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Regional Monitoring Program
for Water Quality in San Francisco Estuary

Guadalupe Watershed Model

Year 1 Report

Prepared by
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San Francisco Estuary Institute, Oakland, CA

December 2009

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Abstract

This report summarizes year 1 progress of the Guadalupe Watershed Model project. The objective of the Guadalupe Watershed Model project is to increase our understanding of the source, release, and transport of sediment and contaminants to San Francisco Bay from a large mixed land-use, highly urbanized watershed in the South Bay. To reach this objective, a numerical model was developed to simulate the movement of constituents through the Guadalupe River Watershed, chosen primarily because of the richness of existing data and secondarily because of complex and imminent management towards reaching loads targets imposed by the Guadalupe River Hg TMDL. The first phase in this project is developing the hydrologic portion of the model, which provides the basis for modeling sediment, Hg and PCBs in later phases. The Guadalupe Watershed Model is a prototype for what is likely to be a family of watershed models for improving estimates of Pollutants of Concern loads to the whole Bay or major compartments of the Bay. This report details the set-up, parameterization, calibration, and validation of the hydrological portion of the Guadalupe River Watershed model. The report also discusses conclusions regarding model performance and recommendations for model improvement.

The hydrological model was developed using the watershed modeling software Hydrological Simulation Program – FORTRAN (HSPF). Developing an HSPF model requires spatial data inputs, such as topography and land use, and temporal data, such as rainfall and evaporation. Accordingly, part of developing the model was identifying and obtaining appropriate data, mostly from local, state and federal agencies. Once all necessary watershed-specific data were obtained, the watershed boundary was delineated and divided into subbasins and hydrologic segments for parameterization.

After initial set-up, the model was calibrated and validated. Input time-series were separated into two subsets: WY 2000-2005 for calibration and WY 2006-2007 for validation. Calibration was an iterative process of making parameter changes and, at times, model set-up changes, running the model, and comparing the simulated model outputs to observed data. Once reasonable model performance was obtained, the model was tested on the reserved data to check that it was robust and not overcalibrated to the calibration period. Using the calibration and validation results, model performance was evaluated and ways to improve the model were identified.

Overall, the model performed very well for daily mean flow and storm events (R^2=0.97-0.98). For storm events, the model generally simulated peaks within several hours of observed peaks and the shape of simulated storm hydrographs matched observed storm runoff quite well for many different antecedent conditions and precipitation patterns, suggesting that the model accurately captured the behavior of water flowing through the watershed. However, the model performed poorly for annual flow volumes (31% maximum error). An approach to improve this aspect of model performance was identified that included the use of an expanded dataset (WY 1995-1999) to improve the robustness of the model during a wider range of climatic conditions.

1.0 Introduction

High concentrations of PCBs and mercury (Hg) have been detected in sediments on the Bay margin in a number of locations, including the mouth of Guadalupe River (Alviso Slough), providing support for the hypothesis that watersheds are impacting the environmental quality of the Bay. To further test this hypothesis, the Estuary Interface Pilot study was initiated in 1998, resulting in further strong evidence of a linkage between watershed loads and water quality at the Bay margin for Hg, PCBs, and other pollutants of concern (Leatherbarrow et al., 2003). The Estuary Interface Pilot study, along with a new estimate of suspended sediments entering the Bay from the Central Valley (McKee et al., 2002; 2006), led the Sources Pathways and Loadings Workgroup to recommend detailed load studies at Mallard Island on the Sacramento River at Pittsburg and Highway 101 on the Guadalupe River in San Jose (Leatherbarrow et al., 2003; McKee et al., 2004; 2005; 2006; David et al., in review). These studies were initiated within the longer term vision of developing load estimates for the San Francisco Bay Hg and PCB TMDLs and studying a total of six observation watersheds over a decade or more, assessing load trends, using models to extrapolate data, and exploring the potential for best management practices (BMPs) to reduce loads (Davis et al., 2000; 2001). The Guadalupe River Watershed Model represents the first in what is envisioned at this stage to be a trilogy of modeling including two watershed specific load models and a regional scale model (Oram, in review).

The Regional Water Quality Control Board (RWQCB), Santa Clara Valley Water District, University of California at Santa Cruz, San Francisco Estuary Institute (SFEI), and other agencies have developed an extensive database of contaminant concentrations in water, sediment, and fish tissues in the Guadalupe River watershed (Austin, 2006). In part based on these data, the Guadalupe River Watershed TMDL identifies mercury fish targets, bed and suspended sediment targets for runoff from mining areas, and load allocations from urban areas (Austin, 2006). The Bay Hg TMDL calls for Guadalupe River watershed load reductions of 98% and the Bay PCB TMDL calls for load reductions of greater than 95% for urban areas (Austin and Looker, 2006; SFBRWQCB, 2004 and 2008). The Hg TMDLs include an analysis that links the reduction of total Hg load to a biological response. While there are arguments that system complexities may confound this linkage, the implementation plans of the TMDLs include an analysis of high-leverage sources and processes. In the case of PCBs the linkage is more established, and, until improved information on biologically important forms of Hg becomes available, managers are making efforts to reduce total loads of both Hg and PCBs to the Bay. Managers in the Guadalupe River Watershed have already started implementing management actions to mitigate contaminant effects including experimenting with aeration in reservoirs to reduce mercury methylation and removal of contaminated sediment from drainage lines.

The availability of abundant data and these management issues make Guadalupe River Watershed an ideal location to begin to explore the use of models for better understanding water, suspended sediment, and pollutants of concern in the urban landscape and their impact on a local Bay margin in the wider San Francisco Bay context.

Further iterations of such a model also could be used to predict the influence of BMP scenarios on pollutants of concern loads. For example, Santa Clara County managers may be interested in learning if mass removed from drainage lines results in an equivalent reduction in annual load to the Bay, or if a particular suite of urban BMPs are effective at the watershed scale for removing significant mass. While these kinds of questions may be relevant to Santa Clara County managers, as yet they have not been explicitly identified. In the meantime, the Guadalupe River Watershed Model is a prototype for what is likely to be a family of watershed models for improving estimates of Pollutants of Concern loads to major compartments of the Bay and the Bay as a whole.

The aim of the Guadalupe Watershed Model project is to understand the source, release, and transport of constituents to San Francisco Bay from a large, mixed land-use, highly urbanized watershed in the South Bay. To meet this aim, a numerical model is being developed to simulate the movement of constituents through the Guadalupe River watershed, chosen mainly because of the richness of available data and secondarily because of complex and urgent management needs. In developing any solute-transport model, representation of the governing physical processes is an initial and fundamental requirement. Given there are few applications of HSPF modeling Hg and PCBs transport processes, governing equations will have to be developed. This two-year study has the following key objectives:

Year 1: Develop, calibrate, and validate hydrologic model of Guadalupe River watershed

Year 2:

- Extend model to include sediment and contaminants (Hg and PCBs)
- Improve the accuracy of Hg and PCB mass load calculations for the last six years when suspended sediment loads have been measured and extrapolate in time
- Establish model input and calibration parameters that may reduce the effort required to develop future watershed models in the Bay Area.

This year 1 progress report summarizes the set-up, parameterization, calibration, and validation of the hydrological portion of the Guadalupe Watershed Model.

2.0 Watershed Characteristics

Location

The Guadalupe River watershed is located in the Santa Clara Valley basin and drains to Lower South San Francisco Bay (Figure 2.1). The Guadalupe River watershed is one of 13 drainages that constitute the basin and the second largest in terms of area. The Guadalupe River watershed is bounded on the west by the San Tomas Creek watershed, on the east by the Coyote Creek watershed, and to the south by coastal watersheds.

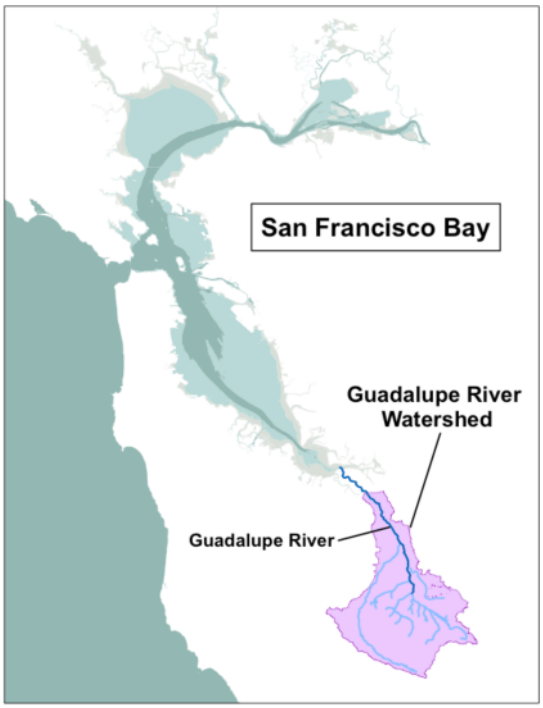

Figure 2-1 - Watershed Location

Physiology

Guadalupe Creek flows from its headwaters in the eastern Santa Cruz Mountains to its confluence with Alamitos Creek in the city of San Jose where it becomes Guadalupe River and continues its journey through the city, past the San Jose International Airport, and beyond Highway 101. The influence from the ocean tides begins between the Montague Expressway and Highway 237, before the river ultimately discharges to the South Bay via Alviso Slough. The Guadalupe River watershed encompasses approximately 170 mi^2. The watershed is the fourth largest in the nine-county Bay Area by area and the fifth largest in terms of annual discharge volume to the Bay (McKee et al., 2003). There are five main tributaries in the Guadalupe Watershed: Los Gatos Creek, Ross Creek, Guadalupe Creek, Alamitos Creek, and Canoas Creek. The subwatersheds of Los Gatos Creek, Ross Creek, Guadalupe Creek, and Alamitos Creek gather runoff from the Santa Cruz Mountains, notable high points being Mt. Thayer (elevation 3,486 ft) and Mt. Umunum (elevation 483 ft), and the summit of Loma Prieta (elevation 3,790 ft) (USGS Los Gatos quad sheet (2005) and Loma Prieta quad sheet (1999)).

Climate and Hydrology

The Guadalupe Watershed has a mild Mediterranean-type climate with a cool wet winter season and a warm dry summer season. Average monthly temperatures range from a maximum of 27.8 °C (82.1 °F) in July to a minimum of 14.4 °C (57.9 °F) in January (WRCC, 2008). Rainfall in the Guadalupe River watershed is predominantly maritime, with regional-scale weather systems moving on shore in response to the position of the Pacific high-pressure zone and westerly winds that bring moist air from the Pacific Ocean. Rainfall measurements began in San Jose in 1875, providing for that location one

of the longest running collated and published records in the Bay Area. Annual rainfall in San Jose averages 14.5 inches with the maximum annual rainfall at 200% of the average and the minimum at 40% of the average (McKee et al., 2003). Locations in the highest extremities of the watershed can receive in excess of 60 inches annually. Rainfall follows a seasonal pattern with a pronounced wet season that generally begins in October or November and can last to April or May. During this period an average of 89% of the annual rainfall occurs (McKee et al., 2003).

Runoff in the Guadalupe River watershed exhibits patterns similar to those of its rainfall; high inter-annual variability, successive years of low or high runoff, and a highly seasonal runoff pattern. To a small extent, the runoff pattern is dampened by the operation of storage reservoirs in the upper parts of tributary creeks. There are five major reservoirs in the watershed with a total storage capacity of 35,778 acre-feet, almost equivalent to the mean annual runoff. Reservoirs are located on Los Gatos Creek (Lexington Reservoir and Vasona Reservoir), Guadalupe Creek (Guadalupe Reservoir), Alamitos Creek (Almaden Reservoir), and Calero Creek (Calero Reservoir) for water supply and flood mitigation (Figure 2.2).

The Guadalupe River Watershed is instrumented with numerous meteorological stations (Figure 2.2) and streamflow gauges (Figure 2.3). There are 11 precipitation stations operated by the Santa Clara Valley Water District (SCVWD) and the National Oceanographic and Atmospheric Administration (NOAA). There is a pan evaporation station, which is operated by SCVWD, and an evapotranspiration station, which is operated by California Irrigation Management Information Systems (CIMIS). Between the U.S. Geologic Survey (USGS) and the SCVWD, about 20 sites in the Guadalupe Watershed are monitored for streamflow (the exact number of sites fluctuates year to year as gauges are brought into and taken out of service). There are a number of long-term records for discharge in the watershed; of particular note, the USGS gauge 11169000 was operated from water year (WY) 1930 to April 2003 before it was discontinued and replaced with USGS gauge 11169025 in May 2002 (an 11-month overlap). Rainfall and stream flow information collected by SCVWD as part of their water management and flood alert system is available at http://alert.valleywater.org/.

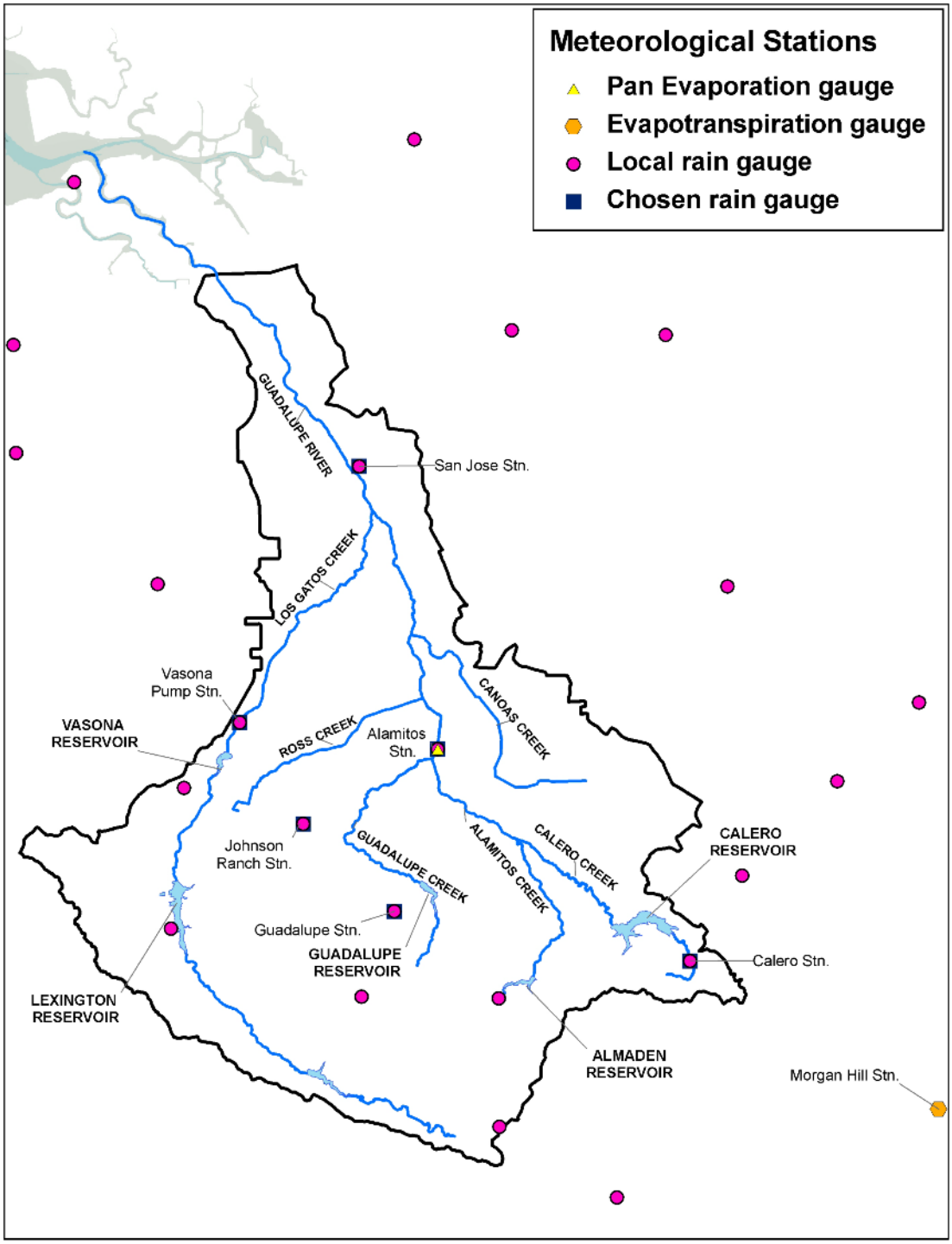

Figure 2-2 - Meteorological Stations

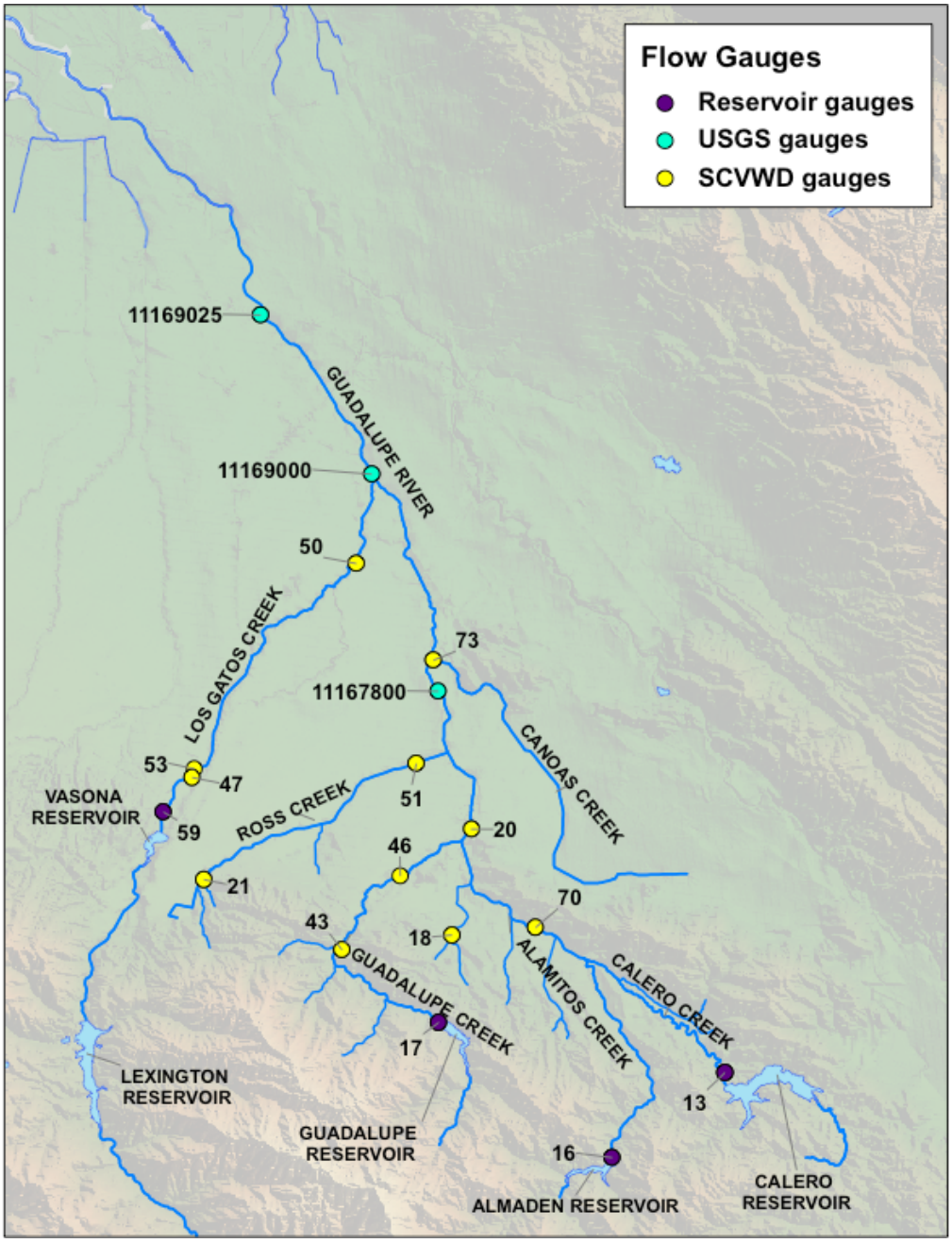

Figure 2-3 - Streamflow Gauges

Soils and Sediment Transport

The dominant soil texture in Guadalupe River Watershed is loam. The soil in the lower portion of the watershed is clay, while the rest of the watershed has a mixture of clay loam, silt loam, and loam (SCVURPPP, 2006). The distribution of soil types and hydrologic soil groups is shown in Figure 2.4. Hydrologic soil groups are based on soil infiltration rates, and range from A (fast draining) to D (very slow draining). In the Guadalupe River watershed, soil infiltration rates vary from moderate to very slow.

The movement of soil in California in general and in the Guadalupe River watershed is highly event driven. The majority of sediment discharge occurs during short-lasting, intense winter storms (Kroll, 1975; McKee et al., 2003). On average, about 90% of the sediment load occurs during just a few days per year (Kroll, 1975, Warrick and Milliman, 2003; McKee et al., 2003; McKee et al., 2004). Suspended sediment concentrations are closely correlated with flow in part because the extensive dry season essentially returns the system to the same initial condition by the start of the wet season (Krone, 1979). Suspended sediment load in the Guadalupe River watershed, like most watersheds in the area, appears to be transport-limited, rather than supply-limited.

