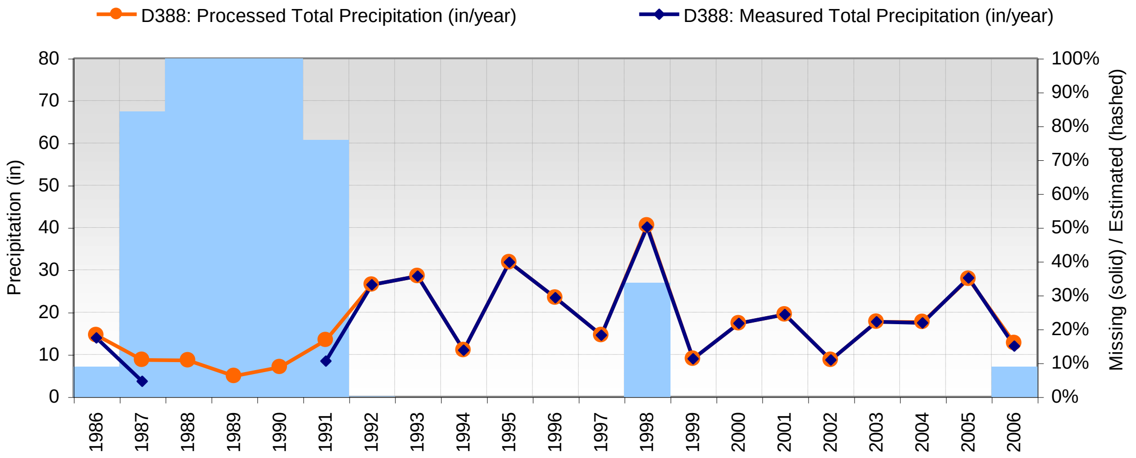


Figure A-108. Total precipitation at Paramount County Fire Station (D388)

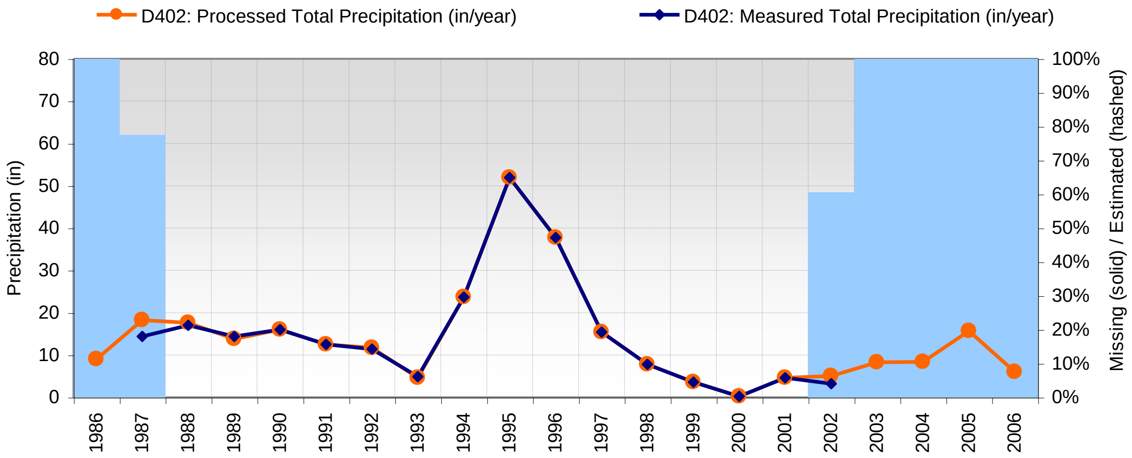


Figure A-109. Total precipitation at Cedar Springs (D402)

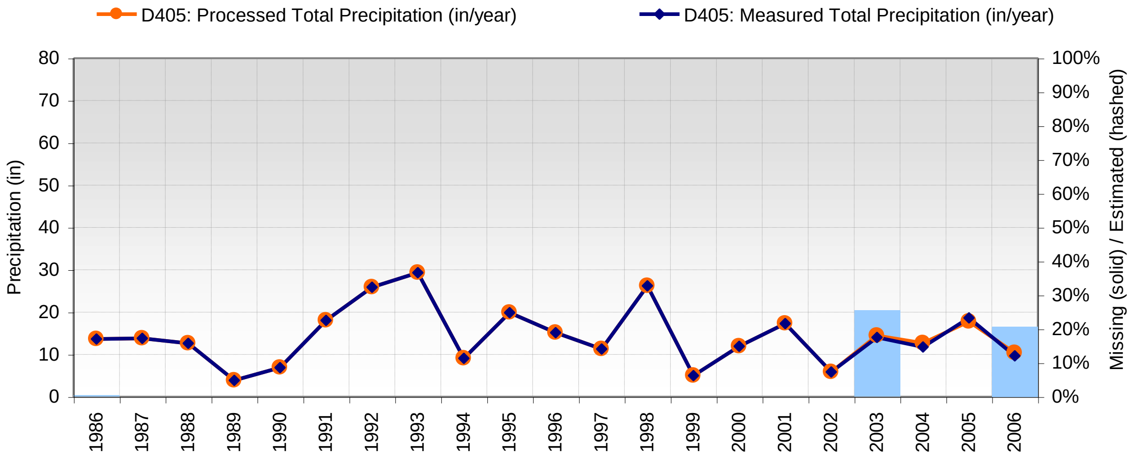


Figure A-110. Total precipitation at Soledad Canyon (D405)

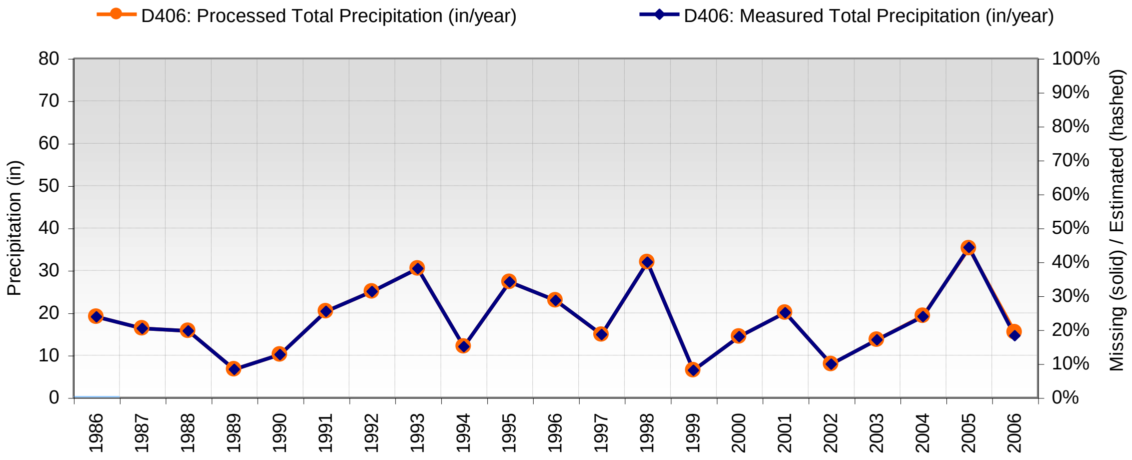


Figure A-111. Total precipitation at West Azusa (D406)

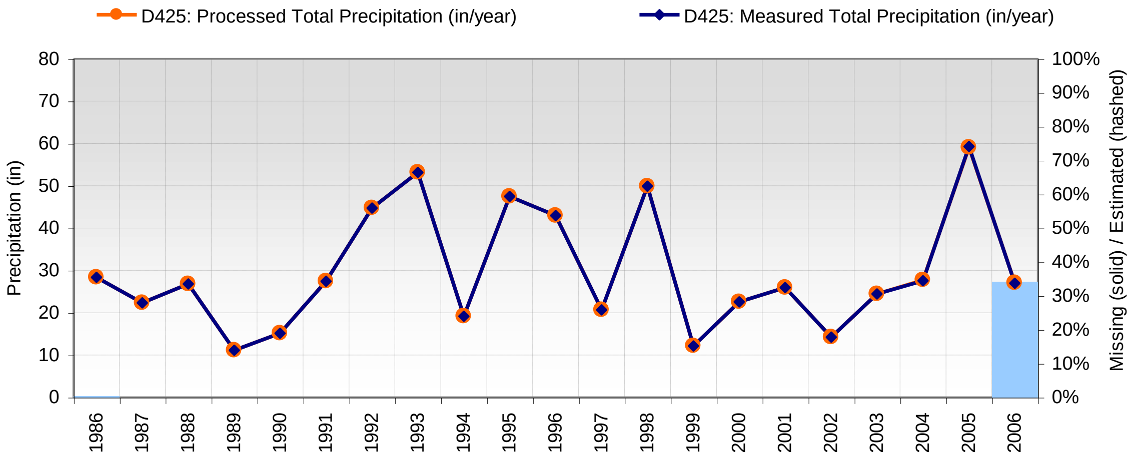


Figure A-112. Total precipitation at San Gabriel Dam (D425)

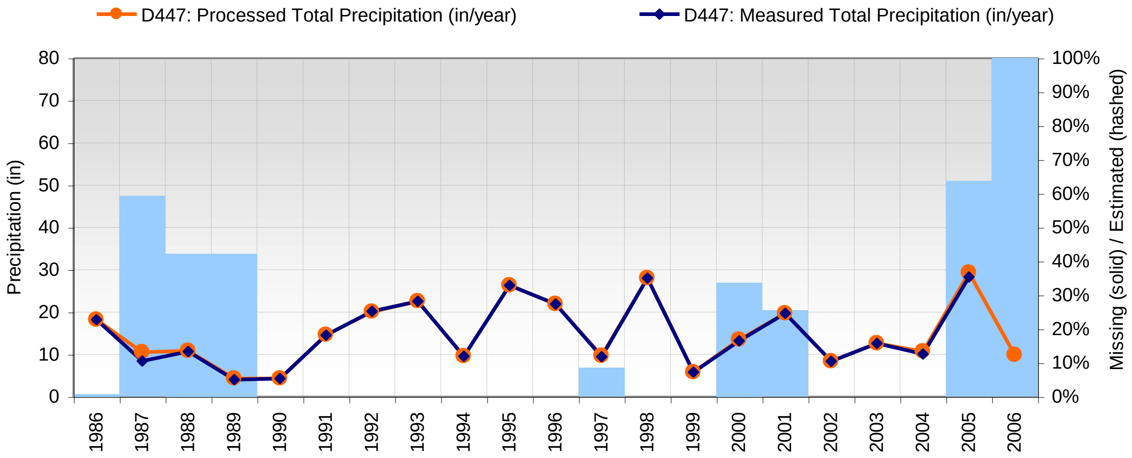


Figure A-113. Total precipitation at Carbon Canyon (D447)

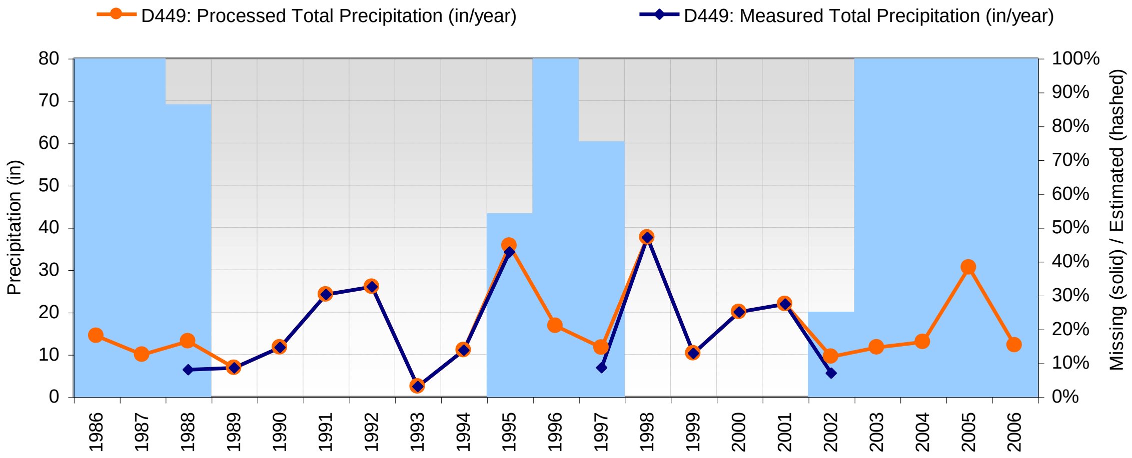


Figure A-114. Total precipitation at Eaton Wash Dam (D449)

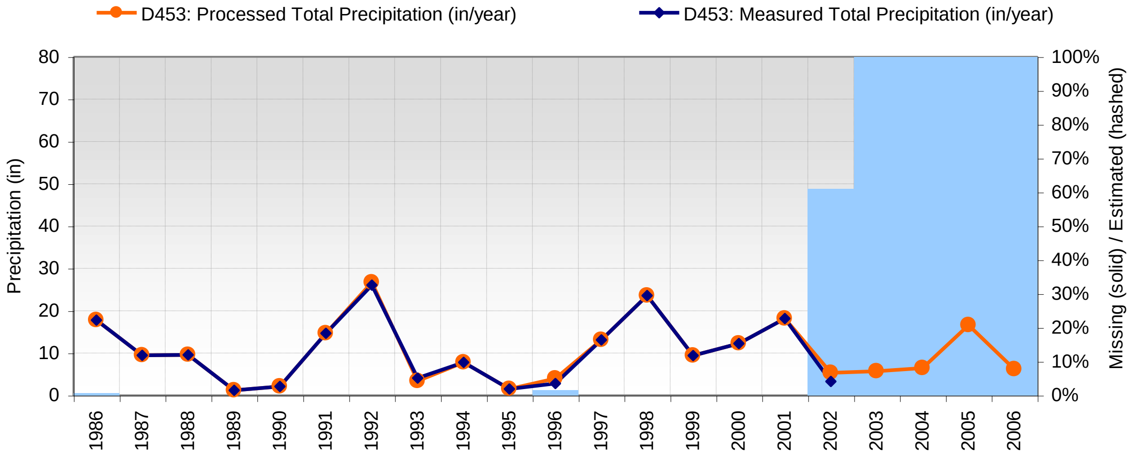


Figure A-115. Total precipitation at Devils Gate Dam (D453)

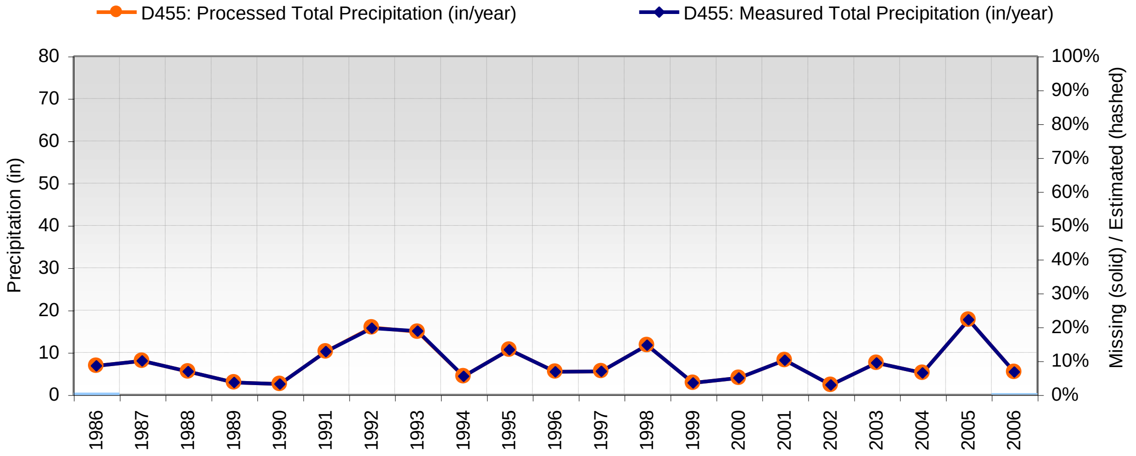


Figure A-116. Total precipitation at Lancaster (D455)

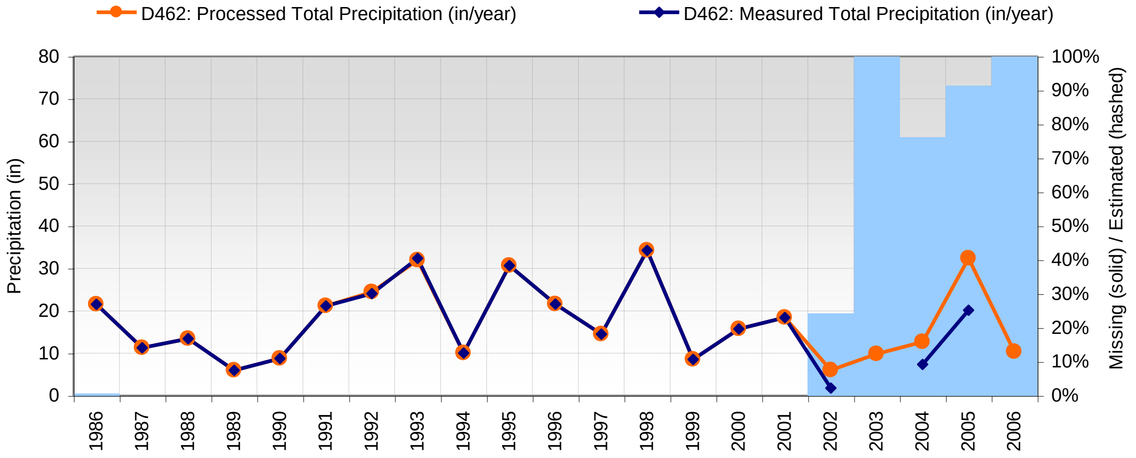


Figure A-117. Total precipitation at Los Angeles Hillcrest Country Club (D462)

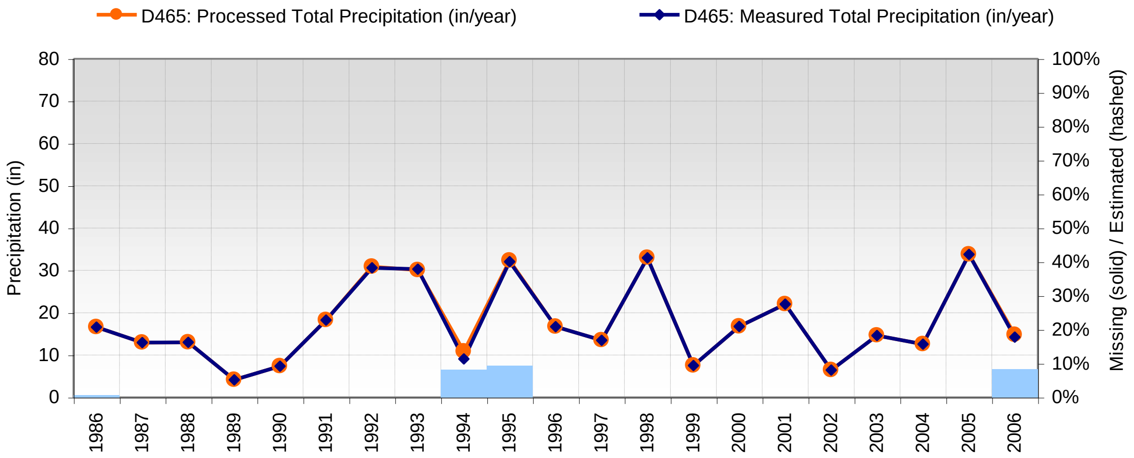


Figure A-118. Total precipitation at Sepulveda Dam (D465)

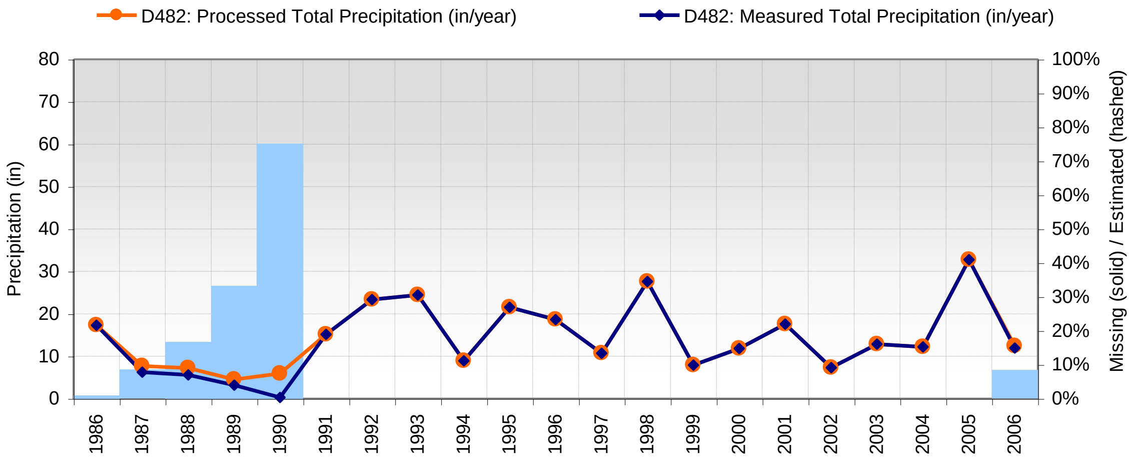


Figure A-119. Total precipitation at Los Angeles USC (D482)

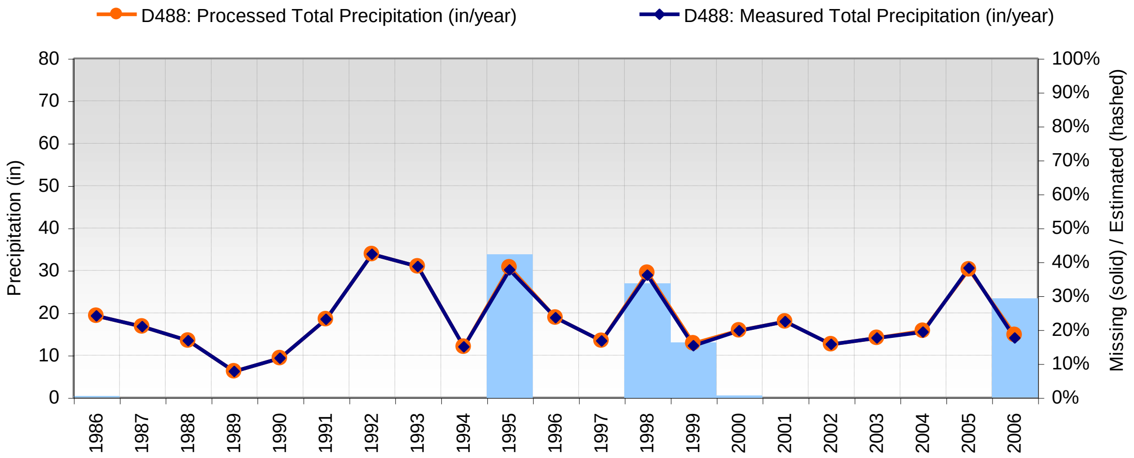


Figure A-120. Total precipitation at Kagel Canyon (D488)

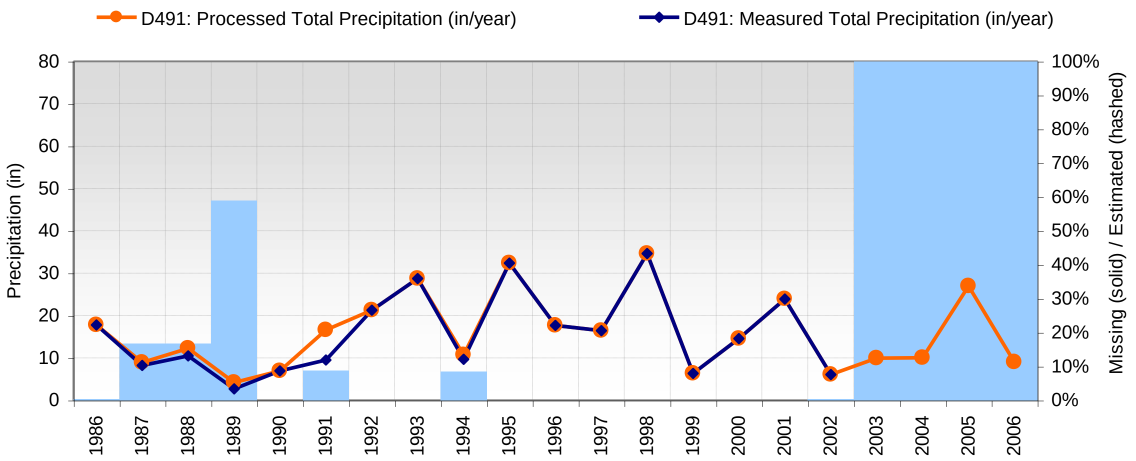


Figure A-121. Total precipitation at Pacific Palisades (D491)

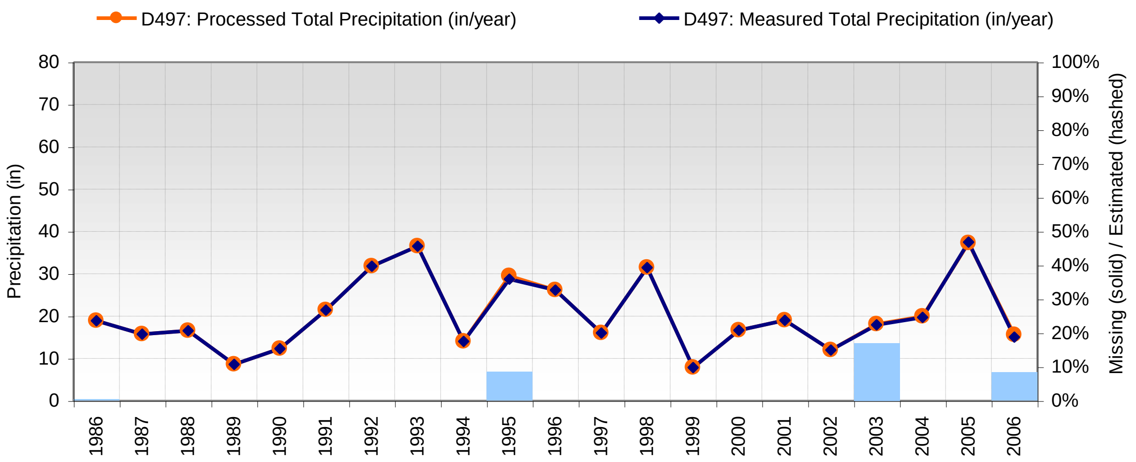


Figure A-122. Total precipitation at Claremont (D497)

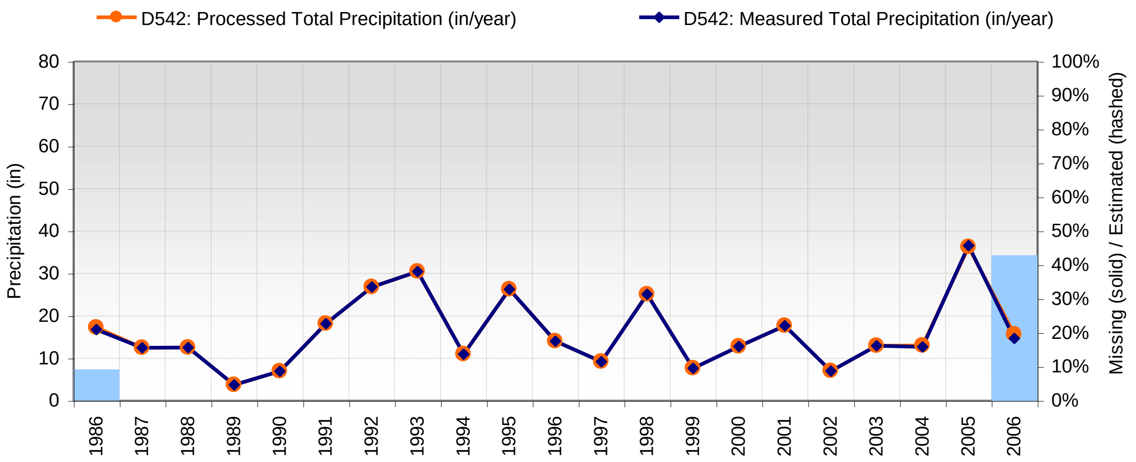


Figure A-123. Total precipitation at Fairmont (D542)

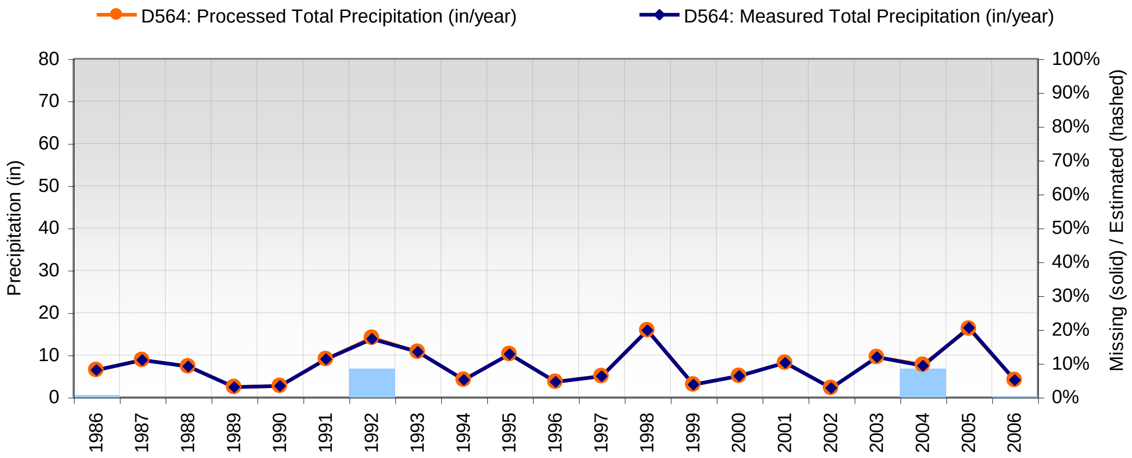


Figure A-124. Total precipitation at Llan (D564)

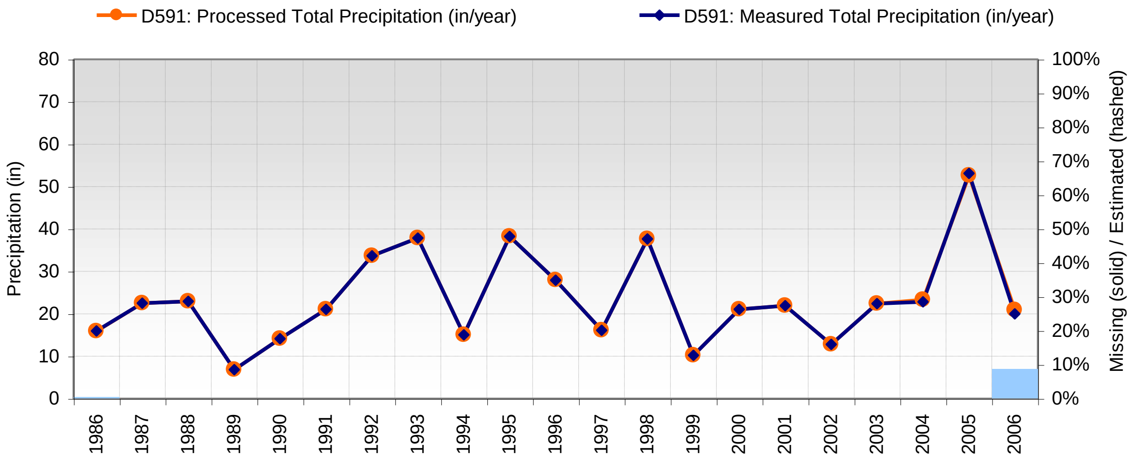


Figure A-125. Total precipitation at Santa Anita Reservoir (D591)

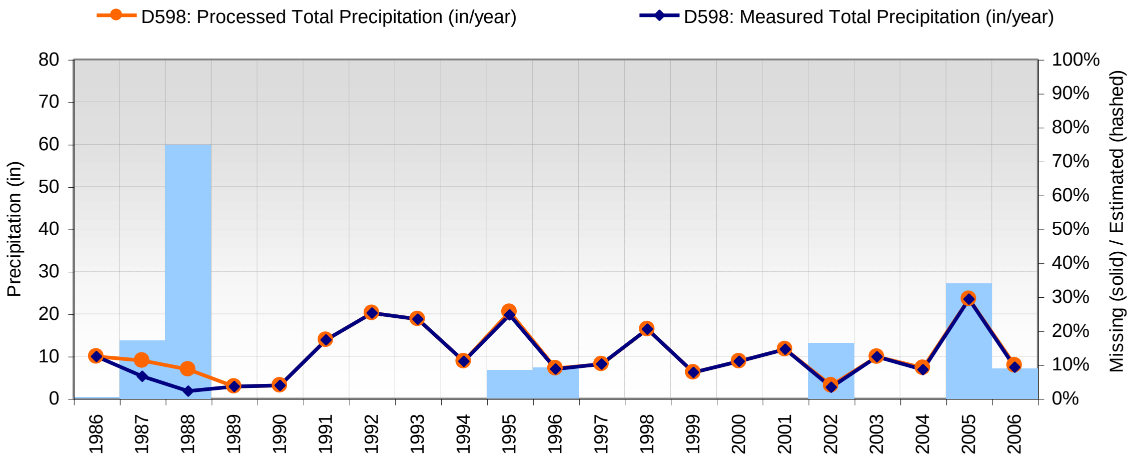


Figure A-126. Total precipitation at Neenach (D598)

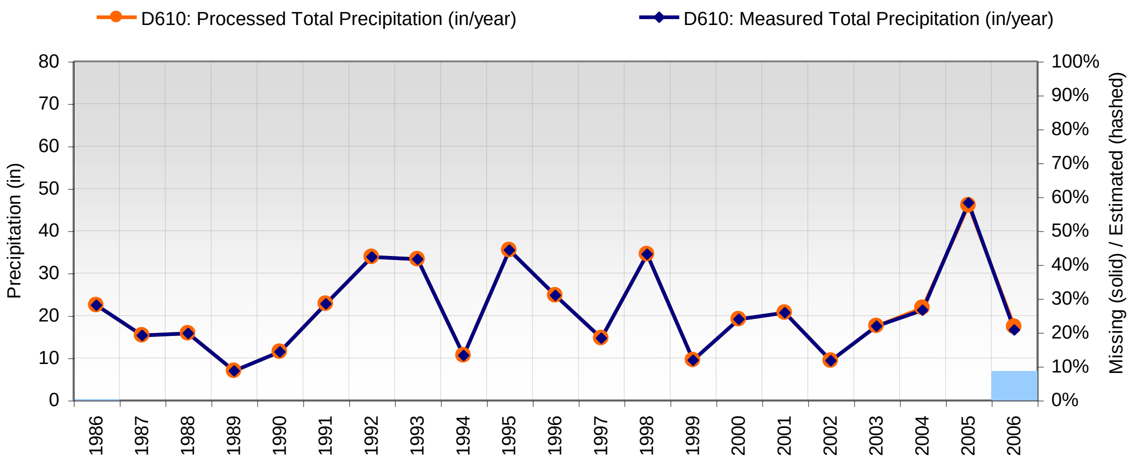


Figure A-127. Total precipitation at Pasadena City Hall (D610)

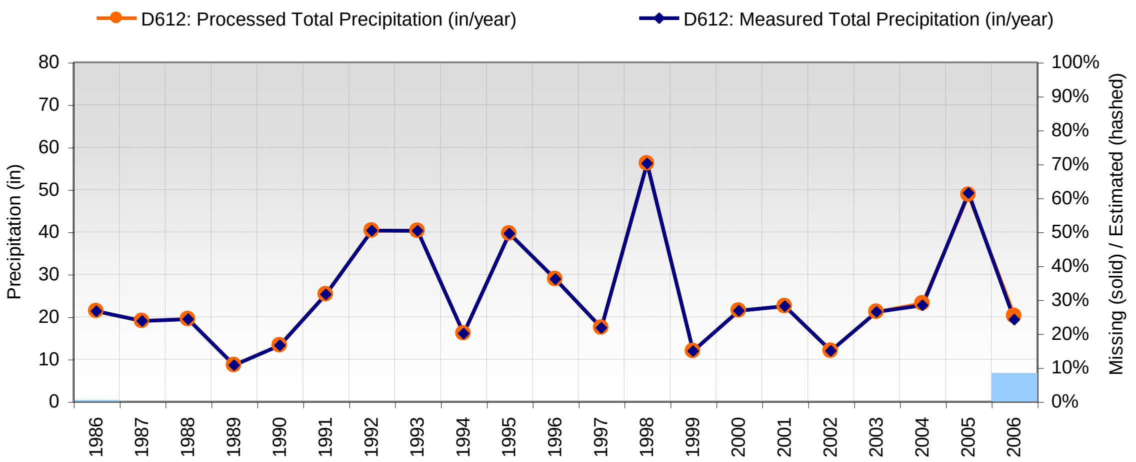


Figure A-128. Total precipitation at Pasadena Chlorine Plant (D612)

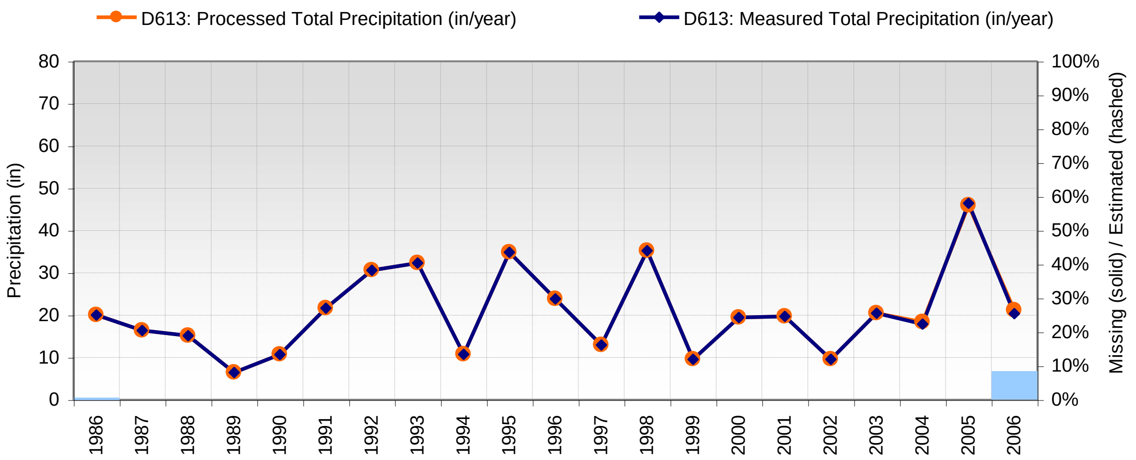


Figure A-129. Total precipitation at Old Man Mountain Alert (D613)

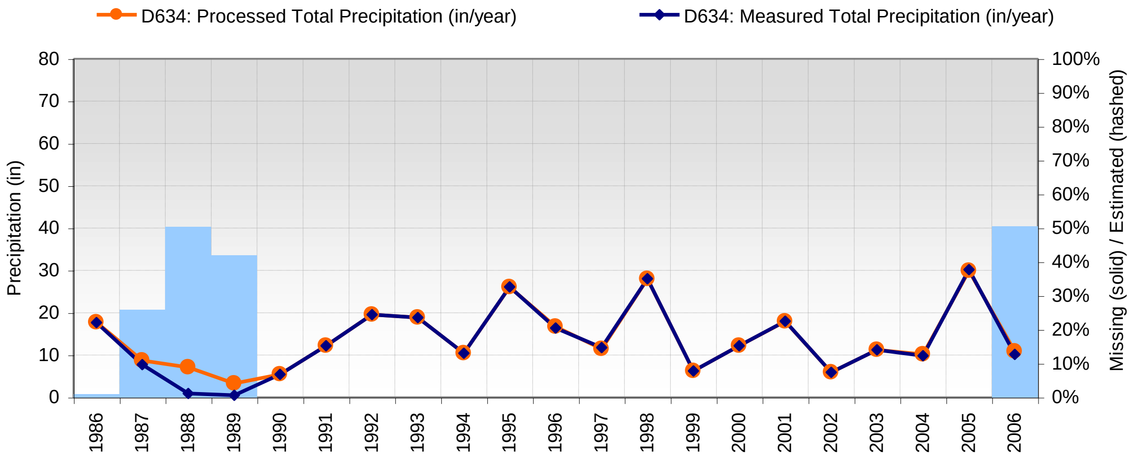


Figure A-130. Total precipitation at Santa Monica (D634)

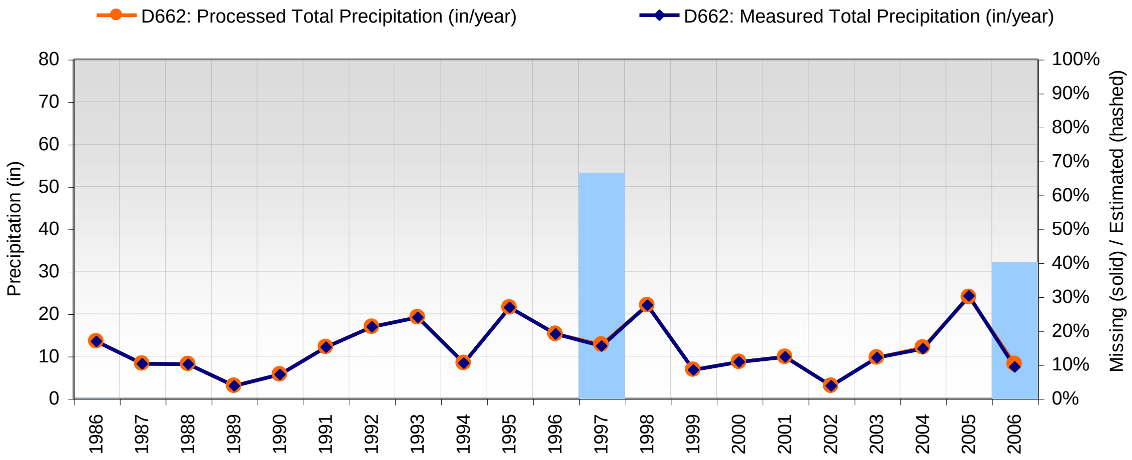


Figure A-131. Total precipitation at Long Beach Airport (D662)

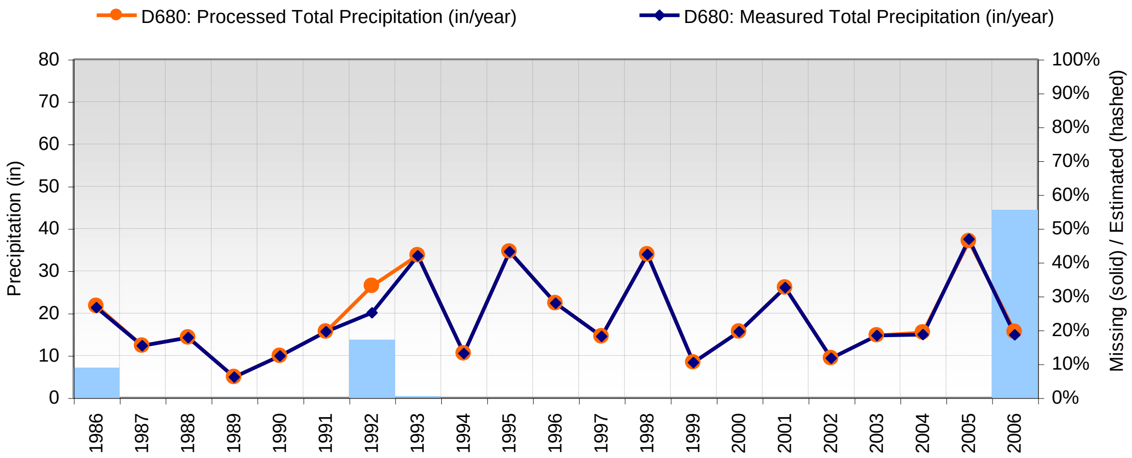


Figure A-132. Total precipitation at Westwood UCLA (D680)

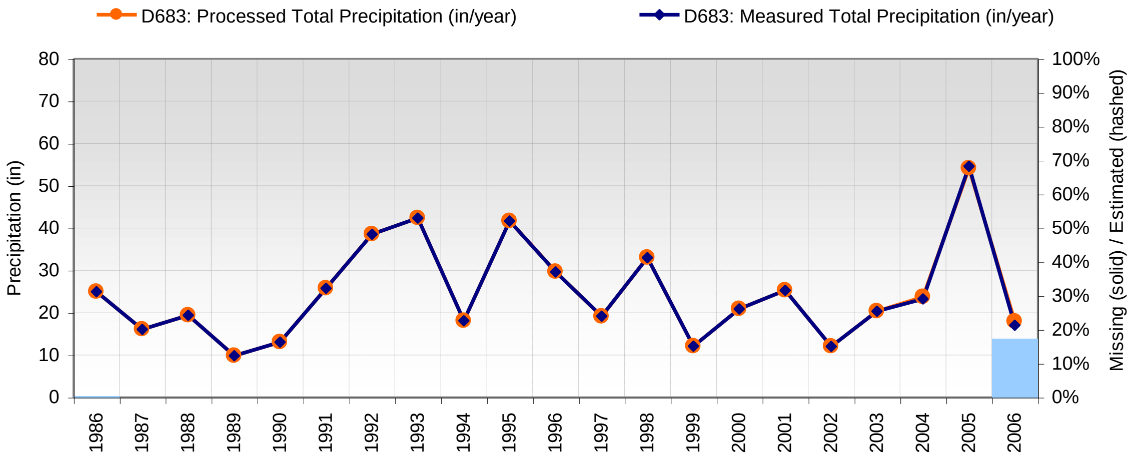


Figure A-133. Total precipitation at Sunset Ridge (D683)

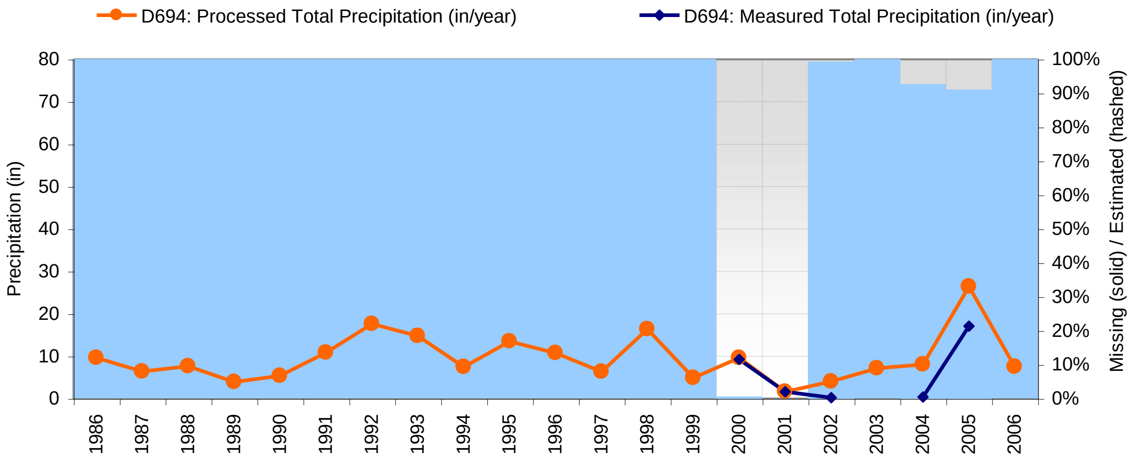


Figure A-134. Total precipitation at Big Tujunga Canyon Camp 15 (D694)

