HYDROLOGICAL SIMULATION PROGRAM–FORTRAN MODELING OF THE SINCLAIR-DYES INLET WATERSHED FOR THE PUGET SOUND NAVAL SHIPYARD AND INTERMEDIATE MAINTENANCE FACILITY ENVIRONMENTAL INVESTMENT PROJECT – FY 2006 REPORT

Friday, September 29, 2006

US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
(601) 634-3441

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Prepared for

Puget Sound Naval Shipyard and Intermediate Maintenance Facility
Environmental Division

Prepared by

US Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory
Hydrologic Systems Branch
Watershed Systems Group
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Environmental Investment (ENVVEST) project was initiated, under a final project agreement among PSNS & IMF, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology (WDOE) on September 25th 2000 (Navy, Ecology, and USEPA, 2000), to develop better ways to protect and improve environmental quality than can be accomplished under the current regulatory framework. One goal of the effort is to develop an integrated watershed modeling system for the Sinclair–Dyes Inlet watershed in Kitsap County, Washington (Figure 1). Selected watershed and receiving water models will be capable of simulating water quantity and water quality for both existing and future conditions. These model simulations will be used to address system–wide issues related to ecological risk assessment and environmental resource management for the Sinclair–Dyes Inlet watershed. The watershed model is an application of the Hydrological Simulation Program – FORTRAN (HSPF) model. Hydrology and non–point source contaminant loads, computed using a number of HSPF models, will serve as input to the Curvilinear Hydrodynamics in 3 Dimensions (CH3D) and WASP receiving water models.

U.S. Environmental Protection Agency (EPA) sponsored public domain Hydrological Simulation Program – FORTRAN (HSPF) models have been deployed to the Sinclair and Dyes Inlet watershed in Kitsap County, Washington, USA (see Figure 1) in support of ongoing technical studies for the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Environmental Investment (ENVVEST) project (ENVVEST Regulatory Working Group, 2002). The U.S. Army Engineer Research and Development Center (ERDC) System-wide water resources program (SWRRP) tool catalog HSPF model description (Price, D.L., personal communication, 2005) is provided in Appendix 1.

The objective of this document is to summarize activities related to Hydrological Simulation Program–Fortran (HSPF) model development, and associated model determination and application for the Sinclair–Dyes Inlet watershed located in Kitsap County, Washington. These efforts support the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Environmental Investment (ENVVEST) Project (Navy, Ecology, and USEPA 2000). This document identifies and describes the watershed characteristics and types of data that were utilized for each model, and presents the approach that was followed for constructing, calibrating, and verifying the HSPF models. This report supersedes any previous U.S. Army ERDC reports documenting HSPF simulation modeling in the Sinclair-Dyes Inlet watershed for the Puget Sound Naval Shipyard and Intermediate Maintenance Facility Environmental Investment project.

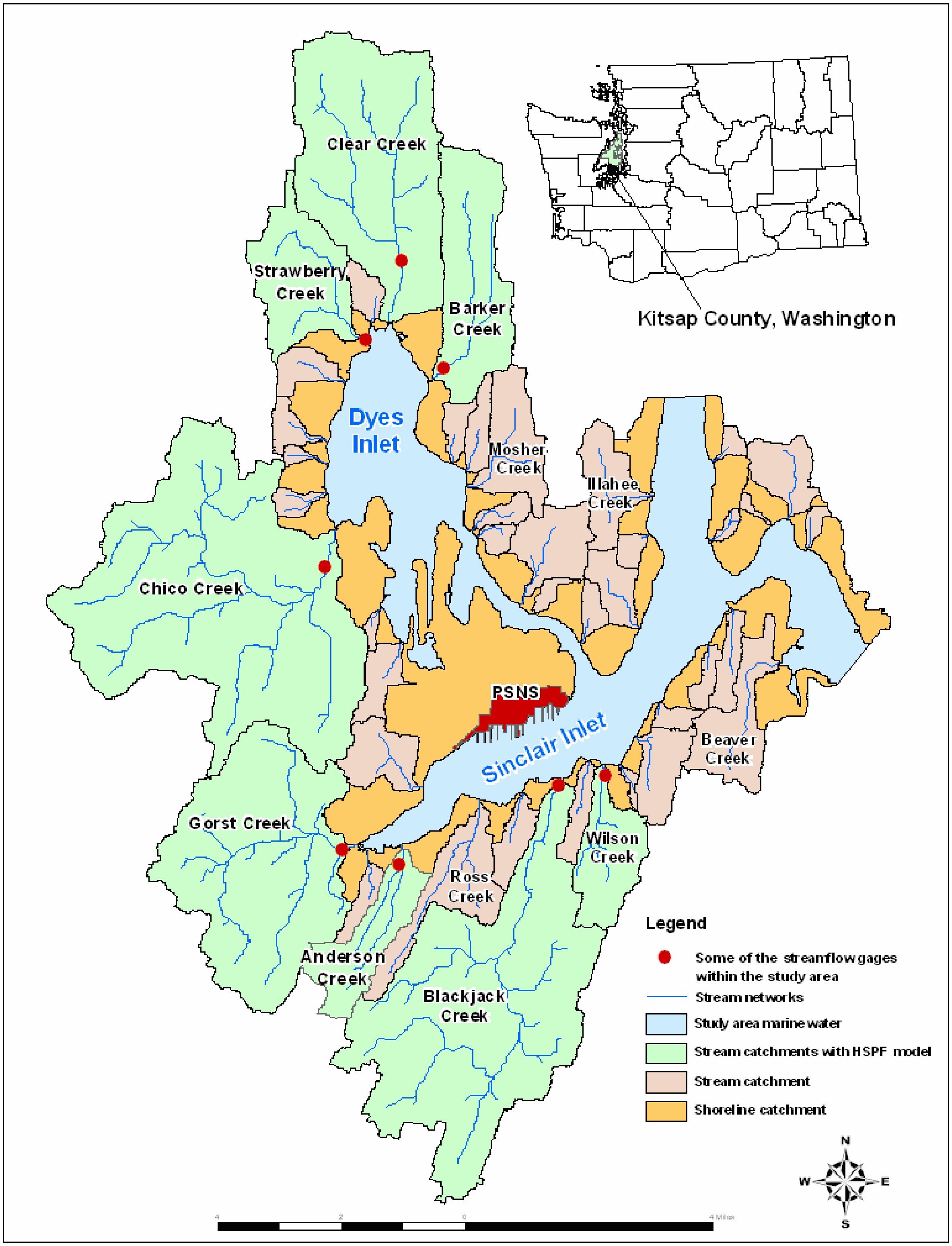

Figure 1. PSNS & IMF Project ENVVEST Study Area.

2.0 DATA COLLECTION

This section describes the physical watershed–specific, meteorological, hydrological, water quality, and other data that were collected and utilized to support HSPF simulation of the Sinclair–Dyes Inlet watershed.

2.1 PHYSICAL DATA

Physical watershed–specific data relevant to HSPF model deployment were obtained from Geographic Information Systems (GIS) databases, field observations, and engineering specifications. The Environmental Systems Research Institute, Inc. (ESRI) ArcGIS and ArcView GIS software packages were utilized for mapping and evaluation of GIS data at multiple scales. Physical watershed–specific data for the Sinclair–Dyes Inlet watershed, in a GIS ready format, were obtained from

1. National Elevation Dataset (NED) data obtained from the United States Geological Survey Seamless Data Distribution System (http://seamless.usgs.gov/website/seamless/viewer.php) (See Figure 2)
2. Soils data obtained from the United States Department of Agriculture (http://soildatamart.nrcs.usda.gov/) (See Figure 3)
3. Land Use and Land Cover (LULC) data (See Figure 4)
    a. Proprietary thematic mapper data provided to support the analysis, and
    b. National Land Cover Data obtained from the United States Geological Survey Seamless Data Distribution System (http://seamless.usgs.gov/website/seamless/viewer.php)

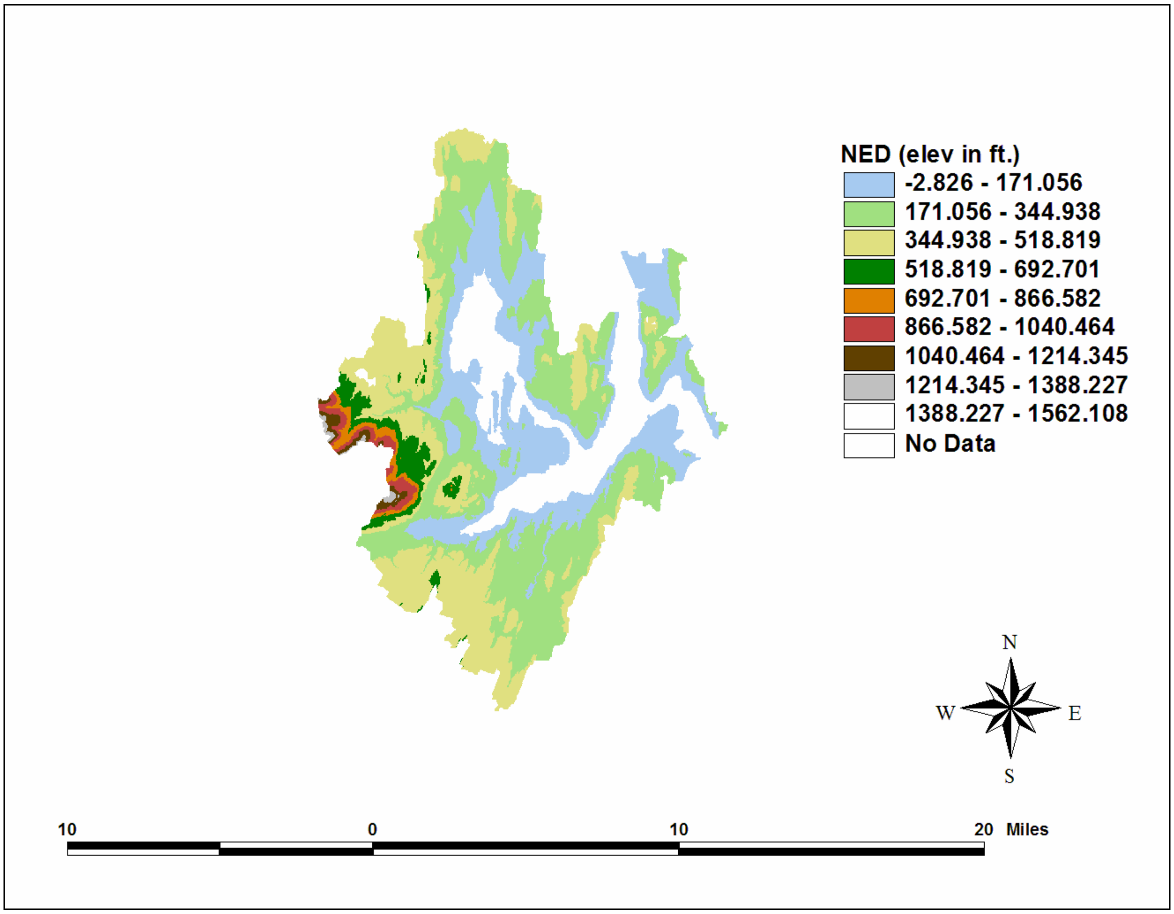

Figure 2. NED data.

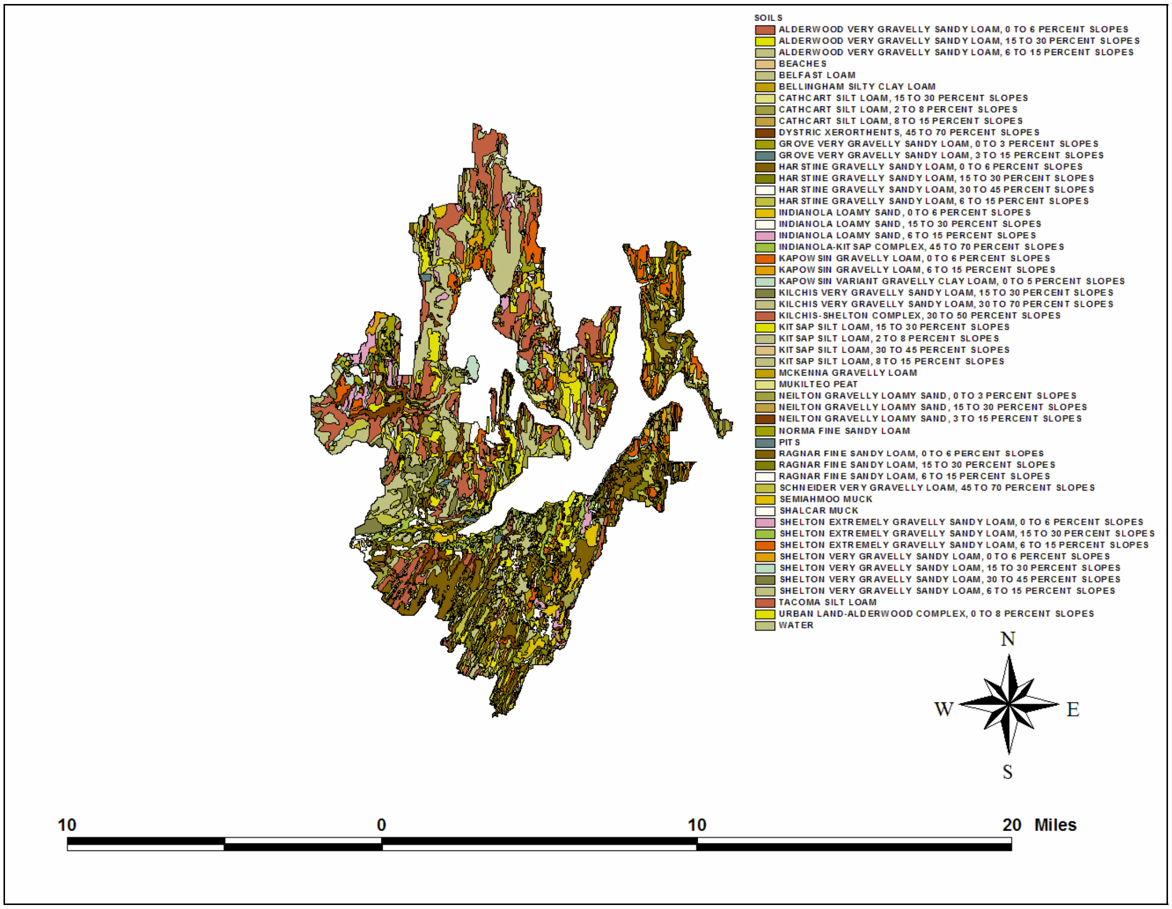

Figure 3. Soils data.

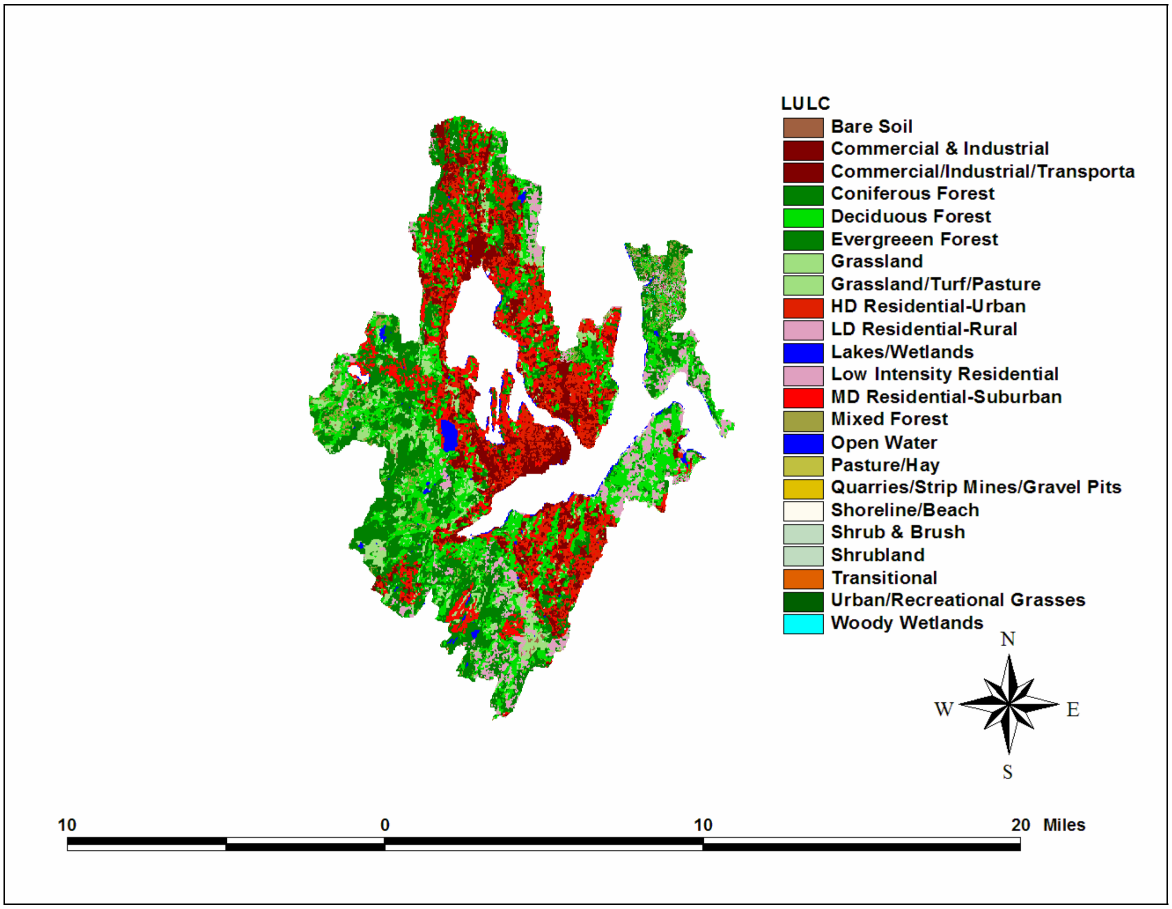

Figure 4. LULC data.

Channel information was approximated based on field observations and available data. The Washington State Department of Fish and Wildlife provided bathymetry data, and other ancillary information, for Kitsap Lake, Island Lake and Wildcat Lake.

2.2 METEOROLOGICAL DATA

A climate summary of mean monthly temperatures for Bremerton, Washington, obtained from the Western Regional Climate Center, indicated that it would not be necessary to model snow accumulation and melt for the Sinclair–Dyes Inlet watershed. As a result, the meteorological time series data requirements for an HSPF hydrologic model included precipitation and potential evapotranspiration.

The Kitsap Public Utilities District (KPUD) provided precipitation data collected at a fifteen minute time interval for four gages located within the Sinclair–Dyes Inlet watershed (Figure 5). The Environmental Division of the PSNS & IMF provided precipitation data for one tipping-bucket gage located within the PSNS & IMF (Figure 5). The City of Bremerton, Washington provided precipitation data for eight tipping-bucket gages located within the Sinclair–Dyes Inlet watershed (Figure 5). The Environmental Company (TEC) provided precipitation data collected at a five minute time interval for one gage located within the Sinclair–Dyes Inlet watershed (Figure 5). Hourly precipitation data associated with the weather station located at the Seattle-Tacoma International Airport was obtained from the U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) meteorological database. Table 1 summarizes the periods of record, missing values, and locations for the gages from which precipitation data were collected.

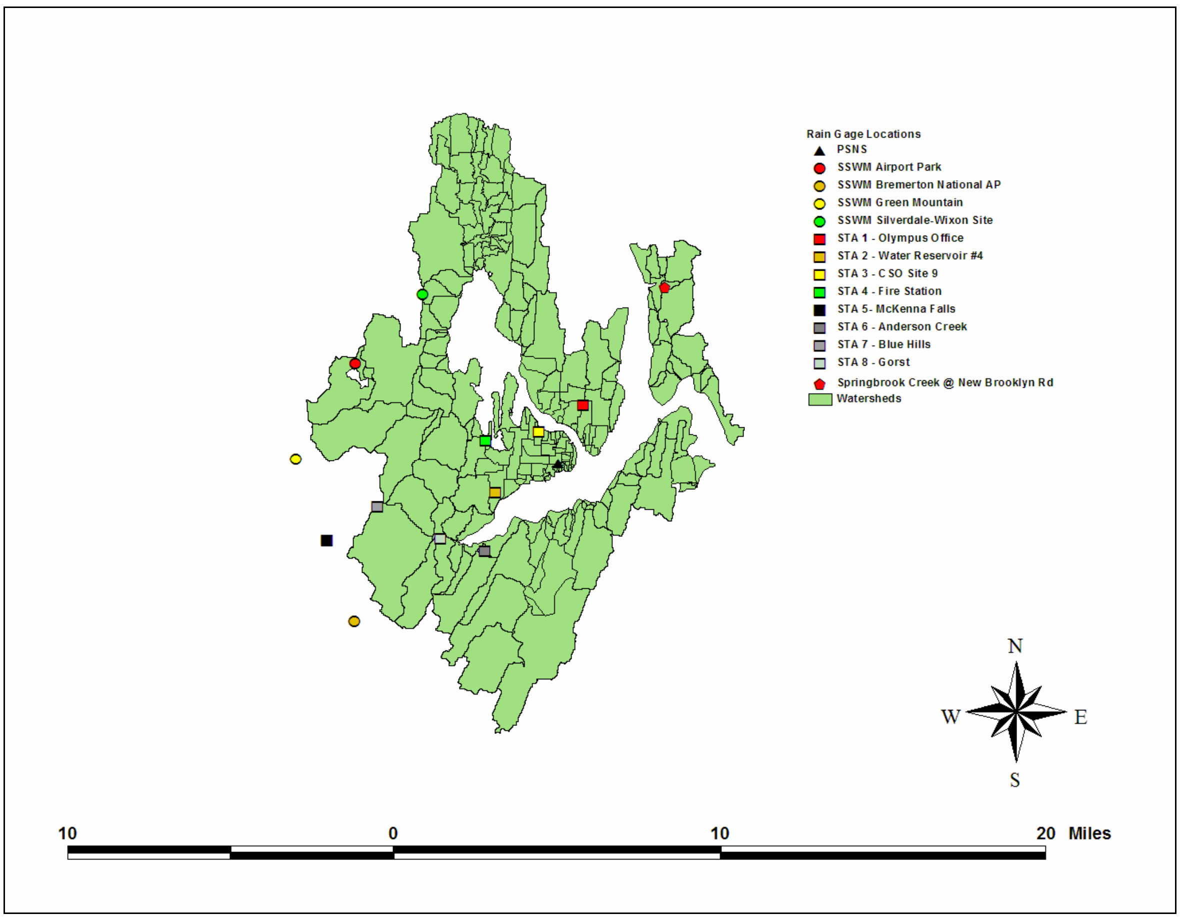

Figure 5. Locations of precipitation gages within and surrounding the Sinclair-Dyes Inlet watershed.

Station Name	# of Missing Values / Missing Periods	Period of Record	Location	
			Long. (DD)	Lat. (DD)
PSNS	0 reported missing	11/03/1999 – 06/13/2006	47.56398	-122.63447
KPUD Airport Park	19450 missing; 02/01/2001 07:00 - 02/28/2001 23:45 08/01/2002 00:00 - 9/9/2002 23:45 10/25/2003 23:00 - 11/05/2003 12:45 08/03/2004 19:00 - 09/08/2004 08:00 12/18/2004 00:15 - 03/10/2005 12:00 05/15/2005 03:45 - 05/19/2005 10:15 09/29/2005 03:15 - 09/30/2005 23:45	01/01/2001 00:00 – 09/30/2005 23:45	47.60583	-122.76888
KPUD Bremerton National Airport	15297 missing; 02/01/2001 07:00 - 02/28/2001 23:45 11/02/2003 03:30 - 11/03/2003 11:45 11/27/2003 04:30 - 12/08/2003 10:45 02/11/2004 16:00 - 02/27/2004 11:00 05/03/2004 00:15 - 05/17/2004 13:30 12/18/2004 00:15 - 03/10/2005 12:00 05/15/2005 03:45 - 05/19/2005 10:15 09/29/2005 03:15 - 09/30/2005 23:45	01/01/2001 00:00 - 09/30/2005 23:45	47.49194	-122.76527
KPUD Green Mountain	10271 missing; 2001/02/01 07:00 - 2001/02/28 23:45 2002/04/17 00:00 - 2002/05/01 23:45 2003/03/03 22:15 - 2003/04/07 10:00 2003/12/26 02:30 - 2004/01/23 11:15 2004/03/29 03:00 - 2004/03/30 12:30	01/01/2001 00:00 – 06/04/2004 00:00	47.56333	-122.80638
KPUD Silverdale-Wixon Site	18767 missing; 2001/02/01 00:00 - 2001/02/28 23:45 2002/05/13 00:00 - 2002/06/07 23:45 2002/08/13 00:00 - 2002/09/11 23:45 2004/02/03 19:00 - 2004/03/01 09:45 2004/10/10 02:30 - 2004/11/28 23:45 2004/11/29 00:15 - 2004/11/29 23:45 For 2004/11/30 - 2005/01/03, each day for the period 01:00 - 23:45 2005/01/04 01:00 - 2005/01/04 11:15	01/01/2001 00:00 - 09/30/2005 23:45	47.63750	-122.72583

Table 1. Summary information of the data collected for precipitation gages located within and surrounding the Sinclair-Dyes Inlet watershed.

Station Name	# of Missing Values / Missing Periods	Period of Record	Location	
			Long. (DD)	Lat. (DD)
City of Bremerton Station 1	7369 missing; 2003/04/02 00:45 - 2003/04/02 15:30 2003/04/24 18:45 - 2003/05/01 01:00 2003/05/30 16:00 - 2003/06/13 02:15 2003/06/30 06:30 - 2003/07/01 00:30 2003/08/09 21:45 - 2003/10/01 14:45 2003/10/21 15:00 - 2003/10/22 13:15 2003/11/05 16:00 - 2003/11/07 16:00 2003/04/02 00:45 - 2003/04/02 15:30 2003/04/24 18:45 - 2003/05/01 01:00 2003/05/30 16:00 - 2003/06/13 02:15 2003/06/30 06:30 - 2003/07/01 00:30 2003/08/09 21:45 - 2003/10/01 14:45 2003/10/21 15:00 - 2003/10/22 13:15 2003/11/05 16:00 - 2003/11/07 16:00	1992/01/01 00:30 - 2006/06/18 12:00	47.59000	-122.61916
City of Bremerton Station 2	1458 missing; 2003/05/01 12:15 - 2003/05/04 02:15 2003/06/04 14:30 - 2003/06/13 01:30 2003/06/30 08:00 - 2003/07/01 00:30 2003/08/06 14:30 - 2003/08/09 05:45 2003/10/21 07:00 - 2003/10/22 01:30	1992/01/01 00:30 - 2006/06/16 10:45	47.55027	-122.67527
City of Bremerton Station 3	9531 missing; 2003/04/24 19:15 - 2003/05/04 02:15 2003/07/01 12:30 2003/09/03 12:30 - 2003/12/02 11:30	1997/01/01 00:30 - 2006/06/16 10:30	47.57805	-122.64722
City of Bremerton Station 4	4515 missing; 2003/06/03 00:15 - 2003/07/12 23:00 2003/09/03 13:15 - 2003/09/06 23:00 2003/10/01 13:45 - 2003/10/04 06:00 2003/10/21 14:00 - 2003/10/22 13:00	1999/10/21 10:15 - 2005/10/05 00:00	47.57333	-122.68250
City of Bremerton Station 5	20540 missing; 2002/11/13 15:00 - 2003/01/11 14:30 2003/02/19 14:15 - 2003/07/10 07:15 2003/09/23 09:45 - 2003/10/04 05:45 2003/10/29 09:15 - 2003/11/01 18:45	2001/11/20 14:45 - 2006/04/30 16:00	47.52722	-122.78444
City of Bremerton Station 6	10803 missing; 2003/03/20 10:30 - 2003/07/10 10:00 2003/08/06 01:30 - 2003/08/06 14:00 2003/09/23 10:45	2002/02/07 17:00 - 2006/06/13 08:00	47.52430	-122.68125

Table 1 (continued). Summary information of the data collected for precipitation gages located within and surrounding the Sinclair-Dyes Inlet watershed.

Station Name	# of Missing Values / Missing Periods	Period of Record	Location	
			Long. (DD)	Lat. (DD)
City of Bremerton Station 7	10256 missing; 2003/02/19 15:00 - 2003/05/08 10:15 2003/05/29 09:45 - 2003/06/10 08:15 2003/07/10 08:30 - 2003/07/12 16:00 2003/08/06 11:15 - 2003/08/09 06:15 2003/09/23 10:30 - 2003/10/01 06:15 2003/10/29 09:45 - 2003/11/02 12:15	2002/02/19 11:00 - 2006/01/31 15:00	47.54280	-122.75216
City of Bremerton Station 8	31834 missing; 2003/05/29 10:30 - 2003/10/28 14:45 12/18/2003 15:00 - 06/15/2004 00:45	2003/01/08 13:30 - 2006/06/13 09:45	47.52944	-122.71055
TEC Springbrook Creek Site	20306 missing 2004/11/10 09:55 - 2004/12/01 09:25 04/07/2005 09:25 - 04/07/2005 10:25 07/22/2005 12:00 - 07/22/2005 12:05 08/15/2005 14:50 - 08/19/2005 08:50 10/14/2005 09:20 - 10/14/2005 09:25 01/17/2006 13:00 - 03/04/2006 06:00	2004/03/31 13:00 - 2006/05/30 06:50	47.643	-122.56767
Seattle-Tacoma Airport – BASINS dataset	0 missing	01/01/1970 – 12/31/1996	47.45	-122.3

Table 1 (continued). Summary information of the data collected for precipitation gages located within and surrounding the Sinclair-Dyes Inlet watershed.

Potential evapotranspiration is typically prescribed by multiplying pan evaporation data by a pan coefficient. Actual evapotranspiration is subsequently simulated based on the input potential evapotranspiration data, model algorithms, and evapotranspiration parameters. To support the computation of Penman Pan Evaporation data (USEPA 1999), which would subsequently support HSPF simulation, daily maximum temperature, minimum temperature, mean dew point, and mean wind speed data were collected from the National Climatic Data Center (http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html) for Bremerton, WA and Seattle, WA for the periods 01/01/1994 – 12/31/2005 and 01/01/1996 – 12/31/2005, respectively. Table 2 summarizes the missing values and locations for the collected daily maximum temperature, minimum temperature, dew point temperature, and wind speed data, respectively.

Station Name	# of Missing Values				Location	
	T_{max}	T_{min}	T_d	W	Long. (DD)	Lat. (DD)
Bremerton National Airport	178	138	118	129	47.49194	-122.76527
Seattle-Tacoma Airport	11	11	11	11	47.45	-122.3

Table 2. Summary information of the daily maximum temperature, T_{max}, minimum temperature, T_{min}, dew point temperature, T_d, and wind speed, W, data collected for two stations located within and surrounding the Sinclair-Dyes Inlet watershed.

Daily total solar radiation data for Seattle, WA was collected from the University of Oregon Solar Radiation Monitoring Laboratory (http://solardat.uoregon.edu) for the period 01/01/1996 – 12/31/2005. There were 299 missing values associated with this collected solar radiation dataset for the period 01/01/1996 – 12/31/2005. A plot of this dataset is shown in Figure 6.

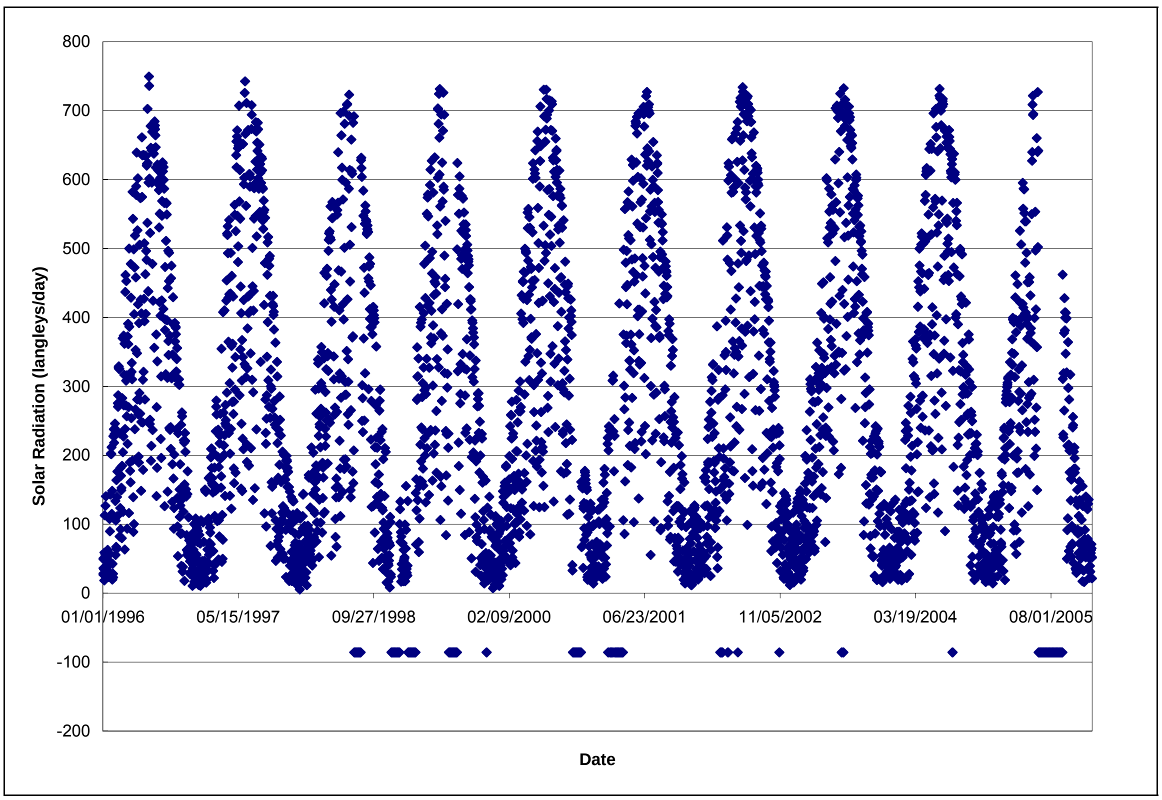

Figure 6. Daily total solar radiation data, in langleys/day, for Seattle, WA collected from the University of Oregon Solar Radiation Monitoring Laboratory (http://solardat.uoregon.edu). Missing data is reported with a value of approximately -86.

Daily and hourly meteorological data (e.g., hourly precipitation, hourly Penman pan evaporation, hourly air temperature, hourly wind speed, hourly solar radiation, hourly dew point temperature, hourly cloud cover, daily maximum temperature, daily minimum temperature, daily solar radiation, …) associated with the Seattle-Tacoma Airport weather station, for the period 01/01/1970 – 12/31/1995, was obtained from the U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) meteorological database. The noted data obtained from the BASINS meteorological database contained no missing values.

2.3 HYDROLOGICAL DATA

Data is required to calibrate and verify processes simulated by HSPF. Model calibration and verification data are not input to HSPF, but are used to support parameter estimation, evaluation of model performance, and prediction.

2.3.1 Flow Data

Figure 7 depicts the flow monitoring locations within the Sinclair-Dyes Inlet watershed for which data was collected to support HSPF hydrologic model calibration and verification. The Table presented in Appendix 2 lists the station names, periods of record, periods of missing data, and locations for the collected flow data associated with the flow monitoring stations shown in Figure 7. Table 3 lists the flow monitoring stations, their locations, and the organization that maintains each station and collected and provided the flow data in support of the HSPF model deployments in the Sinclair-Dyes Inlet watershed.

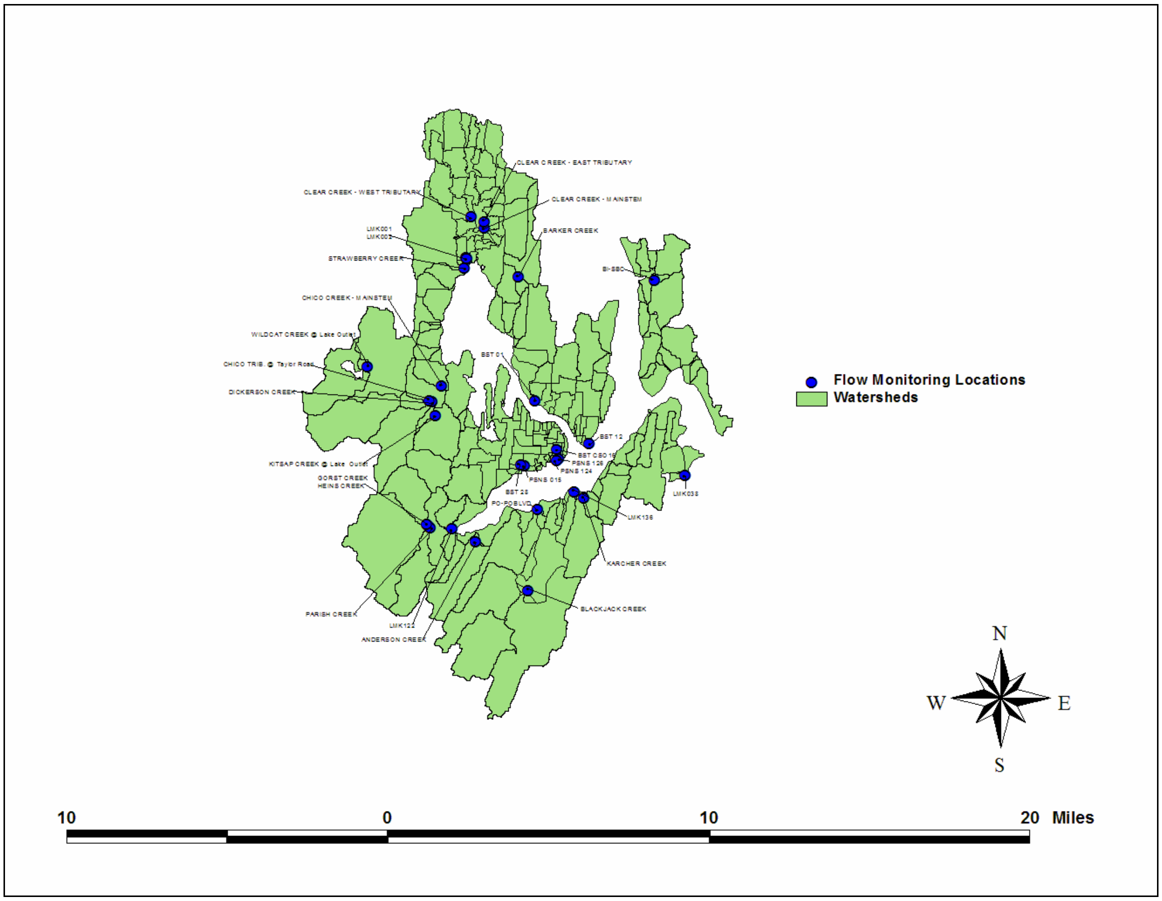

Figure 7. Flow monitoring locations for which data was collected to support HSPF simulation.

Station Name	Location		Maintained By
	Long. (DD)	Lat. (DD)	
ANDERSON CREEK	-122.68222222	47.52361111	KPUD
KARCHER CREEK	-122.61166667	47.54416667	KPUD
DICKERSON CREEK	-122.71361111	47.58611111	KPUD
WILDCAT CREEK @ Lake Outlet	-122.75722222	47.60111111	KPUD
KITSAP CREEK @ Lake Outlet	-122.71083333	47.57972222	KPUD
CHICO TRIB. @ Taylor Road	-122.71527778	47.58638889	KPUD
CHICO CREEK - MAINSTEM	-122.70750000	47.59333333	KPUD
CLEAR CREEK - MAINSTEM	-122.68111111	47.66500000	KPUD
CLEAR CREEK - EAST TRIBUTARY	-122.68166667	47.66750000	KPUD
CLEAR CREEK - WEST TRIBUTARY	-122.69027778	47.66972222	KPUD
BARKER CREEK	-122.65777778	47.64333333	KPUD
STRAWBERRY CREEK	-122.69388889	47.64638889	KPUD
GORST CREEK	-122.71388889	47.53027778	KPUD
PARISH CREEK	-122.71250000	47.52944444	KPUD
HEINS CREEK	-122.71500000	47.53083333	KPUD
BLACKJACK CREEK	-122.64638889	47.50194444	KPUD
STEEL CREEK	NA	NA	KPUD
PSNS 126	-122.62876000	47.56175000	TEC

PSNS 124	-122.62996000	47.56115000	TEC
PSNS 015	-122.65078000	47.55817000	TEC
B-ST CSO16	-122.63018000	47.56592000	TEC
BST 28	-122.65315000	47.55867000	TEC
BST 12	-122.60853000	47.56933000	TEC
BST 01	-122.64474000	47.58744000	TEC
GORST NAVY CITY METALS - LMK122	-122.69831000	47.52915000	TEC
PO-POBLVD	-122.64147000	47.53876000	TEC
ANNAPOLIS - LMK136	-122.61814000	47.54682000	TEC
MANCHESTER - LMK038	-122.54409000	47.55569000	TEC

Table 3. Flow monitoring stations, their locations and the organization that maintains each station.

2.3.2 Other Hydrologic Data

Information pertaining to lake levels/storages and human water use and disposal was requested; however, no other hydrologic data besides the flow data noted in the previous section was provided to support the HSPF model deployments in the Sinlcair-Dyes Inlet watershed described herein.

2.4 WATER QUALITY DATA

Event mean concentrations (EMCs) for total suspended solids that were computed by the Battelle Marine Sciences Laboratory were provided to support HSPF sediment simulation. A summary of this data is presented in Table 4. Table 5 summarizes turbidity data that was collected and provided by TEC to further support HSPF sediment simulation.

Stormwater Sample Type	Sample Station	Site Description	Start Date	Comp Start Time	End Date	Comp End Time	TSS mg/L
Stream	AC	ANDERSON CREEK	01/22/03	425	01/22/03	2210	44
Stream	AC	ANDERSON CREEK	01/29/03	934	01/30/03	319	16
Stream	AC	ANDERSON CREEK	01/30/03	1242	01/31/03	627	
Stream	AC	ANDERSON CREEK	02/15/03	815	02/16/03	1414	8
Stream	AC	ANDERSON CREEK	02/16/03	829	02/17/03	214	
Stream	AC	ANDERSON CREEK	01/17/05	26	01/18/05	1111	88
Stream	AC	ANDERSON CREEK	01/22/05	538	01/22/05	2323	5
Stream	AC-LOW	ANDERSON CREEK (Lower)	01/17/05	145	01/17/05	2100	124.6667
Stream	AC-LOW	ANDERSON CREEK (Lower)	01/22/05	750	01/22/05	2230	6.666667
Stream	BA	BARKER CREEK	12/15/02	1400	12/16/02	1400	59
Stream	BA	BARKER CREEK	01/11/03	1600	01/12/03	1600	49
Stream	BA	BARKER CREEK	03/08/03	1701	03/09/03	1046	
Stream	BA	BARKER CREEK	03/12/03	1004	03/13/03	349	175

Stream	BA	BARKER CREEK	03/26/05	142	03/26/05	1757	16
Stream	BA	BARKER CREEK	03/31/05	2000	04/01/05	1030	47
Stream	BI-SBC	SPRINGBROOK CREEK	04/19/04	2002	04/20/04	1200	
Stream	BI-SBC	SPRINGBROOK CREEK	05/26/04	815	05/26/04	1900	7.5
Stream	BI-SBC	SPRINGBROOK CREEK	10/18/04	1900	10/19/04	701	8
Stream	BI-SBC	SPRINGBROOK CREEK	03/31/05	1849	04/01/05	1304	24
Stream	BI-SBC	SPRINGBROOK CREEK	04/10/05	2047	04/11/05	847	21
Stream	BL	BLACKJACK CREEK	01/22/03	315	01/22/03	2223	33
Stream	BL	BLACKJACK CREEK	01/29/03	955	01/30/03	340	13
Stream	BL	BLACKJACK CREEK	01/30/03	1235	01/31/03	620	
Stream	BL	BLACKJACK CREEK	02/15/03	825	02/16/03	1410	10
Stream	BL	BLACKJACK CREEK	03/08/03	1537	03/09/03	922	
Stream	BL	BLACKJACK CREEK	02/28/05	1538	03/01/05	1123	7
Stream	BL	BLACKJACK CREEK	03/19/05	1240	03/20/05	640	19
Stream	CC	CLEAR CREEK (Main)	12/15/02	1400	12/16/02	1400	15
Stream	CC	CLEAR CREEK (Main)	01/11/03	1600	01/12/03	1600	25
Stream	CC	CLEAR CREEK (Main)	03/08/03	1639	03/09/03	1024	
Stream	CC	CLEAR CREEK (Main)	03/12/03	1011	03/13/03	356	31
Stream	CC	CLEAR CREEK (Main)	03/26/05	133	03/27/05	918	26
Stream	CC	CLEAR CREEK (Main)	03/31/05	2157	04/01/05	1042	22
Stream	CE	CLEAR CREEK (East)	12/15/02	1400	12/16/02	1400	7
Stream	CE	CLEAR CREEK (East)	01/11/03	1600	01/12/03	1600	12
Stream	CE	CLEAR CREEK (East)	03/08/03	1743	03/09/03	1128	
Stream	CE	CLEAR CREEK (East)	03/12/03	1012	03/13/03	357	30
Stream	CH	CHICO CREEK (Main Stem)	12/15/02	1400	12/16/02	1400	31
Stream	CH	CHICO CREEK (Main Stem)	01/11/03	1600	01/12/03	1600	25
Stream	CH	CHICO CREEK (Main Stem)	01/22/03	315	01/22/03	2205	70
Stream	CH	CHICO CREEK (Main Stem)	01/29/03	1115	01/30/03	500	42
Stream	CH	CHICO CREEK (Main Stem)	01/30/03	1300	01/31/03	645	
Stream	CH	CHICO CREEK (Main Stem)	02/15/03	810	02/16/03	1437	41
Stream	CH	CHICO CREEK (Main Stem)	02/16/03	1452	02/17/03	237	
Stream	CH	CHICO CREEK (Main Stem)	03/12/03	959	03/13/03	944	92
Stream	CH	CHICO CREEK (Main Stem)	03/26/05	56	03/27/05	856	19
Stream	CH	CHICO CREEK (Main Stem)	03/31/05	1819	04/01/05	1019	8
Stream	CT	CHICO CREEK (Taylor Road)	01/22/03	315	01/22/03	2157	16
Stream	CT	CHICO CREEK (Taylor Road)	01/29/03	949	01/30/03	334	6
Stream	CT	CHICO CREEK (Taylor Road)	01/30/03	1258	01/31/03	643	
Stream	CT	CHICO CREEK (Taylor Road)	02/15/03	815	02/16/03	1432	3
Stream	CT	CHICO CREEK (Taylor Road)	02/16/03	1447	02/17/03	232	
Stream	CW	CLEAR CREEK (West)	12/15/02	1400	12/16/02	1400	17
Stream	CW	CLEAR CREEK (West)	01/11/03	1600	01/12/03	1600	21
Stream	CW	CLEAR CREEK (West)	03/08/03	1740	03/09/03	1125	
Stream	CW	CLEAR CREEK (West)	03/12/03	1016	03/13/03	401	95
Stream	GC	GORST CREEK (Upper)	01/22/03	315	01/22/03	2200	50
Stream	GC	GORST CREEK (Upper)	01/29/03	923	01/30/03	308	34
Stream	GC	GORST CREEK (Upper)	01/30/03	1245	01/31/03	630	
Stream	GC	GORST CREEK (Upper)	02/15/03	1051	02/16/03	849	16
Stream	GC	GORST CREEK (Upper)	02/16/03	904	02/17/03	249	
Stream	GC	GORST CREEK (Upper)	01/17/05	1	01/18/05	1046	107
Stream	GC	GORST CREEK (Upper)	01/22/05	530	01/22/05	2000	11
Stream	GC-M	GORST CREEK (Mouth)	01/17/05	130	01/17/05	2050	40.33333
Stream	GC-M	GORST CREEK (Mouth)	01/22/05	753	01/22/05	2205	5.666667
Stream	GC-SAM	GORST CREEK (Sam Christopherson Road)	01/17/05	1	01/18/05	1046	63
Stream	GC-SAM	GORST CREEK (Sam Christopherson Road)	01/22/05	928	01/22/05	2258	8
Stream	LMK136	Annapolis Creek	04/19/04	1910	04/20/04	840	30
Stream	LMK136	Annapolis Creek	05/26/04	720	05/27/04	1515	32
Stream	LMK136	Annapolis Creek	10/18/04	1952	10/19/04	1030	29
Stream	LMK136	Annapolis Creek	01/17/05	54	01/18/05	828	153
Stream	LMK136	Annapolis Creek	01/22/05	641	01/22/05	2046	8
Stream	OC	OLNEY CK. (KARCHER CK.)	01/22/03	315	01/22/03	2237	210
Stream	OC	OLNEY CK. (KARCHER CK.)	01/29/03	1030	01/30/03	415	57
Stream	OC	OLNEY CK. (KARCHER CK.)	01/30/03	1302	01/31/03	647	
Stream	OC	OLNEY CK. (KARCHER CK.)	02/15/03	830	02/16/03	1415	63
Stream	OC	OLNEY CK. (KARCHER CK.)	03/08/03	1529	03/09/03	914	

Stream	OC	OLNEY CK. (KARCHER CK.)	02/28/05	1558	03/01/05	1043	59
Stream	OC	OLNEY CK. (KARCHER CK.)	03/19/05	1236	03/20/05	636	151
Stream	SC	STRAWBERRY CREEK	12/15/02	1400	12/16/02	1400	10
Stream	SC	STRAWBERRY CREEK	01/11/03	1600	01/12/03	1600	11
Stream	SC	STRAWBERRY CREEK	03/08/03	1649	03/09/03	1034	
Stream	SC	STRAWBERRY CREEK	03/12/03	1139	03/13/03	524	94
Stream	SC	STRAWBERRY CREEK	03/26/05	834	03/27/05	819	41
Stream	SC	STRAWBERRY CREEK	03/31/05	2032	04/01/05	1102	46
Outfalls							
Stormwater Outfall	B-ST28	Callow Ave (SW2)	04/19/04	1715	04/20/04	510	79
Stormwater Outfall	B-ST28	Callow Ave (SW2)	05/26/04	650	05/26/04	1245	116
Stormwater Outfall	B-ST28	Callow Ave (SW2)	10/18/04	1901	10/19/04	956	31
Stormwater Outfall	B-ST28	Callow Ave (SW2)	02/28/05	1521	03/01/05	1141	81
Stormwater Outfall	B-ST28	Callow Ave (SW2)	03/19/05	1254	03/20/05	954	49
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	04/19/04	1805	04/20/04	1015	5
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	05/26/04	740	05/26/04	1730	34
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	10/18/04	2014	10/19/04	1230	
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	03/19/05	1318	03/20/05	1018	205
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	03/26/05	136	03/26/05	1930	28
Stormwater Outfall	B-ST12	Trenton Ave (SW 4)	03/31/05	1907	04/01/05	920	16
Stormwater Outfall	B-ST/CSO16	Pacific Ave (SW3)	04/19/04	1736	04/19/04	2341	26
Stormwater Outfall	B-ST/CSO16	Pacific Ave (SW3)	05/26/04	720	05/26/04	1815	69
Stormwater Outfall	B-ST/CSO16	Pacific Ave (SW3)	10/18/04	1930	10/19/04	930	
Stormwater Outfall	B-ST/CSO16	Pacific Ave (SW3)	02/28/05	1452	03/01/05	907	75
Stormwater Outfall	B-ST/CSO16	Pacific Ave (SW3)	03/19/05	1308	03/20/05	1008	51
Stormwater Outfall	B-ST01	Pine Rd (SW1)	04/19/04	1840	04/20/04	1045	105
Stormwater Outfall	B-ST01	Pine Rd (SW1)	05/26/04	825	05/26/04	1530	52
Stormwater Outfall	B-ST01	Pine Rd (SW1)	10/18/04	1715	10/19/04	1125	20
Stormwater Outfall	B-ST01	Pine Rd (SW1)	03/26/05	115	03/26/05	1845	55.33333
Stormwater Outfall	B-ST01	Pine Rd (SW1)	03/31/05	1750	03/31/05	955	15
Stormwater Outfall	LMK122	Navy City	04/19/04	1704	04/20/04	459	20
Stormwater Outfall	LMK122	Navy City	05/26/04	755	05/26/04	1350	48
Stormwater Outfall	LMK122	Navy City	10/18/04	1933	10/19/04	728	
Stormwater Outfall	LMK122	Navy City	01/16/05	2357	01/18/05	902	92
Stormwater Outfall	LMK122	Navy City	01/22/05	922	01/22/05	2237	8
Stormwater Outfall	SW6	Silverdale Mall LMK001+2	04/19/04	1721	04/20/04	516	23
Stormwater Outfall	SW6	Silverdale Mall LMK001+2	05/26/04	630	05/26/04	1525	39

Stormwater Outfall	SW6	Silverdale Mall LMK001+2	10/18/04	2122	10/19/04	317	34
Stormwater Outfall	SW6	Silverdale Mall LMK001+2	03/26/05	140	03/26/05	1950	30
Stormwater Outfall	SW6	Silverdale Mall LMK001+2	03/31/05	2036	04/01/05	1016	15
Stormwater Outfall	LMK038	Manchester	04/19/04	1827	04/20/04	622	11
Stormwater Outfall	LMK038	Manchester	05/26/04	653	05/26/04	1248	64
Stormwater Outfall	LMK038	Manchester	10/18/04	2014	10/19/04	809	
Stormwater Outfall	LMK038	Manchester	01/17/05	213	01/18/05	803	113
Stormwater Outfall	LMK038	Manchester	01/22/05	820	01/22/05	2115	8
Stormwater Outfall	PO-POBLVD	Port Orchard Blvd	05/26/04	659	05/26/04	1254	149
Stormwater Outfall	PO-POBLVD	Port Orchard Blvd	10/18/04	1919	10/19/04	1014	46
Stormwater Outfall	PO-POBLVD	Port Orchard Blvd	01/17/05	47	01/18/05	845	87
Stormwater Outfall	PO-POBLVD	Port Orchard Blvd	01/22/05	628	01/22/05	2028	6
Road Runoff	WADOT-01A	Gorst - Drain before Viking Fence	01/17/05	155	01/17/05	2110	99.33333
Road Runoff	WADOT-01A	Gorst - Drain before Viking Fence	01/22/05	733	01/22/05	2220	27.66667
Road Runoff	WADOT-01A	Gorst - Drain before Viking Fence	02/28/05	1705	02/28/05	2238	76.66667
Road Runoff	WADOT-01A	Gorst - Drain before Viking Fence	03/19/05	1428	03/19/05	1815	48.66667
Road Runoff	WADOT-02	Gorst - Drain past Elandan Gardens	01/17/05	110	01/17/05	2040	234.3333
Road Runoff	WADOT-02	Gorst - Drain past Elandan Gardens	01/22/05	919	01/22/05	2145	217
Road Runoff	WADOT-02	Gorst - Drain past Elandan Gardens	02/28/05	1645	02/28/05	2206	91
Road Runoff	WADOT-02	Gorst - Drain past Elandan Gardens	03/19/05	1420	03/19/05	1800	146.6667
Road Runoff	WADOT-03	Gorst - Drain by Gorst Subaru	01/17/05	120	01/17/05	2030	134
Road Runoff	WADOT-03	Gorst - Drain by Gorst Subaru	01/22/05	725	01/22/05	2155	56
Road Runoff	WADOT-03	Gorst - Drain by Gorst Subaru	02/28/05	1655	02/28/05	2216	22
Road Runoff	WADOT-03	Gorst - Drain by Gorst Subaru	03/19/05	1412	03/19/05	1805	151.6667
Industrial Outfall	PSNS008	Naval Station Industrial	05/26/04	1440	05/26/04	1540	45
Industrial Outfall	PSNS015	Naval Station McDonalds	04/19/04	1725	04/20/04	520	46
Industrial Outfall	PSNS015	Naval Station McDonalds	05/26/04	716	05/26/04	1611	168
Industrial Outfall	PSNS015	Naval Station McDonalds	10/18/04	2110	10/19/04	1030	88
Industrial Outfall	PSNS015	Naval Station McDonalds	02/28/05	1741	03/01/05	1221	26
Industrial Outfall	PSNS015	Naval Station McDonalds	03/19/05	1238	03/20/05	938	34
Industrial Outfall	PSNS101	PSNS Industrial (CIA)	05/26/04	1409	05/26/04	1932	32
Industrial Outfall	PSNS115.1	PSNS Dry Dock	05/26/04	1243	05/26/04	1947	5
Industrial Outfall	PSNS124	PSNS CIA Building 438 near Dry Dock #2	04/19/04	1920	04/20/04	945	19.66667
Industrial Outfall	PSNS124	PSNS CIA Building 438 near Dry Dock #2	05/26/04	825	05/26/04	1815	17.33333

Industrial Outfall	PSNS124	PSNS CIA Building 438 near Dry Dock #2	10/18/04	2200	10/19/04	715	12
Industrial Outfall	PSNS124	PSNS CIA Building 438 near Dry Dock #2	02/28/05	2326	03/01/05	523	8
Industrial Outfall	PSNS124	PSNS CIA Building 438 near Dry Dock #2	03/19/05	2326	03/01/05	523	8
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	04/19/04	1743	04/20/04	830	25
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	05/26/04	707	05/26/04	1602	39
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	05/26/04	1213	05/26/04	2037	32
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	10/18/04	2135	10/19/04	730	24
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	02/28/05	1732	03/01/05	1316	17
Industrial Outfall	PSNS126	PSNS Downstream of CSO-16	03/19/05	1227	03/20/05	927	36
WWTP Outfall	B-WWTP	Bremerton WWTP	05/26/04	840	05/26/04	1148	9.666667
WWTP Outfall	B-WWTP	Bremerton WWTP	10/19/04	730	10/19/04	930	ND
WWTP Outfall	B-WWTP	Bremerton WWTP	03/01/05	725	03/01/05	1110	2
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	10/19/04	822	10/19/04	1405	36
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	05/26/04	825	05/27/04	1530	19.5
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	01/17/05	1045	01/17/05	1530	82
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	01/22/05	730	01/22/05	1500	14
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	03/01/05	800	03/01/05	1245	8
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	03/19/05	1300	03/19/05	1800	12
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	03/26/05	800	03/26/05	1500	9
WWTP Outfall	KAR-WWTP	Karcher Creek WWTP	04/10/05	730	04/01/05	1000	104

Table 4. Summary of Event Mean Concentrations for Storms Sampled from 2002-2005.

Station	Start Dates	End Dates	Notes
AC	2/14/2003 11:30	2/17/2003 9:30	Data at 5 minute intervals
	1/21/2005 17:55	1/22/2005 23:20	Data at 5 minute intervals
	1/16/2005 21:35	1/22/2005 23:20	Data at 5 minute intervals
BA	2/14/2003 10:20	2/17/2003 8:50	Data at 5 minute intervals
	3/7/2003 13:40	3/7/2003 13:50	Data at 5 minute intervals
	3/7/2003 18:25	3/18/2003 9:10	Data at 5 minute intervals
	3/7/2003 13:40	3/7/2003 13:50	Data at 5 minute intervals
	3/7/2003 18:25	6/13/2003 9:45	Data at 5 minute intervals
	3/25/2005 16:35	4/1/2005 10:40	Data at 5 minute intervals
BI-SBC	3/25/2005 18:45	3/26/2005 21:10	Data at 5 minute intervals
	3/30/2005 8:45	4/1/2005 13:10	Data at 5 minute intervals
	4/10/2005 14:05	4/10/2005 14:20	Data at 5 minute intervals
	4/10/2005 15:25	4/11/2005 8:30	Data at 5 minute intervals
BL	1/21/2003 19:05	1/21/2003 19:10	Data at 5 minute intervals
	1/21/2003 22:40	1/23/2003 9:40	Data at 5 minute intervals
	1/21/2003 19:05	1/21/2003 19:10	Data at 5 minute intervals
	1/21/2003 22:40	1/23/2003 9:40	Data at 5 minute intervals
	2/14/2003 11:55	2/14/2003 12:05	All values 11.4 - Data at 5 minute intervals
	2/14/2003 13:45	2/15/2003 15:15	All values 11.4 - Data at 5 minute intervals
	5/14/2003 8:00	6/7/2003 10:15	Data at 15 minute intervals

	2/11/2005 16:10	3/20/2005 11:10	Data at 5 minute intervals
CC	5/14/2003 10:30	6/13/2003 9:30	Data at 15 minute intervals
	5/14/2003 10:30	6/13/2003 9:30	Data at 15 minute intervals
	3/12/2003 12:04	3/13/2003 19:13	Data at approximately 10 minute intervals
	5/14/2003 10:30	6/13/2003 9:30	Data at 15 minute intervals
	3/25/2005 17:00	3/27/2005 9:25	Data at 5 minute intervals
	3/30/2005 9:30	4/1/2005 10:50	Data at 5 minute intervals
CE	1/11/2003 11:25	1/12/2003 15:45	Data at 5 minute intervals
	3/7/2003 18:35	3/9/2003 17:30	Data at 5 minute intervals
	3/12/2003 9:25	3/13/2003 16:30	Data at 5 minute intervals
CH	3/12/2003 8:00	3/18/2003 10:10	Data at 5 minute intervals
	3/25/2005 15:40	4/1/2005 10:25	Many bogus values - Data at 5 minute intervals
	3/31/2005 11:00	4/1/2005 10:25	Many bogus values - Data at 5 minute intervals
CT	1/28/2003 16:05	2/17/2003 8:50	Data at 5 minute intervals
	5/14/2003 9:45	5/28/2003 7:30	Most are 0 - Data at 15 minute intervals
CW	2/14/2003 9:20	3/18/2003 9:45	Data at 5 minute intervals
GC	1/21/2003 22:00	1/31/2003 12:00	Data at 5 minute intervals
	1/28/2003 16:05	2/6/2003 10:25	Data at 5 minute intervals
	2/16/2003 11:10	2/17/2003 9:05	Data at 5 minute intervals
	5/14/2003 9:00	6/5/2003 12:00	Data at 15 minute intervals
	1/15/2005 8:00	1/22/2005 20:00	Data at 5 minute intervals
	1/21/2005 16:55	1/22/2005 20:00	Data at 5 minute intervals
GC-SAN	1/15/2005 8:55	1/22/2005 23:00	Data at 5 minute intervals
	1/21/2005 17:25	1/22/2005 23:00	Data at 5 minute intervals
OC	5/28/2003 8:45	6/27/2003 7:45	Data at 15 minute intervals
	3/18/2005 10:40	3/20/2005 11:40	Data at 5 minute intervals
SBC	2/14/2003 9:20	3/18/2003 10:10	Data at 5 minute intervals
	3/12/2003 8:00	3/18/2003 10:10	Data at 5 minute intervals
	3/25/2005 15:50	4/1/2005 10:25	Many bogus values - Data at 5 minute intervals
SC	1/11/2003 10:30	1/12/2003 17:15	Data at 5 minute intervals
	3/25/2005 16:15	4/1/2005 11:00	Many bogus values - Data at 5 minute intervals
	3/25/2005 16:15	4/1/2005 11:00	Many bogus values - Data at 5 minute intervals

Table 5. Summary of turbidity data collected and provided by TEC.

2.5 LITERATURE SEARCH

A literature search was conducted to identify additional data that could be imparted to the model determination process.

2.5.1 Hydrologic Response

Beyerlein (1999) summarized the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow, and evapotranspiration based on the Seattle-Tacoma Airport weather station precipitation record from 1948 – 1996.

3.0 DATA PROCESSING OF THE TIME SERIES DATA

3.1 PRECIPITATION DATA

For precipitation gages that were used for simulation, missing precipitation data were filled in using simple regression relationships that were established with neighboring stations for periods of coincident data. Precipitation data processing differed based on original raw data formats. That is, the original raw precipitation data from the KPUD, the City of Bremerton, the Puget Sound Naval Shipyard and Intermediate Maintenance Facility, and TEC all came in different formats and required different methods to process the data into a format usable for HSPF simulation. For some locations the processing involved, in addition to filling in the missing data as noted, computing mass curves and subsequently differencing to a periodic time interval.

3.2 EVAPORATION DATA

Missing daily maximum temperature, minimum temperature, mean dew point temperature, and mean wind speed data associated with the stations at Bremerton and Seattle were filled in either using the other stations data or by interpolation. The daily maximum temperature, minimum temperature, mean dew point temperature, mean wind speed, and solar radiation data were utilized to compute Penman pan evaporation data for Bremerton and Seattle for the periods January 1, 1994 – December 31, 2005 and January 1, 1996 – December 31, 2005, respectively, using the data processing capabilities encapsulated in the public domain WDMUtil software system (USEPA 1999). The computed Penman pan evaporation data for Seattle were subsequently concatenated to an already existing Penman pan evaporation data set associated with the Seattle-Tacoma Airport weather station contained within the U.S. EPA BASINS meteorological database.

3.3 CONSTRUCTION OF THE INPUT WDM FILE

The ANNIE and WDMUtil utility software packages, and also TSPROC (Doherty 2003), all in the public domain, were principally used to process, input, manipulate, and manage the time series data in a Watershed Data Management (WDM) file (Flynn et al. 1995). Table 6 lists some of the relevant data set numbers (DSNs) contained within the input WDM file that was prepared for the study (DTMAX = maximum mean daily temperature; DTMIN = minimum mean daily temperature; DDPTP = mean daily dew point temperature; DWND = mean wind speed or total wind travel for the day; DEVP = daily Penman Pan Evaporation; EVAP = disaggregated Penman Pan Evaporation; DSOL = Global Solar Radiation data; PREC = precipitation; ATEM = hourly air temperature; SOLR = hourly solar radiation data; DEWP = hourly dew point temperature data; CLOU = cloud cover data; FLOW = flow data).

DSN	Constituent	Start	End	Description
1	DTMAX	1/1/1994	12/31/2005	BREM - DAILY T MAX (Deg F)
2	DTMIN	1/1/1994	12/31/2005	BREM - DAILY T MIN (Deg F)
3	DDPTP	1/1/1994	12/31/2005	BREM - DAILY DEW POINT TEMP (Deg F)
4	DWND	1/1/1994	12/31/2005	BREM - DAILY WIND (MpH)
5	DWND	1/1/1994	12/31/2005	computed total daily wind travel for Bremerton
6	DEVP	1/1/1994	12/31/2005	computed daily pan evaporation (in) for Bremerton
7	EVAP	1/1/1994	12/31/2005	disaggregated PET (daily to hourly) for Bremerton
8	EVAP	1/1/1994	12/31/2005	disaggregated PET (hourly to 15 minute) for Bremerton
101	DTMAX	1/1/1996	12/31/2005	WA SEATTLE TACOMA AIRPORT - DAILY T MAX (Deg F)
102	DTMIN	1/1/1996	12/31/2005	WA SEATTLE TACOMA AIRPORT - DAILY T MIN (Deg F)
103	DDPTP	1/1/1996	12/31/2005	WA SEATTLE TACOMA AIRPORT - DAILY DPTP (Deg F)
104	DWND	1/1/1996	12/31/2005	WA SEATTLE TACOMA AIRPORT - DAILY WIND (MpH)
105	DSOL	1/1/1970	12/31/2005	WA SEATTLE TACOMA AIRPORT - DAILY SOLAR Rad
106	DWND	1/1/1996	12/31/2005	computed total daily wind travel
107	DEVP	1/1/1996	12/31/2005	computed daily pan evaporation (in)
108	EVAP	1/1/1996	12/31/2005	disaggregated PET (daily to hourly)
109	EVAP	1/1/1996	12/31/2005	disaggregated PET (hourly to 15 minute)
111	PREC	1/1/1970	12/31/1996	WA SEATTLE TACOMA AIRPO
112	EVAP	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
113	ATEM	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
114	WIND	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
115	SOLR	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
116	PEVT	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
117	DEWP	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
118	CLOU	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
119	TMAX	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
120	TMIN	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
121	DWND	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
122	DCLO	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
123	DPTP	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
124	DSOL	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
125	DEVT	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
126	DEVP	1/1/1970	12/31/1995	WA SEATTLE TACOMA AIRPO
201	FLOW	3/31/2004	11/10/2004	5 Minute Flow for Springbrook Creek on BI
202	PREC	3/31/2004	11/10/2004	5 Minute Prec for Springbrook Creek on BI

205	FLOW	3/31/2004	1/1/2005	15 Minute Flow for Springbrook Creek on BI
207	FLOW	3/18/2004	11/10/2004	15 Minute Flow for Trenton
209	FLOW	3/18/2004	11/10/2004	15 Minute Flow for B-ST 01
245	FLOW	10/1/1991	9/30/1997	Daily Flow for Barker Creek
246	FLOW	10/1/1993	9/30/2000	Daily Flow for Clear Creek
248	FLOW	10/1/1991	9/30/1999	MEAN DAILY Q FOR STREAM # 248 - STRAWBERRY CK
259	FLOW	4/1/1991	3/18/1996	OBSERVED FLOW AT MAIN BASIN OUTLET GAGE
268	FLOW	10/24/1990	9/24/1996	MEAN DAILY Q FOR STREAM # 268 - GORST CK
272	FLOW	10/1/1994	9/30/2000	Daily Flow for Anderson Creek
279	FLOW	10/1/1992	5/31/1993	MEAN DAILY Q FOR STREAM # 279 - BLACKJACK CK
282	FLOW	10/1/1996	9/30/2000	Daily Flow for Karcher Creek
301	FLOW	4/5/2004	11/9/2004	15 Minute Flow for PO-POBLVD
303	FLOW	4/5/2004	11/10/2004	15 Minute Flow for LMK 136
305	FLOW	3/16/2004	11/10/2004	15 Minute Flow for PSNS 126
307	FLOW	3/24/2004	10/25/2004	15 Minute Flow for PSNS 124
309	FLOW	3/16/2004	11/10/2004	15 Minute Flow for PSNS 015
311	FLOW	4/7/2004	11/10/2004	15 Minute Flow for LMK001
313	FLOW	4/5/2004	11/10/2004	15 Minute Flow for LMK002
315	FLOW	4/5/2004	11/10/2004	15 Minute Flow for LMK122
317	FLOW	3/16/2004	11/10/2004	15 Minute Flow for LMK038
319	FLOW	3/19/2004	11/10/2004	15 Minute Flow for CSO16
321	FLOW	3/17/2004	9/29/2004	15 Minute Flow for BST28
600	PREC	1/1/2001	6/4/2004	15 Minute Precipitation at GM - unprocessed observed data
610	PREC	1/1/2001	9/30/2005	15 Minute Precipitation at BA - unprocessed observed data
620	PREC	1/1/2001	9/30/2005	15 Minute Prec. at Silverdale-Wixon - unprocessed observed data
630	PREC	1/1/2001	9/30/2005	15 Minute Prec. at Airport Park - unprocessed observed data
640	PREC	10/1/2003	6/22/2004	15 Minute Prec. at KPUD Station - unprocessed observed data
1003	PREC	11/3/1999	6/13/2006	15 Minute Precipitation at PSNS
1011	PREC	1/1/1992	12/22/2004	15 Minute Prec. at City of Brem. Sta. 1 - unprocessed observed data
1012	PREC	1/1/1992	12/19/2004	15 Minute Prec. at City of Brem. Sta. 2 - unprocessed observed data
1013	PREC	1/1/1997	12/22/2004	15 Minute Prec. at City of Brem. Sta. 3 - unprocessed observed data
1014	PREC	10/21/1999	12/22/2004	15 Minute Prec. at City of Brem. Sta. 4 - unprocessed observed data
1015	PREC	11/20/2001	4/20/2004	15 Minute Prec. at City of Brem. Sta. 5 - unprocessed observed data
1016	PREC	2/7/2002	5/12/2004	15 Minute Prec. at City of Brem. Sta. 6 - unprocessed observed data
1017	PREC	2/19/2002	12/31/2004	15 Minute Prec. at City of Brem. Sta. 7 - unprocessed observed data
1018	PREC	1/8/2003	12/18/2003	15 Minute Prec. at City of Brem. Sta. 8 - unprocessed observed data
2231	FLOW	10/1/2000	9/30/2002	15 Minute Flow for steel creek
2451	FLOW	10/1/2000	9/30/2005	15 Minute Flow for Barker Creek
2461	FLOW	10/1/1996	9/30/2005	15 Minute Flow for Clear Creek
2462	FLOW	12/3/2000	9/30/2005	15 Minute Flow for Clear Creek East
2463	FLOW	10/1/2000	9/30/2003	15 Minute Flow for Clear Creek West
2481	FLOW	10/1/2001	9/30/2005	15 Minute Flow for Strawberry Creek
2591	FLOW	10/1/1999	9/30/2005	15 Minute Flow for Chico Creek
2592	FLOW	10/1/2000	9/30/2003	15 Minute Flow for Chico Creek Tributary at Tayl
2593	FLOW	10/1/2000	9/30/2005	15 Minute Flow for Dickerson Creek
2594	FLOW	10/1/2000	9/30/2005	15 Minute Flow for Kitsap Creek at lake outlet
2595	FLOW	10/1/2000	9/30/2002	15 Minute Flow for kitsap lake at control
2596	FLOW	10/1/2000	9/30/2005	15 Minute Flow for wildcat creek at lake outlet
2597	FLOW	10/1/2002	9/30/2003	15 Minute Stage for kitsap lake at control
2681	FLOW	10/1/2000	9/30/2003	15 Minute Flow for Gorst Creek
2683	FLOW	10/1/2001	9/30/2003	15 Minute Flow for Parish Creek
2684	FLOW	10/1/2001	9/30/2003	15 Minute Flow for Heins Creek
2721	FLOW	10/1/1994	9/25/2003	15 Minute Flow for Anderson Creek
2791	FLOW	10/1/2000	9/30/2005	15 Minute Flow for Blackjack Creek
2821	FLOW	10/1/1996	9/16/2003	15 Minute Flow for Karcher Creek

Table 6. Brief description of some of the relevant data set numbers contained within the input WDM file that was prepared for the study.

Appendix 3 contains plots of the observed datasets that were processed and input into the input WDM file that was prepared for this study (The noted plots are based on data that was collected through June 30, 2006). For most flow data, negative values (equal to either -9.99 or -999.9) correspond with missing data. However, for some flow monitoring locations the observed negative values are associated with significant data error and/or tidal influence.

3.4 TURBIDITY DATA

The turbidity data that was collected and provided to support HSPF sediment simulation was processed to compute EMC's for turbidity to compare with the corresponding TSS event mean concentration data (see Table 4). The planned intent was to establish a regression relationship for single or multiple sites and to then use the established regression relationship(s) to augment existing sediment concentration data for those periods where turbidity data was collected. However, this was not possible, for one of several possible reasons:

a. No observed TSS EMC for a given location and period of interest.
b. No observed flow data for a given location and period of interest.
c. No observed turbidity data for a given location and period of interest.
d. Noisy turbidity data precluded ability to perform the analysis for a given location and period of interest.

Moreover, for those few sites and periods for which a turbidity EMC could be computed to compare against an existing TSS EMC, presumed turbidity "outliers" had to be manually removed from the raw TEC datasets provided.

4.0 HSPF HYDROLOGIC MODEL DEVELOPMENT

This section describes relevant features of the development process for the HSPF models that were developed for the Sinclair–Dyes Inlet watershed.

4.1 WATERSHED DELINEATION

The sub–watersheds of the Sinclair–Dyes Inlet watershed depicted in Figure 8 were delineated using

1. the NED digital elevation model (DEM) data and industry standard DEM processing algorithms,
2. information pertaining to the urban drainage systems, and
3. pre–existing watershed delineation efforts.

Table 7 specifies the approximate upstream drainage area associated with each flow monitoring location identified in Figure 7.

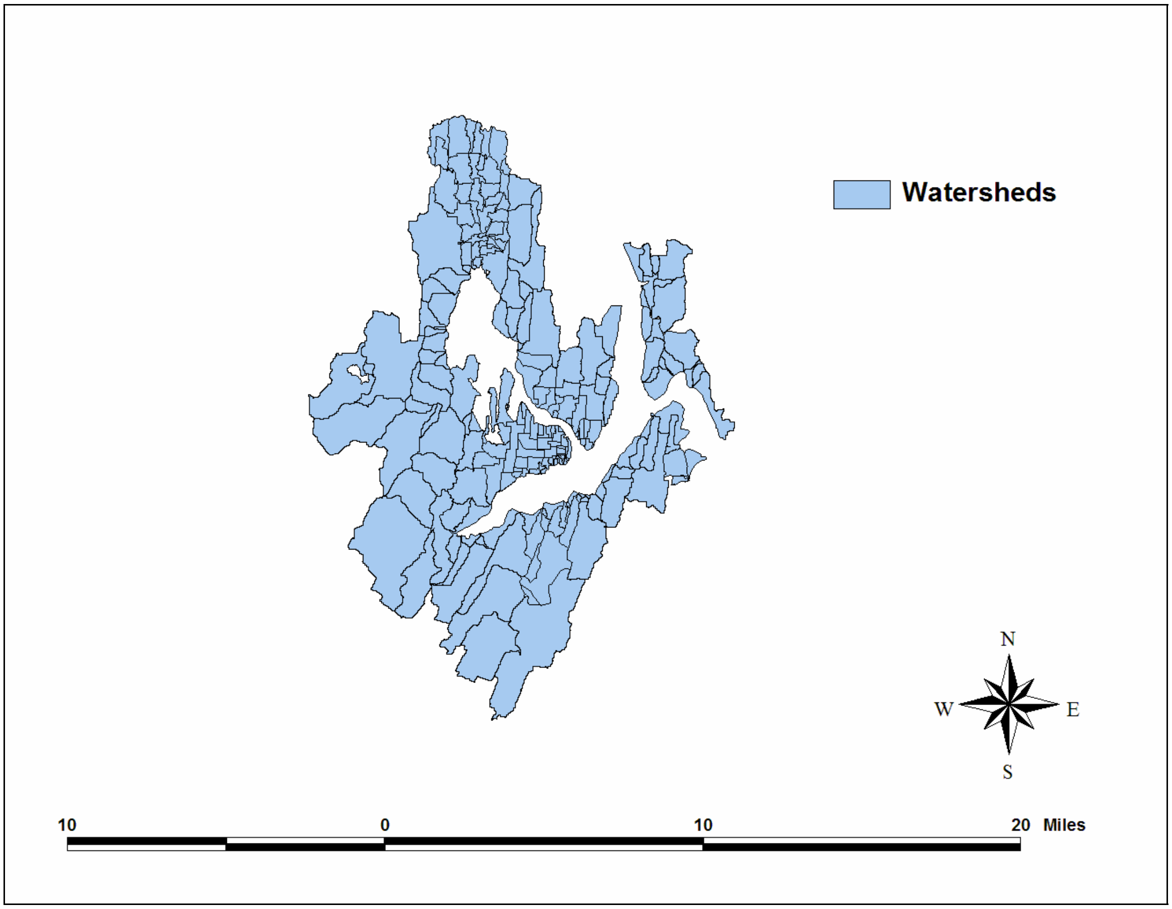

Figure 8. Delineated watersheds.

Watershed	Contributing Drainage Area (acres)
ANDERSON CREEK – BREMERTON	1220
BARKER CREEK	2561
BLACKJACK CREEK	6996
CHICO CREEK MAINSTEM	9650
CHICO TRIB. @ Taylor Road	5915
CLEAR CREEK	4606
CLEAR CREEK – WEST TRIBUTARY	2247
DICKERSON CREEK	1474
GORST CREEK (AT MOUTH = LOCATION OF OLD FLOW MONITORING LOCATION)	6142
HEINS CREEK	1005
KARCHER CREEK	1225
KITSAP CREEK @ Lake Outlet	1589
PARISH CREEK	1092
STRAWBERRY CREEK	1911
WILDCAT CREEK @ Lake Outlet	1488
PSNS 126	53.6
PSNS 124	18.1
PSNS 015	101.2
BST CSO 16	28.2
BST 28	402
BST 12	194
BST 01	862

LMK 122	330
PO-POBLVD	294
LMK 136	294
LMK 038	59.4
LMK 001	140
LMK 002	88.5
BI-SBC	845

Table 7. Drainage areas associated with the flow monitoring locations identified in Figure 7.

4.2 TOPOLOGY

The Sinclair-Dyes Inlet watershed was discretized into 215 sub-watersheds using the delineation procedures noted in the previous section. Each delineated sub-watershed was arbitrarily assigned a unique numeric ID, and, together with hydrography data and other ancillary information, the model topology was subsequently manually determined. Figures 9 and 10 below and Table 4.1 in Appendix 4 show and depict the assigned ID labels and the established model topology for the Sinclair-Dyes Inlet sub-watersheds.

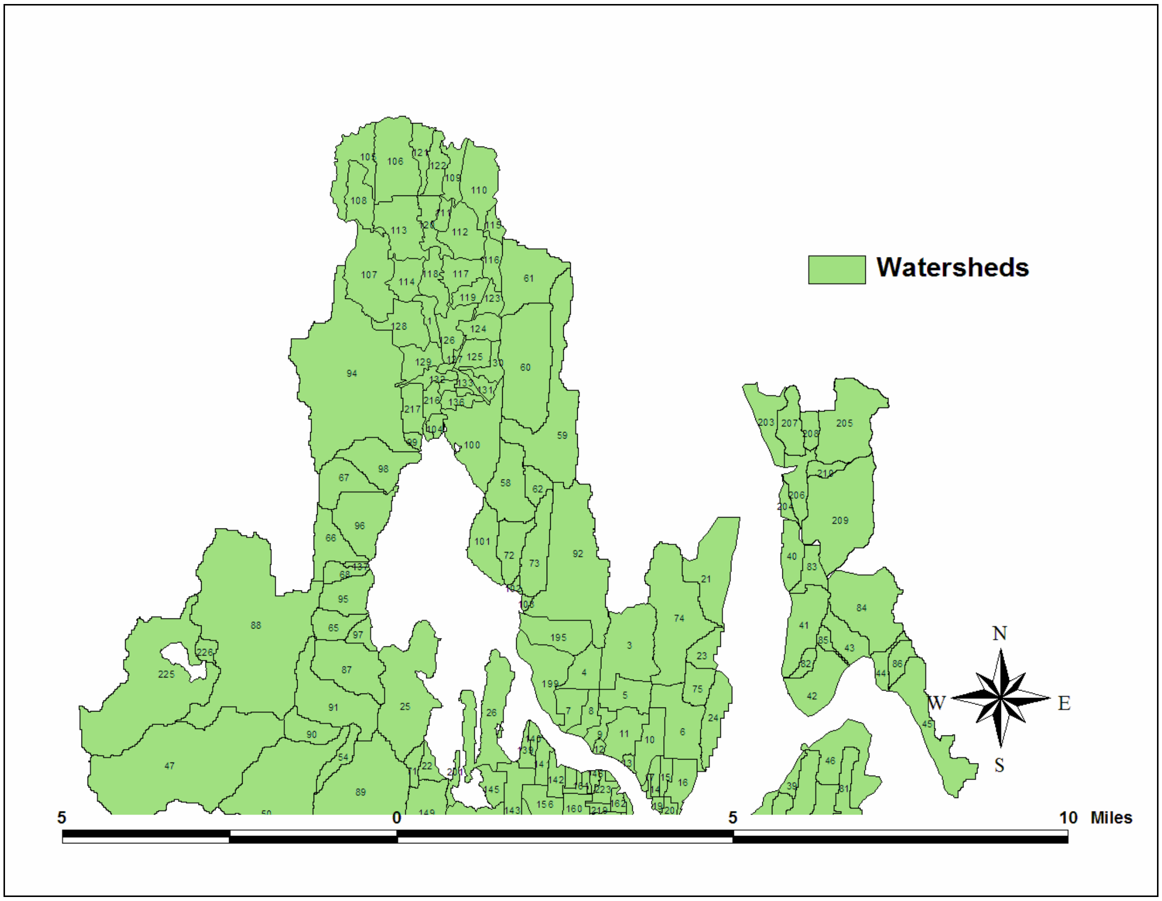

Figure 9. Assigned unique numeric ID labels for each delineated sub-watershed.

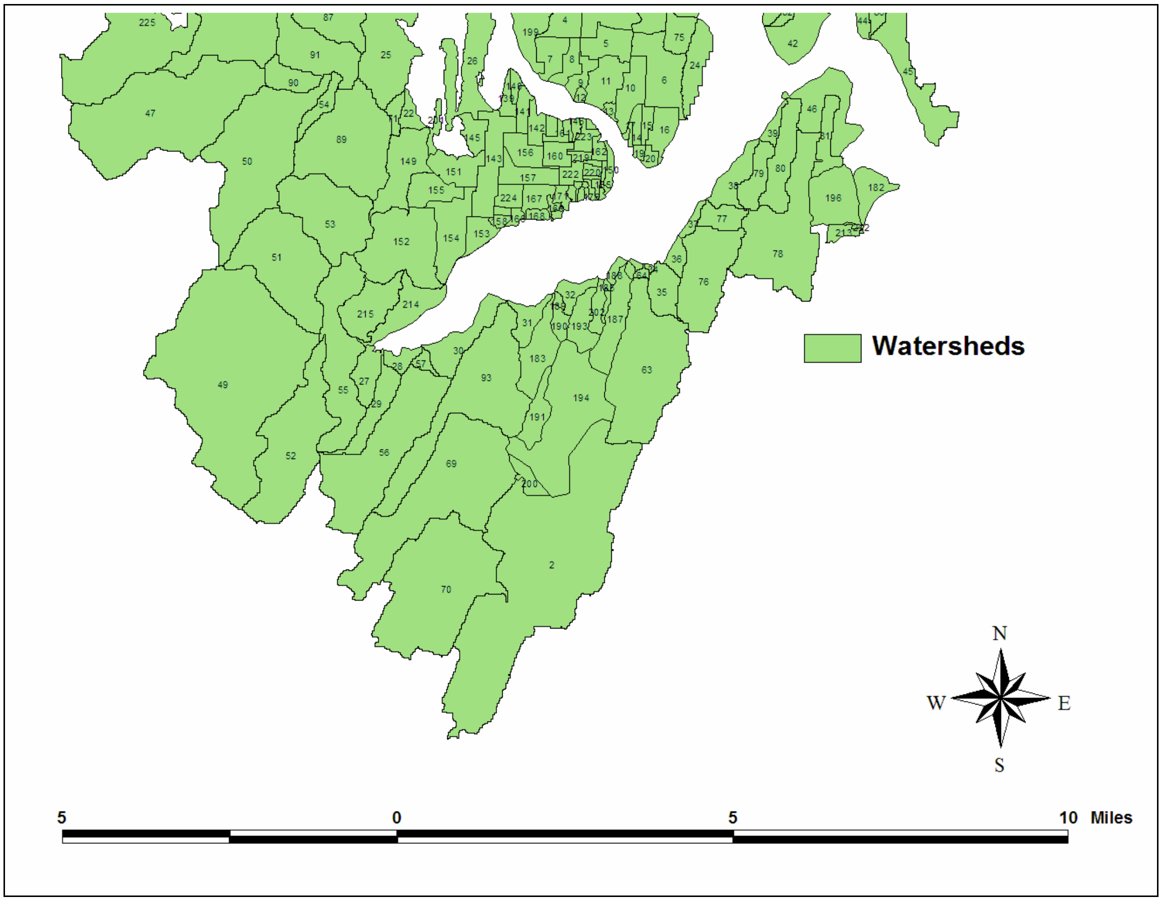

Figure 10. Assigned unique numeric ID labels for each delineated sub-watershed.