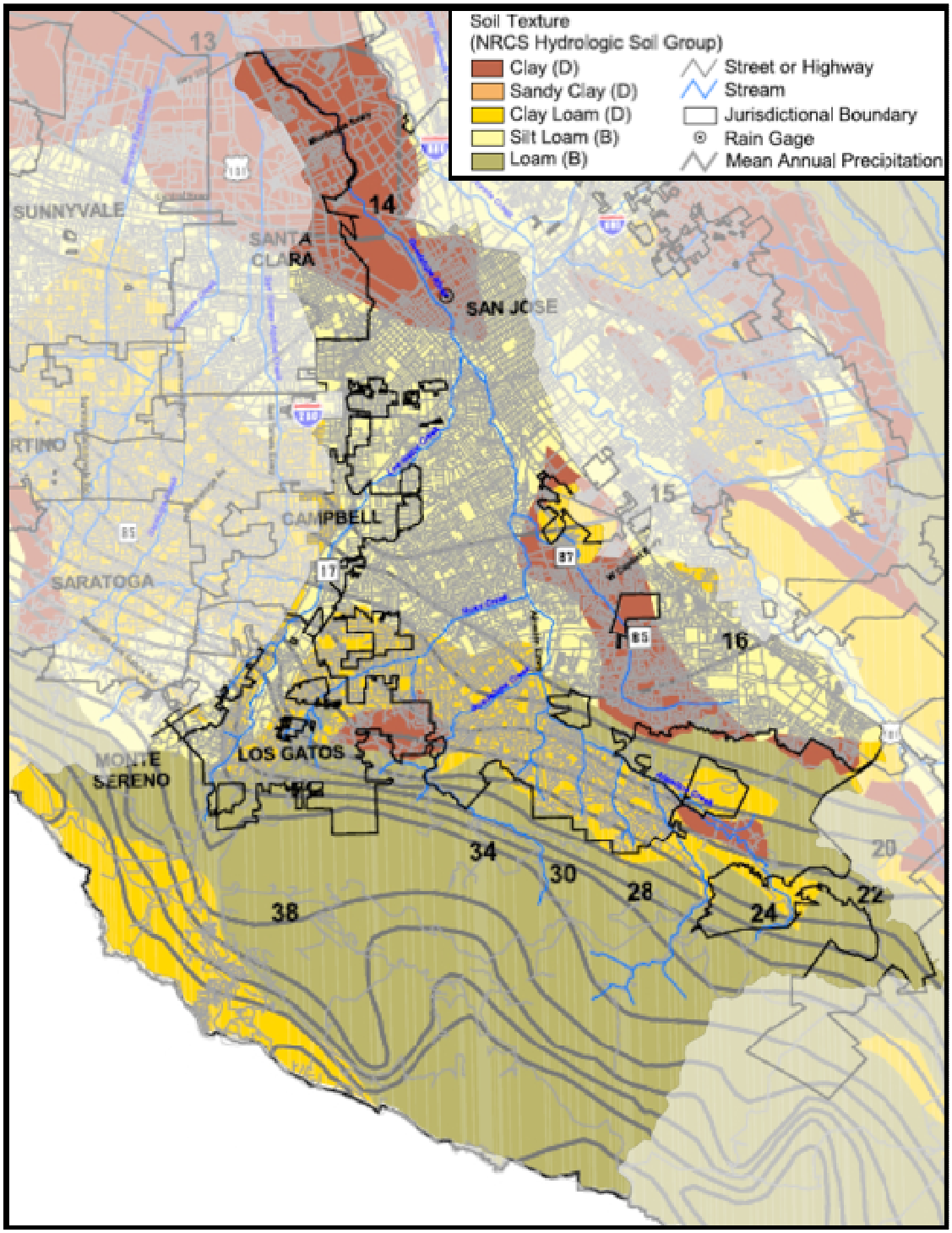

Figure 2-4 - Soil Texture and Hydrologic Groups (SCVWD 2004)

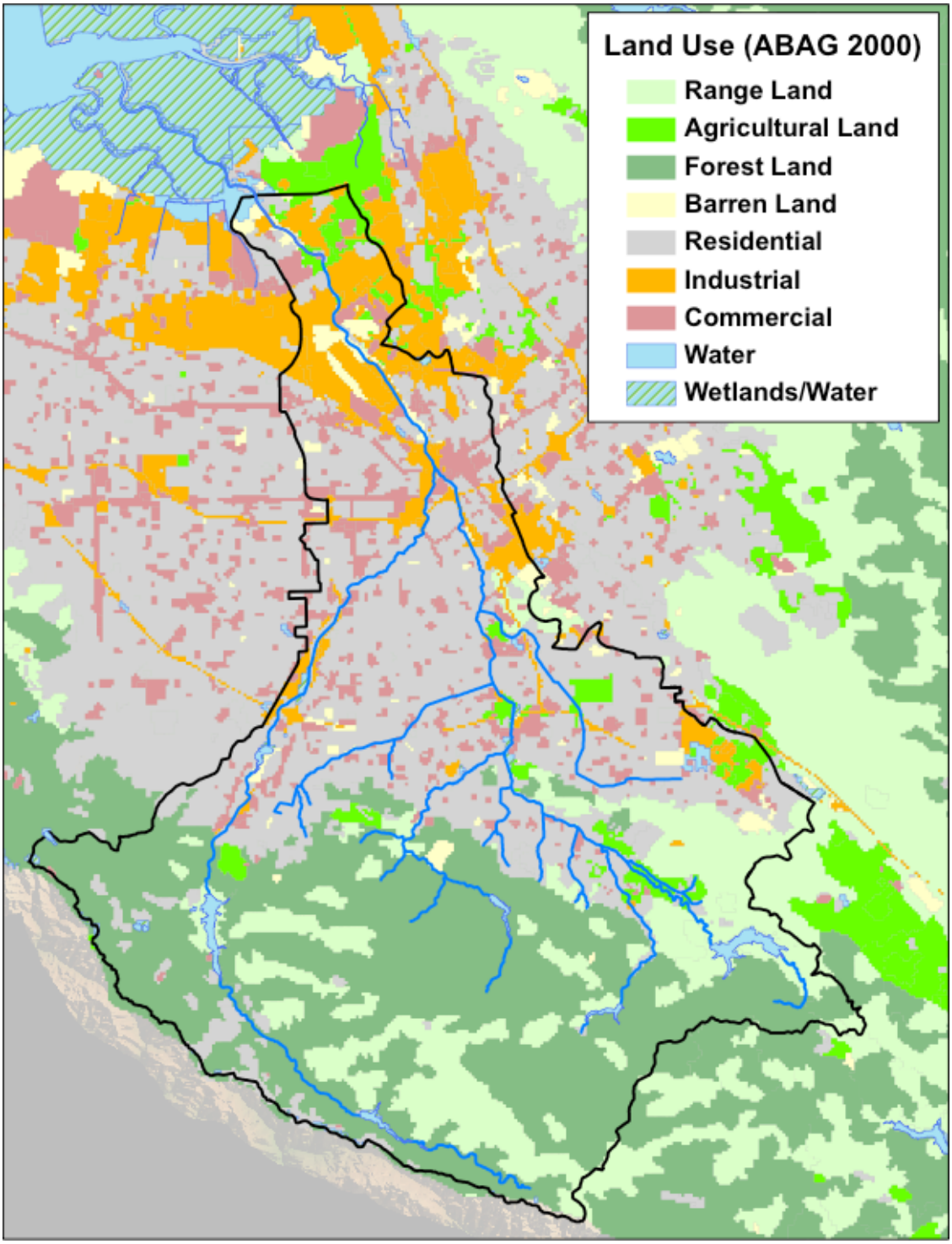

Figure 2-5 - Land Use and Land Cover (ABAG 2000)

Land use and population

The Santa Clara Valley was almost exclusively used for agriculture before the World War II era. As the electronics industry began to develop in the 1960's, the valley

underwent large and rapid-paced population growth and subsequent urban development. Current land uses in the Guadalupe River watershed are composed of a mix of agricultural and rangeland activities in the upper watershed and urban and suburban land use in the lower watershed (Figure 2.5). Urban development in the lower watershed has dramatically increased the amount of impervious cover, leading to increases in both the volume and peak flow of runoff during storms.

Between 1940 and 2000, population in Santa Clara County increased from approximately 175,000 to 1.68 million people (800%) (MTC and ABAG, 2002). As of 2000, approximately 53% of the people in Santa Clara County lived in the City of San Jose, much of which lies within the Guadalupe River watershed. Estimates of projected population in Santa Clara County suggest that population will increase by approximately 480,000 more people between 2000 and 2025 (SCDF, 2001).

Known contaminant sources

Historic agricultural and mercury mining activities and more recent urban development and population growth in the Guadalupe River watershed have resulted in widespread distribution of contaminant sources in the watershed. The inoperative mining district of New Almaden (within the Alameda Quicksilver County Park), which at one time was the largest supplier of mercury in North America, is responsible for historic deposits of mercury that continue to flow to the Bay via a drainage network (Abu-Saba and Tang, 2000). While the manufacturing of PCBs was banned in the 1970s, PCB use during the 1950s and 1960s in power transmission, small capacitors, hydraulic fluids, plasticizers, paints, inks, carbonless copy paper, and flame retardants left a legacy of these long-lived compounds dispersed unevenly in urban environments. Urban conveyance systems continue to transport PCBs and organochlorine (OC) pesticides (DDT, chlordane, and dieldrin), Hg and other pollutants of concern through the Guadalupe River watershed (KLI, 2002; Leatherbarrow et al., 2002; McKee et al., 2006). The majority of the pollutants of concern in the Guadalupe River watershed are highly sediment-associated (in technical terms this means they have high K_d, K_{oc}, and K_{ow} relative to metals like copper or silver, which a greater portion of are in the dissolved phase in the environment), thereby highlighting the importance of understanding sediment transport in this watershed.

Channel modifications (past and present)

The Guadalupe River has been subject to morphological modifications since 1866, when a canal was dug to relieve flooding of a then rapidly expanding orchard agriculture (SCBWMI, 2000). In the 1960s, Canoas and Ross Creeks were realigned. In 1975, about 3,000 feet of the Guadalupe River channel was widened and moved eastward and the original channel was filled to make way for the Almaden Expressway. In the late 1970s, Alamitos Creek was widened and levees were built from Bertram Bridge downstream to its confluence with Guadalupe Creek, a distance of approximately 6 miles. Currently, the U.S. Army Corps of Engineers is working on flood control projects along the Guadalupe River, including the recently completed “downtown project” designed to provide flood protection to downtown San Jose's technology and commercial industries and established residential neighborhoods, protect and improve water quality of the river, preserve and

enhance the river's habitat, fish and wildlife, and provide recreational and open space benefits. By modifying the channel, replacing bridges, protecting against erosion and building a bypass box culvert to handle high flows, the capacity of the channel was improved in the down town area to handle 14,600 cfs upstream of the confluence with Los Gatos Creek and 17,000 cfs downstream of the confluence.

3.0 Model Overview

3.1. Model Selection

The watershed modeling software Hydrological Simulation Program – FORTRAN (HSPF), a comprehensive watershed model of hydrology and water quality, was chosen for this project. HSPF is part of the EPA BASINS modeling system, a public domain software jointly supported and maintained by the U.S. EPA and the USGS. BASINS/HSPF is widely used across the United States for watershed modeling. HSPF has been used locally for calibration models to parameterize the Bay Area Hydrology Model software for engineering drainage design of development projects to minimize hydromodification impacts, and to estimate the relative contribution of various anthropogenic sources of copper in stormwater runoff for the Brake Pad Partnership. In Southern California, HSPF was used to model mercury for TMDL linkage analysis (Larry Walker Associates, 2006). Thus far, no published studies have used HSPF to model PCBs. The model is suitable for the Guadalupe Watershed Model project because it includes the necessary watershed and stream processes and includes water quality modules.

3.2. Input Data

In order to accurately model a hydrologic system, all water sources and sinks must be included. For undeveloped watersheds, specifically those with no hydromodification, precipitation (source) and evaporation (sink) data drive the model simulations. However, hydromodified watersheds can have numerous other water sources, such as reservoir releases and irrigation, and other water sinks, such as diversions and percolation ponds. For a given watershed to be modeled, all pertinent water data, including water management practices, must be obtained for the simulation time period. Often it is the availability of precipitation and flow data that constrains the simulation period.

3.2.1. Meteorological

Hydrologic model performance is highly dependent on the accuracy and quality of precipitation data. Especially in a watershed with large elevation changes (approximately sea-level to 3000 feet in the modeled portion of the Guadalupe River watershed), rainfall tends to vary greatly with location and time. Therefore, high quality precipitation data with high temporal and spatial resolution are needed. Fortunately, the Guadalupe River watershed contains high-resolution rainfall gauges well distributed across the watershed at different elevations.

Evaporation is not as spatially or temporally variable as precipitation; hence lower resolution data from more remote sources are adequate for modeling evaporation. However, local evaporation and evapotranspiration data were available for the Guadalupe River watershed (Figure 2.2).

Precipitation Data

High-resolution precipitation data (15-minute intervals) were obtained from Santa Clara Valley Water District (SCVWD) for five precipitation gauges located within the watershed and one gauge just outside (Table 3.1 and Figure 3.4). The time period of the rainfall data (WY[1] 2000-2007) was chosen such that it overlaps with sediment and contaminant data collected for the Guadalupe River by SFEI, USGS and funding partners [SCVWD, USACE, SCVURPPP]. It should be noted that the chosen period lacks extremely wet years, resulting in a calibration skewed to average and dry years. Precipitation data were inspected and several extreme outliers for Guadalupe and San Jose rainfall gauges were removed and replaced with an upper bound set by the local maximum precipitation rate.

Table 3-1 - Annual Rainfall (inches) for Precipitation Stations

Water Year	San Jose (elev. 70')	Alamitos (elev. 180')	Vasona (elev. 250')	Calero (elev. 550')	Johnson Ranch (elev. 750')	Guadalupe (elev. 1700')
2000	13.4	14.5	19.7	21.4	25.5	63.4
2001	11.4	12.3	14.5	17.3	20.5	35.8
2002	8.3	9.3	13.7	15.3	12.1	36.9
2003	15.2	17.6	23.8	21.5	28.2	43.4
2004	13.1	13.2	18.0	19.2	19.8	33.8
2005	25.2	20.5	24.1	27.1	28.2	36.1
2006	23.8	16.3	24.8	28.4	28.9	51.7
2007	9.0	7.2	8.5	9.3	9.5	19.2
Avg:	14.9	13.9	18.4	19.9	21.6	40.0

Evaporation Data

Hourly reference evapotranspiration (ETo) data were obtained for Morgan Hill from California Irrigation Management Information Systems (CIMIS). Monthly pan evaporation data from the Los Alamitos Recharge Facility in San Jose was obtained from SCVWD. Both sites are shown in Figure 2.2. Monthly pan evaporation factors were used to convert reference evapotranspiration to potential evapotranspiration (PET) following the method of AQUA TERRA Consultants (2006). HSPF uses PET to drive the hydrologic water balance equations.

3.2.2. Reservoir Flows

The Guadalupe River watershed contains five reservoirs. The reservoirs are located on Los Gatos Creek, Guadalupe Creek, Alamitos Creek, and Arroyo Calero. Two of the reservoirs (Lexington; Vasona) are located on Los Gatos Creek, and the creek flows through the downstream reservoir, so only the downstream reservoir release data was required for modeling purposes. Reservoir release data were obtained for the four

[1] A Water Year (WY) is defined as October 1st through September 31st.

reservoirs from SCVWD in 15-minute increments for WY 2000-2007. The annual release volumes are shown in Table 3.2.

Table 3-2 - Annual reservoir releases (10^6 cubic feet)

Water Year	Almaden Res.	Calero Res.	Guadalupe Res.	Vasona Res.	Total
2000	176	165	251	1,375	1,967
2001	118	288	182	562	1,150
2002	56	260	139	575	1,030
2003	192	182	186	758	1,318
2004	218	158	183	764	1,322
2005	247	170	233	1,159	1,808
2006	262	223	353	2,390	3,229
2007	9	220	83	361	672
Average:	160	208	201	993	1,562

Table 3.2 shows that, of all the reservoirs, Vasona Reservoir consistently contributed the largest volume of water. On average, between 2000 and 2007, Vasona Reservoir contributed nearly two-thirds of the total reservoir flow to Guadalupe River.

3.2.3. Diversion Flows

There were three gauged diversions in the watershed – two ditches diverted water from Los Gatos Creek, and Los Capitancillos percolation ponds were replenished from Guadalupe Creek. Flow gauge data were obtained from SCVWD for the three diversions for WY 2000-2007.

3.3. Model Set-up

3.3.1. Watershed Boundary Delineation

The first step in setting up a hydrological model is deciding what drainage area to include in the model. SCVWD defines the drainage area contributing to Guadalupe River as shown in Figure 3.1. However, the model boundary needed to be adjusted to achieve an appropriate level of simplicity while preserving key watershed features and processes. Specifically, the model's watershed boundary (Figure 3.1) was adjusted to exclude reservoirs and their upstream watersheds (for rest of this report, the modeled area is referred to as 'lower Guadalupe River watershed' to distinguish it from the entire watershed). Reservoir releases were then included as point-source inputs into the appropriate streams and/or channels. By delineating the watershed in this way, the model is able to account for the influence of managed reservoir flows without having to model the internal dynamics of the reservoirs themselves. This simplification does pose challenges for potential future uses of the model. Specifically, suspended sediment and contaminant boundary conditions, including Hg speciation and partitioning, will need to be developed for each reservoir discharge – there is some data but, in general, these boundaries are poorly constrained. A sensitivity analysis will likely reveal how important these boundaries are for suspended sediment and pollutants of concern.

Figure 3-1 - Entire and Modeled Watershed

The modeled portion is the downstream two-thirds of the overall watershed (a 65,835 acres [103 sq. miles] subset), which contains 68% developed land and 32% undeveloped land. The portion removed in order to exclude reservoir operations from the model is mostly undeveloped land located in the Santa Cruz Mountains.

3.3.2. Segmentation

The process of watershed segmentation divides the modeled area into logical segments, called subbasins, based on topography, drainage patterns, meteorological variability, soil types, land cover and land use. Other boundary considerations for subbasins include locations of dams/reservoirs and flow gauges, as well as model objectives, e.g., delineating particular areas of interest for model usage. The purpose of segmentation is to allow for parameterization and analysis of local (sub-watershed scale) conditions within a watershed.

Table 3-3 - Data Used for Watershed Segmentation

GIS Coverage / Map	Source	Comment
Digital Elevation Model (DEM)	USGS	National Elevation Dataset (NED)
Hydrography/Stream Network	USGS	National Hydrography Dataset (NHD-Plus)
Watershed boundary	SCVWD	-
Catchments	USGS	National Hydrography Dataset (NHD-Plus)
Stormdrain catchments	WLA	Catchment boundaries incorporating stormdrains
Land use	ABAG	ABAG 2000 Existing Land Use data set
Hydrologic soil groups map	SCVWD	Based on USDA SCS map
Isohyetal map	SCVWD	-
Meteorological stations	SCVWD	-
Streamflow gauges	SCVWD, USGS	-
Reservoirs	SCVWD	-

WLA: William Lettis & Associates, Inc.
ABAG: Association of Bay Area Governments

GIS coverages defining geologic, hydrologic, and anthropologic boundaries and systems were obtained from different sources. Stream segments were derived from the National Hydrography Dataset (NHD-Plus) in BASINS. Table 3.3 summarizes the coverages used in the segmentation process. Ultimately, pre-existing Guadalupe subbasin delineations (Figure 3.2) from National Hydrographic Dataset (NHD) and William Lettis & Associates, Inc. (WLA) were combined with various considerations such as flow and precipitation gauge locations to create the model subbasins (Figure 3.3).

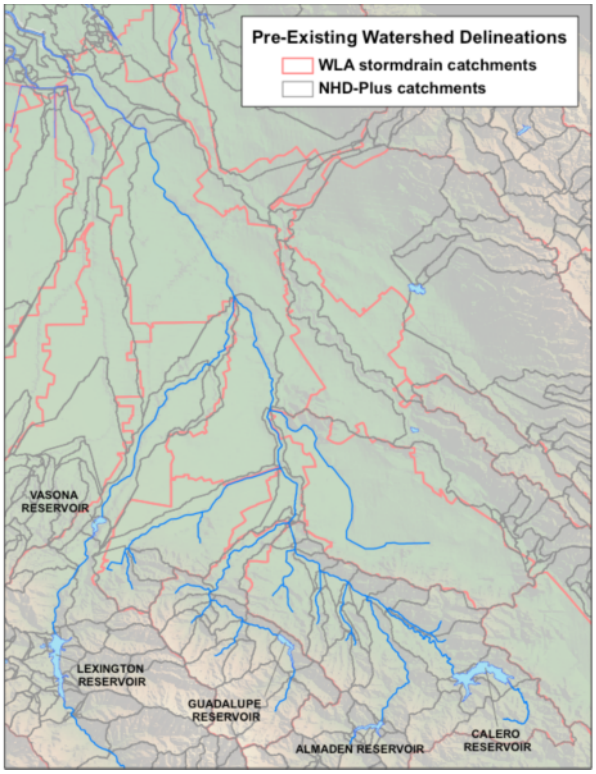

Figure 3-2 - Pre-existing Subbasin Delineations

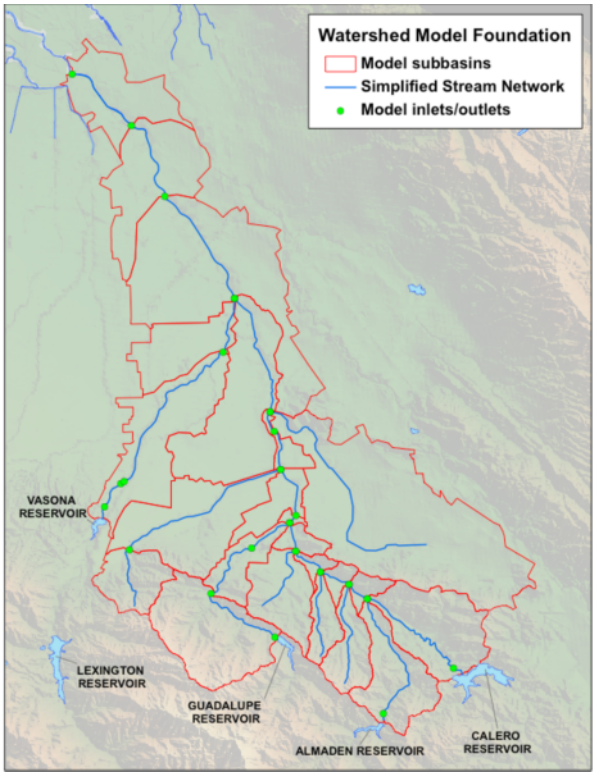

Figure 3-3 - Model Subbasins

When a watershed is divided into subbasins, the hydrographic divisions follow the same geographic boundaries as the land-based delineations. HSPF defines one hydrographic segment, called a reach, per subbasin. If there are multiple streams in a subbasin, HSPF simplifies them down to one reach in the model. Based on the length of the reach, the drainage area, and the elevation change over the course of the reach, HSPF calculates depth:surface area:volume:discharge relationships. This information is stored in FTABLES (function tables) for each model reach segment. For this version of the watershed model, default FTABLES were used; however, before adding sediment into the model, the FTABLES likely will be refined via hydraulic calibration.