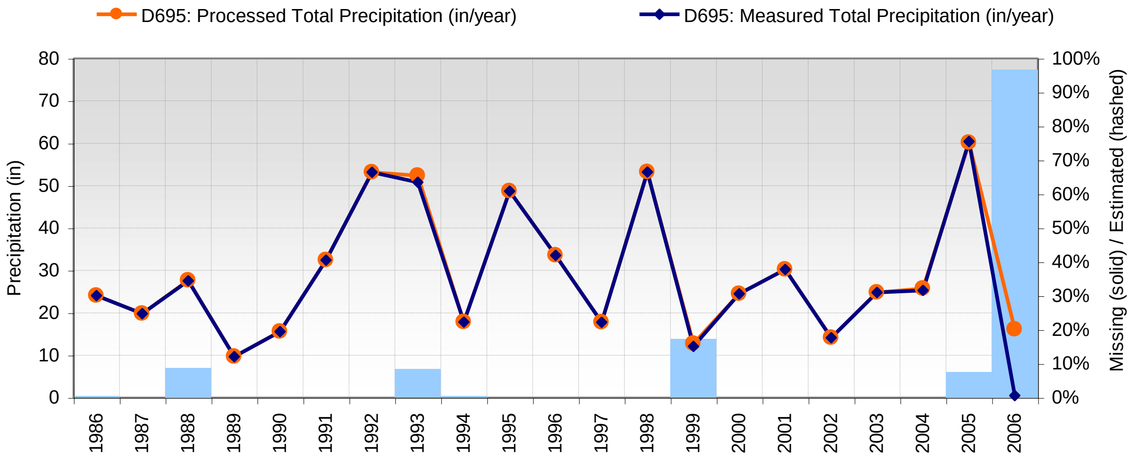


Figure A-135. Total precipitation at Tujunga Cyn Vogel Flat (D695)

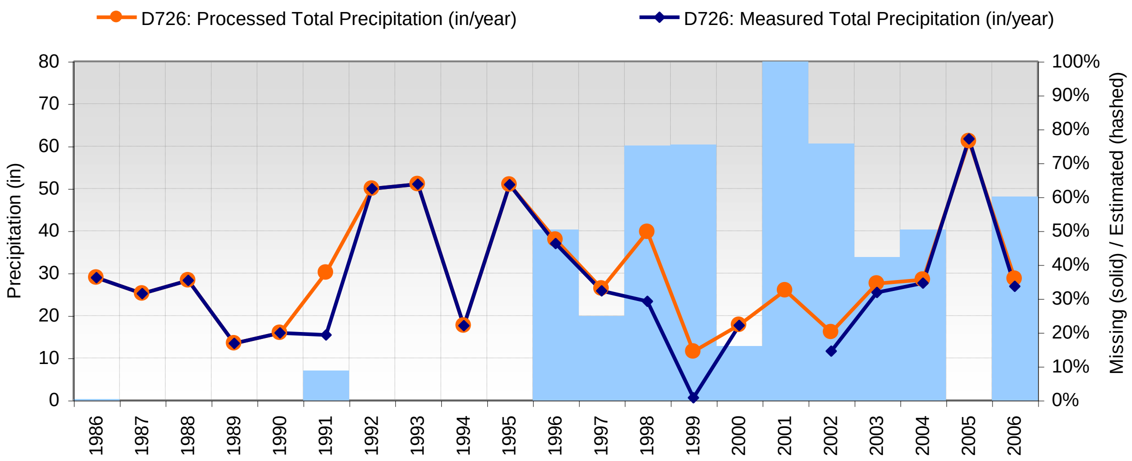


Figure A-136. Total precipitation at Angeles Crest Guard Station (D726)

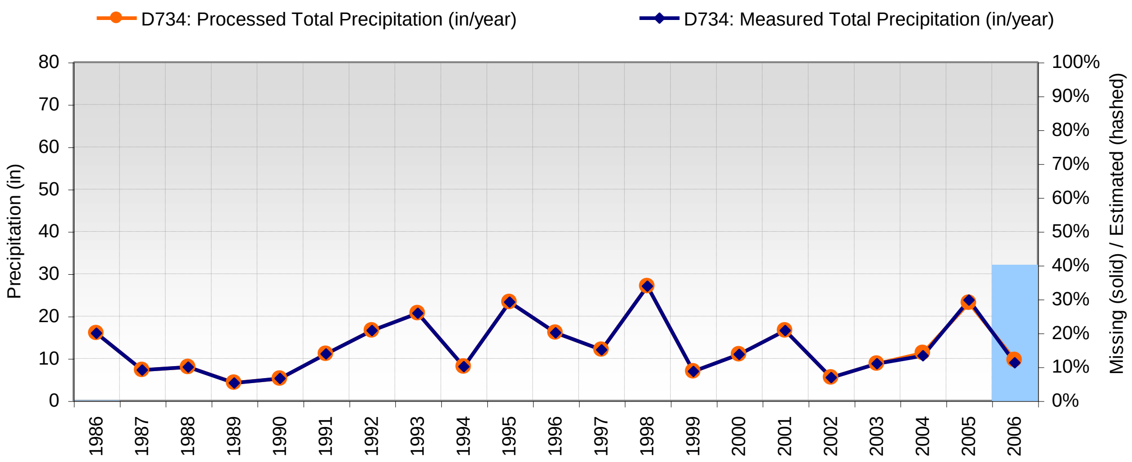


Figure A-137. Total precipitation at Los Angeles International Airport (D734)

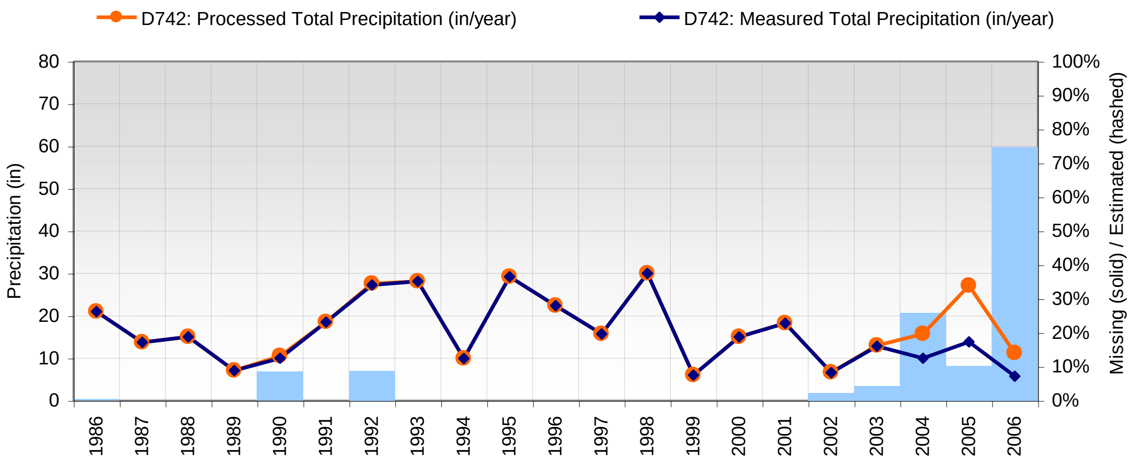


Figure A-138. Total precipitation at San Gabriel Fire Department (D742)

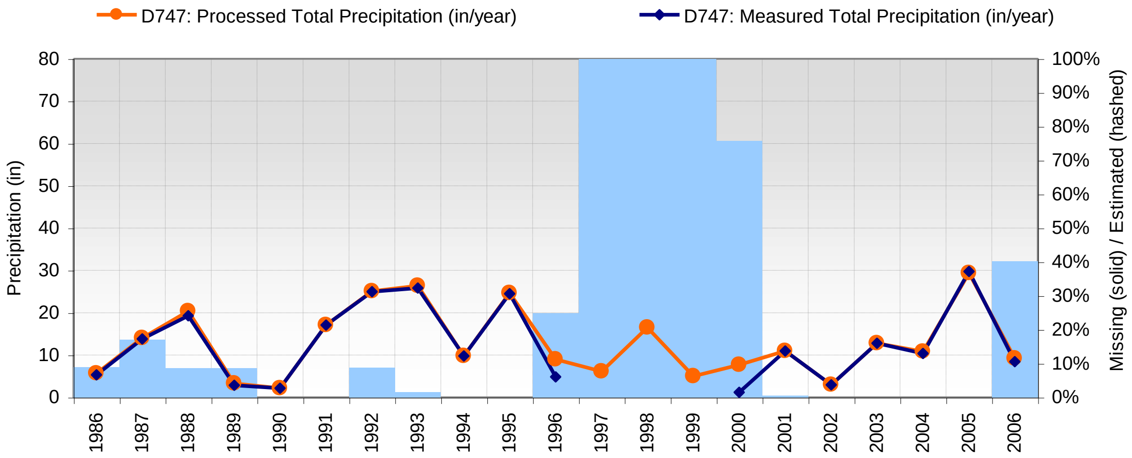


Figure A-139. Total precipitation at Sandberg Airways Station (D747)

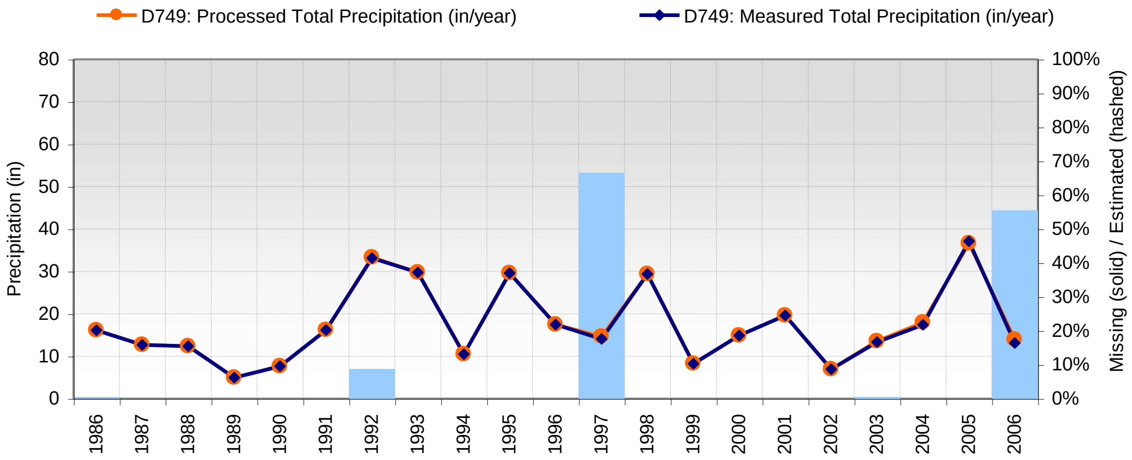


Figure A-140. Total precipitation at Burbank Valley Pump Plant (D749)

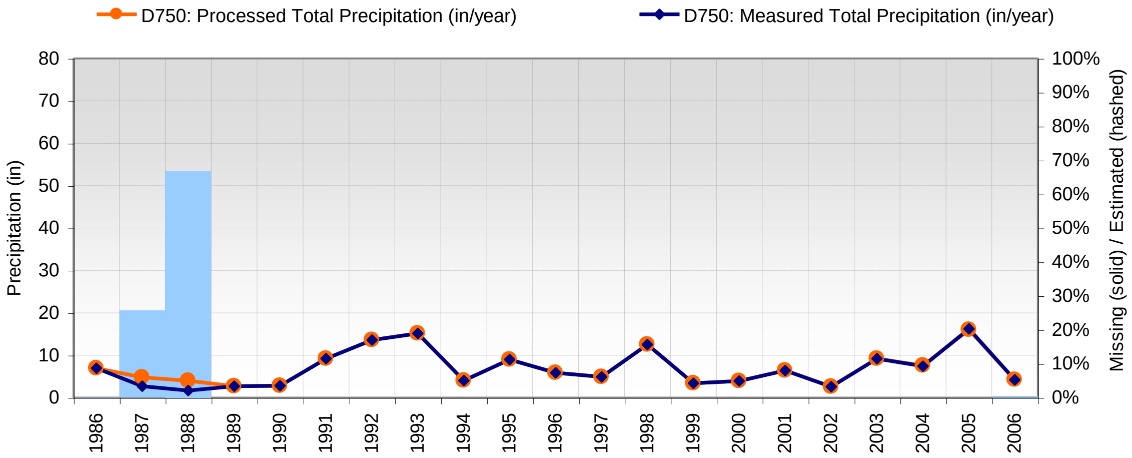


Figure A-141. Total precipitation at Palmdale F.A.A. Airport (D750)

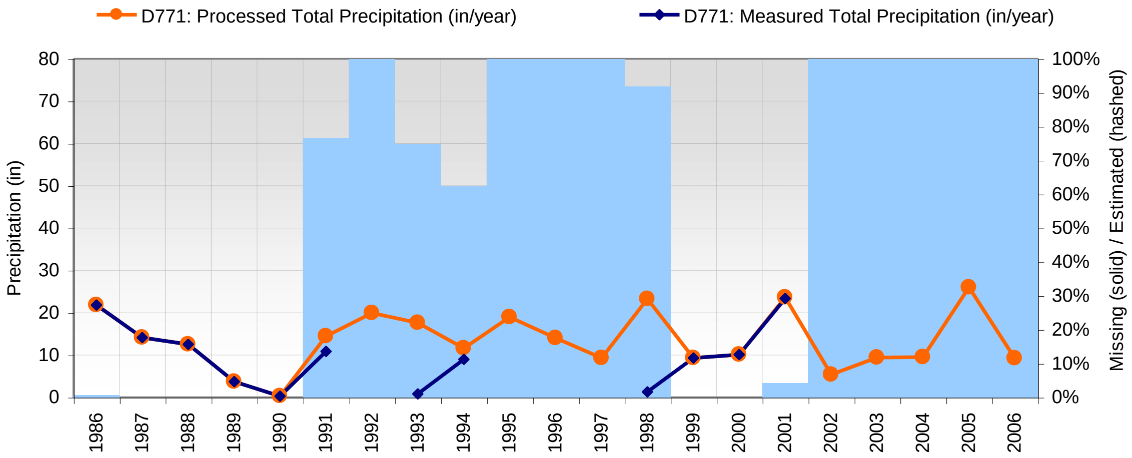


Figure A-142. Total precipitation at Pacific Palisades Riviera Country Club (D771)

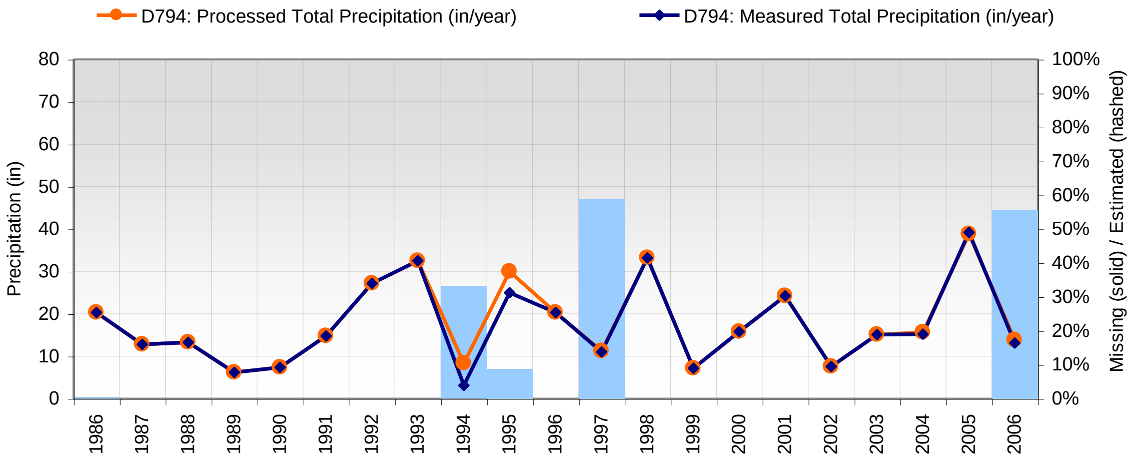


Figure A-143. Total precipitation at Lower Franklin Reservoir (D794)

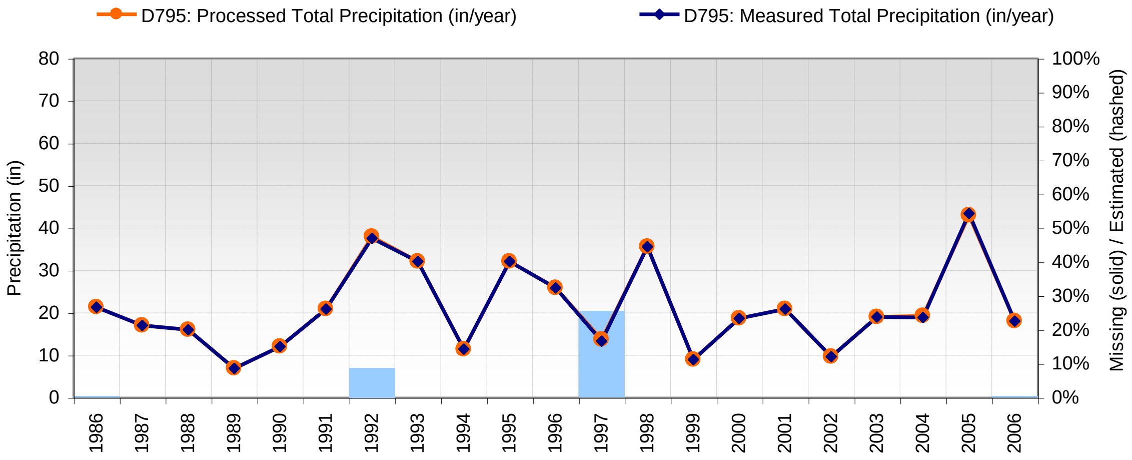


Figure A-144. Total precipitation at Pasadena Jourdan (D795)

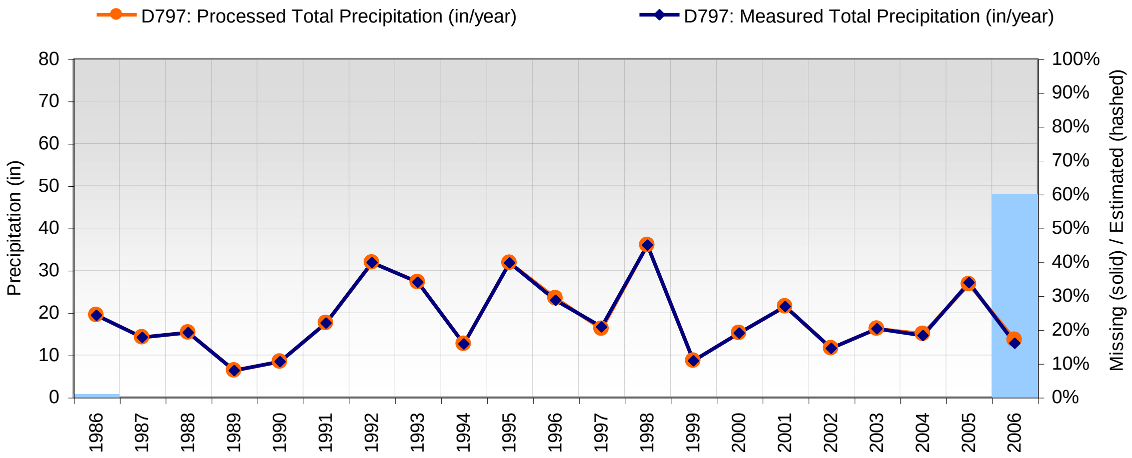


Figure A-145. Total precipitation at De Soto Reservoir (D797)

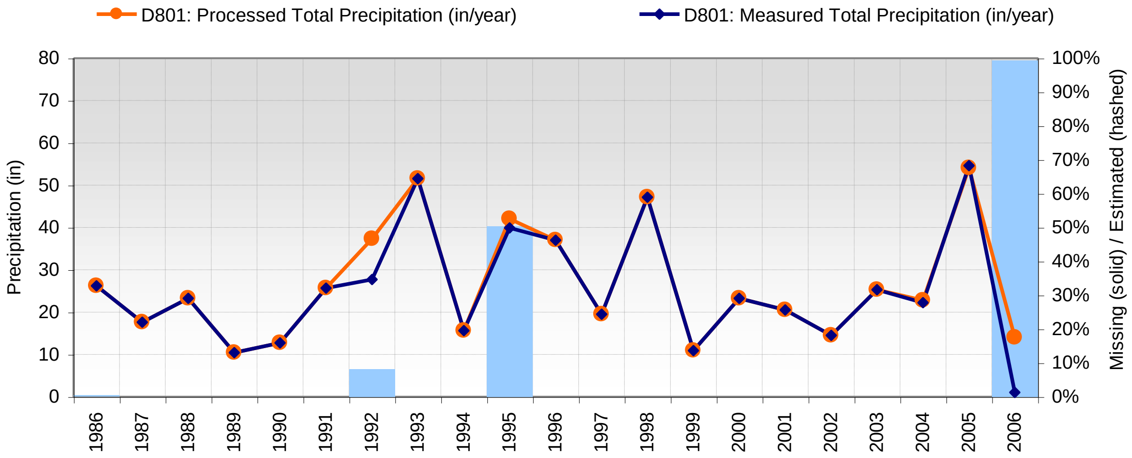


Figure A-146. Total precipitation at Magic Mountain (D801)

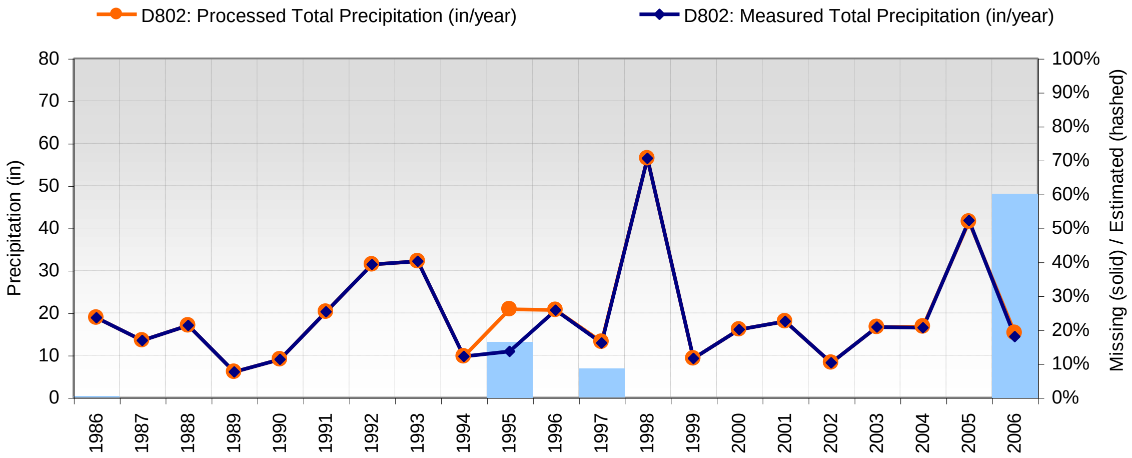


Figure A-147. Total precipitation at Eagle Rock Reservoir (D802)

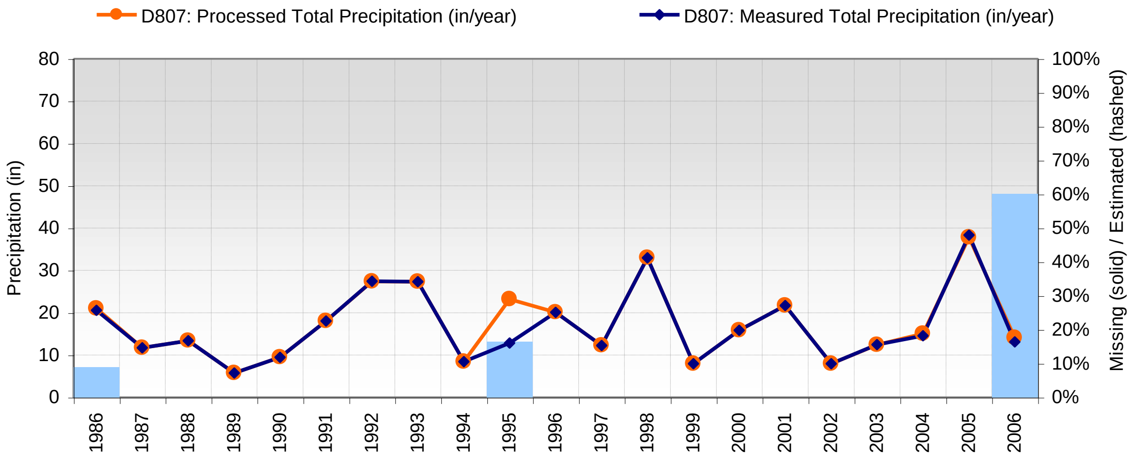


Figure A-148. Total precipitation at Ascot Reservoir (D807)

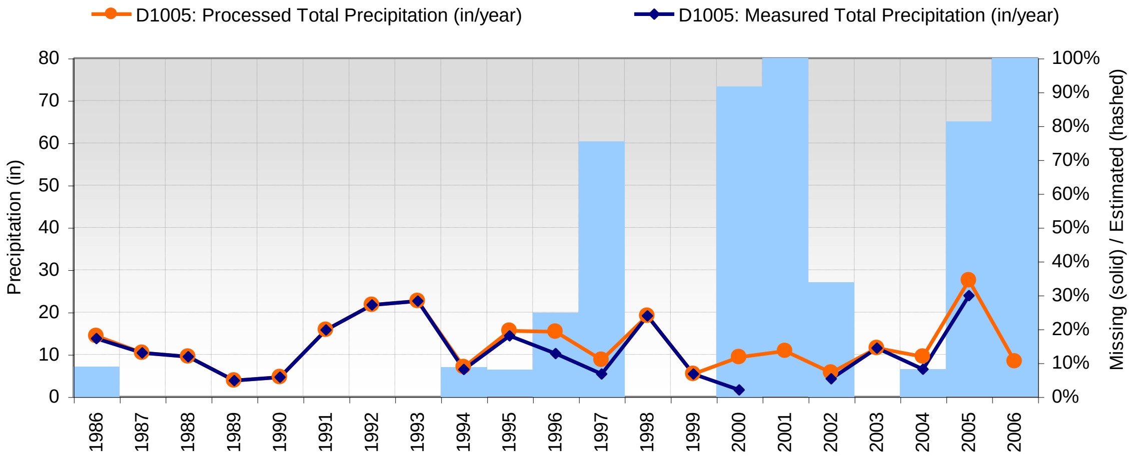


Figure A-149. Total precipitation at Mint Canyon Fire Station (D1005)

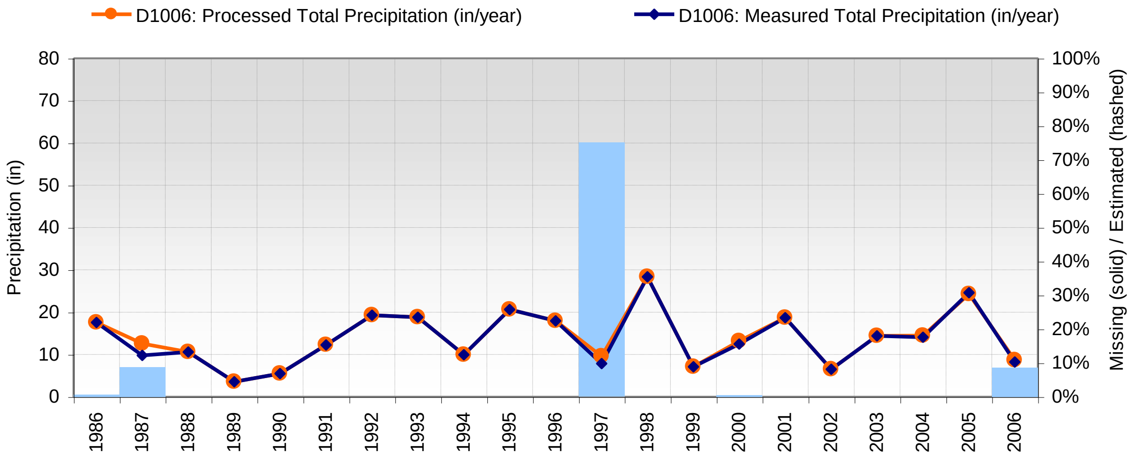


Figure A-150. Total precipitation at San Pedro City Reservoir (D1006)

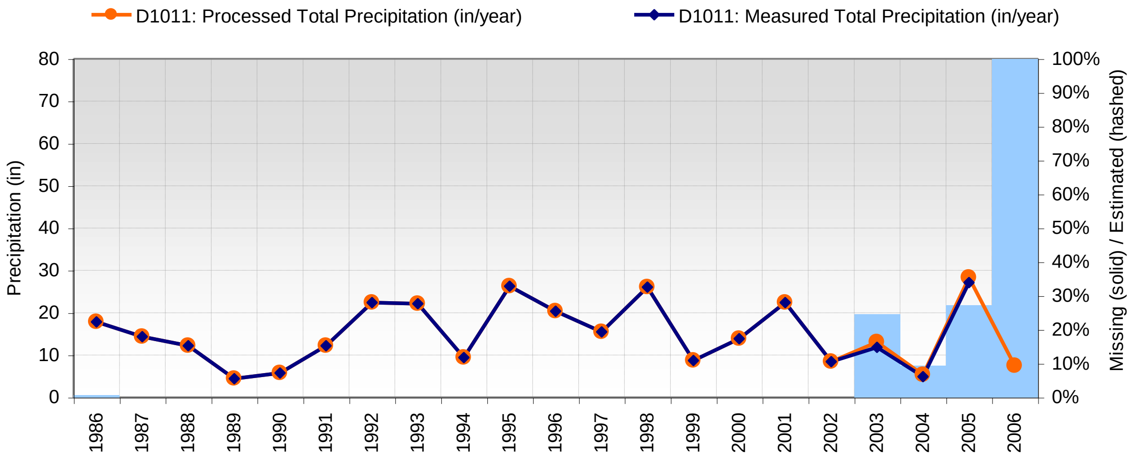


Figure A-151. Total precipitation at Palos Verdes Fire Station (D1011)

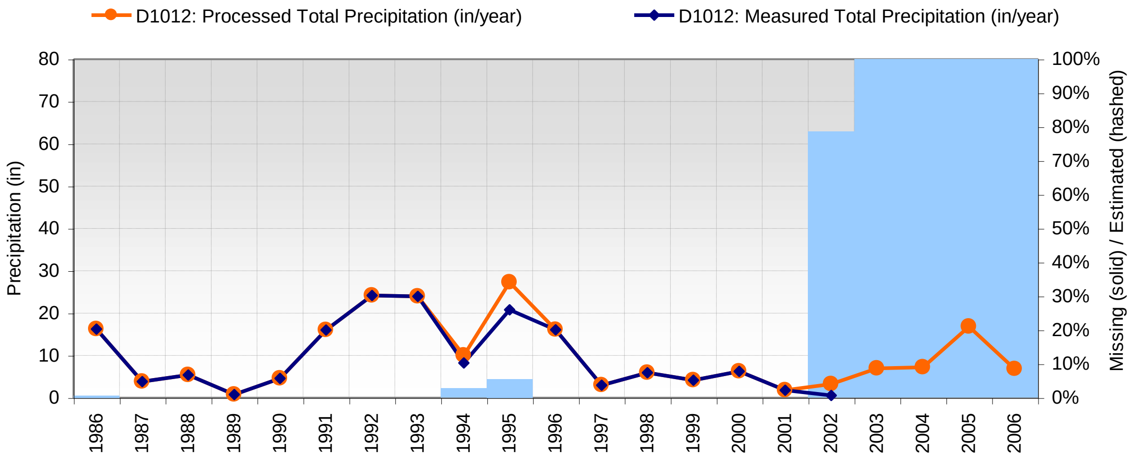


Figure A-152. Total precipitation at Castaic Junction (D1012)

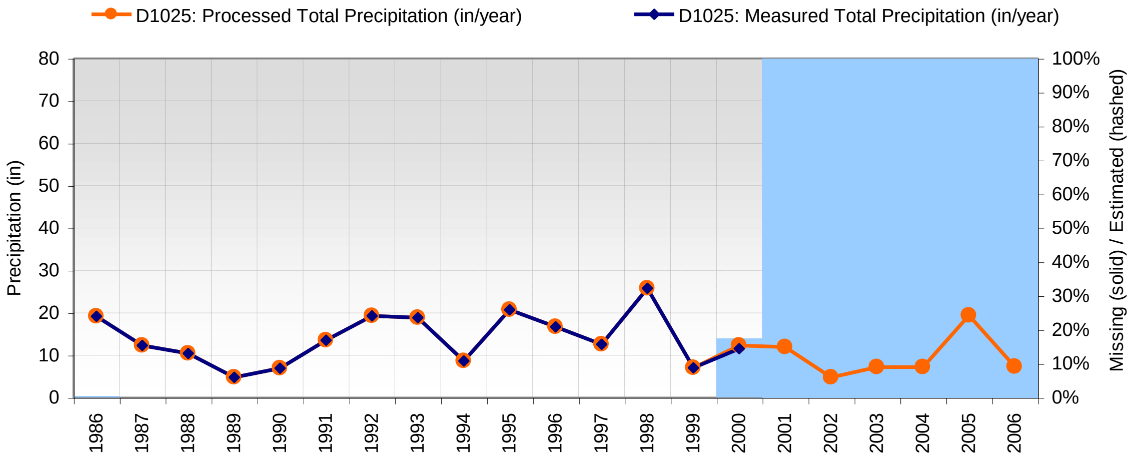


Figure A-153. Total precipitation at Malibu Beach Dunne (D1025)

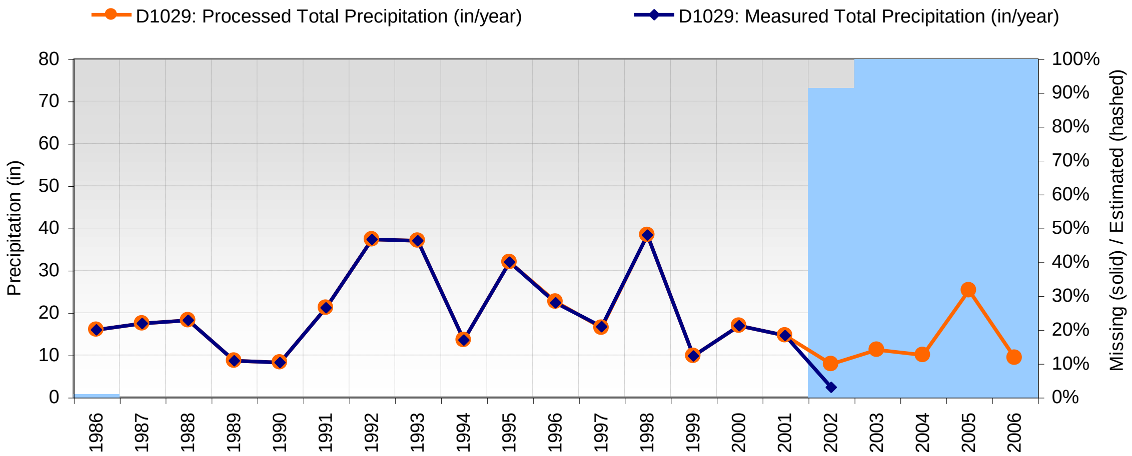


Figure A-154. Total precipitation at Tujunga Mill Creek Summit Ranger Station (D1029)

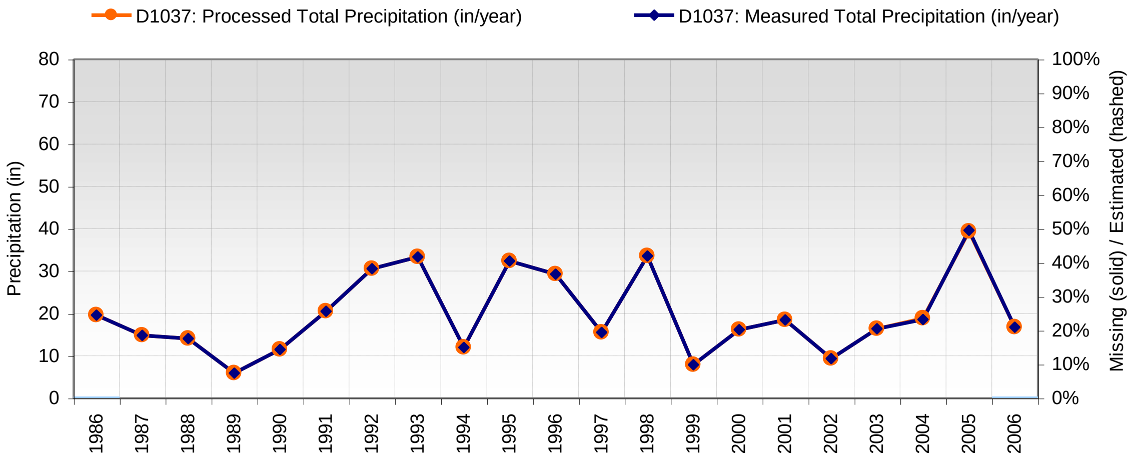


Figure A-155. Total precipitation at Arcadia Arboretum (D1037)

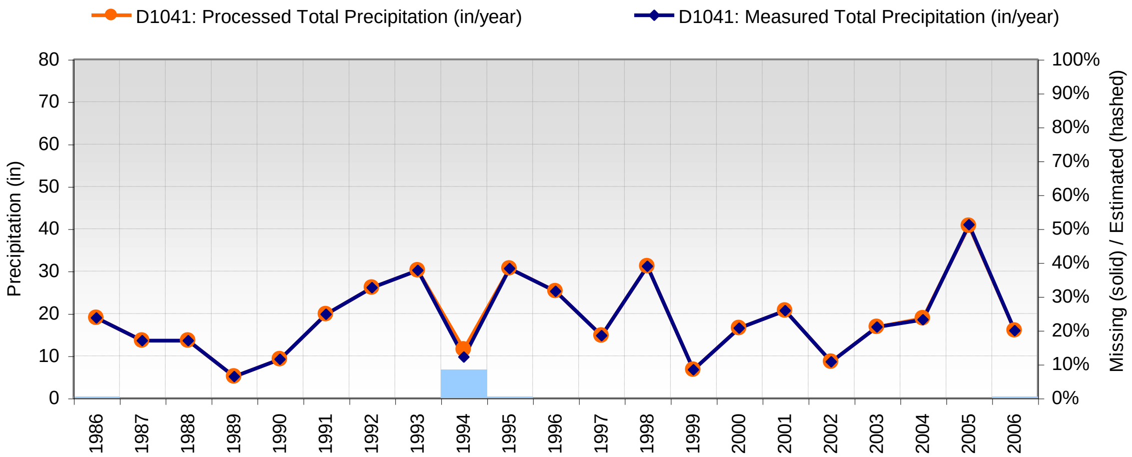


Figure A-156. Total precipitation at Santa Fe Dam (D1041)

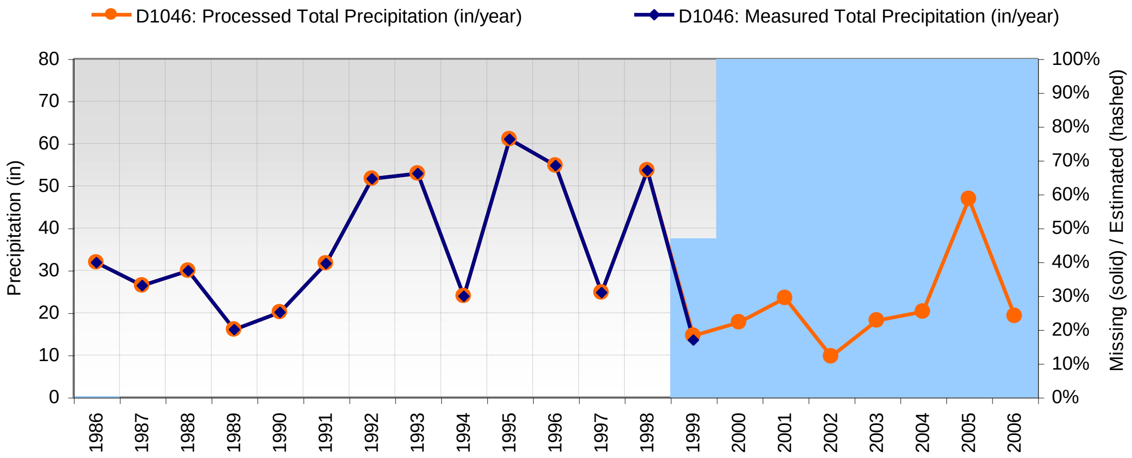


Figure A-157. Total precipitation at Santa Anita Canyon Chantry Flat (D1046)

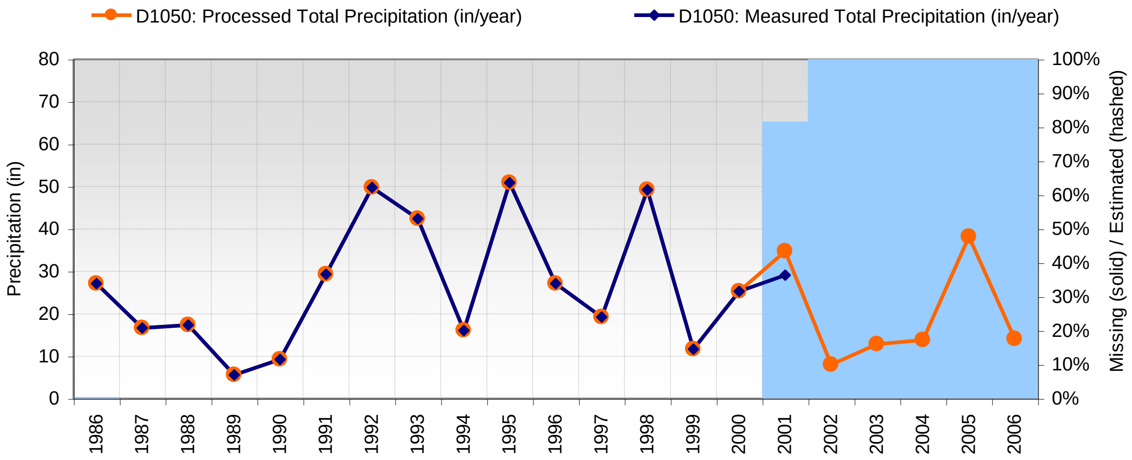


Figure A-158. Total precipitation at Old Topanga (D1050)

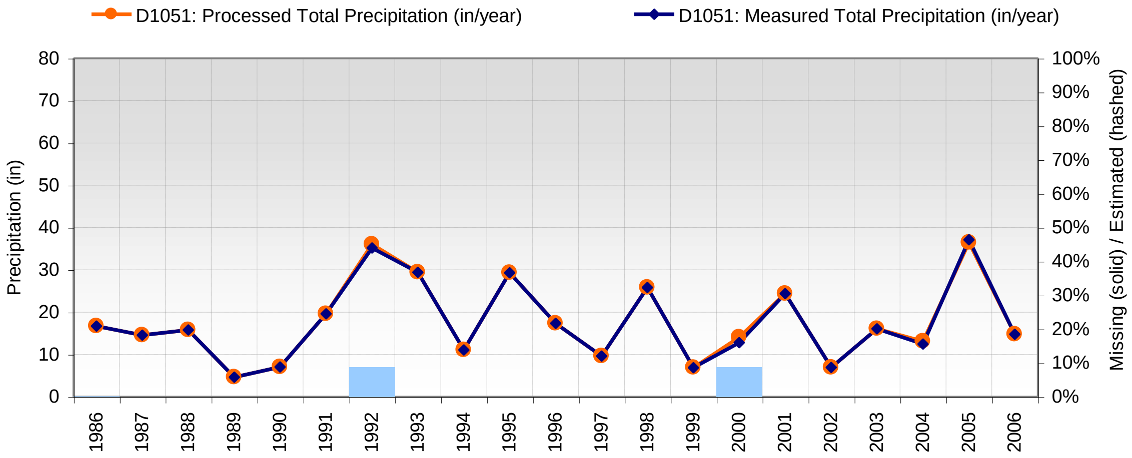


Figure A-159. Total precipitation at Canoga Park Pierce College (D1051)

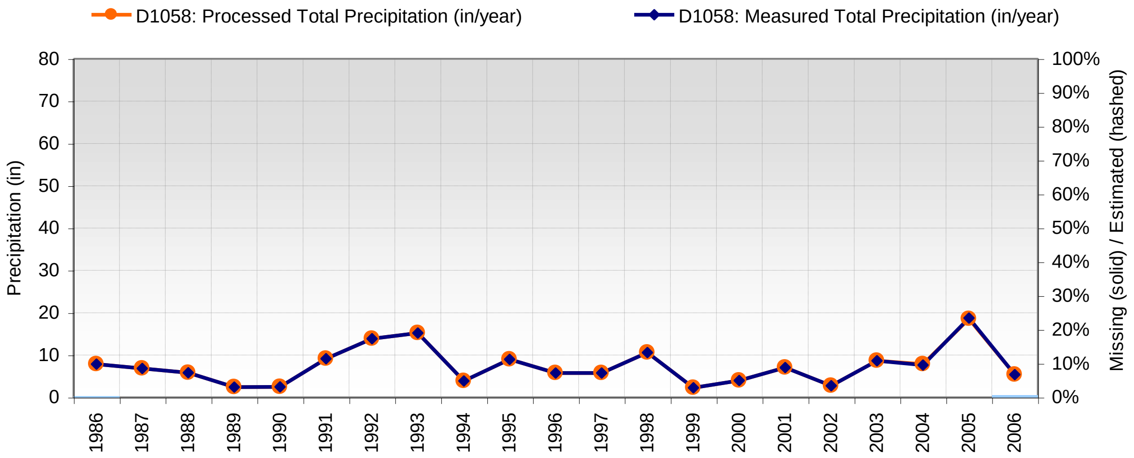


Figure A-160. Total precipitation at Palmdale (D1058)

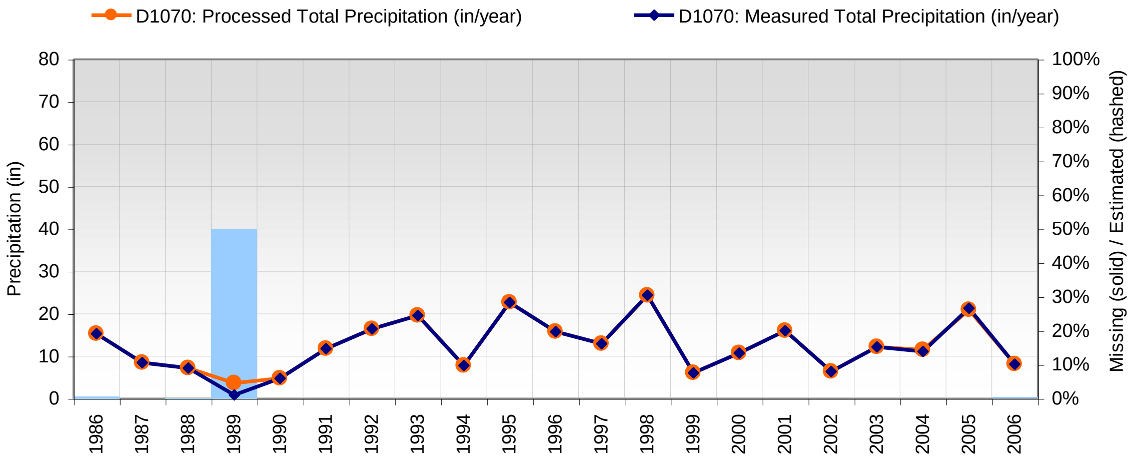


Figure A-161. Total precipitation at Manhattan Beach (D1070)