4.3 LAND SEGMENTATION

For an HSPF model, the watershed is subdivided into individual land segments that are assumed to produce a homogeneous hydrologic and water quality response. The purpose of the land segmentation within the watershed is to construct a conceptual model with the minimum number of land segments needed to simulate the hydrologic processes (Dinicola 1990). Factors that influence land segmentation for a typical HSPF model application include the meteorological forcing terms, characteristics of the watershed system itself (e.g., topography, geology, soils, land use, channel properties, etc.), and calibration endpoints, among others. A given land segment may contain one or many modeled sub–watersheds. A set of pervious land areas, directly connected impervious land areas, and reaches that may be open or closed channels, or completely mixed impoundments constitute the land area and hydrography for a given land segment. A drainage area, or a sub–watershed, is associated with each specified reach.

To support parameterization of models for ungaged areas, seventeen land segments were defined as shown in Figure 11. The defined land segmentation was based on geographic proximity. As noted, the land segmentation depicted in Figure 11 was specified for the purpose of parameterizing models for ungaged watersheds. To support calibration of the gaged watershed systems, unique land segments were specified for the drainage areas above flow monitoring locations. For example, Figure 12 depicts the five land segments that were defined for the Chico Creek HSPF model.

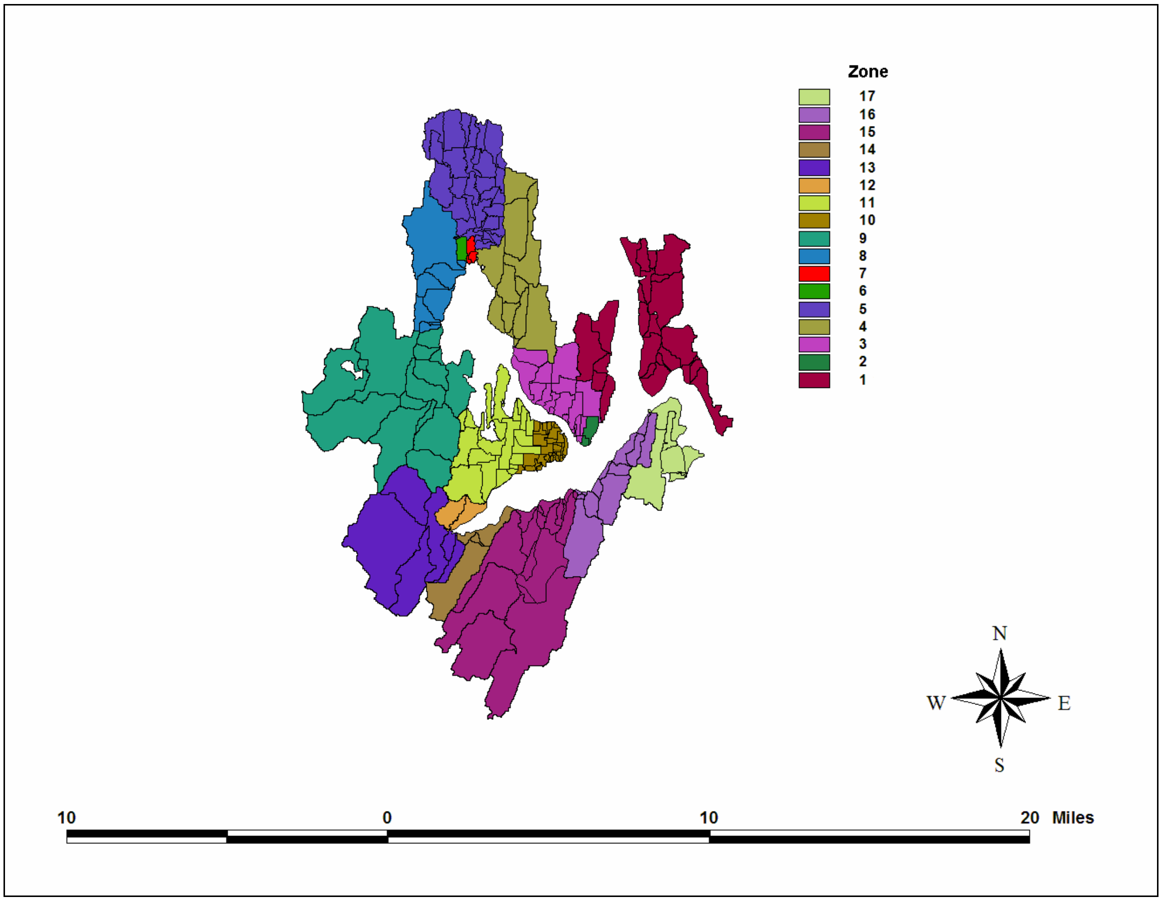

Figure 11. Land segmentation defined to support parameterization of ungaged systems.

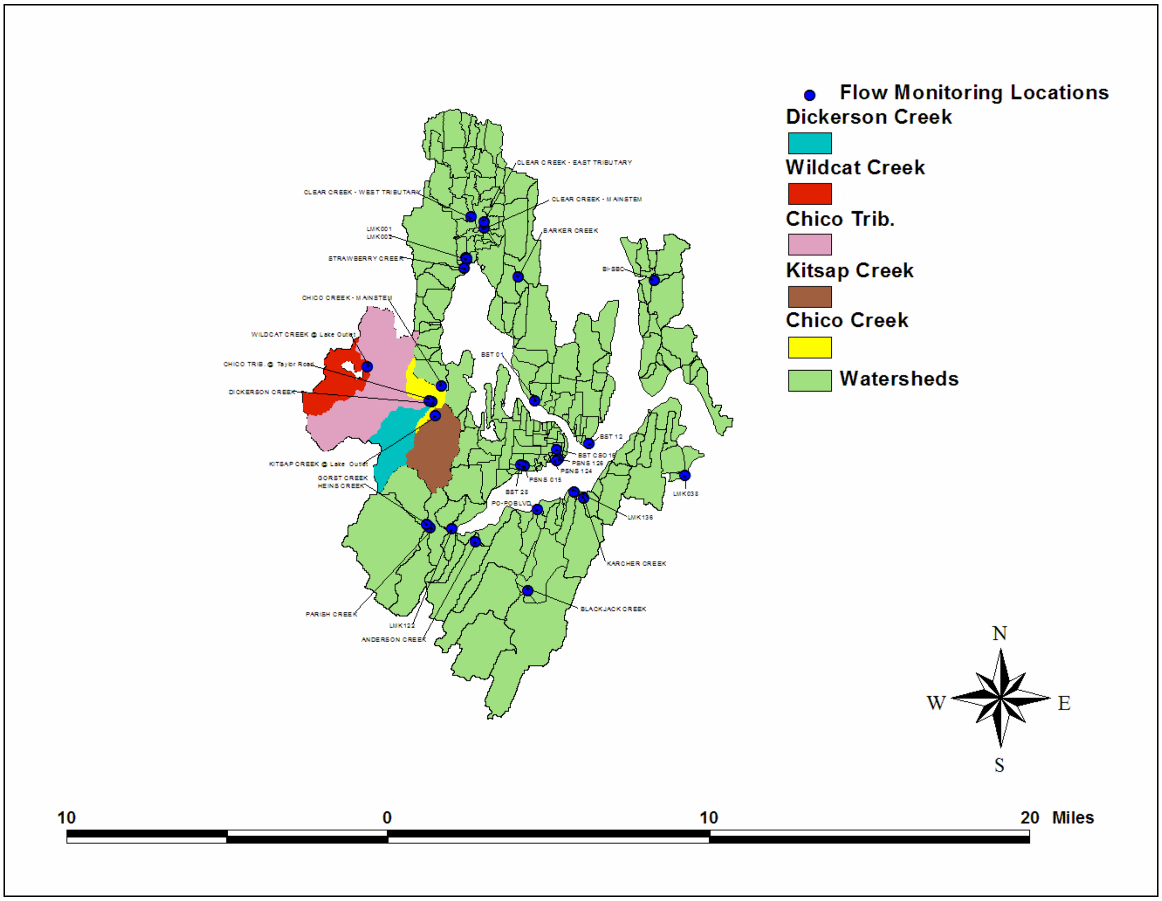

Figure 12. Land segmentation for calibration of the HSPF model for Chico Creek.

4.4 LANDSCAPE FEATURES REFLECTED

One of the notable strengths of the HSPF model is its ability to account for a multiplicity of areally associated factors relevant to the hydrologic and water quality response within a given modeled watershed system. For this study, the areal distribution of the following LULC classes were represented in each HSPF model:

1. FOREST
2. PASTURE
3. LAWN
4. RURAL RESIDENTIAL
5. SUBURBAN
6. MULTI-FAMILY

7. COMMERCIAL
8. BAREGROUND
9. IMPERVIOUS

This information was determined using available GIS data and analysis tools, and it was subsequently mapped into the SCHEMATIC block of the Users Control Input (UCI) file, the main HSPF model ASCII input file, after elementary conversion software was written to appropriately process and format the data. Directly connected impervious surface was associated with the modeled urban land covers in the HSPF models. The urban land covers within a given modeled sub-watershed were partitioned between pervious land area and directly connected impervious land area based on available guidance (Alley and Veenhuis, 1983).

4.5 FTABLES

With the exception of Kitsap Lake, Wildcat Lake, and Island Lake, stage–discharge relationships for each reach within each sub-watershed were specified based on either application of Manning's equation and information obtained from field observations or stream gaging station information obtained from KPUD. FTABLES for Island Lake, Kitsap Lake, and Wildcat Lake were specified based on bathymetry data provided by the Washington State Department of Fish and Wildlife and an assumed outflow relation. The bathymetry data provided by the Washington State Department of Fish and Wildlife had to be scanned, geo-referenced, and further processed within a GIS prior to actually conducting the GIS-based analysis to compute depth, area, volume relationships for the three noted lakes.

4.6 OTHER

For all modeled systems, the simulation time step was less than or equal to fifteen minutes, which equaled the temporal resolution of the input meteorological forcing data. Precipitation data were assigned to each subwatershed system to be calibrated, and also to those ungaged systems that piggybacked off the calibrated systems (see Figures 9, 10, and 11, and Table 4.1 in Appendix 4), as prescribed in Table 8. Multiple WDM files were prepared to receive and store simulated data.

Gaged Watershed	Precipitation Gages Used to Support Simulation	Weight
ANDERSON CREEK – BREMERTON	City of Bremerton Gage 2 KPUD Bremerton National AP	0.5 0.5
BARKER CREEK	KPUD Silverdale – Wixon	1.0
BLACKJACK CREEK	City of Bremerton Gage 2 KPUD Bremerton National AP	0.5 0.5
CHICO CREEK MAINSTEM	City of Bremerton Gage 4 KPUD Airport Park	0.5 0.5
CHICO TRIB. @ Taylor Road	KPUD Green Mountain KPUD Airport Park	0.5 0.5
CLEAR CREEK	KPUD Silverdale – Wixon	1.0
CLEAR CREEK – WEST TRIBUTARY	KPUD Silverdale – Wixon	1.0
DICKERSON CREEK	City of Bremerton Gage 4 KPUD Green Mountain KPUD Airport Park	1/3 1/3 1/3
GORST CREEK	City of Bremerton Gage 2 KPUD Bremerton National AP	0.5 0.5
HEINS CREEK	City of Bremerton Gage 2	1.0
KARCHER CREEK	City of Bremerton Gage 2	1.0
KITSAP CREEK @ Lake Outlet	KPUD Green Mountain	1.0
PARISH CREEK	KPUD Bremerton National AP	1.0
STRAWBERRY CREEK	KPUD Silverdale – Wixon	1.0
WILDCAT CREEK @ Lake Outlet	KPUD Green Mountain KPUD Airport Park	0.5 0.5
PSNS 126	PSNS	1.0
PSNS 124	PSNS City of Bremerton Gage 3	0.5 0.5
PSNS 015	PSNS	1.0
BST CSO 16	PSNS	1.0
BST 28	PSNS	1.0
BST 12	City of Bremerton Gage 1 City of Bremerton Gage 4	0.5 0.5
BST 01	PSNS City of Bremerton Gage 4	0.0 1.0
LMK 122	City of Bremerton Gage 2	1.0
PO-POBLVD	City of Bremerton Gage 2	1.0
LMK 136	NA	NA
LMK 038	PSNS	1.0
LMK 001	KPUD Silverdale – Wixon	1.0
LMK 002	KPUD Silverdale – Wixon	1.0
BI-SBC	City of Bremerton Gage 1	1.0

Table 8. Assignment of precipitation data to modeled watershed systems.

5.0 HSPF HYDROLOGIC MODEL CALIBRATION AND VERIFICATION

Conceptual model structures for the continuous simulation of watershed hydrology (e.g., HSPF) are predefined, prior to modeling, by the hydrologist's understanding of the watershed system. With conceptual model structures, it is not possible to independently measure at least some of the model parameters; hence, they must be estimated through a formal model calibration exercise. Hence, the efficacy of a conceptual model structure to inform watershed management is heavily reliant upon observed system response data and the information that one can reliably "tap" from it during the calibration process.

5.1 PERCEPTUAL MODEL

For each watershed system that was calibrated, the perceptual model was to fit

1. the hard data (i.e., the observed flow data),
2. predetermined expectations for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and evapotranspiration for each land use / land cover represented in the model, as noted in section 4.4,

and during this process to supply additional water to the system only if necessary to improve upon the fits noted above (to accommodate, likely, significant groundwater discharge to the stream). Moreover, any excess input precipitation that was not utilized to fit the hard data and to satisfy the targets established for the partition of average annual precipitation was modeled as recharge to inactive groundwater (see Bicknell et al. 2001 for details about the HSPF model structure).

5.2 METHODS

In addition to the missing data summarized in Appendix 2 for each flow monitoring location, inspection of the observed flow datasets in Appendix 3 indicate that, at least for some sites (see Figures A.3.22, 23, 24, 33, 34, 35, 36, 37, 38, 39, 40, 41, 46, 50, 51, & 57 for the more obvious datasets plagued with significant data noise/error), the observed flow data are contaminated by a fair amount of noise. The (significant) data noise associated with the observed flow data was of concern in light of the desired model complexity (see section 4.4) and the fact that if one attempts to overfit such data, the noise may control the major features of the model, and that in the worst case, the generalized inverse solution can be nothing more than a noise amplifier. A stable solution to the inverse problem (regardless of how ill-posed it is), and avoidance of the deleterious effects of numerical instability on both the parameter estimation process itself, and on the outcomes of that process, namely the set of estimated parameter values can be achieved through use of "regularization", a mathematical term that, in its broadest sense, refers to any measure that is taken to ensure that a stable solution is obtained to an otherwise ill-posed inverse problem. Mathematical regularization methodologies such as truncated singular value decomposition and Tikhonov regularization, used as a means for model calibration, have recently been demonstrated to support highly parameterized contexts (Skahill and Frankenstein, 2006; Skahill and Doherty, 2006; Doherty and Skahill, 2006), which are a direct consequence of model deployments in watershed settings where multiple vegetative types, soils, and land uses, among other relevant physical characteristics, are operative. A key point associated with the use of regularization is to understand that solutions are selected to sacrifice fit to the data in exchange for stability (Aster et al. 2005).

The numerous missing flow data points at many of the flow monitoring locations together with the potentially high number of suspect data points, for the same locations, made the conventional use of HSPEXP (Lumb et al. 1994) highly problematical to support HSPF hydrologic model calibration for this study. Methods were needed/desired to

1. Compare measured and modeled flows over multiple non-contiguous time windows in order to accommodate suspect and/or missing observations.
2. Weight data, say for example, to guide a prediction specific calibration effort (Moore and Doherty, 2005) or to accommodate suspect and/or missing observations.

3. Formulate a multi-criterion objective function wherein different measurement types (e.g., flows, reservoir storages, evapotranspiration, snow water equivalent, …), or the same measurement type processed in different ways (e.g., flow, baseflow, quickflow (e.g., direct surface runoff, interflow), volume aggregations, …), comprises separate components of a composite global objective function (Madsen, 2000; Boyle et al, 2000; Doherty and Johnston, 2003).
4. Calibrate multiple adjacent gaged subwatersheds individually, with due recognition of the desirability of inter-subwatershed parameter similarity (i.e., parameter values in adjacent areas that are associated with similar physiographic features relevant to hydrologic response be at least broadly similar), rather than calibrating each subwatershed model independently of the others.
5. Efficiently calibrate the conceptual HSPF watershed models (likely in practice, for more parsimonious contexts), for while measures can thus be taken to ensure mathematical tractability of an inverse problem posed on the basis of a properly-processed calibration dataset, it is rarely possible to avoid the fact that when calibrating conceptual watershed model structures the objective function will often contain local minima in addition to its global minimum (Wagener, Wheater, and Gupta, 2004 and references cited therein).

Enhancements (Skahill and Doherty, 2006) and adaptations (Doherty and Skahill, 2006) to the Gauss Marquardt Levenberg (GML) method of computer-based parameter estimation (Levenburg, 1944; Marquardt, 1963), and a model independent protocol (Skahill, 2006) wherein the inversion methods communicate with a model through the model's own input and output files, were utilized to calibrate the HSPF hydrologic models deployed in the Sinclair-Dyes Inlet watershed. Theory associated with these methods is presented in Appendix 5.

5.2.1 Chico Creek

The Chico Creek HSPF model includes separate submodels for the drainage areas upstream of five flow monitoring locations (Kitsap Creek, Wildcat Creek, Chico Creek

Tributary at Taylor Road, Dickerson Creek, and Chico Creek mainstem) located within the watershed (see Figure 12). To accommodate the observed flow data at the five locations within the watershed, five distinct land segments were specified for this model, as shown in Figure 12.

The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. To account for the pervious land areas represented within each land segment, for each land segment, eight instances of all but the first three parameters listed in Table 9 required estimation. Five instances of the second and third parameters listed in Table 9 required estimation, one instance for each subwatershed model. In contrast, the first adjustable model parameter type listed in Table 9, IMP, pertains to all five subwatersheds simultaneously. It possessed four instances however, one for each of four land use types occurring within the Chico Creek watershed. Thus a total of $414 = 8 \cdot 5 \cdot 10 + 2 \cdot 5 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 31st Dec 2002. Values for the 414 adjustable model parameters were estimated by matching observed and simulated flow data over twenty-three non-contiguous time intervals and also by matching 170 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within each of the five distinct land segments, with their simulated counterparts. This resulted in a total of 14,873 observations for use in the HSPF hydrologic calibration process for Chico Creek. The twenty-three flow comparison periods were identified based on a manual inspection of the observed flow data. They were formulated in order to accommodate the noted noise contaminating the observed flow data (see, for example, Figures A3.50, 13, and 14), and they are summarized in Table 10. The 170 targets are summarized in Table 11. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Chico Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted 193 groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Parameter name	Parameter function	Bounds imposed during calibration process
IMP	percent effective impervious area	11% - 19% for med. dens. residential 19% - 32% for high dens. residential 51% - 98% for comm. and industrial 7% - 10% for acreage and rural residential (Alley and Veenhuis, 1983)
INSUR	Manning's n for the impervious overland flow plane	0.01 – 0.15
RETSC	retention (interception) storage capacity of the impervious surface	0.01- 0.3
AGWETP	fraction of ET taken from groundwater (after accounting for that taken from other sources)	0.0 – 0.2
AGWRC	groundwater recession parameter	0.833 – 0.999 day^{-1}
DEEPFR	fraction of groundwater inflow that goes to inactive groundwater	0.0 – 0.2
INFILT	related to infiltration capacity of the soil	0.001 – 1.0 in/hr
INTFW	interflow inflow parameter	1.0 – 10.0
IRC	interflow recession parameter	0.30 - 0.85 day^{-1}
NSUR	Manning's n for the overland flow plane	0.05 – 0.5
LZETP	lower zone ET parameter - an index of the density of deep-rooted vegetation	0.1 - 0.9
LZSN	lower zone nominal storage	2- 15 in
UZSN	upper zone nominal storage	0.05 - 2 in

Table 9. Parameters estimated in calibration of Chico Creek subwatershed models.

Kitsap Creek at Lake Outlet					
	15 Min. Data	Daily			
	1	1	2	3	4
DATE_1	3/3/2002	1/1/2001	8/3/2001	2/5/2002	4/9/2002
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	3/25/2002	7/7/2001	1/8/2002	4/7/2002	12/31/2002
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Wildcat Creek at Lake Outlet						
	15 Min. Data	Daily				
	1	1	2	3	4	5
DATE_1	3/3/2002	1/1/2001	8/3/2001	10/1/2001	6/7/2002	10/1/2002
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	3/25/2002	5/26/2001	9/4/2001	4/7/2002	9/9/2002	12/8/2002
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Chico Tributary at Taylor Road					
	15 Min. Data	Daily			
	1	1	2	3	4
DATE_1	11/1/2001	1/1/2001	5/21/2002	11/14/2002	12/15/2002
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	11/30/2001	12/31/2001	9/30/2002	12/13/2002	12/31/2002
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Dickerson Creek			
	15 Min. Data	Daily	
	1	1	2
DATE_1	3/3/2002	1/1/2001	1/26/2002
TIME_1	0:00:00	0:00:00	0:00:00
DATE_2	3/25/2002	12/31/2001	12/25/2002
TIME_2	23:45:00	23:45:00	23:45:00

Chico Creek Mainstem				
	15 Min. Data	Daily		
	1	1	2	3
DATE_1	3/3/2002	1/1/2001	11/15/2001	1/15/2002
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	3/25/2002	8/19/2001	1/1/2002	9/30/2002
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00

Table 10. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Chico Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Kitsap Creek	SUBURBAN	1	12.73	16.93	9.01	17.03
	MULTI-FAMILY	2	22.81	11.90	6.32	14.67
	COMMERCIAL	3	40.20	3.20	1.70	10.60
	RURAL RESIDENTIAL	4	2.24	17.41	13.34	22.71
	LAWN	5	0.83	22.88	12.17	19.82
	PASTURE	6	0.40	18.14	13.88	23.28
	FOREST	7	0.12	11.57	18.32	25.69
	BAREGROUND	10	25.25	10.68	5.68	14.10
Wildcat Creek	SUBURBAN	12	12.07	16.06	8.54	16.15
	MULTI-FAMILY	13	21.63	11.28	6.00	13.92
	COMMERCIAL	14	38.13	3.04	1.61	10.05
	RURAL RESIDENTIAL	15	2.13	16.51	12.65	21.53
	LAWN	16	0.79	21.70	11.54	18.79
	PASTURE	17	0.38	17.20	13.17	22.08
	FOREST	18	0.12	10.97	17.37	24.36
	BAREGROUND	21	23.94	10.13	5.38	13.37
Chico Trib.	SUBURBAN	23	12.07	16.06	8.54	16.15
	MULTI-FAMILY	24	21.63	11.28	6.00	13.92
	COMMERCIAL	25	38.13	3.04	1.61	10.05
	RURAL RESIDENTIAL	26	2.13	16.51	12.65	21.53
	LAWN	27	0.79	21.70	11.54	18.79
	PASTURE	28	0.38	17.20	13.17	22.08
	FOREST	29	0.12	10.97	17.37	24.36
	BAREGROUND	32	23.94	10.13	5.38	13.37
Dickerson Creek	SUBURBAN	34	11.51	15.31	8.14	15.39
	MULTI-FAMILY	35	20.62	10.75	5.72	13.26
	COMMERCIAL	36	36.34	2.90	1.53	9.58
	RURAL RESIDENTIAL	37	2.03	15.74	12.06	20.53
	LAWN	38	0.75	20.68	11.00	17.91
	PASTURE	39	0.36	16.40	12.55	21.05
	FOREST	40	0.11	10.46	16.56	23.22
	BAREGROUND	43	22.82	9.65	5.13	12.75
Chico Creek Mainstem	SUBURBAN	45	10.91	14.52	7.72	14.60
	MULTI-FAMILY	46	19.55	10.20	5.42	12.58
	COMMERCIAL	47	34.47	2.75	1.46	9.08
	RURAL RESIDENTIAL	48	1.92	14.93	11.43	19.47
	LAWN	49	0.72	19.62	10.43	16.99
	PASTURE	50	0.34	15.55	11.90	19.96
	FOREST	51	0.11	9.92	15.71	22.02
	BAREGROUND	54	21.64	9.15	4.87	12.09
	IMPERVIOUS - KITSAP CK	111	46.61			9.09
	IMPERVIOUS - WILDCAT CK	121	44.20			8.62
	IMPERVIOUS - CHICO TRIB.	131	44.20			8.62
	IMPERVIOUS - DICKERSON	141	42.13			8.22
	IMPERVIOUS - CHICO MAINSTEM	151	39.96			7.79

Table 11. Predetermined targets for matching with simulated counterparts as part of the Chico Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

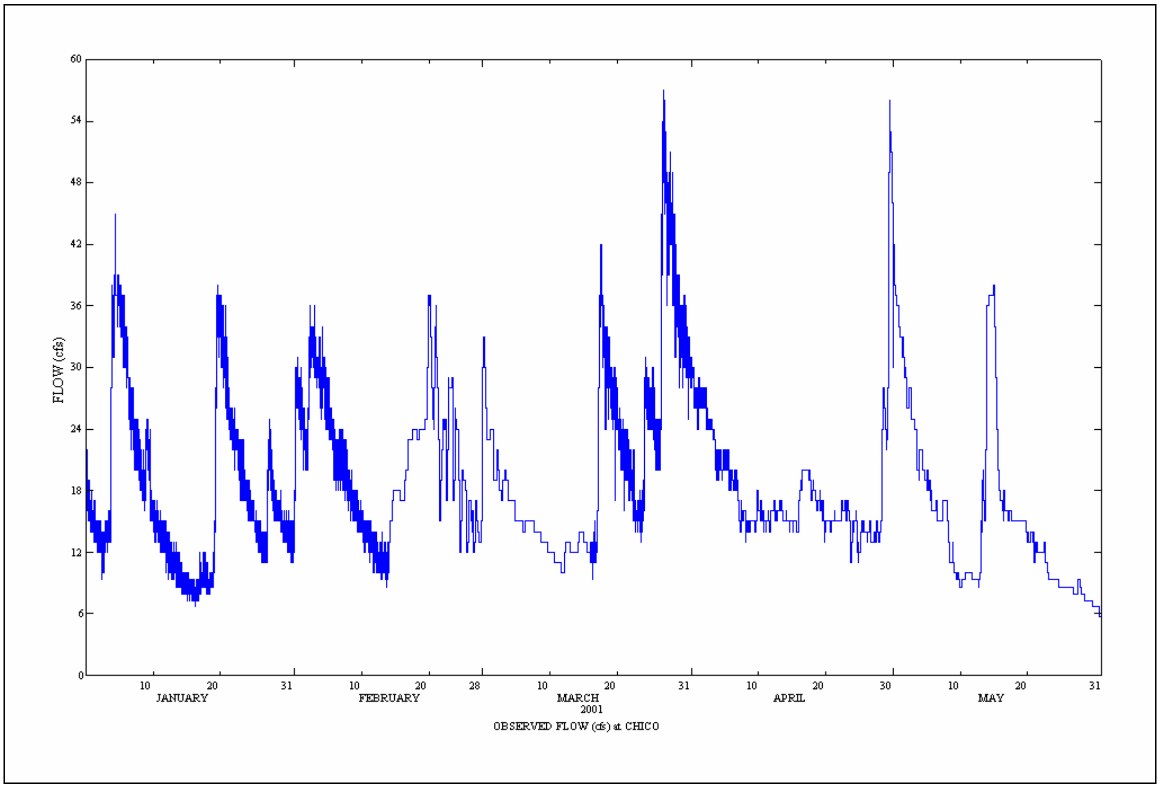

Figure 13. Observed 15 minute flow data at Chico Creek Mainstem.

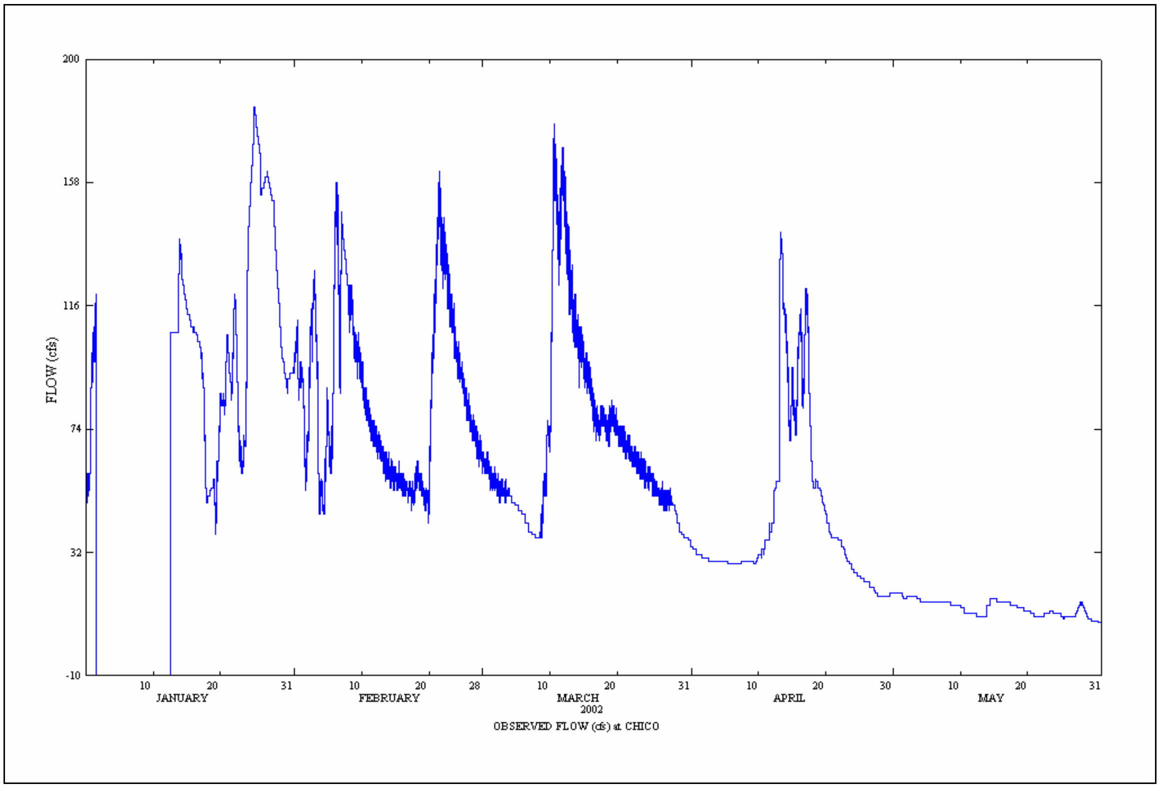

Figure 14. Observed 15 minute flow data at Chico Creek Mainstem.

5.2.2 Strawberry Creek

As indicated in Figures 9 and 11, a single land segment was employed for the Strawberry Creek HSPF model.

With the exception of the interception parameter CEPSC, for which 7 instances were established to be adjustable, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000) (The lower and upper bounds specified for the seven instances of the parameter CEPSC were also based on USEPA (2000) and, for each instance, were set at 0.005 and 0.4, respectively). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named

AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Strawberry Creek watershed. Thus a total of $93 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 7$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 93 adjustable model parameters were estimated by matching observed and simulated flow data over nine non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 1,959 observations for use in the HSPF hydrologic calibration process for Strawberry Creek. The nine flow comparison periods were identified based on a manual inspection of the observed flow data. They were formulated in order to principally accommodate the noted missing observed flow data (see, for example, Figure A3.49) and observed date-time stamp errors associated with the observed flow and/or precipitation data (see Figure 15), but also to accommodate periods with significant data error, and they are summarized in Table 12. The 34 targets are summarized in Table 13. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Strawberry Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Strawberry Creek									
	15 Min. Data	Daily							
	1	1	2	3	4	5	6	7	8
DATE_1	3/11/2003	10/6/2001	10/6/2002	12/6/2002	1/8/2003	2/9/2003	4/4/2003	6/6/2003	7/17/2003
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	3/23/2003	10/2/2002	11/5/2002	1/4/2003	2/5/2003	3/31/2003	6/2/2003	7/13/2003	9/30/2003
TIME_2	23:30:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 12. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Strawberry Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Strawberry Creek	SUBURBAN	1	10.88	14.47	7.70	14.55
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40
	LAWN	5	0.71	19.55	10.39	16.93
	PASTURE	6	0.34	15.50	11.86	19.89
	FOREST	7	0.11	9.88	15.65	21.95
	BAREGROUND	10	21.57	9.12	4.85	12.05
	IMPERVIOUS - STRAWBERRY CK	111	39.82			7.77

Table 13. Predetermined targets for matching with simulated counterparts as part of the Strawberry Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

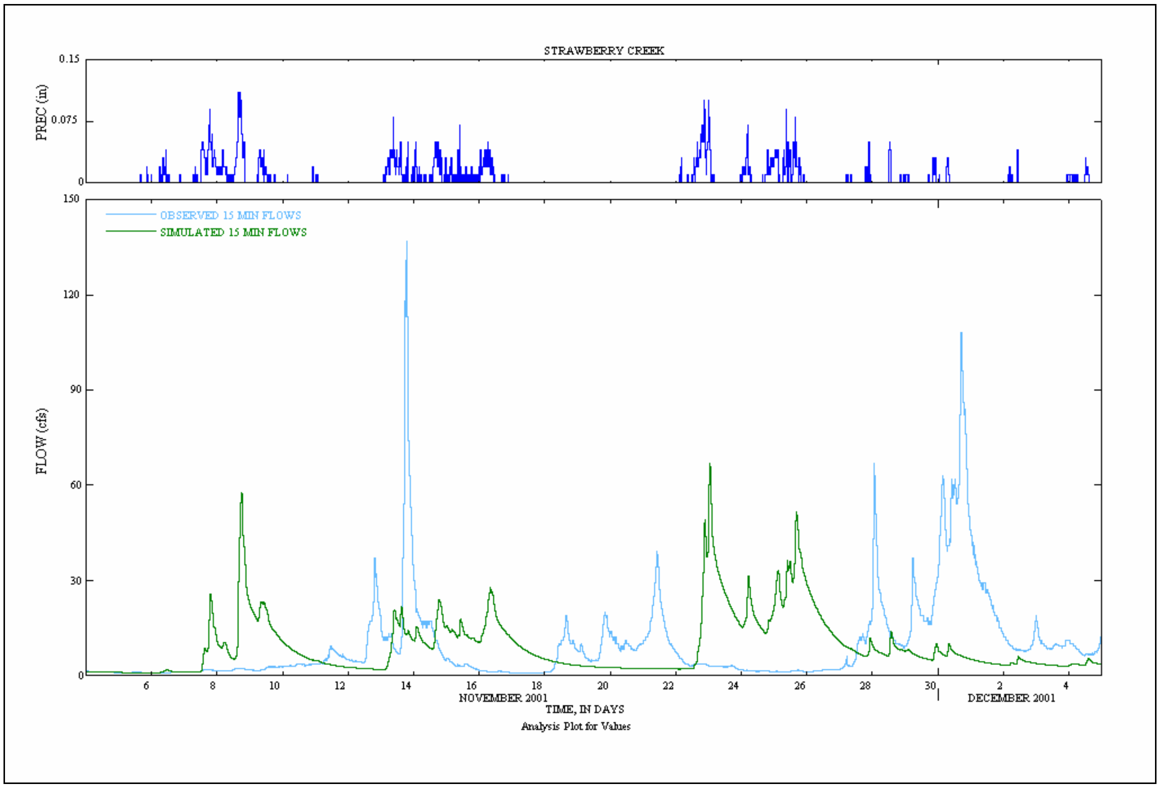

Figure 15. Observed and simulated 15 minute flow data at Strawberry Creek, and driving 15 minute precipitation data.

5.2.3 Clear Creek

The Clear Creek HSPF model includes separate submodels for the drainage areas upstream of two flow monitoring locations (Clear Creek West and Clear Creek mainstem) located within the watershed (see Figure 12). To accommodate the observed flow data at the two locations within the watershed, two distinct land segments were specified for this model, one for the drainage area contributing to the flow monitoring location at Clear Creek West and the other land segment for the remaining watershed area.

With the exception of the interception parameter CEPSC, for which 7 instances were established to be adjustable within each land segment, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table

9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000) (The lower and upper bounds specified for the parameter CEPSC were also based on USEPA (2000) and, for each instance, were set at 0.005 and 0.4, respectively). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. To account for the pervious land areas represented within each land segment, for each land segment, eight instances of all but the first three parameters listed in Table 9 required estimation. A single instance of the second and third parameters listed in Table 9 required estimation. As with the second and third adjustable model parameter types listed in Table 9, the first adjustable model parameter type listed in Table 9, IMP, pertains to the two subwatersheds simultaneously. It possessed four instances however, one for each of four land use types occurring within the Clear Creek watershed. Thus a total of $180 = 8 \cdot 2 \cdot 10 + 2 + 4 + 7 \cdot 2$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 180 adjustable model parameters were estimated by matching observed and simulated flow data over twelve non-contiguous time intervals and also by matching 68 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within each of the two distinct land segments, with their simulated counterparts. This resulted in a total of 2,466 observations for use in the HSPF hydrologic calibration process for Clear Creek. The twelve flow comparison periods are summarized in Table 14 and they were identified based on a manual inspection of the observed flow data. They were formulated in order to accommodate the noted missing observed flow data, observed date-time stamp errors associated with the observed flow and/or precipitation data (see Figure 16), and the noted observed noise contaminating the observed flow data. The 68 targets are equivalent to those summarized in Table 13 for Strawberry Creek. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the “observation” employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Clear Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted 80 groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Clear Creek West						
	15 Min. Data	Daily				
	1	1	2	3	4	5
DATE_1	1/1/2003	1/1/2001	5/9/2001	3/7/2002	10/2/2002	3/2/2003
TIME_1	12:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	1/5/2003	4/28/2001	11/5/2001	9/30/2002	2/27/2003	5/4/2003
TIME_2	23:30:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Clear Creek						
	15 Min. Data	Daily				
	1	1	2	3	4	5
DATE_1	12/7/2002	10/1/2001	1/18/2002	2/9/2002	11/26/2002	12/21/2002
TIME_1	12:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	12/17/2002	10/31/2001	2/7/2002	4/9/2002	12/19/2002	4/3/2003
TIME_2	23:30:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 14. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Clear Creek HSPF hydrologic model calibration.

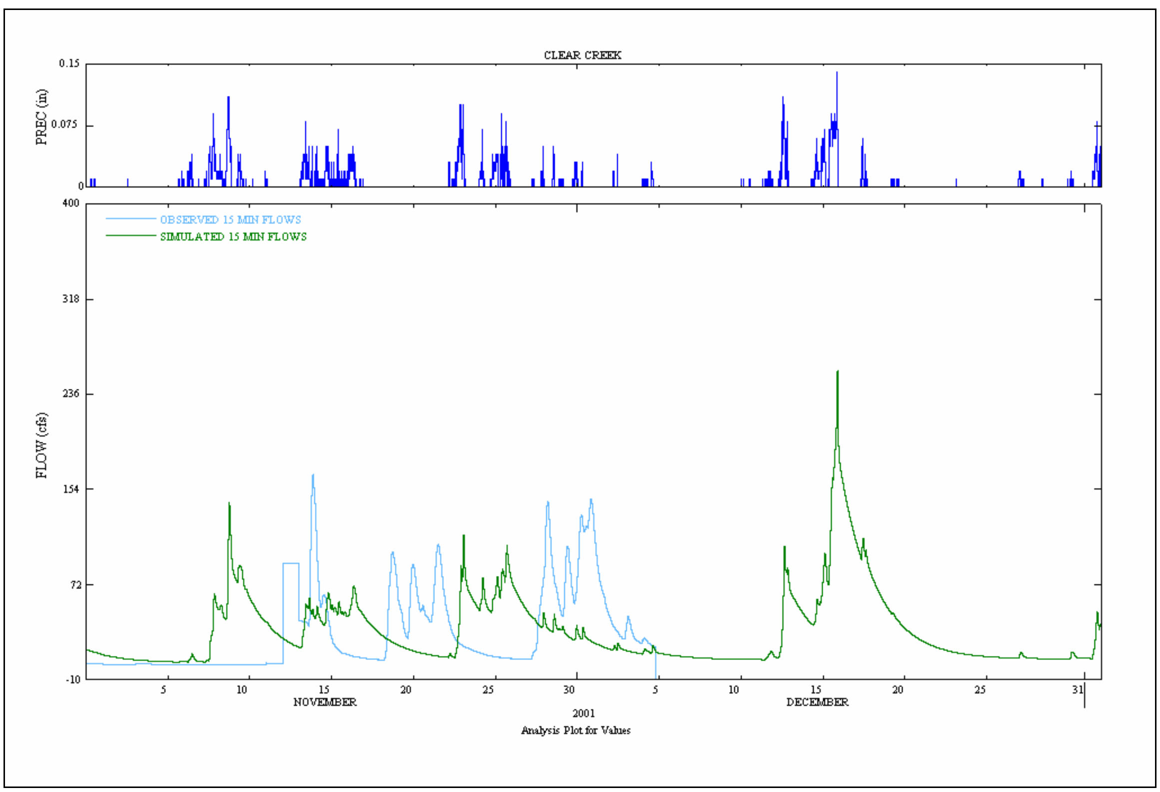

Figure 16. Observed and simulated 15 minute flow data at Clear Creek, and driving 15 minute precipitation data.

5.2.4 Barker Creek

A single land segment was employed for the Barker Creek HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Barker Creek watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. In consideration of the perceptual model, the constant supply of external water was supplied to the system labeled with the ID of 59, as shown in Figure 9. The constant supply of external water was necessary to fit the observed base flow at the Barker Creek flow monitoring location. The location for specification of the constant supply of external water was chosen to be consistent with observations (Golder Associates, 2004). Application of the constant supply of external water into the automatic calibration process was, in effect, to supply the minimum amount required to achieve a reasonable fit to the observed data. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over seven non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. One piece of prior information was also included into the parameter estimation process. The prior information included specification of a preferred value for the parameter x, namely, 10^{-5}, or effectively zero. This resulted in a total of 2,135 observations for use in the HSPF hydrologic calibration process for Barker Creek. The seven flow comparison periods were identified based on a manual inspection of the observed flow data. They were formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.45), observed date-time stamp errors associated with the observed flow and/or precipitation data (see Figure 17), and periods with presumed significant observed data error, and they are summarized in Table 15. The 34 targets are equivalent to those summarized in Table 13 for Strawberry Creek. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the “observation” employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Barker Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Barker Creek							
	15 Min. Data	Daily					
	1	1	2	3	4	5	6
DATE_1	3/11/2003	1/6/2001	3/1/2002	12/5/2002	4/4/2003	6/6/2003	7/13/2003
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	3/23/2003	10/31/2001	11/20/2002	3/31/2003	5/31/2003	7/9/2003	9/30/2003
TIME_2	23:30:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 15. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Barker Creek HSPF hydrologic model calibration.

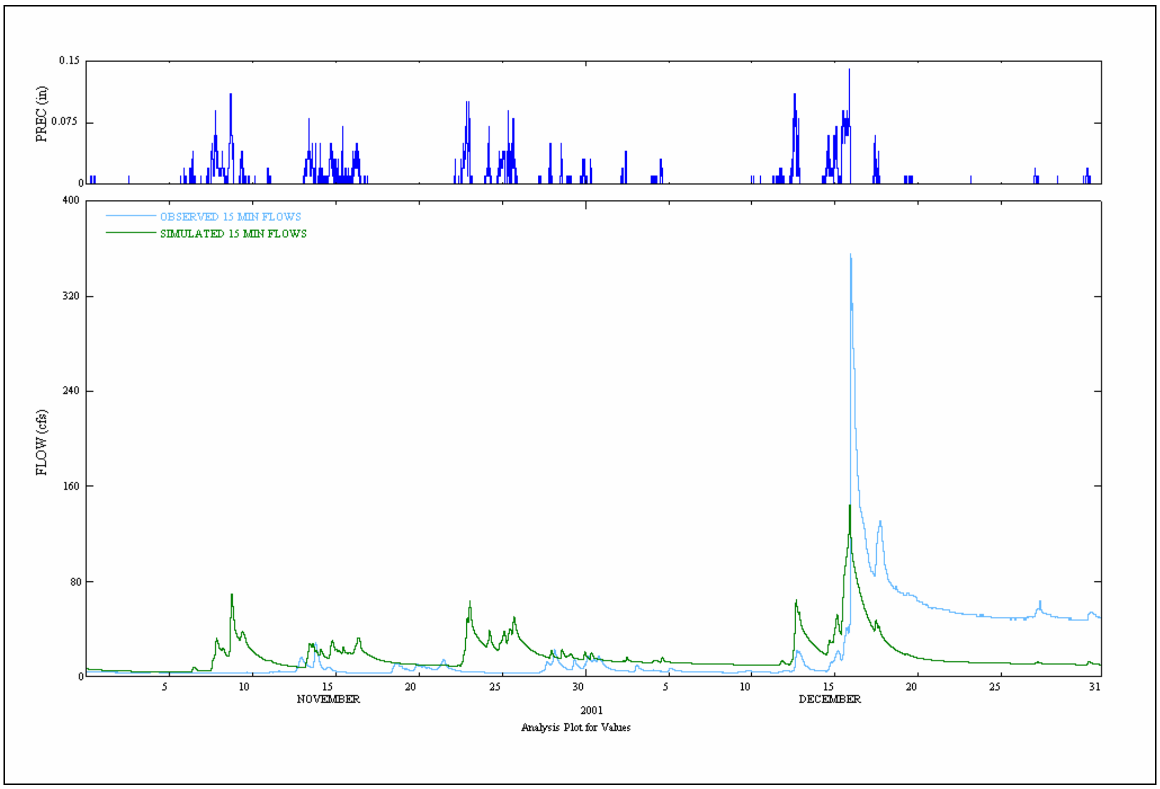

Figure 17. Observed and simulated 15 minute flow data at Barker Creek, and driving 15 minute precipitation data.

5.2.5 Karcher Creek

A single land segment was employed for the Karcher Creek HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Karcher Creek watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over nine non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. One piece of prior information was also included into the parameter estimation process. The prior information included specification of a preferred value for the parameter x, namely, 10^{-5}, or effectively zero. This resulted in a total of 952 observations for use in the HSPF hydrologic calibration process for Karcher Creek. The nine flow comparison periods were identified based on a manual inspection of the observed flow data. They were formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.32 and Figure A3.62), observed date-time stamp errors associated with the observed flow and/or precipitation data, time shifts between the driving precipitation data and observed system response data (see Figures 18 and 19) (due to this phenomenon there was no comparison between simulated and observed 15 minute flows), and periods with presumed significant observed data error, and they are summarized in Table 16. The 34 targets are summarized in Table 17. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Karcher Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Karcher Creek									
	Daily								
	1	2	3	4	5	6	7	8	9
DATE_1	4/12/1997	12/18/1997	1/31/1998	4/25/1998	9/2/1998	10/2/1998	3/3/1999	6/4/1999	12/1/2002
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	10/28/1997	1/27/1998	4/21/1998	8/26/1998	9/27/1998	2/27/1999	5/31/1999	8/15/1999	4/13/2003
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 16. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Karcher Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Karcher Creek	SUBURBAN	1	10.31251	13.71675	7.296378	13.79437
	MULTI-FAMILY	2	18.47381	9.636097	5.122988	11.88711
	COMMERCIAL	3	32.56757	2.59476	1.375001	8.582669
	RURAL RESIDENTIAL	4	1.81721	14.10554	10.80354	18.39371
	LAWN	5	0.6762457	18.53578	9.85545	16.05252
	PASTURE	6	0.3213359	14.69281	11.24676	18.8591
	FOREST	7	9.97E-02	9.369543	14.84065	20.81013
	BAREGROUND	10	20.4513	8.649201	4.598123	11.42138
	IMPERVIOUS - KARCHER CK	111	37.75709			7.36291

Table 17. Predetermined targets for matching with simulated counterparts as part of the Karcher Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

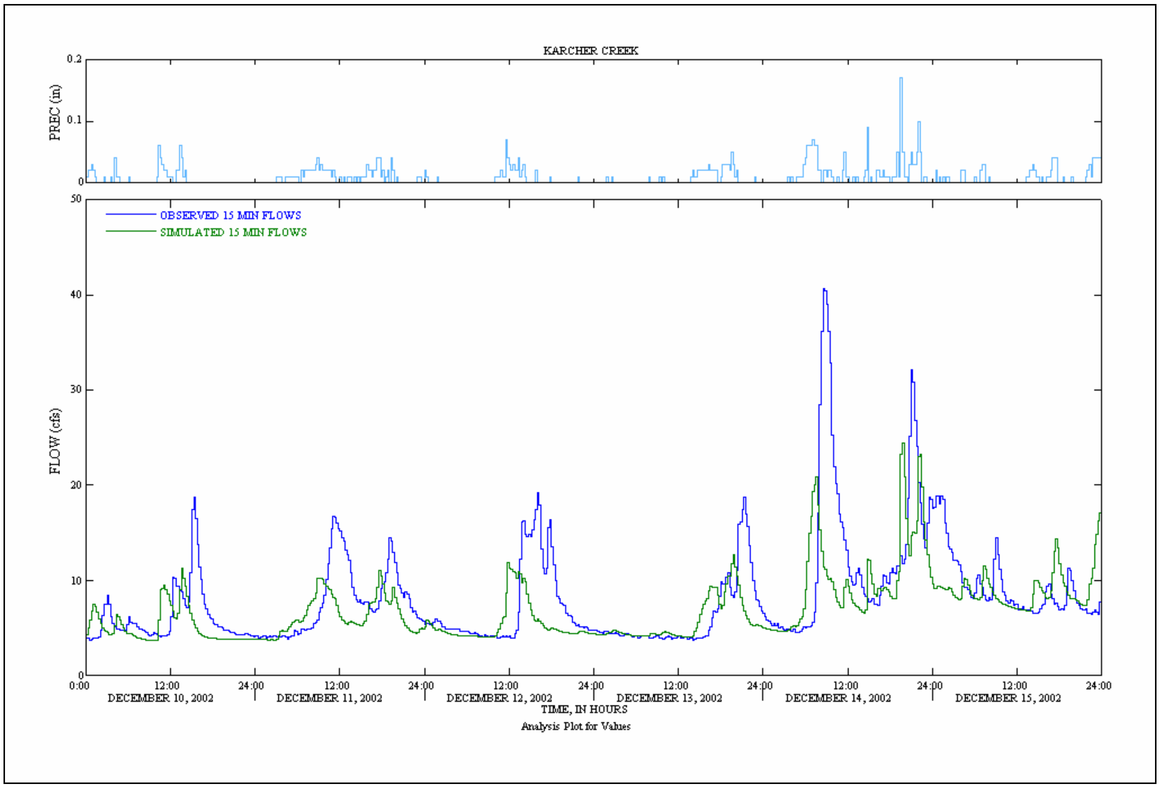

Figure 18. Observed and simulated 15 minute flow data at Karcher Creek, and driving 15 minute precipitation data.

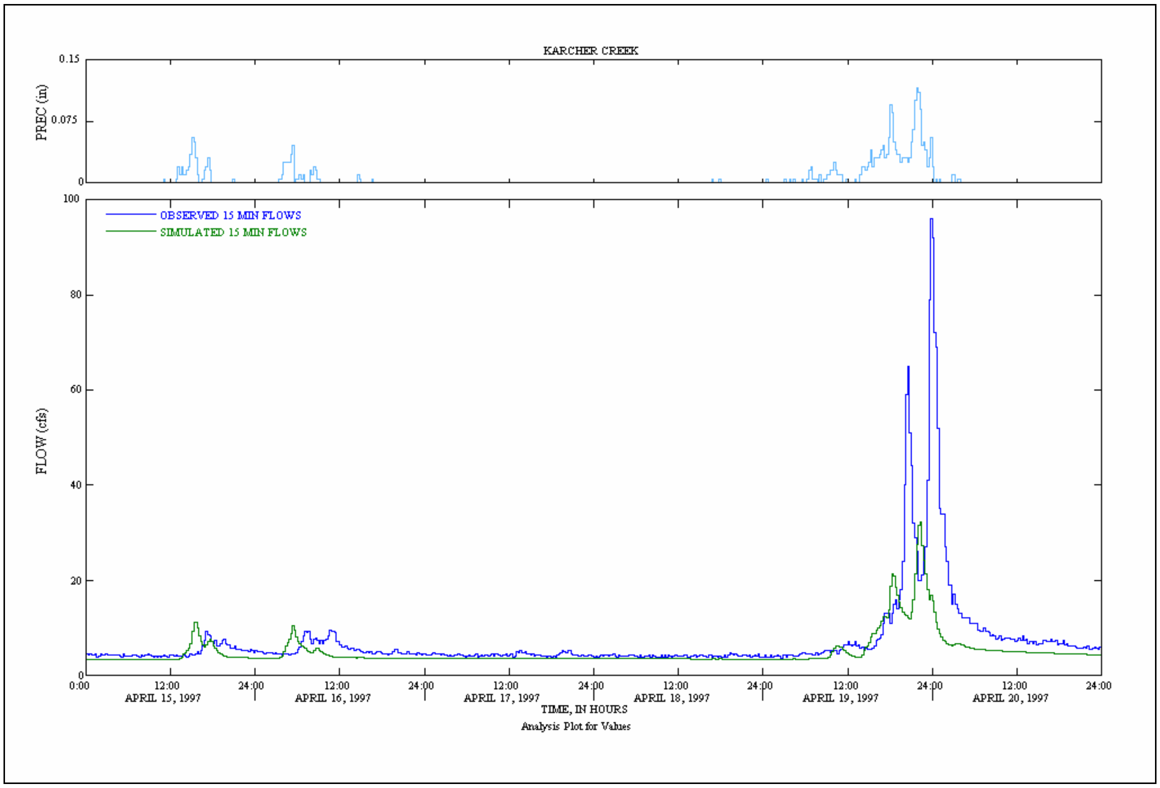

Figure 19. Observed and simulated 15 minute flow data at Karcher Creek, and driving 15 minute precipitation data.

5.2.6 Blackjack Creek

A single land segment was employed for the Blackjack Creek HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Blackjack

Creek watershed. Thus a total of $86 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 30th Apr 2003. Values for the 86 adjustable model parameters were estimated by matching observed and simulated flow data over five non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 3,498 observations for use in the HSPF hydrologic calibration process for Blackjack Creek. The five flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.61), and they are summarized in Table 18. The 34 targets are summarized in Table 19. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Blackjack Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Blackjack Creek					
	15 Min. Data	Daily			
	1	1	2	3	4
DATE_1	1/1/2003	1/1/2001	3/1/2001	12/12/2002	3/1/2003
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	1/28/2003	2/26/2001	9/30/2002	2/27/2003	4/30/2003
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 18. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Blackjack Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Blackjack Creek	SUBURBAN	1	9.99	13.29	7.07	13.36
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51
	COMMERCIAL	3	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81
	LAWN	5	0.65	17.95	9.55	15.55
	PASTURE	6	0.31	14.23	10.89	18.27
	FOREST	7	0.10	9.07	14.37	20.16
	BAREGROUND	10	19.81	8.38	4.45	11.06
	IMPERVIOUS - BLACKJACK CK	111	36.57			7.13

Table 19. Predetermined targets for matching with simulated counterparts as part of the Blackjack Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.7 Anderson Creek

A single land segment was employed for the Anderson Creek HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Anderson Creek watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 31st Dec 2002. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over six non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 8,837 observations for use in the HSPF hydrologic calibration process for Anderson Creek. The six flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.30 and Figure A3.60), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 20. The 34 targets are summarized in Table 21. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Anderson Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Anderson Creek						
	15 Min. Data	Daily				
	1	1	2	3	4	5
DATE_1	12/5/1998	10/1/1996	12/20/1996	2/20/1997	10/1/1997	3/20/1998
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	2/15/1999	12/18/1996	2/11/1997	9/8/1997	3/18/1998	9/30/2001
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00	23:45:00

Table 20. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Anderson Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Anderson Creek	SUBURBAN	1	9.99	13.29	7.07	13.36
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51
	COMMERCIAL	3	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81
	LAWN	5	0.65	17.95	9.55	15.55
	PASTURE	6	0.31	14.23	10.89	18.27
	FOREST	7	0.10	9.07	14.37	20.16
	BAREGROUND	10	19.81	8.38	4.45	11.06
	IMPERVIOUS - ANDERSON CK	111	36.57			7.13

Table 21. Predetermined targets for matching with simulated counterparts as part of the Anderson Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.8 Gorst Creek

The Gorst Creek HSPF model includes separate submodels for the drainage areas upstream of three flow monitoring locations (Heins Creek, Parish Creek, and Gorst Creek) located within the watershed (see Figure 12). To accommodate the observed flow data at the three locations within the watershed, three distinct land segments were specified for this model.

The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. To account for the pervious land areas represented within each land segment, for each land segment, eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to all three subwatersheds simultaneously. It possessed four instances however, one for each of four land use types occurring within the Gorst Creek watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to Gorst Creek to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $247 = 8 \cdot 3 \cdot 10 + 2 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 2nd Feb 2003. Values for the 247 adjustable model parameters were estimated by matching observed and simulated flow data over six non-contiguous time intervals and also by matching 102 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within each of the three distinct land segments, with their simulated counterparts. This resulted in a total of 8,191 observations for use in the HSPF hydrologic calibration process for Gorst Creek. The six flow comparison periods were identified based on a manual inspection of the observed flow data. They were formulated in order to accommodate missing data and the noted noise contaminating the observed flow data (see, for example, Figures A3.29, A3.57, A3.58, and A3.59), and they are summarized in Table 22. The 102 targets are summarized in Table 23. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the “observation” employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Gorst Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted 108 groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Heins Creek		
	15 Min. Data	Daily
	1	1
DATE_1	12/14/2002	10/2/2002
TIME_1	18:00:00	0:00:00
DATE_2	12/18/2002	2/2/2003
TIME_2	23:45:00	23:45:00

Parish Creek		
	15 Min. Data	Daily
	1	1
DATE_1	3/7/2002	3/1/2002
TIME_1	0:00:00	0:00:00
DATE_2	4/30/2002	9/30/2002
TIME_2	23:45:00	23:45:00

Gorst Creek		
	15 Min. Data	Daily
	1	1
DATE_1	11/13/2001	1/1/2001
TIME_1	0:00:00	0:00:00
DATE_2	11/30/2001	11/30/2001
TIME_2	23:45:00	23:45:00

Table 22. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Gorst Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Heins Creek	SUBURBAN	1	9.99	13.29	7.07	13.36
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51
	COMMERCIAL	3	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81
	LAWN	5	0.65	17.95	9.55	15.55
	PASTURE	6	0.31	14.23	10.89	18.27
	FOREST	7	0.10	9.07	14.37	20.16
	BAREGROUND	10	19.81	8.38	4.45	11.06
Parish Creek	SUBURBAN	12	9.99	13.29	7.07	13.36
	MULTI-FAMILY	13	17.89	9.33	4.96	11.51
	COMMERCIAL	14	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	15	1.76	13.66	10.46	17.81
	LAWN	16	0.65	17.95	9.55	15.55
	PASTURE	17	0.31	14.23	10.89	18.27
	FOREST	18	0.10	9.07	14.37	20.16
	BAREGROUND	21	19.81	8.38	4.45	11.06
Gorst Creek	SUBURBAN	23	9.99	13.29	7.07	13.36
	MULTI-FAMILY	24	17.89	9.33	4.96	11.51
	COMMERCIAL	25	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	26	1.76	13.66	10.46	17.81
	LAWN	27	0.65	17.95	9.55	15.55
	PASTURE	28	0.31	14.23	10.89	18.27
	FOREST	29	0.10	9.07	14.37	20.16
	BAREGROUND	32	19.81	8.38	4.45	11.06

Table 23. Predetermined targets for matching with simulated counterparts as part of the Gorst Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.9 Springbrook Creek

A single land segment was employed for the Springbrook Creek HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between

5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the Springbrook Creek watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 2000 to 7th Nov 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over two non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 410 observations for use in the HSPF hydrologic calibration process for Springbrook Creek. The two flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.22), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 24. The 34 targets are summarized in Table 25. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Springbrook Creek HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Springbrook Creek		
	15 Min. Data	Daily
	1	1
DATE_1	11/2/2004	5/9/2004
TIME_1	0:00:00	0:00:00
DATE_2	11/3/2004	11/7/2004
TIME_2	23:45:00	23:45:00

Table 24. Non-contiguous time intervals used for matching observed and simulated flow data as part of the Springbrook Creek HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Springbrook Creek	SUBURBAN	1	9.99	13.29	7.07	13.36
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51
	COMMERCIAL	3	31.54	2.51	1.33	8.31
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81
	LAWN	5	0.65	17.95	9.55	15.55
	PASTURE	6	0.31	14.23	10.89	18.27
	FOREST	7	0.10	9.07	14.37	20.16
	BAREGROUND	10	19.81	8.38	4.45	11.06
	IMPERVIOUS - SPRINGBROOK CK	111	36.57			7.13

Table 25. Predetermined targets for matching with simulated counterparts as part of the Springbrook Creek HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.10 BST 12

Noise contaminated the observed flow data for site BST 12 to such an extent that no attempt was made to calibrate the HSPF model that was developed for BST 12 (see Figures 20 – 27).

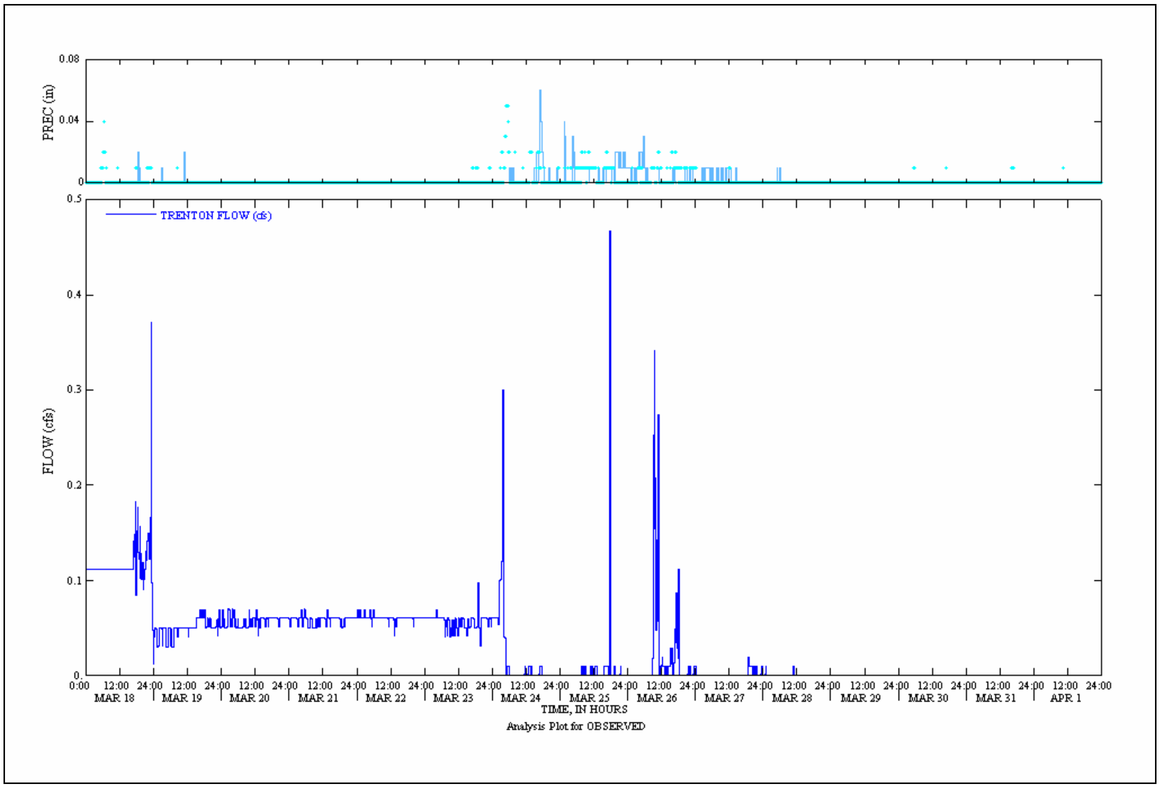

Figure 20. Driving precipitation data and observed flow for BST 12.

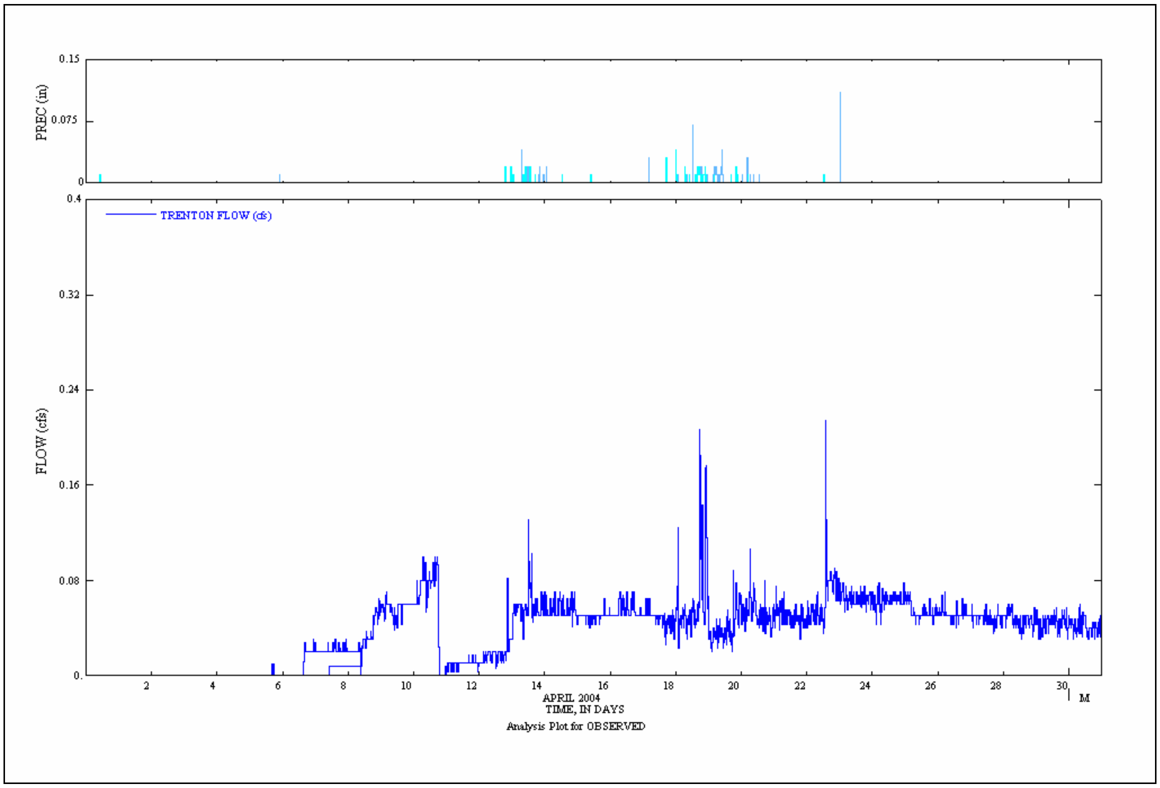

Figure 21. Driving precipitation data and observed flow for BST 12.

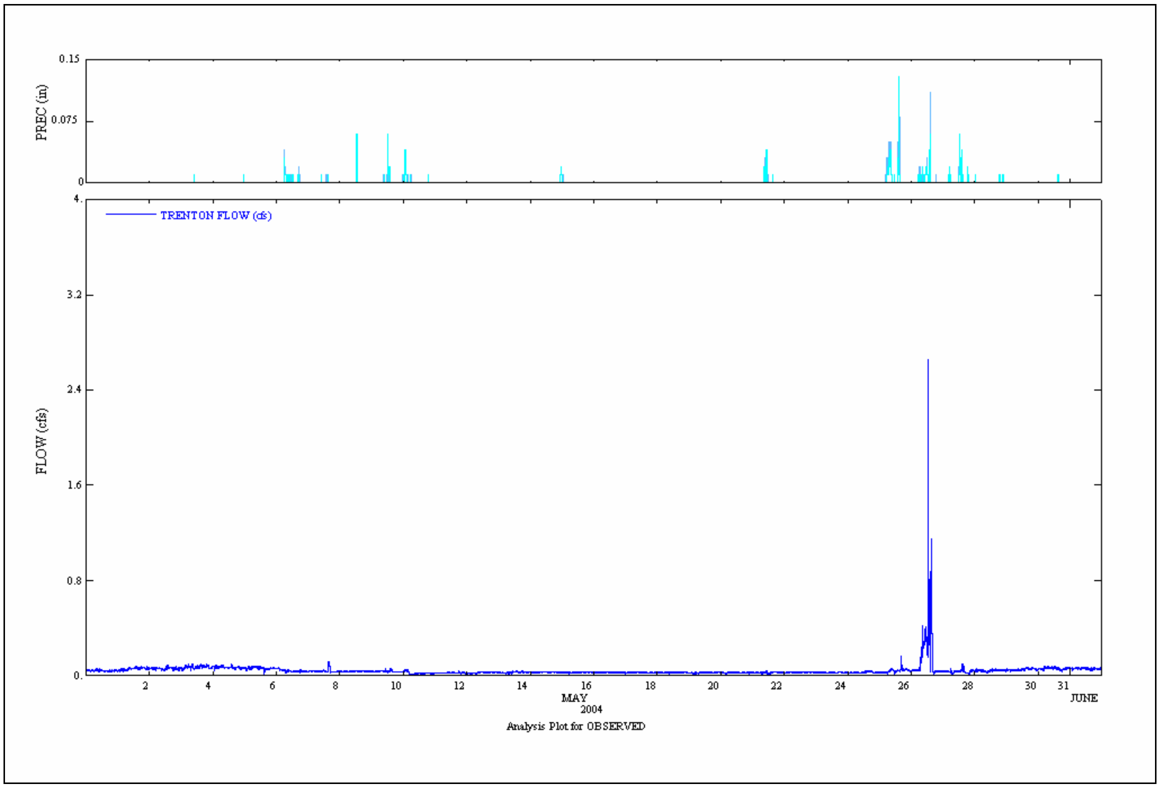

Figure 22. Driving precipitation data and observed flow for BST 12.

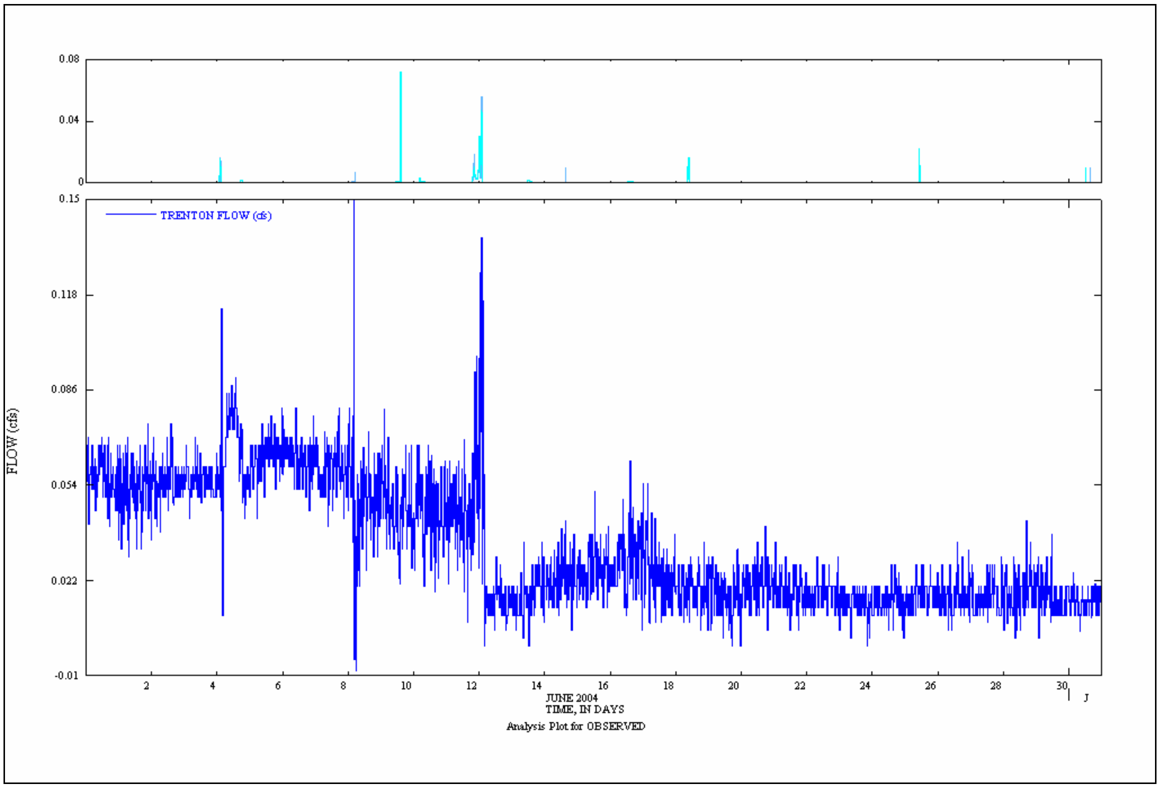

Figure 23. Driving precipitation data and observed flow for BST 12.

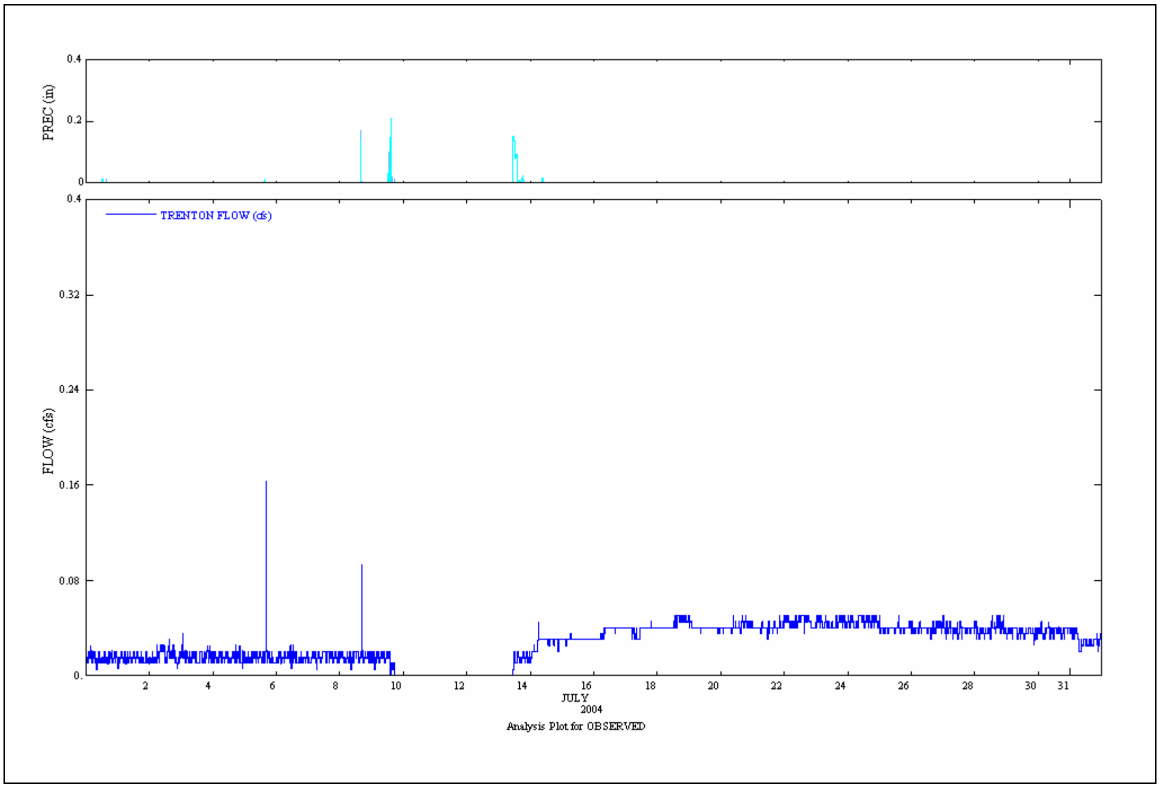

Figure 24. Driving precipitation data and observed flow for BST 12.

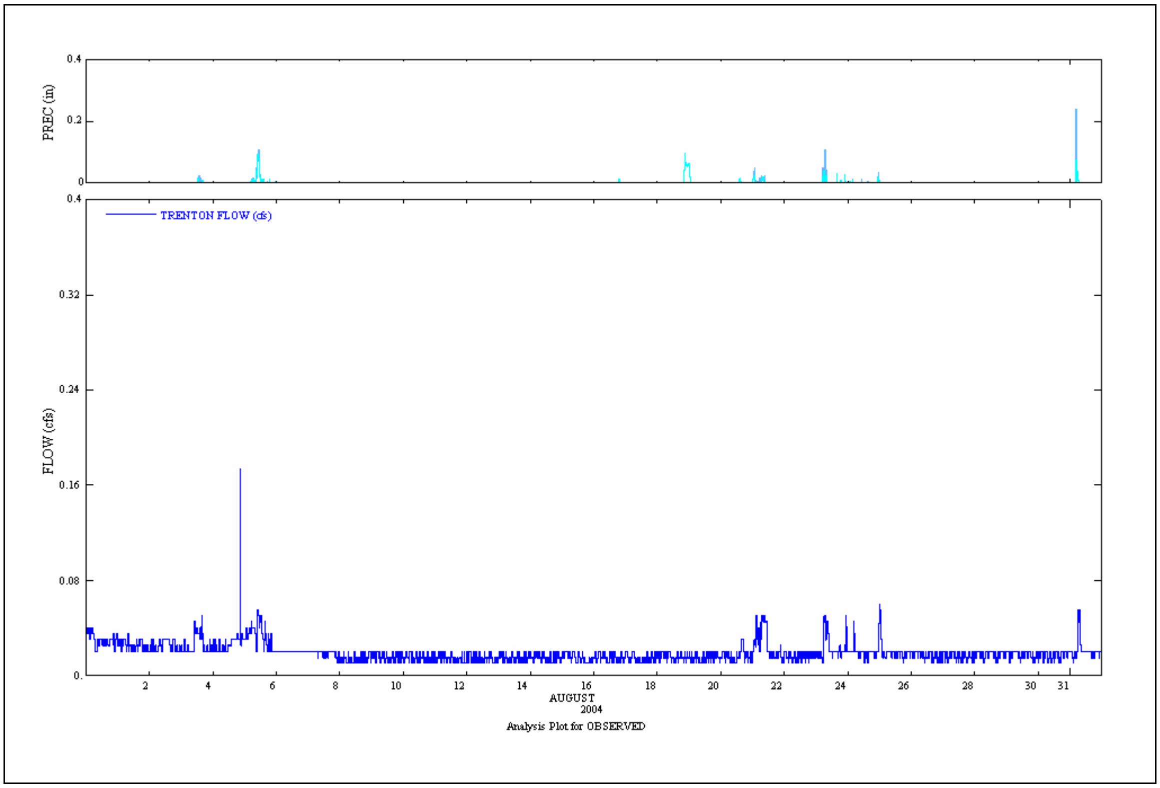

Figure 25. Driving precipitation data and observed flow for BST 12.

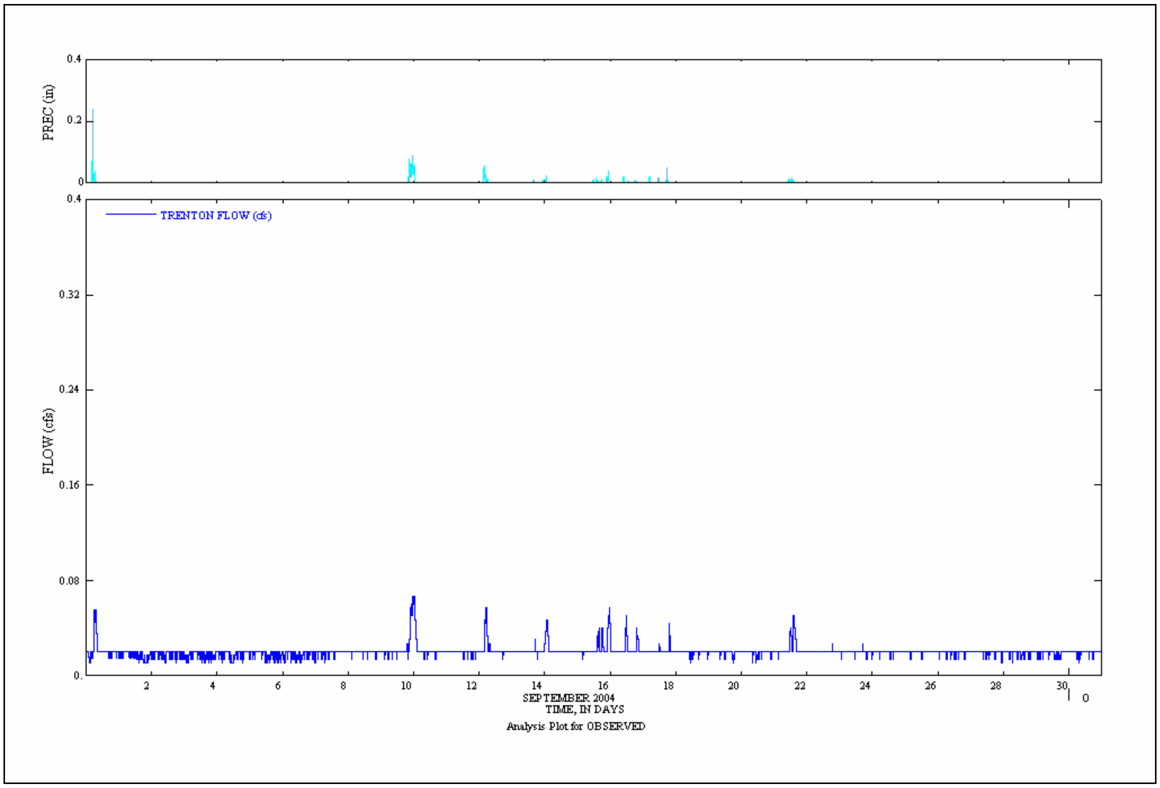

Figure 26. Driving precipitation data and observed flow for BST 12.

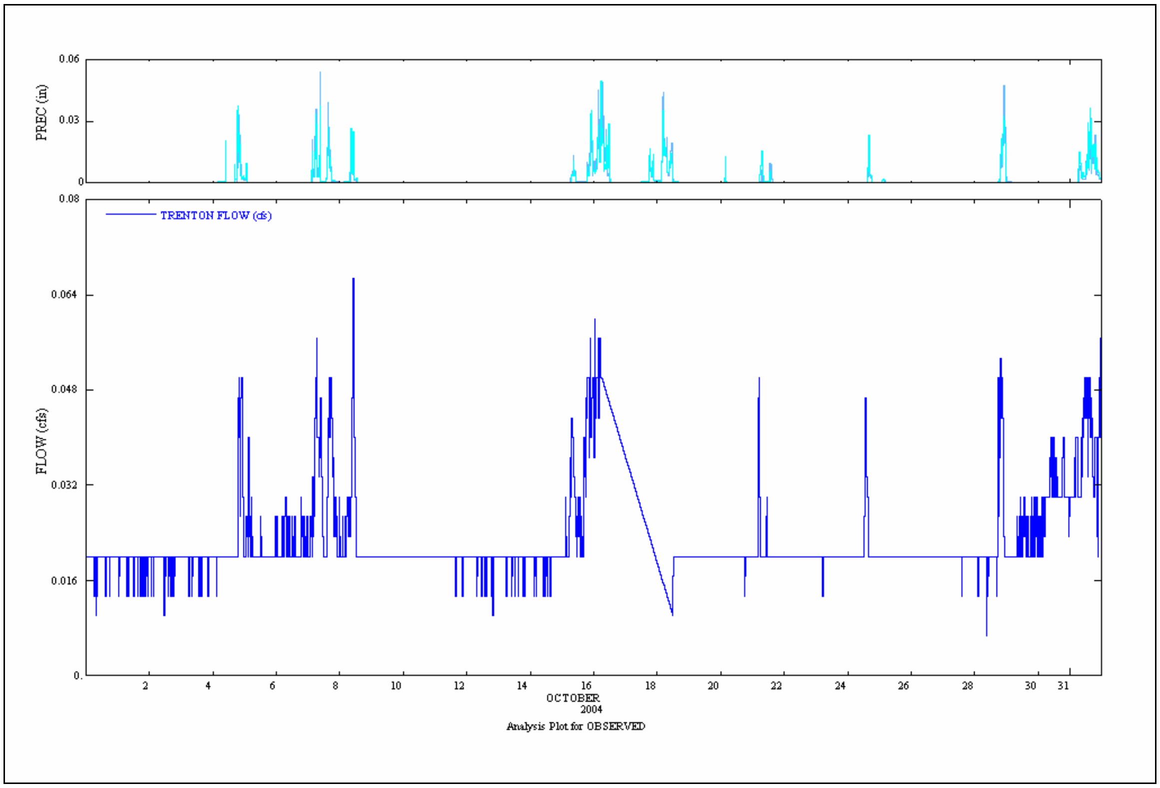

Figure 27. Driving precipitation data and observed flow for BST 12.