Meteorological segmentation is the process of assigning representative weather stations to subbasins. The Guadalupe Watershed Model meteorological segmentation was an iterative process that shifted from initial proximity-based assignments to more elevation-based assignments (Figure 3.4). The final rain gauge assignments correspond reasonably well with a local isohyetal map generated by SCVWD.

Following the initial model set-up, one additional reach and associated subbasin (shown in red hatched lines in Figure 3.4) were created to accommodate meteorological segmentation at the high elevation, high rainfall Guadalupe precipitation station. Originally the entire Guadalupe Creek headwaters subbasin was assigned to the Guadalupe precipitation station. However, this segmentation resulted in considerable overprediction of Guadalupe Creek flow as well as overtopping of stream banks. Based

upon elevation, the subbasin was split into 20% assignment to Guadalupe precipitation station (1700') and 80% to the nearby Johnson Ranch precipitation station (750'). To allow for this subbasin division, an additional reach (with the same hydraulic characteristics) was created as a short segment of the original reach and 20% of the associated land was re-allocated to the new reach.

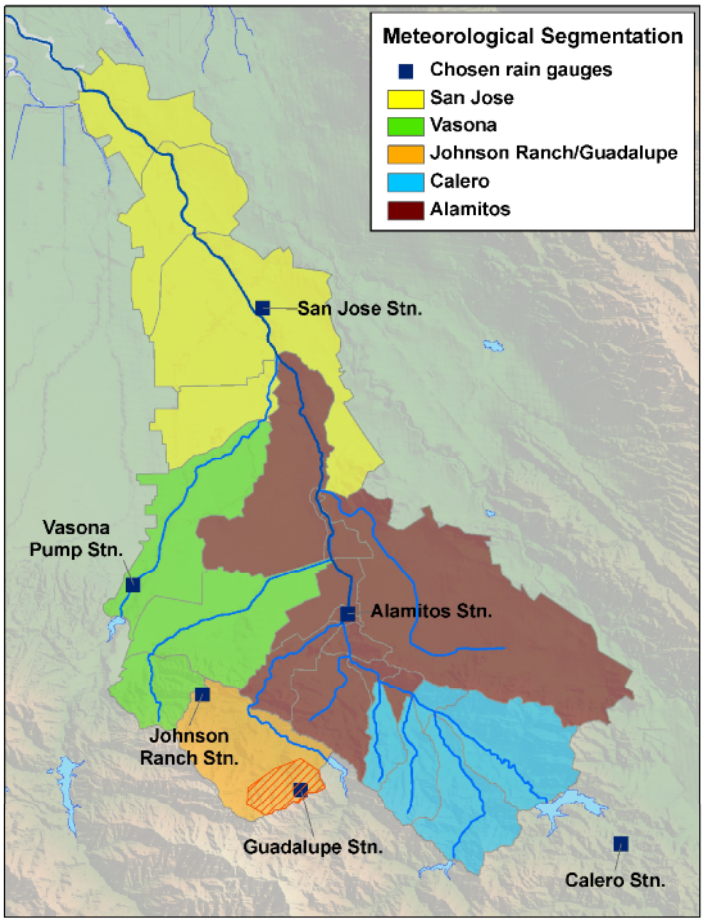

Figure 3-4 - Meteorological Segmentation

3.3.3. Land Categories

Land in an HSPF model is categorized as either pervious or impervious. These two categories are treated very differently in the model. Pervious land allows for infiltration and moisture storage, and impervious land does not. The model allows for further subdivisions of these major land categories based on land use and vegetative cover. Table 3.4 indicates the land categories used, percent imperviousness, and relative amounts present in watershed. Although the percent imperviousness estimates may vary with region and age of development, the USGS's Land Use/Land Cover GIRAS dataset was used because it was supplied as a default in the HSPF model.

Table 3-4 – Land Use Breakdown and Estimated Imperviousness

Land Use	% Imperv.	Area (acres)	% of watershed
Residential	50	30,546	46%
Commercial	50	7,047	11%
Industrial	50	7,393	11%
Barren	0	1,968	3%
Agriculture	0	3,101	5%
Range land	0	6,489	10%
Forest	0	8,539	13%
Wetland/water	0	752	1%
Total Developed	50	44,986	68%
Total Undeveloped	0	20,849	32%

The percent imperviousness estimates from USGS's Land Use/Land Cover GIRAS dataset are highly aggregated. Much higher resolution impervious estimates exist – for example, residential land use can be divided into low-, medium-, and high-density residential categories, each with their own % imperviousness – and may improve model performance if impervious estimates are too coarse.

3.4. Model Calibration

Calibration of a HSPF model is an iterative process of making parameter changes and sometimes model set-up changes, running the model and comparing the simulated model outputs to observed data. The calibration procedure is well documented by Donigian (2002).

The input data set period (WY 2000-2007) was separated into a calibration period (WY 2000-2005) and a validation period (WY 2006-2007). The validation period data set was set aside in order to later test the model's ability to simulate beyond the time period of the calibration dataset. Model validation is discussed in Section 3.5.

Since the lower Guadalupe River watershed is highly gauged, it was possible to calibrate from upstream to downstream using several sites. Three calibration sites (Table 3.5) were chosen on the basis of stream gauge data quality and drainage area characteristics. The streamflow gauge data quality was checked through comparison with local precipitation data, as well as with reservoir release data when relevant. Once gauges with acceptable data quality were identified, three were selected to represent a broad range of drainage area characteristics such as size, slope, and imperviousness.

Table 3-5 - Calibration Sites

Gauge Station	Stream	Drainage Area	% Slope	% Eff. Imperv.	Data Source	Time Interval	Period of Data
11169025	Guadalupe River	58,914 ac.	5%	34.1%	USGS	15-min.	WY 2003-2005
43	Guadalupe Creek	4,351 ac.	19%	0.2%	SCVWD	15-min.	WY 2000-2005
73	Canoas Creek	11,718 ac.	3%	35.1%	SCVWD	15-min.	WY 2000-2005

Two Guadalupe River tributaries with very different surrounding landscapes were chosen as upstream calibration sites. The first, Guadalupe Creek, flows through a steep undeveloped area. The second, Canoas Creek, flows through a mostly flat mixed-development area. Guadalupe Creek is reservoir fed while Canoas Creek is not. The final calibration site was the most downstream gauge (USGS #11169025) on the Guadalupe River. USGS Gauge #11169025 is about 5 miles upstream from the bottom of the watershed (delineated by the freshwater/tidal boundary). Because the gauge commenced recording in May 2002, the calibration period for this location was WY 2003-2005.

Calibration efforts focused on improving the overall accuracy of model predictions during both storm events and dry-weather conditions. Parameters adjusted during calibration include upper zone nominal soil moisture storage (UZSN), lower zone nominal soil moisture storage (LZSN), lower zone evapotranspiration (LZETP), evapotranspiration from baseflow (BASETP), infiltration (INFILT), interflow (INTFW), variable groundwater recession (KVARY), base groundwater recession (AGWRC), interflow recession (IRC), and deep recharge (DEEPFR). Initial values for these calibration parameters were obtained from several local watershed hydrologic modeling studies (e.g., AQUA TERRA Consultants, 2006; Clear Creek Solutions, Inc., 2007), and assigned to watershed segments based on soil type, land use, and slope. Calibration parameters were then adjusted within reasonable limits (as defined in BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF (US EPA, 2000)) to improve the fit of the simulated flow rates to the observed flow rates. Guadalupe Creek and Canoas Creek were calibrated first. The relevant parameters then were applied to other areas of the watershed based upon land use, slope and soil type. Finally, the entire watershed was calibrated to the Guadalupe River site, allowing some of the previously determined parameters to be adjusted slightly to obtain a better fit to observations. Calibration statistics and graphs are presented in the following sections for the tributary sites, followed by a more extensive calibration presented for Guadalupe River.

The model then was evaluated according to the following criteria:

Table 3-6 - Hydrological Model Performance Criteria (Donigian, 2002)

Rating	% Difference between simulated and observed flow rates*
Very Good	< 10
Good	10 – 15
Fair	15 – 25
Poor	> 25

*monthly and annual flow rates only; individual storm peaks may differ more

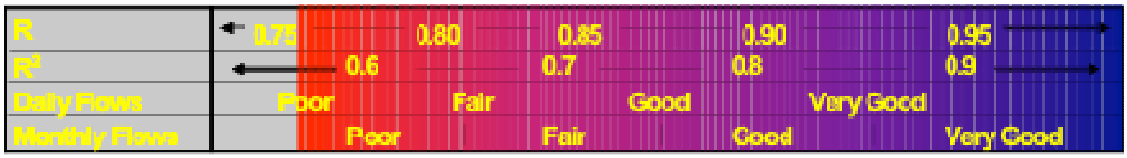

Figure 3-5 – Correlation Coefficient (R and R^2) Ranges for Model Performance (Donigian, 2002)

3.4.1. Tributaries - Stream Flow

Annual Flow

Annual flow volumes were the first metric used to evaluate model performance. It was important to understand whether or not the model properly simulated streamflows at this very basic level. By integrating over a year, the details of processes that take place at shorter time scales (e.g., infiltration, soil storage) become less important. The annual flow volume analysis therefore indicates whether the basic model set-up is appropriate (i.e., Is the model delineation appropriate? Are the input precipitation and evaporation data appropriate? Are water imports and/or diversions accounted for?).

Comparisons of simulated versus observed annual flow volumes are presented in Tables 3.7 and 3.8. The annual simulated flow volumes for Guadalupe Creek are fairly similar to the observed flow volumes with a maximum difference of 15%. However, the simulation tends to overestimate flow during wet years, and underestimate flow during dry years.

The annual simulated flow volumes for Canoas Creek tend to be higher than the observed flow volumes by 33% on average, with even higher differences for individual years. Adjusting calibration parameters within realistic bounds could not account for the differences between simulated and observed.

Table 3-7 - Annual Simulated and Observed Flow Volumes for WY 2000-2005 for Guadalupe Creek and Precipitation for Johnson Ranch and Guadalupe Stations

Water Year	Johnson Ranch Precipitation (in)	Guadalupe Precipitation (in)	Sim. Flow Volume (10^6*cubic feet)	Obs. Flow Volume (10^6*cubic feet)	% Difference from Obs. Flow Volume
2000	25.5	63.4	447.4	462.2	-3.2%
2001	20.5	35.8	229.3	227.7	0.7%
2002	12.1	36.9	169.9	148.8	14.2%
2003	28.2	43.4	318.6	305.9	4.2%
2004	19.8	33.8	247.3	224.7	10.1%
2005	28.2	36.1	290.6	341.8	-15.0%
Average	22.4	41.6	283.8	285.5	-0.6%

Table 3-8 - Annual Simulated and Observed Flow Volumes for WY 2000-2005 for Canoas Creek and Precipitation for Alamitos Station

Water Year	Precipitation (in)	Sim. Flow Volume (10^6*cubic feet)	Obs. Flow Volume (10^6*cubic feet)	% Difference from Obs. Flow Volume
2000	14.5	182.1	193.9	-6.1%
2001	12.3	140.6	108.9	29.1%
2002	9.3	97.5	62.4	56.3%
2003	17.6	235.1	144.9	62.2%
2004	13.2	162.2	123.6	31.2%
2005	20.5	258.0	173.4	48.8%
Average	14.6	179.2	134.5	33.2%

Daily Flow

Daily flows were the second metric analyzed during model calibration. While the annual flow volumes presented above were an important metric for testing the basic parameterizations of the model, they did not indicate how well the model simulated the magnitude and timing of storm events. Daily stream flow is more appropriate for a magnitude and timing analysis.

Figures 3.6 through 3.9 illustrate the daily mean flow over the calibration period in both arithmetic and logarithmic format for Guadalupe Creek and Canoas Creek, respectively. The arithmetic scale allows for the comparison of the simulated and observed peak flows, whereas the logarithmic scale allows for the comparison of simulated and observed baseflow.

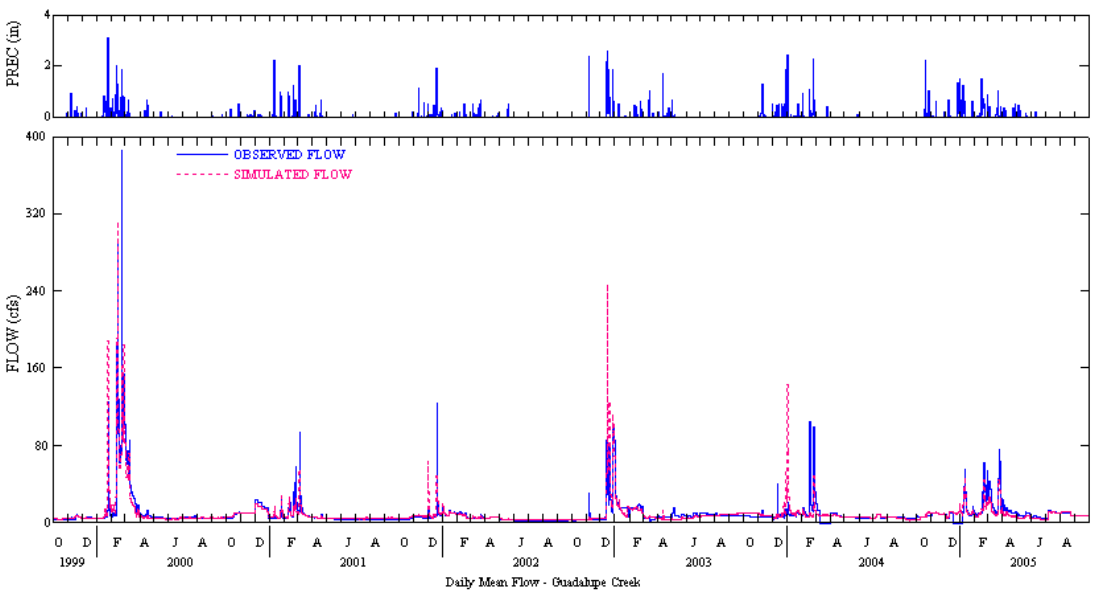

Figure 3-6 - Arithmetic Scale Calibration Daily Flow Simulations for Guadalupe Creek with Precipitation from Johnson Ranch Station

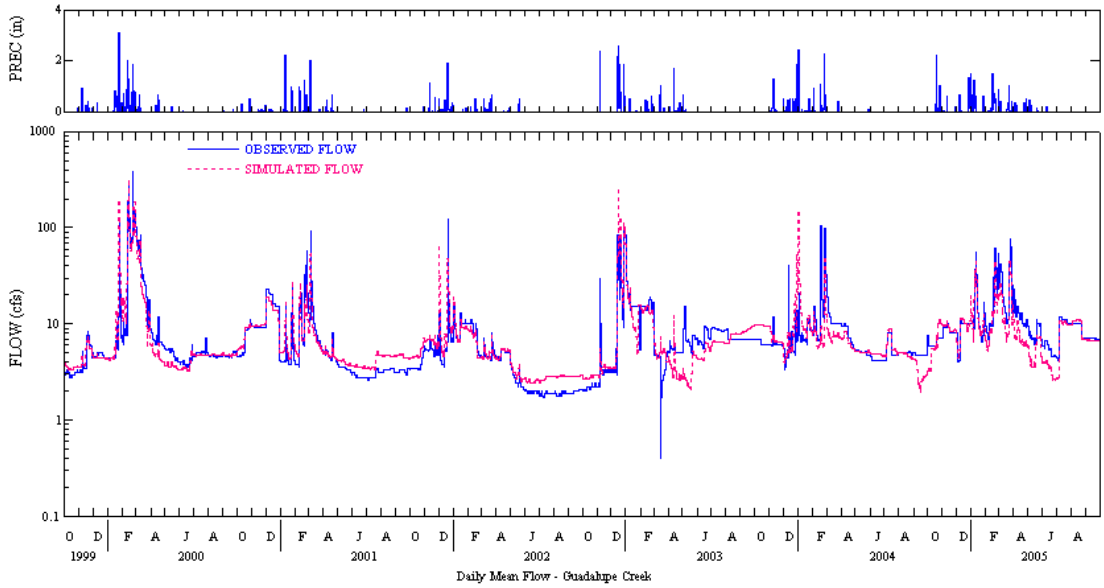

Figure 3-7 - Logarithmic Scale Calibration Daily Flow Simulations for Guadalupe Creek with Precipitation from Johnson Ranch Station

From Figures 3.6 and 3.7, it is evident that the model performed reasonably well for Guadalupe Creek, capturing both peak flows and baseflows. The model does not show any systematic bias towards over- or underprediction on a short-term (daily) basis.

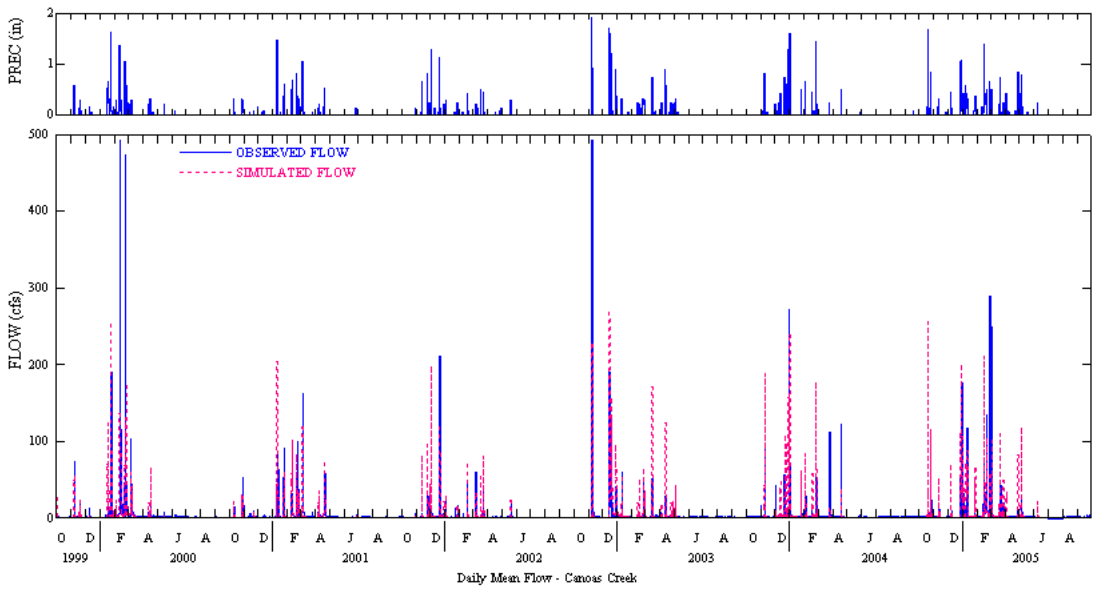

Figure 3-8 - Arithmetic Scale Calibration Daily Flow Simulations for Canoas Creek with Precipitation from Alamitos Station

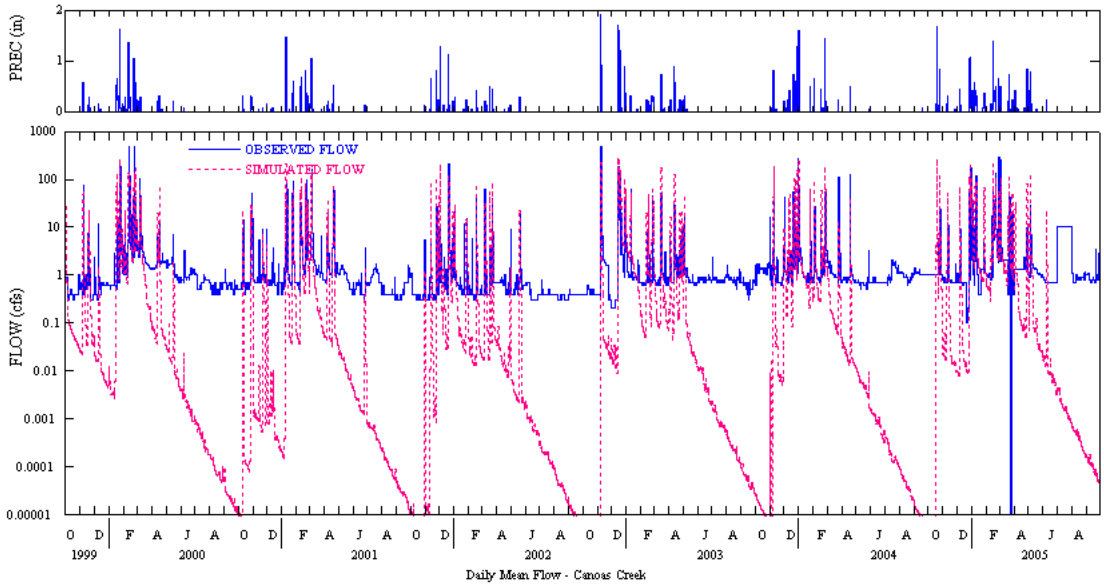

Figure 3-9 - Logarithmic Scale Calibration Daily Flow Simulations for Canoas Creek with Precipitation from Alamitos Station

The model did not perform as well for Canoas Creek. Peak flows (Figure 3.8) were underestimated for large storm events while they were overestimated for medium to small storm events. Additionally, Figure 3.9 shows that baseflow was considerably underestimated. Adjustment of model parameters within "realistic" bounds was unable to significantly improve the simulation of Canoas Creek.