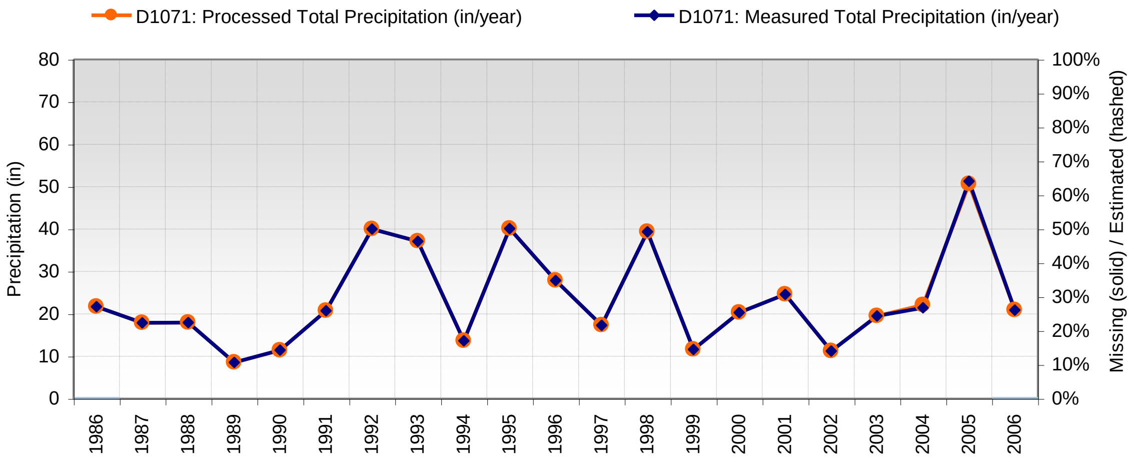


Figure A-162. Total precipitation at Descanso Gardens (D1071)

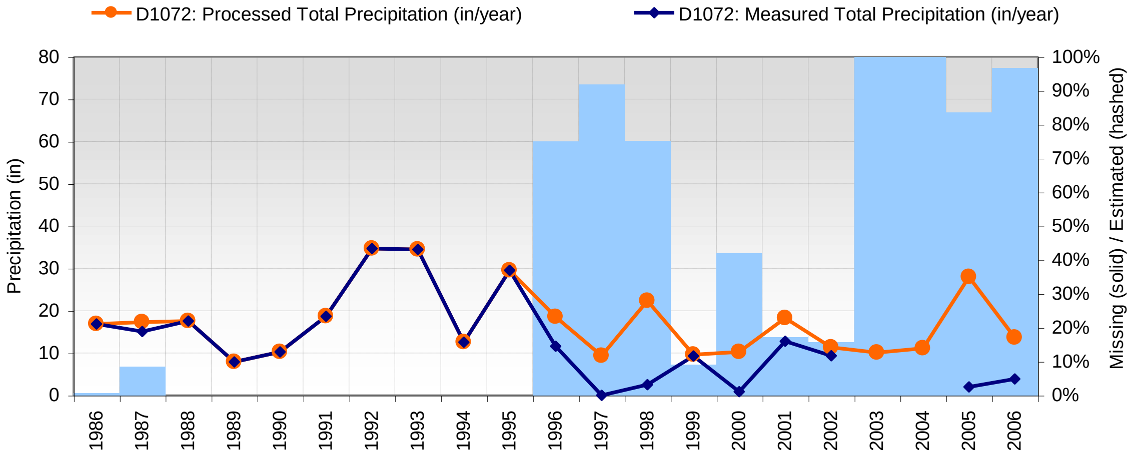


Figure A-163. Total precipitation at Little Tujunga Ranger Station (D1072)

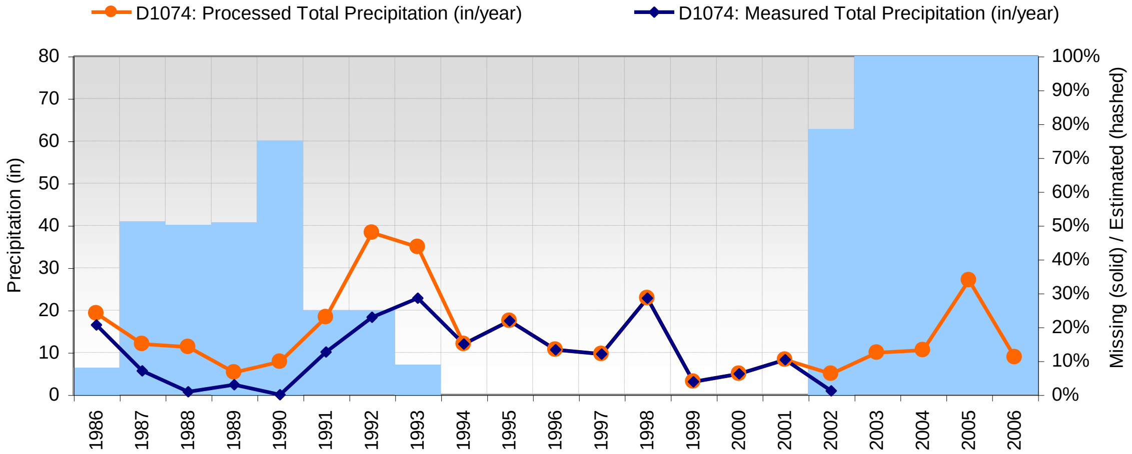


Figure A-164. Total precipitation at Little Gleason (D1074)

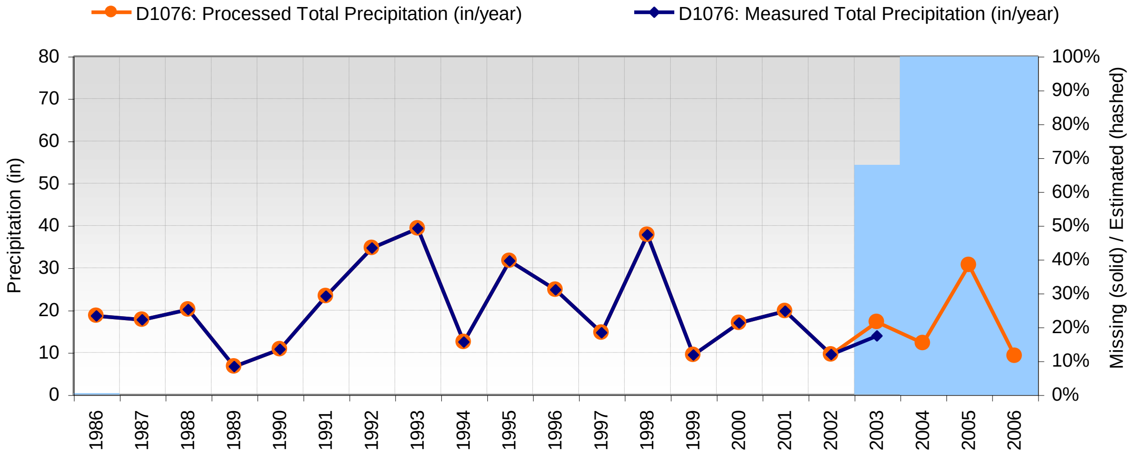


Figure A-165. Total precipitation at Monte Cristo Ranger Station (D1076)

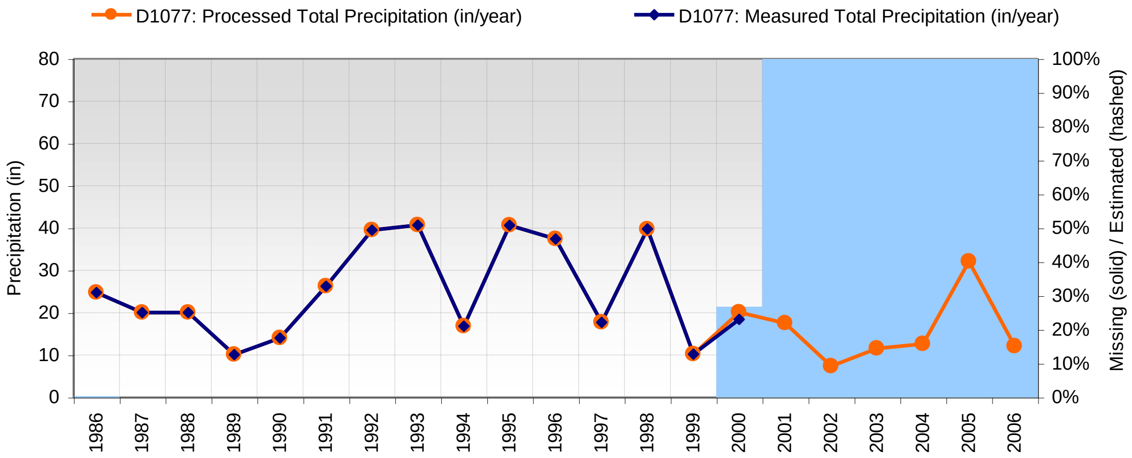


Figure A-166. Total precipitation at Monrovia Five Points (D1077)

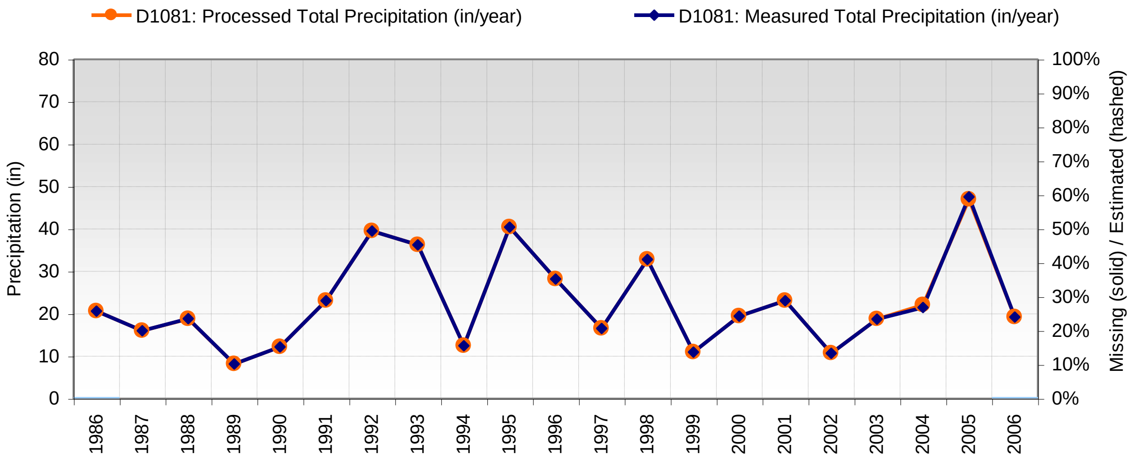


Figure A-167. Total precipitation at Glendale Gregg (D1081)

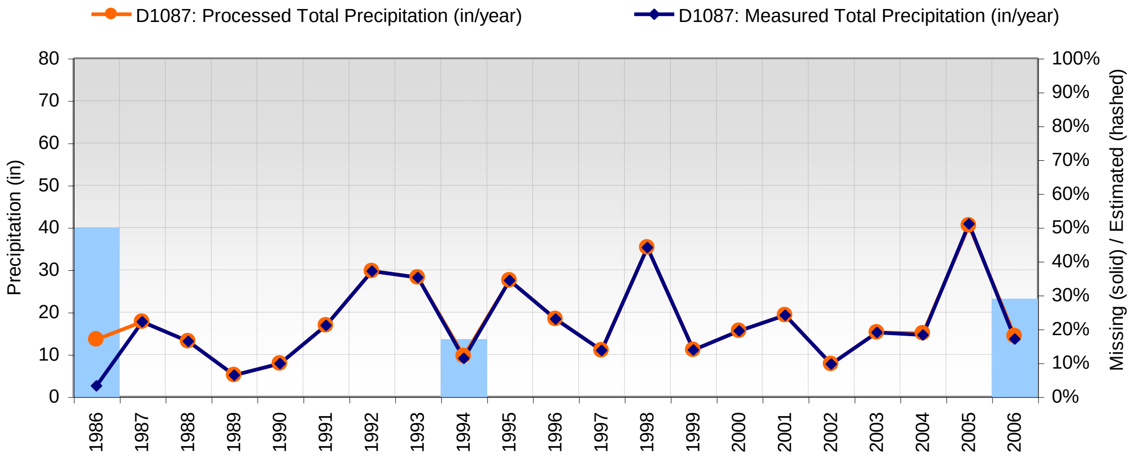


Figure A-168. Total precipitation at Green Verdugo Pumping Plant (D1087)

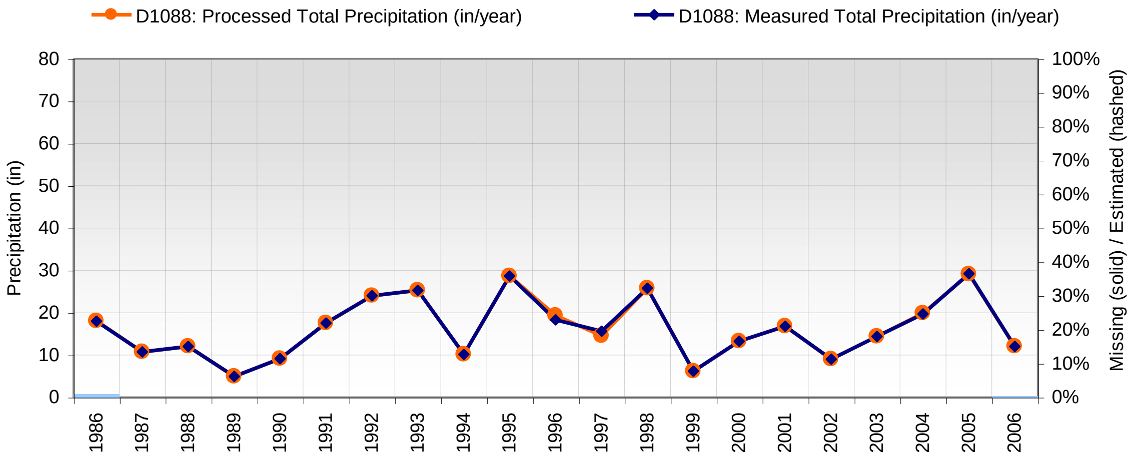


Figure A-169. Total precipitation at La Habra Heights Mutual Water Co (D1088)

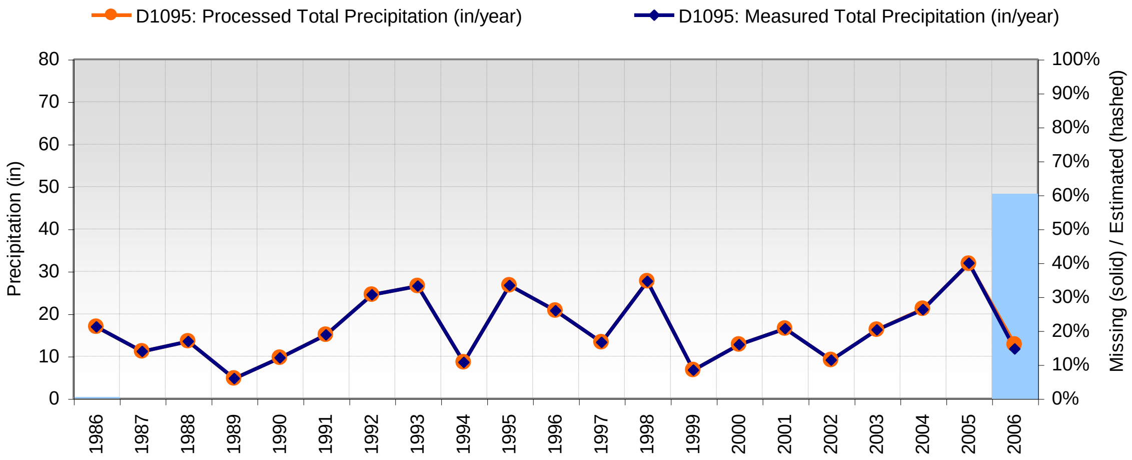


Figure A-170. Total precipitation at Orange County Reservoir (D1095)

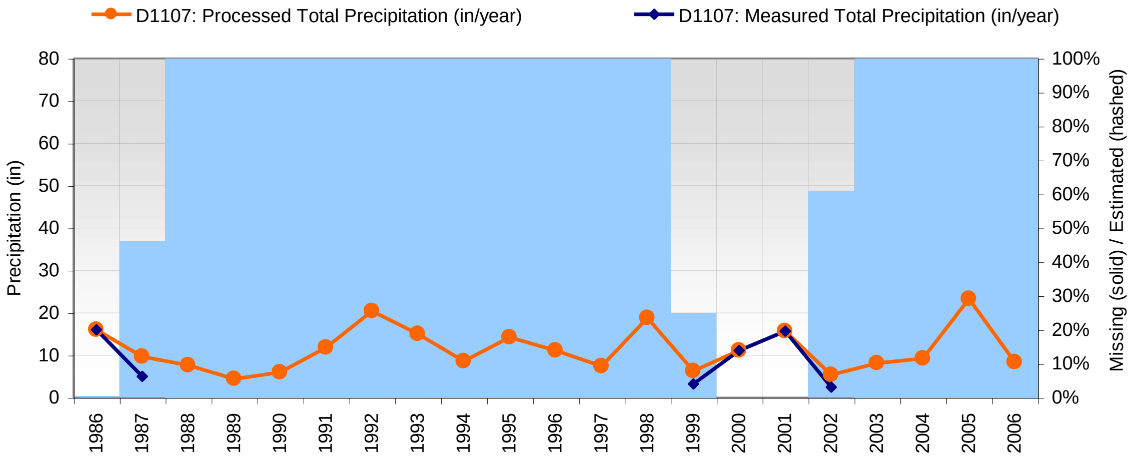


Figure A-171. Total precipitation at La Tuna Canyon (D1107)

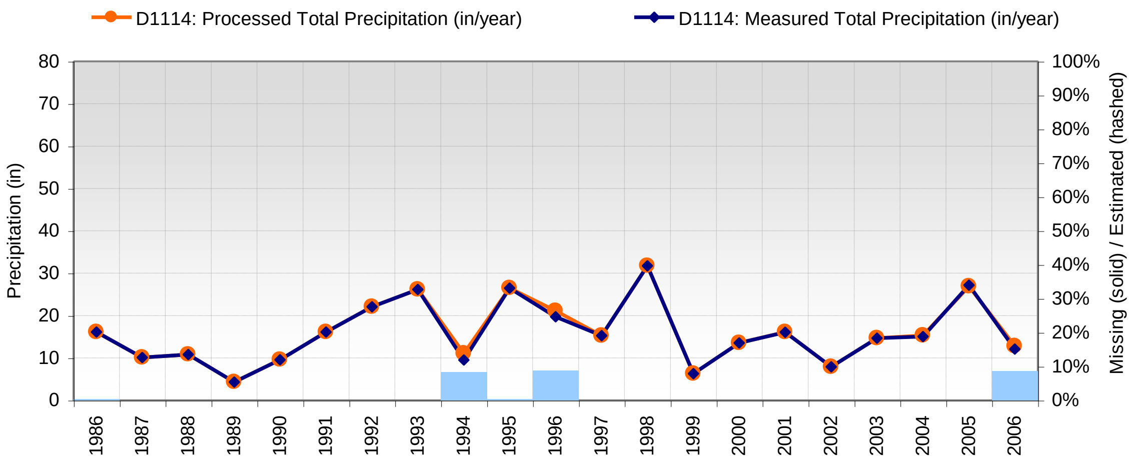


Figure A-172. Total precipitation at Whittier Narrows Dam (D1114)

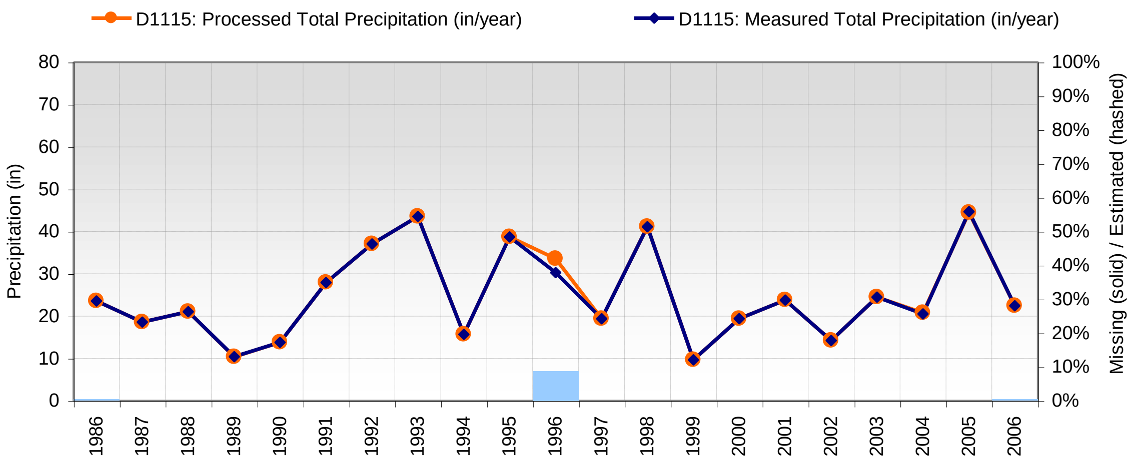


Figure A-173. Total precipitation at San Antonio Dam (D1115)

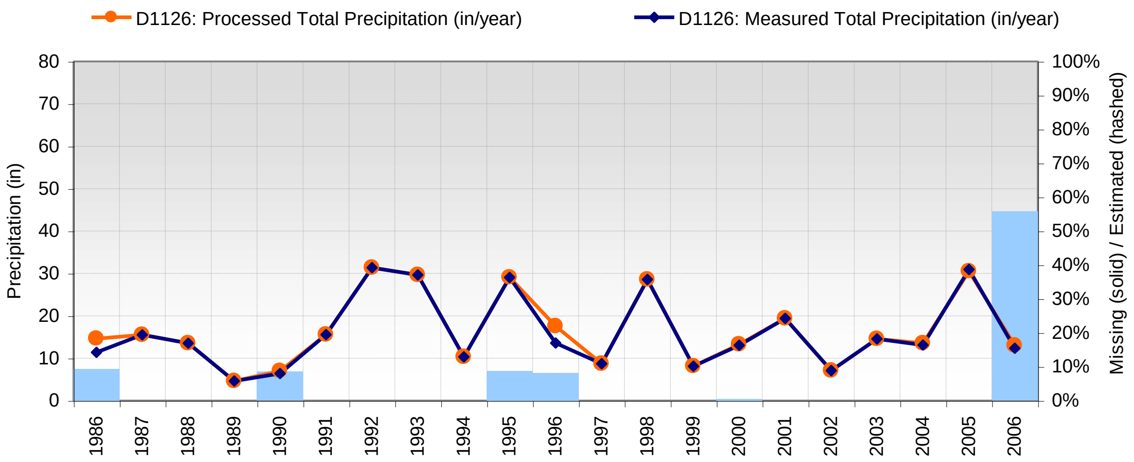


Figure A-174. Total precipitation at Los Angeles East Valley (D1126)

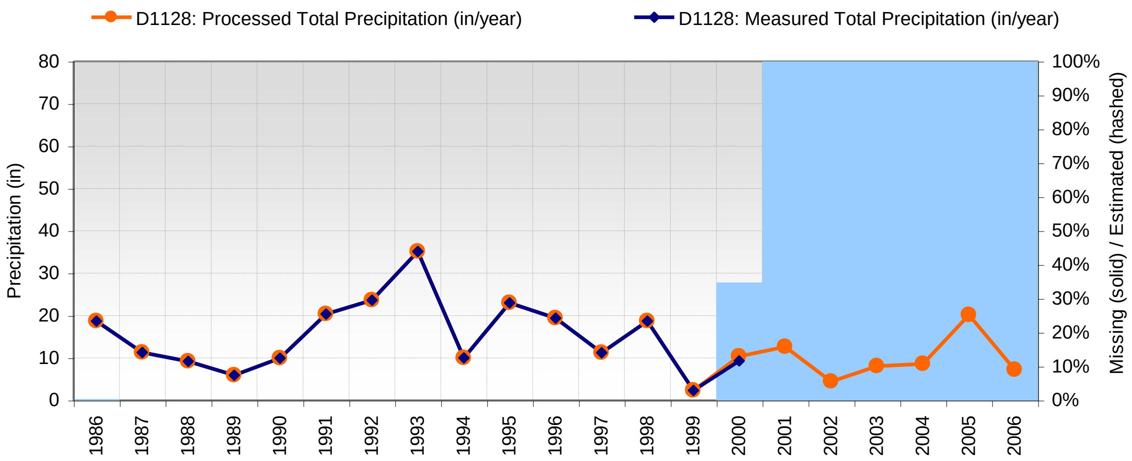


Figure A-175. Total precipitation at Wrightwood (D1128)

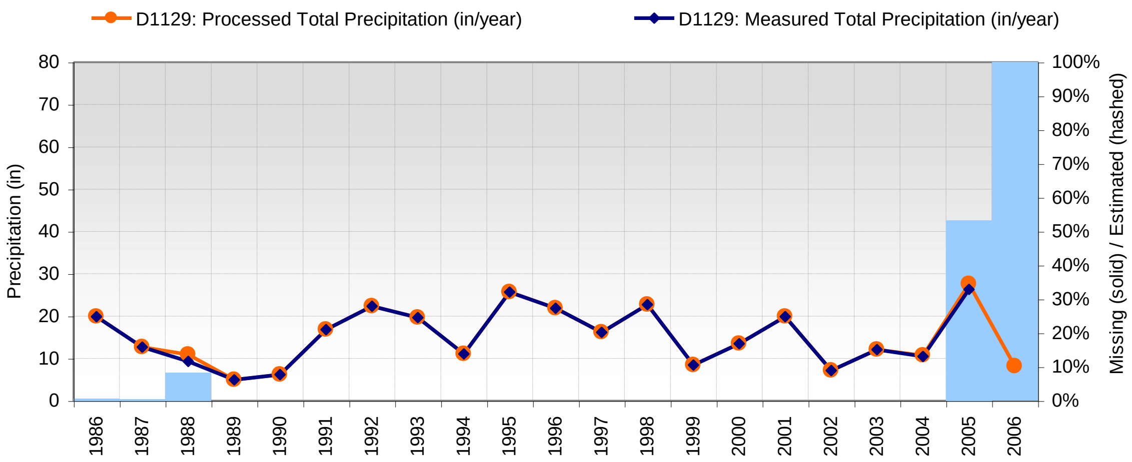


Figure A-176. Total precipitation at Nicholas Canyon (D1129)

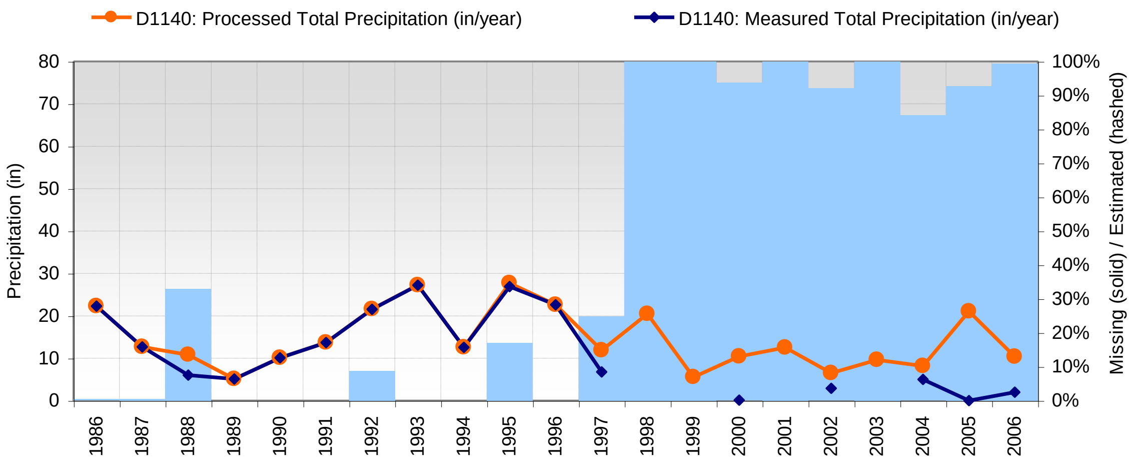


Figure A-177. Total precipitation at Rosemead (D1140)

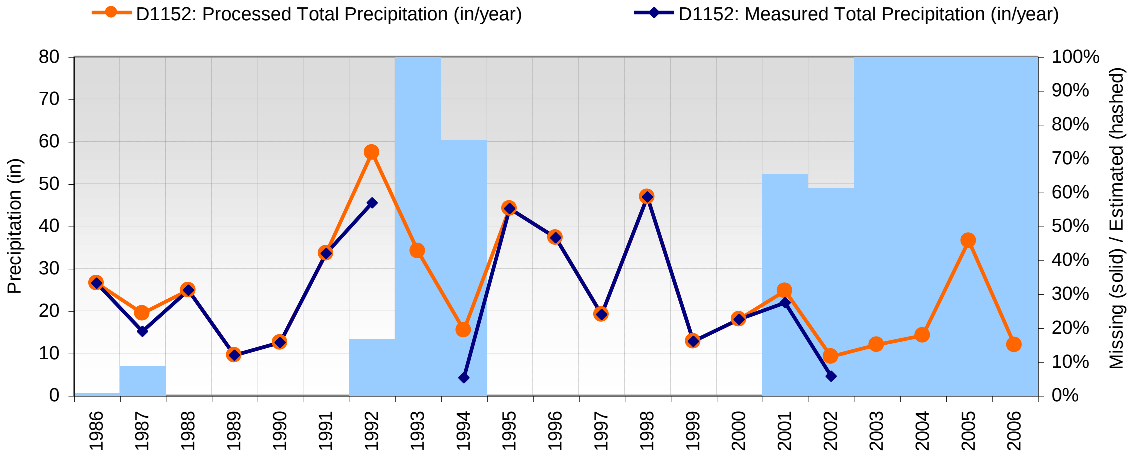


Figure A-178. Total precipitation at Clear Creek Ranger Station (D1152)

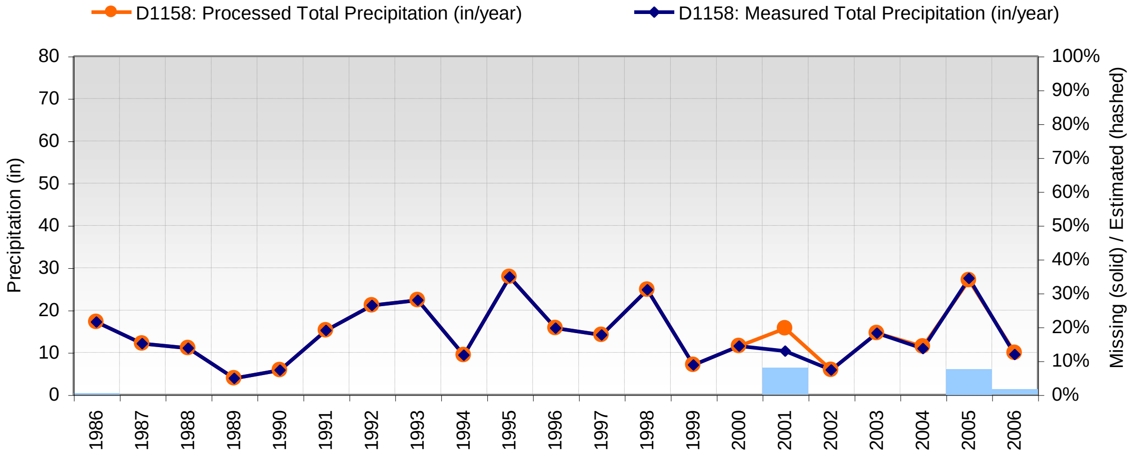


Figure A-179. Total precipitation at Torrance Municipal Airport (D1158)

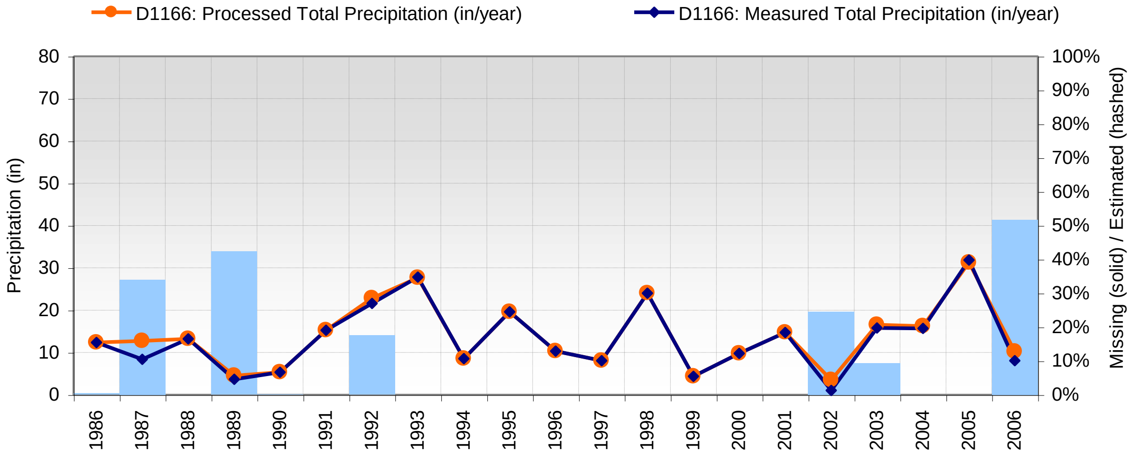


Figure A-180. Total precipitation at Mile High Ranch (D1166)

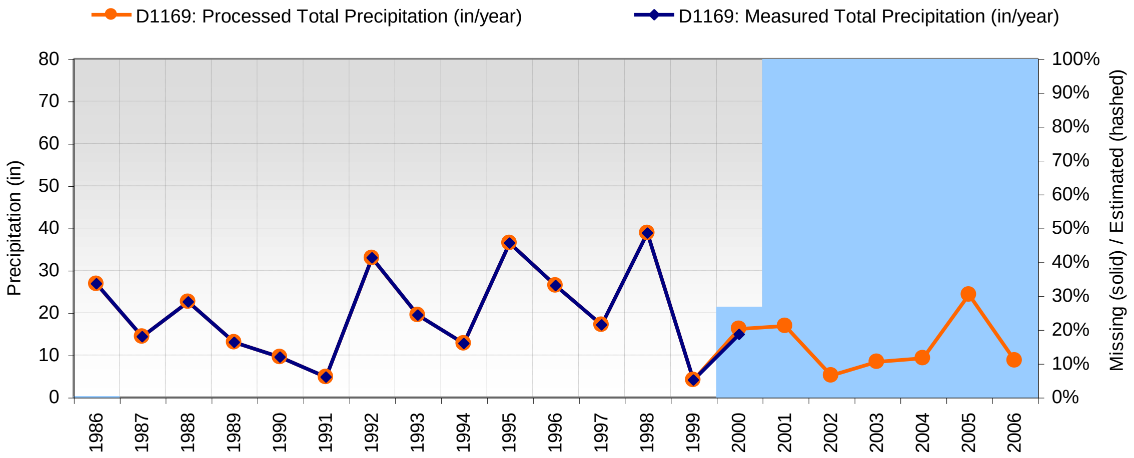


Figure A-181. Total precipitation at Piru Temescal Guard Station (D1169)

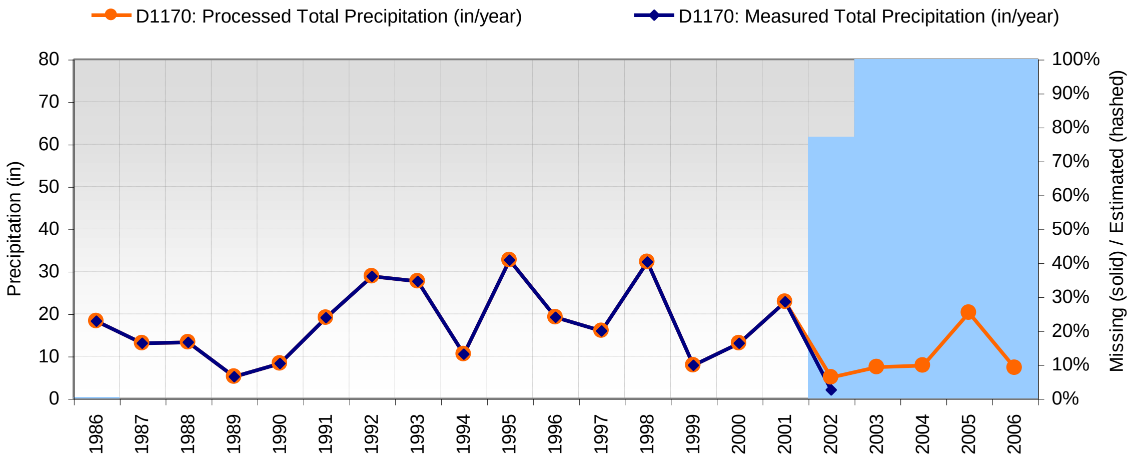


Figure A-182. Total precipitation at Thousand Oaks Weather Station (D1170)

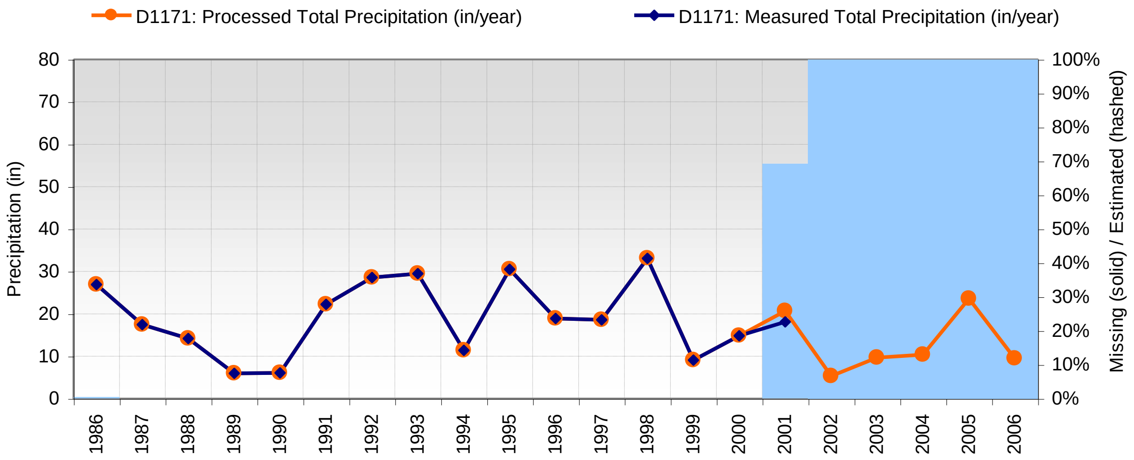


Figure A-183. Total precipitation at Camulos Ranch (D1171)

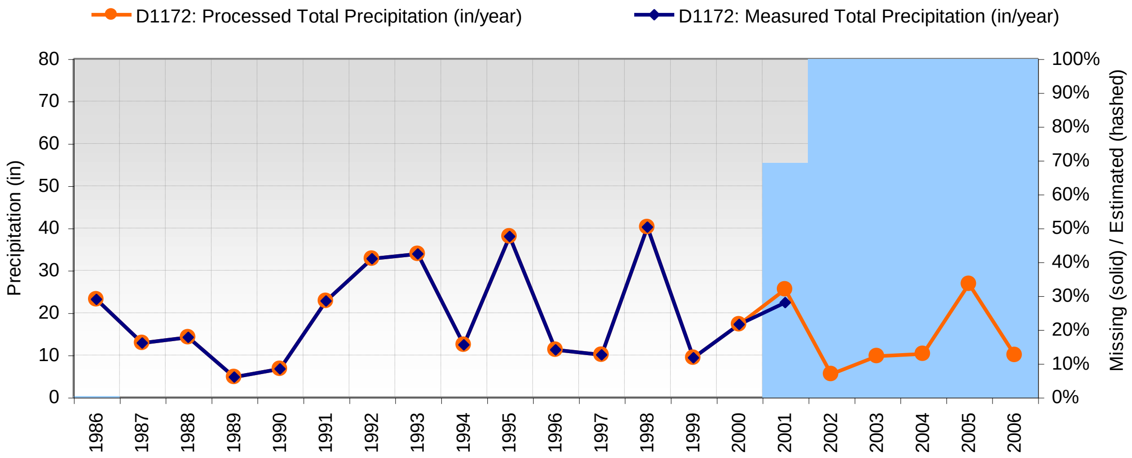


Figure A-184. Total precipitation at Piru Canyon above Piru Lake (D1172)

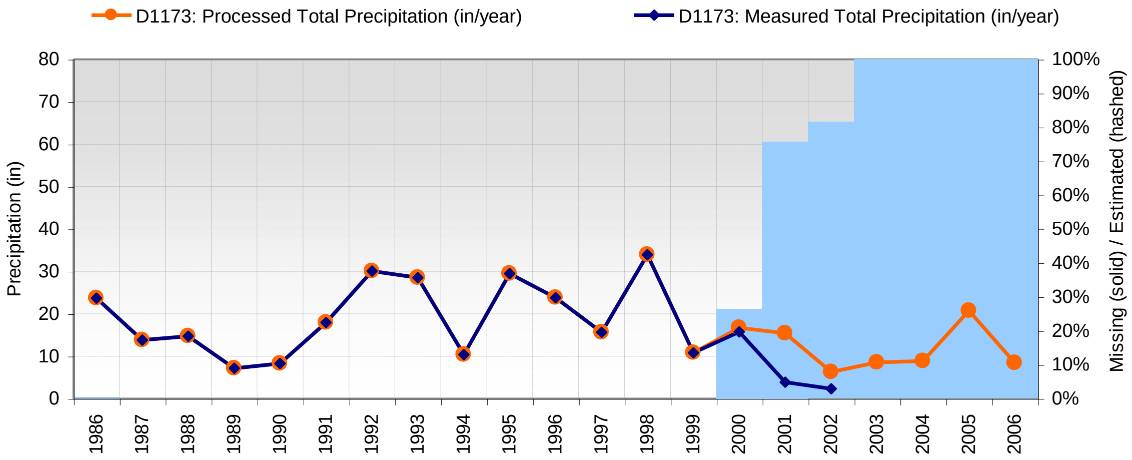


Figure A-185. Total precipitation at Tapo Canyon (D1173)

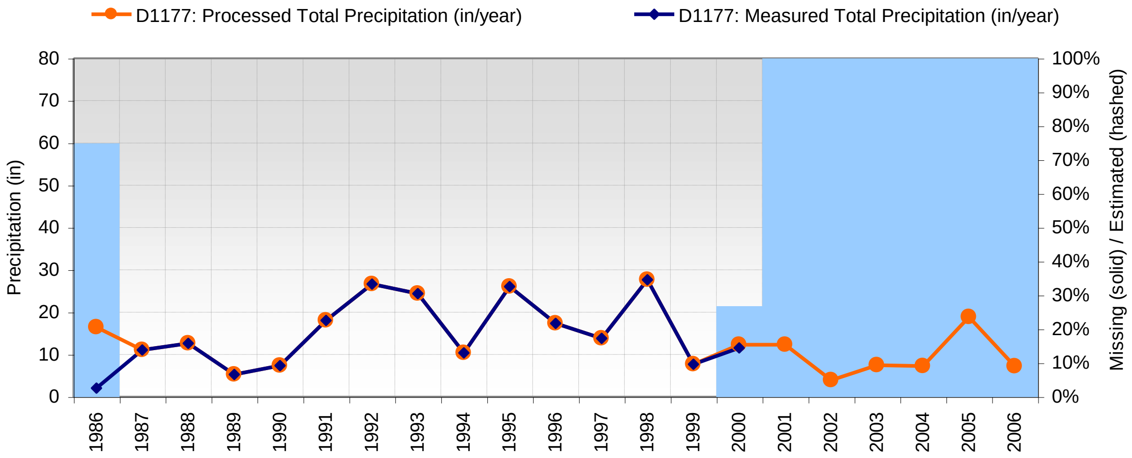


Figure A-186. Total precipitation at Bard Reservoir (D1177)

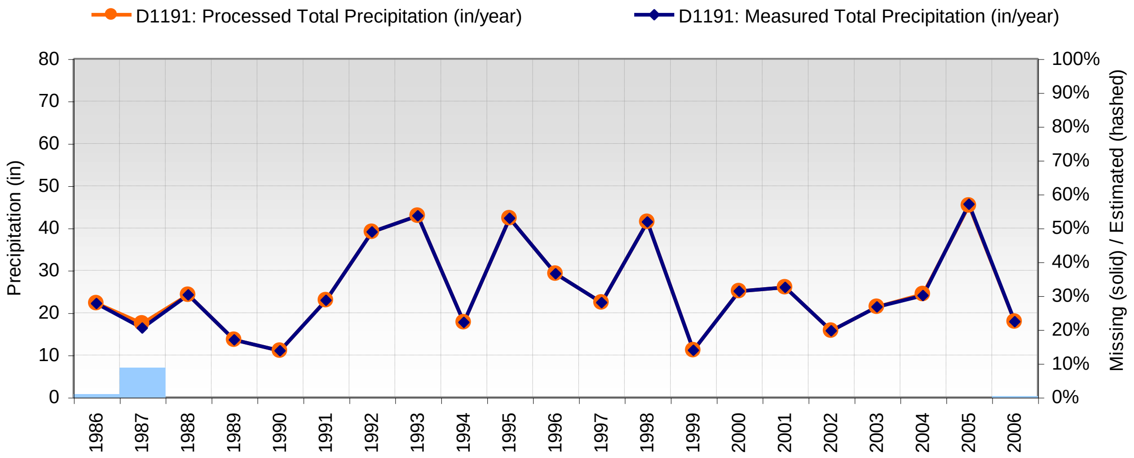


Figure A-187. Total precipitation at Bear Divide (D1191)