5.2.11 BST 01

A single land segment was employed for the BST 01 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the BST 01 watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 2000 to 8th Oct 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over nine non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 1,188 observations for use in the HSPF hydrologic calibration process for BST 01. The nine flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.24), and they are summarized in Table 26. The 34 targets are summarized in Table 27. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the BST 01 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

	BST01								
	15 Min. Data								
	1	2	3	4	5	6	7	8	9
DATE_1	3/24/2004	4/19/2004	5/26/2004	6/13/2004	7/9/2004	9/10/2004	9/13/2004	10/5/2004	10/8/2004
TIME_1	0:00:00	15:00:00	0:00:00	0:00:00	12:00:00	18:00:00	0:00:00	18:00:00	6:00:00
DATE_2	3/26/2004	4/20/2004	5/29/2004	6/13/2004	7/10/2004	9/11/2004	9/13/2004	10/6/2004	10/8/2004
TIME_2	11:45:00	6:00:00	11:45:00	23:45:00	23:45:00	11:45:00	23:45:00	11:45:00	15:00:00

Table 26. Non-contiguous time intervals used for matching observed and simulated flow data as part of the BST 01 HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
BST01	SUBURBAN	1	10.88	14.47	7.70	14.55
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40
	LAWN	5	0.71	19.55	10.39	16.93
	PASTURE	6	0.34	15.50	11.86	19.89
	FOREST	7	0.11	9.88	15.65	21.95
	BAREGROUND	10	21.57	9.12	4.85	12.05
	IMPERVIOUS - BST01	111	39.82			7.77

Table 27. Predetermined targets for matching with simulated counterparts as part of the BST 01 HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.12 LMK001

A single land segment was employed for the LMK001 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the LMK001 watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 2nd Nov 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over ten non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 566 observations for use in the HSPF hydrologic calibration process for LMK001. The ten flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.38), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 28. The 34 targets are summarized in Table 29. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the LMK001 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

LMK001										
	15 Min. Data									
	1	2	3	4	5	6	7	8	9	10
DATE_1	6/13/2004	7/10/2004	8/22/2004	9/10/2004	10/5/2004	10/8/2004	10/17/2004	10/19/2004	10/29/2004	11/2/2004
TIME_1	0:00:00	14:00:00	2:00:00	19:00:00	19:00:00	4:00:00	0:00:00	5:00:00	20:00:00	0:00:00
DATE_2	6/13/2004	7/10/2004	8/22/2004	9/11/2004	10/5/2004	10/8/2004	10/17/2004	10/19/2004	10/30/2004	11/2/2004
TIME_2	4:00:00	16:00:00	16:00:00	16:00:00	23:45:00	22:00:00	23:45:00	16:00:00	4:00:00	23:45:00

Table 28. Non-contiguous time intervals used for matching observed and simulated flow data as part of the LMK001 HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
LMK001	SUBURBAN	1	10.88	14.47	7.70	14.55
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40
	LAWN	5	0.71	19.55	10.39	16.93
	PASTURE	6	0.34	15.50	11.86	19.89
	FOREST	7	0.11	9.88	15.65	21.95
	BAREGROUND	10	21.57	9.12	4.85	12.05
	IMPERVIOUS - LMK001	111	39.82			7.77

Table 29. Predetermined targets for matching with simulated counterparts as part of the LMK001 HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.13 LMK002

A single land segment was employed for the LMK002 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the LMK002 watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of

$87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 10th Sep 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over six non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 151 observations for use in the HSPF hydrologic calibration process for LMK002. The six flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.39), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 30. The 34 targets are summarized in Table 31. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the LMK002 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

LMK002						
	15 Min. Data					
	1	2	3	4	5	6
DATE_1	10/8/2004	10/19/2004	10/29/2004	11/2/2004	7/10/2004	9/10/2004
TIME_1	4:00:00	5:00:00	18:00:00	2:00:00	14:00:00	20:00:00
DATE_2	10/8/2004	10/19/2004	10/29/2004	11/2/2004	7/10/2004	9/10/2004
TIME_2	11:45:00	10:00:00	23:45:00	6:00:00	16:00:00	23:00:00

Table 30. Non-contiguous time intervals used for matching observed and simulated flow data as part of the LMK002 HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
LMK002	SUBURBAN	1	10.88	14.47	7.70	14.55
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40
	LAWN	5	0.71	19.55	10.39	16.93
	PASTURE	6	0.34	15.50	11.86	19.89
	FOREST	7	0.11	9.88	15.65	21.95
	BAREGROUND	10	21.57	9.12	4.85	12.05
	IMPERVIOUS - LMK002	111	39.82			7.77

Table 31. Predetermined targets for matching with simulated counterparts as part of the LMK002 HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.14 LMK122

Tidal influence and/or noise contaminated the observed flow data for site LMK122 to such an extent that no attempt was made to calibrate the HSPF model that was developed for LMK122 (see Figures 28 – 34).

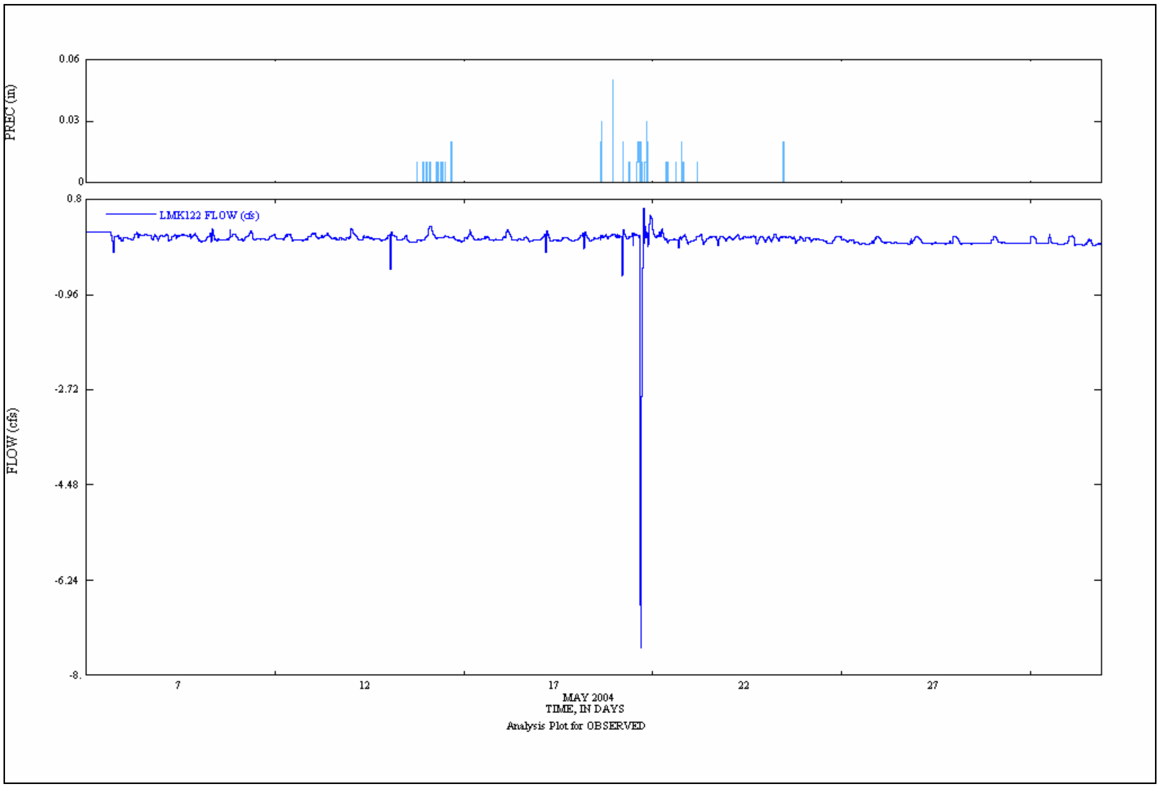

Figure 28. Driving precipitation data and observed flow for LMK122.

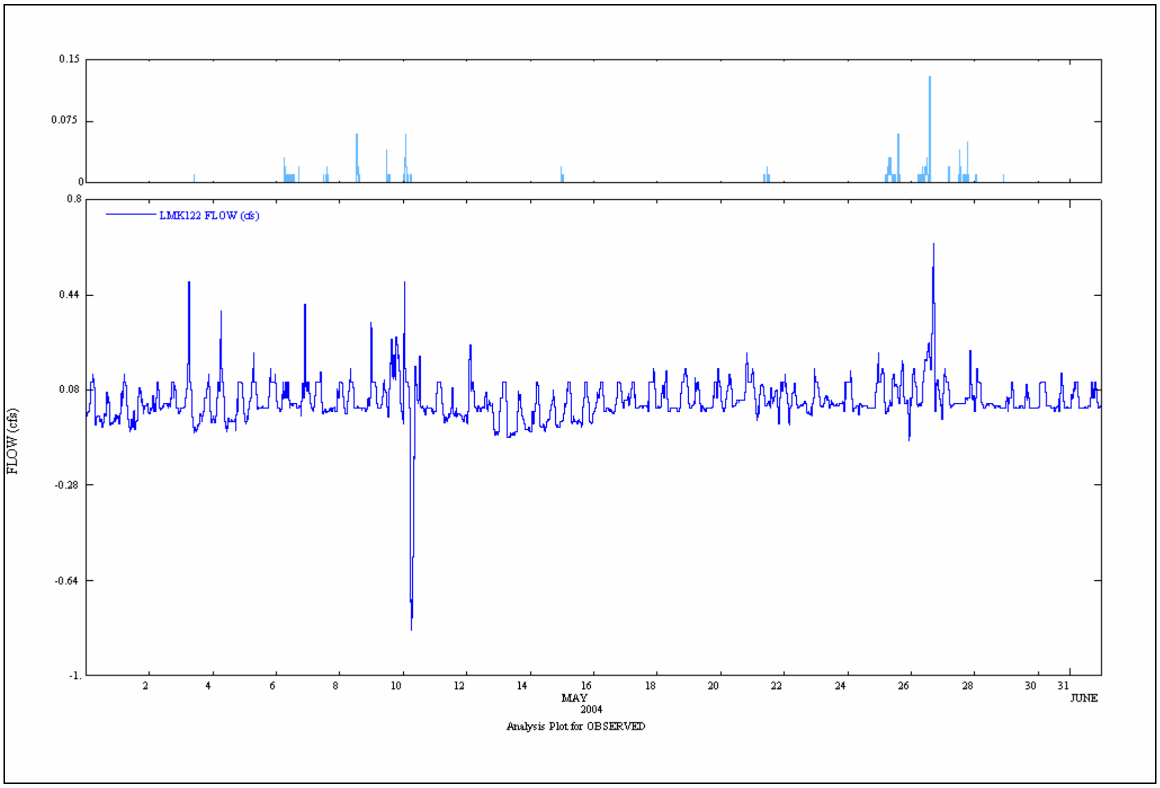

Figure 29. Driving precipitation data and observed flow for LMK122.

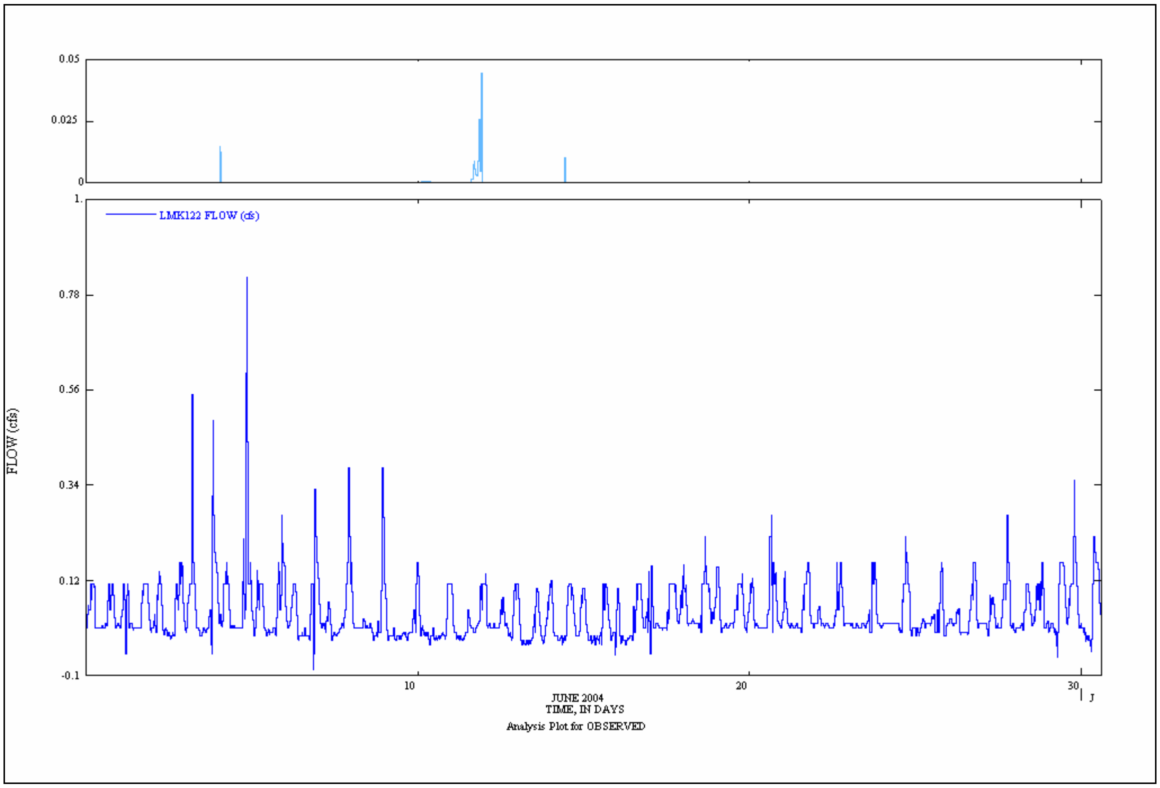

Figure 30. Driving precipitation data and observed flow for LMK122.

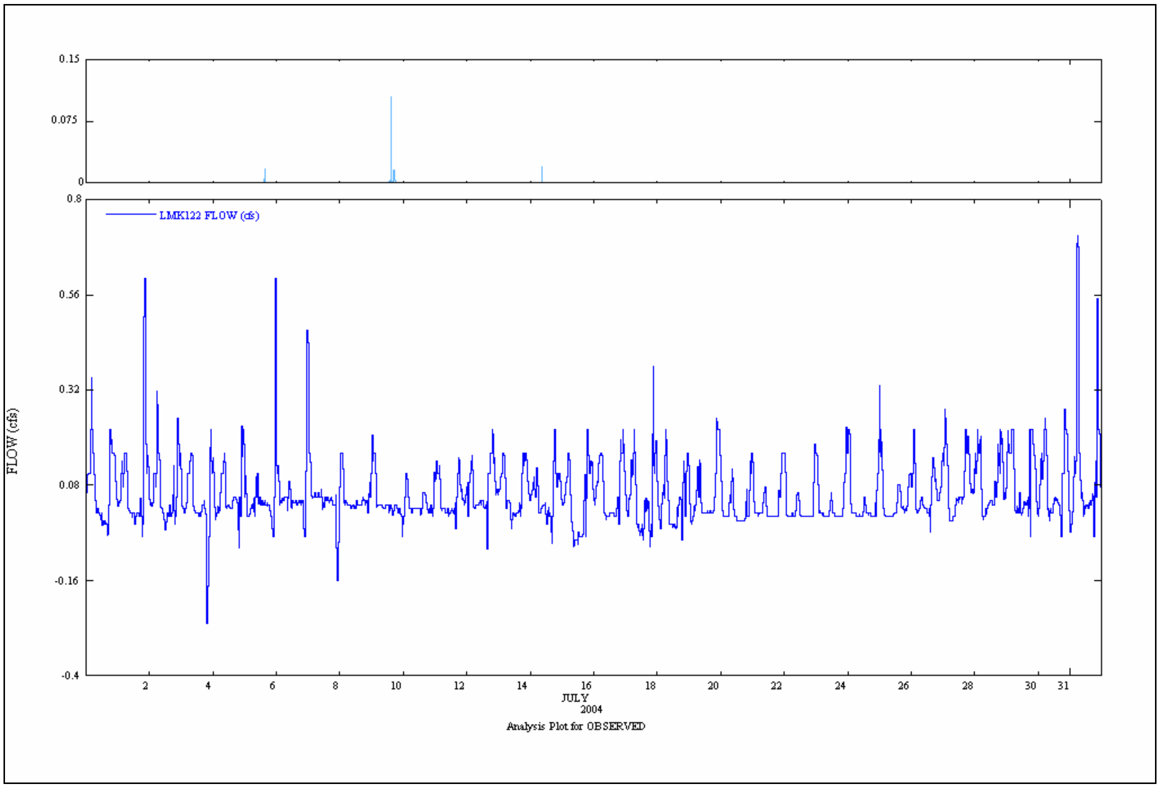

Figure 31. Driving precipitation data and observed flow for LMK122.

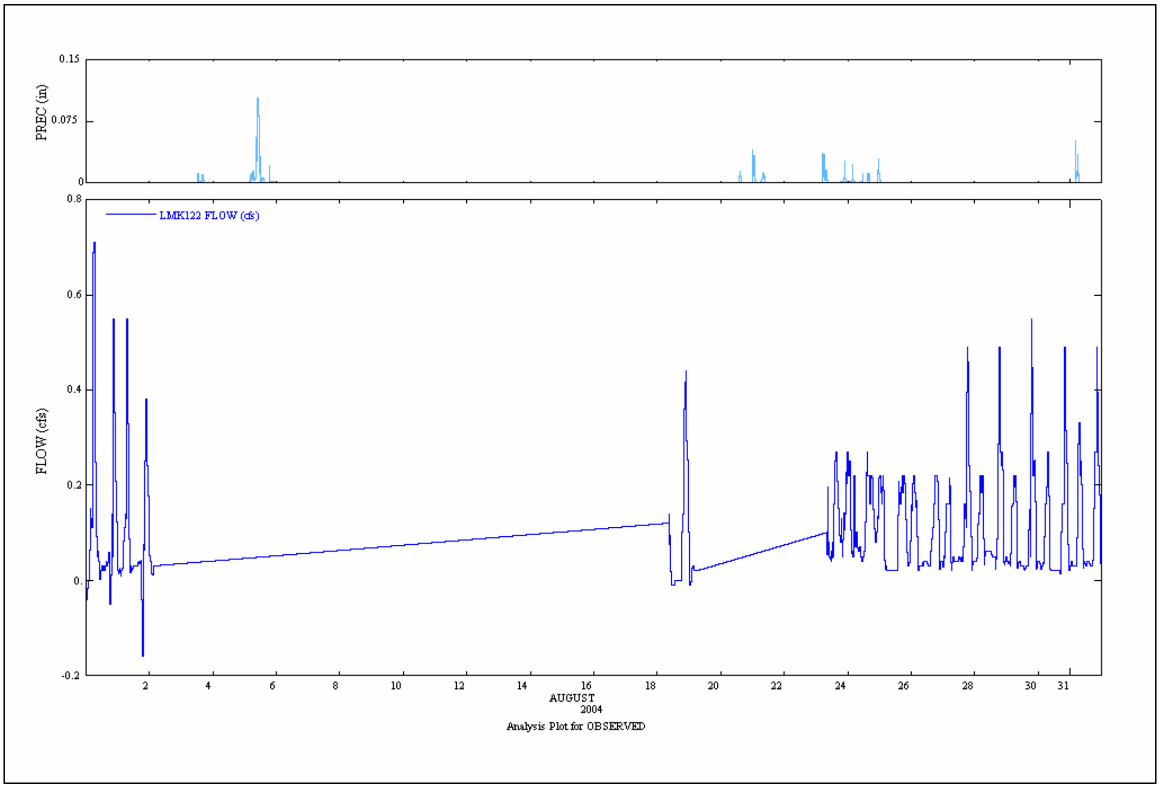

Figure 32. Driving precipitation data and observed flow for LMK122.

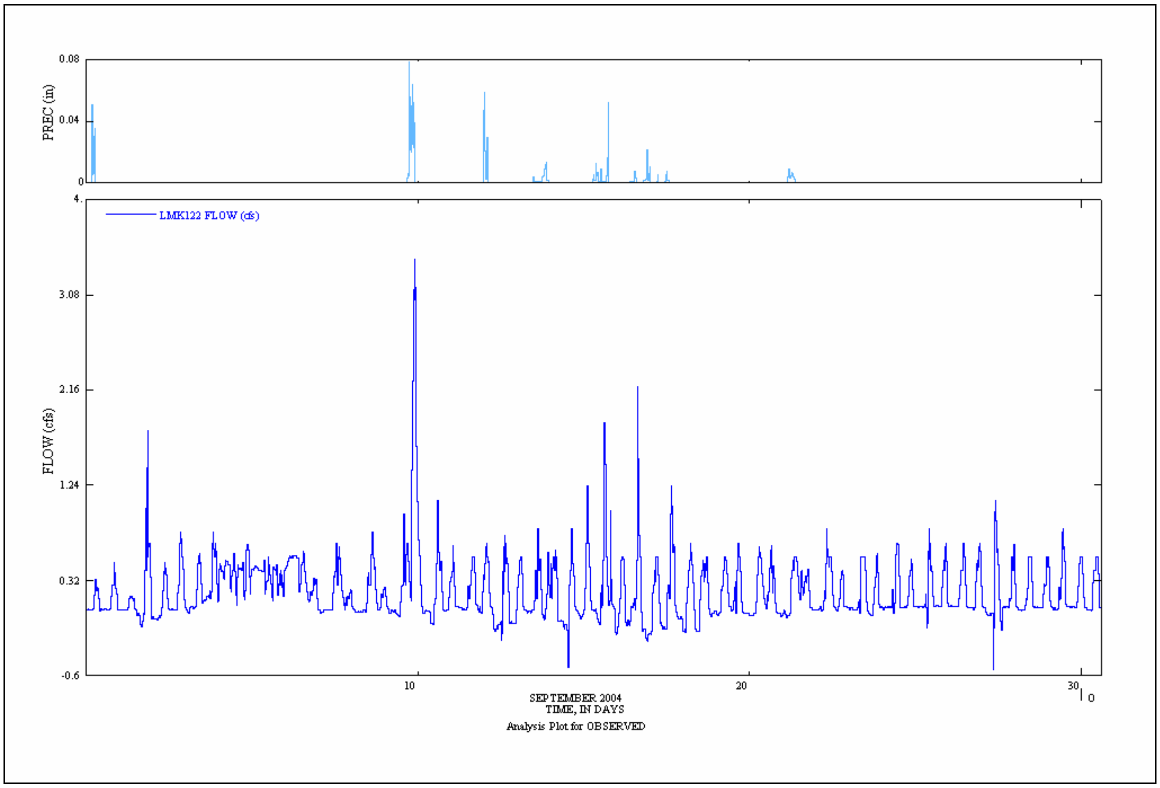

Figure 33. Driving precipitation data and observed flow for LMK122.

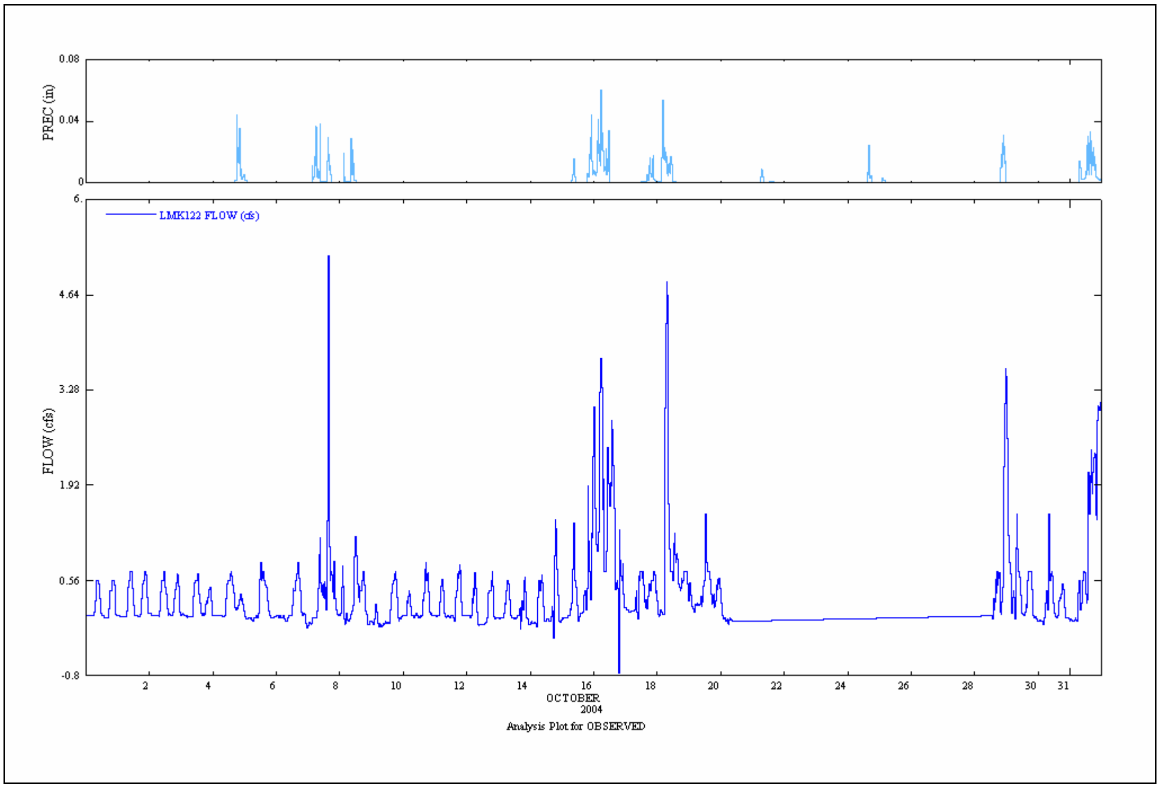

Figure 34. Driving precipitation data and observed flow for LMK122.

5.2.15 PO-POBLVD

Noise contaminated the observed flow data for site PO-POBLVD to such an extent that no attempt was made to calibrate the HSPF model that was developed for PO-POBLVD (see Figures 35 – 41).

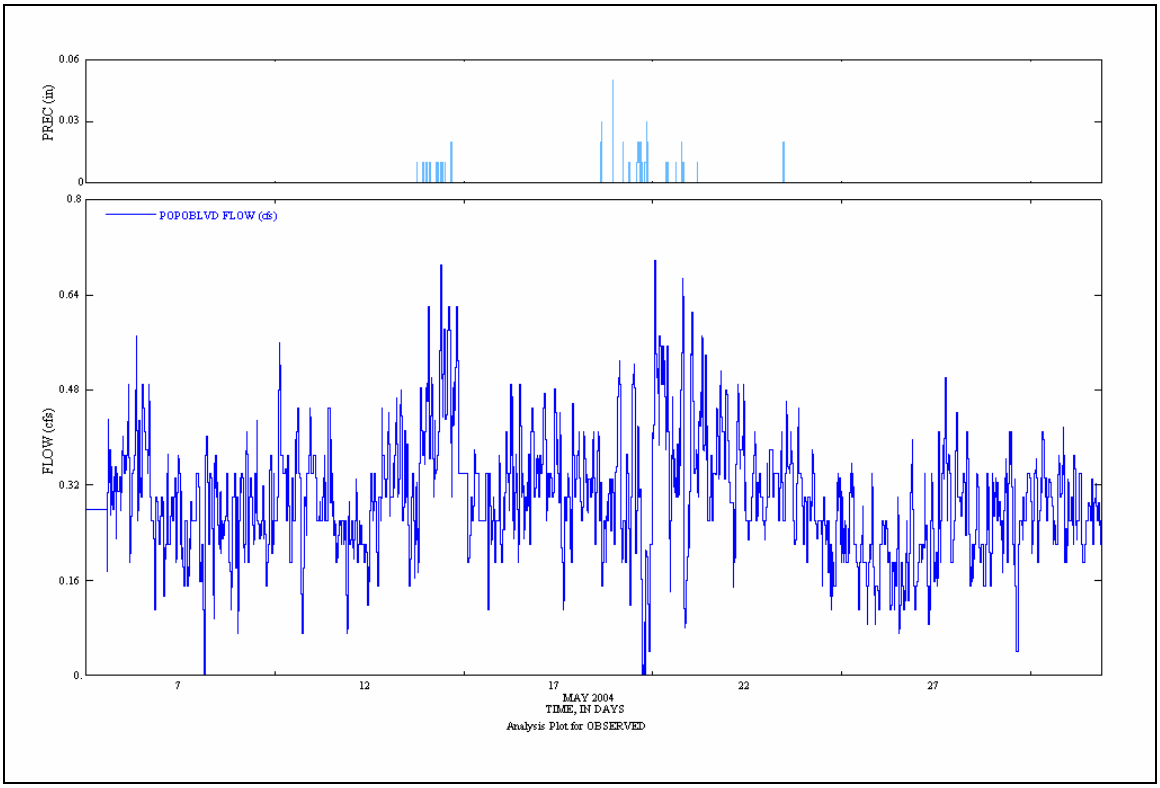

Figure 35. Driving precipitation data and observed flow for PO-POBLVD.

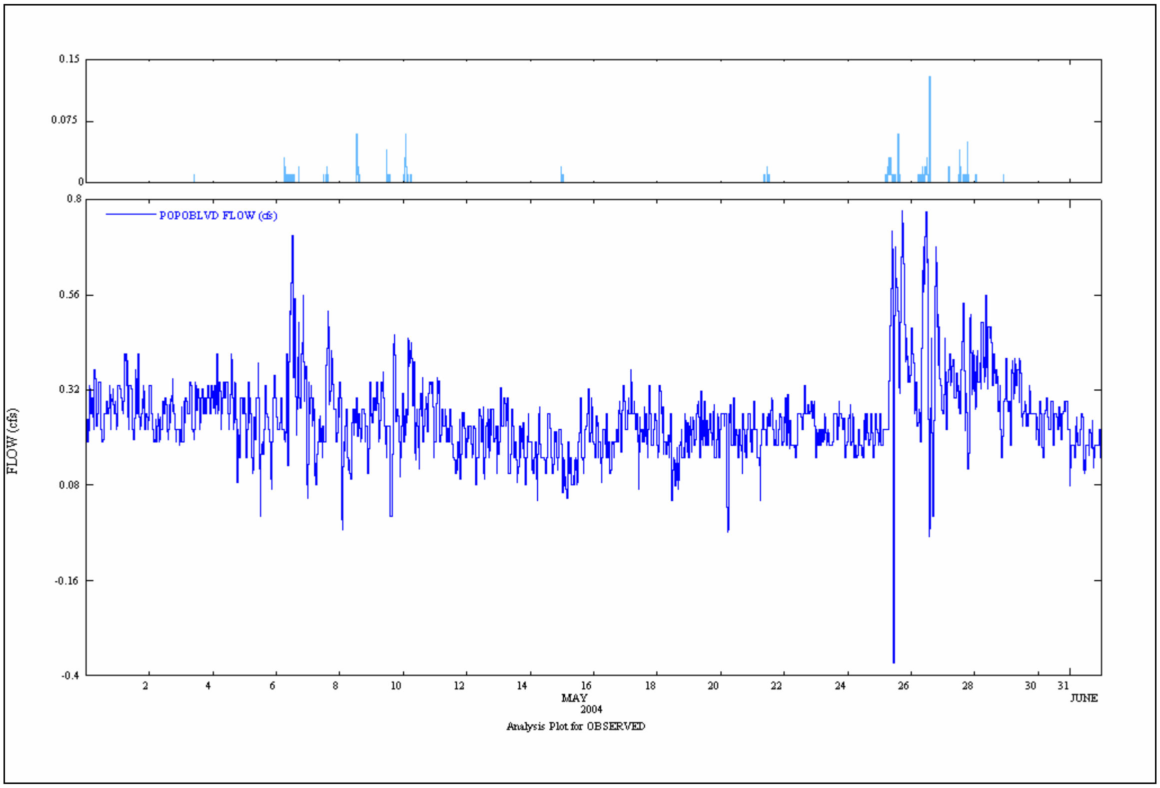

Figure 36. Driving precipitation data and observed flow for PO-POBLVD.

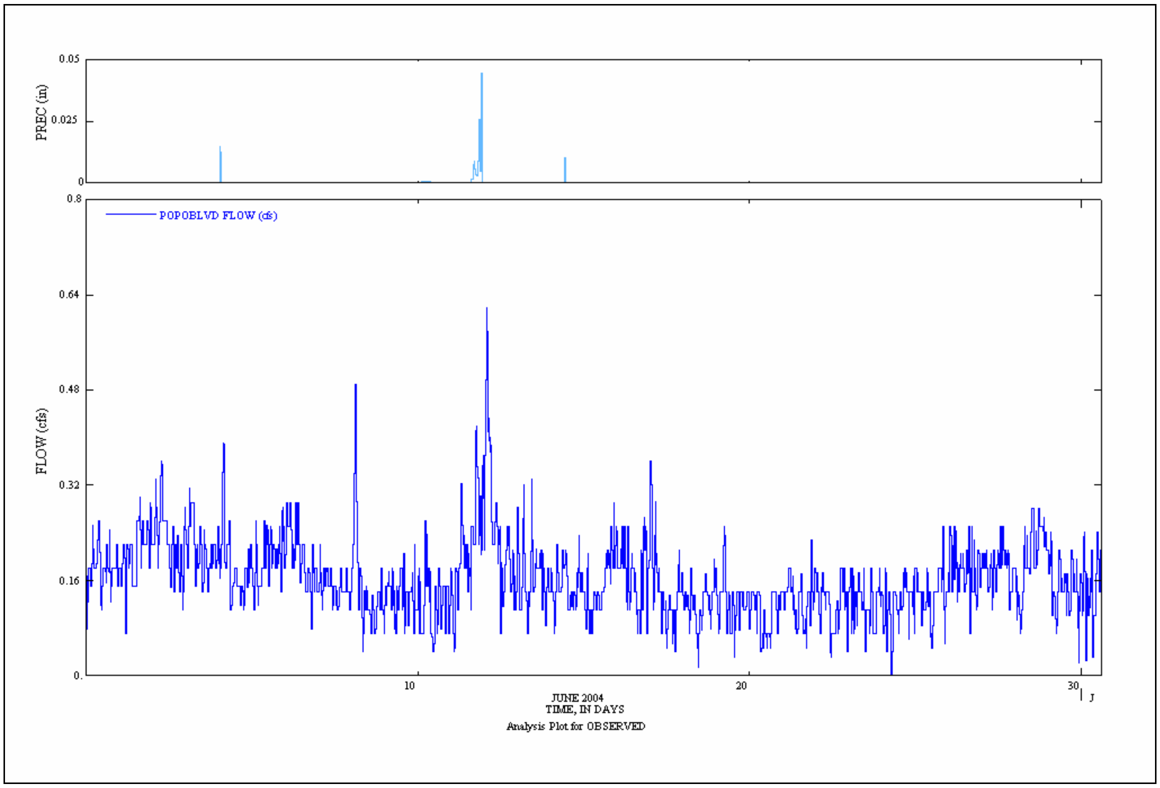

Figure 37. Driving precipitation data and observed flow for PO-POBLVD.

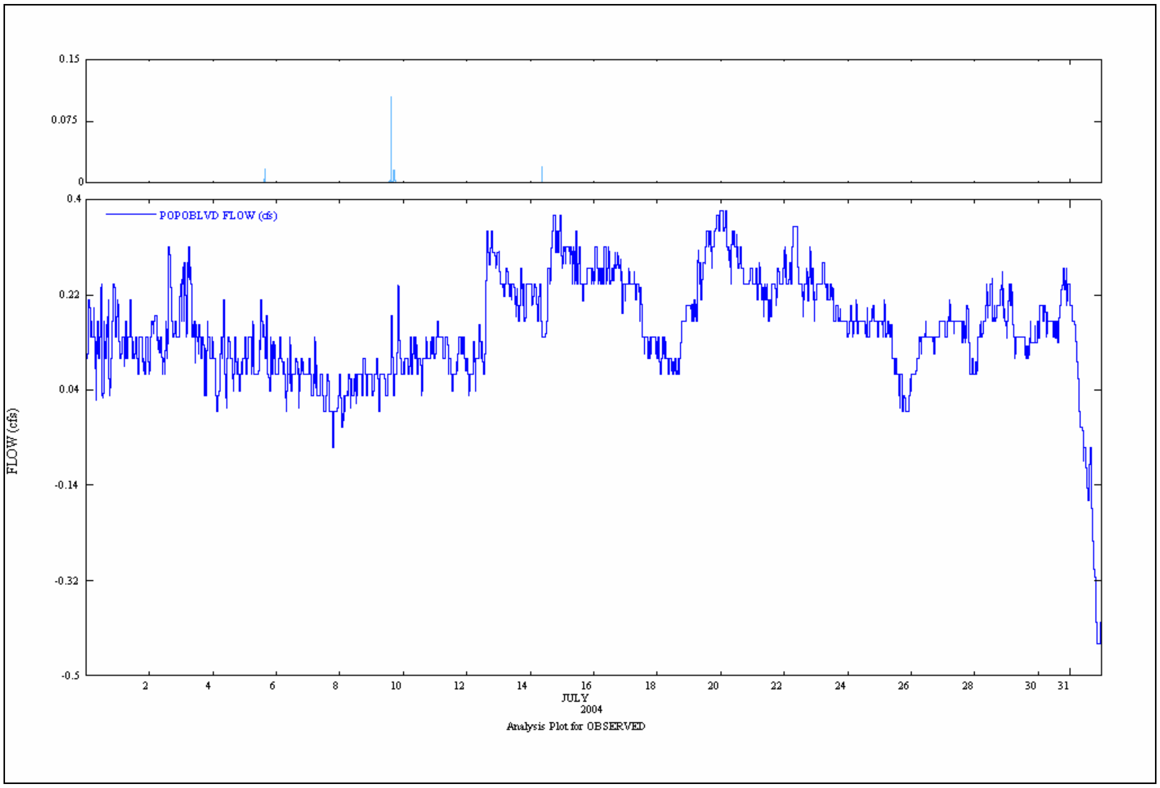

Figure 38. Driving precipitation data and observed flow for PO-POBLVD.

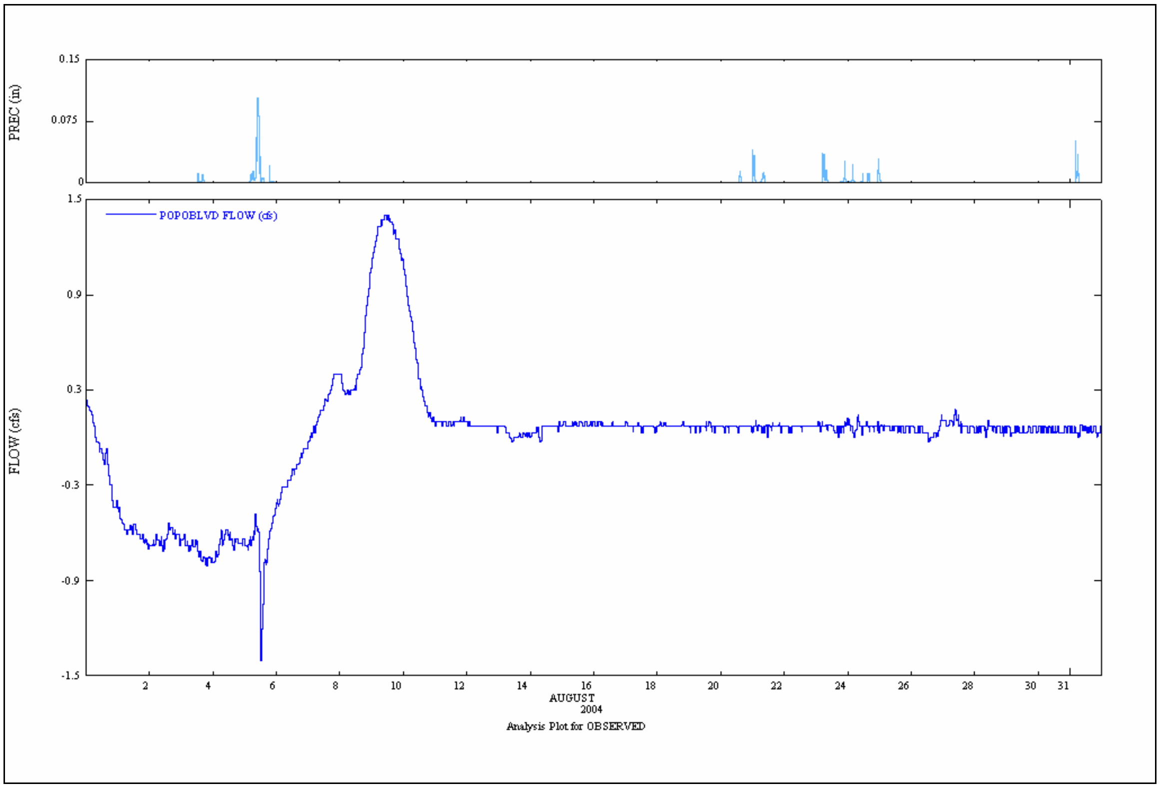

Figure 39. Driving precipitation data and observed flow for PO-POBLVD.

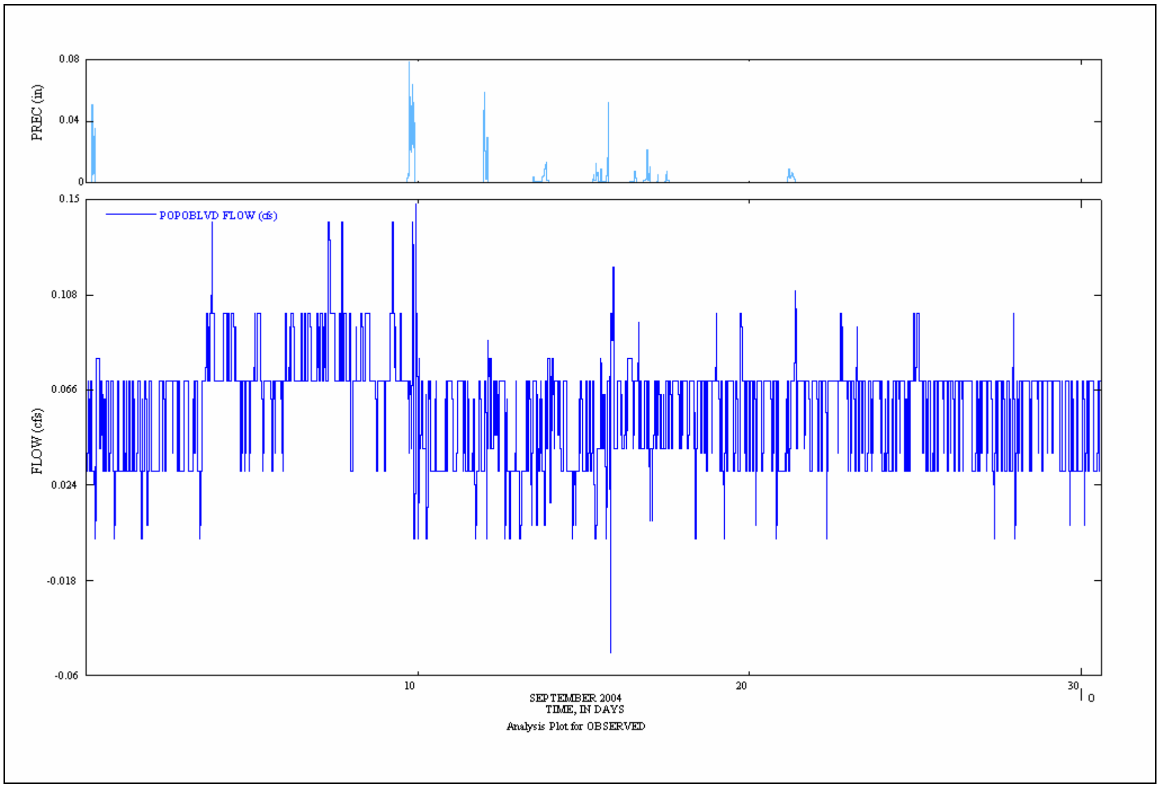

Figure 40. Driving precipitation data and observed flow for PO-POBLVD.

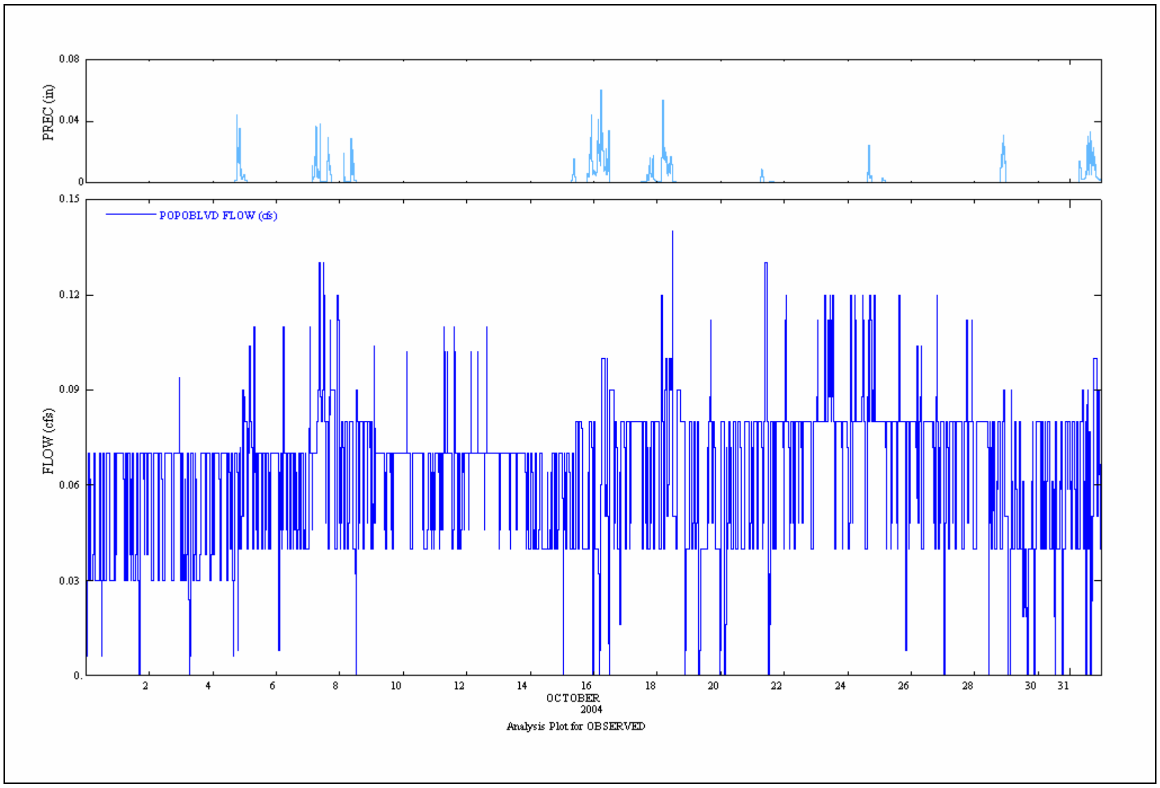

Figure 41. Driving precipitation data and observed flow for PO-POBLVD.

5.2.16 LMK136

Tidal influence and/or noise contaminated the observed flow data for site LMK136 to such an extent that no attempt was made to calibrate the HSPF model that was developed for LMK136 (see Figures 42 – 48).

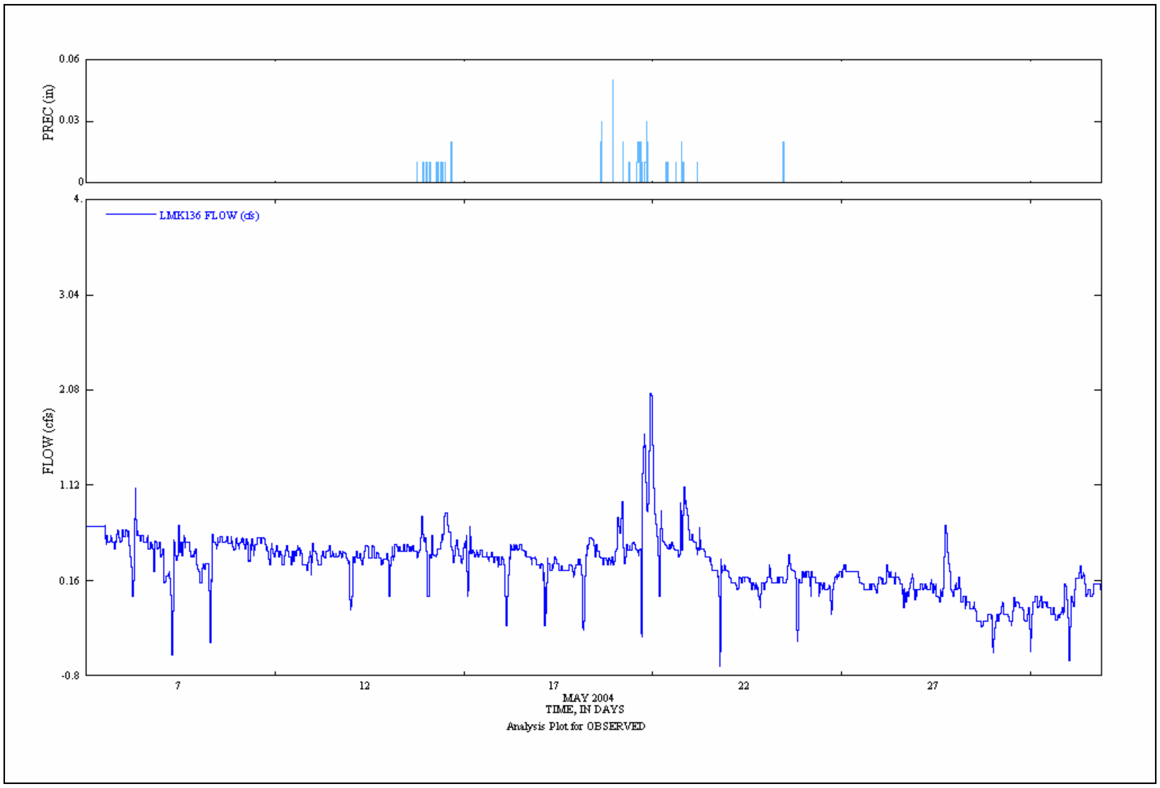

Figure 42. Driving precipitation data and observed flow for LMK136.

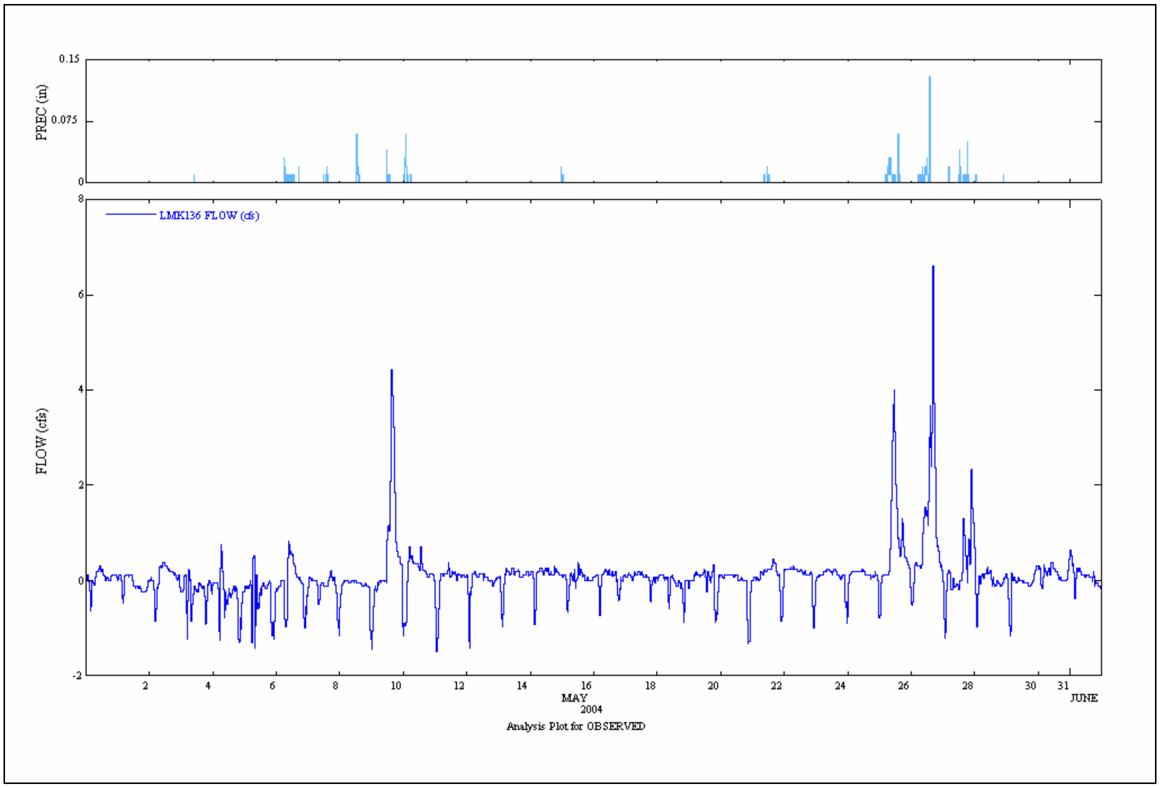

Figure 43. Driving precipitation data and observed flow for LMK136.

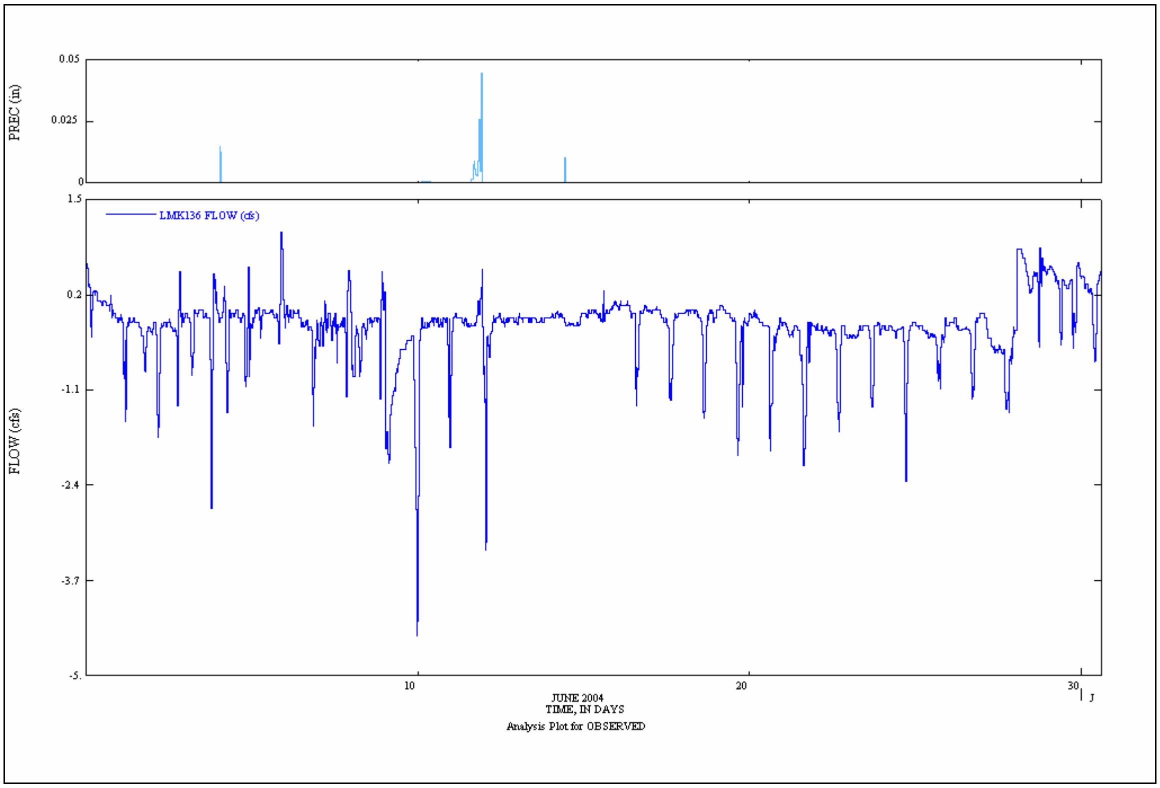

Figure 44. Driving precipitation data and observed flow for LMK136.

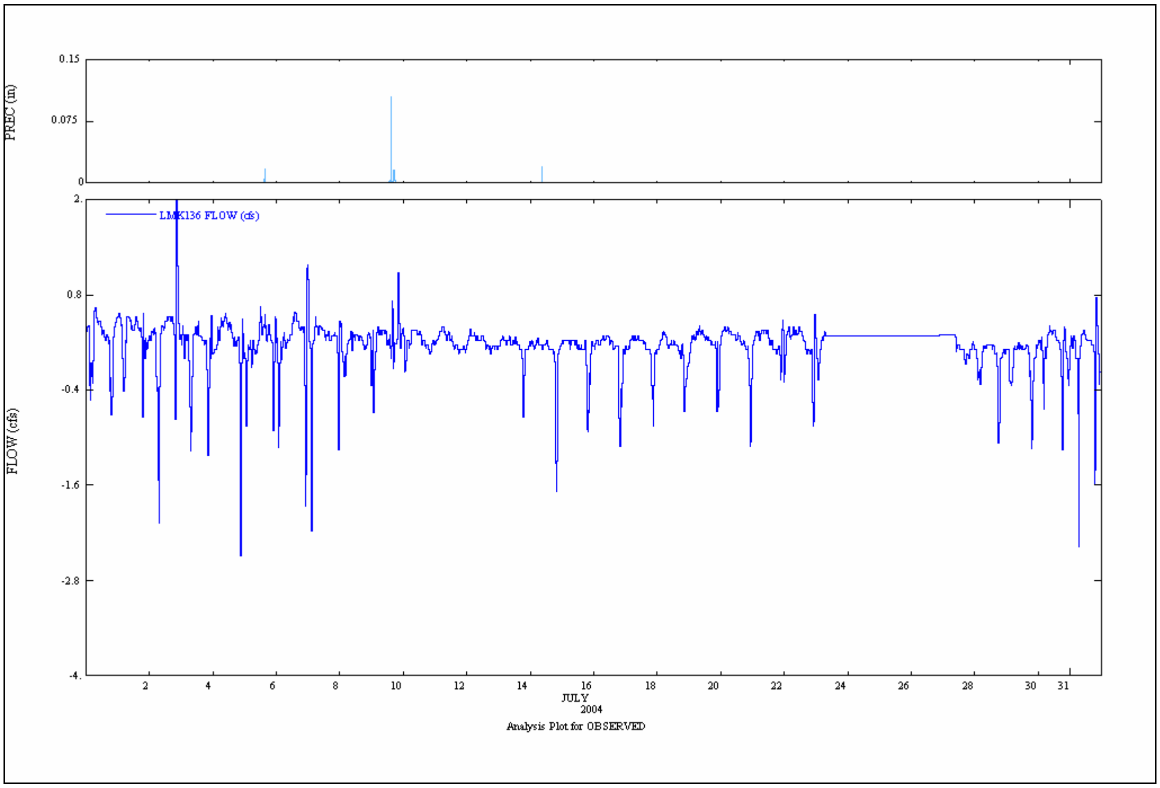

Figure 45. Driving precipitation data and observed flow for LMK136.

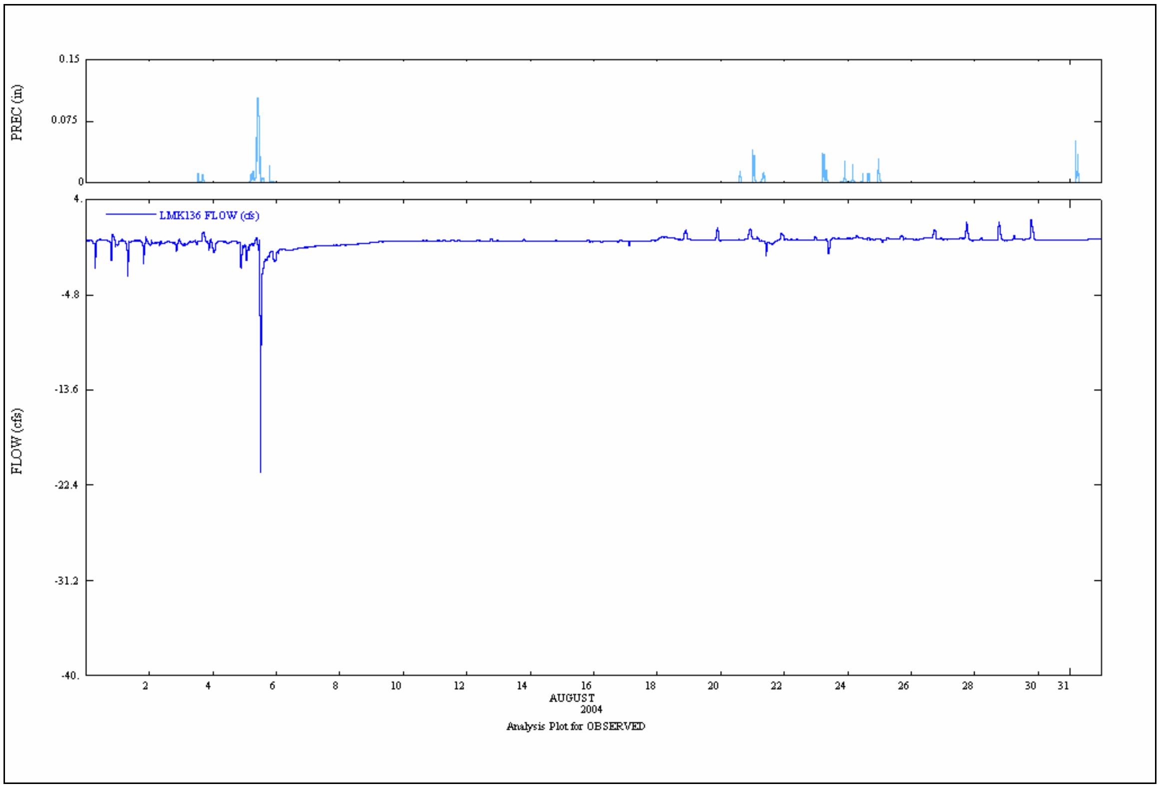

Figure 46. Driving precipitation data and observed flow for LMK136.

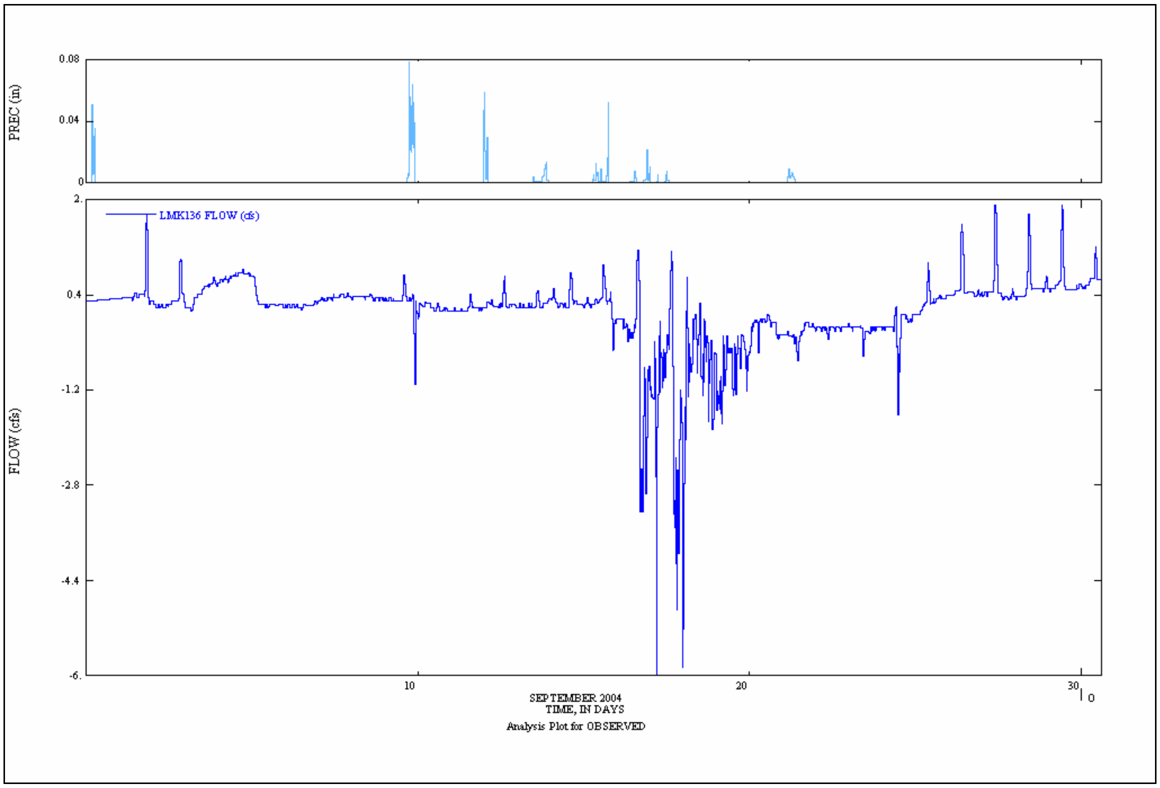

Figure 47. Driving precipitation data and observed flow for LMK136.

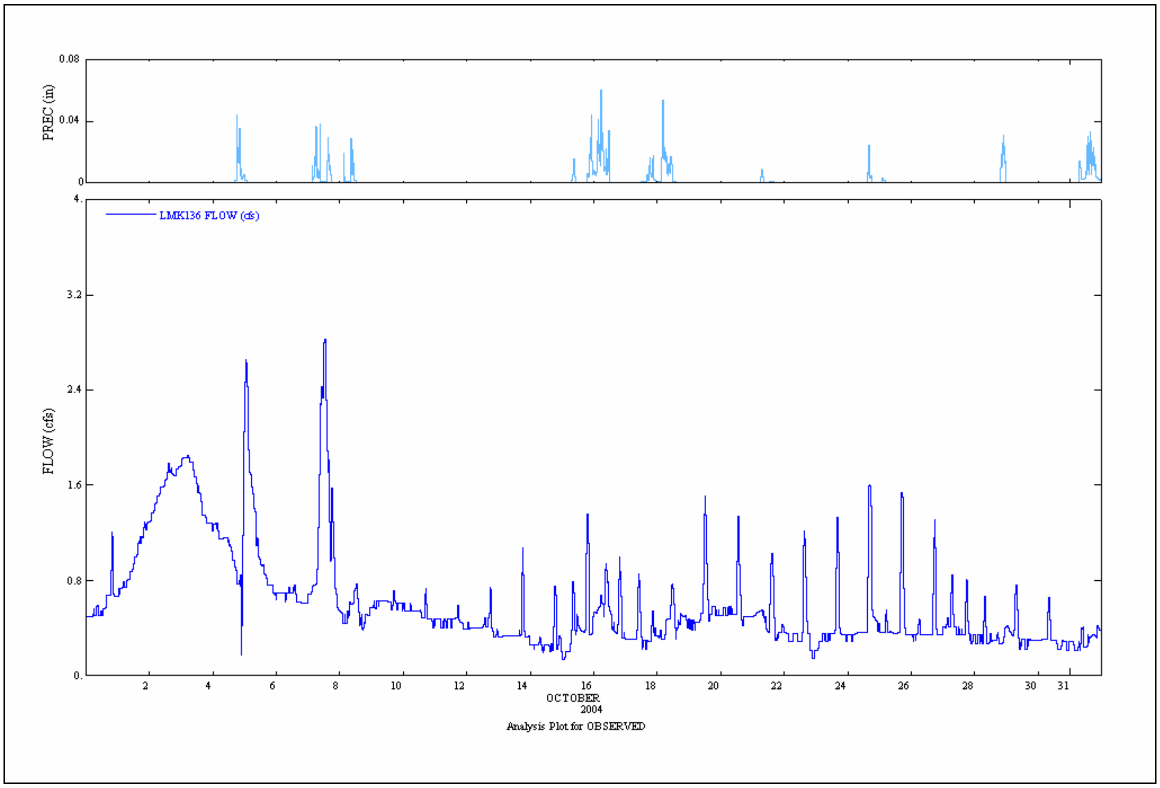

Figure 48. Driving precipitation data and observed flow for LMK136.

5.2.17 LMK038

A single land segment was employed for the LMK038 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the LMK038 watershed. In addition to the parameters listed in Table 9, an additional parameter, x, was specified to be adjustable. The adjustable parameter x weighted an external data source of water that was supplied to the system to improve upon model to measurement misfit, primarily to improve the fit between measured and simulated base flows. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 3rd Nov 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over a single time interval and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 323 observations for use in the HSPF hydrologic calibration process for LMK038. The single flow comparison period was identified based on a manual inspection of the observed flow data. It was principally formulated in order to accommodate a noted time shift between the driving precipitation data and the observed system response for most of the record, but also to accommodate missing observed flow data (see, for example, Figure A3.41), any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 32. The 34 targets are summarized in Table 33. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the LMK038 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

Manchester	
	15 Min. Data
	1
DATE_1	11/1/2004
TIME_1	0:00:00
DATE_2	11/3/2004
TIME_2	23:45:00

Table 32. Time interval used for matching observed and simulated flow data as part of the LMK038 HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
Manchester	SUBURBAN	1	10.31	13.72	7.30	13.79
	MULTI-FAMILY	2	18.47	9.64	5.12	11.89
	COMMERCIAL	3	32.57	2.59	1.38	8.58
	RURAL RESIDENTIAL	4	1.82	14.11	10.80	18.39
	LAWN	5	0.68	18.54	9.86	16.05
	PASTURE	6	0.32	14.69	11.25	18.86
	FOREST	7	0.10	9.37	14.84	20.81
	BAREGROUND	10	20.45	8.65	4.60	11.42
	IMPERVIOUS - MANCHESTER	111	37.76			7.36

Table 33. Predetermined targets for matching with simulated counterparts as part of the LMK038 HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.18 B-ST CSO16

A single land segment was employed for the B-ST CSO16 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 34. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. A single instance of each parameter listed in Table 34 required estimation. Thus a total of 9 model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 20th Mar 2004 to 8th Nov 2004. Values for the 9 adjustable model parameters were estimated by matching observed and simulated flow data over five non-contiguous time intervals. This resulted in a total of 21,602 observations for use in the HSPF hydrologic calibration process for Springbrook Creek. However, a non-zero weight was only applied to non-zero flow observations, thus only 1,452 of the 21,602 total observations were actually seen during the inversion process. The five flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.42), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 35. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI and trajectory repulsion functionalities (see Appendix 5) were employed to calibrate the B-ST CSO16 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function.

Parameter name	Parameter function	Bounds imposed during calibration process	
		Lower bound	Upper bound
Y	Weight for precipitation data	1	1.05
IMP3	percent effective impervious area	0.51	0.98
LZSN	lower zone nominal storage	2	15
INFILT	related to infiltration capacity of the soil	0.001	1
AGWRCTRNS	groundwater recession parameter	5	999
UZSN	upper zone nominal storage	0.05	2
INTFW	interflow inflow parameter	1.00E+00	1.00E+01
IRC	interflow recession parameter	0.3	0.85
LZETP	lower zone ET parameter - an index of the density of deep-rooted vegetation	0.1	0.9

Table 34. Parameters estimated in calibration of the B-ST CSO16 HSPF model.

CSO16					
	15 Min. Data				
	1	2	3	4	5
DATE_1	3/20/2004	6/13/2004	9/20/2004	10/17/2004	11/2/2004
TIME_1	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
DATE_2	6/11/2004	9/14/2004	10/15/2004	10/31/2004	11/8/2004
TIME_2	23:45:00	23:45:00	23:45:00	23:45:00	0:00:00

Table 35. Non-contiguous time intervals used for matching observed and simulated flow data as part of the B-ST CSO16 HSPF hydrologic model calibration.

5.2.19 BST 28

A single land segment was employed for the BST 28 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 9. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. Eight instances of all but the first three parameters listed in Table 9 required estimation. The first adjustable model parameter type listed in Table 9, IMP, pertains to the entire watershed. It possessed four instances however, one for each of four land use types occurring within the BST 28 watershed. In addition to the parameters listed in Table 9, an additional parameter, y, was specified to be adjustable. The adjustable parameter y weighted the precipitation data source. The parameter y was selected for adjustment to improve upon previous model to measurement misfits that were deemed inadequate, in effect, “to fit the data at all costs”. Thus a total of $87 = 8 \cdot 1 \cdot 10 + 2 \cdot 1 + 4 + 1$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 2000 to 22nd Sep 2004. Values for the 87 adjustable model parameters were estimated by matching observed and simulated flow data over fourteen non-contiguous time intervals and also by matching 34 predetermined targets (in effect, synthetic observations), which expressed the expectation for the partition of average annual precipitation across the modeled pervious land areas and impervious area within the single land segment, with their simulated counterparts. This resulted in a total of 3,743 observations for use in the HSPF hydrologic calibration process for BST 28. The fourteen flow comparison periods were identified based on a manual inspection of the observed flow data. They were principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.43), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error, and they are summarized in Table 36. The 34 targets are summarized in Table 37. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the BST 28 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation groups that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each group such that the parameter estimation engine saw each of them as of equal importance.

BST 28														
	15 Min. Data													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DATE_1	3/18/2004	7/1/2004	7/18/2004	8/6/2004	8/21/2004	8/22/2004	8/24/2004	9/9/2004	9/12/2004	9/14/2004	9/16/2004	9/17/2004	9/18/2004	9/22/2004
TIME_1	0:00:00	0:00:00	0:00:00	10:45:00	19:30:00	7:00:00	5:45:00	15:15:00	22:30:00	21:45:00	13:15:00	12:30:00	5:00:00	8:15:00
DATE_2	3/31/2004	7/12/2004	7/21/2004	8/7/2004	8/22/2004	8/23/2004	8/24/2004	9/11/2004	9/13/2004	9/15/2004	9/17/2004	9/18/2004	9/19/2004	9/22/2004
TIME_2	23:45:00	23:45:00	23:45:00	6:15:00	6:00:00	1:45:00	7:15:00	15:00:00	15:15:00	11:15:00	11:45:00	4:15:00	9:30:00	17:30:00

Table 36. Non-contiguous time intervals used for matching observed and simulated flow data as part of the BST 28 HSPF hydrologic model calibration.

		"OBSERVED"				
		ID	SURO	IFWO	AGWO	TAET
BST02	SUBURBAN	1	8.21	10.92	5.81	10.98
	MULTI-FAMILY	2	14.71	7.67	4.08	9.46
	COMMERCIAL	3	25.93	2.07	1.09	6.83
	RURAL RESIDENTIAL	4	1.45	11.23	8.60	14.65
	LAWN	5	0.54	14.76	7.85	12.78
	PASTURE	6	0.26	11.70	8.95	15.02
	FOREST	7	0.08	7.46	11.82	16.57
	BAREGROUND	10	16.28	6.89	3.66	9.09
	IMPERVIOUS - BST02	111	30.06			5.86

Table 37. Predetermined targets for matching with simulated counterparts as part of the BST 28 HSPF hydrologic model calibration (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

5.2.20 PSNS 126

The model obtained for the upstream urban site B-ST CSO16 was employed for the PSNS 126 flow monitoring location, with the exception that the precipitation data was adjusted to improve model to measurement misfit (i.e., the precipitation was more heavily weighted at PSNS 126 in comparison to B-ST CSO16).

5.2.21 PSNS 124

Tidal influence and/or noise contaminated the observed flow data for site PSNS 124 to such an extent that no attempt was made to calibrate the HSPF model that was developed for PSNS 124 (see Figures 49 – 56).

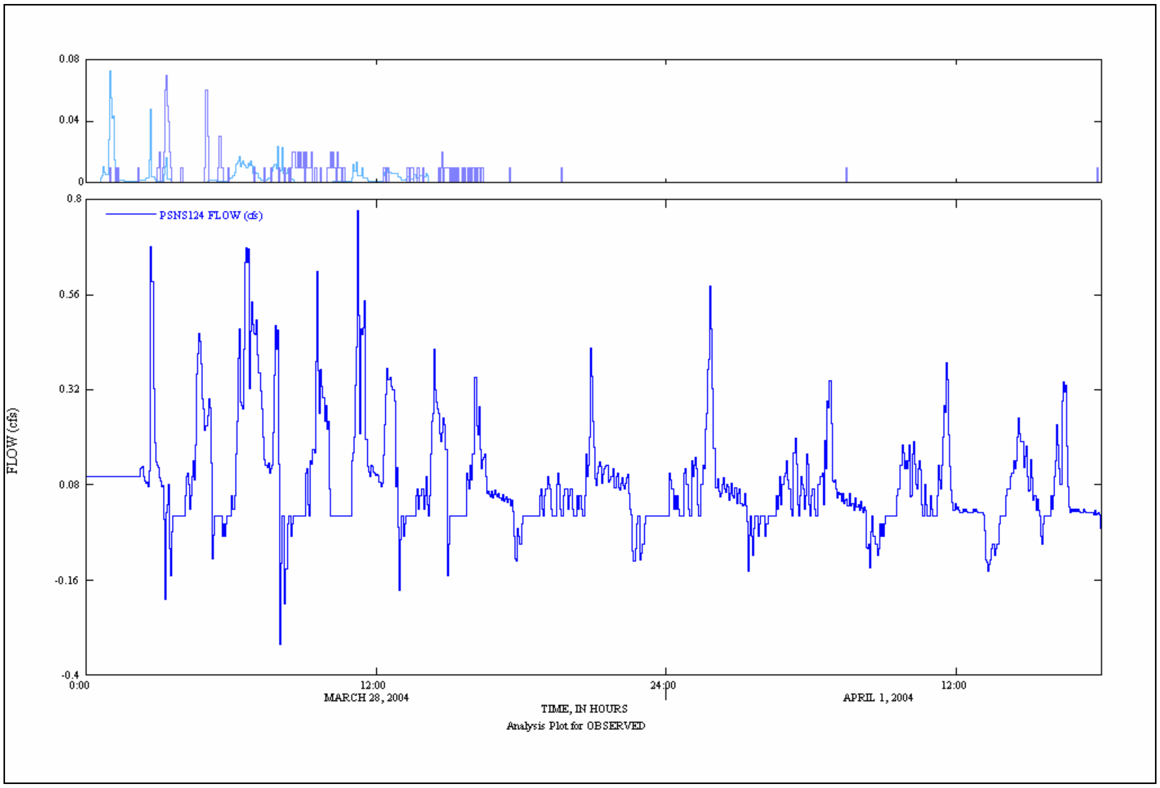

Figure 49. Driving precipitation data and observed flow for PSNS 124.

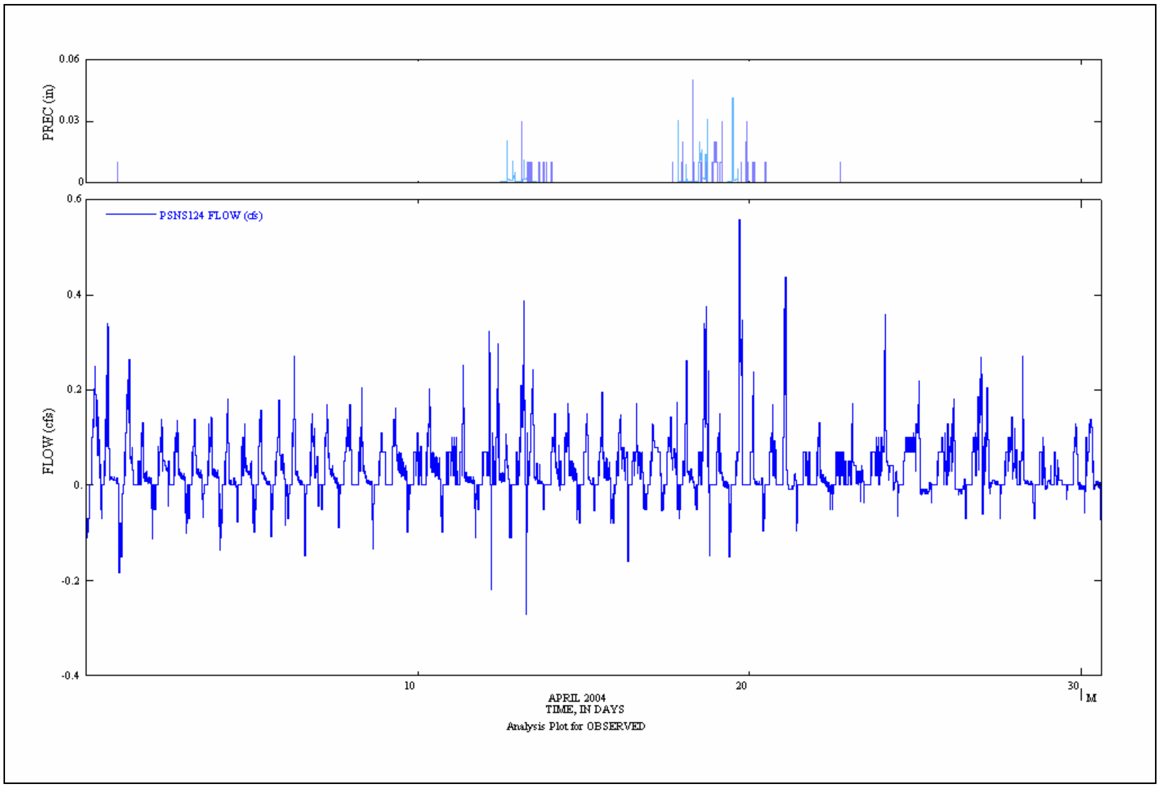

Figure 50. Driving precipitation data and observed flow for PSNS 124.

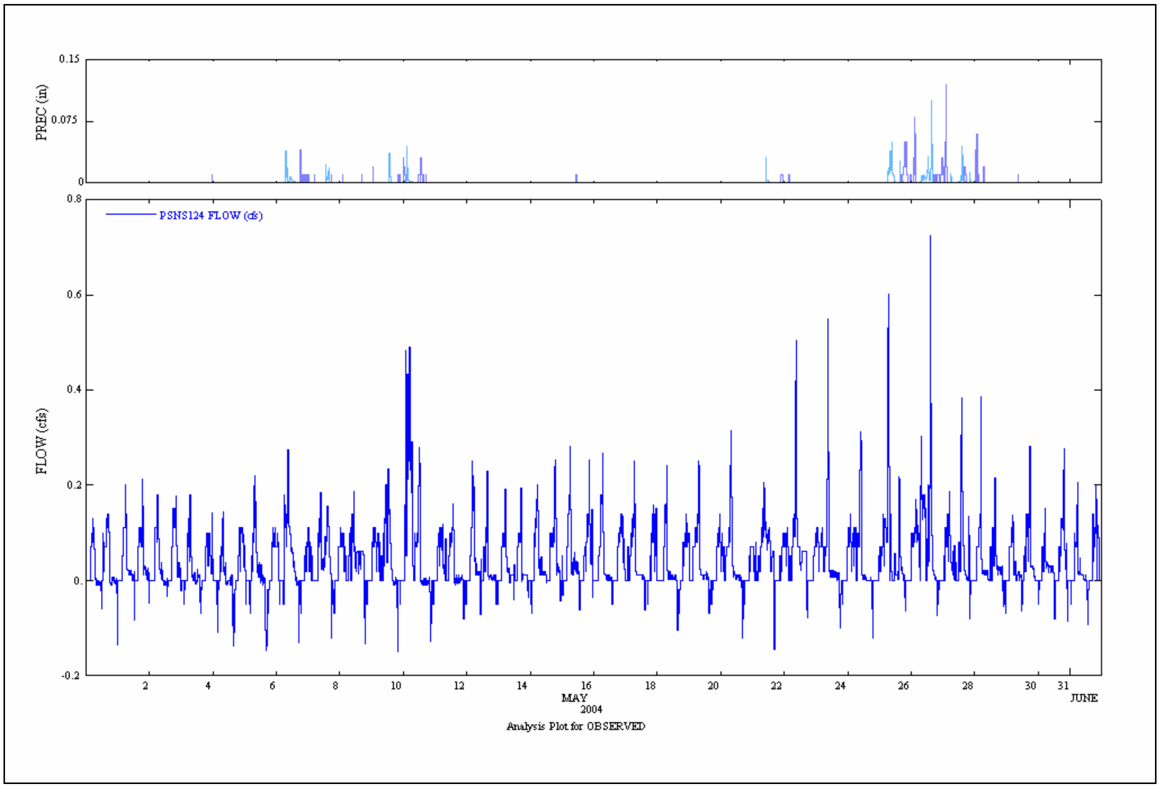

Figure 51. Driving precipitation data and observed flow for PSNS 124.

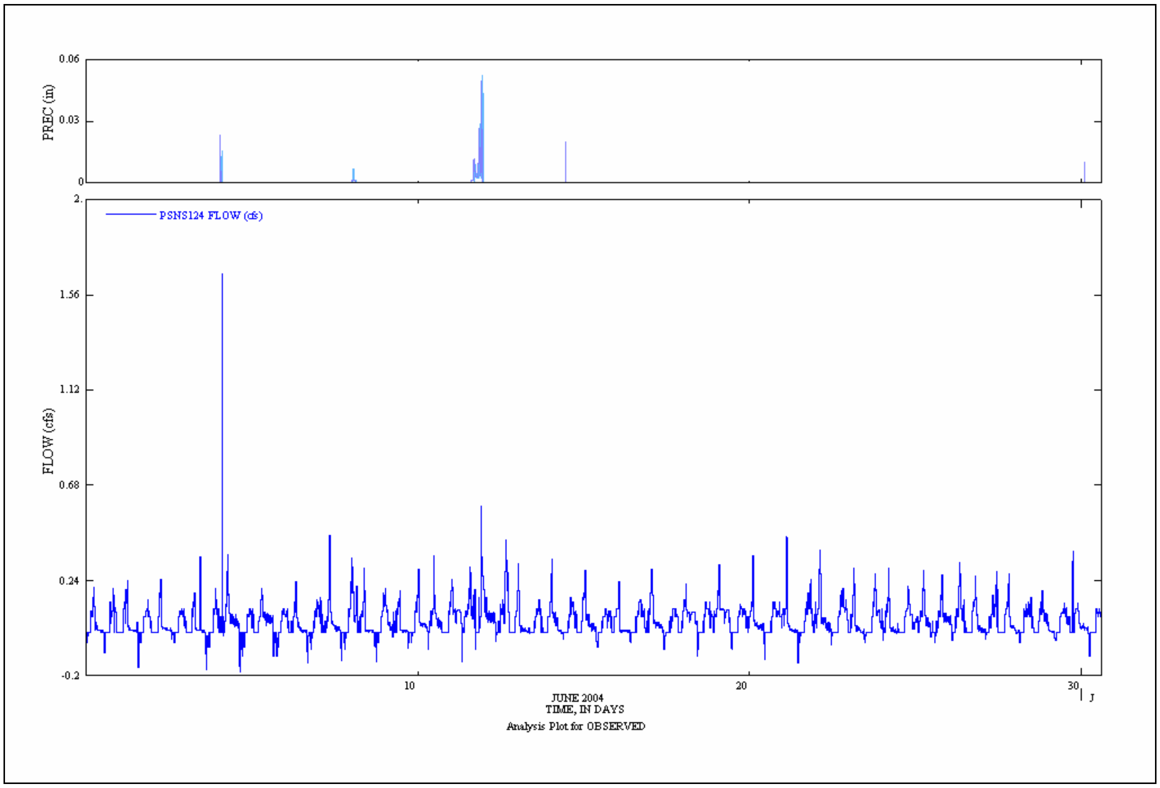

Figure 52. Driving precipitation data and observed flow for PSNS 124.