3.4.2. Tributaries - Flow Frequency

Flow duration curves are another useful means for analyzing model performance. These curves yield some insight into the overall hydrologic regime of the contributing watershed. The shape of a flow-duration curve in its upper and lower regions is particularly significant in evaluating the stream and basin characteristics. The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Regulation of floods, by reservoir storage for example, will generally result in a much flatter curve near the upper limit. In the low-flow region a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater contribution that sustains baseflow to the stream.

Flow duration curves for Guadalupe Creek and Canoas Creek are presented in Figures 3.10 and 3.11, respectively.

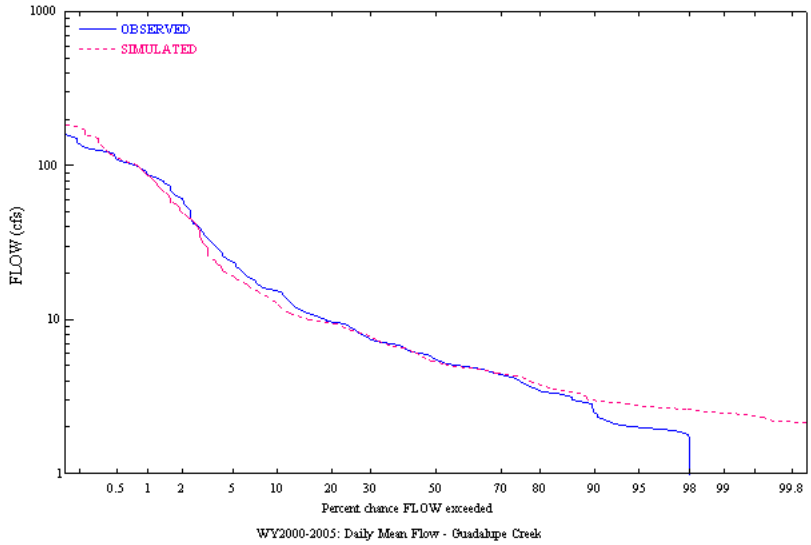

Figure 3-10 - Calibration Flow Duration Curves for Guadalupe Creek

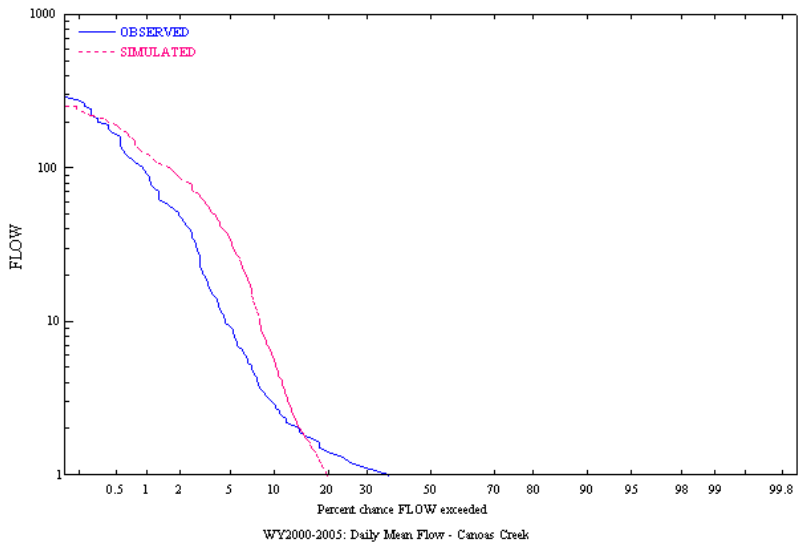

Figure 3-11 - Calibration Flow Duration Curves for Canoas Creek

The observed and simulated flow duration curves match quite well for Guadalupe Creek (Figure 3.10). However, it should be noted that the flow duration curve is an average, and positive and negative errors can balance out (as seen in Table 3.1), giving the appearance of a better fit. Discrepancies in the very low flow regime are not seen as critical as there is potentially as much uncertainty in the actual measurement of these extremely low flows as there is in the simulation of these flows.

The simulated flow duration curve did not match the observed flow duration curve for Canoas Creek (Figure 3.11). As noted for the Canoas Creek daily mean flow comparisons (Figures 3.8 and 3.9), the simulated flow rates were underestimated at high

flow rates, overestimated for the middle of the flow regime, and underestimated for baseflows (although gauge errors render very low flow comparisons questionable).

3.4.3. Guadalupe River - Stream Flow

Annual Flow

Annual flow volumes for the entire Guadalupe River watershed are presented in Table 3.9 along with annual precipitation for Alamitos precipitation station (the most central meteorological station) for WY 2003-2005. The model systematically underpredicted flows at the bottom of the watershed, with the most dramatic underprediction occurring during the driest year. Again, adjustment of calibration parameters within "realistic" ranges was unable to significantly improve model performance.

Table 3-9 - Annual Simulated and Observed Flow Volumes for WY 2003-2005 for Guadalupe River and Precipitation for Alamitos Station

Water Year	Precipitation (in)	Sim. Flow Volume (10^6*cubic feet)	Obs. Flow Volume (10^6*cubic feet)	% Difference from Obs. Flow Volume
2003	17.6	2,042.3	2,147.8	-4.9%
2004	13.2	1,438.9	1,872.0	-23.1%
2005	20.5	2,431.1	2,590.4	-6.6%
Average	15.2	1,970.8	2,203.4	-10.6%

Monthly Flow

Figure 3.12 shows the observed and simulated monthly mean flows for Guadalupe River along with total monthly precipitation for Alamitos Station. Monthly mean flows are a useful metric for how well the model performs on a seasonal basis. For the calibration period (WY2003-2005), the simulation fluctuated between over- and underestimating flow for wetter months, but fairly consistently underestimated flow during dry months. As seen in Table 3.7, the model tended to overpredict flow during the two wetter years and underpredict flow during the dry year.

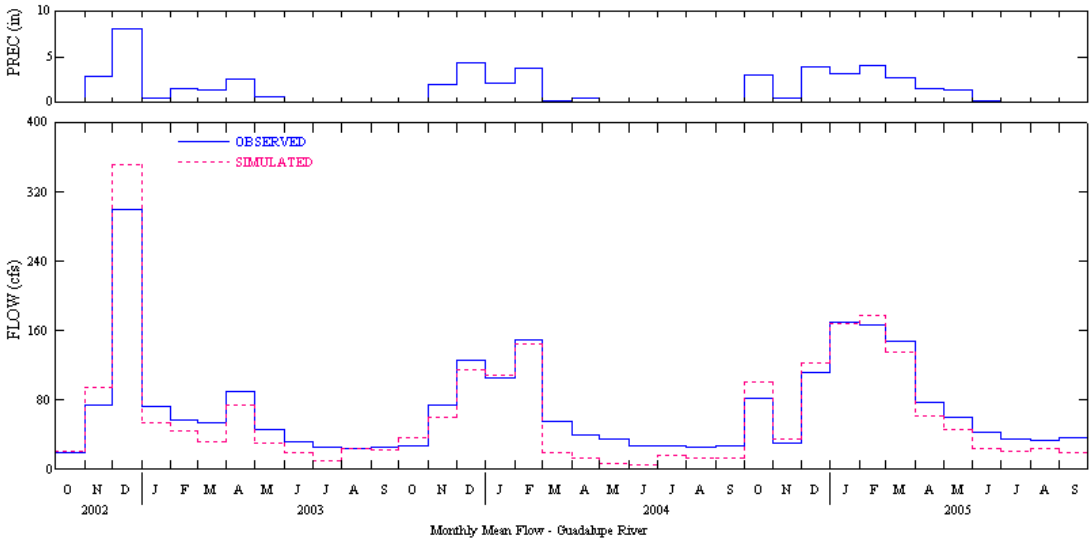

Figure 3-12 - Monthly Mean Flow for Guadalupe River and Total Monthly Precipitation for Alamitos Station for WY 2003-2005

Table 3.10 compares observed and simulated monthly mean flows, which have been averaged across the simulation period. This metric shows the ability of the model to simulate seasonal trends over the long term. During the calibration period, monthly mean flows tended to be overestimated in early wet season (Oct. through Dec.), reasonably estimated mid-wet season (Jan. to Feb.), and finally underestimated in late wet season (Mar. to Apr.) and throughout the dry season (May through Sep.). The overall trend was an underestimation of flow.

Table 3-10 - Mean Monthly Flows for Guadalupe River (averaged over WY 2003-2005)

Month	Avg. Sim. Flow (cfs)	Avg. Obs. Flow (cfs)	% Difference
Oct	54.8	42.6	28.6%
Nov	63.8	58.9	8.4%
Dec	203.0	179.3	13.2%
Jan	111.4	115.8	-3.8%
Feb	122.2	123.9	-1.3%
Mar	62.1	85.1	-27.0%
Apr	49.4	68.2	-27.6%
May	27.2	47.0	-42.2%
Jun	15.8	33.7	-53.0%
Jul	14.9	29.0	-48.6%
Aug	20.2	27.6	-26.7%
Sep	17.6	28.8	-38.9%
Average	63.5	70.0	-9.2%

Daily Flow

Figures 3.13 and 3.14 illustrate the mean daily flow over the calibration period in both arithmetic and logarithmic form for Guadalupe River. The arithmetic scale allows comparison of the simulated and observed peak flows, whereas the logarithmic scale allows comparison of simulated and observed baseflow. The model performed well during storm events (Figure 3.13) for Guadalupe River. Except for WY 2004 the model slightly overestimated peak flow. However, the model did not properly capture baseflow (Figure 3.14). Although occasionally the simulated baseflow fluctuated above the observed baseflow, the general simulation trend was to underestimate baseflow by 10 to 20 cfs during drier months. This finding is further evident in the scatter plot of simulated versus observed daily flows (Figure 3.15). The negative intercept (-16.5 cfs) highlights the systematic underprediction of stream flows at the bottom of the watershed.

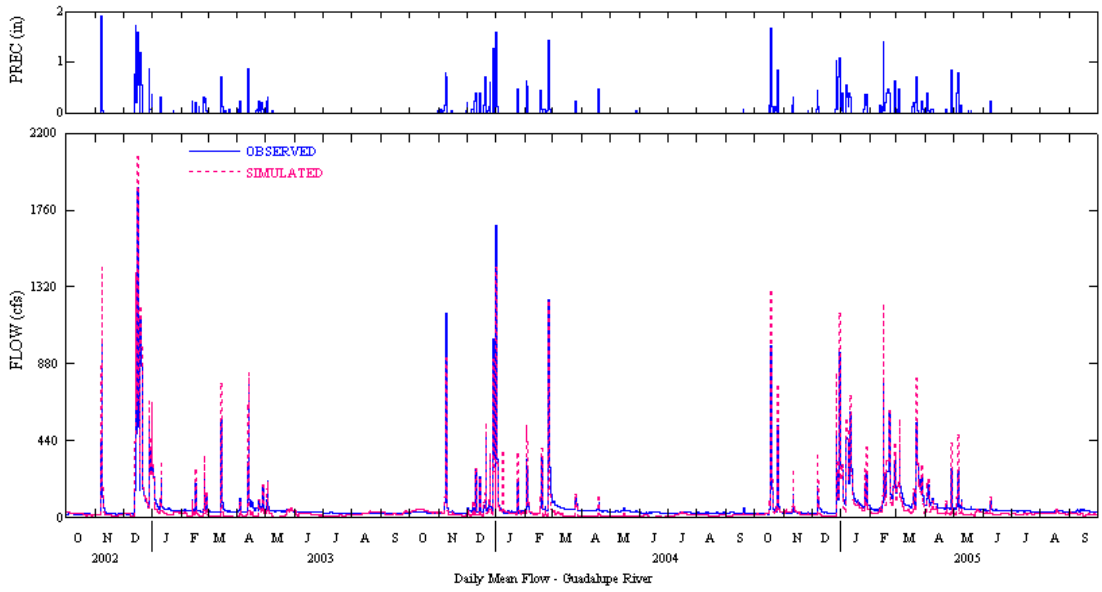

Figure 3-13 - Arithmetic Scale Calibration Daily Flow Simulations for Guadalupe River with Precipitation from Alamitos Station

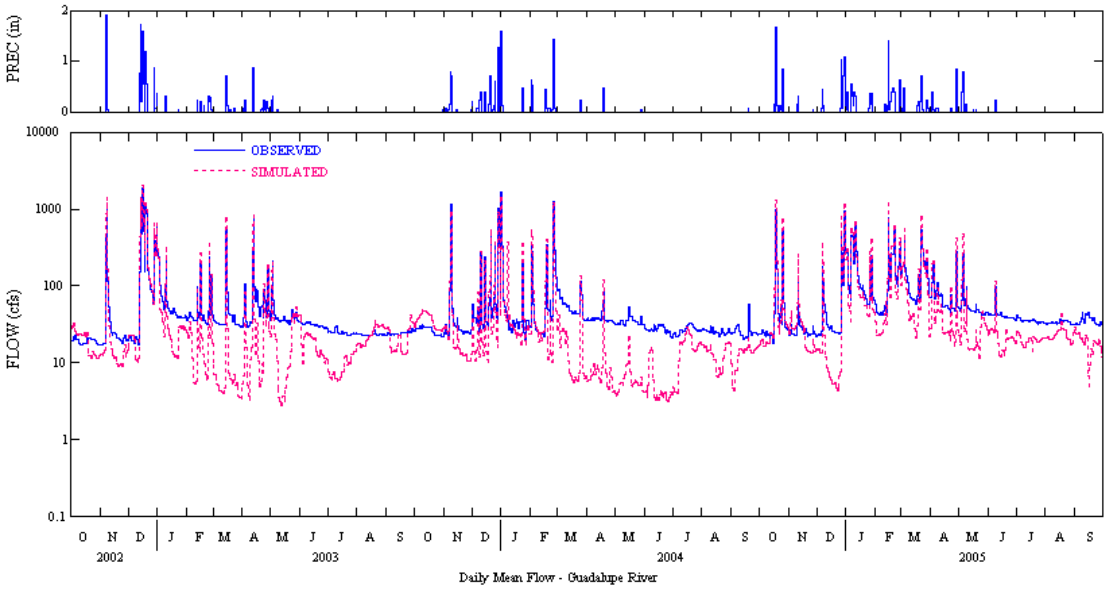

Figure 3-14 - Logarithmic Scale Calibration Daily Flow Simulations for Guadalupe River with Precipitation from Alamitos Station

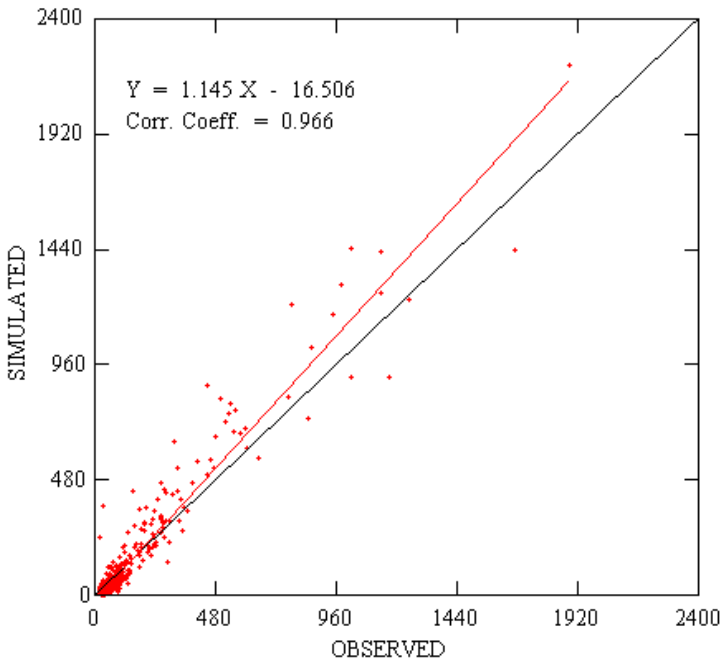

Figure 3-15 - Observed versus Simulated Daily Mean Flow (cfs) for Guadalupe River (WY 2002-2005)

3.4.4. Guadalupe River - Flow Frequency

Figure 3.16 shows the simulated and observed flow duration curves for Guadalupe River for WY 2003-2005. The observed and simulated flow duration curves are similar for high- and medium-flow regimes, but the model deviated considerably during the low-flow regime (Figure 3.16). The model underestimated (base) flow when observed flow was below approximately 80 cfs.

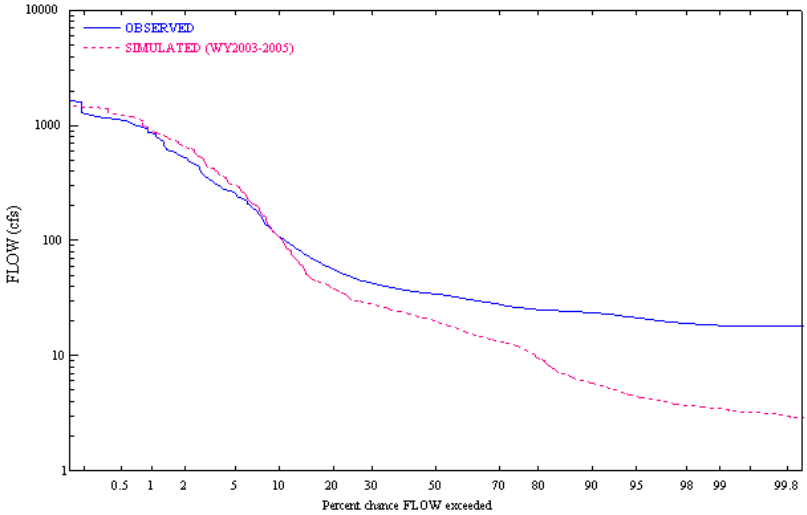

Figure 3-16 - Calibration Flow Duration Curves for Guadalupe River

3.4.5. Guadalupe River - Storm Events

The preceding analyses illustrate how the model performed for long time scales. The aim of those tests was to identify any systematic under- or overprediction of flows over the course of a year. Here the model is evaluated in regards to its ability to simulate individual storms events.

Figure 3.17 shows hourly observed and simulated flow for a range of storm events within the calibration period. The general shape of simulated hydrographs matched observed hydrographs quite well for many different antecedent conditions and precipitation patterns. The model is accurately capturing the general behavior of water flowing through the watershed at the scale of individual storms. However, the model is not capturing all of the watershed details as the simulated flow tended to peak earlier than observations (between <1 and 3 hours early) and often exhibited higher peak flows.

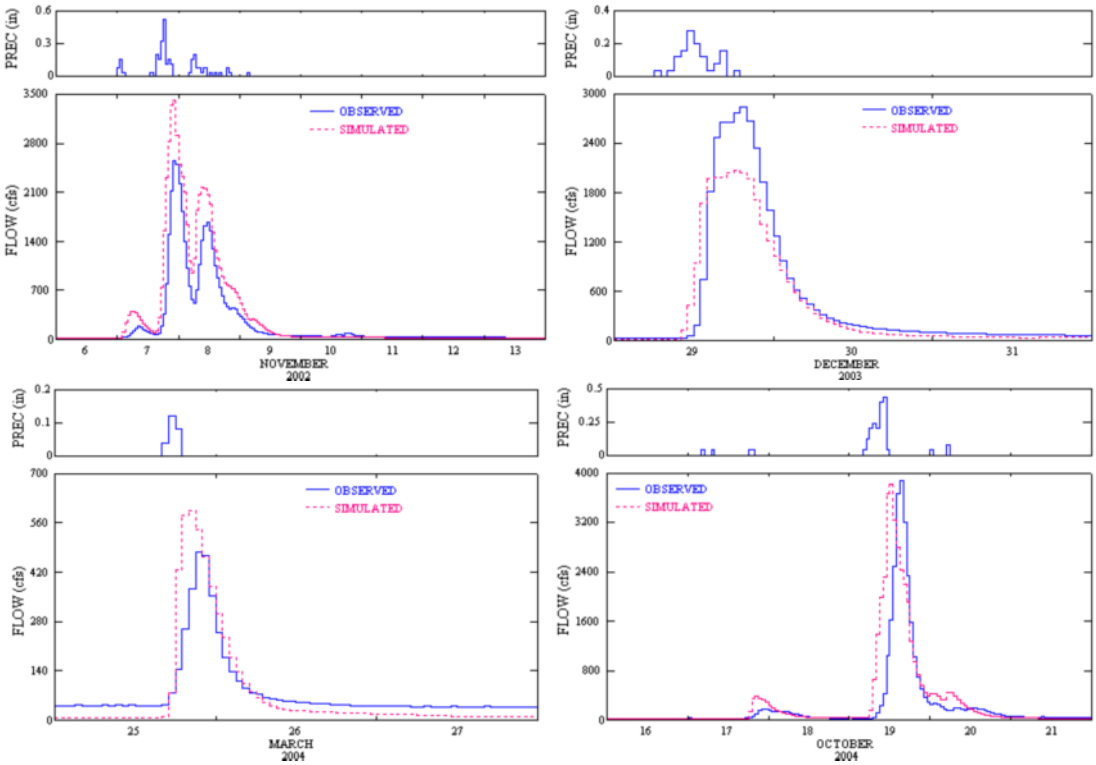

Figure 3-17 - Simulation of Select Storm Events (WY 2003-2005) for Guadalupe River

3.4.6. Guadalupe River - Water Balance

Table 3.11 shows the model-calculated water balance for separate land use categories. The water balance depths (inches) (equivalent to area normalized volumes per year) are averaged in space (i.e., across the watershed) and time so that they represent the contribution of individual land-use types for the calibration period WY 2003-2005.