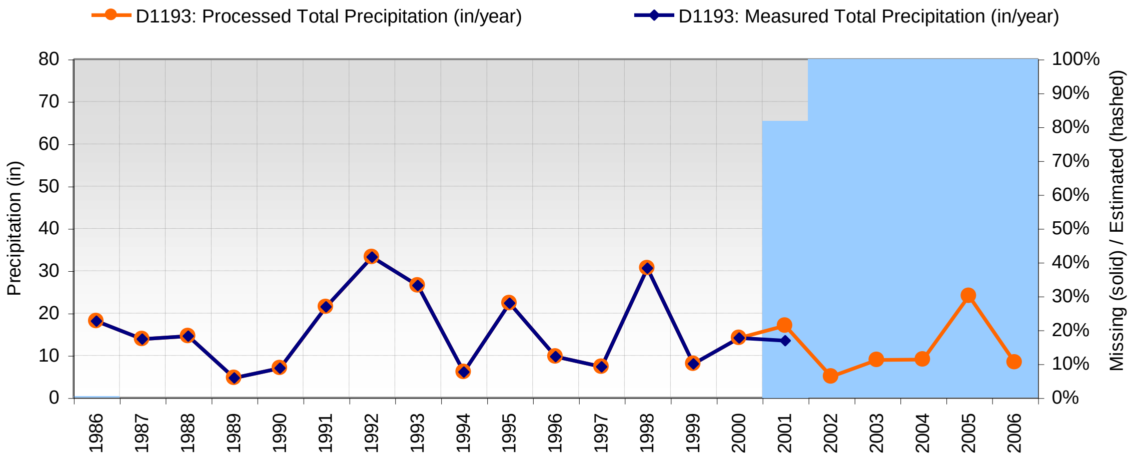


Figure A-188. Total precipitation at Westlake Village (D1193)

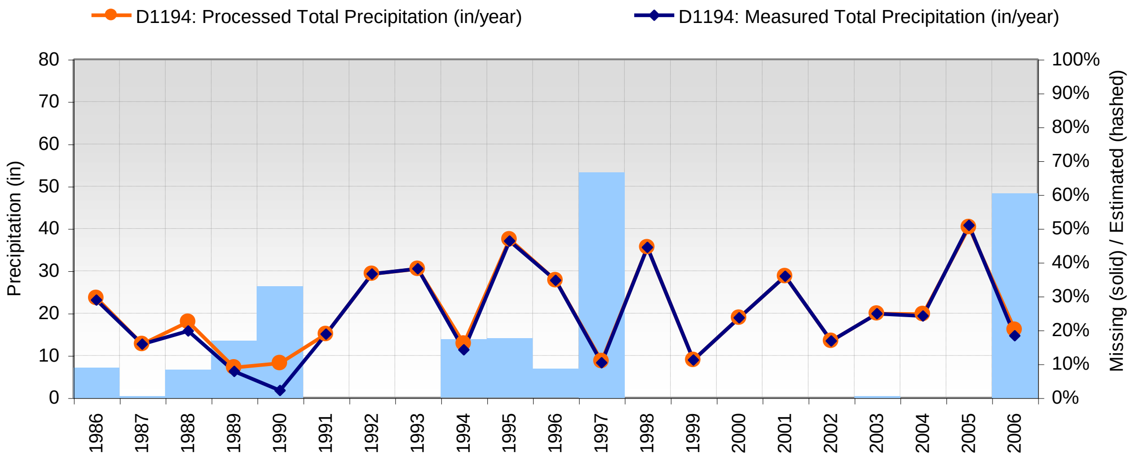


Figure A-189. Total precipitation at Santa Ynez Reservoir (D1194)

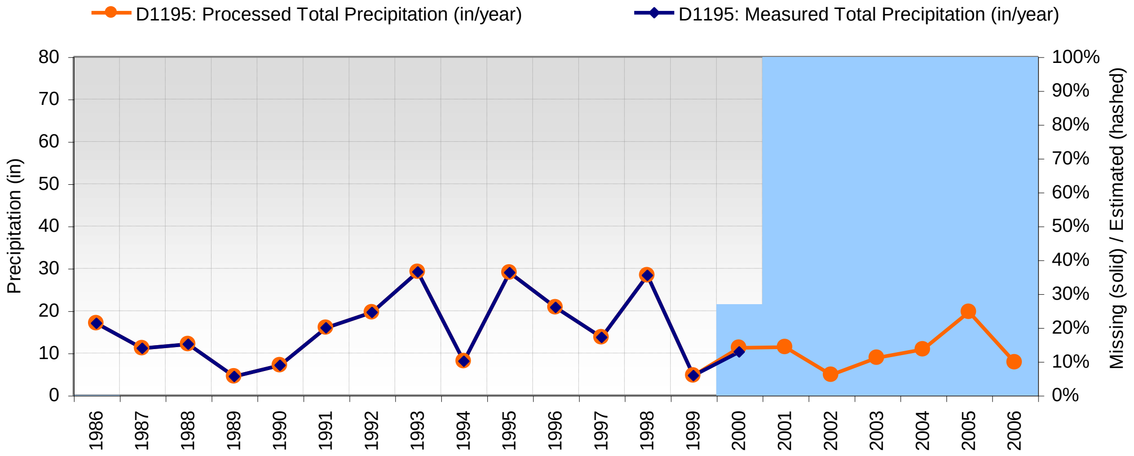


Figure A-190. Total precipitation at Chino Fire Station No.2 (D1195)

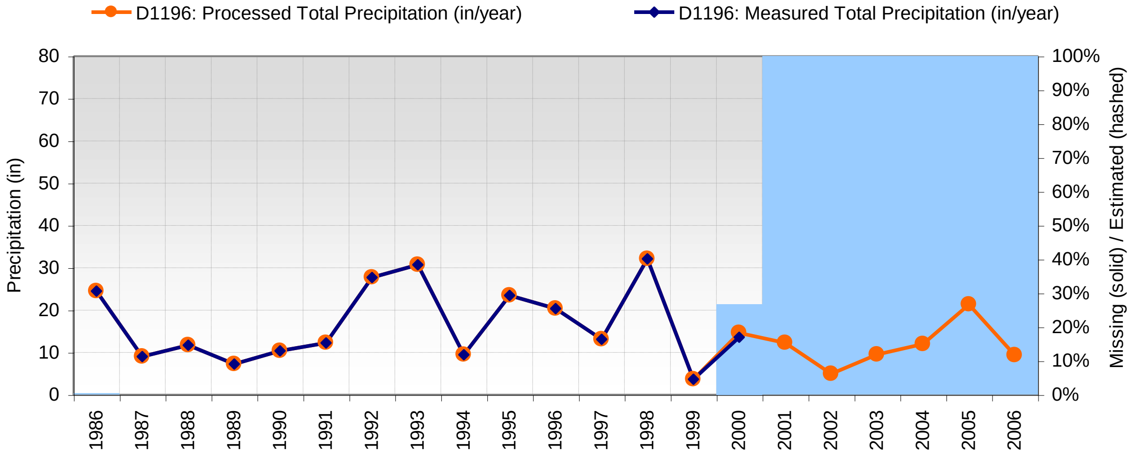


Figure A-191. Total precipitation at Montclair Fire Station (D1196)

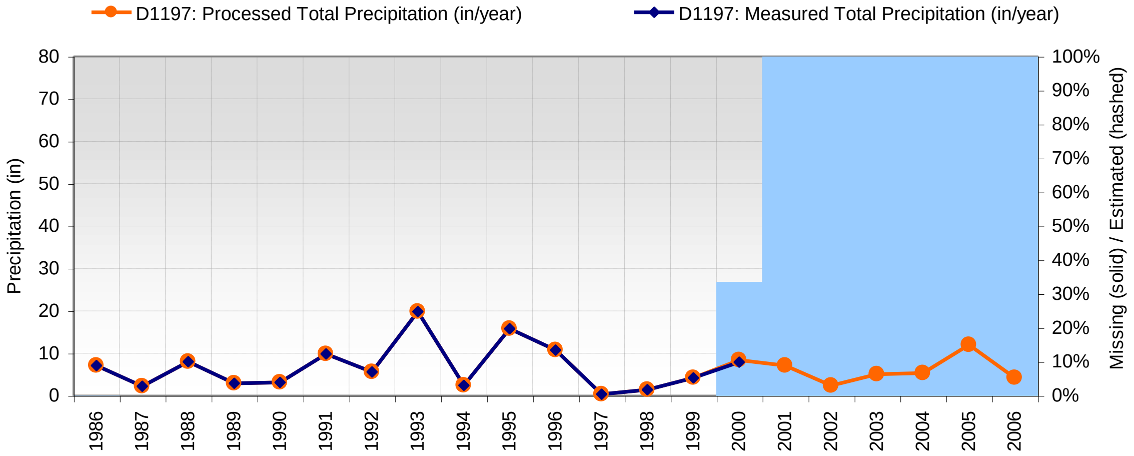


Figure A-192. Total precipitation at Cajon West Summit (D1197)

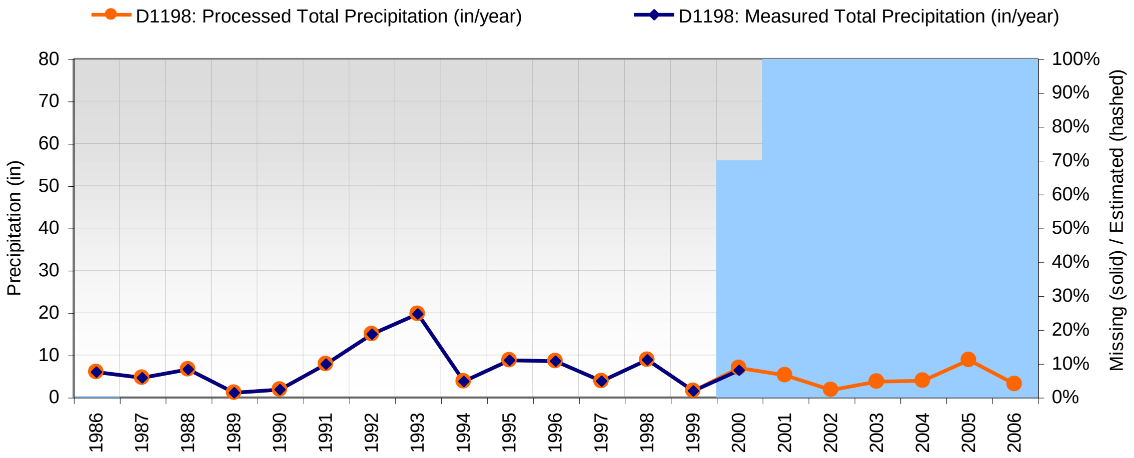


Figure A-193. Total precipitation at Phelan Fire Control (D1198)

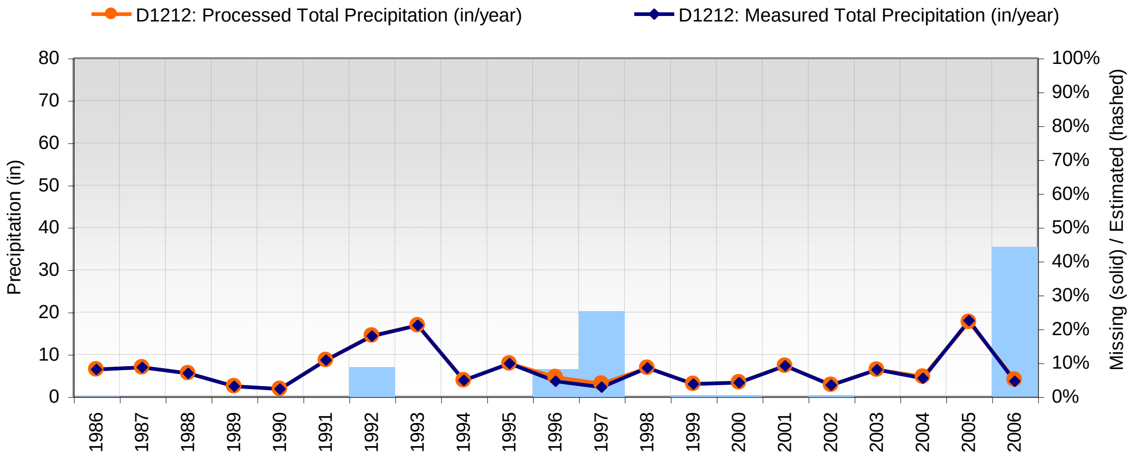


Figure A-194. Total precipitation at Lancaster Fss Faa (D1212)

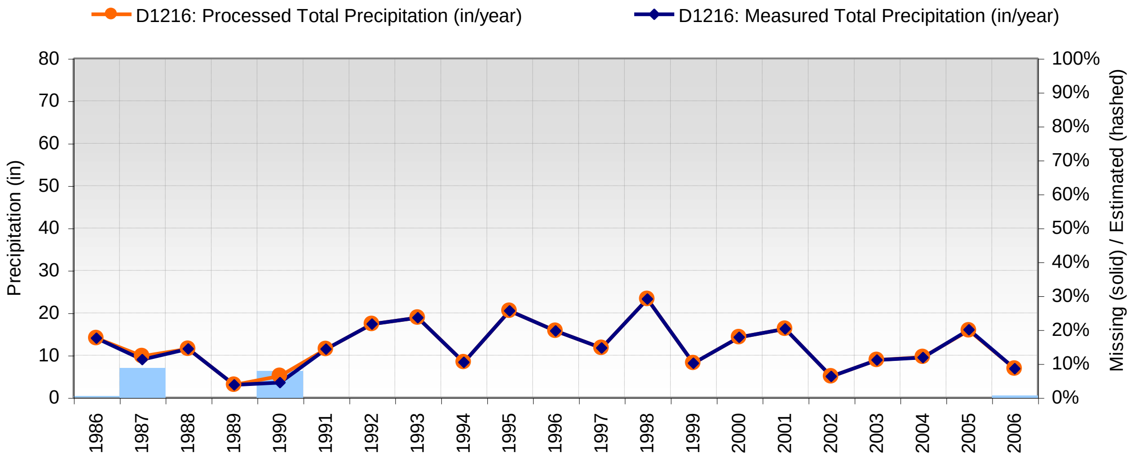


Figure A-195. Total precipitation at Rancho Palos Verdes (D1216)

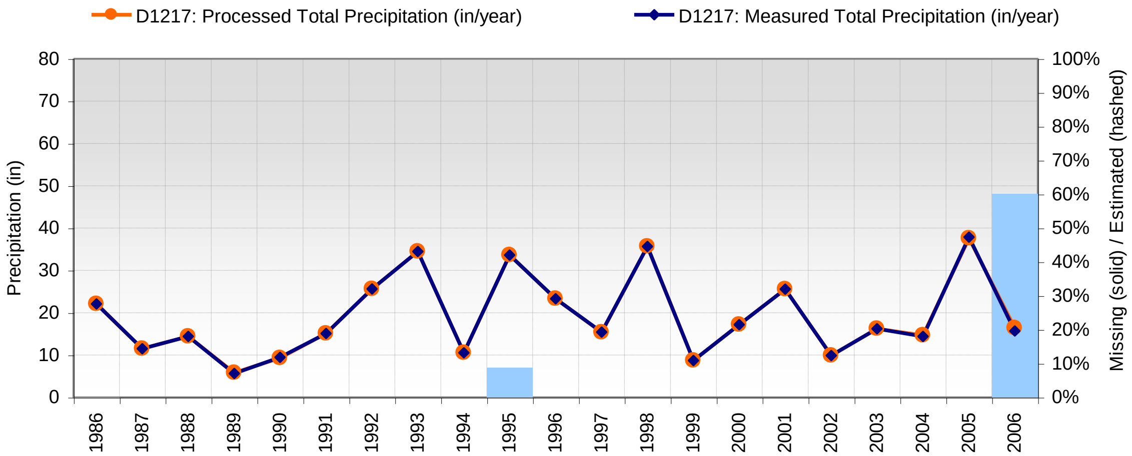


Figure A-196. Total precipitation at Los Angeles Country Club (D1217)

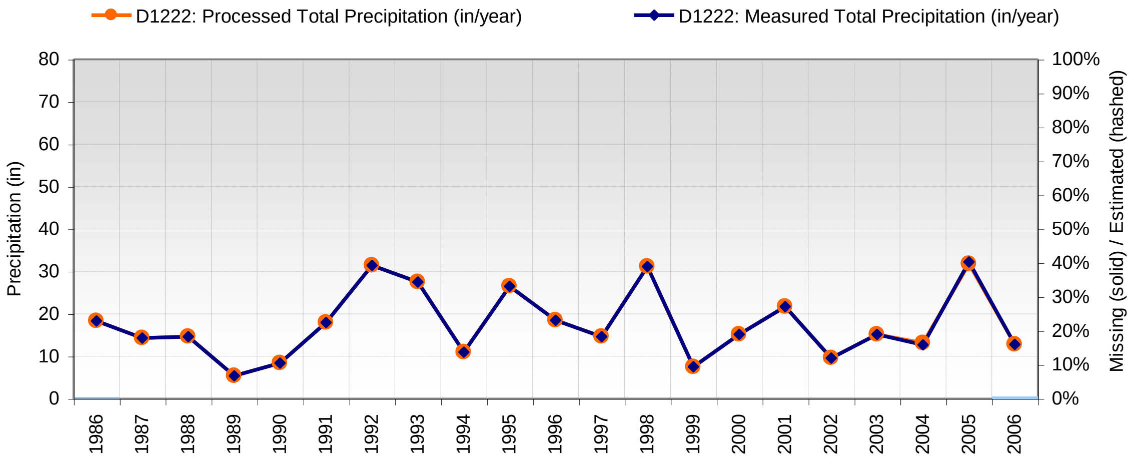


Figure A-197. Total precipitation at Northridge Garland (D1222)

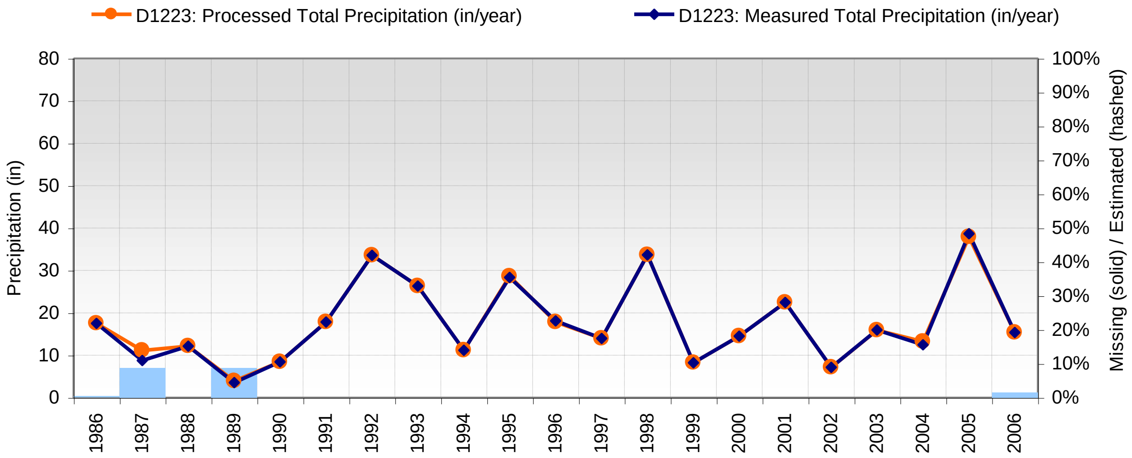


Figure A-198. Total precipitation at Woodland Hills Sherman (D1223)

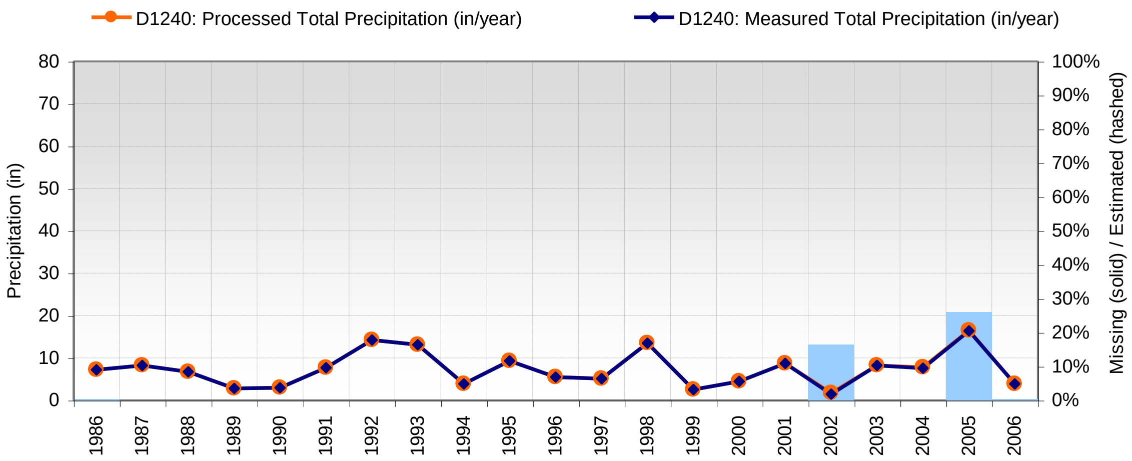


Figure A-199. Total precipitation at Pearblossom Cal. D.W.R. Booster Sta (D1240)

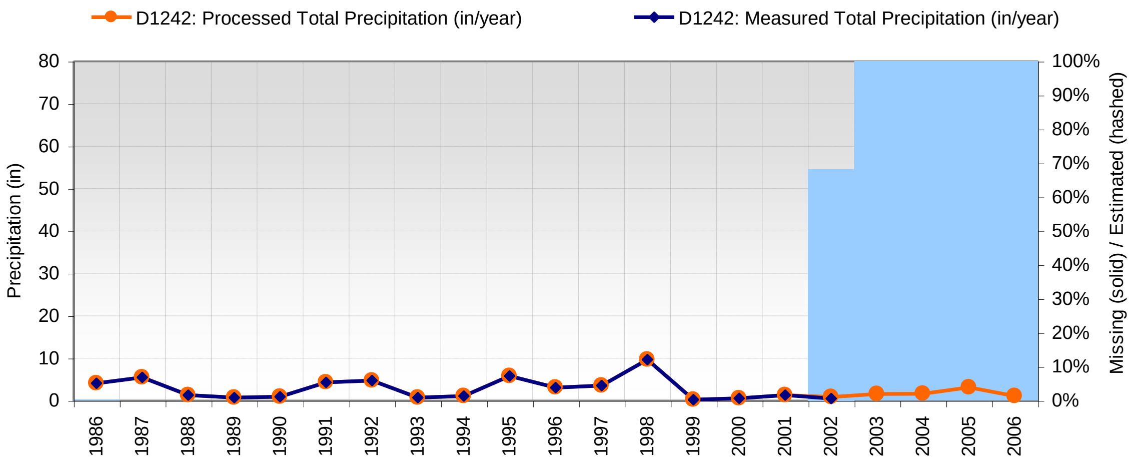


Figure A-200. Total precipitation at Rocky Buttes (D1242)

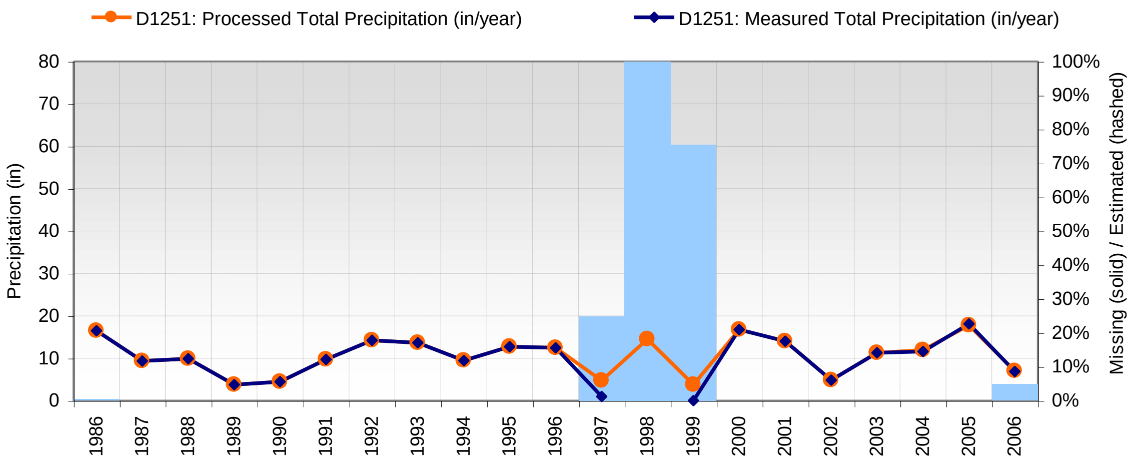


Figure A-201. Total precipitation at Palos Verdes Whites Point (D1251)

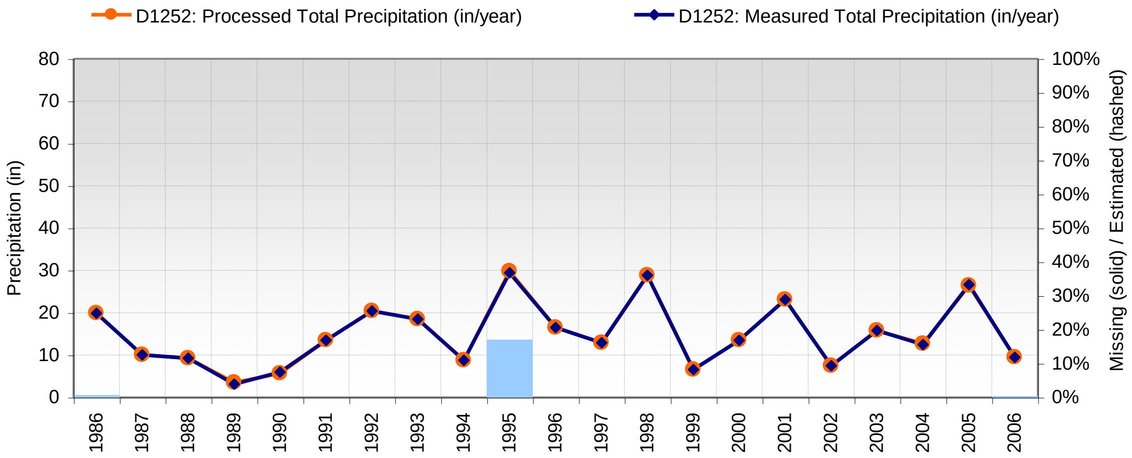


Figure A-202. Total precipitation at Palos Verdes Landfill (D1252)

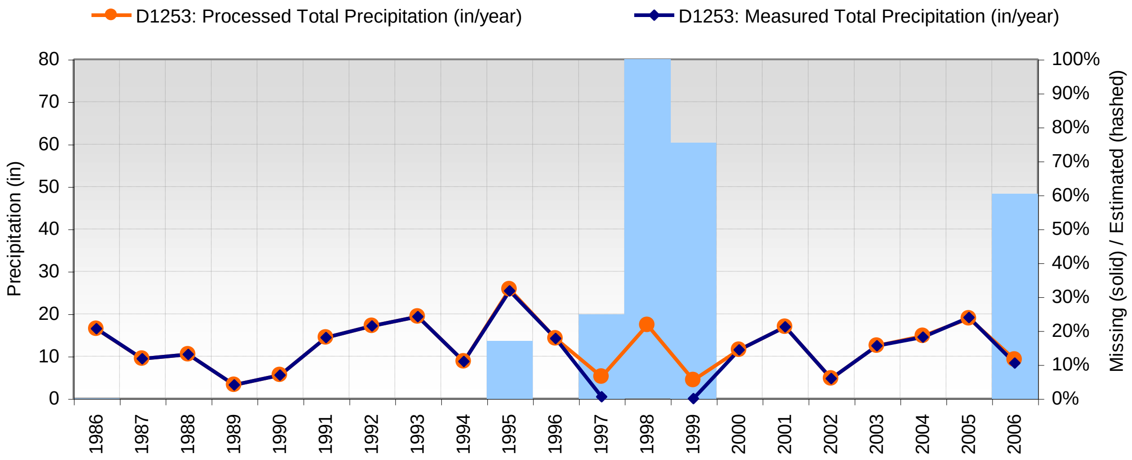


Figure A-203. Total precipitation at Carson County Sanitation (D1253)

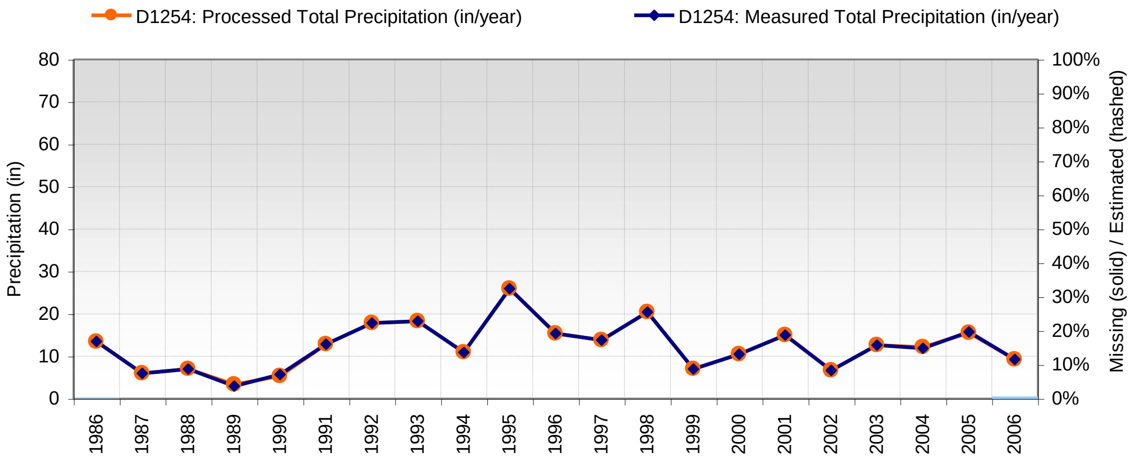


Figure A-204. Total precipitation at Long Beach Reclamation Plant (D1254)

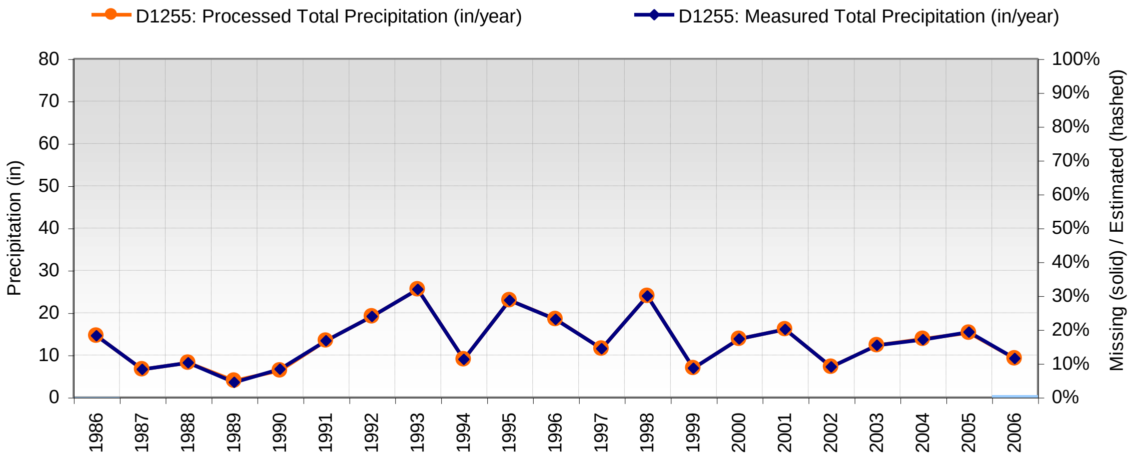


Figure A-205. Total precipitation at Los Coyotes Reclamation Plant (D1255)

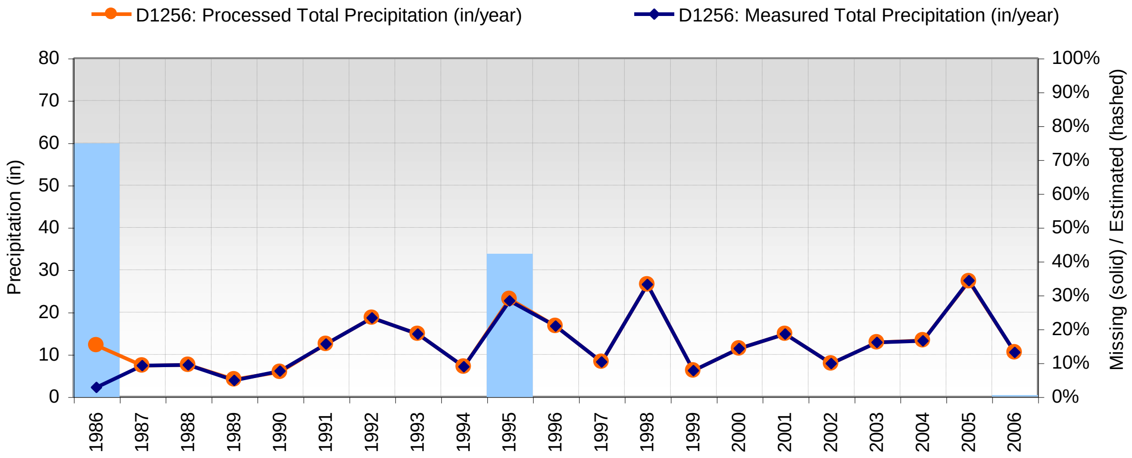


Figure A-206. Total precipitation at South Gate Transfer Station (D1256)

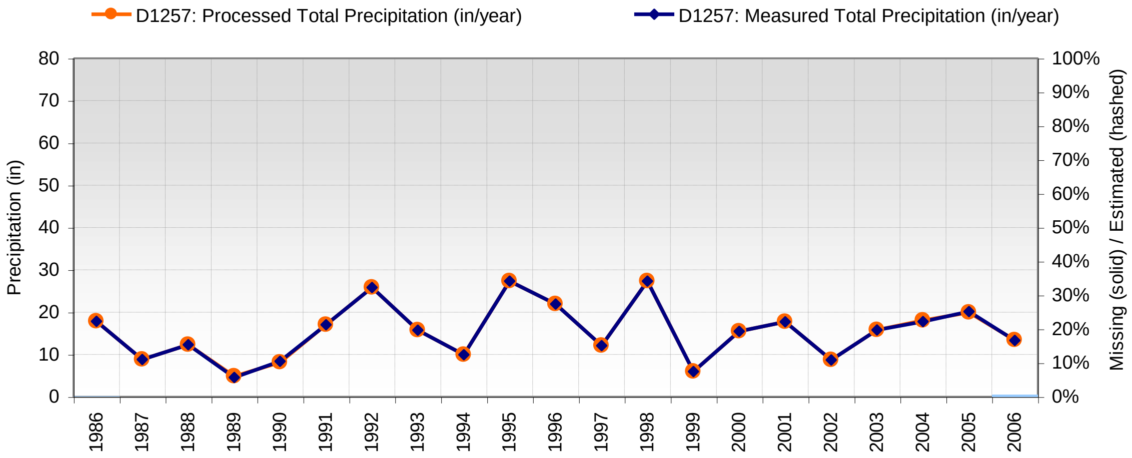


Figure A-207. Total precipitation at San Jose Creek Reclamation Plant (D1257)

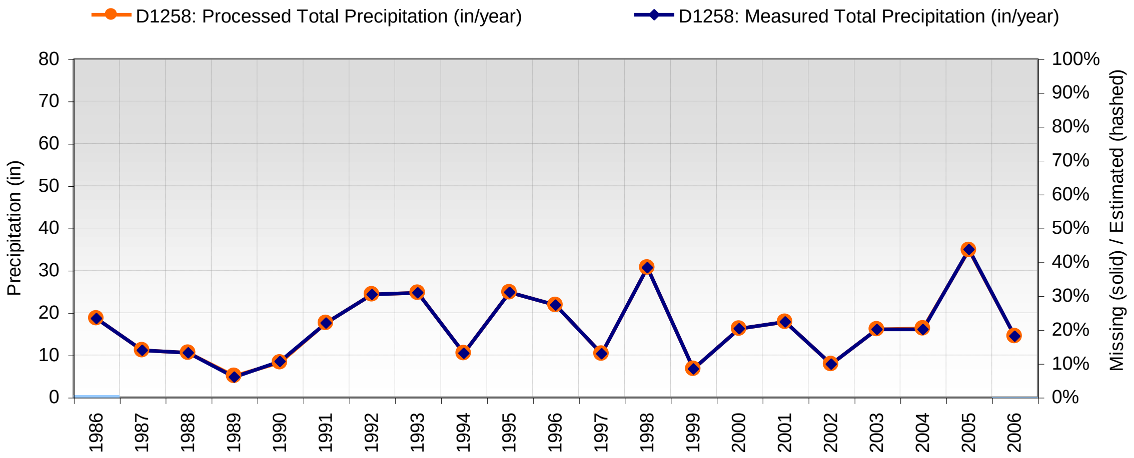


Figure A-208. Total precipitation at Puente Hills Landfill (D1258)

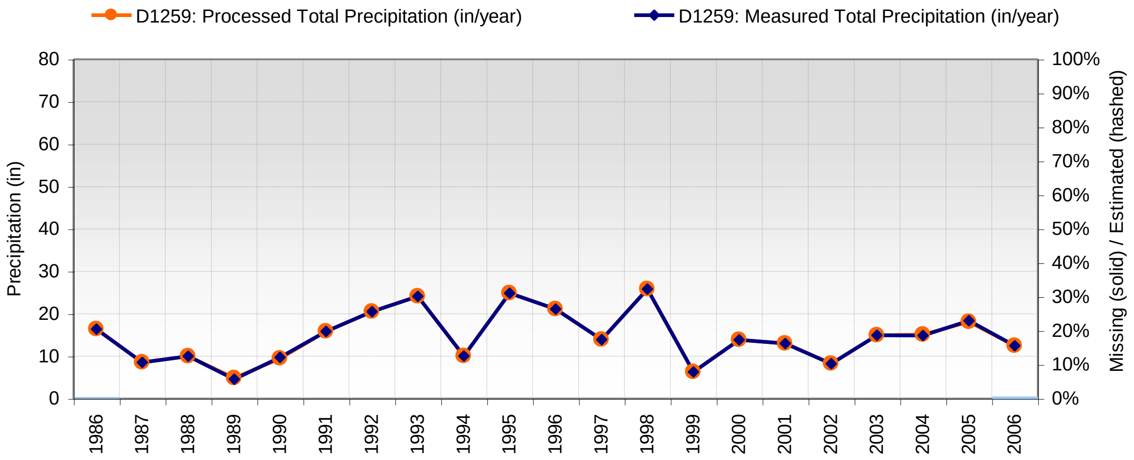


Figure A-209. Total precipitation at Whittier Narrows Reclamation Plant (D1259)

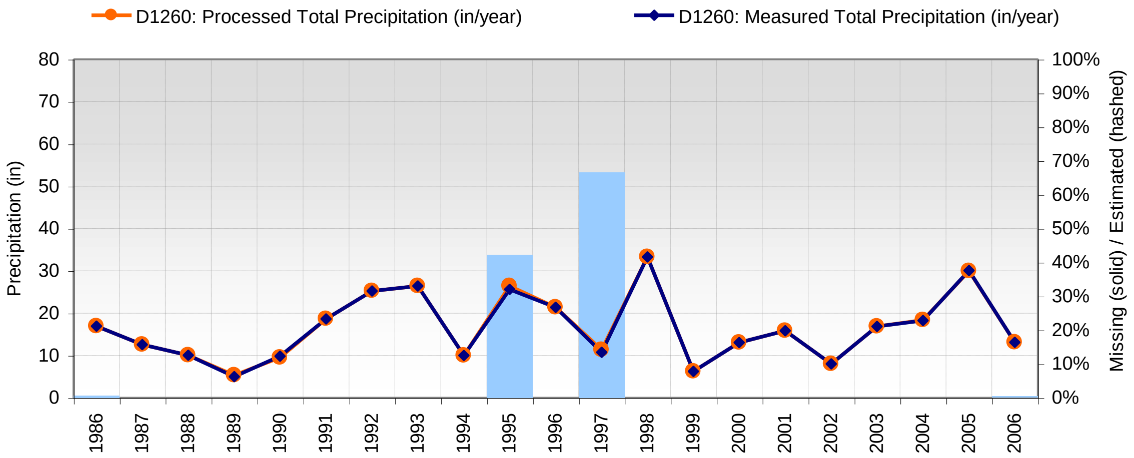


Figure A-210. Total precipitation at Spadra Landfill (D1260)

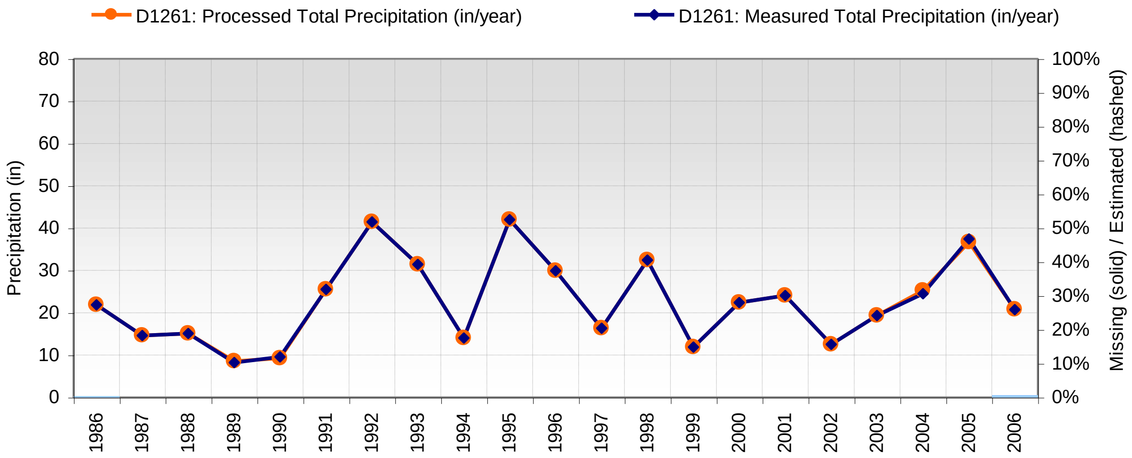


Figure A-211. Total precipitation at La Canada Reclamation Plant (D1261)

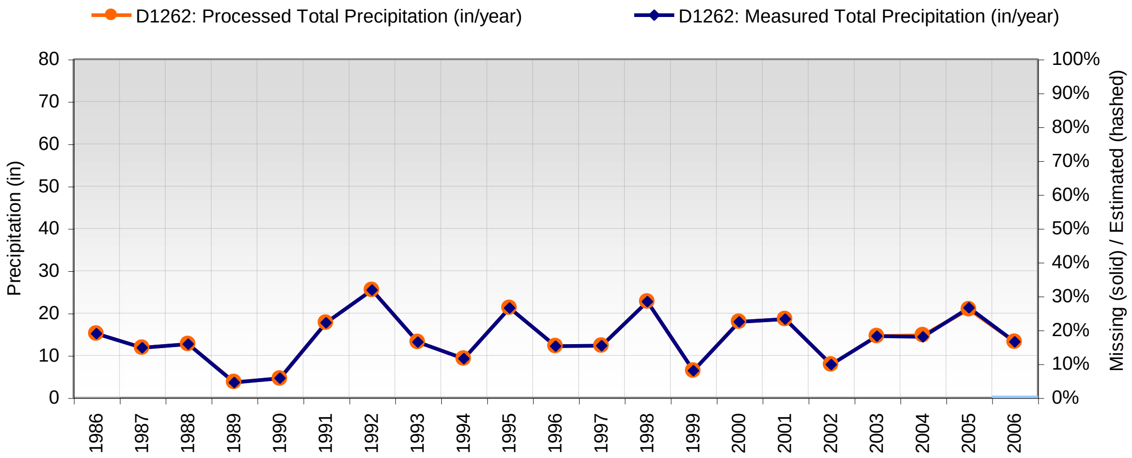


Figure A-212. Total precipitation at Saugus Reclamation Plant (D1262)

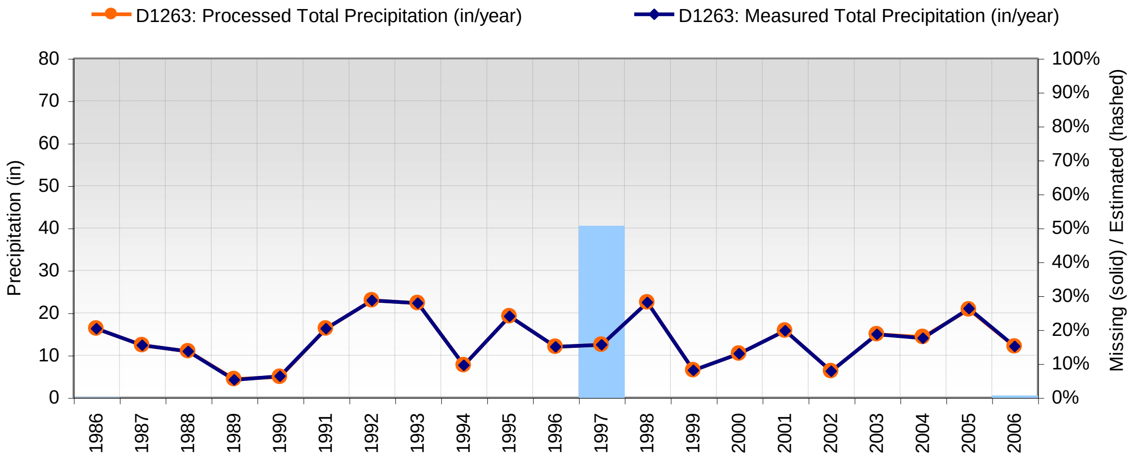


Figure A-213. Total precipitation at Valencia Reclamation Plant (D1263)

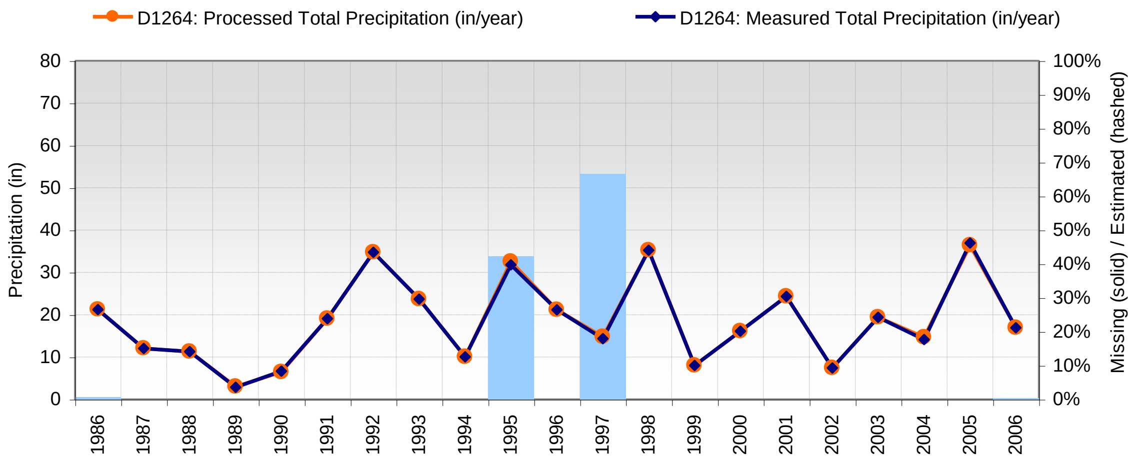


Figure A-214. Total precipitation at Calabasas Landfill (D1264)