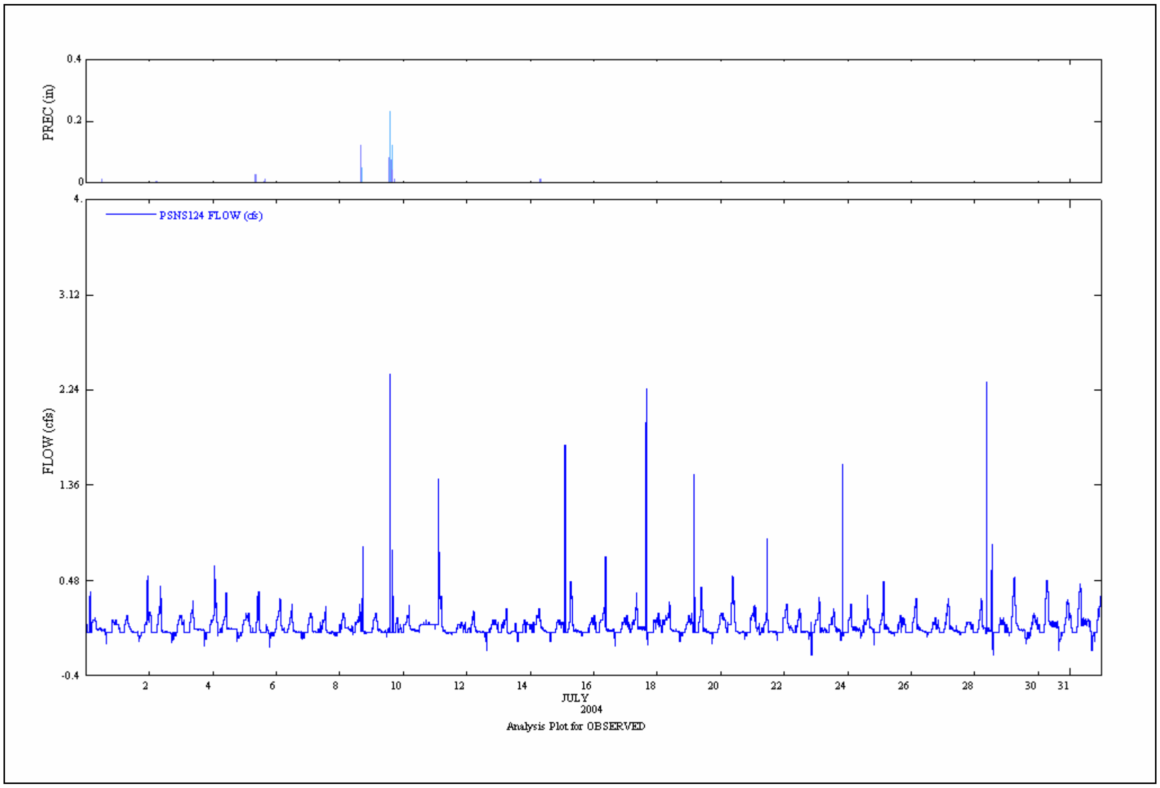

Figure 53. Driving precipitation data and observed flow for PSNS 124.

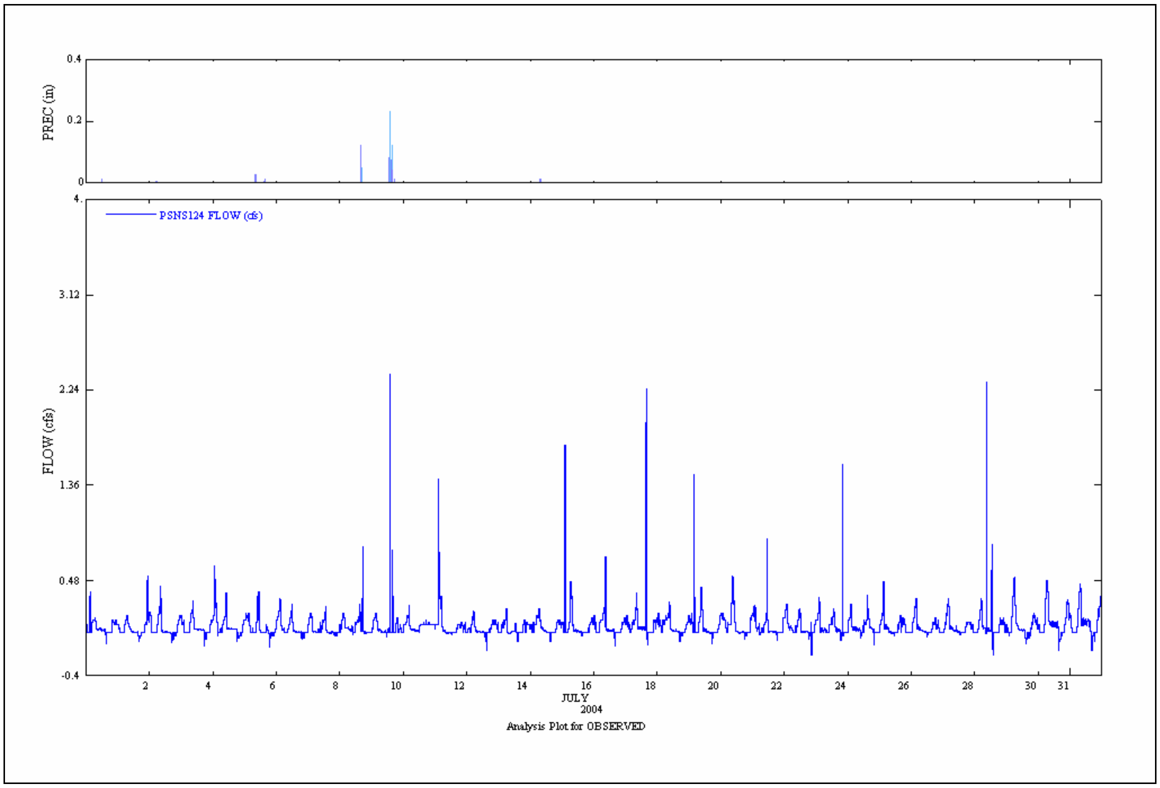

Figure 54. Driving precipitation data and observed flow for PSNS 124.

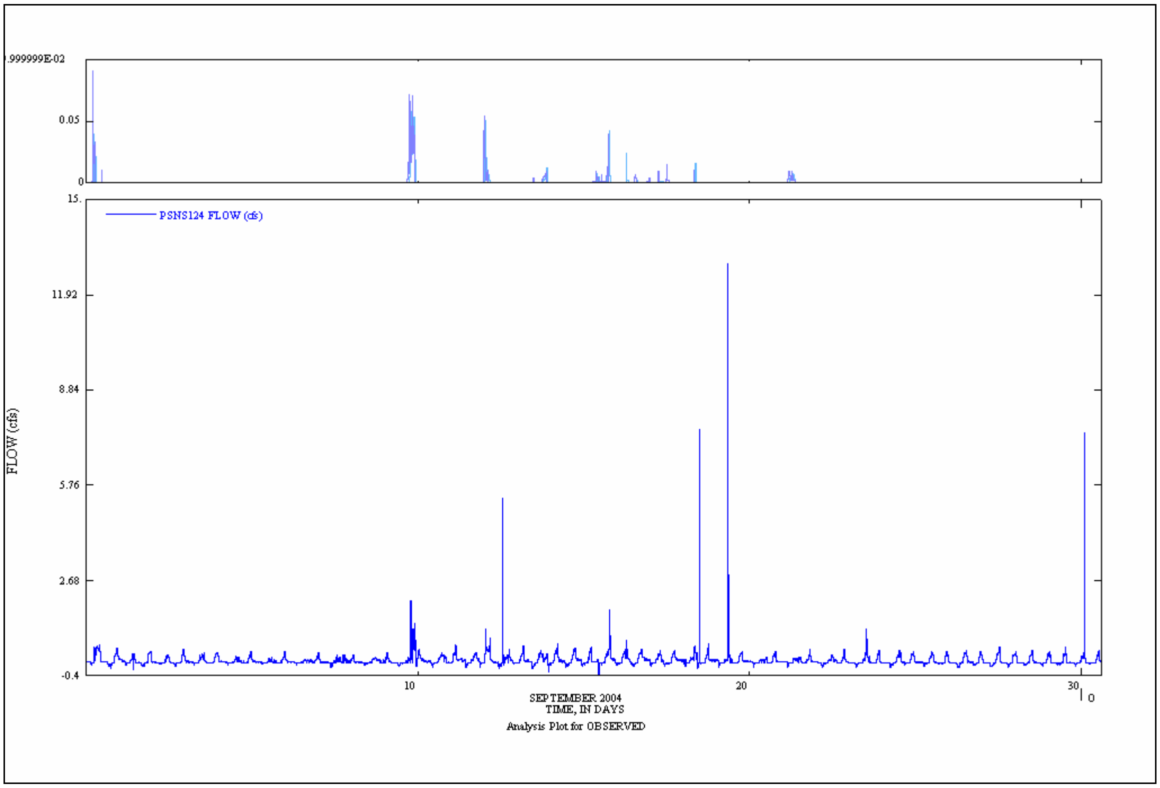

Figure 55. Driving precipitation data and observed flow for PSNS 124.

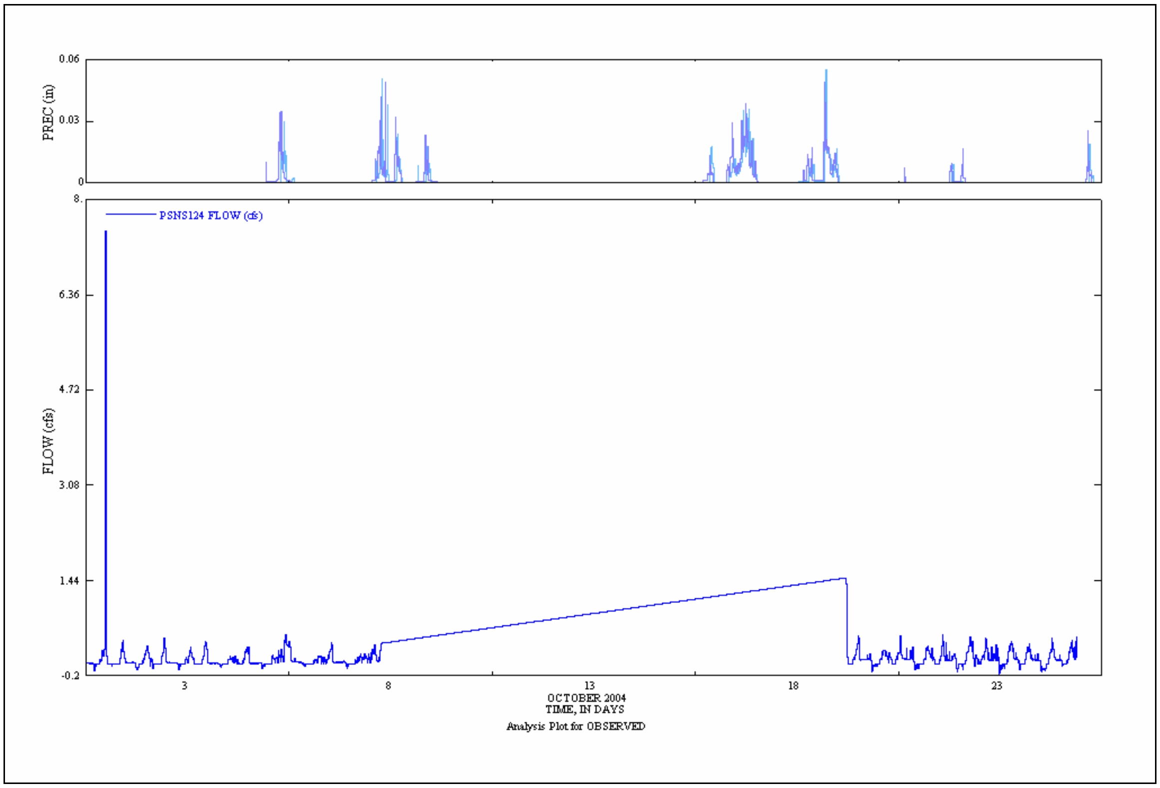

Figure 56. Driving precipitation data and observed flow for PSNS 124.

5.2.22 PSNS 015

A single land segment was employed for the PSNS 015 HSPF model. The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 38. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2000). Note that, in order to circumvent hypersensitivity of the AGWRC parameter as it approaches 1.0, it was transformed prior to estimation; the transformed parameter (named AGWRCTRANS in the present study) can vary between 5.0 and 999.0 as AGWRC varies between 0.833 and 0.999. A single instance of all the parameters listed in Table 38 required estimation. Thus a total of 11 model parameters required estimation through the calibration process. The parameter a and z were selected for adjustment to improve upon previous model to measurement misfits that were deemed inadequate, in effect, "to fit the data at all costs". In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was solely for 2^{nd} Nov 2004. Values for the 11 adjustable model parameters were estimated by matching observed and simulated flow data over this single time interval. This resulted in a total of 55 observations for use in the HSPF hydrologic calibration process for PSNS 015. The flow comparison period was identified based on a manual inspection of the observed flow data. It was principally formulated in order to accommodate the noted missing observed flow data (see, for example, Figure A3.37), but also to accommodate any observed date-time stamp errors associated with the observed flow and/or precipitation data, and periods with presumed significant observed data error. The flows were transformed according to the equation (Box and Cox, 1964):-

$$h_i = \ln(q_i + 0.0001)$$

where h_i is the "observation" employed in the actual parameter estimation process, and q_i is the corresponding flow. (As stated in Appendix 5, this type of transformation is one of a continuum of flow transformations often employed in the calibration of watershed models to promote homoscedascity of measurement noise; see, for example, Bates and Campbell, 2001.)

The GML method together with the TPI and trajectory repulsion functionalities (see Appendix 5) were employed to calibrate the PSNS 015 HSPF hydrologic model. A weight of one was uniformly assigned to each element of the above noted observation group that constituted the objective function.

Parameter name	Parameter function	Bounds imposed during calibration process	
		Lower bound	Upper bound
A	Weight for land area	1	10
Z	Weight for precipitation data	1	5
IMP2	percent effective impervious area	0.19	0.32
IMP3	percent effective impervious area	0.51	0.98
LZSN	lower zone nominal storage	2	15
INFILT	related to infiltration capacity of the soil	0.001	1
UZSN	upper zone nominal storage	0.05	2
INTFW	interflow inflow parameter	1.00E+00	1.00E+01
IRC	interflow recession parameter	0.3	0.85
LZETP	lower zone ET parameter - an index of the density of deep-rooted vegetation	0.1	0.9
RETSC	retention storage capacity of the impervious surface	0.01	0.3

Table 38. Parameters estimated in calibration of the PSNS 015 HSPF model.

5.3 RESULTS

Calibration and verification results were presented by means of graphical and statistical summaries. The Nash and Sutcliffe efficiency score, *ES*, correlation coefficient, *R*, and coefficient of determination, R^2, defined below, were used to quantitatively assess model performance.

$$M_f = \frac{1}{n}\sum_{i=1}^{n} Q_f(i)$$

$$M_o = \frac{1}{n}\sum_{i=1}^{n} Q_o(i)$$

$$ES = \left[\frac{\sum_{i=1}^{n}(Q_o - M_o)^2 - \sum_{i=1}^{n}(Q_o - Q_f)^2}{\sum_{i=1}^{n}(Q_o - M_o)^2}\right]$$

$$R^2 = \left[\frac{\frac{1}{n}\sum_{i=1}^{n} Q_o Q_f - M_o M_f}{\left(\frac{1}{n}\sum_{i=1}^{n} Q_o^2 - M_o^2\right)\left(\frac{1}{n}\sum_{i=1}^{n} Q_f^2 - M_f^2\right)} \right]^2$$

where Q_f and Q_o are the simulated and observed streamflow, respectively.

Values of the Nash and Sutcliffe efficiency score, *ES*, range from 1 to $-\infty$. When model predictions equal observed values, *ES* equals 1. Negative values of *ES* imply that the model's predictive power is worse than simply using the mean of the observed values. Donigian (2002) provided correlation coefficient and coefficient of determination value ranges for assessing HSPF hydrologic model performance at the daily and monthly timescales. "Very Good", "Good", "Fair", and "Poor" HSPF hydrologic model simulations would have R^2 value ranges of approximately 0.85–1.00, 0.75–0.85, 0.65–0.75, and 0.00–0.65, respectively, at the monthly timescale and 0.80–1.00, 0.70–0.80, 0.60–0.70, and 0.00–0.60, respectively, at the daily timescale.

5.3.1 Chico Creek

The calibration inversion run was manually terminated after 5493 model calls, which resulted in reducing the objective function from a starting value of 76108 to a final value of 2594. In consideration of the perceptual model, no external water was supplied to any of the five systems to achieve the calibration and verification results summarized in this section. Table 39 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data for each of the five systems (12258 missing of 175296 15 minute flow data points for Kitsap Creek at Lake Outlet, 25902 missing of 175296 15 minute flow data points for Wildcat Creek at Lake Outlet, 13604 missing of 105120 15 minute flow data points for Chico Tributary at Taylor Road, 8512 missing of 175296 15 minute flow data points for Dickerson Creek, and 21417 missing of 210432 15 minute flow data points for Chico Creek Mainstem; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 40 and Figures 57 - 78 suggest that the calibrated and verified Chico Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale), not only at the mouth of Chico Creek, but also at points interior. The fits depicted in Figures 57 - 60, which compare simulated and observed 15 minute flows, are quite remarkable in light of the objective function formulation wherein for each subwatershed just a brief time window was included into the objective function for comparing simulated and observed 15 minute flows (see Table 10). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were exceptional.

ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.2303
IMP3	0.8993
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Kitsap Creek	SUBURBAN	1	2.02	0.0306	20.46	0.0096	0.0097	0.2827	0.0963	1.623988	0.7471985	0.3939317
	MULTI-FAMILY	2	2.00	0.0178	19.43	0.0099	0.0095	0.1524	0.0864	1.282691	0.7190768	0.2212692
	COMMERCIAL	3	2.00	0.0034	18.30	0.0098	0.0087	0.0523	0.0530	1.021597	0.7004508	0.1050332
	RURAL RESIDENTIAL	4	5.72	0.0529	21.00	0.0099	0.0101	0.4907	0.1069	2.721694	0.7547348	0.6595884
	LAWN	5	4.07	0.0508	20.43	0.0087	0.0113	0.2869	0.1238	4.704098	0.85	0.487164
	PASTURE	6	5.75	0.0632	24.61	0.0097	0.0102	0.4598	0.1183	4.52093	0.85	0.6837698
	FOREST	7	7.82	0.0875	89.83	0.0071	0.0272	1.3634	0.1885	3.201501	0.85	0.5043471
	BAREGROUND	10	2.00	0.0064	18.77	0.0102	0.0090	0.1195	0.0500	1.047925	0.6851021	0.1846999
Wildcat Creek	SUBURBAN	12	3.01	0.0262	42.14	0.0103	0.0177	0.2176	0.1078	1.644167	0.5973202	0.2497785
	MULTI-FAMILY	13	2.00	0.0158	27.57	0.0100	0.0096	0.1556	0.0855	1.295246	0.647991	0.1563047
	COMMERCIAL	14	2.00	0.0010	17.71	0.0106	0.0087	0.0500	0.0500	1.010252	0.6699872	0.1
	RURAL RESIDENTIAL	15	5.04	0.0498	18.40	0.0100	0.0099	0.4851	0.1057	2.480373	0.6812385	0.6526893
	LAWN	16	2.07	0.0499	7.41	0.0100	0.0069	0.6865	0.1250	4.866737	0.6848357	0.8665731
	PASTURE	17	4.95	0.0558	39.53	0.0110	0.0082	0.6150	0.1165	4.509738	0.6670853	0.5897357
	FOREST	18	9.86	0.0859	32.51	0.0216	0.0043	0.6261	0.2213	3.253211	0.5887161	0.5301729
	BAREGROUND	21	2.00	0.0060	14.08	0.0113	0.0080	0.1355	0.0500	1.07597	0.7028719	0.1296462
Chico Trib.	SUBURBAN	23	2.10	0.0281	23.81	0.0096	0.0096	0.2507	0.0995	1.66624	0.7561434	0.333581
	MULTI-FAMILY	24	2.00	0.0167	19.83	0.0098	0.0093	0.1325	0.0858	1.289932	0.7096169	0.1956422
	COMMERCIAL	25	2.00	0.0032	18.44	0.0098	0.0086	0.0500	0.0510	1.02278	0.718049	0.1
	RURAL RESIDENTIAL	26	5.04	0.0497	20.56	0.0100	0.0101	0.4875	0.1060	2.470934	0.7738584	0.6460671
	LAWN	27	9.40	0.0360	11.02	0.0098	0.0101	0.3268	0.1450	5.469001	0.7695322	0.3059156
	PASTURE	28	4.69	0.0597	19.00	0.0101	0.0093	0.5624	0.1239	4.64606	0.8284123	0.7360277
	FOREST	29	6.54	0.0949	27.17	0.0075	0.0025	0.5491	0.3396	1.943583	0.7785243	0.9
	BAREGROUND	32	2.00	0.0062	29.91	0.0106	0.0069	0.0957	0.0500	1.038597	0.6919558	0.1834811
Dickerson Creek	SUBURBAN	34	2.00	0.0258	20.56	0.0095	0.0094	0.2201	0.0955	1.659808	0.7136462	0.2825628
	MULTI-FAMILY	35	2.00	0.0151	19.64	0.0098	0.0092	0.1126	0.0838	1.268744	0.7050788	0.1682349
	COMMERCIAL	36	2.00	0.0029	18.78	0.0097	0.0084	0.0500	0.0500	1.026045	0.7174825	0.1
	RURAL RESIDENTIAL	37	4.50	0.0468	20.15	0.0100	0.0101	0.4567	0.1046	2.518719	0.705657	0.6062201
	LAWN	38	6.63	0.0293	38.27	0.0098	0.0119	0.6423	0.1240	6.353815	0.495274	0.2215045
	PASTURE	39	4.80	0.0560	21.07	0.0101	0.0097	0.4201	0.1181	4.835769	0.6298187	0.5581739
	FOREST	40	14.76	0.0591	66.00	0.0129	0.0287	1.1001	0.1487	3.770148	0.8375526	0.3965123
	BAREGROUND	43	2.00	0.0055	23.31	0.0111	0.0088	0.1178	0.0500	1.075583	0.6353797	0.1
Chico Creek Mainster	SUBURBAN	45	2.00	0.0265	22.56	0.0096	0.0093	0.1907	0.0961	1.609289	0.6882	0.2501812
	MULTI-FAMILY	46	2.00	0.0156	19.99	0.0098	0.0090	0.1012	0.0829	1.255367	0.7034059	0.1517376
	COMMERCIAL	47	2.00	0.0028	19.03	0.0097	0.0084	0.0500	0.0500	1.025245	0.7059482	0.1
	RURAL RESIDENTIAL	48	3.96	0.0483	19.00	0.0104	0.0100	0.4536	0.1038	2.36866	0.6783708	0.5900149
	LAWN	49	2.24	0.0479	21.95	0.0099	0.0099	0.3495	0.1118	4.30968	0.6649271	0.4981006
	PASTURE	50	4.04	0.0581	19.50	0.0103	0.0101	0.4349	0.1148	4.26156	0.6761361	0.5995493
	FOREST	51	5.89	0.0889	83.36	0.0223	0.0106	0.5732	0.1136	2.56054	0.39239	0.6763952
	BAREGROUND	54	2.00	0.0058	17.27	0.0106	0.0088	0.0704	0.0500	1.0142	0.6346705	0.1444946

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - KITSAP CK	111	0.1001	0.1477
IMPERVIOUS - WILDCAT CK	121	0.0980	0.1282
IMPERVIOUS - CHICO TRIB.	131	0.1017	0.1285
IMPERVIOUS - DICKERSON	141	0.1001	0.1085
IMPERVIOUS - CHICO MAINSTEM	151	0.1002	0.1033

Table 39. Identified model resulting from calibration inversion run.

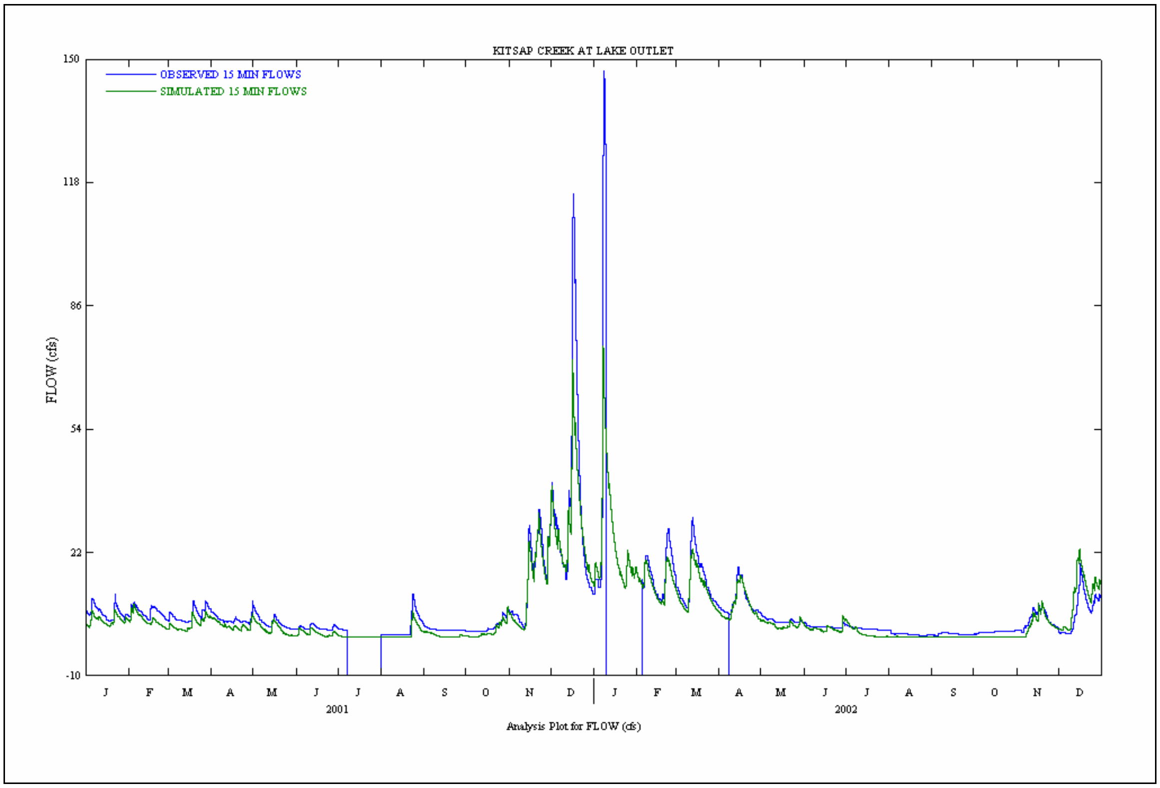

Figure 57. Calibrated model results for Kitsap Creek at Lake Outlet.

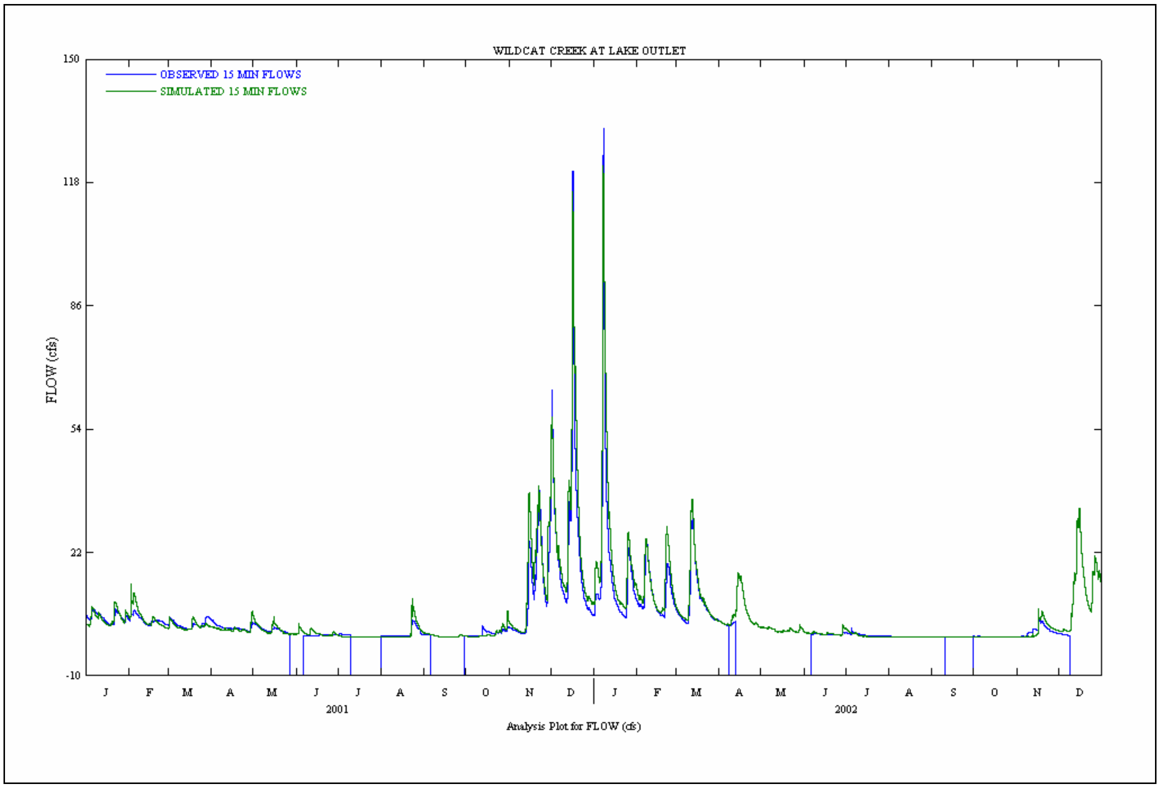

Figure 58. Calibrated model results for Wildcat Creek at Lake Oulet.

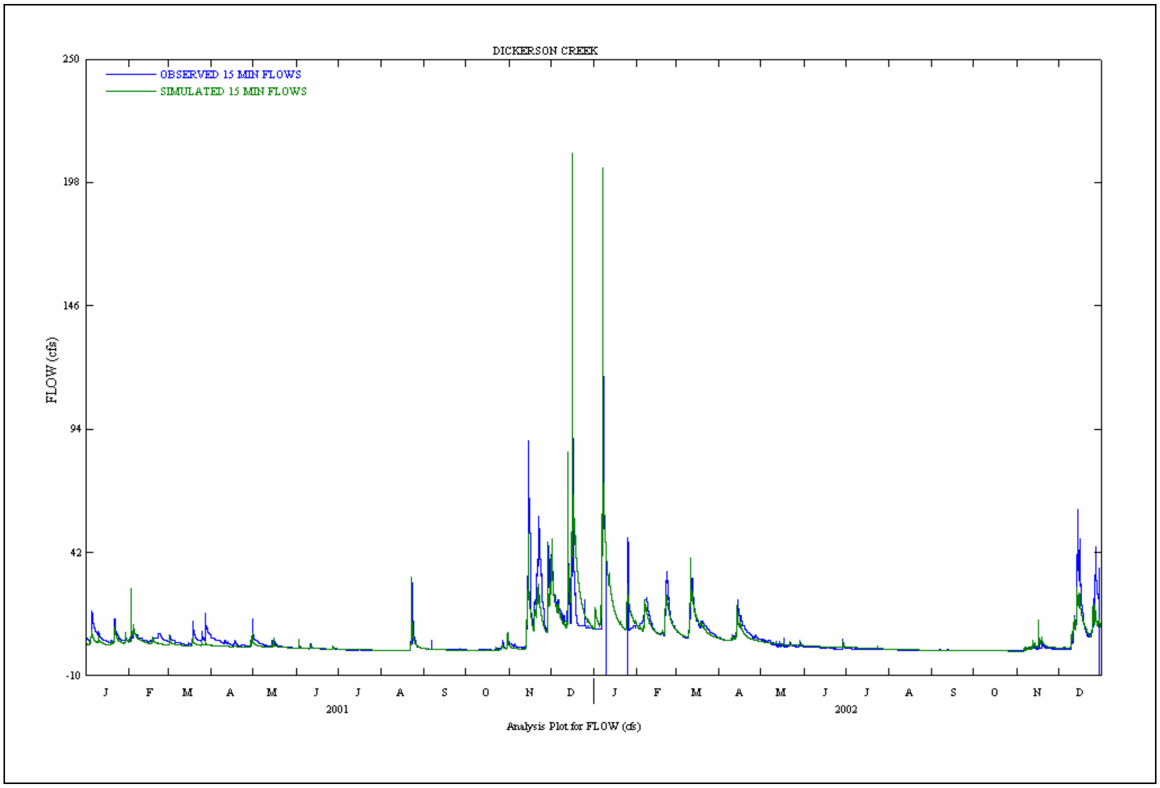

Figure 59. Calibrated model results for Dickerson Creek.

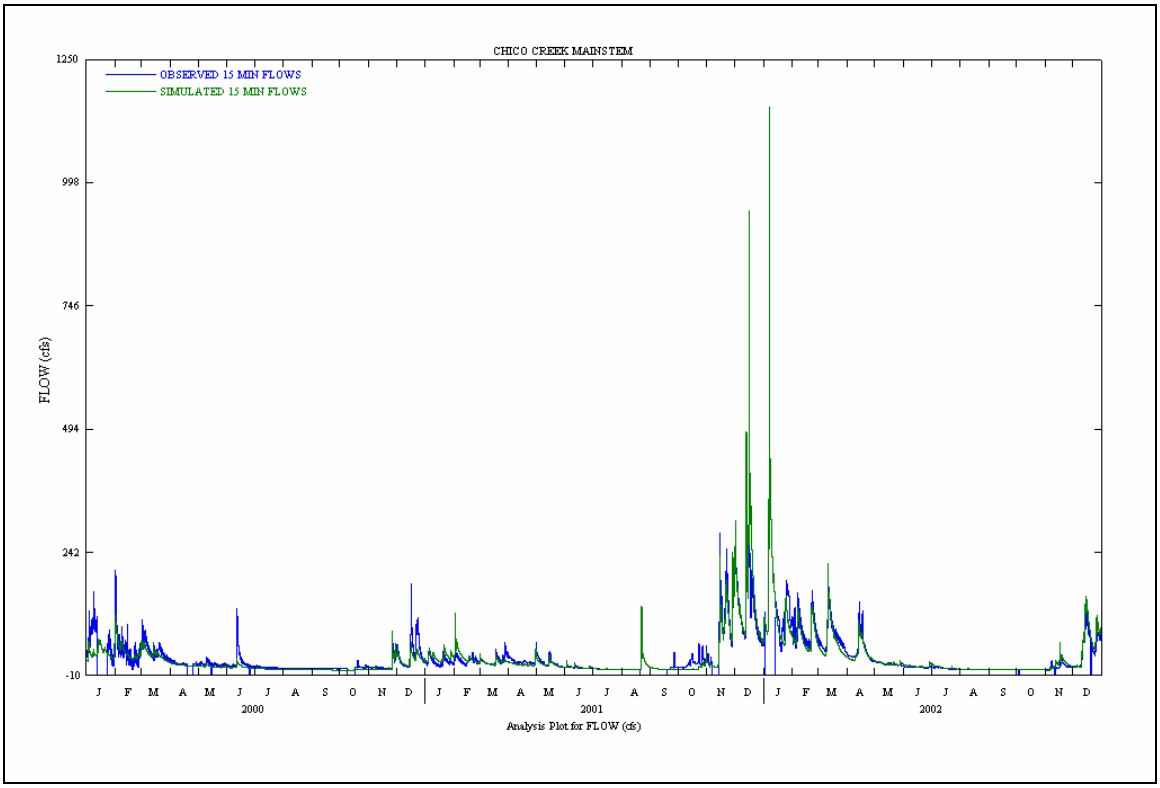

Figure 60. Calibrated model results for Chico Creek Mainstem.

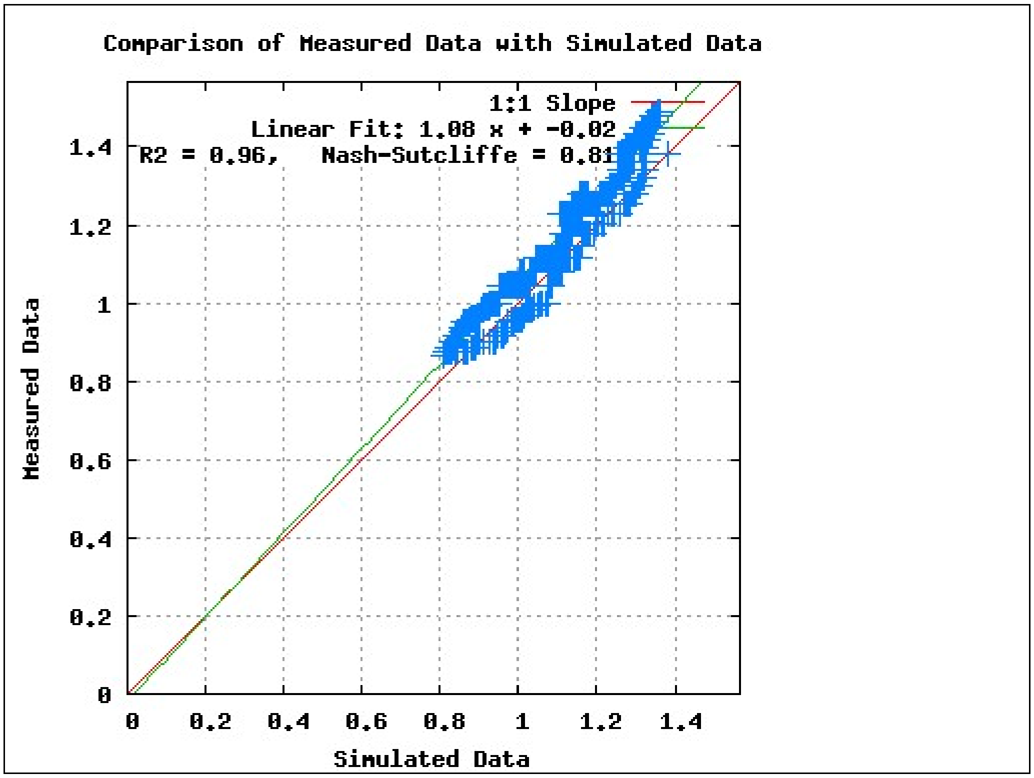

Figure 61. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Kitsap Creek at Lake Outlet.

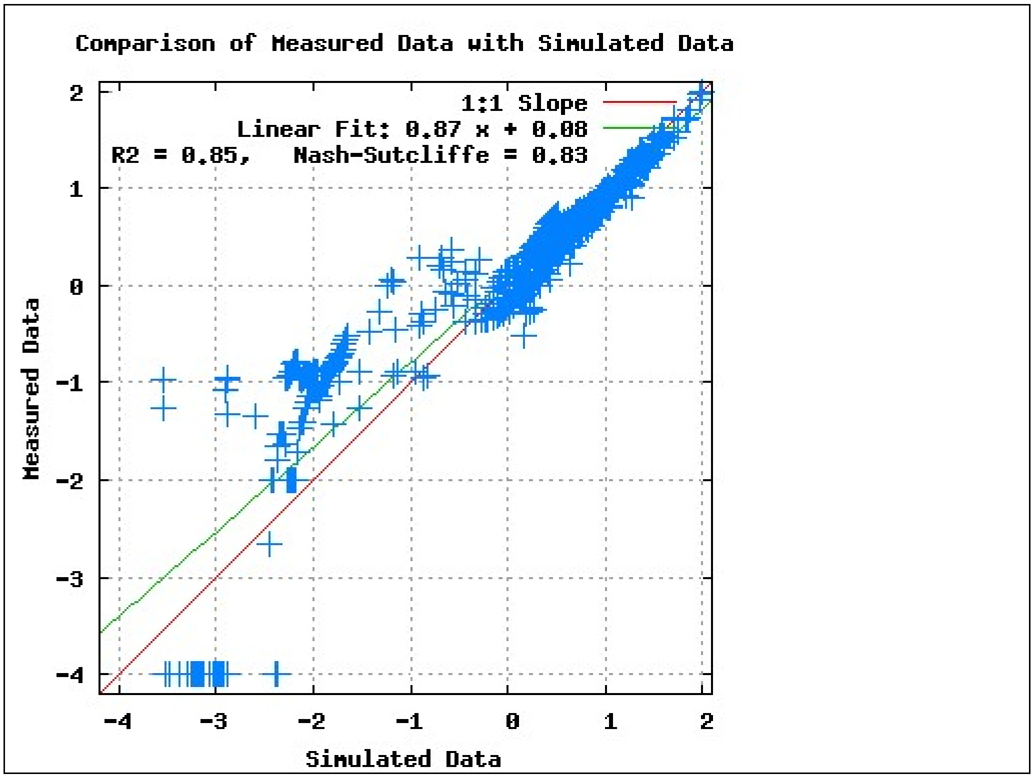

Figure 62. Comparison of the simulated and observed mean daily flow data that was used for calibration for Wildcat Creek at Lake Oulet.

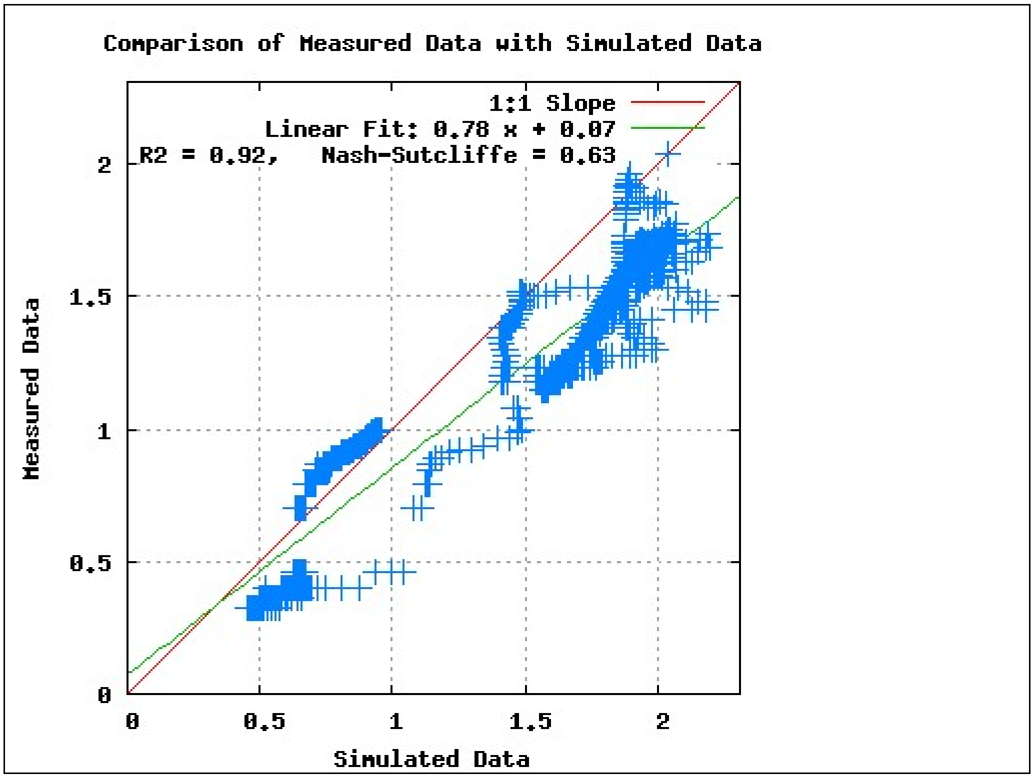

Figure 63. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Chico Tributary at Taylor Road.

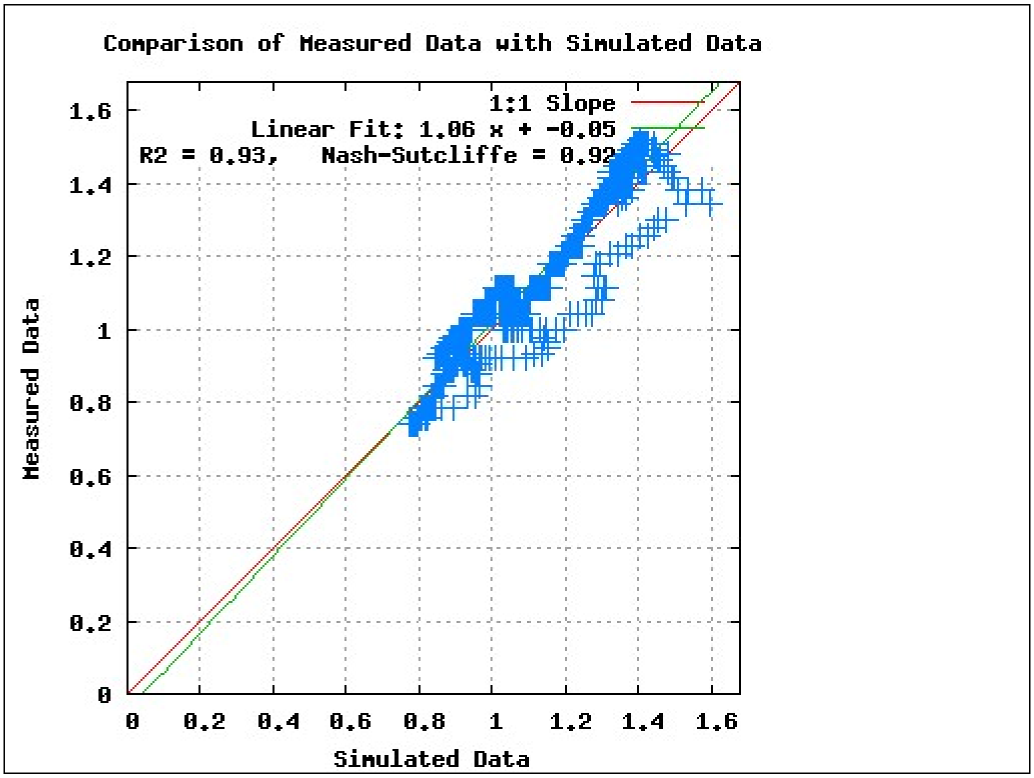

Figure 64. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Dickerson Creek.

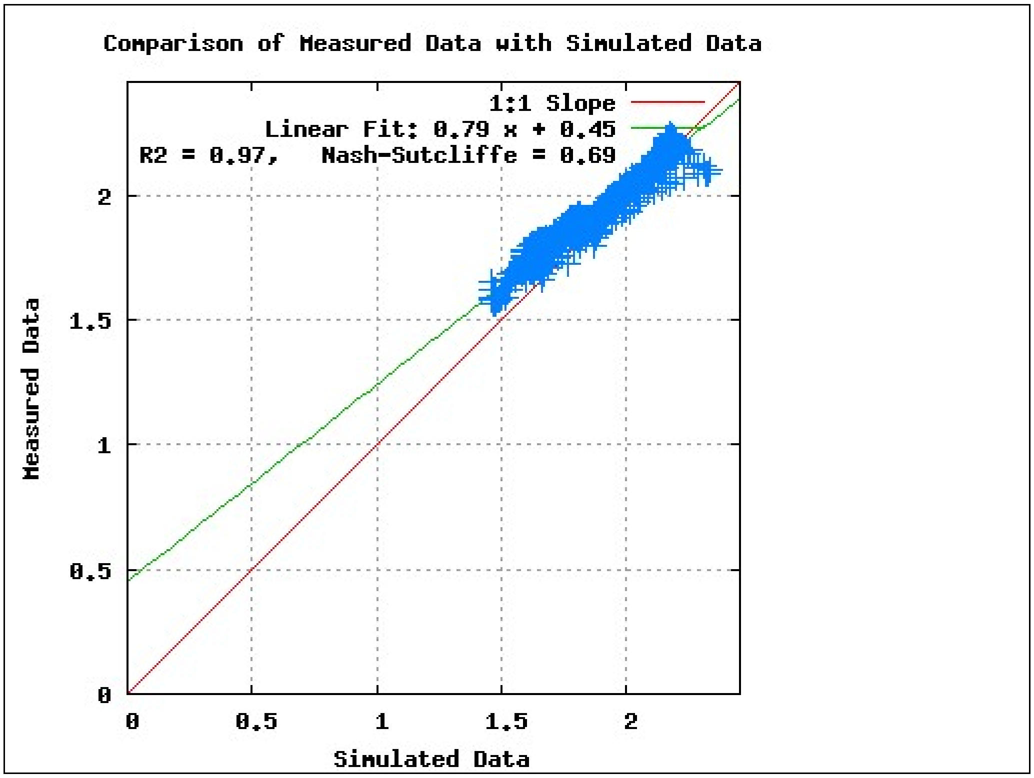

Figure 65. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Chico Creek Mainstem.

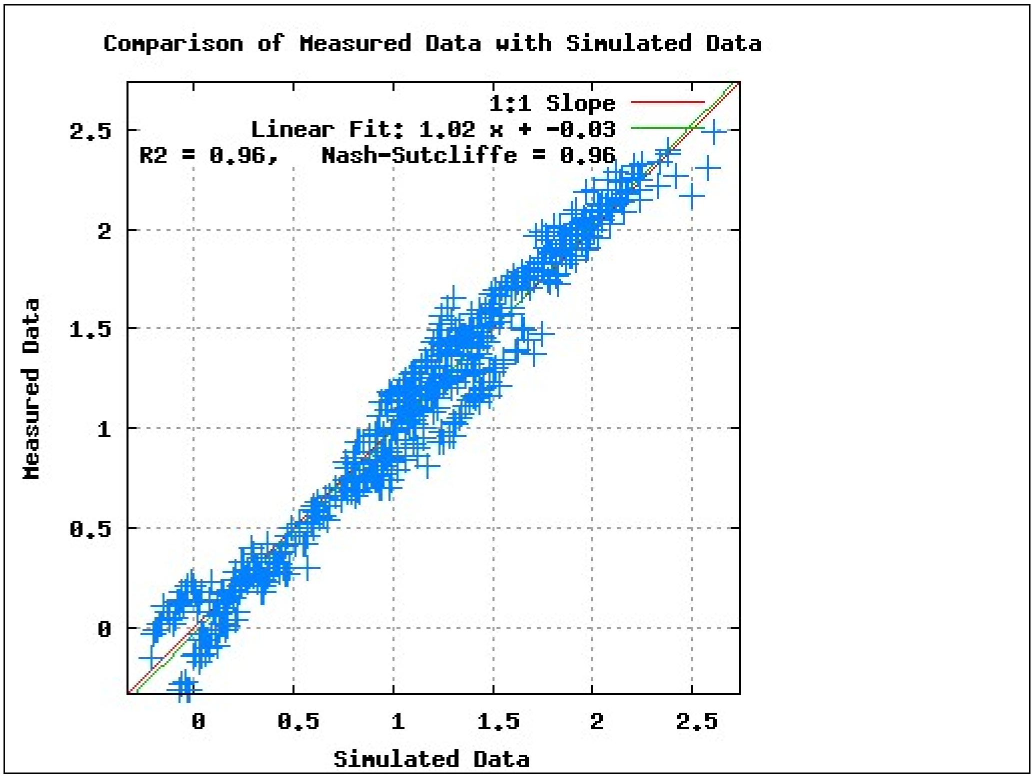

Figure 66. Comparison of the simulated and observed mean daily flow data that was used for calibration for Chico Creek Mainstem.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Kitsap Creek	SUBURBAN	1	12.73	16.93	9.01	17.03	1	12.69	16.93	8.99	17.01	1	-0.32	-0.03	-0.15	-0.14
	MULTI-FAMILY	2	22.81	11.90	6.32	14.67	2	22.77	11.90	6.32	14.67	2	-0.15	0.00	-0.03	-0.04
	COMMERCIAL	3	40.20	3.20	1.70	10.60	3	39.68	3.14	1.64	11.31	3	-1.31	-1.87	-3.41	6.78
	RURAL RESIDENTIAL	4	2.24	17.41	13.34	22.71	4	2.25	17.42	13.34	22.71	4	0.22	0.02	0.00	0.00
	LAWN	5	0.83	22.88	12.17	19.82	5	0.81	22.88	12.20	19.74	5	-2.84	-0.03	0.24	-0.41
	PASTURE	6	0.40	18.14	13.88	23.28	6	0.43	18.15	13.88	23.28	6	8.23	0.08	-0.02	0.01
	FOREST	7	0.12	11.57	18.32	25.69	7	0.31	11.56	18.82	25.44	7	149.21	-0.07	2.74	-0.97
	BAREGROUND	10	25.25	10.68	5.68	14.10	10	25.19	10.67	5.66	14.11	10	-0.23	-0.04	-0.31	0.11
Wildcat Creek	SUBURBAN	12	12.07	16.06	8.54	16.15	12	12.09	16.07	8.56	16.09	12	0.14	0.08	0.16	-0.37
	MULTI-FAMILY	13	21.63	11.28	6.00	13.92	13	21.61	11.28	6.00	13.89	13	-0.08	0.00	-0.02	-0.16
	COMMERCIAL	14	38.13	3.04	1.61	10.05	14	36.20	3.07	1.44	12.22	14	-5.07	0.91	-10.27	21.58
	RURAL RESIDENTIAL	15	2.13	16.51	12.65	21.53	15	2.11	16.50	12.65	21.53	15	-0.69	-0.09	0.00	0.00
	LAWN	16	0.79	21.70	11.54	18.79	16	0.70	21.61	11.55	18.82	16	-12.03	-0.42	0.13	0.16
	PASTURE	17	0.38	17.20	13.17	22.08	17	0.44	17.24	13.17	22.08	17	16.37	0.24	0.01	0.00
	FOREST	18	0.12	10.97	17.37	24.36	18	0.22	11.00	17.43	24.29	18	90.48	0.24	0.30	-0.32
	BAREGROUND	21	23.94	10.13	5.38	13.37	21	23.63	10.15	5.43	13.57	21	-1.31	0.26	0.83	1.45
Chico Trib.	SUBURBAN	23	12.07	16.06	8.54	16.15	23	11.96	16.06	8.53	16.17	23	-0.94	-0.02	-0.17	0.11
	MULTI-FAMILY	24	21.63	11.28	6.00	13.92	24	21.57	11.28	5.98	13.93	24	-0.28	-0.01	-0.21	0.10
	COMMERCIAL	25	38.13	3.04	1.61	10.05	25	37.44	2.97	1.55	10.94	25	-1.82	-2.10	-3.75	8.90
	RURAL RESIDENTIAL	26	2.13	16.51	12.65	21.53	26	2.12	16.51	12.65	21.54	26	-0.22	-0.02	-0.01	0.00
	LAWN	27	0.79	21.70	11.54	18.79	27	0.70	21.80	11.53	18.83	27	-11.89	0.44	-0.06	0.21
	PASTURE	28	0.38	17.20	13.17	22.08	28	0.36	17.18	13.17	22.08	28	-3.77	-0.10	0.00	0.00
	FOREST	29	0.12	10.97	17.37	24.36	29	0.55	11.03	17.21	24.28	29	373.48	0.51	-0.95	-0.34
	BAREGROUND	32	23.94	10.13	5.38	13.37	32	23.89	10.13	5.39	13.40	32	-0.22	0.05	0.15	0.21
Dickerson Creek	SUBURBAN	34	11.51	15.31	8.14	15.39	34	11.45	15.30	8.12	15.37	34	-0.48	-0.05	-0.26	-0.18
	MULTI-FAMILY	35	20.62	10.75	5.72	13.26	35	20.55	10.75	5.70	13.29	35	-0.34	-0.01	-0.38	0.19
	COMMERCIAL	36	36.34	2.90	1.53	9.58	36	35.30	2.82	1.45	10.85	36	-2.87	-2.76	-5.45	13.31
	RURAL RESIDENTIAL	37	2.03	15.74	12.06	20.53	37	2.03	15.74	12.06	20.53	37	-0.08	-0.03	0.00	0.00
	LAWN	38	0.75	20.68	11.00	17.91	38	0.71	20.73	11.00	17.90	38	-5.34	0.23	0.02	-0.06
	PASTURE	39	0.36	16.40	12.55	21.05	39	0.37	16.39	12.55	21.05	39	1.96	-0.02	0.00	0.00
	FOREST	40	0.11	10.46	16.56	23.22	40	0.29	10.48	16.77	23.25	40	160.40	0.21	1.24	0.12
	BAREGROUND	43	22.82	9.65	5.13	12.75	43	22.72	9.65	5.11	12.85	43	-0.46	0.00	-0.51	0.83
Chico Creek Mainstem	SUBURBAN	45	10.91	14.52	7.72	14.60	45	10.90	14.51	7.72	14.59	45	-0.15	-0.01	-0.08	-0.04
	MULTI-FAMILY	46	19.55	10.20	5.42	12.58	46	19.51	10.20	5.41	12.63	46	-0.20	-0.01	-0.27	0.40
	COMMERCIAL	47	34.47	2.75	1.46	9.08	47	33.25	2.65	1.33	10.62	47	-3.53	-3.37	-8.73	16.91
	RURAL RESIDENTIAL	48	1.92	14.93	11.43	19.47	48	1.93	14.96	11.43	19.47	48	0.36	0.22	0.01	0.02
	LAWN	49	0.72	19.62	10.43	16.99	49	0.71	19.58	10.43	16.98	49	-0.60	-0.18	-0.02	-0.04
	PASTURE	50	0.34	15.55	11.90	19.96	50	0.36	15.58	11.90	19.96	50	7.32	0.21	0.00	0.01
	FOREST	51	0.11	9.92	15.71	22.02	51	0.41	9.95	15.97	22.05	51	287.84	0.33	1.69	0.12
	BAREGROUND	54	21.64	9.15	4.87	12.09	54	21.58	9.15	4.86	12.16	54	-0.28	-0.01	-0.13	0.60
	IMPERVIOUS - KITSAP CK	111	46.61			9.09	111	46.64			9.11	111	0.06			0.26
	IMPERVIOUS - WILDCAT CK	121	44.20			8.62	121	44.24			8.65	121	0.09			0.31
	IMPERVIOUS - CHICO TRIB.	131	44.20			8.62	131	44.24			8.65	131	0.08			0.37
	IMPERVIOUS - DICKERSON	141	42.13			8.22	141	42.16			8.24	141	0.07			0.32
	IMPERVIOUS - CHICO MAINSTEM	151	39.96			7.79	151	39.99			7.82	151	0.07			0.33

Table 40. Comparison of simulated and observed targets for the partition of average annual precipitation.

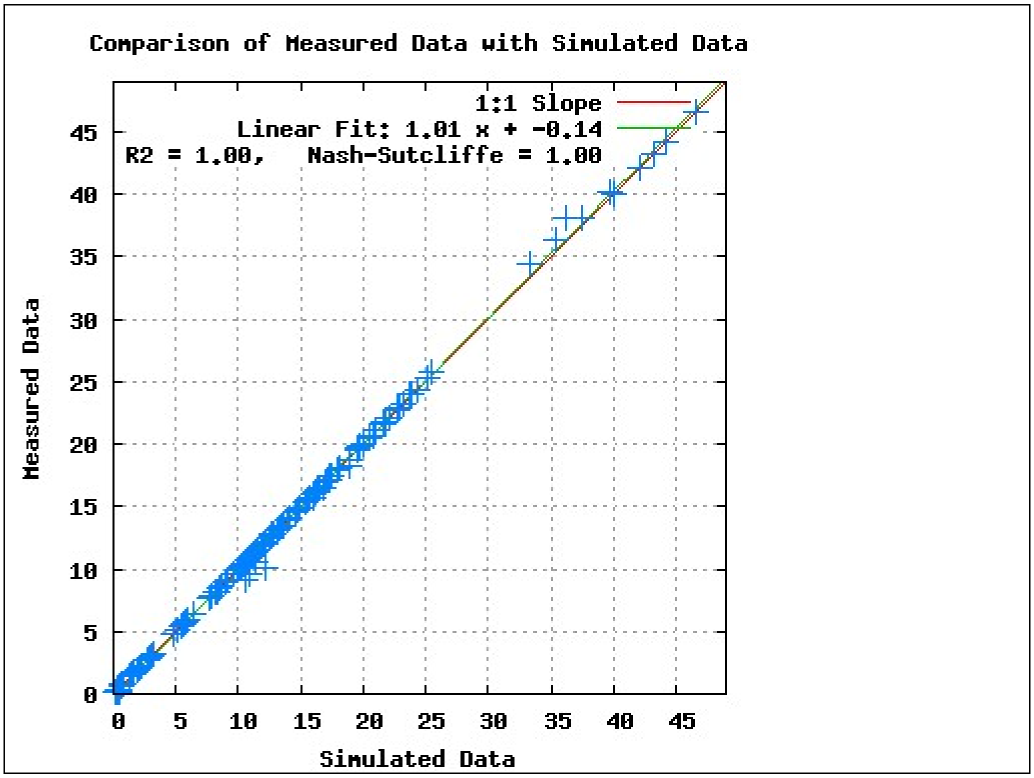

Figure 67. Comparison of simulated and observed targets for the partition of average annual precipitation.

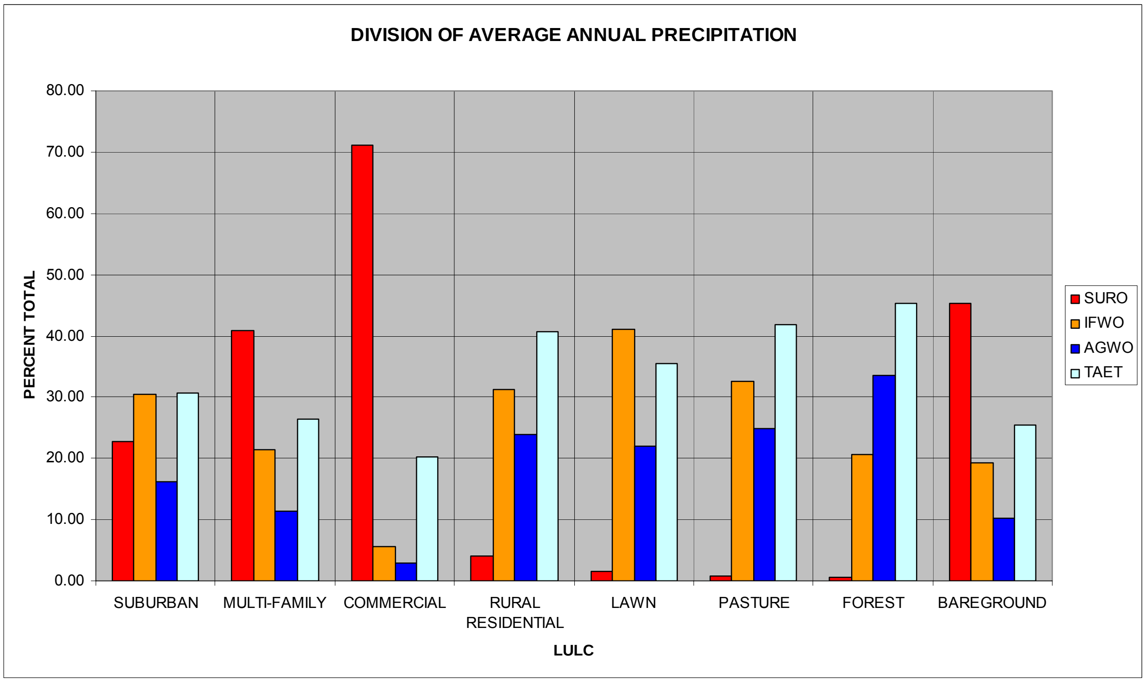

Figure 68. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Kitsap Creek at Lake Outlet.

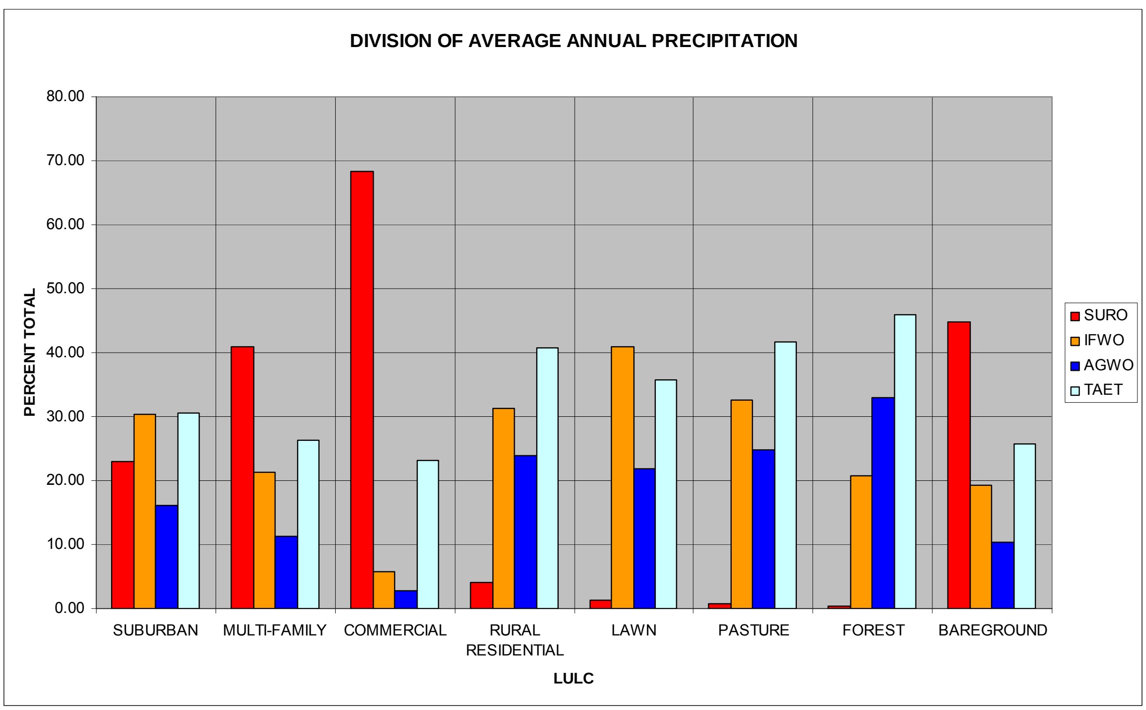

Figure 69. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Wildcat Creek at Lake Oulet.

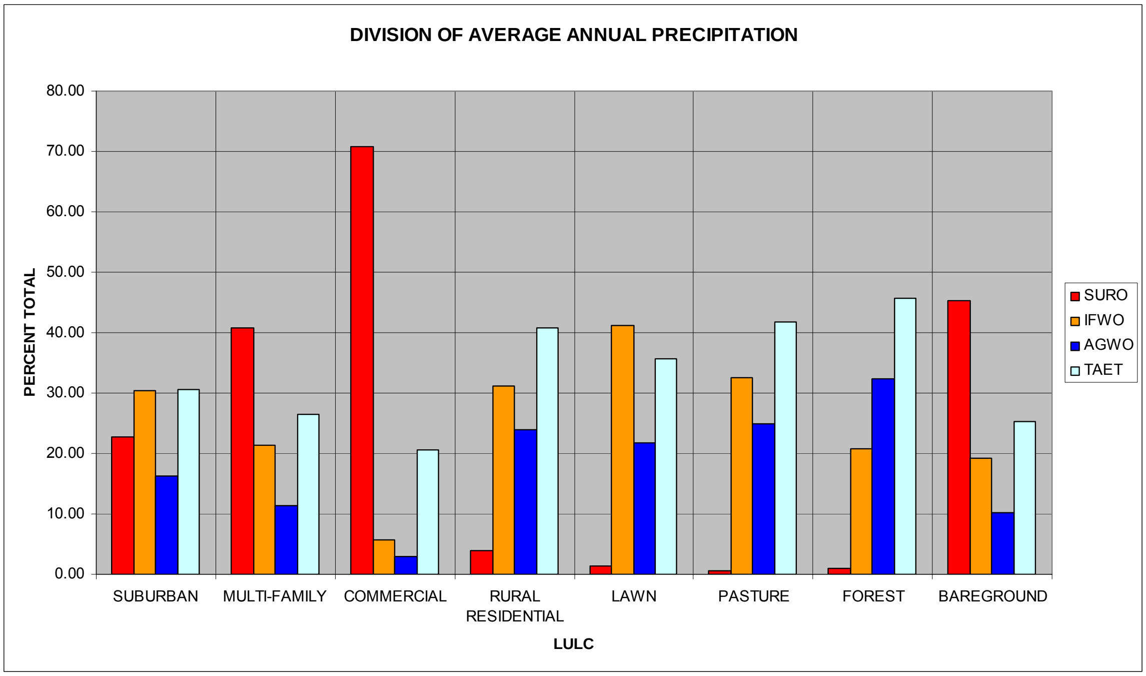

Figure 70. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Chico Tributary at Taylor Road.

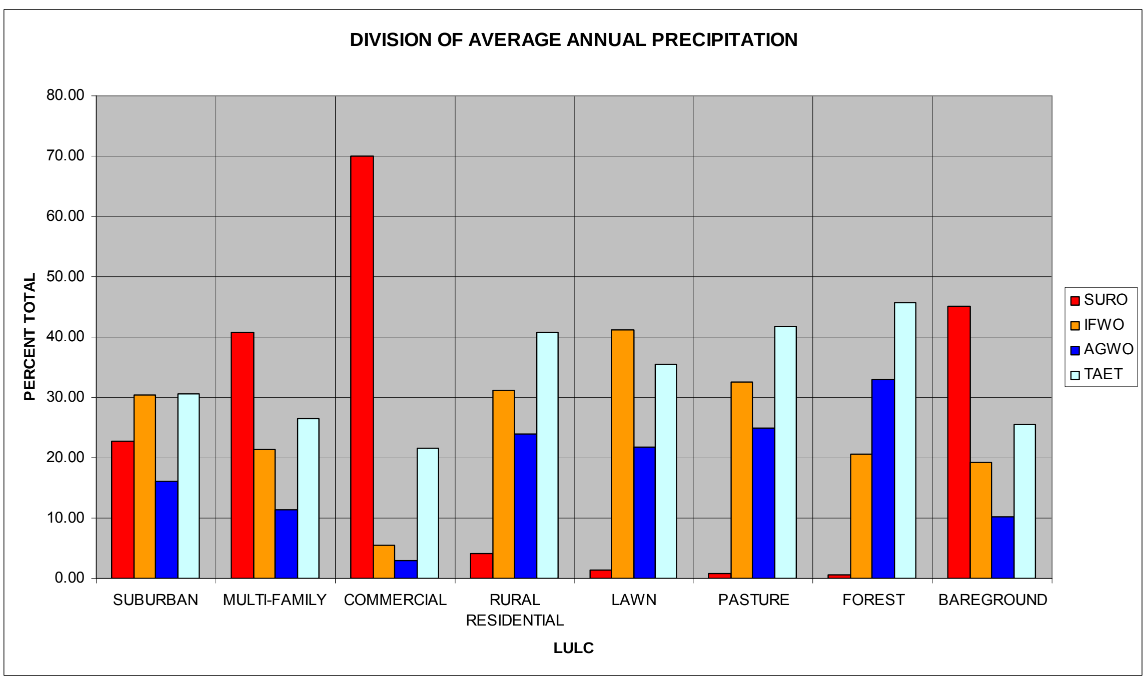

Figure 71. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Dickerson Creek.

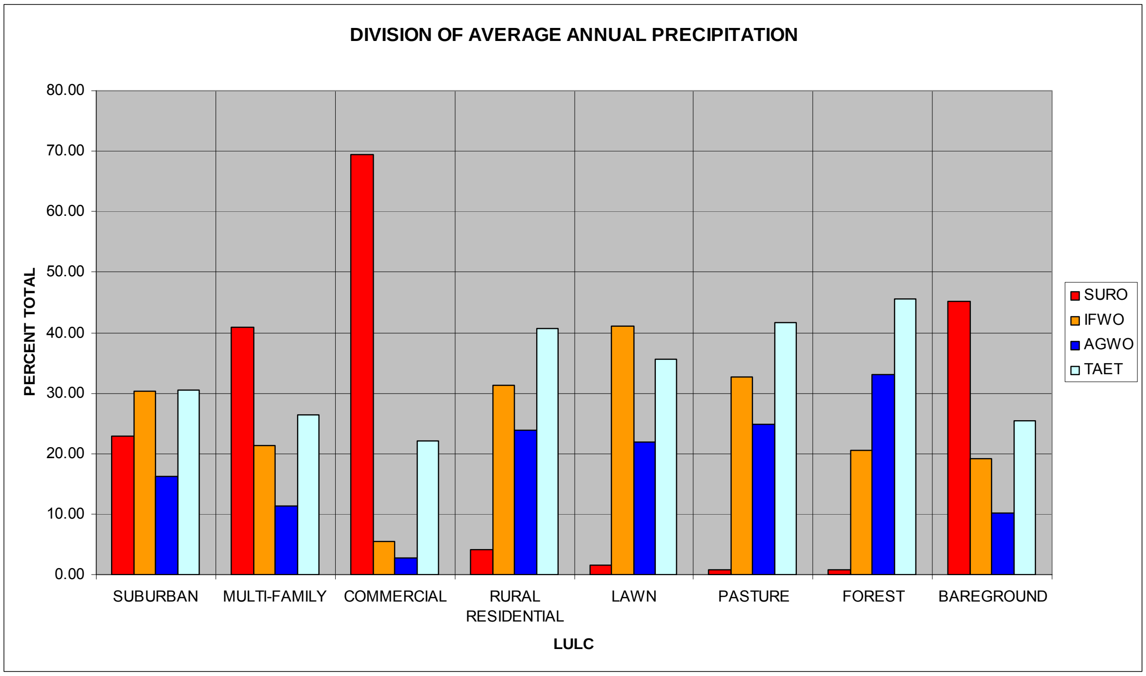

Figure 72. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Chico Creek Mainstem.

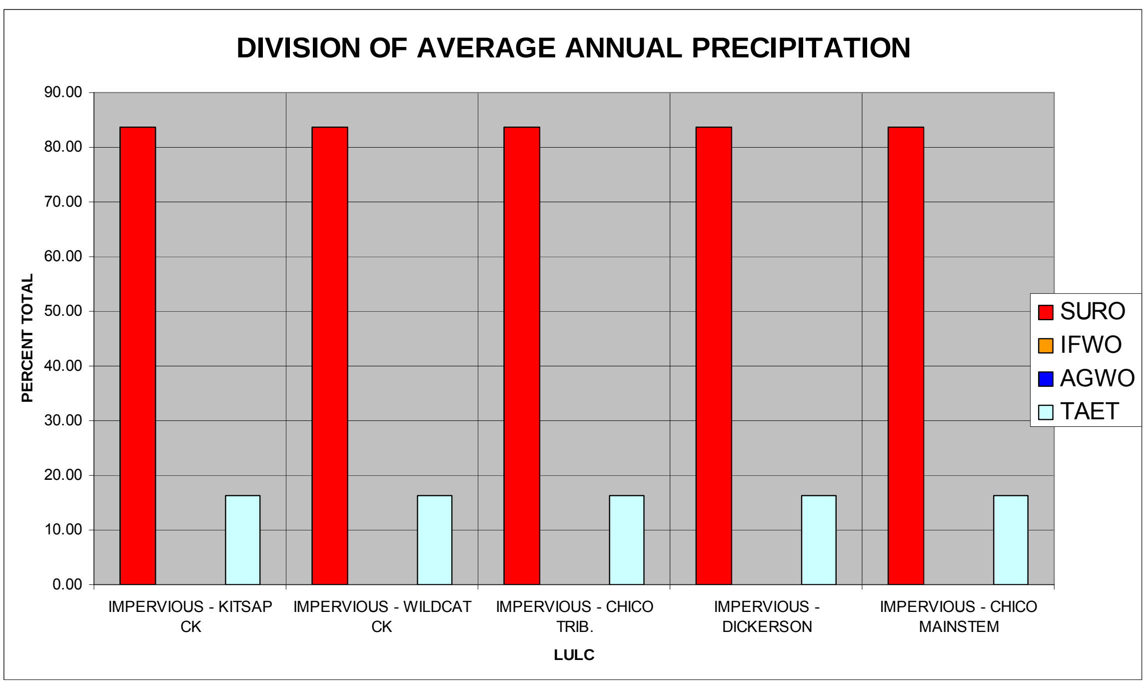

Figure 73. Simulated SURO and TAET for the impervious area for each of the five systems.

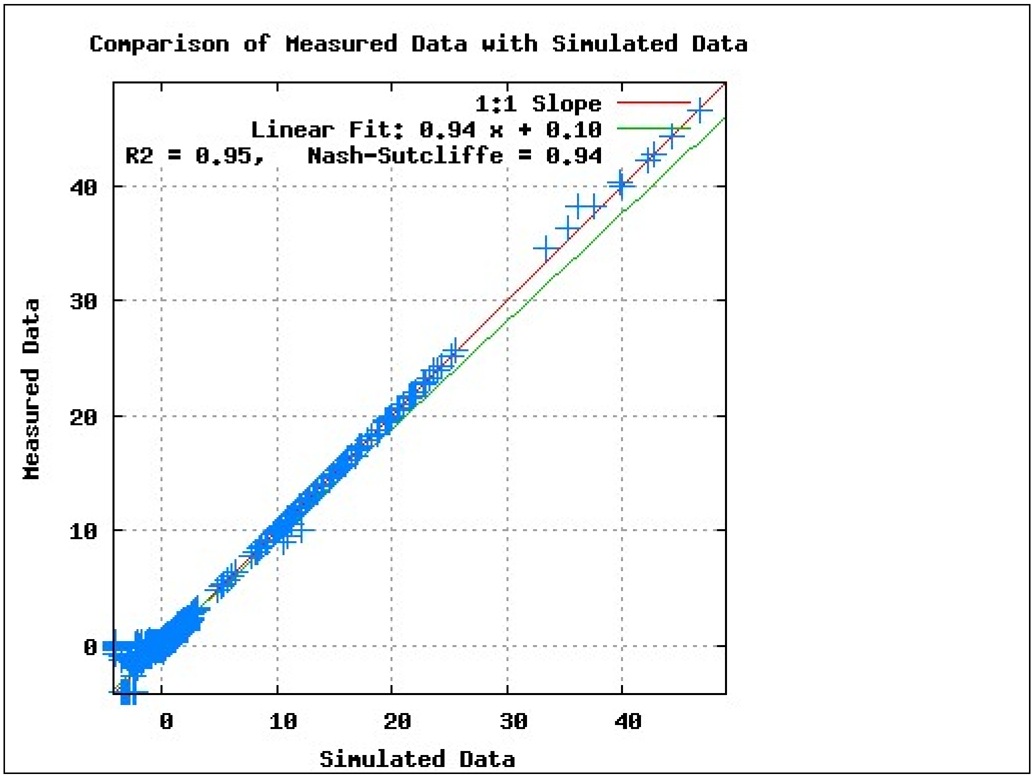

Figure 74. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Chico Creek HSPF hydrologic model.

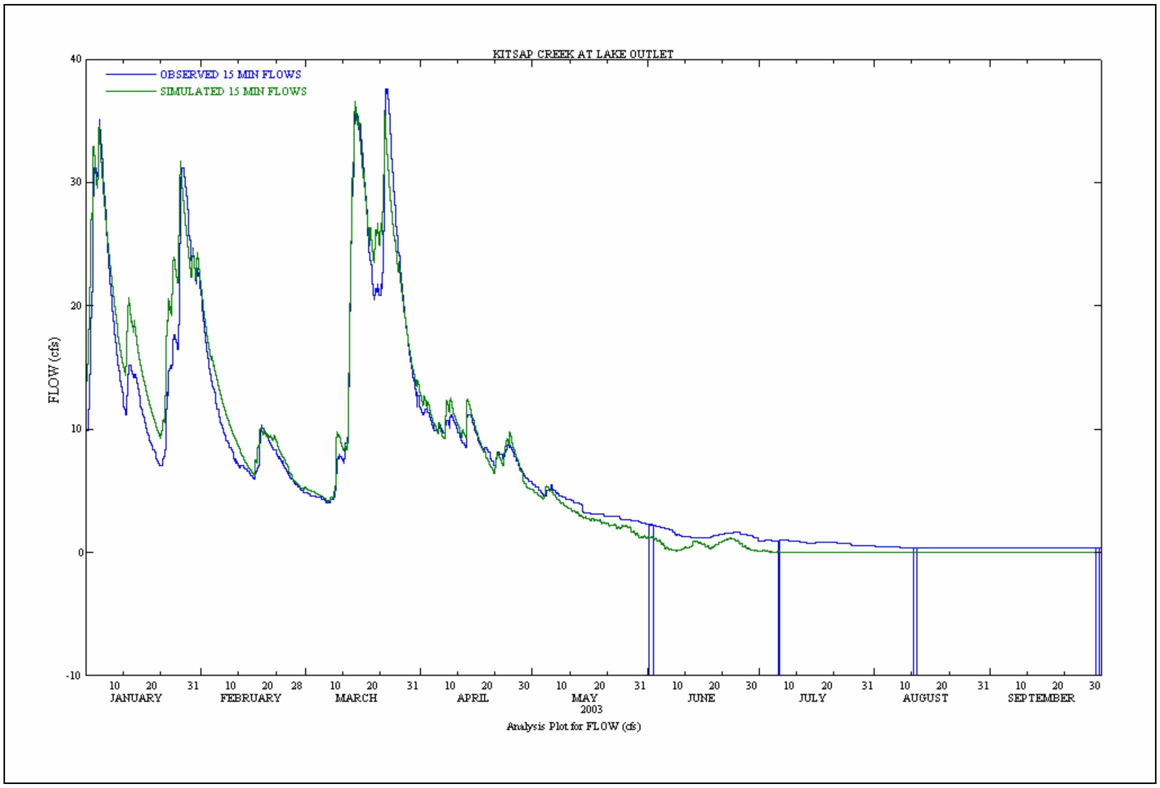

Figure 75. Hydrologic model verification results for Kitsap Creek at Lake Outlet.

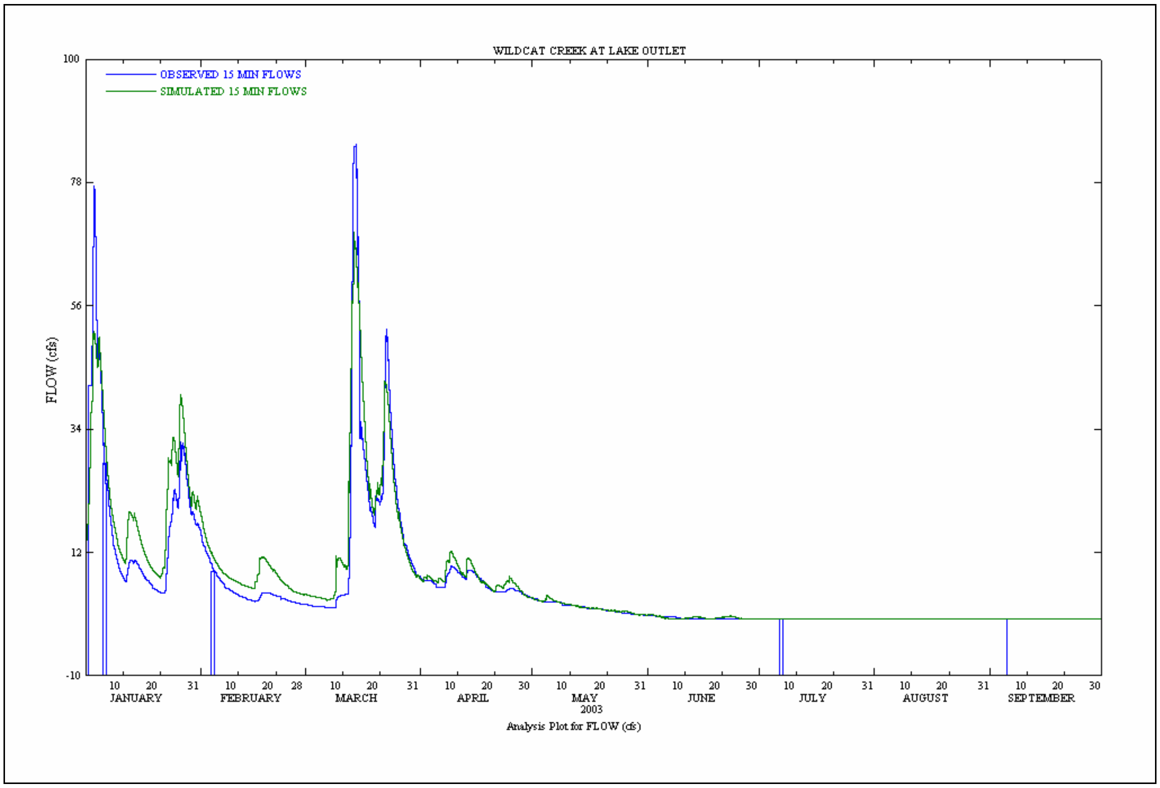

Figure 76. Hydrologic model verification results for Wildcat Creek at Lake Oulet.

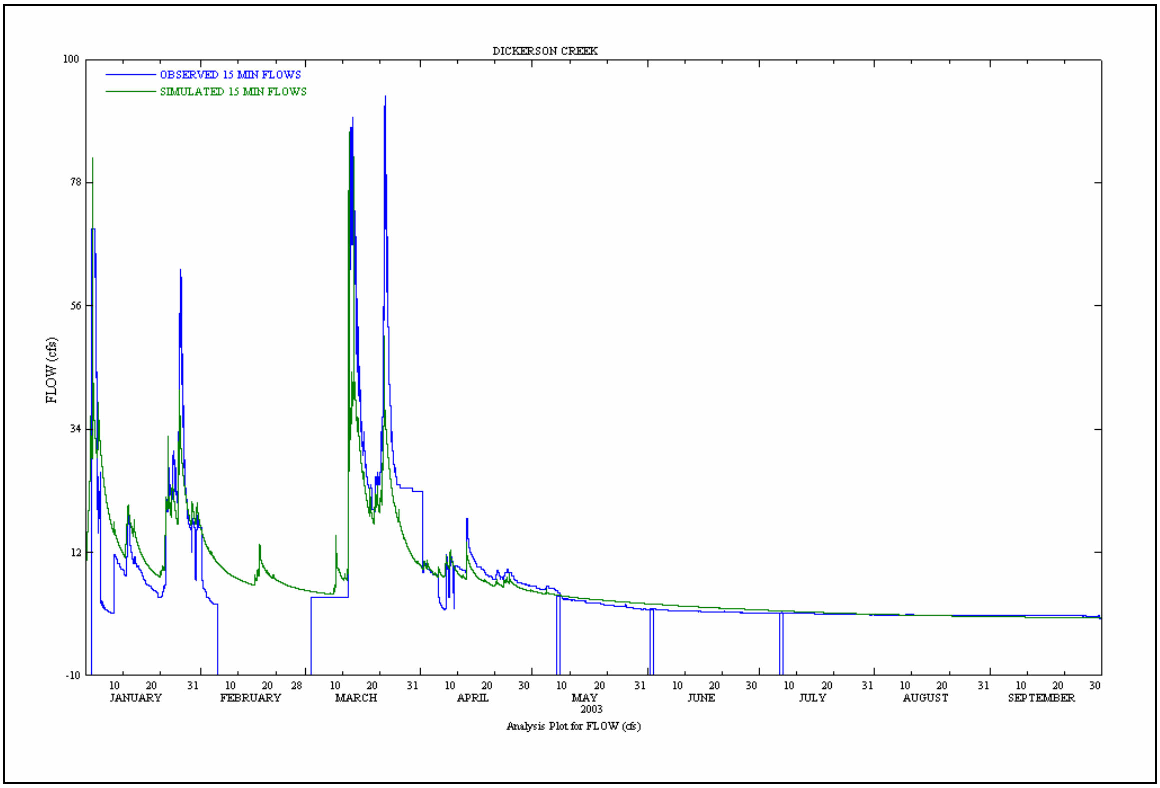

Figure 77. Hydrologic model verification results for Dickerson Creek.