Table 3-11 - Guadalupe Watershed Water Balance (inches) for WY 2003-2005

	Forest	Range	Agri	Barren	Com/Ind	Resident	Imperv	Overall
Rainfall	24.16	20.62	19.14	18.36	18.19	18.88	18.66	19.59
Surface Runoff	0.34	0.17	0.45	0.13	0.07	0.29	14.69	5.24
Interflow	1.16	0.62	0.31	0.25	0.08	0.20		0.29
Baseflow	1.41	1.21	0.56	0.49	0.47	0.56		0.53
Total Runoff	2.91	2.01	1.33	0.87	0.62	1.05	14.69	6.06
Deep Groundwater	0.10	0.19	0.55	0.45	0.48	0.57		0.26
Total/Actual Evaporation	22.55	19.69	18.66	18.43	18.49	18.66	3.77	14.10
Change in Soil Storage	-1.39	-1.13	-1.37	-1.35	-1.35	-1.37		-0.87

The Guadalupe River watershed water balance (Table 3.11) shows that the forested area generally receives the most rain per unit area, as would be expected given most of the forest is located in the higher altitude, higher rainfall area of the watershed. The forest area has a higher runoff volume than all other pervious categories, which, combined with its location in steep terrain, probably leads to erosion and high suspended sediment concentrations in local streams. This hypothesis is consistent with qualitative data collected by L McKee in Guadalupe Creek during a small rainstorm when just a small change in stage (3.9 inches) caused an increase in turbidity from <50 to >1000 NTU.

The water balance (Table 3.11) confirms that, for the range of rainfall tested, impervious surfaces generate the highest levels of runoff per unit area – five times greater than the highest pervious land runoff. Since the current imperviousness estimate designates a third of the Guadalupe River watershed as impervious surface, these paved and built-up surfaces will be contributing the most runoff during low to moderate rainfall years, which has implications for what types of contaminants the runoff contains and what type of management options should be considered.

3.5. Model Validation

Following the calibration of the model to WY 2000-2005 streamflow data, the model was tested on data from WY 2006-2007. Testing the model on non-calibration data serves as a check that the model is robust and has not been overcalibrated to a specific set of data.

3.5.1. Guadalupe River - Stream Flow

Annual Flow

Table 3.12 contains annual precipitation for Alamitos precipitation station (the most central meteorological station), simulated and observed runoff volumes, and percent differences for both years of validation.

Table 3-12 - Annual Simulated and Observed Flow Volumes for WY 2006-2007 for Guadalupe River and Precipitation for Alamitos Station

Water Year	Precipitation (in)	Sim. Flow Volume (10^6*cubic feet)	Obs. Flow Volume (10^6*cubic feet)	% Difference
2006	16.3	4,371.3	4,473.5	-2.3%
2007	7.2	870.4	1,259.5	-30.9%

The model was calibrated to a moderate rainfall range (13.2 to 20.5 in/yr) and performed best for average rainfall years (2003 and 2006). Not surprisingly, the model performed poorly for an extremely dry year (2007) with only 7.2 inches of rainfall, which was outside the calibration range of precipitation. As during the calibration period, the model consistently underpredicted annual flow volumes.

Monthly Flow

Figure 3.18 shows the observed and simulated monthly mean flows over the validation period along with total monthly precipitation. During the validation period, the simulation fluctuated between over- and underestimating flow for wetter months, but fairly consistently underestimated flow during dry months. This seasonal bias of the simulation is similar to the pattern shown during the calibration period.

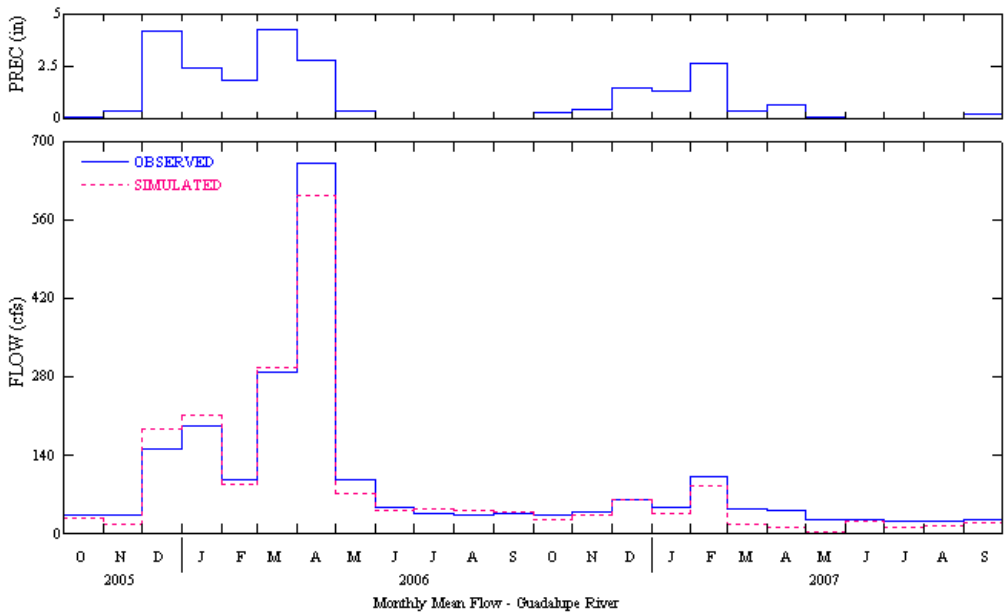

Figure 3-18 - Monthly Mean Flows for Guadalupe River and Total Monthly Precipitation for Alamitos Station for WY 2006-2007

Table 3.13 compares observed and simulated monthly mean flows, which have been averaged across the validation period, to look for seasonal biases in the model. Unlike the calibration simulation, which showed a trend (overestimated flow during wet season, underestimated flow during dry season), the simulated monthly mean flows here did not show a consistent pattern relative to the observed flow-rate data. The lack of a

discernible pattern is not surprising given that there are only two years in this analysis and one of the two years was extremely dry. This indicated that, for the Bay Area, a longer period should be chosen for both the calibration and verification data sets; this may be a challenge for modeling other watersheds in the future if such long-term (>10 year) data do not exist.

Table 3-13 - Mean Monthly Flows for Guadalupe River (averaged over WY 2006-2007)

Month	Avg. Sim. Flow (cfs)	Avg. Obs. Flow (cfs)	Avg. Residual (cfs)	% Error
Oct	27.2	32.9	-5.7	-17.3%
Nov	24.2	35.6	-11.4	-31.9%
Dec	122.9	106.2	16.8	15.8%
Jan	122.8	120.2	2.6	2.2%
Feb	86.0	98.5	-12.5	-12.7%
Mar	156.9	165.9	-8.9	-5.4%
Apr	306.6	351.4	-44.8	-12.7%
May	36.9	61.0	-24.1	-39.5%
Jun	32.2	35.5	-3.3	-9.2%
Jul	27.6	29.0	-1.4	-4.8%
Aug	27.0	27.6	-0.6	-2.0%
Sep	28.6	31.2	-2.6	-8.2%
Average	83.2	91.2	-8.0	-8.8%

Daily Flow

Figures 3.19 and 3.20 illustrate the daily mean flow over the calibration and validation periods in arithmetic and logarithmic format, respectively. The arithmetic scale allows comparison of the simulated and observed peak flows, whereas the logarithmic scale allows comparison of simulated and observed baseflow. The model performed well capturing storm events (Figure 3.19) for Guadalupe River during the validation period, as it did during the calibration period. The model did, however, consistently overestimate peak flow.

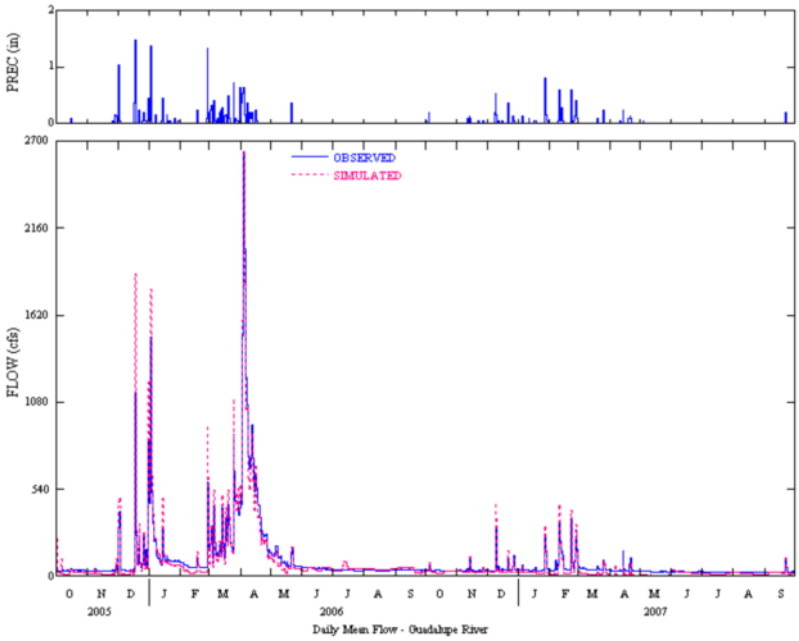

Figure 3-19 - Arithmetic Scale Validation Daily Flow Simulations for Guadalupe River with Precipitation from Alamitos Station

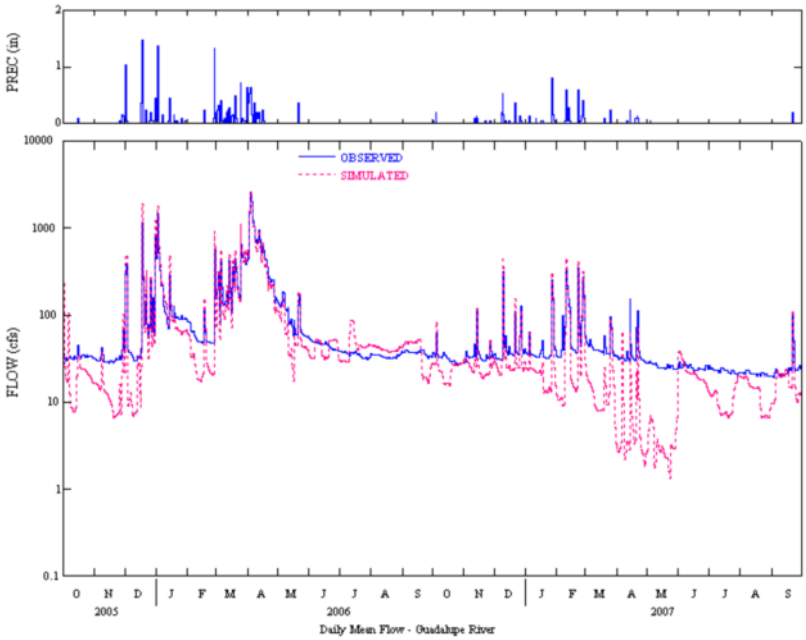

Figure 3-20 - Logarithmic Scale Validation Daily Flow Simulations for Guadalupe River

From Figure 3.20 it is apparent that the model did not properly simulate baseflow during the validation period (similar to calibration period). Although occasionally the simulated

baseflow fluctuated above the observed baseflow, the general simulation trend was to underestimate baseflow by 10 to 20 cfs during drier months. This finding is further evident in Figure 3.21, which shows a scatter plot of observed versus simulated daily mean flow for the validation period. The negative intercept indicates that the model underpredicted baseflow during the validation period by approximately 12 cfs.

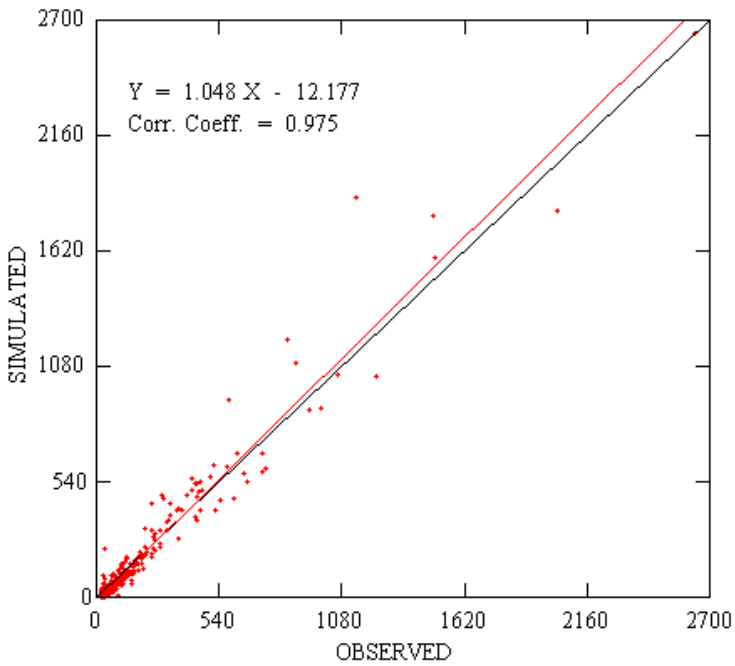

Figure 3-21 - Observed versus Simulated Daily Mean Flow (cfs) for Guadalupe River (WY 2006-2007)

3.5.2. Guadalupe River - Flow Frequency

During the validation period, the observed and simulated flow duration curves were similar for high- and medium-flow regimes, but the model deviated considerably during the low-flow regime (Figure 3.22). This is the same simulated flow frequency pattern observed during calibration. The model underestimated baseflow when observed flow was below 30 cfs during the validation period.

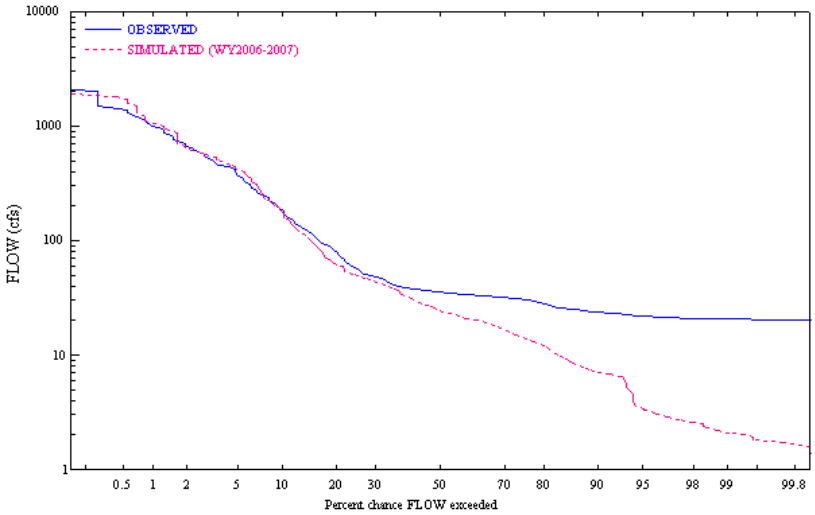

Figure 3-22 - Validation Flow Duration Curves for Guadalupe River

3.5.3. Guadalupe River - Storm Events

Figure 3.23 show hourly observed and simulated flow and precipitation for a range of storm events in the validation period. The general shape of the simulated storm hydrograph matched the observed storm hydrograph quite well for many different antecedent conditions and precipitation patterns, suggesting that the model accurately captured the behavior of water flowing through the watershed at the scale of individual storms. During the validation period, the simulated flow tended to peak slightly too soon (between <1 and 5 hours early) and peak flows were generally too high, as they were in the calibration period. Given the width of the hydrograph is only 12-24 hours, and the base to peak flow rise occurs in 4-12 hours, this is an area that may need some further attention in subsequent versions of the model.

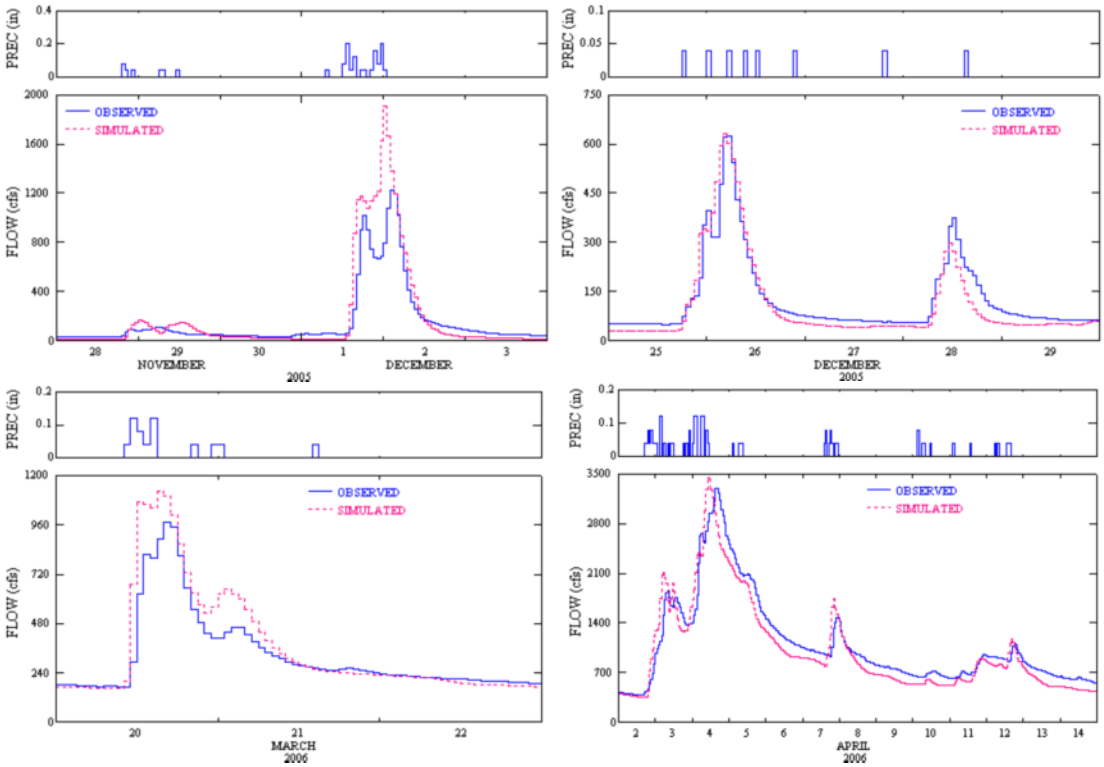

Figure 3-23 - Simulation of Select Storm Events (WY 2006-2007) for Guadalupe River

3.5.4. Guadalupe River - Water Balance

Table 3.14 shows the model-calculated water balance (in inches) for separate land use categories. The water balance depths (inches) are averaged spatially (i.e., across the watershed) and temporally so that they represent the contribution of individual land-use types for the validation period WY 2006-2007. The water balance from the validation (WY 2006-2007) reflects the lower rainfall during that period relative to the calibration period. The relative distribution of the water balance for the validation period was similar to that of the calibration period (i.e., rainfall highest in high elevations; these high elevations are typically forest land; impervious surfaces generate the vast majority of the runoff).

Table 3-14 - Guadalupe Watershed Water Balance (inches) for WY 2006-2007

	Forest	Range	Agri	Barren	Com/Ind	Resident	Imperv	Overall
Rainfall	19.27	16.18	15.51	15.39	15.29	14.44	14.71	15.51
Surface Runoff	0.09	0.08	0.26	0.06	0.11	0.15	11.00	3.88
Interflow	0.86	0.48	0.21	0.14	0.04	0.11		0.20
Baseflow	1.07	0.92	0.43	0.41	0.40	0.35		0.39
Total Runoff	2.02	1.48	0.90	0.61	0.47	0.61	11.00	4.47
Deep Groundwater	0.07	0.15	0.43	0.39	0.41	0.36		0.19
Total/Actual Evaporation	19.26	16.53	16.25	16.47	16.49	15.52	3.73	12.21
Change in Soil Storage	-2.09	-1.97	-2.07	-2.08	-2.08	-2.04		-1.34

3.6. Discussion of Calibration and Validation Results

Overall the model generally captured storm events, which suggests that the basic model set-up is sound. However, there are aspects of the model that clearly need to be adjusted to improve the fit of the simulations to observed data. A discussion of model performance at each calibration site is presented here and factors whose adjustments could improve model performance are identified. Later, in Section 5, a planned approach for improving the model is presented.

The model performed well for Guadalupe Creek, exhibiting annual flow volume errors of 15% or less (Table 3.7). It also successfully predicted peak and baseflows (Figures 3.6, 3.7 and 3.10). However, it slightly overpredicted annual flow volumes in wet years and underpredicted in dry years (Table 3.7). This bias could be caused by either incorrect meteorological segmentation or soil parameters.

The model performed poorly for Canoas Creek, overestimating annual flow volumes by 29% to 62% (Table 3.8), except for one year where it underestimated flow by 6%. It also underestimated very low baseflow (Figure 3.10). The model also did not properly predict storm event peaks; it underestimated peaks for large storm events and overestimated for medium to small storm events (Figure 3.9 and 3.11). Based on the large-scale systematic overestimation of annual flow volumes, it is likely that the meteorological segmentation of the subwatershed did not accurately represent its true precipitation patterns and/or there is an undocumented diversion from the subbasin. The incorrect meteorological segmentation hypothesis is also supported by the difficulties the model had in predicting storm event peaks. The consistent underestimation of very low baseflow (<2 cfs) during dry months indicates that the estimate of imperviousness of the subwatershed was incorrect and/or that water imports (e.g., for urban irrigation) occur during dry periods and lead to higher than expected baseflows. However, it should be noted that flows of this magnitude are subject to measurement error. Adjusting impervious estimates would

impact the flow volumes by allowing more or less infiltration. In the second version of the model being developed in 2009, a focused effort will be made to check the data input and data structure of the Canoas Creek portion of the model.

The model performance varied for the lower Guadalupe River. The observed and simulated daily mean flows had correlation coefficients of 0.97 to 0.98 (Figures 3.15 and 3.21), warranting a 'very good' model rating (Figure 3.5). However, simulated annual flow volumes varied between 2% and 31% from observed data (Tables 3.9 and 3.12), which span the entire range of model performance from 'very good' to 'poor' (Table 3.6). Also, the model systematically underpredicted annual flow volumes with a bias toward more extreme underprediction during drier years (Tables 3.9 and 3.12). The adjustment of calibration parameters within "realistic" ranges was unable to significantly improve model performance. Accordingly, it is likely that total water inputs to the watershed were too low in the model. This may potentially indicate that the meteorological segmentation of the model did not allocate enough area to high-elevation, high-rainfall gauges. Additionally, it may indicate that water imports, namely urban irrigation, are missing from the model. The tendency of the model towards more extreme underprediction during drier years supports the urban irrigation hypothesis since landscaping requires more water during drier years and would thus generate more runoff as baseflow.