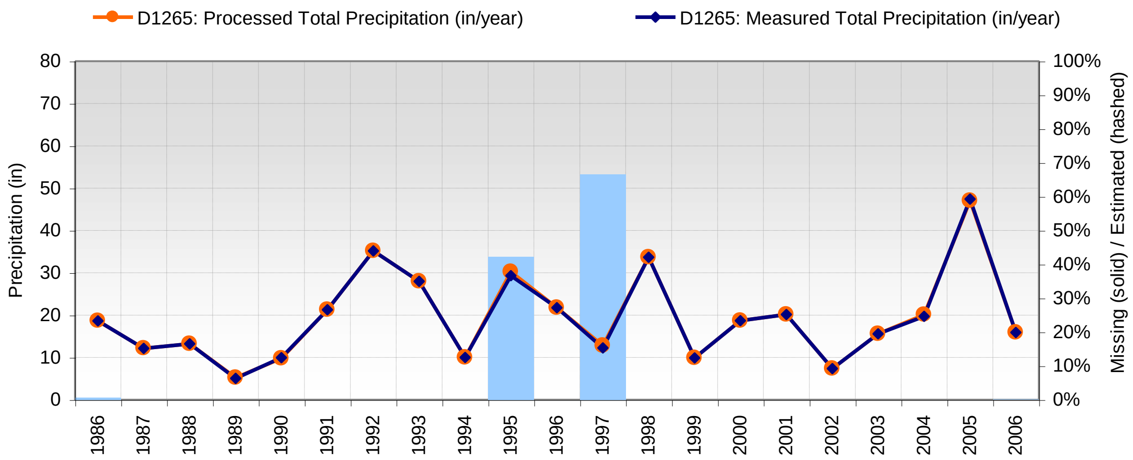


Figure A-215. Total precipitation at Scholl Canyon Landfill (D1265)

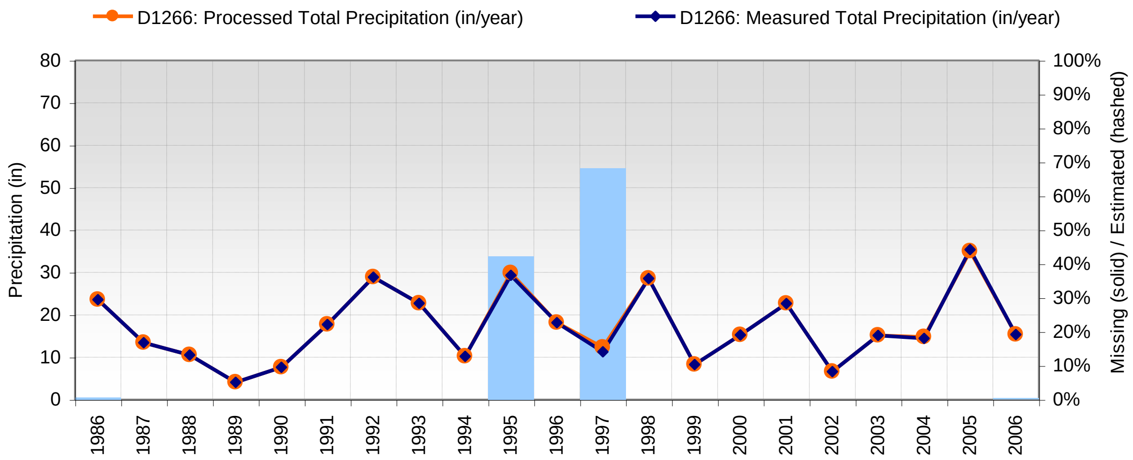


Figure A-216. Total precipitation at Mission Canyon Landfill (D1266)

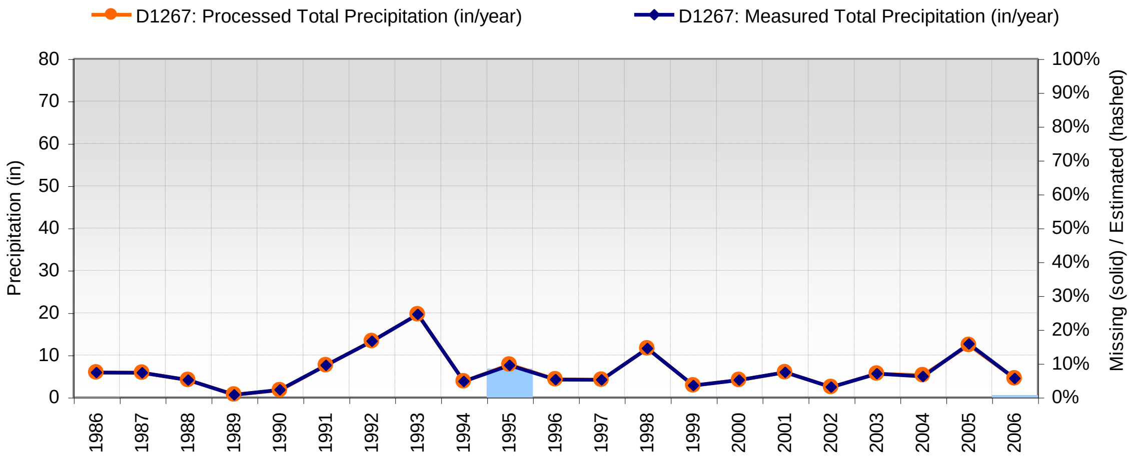


Figure A-217. Total precipitation at Lancaster Reclamation Plant (D1267)

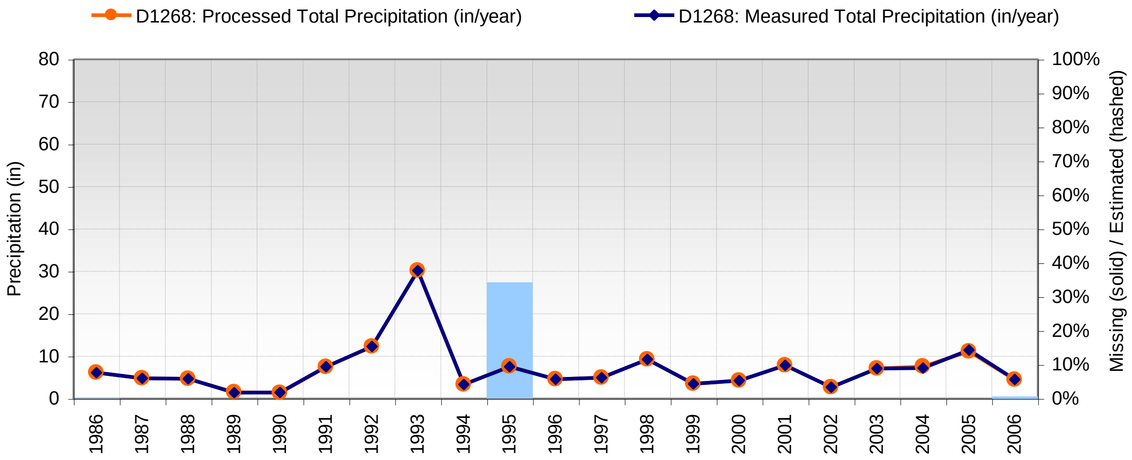


Figure A-218. Total precipitation at Palmdale Reclamation Plant (D1268)

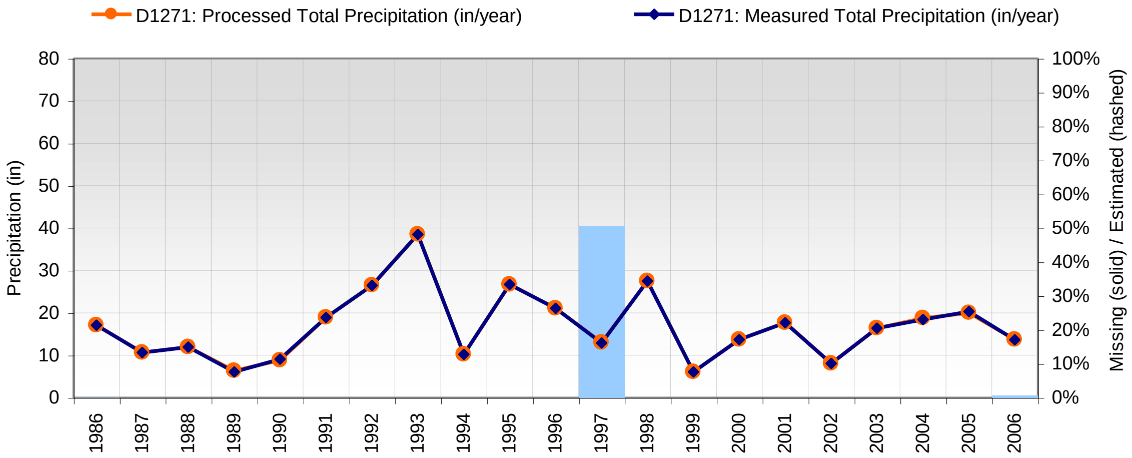


Figure A-219. Total precipitation at Pomona Reclamation Plant (D1271)

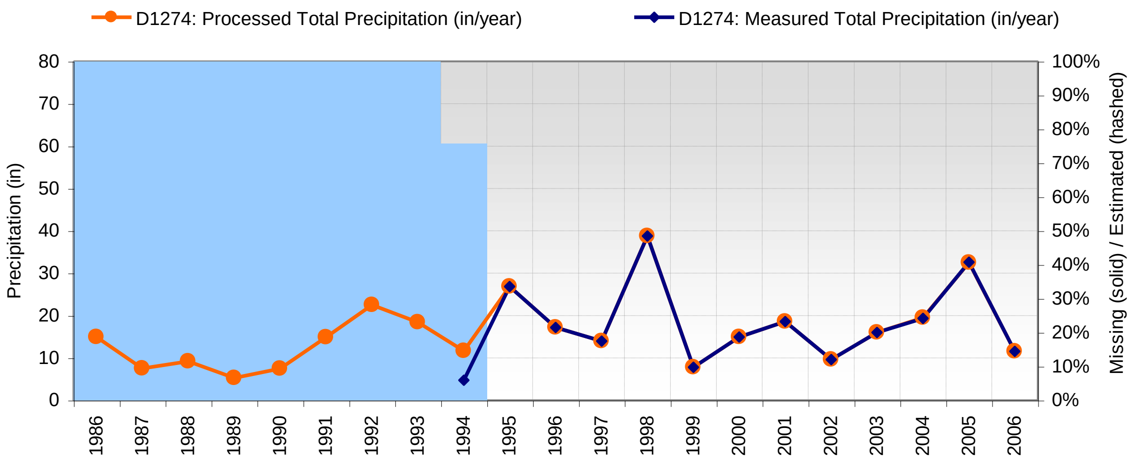


Figure A-220. Total precipitation at Valna Dr (D1274)

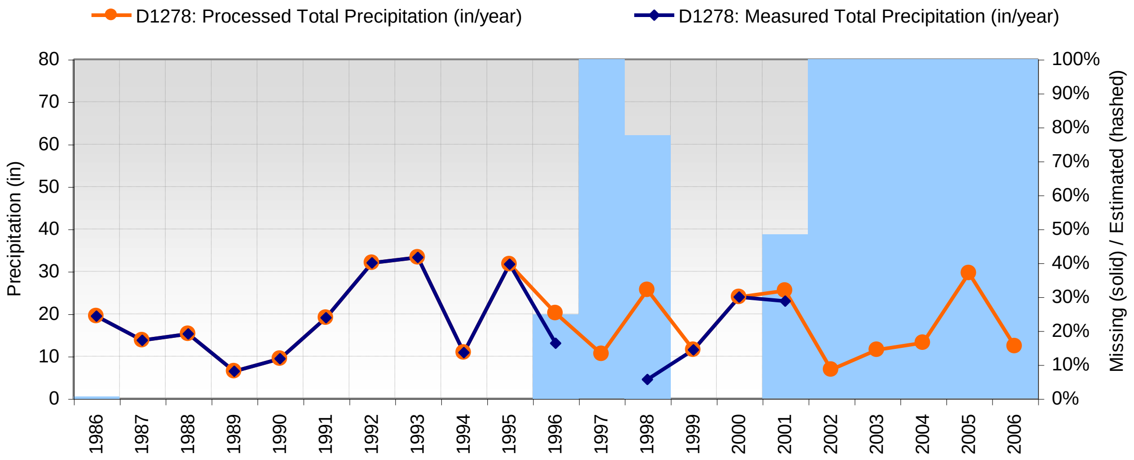


Figure A-221. Total precipitation at La Canada Flintridge (D1278)

Appendix B – Quality Control Process Summary for Pan Evaporation Data

The Los Angeles County DPW provided pan evaporation data. Missing daily observed evaporation total patched using the Normal Ratio Method, which involves weighted estimates from nearby evaporation stations with complete data. Daily pan evaporation totals were disaggregated to an hourly time step by using a sin curve over available daylight hours. Daylight hours (sunrise to sunset) were derived as a function of latitude and the curvature of the earth. Table B-1 and is an inventory of all reported pan evaporation data in the county. The grayed-out stations were not considered for modeling purposes because of poor data quality or quantity.

Table B-1. Inventory of reported pan evaporation data in the county (Processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Evaporation *	
			Start	End		Measured	Processed
Pacoima Dam	D33	1,500	10/02/87	05/31/08	93.1%	6.2	94.6
Big Tujunga Dam	D46	2,315	10/01/91	05/31/08	37.7%	60.8	95.6
Santa Anita Dam	D63	1,400	10/08/91	02/02/07	37.7%	32.9	51.9
San Dimas Dam	D89	1,350	10/02/87	02/02/07	22.2%	41.6	51.4
Puddingstone Dam	D96	1,030	10/02/87	02/02/07	17.6%	43.3	52.0
Big Dalton Dam	D223	1,587	10/02/87	02/02/07	17.6%	43.3	52.0
Castaic Dam	D252	1,150	10/01/91	02/02/07	44.5%	54.2	96.3
San Gabriel Dam Number	D334	2,300	10/02/87	02/02/07	24.6%	41.4	52.4
Morris Dam	D390	1,210	10/02/87	02/02/07	20.8%	67.4	85.0
Pyramid Reservoir	D409	2,505	10/01/91	02/02/07	47.1%	55.1	102.7
San Gabriel Dam	D425	1,481	10/02/87	01/31/07	35.6%	47.9	72.7
Neenach	D598	3,062	07/01/02	02/02/07	89.4%	15.0	156.9
Palmdale	D1058	2,595	10/01/91	02/02/07	34.2%	59.2	88.4
Descanso Gardens	D1071	1,325	10/02/87	02/02/07	22.4%	38.3	47.5
Pearblossom Cal. D.W.R. Booster Sta	D1240	3,050	07/01/02	02/02/07	88.8%	14.2	132.1

* Measured and processed evaporation totals represent average annual values between 1987 and 2006
Grey-highlighted stations were not considered for modeling purposes because of poor data quality or quantity.

Figures B-1 through B-15 present graphical summary of measured versus processed monthly evaporation totals from 1987 through 2006 for each of the stations listed in Table B-1. Estimated monthly potential ET is also plotted on each graph as a function of processed pan evaporation and monthly variable pan evaporation coefficients provided by the county DPW. Figures B-16 through B-21 present computed versus extended potential ET at six NCDC stations primarily in the lower elevation areas of the watershed.

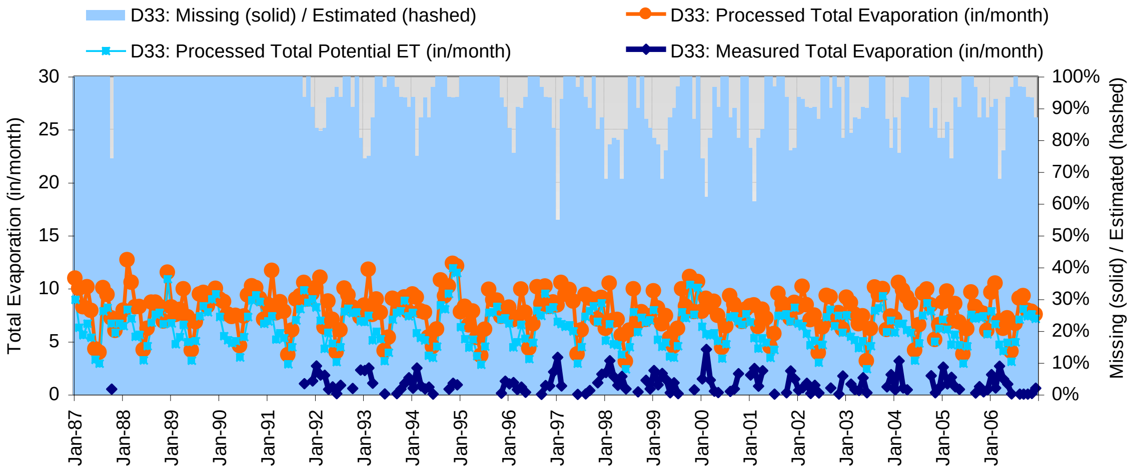


Figure B-1. Total evaporation at Pacoima Dam (D33), 1987–2006.

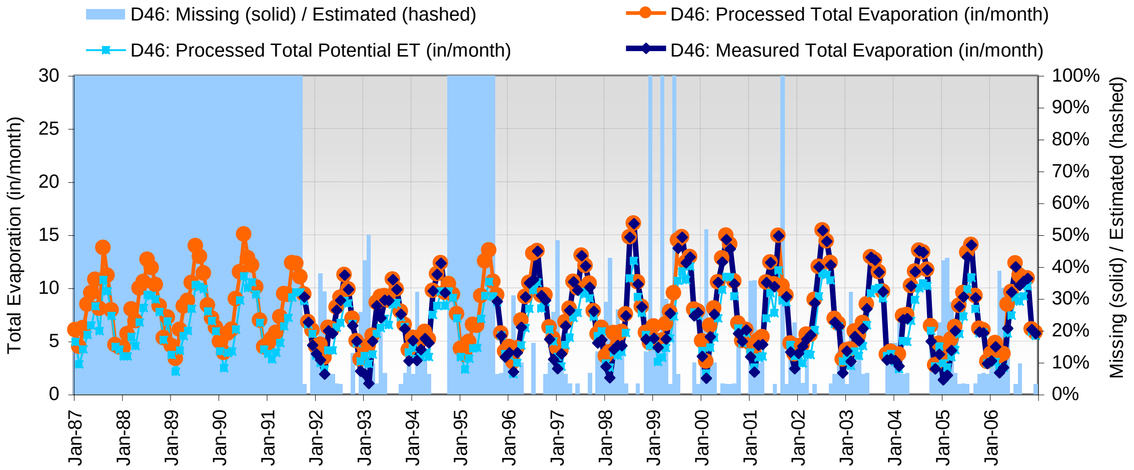


Figure B-2. Total evaporation at Big Tujunga Dam (D46), 1987–2006.

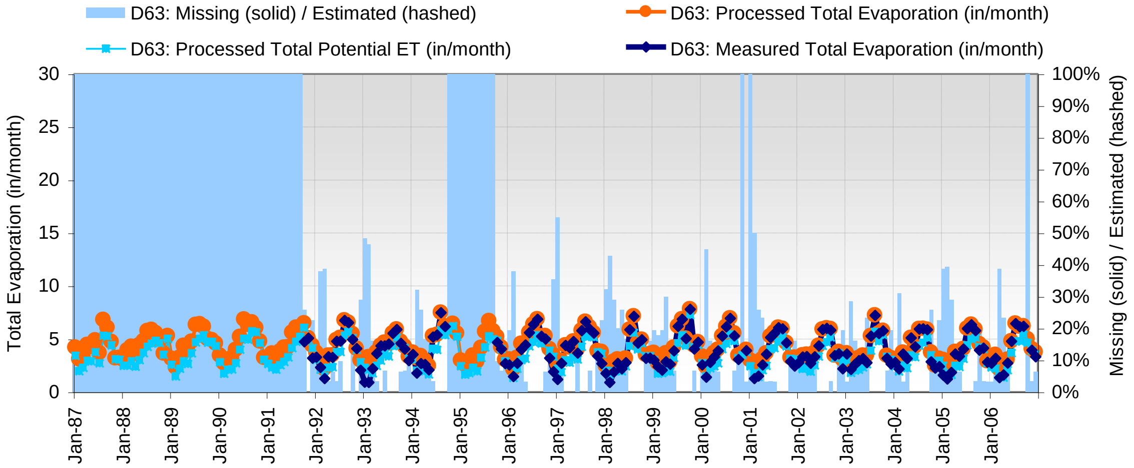


Figure B-3. Total evaporation at Santa Anita Dam (D63), 1987–2006.

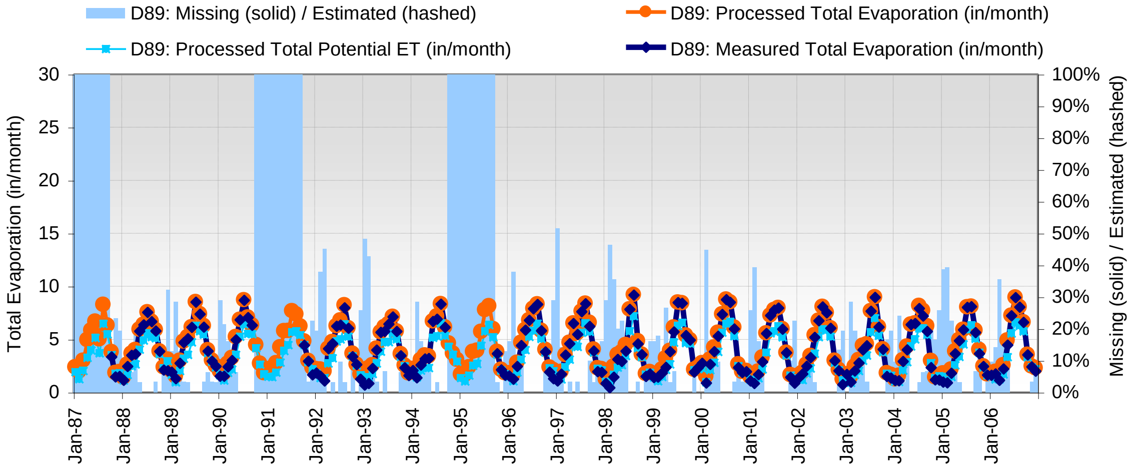


Figure B-4. Total evaporation at San Dimas Dam (D89), 1987–2006.

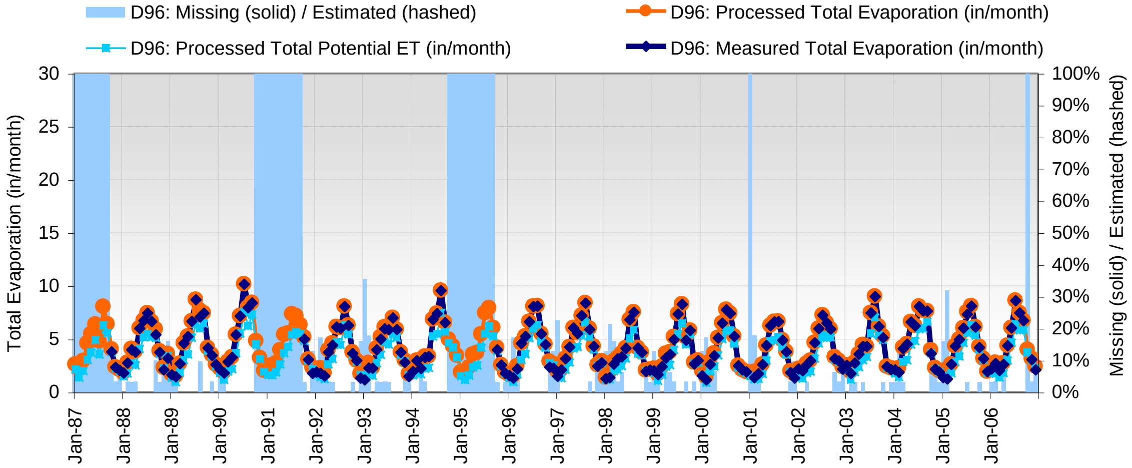


Figure B-5. Total evaporation at Puddingstone Dam (D96), 1987–2006.

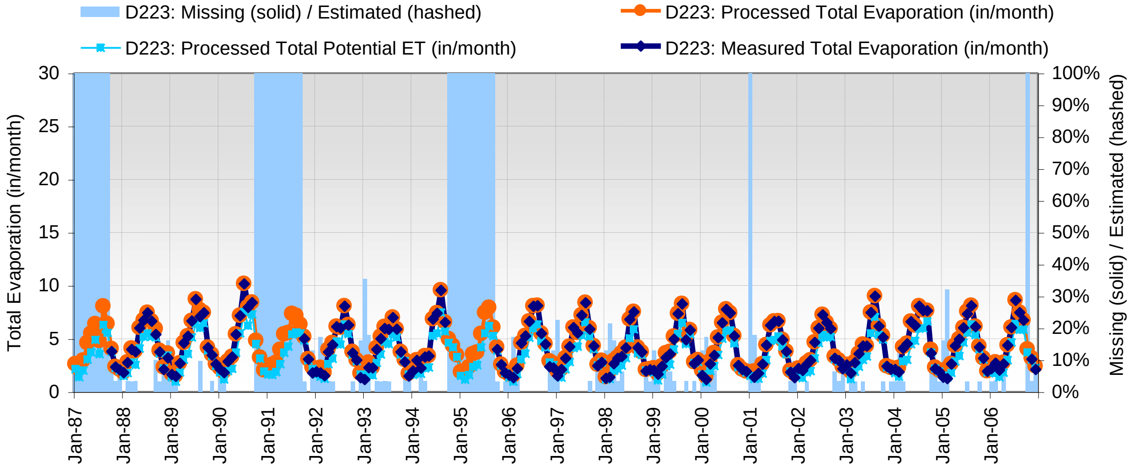


Figure B-6. Total evaporation at Big Dalton Dam (D223), 1987–2006.

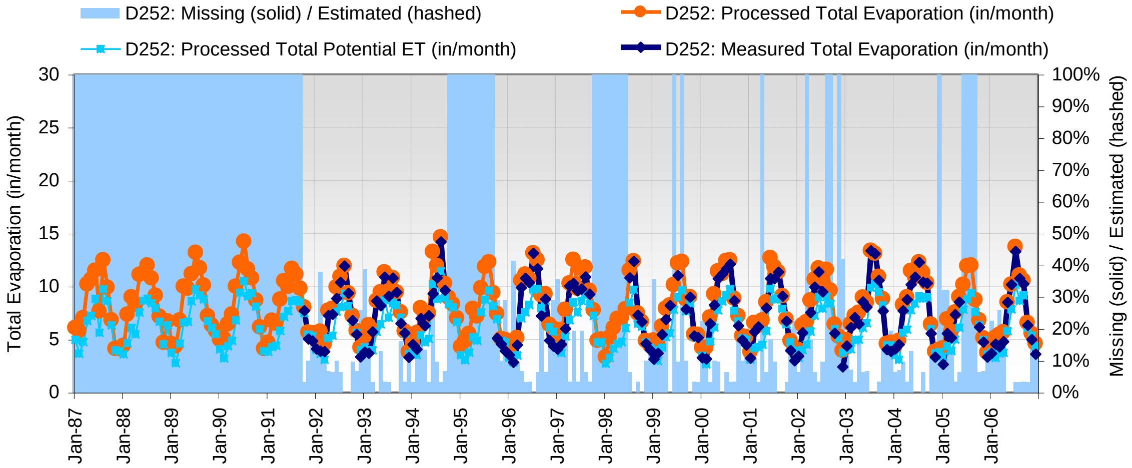


Figure B-7. Total evaporation at Castaic Dam (D252), 1987–2006.

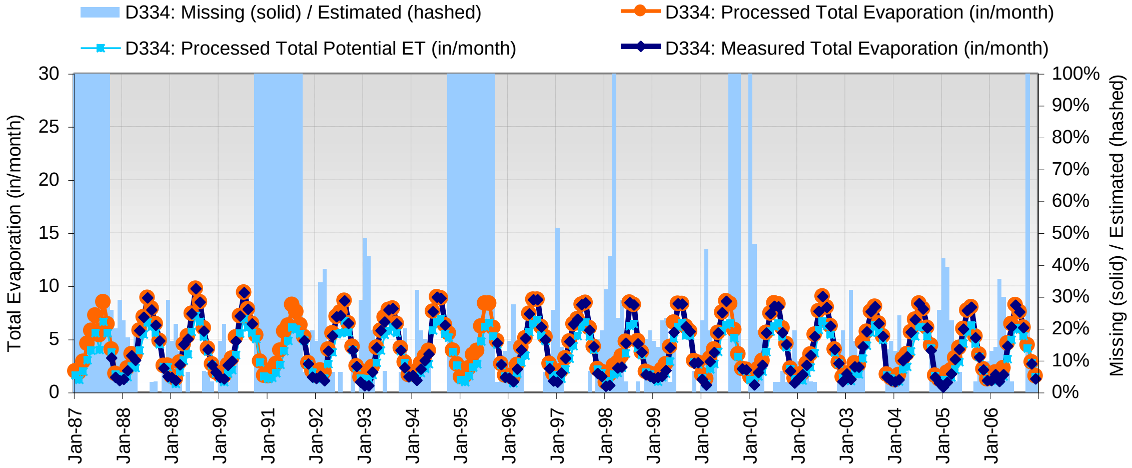


Figure B-8. Total evaporation at San Gabriel Dam (D334), 1987–2006.

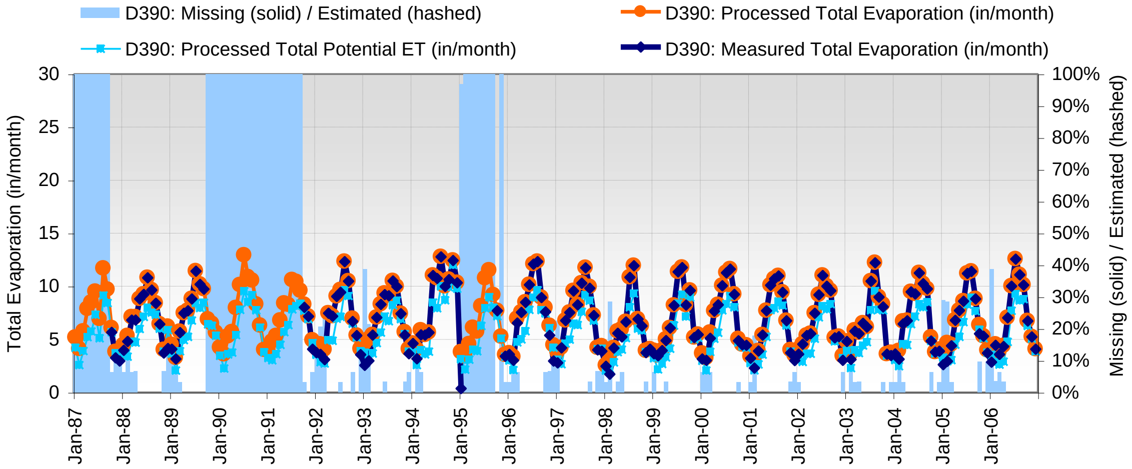


Figure B-9. Total evaporation at Morris Dam (D390), 1987–2006.

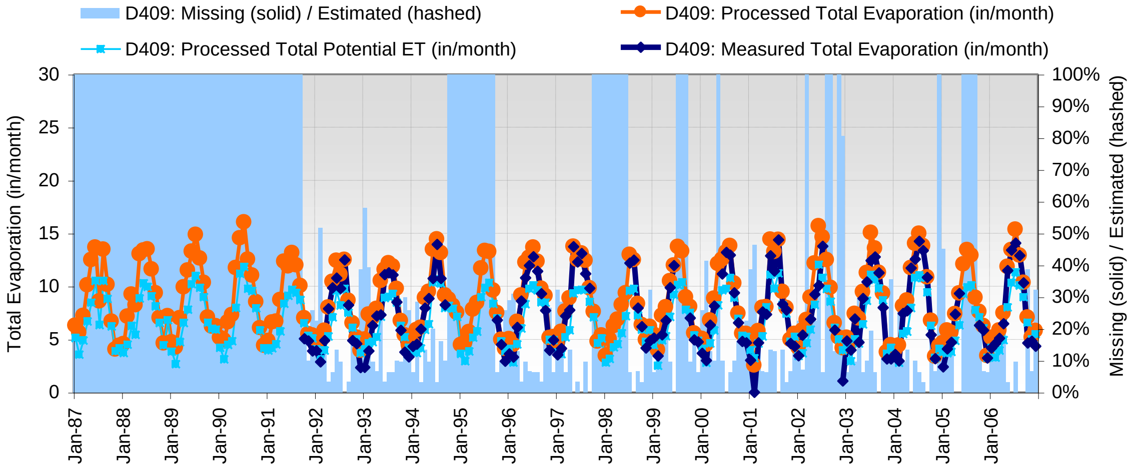


Figure B-10. Total evaporation at Pyramid Reservoir (D409), 1987–2006.

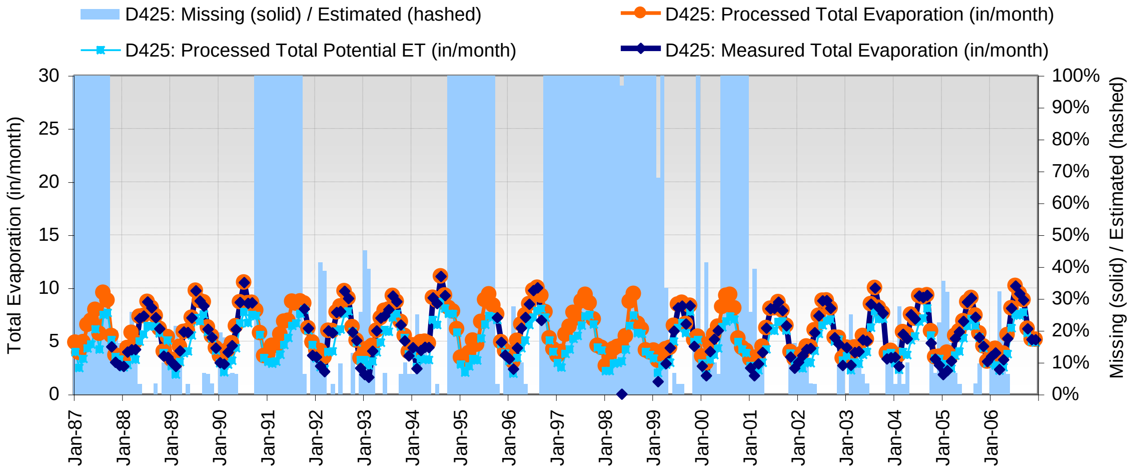


Figure B-11. Total evaporation at San Gabriel Dam (D425), 1987–2006.

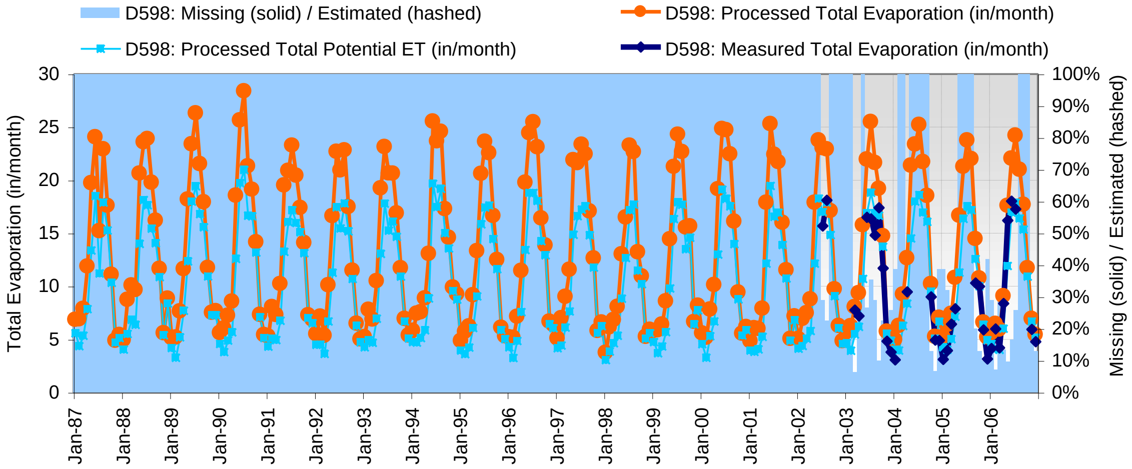


Figure B-12. Total evaporation at Neenach (D598), 1987–2006.

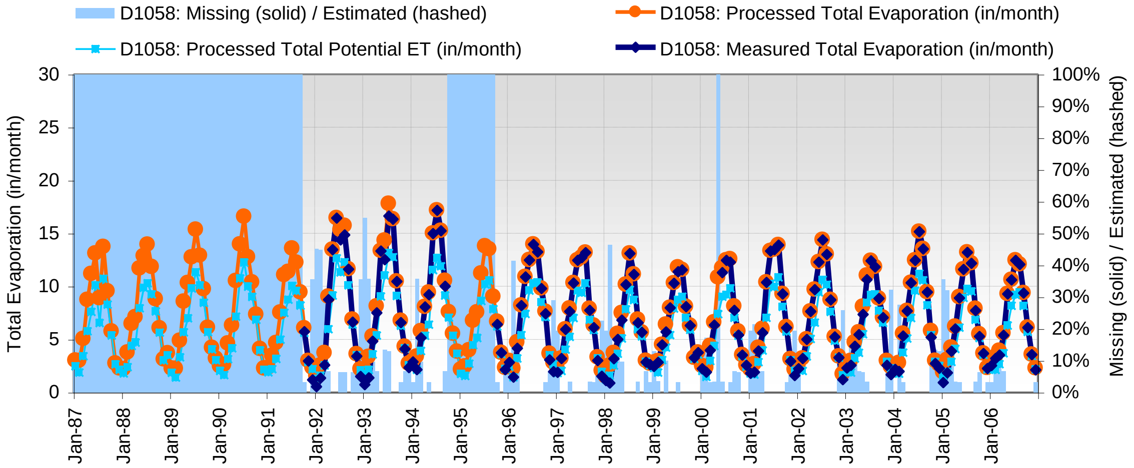


Figure B-13. Total evaporation at Palmdale (D1058), 1987–2006.

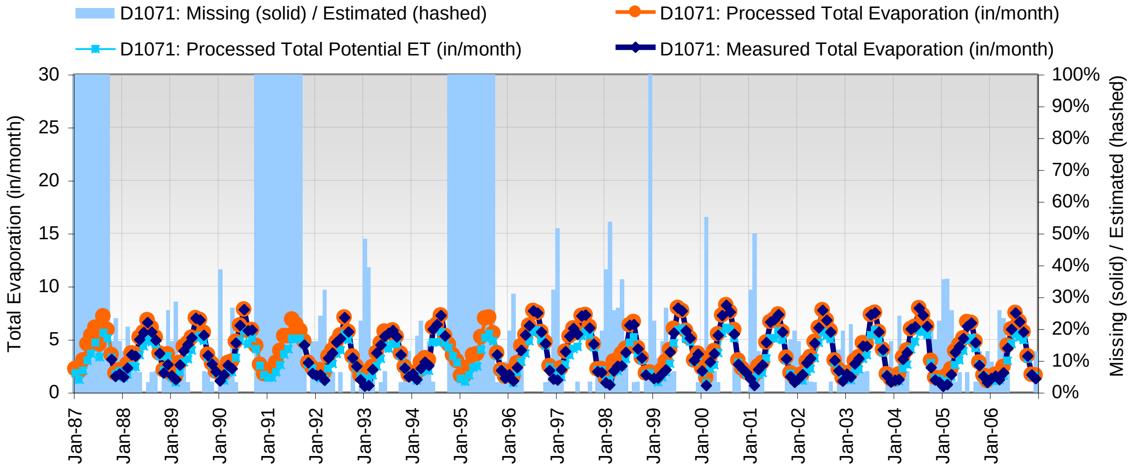


Figure B-14. Total evaporation at Descanso Gardens (D1071), 1987–2006.

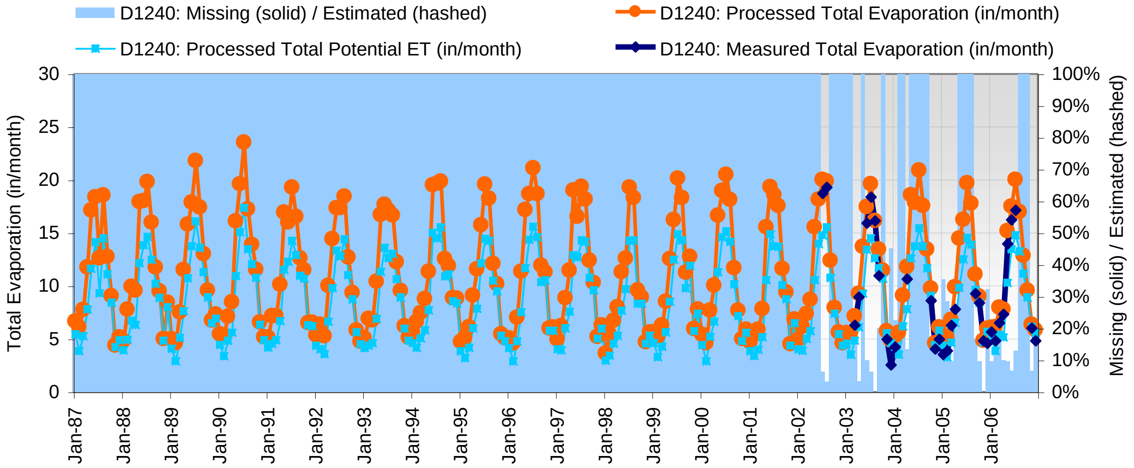


Figure B-15. Total evaporation at Pearblossom Cal. D.W.R. Booster sta (D1240), 1987–2006.

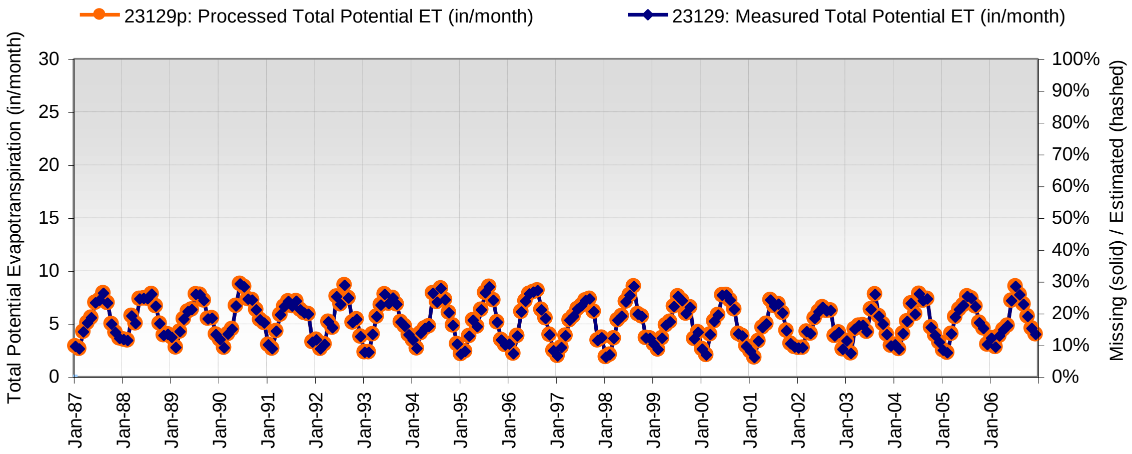


Figure B-16. Total Potential ET at Long Beach Daugherty Fl (23129), 1987–2006.

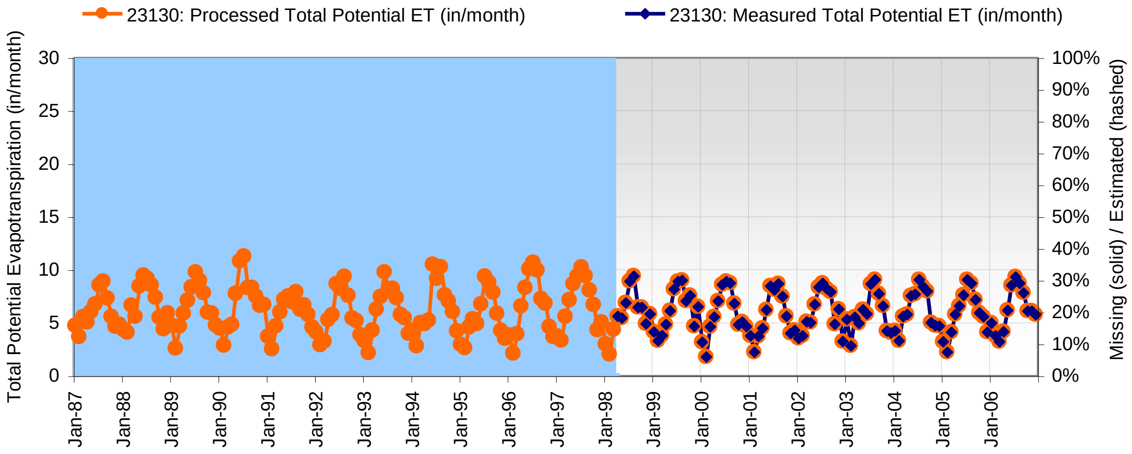


Figure B-17. Total potential ET at 23130 (23130), 1987–2006.

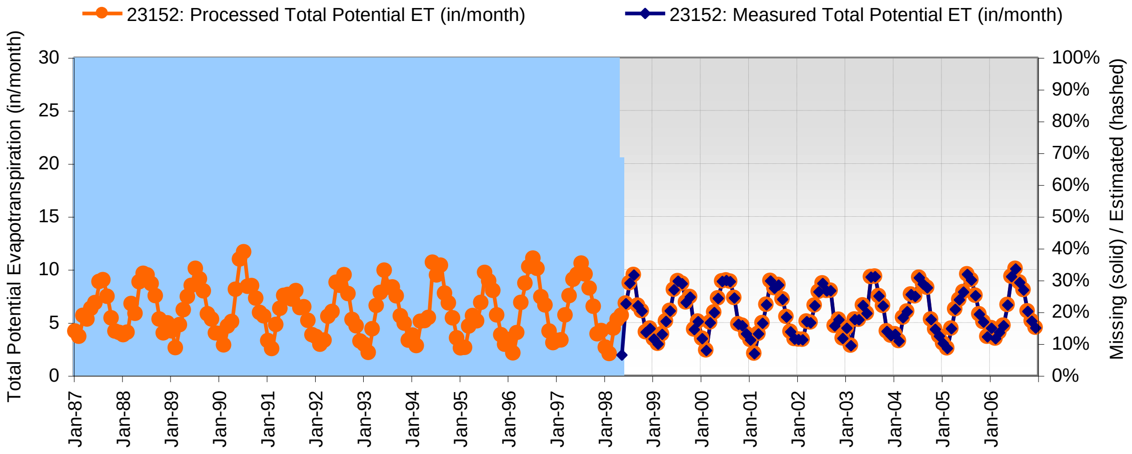


Figure B-18. Total potential ET at 23152 (23152), 1987–2006.