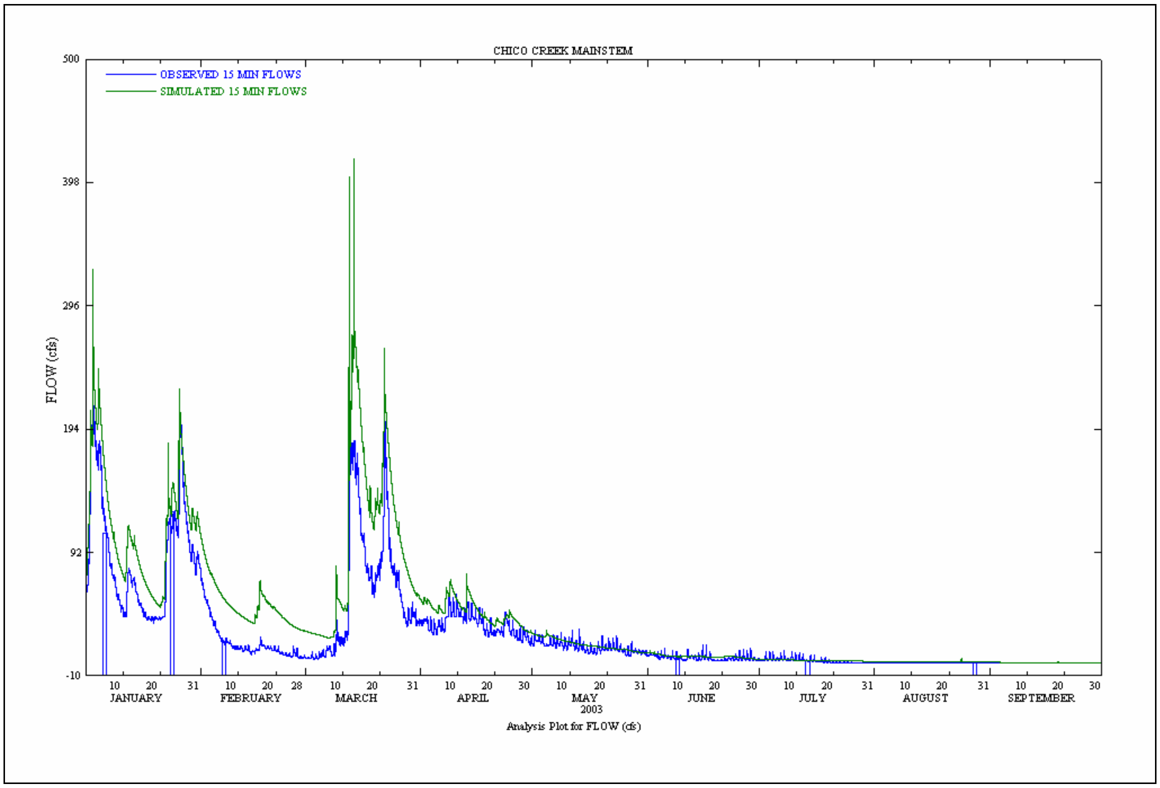

Figure 78. Hydrologic model verification results for Chico Creek Mainstem.

5.3.2 Strawberry Creek

Two separate calibration inversion runs were performed with the Strawberry Creek HSPF hydrologic model, the only difference between the two being the starting initial model estimate, and therein the only difference being the initial values specified for the parameter DEEPFR. In the first case, DEEPFR was uniformly set to 0.01; whereas, in the second case, DEEPFR was uniformly set to 0.2. Both inversion runs ran to completion, with the first terminating after 3313 model calls, which resulted in reducing the objective function from a starting value of 34419 to a final value of 816.3 The second inversion run terminated after 4141 model calls, which resulted in reducing the objective function from a starting value of 38471 to a final value of 937. In consideration of the perceptual model, no external water was supplied to the system to achieve the calibration and verification results summarized in this section. Table 41 lists the identified parameter sets that resulted from the two separate calibration inversion runs.

As with the Chico Creek model, the large quantity of missing flow data for the system (46408 missing of 140256 15 minute flow data points for Strawberry Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 42 and Figures 79 - 95 suggest that the calibrated Strawberry Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within the watershed system, were exceptional.

ADJUSTABLE MODEL PARAMETERS

	Inversio	Inversion 2
IMP1	0.1900	0.1900
IMP2	0.3181	0.3200
IMP3	0.8345	0.8282
IMP4	0.0700	0.1000

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP	CEPSC
Strawberry Creek - inversion 1	SUBURBAN	1	13.00	0.0196	6.13	0.0116	0.0049	0.1752	0.1250	1.69008	0.85	0.194953	5.02E-03
	MULTI-FAMILY	2	6.48	0.0115	95.24	0.0159	0.0080	0.1355	0.2799	1.29594	0.85	0.111211	5.14E-03
	COMMERCIAL	3	2.00	0.0026	12.96	0.0103	0.0084	0.0500	0.0553	1.06722	0.85	0.1	8.16E-03
	RURAL RESIDENTIAL	4	5.60	0.0460	18.50	0.0089	0.0085	0.4363	0.1009	2.4366	0.849469	0.445074	1.48E-02
	LAWN	5	11.75	0.0394	120.06	0.0115	0.0066	0.1394	0.0949	4.26175	0.3	0.314917	5.05E-03
	PASTURE	6	5.82	0.0526	11.39	0.0090	0.0093	0.4110	0.1126	4.37314	0.849017	0.495459	1.13E-02
	FOREST	7	9.20	0.0784	180.21	0.0111	0.0081	0.7199	0.4711	6.05725	0.3	0.46756	5.00E-03
	BAREGROUND	10	3.09	0.0125	217.69	0.0105	0.0105	0.1523	0.0811	1.26033	0.85	0.101335	
Strawberry Creek - inversion 2	SUBURBAN	1	3.40	0.0214	6.07	0.0557	0.0061	0.3879	0.1085	1.79852	0.3	0.143864	5.49E-03
	MULTI-FAMILY	2	2.86	0.0165	244.95	0.1076	0.0048	0.1563	0.1263	1.20238	0.3	0.109892	5.11E-03
	COMMERCIAL	3	2.00	0.0031	15.18	0.1141	0.0069	0.0500	0.0500	1.00514	0.85	0.1	1.12E-02
	RURAL RESIDENTIAL	4	4.97	0.0484	18.32	0.0207	0.0089	0.4591	0.1033	2.37579	0.844681	0.486041	1.79E-02
	LAWN	5	9.82	0.0350	7.84	0.0363	0.0055	0.3132	0.1008	4.83034	0.845656	0.276229	5.00E-03
	PASTURE	6	5.60	0.0545	11.43	0.0249	0.0090	0.4385	0.1206	4.83575	0.845032	0.496257	1.65E-02
	FOREST	7	9.22	0.0921	200.62	0.0256	0.0125	0.3885	0.4539	3.32809	0.3	0.478766	2.22E-02
	BAREGROUND	10	6.18	0.0127	191.69	0.1022	0.0050	0.1435	0.0785	1.24183	0.776094	0.104485	

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - STRAWBERRY CK - INVERSION 1	111	0.1400	0.1227
IMPERVIOUS - STRAWBERRY CK - INVERSION 2	111	0.1115	0.1226

Table 41. Identified model resulting from calibration inversion run.

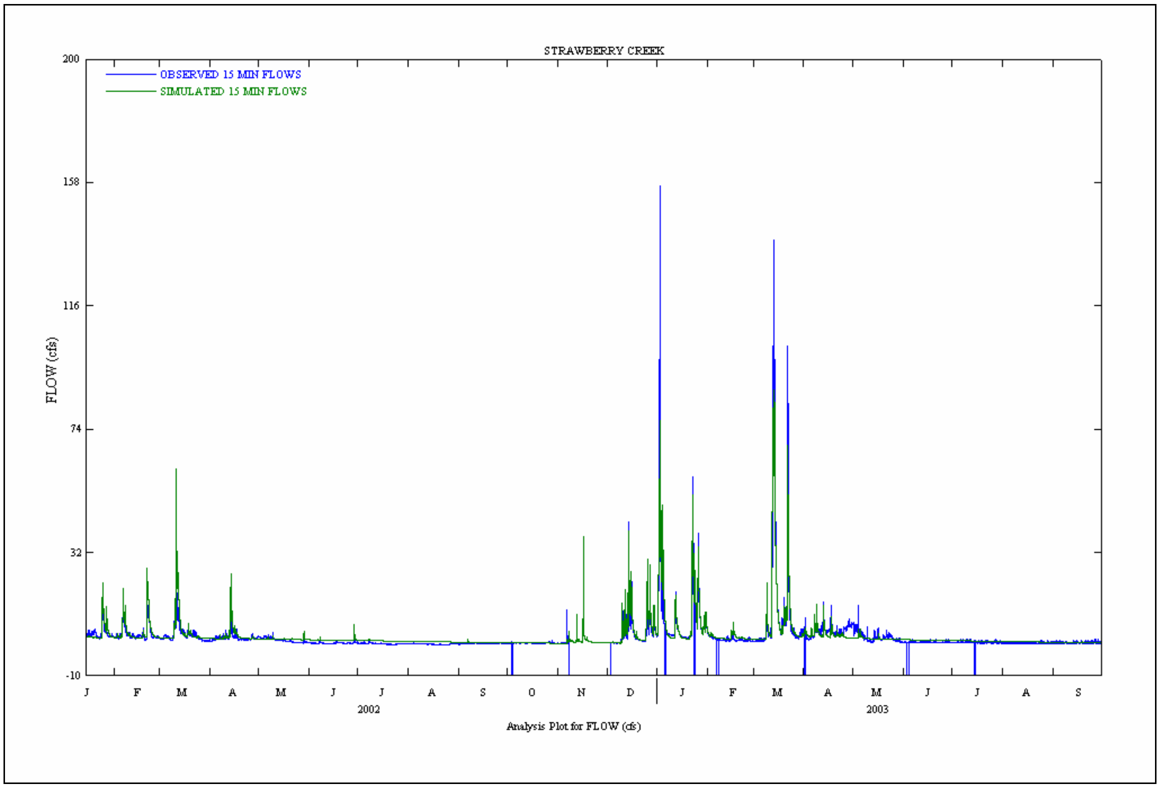

Figure 79. Calibration inversion run 1 model results for Strawberry Creek.

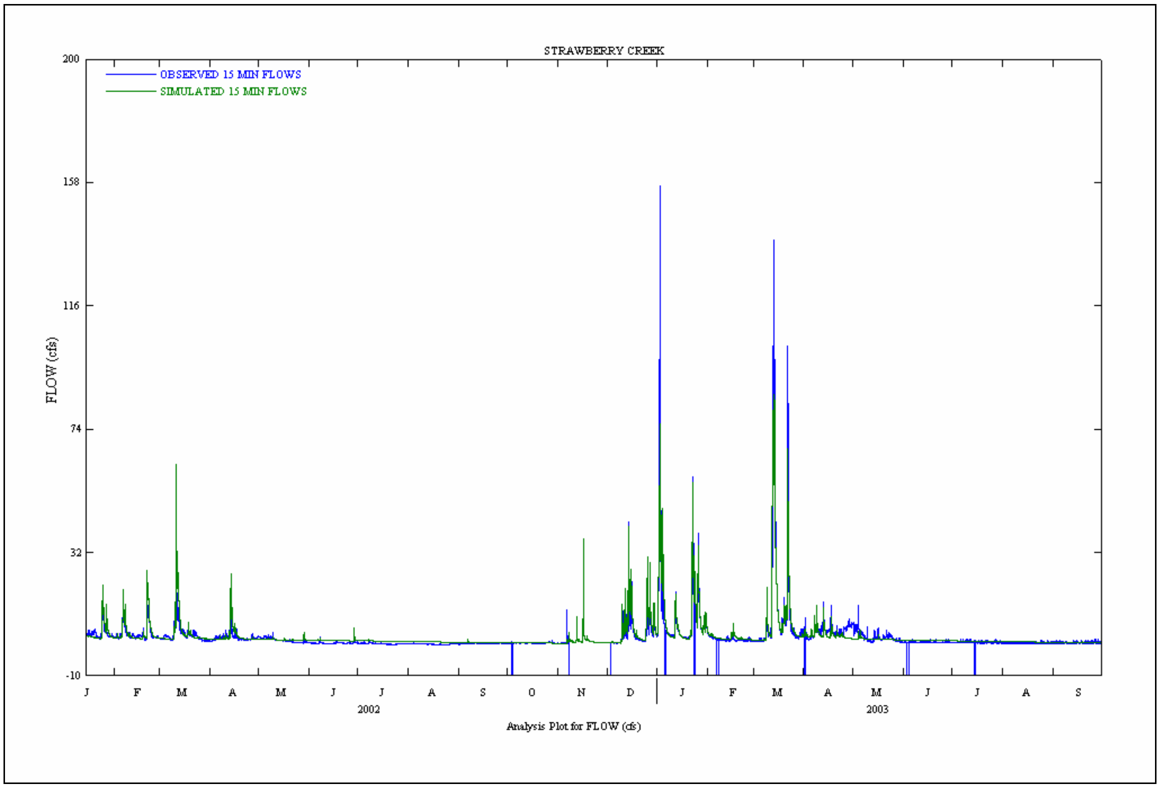

Figure 80. Calibration inversion run 2 model results for Strawberry Creek.

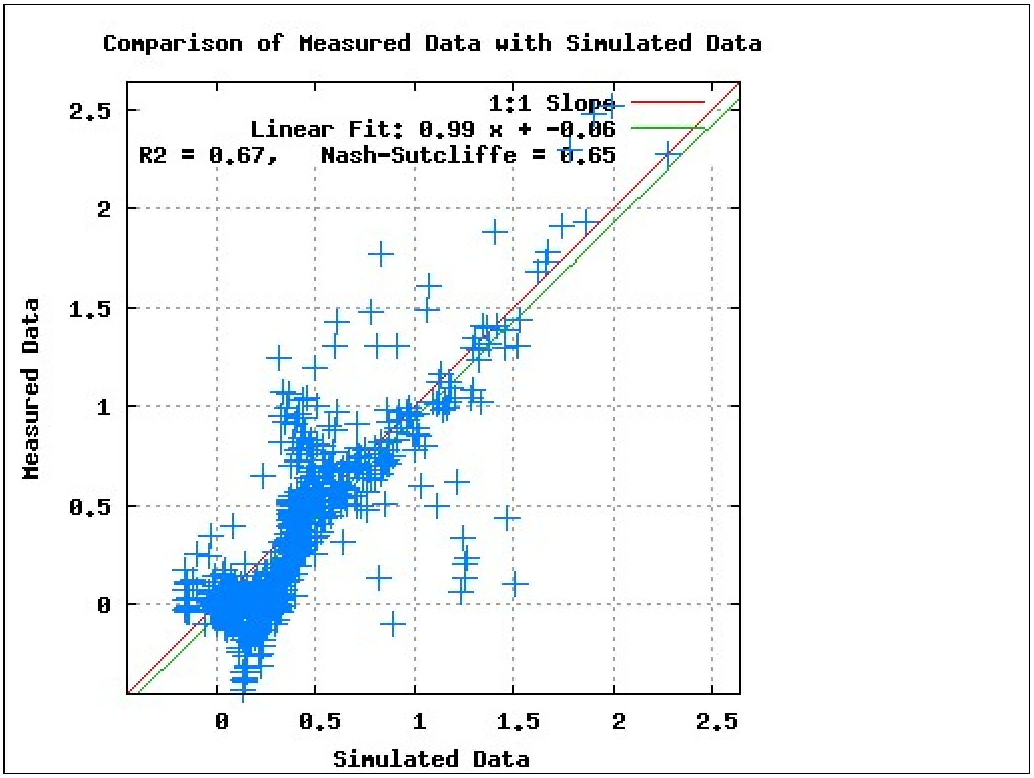

Figure 81. Comparison of the simulated and observed daily flow data that was used for calibration for Strawberry Creek (inversion run 1).

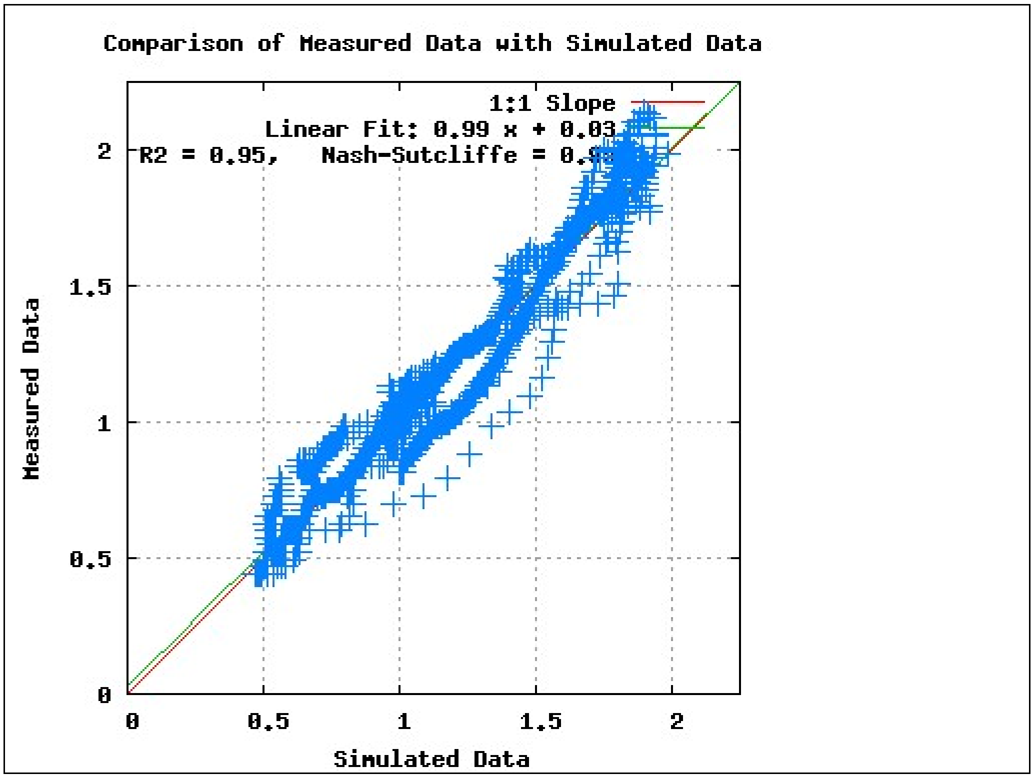

Figure 82. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Strawberry Creek (inversion run 1).

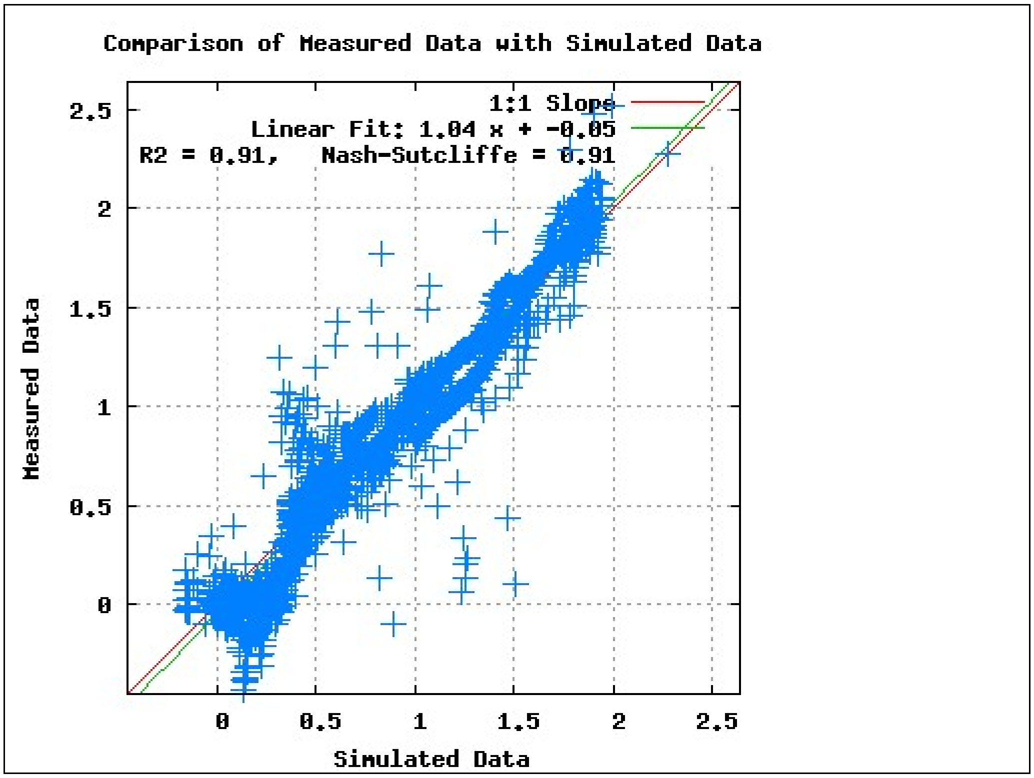

Figure 83. Comparison of the simulated and observed flow data (daily and 15 minute) that was used for calibration for Strawberry Creek (inversion run 1).

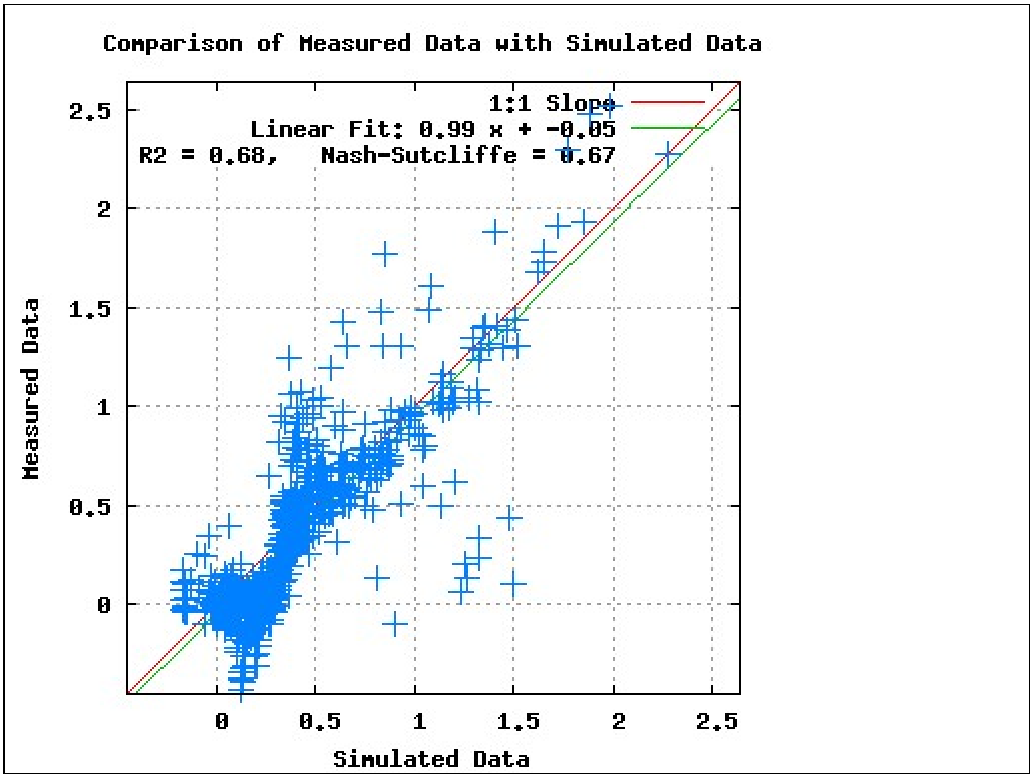

Figure 84. Comparison of the simulated and observed daily flow data that was used for calibration for Strawberry Creek (inversion run 2).

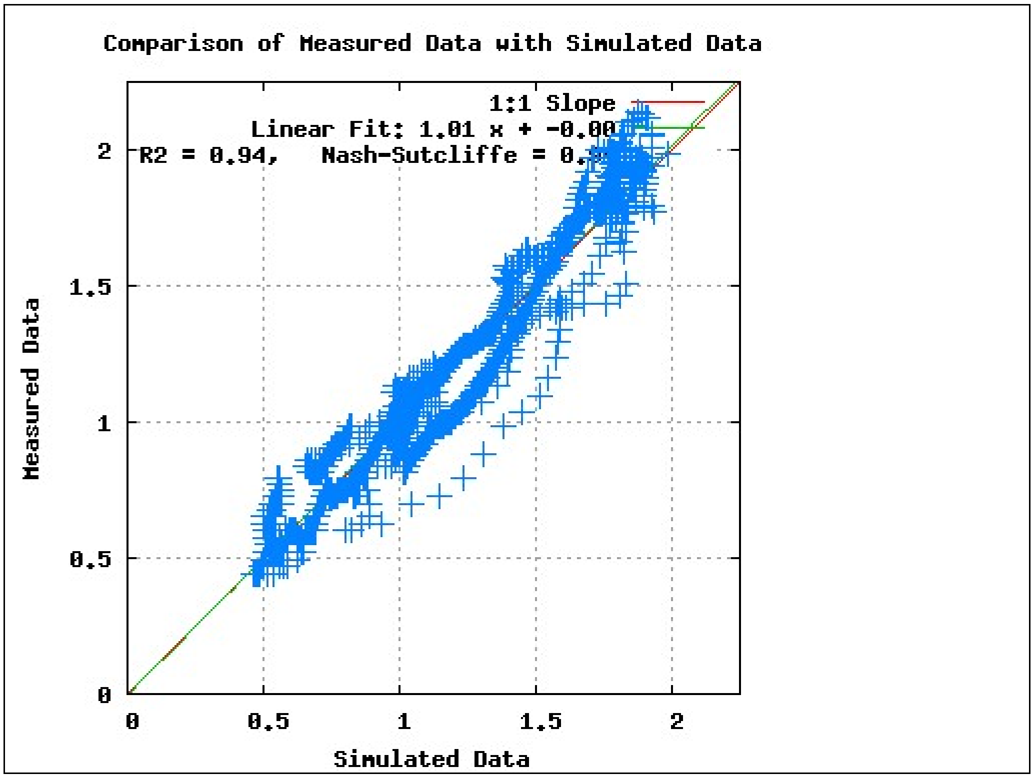

Figure 85. Comparison of the simulated and observed 15 minute flow data that was used for calibration for Strawberry Creek (inversion run 2).

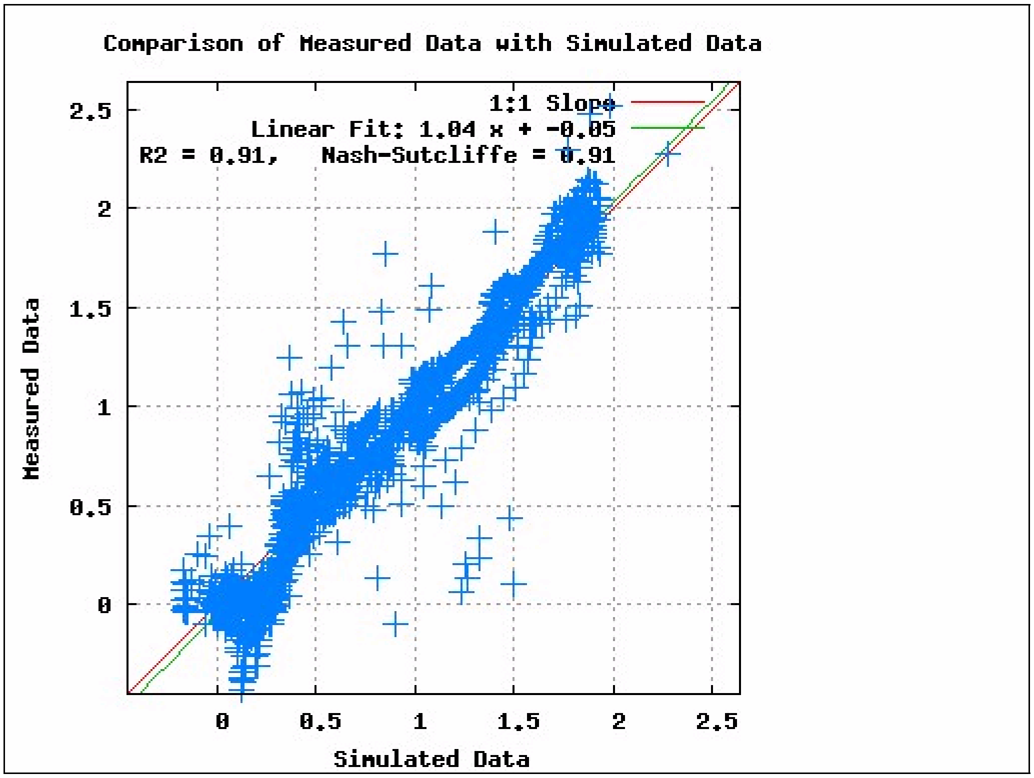

Figure 86. Comparison of the simulated and observed flow data (daily and 15 minute) that was used for calibration for Strawberry Creek (inversion run 2).

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Strawberry Creek - inversion 1	SUBURBAN	1	10.88	14.47	7.70	14.55	1	10.65	14.44	7.63	14.45	1	-2.10	-0.15	-0.91	-0.68
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	19.28	10.16	5.33	12.47	2	-1.07	0.01	-1.29	-0.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	33.74	2.71	1.26	9.89	3	-1.78	-1.15	-12.78	9.24
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.90	14.84	11.39	19.40	4	-0.67	-0.23	-0.02	0.00
	LAWN	5	0.71	19.55	10.39	16.93	5	0.65	19.20	10.38	16.89	5	-8.81	-1.79	-0.13	-0.26
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.32	15.48	11.86	19.89	6	-6.41	-0.13	0.01	-0.01
	FOREST	7	0.11	9.88	15.65	21.95	7	0.08	9.76	14.80	21.87	7	-24.49	-1.20	-5.44	-0.35
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	21.31	9.12	4.80	12.00	10	-1.18	-0.07	-1.09	-0.36
Strawberry Creek - inversion 2	SUBURBAN	1	10.88	14.47	7.70	14.55	1	10.57	14.43	7.67	14.38	1	-2.77	-0.29	-0.31	-1.15
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	18.66	10.15	5.32	12.32	2	-4.22	-0.12	-1.54	-1.75
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	33.48	2.67	1.28	10.00	3	-2.52	-2.51	-11.62	10.45
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.88	14.77	11.36	19.39	4	-2.03	-0.70	-0.32	-0.02
	LAWN	5	0.71	19.55	10.39	16.93	5	0.63	19.12	10.39	16.87	5	-11.29	-2.22	-0.07	-0.34
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.24	15.40	11.82	19.89	6	-29.63	-0.63	-0.32	-0.03
	FOREST	7	0.11	9.88	15.65	21.95	7	0.10	9.81	14.31	21.92	7	-5.82	-0.76	-8.56	-0.11
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	20.81	9.10	4.77	11.92	10	-3.51	-0.20	-1.60	-1.01
	IMPERVIOUS - STRAWBERRY CK - INVERSION 1	111	39.82			7.77	111	39.82			7.77	111	0.00			0.00
	IMPERVIOUS - STRAWBERRY CK - INVERSION 2	111	39.82			7.77	111	39.82			7.76	111	0.00			-0.02

Table 42. Comparison of simulated and observed targets for the partition of average annual precipitation for inversion run 1 and inversion run 2.

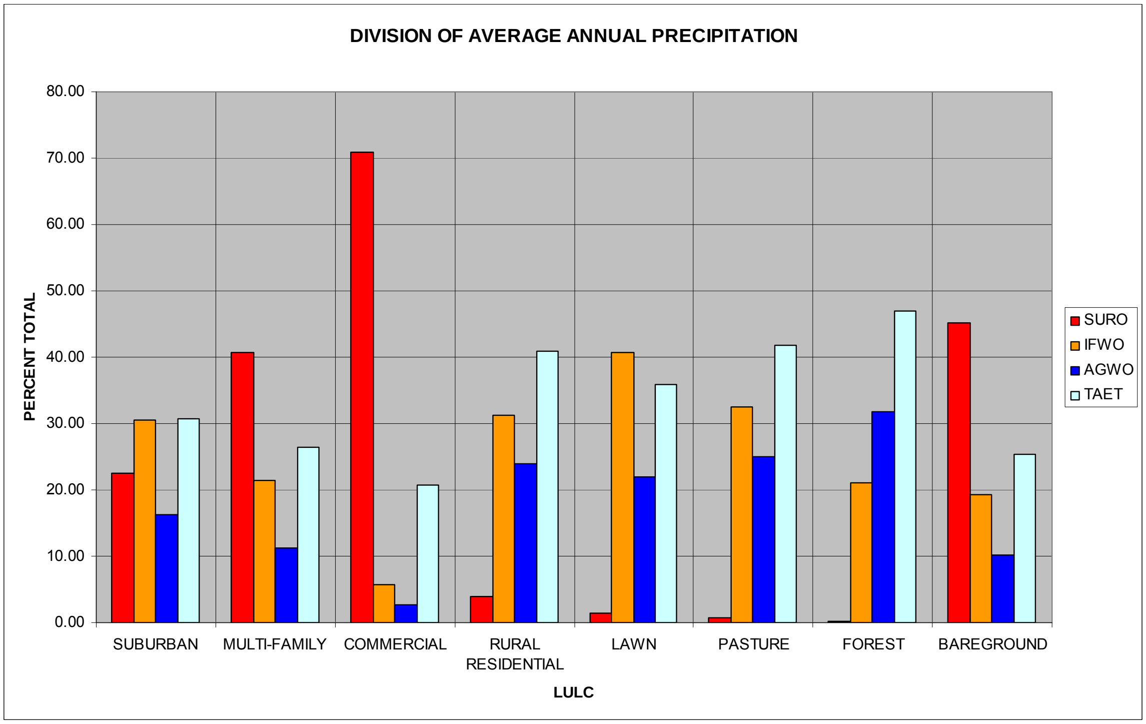

Figure 87. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Strawberry Creek (inversion run 1).

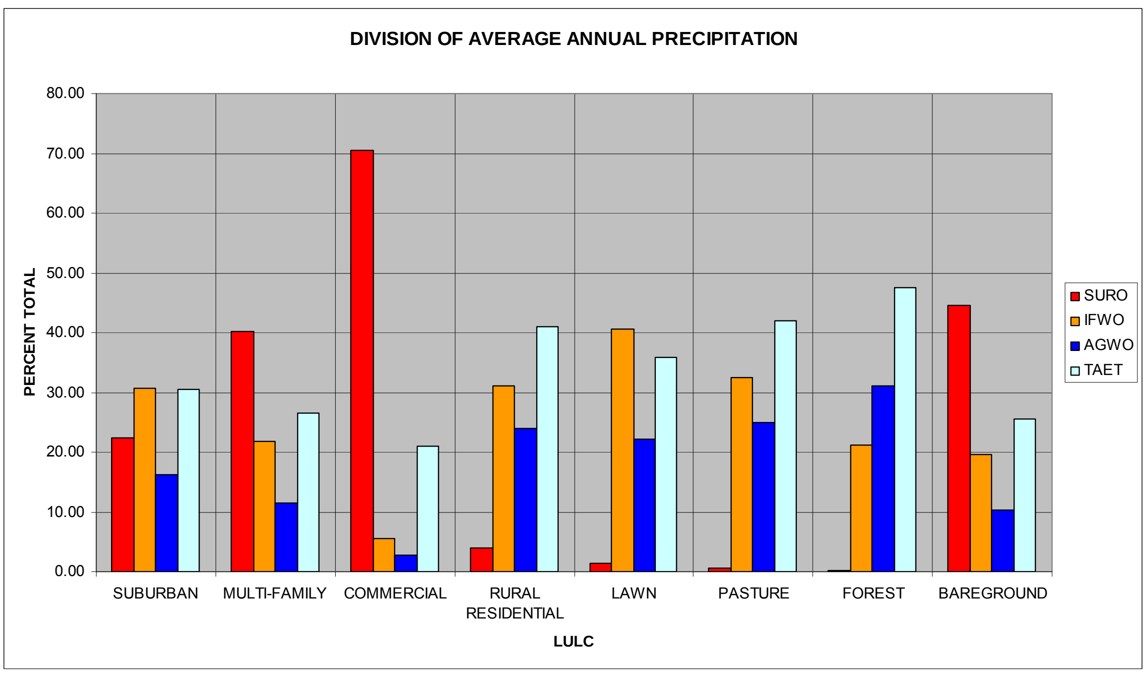

Figure 88. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Strawberry Creek (inversion run 2).

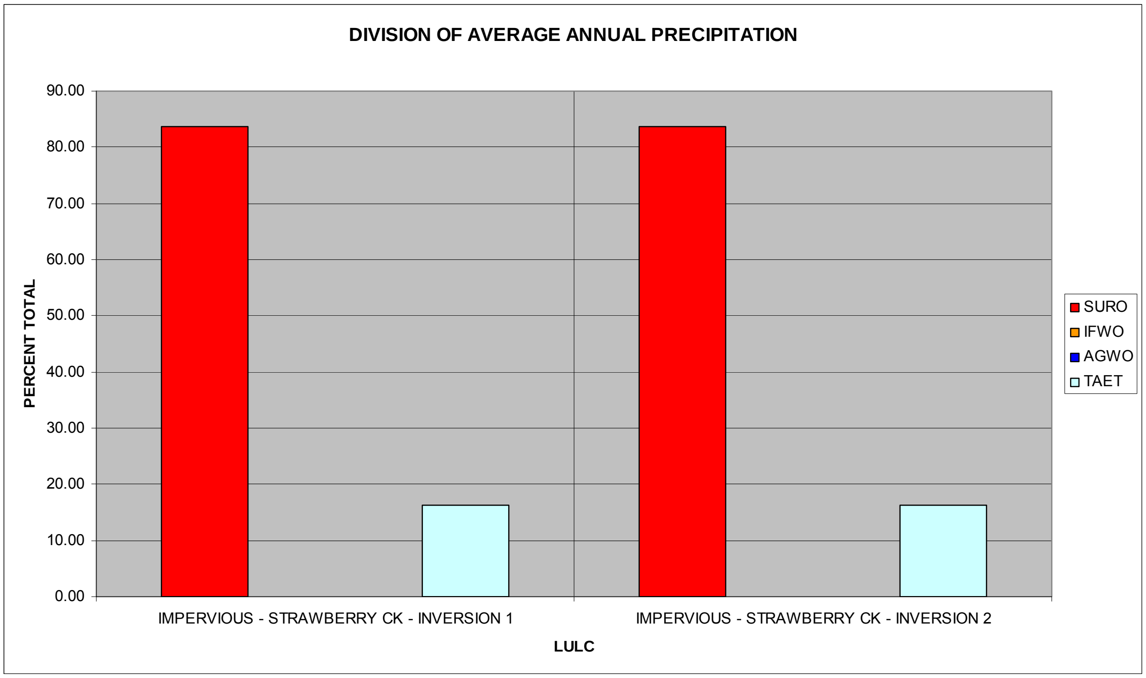

Figure 89. Simulated SURO and TAET for the impervious area for the calibrated model (inversion runs 1 and 2).

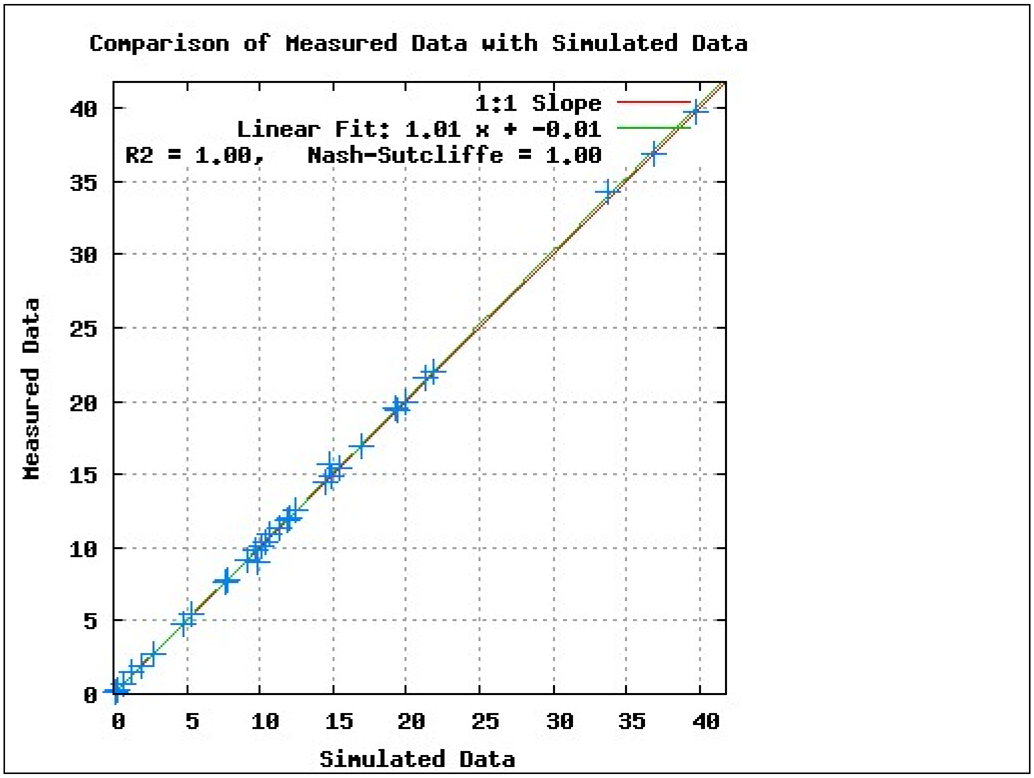

Figure 90. Comparison of simulated and observed targets for the partition of average annual precipitation (inversion run 1).

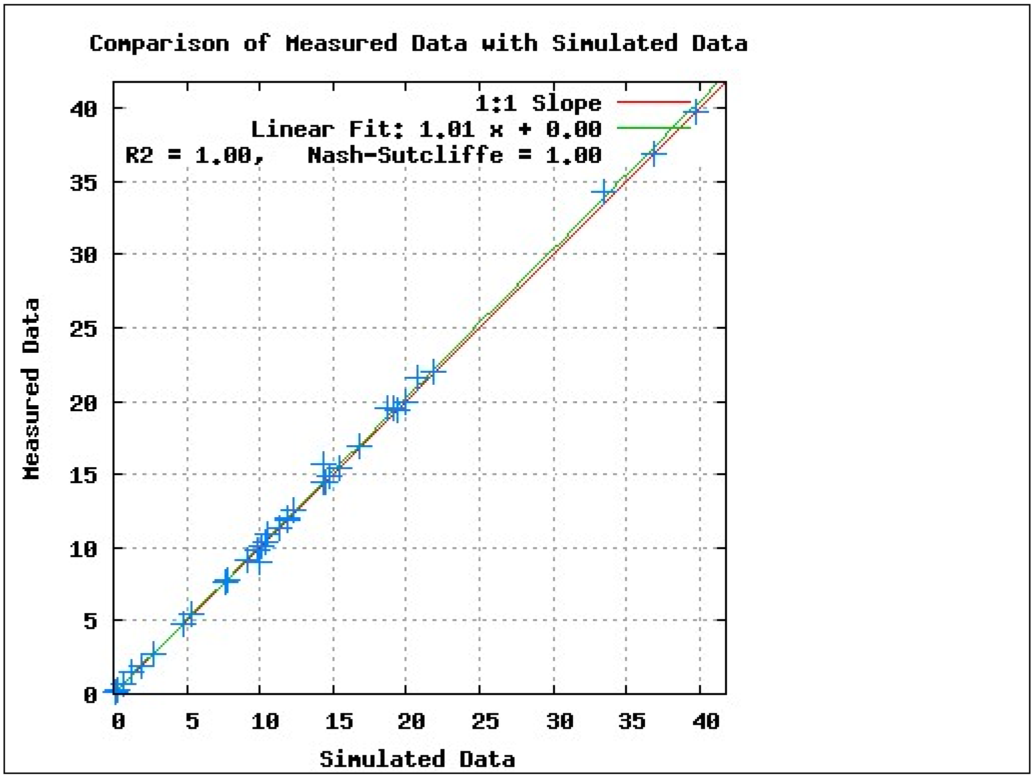

Figure 91. Comparison of simulated and observed targets for the partition of average annual precipitation (inversion run 2).

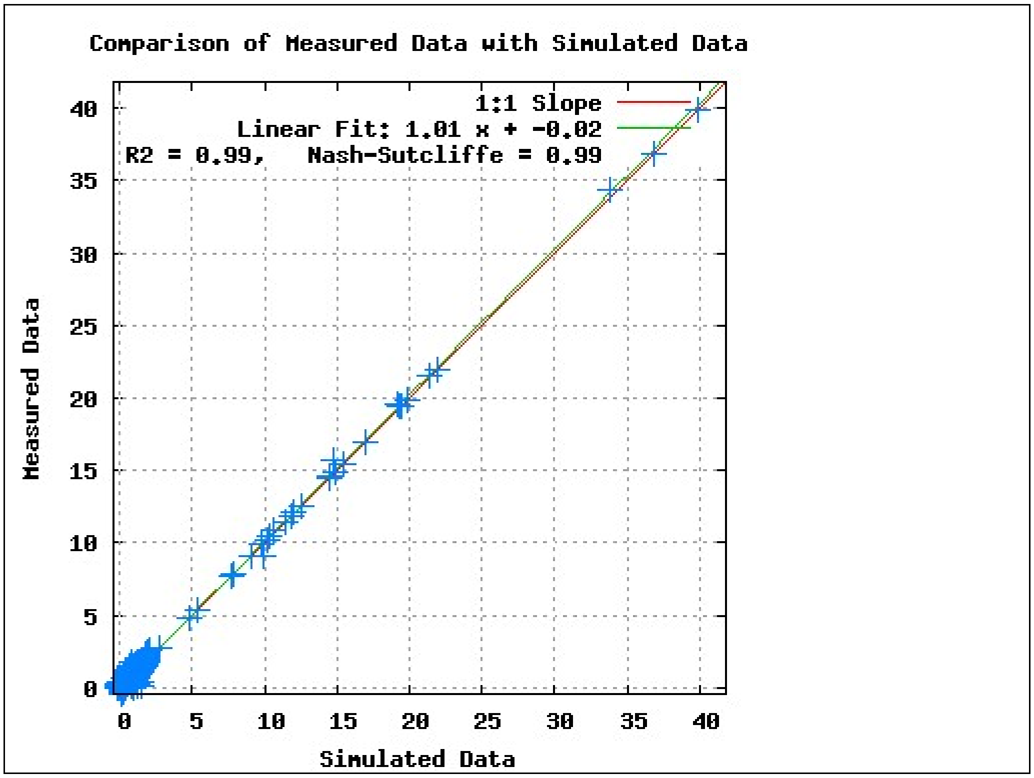

Figure 92. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Strawberry Creek HSPF hydrologic model (inversion run 1).

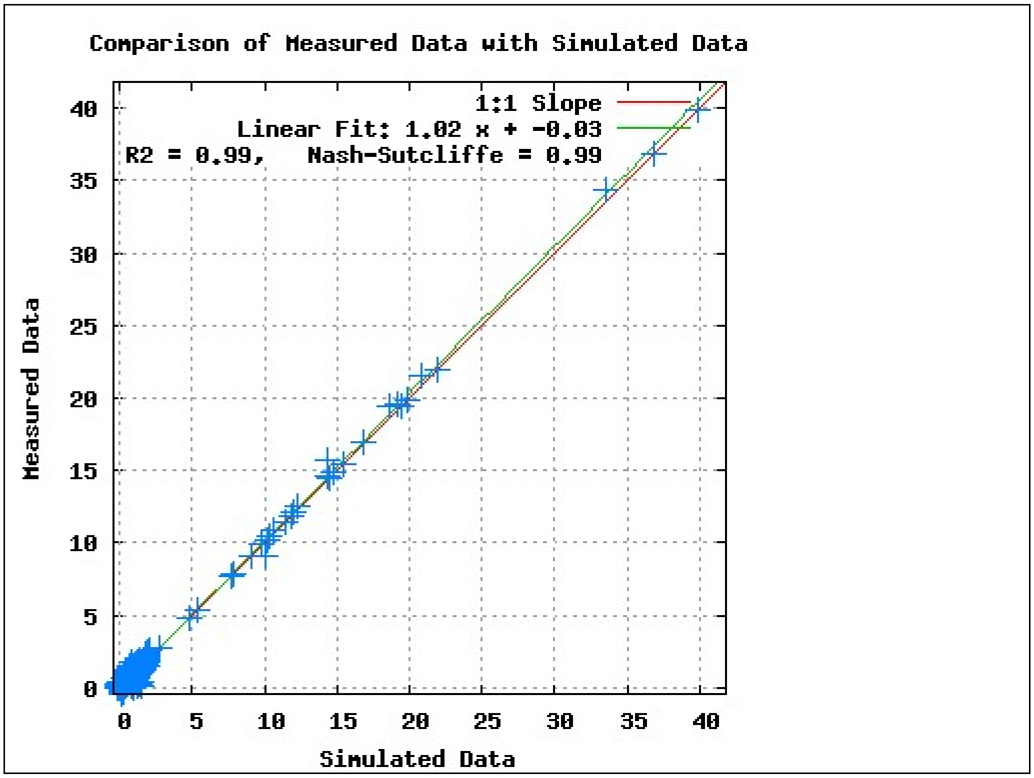

Figure 93. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Strawberry Creek HSPF hydrologic model (inversion run 2).

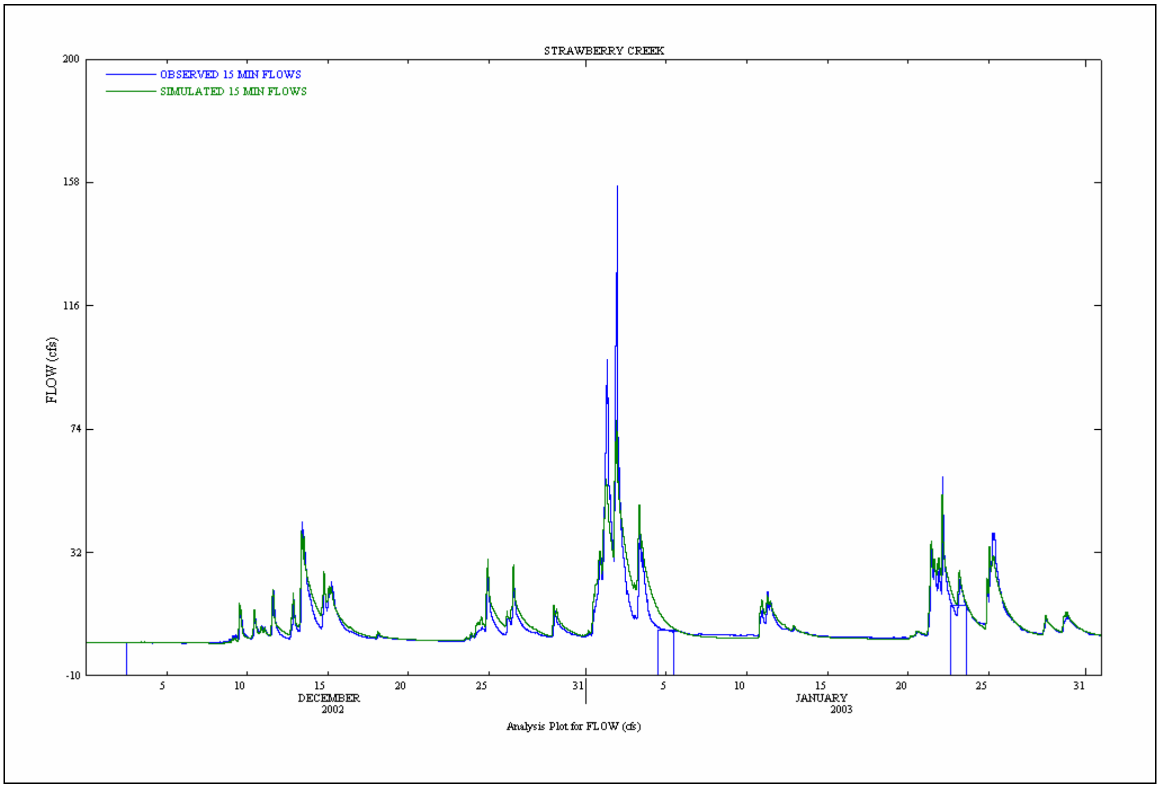

Figure 94. Hydrologic model verification results for Strawberry Creek (associated with inversion run 1 results).

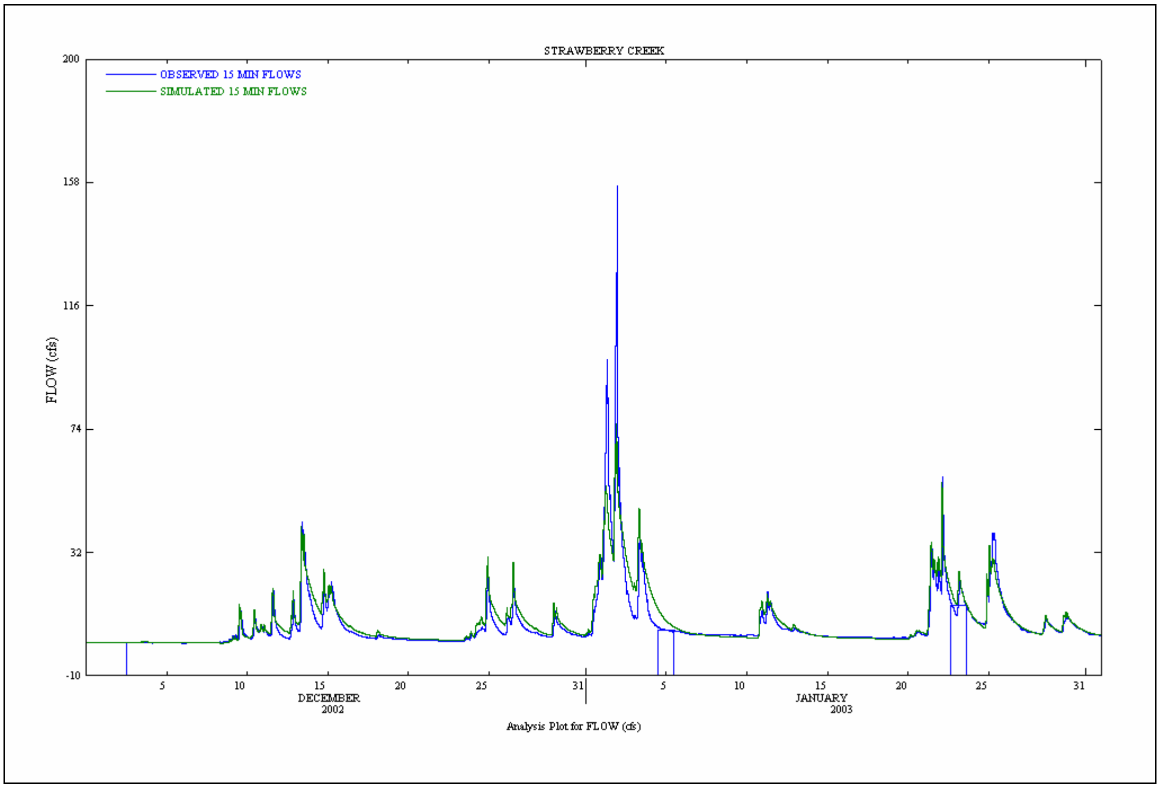

Figure 95. Hydrologic model verification results for Strawberry Creek (associated with inversion run 2 results).

5.3.3 Clear Creek

The calibration inversion run was manually terminated after 2620 model calls, which resulted in reducing the objective function from a starting value of 3416.8 to a final value of 97.96. In consideration of the perceptual model, no external water was supplied to either of the two systems to achieve the calibration and verification results summarized in this section. Table 43 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data for the two systems (18639 missing of 105120 15 minute flow data points for Clear Creek West, and 52996 missing of 315552 15 minute flow data points for Clear Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of

HSPF hydrologic model performance; however, the information summarized in Table 44 and Figures 96 - 106 suggest that the calibrated and verified Clear Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were exceptional.

ADJUSTABLE MODEL PARAMETERS

IMP1	0.1603
IMP2	0.3200
IMP3	0.9147
IMP4	0.1000

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP	CEPSC
Clear Creek West	SUBURBAN	1	2.00	0.0275	33.00	0.0104	0.0089	0.2598	0.0835	1.610407	0.85	0.2568007	1.79E-02
	MULTI-FAMILY	2	2.00	0.0163	26.60	0.0104	0.0091	0.1207	0.0891	1.248773	0.85	0.1644099	1.67E-02
	COMMERCIAL	3	2.00	0.0032	23.16	0.0100	0.0080	0.0506	0.0535	1	0.85	0.1	1.65E-02
	RURAL RESIDENTIAL	4	4.63	0.0491	20.72	0.0092	0.0099	0.4603	0.1049	2.309657	0.7019831	0.5561117	2.13E-02
	LAWN	5	3.57	0.0481	157.53	0.0106	0.0184	0.3384	0.1149	3.905645	0.85	0.3395035	1.78E-02
	PASTURE	6	6.76	0.0509	59.31	0.0106	0.0097	0.4261	0.1150	4.21494	0.6466969	0.4240909	1.90E-02
	FOREST	7	15.00	0.0692	253.97	0.0057	0.0385	0.9553	0.3974	5.063626	0.3089011	0.3753522	1.40E-02
	BAREGROUND	10	2.00	0.0124	19.47	0.0102	0.0093	0.1232	0.0751	1.218432	0.7006133	0.1704058	
Clear Creek	SUBURBAN	12	2.00	0.0281	17.83	0.0099	0.0097	0.2205	0.0897	1.568825	0.5052708	0.2926539	1.98E-02
	MULTI-FAMILY	13	2.00	0.0161	18.23	0.0101	0.0093	0.1077	0.0945	1.244421	0.85	0.1909822	1.77E-02
	COMMERCIAL	14	2.00	0.0032	18.26	0.0098	0.0084	0.0500	0.0505	1	0.7135161	0.1	1.67E-02
	RURAL RESIDENTIAL	15	4.75	0.0495	20.44	0.0093	0.0100	0.4285	0.1029	2.298784	0.5917368	0.5439911	2.10E-02
	LAWN	16	3.13	0.0453	14.49	0.0105	0.0101	0.4013	0.1035	4.126303	0.3	0.3876767	2.60E-02
	PASTURE	17	5.17	0.0552	20.58	0.0094	0.0101	0.4353	0.1132	3.975979	0.5914529	0.5759583	2.16E-02
	FOREST	18	15.00	0.0635	17.34	0.0021	0.0103	0.8613	0.1354	3.581311	0.3	0.3917831	4.26E-02
	BAREGROUND	21	2.00	0.0124	19.44	0.0102	0.0094	0.1198	0.0775	1.212846	0.7090956	0.1752182	

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS	111	0.1184	0.1225

Table 43. Identified model resulting from calibration inversion run.

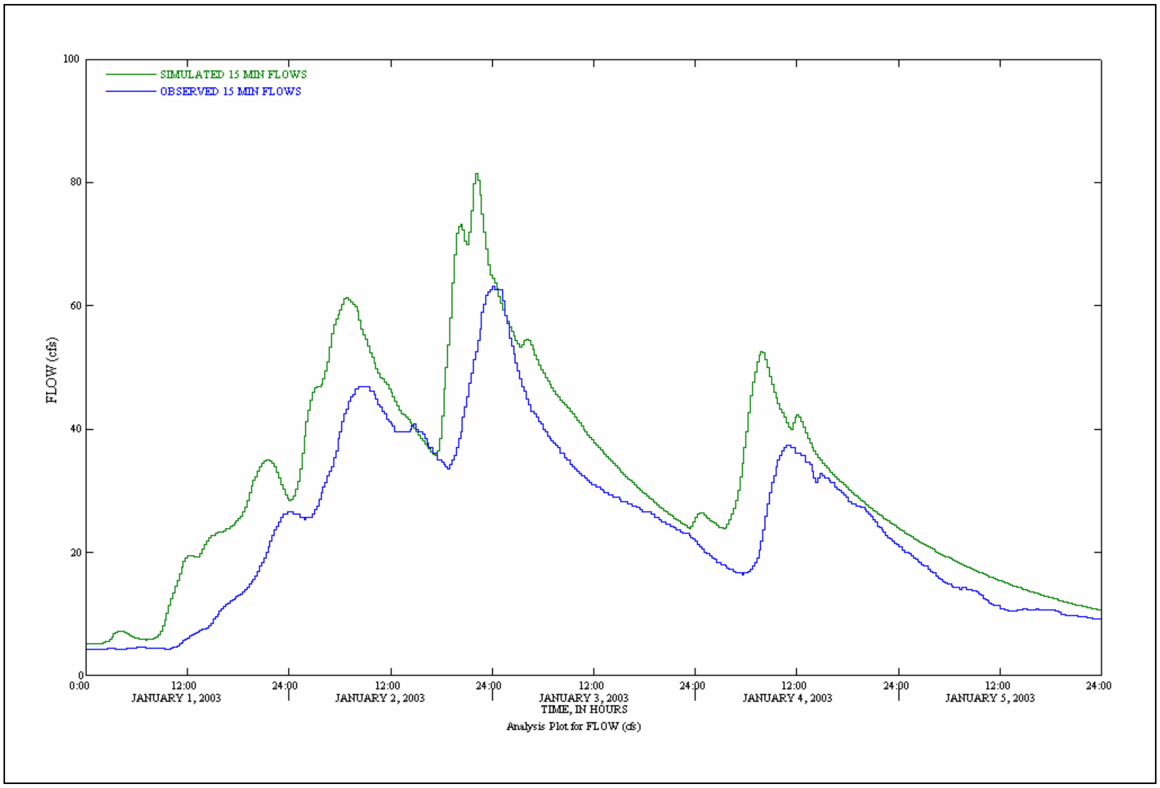

Figure 96. Comparison of the simulated and observed 15 minute flow data that was used for calibration at Clear Creek West.

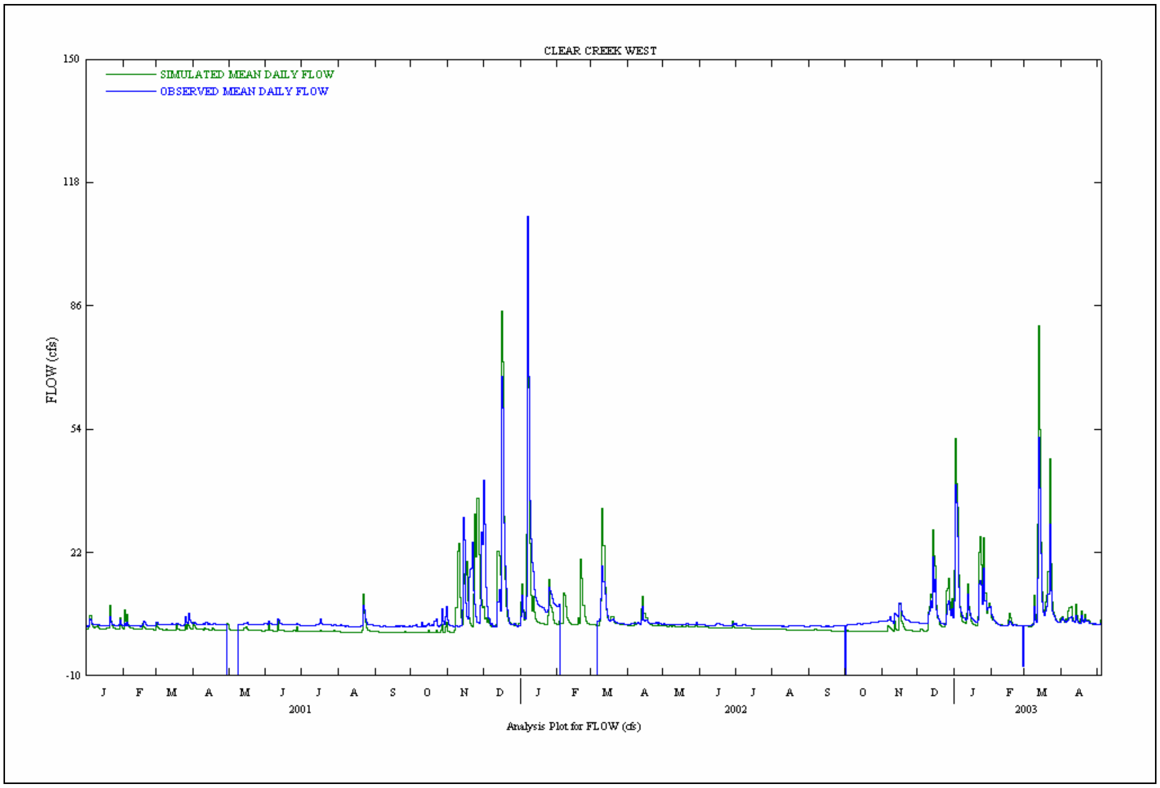

Figure 97. Comparison of simulated and observed mean daily flow at Clear Creek West for the hydrologic model calibration period.

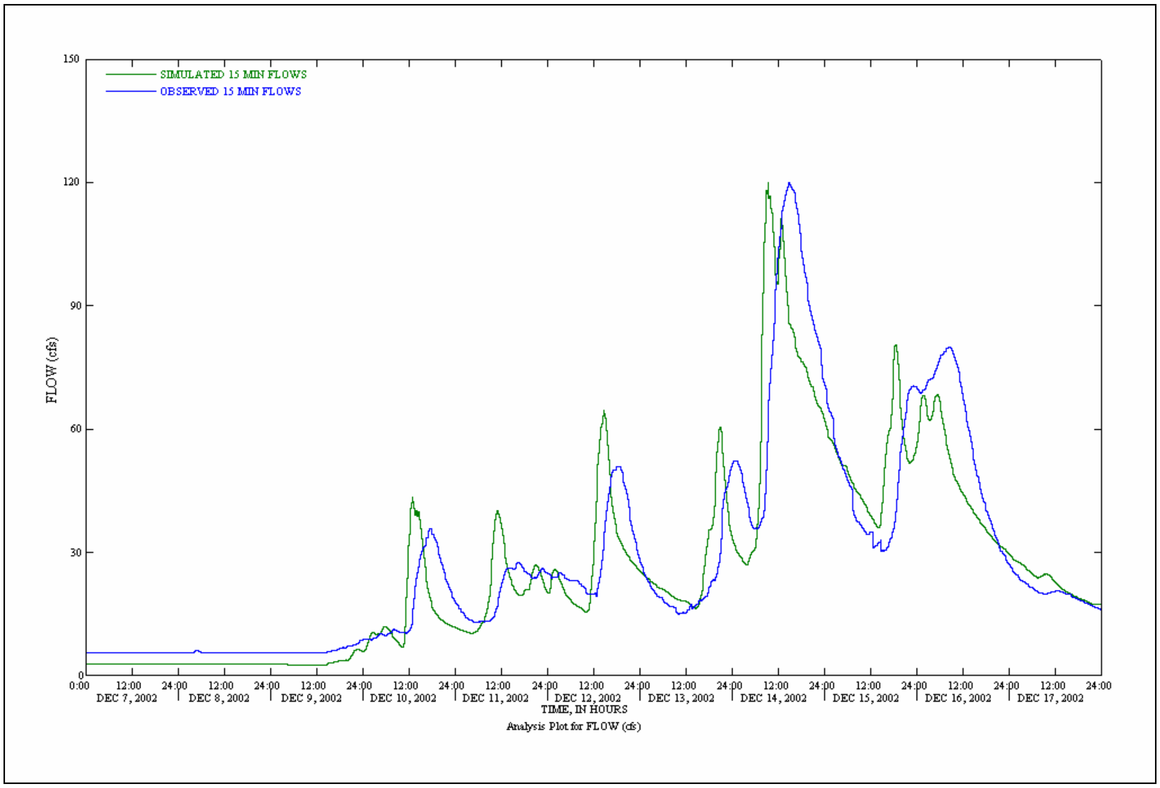

Figure 98. Comparison of the simulated and observed 15 minute flow data that was used for calibration at Clear Creek.

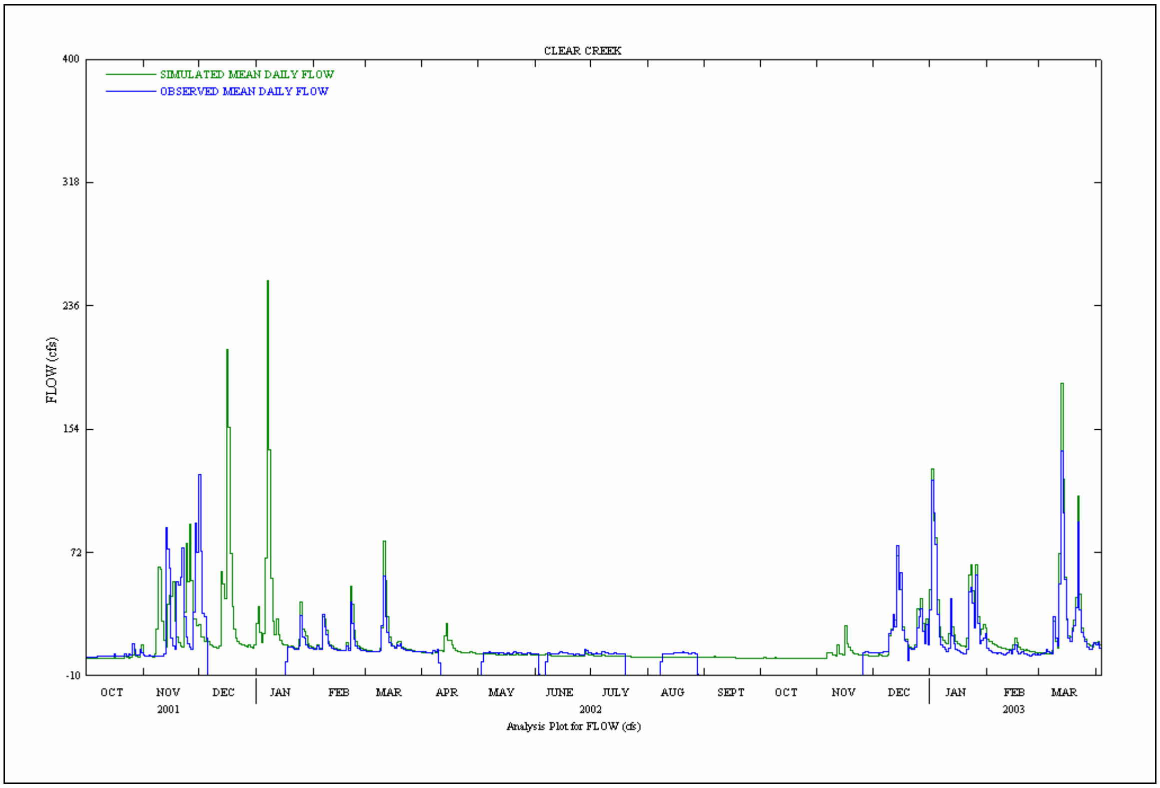

Figure 99. Comparison of simulated and observed mean daily flow at Clear Creek for the hydrologic model calibration period.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Clear Creek West	SUBURBAN	1	10.88	14.47	7.70	14.55	1	10.80	14.47	7.73	14.55	1	-0.67	0.01	0.42	-0.02
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	19.29	10.17	5.44	12.66	2	-1.00	0.04	0.75	0.95
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	33.13	2.75	1.49	10.21	3	-3.53	0.66	2.53	12.82
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.90	14.84	11.39	19.40	4	-0.72	-0.27	-0.01	-0.01
	LAWN	5	0.71	19.55	10.39	16.93	5	0.66	19.22	10.39	16.86	5	-7.88	-1.69	-0.06	-0.44
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.31	15.41	11.86	19.89	6	-8.78	-0.55	0.01	-0.01
	FOREST	7	0.11	9.88	15.65	21.95	7	0.09	9.36	14.28	21.79	7	-13.09	-5.30	-8.79	-0.72
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	21.48	9.12	4.82	12.15	10	-0.43	0.01	-0.54	0.86
Clear Creek	SUBURBAN	12	10.88	14.47	7.70	14.55	12	10.87	14.46	7.69	14.53	12	-0.08	-0.06	-0.09	-0.09
	MULTI-FAMILY	13	19.48	10.16	5.40	12.54	13	19.36	10.15	5.34	12.72	13	-0.62	-0.17	-1.23	1.47
	COMMERCIAL	14	34.35	2.74	1.45	9.05	14	33.18	2.74	1.48	10.18	14	-3.39	0.05	2.28	12.50
	RURAL RESIDENTIAL	15	1.92	14.88	11.39	19.40	15	1.90	14.84	11.39	19.40	15	-0.69	-0.26	-0.01	-0.01
	LAWN	16	0.71	19.55	10.39	16.93	16	0.71	19.51	10.39	16.90	16	-0.01	-0.18	-0.01	-0.16
	PASTURE	17	0.34	15.50	11.86	19.89	17	0.33	15.45	11.86	19.89	17	-2.13	-0.32	-0.01	0.00
	FOREST	18	0.11	9.88	15.65	21.95	18	0.19	9.84	15.23	21.90	18	80.11	-0.46	-2.67	-0.23
	BAREGROUND	21	21.57	9.12	4.85	12.05	21	21.48	9.12	4.82	12.15	21	-0.41	0.01	-0.53	0.83
	IMPERVIOUS - CLEAR CK W	111	39.82			7.77	111	39.83			7.76	111	0.01			-0.06
	IMPERVIOUS - CLEAR MAINSTEM	121	39.82			7.77	121	39.83			7.76	121	0.01			-0.06

Table 44. Comparison of simulated and observed targets for the partition of average annual precipitation.

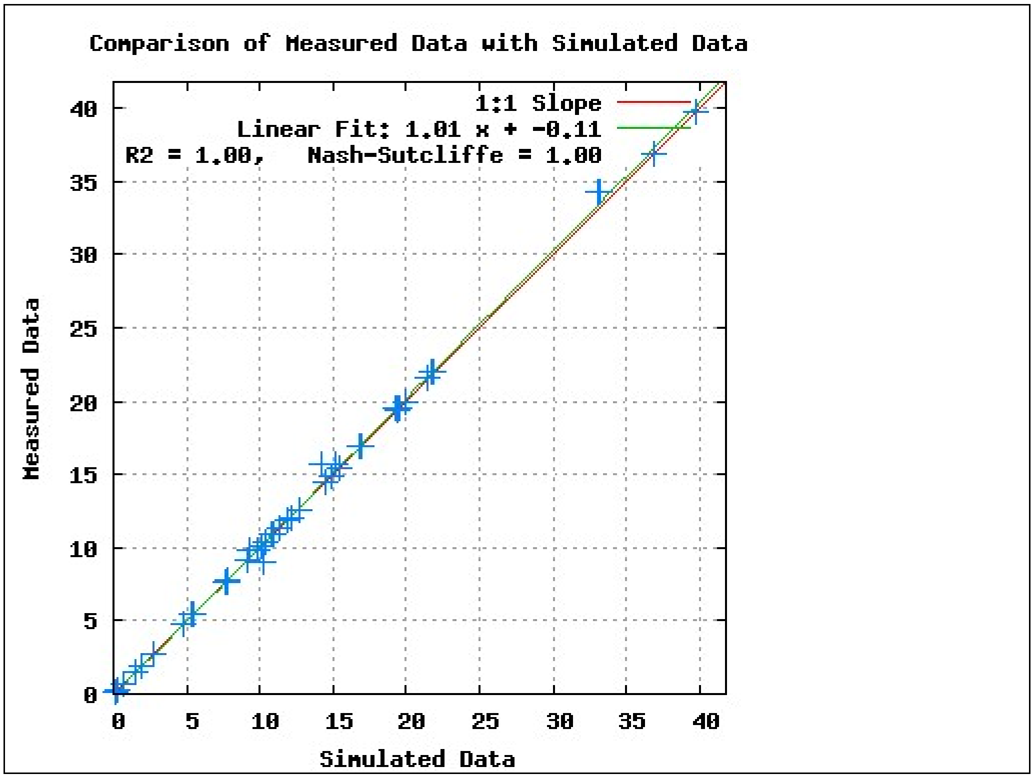

Figure 100. Comparison of simulated and observed targets for the partition of average annual precipitation.

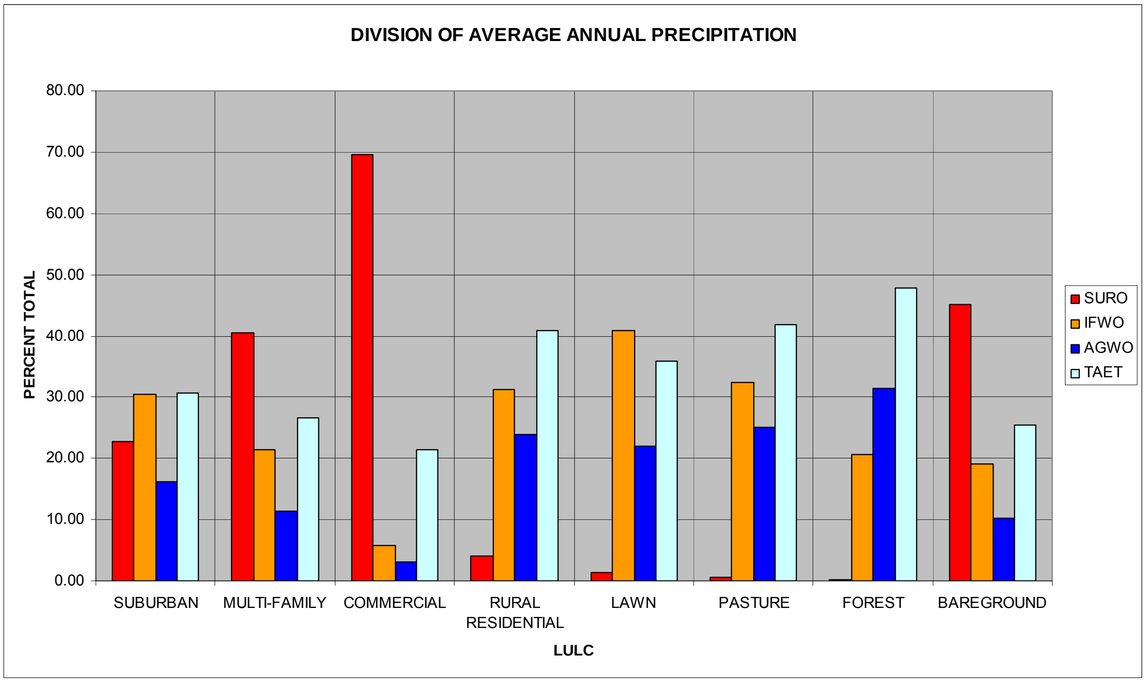

Figure 101. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Clear Creek West.

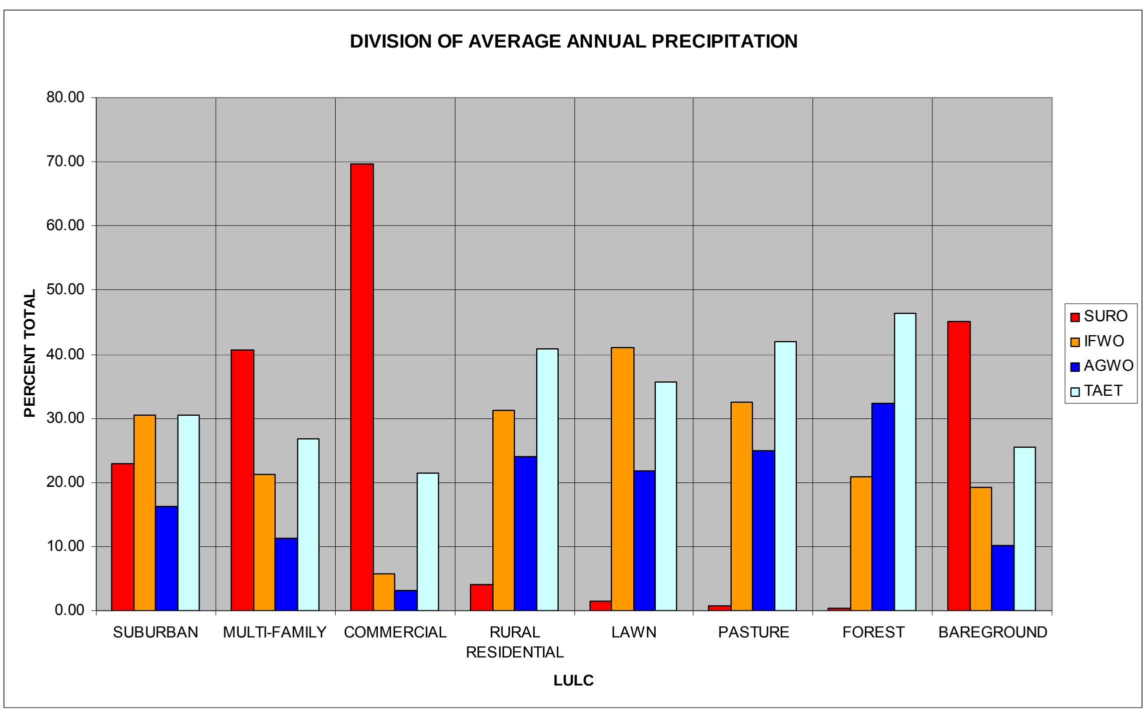

Figure 102. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Clear Creek.

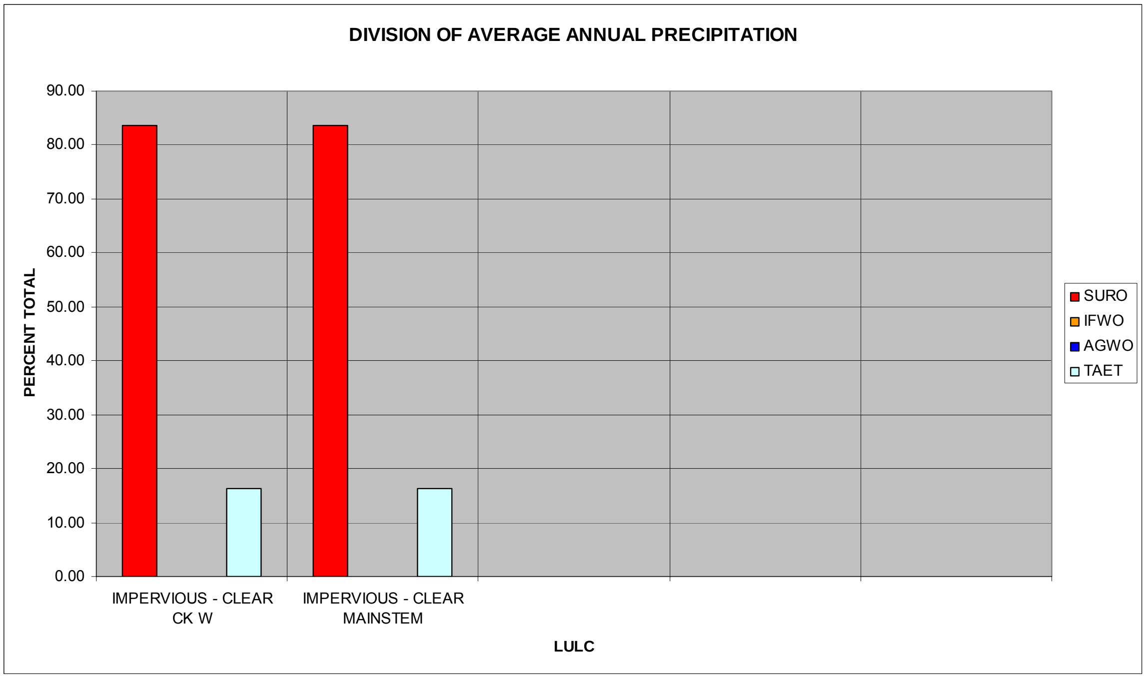

Figure 103. Simulated SURO and TAET for the impervious area for each of the two systems.

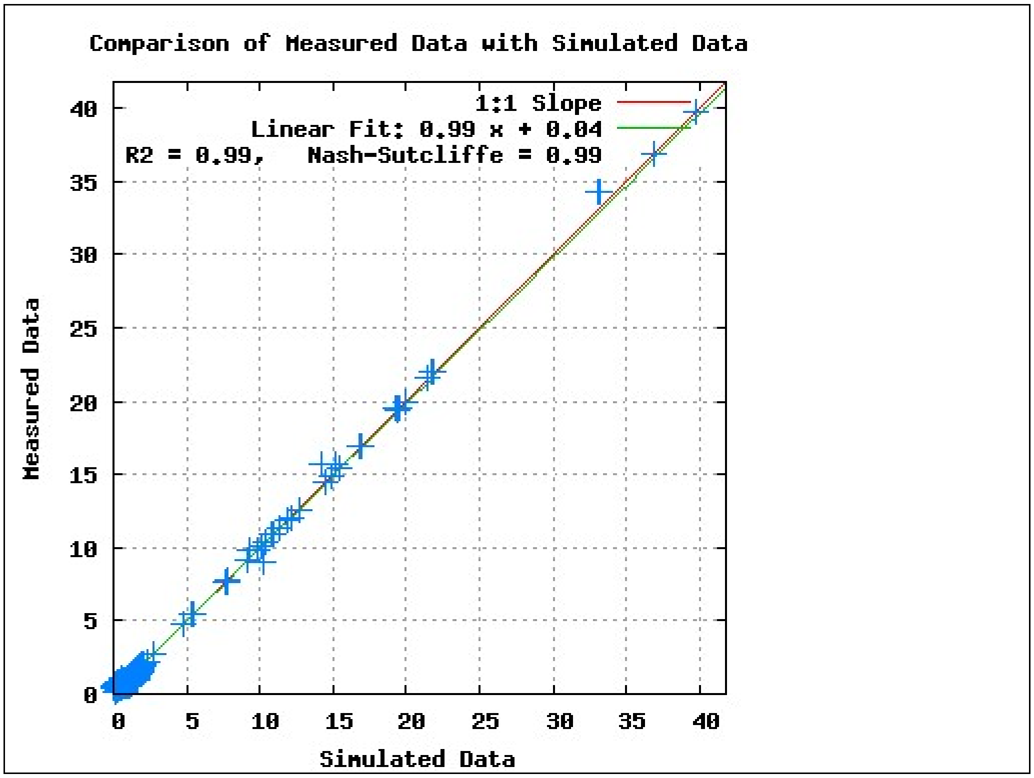

Figure 104. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Clear Creek HSPF hydrologic model.