The model demonstrated a strong seasonal bias in the simulated monthly flow (Figures 3.12 and 3.18) for lower Guadalupe River, consistently underestimating flow during dry months by about 10 to 30 cfs. However, the simulated daily flow in log scale (Figures 3.14 and 3.20) showed that the model underestimated baseflow all year round, including between storm events in the wet season, although less than in the dry season. Underprediction of baseflow can result from underestimation of infiltration rates, overestimation of impervious area, and/or missing low flow water imports. During the calibration process, the model showed little sensitivity to infiltration rates. It is therefore reasonable to suspect that the underprediction of baseflow most likely results from a combination of overestimation of impervious area and a lack of urban irrigation in the model. The model performed well capturing storm events on an hourly basis for the lower Guadalupe River. However, the simulated hydrograph tended to peak 1 to 3 hours earlier than observations and often exhibited slightly higher peak flows. Based on these results as well as the previous results showing little sensitivity to infiltration rates, it is most probable that impervious area is overestimated, reducing infiltration and increasing immediate storm runoff.

It must be noted that the period to which the model was calibrated did not include any unusually high rainfall years. Ideally, calibration and validation periods should each contain a wide range of wet to dry years in order to account for all conditions. Unfortunately, the time period covered by the most downstream gauge only contained moderately high to very low rainfall years, which skewed the model towards those conditions and reduced its robustness in the case of extremely high rainfall years. It is promising, though, that calibration and validation results were comparable. This finding lends confidence that the model is not 'overcalibrated' to a specific set of data. Rather, the model appears to be relatively robust in terms of the range of meteorological

conditions to which it can be applied so long as those meteorological conditions do not include extreme dry or wet years.

4.0 Model Application

4.1. Travel Times

Given the ability to simulate flow at the scale of individual storms it was deemed appropriate to apply the model to estimate travel times throughout the watershed. Artificial 24-hour high intensity rain pulses were generated and used on a background of precipitation from Alamitos stations (Figure 4.1). Three pulses were generated to test different antecedent conditions: slightly wet (December 2006), wet (March 2007), and dry (August 2007).

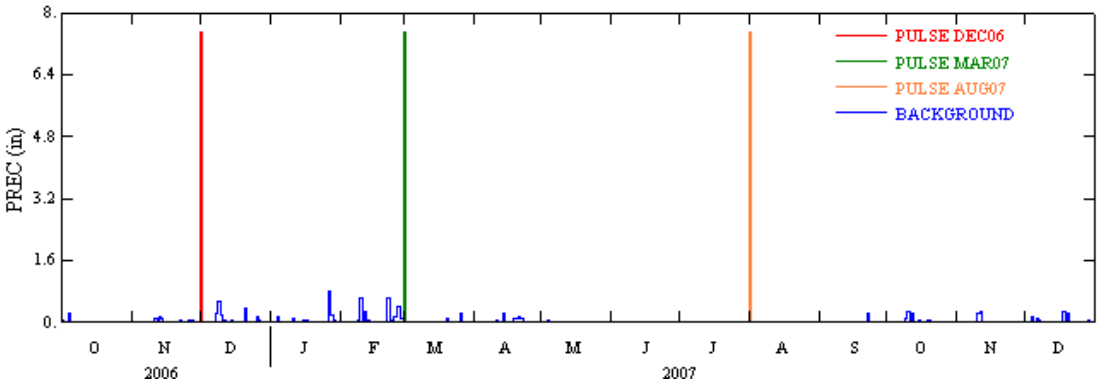

Figure 4-1 - Precipitation Pulses Used to Generate Lag Time Maps

The artificial rainfall was applied to each model segment separately. For each region, the hydrograph at the bottom of the watershed was then compared to these artificial precipitation records to determine a lag time (defined as the elapsed time between peak precipitation and peak flow). Results from each pulse are presented in Figure 4.2 as a series of maps.

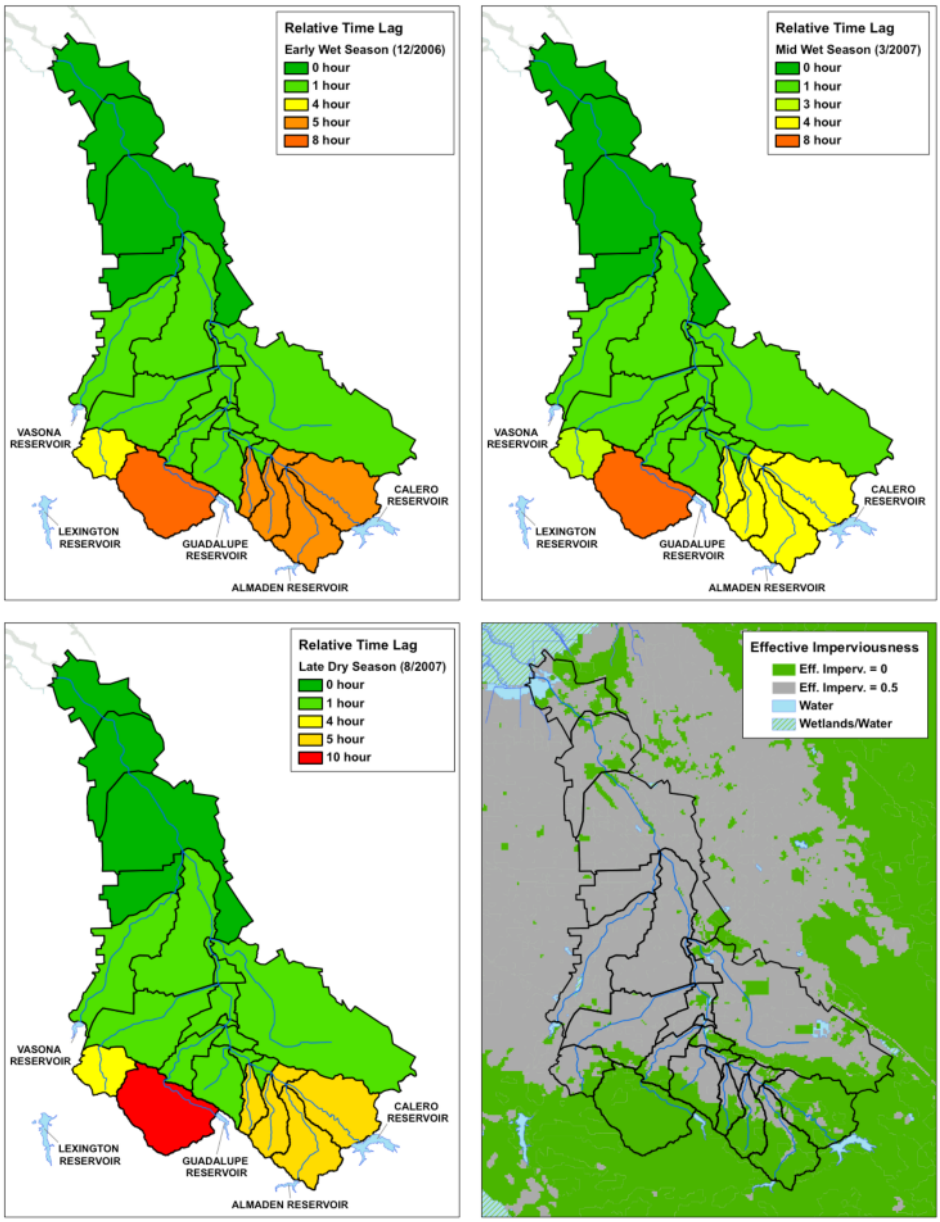

Figure 4-2 – Lag Time Maps Compared to Imperviousness

Short lag times (1 hour) were observed for mid-watershed areas, which fits with their high level of imperviousness leading to rapid runoff. The lag times from the upstream areas are longer (3-10 hours) and seem to depend on their level of development. The upper reaches of Ross Creek, Guadalupe Creek, and Alamitos Creek all are approximately the same distance from the bottom of the watershed, yet they have different lag times, which correlate with their imperviousness. Upper Guadalupe Creek has less than 1% effective impervious area (E.I.A.) and shows lag times of 8-10 hours, Alamitos Creek area has about 13% E.I.A. and lag times of 4-5 hours, and Ross Creek has 33% E.I.A. and shows lag times of 3-4 hours. Lag times from developed areas did

not depend upon antecedent rainfall conditions, while lag times from undeveloped areas did. This is to be expected given that undeveloped areas have more soil moisture storage capacity, which acts like a sponge, whereas developed areas tend to have immediate runoff and little storage capacity.

Lag times are presented here as a demonstration of model applications. However, further analysis of such model applications often help lend confidence in model performance. Given the availability of streamflow, precipitation, and reservoir release data throughout the Guadalupe River watershed, it is reasonable to believe that observed lag times could be calculated. Thus, it is anticipated that, where sufficient data allow, the modeled lag times presented here will be compared to observed lag times. This analysis will help improve model performance and ultimately bolster confidence in model predictions.

5.0 Conclusions and Recommendations

Because the need for model improvement was recognized early on, a first-order assessment of model performance was performed. This consisted of mainly graphical comparisons and few statistical tests, as the visual assessments provided adequate information for determining which aspects of the model need to be revisited. In the next phase of model development, when the model is considered fully developed, more statistical tests will be incorporated into the analysis of the model to allow finer refinement and optimization for answering specific questions.

Visual assessment of the model output relative to observed data showed that the model performed well for storm events in terms of both timing and flow magnitude at the bottom of the watershed. The general shape of simulated storm hydrographs (on an hourly basis) matched observed storm runoff quite well for many different antecedent conditions and precipitation patterns, suggesting that the model accurately captured the behavior of water flowing through the watershed. The model performed very well for daily mean flow (R^2=0.97-0.98 from Figures 3.15 and 3.21; see Figure 3.5 for performance evaluation). However, the model performed inconsistently for annual flow volumes; several years it performed very well (<10% error; see Table 3.6 for performance criteria), but other years it performed fairly (23% error (Table 3.9)) or poorly (31% error (Table 3.12)).

Another aspect of model performance is its robustness; the model has not been calibrated to or tested on data from high rainfall years, limiting assurance of its robustness under more extreme climatic conditions. This is an important issue since much of the suspended sediment transport in the Bay Area occurs during very wet years. For example, for Alameda Creek where there is a long suspended sediment record, the wettest 7 years in the last 50 are estimated to have transported about 52% of the suspended sediment load (McKee, SFEI, unpublished data).

The following recommendations are provided to improve the model performance:

1. Extend calibration period
Calibration and validation periods should each contain a wide range of wet to dry years in order to account for all conditions. Unfortunately, the simulated time period contains only moderately high to very low rainfall years, which skews the model towards those conditions and reduces its robustness in the case of extremely high rainfall years. Streamflow and precipitation data from higher rainfall years (WY 1995-1999) have been obtained and should be used to extend the calibration and validation periods (although a less ideal flow gauge will need to substitute for the Guadalupe River gauge currently used). Water year 1995 had the largest peak flow on record and WY 1998 had the 7th largest peak flow during the 77-year record in the Guadalupe River watershed. Water years 1999 and 2007 had the 15th and 16th lowest peak flows of the 77-year record. Thus the proposed temporal space for the next run of the model should result in an improvement.

2. Add urban irrigation into model
Simulation results from Canoas Creek and Guadalupe River clearly show a missing dry season baseflow, while Guadalupe Creek simulation results do not lack baseflow. Given that the Guadalupe Creek area is undeveloped while the other stream locations are developed, and that the missing flow is specific to the dry season, the most likely source of missing flow is urban irrigation. Aside from accurately modeling flow volumes, urban irrigation could be important for properly modeling contaminant concentrations carried by urban runoff and, in particular, methylmercury given preliminary evidence that concentrations and loads may be disproportionably high during wet season base flow and dry weather flow (McKee, SFEI, unpublished data).

3. Revise estimates of effective impervious area
Results showing over estimation of annual flow volumes at residential upstream points (Canoas Creek and Ross Creek (not shown)) and underestimation of flow volumes at the highly industrial and commercial downstream location (Guadalupe River) suggest that treating all developed land as 50% impervious may not be realistic. Land-use- and housing-density-specific imperviousness coefficients were obtained from SCVWD, and will be incorporated into the model during the next phase of development to create a more realistic distribution of pervious and impervious land across the watershed.

4. Adjust meteorological segmentation
Based on results from Canoas Creek and Ross Creek (not shown), it is recommended that meteorological segmentation be implemented at a finer resolution. Specifically, large subbasins containing substantial elevation changes should be broken up based on altitude and rainfall gauges should be re-assigned.

5. Re-evaluate calibration parameters
The "realistic" range of HSPF calibration parameters was taken from EPA (2000). During model calibration, care was taken to not use parameter values outside of these ranges. The ranges reported by EPA (2000) represent typical values from observations and modeling efforts; however, the majority of the studies were conducted in regions of

the U.S. with quite different climates than the California Bay Area. Thus, there is no real reason to assume that these ranges are the only possibilities for the Guadalupe River watershed. The hydrologic model, therefore, should be re-calibrated with less consideration of these previously reported ranges, while still ensuring that the calibrated values are physically possible and reasonable. Subsequent comparison of calibrated values to these ranges could then be used to rank the Guadalupe River watershed in the context of prior studies.

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7.0 Appendix – HSPF UCI File

```
RUN

GLOBAL
  UCI Created by WinHSPF for Gua_WLA6
  START       1999/10/01 00:00  END    2005/09/30 24:00
  RUN INTERP OUTPT LEVELS    4    0
  RESUME     0 RUN     1                          UNITS    1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME-------------------------------------------------->
MESSU      24   Gua_WLA6.ech
           91   Gua_WLA6.out
WDM1       25   Gua_WLA6.wdm
WDM3       93   ..\..\data\Custom\WDM\UsableInputs\Guadalupe\Guad_clb.wdm
BINO       92   Gua_WLA6.hbn
END FILES

OPN SEQUENCE
    INGRP              INDELT 00:15
      PERLND     601
      PERLND     602
      PERLND     603
      PERLND     604
      PERLND     606
      PERLND     607
      PERLND     608
      PERLND     605
      IMPLND     602
      IMPLND     603
      IMPLND     604
      PERLND     502
      PERLND     503
      PERLND     505
      PERLND     506
      PERLND     507
      PERLND     508
      PERLND     504
      PERLND     501
      IMPLND     502
      IMPLND     503
      IMPLND     504
      PERLND     402
      PERLND     405
      PERLND     406
      PERLND     407
      PERLND     408
      IMPLND     402
      PERLND     101
      PERLND     102
      PERLND     103
      PERLND     104
      PERLND     105
      PERLND     106
      PERLND     107
      IMPLND     102
      IMPLND     103
      IMPLND     104
      PERLND     302
      PERLND     303
      PERLND     305
      PERLND     306
      PERLND     307
      PERLND     308
      IMPLND     302
      IMPLND     303
      PERLND     202
      PERLND     203
      PERLND     204
      PERLND     205
      PERLND     206
      PERLND     207
      PERLND     208
      PERLND     201
      IMPLND     202
```

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      IMPLND     203
      IMPLND     204
      PERLND     708
      RCHRES      10
      RCHRES      25
      RCHRES       5
      RCHRES       3
      RCHRES       4
      RCHRES       9
      RCHRES      13
      RCHRES      16
      RCHRES      15
      RCHRES      24
      RCHRES      12
      RCHRES      11
      RCHRES       1
      RCHRES      22
      RCHRES       2
      RCHRES      17
      RCHRES       8
      RCHRES      18
      RCHRES      19
      RCHRES       6
      RCHRES       7
      RCHRES      20
      RCHRES      21
      RCHRES      23
      RCHRES      14
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
*** <PLS >               Active Sections                                ***
*** x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  101  708    0    0    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** < PLS>                       Print-flags                            PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  101  708    5    5    5    5    5    5    5    5    5    5    5    5    1    9
  END PRINT-INFO

  BINARY-INFO
*** < PLS>               Binary Output Flags                            PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  101  708    5    5    5    5    5    5    5    5    5    5    5    5    1    9
  END BINARY-INFO

  GEN-INFO
***             Name                  Unit-systems   Printer BinaryOut
*** <PLS >                                t-series Engl Metr Engl Metr
*** x -  x                                 in  out
  101     Wetlands/Water                    1    1    0    0   92    0
  102     Residential                       1    1    0    0   92    0
  103     Commercial                        1    1    0    0   92    0
  104     Industrial                        1    1    0    0   92    0
  105     Barren Land                       1    1    0    0   92    0
  106     Agriculture                       1    1    0    0   92    0
  107     Range Land                        1    1    0    0   92    0
  201     Wetlands/Water                    1    1    0    0   92    0
  202     Residential                       1    1    0    0   92    0
  203     Commercial                        1    1    0    0   92    0
  204     Industrial                        1    1    0    0   92    0
  205     Barren Land                       1    1    0    0   92    0
  206     Agriculture                       1    1    0    0   92    0
  207     Range Land                        1    1    0    0   92    0
  208     Forest Land                       1    1    0    0   92    0
  302     Residential                       1    1    0    0   92    0
  303     Commercial                        1    1    0    0   92    0
  305     Barren Land                       1    1    0    0   92    0
  306     Agriculture                       1    1    0    0   92    0
  307     Range Land                        1    1    0    0   92    0
  308     Forest Land                       1    1    0    0   92    0
  402     Residential                       1    1    0    0   92    0
  405     Barren Land                       1    1    0    0   92    0
  406     Agriculture                       1    1    0    0   92    0
  407     Range Land                        1    1    0    0   92    0
  408     Forest Land                       1    1    0    0   92    0
  501     Wetlands/Water                    1    1    0    0   92    0
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  502     Residential                        1    1    0    0   92    0
  503     Commercial                         1    1    0    0   92    0
  504     Industrial                         1    1    0    0   92    0
  505     Barren Land                        1    1    0    0   92    0
  506     Agriculture                        1    1    0    0   92    0
  507     Range Land                         1    1    0    0   92    0
  508     Forest Land                        1    1    0    0   92    0
  601     Wetlands/Water                     1    1    0    0   92    0
  602     Residential                        1    1    0    0   92    0
  603     Commercial                         1    1    0    0   92    0
  604     Industrial                         1    1    0    0   92    0
  605     Barren Land                        1    1    0    0   92    0
  606     Agriculture                        1    1    0    0   92    0
  607     Range Land                         1    1    0    0   92    0
  608     Forest Land                        1    1    0    0   92    0
  708     Forest Land                        1    1    0    0   92    0
  END GEN-INFO

  PWAT-PARM1
*** <PLS >                    Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC  HWT IRRG IFRD
  101  708    0    1    1    1    0    0    0    0    1    1    0    0    0
  END PWAT-PARM1

  PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x                (in)   (in/hr)      (ft)               (1/in)   (1/day)
  101             1.    11.000     0.080       400      0.05     2.000     0.900
  102             1.     8.500     0.070       400      0.05     3.000     0.900
  103             1.     8.500     0.070       400      0.05     3.000     0.900
  104             1.     8.500     0.070       400      0.05     3.000     0.900
  105             0.     8.500     0.070       400      0.05     3.000     0.900
  106             0.     8.500     0.070       400      0.05     3.000     0.900
  107             1.    11.000     0.070       400      0.05     2.000     0.900
  201             1.    10.000     0.080       400      0.05     2.000     0.950
  202             1.     8.500     0.070       400      0.05     3.000     0.950
  203             1.     8.500     0.070       400      0.05     3.000     0.950
  204             1.     8.500     0.070       400      0.05     3.000     0.950
  205             0.     8.500     0.070       400      0.05     3.000     0.950
  206             0.     8.500     0.070       400      0.05     3.000     0.950
  207             1.    11.000     0.090       400      0.05     1.200     0.950
  208             1.    11.000     0.100       400      0.05     1.200     0.950
  302             1.     7.500     0.030       350      0.10     3.000     0.950
  303             1.     7.500     0.030       350      0.10     3.000     0.950
  305             0.     7.500     0.050       350      0.10     1.800     0.950
  306             0.     7.500     0.050       350      0.10     1.800     0.950
  307             1.     9.000     0.080       350      0.10     1.200     0.950
  308             1.     9.000     0.090       350      0.10     1.200     0.950
  402             1.     6.500     0.022       300      0.15     3.000     0.980
  405             0.     5.000     0.035       300      0.15     1.800     0.980
  406             0.     5.000     0.035       300      0.15     1.800     0.980
  407             1.     7.000     0.060       300      0.15     1.200     0.980
  408             1.     7.000     0.070       300      0.15     1.200     0.980
  501             1.     7.500     0.050       350      0.10     2.000     0.950
  502             1.     7.500     0.030       350      0.10     3.000     0.950
  503             1.     7.500     0.030       350      0.10     3.000     0.950
  504             1.     7.500     0.030       350      0.10     3.000     0.950
  505             0.     7.500     0.050       350      0.10     1.800     0.950
  506             0.     7.500     0.050       350      0.10     1.800     0.950
  507             1.     9.000     0.080       350      0.10     1.200     0.950
  508             1.     9.000     0.090       350      0.10     1.200     0.950
  601             1.     8.500     0.080       400      0.05     2.000     0.950
  602             1.     8.500     0.070       400      0.05     3.000     0.950
  603             1.     8.500     0.070       400      0.05     3.000     0.950
  604             1.     8.500     0.070       400      0.05     3.000     0.950
  605             0.     8.500     0.070       400      0.05     3.000     0.950
  606             0.     8.500     0.070       400      0.05     3.000     0.950
  607             1.    11.000     0.080       400      0.05     1.200     0.950
  608             1.    11.000     0.090       400      0.05     1.200     0.950
  708             1.     7.000     0.070       300      0.15     1.200     0.980
  END PWAT-PARM2