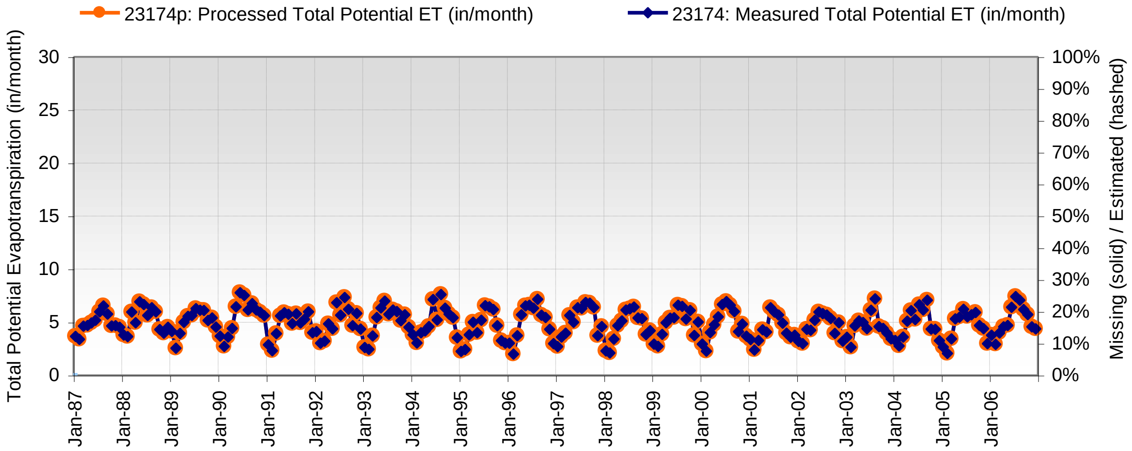


Figure B-19. Total potential ET at Los Angeles Intl Arpt (23174), 1987–2006.

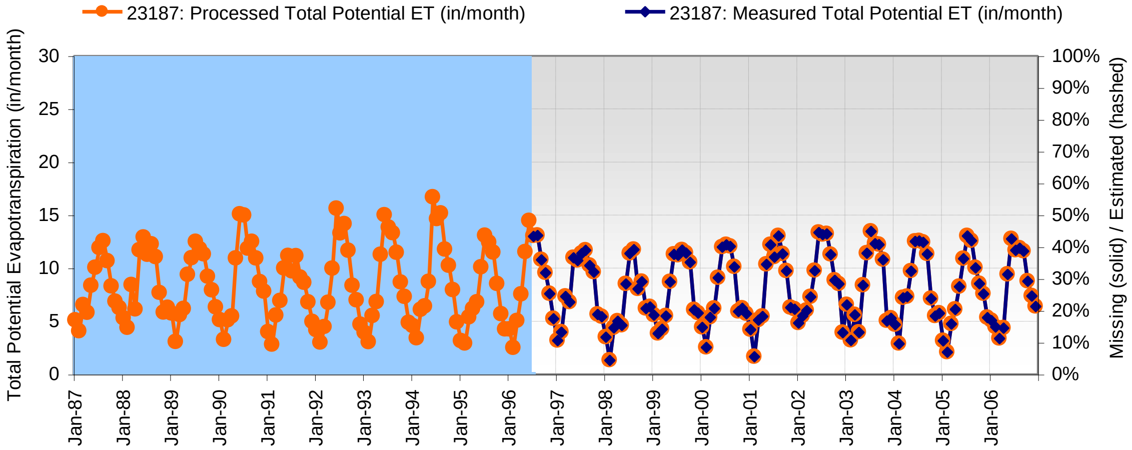


Figure B-20. Total potential ET at Sandberg (23187), 1987–2006.

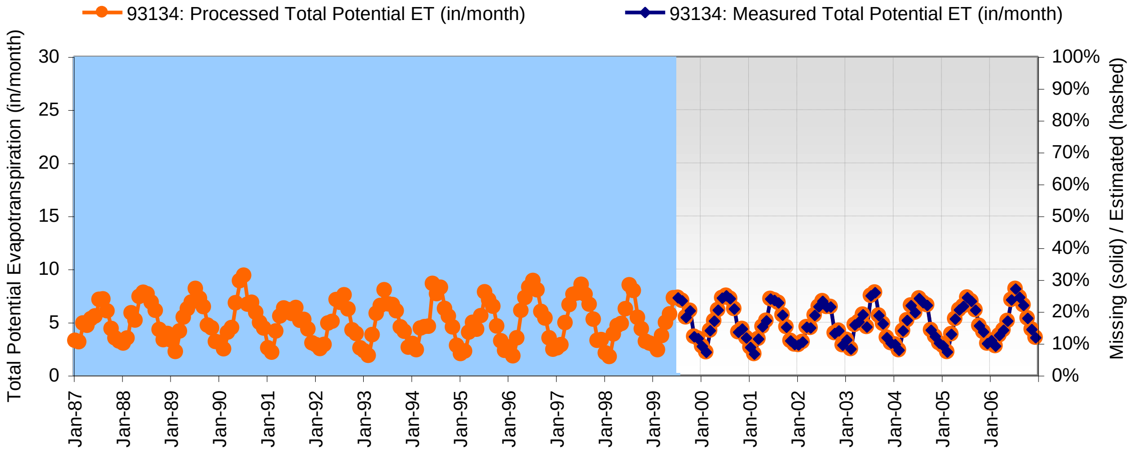


Figure B-21. Total potential ET at Los Angeles Downtown US (93134), 1987–2006.

Appendix C – Precipitation Station Inventory

Table C-1. Inventory of selected LACDPW daily rainfall data (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Vincent Patrol Station	D120	3,135	10/24/27	12/26/06	2.6%	9.0	9.0
Sierra Madre Dam	D144	1,100	12/02/28	12/21/06	1.0%	26.5	26.8
Tanbark Flats	D158	2,750	02/29/28	05/24/02	23.9%	12.3	19.8
Montana Ranch	D225	47	11/03/15	12/25/06	0.0%	13.1	13.1
Los Angeles 96th and Central	D291	121	10/21/87	05/22/02	27.1%	9.9	13.5
Signal Hill City Hall	D415	140	10/05/39	02/27/01	29.2%	9.1	12.4
Monte Nido	D435	600	10/11/87	05/23/02	27.2%	16.2	22.0

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Table C-2. Inventory of selected LACFCD daily rainfall data (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
North Hollywood Lakeside	D13	550	10/19/76	12/26/06	0.1%	20.3	20.3
Sepulveda Canyon at Mulholland	D17	1,425	10/25/27	06/02/02	23.2%	16.1	21.5
Girard Reservoir	D20	986	10/23/40	06/27/06	2.5%	20.3	20.4
Newhall Soledad	D32	1,243	09/29/46	01/14/06	15.7%	13.5	16.5
Pacoima Dam	D33	1,500	12/02/15	04/22/07	0.0%	19.8	19.8
Redondo Beach City Hall	D42	70	10/14/63	01/01/06	5.0%	12.5	13.0
Palos Verdes Estates	D43	216	10/24/59	12/21/06	2.3%	13.2	13.5
Clear Creek City School Daily Automatic	D47	3,150	10/11/87	05/22/02	26.9%	21.9	29.8
Santa Anita Dam	D63	1,400	10/02/63	11/27/06	3.4%	27.6	28.6
Sawpit Dam	D68	1,375	11/12/65	05/20/02	23.5%	20.3	27.5
San Dimas Dam	D89	1,350	10/02/56	11/27/06	0.9%	24.2	24.3
Claremont Police Station	D93	1,170	10/05/74	12/26/06	0.0%	18.1	18.1
Puddingstone Dam	D96	1,030	10/08/66	07/22/06	2.2%	19.3	19.3
Whittier City Yard	D106	300	12/22/83	12/29/06	0.0%	13.4	13.4
El Monte Fire Station	D108	275	10/14/63	09/15/06	1.4%	15.6	15.6
West Arcadia	D109	547	10/15/49	12/26/06	0.5%	19.2	19.3
Elizabeth Lake Canyon	D128	2,075	02/29/28	09/30/97	51.3%	9.3	21.5
Puddingstone Diversion	D134	1,160	10/15/84	11/27/06	0.4%	20.0	20.0
La Mirada Standard Oil Company	D156	75	10/21/87	05/22/02	27.3%	10.5	14.7
Potrero Heights	D170	285	09/29/67	12/27/06	0.0%	17.4	17.4
La Verne Leader	D196	1,050	10/01/68	12/16/06	1.4%	17.6	17.9
Big Dalton Dam	D223	1,587	10/06/73	11/27/06	1.7%	27.6	27.7
San Gabriel Bruington	D227	472	10/21/53	12/26/06	0.5%	19.5	19.5
La Crescenta	D251	1,440	11/17/67	12/26/06	0.0%	23.9	23.9
Castaic Dam	D252	1,150	10/02/72	10/13/06	3.6%	16.4	16.8
Mount San Antonio College	D255	720	11/04/69	09/11/06	1.5%	16.3	16.3
Acton Escondido Canyon	D261	2,960	10/22/71	05/22/02	23.3%	7.8	10.9

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Diamond Bar Fire Station	D269	870	08/19/82	09/19/05	7.2%	17.3	18.0
Flintridge Sacred Heart	D280	1,600	10/05/74	05/22/02	23.1%	16.8	22.4
Crystal Lake East Pine Flat	D283	370	09/29/59	06/01/02	22.9%	26.3	35.3
Gorman Sheriff	D298	3,835	10/21/87	04/28/02	27.8%	8.2	11.2
Zuma Beach	D306	15	09/13/68	12/26/06	0.0%	15.7	15.7
San Gabriel Dam Number	D334	2,300	10/11/47	12/01/06	1.3%	35.0	35.5
Mt. Wilson Observatory	D338	5,709	05/06/87	07/30/06	5.3%	32.0	33.9
Lechuaza Patrol Station	D352	1,620	12/03/56	01/28/05	29.2%	12.0	16.8
Briggs Terrace	D373	2,200	10/06/73	12/21/06	1.8%	27.3	27.6
San Gabriel East Fork	D379	1,600	10/01/39	05/22/02	23.3%	13.6	20.0
Paramount County Fire Station	D388	80	11/17/67	11/25/06	25.2%	15.9	17.9
Olive View Sanitarium	D395	1,425	01/11/81	09/29/98	41.5%	12.8	22.3
Soledad Canyon	D405	2,150	11/18/61	10/13/06	2.3%	14.3	14.4
West Azusa	D406	505	12/21/41	01/30/07	0.0%	18.3	18.3
San Gabriel Dam	D425	1,481	10/10/41	12/26/06	1.7%	29.7	29.7
Carbon Canyon	D447	50	10/26/64	05/09/05	18.8%	13.9	14.8
Eaton Wash Dam	D449	880	11/11/88	09/28/02	42.1%	11.2	18.6
Los Angeles Hillcrest Country Club	D462	185	10/23/51	01/28/05	19.6%	15.0	18.2
Sepulveda Dam	D465	683	02/27/57	11/27/06	1.3%	17.4	17.5
Los Angeles Usc	D482	208	09/29/38	11/27/06	7.1%	14.0	14.6
Kagel Canyon	D488	1,450	12/02/47	10/13/06	6.1%	18.2	18.4
Pacific Palisades	D491	293	10/09/75	12/27/02	25.5%	12.5	17.2
Claremont	D497	1,350	02/07/38	11/27/06	1.7%	20.2	20.3
Santa Anita Reservoir	D591	1,205	10/05/75	11/26/06	0.5%	23.9	23.9
Pasadena City Hall	D610	864	09/29/35	11/26/06	0.5%	21.0	21.0
Pasadena Chlorine Plant	D612	1,160	03/02/73	11/27/06	0.4%	25.2	25.3
Pasadena Hurlbut Fire Station	D613	779	10/17/72	11/27/06	0.4%	20.7	20.7
Santa Monica	D634	94	12/06/59	06/26/06	8.5%	13.1	13.9
Westwood U.C.L.A.	D680	430	05/10/57	06/08/06	3.7%	18.4	18.7
Sunset Ridge	D683	2,110	02/27/81	11/26/06	0.9%	24.6	24.7
Tujunga Cyn Vogel Flat	D695	1,850	11/03/53	10/13/06	7.0%	28.6	29.9
Los Angeles Ducommun St.	D716	306	01/01/00	05/22/06	3.0%	16.5	16.6
Burbank Valley Pump Plant	D749	655	10/08/66	06/08/06	6.6%	17.4	17.5
Pasadena Jourdan	D795	860	01/07/49	12/26/06	1.8%	20.9	21.0
De Soto Reservoir	D797	1,127	10/10/48	05/22/06	3.0%	18.4	18.5
Magic Mountain	D801	4,720	11/04/66	12/30/05	7.9%	25.0	27.1
Eagle Rock Reservoir	D802	970	10/04/75	05/22/06	4.3%	19.0	20.1
Ascot Reservoir	D807	620	11/08/54	05/22/06	3.8%	16.6	17.5
Mint Canyon Fire Station	D1005	2,300	11/12/65	05/07/05	26.6%	9.8	12.9
San Pedro City Reservoir	D1006	150	10/30/44	11/26/06	4.7%	13.5	13.8
Castaic Junction	D1012	1,005	10/12/68	03/17/02	24.3%	7.3	10.9
Malibu Beach Dunne	D1025	160	05/12/49	10/26/00	30.9%	9.4	14.0
Tujunga Mill Creek Summit Ranger Station	D1029	4,990	12/10/75	01/29/02	24.6%	15.7	21.7
Arcadia Arboretum	D1037	565	10/23/50	12/26/06	0.0%	19.8	19.8

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Santa Fe Dam	D1041	427	05/01/50	12/26/06	0.5%	18.7	18.7
Old Topanga	D1050	1,000	10/15/84	03/06/01	29.1%	19.9	27.3
Canoga Park Pierce College	D1051	800	10/02/62	01/30/07	0.9%	17.5	17.7
Manhattan Beach	D1070	182	11/03/53	12/26/06	2.5%	12.2	12.4
Descanso Gardens	D1071	1,325	11/12/55	12/26/06	0.0%	23.6	23.6
Monte Cristo Ranger Station	D1076	3,360	10/28/68	04/25/03	18.4%	17.2	22.1
Glendale Gregg	D1081	1,350	10/17/77	12/26/06	0.0%	22.8	22.8
Green Verdugo Pumping Plant	D1087	1,340	01/29/55	09/13/06	2.3%	17.9	18.0
La Habra Heights Mutual Water Co	D1088	445	10/02/56	12/26/06	0.1%	16.1	16.1
Orange County Reservoir	D1095	660	11/08/54	05/21/06	3.0%	16.4	16.5
Dominguez Water Co	D1113	30	11/06/55	05/21/02	23.1%	8.9	11.9
Whittier Narrows Dam	D1114	239	10/09/57	11/26/06	1.3%	15.7	15.9
San Antonio Dam	D1115	2,120	10/02/56	12/26/06	0.5%	24.8	25.0
Los Angeles East Valley	D1126	780	12/03/57	06/09/06	4.1%	16.3	16.6
Nicholas Canyon	D1129	340	12/13/82	06/16/05	8.1%	14.4	15.2
Torrance Municipal Airport	D1158	102	11/18/61	12/26/06	0.9%	14.0	14.5
Piru Canyon above Piru Lake	D1172	1,120	10/06/73	04/20/01	28.5%	14.4	20.4
Bear Divide	D1191	2,700	10/10/71	12/26/06	0.5%	25.5	25.7
Carson Fire Station	D1192	92	01/06/73	09/25/97	46.3%	5.8	11.9
Westlake Village	D1193	885	12/30/73	03/05/01	29.1%	11.6	16.2
Santa Ynez Reservoir	D1194	735	10/06/73	05/21/06	11.5%	19.8	20.6
Rancho Palos Verdes	D1216	780	11/01/79	12/25/06	0.9%	11.9	12.1
Northridge Garland	D1222	911	05/02/82	12/25/06	0.1%	17.4	17.4
Woodland Hills Sherman	D1223	1,035	02/03/72	12/30/06	1.0%	17.5	17.7
Palos Verdes Landfill	D1252	400	10/20/85	12/26/06	0.9%	14.6	14.6
Carson County Sanitation	D1253	40	10/04/85	05/21/06	13.9%	10.8	12.7
Long Beach Reclamation Plant	D1254	20	10/03/85	12/25/06	0.1%	12.3	12.3
Los Coyotes Reclamation Plant	D1255	70	10/20/85	12/25/06	0.1%	13.2	13.2
South Gate Transfer Station	D1256	100	10/01/86	12/26/06	2.2%	12.8	12.8
San Jose Creek Reclamation Plant	D1257	275	10/20/85	12/25/06	0.1%	15.3	15.3
Whittier Narrows Reclamation Plant	D1259	225	10/06/85	12/25/06	0.1%	14.5	14.5
La Canada Reclamation Plant	D1261	1,800	10/04/85	12/25/06	0.1%	22.7	22.7
Saugus Reclamation Plant	D1262	1,150	10/06/85	12/25/06	0.1%	14.0	14.0
Calabasas Landfill	D1264	800	10/19/85	12/26/06	5.5%	18.3	18.4
Pomona Reclamation Plant	D1271	786	10/05/85	12/25/06	2.6%	16.7	16.7

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Table C-3. Inventory of selected NCDC daily rainfall data (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Culver city	042214	55	01/01/35	12/31/06	4.2%	12.8	14.0
Los Angeles Intl Ap	045114	97	01/01/44	12/31/06	0.1%	12.7	12.7
Sandberg	047735	4,510	01/01/48	12/31/06	23.1%	10.9	14.1
San Gabriel Canyon P H	047776	744	01/01/48	12/31/06	1.7%	24.1	24.1

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Table C-4. Inventory of selected OBSERVER daily rainfall data (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Glendora	D174	930	06/29/67	12/28/06	2.7%	18.3	18.5
Beverly Hills City Hall	D228	255	10/06/32	12/25/06	9.7%	16.6	17.7
Henninger Flats	D235	2,550	10/26/64	12/27/06	1.7%	28.2	28.6
Hollywood Dam	D238	750	09/29/29	05/22/06	6.4%	17.6	18.6
Lake Los Angeles	D293	1,150	10/18/78	08/04/06	2.0%	19.6	19.6
Spadra Laterm Hospital	H356	1,580	02/27/30	01/28/07	3.7%	15.8	17.3
Covina City Yard	D387	508	10/01/39	12/26/06	0.0%	17.1	17.1
Morris Dam	D390	1,210	10/14/34	11/27/06	0.4%	25.8	25.9
Hansen Dam	D436	1,110	11/01/60	12/26/06	0.9%	16.7	16.8

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Table C-5. Inventory of selected PRIVATE daily rainfall data (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Woodland Hills	D21	875	11/04/69	12/26/06	0.0%	16.9	16.9
Northridge	D25	810	10/02/63	05/22/06	3.5%	16.5	16.6
Colby's Daily Automatic	D53	3,620	10/11/87	05/22/02	26.9%	13.0	17.8
Monrovia News	D67	602	04/02/76	09/22/00	31.4%	14.3	21.2
Altadena Rubio Canyon	D176	1,125	10/30/21	12/28/06	0.5%	22.7	22.7
Glendora City Hall	D287	785	11/17/67	07/23/07	0.9%	22.8	22.9
Lake Sherwood Estates	D377	960	10/15/49	01/21/04	22.3%	15.6	19.7
Highland Park	D394	620	10/04/39	04/20/01	28.5%	12.9	17.8

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Table C-6. Inventory of selected daily rainfall data reported by other agencies (processed: 1/1/1987–12/31/2006)

Station name	Station ID	Elevation (ft)	Collection period		Percent missing	Precipitation *	
			Start	End		Measured	Processed
Topanga	D6	745	12/12/75	04/17/02	24.0%	17.5	23.9
Upper Franklin Canyon	D11	867	09/08/75	06/08/06	5.3%	18.8	19.8
Chatsworth Reservoir	D23	900	11/17/67	05/22/06	5.6%	16.3	16.4
Big Tujunga Dam	D46	2,315	10/04/45	12/08/05	19.5%	23.1	26.3
Camp Hi Hill (Opids)	D57	4,250	10/30/78	05/23/02	23.1%	21.1	29.6
San Francisquito Canyon	D125	2,105	07/04/50	12/27/06	0.8%	18.6	18.7
Arcadia Pumping Plant	D167	611	09/29/67	12/27/06	6.0%	21.6	22.6
Duarte	D172	548	09/29/48	05/05/03	18.6%	14.8	18.7
La Canada Irrigation District	D175	1,915	01/30/39	01/30/07	0.0%	26.3	26.3
Glendale Andree	D216	615	12/02/80	12/26/06	0.1%	19.2	19.2
Stone Canyon Reservoir	D237	865	10/02/56	06/08/06	6.5%	20.8	21.8
Silver Lake Reservoir	D336	445	10/07/30	05/22/06	4.7%	16.8	17.1
Pyramid Reservoir	D409	2,505	03/09/67	10/01/06	3.8%	17.3	17.7
Angeles Forest Aliso Cyn. Wagon Wheel	D423	3,920	10/09/75	05/22/02	23.3%	12.4	17.6

* Measured and processed precipitation totals represent average annual values between 1987 and 2006

Appendix D – Point Source Data Review

The following summary is a description of major point source facilities in the LAR watershed. The data review summarizes information that was available from the Internet. The associated data source Web link where the information was retrieved is provided for each facility.

Tapia Water Reclamation Facility

Data source: http://www.lvmwd.com/index.aspx?page=72. The Tapia Water Reclamation Facility (TWRF) treats wastewater, transforming it into high-quality recycled water. That enables beneficial reuse of limited statewide water resources while reducing dependence on imported water. The facility is along Malibu Canyon Road in unincorporated LA County. Constructed at a low point in the Malibu Creek watershed, allowing wastewater to flow by gravity to the treatment facility, reducing the need for pumps, infrastructure, and energy use. it was built in 1965 with a capacity of 0.5 mgd (mgd). It was expanded several times—in 1968 to a capacity of 2 mgd; 1972 to a capacity of 4 mgd; 1984 to a capacity of 8 mgd; 1986 to a capacity of 10 mgd; 1994 to current capacity of 16 mgd. It began water recycling in 1972. TWRF treats an average of 9.5 mgd of wastewater. It has six aeration tanks, each 160 feet by 30 feet and 15 feet deep, with 540 air injectors capable of adding 2,100 cubic feet of air/minute. It has twelve filters for tertiary treatment, each with a surface area of 253 square feet and a 4-foot-deep bed of anthracite coal over one foot of gravel.

TWRF applies state-of-the-art technology to transform wastewater into high-quality recycled water that is used to irrigate public and commercial landscaping such as golf courses, school grounds, highway medians and parks. Wastewater is potable water that has been used in a home or business.

Wastewater entering TWRF is 99 percent water and 1 percent solids and inert materials. The first step removes the inert materials. Larger items, like rags and paper, are removed by passing the wastestream through a vertical slatted bar screen. Finer materials (egg shells and coffee grinds) are removed in a *grit chamber*. There, the flow is slowed and air is injected to keep small, organic particles suspended while the heavier, inert materials fall to the bottom. The items removed from the wastewater to that point go to a landfill. TWRF has a capacity to process up to 16 mgd of wastewater, but averages about 9 .5 million. By recycling wastewater, Tapia provides an additional *source* of water for communities. About 20 percent of all the water delivered by LVMWD has been recycled for irrigation use. During the hot summer months, irrigation consumes all the recycled water Tapia produces, with the added benefit of reducing the demand for potable water by that same amount.

Burbank Water Reclamation Plant

Data source: http://www.ci.burbank.ca.us/PublicWorks/eng-envir-wrs/water_rec_plant.htm. The Burbank Water Reclamation Plant (BWRP) is a tertiary wastewater treatment plant that treats 9 mgd of sewage. The BWRP was built in 1966 to meet the wastewater and sewer needs of the growing residential population and expanding commercial industries in Burbank. Before the BWRP was built, Burbank sent all its wastewater to the City of LA for treatment and disposal. Originally built to treat 6 mgd, the city upgraded the BWRP to the current 9 mgd in 1971. The plant was upgraded in 2000 to ensure that it meets new stringent regulations raising the quality of the cleaned wastewater it discharges after the treatment process. The plant was upgraded again in 2002 to remove ammonia from the wastewater. The BWRP is at 740 North Lake Street.

Malibu Mesa Wastewater Reclamation Plant

Data source: http://ladpw.org/SMD/SMD/Page_03.cfm. The Malibu Mesa Wastewater Reclamation Plant is at 3863 Malibu Canyon Drive. It is a tertiary wastewater treatment plant. The capacity of the plant is 200,000 gallons per day of domestic wastewater. Treatment processes include comminution, activated sludge biological treatment, secondary clarification, coagulation, sand filtration, and ultraviolet disinfection. The reclaimed water is primarily used for irrigation on Pepperdine University campus.

West Basin Municipal Water District

Data source: http://www.mwdh2o.com/mwdh2o/pages/memberag /agencies/westbasin.htm. West Basin Municipal Water District is at 17140 S. Avalon Blvd., Suite 210, Carson, California. The plant has a service area of 185 square miles and serves a population of 900,000. Since the early 1990s, West Basin has established itself as a leader in water supply management because of its diverse mix of education, conservation, water recycling and desalination programs. The West Basin Water Recycling Facility, the largest facility of its type in the nation, provides billions of gallons of recycled water to users throughout southwest LA County. Since the fourth expansion of the facility, West Basin has partnered with the Water Replenishment District of Southern California to provide water for barrier injection to protect the groundwater wells from seawater intrusion. The West Basin Water Recycling Facility is also the home of West Basin's award-winning children's education program.

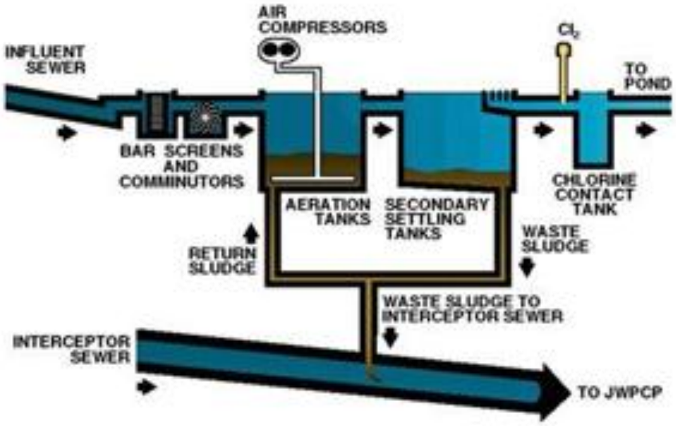
Joint Water Pollution Control Plant

Data source: http://www.lacsd.org/about/wastewater_facilities /jwpcp/default.asp. The Joint Water Pollution Control Plant (JWPCP) is at 24501 S. Figueroa Street, Carson, California. The plant occupies approximately 420 acres to the east of the Harbor (110) Freeway. The JWPCP is one of the largest wastewater treatment plants in the world and is the largest of the district's wastewater treatment plants. The facility provides both primary and secondary treatment for approximately 300 mgd of wastewater.

Solids collected in Primary Treatment and Secondary Treatment are processed in anaerobic digestion tanks where bacteria break down organic material and produce methane gas. After digestion, the solids are dewatered at solids processing and hauled off-site for use in composting and land application, or combined with municipal solid waste for co-disposal. Methane gas generated in the anaerobic digestion process is used to produce power and digester heating steam in a total energy facility that uses gas turbines and waste-heat recovery steam generators. The on-site generation of electricity permits the JWPCP to produce most of its electricity. The plant serves a population of approximately 3.5 million people throughout LA County. Before discharge, the treated wastewater is disinfected with hypochlorite and sent to the Pacific Ocean through a network of outfalls. The outfalls extend 2 miles off the Palos Verdes Peninsula to a depth of 200 feet.

La Cañada Water Reclamation Plant

Data source: http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/la_canada.asp. The La Cañada WRP is at 533 Meadowview Drive, La Cañada Flintridge. The plant occupies approximately one-third of an acre on the grounds of the La Cañada Flintridge Country Club. The plant began operation on October 5, 1962 with a capacity of 0.1 mgd. The La Cañada WRP provides extended aeration secondary treatment for 200,000 gallons of wastewater per day (see flow diagram below). The plant serves the country club and 425 surrounding homes. All the disinfected, secondary effluent is put into the four lakes on the 105-acre country club golf course. Lake water (augmented by potable water during the summer) is used for landscape irrigation of the golf course.



Long Beach Water Reclamation Plant

Data source:
http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/long_beach.asp.
The Long Beach WRP is at 7400 E. Willow Street, Long Beach. The plant occupies 17 acres west of the SGR (605) Freeway. It initially began operation in 1973. The Long Beach WRP provides primary, secondary, and tertiary treatment for 25 mgd of wastewater (see flow diagram below). The plant serves a population of approximately 250,000 people. Almost 5 mgd of the purified water is reused at more than 40 reuse sites. Reuse includes landscape irrigation of schools, golf courses, parks, and greenbelts and the re-pressurization of oil-bearing strata.

Los Coyotes Water Reclamation Plant

Data source:
http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/los_coyotes.asp
The Los Coyotes WRP is at 16515 Piuma Avenue in Cerritos, California, and occupies 34 acres at the northwest junction of the SGR (605) and the Artesia (91) freeways. Twenty of the thity-four acres are occupied by the Iron Wood Nine Golf Course, which is built on adjoining district property. The plant began operation on May 25, 1970, and initially had a capacity of 12.5 mgd and consisted of primary treatment and secondary treatment with activated sludge. The Los Coyotes WRP provides primary, secondary, and tertiary treatment for 37 mgd of wastewater (see flow diagram below). The plant serves a population of approximately 370,000 people. Over 5 mgd of the purified water is reused at more than 200 reuse sites. Reuse includes landscape irrigation of schools, golf courses, parks, nurseries, and greenbelts; and industrial use at local companies for carpet dying and concrete mixing.

Pomona Water Reclamation Plant

Data source:
http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/pomona.asp.
The Pomona WRP is at 295 Humane Way in Pomona, California. The plant occupies 14 acres northeast of the intersection of the Pomona (60) and Orange (57) freeways. The original plant, owned by the cities of Pomona, Claremont, and La Verne, was placed into operation in July 1926 with effluent reuse beginning in 1927. Stage I of the present plant was completed in June 1966 and replaced the Tri-City Plant. The Pomona WRP provides primary, secondary, and tertiary treatment for 13 mgd of wastewater (see flow diagram below). The plant serves a population of approximately 130,000 people. Approximately 8 mgd of the purified water is reused at more than 90 different reuse sites. Reuse includes landscape irrigation of parks, schools, golf courses, greenbelts, and such; irrigation and dust control at the Spadra Landfill; and industrial use by local paper manufacturers. The remainder of the purified water is put back into the San Jose Creek channel where it makes its way to the unlined portion of

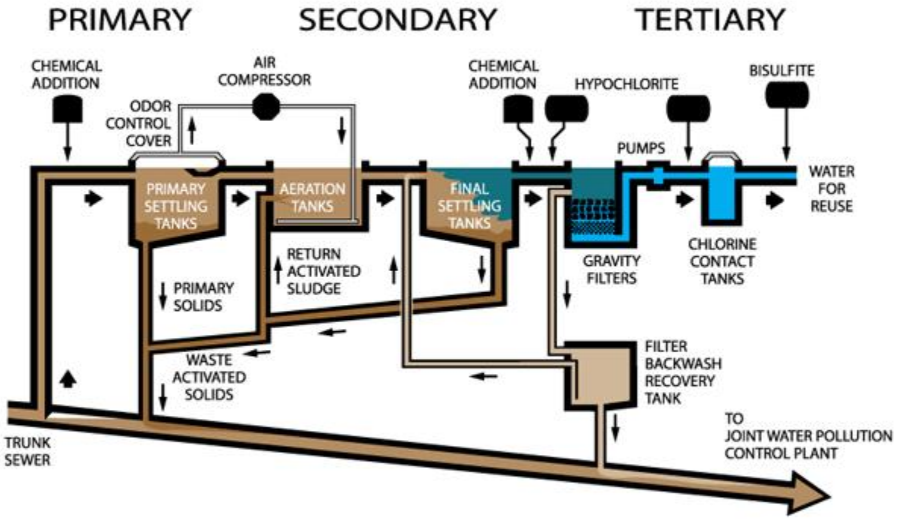
the SGR. Therefore, nearly 100 percent of the water is reused because most of the river water percolates into the groundwater.

San Jose Water Reclamation Plant

Data source:
http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/san_jose_creek/default.asp. The San Jose WRP is at 1965 Workman Mill Road, in unincorporated LA County, next to the City of Whittier. The plant occupies 39 acres north of the Pomona (60) Freeway on both sides of the San Gabriel (605) Freeway and started operation in June 1971. The San Jose Creek WRP provides primary, secondary, and tertiary treatment for 100 mgd of wastewater (see flow diagram below). The plant serves a largely residential population of approximately one million people. Approximately 35 mgd of the purified water is reused at 17 different reuse sites. That includes groundwater recharge and irrigation of parks, schools, and greenbelts.

Whittier Narrows Water Reclamation Plant

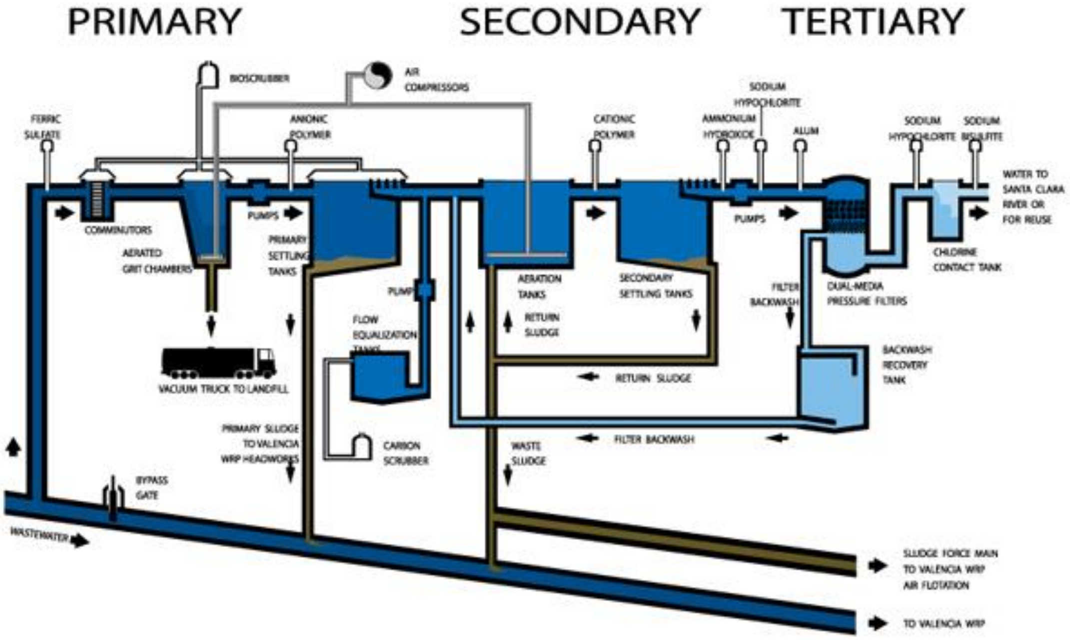
Data source:
http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/whittier_narrows.asp). The Whittier Narrows WRP is at 301 N. Rosemead Blvd., El Monte. The plant occupies 27 acres south of the Pomona (60) Freeway. The plant was originally constructed to demonstrate the feasibility of largescale water reclamation. The original plant was placed in operation on July 26, 1962, and consisted of primary sedimentation and secondary treatment with activated sludge. The Whittier Narrows WRP was the first reclamation plant built by the districts in 1962. It provides primary, secondary, and tertiary treatment for 15 mgd of wastewater (see flow diagram below). The plant serves a population of approximately 150,000 people. Virtually all the purified water is reused as groundwater recharge into the Rio Hondo and San Gabriel Coastal Spreading Grounds or for irrigation at an adjacent nursery.



Schematic for the Long Beach, Los Coyotes, Pomona, San Jose, and Whittier Narrows WRPs.

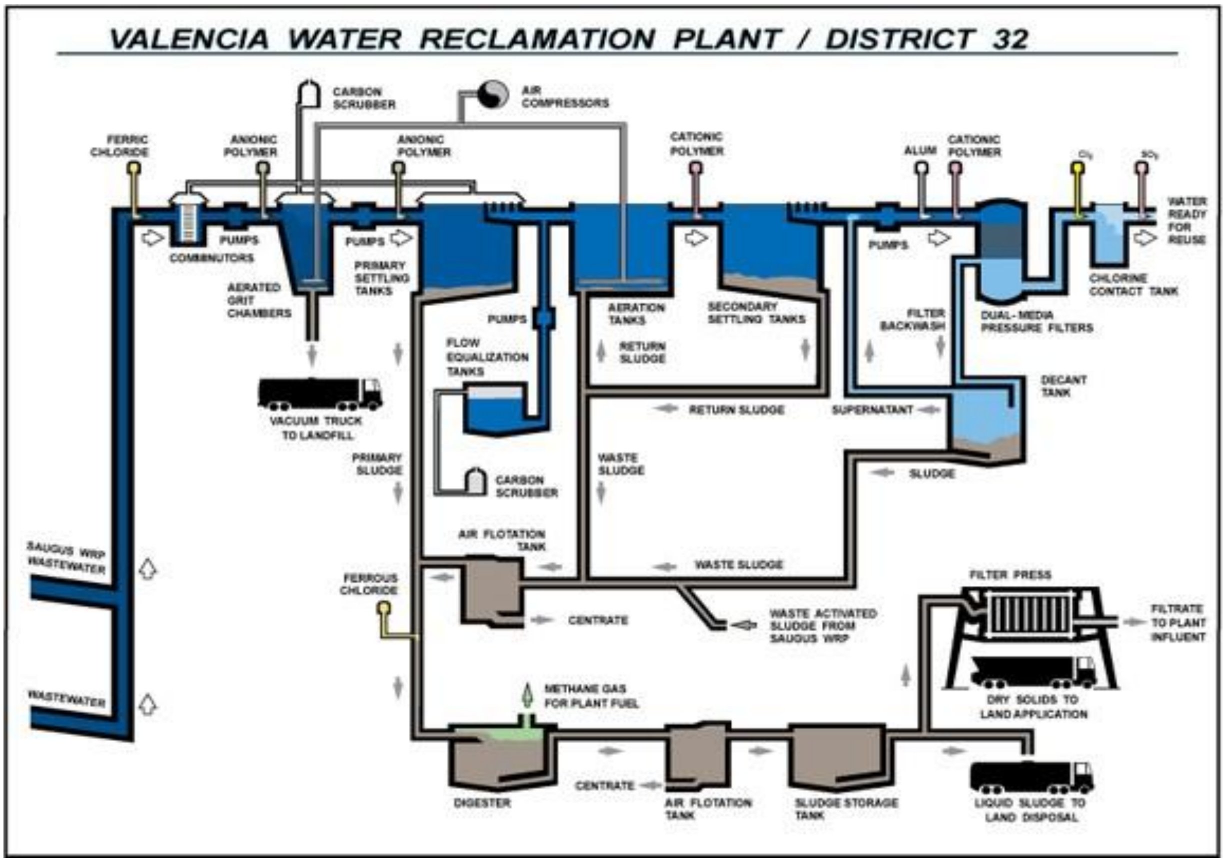
Saugus Water Reclamation Plant

The Saugus WRP is at 26200 Springbrook Avenue. The plant occupies 4 acres east of San Fernando Road in the city of Santa Clarita and was put into operation in July 1962 with a capacity of 0.25 mgd. The Saugus WRP provides primary, secondary, and tertiary treatment for 7 mgd of wastewater (see flow diagram below). The Saugus WRP operates with the Valencia WRP as part of the Santa Clarita Valley Sanitation District. No facilities for solids processing are at the Saugus WRP. Instead, all wastewater solids are conveyed by trunk sewers to the Valencia WRP for treatment.



Valencia Water Reclamation Plant

Data source:
http://www.lacsd.org/about/wastewater_facilities/santa_clarita_valley_water_reclamation_plants/valencia.asp. The Valencia WRP is at 28185 The Old Road in Valencia, California. The plant occupies 27 acres west of the Golden State (5) Freeway. The treatment plant was constructed in 1967 and initially had a capacity of 1.5 mgd of secondary treatment. The Valencia WRP is a tertiary treatment plant with solids processing facilities. The plant provides primary, secondary, and tertiary treatment for 21.6 mgd of wastewater (see flow diagram below). The Valencia WRP processes all wastewater solids generated in the Santa Clarita Valley Sanitation District (i.e., from the Saugus and Valencia WRPs). The wastewater solids are anaerobically digested, stored, and then dewatered using plate and frame filter presses. The dewatered cake, or biosolids, is hauled away for agricultural land application. Methane gas is produced during the digestion process and is used by a cogeneration process that heats water and produces electricity.



Hyperion Treatment Plant

Data source: http://www.lacity.org/san/lasewers /treatment_plants/hyperion/index.htm. The Hyperion Treatment Plant is at 12000 Vista del Mar, Playa del Rey. It is the city's oldest and largest wastewater treatment facility. The plant has been operating since 1894. The plant has been expanded and improved numerous times over the past 100+ years. Today, leading edge technological innovations capitalize on the opportunity to recover wastewater bio-resources that are used for energy generation and agricultural applications. In addition, air emission controls, and odor management facilities are integrated in all improvements.

History

The City of LA built and started operating the first treatment facility at the Hyperion site in 1925: a simple screening plant. This plant remained in operation until 1950. Just after the end of World War II, the city began to develop plans for a full secondary treatment plant at the Hyperion site. When the new Hyperion Treatment Plant opened in 1950, it included a full secondary treatment system and biosolids processing to produce a heat-dried fertilizer. It was among the first facilities in the world to capture energy from biogas by operating anaerobic digesters, which have yielded a fuel gas by-product for more than 50 years. At the time, Hyperion was the first large secondary treatment plant on the West Coast and one of the most modern facilities in the world. In the 1950s, the population of LA grew dramatically. To keep up with this growth and the associated higher wastewater flows, Hyperion's treatment levels were cut back. By 1957 the new plant was discharging a blend of secondary and primary effluent through a 5-mile ocean outfall. Hyperion also stopped its biosolids-to-fertilizer program and began discharging digested sludge into SMB through a separate, 7-mile ocean outfall.

1980s—Sludge out of SMB

Marine life in SMB suffered from the continuous discharge of 25 million pounds of wastewater solids (sludge) per month. Samples of the ocean floor where sludge had been discharged for 30 years demonstrated that the only living creatures were worms and a hardy species of clam. Additionally, coastal monitoring revealed that bay waters often did not meet quality standards as the result of Hyperion's effluent. Those issues resulted in the city entering into a CD with EPA and California to build major facility upgrades at Hyperion. In 1980 LA launched a massive sludge-out to full secondary program to capture all biosolids and keep them from entering the bay. The sludge-out portion of the program was completed in 1987.

1990s—Full Secondary System Rebuilt

The $1.6 billion sludge-out to full secondary construction program replaced nearly every 1950-vintage wastewater processing system at Hyperion while the plant continuously treated 350 mgd and met all NPDES permit requirements. Today, further improvements at Hyperion are being planned and built to keep the plant on the leading edge environmental protection.

Terminal Island Water Reclamation Plant

Data source: http://www.lacity.org/san/lasewers/treatment_plants/terminal_island/index.htm. The Terminal Island WRP/Advanced Water Treatment Facility is at 445 Ferry Street, Los Angeles. It is 20 miles south of downtown LA in San Pedro. The plant treats wastewater from more than 130,000 people and 100 businesses in the heavily industrialized Los Angeles Harbor area, including the communities of Wilmington, San Pedro, and a portion of Harbor City. The plant has recently become the third LA wastewater treatment plant to produce reclaimed water and one of the few plants in the country that produce water using reverse osmosis. The exceptional quality water will soon be used as a potable water replacement in Harbor area industrial applications and as a barrier against seawater intrusion. The plant also produces biosolids and biogas for beneficial reuse. The Terminal Island WRP was built in 1935 and has undergone numerous improvements and upgrades in 1977, 1981, and 1997 to comply with increasingly stringent state and federal clean water regulations. In 1977 the treatment plant upgraded its facilities so that all wastewater could be treated to the secondary level. This upgrade also included this country's first egg-shaped digesters for processing sludge to beneficial biosolids. In 1997 the plant was upgraded to the tertiary treatment level, allowing the plant to distribute reclaimed water for reuse in the Harbor area. Those were major steps toward improving the health of the Harbor and ocean environments.

In 1985 the Regional Board adopted an order requiring cessation of TITP's effluent discharge to the Harbor. The DPW grappled with the decision of whether to construct a new, conventional, deep-water ocean outfall to discharge Terminal Island's secondary effluent outside the Los Angeles Harbor, or to try something completely *outside the box.*

The city decided to install one of the world's most technologically advanced water reclamation treatment systems. In 1995 DPW, Water and Power, Environmental Affairs, Recreation and Parks and the Harbor Department agreed to develop a facility that would include microfiltration followed by reverse osmosis technology. Construction was completed on the $23 million project in 2002. The new facility is capable of processing 4.5 mgd and the water meets all drinking water quality standards. Today it is used as valuable boiler feed water for local industries, saving millions of gallons of potable water each day.

Donald C. Tillman Water Reclamation Plant

Data source: http://www.lacity.org/san/lasewers/treatment_plants /tillman/index.htm. The Donald C. Tillman WRP is at 6100 Woodley Avenue, Van Nuys. It combines advanced wastewater treatment technology with the beauty and tranquility of its landscaped gardens. The Japanese gardens are irrigated with reclaimed water from the plant and are open to the public on a year round basis. The plant provides reclaimed water to many users in the

San Fernando Valley and the DPW is collaborating with other city departments to expand this program. The Donald C. Tillman WRP began continuous operation in 1985. Its facilities were designed to treat 40 mgd of wastewater and serve the area between Chatsworth and Van Nuys in western portion of the San Fernando Valley. The plant was named after Mr. Tillman, who was the city engineer from 1972 to 1980. A major construction project that doubled the capacity of DCT was completed in 1991—expanding the plant from 40 mgd to 80 mgd and 26 mgd of water recycled. The Tillman Plant, together with the Los Angeles-Glendale WRP are the leading producers of reclaimed water in the San Fernando Valley. The plant is able to provide critical hydraulic relief to the city's major sewers downstream, which badly need the additional capacity to serve other portions of the city south of the valley.

Los Angeles-Glendale Water Reclamation Plant

Data source: http://www.lacity.org/san/lasewers/treatment_plants /la_glendale/index.htm. The Los Angeles-Glendale WRP is at 4600 Colorado Boulevard, Los Angeles. It is strategically located to serve east San Fernando Valley communities that are both in and outside the LA city limits. The plant's highly treated wastewater meets or exceeds the water quality standards for reclaimed water for irrigation and industrial processes. This water reuse conserves over one billion gallons of potable water per year. The plant is highly automated and staff can control processes from the onsite control room or at remote locations. In 1976 the Los Angeles-Glendale WRP started operations as the first WRP in the city. The cities of LA and Glendale co-own the plant, and the City of LA Bureau of Sanitation operates and maintains it. Each city pays 50 percent of the costs and receives an equal share of the recycled water. The plant processes around 20 mgd of wastewater and 4.5 mgd of water reclaimed . In addition to its role as a leading producer of reclaimed water, the Los Angeles-Glendale WRP is another regionally strategic facility in the city's overall wastewater system. By processing flows in the eastern San Fernando Valley, the plant is able to provide critical hydraulic relief to the city's major sewers downstream, which badly need the additional capacity to serve other portions of the city south of the valley.