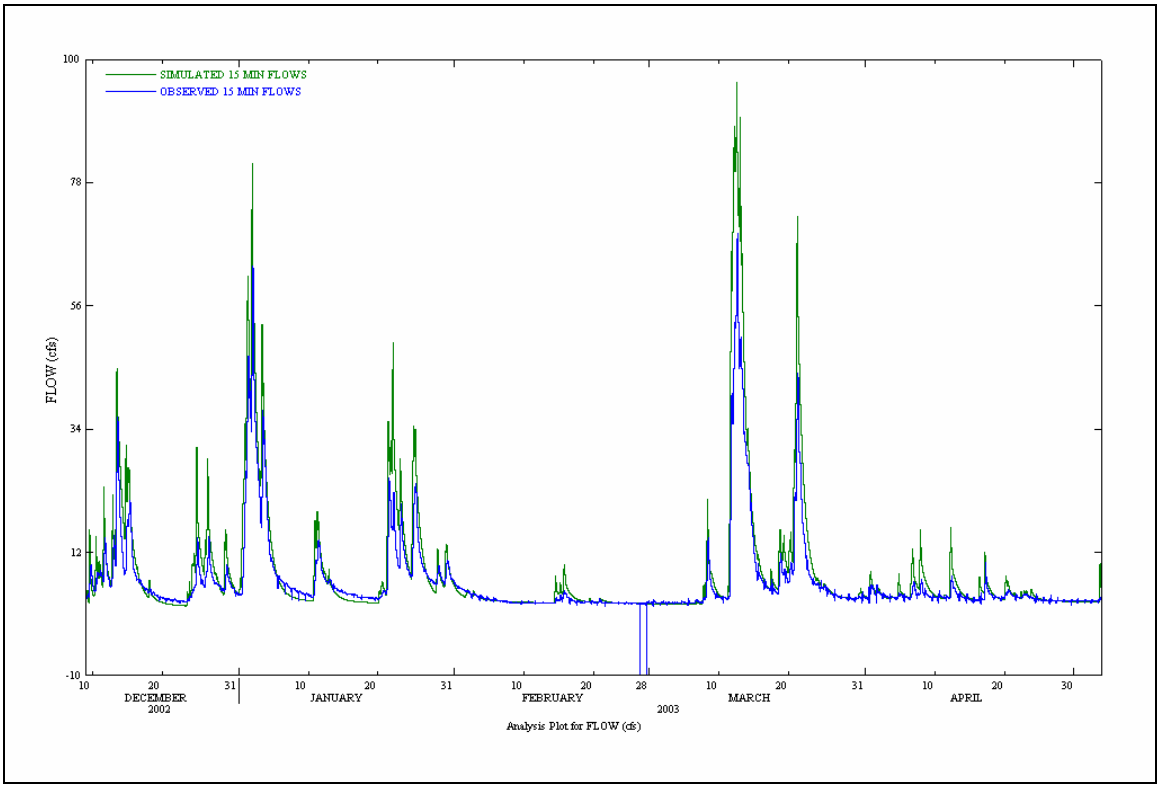

Figure 105. Verification results of simulated and observed 15 minute flows at Clear Creek West.

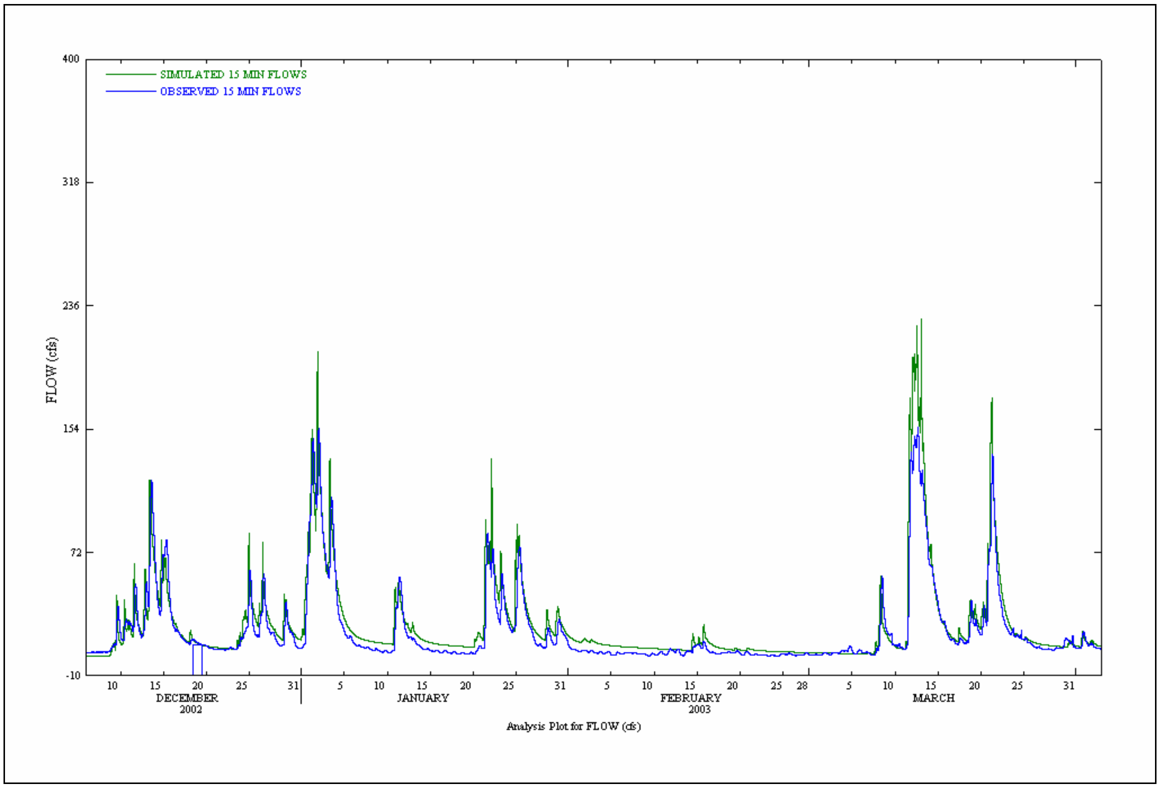

Figure 106. Verification results of simulated and observed 15 minute flows at Clear Creek.

5.3.4 Barker Creek

The calibration inversion run terminated after 4606 model calls, which resulted in reducing the objective function from a starting value of 14293 to a final value of 787.7. Table 45 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data at the Barker Creek flow monitoring location (20853 missing of 175296 15 minute flow data points for Barker Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance. The information summarized in Table 46 and Figures 107 - 118 suggest that the calibrated and verified Barker Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were exceptional.

ADJUSTABLE MODEL PARAMETERS

IMP1	0.1181
IMP2	0.2560
IMP3	0.5100
IMP4	0.1000

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Barker Creek	SUBURBAN	1	5.05	0.0221	33.48	0.0098	0.0089	0.2089	0.1268	1.672484	0.3	0.1808741
	MULTI-FAMILY	2	4.87	0.0142	31.12	0.0151	0.0114	0.0531	0.2879	1.134843	0.3	0.1862538
	COMMERCIAL	3	2.99	0.0020	13.73	0.0106	0.0043	0.0500	0.0500	1.185775	0.3770132	0.1
	RURAL RESIDENTIAL	4	2.38	0.0343	30.06	0.0103	0.0119	2.0000	0.5000	2.143833	0.85	0.3172097
	LAWN	5	15.00	0.0371	33.09	0.0065	0.0047	0.1532	0.1217	3.872728	0.3	0.2969382
	PASTURE	6	4.37	0.0509	30.90	0.0109	0.0110	0.8410	0.1713	4.21799	0.85	0.4507762
	FOREST	7	14.07	0.1324	198.57	0.0009	0.0025	0.0500	0.1354	5.774282	0.85	0.4406792
	BAREGROUND	10	4.43	0.0112	19.81	0.0099	0.0095	0.1477	0.0778	1.318185	0.7005069	0.1034117

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - BARKER CK	111	0.1500	0.1227

Table 45. Identified model resulting from calibration inversion run.

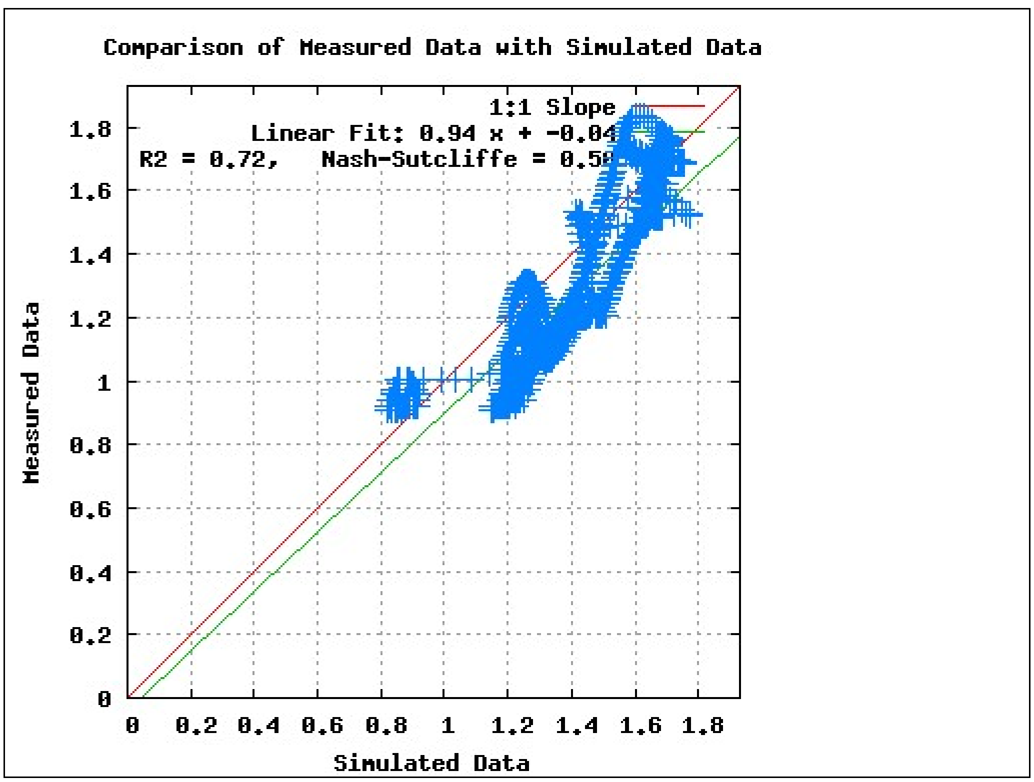

Figure 107. Comparison of the simulated and observed 15 minute flow data that was used for calibration at Barker Creek.

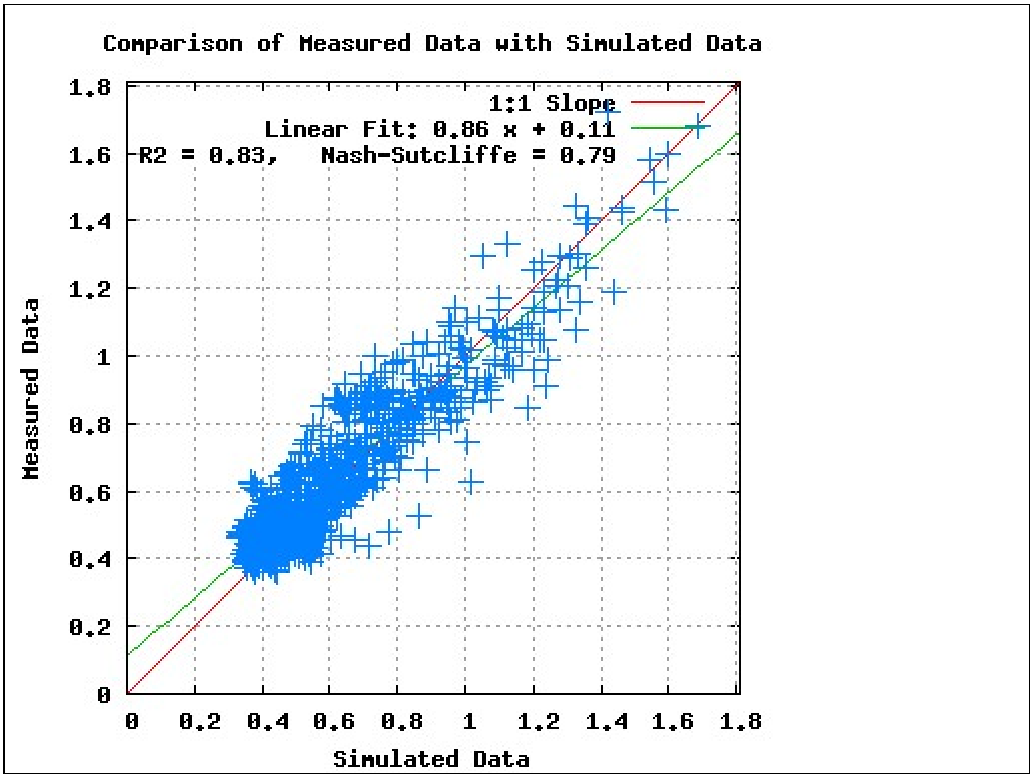

Figure 108. Comparison of the simulated and observed mean daily flow data that was used for calibration at Barker Creek.

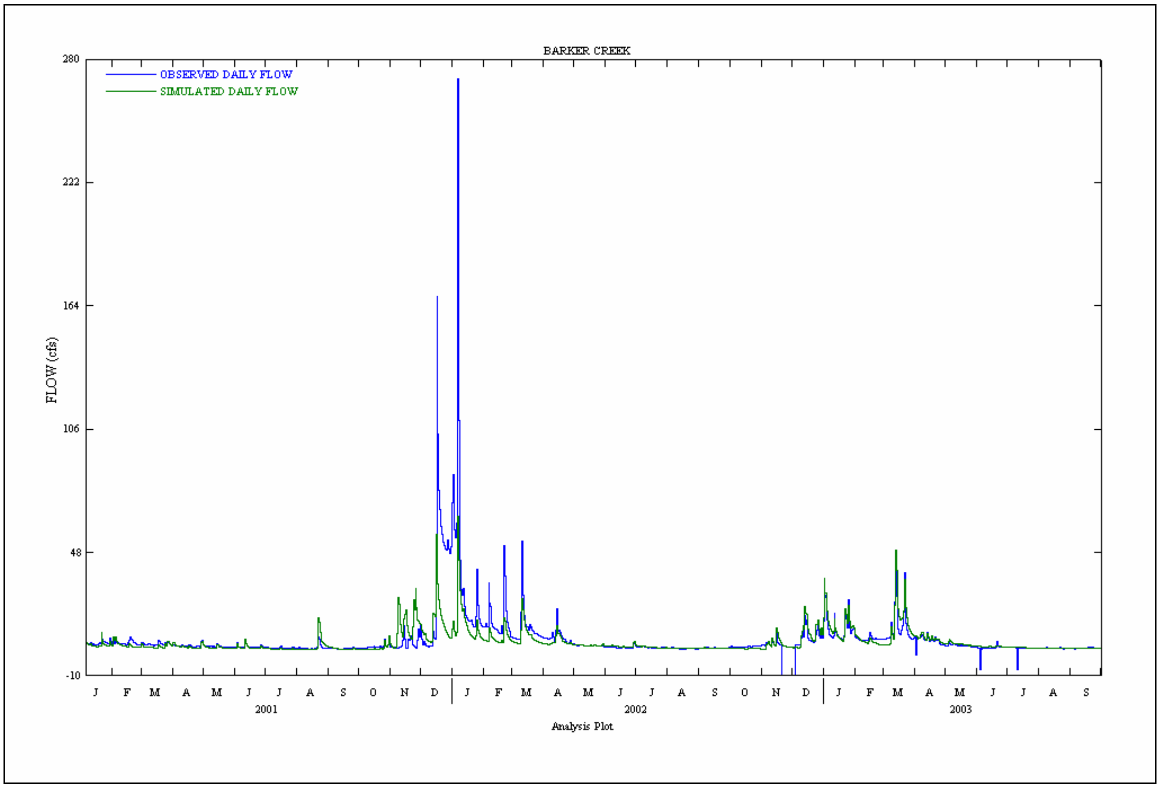

Figure 109. Comparison of simulated and observed mean daily flow at Barker Creek for the hydrologic model calibration period(s).

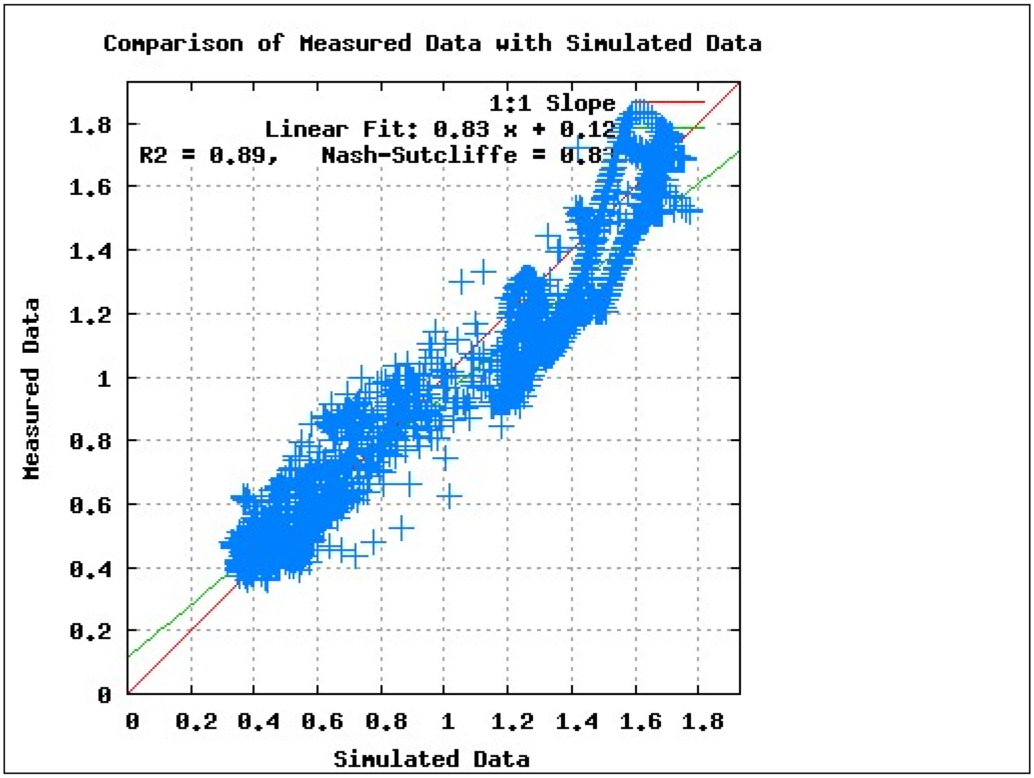

Figure 110. Comparison of the simulated and observed flow data (15 minute and daily) that was used for calibration at Barker Creek.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Barker Creek	SUBURBAN	1	10.8763	14.47	7.6953	14.55	1	10.8	14.46	7.639	14.53	1	-0.72	-0.08	-0.73	-0.15
	MULTI-FAMILY	2	19.4837	10.16	5.4031	12.54	2	19.42	10.16	5.3807	12.52	2	-0.32	-0.01	-0.41	-0.14
	COMMERCIAL	3	34.348	2.737	1.4502	9.052	3	33.88	2.698	0.9632	10.08	3	-1.37	-1.40	-33.58	11.41
	RURAL RESIDENTIAL	4	1.91655	14.88	11.394	19.4	4	1.913	14.84	11.369	19.39	4	-0.17	-0.27	-0.22	-0.03
	LAWN	5	0.713214	19.55	10.394	16.93	5	0.699	19.29	10.35	16.92	5	-1.94	-1.32	-0.43	-0.05
	PASTURE	6	0.338903	15.5	11.862	19.89	6	0.313	15.45	11.856	19.88	6	-7.50	-0.30	-0.05	-0.03
	FOREST	7	0.105125	9.882	15.652	21.95	7	0.08	9.594	15.109	21.5	7	-23.80	-2.91	-3.47	-2.04
	BAREGROUND	10	21.5693	9.122	4.8495	12.05	10	21.45	9.119	4.8164	12.04	10	-0.54	-0.03	-0.68	-0.09
	IMPERVIOUS - BARKER CK	111	39.8212			7.765	111	39.82			7.765	111	0.00			0.00

Table 46. Comparison of simulated and observed targets for the partition of average annual precipitation.

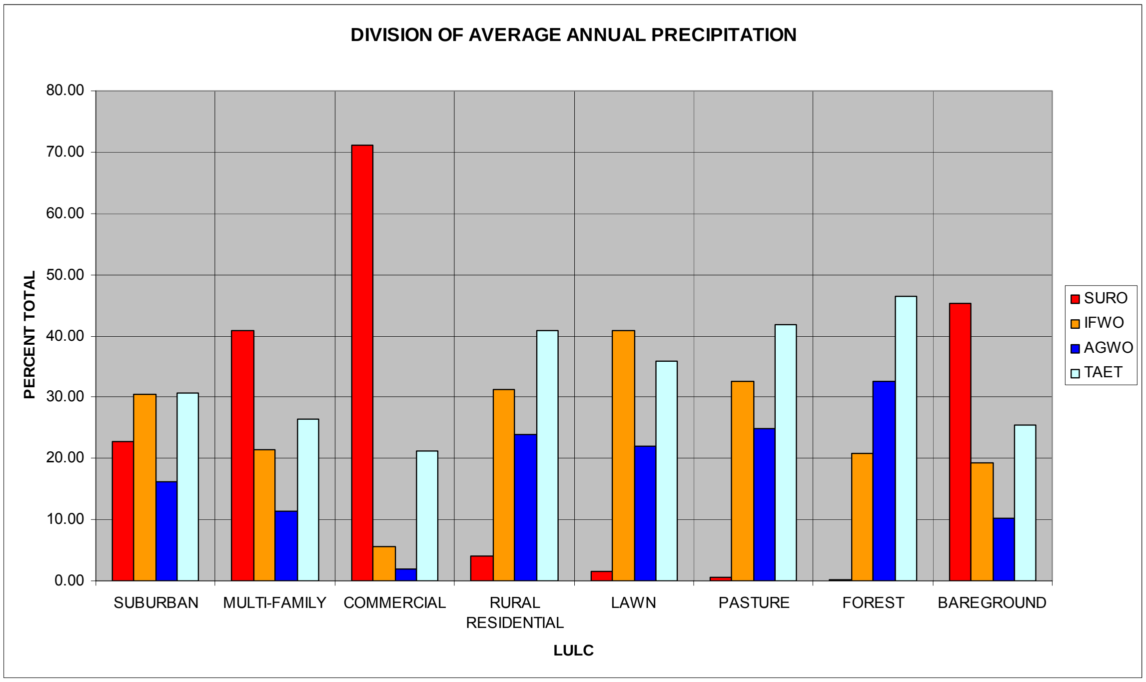

Figure 111. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Barker Creek.

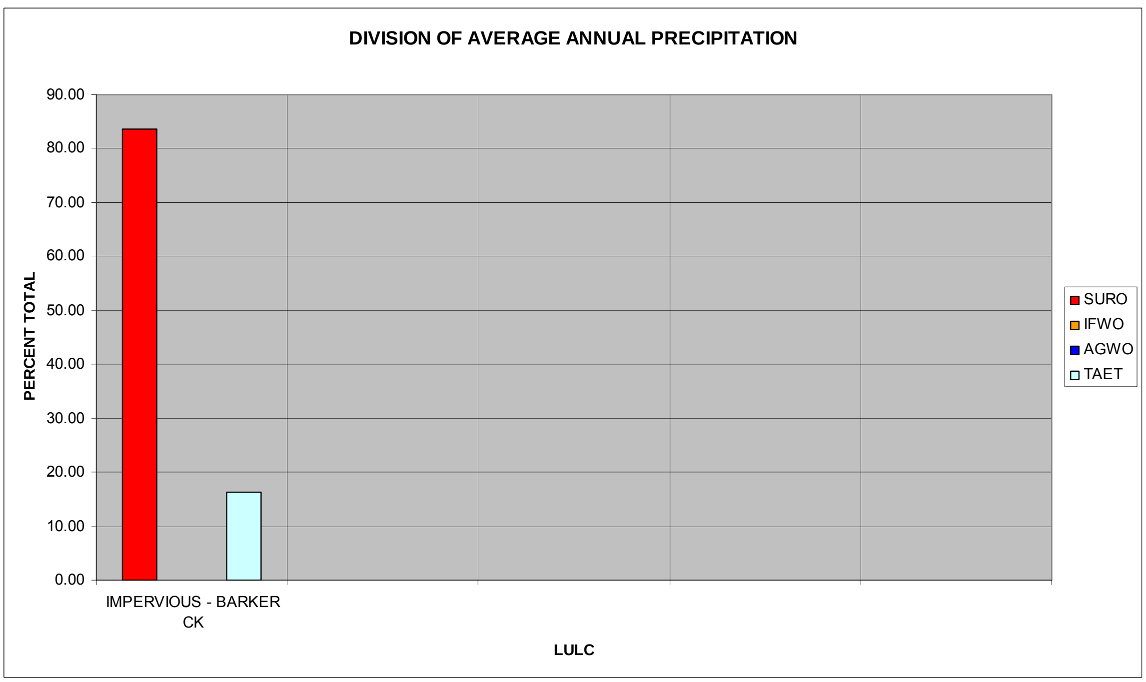

Figure 112. Simulated SURO and TAET for the impervious area for Barker Creek.

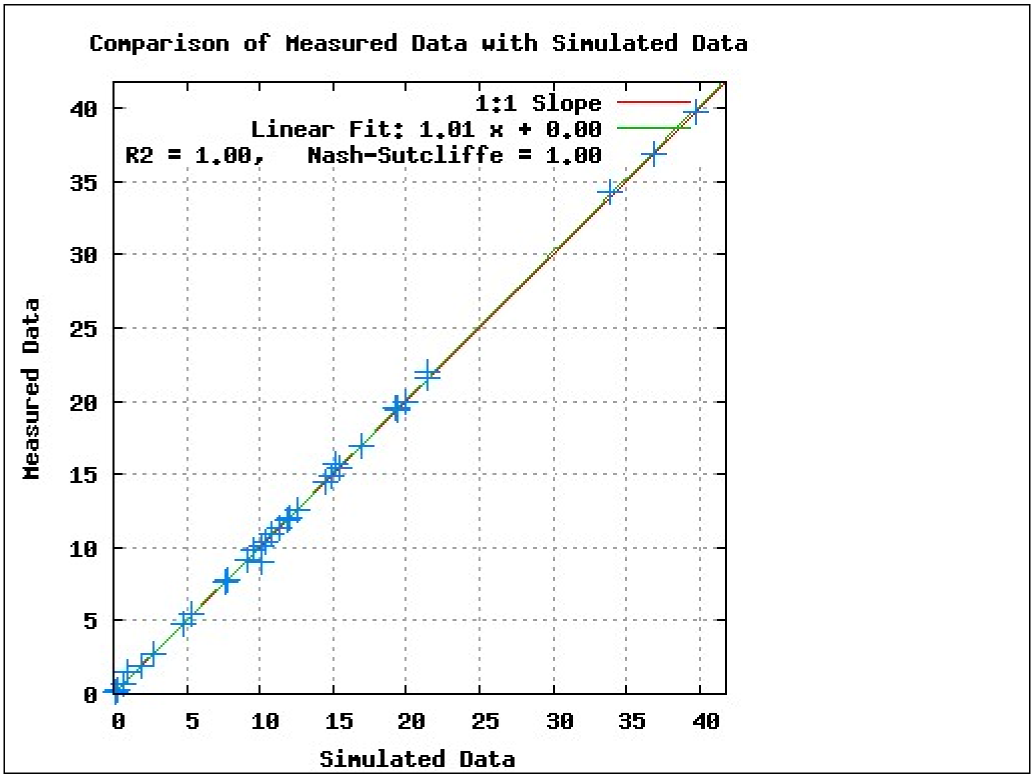

Figure 113. Comparison of simulated and observed targets for the partition of average annual precipitation.

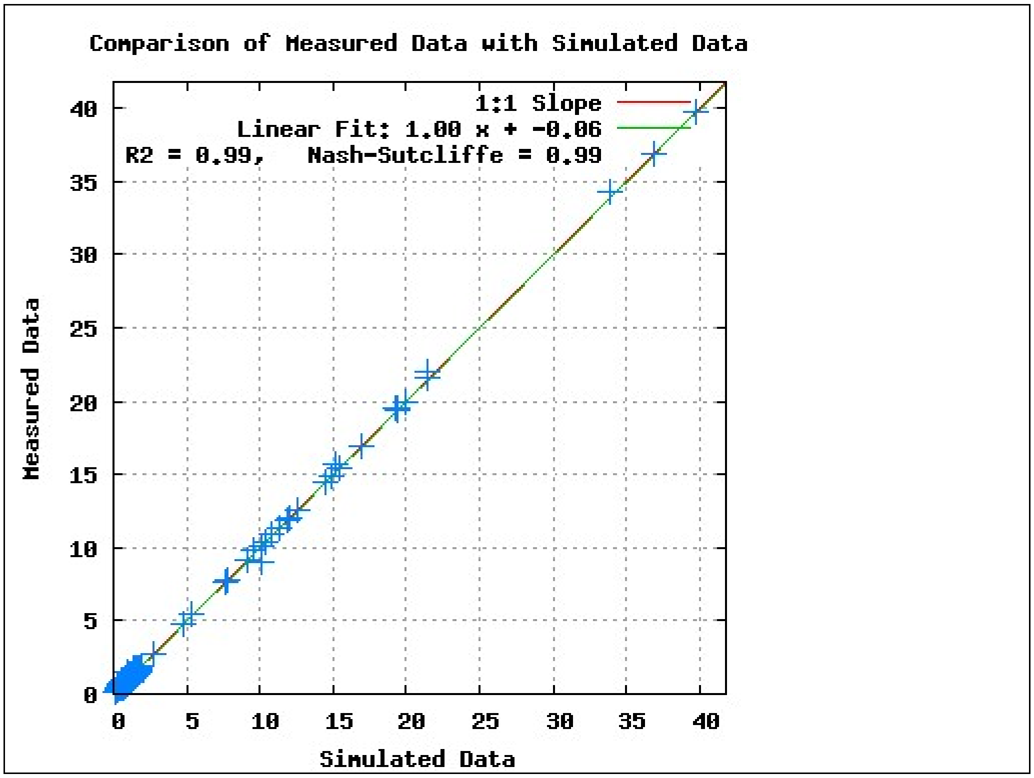

Figure 114. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Barker Creek HSPF hydrologic model.

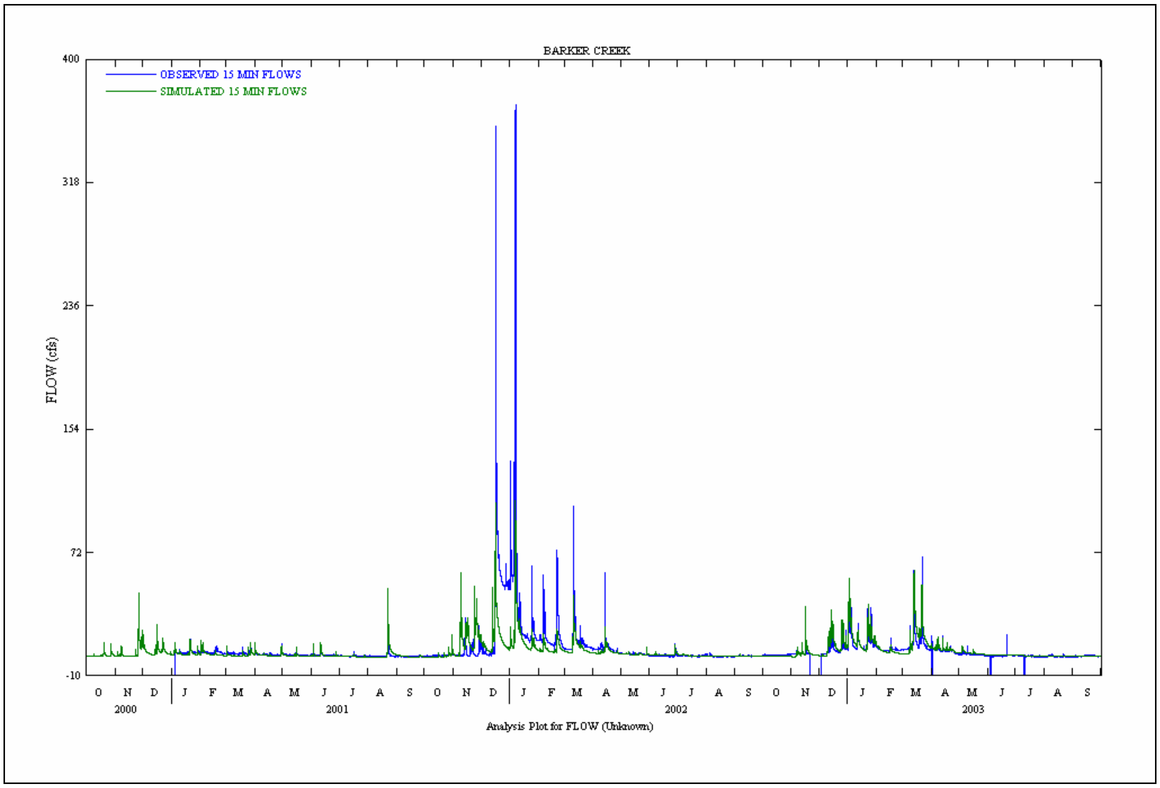

Figure 115. Verification results of simulated and observed 15 minute flows at Barker Creek.

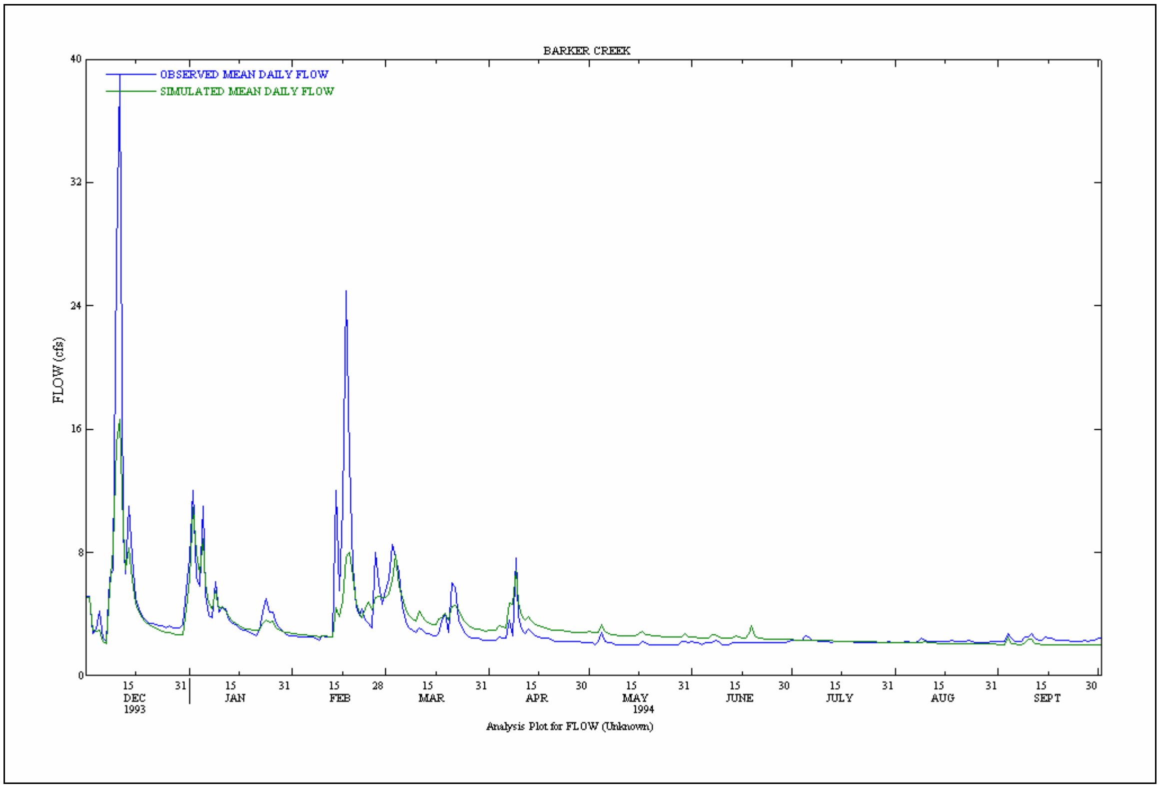

Figure 116. Verification results of simulated and observed mean daily flows at Barker Creek.

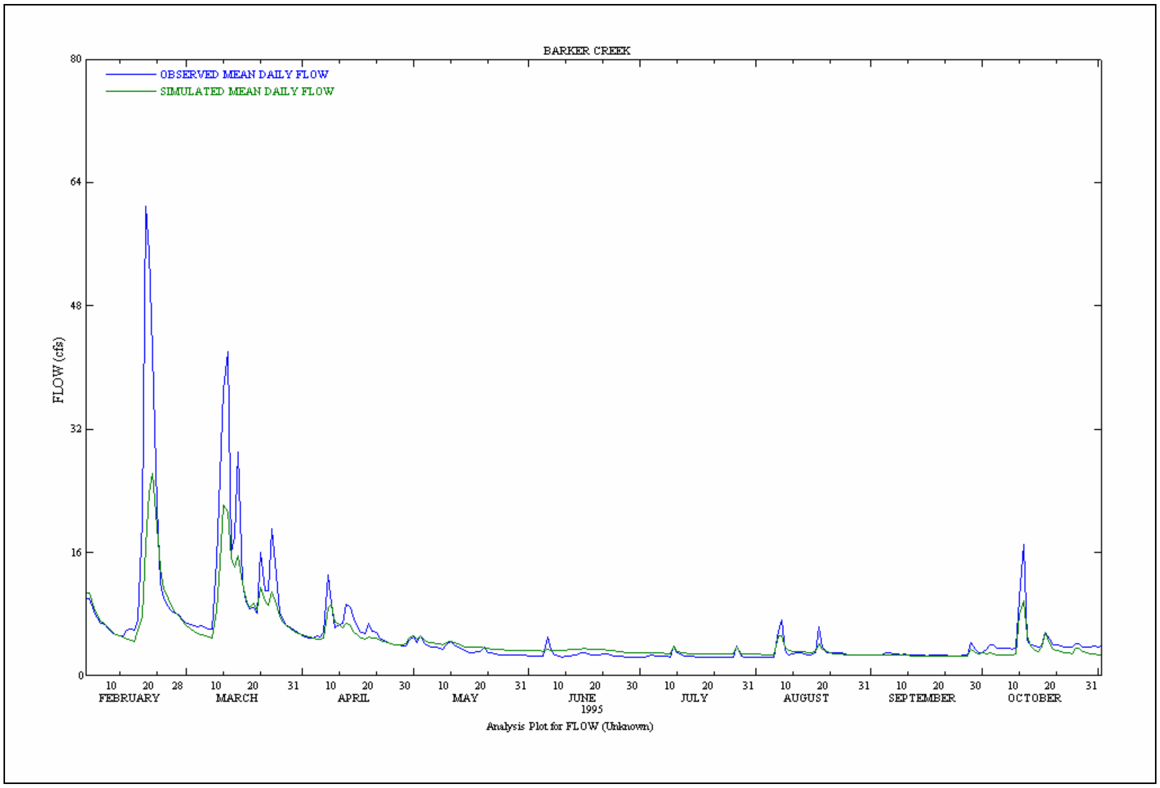

Figure 117. Verification results of simulated and observed mean daily flows at Barker Creek.

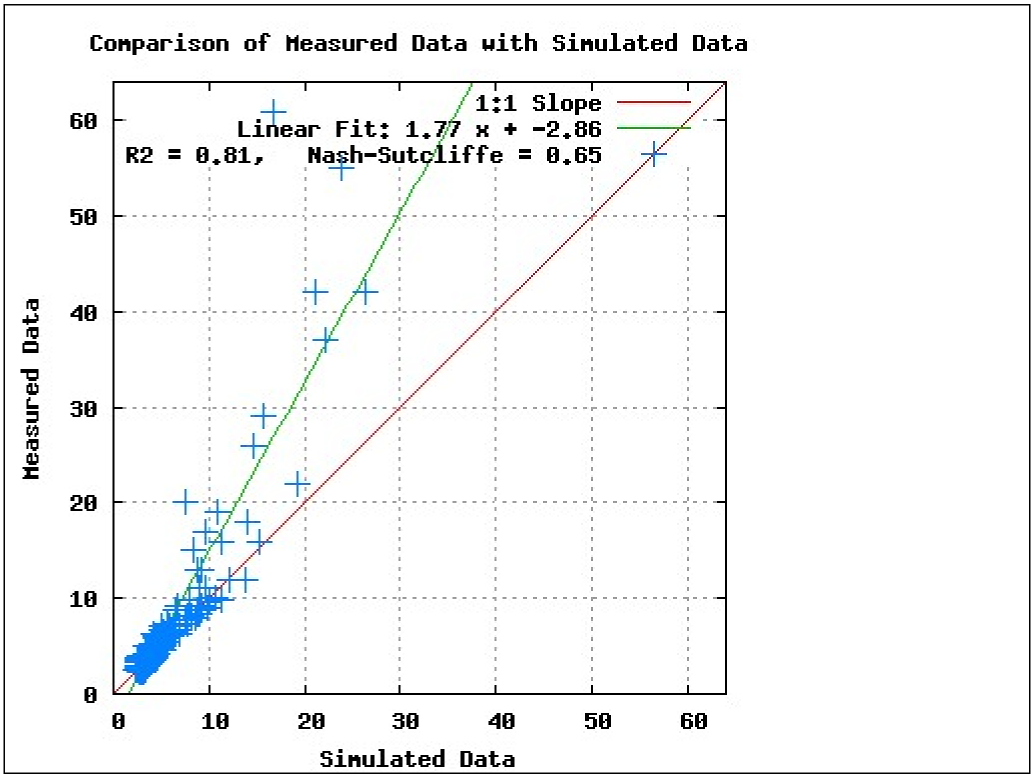

Figure 118. Summary of verification results of simulated and observed mean daily flows at Barker Creek presented in the previous Figure, Figure 117.

5.3.5 Karcher Creek

The calibration inversion run terminated after 2521 model calls, which resulted in reducing the objective function from a starting value of 2853.5 to a final value of 154. Table 47 lists the identified parameter set that resulted from the calibration inversion run. HSPF hydrologic calibration for Karcher Creek was complicated by the fact that there is a date time stamp error between the 15 minute driving precipitation and the observed 15 minute flow data at the Karcher Creek flow monitoring location.

The large quantity of missing flow data at the Karcher Creek flow monitoring location (455 missing of 1461 mean daily flow data points and 54712 missing of 243971 15 minute flow data points for Karcher Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of

HSPF hydrologic model performance. The information summarized in Table 48 and Figures 119 - 124 suggest that the calibrated and verified Karcher Creek HSPF hydrologic model is predictive at the daily time scale. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

ADJUSTABLE MODEL PARAMETERS

IMP1	0.1900
IMP2	0.3200
IMP3	0.7075
IMP4	0.0850

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Karcher Creek	SUBURBAN	1	7.23	0.0196	22.29	0.0109	0.0094	0.2498	0.0913	1.718016	0.782316	0.1249208
	MULTI-FAMILY	2	15.00	0.0124	46.00	0.0157	0.0059	0.1088	0.0962	1.297126	0.85	0.1002375
	COMMERCIAL	3	4.97	0.0019	19.33	0.0108	0.0066	0.0500	0.0500	1.152089	0.7336888	0.1
	RURAL RESIDENTIAL	4	7.68	0.0379	20.61	0.0099	0.0100	0.4303	0.1063	2.479987	0.7719327	0.3233664
	LAWN	5	13.28	0.0322	27.65	0.0126	0.0090	0.2590	0.1063	4.40216	0.85	0.232364
	PASTURE	6	7.19	0.0470	20.11	0.0098	0.0101	0.4115	0.1262	5.284736	0.7000519	0.3389807
	FOREST	7	15.00	0.1668	999.00	0.0750	0.2000	2.0000	0.3525	1	0.3	0.3
	BAREGROUND	10	4.06	0.0094	19.74	0.0108	0.0094	0.1066	0.0717	1.195597	0.7001074	0.1005184

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - BARKER CK	111	0.1500	0.1033

Table 47. Identified model resulting from calibration inversion run.

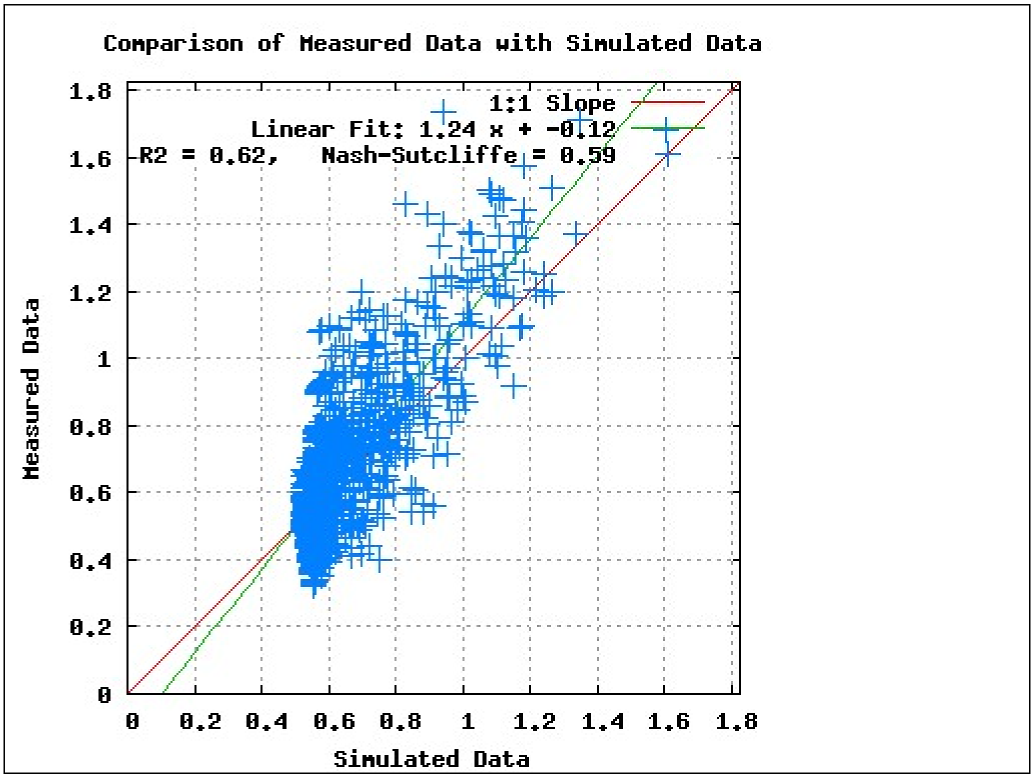

Figure 119. Comparison of the simulated and observed mean daily flow data that was used for calibration at Karcher Creek.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Karcher Creek	SUBURBAN	1	10.31251	13.72	7.2964	13.79	1	10.34	13.72	7.3085	13.8	1	0.23	-0.01	0.17	0.04
	MULTI-FAMILY	2	18.47381	9.636	5.123	11.89	2	18.48	9.641	5.1312	11.88	2	0.04	0.05	0.16	-0.02
	COMMERCIAL	3	32.56757	2.595	1.375	8.583	3	31.58	2.521	0.8699	10.21	3	-3.03	-2.83	-36.73	18.90
	RURAL RESIDENTIAL	4	1.81721	14.11	10.804	18.39	4	1.817	14.1	10.797	18.4	4	-0.01	-0.04	-0.06	0.01
	LAWN	5	0.6762457	18.54	9.8555	16.05	5	0.679	18.58	9.8665	16.06	5	0.47	0.23	0.11	0.02
	PASTURE	6	0.3213359	14.69	11.247	18.86	6	0.317	14.69	11.245	18.86	6	-1.28	-0.04	-0.02	0.00
	FOREST	7	9.97E-02	9.37	14.841	20.81	7	0.604	10.23	15.082	15.89	7	506.10	9.21	1.62	-23.65
	BAREGROUND	10	20.4513	8.649	4.5981	11.42	10	20.47	8.65	4.6018	11.42	10	0.08	0.01	0.08	0.01

Table 48. Comparison of simulated and observed targets for the partition of average annual precipitation.

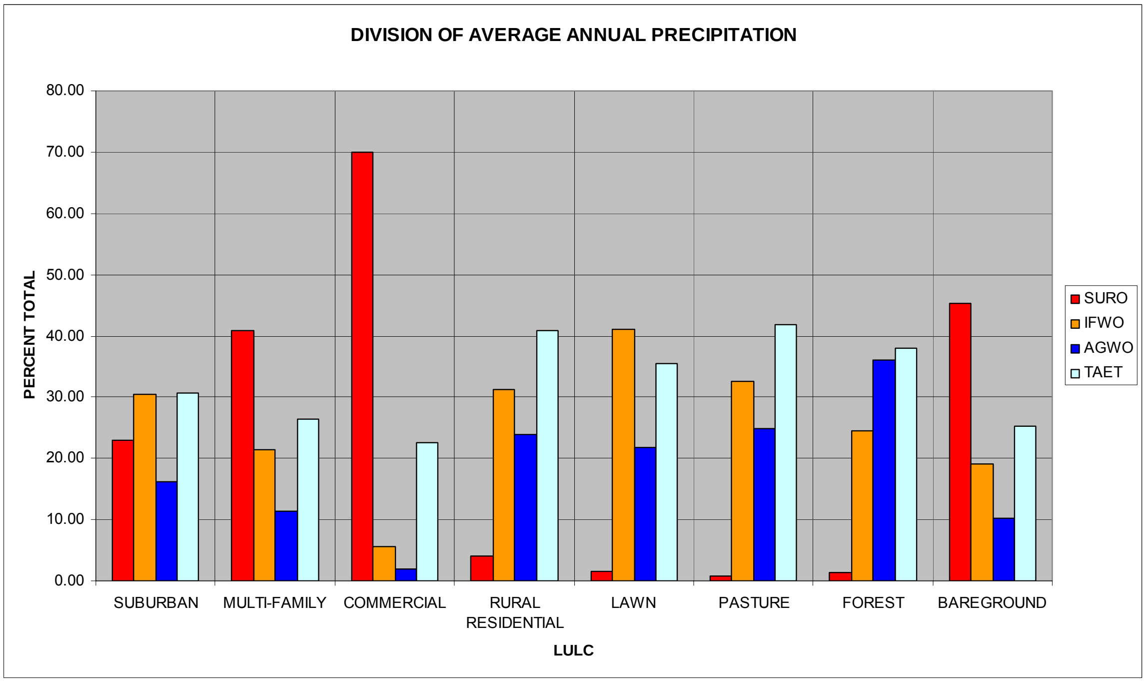

Figure 120. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Karcher Creek.

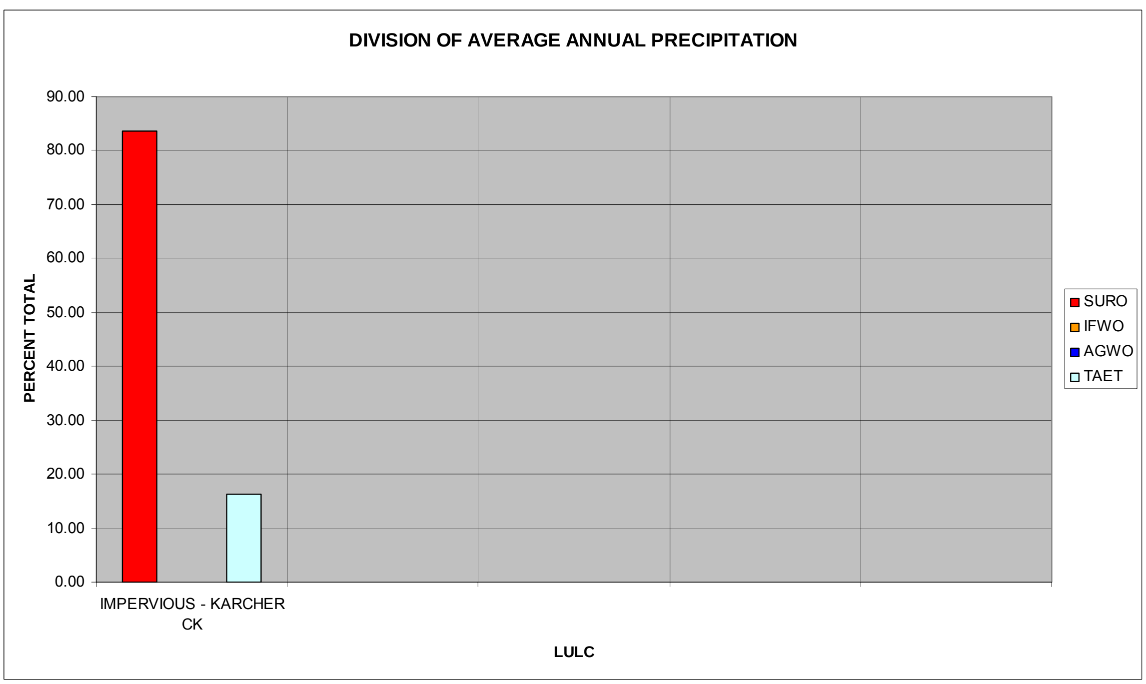

Figure 121. Simulated SURO and TAET for the impervious area for Karcher Creek.

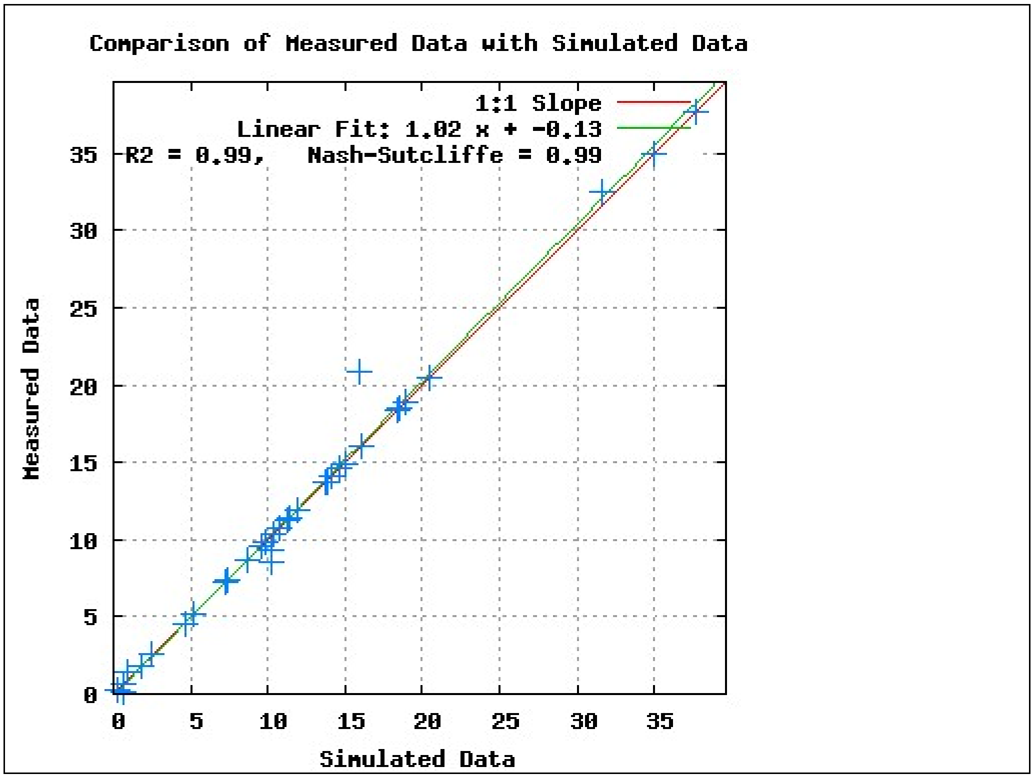

Figure 122. Comparison of simulated and observed targets for the partition of average annual precipitation.

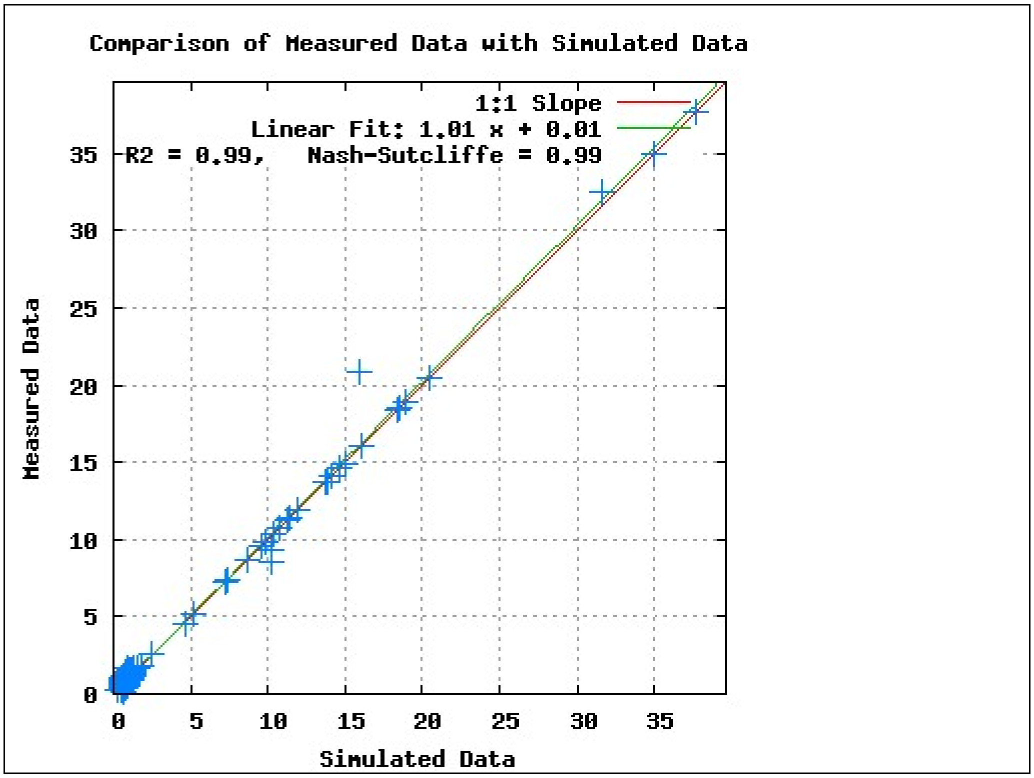

Figure 123. Comparison of all the data (mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Karcher Creek HSPF hydrologic model.

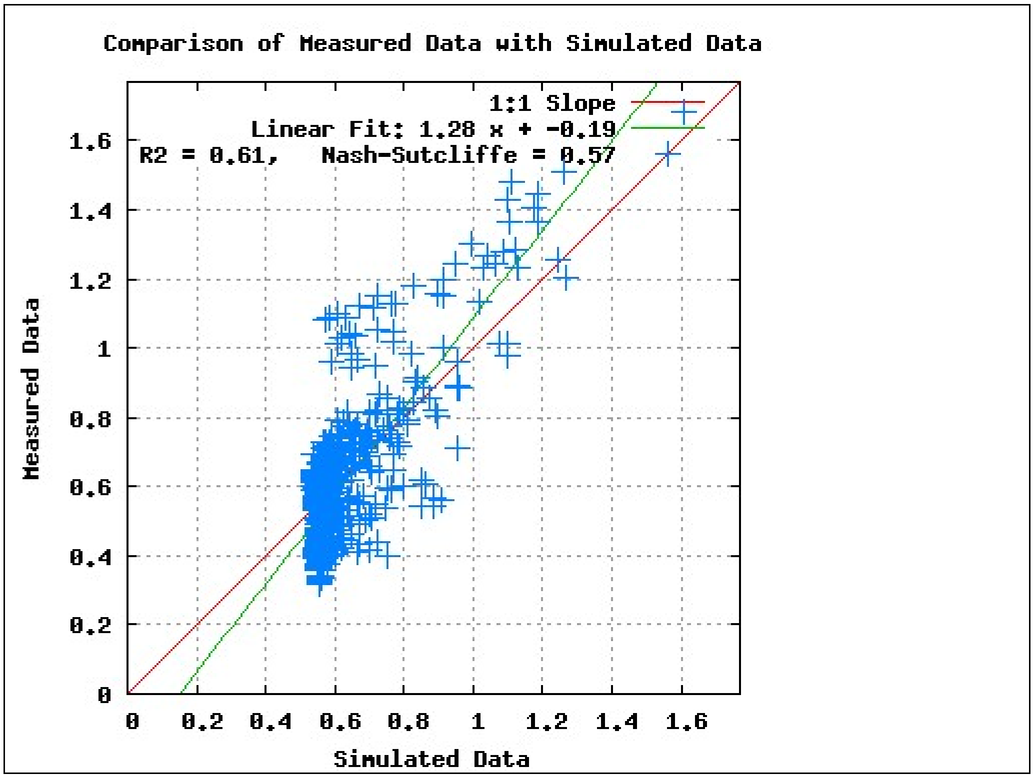

Figure 124. Verification results which compare simulated and observed flows

5.3.6 Blackjack Creek

The calibration inversion run was manually terminated after 2410 model calls, which resulted in reducing the objective function from a starting value of 14550 to a final value of 531.1. Table 49 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data at the Blackjack Creek flow monitoring location (43871 missing of 175296 15 minute flow data points for Blackjack Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance. The information summarized in Table 50 and Figures 125 - 131 suggest that the calibrated and verified Blackjack Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

BLACKJACK CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.1900
IMP3	0.5100
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Blackjack Creek	SUBURBAN	1	3.34	0.0205	30.86	0.0111	0.0093	0.1496	0.1365	1.53288	0.583053	0.146897
	MULTI-FAMILY	2	2.35	0.0132	22.93	0.0102	0.0089	0.0839	0.0937	1.22151	0.627691	0.1
	COMMERCIAL	3	2.00	0.0017	18.33	0.0092	0.0055	0.0500	0.0500	1.18098	0.670788	0.1
	RURAL RESIDENTIAL	4	10.72	0.0336	36.76	0.0124	0.0096	0.3194	0.1013	2.3619	0.378568	0.289914
	LAWN	5	15.00	0.0379	123.06	0.0278	0.0069	0.0500	0.1045	3.27324	0.85	0.292489
	PASTURE	6	4.94	0.0494	50.40	0.0109	0.0096	0.3278	0.1128	3.60547	0.407088	0.314294
	FOREST	7	15.00	0.1351	227.57	0.1576	0.2000	2.0000	0.5000	1.44839	0.461859	0.6
	BAREGROUND	10	2.32	0.0101	21.83	0.0106	0.0088	0.0969	0.1010	1.22592	0.647219	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - BLACKJACK CK	111	0.1051	0.0822

Table 49. Identified model resulting from calibration inversion run.

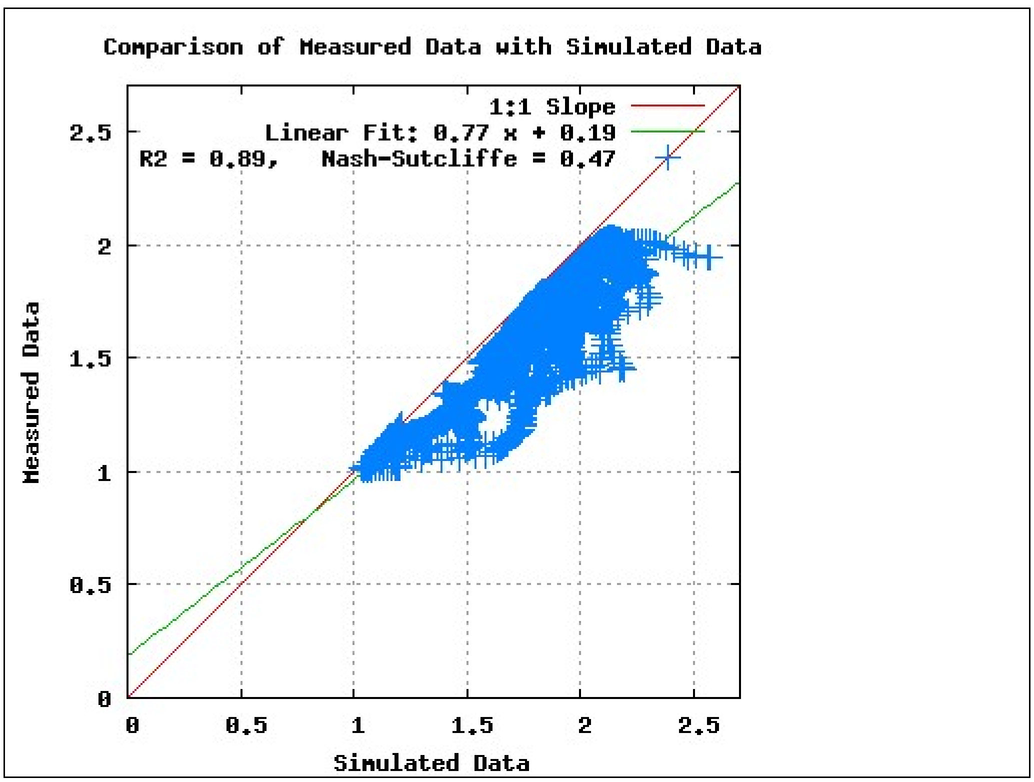

Figure 125. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Blackjack Creek HSPF hydrologic model.

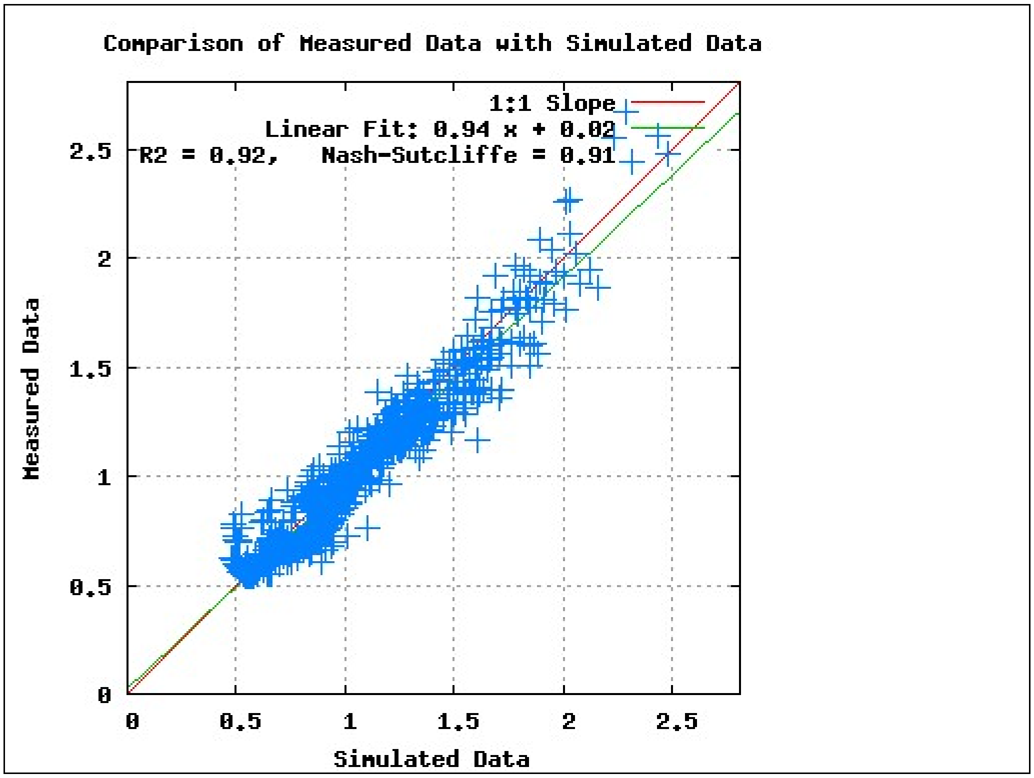

Figure 126. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Blackjack Creek HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Blackjack Creek	SUBURBAN	1	9.99	13.29	7.07	13.36	1	9.91	13.28	7.07	13.38	1	-0.79	-0.07	0.03	0.18
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51	2	17.80	9.33	4.97	11.57	2	-0.54	-0.03	0.21	0.48
	COMMERCIAL	3	31.54	2.51	1.33	8.31	3	30.09	2.46	0.89	10.39	3	-4.60	-2.13	-32.98	25.01
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81	4	1.76	13.66	10.46	17.83	4	-0.01	-0.04	-0.03	0.11
	LAWN	5	0.65	17.95	9.55	15.55	5	0.64	17.61	9.56	15.72	5	-2.47	-1.91	0.15	1.12
	PASTURE	6	0.31	14.23	10.89	18.27	6	0.31	14.23	10.89	18.29	6	0.69	0.03	-0.03	0.15
	FOREST	7	0.10	9.07	14.37	20.16	7	0.13	6.55	14.21	15.16	7	39.35	-27.82	-1.16	-24.79
	BAREGROUND	10	19.81	8.38	4.45	11.06	10	19.69	8.38	4.47	11.13	10	-0.61	-0.02	0.44	0.65
	IMPERVIOUS - BLACKJACK CK	111	36.57			7.13	111	36.59			7.15	111	0.07			0.32

Table 50. Comparison of simulated and observed targets for the partition of average annual precipitation.

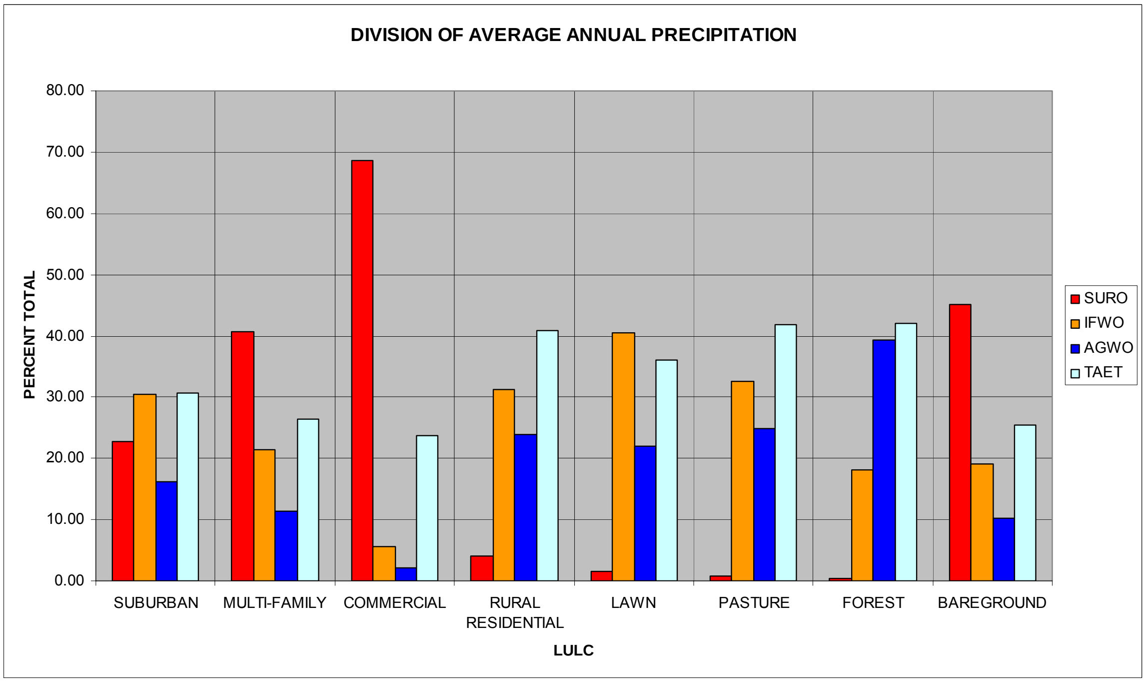

Figure 127. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Blackjack Creek.

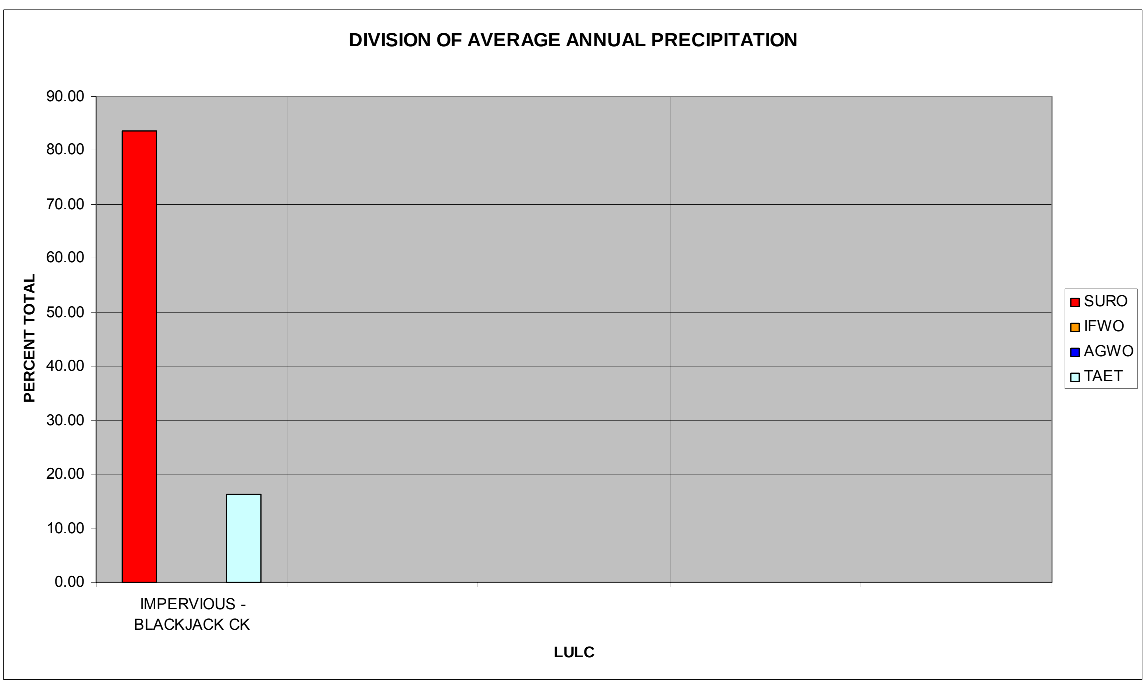

Figure 128. Simulated SURO and TAET for the impervious area for Blackjack Creek.

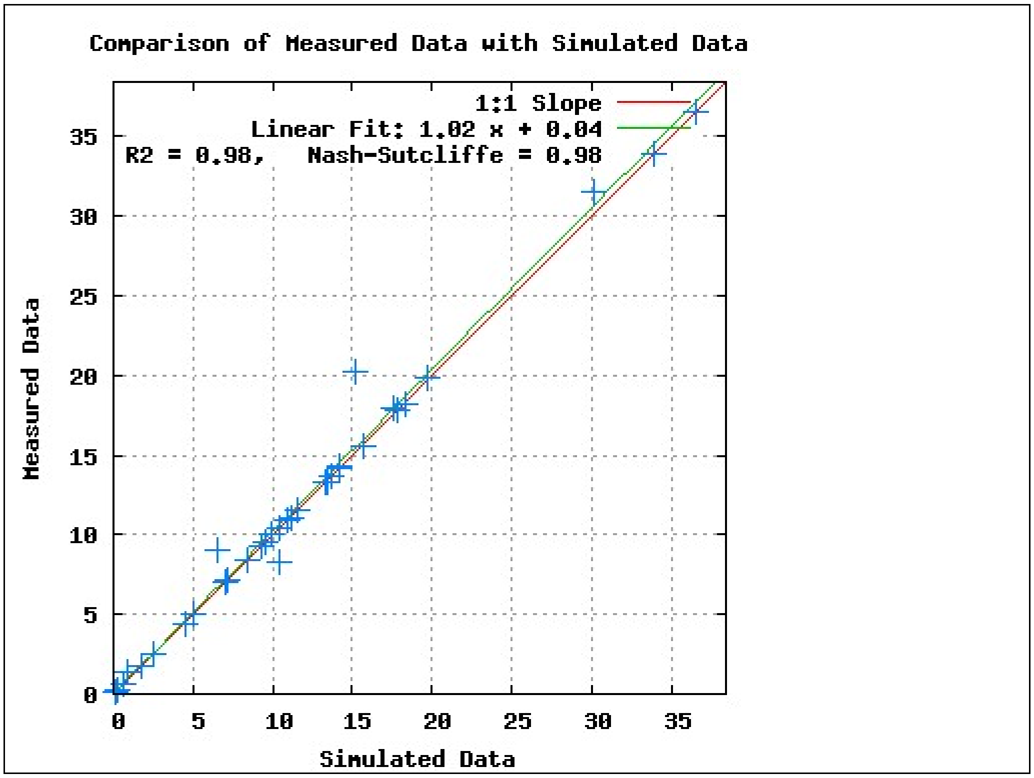

Figure 129. Blackjack Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

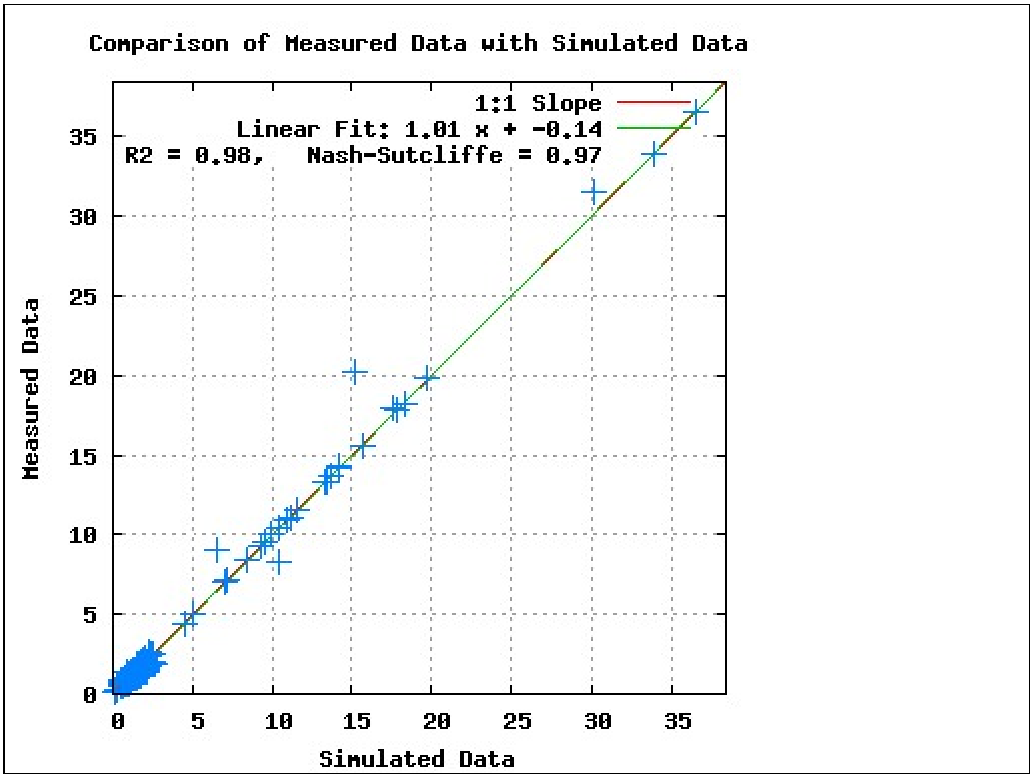

Figure 130. Blackjack Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Blackjack Creek HSPF hydrologic model.

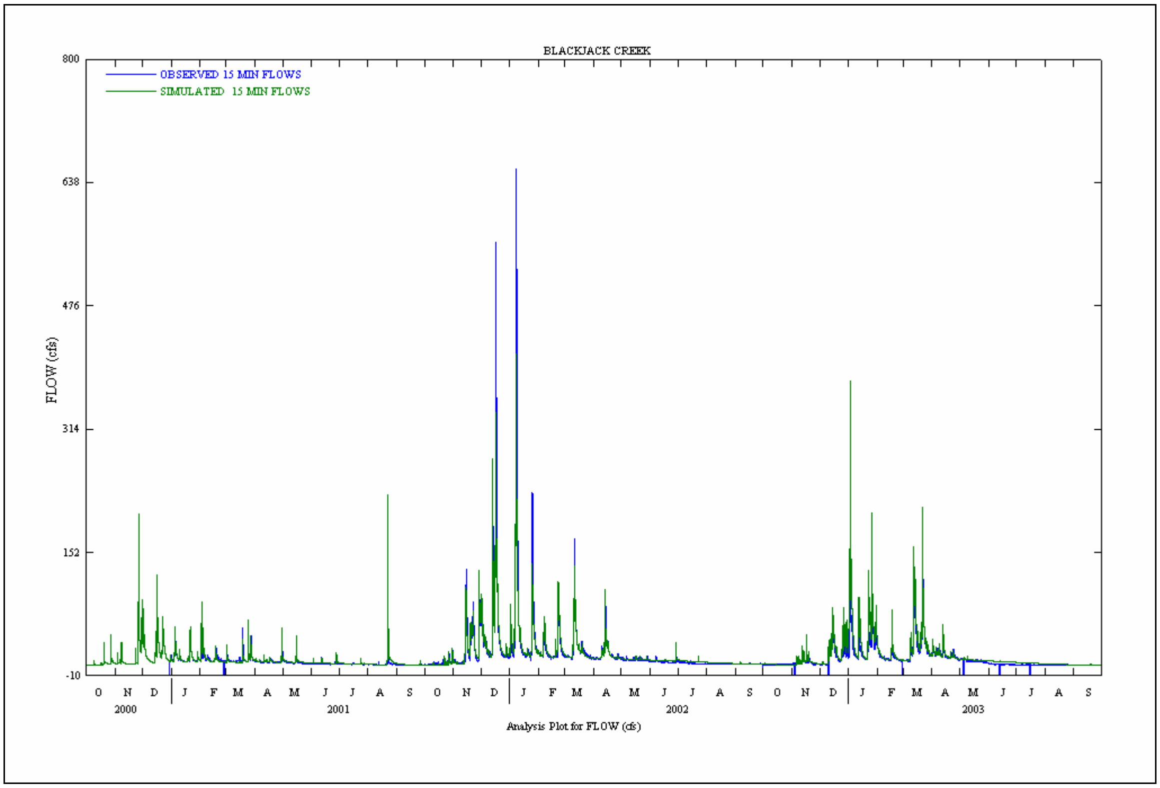

Figure 131. Verification results of simulated and observed 15 minute flows at Blackjack Creek.

5.3.7 Anderson Creek

The calibration inversion run was manually terminated after 1082 model calls, which resulted in reducing the objective function from a starting value of 8865.6 to a final value of 425.5. Table 51 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data at the Anderson Creek flow monitoring location (26332 missing of 315072 15 minute flow data points for Anderson Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance. The information summarized in Table 52 and Figures 132 - 138 suggest that the calibrated and verified Anderson Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

ANDERSON CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1900
IMP2	0.1903
IMP3	0.8300
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Anderson Creek	SUBURBAN	1	15.00	0.0181	7.11	0.0078	0.0097	0.2163	0.1208	1.66631	0.349734	0.1
	MULTI-FAMILY	2	8.08	0.0127	12.04	0.0096	0.0094	0.0720	0.0879	1.26163	0.85	0.1
	COMMERCIAL	3	7.95	0.0014	56.40	0.0035	0.0004	0.0500	0.0500	1.30872	0.689976	0.1
	RURAL RESIDENTIAL	4	7.95	0.0313	10.07	0.0170	0.0107	0.5692	0.1193	2.54317	0.375628	0.25373
	LAWN	5	15.00	0.0268	529.14	0.0286	0.0078	0.5663	0.1005	5.01751	0.3	0.148195
	PASTURE	6	10.20	0.0345	6.08	0.0077	0.0126	0.6204	0.1130	4.50006	0.3	0.250482
	FOREST	7	15.00	0.1144	120.57	0.0583	0.2000	2.0000	0.4519	1.06671	0.665369	0.3
	BAREGROUND	10	6.84	0.0099	12.64	0.0101	0.0094	0.0851	0.0661	1.27285	0.85	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - ANDERSON CK	111	0.1269	0.0823

Table 51. Identified model resulting from calibration inversion run.

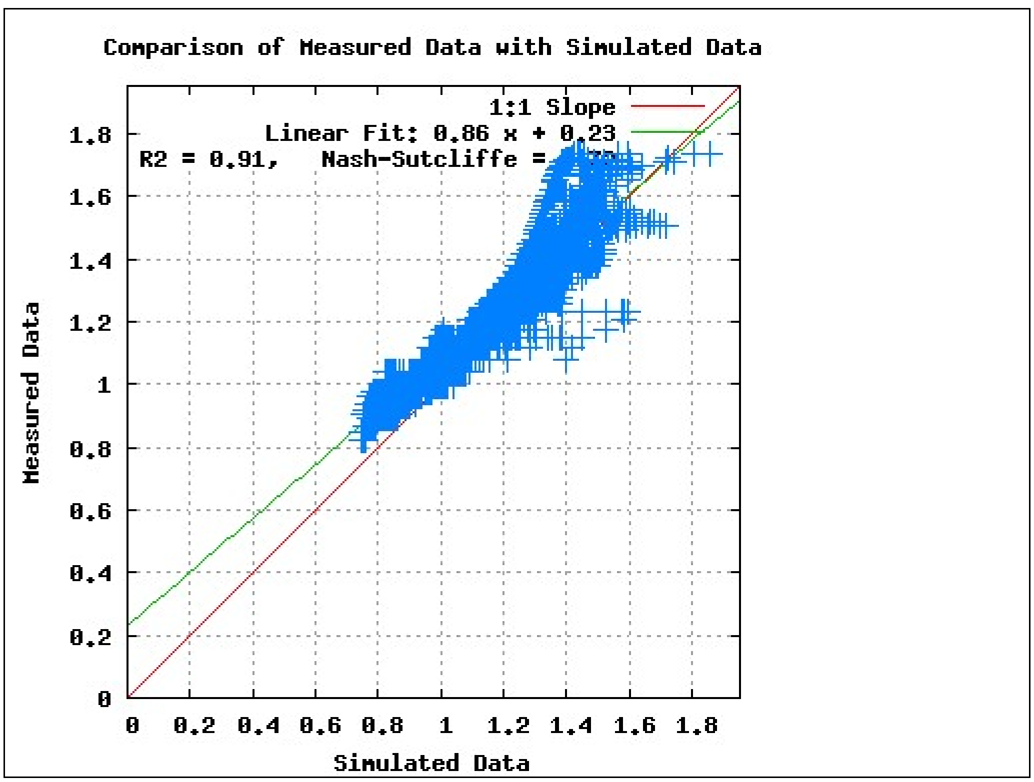

Figure 132. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Anderson Creek HSPF hydrologic model.