  PWAT-PARM3
*** < PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
  101            40.       35.        2.        2.     0.150     0.150     0.000
  102            40.       35.        2.        2.     0.450     0.150     0.000
  103            40.       35.        2.        2.     0.450     0.150     0.000
  104            40.       35.        2.        2.     0.450     0.150     0.000
  105            40.       35.        2.        2.     0.450     0.150     0.000
  106            40.       35.        2.        2.     0.450     0.150     0.000
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  107            40.       35.        2.        2.     0.150     0.150     0.000
  201            40.       35.        2.        2.     0.150     0.150     0.000
  202            40.       35.        2.        2.     0.450     0.150     0.000
  203            40.       35.        2.        2.     0.450     0.150     0.000
  204            40.       35.        2.        2.     0.450     0.150     0.000
  205            40.       35.        2.        2.     0.450     0.150     0.000
  206            40.       35.        2.        2.     0.450     0.150     0.000
  207            40.       35.        2.        2.     0.120     0.080     0.000
  208            40.       35.        2.        2.     0.120     0.080     0.000
  302            40.       35.        2.        2.     0.450     0.150     0.000
  303            40.       35.        2.        2.     0.450     0.150     0.000
  305            40.       35.        2.        2.     0.450     0.150     0.000
  306            40.       35.        2.        2.     0.450     0.150     0.000
  307            40.       35.        2.        2.     0.120     0.080     0.000
  308            40.       35.        2.        2.     0.120     0.080     0.000
  402            40.       35.        2.        2.     0.060     0.150     0.000
  405            40.       35.        2.        2.     0.060     0.150     0.000
  406            40.       35.        2.        2.     0.060     0.150     0.000
  407            40.       35.        2.        2.     0.020     0.080     0.000
  408            40.       35.        2.        2.     0.020     0.080     0.000
  501            40.       35.        2.        2.     0.150     0.150     0.000
  502            40.       35.        2.        2.     0.450     0.150     0.000
  503            40.       35.        2.        2.     0.450     0.150     0.000
  504            40.       35.        2.        2.     0.450     0.150     0.000
  505            40.       35.        2.        2.     0.450     0.150     0.000
  506            40.       35.        2.        2.     0.450     0.150     0.000
  507            40.       35.        2.        2.     0.120     0.080     0.000
  508            40.       35.        2.        2.     0.120     0.080     0.000
  601            40.       35.        2.        2.     0.150     0.150     0.000
  602            40.       35.        2.        2.     0.450     0.150     0.000
  603            40.       35.        2.        2.     0.450     0.150     0.000
  604            40.       35.        2.        2.     0.450     0.150     0.000
  605            40.       35.        2.        2.     0.450     0.150     0.000
  606            40.       35.        2.        2.     0.450     0.150     0.000
  607            40.       35.        2.        2.     0.120     0.080     0.000
  608            40.       35.        2.        2.     0.120     0.080     0.000
  708            40.       35.        2.        2.     0.020     0.080     0.000
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x       (in)      (in)                        (1/day)
  101           0.100     1.500     0.35     1.000     0.800     0.000
  102           0.060     0.700     0.25     0.900     0.400     0.000
  103           0.060     0.700     0.25     0.800     0.400     0.000
  104           0.060     0.700     0.25     0.800     0.400     0.000
  105           0.060     0.700     0.25     0.900     0.400     0.000
  106           0.060     0.700     0.25     0.900     0.400     0.000
  107           0.020     1.000     0.25     0.900     0.700     0.000
  201           0.100     1.500     0.35     1.000     0.800     0.000
  202           0.060     0.700     0.25     0.900     0.400     0.000
  203           0.060     0.700     0.25     0.800     0.400     0.000
  204           0.060     0.700     0.25     0.800     0.400     0.000
  205           0.060     0.700     0.25     0.900     0.400     0.000
  206           0.060     0.700     0.25     0.900     0.400     0.000
  207           0.020     1.000     0.25     1.200     0.700     0.000
  208           0.100     1.500     0.35     1.500     0.800     0.000
  302           0.060     0.500     0.25     1.000     0.500     0.000
  303           0.060     0.500     0.25     1.000     0.500     0.000
  305           0.060     0.500     0.25     1.000     0.500     0.000
  306           0.060     0.500     0.25     1.000     0.500     0.000
  307           0.020     0.700     0.25     1.200     0.500     0.000
  308           0.100     1.200     0.35     1.500     0.500     0.000
  402           0.060     0.350     0.25     2.000     0.300     0.000
  405           0.060     0.350     0.25     2.000     0.300     0.000
  406           0.060     0.350     0.25     2.000     0.300     0.000
  407           0.020     0.600     0.25     2.300     0.400     0.000
  408           0.100     1.000     0.35     2.600     0.450     0.000
  501           0.100     1.200     0.35     1.000     0.500     0.000
  502           0.060     0.500     0.25     0.800     0.500     0.000
  503           0.060     0.500     0.25     0.800     0.500     0.000
  504           0.060     0.500     0.25     0.800     0.500     0.000
  505           0.060     0.500     0.25     0.800     0.500     0.000
  506           0.060     0.500     0.25     0.800     0.500     0.000
  507           0.020     0.700     0.25     1.200     0.500     0.000
  508           0.100     1.200     0.35     1.500     0.500     0.000
  601           0.100     1.500     0.35     1.000     0.500     0.000
  602           0.060     0.700     0.25     0.800     0.500     0.000
  603           0.060     0.700     0.25     0.800     0.500     0.000
  604           0.060     0.700     0.25     0.800     0.500     0.000
  605           0.060     0.700     0.25     0.800     0.500     0.000
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  606          0.060     0.700      0.25     0.800     0.500     0.000
  607          0.020     1.000      0.25     1.200     0.700     0.000
  608          0.100     1.500      0.35     1.500     0.800     0.000
  708          0.100     1.000      0.35     2.600     0.450     0.000
  END PWAT-PARM4

  PWAT-STATE1
*** < PLS>  PWATER state variables (in)
*** x  - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  101  708      0.01      0.01      0.15      0.01       4.0      0.05      0.01
  END PWAT-STATE1

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  102  106  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  107       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  201       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  202  206  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  207       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  208       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  302  306  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  307       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  308       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  402  406  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  407       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  408       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  501  506  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  507       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  508       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  601  606  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  607       0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  608       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  708       0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2  0.2
  END MON-INTERCEP

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  102  106  0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  107       0.5  0.5  0.5  0.6  0.6  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  201       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  202  206  0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  207       0.5  0.5  0.5  0.6  0.6  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  208       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  302  306  0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  307       0.5  0.5  0.5  0.6  0.6  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  308       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  402  406  0.5  0.5  0.5  0.6  0.7  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  407       0.4  0.4  0.4  0.5  0.5  0.6  0.6  0.6  0.6  0.6  0.5  0.4
  408       0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  501       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  502  506  0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  507       0.5  0.5  0.5  0.6  0.6  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  508       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  601       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  602  606  0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  607       0.5  0.5  0.5  0.6  0.6  0.7  0.7  0.7  0.7  0.7  0.6  0.5
  608       0.7  0.7  0.7  0.8  0.9  0.9  0.9  0.9  0.9  0.9  0.8  0.7
  708       0.6  0.6  0.6  0.7  0.8  0.8  0.8  0.8  0.8  0.8  0.7  0.6
  END MON-LZETPARM
END PERLND

IMPLND
  ACTIVITY
*** <ILS >                Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  102  604    0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
*** <ILS > ******** Print-flags ******** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  102  604    5    5    5    5    5    5    1    9
  END PRINT-INFO

  BINARY-INFO
*** <ILS > **** Binary-Output-flags **** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
```

```
  102  604    5    5    5    5    5    5    1    9
  END BINARY-INFO

  GEN-INFO
***              Name             Unit-systems   Printer BinaryOut
*** <ILS >                            t-series Engl Metr Engl Metr
*** x -  x                             in  out
  102     Residential                   1    1    0    0   92    0
  103     Commercial                    1    1    0    0   92    0
  104     Industrial                    1    1    0    0   92    0
  202     Residential                   1    1    0    0   92    0
  203     Commercial                    1    1    0    0   92    0
  204     Industrial                    1    1    0    0   92    0
  302     Residential                   1    1    0    0   92    0
  303     Commercial                    1    1    0    0   92    0
  402  502Residential                   1    1    0    0   92    0
  503     Commercial                    1    1    0    0   92    0
  504     Industrial                    1    1    0    0   92    0
  602     Residential                   1    1    0    0   92    0
  603     Commercial                    1    1    0    0   92    0
  604     Industrial                    1    1    0    0   92    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  102  604    0    0    0    0    1
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  102  104       500  0.002581      0.05       0.1
  202  204       300  0.048273      0.05       0.1
  302  303       200  0.135203      0.05       0.1
  402            150  0.188268      0.05       0.1
  502  503       150  0.170094      0.05       0.1
  504            200  0.117906      0.05       0.1
  602  604       300    0.0559      0.05       0.1
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  102  604       40.       35.
  END IWAT-PARM3

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  102  604      0.01      0.01
  END IWAT-STATE1
END IMPLND

RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    1   25    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    1   25    5    5    5    5    5    5    5    5    5    5    1    9
  END PRINT-INFO

  BINARY-INFO
*** RCHRES  Binary Output level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    1   25    5    5    5    5    5    5    5    5    5    5    1    9
  END BINARY-INFO

  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                             t-series  Engl Metr LKFG
*** x -  x                               in  out
    1     Alamitos Creek          1         1    1   91    0    0   92    0
    2     Guadalupe River         1         1    1   91    0    0   92    0
    3     Randol Creek            1         1    1   91    0    0   92    0
    4     Greystone Creek         1         1    1   91    0    0   92    0
```

```
    5     Guadalupe Creek         1         1    1   91    0    0   92    0
    6    8Guadalupe River         1         1    1   91    0    0   92    0
*******************************************************************************
***this reach has 2 exits: 1=percolation pond diversion, 2=downstream flow
    9     Guadalupe Creek         2         1    1   91    0    0   92    0
*******************************************************************************
   10     McAbee/Golf Cks         1         1    1   91    0    0   92    0
   11   13Alamitos Creek          1         1    1   91    0    0   92    0
   14     Guadalupe River         1         1    1   91    0    0   92    0
   15     Calero, Arroyo          1         1    1   91    0    0   92    0
   16   17Ross Creek              1         1    1   91    0    0   92    0
   18     Canoas Creek            1         1    1   91    0    0   92    0
   19     Gatos Creek, Los        1         1    1   91    0    0   92    0
   20   21Guadalupe River         1         1    1   91    0    0   92    0
*******************************************************************************
***this reach has 3 exits: 1=ditch div, 2=ditch div, 3=downstream flow
   22     Gatos Creek, Los        3         1    1   91    0    0   92    0
*******************************************************************************
   23     Guadalupe River         1         1    1   91    0    0   92    0
   24     Alamitos Creek          1         1    1   91    0    0   92    0
   25     GUAD MET STN CONTRIB    1         1    1   91    0    0   92    0
  END GEN-INFO

  HYDR-PARM1
***         Flags for HYDR section
***RC HRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
*** x  - x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
    1    8   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
***this reach has 2 exits*assign ftable column for downstream*assign exit priority
    9        0  1  1  1    0  4  0  0  0       1  0  0  0  0       1  1  1  1  1
*******************************************************************************
   10   21   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
***this reach has 3 exits*assign ftable column for downstream*assign exit priority
   22        0  1  1  1    0  0  4  0  0       1  2  0  0  0       1  1  1  1  1
*******************************************************************************
   23   25   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
*** RCHRES FTBW FTBU       LEN     DELTH     STCOR        KS      DB50
*** x -  x             (miles)      (ft)      (ft)                 (in)
    1         0    1       0.8        36       3.2       0.5      0.01
    2         0    2      0.26         3       3.2       0.5      0.01
    3         0    3      2.94      1000       3.2       0.5      0.01
    4         0    4      2.45       672       3.2       0.5      0.01
    5         0    5      2.45       305       3.2       0.5      0.01
    6         0    6      1.15        13       3.2       0.5      0.01
    7         0    7       0.6        10       3.2       0.5      0.01
    8         0    8      1.47        30       3.2       0.5      0.01
    9         0    9      3.27       174       3.2       0.5      0.01
   10         0   10      2.13       171       3.2       0.5      0.01
   11         0   11         1        10       3.2       0.5      0.01
   12         0   12      0.87        43       3.2       0.5      0.01
   13         0   13      4.06       302       3.2       0.5      0.01
   14         0   14      2.29        16       3.2       0.5      0.01
   15         0   15      3.93       148       3.2       0.5      0.01
   16         0   16      1.77       833       3.2       0.5      0.01
   17         0   17      4.88       171       3.2       0.5      0.01
   18         0   18      7.26        43       3.2       0.5      0.01
   19         0   19       1.6        39       3.2       0.5      0.01
   20         0   20      3.53        62       3.2       0.5      0.01
   21         0   21      3.52        39       3.2       0.5      0.01
   22         0   22      6.17       171       3.2       0.5      0.01
   23         0   23      2.46        23       3.2       0.5      0.01
   24         0   24      0.66        13       3.2       0.5      0.01
   25         0   25       0.3        50       3.2       0.5      0.01
  END HYDR-PARM2

  HYDR-INIT
***         Initial conditions for HYDR section
***RC HRES       VOL  CAT Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft      for each possible   exit  for each possible exit,ft3
    1              7       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    2    3         3       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    4              1       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    5              7       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    6             20       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    7              0       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    8             19       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
    9             12       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   10              3       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
```

```
   11              6       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   12              5       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   13              7       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   14            100       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   15              9       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   16              2       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   17             20       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   18             56       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   19              7       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   20            101       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   21            138       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   22             19       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   23            103       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   24              3       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
   25              7       4.2  4.5  4.5  4.5  4.2       2.1  1.2  0.5  1.2  1.8
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE     10
 rows cols                                  ***
    8    4
     depth      area    volume  outflow1 ***
       0.0      3.55       0.0       0.0
       0.1       3.6      0.37      1.13
      1.03      4.08      3.91     52.09
      1.28      4.21      4.97     75.58
       1.6      12.7      8.99     99.66
      1.92     13.03     13.11    183.49
      33.0     45.15    917.26  91414.96
     64.08     77.28   2819.99  412547.0
  END FTABLE 10
  FTABLE     25
 rows cols                                  ***
    8    4
     depth      area    volume  outflow1 ***
       0.0      6.23       0.0       0.0
      0.13      6.31      0.84       3.6
      1.34      7.02       8.9    166.26
      1.68      7.22     11.29     241.1
       2.1     21.77     20.32     314.9
      2.52     22.27     29.56    578.52
     43.23     70.62   1920.43 270102.91
     83.95    118.97   5779.92 1188123.0
  END FTABLE 25
  FTABLE      5
 rows cols                                  ***
    8    4
     depth      area    volume  outflow1 ***
       0.0      6.23       0.0       0.0
      0.13      6.31      0.84      3.37
      1.34      7.03      8.91    155.59
      1.68      7.23      11.3    225.63
       2.1      21.8     20.35     294.7
      2.52      22.3     29.61    541.43
     43.23     70.72   1923.14 252774.89
     83.94    119.15   5788.121111906.13
  END FTABLE  5
  FTABLE      3
 rows cols                                  ***
    8    4
     depth      area    volume  outflow1 ***
       0.0      3.82       0.0       0.0
      0.09      3.88      0.34       1.4
      0.88      4.44      3.62     64.76
       1.1       4.6      4.61     93.98
      1.37     13.88      8.36    124.72
      1.64     14.27     12.22    229.97
     28.23     52.12    894.73 119268.43
     54.82     89.98   2783.67 546130.63
  END FTABLE  3
  FTABLE      4
 rows cols                                  ***
    8    4
     depth      area    volume  outflow1 ***
       0.0      2.33       0.0       0.0
      0.07      2.37      0.17      0.67
      0.72      2.76      1.83     30.71
       0.9      2.87      2.34      44.6
      1.13      8.65      4.26     59.68
      1.35      8.92      6.24    110.26
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     23.2     34.85    484.38   60338.1
    45.05     60.78   1529.07 281284.09
 END FTABLE  4
 FTABLE      9
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0       9.8       0.0       0.0
     0.15      9.92      1.47      3.11
     1.49     10.98     15.52    143.44
     1.87     11.28     19.67    207.99
     2.33     33.98     35.36    270.71
      2.8     34.71     51.39    496.97
    48.07     106.4   3245.77 226547.69
    93.35    178.09   9685.68 986438.44
 END FTABLE  9
 FTABLE     13
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      7.65       0.0       0.0
     0.11      7.76      0.86      1.41
     1.11      8.74       9.1     65.02
     1.39      9.01     11.56     94.32
     1.73     27.18     20.88     124.0
     2.08     27.86     30.43    228.15
    35.74     94.06   2082.18 111444.38
    69.39    160.26   6361.85 499177.88
 END FTABLE 13
 FTABLE     16
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      2.48       0.0       0.0
     0.09      2.52      0.23      1.94
     0.92      2.87      2.46     89.31
     1.15      2.97      3.14    129.62
     1.44      8.97      5.68    171.65
     1.73      9.21       8.3    316.35
    29.64      33.1    598.93 161982.75
    57.56     56.99   1856.51 738375.81
 END FTABLE 16
 FTABLE     15
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      8.71       0.0       0.0
     0.12      8.82      1.08       1.4
     1.23      9.88     11.43      64.5
     1.54     10.17     14.52     93.55
     1.92     30.66     26.17    122.54
     2.31     31.39      38.1    225.28
    39.61    102.43   2534.16 107341.34
    76.92    173.47   7680.37 476126.41
 END FTABLE 15
 FTABLE     24
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0       2.2       0.0       0.0
     0.16      2.23      0.35      2.32
     1.59      2.46       3.7    107.02
     1.99      2.52      4.69    155.17
     2.49      7.59      8.43    201.56
     2.98      7.75     12.24    369.85
    51.19      23.3    760.74 166313.98
     99.4     38.84   2258.57 719801.19
 END FTABLE 24
 FTABLE     12
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      3.37       0.0       0.0
     0.18       3.4      0.59      5.04
     1.76      3.74      6.24    232.38
      2.2      3.83       7.9    336.89
     2.75     11.53     14.17    436.34
     3.29     11.77     20.57    800.16
    56.56     34.25   1246.15 352270.34
   109.82     56.74   3669.581510015.88
 END FTABLE 12
```

```
 FTABLE     11
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      4.19       0.0       0.0
     0.19      4.23      0.78      2.69
     1.85      4.64      8.18    124.08
     2.32      4.75     10.35    179.89
      2.9      14.3     18.56     232.6
     3.48     14.58     26.92    426.38
    59.68     41.74   1609.43 185672.23
   115.88      68.9   4718.43  791774.0
 END FTABLE 11
 FTABLE      1
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      3.94       0.0       0.0
      0.2      3.98      0.81      7.87
     2.05      4.34      8.46    363.36
     2.56      4.44     10.71    526.73
      3.2     13.36     19.17    679.26
     3.84     13.61     27.79   1244.43
    65.86      37.8   1621.83 531309.38
   127.88     61.98   4716.052244222.25
 END FTABLE  1
 FTABLE     22
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0     16.25       0.0       0.0
     0.14     16.46      2.25      1.71
     1.37     18.31     23.75     79.05
     1.72     18.82     30.13    114.64
     2.15     56.72     54.21     149.6
     2.58     58.01     78.84    274.79
    44.23    182.61   5090.71 127628.41
    85.89    307.22  15293.46 560180.38
 END FTABLE 22
 FTABLE      2
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      1.63       0.0       0.0
     0.24      1.65      0.39      6.78
     2.38      1.78      4.07    312.85
     2.98      1.82      5.15    453.46
     3.72      5.49       9.2    582.47
     4.47      5.58     13.32   1066.19
    76.72      14.8    749.69 442180.72
   148.97     24.02   2152.331840445.25
 END FTABLE  2
 FTABLE     17
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0     15.46       0.0       0.0
     0.15     15.65      2.41      2.82
     1.55     17.29     25.34    130.18
     1.93     17.75     32.11    188.76
     2.42     53.48     57.69    245.41
      2.9     54.62     83.82     450.4
    49.79    165.57   5246.11 203749.36
    96.68    276.51  15610.36 884179.31
 END FTABLE 17
 FTABLE      8
rows cols                                  ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      9.47       0.0       0.0
     0.24      9.55      2.32      9.34
     2.44     10.34     24.21    431.32
     3.06     10.55     30.59     625.2
     3.82     31.77     54.66    802.55
     4.58     32.31     79.14   1468.81
    78.69     85.06   4428.37 606334.56
    152.8    137.81  12686.552517522.75
 END FTABLE  8
 FTABLE     18
rows cols                                  ***
   8    4
```

```
    depth      area    volume  outflow1 ***
      0.0     34.22       0.0       0.0
      0.2     34.57      6.87      2.63
      2.0     37.74     71.83    121.28
      2.5     38.62     90.88    175.82
     3.12    116.29    162.74    226.88
     3.74    118.49    235.97     415.7
    64.25    331.61  13853.81  178352.5
   124.76    544.73   40367.7 755150.19
 END FTABLE 18
 FTABLE     19
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      5.41       0.0       0.0
     0.16      5.47      0.88      2.73
     1.62      6.03      9.24    125.81
     2.02      6.19     11.71    182.41
     2.52     18.65     21.03    236.84
     3.03     19.04     30.54    434.56
     52.0     56.91   1890.35 194743.17
   100.98     94.79   5605.04 841563.44
 END FTABLE 19
 FTABLE      6
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0       8.9       0.0       0.0
     0.27      8.98      2.46     10.26
     2.75      9.67     25.53    473.78
     3.44      9.86     32.25     686.7
      4.3     29.68     57.54    879.02
     5.16     30.16     83.25    1607.8
    88.51     76.69   4536.14  649941.0
   171.86    123.22  12867.11 2668301.0
 END FTABLE  6
 FTABLE      7
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0      0.12       0.0       0.0
     0.03      0.13       0.0      0.01
     0.28      0.16      0.04      0.32
     0.35      0.17      0.05      0.47
     0.43      0.52      0.09      0.67
     0.52      0.55      0.14      1.25
     8.91      3.01     15.05    929.75
     17.3      5.47      50.6   4692.68
 END FTABLE  7
 FTABLE     20
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0     37.29       0.0       0.0
     0.34     37.57      12.6      24.4
     3.37     40.17    130.32   1126.64
     4.21     40.89    164.42   1632.88
     5.26    123.02    292.85   2080.84
     6.31    124.82    423.17   3802.42
   108.32    299.53  22067.191486230.88
   210.33    474.24  61532.86 5985537.0
 END FTABLE 20
 FTABLE     21
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0     44.88       0.0       0.0
     0.38      45.2     17.15      28.9
     3.81     48.12     177.1   1334.65
     4.76     48.93     223.3   1934.33
     5.95    147.21     397.3   2458.73
     7.14    149.24    573.71   4490.54
   122.59    345.99  29159.751721832.38
   238.03    542.75  80460.16 6854305.5
 END FTABLE 21
 FTABLE     23
rows cols                                ***
   8    4
    depth      area    volume  outflow1 ***
      0.0     32.62       0.0       0.0
     0.39     32.85     12.79     28.67
```