Appendix E – Inventory of Hydrological Monitoring Stations

Table E-1. Selected USGS station summary

Source ID	Station number	Station description	Start date	End date	# of samples	Avg flow (cfs)	Min flow (cfs)	Max flow (cfs)
USGS	11085000	San Gabriel R Below Santa Fe Dam Nr Baldwin Pk Ca	1/1/1970	8/1/2008	14,093	59.38	0.00	18,100
USGS	11087020	San Gabriel R above Whittier Narrows Dam Ca	1/1/1970	8/1/2008	14,093	199.11	0.00	29,600
USGS	11092450	Los Angeles R A Sepulveda Dam Ca	1/1/1970	8/1/2008	5,747	92.66	0.46	9,750
USGS	11097000	Big Tujunga C Below Hansen Dam Ca	1/1/1970	8/1/2008	14,093	33.57	0.00	11,400
USGS	11097260	Wildwood Canyon Cr A Burbank Ca	2/1/2006	9/30/2007	607	0.03	0.00	11
USGS	11098000	Arroyo Seco Nr Pasadena Ca	1/1/1970	8/1/2008	14,093	10.74	0.00	2,010
USGS	11101250	Rio Hondo above Whittier Narrows Dam Ca	1/1/1970	8/1/2008	14,093	54.49	0.06	7,510
USGS	11102300	Rio Hondo below Whittier Narrows Dam Ca	1/1/1970	9/30/2007	13,787	164.63	0.00	21,200
USGS	11103000	Los Angeles R A Long Beach Ca	1/1/1970	9/30/1992	6,482	352.65	5.30	52,000
USGS	11105510	Malibu C A Malibu Ca	12/6/2007	8/1/2008	240	65.03	0.00	3,000
USGS	11107745	Santa Clara R above River Station Nr Lang Ca	1/1/1970	9/30/2005	4,160	6.65	0.00	1,620
USGS	11107770	Mint Cyn C A Sierra Hwy Nr Saugus Ca	11/5/2001	9/30/2005	1,426	0.82	0.00	229
USGS	11107860	Bouquet C Nr Saugus Ca	10/1/1970	9/30/2003	2,460	0.57	0.00	122
USGS	11107870	Bouquet C Below Haskell Cyn C Nr Saugus Ca	10/1/2003	9/30/2005	731	6.29	0.00	1,050
USGS	11108000	Santa Clara R Nr Saugus Ca	2/15/2002	9/30/2005	1,324	40.74	0.42	7,580
USGS	11108075	Castaic C above Fish C Nr Castaic Ca	10/1/1976	9/30/1993	2,556	9.07	0.00	1,610
USGS	11108080	Fish C above Castaic C Nr Castaic Ca	10/1/1976	9/30/1993	2,556	11.42	0.00	999
USGS	11108090	Elderberry Cyn C above Castaic C Nr Castaic Ca	10/1/1977	9/30/1993	2,191	1.21	0.00	200
USGS	11108095	Necktie Cyn C above Castaic C Nr Castaic Ca	10/1/1976	9/30/1993	2,556	1.42	0.00	333
USGS	11108130	Elizabeth Lake Cyn C above Castaic Lake Nr Castaic Ca	10/1/1976	9/30/1993	2,556	15.25	0.00	1,670
USGS	11108134	Castaic C Below Mwd Div Below Castaic Lake Nr Castaic	10/1/1994	9/30/2007	4,748	20.98	0.00	6,790
USGS	11108135	Castaic Lagoon Parshall Fl Nr Castaic Ca	10/1/1976	9/30/1994	2,921	11.02	0.00	3,000

Source ID	Station number	Station description	Start date	End date	# of samples	Avg flow (cfs)	Min flow (cfs)	Max flow (cfs)
USGS	11109395	Canada De Los Alamos above Pyramid Lake Ca	10/1/1976	9/30/2003	6,208	4.06	0.30	1,220
USGS	11109398	Wb Ca Aqueduct A William Warne Pp Nr Gorman Ca	10/1/1995	9/30/2007	4,383	759.16	0.00	2,830
USGS	11109525	Piru C Below Pyramid Lake Nr Gorman Ca	10/1/1988	9/30/2007	6,939	48.20	2.90	6,000
USGS	11109550	Piru C above Frenchmans Flat Ca	10/1/1976	5/7/2008	1,393	81.91	0.00	5480
USGS	11088500	Brea C Below Brea Dam Nr Fullerton Ca	10/9/2007	10/7/2008	365	4.25	0.39	208
USGS	11089500	Fullerton C Below Fullerton Dam Nr Brea Ca	10/9/2007	10/6/2008	364	1.89	0.22	85
USGS	11109600	Piru Creek above Lake Piru Ca	10/9/2007	10/4/2008	346	65.65	0.47	2,590

Table E-2. Hydrology data summary

Watershed	Subbasin ID	Station ID	Start date	End date	# of samples	Average flow (cfs)	Min flow (cfs)	Max flow (cfs)	St Dev Flow (cfs)
Ballona Creek	1007	11103500	1/1/1970	9/30/1978	3,195	52.20	4.20	4440.00	233.77
Ballona Creek	1007	ME05	2/19/2001	2/22/2004	2,835	1821.95	21.14	13991.00	1535.02
Ballona Creek	1125	LU20	2/17/2002	2/17/2002	243	0.03	0.00	0.21	0.04
Ballona Creek	1026	LU07	2/17/2002	2/17/2002	241	0.08	0.00	0.27	0.06
Ballona Creek	1124	LU03	2/19/2001	2/3/2004	173	1.12	0.00	5.04	1.58
Ballona Creek	1116	ME06	2/10/2001	4/7/2001	73	12.04	0.01	106.69	20.70
Dominguez Channel	2042	ME08	3/17/2002	2/22/2004	1,362	511.46	0.00	1252.00	380.45
Dominguez Channel	2007	LU13	3/15/2003	3/15/2003	695	4.13	0.00	13.23	2.82
Dominguez Channel	2056	LU02	2/17/2002	2/3/2004	577	0.11	0.00	0.89	0.21
Dominguez Channel	2010	LU09	2/10/2001	3/18/2002	494	1.78	0.00	63.60	6.61
Los Angeles River	6513	F252	10/1/1992	7/1/2008	133,246	19.86	0.00	4428.49	106.31
Los Angeles River	6655	F300	10/1/1996	7/1/2008	93,571	182.73	6.45	23653.99	816.30
Los Angeles River	6473	F57C	10/1/1998	8/5/2008	86,311	254.59	1.29	31886.55	1042.60
Los Angeles River	6599	E285	2/1/1999	7/1/2008	82,520	21.10	0.79	4296.44	80.88
Los Angeles River	6013	F319	4/1/2002	7/2/2008	54,829	406.70	62.79	66866.86	2482.28
Los Angeles River	6044	F37B	10/1/2002	7/2/2008	50,437	10.97	0.00	7756.25	119.83
Los Angeles River	6104	F45B	9/29/2003	7/7/2008	41,845	102.48	0.00	40856.11	1175.28

Watershed	Subbasin ID	Station ID	Start date	End date	# of samples	Average flow (cfs)	Min flow (cfs)	Max flow (cfs)	St Dev Flow (cfs)
Los Angeles River	6173	11101250	1/1/1970	8/1/2008	14,093	54.49	0.06	7510.00	250.18
Los Angeles River	6453	11098000	1/1/1970	8/1/2008	14,093	10.74	0.00	2010.00	51.46
Los Angeles River	6726	11097000	1/1/1970	8/1/2008	14,093	33.57	0.00	11400.00	241.45
Los Angeles River	6129	11102300	1/1/1970	9/30/2007	13,787	164.63	0.00	21200.00	706.17
Los Angeles River	6006	11103000	1/1/1970	9/30/1992	6,482	352.65	5.30	52000.00	1826.44
Los Angeles River	6868	11092450	1/1/1970	8/1/2008	5,747	92.66	0.46	9750.00	390.95
Los Angeles River	6100	11102500	1/1/1970	9/30/1979	3,560	41.84	0.00	13800.00	488.42
Los Angeles River	6473	11097500	1/1/1970	9/30/1979	3,560	149.82	1.60	22700.00	826.85
Los Angeles River	6719	11093000	1/1/1970	9/30/1979	3,560	10.59	0.00	940.00	45.07
Los Angeles River	6136	11101500	1/1/1970	9/30/1978	3,195	50.81	0.00	4250.00	202.55
Los Angeles River	6350	11098500	1/1/1970	9/30/1978	3,195	199.02	1.80	31900.00	1220.54
Los Angeles River	6132	11102000	1/1/1970	9/30/1977	2,830	0.96	0.00	27.00	2.27
Los Angeles River	6774	11095500	1/1/1970	9/30/1977	2,830	15.52	0.30	970.00	33.19
Los Angeles River	6007	ME03	1/26/2001	2/3/2004	1,743	2598.86	3.21	26720.00	3605.84
Los Angeles River	6174	11101380	10/1/1975	9/30/1979	1,461	9.69	0.30	836.00	48.21
Los Angeles River	6738	11096500	1/1/1970	9/30/1973	1,369	1.03	0.00	477.00	13.85
Los Angeles River	6803	11093490	1/1/1970	9/30/1973	1,369	0.62	0.00	38.00	1.48
Los Angeles River	6515	ME02	1/26/2001	11/1/2003	884	1751.75	107.41	13000.00	1992.08
Los Angeles River	6801	11094000	1/1/1970	9/30/1971	638	11.92	0.50	1050.00	45.97
Los Angeles River	6609	11097260	2/1/2006	9/30/2007	607	0.03	0.00	11.00	0.46
Los Angeles River	6953	LU14	2/19/2001	2/2/2004	496	0.78	0.00	4.53	1.06
Los Angeles River	6180	11101180	6/6/1973	2/5/1975	416	3.93	0.65	329.00	20.98
Los Angeles River	6269	11100760	2/7/1974	2/5/1975	364	3.03	0.39	208.00	14.78
Los Angeles River	6335	11100500	10/2/1978	9/14/1979	337	6.29	0.03	220.00	20.63
Los Angeles River	6927	11092000	9/7/1973	8/6/1974	334	2.23	0.00	212.00	14.12
Los Angeles River	6212	11101080	10/3/1973	12/19/1974	317	4.01	0.34	197.00	16.62
Los Angeles River	6044	11102750	2/1/1974	1/3/1975	308	5.77	0.00	424.00	29.51

Watershed	Subbasin ID	Station ID	Start date	End date	# of samples	Average flow (cfs)	Min flow (cfs)	Max flow (cfs)	St Dev Flow (cfs)
Los Angeles River	6343	11100000	1/1/1970	10/13/1970	286	4.58	0.24	99.00	10.20
Los Angeles River	6132	11087100	1/1/1970	9/30/1970	273	0.03	0.00	5.90	0.36
Los Angeles River	6473	ME01	1/26/2001	11/13/2001	263	1125.30	96.60	9270.00	1590.52
Los Angeles River	6511	LU01	2/10/2001	3/17/2002	248	0.68	0.00	19.87	2.10
Los Angeles River	6376	LU10	2/17/2002	2/17/2002	237	0.01	0.00	0.06	0.01
Los Angeles River	6385	LU06	2/17/2002	2/17/2002	231	11.89	0.00	47.31	11.30
Los Angeles River	6976	LU08	2/19/2001	3/17/2002	137	0.07	0.00	0.64	0.13
Los Angeles River	6304	11084950	12/19/1973	4/1/1974	104	6.82	0.00	51.00	13.03
Los Angeles River	6402	ME04	2/9/2001	4/7/2001	81	174.32	0.84	768.17	192.95
Los Angeles River	6624	LU17	2/19/2001	3/5/2001	64	0.26	0.00	1.55	0.35
Los Angeles River	6383	LU19	4/7/2001	4/7/2001	29	0.77	0.12	2.02	0.67
Los Angeles River	6304	LU11	4/7/2001	4/7/2001	27	0.27	0.06	0.61	0.13
Malibu Creek	3103	ME07	5/2/2003	1/8/2005	6,482	36.75	0.00	773.69	121.53
Malibu Creek	3002	11105500	1/1/1970	9/30/1979	3,560	28.86	0.51	7620.00	185.75
Malibu Creek	3059	11104000	1/1/1970	9/30/1979	3,560	6.80	0.00	2680.00	64.84
Malibu Creek	3006	LU24	2/24/2003	2/25/2003	1,179	6.25	0.04	24.15	5.73
Malibu Creek	3225	LU04	3/17/2002	3/17/2002	334	0.29	0.00	4.08	0.62
Malibu Creek	3001	11105510	12/6/2007	8/1/2008	240	65.03	0.00	3000.00	275.77
Malibu Creek	3035	LU23	2/24/2003	2/25/2003	20	5.79	0.02	12.73	3.95
San Gabriel River	5504	F279C	1/23/2001	3/19/2008	226,796	43.03	0.00	4647.00	191.50
San Gabriel River	5397	F40	10/1/1990	7/7/2008	151,527	8.02	0.00	986.10	48.40
San Gabriel River	5367	F304	10/1/1990	7/1/2008	142,328	20.24	0.00	5400.19	122.50
San Gabriel River	5426	F274B	10/1/1995	7/1/2008	108,209	27.48	0.00	8523.30	147.05
San Gabriel River	5104	F42B	10/1/1995	7/14/2008	106,374	153.00	0.16	12089.32	301.52
San Gabriel River	5412	F303	10/17/1996	7/2/2008	101,818	7.21	0.00	1389.02	34.82
San Gabriel River	5157	F312B	10/1/1997	7/14/2008	92,415	70.94	0.00	11062.59	256.16
San Gabriel River	5124	F262C	10/1/1996	7/14/2008	89,974	29.99	0.00	8068.37	311.12

Watershed	Subbasin ID	Station ID	Start date	End date	# of samples	Average flow (cfs)	Min flow (cfs)	Max flow (cfs)	St Dev Flow (cfs)
San Gabriel River	5267	U8	5/15/1999	7/7/2008	80,191	157.62	0.00	20614.02	642.02
San Gabriel River	5255	F190	4/1/2001	7/1/2008	63,524	134.77	0.00	20597.08	675.56
San Gabriel River	5001	F354	9/30/2003	7/14/2008	41,872	138.31	0.00	21000.44	683.98
San Gabriel River	5504	F279C	10/1/1955	4/30/1991	15,764	7.74	0.00	1460.00	47.88
San Gabriel River	5156	11087020	1/1/1970	8/1/2008	14,093	199.11	0.00	29600.00	953.57
San Gabriel River	5244	11085000	1/1/1970	8/1/2008	14,093	59.38	0.00	18100.00	530.78
San Gabriel River	5264	11084500	1/1/1970	9/30/1979	3,560	4.77	0.00	480.00	17.40
San Gabriel River	5322	11080500	1/1/1970	9/30/1979	3,560	72.50	8.00	6360.00	219.32
San Gabriel River	5104	11088000	1/1/1970	9/30/1979	3,432	78.06	0.00	5560.00	315.36
San Gabriel River	5147	11087500	1/1/1970	9/30/1978	3,195	97.24	0.00	6630.00	381.14
San Gabriel River	5157	11086990	1/1/1970	9/30/1978	3,195	36.72	2.00	2740.00	135.30
San Gabriel River	5279	11082000	1/1/1970	9/30/1978	3,195	72.74	5.10	7260.00	277.38
San Gabriel River	5412	11086300	1/1/1970	9/30/1978	3,195	5.45	0.00	703.00	24.64
San Gabriel River	5102	SG01	2/25/2004	2/11/2005	3,154	5392.90	0.00	19574.00	4507.21
San Gabriel River	5369	SG04	12/27/2004	2/11/2005	2,737	1075.88	50.30	7239.00	1180.12
San Gabriel River	5002	SG02	2/25/2004	2/11/2005	2,721	1245.51	103.00	4832.00	1151.35
San Gabriel River	5158	SG03	12/27/2004	2/11/2005	2,514	667.88	1.59	2092.00	502.41
San Gabriel River	5499	F279B	10/1/1949	9/30/1955	2,191	6.21	0.00	836.00	40.98
San Gabriel River	5103	LU25	12/28/2004	2/11/2005	1,180	0.23	0.00	2.79	0.44
San Gabriel River	5486	11086500	1/1/1970	9/30/1971	638	0.43	0.00	15.00	1.22
San Gabriel River	5050	11088500	10/9/2007	10/7/2008	365	4.25	0.39	208.00	16.50
San Gabriel River	5033	11089500	10/9/2007	10/6/2008	364	1.89	0.22	85.00	6.91
San Gabriel River	5143	11102250	1/1/1970	9/30/1970	273	0.00	0.00	0.00	0.00
San Gabriel River	5305	11080880	10/30/1974	2/5/1975	99	8.71	0.45	37.00	11.81
San Gabriel River	5397	11085560	5/17/1974	8/1/1974	77	14.69	12.00	22.00	2.00
San Gabriel River	5440	LU15	4/7/2001	4/7/2001	28	60.83	7.84	134.22	34.65
Santa Clara River	4091	F92C	2/1/2000	8/5/2008	64,471	41.42	0.00	12602.10	211.11

Watershed	Subbasin ID	Station ID	Start date	End date	# of samples	Average flow (cfs)	Min flow (cfs)	Max flow (cfs)	St Dev Flow (cfs)
Santa Clara River	4201	F328	10/1/2003	8/5/2008	41,422	7.29	0.00	572.78	23.94
Santa Clara River	4160	F377	11/11/2005	8/5/2008	23,966	1.01	0.00	800.06	15.11
Santa Clara River	4236	F93B	11/15/2005	8/2/2008	23,784	5.51	0.00	140.42	17.65
Santa Clara River	4314	11109525	10/1/1988	9/30/2007	6,939	48.20	2.90	6000.00	206.12
Santa Clara River	4327	11109395	10/1/1976	9/30/2003	6,208	4.06	0.30	1220.00	26.39
Santa Clara River	4030	11108134	10/1/1994	9/30/2007	4,748	20.98	0.00	6790.00	177.85
Santa Clara River	4315	11109398	10/1/1995	9/30/2007	4,383	759.16	0.00	2830.00	540.97
Santa Clara River	4236	11107745	1/1/1970	9/30/2005	4,160	6.65	0.00	1620.00	48.39
Santa Clara River	4062	11108092	10/1/1995	9/13/2005	3,636	22127 Ac-Ft	13178 Ac-Ft	31537 Ac-Ft	2790 Ac-Ft
Santa Clara River	4030	11108135	10/1/1976	9/30/1994	2,921	11.02	0.00	3000.00	77.04
Santa Clara River	4036	11108130	10/1/1976	9/30/1993	2,556	15.25	0.00	1670.00	71.86
Santa Clara River	4061	11108095	10/1/1976	9/30/1993	2,556	1.42	0.00	333.00	13.31
Santa Clara River	4065	11108080	10/1/1976	9/30/1993	2,556	11.42	0.00	999.00	60.98
Santa Clara River	4075	11108075	10/1/1976	9/30/1993	2,556	9.07	0.00	1610.00	59.58
Santa Clara River	4009	11108145	1/1/1970	9/30/1976	2,464	7.50	0.00	1910.00	46.38
Santa Clara River	4170	11107860	10/1/1970	9/30/2003	2,460	0.57	0.00	122.00	3.64
Santa Clara River	4063	11108090	10/1/1977	9/30/1993	2,191	1.21	0.00	200.00	8.68
Santa Clara River	4201	11107770	11/5/2001	9/30/2005	1,426	0.82	0.00	229.00	9.95
Santa Clara River	4314	11109550	10/1/1976	5/7/2008	1,393	81.91	0.00	5480.00	327.87
Santa Clara River	4091	11108000	2/15/2002	9/30/2005	1,324	40.74	0.42	7580.00	348.41
Santa Clara River	4117	11107922	10/1/1975	9/30/1977	731	1.27	0.00	157.00	9.93
Santa Clara River	4160	11107870	10/1/2003	9/30/2005	731	6.29	0.00	1050.00	57.26
Santa Clara River	4418	11109600	10/9/2007	10/4/2008	346	65.65	0.47	2590.00	177.08

Appendix F – Hydrology Calibration Graphs and Tables

This appendix presents the hydrology calibration results for four USGS gages throughout the Los Angeles regional watersheds. The catchment areas for the gages are large, mixed soils, and mixed use. The stations are listed below, and a summary of the error statistics is presented in Table F-1.

- USGS 11087020 SGR above Whittier Narrows Dam CA (SGR watershed)
- USGS 11109525 Piru Creek below Pyramid Lk near Gorman CA (SCR watershed)
- USGS 11098000 Arroyo Seco near Pasadena CA (LAR watershed)
- USGS 11092450 LAR at Sepulveda Dam CA (LAR watershed)

Table F-1. Summary of error statistics for the calibration locations presented in this appendix

Errors (Simulated-Observed)	11087020	11109525	11098000	11092450
Error in total volume	-12.38	-1.45	-12.70	1.25
Error in 50% lowest flows	-22.02	1.02	-76.56	0.71
Error in 10% highest flows	7.01	-1.43	-2.66	0.56
Seasonal volume error - Summer	-25.11	-14.91	-80.49	0.21
Seasonal volume error - Fall	-26.61	0.69	-38.00	1.63
Seasonal volume error - Winter	3.04	0.00	2.69	1.67
Seasonal volume error - Spring	-24.76	-0.18	-53.14	0.11
Error in storm volumes	-3.29	-10.05	12.52	-4.35
Error in summer storm volumes	-10.74	-14.68	-86.90	-25.58
Nash-Sutcliffe Coefficient of Efficiency, E	0.177	0.838	0.113	0.777
Baseline adjusted coefficient (Garrick), E'	-0.015	0.836	0.482	0.686

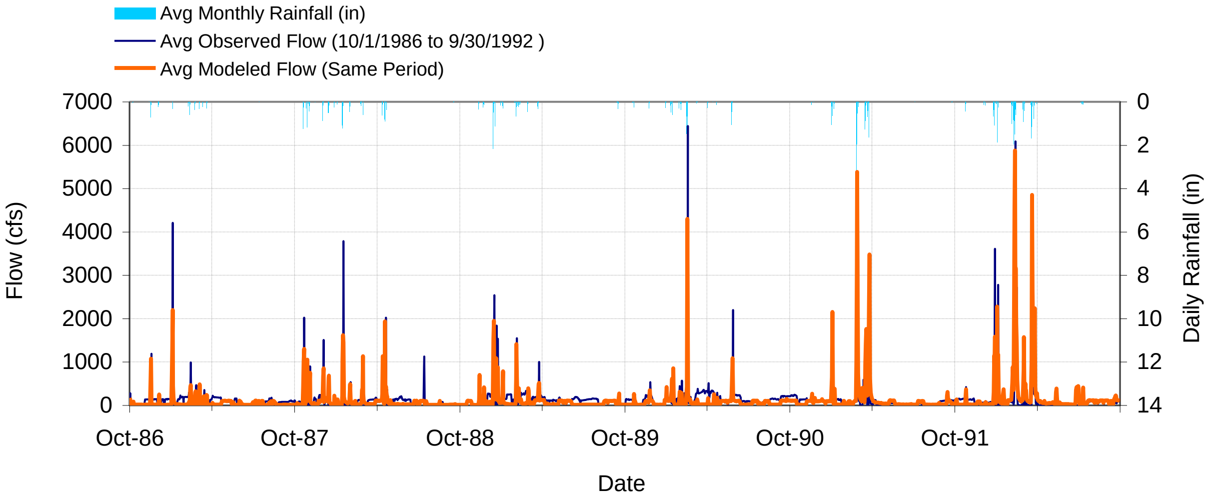


Figure F-1. Mean daily flow: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

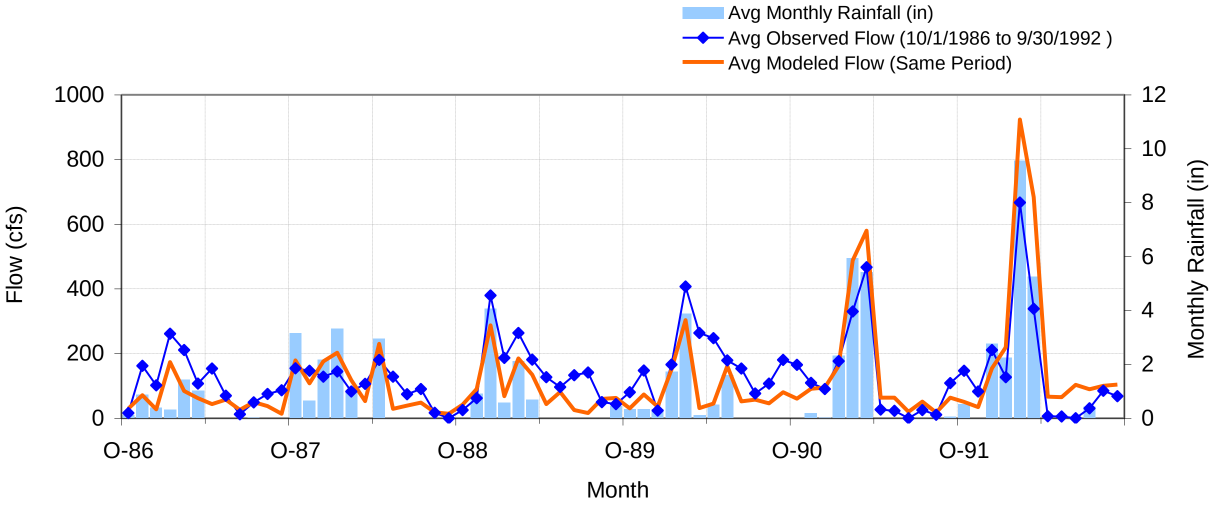


Figure F-2. Mean monthly flow: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

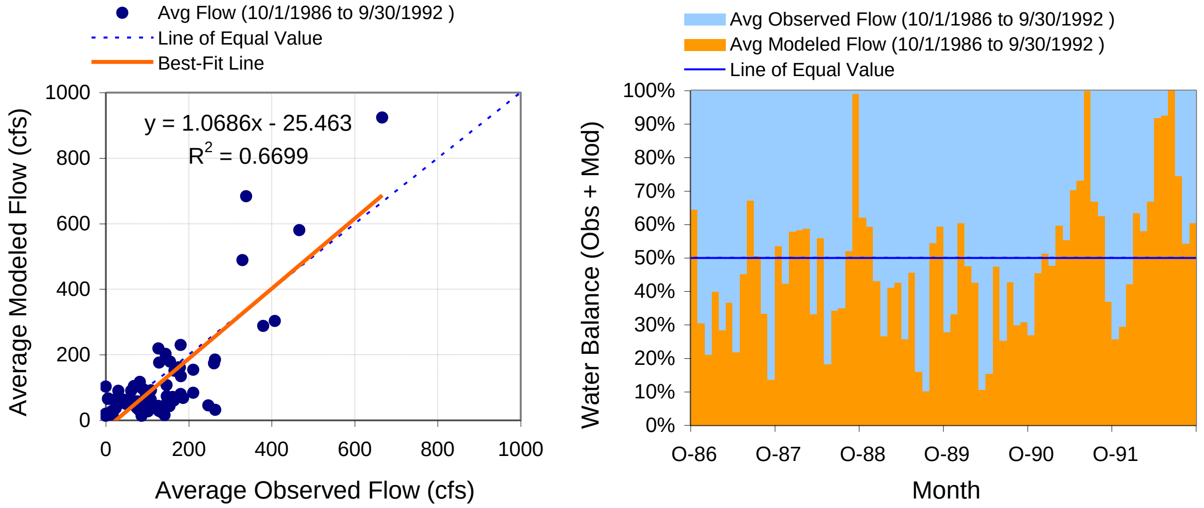


Figure F-3. Monthly flow regression and temporal variation: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

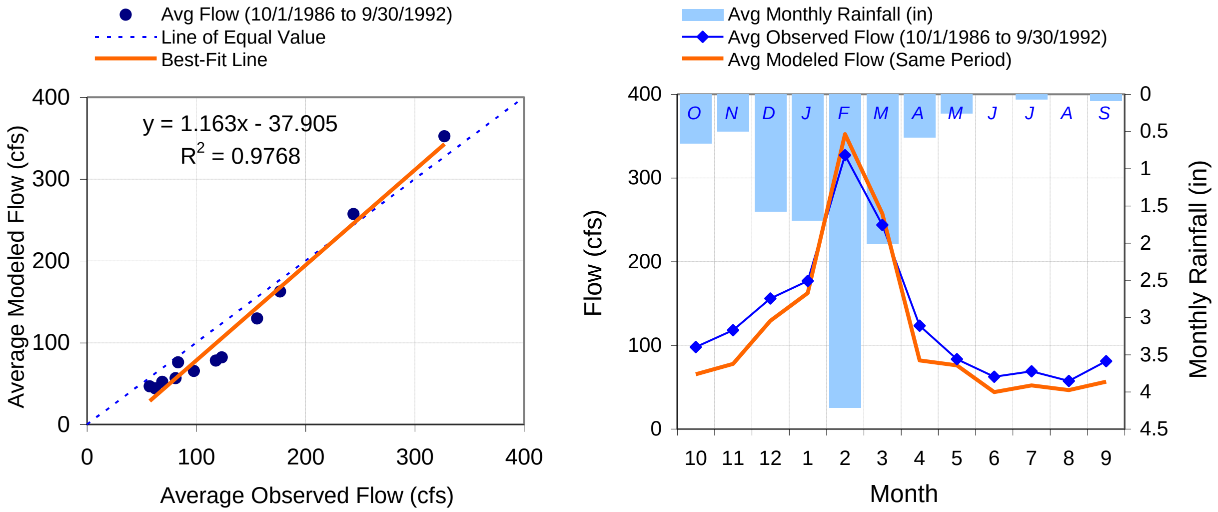


Figure F-4. Seasonal regression and temporal aggregate: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

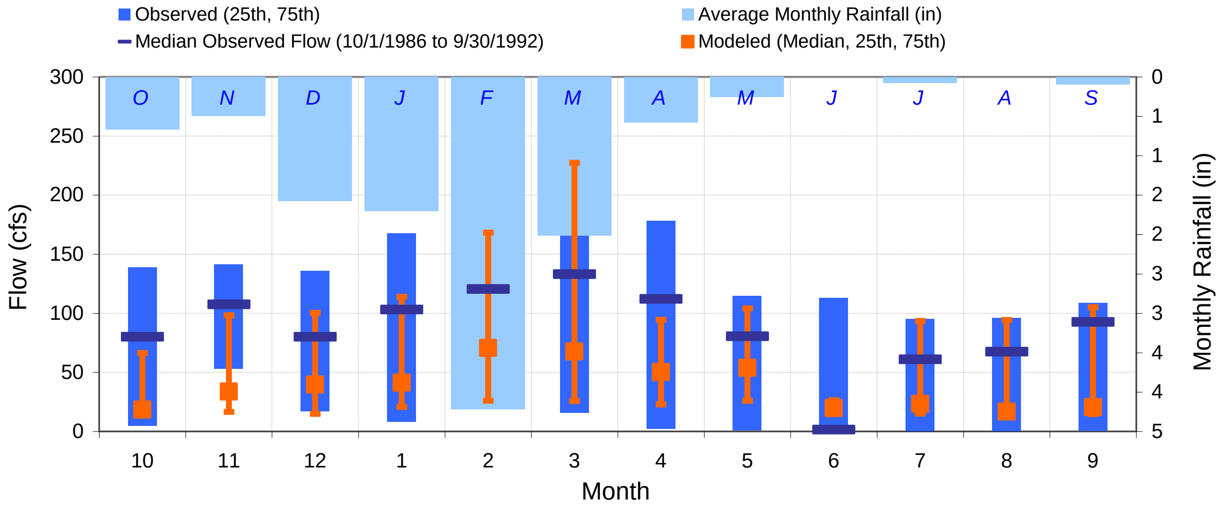


Figure F-5. Seasonal medians and ranges: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

Table F-2. Seasonal summary: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	98.01	80.00	4.63	138.75	65.38	18.51	14.44	66.39
Nov	118.12	107.50	53.00	141.25	77.92	33.71	16.46	98.15
Dec	155.87	80.00	16.75	135.75	129.42	39.67	14.87	100.38
Jan	176.83	103.00	8.15	167.75	162.56	41.31	20.66	113.95
Feb	327.30	120.50	21.50	246.25	352.25	70.68	25.93	168.30
Mar	243.93	133.00	15.75	271.25	257.27	67.72	25.85	227.40
Apr	123.52	112.00	2.40	178.25	82.05	50.20	22.88	94.53
May	83.49	80.50	1.15	114.75	76.04	53.93	26.04	104.10
Jun	62.30	1.40	0.00	113.00	44.11	19.61	15.33	26.45
Jul	68.86	61.00	0.00	95.00	52.12	23.22	15.14	93.49
Aug	57.33	67.50	0.00	95.75	46.56	16.72	13.61	94.19
Sep	81.13	92.50	0.70	109.00	56.45	20.48	14.71	105.06

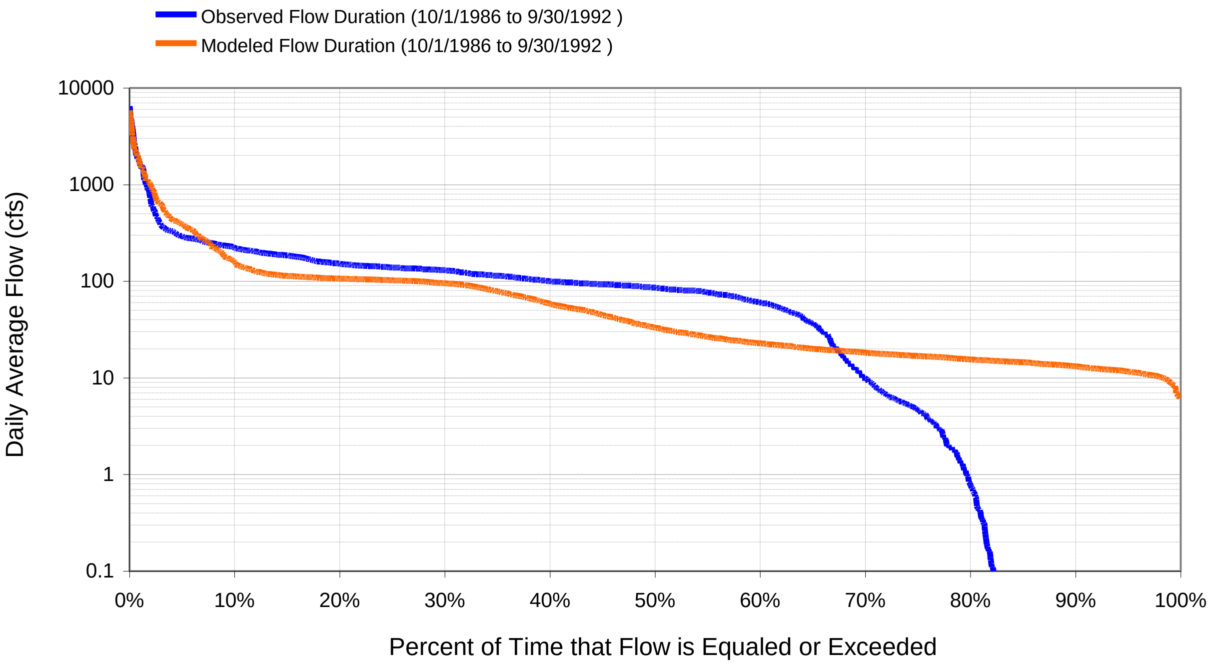


Figure F-6. Flow exceedance: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

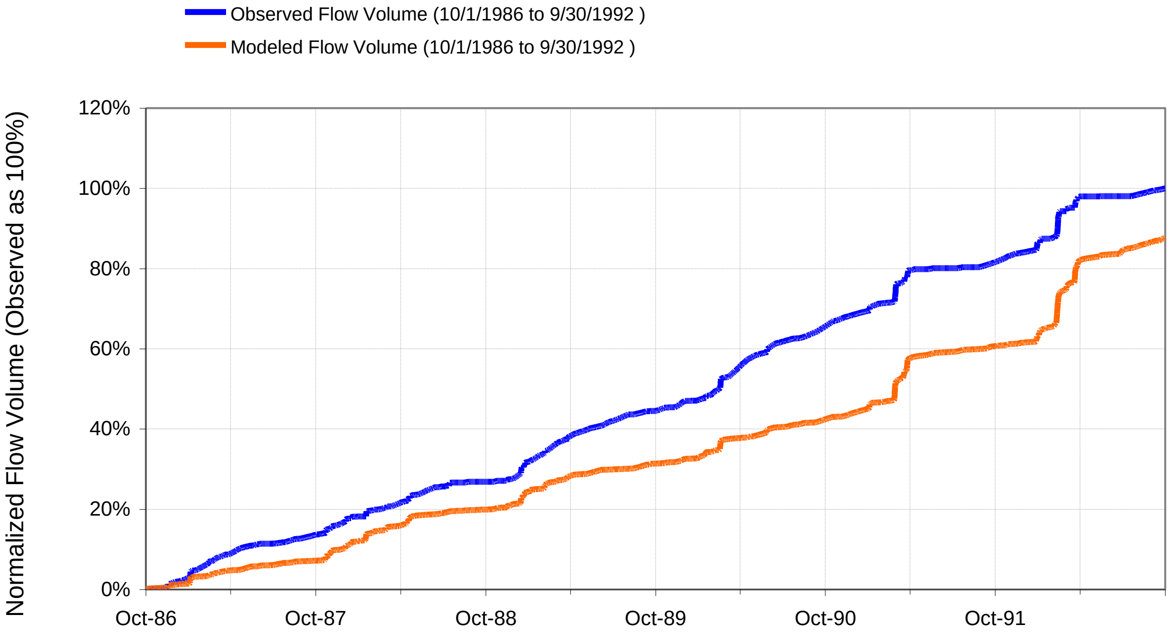


Figure F-7. Flow accumulation: Model Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

Table F-3. Outlet 5156 vs. USGS 11087020 San Gabriel R Ab Whittier Narrows Dam CA

LSPC Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM SUBBASIN 5156 6-Year Analysis Period: 10/1/1986 - 9/30/1992 Flow volumes are (inches/year) for upstream drainage area		**USGS 11087020 SAN GABRIEL R AB WHITTIER NARROWS DAM CA** Hydrologic Unit Code: 18070106 Latitude: 34.03417767 Longitude: -118.0381225 Drainage Area (sq-mi): 442		
Total Simulated In-stream Flow:	**3.56**	Total Observed In-stream Flow:		**4.06**
Total of simulated highest 10% flows:	**2.23**	Total of Observed highest 10% flows:		**2.08**
Total of Simulated lowest 50% flows:	**0.28**	Total of Observed Lowest 50% flows:		**0.35**
Simulated Summer Flow Volume (months 7-9):	**0.40**	Observed Summer Flow Volume (7-9):		**0.53**
Simulated Fall Flow Volume (months 10-12):	**0.70**	Observed Fall Flow Volume (10-12):		**0.96**
Simulated Winter Flow Volume (months 1-3):	**1.93**	Observed Winter Flow Volume (1-3):		**1.88**
Simulated Spring Flow Volume (months 4-6):	**0.52**	Observed Spring Flow Volume (4-6):		**0.69**
Total Simulated Storm Volume:	**2.23**	Total Observed Storm Volume:		**2.31**
Simulated Summer Storm Volume (7-9):	**0.15**	Observed Summer Storm Volume (7-9):		**0.17**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-12.38	10		
Error in 50% lowest flows:	-22.02	10		
Error in 10% highest flows:	7.01	15		
Seasonal volume error - Summer:	-25.11	30		
Seasonal volume error - Fall:	-26.61	30		
Seasonal volume error - Winter:	3.04	30		
Seasonal volume error - Spring:	-24.76	30		
Error in storm volumes:	-3.29	20		
Error in summer storm volumes:	-10.74	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.177	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	-0.015			

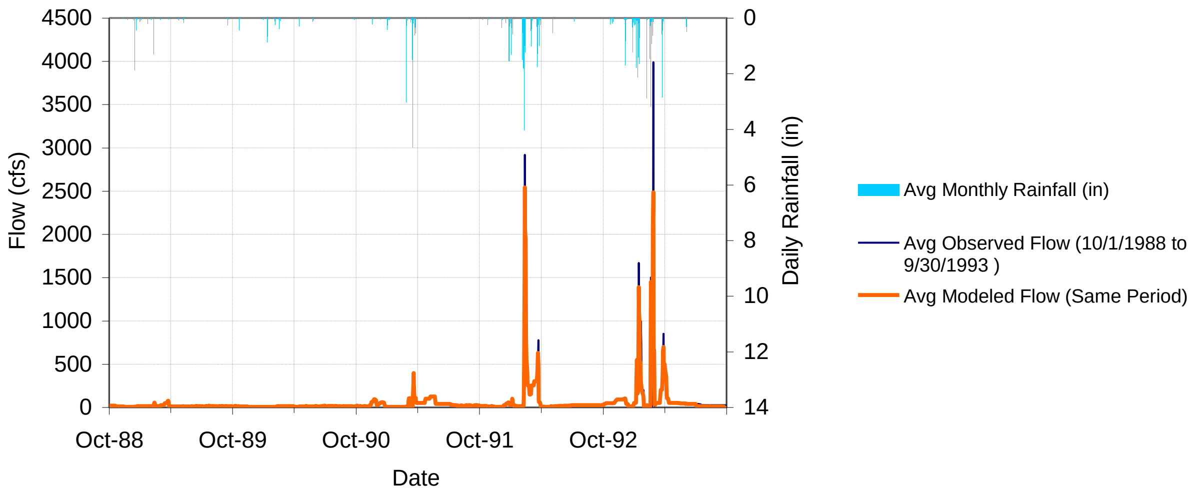


Figure F-8. Mean daily flow: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

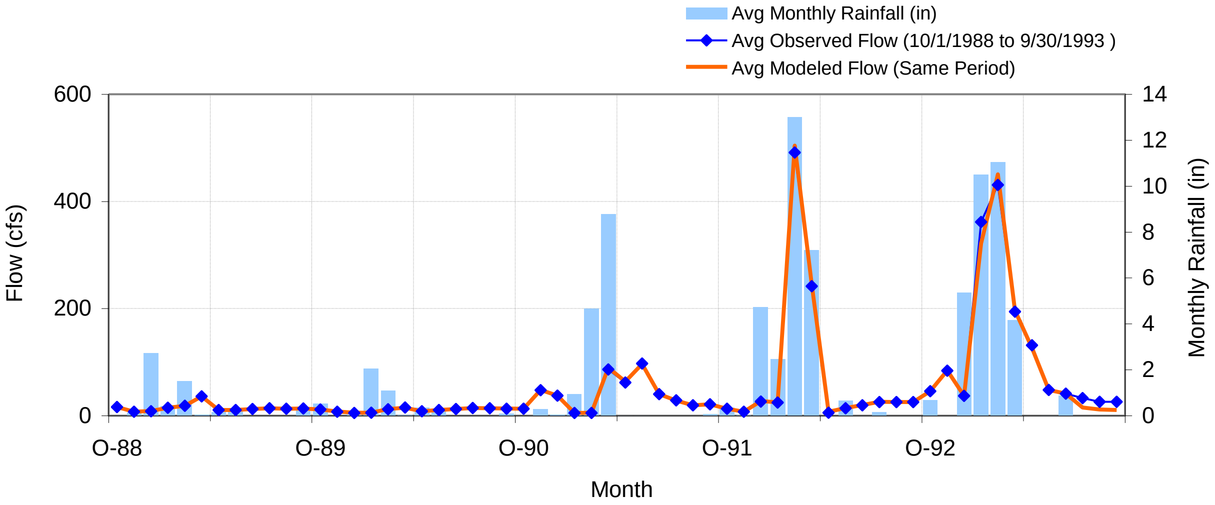


Figure F-9. Mean monthly flow: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

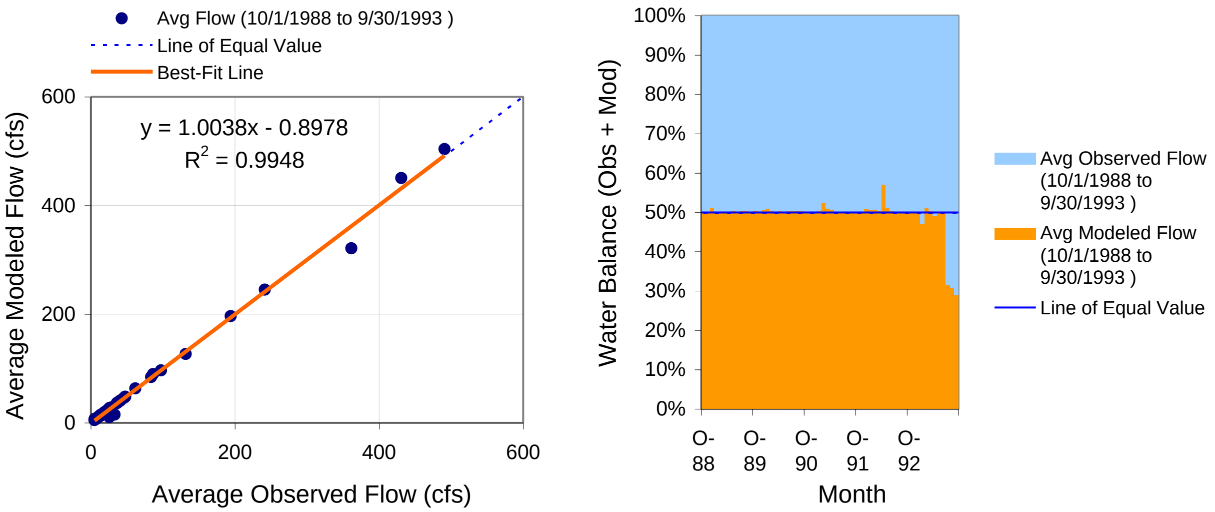


Figure F-10. Monthly flow regression and temporal variation: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

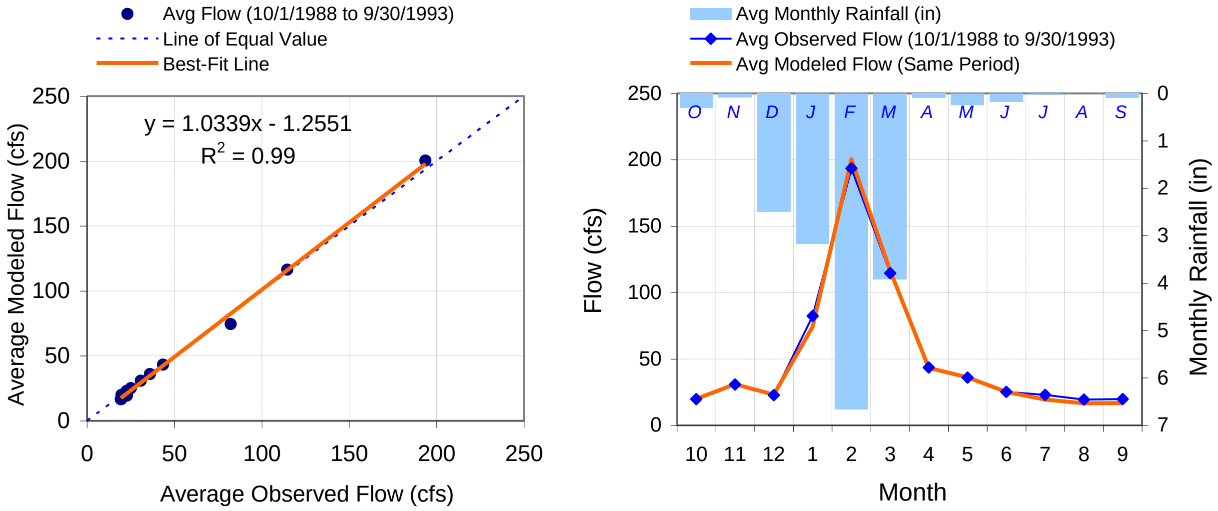


Figure F-11. Seasonal regression and temporal aggregate: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