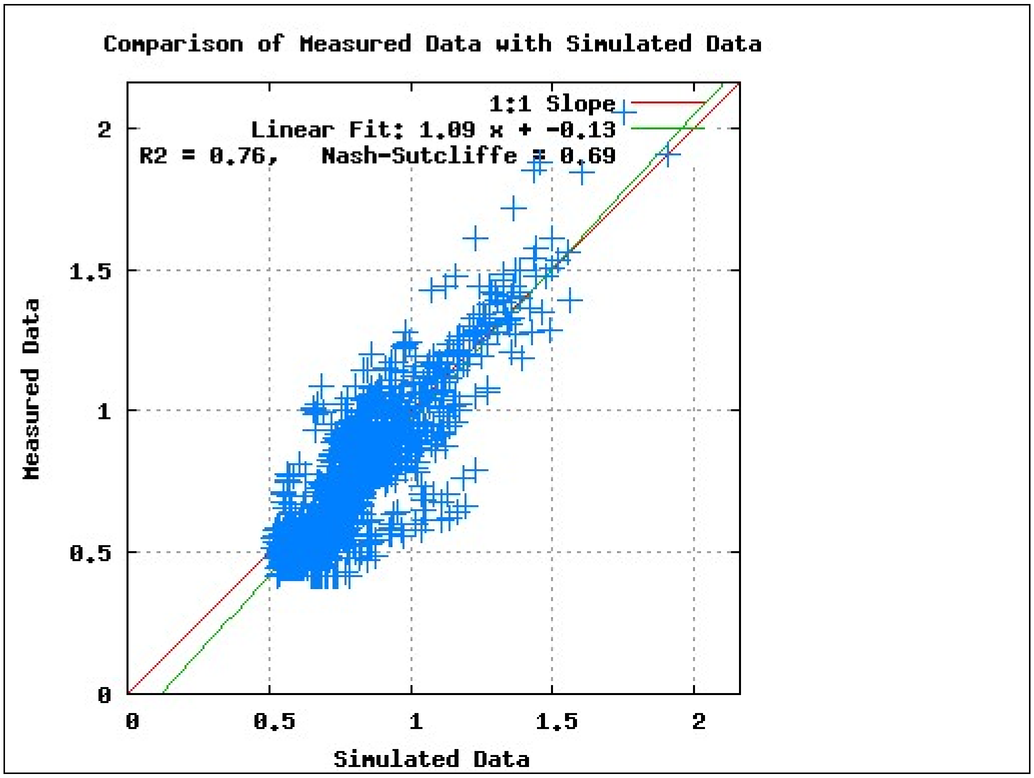

Figure 133. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Anderson Creek HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Anderson Creek	SUBURBAN	1	9.99	13.29	7.07	13.36	1	10.00	13.29	7.08	13.37	1	0.16	0.02	0.20	0.08
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51	2	17.94	9.34	4.98	11.53	2	0.25	0.07	0.36	0.13
	COMMERCIAL	3	31.54	2.51	1.33	8.31	3	30.31	2.45	0.67	10.44	3	-3.90	-2.40	-49.92	25.65
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81	4	1.76	13.73	10.50	17.80	4	0.11	0.49	0.34	-0.06
	LAWN	5	0.65	17.95	9.55	15.55	5	0.63	17.80	9.55	15.65	5	-3.08	-0.83	0.00	0.68
	PASTURE	6	0.31	14.23	10.89	18.27	6	0.34	14.36	10.91	18.30	6	9.65	0.93	0.15	0.17
	FOREST	7	0.10	9.07	14.37	20.16	7	0.72	10.89	14.65	16.37	7	643.61	19.98	1.91	-18.76
	BAREGROUND	10	19.81	8.38	4.45	11.06	10	19.85	8.38	4.47	11.07	10	0.22	0.02	0.39	0.08
	IMPERVIOUS - ANDERSON CK	111	36.57			7.13	111	36.59			7.16	111	0.06			0.35

Table 52. Comparison of simulated and observed targets for the partition of average annual precipitation.

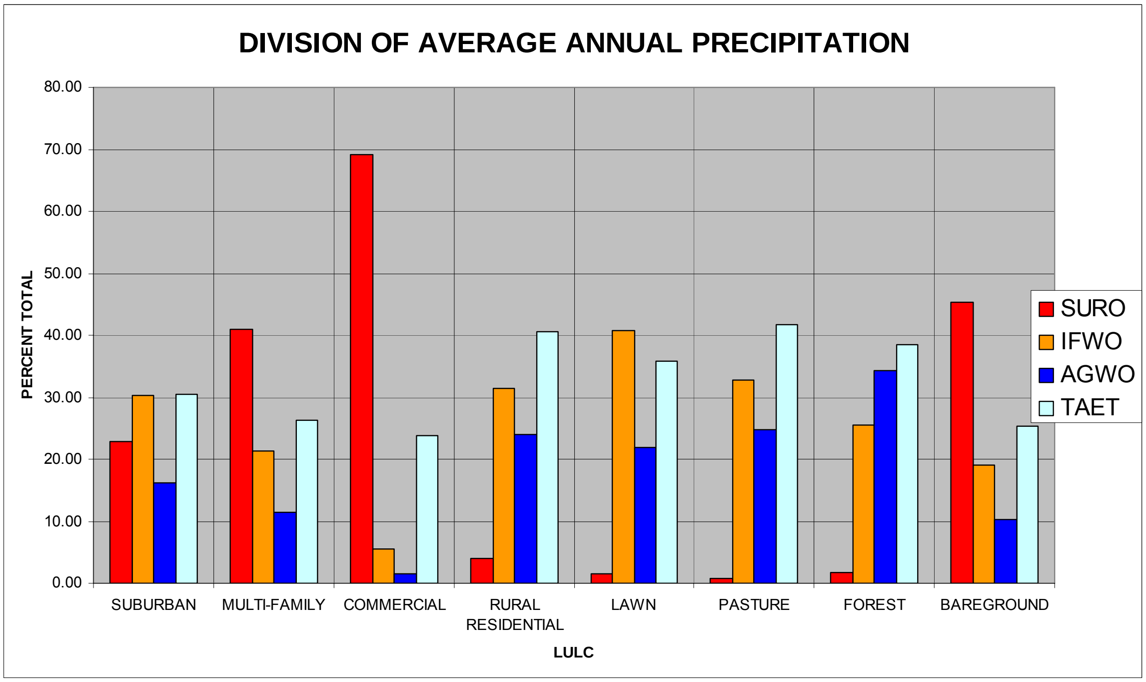

Figure 134. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Anderson Creek.

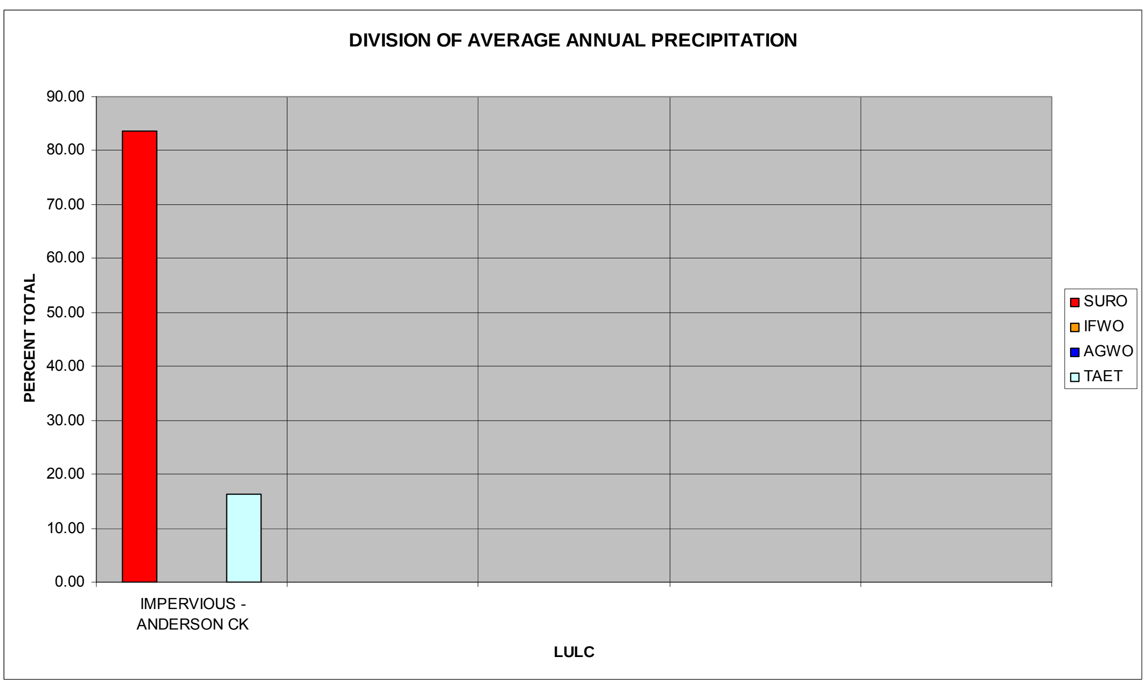

Figure 135. Simulated SURO and TAET for the impervious area for Anderson Creek.

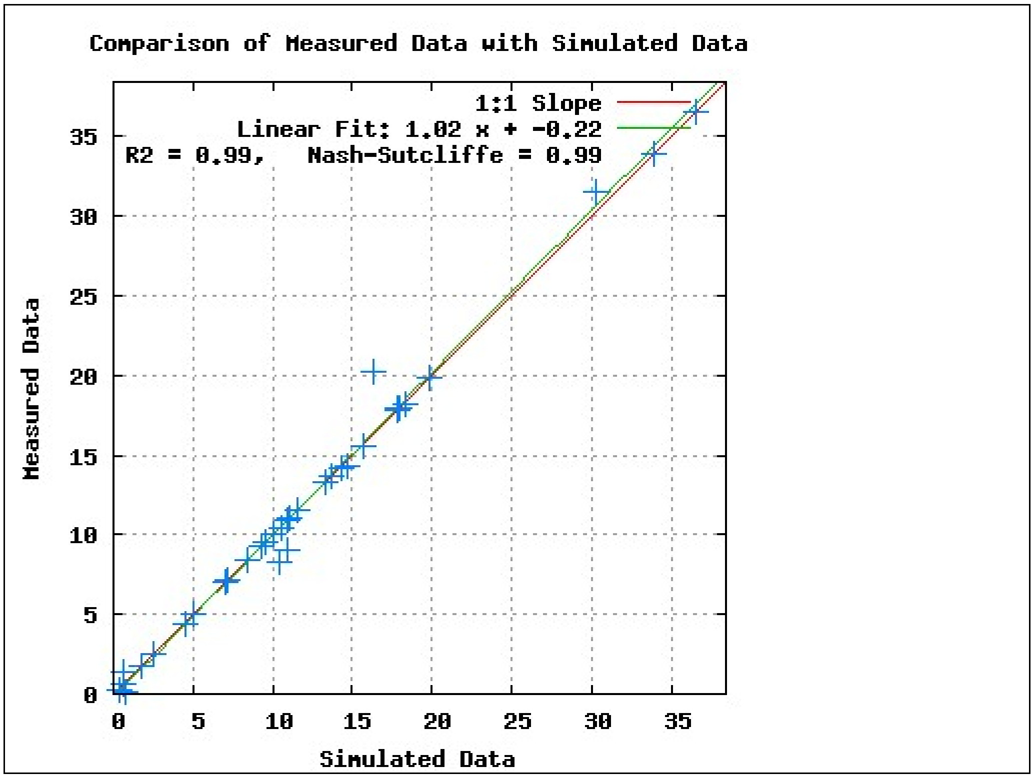

Figure 136. Anderson Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

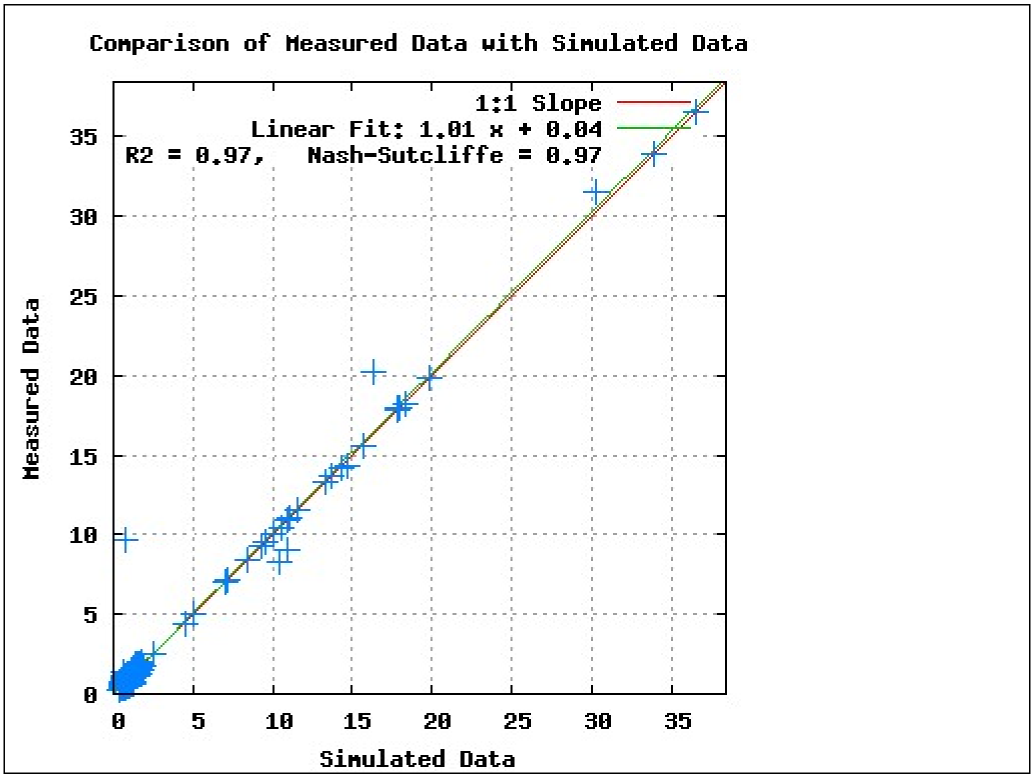

Figure 137. Anderson Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Anderson Creek HSPF hydrologic model.

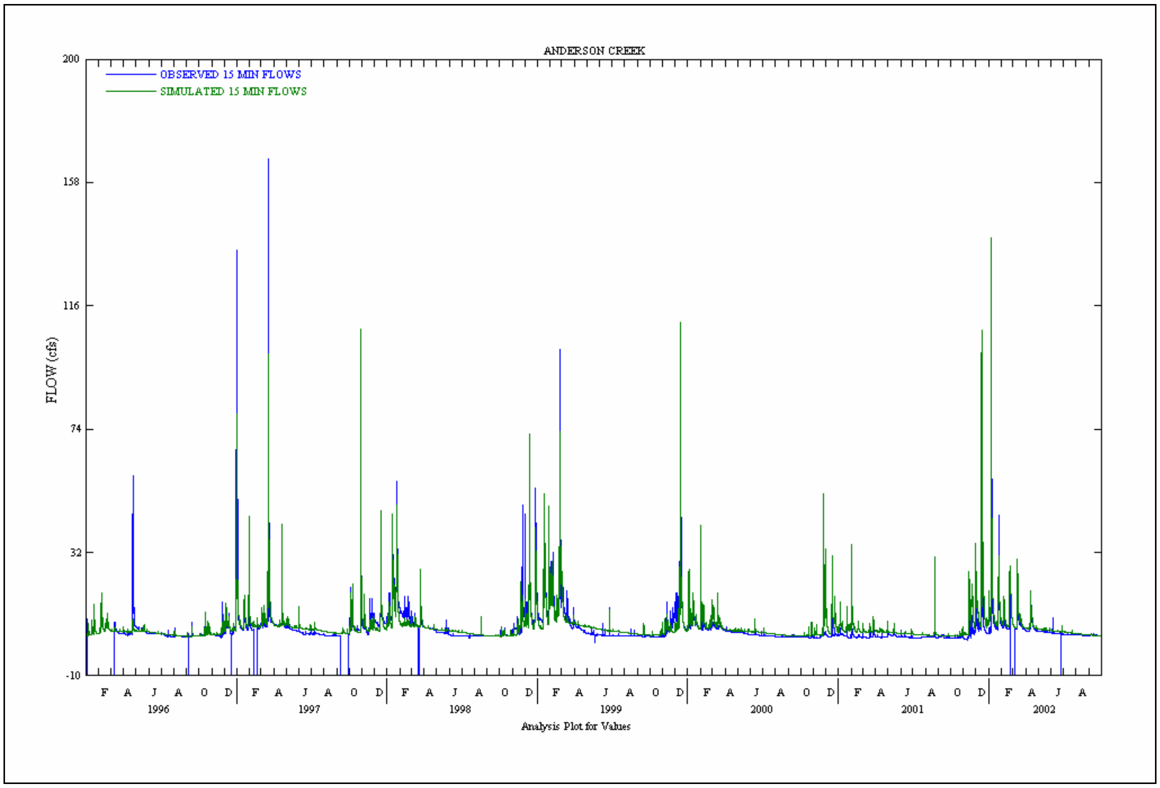

Figure 138. Verification results of simulated and observed 15 minute flows at Anderson Creek.

5.3.8 Gorst Creek

The calibration inversion run was manually terminated after 9660 model calls, which resulted in reducing the objective function from a starting value of 13240 to a final value of 233.2. Tables 53 - 55 lists the identified parameter set that resulted from the calibration inversion run.

The large quantity of missing flow data for each of the three systems (24869 missing of 70035 15 minute flow data points for Heins Creek, 18909 missing of 70033 15 minute flow data points for Parish Creek, and 38824 missing of 105074 15 minute flow data points for Gorst Creek; see Appendix 2 for additional details), together with the limited calibration data, made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 56 and Figures 139 - 157 suggest that the calibrated and verified Gorst Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

HEINS CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.2036
IMP3	0.9800
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Heins Creek	SUBURBAN	1	4.60	0.0206	19.61	0.0101	0.0096	0.1985	0.0930	1.61457	0.701594	0.111753
	MULTI-FAMILY	2	8.46	0.0047	12.96	0.0123	0.0088	0.0809	0.0500	1.03236	0.488831	0.1
	COMMERCIAL	3	2.00	0.0010	12.86	0.0121	0.0088	0.0500	0.0500	1	0.540375	0.1
	RURAL RESIDENTIAL	4	5.05	0.0229	14.57	0.0125	0.0102	0.3948	0.0865	1.2408	0.554061	0.272902
	LAWN	5	6.05	0.0373	32.22	0.0112	0.0093	0.2004	0.1164	4.9435	0.85	0.237738
	PASTURE	6	4.74	0.0517	19.64	0.0122	0.0099	0.4014	0.1187	4.4251	0.810054	0.33005
	FOREST	7	15.00	0.0851	140.86	0.0579	0.2000	2.0000	0.5000	1.23398	0.85	0.4
	BAREGROUND	10	3.94	0.0110	19.45	0.0101	0.0095	0.1020	0.0775	1.26532	0.608927	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - HEINS CK	111	0.1066	0.0864

Table 53. Identified model resulting from calibration inversion run.

PARISH CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.2036
IMP3	0.9800
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Parish Creek	SUBURBAN	1	4.66	0.0197	20.23	0.0100	0.0096	0.2065	0.0939	1.57424	0.594336	0.116417
	MULTI-FAMILY	2	4.15	0.0127	19.86	0.0101	0.0093	0.0994	0.0820	1.24963	0.611612	0.1
	COMMERCIAL	3	4.01	0.0028	18.64	0.0101	0.0089	0.0500	0.0500	1	0.689579	0.1
	RURAL RESIDENTIAL	4	5.91	0.0372	17.54	0.0115	0.0101	0.4133	0.1012	2.1383	0.498969	0.303813
	LAWN	5	5.32	0.0364	30.41	0.0102	0.0097	0.2018	0.1138	3.84288	0.3	0.245947
	PASTURE	6	5.93	0.0456	18.44	0.0114	0.0100	0.3842	0.1131	3.60977	0.431435	0.315466
	FOREST	7	15.00	0.0822	172.40	0.0110	0.2000	2.0000	0.5000	1.02758	0.834489	0.4
	BAREGROUND	10	3.88	0.0106	19.45	0.0101	0.0094	0.1046	0.0763	1.22478	0.69999	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - PARISH CK	111	0.1066	0.0864

Table 54. Identified model resulting from calibration inversion run.

GORST CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.2036
IMP3	0.9800
IMP4	0.0700

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Gorst Creek	SUBURBAN	1	4.61	0.0192	20.05	0.0100	0.0096	0.2019	0.0933	1.65407	0.68698	0.11149
	MULTI-FAMILY	2	4.08	0.0126	19.61	0.0101	0.0092	0.0921	0.0817	1.28481	0.684318	0.1
	COMMERCIAL	3	4.16	0.0028	18.66	0.0100	0.0086	0.0500	0.0500	1	0.689727	0.1
	RURAL RESIDENTIAL	4	5.99	0.0358	17.74	0.0113	0.0101	0.4218	0.1027	2.34317	0.574401	0.297716
	LAWN	5	7.53	0.0320	50.13	0.0106	0.0095	0.2048	0.1154	4.41057	0.3	0.226346
	PASTURE	6	6.17	0.0434	18.95	0.0113	0.0100	0.3982	0.1146	4.07253	0.541555	0.303827
	FOREST	7	15.00	0.0757	290.60	0.0174	0.2000	2.0000	0.5000	1.36904	0.85	0.4
	BAREGROUND	10	3.71	0.0099	19.53	0.0102	0.0094	0.0993	0.0768	1.24921	0.69427	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - GORST CK	111	0.1066	0.0864

Table 55. Identified model resulting from calibration inversion run.

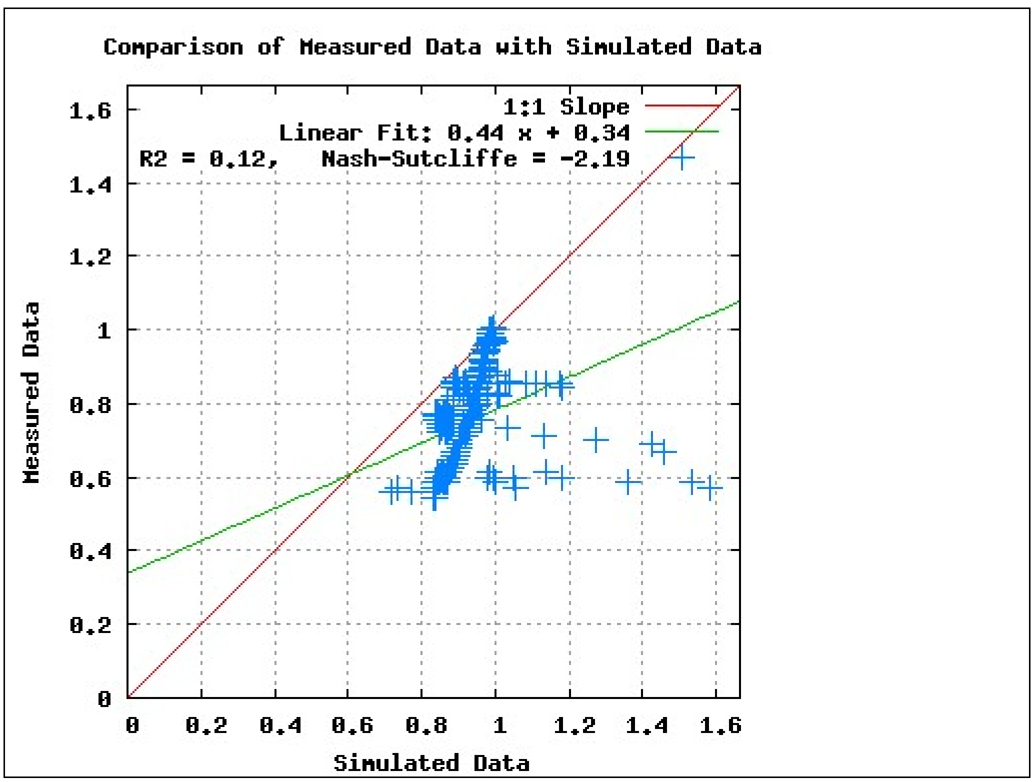

Figure 139. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Heins Creek HSPF hydrologic model.

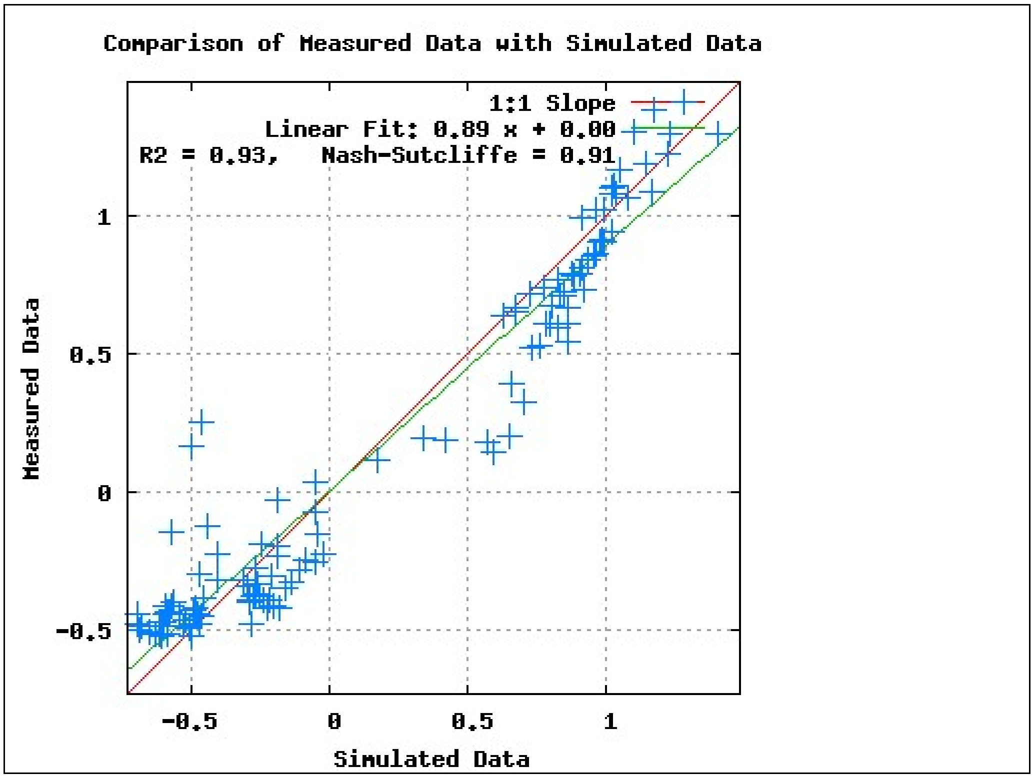

Figure 140. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Heins Creek HSPF hydrologic model.

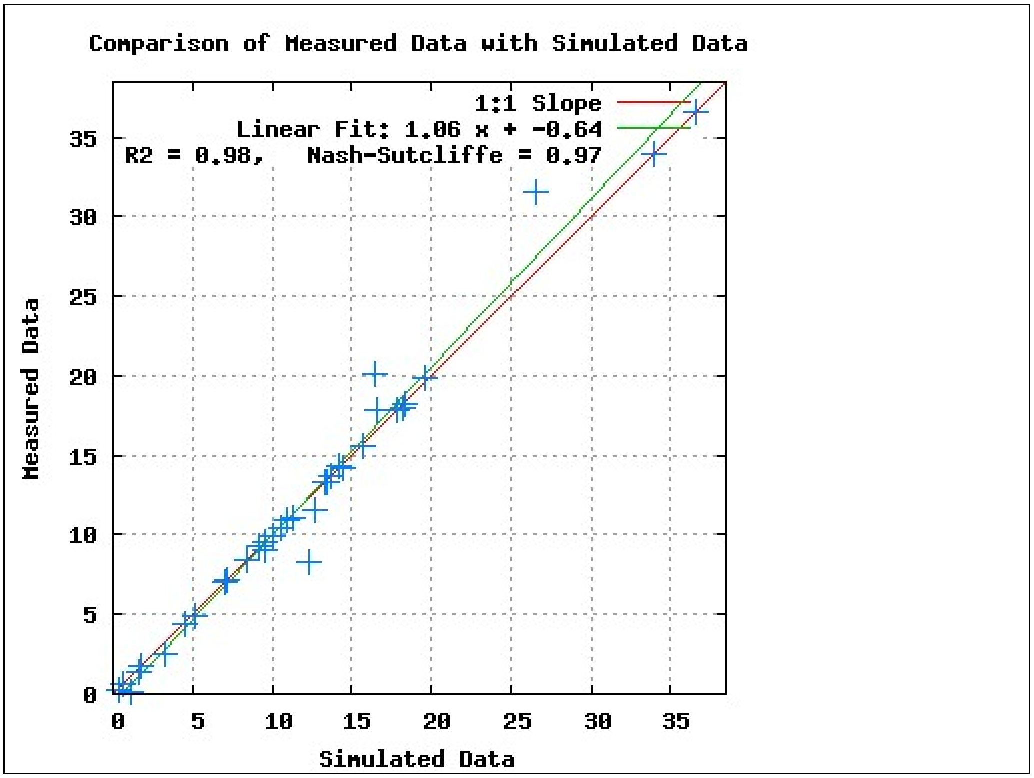

Figure 141. Heins Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

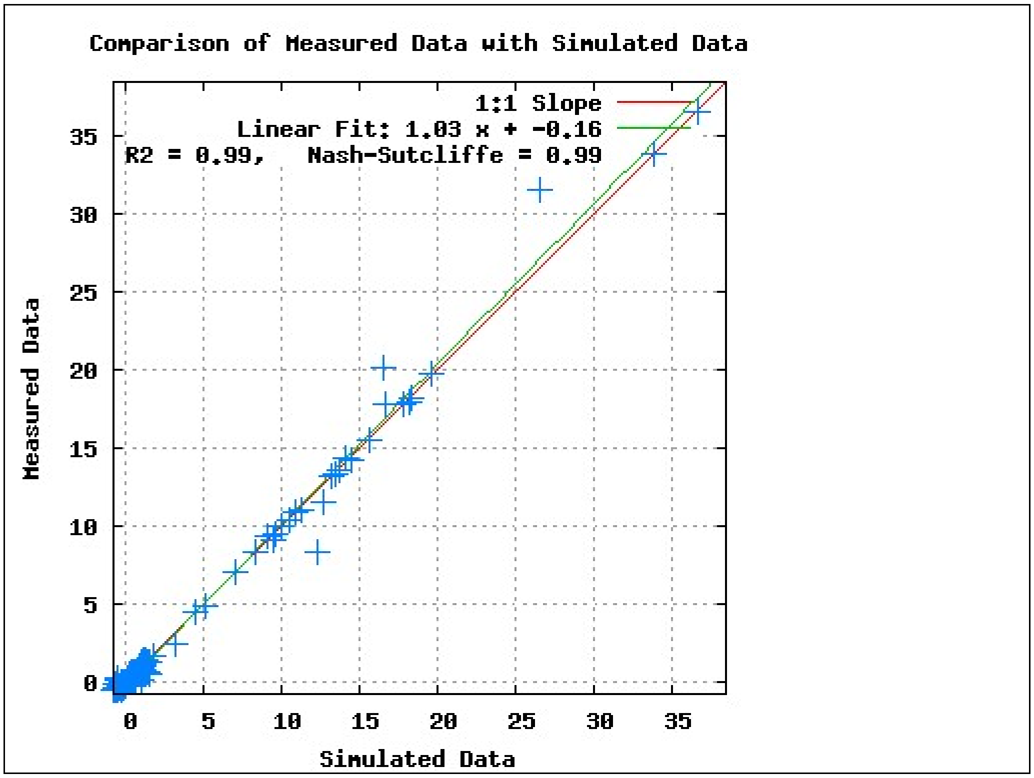

Figure 142. Heins Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Heins Creek HSPF hydrologic model.

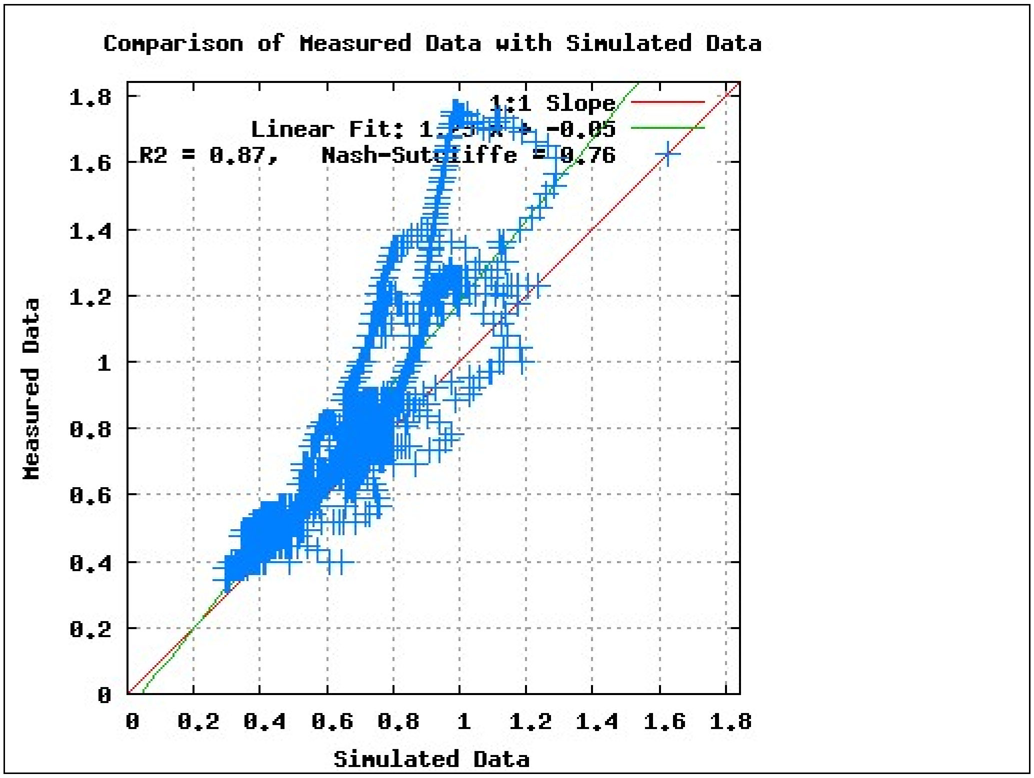

Figure 143. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Parish Creek HSPF hydrologic model.

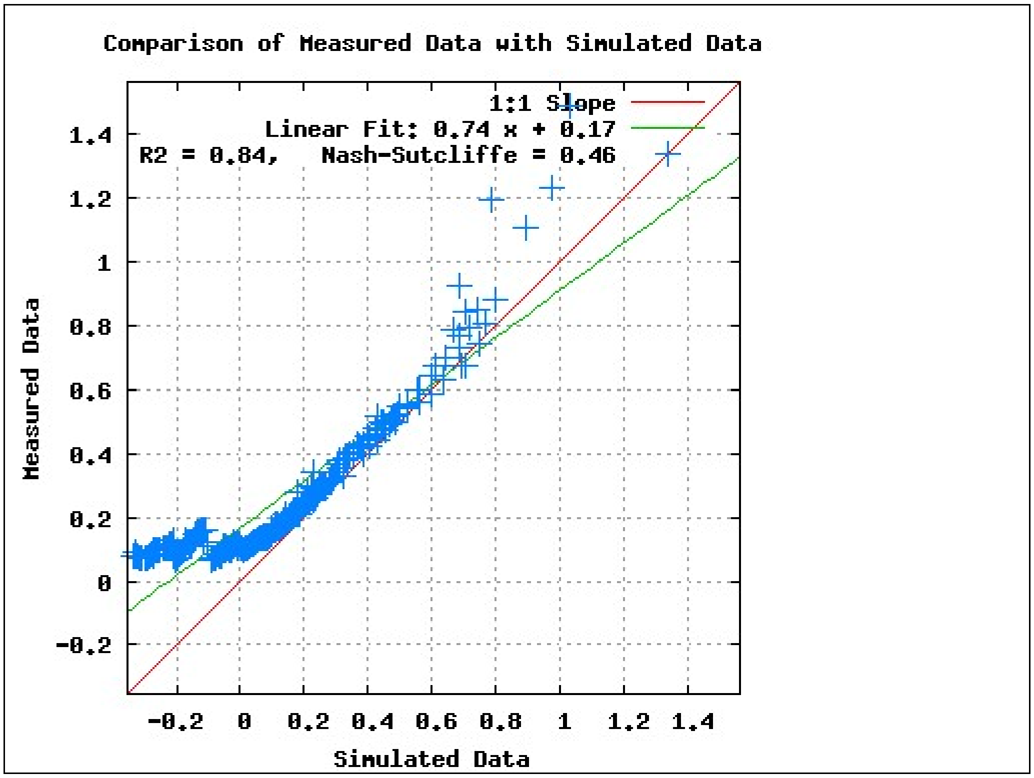

Figure 144. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Parish Creek HSPF hydrologic model.

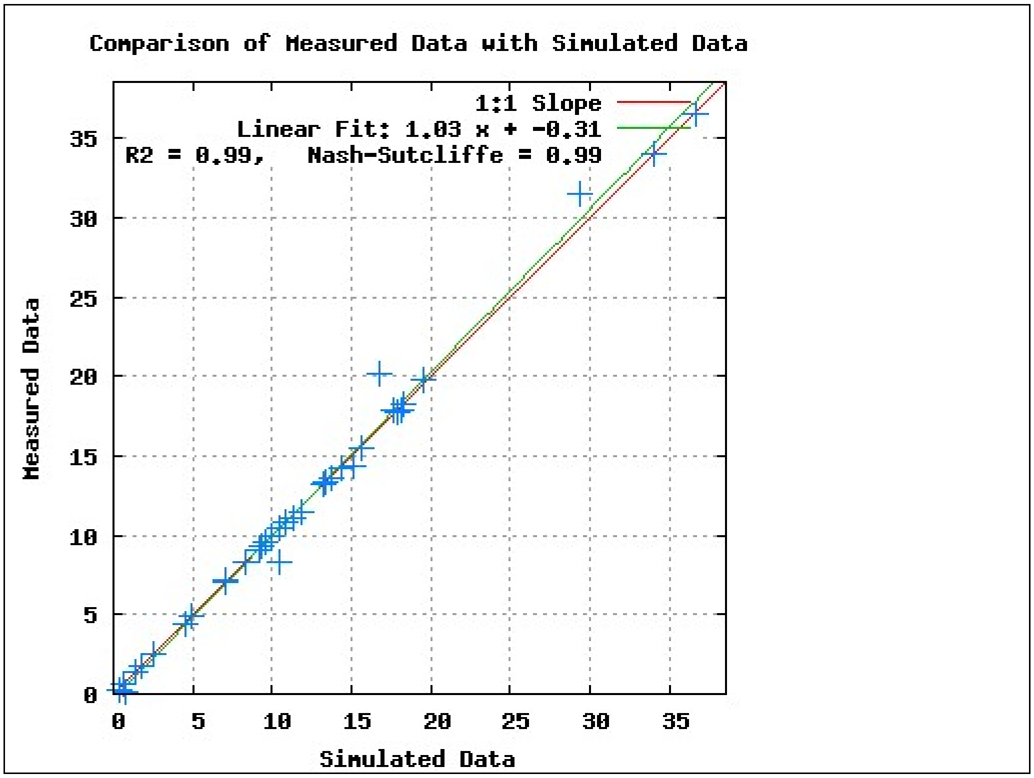

Figure 145. Parish Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

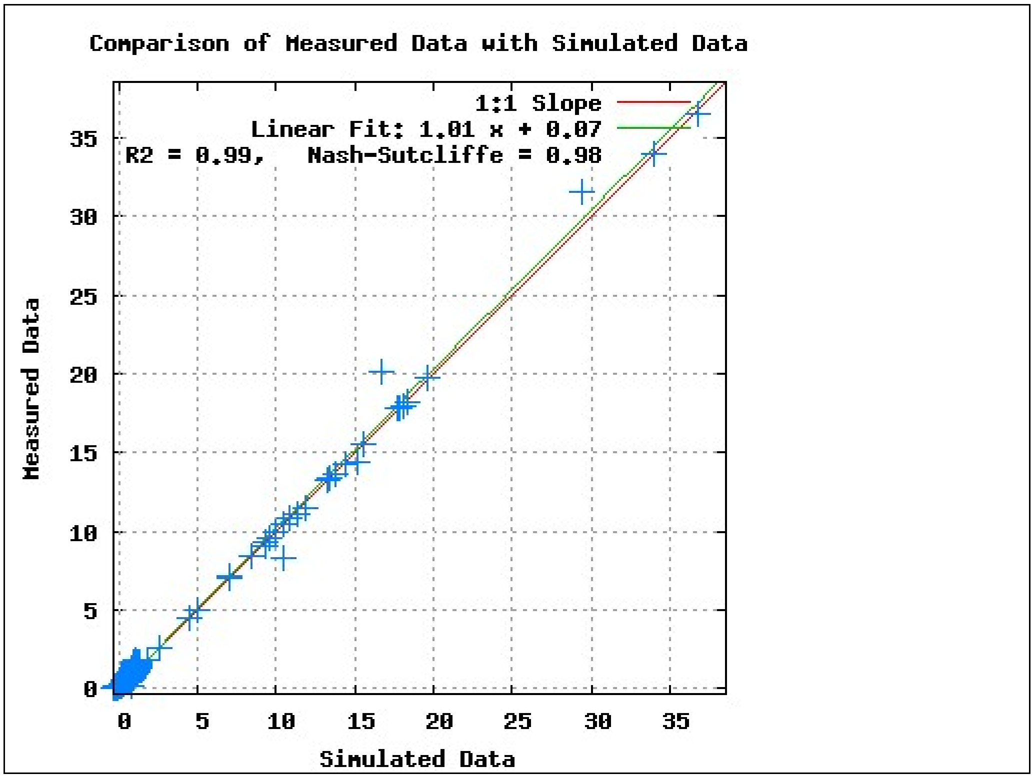

Figure 146. Parish Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Parish Creek HSPF hydrologic model.

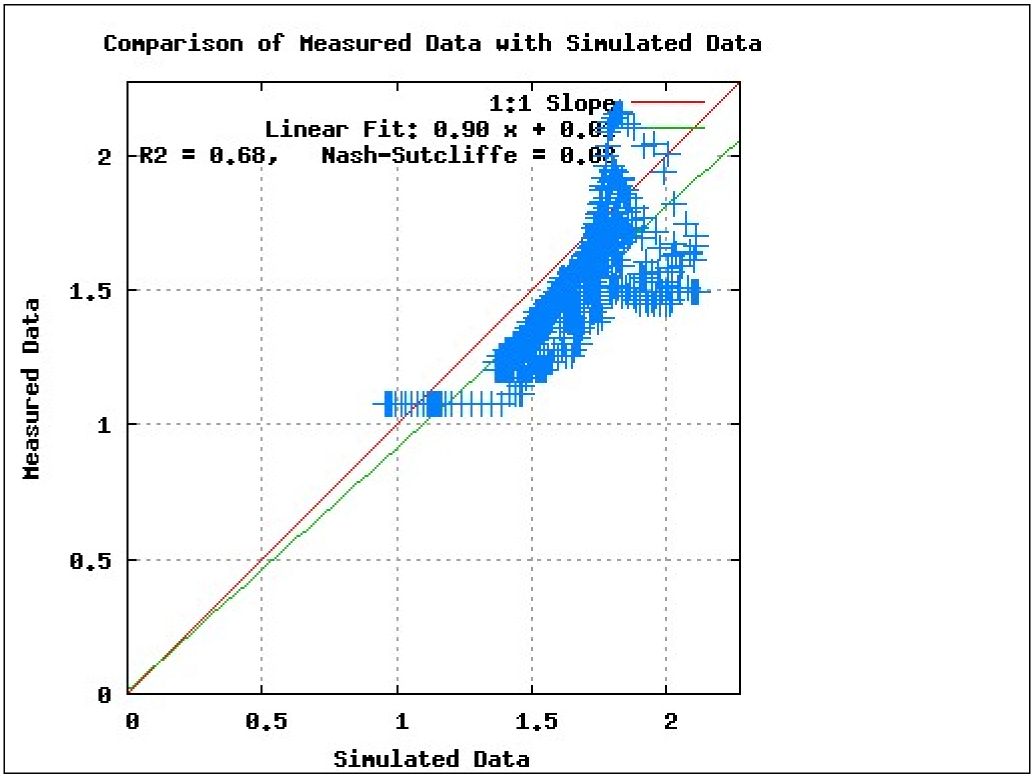

Figure 147. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Gorst Creek HSPF hydrologic model.

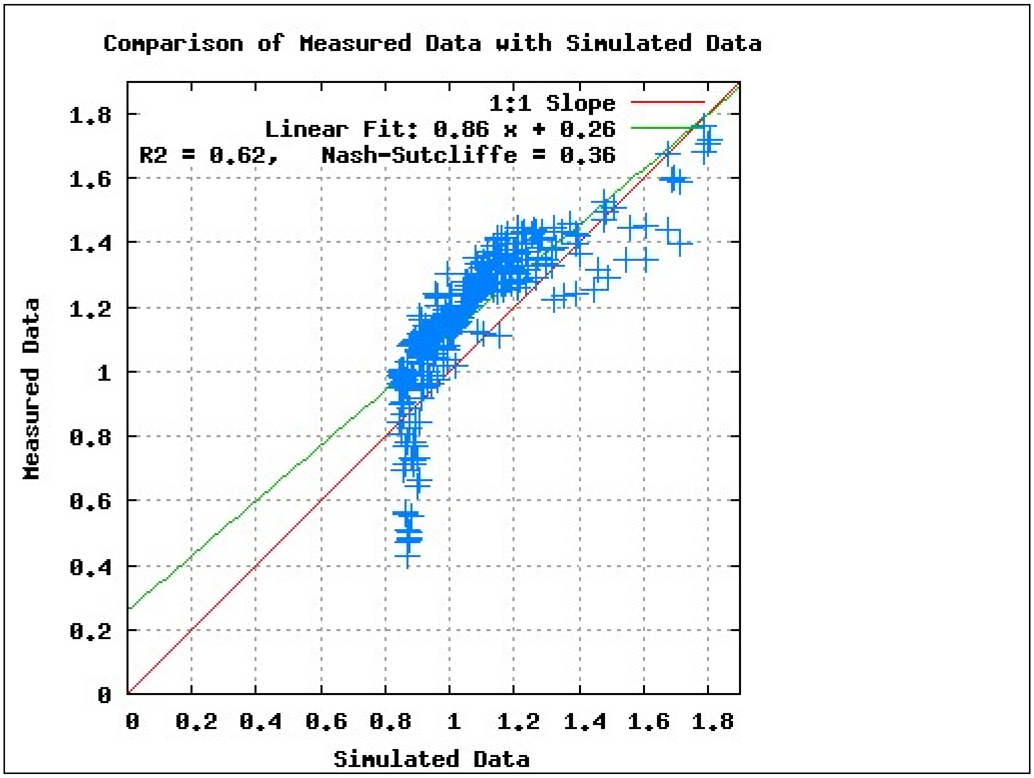

Figure 148. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Gorst Creek HSPF hydrologic model.

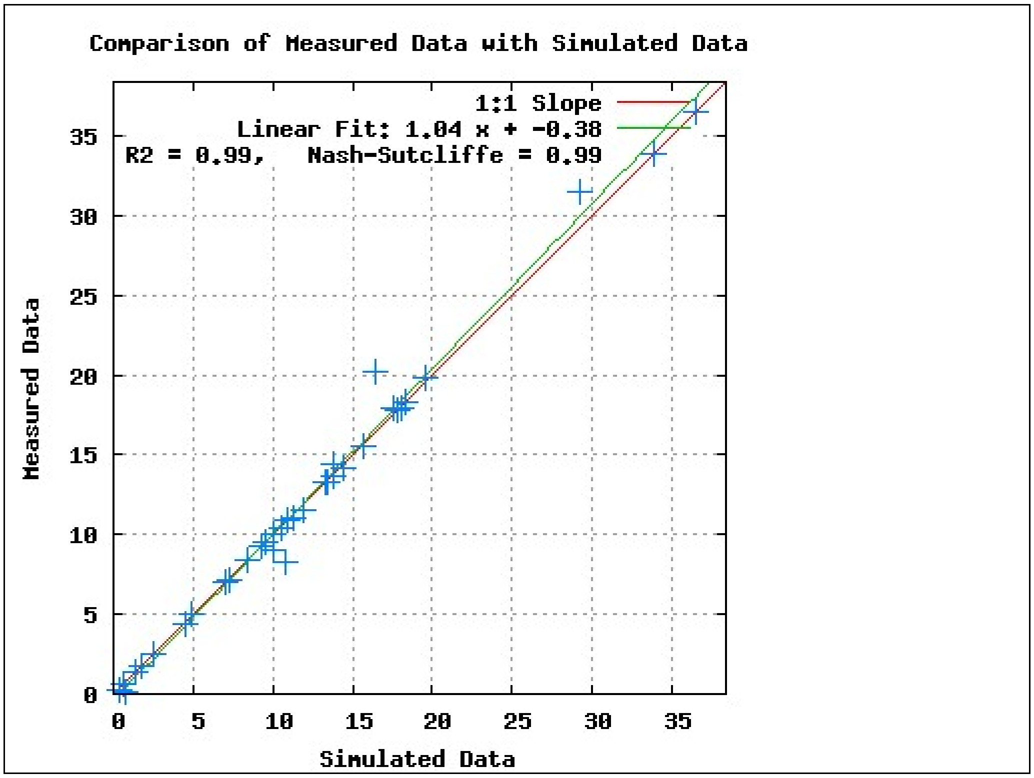

Figure 149. Gorst Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

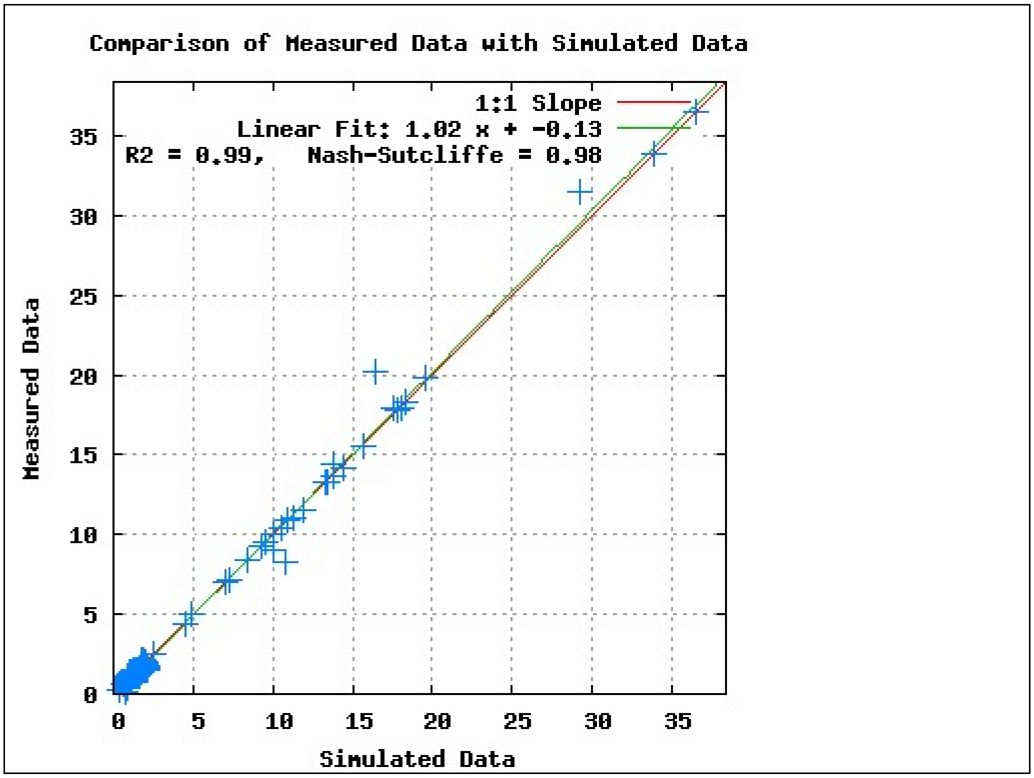

Figure 150. Gorst Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Gorst Creek HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Heins Creek	SUBURBAN	1	9.99	13.29	7.07	13.36	1	10.01	13.29	7.07	13.43	1	0.22	0.04	-0.01	0.55
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51	2	16.63	9.11	5.18	12.66	2	-7.07	-2.34	4.31	9.97
	COMMERCIAL	3	31.54	2.51	1.33	8.31	3	26.53	3.26	1.58	12.38	3	-15.88	29.73	18.98	48.94
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81	4	1.79	13.75	10.52	17.89	4	1.70	0.68	0.54	0.44
	LAWN	5	0.65	17.95	9.55	15.55	5	0.66	18.20	9.59	15.68	5	1.29	1.37	0.50	0.88
	PASTURE	6	0.31	14.23	10.89	18.27	6	0.36	14.50	10.90	18.29	6	17.27	1.90	0.04	0.14
	FOREST	7	0.10	9.07	14.37	20.16	7	1.09	9.49	14.16	16.51	7	1028.37	4.61	-1.49	-18.08
	BAREGROUND	10	19.81	8.38	4.45	11.06	10	19.63	8.37	4.48	11.32	10	-0.89	-0.14	0.49	2.29
Parish Creek	SUBURBAN	12	9.99	13.29	7.07	13.36	12	10.00	13.29	7.07	13.42	12	0.15	0.03	-0.02	0.45
	MULTI-FAMILY	13	17.89	9.33	4.96	11.51	13	17.66	9.32	4.94	11.84	13	-1.29	-0.15	-0.37	2.81
	COMMERCIAL	14	31.54	2.51	1.33	8.31	14	29.43	2.58	1.35	10.47	14	-6.71	2.71	1.33	25.98
	RURAL RESIDENTIAL	15	1.76	13.66	10.46	17.81	15	1.76	13.79	10.50	17.86	15	0.01	0.91	0.33	0.27
	LAWN	16	0.65	17.95	9.55	15.55	16	0.65	18.11	9.57	15.60	16	-0.16	0.89	0.26	0.34
	PASTURE	17	0.31	14.23	10.89	18.27	17	0.32	14.39	10.90	18.31	17	4.02	1.10	0.11	0.23
	FOREST	18	0.10	9.07	14.37	20.16	18	0.77	9.26	15.19	16.74	18	700.91	1.99	5.66	-16.94
	BAREGROUND	21	19.81	8.38	4.45	11.06	21	19.59	8.37	4.48	11.33	21	-1.12	-0.13	0.65	2.46
Gorst Creek	SUBURBAN	23	9.99	13.29	7.07	13.36	23	9.99	13.29	7.05	13.42	23	-0.02	0.01	-0.23	0.46
	MULTI-FAMILY	24	17.89	9.33	4.96	11.51	24	17.60	9.32	4.93	11.89	24	-1.65	-0.16	-0.58	3.31
	COMMERCIAL	25	31.54	2.51	1.33	8.31	25	29.19	2.55	1.34	10.73	25	-7.45	1.37	0.73	29.11
	RURAL RESIDENTIAL	26	1.76	13.66	10.46	17.81	26	1.76	13.78	10.50	17.86	26	0.02	0.89	0.30	0.23
	LAWN	27	0.65	17.95	9.55	15.55	27	0.66	18.11	9.57	15.63	27	0.24	0.88	0.28	0.51
	PASTURE	28	0.31	14.23	10.89	18.27	28	0.33	14.38	10.90	18.30	28	5.06	1.04	0.10	0.21
	FOREST	29	0.10	9.07	14.37	20.16	29	0.71	10.03	13.74	16.46	29	637.48	10.55	-4.39	-18.35
	BAREGROUND	32	19.81	8.38	4.45	11.06	32	19.54	8.36	4.50	11.34	32	-1.36	-0.15	1.07	2.50
	IMPERVIOUS - HEINS CK	111	36.57			7.13	111	36.64			7.10	111	0.18			-0.40
	IMPERVIOUS - PARISH CK	121	36.57			7.13	121	36.74			7.01	121	0.47			-1.65
	IMPERVIOUS - GORST CK	131	36.57			7.13	131	36.47			7.28	131	-0.28			2.07

Table 56. Comparison of simulated and observed targets for the partition of average annual precipitation.

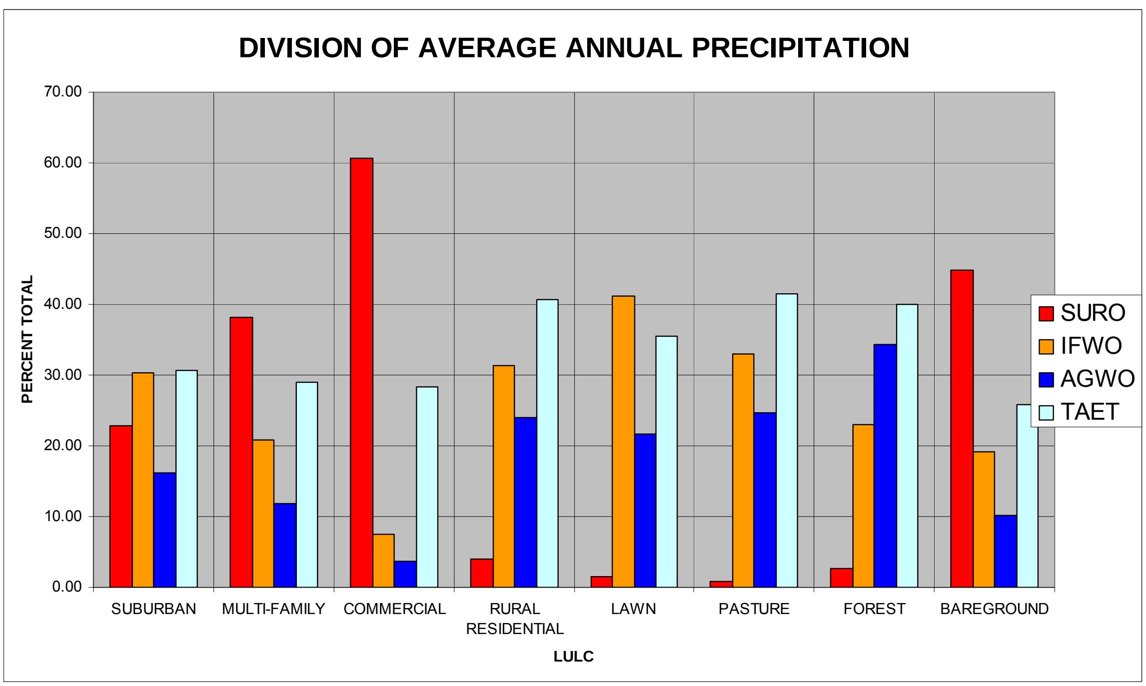

Figure 151. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Heins Creek.

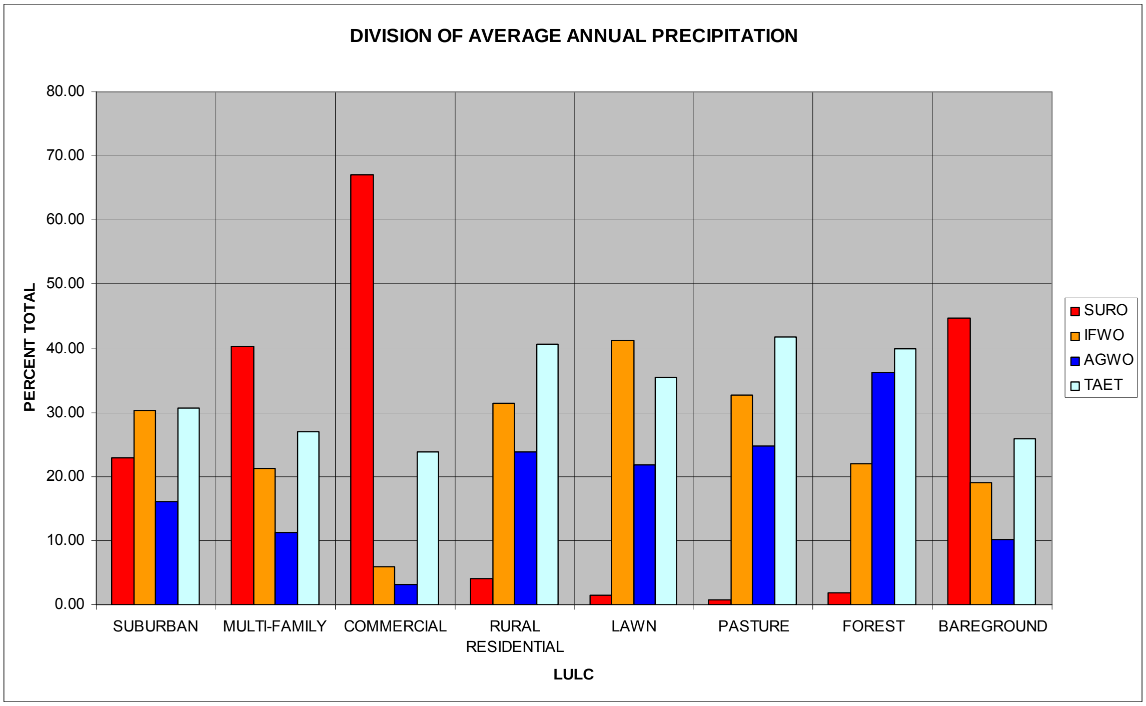

Figure 152. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Parish Creek.

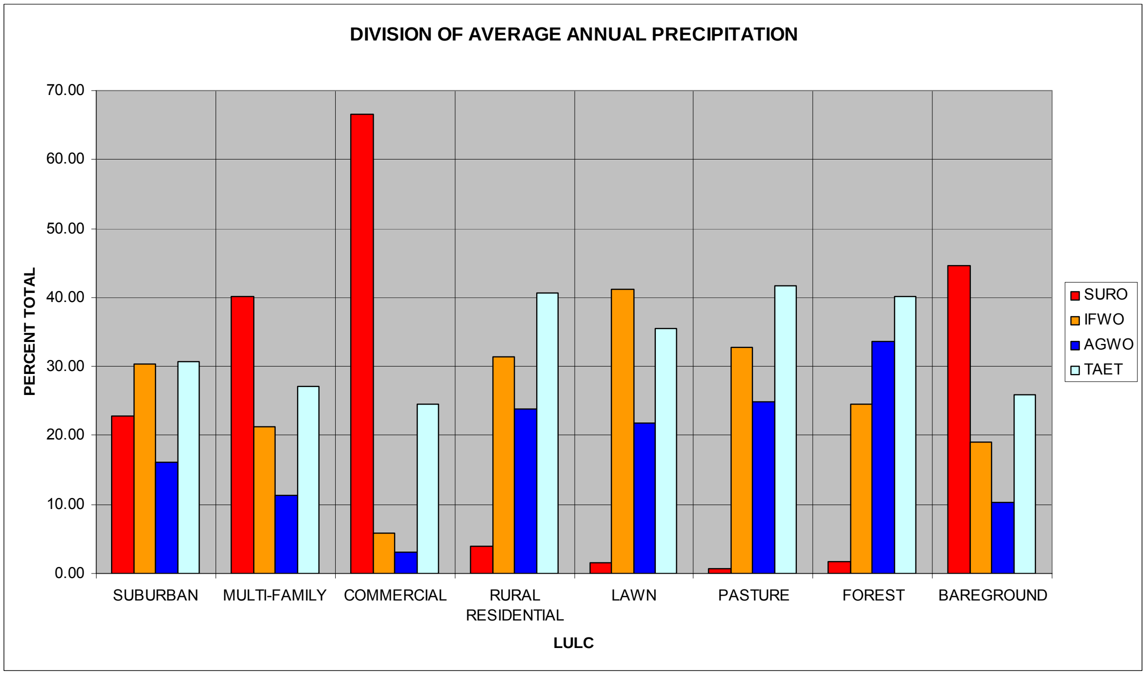

Figure 153. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Gorst Creek.

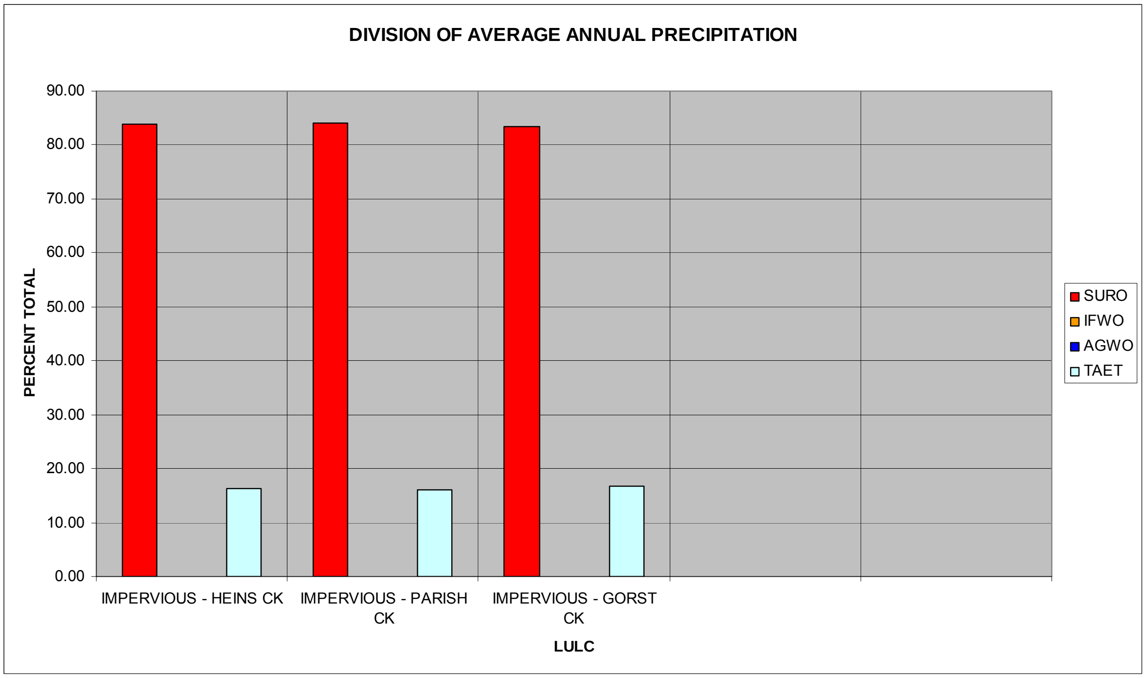

Figure 154. Simulated SURO and TAET for the impervious area for Gorst Creek.

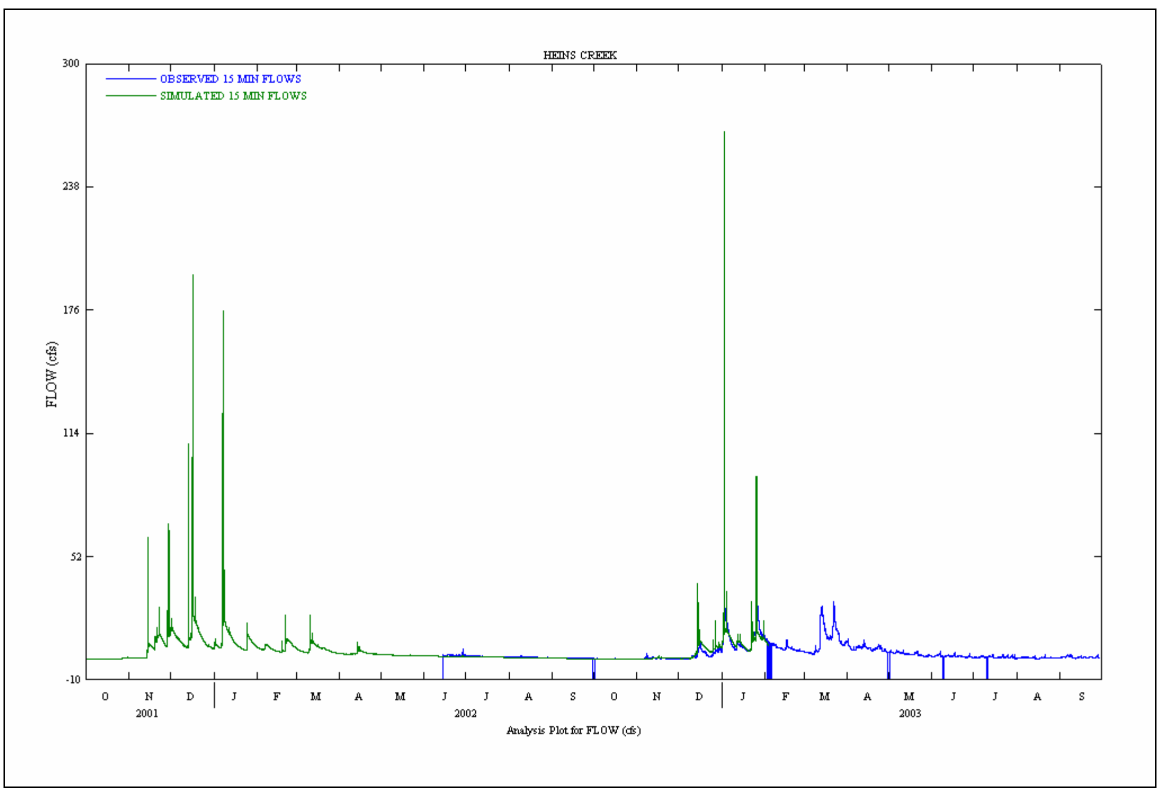

Figure 155. Compare of simulated and observed 15 minute flows for Heins Creek.

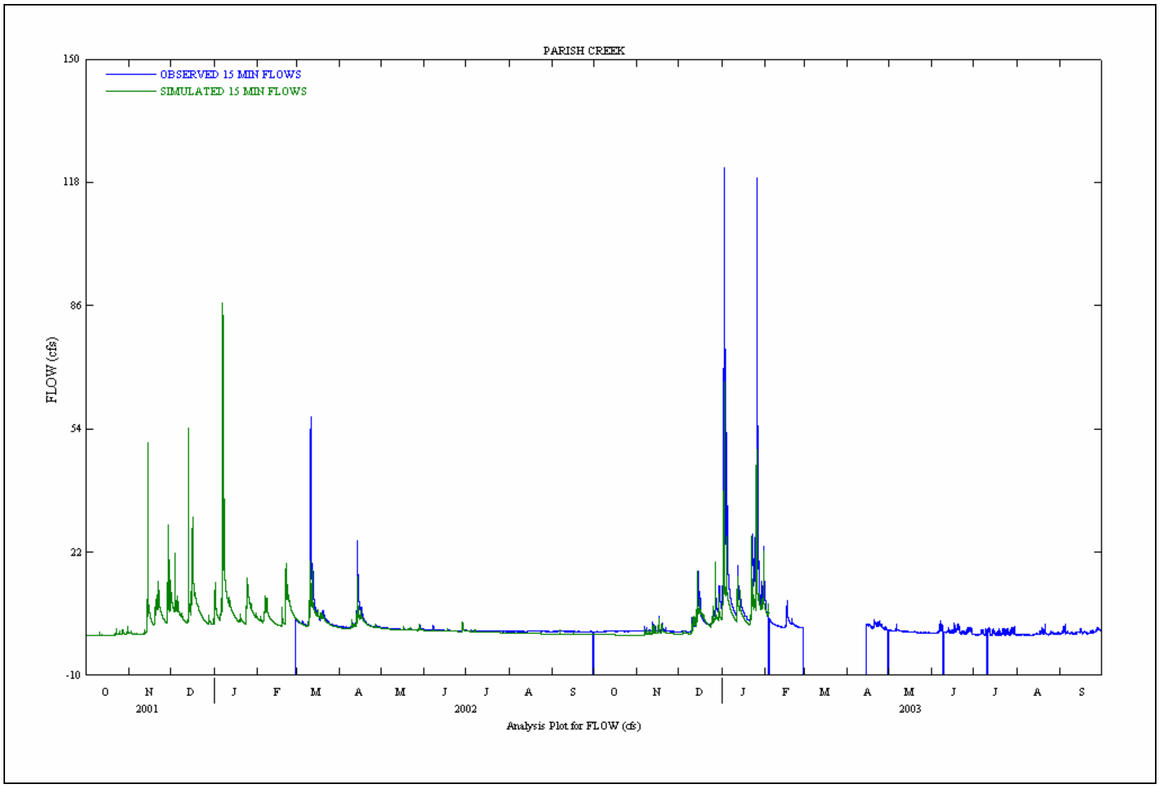

Figure 156. Compare of simulated and observed 15 minute flows for Parish Creek.

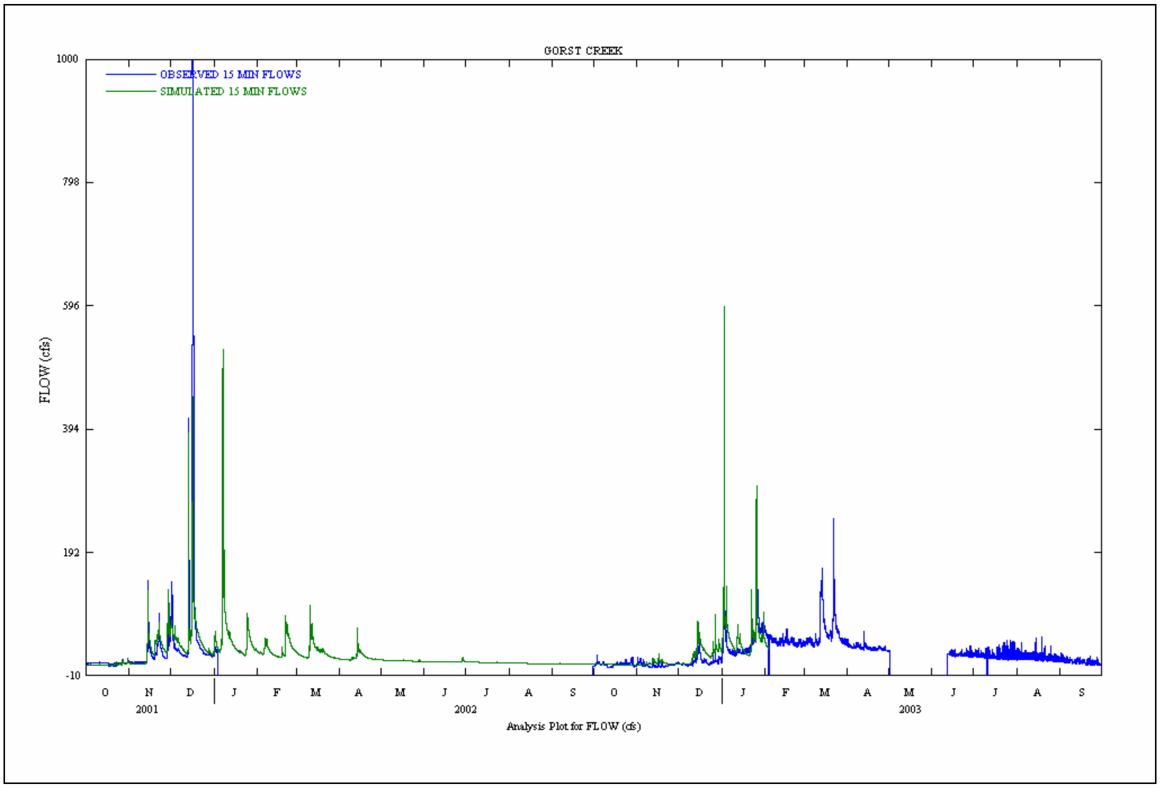

Figure 157. Compare of simulated and observed 15 minute flows for Gorst Creek.

5.3.9 Springbrook Creek

The calibration inversion run terminated after 2727 model calls, which resulted in reducing the objective function from a starting value of 335.78 to a final value of 18.43. Table 57 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 58 and Figures 158 – 164 suggest that the calibrated Springbrook Creek HSPF hydrologic model is predictive (at the 15 minute and daily time scale). The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

SPRINGBROOK CREEK ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.2300
IMP3	0.9567
IMP4	0.1000

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Springbrook Creek	SUBURBAN	1	5.04	0.0200	9.72	0.0062	0.0094	0.2165	0.5000	1.63345	0.538776	0.100145
	MULTI-FAMILY	2	3.57	0.0156	18.92	0.0087	0.0096	0.1579	0.0862	1.41011	0.699698	0.1
	COMMERCIAL	3	5.20	0.0061	18.42	0.0090	0.0087	0.2360	0.0575	1	0.682684	0.1
	RURAL RESIDENTIAL	4	4.30	0.0539	14.34	0.0019	0.0101	0.3535	0.1053	2.45635	0.615473	0.38465
	LAWN	5	3.87	0.0454	15.72	0.0052	0.0100	0.2847	0.1133	4.548	0.3	0.223495
	PASTURE	6	7.19	0.0574	6.20	0.0056	0.0155	0.3213	0.0797	4.40467	0.319609	0.298374
	FOREST	7	10.42	0.0977	50.71	0.0036	0.2000	1.0305	0.5000	1	0.3	0.3
	BAREGROUND	10	3.40	0.0127	13.95	0.0089	0.0098	0.1631	0.2118	1.24359	0.400096	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - SPRINGBROOK CK	111	0.1500	0.0954

Table 57. Identified model resulting from calibration inversion run.

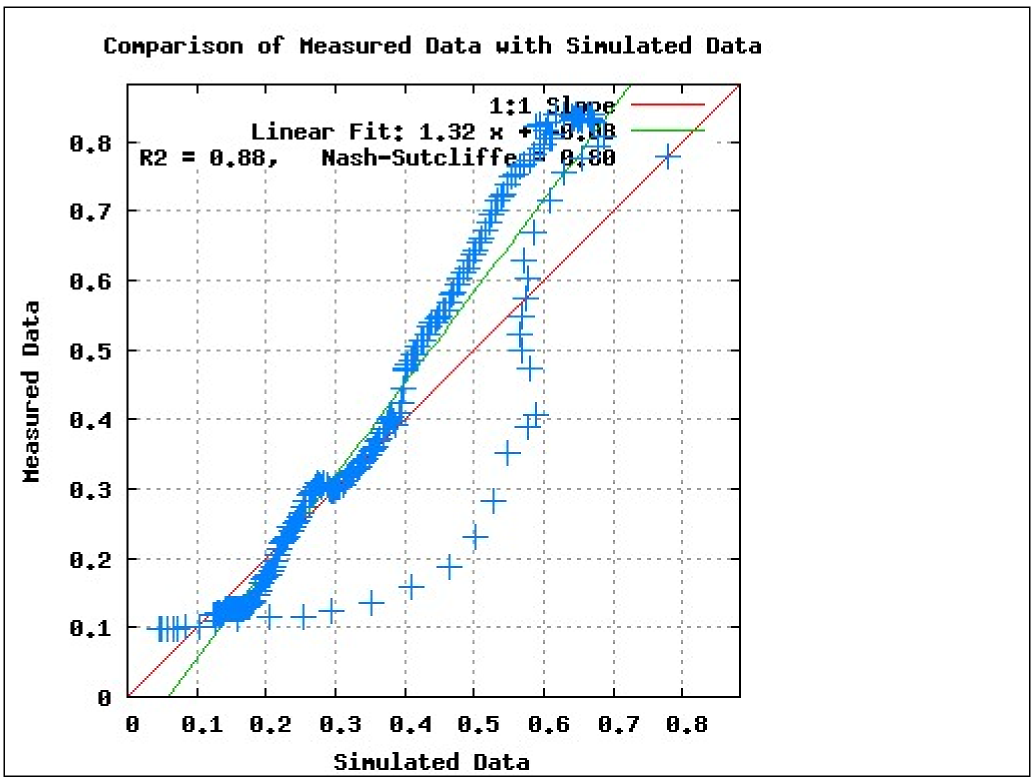

Figure 158. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Springbrook Creek HSPF hydrologic model.

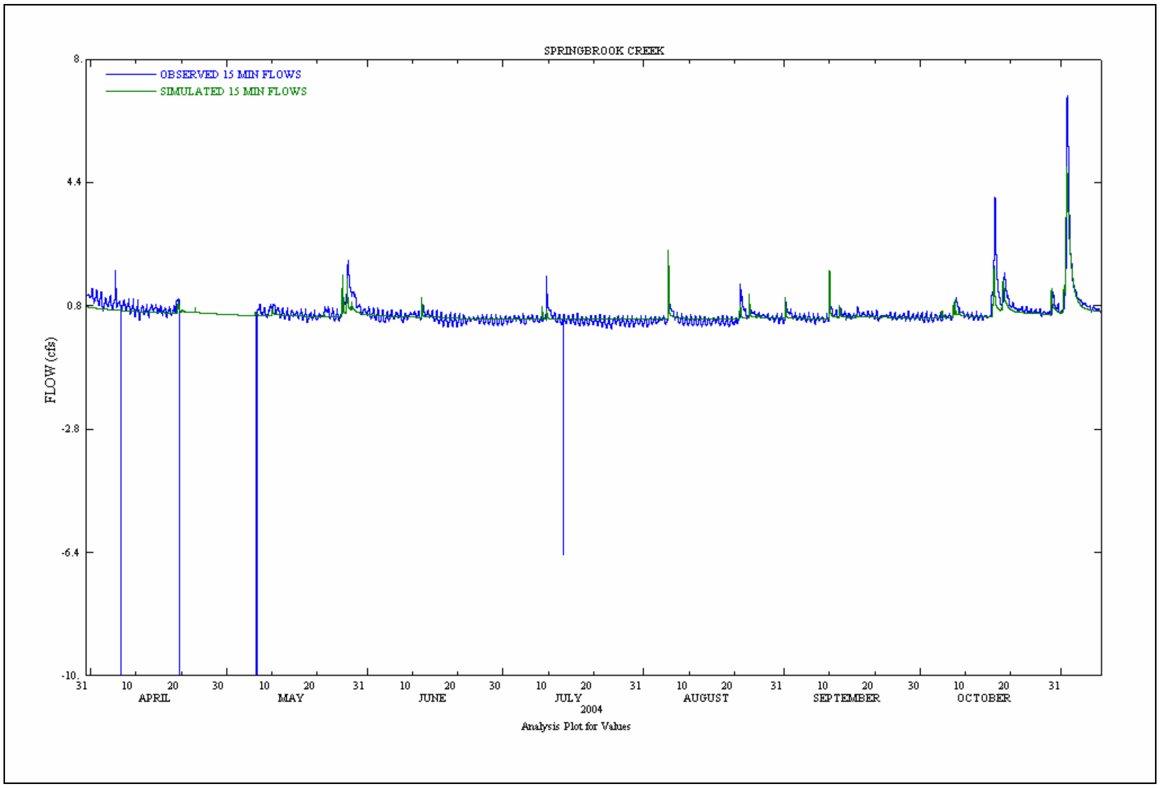

Figure 159. Comparison of simulated and observed 15 minute flow data for the Springbrook Creek HSPF hydrologic model.

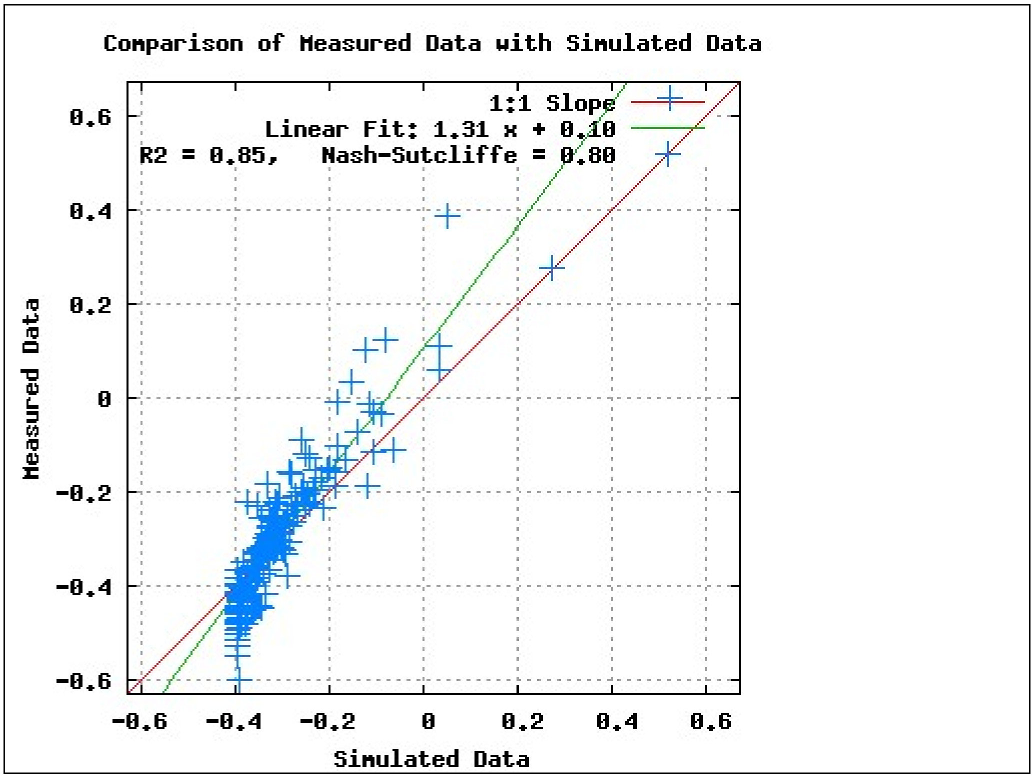

Figure 160. Comparison of simulated and observed Mean Daily flow data that was used to calibrate the Springbrook Creek HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Springbrook Creek	SUBURBAN	1	9.99	13.29	7.07	13.36	1	9.72	13.19	6.81	13.44	1	-2.72	-0.71	-3.64	0.56
	MULTI-FAMILY	2	17.89	9.33	4.96	11.51	2	16.05	9.34	5.07	12.80	2	-10.29	0.12	2.10	11.18
	COMMERCIAL	3	31.54	2.51	1.33	8.31	3	23.45	3.23	2.90	13.70	3	-25.66	28.46	117.56	64.76
	RURAL RESIDENTIAL	4	1.76	13.66	10.46	17.81	4	1.69	13.19	10.44	17.79	4	-3.84	-3.43	-0.27	-0.16
	LAWN	5	0.65	17.95	9.55	15.55	5	0.66	17.49	9.52	15.48	5	0.42	-2.60	-0.26	-0.45
	PASTURE	6	0.31	14.23	10.89	18.27	6	0.39	13.53	10.89	18.24	6	24.12	-4.95	-0.02	-0.11
	FOREST	7	0.10	9.07	14.37	20.16	7	2.36	10.58	14.56	13.77	7	2346.48	16.58	1.31	-31.68
	BAREGROUND	10	19.81	8.38	4.45	11.06	10	17.56	8.38	5.04	12.27	10	-11.36	0.09	13.18	10.89
	IMPERVIOUS - SPRINGBROOK CK	111	36.57			7.13	111	36.42			7.08	111	-0.40			-0.79

Table 58. Comparison of simulated and observed targets for the partition of average annual precipitation.

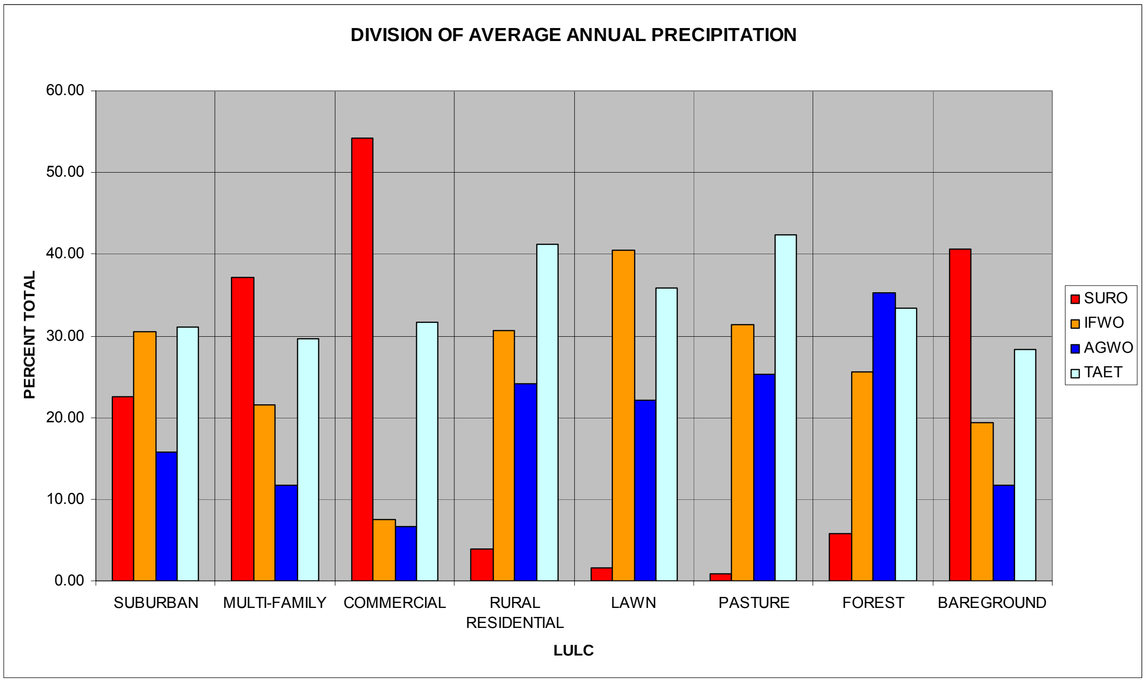

Figure 161. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Springbrook Creek.