```
      3.91     34.94    132.01   1324.33
      4.88     35.53    166.43   1919.38
      6.11    106.87    296.05   2438.54
      7.33    108.32    427.45    4453.2
    125.78    249.37  21612.62 1700888.5
    244.24    390.42  59505.26 6754707.5
  END FTABLE 23
  FTABLE     14
 rows cols                              ***
    8    4
     depth      area    volume  outflow1 ***
       0.0     31.27       0.0       0.0
       0.4     31.49     12.49     26.68
      3.98     33.47    128.88    1232.5
      4.98     34.03    162.47   1786.25
      6.22    102.35    288.97    2268.6
      7.47    103.73    417.18   4142.58
    128.15    237.59   21014.11577846.75
    248.84    371.44  57765.67 6255200.0
  END FTABLE 14
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x ***
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME PERLND 601 608 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME PERLND 601 608 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 601 608 EXTNL  PETINP
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME PERLND 501 508 EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME PERLND 501 508 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 501 508 EXTNL  PETINP
*** Met Seg 2066 J.R
WDM3   111 PREC     ENGLZERO          SAME PERLND 402 408 EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME PERLND 402 408 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 402 408 EXTNL  PETINP
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME PERLND 101 107 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME PERLND 101 107 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 101 107 EXTNL  PETINP
*** Met Seg 1527 VAS
WDM3    51 PREC     ENGLZERO          SAME PERLND 201 308 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME PERLND 201 308 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 201 308 EXTNL  PETINP
*** Met Seg 1526 GUA
WDM3    31 PREC     ENGLZERO          SAME PERLND 708     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME PERLND 708     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME PERLND 708     EXTNL  PETINP
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME IMPLND 602 604 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME IMPLND 602 604 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME IMPLND 602 604 EXTNL  PETINP
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME IMPLND 502 504 EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME IMPLND 502 504 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME IMPLND 502 504 EXTNL  PETINP
*** Met Seg 2066 J.R
WDM3   111 PREC     ENGLZERO          SAME IMPLND 402     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME IMPLND 402     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME IMPLND 402     EXTNL  PETINP
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME IMPLND 102 104 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME IMPLND 102 104 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME IMPLND 102 104 EXTNL  PETINP
*** Met Seg 1527 VAS
WDM3    51 PREC     ENGLZERO          SAME IMPLND 202 303 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME IMPLND 202 303 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME IMPLND 202 303 EXTNL  PETINP
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME RCHRES   1   2 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES   1   2 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES   1   2 EXTNL  POTEV
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME RCHRES   6  12 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES   6  12 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES   6  12 EXTNL  POTEV
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME RCHRES  18     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  18     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  18     EXTNL  POTEV
```

```
*** Met Seg 2065 ALA
WDM3    91 PREC     ENGLZERO          SAME RCHRES  20     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  20     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  20     EXTNL  POTEV
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME RCHRES   3   4 EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES   3   4 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES   3   4 EXTNL  POTEV
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME RCHRES  13     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES  13     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  13     EXTNL  POTEV
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME RCHRES  15     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES  15     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  15     EXTNL  POTEV
*** Met Seg 1513 CAL
WDM3    11 PREC     ENGLZERO          SAME RCHRES  24     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES  24     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  24     EXTNL  POTEV
*** Met Seg 2066 J.R
WDM3   111 PREC     ENGLZERO          SAME RCHRES   5     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES   5     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES   5     EXTNL  POTEV
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME RCHRES  14     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  14     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  14     EXTNL  POTEV
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME RCHRES  19     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  19     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  19     EXTNL  POTEV
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME RCHRES  21     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  21     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  21     EXTNL  POTEV
*** Met Seg 1453 SAN
WDM3   171 PREC     ENGLZERO          SAME RCHRES  23     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  23     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  23     EXTNL  POTEV
*** Met Seg 1527 VAS
WDM3    51 PREC     ENGLZERO          SAME RCHRES  16  17 EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  16  17 EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  16  17 EXTNL  POTEV
*** Met Seg 1527 VAS
WDM3    51 PREC     ENGLZERO          SAME RCHRES  22     EXTNL  PREC
WDM3   173 ATEM     ENGL              SAME RCHRES  22     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  22     EXTNL  POTEV
*** Met Seg 1526 GUA
WDM3    31 PREC     ENGLZERO          SAME RCHRES  25     EXTNL  PREC
WDM3   193 ATEM     ENGL              SAME RCHRES  25     EXTNL  GATMP
WDM3    96 PEVT     ENGL              SAME RCHRES  25     EXTNL  POTEV
******RESERVOIRS************
WDM3  3074 FLOW     ENGL        0.0207SAME RCHRES   5     INFLOW IVOL
WDM3  3072 FLOW     ENGL        0.0207SAME RCHRES  13     INFLOW IVOL
WDM3  3071 FLOW     ENGL        0.0207SAME RCHRES  15     INFLOW IVOL
WDM3  3073 FLOW     ENGL        0.0207SAME RCHRES  22     INFLOW IVOL
******DIVERSIONS************
*** Percolation pond diversion - it has 1st priority and is the Exit # 1 outflow
WDM3  4076 DIV0     ENGL              SAME RCHRES   9     EXTNL  OUTDGT 1
*** Kirk ditch diversion - it has 1st priority and is the Exit # 1 outflow
WDM3  4077 DIV1     ENGL              SAME RCHRES  22     EXTNL  OUTDGT 1
*** Page ditch diversion - it has 2nd priority and is the Exit # 2 outflow
WDM3  4078 DIV2     ENGL              SAME RCHRES  22     EXTNL  OUTDGT 2
END EXT SOURCES

SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***       <sb>
<Name>   x                  <-factor->     <Name>   x        ***        x x
PERLND 602                       650.3     RCHRES  10      2
IMPLND 602                       650.3     RCHRES  10      1
PERLND 603                        38.2     RCHRES  10      2
IMPLND 603                        38.2     RCHRES  10      1
PERLND 605                        22.7     RCHRES  10      2
PERLND 607                          18     RCHRES  10      2
PERLND 608                       797.9     RCHRES  10      2
PERLND 708                         870     RCHRES  25      2
PERLND 402                         6.7     RCHRES   5      2
IMPLND 402                         6.7     RCHRES   5      1
PERLND 405                        83.2     RCHRES   5      2
PERLND 406                        65.5     RCHRES   5      2
```

PERLND	407	409.6	RCHRES	5	2
PERLND	408	2909.2	RCHRES	5	2
RCHRES	25		RCHRES	5	3
PERLND	502	192.6	RCHRES	3	2
IMPLND	502	192.6	RCHRES	3	1
PERLND	503	26.2	RCHRES	3	2
IMPLND	503	26.2	RCHRES	3	1
PERLND	505	8.6	RCHRES	3	2
PERLND	506	18.6	RCHRES	3	2
PERLND	507	279.7	RCHRES	3	2
PERLND	508	754.8	RCHRES	3	2
PERLND	502	202.8	RCHRES	4	2
IMPLND	502	202.8	RCHRES	4	1
PERLND	503	7.1	RCHRES	4	2
IMPLND	503	7.1	RCHRES	4	1
PERLND	507	175.5	RCHRES	4	2
PERLND	508	322.6	RCHRES	4	2
PERLND	601	5.9	RCHRES	9	2
PERLND	602	372.1	RCHRES	9	2
IMPLND	602	372.1	RCHRES	9	1
PERLND	603	38.7	RCHRES	9	2
IMPLND	603	38.7	RCHRES	9	1
PERLND	604	16.8	RCHRES	9	2
IMPLND	604	16.8	RCHRES	9	1
PERLND	605	69.5	RCHRES	9	2
PERLND	607	117.8	RCHRES	9	2
PERLND	608	274.6	RCHRES	9	2
RCHRES	5		RCHRES	9	3
PERLND	502	269.1	RCHRES	13	2
IMPLND	502	269.1	RCHRES	13	1
PERLND	503	10.9	RCHRES	13	2
IMPLND	503	10.9	RCHRES	13	1
PERLND	504	8.6	RCHRES	13	2
IMPLND	504	8.6	RCHRES	13	1
PERLND	505	6.2	RCHRES	13	2
PERLND	506	94	RCHRES	13	2
PERLND	507	638.1	RCHRES	13	2
PERLND	508	1388	RCHRES	13	2
PERLND	302	554.2	RCHRES	16	2
IMPLND	302	554.2	RCHRES	16	1
PERLND	303	7.1	RCHRES	16	2
IMPLND	303	7.1	RCHRES	16	1
PERLND	305	12.4	RCHRES	16	2
PERLND	306	102.1	RCHRES	16	2
PERLND	307	14.8	RCHRES	16	2
PERLND	308	442.2	RCHRES	16	2
PERLND	501	3.4	RCHRES	15	2
PERLND	502	273.7	RCHRES	15	2
IMPLND	502	273.7	RCHRES	15	1
PERLND	503	9.3	RCHRES	15	2
IMPLND	503	9.3	RCHRES	15	1
PERLND	504	9.9	RCHRES	15	2
IMPLND	504	9.9	RCHRES	15	1
PERLND	506	567	RCHRES	15	2
PERLND	507	2340.9	RCHRES	15	2
PERLND	502	131.5	RCHRES	24	2
IMPLND	502	131.5	RCHRES	24	1
PERLND	503	6.6	RCHRES	24	2
IMPLND	503	6.6	RCHRES	24	1
PERLND	506	103.7	RCHRES	24	2
PERLND	507	1.4	RCHRES	24	2
PERLND	508	57.1	RCHRES	24	2
RCHRES	13		RCHRES	24	3
RCHRES	15		RCHRES	24	3
PERLND	602	123.1	RCHRES	12	2
IMPLND	602	123.1	RCHRES	12	1
PERLND	603	13.3	RCHRES	12	2
IMPLND	603	13.3	RCHRES	12	1
PERLND	607	107.2	RCHRES	12	2
RCHRES	3		RCHRES	12	3
RCHRES	24		RCHRES	12	3
PERLND	602	85.1	RCHRES	11	2
IMPLND	602	85.1	RCHRES	11	1
PERLND	603	5.8	RCHRES	11	2
IMPLND	603	5.8	RCHRES	11	1
PERLND	606	4.6	RCHRES	11	2
PERLND	607	104	RCHRES	11	2
PERLND	608	15	RCHRES	11	2
RCHRES	4		RCHRES	11	3
RCHRES	12		RCHRES	11	3
PERLND	601	26.9	RCHRES	1	2

```
PERLND 602                          87     RCHRES   1      2
IMPLND 602                          87     RCHRES   1      1
PERLND 603                         0.5     RCHRES   1      2
IMPLND 603                         0.5     RCHRES   1      1
PERLND 604                         1.2     RCHRES   1      2
IMPLND 604                         1.2     RCHRES   1      1
PERLND 606                        80.9     RCHRES   1      2
PERLND 607                       100.4     RCHRES   1      2
PERLND 608                       120.5     RCHRES   1      2
RCHRES  10                                 RCHRES   1      3
RCHRES  11                                 RCHRES   1      3
PERLND 201                        78.1     RCHRES  22      2
PERLND 202                      1622.2     RCHRES  22      2
IMPLND 202                      1622.2     RCHRES  22      1
PERLND 203                       350.5     RCHRES  22      2
IMPLND 203                       350.5     RCHRES  22      1
PERLND 204                       242.4     RCHRES  22      2
IMPLND 204                       242.4     RCHRES  22      1
PERLND 205                        99.9     RCHRES  22      2
PERLND 601                        20.6     RCHRES   2      2
PERLND 602                        30.8     RCHRES   2      2
IMPLND 602                        30.8     RCHRES   2      1
PERLND 603                        17.3     RCHRES   2      2
IMPLND 603                        17.3     RCHRES   2      1
RCHRES   1                                 RCHRES   2      3
*******************************************************************************
*** transfers to Exit 2 outflow downstream - see MASS-LINK #4
RCHRES   9                                 RCHRES   2      4
*******************************************************************************
PERLND 202                      1732.3     RCHRES  17      2
IMPLND 202                      1732.3     RCHRES  17      1
PERLND 203                       260.6     RCHRES  17      2
IMPLND 203                       260.6     RCHRES  17      1
PERLND 204                          14     RCHRES  17      2
IMPLND 204                          14     RCHRES  17      1
PERLND 205                        59.6     RCHRES  17      2
PERLND 206                        37.5     RCHRES  17      2
PERLND 207                        12.2     RCHRES  17      2
PERLND 208                       376.8     RCHRES  17      2
RCHRES  16                                 RCHRES  17      3
PERLND 601                          43     RCHRES   8      2
PERLND 602                       329.2     RCHRES   8      2
IMPLND 602                       329.2     RCHRES   8      1
PERLND 603                       140.5     RCHRES   8      2
IMPLND 603                       140.5     RCHRES   8      1
PERLND 604                        35.4     RCHRES   8      2
IMPLND 604                        35.4     RCHRES   8      1
PERLND 606                       143.9     RCHRES   8      2
RCHRES   2                                 RCHRES   8      3
PERLND 601                       158.1     RCHRES  18      2
PERLND 602                      3156.5     RCHRES  18      2
IMPLND 602                      3156.5     RCHRES  18      1
PERLND 603                       577.4     RCHRES  18      2
IMPLND 603                       577.4     RCHRES  18      1
PERLND 604                       376.8     RCHRES  18      2
IMPLND 604                       376.8     RCHRES  18      1
PERLND 605                       375.8     RCHRES  18      2
PERLND 606                       824.8     RCHRES  18      2
PERLND 607                      1928.1     RCHRES  18      2
PERLND 608                         210     RCHRES  18      2
PERLND 102                       659.8     RCHRES  19      2
IMPLND 102                       659.8     RCHRES  19      1
PERLND 103                       267.1     RCHRES  19      2
IMPLND 103                       267.1     RCHRES  19      1
PERLND 104                       216.8     RCHRES  19      2
IMPLND 104                       216.8     RCHRES  19      1
PERLND 105                         9.9     RCHRES  19      2
*******************************************************************************
*** transfers to Exit 3 outflow downstream - see MASS-LINK #5
RCHRES  22                                 RCHRES  19      5
*******************************************************************************
PERLND 602                         166     RCHRES   6      2
IMPLND 602                         166     RCHRES   6      1
PERLND 603                        53.6     RCHRES   6      2
IMPLND 603                        53.6     RCHRES   6      1
PERLND 604                         5.1     RCHRES   6      2
IMPLND 604                         5.1     RCHRES   6      1
RCHRES   8                                 RCHRES   6      3
RCHRES  17                                 RCHRES   6      3
PERLND 602                        39.8     RCHRES   7      2
IMPLND 602                        39.8     RCHRES   7      1
```

```
PERLND 604                          2.2     RCHRES   7      2
IMPLND 604                          2.2     RCHRES   7      1
PERLND 606                            0     RCHRES   7      2
RCHRES   6                                  RCHRES   7      3
PERLND 602                       2183.9     RCHRES  20      2
IMPLND 602                       2183.9     RCHRES  20      1
PERLND 603                        362.8     RCHRES  20      2
IMPLND 603                        362.8     RCHRES  20      1
PERLND 604                          112     RCHRES  20      2
IMPLND 604                          112     RCHRES  20      1
PERLND 605                         24.7     RCHRES  20      2
PERLND 607                            0     RCHRES  20      2
RCHRES   7                                  RCHRES  20      3
RCHRES  18                                  RCHRES  20      3
PERLND 101                         27.2     RCHRES  21      2
PERLND 102                       1732.9     RCHRES  21      2
IMPLND 102                       1732.9     RCHRES  21      1
PERLND 103                        945.3     RCHRES  21      2
IMPLND 103                        945.3     RCHRES  21      1
PERLND 104                       1300.6     RCHRES  21      2
IMPLND 104                       1300.6     RCHRES  21      1
PERLND 105                        557.9     RCHRES  21      2
PERLND 106                          7.8     RCHRES  21      2
PERLND 107                        219.3     RCHRES  21      2
RCHRES  19                                  RCHRES  21      3
RCHRES  20                                  RCHRES  21      3
PERLND 102                        347.2     RCHRES  23      2
IMPLND 102                        347.2     RCHRES  23      1
PERLND 103                          251     RCHRES  23      2
IMPLND 103                          251     RCHRES  23      1
PERLND 104                       1050.6     RCHRES  23      2
IMPLND 104                       1050.6     RCHRES  23      1
PERLND 105                        326.5     RCHRES  23      2
PERLND 106                        290.4     RCHRES  23      2
RCHRES  21                                  RCHRES  23      3
PERLND 101                        388.3     RCHRES  14      2
PERLND 102                        324.1     RCHRES  14      2
IMPLND 102                        324.1     RCHRES  14      1
PERLND 103                        133.6     RCHRES  14      2
IMPLND 103                        133.6     RCHRES  14      1
PERLND 104                          304     RCHRES  14      2
IMPLND 104                          304     RCHRES  14      1
PERLND 105                        311.1     RCHRES  14      2
PERLND 106                          760     RCHRES  14      2
PERLND 107                         22.3     RCHRES  14      2
RCHRES  23                                  RCHRES  14      3
END SCHEMATIC

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x         <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
RCHRES   5 HYDR   RO     1 1          AVER WDM1  1002 FLOW   1 ENGL AGGR REPL
*******************************************************************************
*** "O      2" is the downstream outflow; "RO" is total outflow, incl. diversion
RCHRES   9 HYDR   O      2 1          AVER WDM1  1006 FLOW   1 ENGL AGGR REPL
*******************************************************************************
RCHRES  12 ROFLOW ROVOL  1 1 1.4087e-3     WDM   1041 SIMQ   1 ENGL AGGR REPL
*******************************************************************************
*** "O      3" is the downstream outflow; "RO" is total outflow, incl. diversion
RCHRES  22 HYDR   O      3 1          AVER WDM1  1005 FLOW   1 ENGL AGGR REPL
RCHRES  22 ROFLOW ROVOL  1 1 2.6041e-3     WDM   1033 SIMQ   1 ENGL AGGR REPL
RCHRES  17 ROFLOW ROVOL  1 1 1.9374e-3     WDM   1025 SIMQ   1 ENGL AGGR REPL
RCHRES  18 HYDR   RO     1 1          AVER WDM1  1049 FLOW   1 ENGL AGGR REPL
RCHRES  21 HYDR   RO     1 1          AVER WDM1  1004 FLOW   1 ENGL AGGR REPL
RCHRES  21 ROFLOW ROVOL  1 1 2.0369e-4     WDM   1017 SIMQ   1 ENGL AGGR REPL
RCHRES  21 HYDR   RO     1 1          AVER WDM1  8001 FLOW   1 ENGL AGGR REPL
END EXT TARGETS

MASS-LINK
  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
IMPLND     IWTGAS SODOXM                   RCHRES         INFLOW OXIF   1
IMPLND     IWTGAS SOHT                     RCHRES         INFLOW IHEAT  1
IMPLND     SOLIDS SOSLD  1        0.05     RCHRES         INFLOW ISED   1
IMPLND     SOLIDS SOSLD  1        0.55     RCHRES         INFLOW ISED   2
IMPLND     SOLIDS SOSLD  1         0.4     RCHRES         INFLOW ISED   3
  END MASS-LINK    1
MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
```

```
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
PERLND     PWTGAS PODOXM                   RCHRES         INFLOW OXIF   1
PERLND     PWTGAS POHT                     RCHRES         INFLOW IHEAT  1
PERLND     PEST   POPST  1                 RCHRES         INFLOW IDQAL  1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  1 1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  2 1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  3 1
PERLND     SEDMNT SOSED  1        0.05     RCHRES         INFLOW ISED   1
PERLND     SEDMNT SOSED  1        0.55     RCHRES         INFLOW ISED   2
PERLND     SEDMNT SOSED  1         0.4     RCHRES         INFLOW ISED   3
  END MASS-LINK    2
  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
RCHRES     ROFLOW                          RCHRES         INFLOW
  END MASS-LINK    3
  MASS-LINK        4
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
*******************************************************************************
*** this transfers Exit 2 outflow (OVOL   2) downstream
RCHRES     HYDR   OVOL   2                 RCHRES         INFLOW IVOL
  END MASS-LINK    4
  MASS-LINK        5
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
*******************************************************************************
*** this transfers Exit 3 outflow (OVOL   3) downstream
RCHRES     HYDR   OVOL   3                 RCHRES         INFLOW IVOL
  END MASS-LINK    5
  MASS-LINK       90
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
*******************************************************************************
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   4
PERLND     PWATER TAET                     COPY           INPUT  MEAN   5
PERLND     PWATER UZS                      COPY           INPUT  MEAN   6
PERLND     PWATER LZS                      COPY           INPUT  MEAN   7
  END MASS-LINK   90
  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   4
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   5
  END MASS-LINK   91
END MASS-LINK

END RUN
```