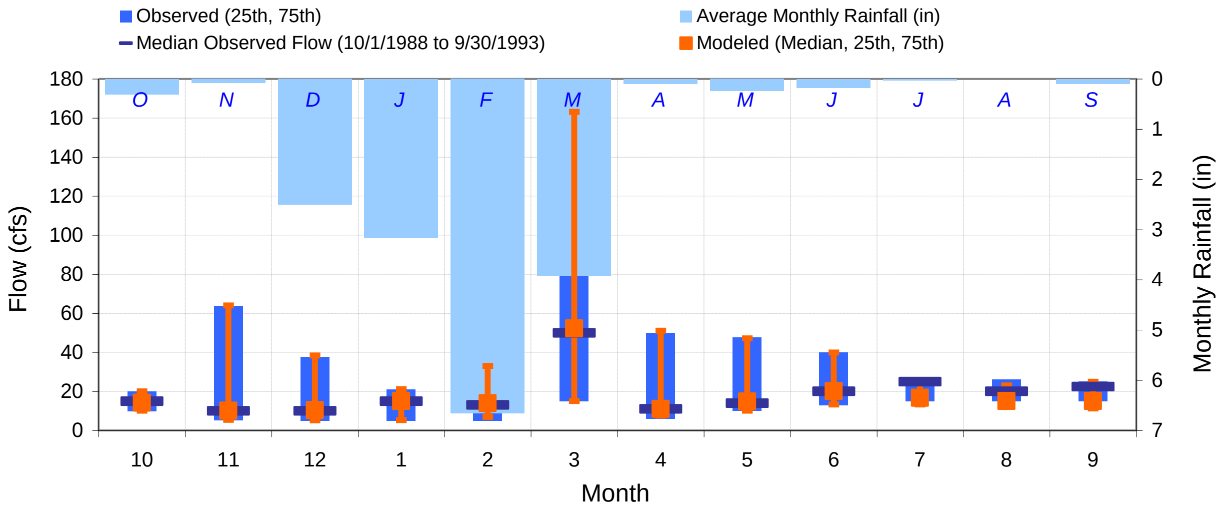


Figure F-12. Seasonal medians and ranges: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

Table F-4. Seasonal summary: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	19.82	15.00	10.00	20.00	19.91	14.26	10.20	20.04
Nov	30.79	10.00	5.25	63.75	30.93	10.10	5.48	64.05
Dec	22.80	10.00	5.00	37.50	23.08	10.43	5.23	38.46
Jan	82.27	15.00	5.00	21.00	74.38	15.04	5.31	21.21
Feb	193.60	13.00	5.00	15.00	200.36	14.01	6.95	33.13
Mar	114.63	50.00	15.00	150.00	116.37	52.23	15.06	163.15
Apr	43.56	11.00	6.00	50.00	43.26	11.04	7.64	51.06
May	36.01	14.00	10.00	47.50	36.06	14.87	10.18	47.18
Jun	25.12	20.00	13.00	40.00	25.18	20.11	13.31	39.94
Jul	22.96	25.00	15.00	26.50	19.45	16.76	13.28	25.18
Aug	19.43	20.00	15.00	26.00	16.65	15.07	12.18	23.05
Sep	19.76	22.50	15.00	25.00	16.78	15.11	11.30	24.91

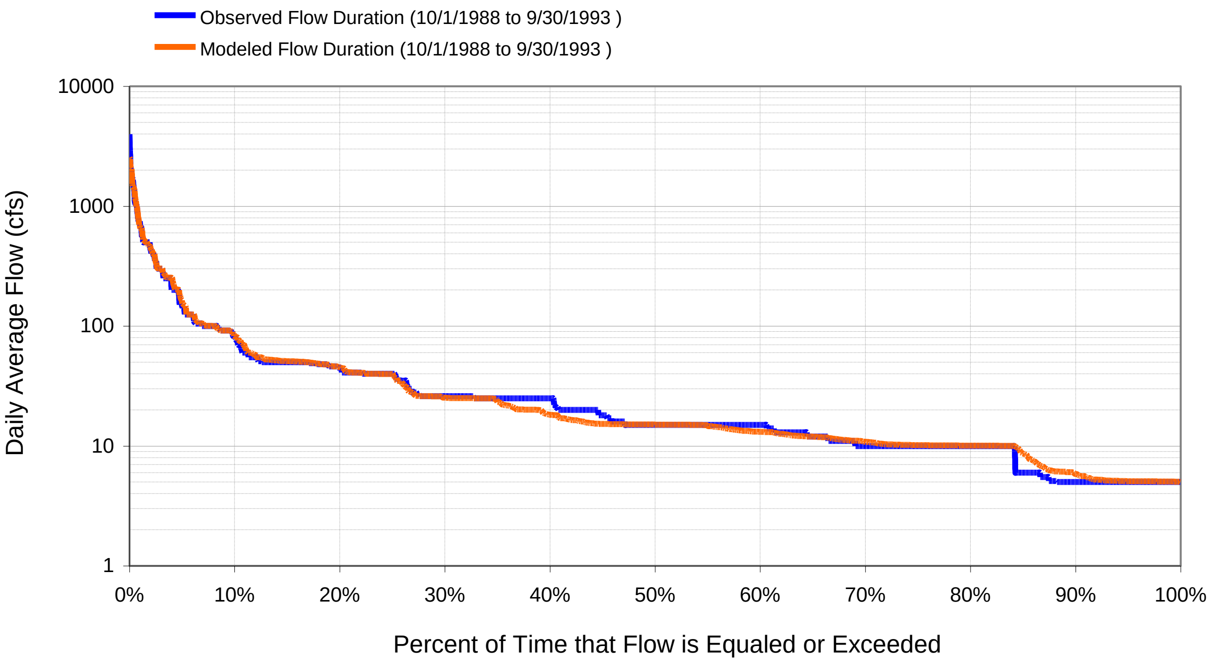


Figure F-13. Flow exceedance: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

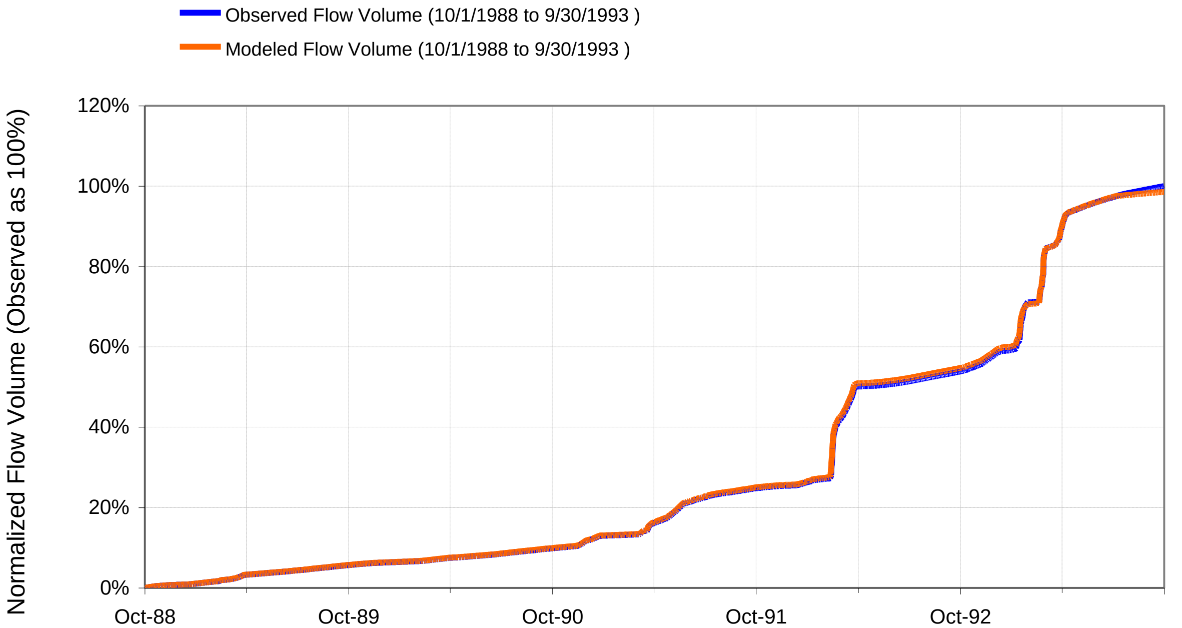


Figure F-14. Flow accumulation: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

Table F-5. Summary statistics: Model Outlet 4314 vs. USGS 11109525 Piru C Bl Pyramid Lk Nr Gorman CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 4314 5-Year Analysis Period: 10/1/1988 - 9/30/1993 Flow volumes are (inches/year) for upstream drainage area		USGS 11109525 PIRU C BL PYRAMID LK NR GORMAN CA Hydrologic Unit Code: 18070102 Latitude: 34.64165299 Longitude: -118.7645362 Drainage Area (sq-mi): 295	
Total Simulated In-stream Flow:	**2.35**	Total Observed In-stream Flow:	**2.38**
Total of simulated highest 10% flows:	**1.53**	Total of Observed highest 10% flows:	**1.56**
Total of Simulated lowest 50% flows:	**0.23**	Total of Observed Lowest 50% flows:	**0.23**
Simulated Summer Flow Volume (months 7-9):	**0.20**	Observed Summer Flow Volume (7-9):	**0.24**
Simulated Fall Flow Volume (months 10-12):	**0.29**	Observed Fall Flow Volume (10-12):	**0.28**
Simulated Winter Flow Volume (months 1-3):	**1.46**	Observed Winter Flow Volume (1-3):	**1.46**
Simulated Spring Flow Volume (months 4-6):	**0.40**	Observed Spring Flow Volume (4-6):	**0.40**
Total Simulated Storm Volume:	**0.88**	Total Observed Storm Volume:	**0.98**
Simulated Summer Storm Volume (7-9):	**0.02**	Observed Summer Storm Volume (7-9):	**0.02**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-1.45	10		
Error in 50% lowest flows:	1.02	10		
Error in 10% highest flows:	-1.43	15		
Seasonal volume error - Summer:	-14.91	30		
Seasonal volume error - Fall:	0.69	30		
Seasonal volume error - Winter:	0.00	30		
Seasonal volume error - Spring:	-0.18	30		
Error in storm volumes:	-10.05	20		
Error in summer storm volumes:	-14.68	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.838	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	0.836			

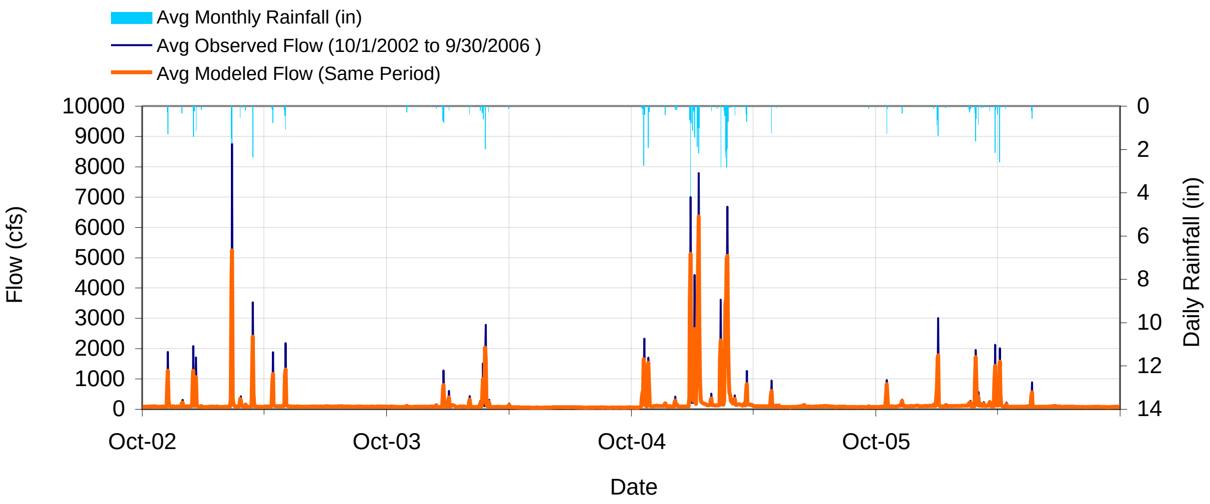


Figure F-15. Mean daily flow: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

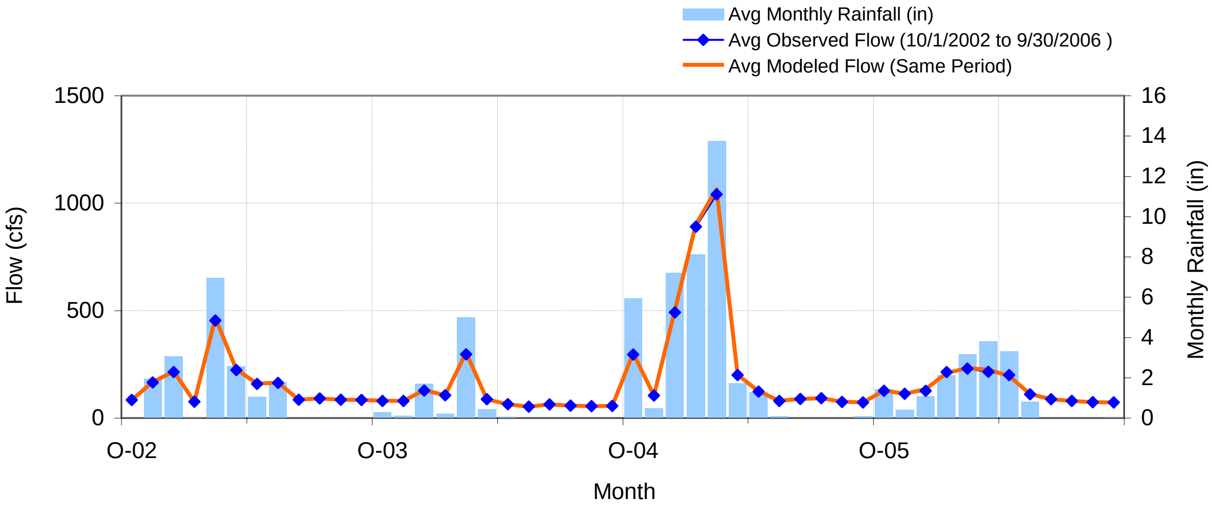


Figure F-16. Mean monthly flow: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

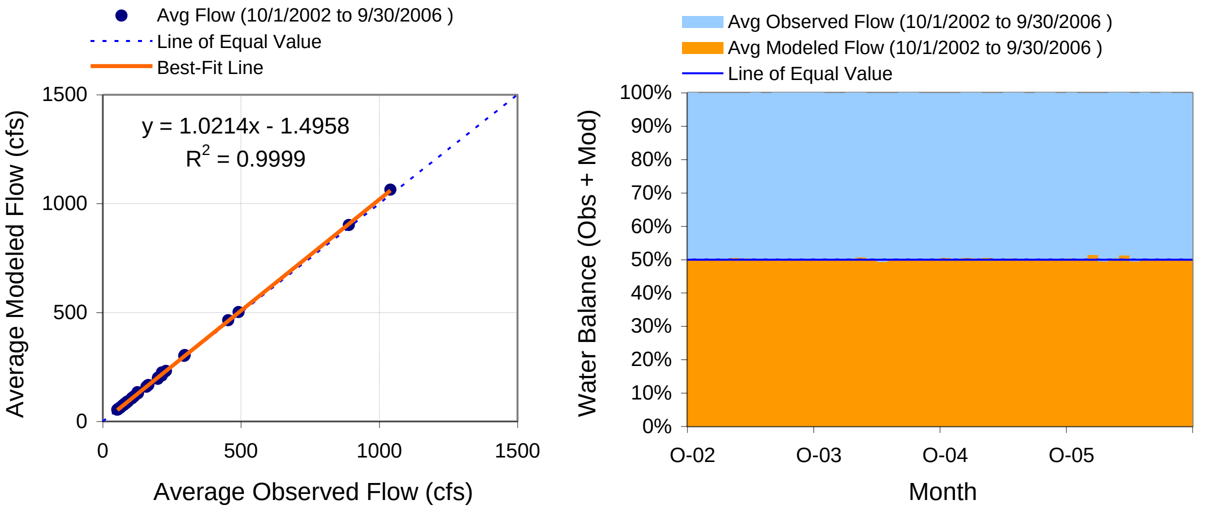


Figure F-17. Monthly flow regression and temporal variation: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

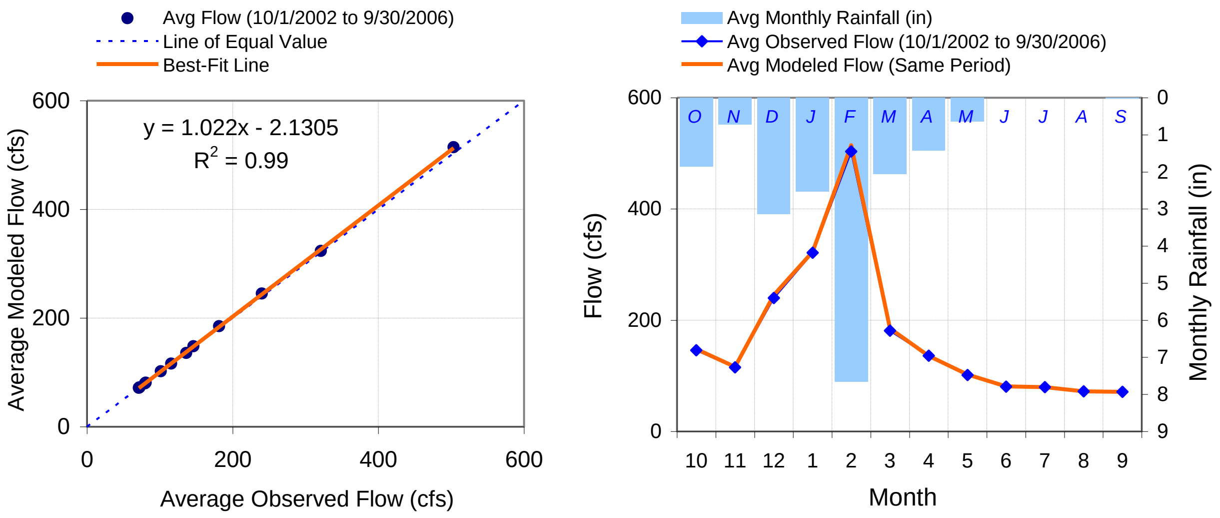


Figure F-18. Seasonal regression and temporal aggregate: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

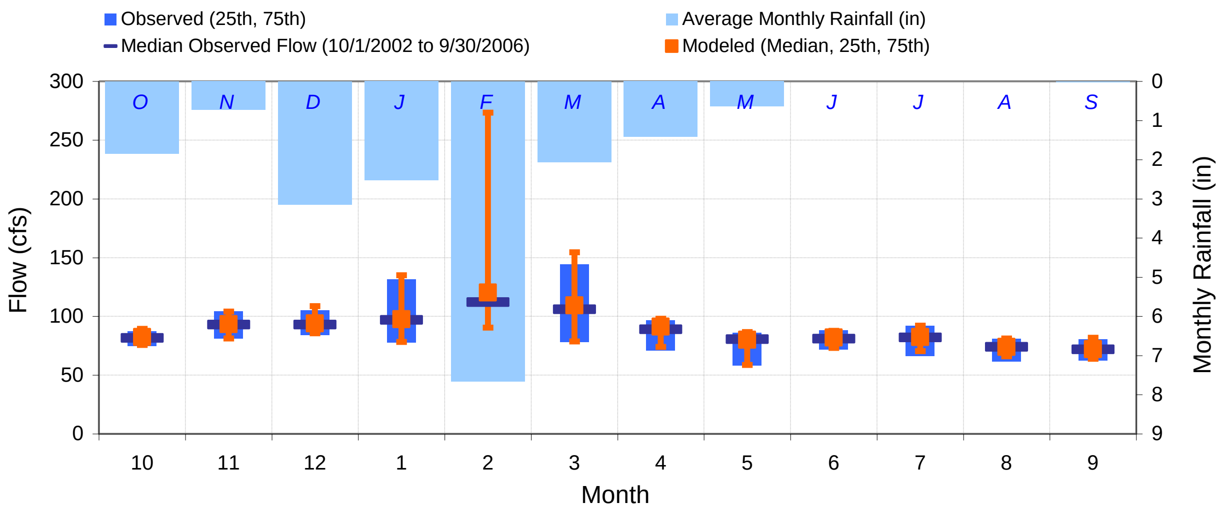


Figure F-19. Seasonal medians and ranges: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

Table F-6. Seasonal summary: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	146.04	81.50	74.75	87.25	148.22	82.45	75.78	89.45
Nov	115.50	93.00	81.00	104.00	116.12	93.43	81.24	104.15
Dec	239.98	93.00	84.00	105.25	245.32	93.91	85.65	108.64
Jan	321.27	97.00	78.00	131.50	323.33	97.64	78.15	135.04
Feb	503.24	112.00	84.00	206.00	514.44	120.19	90.33	273.37
Mar	181.30	106.00	78.00	144.00	185.05	109.34	78.62	154.61
Apr	136.24	89.00	71.00	97.00	135.65	91.22	74.06	98.04
May	101.54	80.50	58.00	86.00	102.22	80.07	58.55	86.56
Jun	80.74	81.00	72.00	88.00	81.00	81.91	73.12	87.73
Jul	79.78	82.00	66.50	92.00	79.87	82.39	70.38	92.00
Aug	72.12	74.00	61.75	81.00	72.30	73.91	66.12	81.17
Sep	71.19	72.00	62.50	80.25	71.40	72.11	63.88	81.84

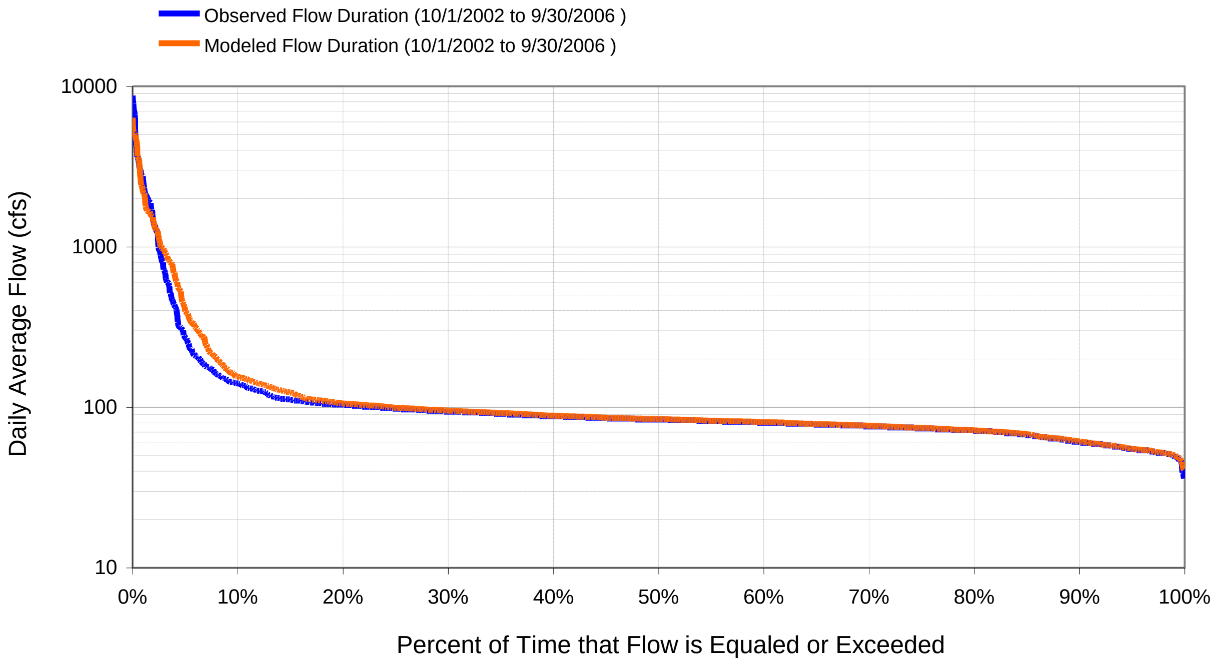


Figure F-20. Flow exceedance: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

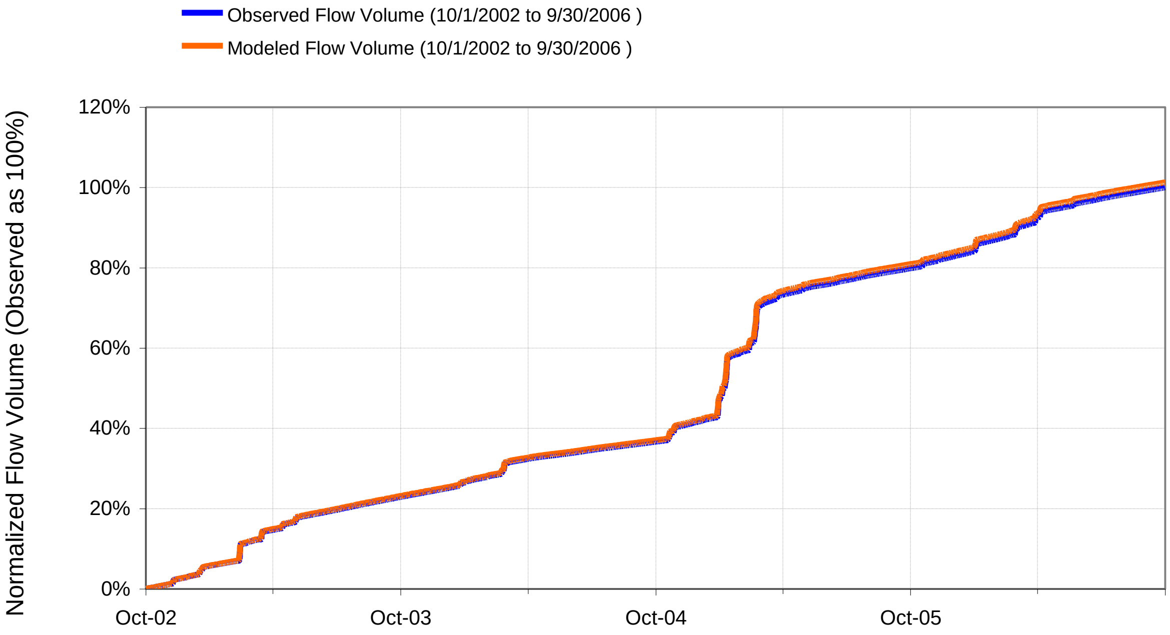


Figure F-21. Flow accumulation: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

Table F-7. Summary statistics: Model Outlet 6868 vs. USGS 11092450 Los Angeles R A Sepulveda Dam CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 6868 4-Year Analysis Period: 10/1/2002 - 9/30/2006 Flow volumes are (inches/year) for upstream drainage area		**USGS 11092450 LOS ANGELES R A SEPULVEDA DAM CA** Hydrologic Unit Code: 18070105 Latitude: 34.16167247 Longitude: -118.466749 Drainage Area (sq-mi): 158	
Total Simulated In-stream Flow:	**14.71**	Total Observed In-stream Flow:	**14.53**
Total of simulated highest 10% flows:	**8.17**	Total of Observed highest 10% flows:	**8.12**
Total of Simulated lowest 50% flows:	**3.08**	Total of Observed Lowest 50% flows:	**3.06**
Simulated Summer Flow Volume (months 7-9):	**1.61**	Observed Summer Flow Volume (7-9):	**1.61**
Simulated Fall Flow Volume (months 10-12):	**3.69**	Observed Fall Flow Volume (10-12):	**3.63**
Simulated Winter Flow Volume (months 1-3):	**7.13**	Observed Winter Flow Volume (1-3):	**7.01**
Simulated Spring Flow Volume (months 4-6):	**2.28**	Observed Spring Flow Volume (4-6):	**2.27**
Total Simulated Storm Volume:	**6.42**	Total Observed Storm Volume:	**6.71**
Simulated Summer Storm Volume (7-9):	**0.06**	Observed Summer Storm Volume (7-9):	**0.08**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	1.25	10		
Error in 50% lowest flows:	0.71	10		
Error in 10% highest flows:	0.56	15		
Seasonal volume error - Summer:	0.21	30		
Seasonal volume error - Fall:	1.63	30		
Seasonal volume error - Winter:	1.67	30		
Seasonal volume error - Spring:	0.11	30		
Error in storm volumes:	-4.35	20		
Error in summer storm volumes:	-25.58	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.777	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	0.686			

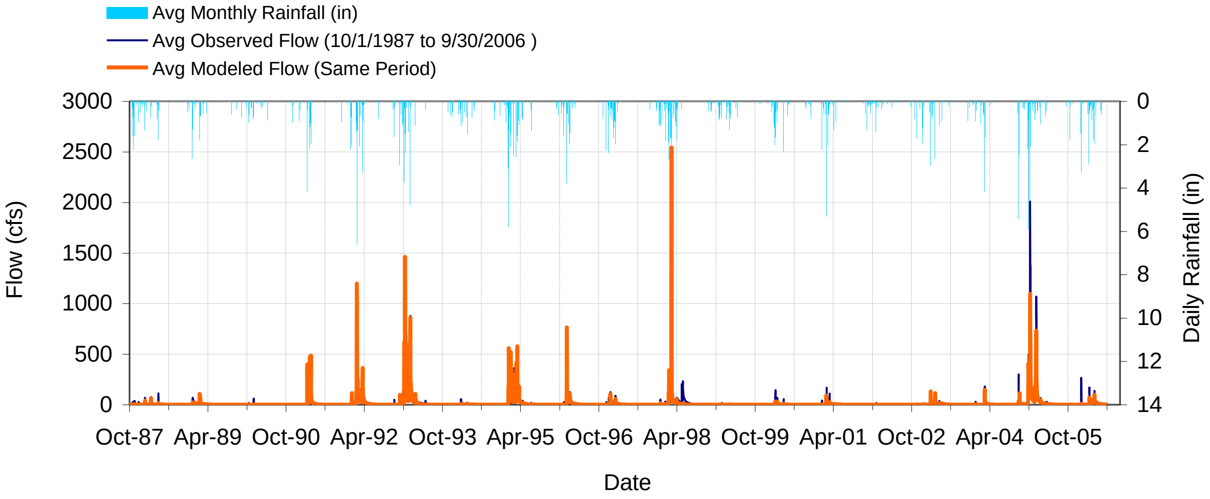


Figure F-22. Mean daily flow: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

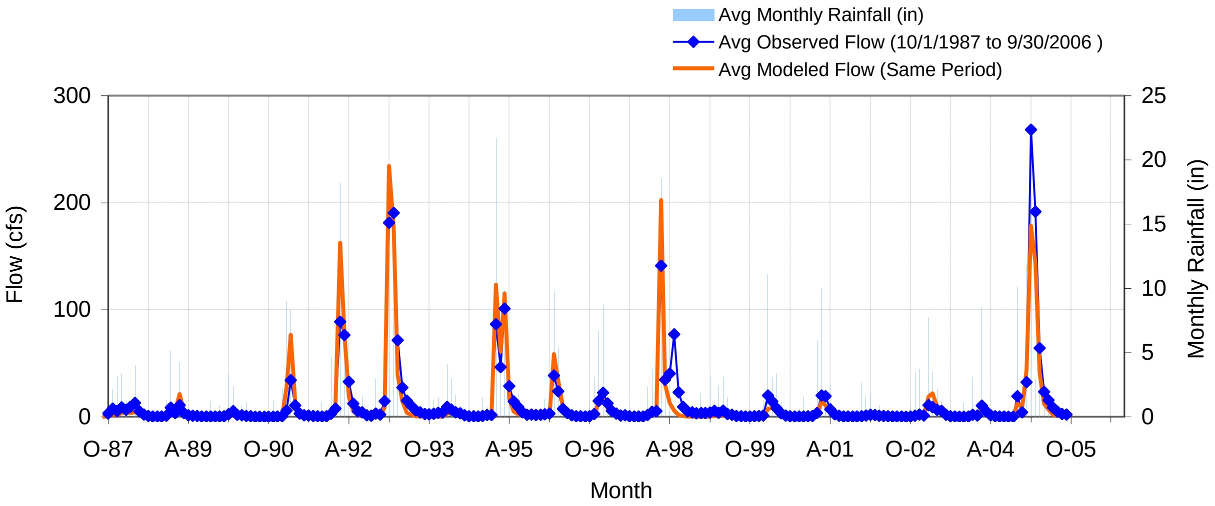


Figure F-23. Mean monthly flow: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

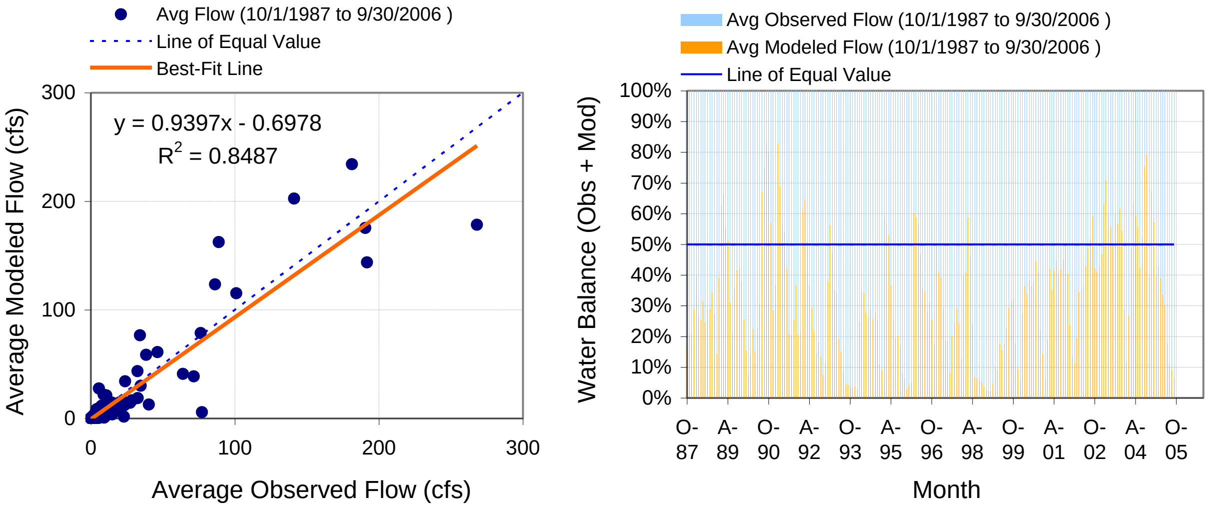


Figure F-24. Monthly flow regression and temporal variation: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

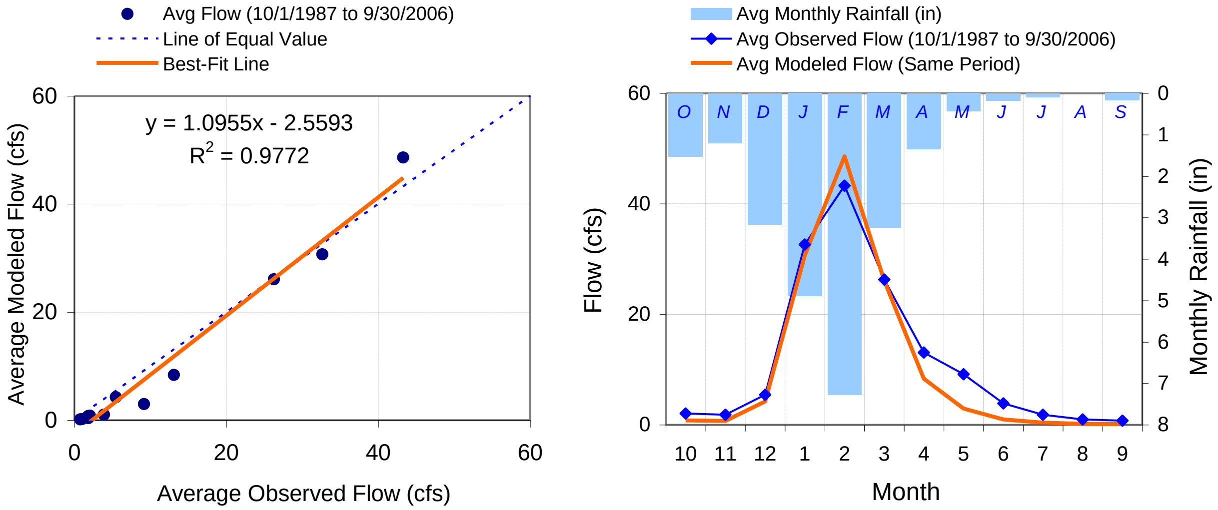


Figure F-25. Seasonal regression and temporal aggregate: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

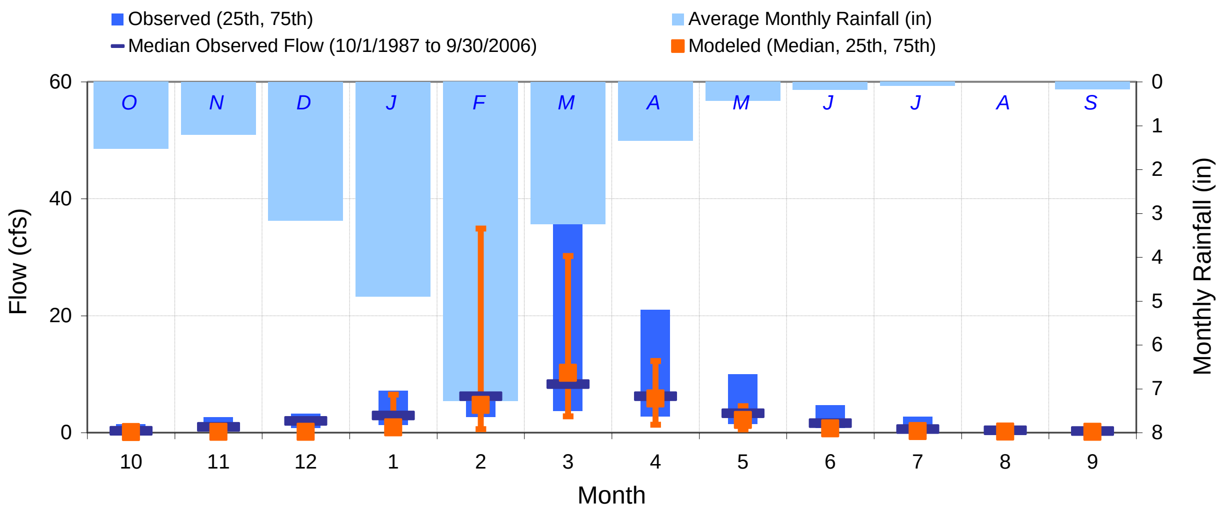


Figure F-26. Seasonal medians and ranges: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

Table F-8. Seasonal summary: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	2.04	0.30	0.14	1.50	0.80	0.10	0.09	0.13
Nov	1.83	0.99	0.39	2.60	0.72	0.13	0.08	0.22
Dec	5.46	2.00	0.77	3.20	4.25	0.14	0.07	1.81
Jan	32.64	2.90	1.30	7.20	30.67	0.90	0.15	6.50
Feb	43.28	6.20	2.70	26.00	48.61	4.72	0.59	34.89
Mar	26.29	8.30	3.70	36.00	26.05	10.24	2.78	30.20
Apr	13.10	6.20	2.80	21.00	8.36	5.81	1.36	12.25
May	9.16	3.30	1.50	10.00	2.95	2.17	0.54	4.54
Jun	3.90	1.60	0.81	4.68	0.99	0.70	0.29	1.49
Jul	1.85	0.58	0.31	2.70	0.38	0.27	0.16	0.53
Aug	1.01	0.36	0.18	1.10	0.19	0.16	0.13	0.23
Sep	0.78	0.26	0.12	0.82	0.14	0.13	0.11	0.15

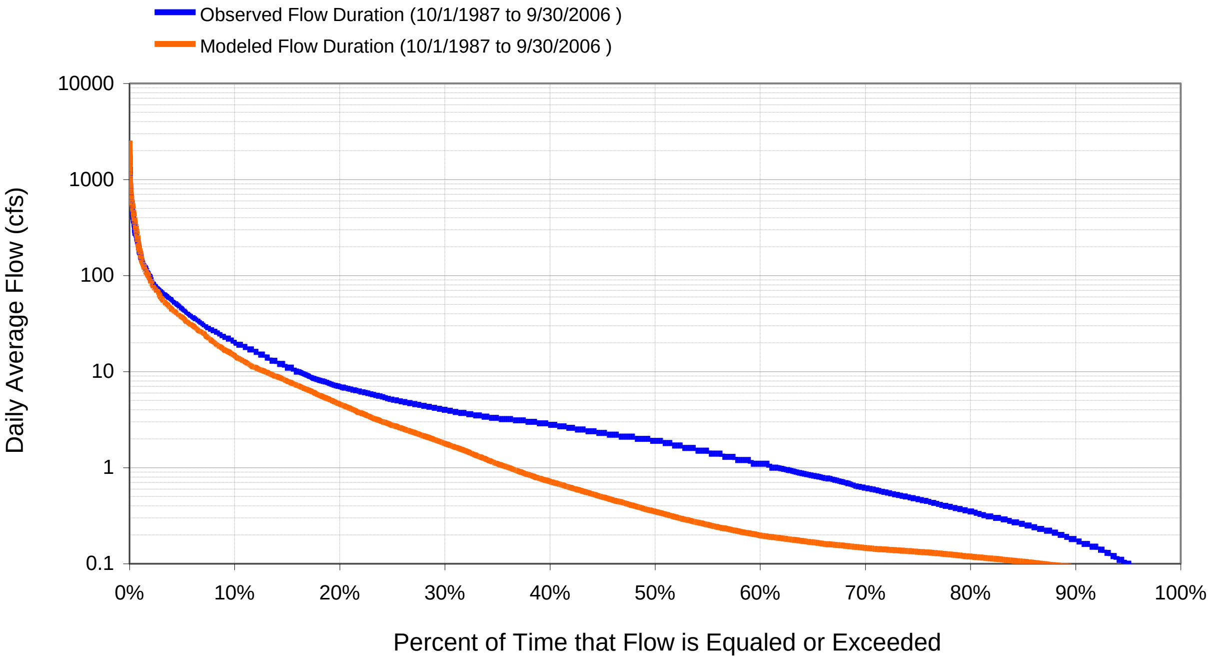


Figure F-27. Flow exceedance: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

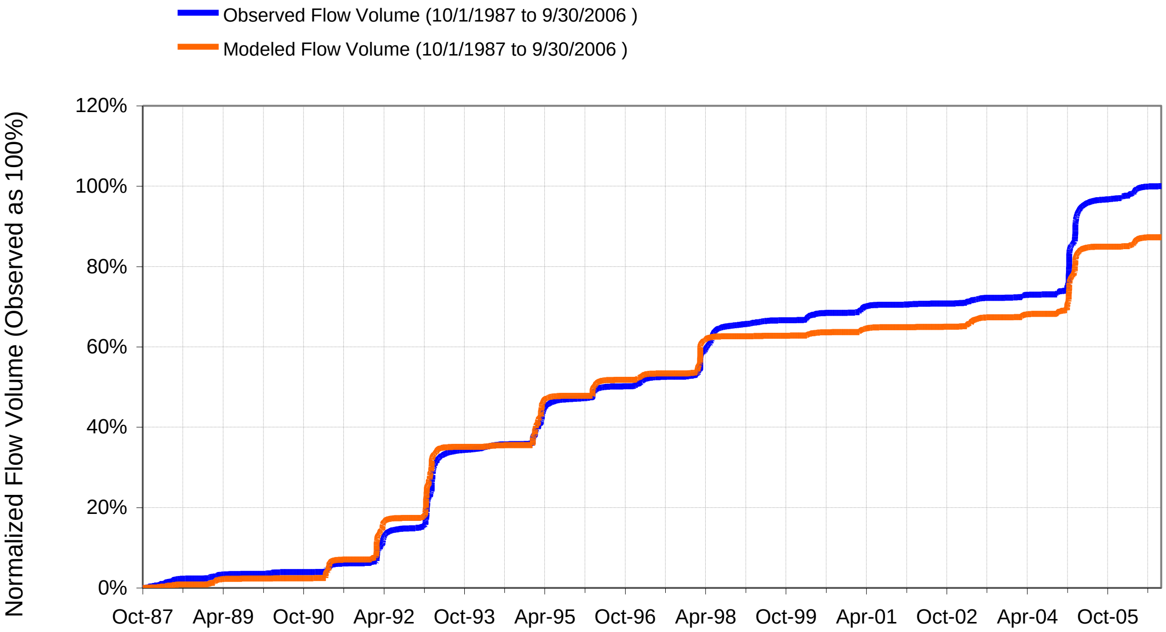


Figure F-28. Flow accumulation: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

Table F-9. Summary statistics: Model Outlet 6453 vs. USGS 11098000 Arroyo Seco Nr Pasadena CA

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 6453 19-Year Analysis Period: 10/1/1987 - 9/30/2006 Flow volumes are (inches/year) for upstream drainage area		**USGS 11098000 ARROYO SECO NR PASADENA CA** Hydrologic Unit Code: 18070105 Latitude: 34.22222629 Longitude: -118.1775727 Drainage Area (sq-mi): 16	
Total Simulated In-stream Flow:	**8.61**	Total Observed In-stream Flow:	**9.86**
Total of simulated highest 10% flows:	**7.45**	Total of Observed highest 10% flows:	**7.65**
Total of Simulated lowest 50% flows:	**0.06**	Total of Observed Lowest 50% flows:	**0.27**
Simulated Summer Flow Volume (months 7-9):	**0.05**	Observed Summer Flow Volume (7-9):	**0.26**
Simulated Fall Flow Volume (months 10-12):	**0.41**	Observed Fall Flow Volume (10-12):	**0.67**
Simulated Winter Flow Volume (months 1-3):	**7.28**	Observed Winter Flow Volume (1-3):	**7.09**
Simulated Spring Flow Volume (months 4-6):	**0.86**	Observed Spring Flow Volume (4-6):	**1.84**
Total Simulated Storm Volume:	**2.31**	Total Observed Storm Volume:	**2.05**
Simulated Summer Storm Volume (7-9):	**0.00**	Observed Summer Storm Volume (7-9):	**0.01**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-12.70	10		
Error in 50% lowest flows:	-76.56	10		
Error in 10% highest flows:	-	15		
Seasonal volume error - Summer:	-80.49	30		
Seasonal volume error - Fall:	-38.00	30		
Seasonal volume error - Winter:	2.69	30		
Seasonal volume error - Spring:	-53.14	30		
Error in storm volumes:	12.52	20		
Error in summer storm volumes:	-86.90	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.113	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	0.482			