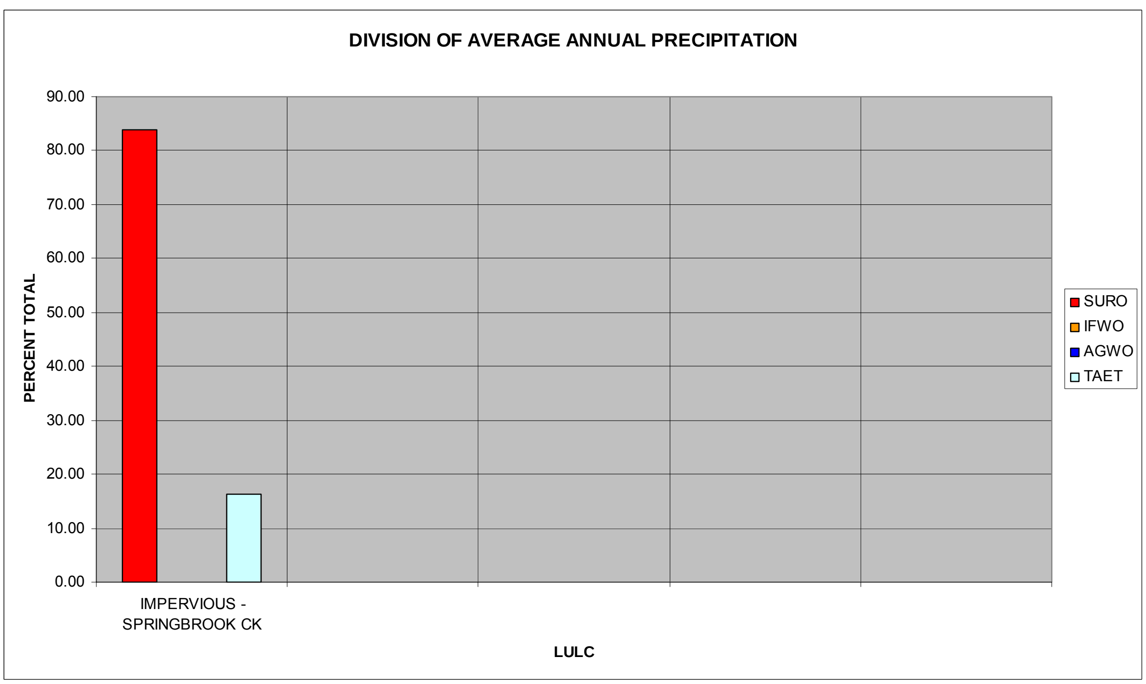

Figure 162. Simulated SURO and TAET for the impervious area for Springbrook Creek.

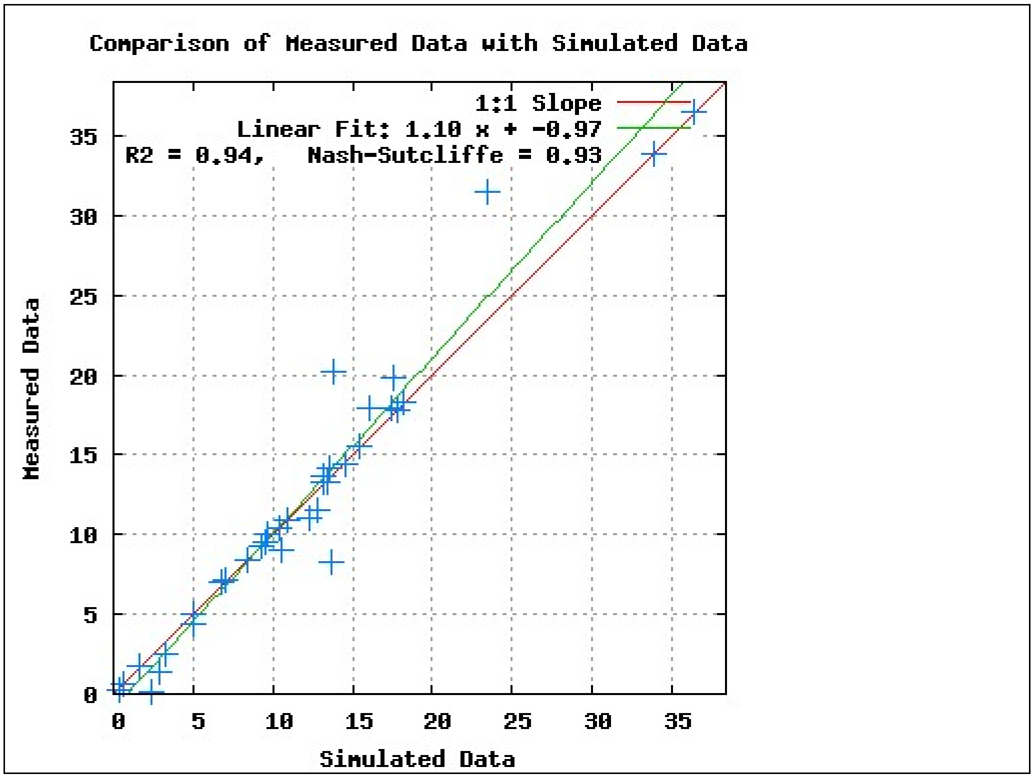

Figure 163. Springbrook Creek - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

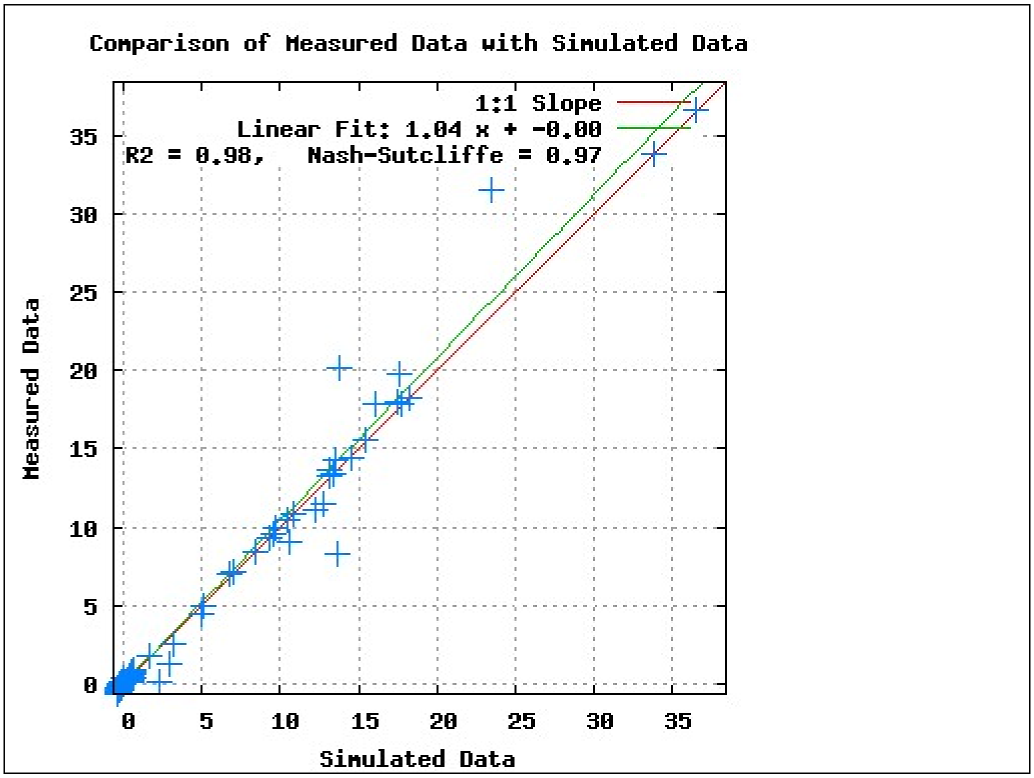

Figure 164. Springbrook Creek - Comparison of all the data, simulated and observed, (15 minute flow, mean daily, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Springbrook Creek HSPF hydrologic model.

5.3.10 BST 12

There are no hydrologic model calibration results to report for BST 12 (see section 5.2.10).

5.3.11 BST 01

The calibration inversion run terminated after 3554 model calls, which resulted in reducing the objective function from a starting value of 6385.9 to a final value of 801.3. Table 59 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 60 and Figures 165 – 170 suggest that the calibrated BST 01 HSPF hydrologic model is predictive. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

BST01 ADJUSTABLE MODEL PARAMETERS

IMP1	0.1100
IMP2	0.1900
IMP3	0.9750
IMP4	0.1000

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
BST01	SUBURBAN	1	15.00	0.0249	5.00	0.0031	0.0104	0.0500	0.0500	1.43784	0.3	0.271287
	MULTI-FAMILY	2	13.95	0.0142	49.09	0.0031	0.0292	0.0500	0.2224	1.09257	0.3	0.187736
	COMMERCIAL	3	6.88	0.0031	7.34	0.0237	0.0056	0.0827	0.2806	1	0.3	0.1
	RURAL RESIDENTIAL	4	13.98	0.0495	37.49	0.0022	0.0239	0.0721	0.0762	2.10534	0.3	0.389797
	LAWN	5	3.69	0.0423	26.19	0.0084	0.0117	0.2862	0.1085	4.01958	0.3	0.327466
	PASTURE	6	4.96	0.0747	70.07	0.0090	0.0163	0.0833	0.1068	2.87648	0.3	0.691806
	FOREST	7	2.14	0.2234	133.13	0.0132	0.2000	0.1894	0.0849	1.62725	0.3	0.9
	BAREGROUND	10	4.60	0.0112	19.83	0.0094	0.0097	0.1590	0.0769	1.24509	0.700004	0.103609

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - BST01	111	0.1500	0.1055

Table 59. Identified model resulting from calibration inversion run.

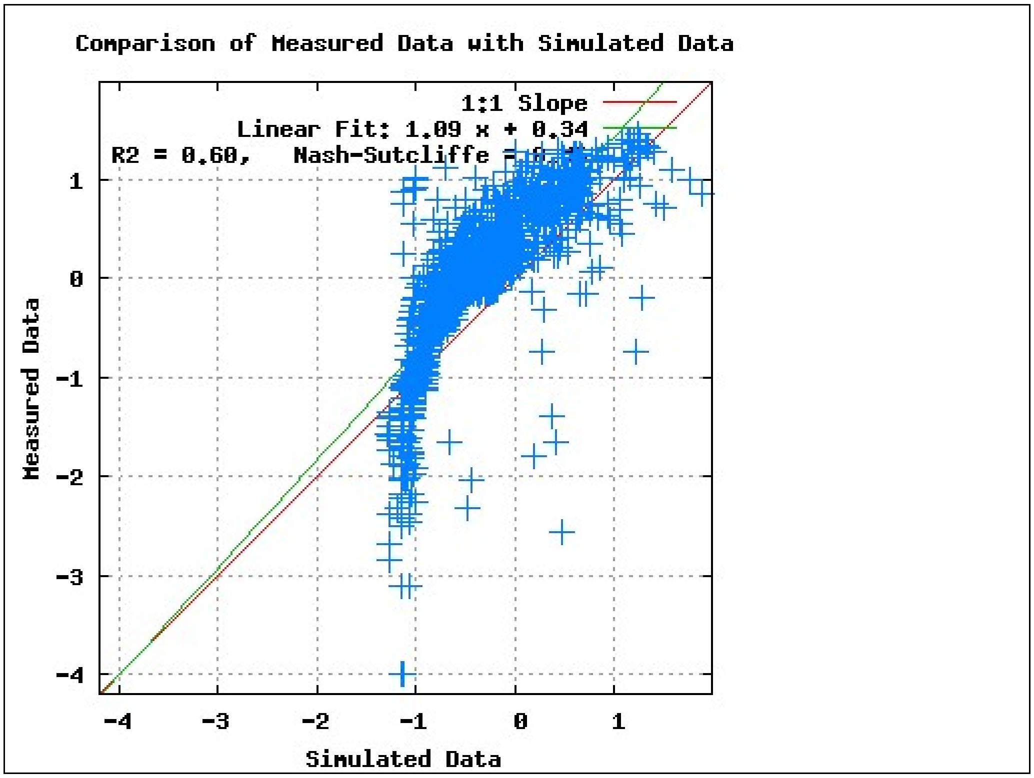

Figure 165. Comparison of simulated and observed 15 minute flow data that was used to calibrate the BST01 HSPF hydrologic model.

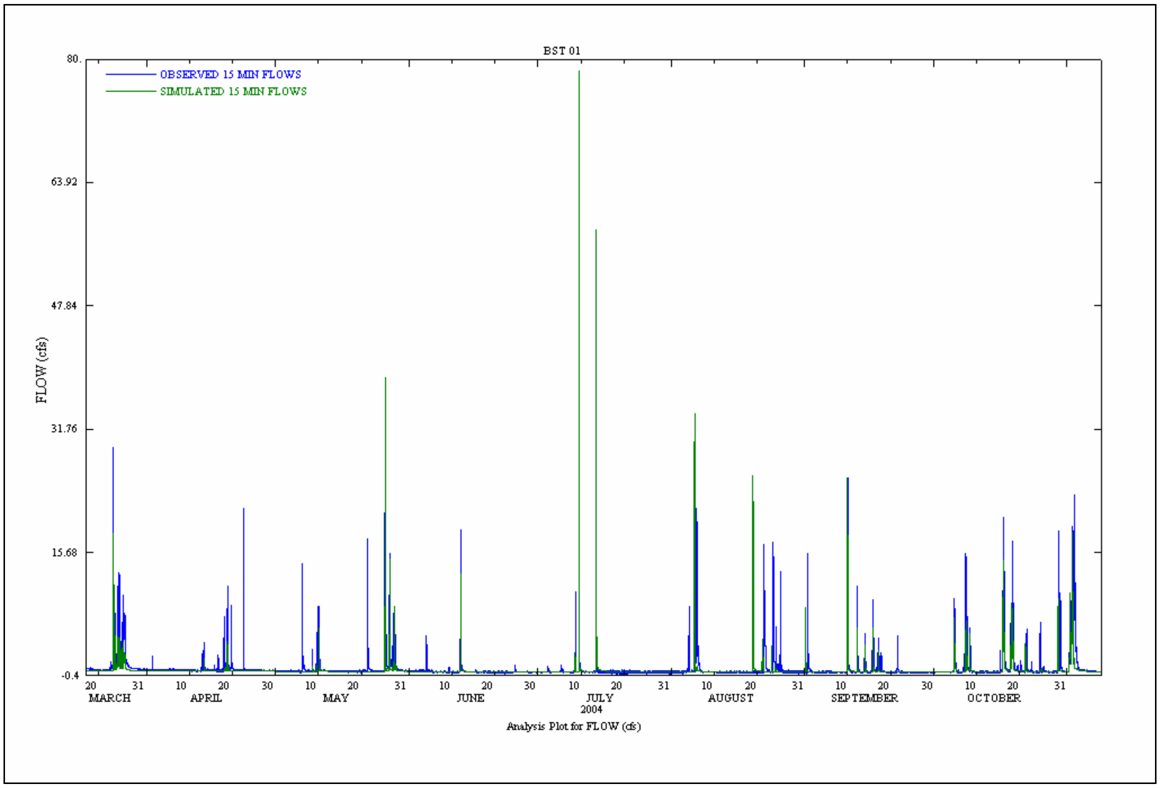

Figure 166. Comparison of simulated and observed 15 minute flow data for BST01 HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
BST01	SUBURBAN	1	10.88	14.47	7.70	14.55	1	10.48	13.72	7.73	15.23	1	-3.63	-5.13	0.50	4.71
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	18.33	9.75	5.41	13.60	2	-5.92	-4.04	0.15	8.46
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	29.94	3.40	2.04	11.88	3	-12.85	24.21	40.99	31.29
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.89	14.78	11.09	19.46	4	-1.38	-0.64	-2.69	0.31
	LAWN	5	0.71	19.55	10.39	16.93	5	0.77	19.26	10.35	16.88	5	8.13	-1.47	-0.44	-0.27
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.43	14.90	12.01	19.87	6	27.60	-3.85	1.28	-0.11
	FOREST	7	0.11	9.88	15.65	21.95	7	0.28	9.67	15.41	21.65	7	168.98	-2.16	-1.54	-1.36
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	20.83	8.80	5.10	12.46	10	-3.44	-3.58	5.24	3.42
	IMPERVIOUS - BST01	111	39.82			7.77	111	39.64			7.75	111	-0.45			-0.26

Table 60. Comparison of simulated and observed targets for the partition of average annual precipitation.

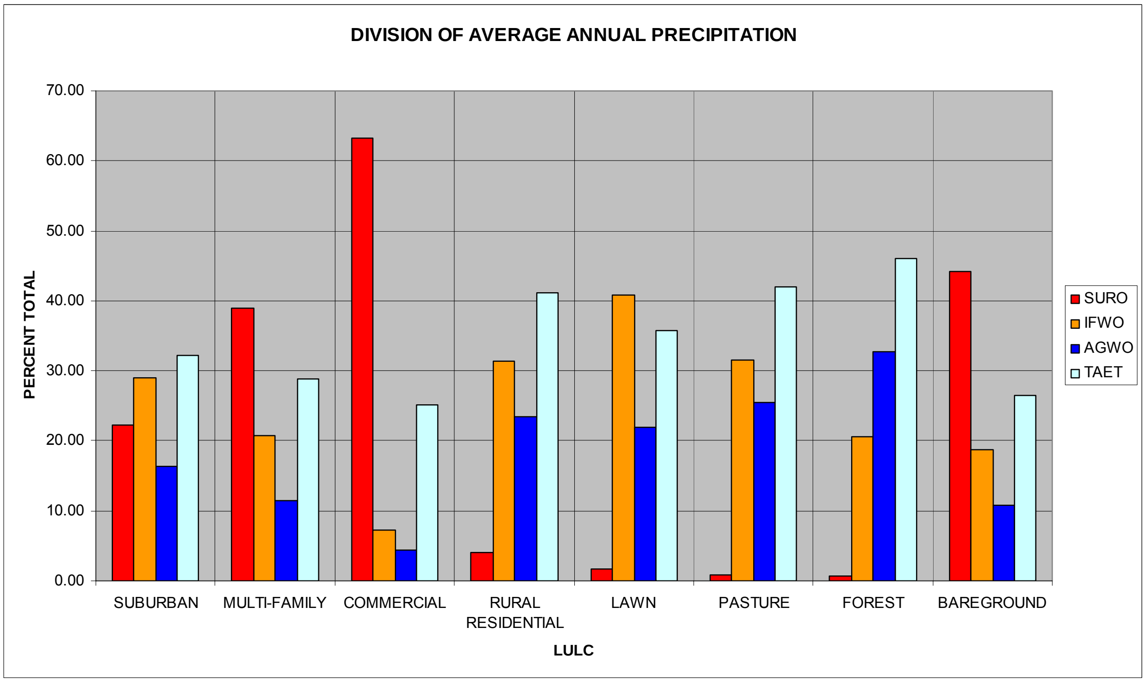

Figure 167. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at BST 01.

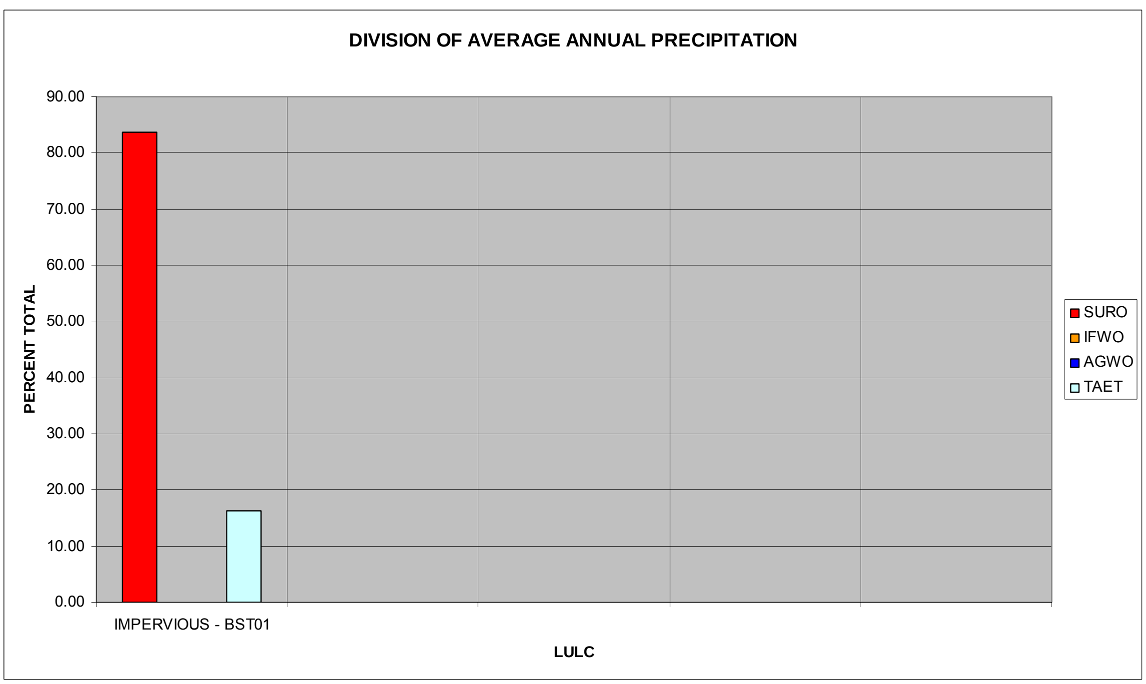

Figure 168. Simulated SURO and TAET for the impervious area for BST 01.

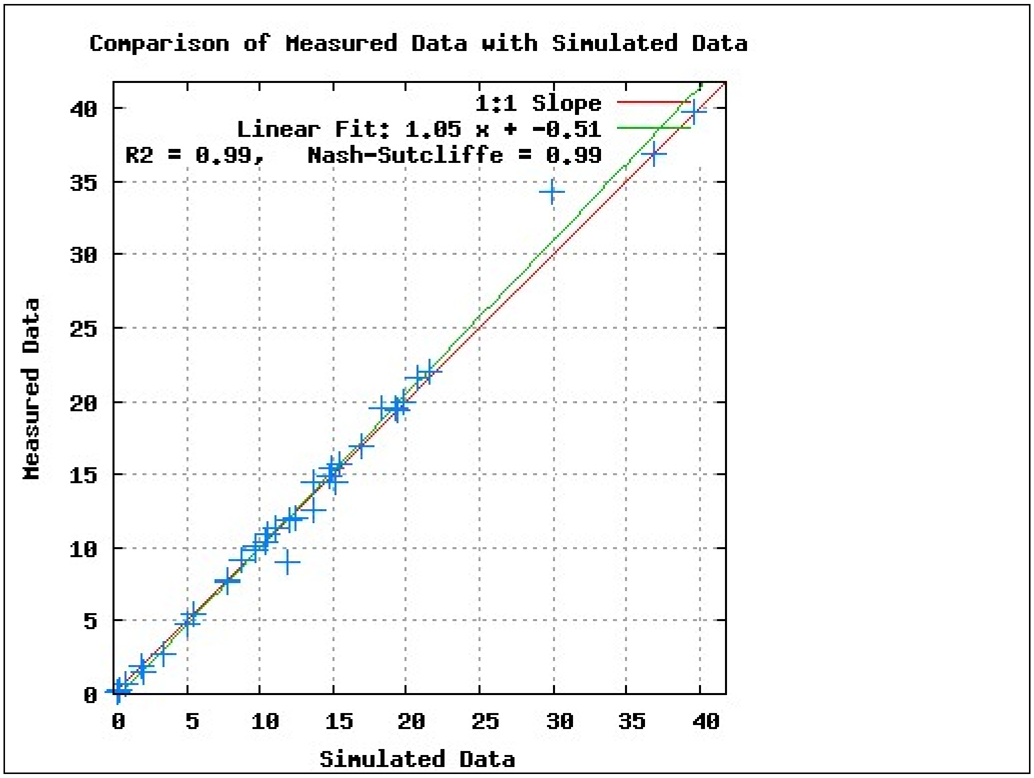

Figure 169. BST01 - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

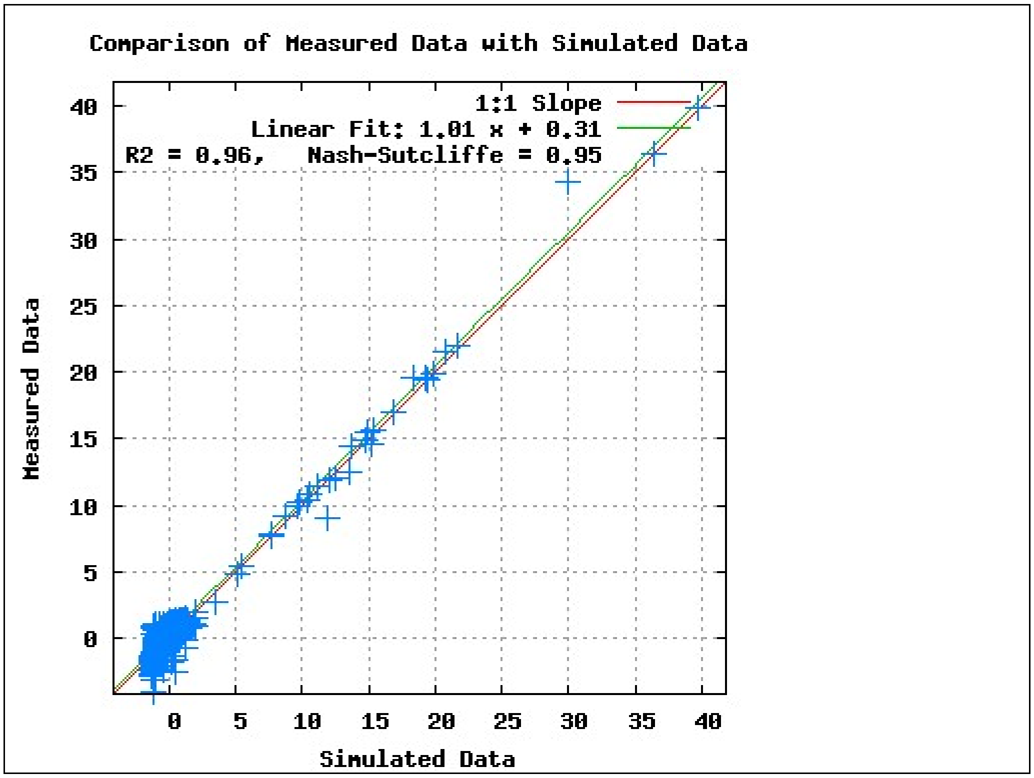

Figure 170. BST01 - Comparison of all the data, simulated and observed, (15 minute flow, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the BST01 HSPF hydrologic model.

5.3.12 LMK001

The calibration inversion run terminated after 2160 model calls, which resulted in reducing the objective function from a starting value of 604.61 to a final value of 36.94. Table 61 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 62 and Figures 171 – 175 suggest that the calibrated LMK001 HSPF hydrologic model is marginally predictive. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

LMK001 ADJUSTABLE MODEL PARAMETERS

IMP1	0.1739
IMP2	0.1900
IMP3	0.7720
IMP4	0.0850

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
LMK001	SUBURBAN	1	2.53	0.0225	12.28	0.0062	0.0121	0.1847	0.0971	1.66565	0.42977	0.224308
	MULTI-FAMILY	2	2.63	0.0129	54.84	0.0081	0.0057	0.1241	0.0851	1.36267	0.568662	0.10337
	COMMERCIAL	3	6.00	0.0020	11.59	0.0085	0.0098	0.0500	0.0530	1.10686	0.644031	0.1
	RURAL RESIDENTIAL	4	5.44	0.0459	19.50	0.0021	0.0095	0.2852	0.0955	1.96391	0.699649	0.489078
	LAWN	5	6.44	0.0419	7.79	0.0030	0.0106	0.1214	0.1438	3.41233	0.3	0.335372
	PASTURE	6	5.40	0.0602	19.61	0.0023	0.0098	0.2981	0.1228	6.49053	0.708146	0.483932
	FOREST	7	6.31	0.1115	5.00	0.0015	0.0136	0.1790	0.0500	6.01542	0.82119	0.549047
	BAREGROUND	10	2.12	0.0101	19.94	0.0084	0.0097	0.1393	0.0791	1.33688	0.699981	0.11672

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - LMK001	111	0.1500	0.1066

Table 61. Identified model resulting from calibration inversion run.

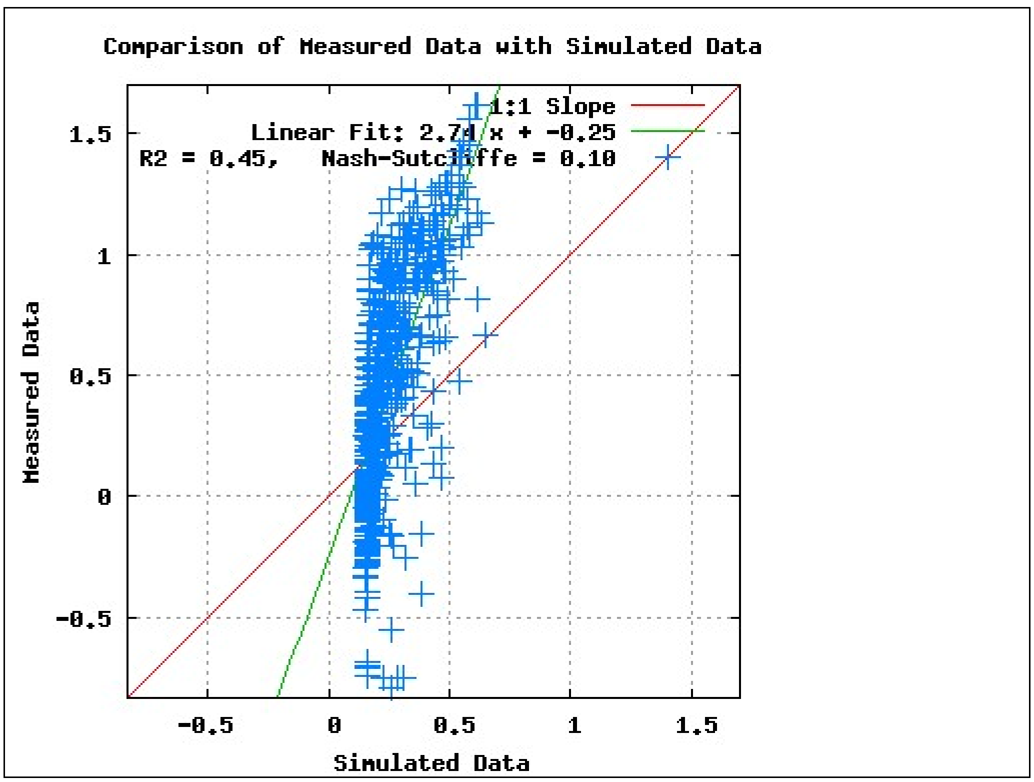

Figure 171. Comparison of simulated and observed 15 minute flow data that was used to calibrate the LMK001 HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
LMK001	SUBURBAN	1	10.88	14.47	7.70	14.55	1	9.76	14.31	7.16	14.34	1	-10.25	-1.10	-6.89	-1.44
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	17.95	10.16	5.06	12.34	2	-7.85	-0.06	-6.30	-1.54
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	31.40	2.54	0.98	10.77	3	-8.59	-7.27	-32.12	18.95
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.91	13.53	10.90	19.29	4	-0.32	-9.05	-4.35	-0.57
	LAWN	5	0.71	19.55	10.39	16.93	5	0.67	17.94	10.13	16.83	5	-5.37	-8.25	-2.51	-0.61
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.20	13.95	11.73	19.75	6	-39.76	-10.00	-1.10	-0.71
	FOREST	7	0.11	9.88	15.65	21.95	7	0.18	9.68	14.75	21.02	7	72.17	-2.06	-5.75	-4.21
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	20.06	9.11	4.45	11.94	10	-6.98	-0.14	-8.30	-0.90
	IMPERVIOUS - LMK001	111	39.82			7.77	111	37.85			7.76	111	-4.95			-0.04

Table 62. Comparison of simulated and observed targets for the partition of average annual precipitation.

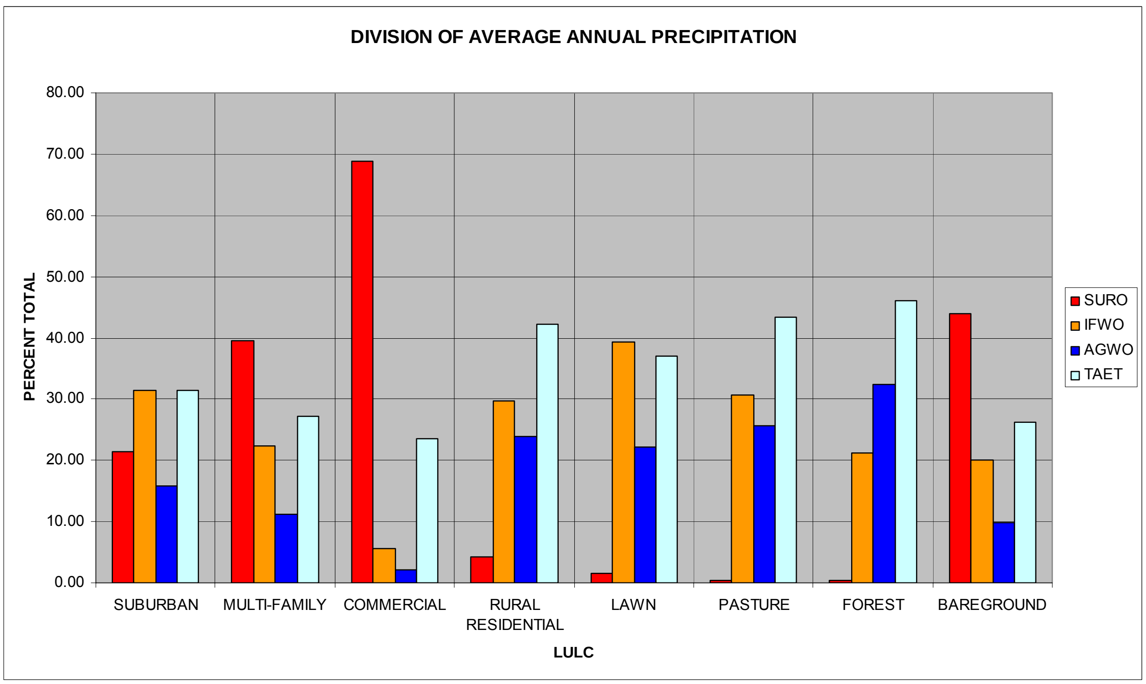

Figure 172. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at LMK001.

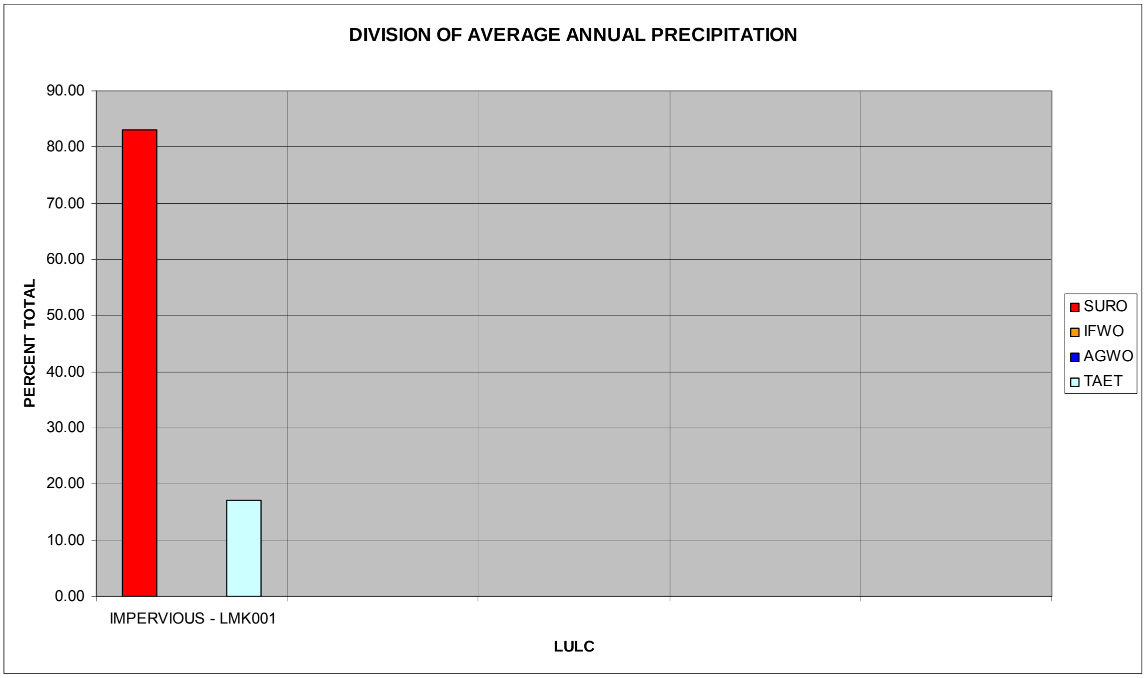

Figure 173. Simulated SURO and TAET for the impervious area for LMK001.

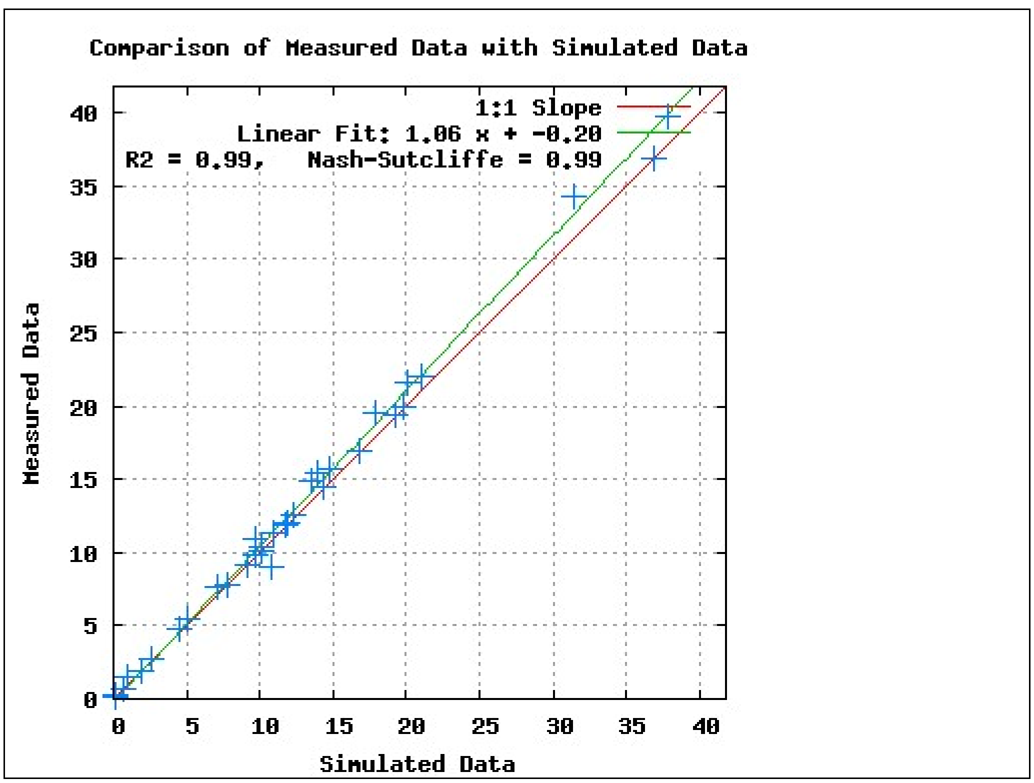

Figure 174. LMK001 - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

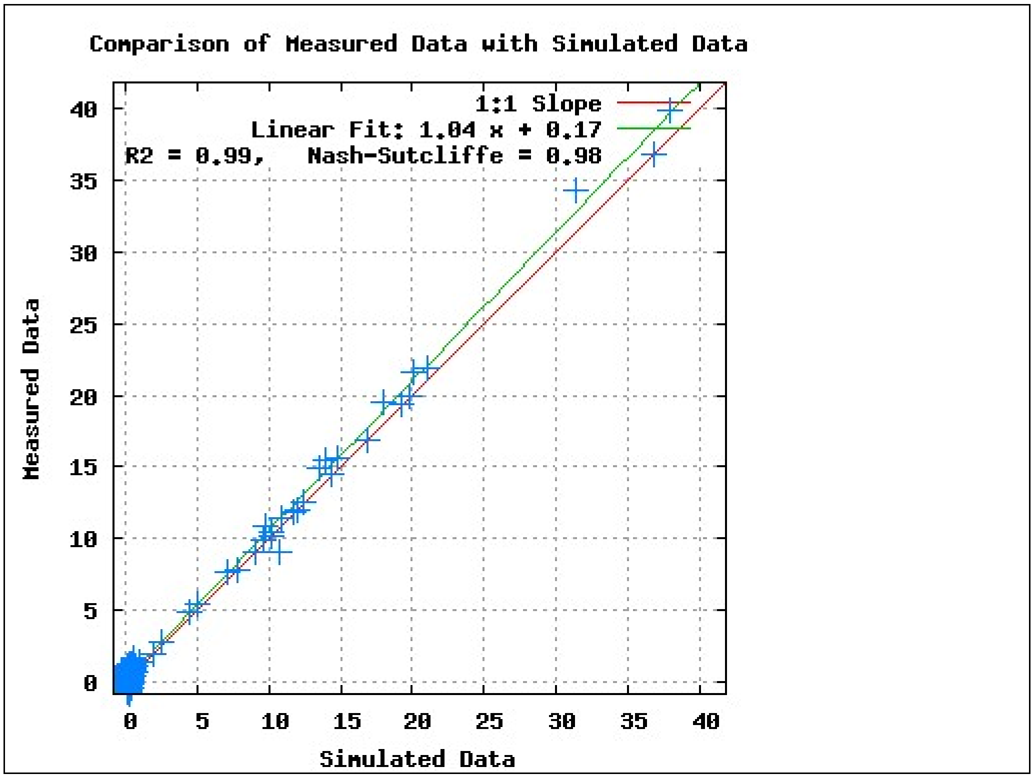

Figure 175. LMK001 - Comparison of all the data, simulated and observed, (15 minute flow, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the LMK001 HSPF hydrologic model.

5.3.13 LMK002

The calibration inversion run terminated after 2006 model calls, which resulted in reducing the objective function from a starting value of 3538.4 to a final value of 209.4. Table 63 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 64 and Figures 176 – 180 suggest that the calibrated LMK002 HSPF hydrologic model is marginally predictive. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

LMK002 ADJUSTABLE MODEL PARAMETERS

IMP1	0.1500
IMP2	0.2300
IMP3	0.9314
IMP4	0.0850

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
LMK002	SUBURBAN	1	2.00	0.0235	19.69	0.0059	0.0096	0.2251	0.0928	1.74022	0.699583	0.250867
	MULTI-FAMILY	2	6.13	0.0144	5.00	0.0020	0.0346	5.0000	0.0500	1.31429	0.469929	0.164562
	COMMERCIAL	3	11.43	0.0017	15.29	0.0625	0.0056	5.0000	0.0645	1.21295	0.769833	0.1
	RURAL RESIDENTIAL	4	5.24	0.0462	19.66	0.0024	0.0097	0.3205	0.1039	2.1603	0.696407	0.499934
	LAWN	5	3.31	0.0422	19.85	0.0050	0.0099	0.3299	0.1124	4.13123	0.697606	0.410433
	PASTURE	6	5.29	0.0595	19.84	0.0028	0.0098	0.3213	0.1474	7.13408	0.698501	0.49235
	FOREST	7	5.76	0.1006	19.87	0.0018	0.0096	0.3500	0.1737	7.18949	0.697818	0.549141
	BAREGROUND	10	2.00	0.0104	19.57	0.0060	0.0090	0.1392	0.0724	1.39908	0.700551	0.136356

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - LMK002	111	0.0473	0.1071

Table 63. Identified model resulting from calibration inversion run.

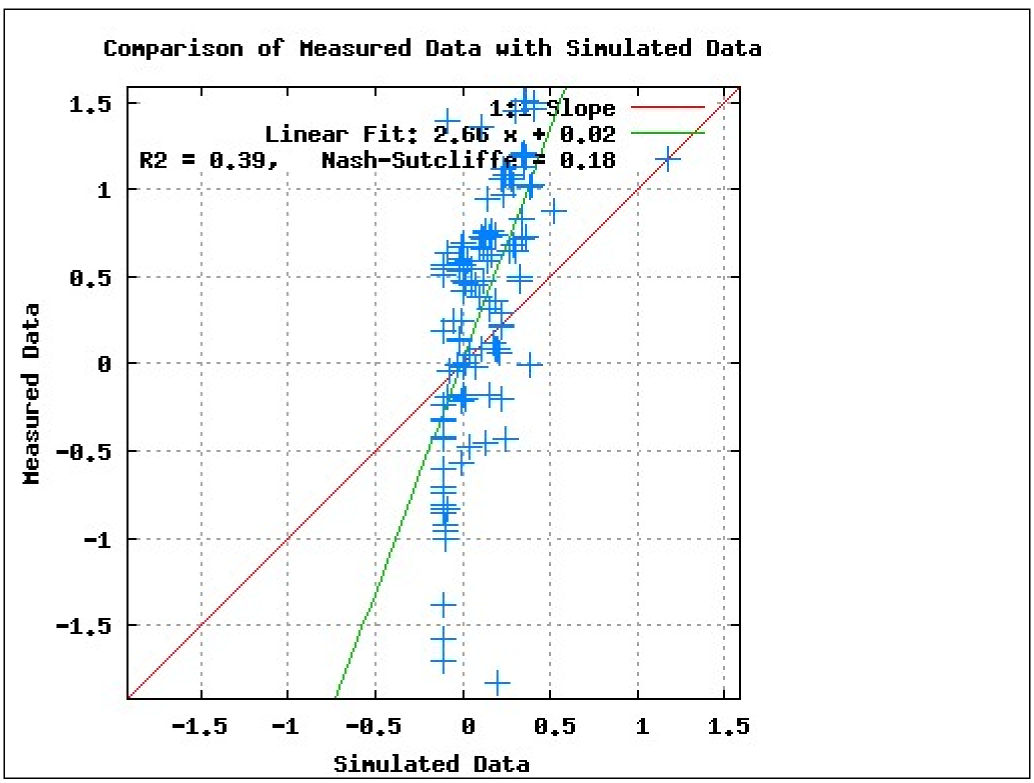

Figure 176. Comparison of simulated and observed 15 minute flow data that was used to calibrate the LMK002 HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
LMK002	SUBURBAN	1	10.88	14.47	7.70	14.55	1	9.83	14.26	7.15	14.34	1	-9.58	-1.44	-7.03	-1.45
	MULTI-FAMILY	2	19.48	10.16	5.40	12.54	2	17.94	10.16	5.03	12.36	2	-7.91	0.02	-6.90	-1.38
	COMMERCIAL	3	34.35	2.74	1.45	9.05	3	31.80	2.57	0.79	10.66	3	-7.41	-5.91	-45.64	17.79
	RURAL RESIDENTIAL	4	1.92	14.88	11.39	19.40	4	1.87	13.46	10.99	19.31	4	-2.68	-9.54	-3.52	-0.47
	LAWN	5	0.71	19.55	10.39	16.93	5	0.64	17.89	10.17	16.89	5	-10.59	-8.48	-2.18	-0.23
	PASTURE	6	0.34	15.50	11.86	19.89	6	0.11	13.96	11.76	19.80	6	-68.42	-9.90	-0.87	-0.46
	FOREST	7	0.11	9.88	15.65	21.95	7	0.07	9.81	14.69	21.05	7	-32.11	-0.72	-6.15	-4.08
	BAREGROUND	10	21.57	9.12	4.85	12.05	10	20.10	9.11	4.44	11.94	10	-6.84	-0.12	-8.50	-0.91
	IMPERVIOUS - LMK002	111	39.82			7.77	111	37.85			7.76	111	-4.95			-0.04

Table 64. Comparison of simulated and observed targets for the partition of average annual precipitation.

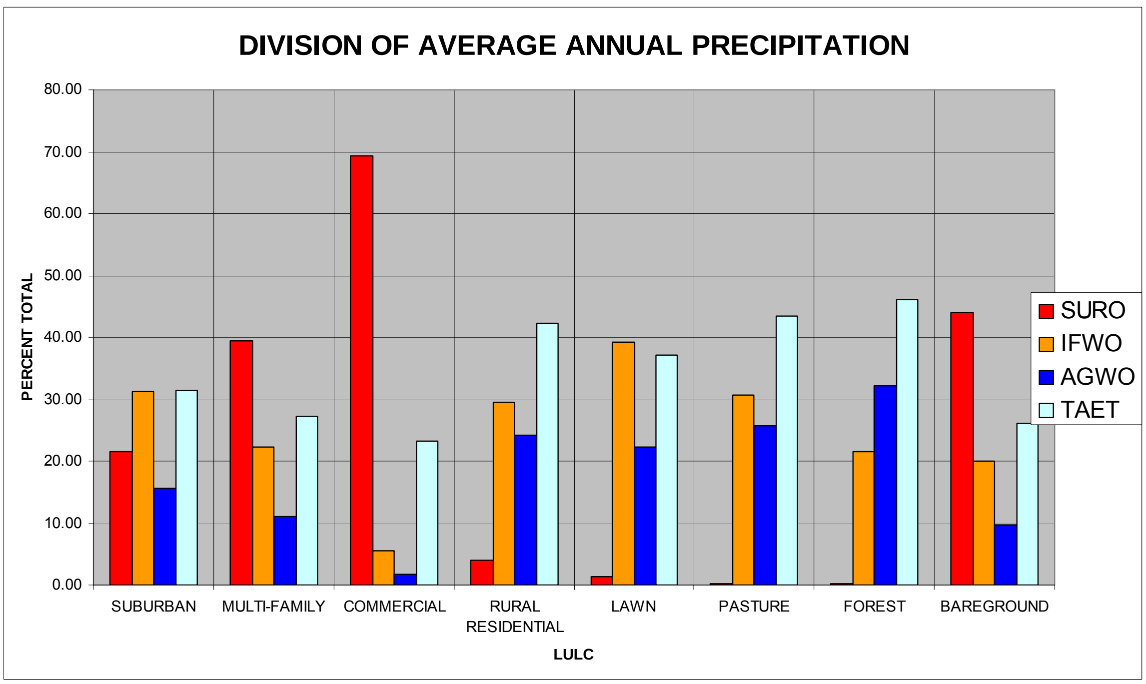

Figure 177. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at LMK002.

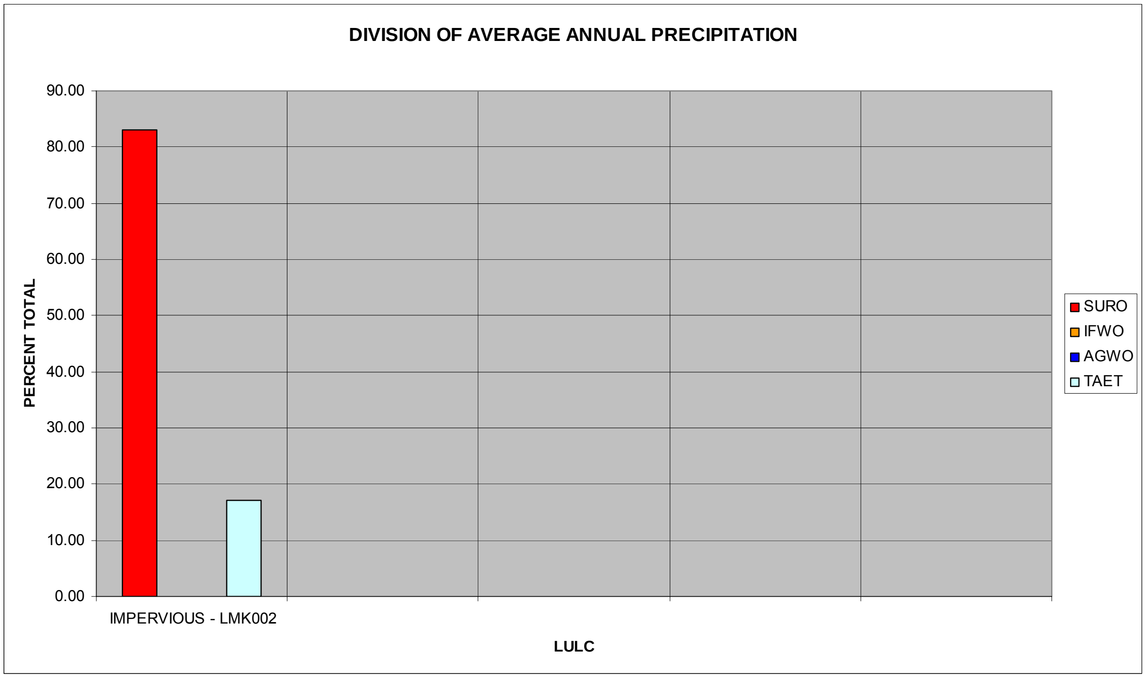

Figure 178. Simulated SURO and TAET for the impervious area for LMK002.

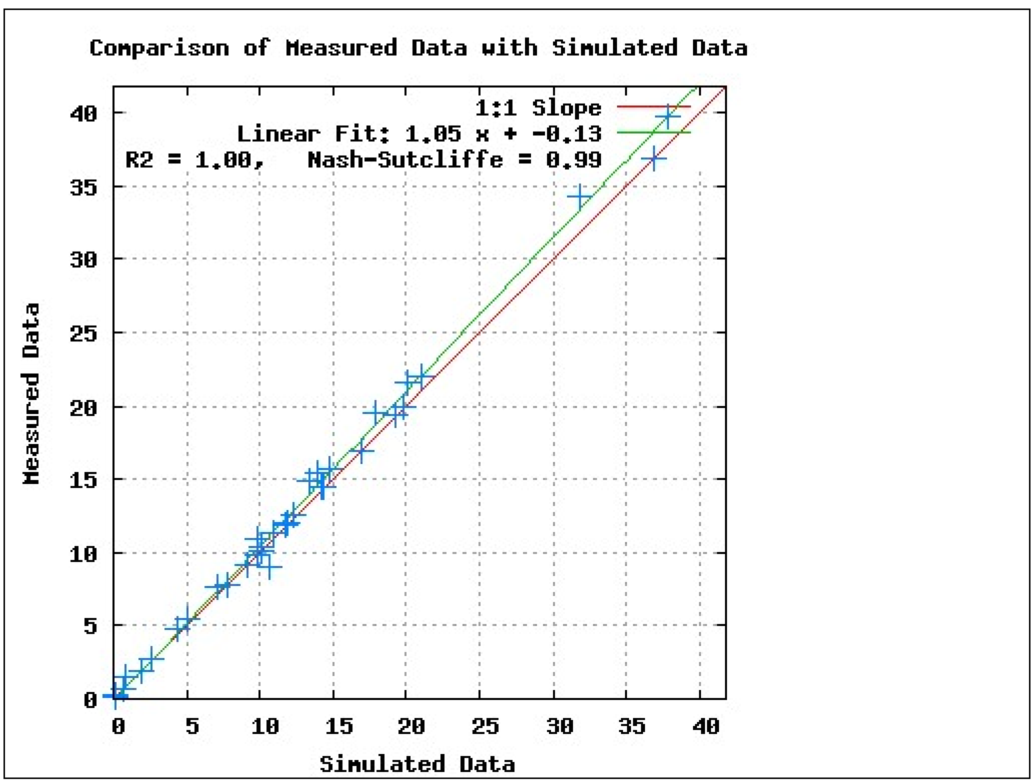

Figure 179. LMK002 - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

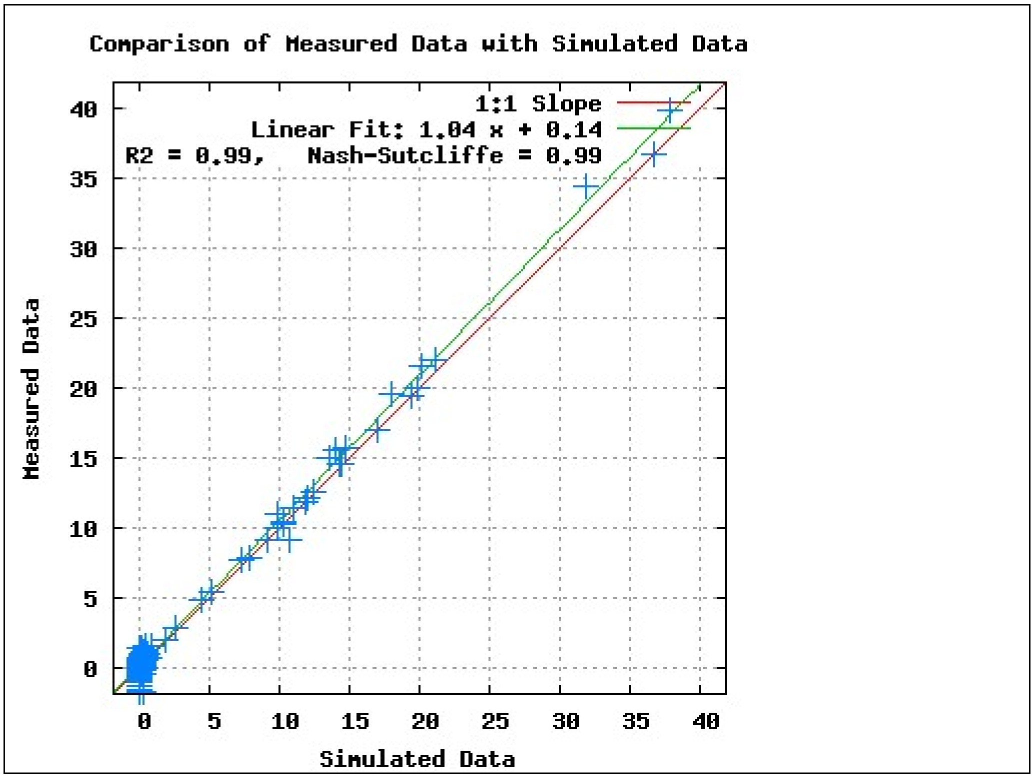

Figure 180. LMK002 - Comparison of all the data, simulated and observed, (15 minute flow, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the LMK002 HSPF hydrologic model.

5.3.14 LMK122

There are no hydrologic model calibration results to report for LMK122 (see section 5.2.14).

5.3.15 PO-POBLVD

There are no hydrologic model calibration results to report for PO-POBLVD (see section 5.2.15).

5.3.16 LMK136

There are no hydrologic model calibration results to report for LMK136 (see section 5.2.16).

5.3.17 LMK038

The calibration inversion run was manually terminated after 2106 model calls, which resulted in reducing the objective function from a starting value of 8792.4 to a final value of 142.1. Table 65 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 66 and Figures 181 – 185 suggest that the calibrated LMK038 HSPF hydrologic model is predictive. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were good.

MANCHESTER ADJUSTABLE MODEL PARAMETERS

IMP1	0.1900
IMP2	0.2300
IMP3	0.8300
IMP4	0.0987

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
Manchester	SUBURBAN	1	4.31	0.0255	73.50	0.0139	0.0076	0.0726	0.0782	1.48217	0.3	0.268043
	MULTI-FAMILY	2	3.15	0.0138	19.63	0.0092	0.0094	0.1193	0.0807	1.30215	0.700393	0.1
	COMMERCIAL	3	14.19	0.0024	13.31	0.0042	0.0009	0.0500	0.0500	1.05859	0.695923	0.1
	RURAL RESIDENTIAL	4	4.09	0.0601	53.70	0.0187	0.0146	0.1173	0.1730	1.76455	0.3	0.9
	LAWN	5	4.44	0.0372	19.97	0.0090	0.0100	0.3331	0.1135	4.3859	0.700026	0.25898
	PASTURE	6	4.18	0.0571	41.43	0.0121	0.0098	0.3999	0.1191	3.94649	0.85	0.506163
	FOREST	7	5.31	0.1401	45.89	0.0171	0.0120	0.0778	0.1664	3.04833	0.3	0.9
	BAREGROUND	10	3.33	0.0111	19.85	0.0094	0.0094	0.1241	0.0775	1.28227	0.699753	0.100011

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - MANCHESTER	111	0.0581	0.1033

Table 65. Identified model resulting from calibration inversion run.

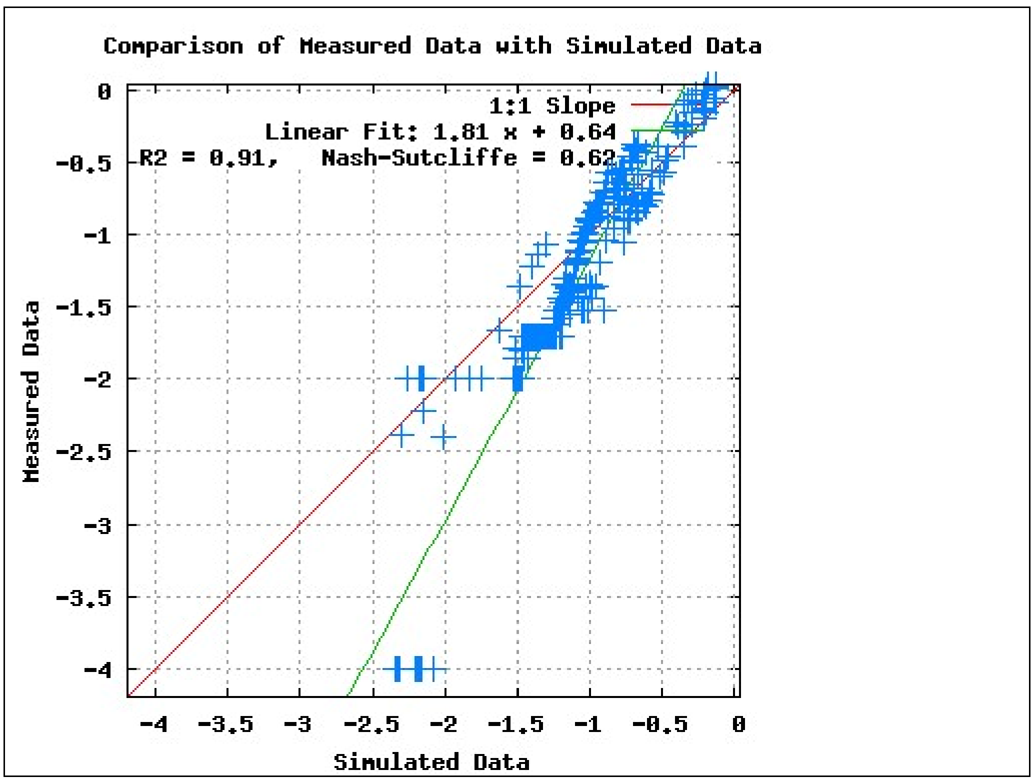

Figure 181. Comparison of simulated and observed 15 minute flow data that was used to calibrate the Manchester HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
Manchester	SUBURBAN	1	10.31	13.72	7.30	13.79	1	10.19	13.67	7.13	14.03	1	-1.17	-0.31	-2.28	1.69
	MULTI-FAMILY	2	18.47	9.64	5.12	11.89	2	18.39	9.64	5.10	11.88	2	-0.47	0.00	-0.51	-0.06
	COMMERCIAL	3	32.57	2.59	1.38	8.58	3	31.35	2.50	1.23	10.25	3	-3.74	-3.54	-10.69	19.46
	RURAL RESIDENTIAL	4	1.82	14.11	10.80	18.39	4	1.81	13.98	10.75	18.39	4	-0.50	-0.93	-0.54	0.00
	LAWN	5	0.68	18.54	9.86	16.05	5	0.67	18.45	9.84	16.05	5	-0.75	-0.45	-0.17	-0.04
	PASTURE	6	0.32	14.69	11.25	18.86	6	0.30	14.63	11.24	18.86	6	-6.62	-0.41	-0.09	0.00
	FOREST	7	0.10	9.37	14.84	20.81	7	0.12	9.33	14.67	20.74	7	24.81	-0.43	-1.17	-0.34
	BAREGROUND	10	20.45	8.65	4.60	11.42	10	20.39	8.65	4.58	11.41	10	-0.32	-0.01	-0.43	-0.07
	IMPERVIOUS - MANCHESTER	111	37.76			7.36	111	37.76			7.37	111	0.01			0.08

Table 66. Comparison of simulated and observed targets for the partition of average annual precipitation.

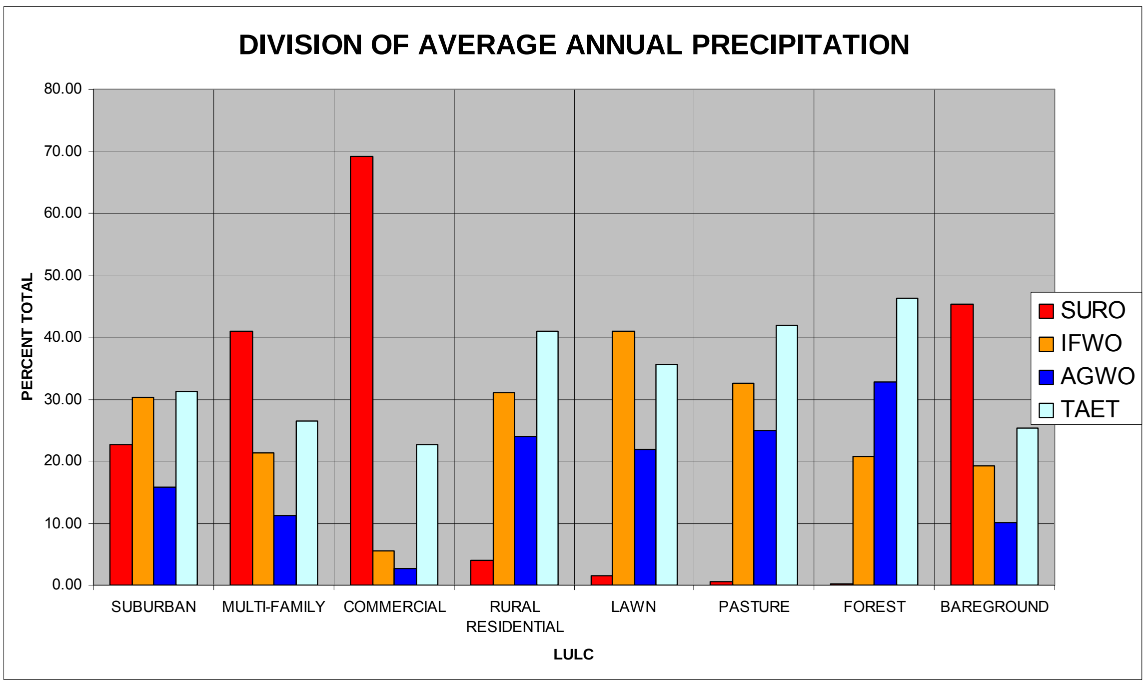

Figure 182. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at LMK038.

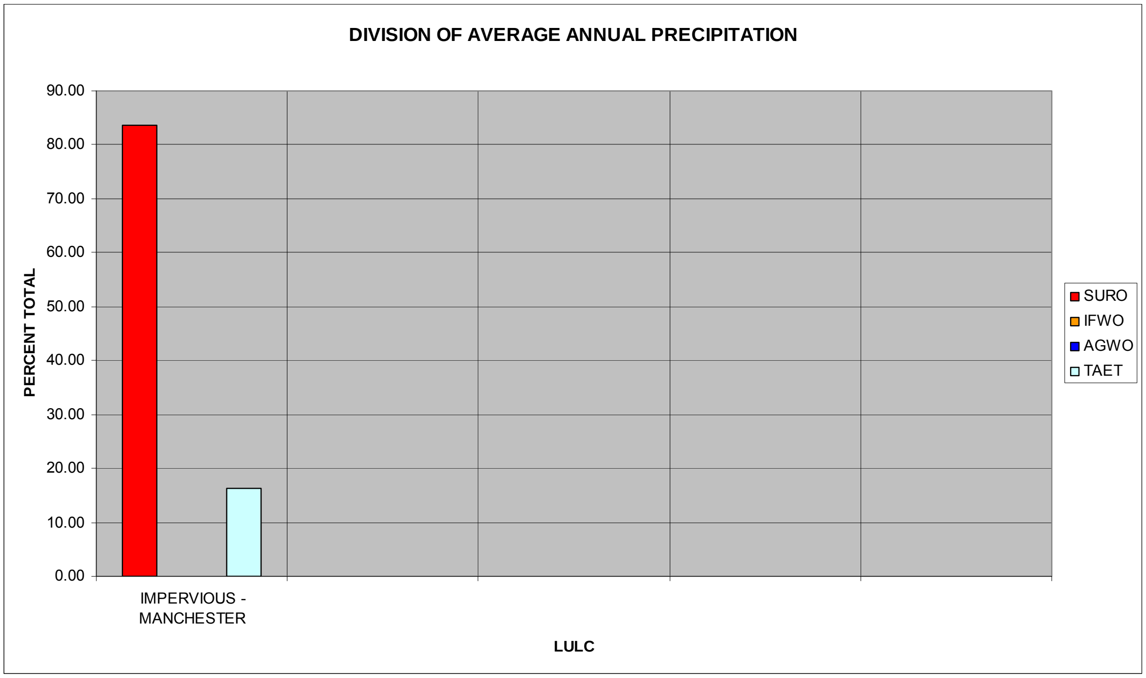

Figure 183. Simulated SURO and TAET for the impervious area for LMK038.

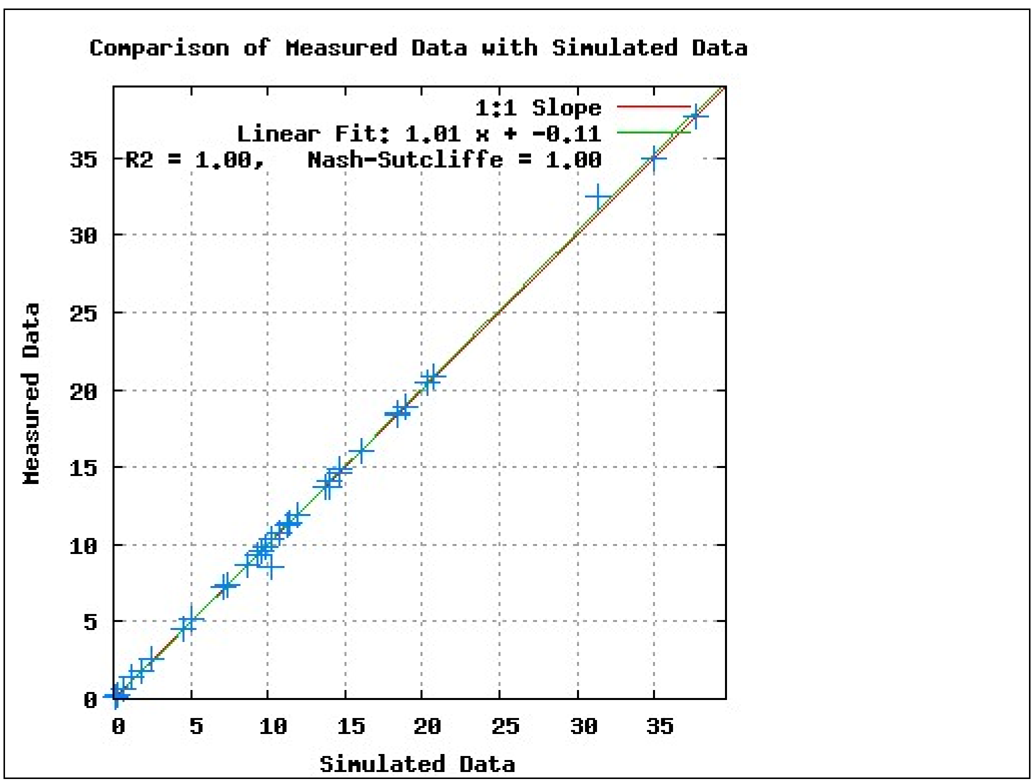

Figure 184. Manchester - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

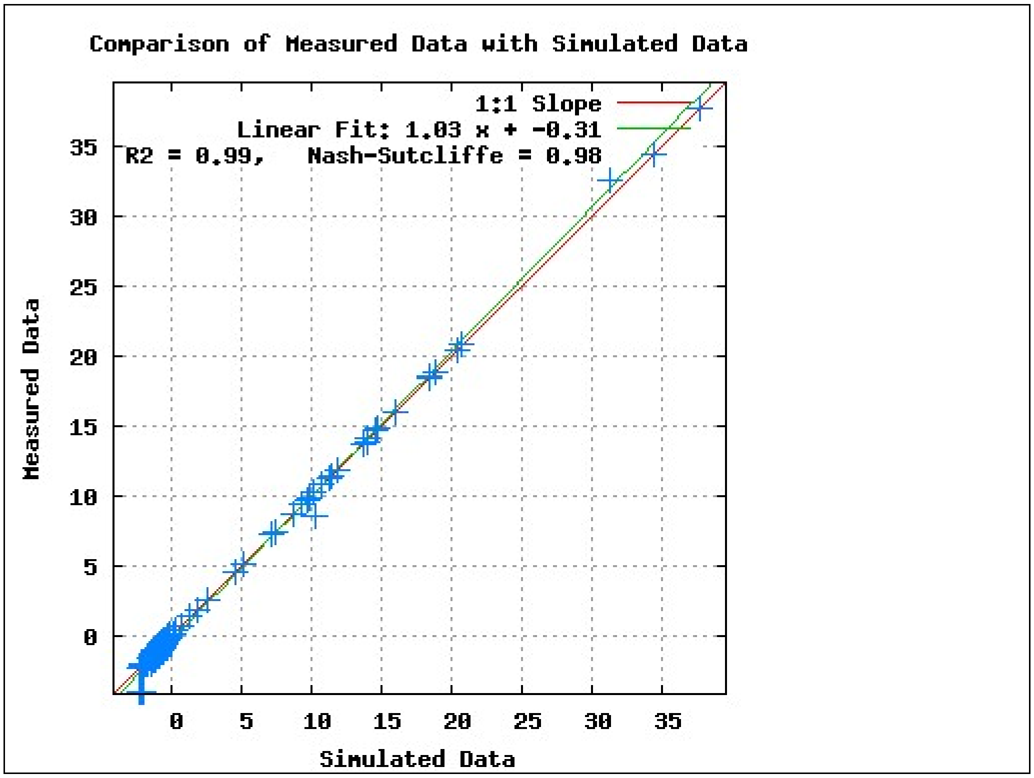

Figure 185. Manchester - Comparison of all the data, simulated and observed, (15 minute flow, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Manchester HSPF hydrologic model.

5.3.18 B-ST CSO16

As indicated in section 5.2.18, the trajectory repulsion scheme was implemented to calibrate the B-ST CSO16 HSPF hydrologic model. This involved 729 pre-inversion random sample runs followed by ten inversion runs, resulting in the model specified in Table 67.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Figures 186 – 188 suggest that the calibrated B-ST CSO16 HSPF hydrologic model is predictive.

CSO16 ADJUSTABLE MODEL PARAMETERS

IMP1	0.1800
IMP2	0.3016
IMP3	0.7344
IMP4	0.0950

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
CSO16	SUBURBAN	1	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	MULTI-FAMILY	2	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	COMMERCIAL	3	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	RURAL RESIDENTIAL	4	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	LAWN	5	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	PASTURE	6	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	FOREST	7	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0.1
	BAREGROUND	10	4.23	1.0000	264.99	0.0000	0.0011	0.2461	0.2500	1	0.3	0

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - CSO16	111	0.0500	0.0085

Table 67. Identified model resulting from calibration inversion run.

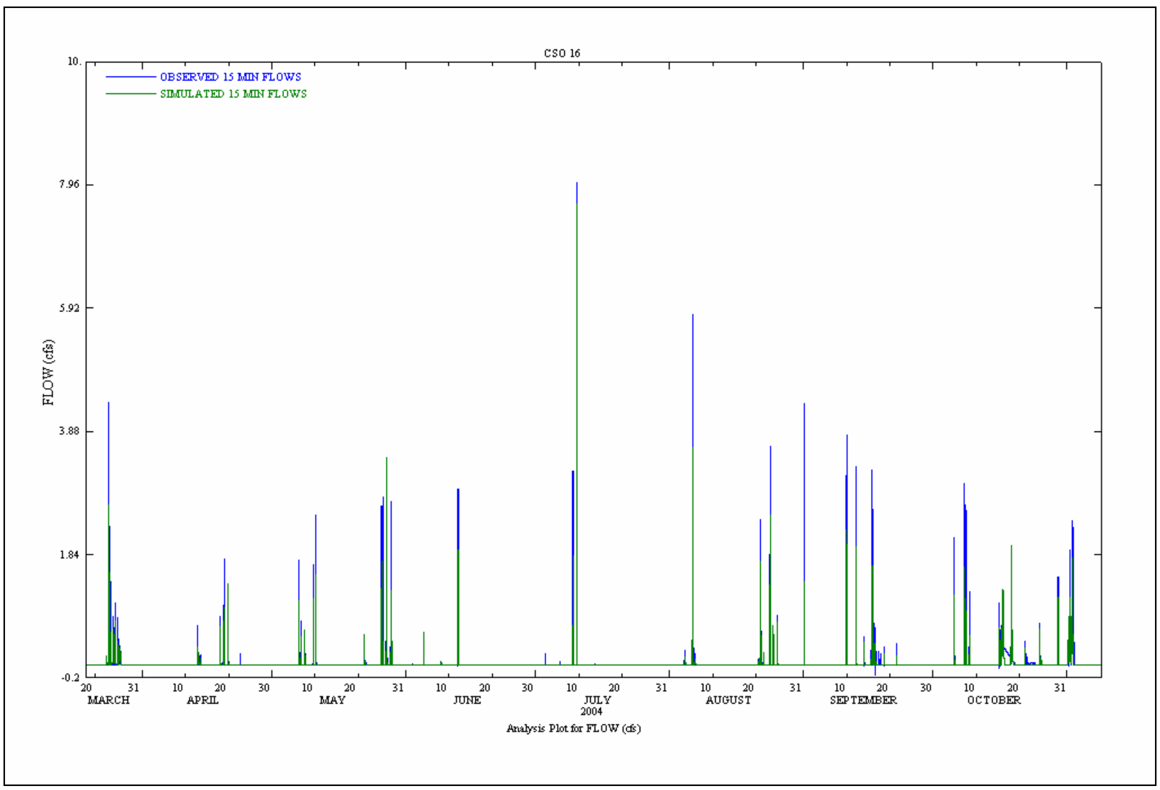

Figure 186. Comparison of simulated and observed 15 minute flow data for the B-ST CSO16 HSPF hydrologic model.

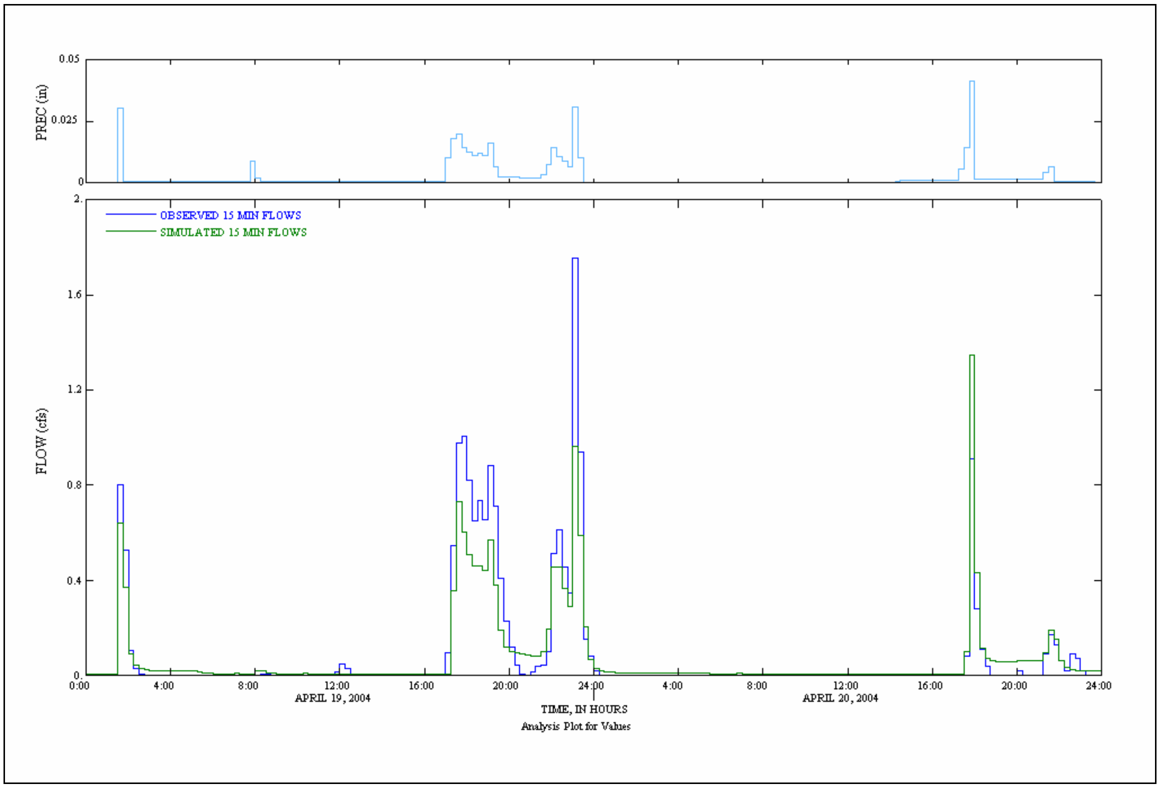

Figure 187. Comparison of simulated and observed 15 minute flow data for the B-ST CSO16 HSPF hydrologic model.

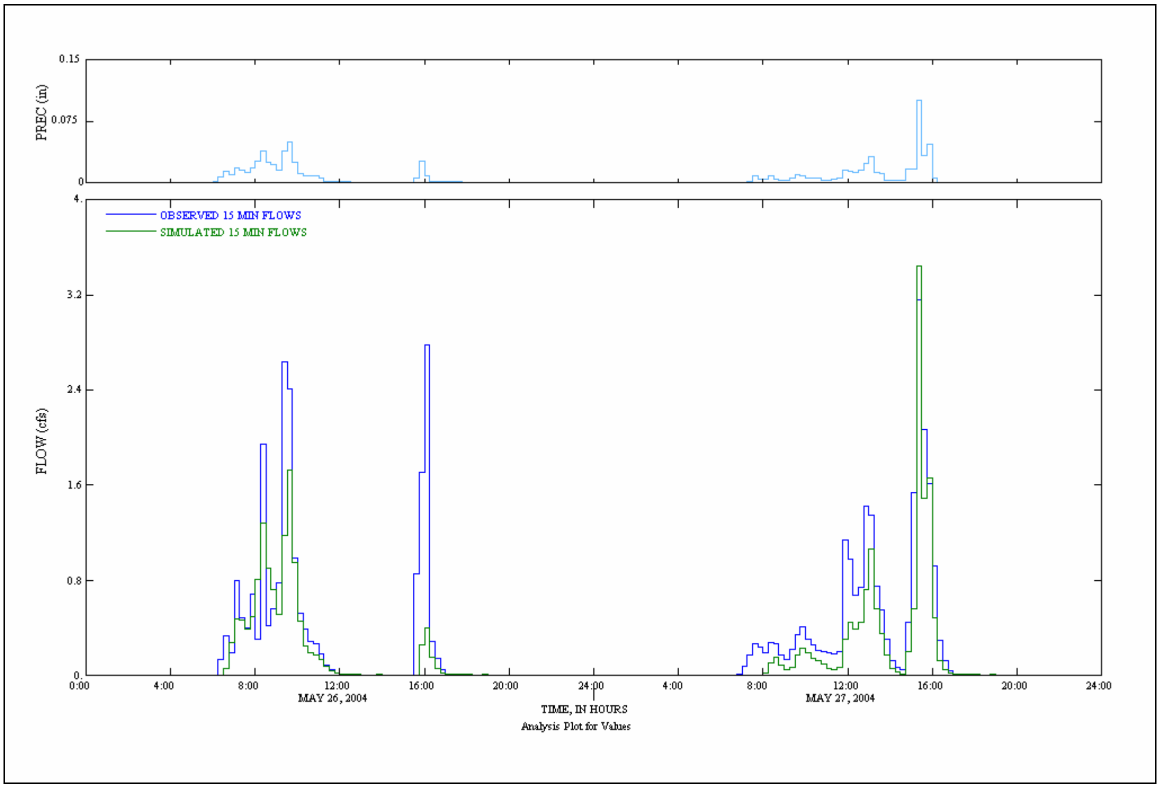

Figure 188. Comparison of simulated and observed 15 minute flow data for the B-ST CSO16 HSPF hydrologic model.

5.3.19 BST 28

The calibration inversion run was manually terminated after 1607 model calls, which resulted in reducing the objective function from a starting value of 52322 to a final value of 19243. Table 68 lists the identified parameter set that resulted from the calibration inversion run.

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Table 69 and Figures 189 – 196 suggest that the calibrated BST 28 HSPF hydrologic model is predictive. The fits to the predetermined targets for the partition of average annual precipitation across direct surface runoff, interflow runoff, baseflow runoff, and total evapotranspiration, for the eight different land uses expressed within each of the five different subwatershed systems, were OK.

BST02 ADJUSTABLE MODEL PARAMETERS

IMP1	0.1900
IMP2	0.3200
IMP3	0.9283
IMP4	0.0850

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	LZSN	INFILT	AGWRCTRNS	DEEPFR	AGWETP	UZSN	NSUR	INTFW	IRC	LZETP
BST02	SUBURBAN	1	15.00	0.0294	34.14	0.0321	0.0463	0.1846	0.2044	1.41885	0.85	0.14577
	MULTI-FAMILY	2	14.74	0.0219	395.70	0.0143	0.0012	0.1735	0.1390	1.40419	0.849731	0.102303
	COMMERCIAL	3	7.27	0.0134	22.78	0.0174	0.0040	0.1150	0.1169	1.00199	0.85	0.100277
	RURAL RESIDENTIAL	4	6.69	0.0368	17.11	0.0120	0.0101	0.4239	0.0965	1.63686	0.742474	0.19257
	LAWN	5	6.70	0.0352	17.35	0.0117	0.0100	0.3771	0.0972	1.93752	0.742615	0.148252
	PASTURE	6	6.58	0.0385	17.12	0.0119	0.0100	0.4296	0.0967	1.66317	0.739256	0.203241
	FOREST	7	15.00	0.0506	16.96	0.0122	0.0035	0.2861	0.1003	1.21077	0.6857	0.231853
	BAREGROUND	10	5.95	0.0205	18.06	0.0113	0.0099	0.2811	0.0896	1.34074	0.72953	0.1

IMPLND ADJUSTABLE MODEL PARAMETERS

		INSUR	RETSC
IMPERVIOUS - BST02	111	0.1229	0.0639

Table 68. Identified model resulting from calibration inversion run.

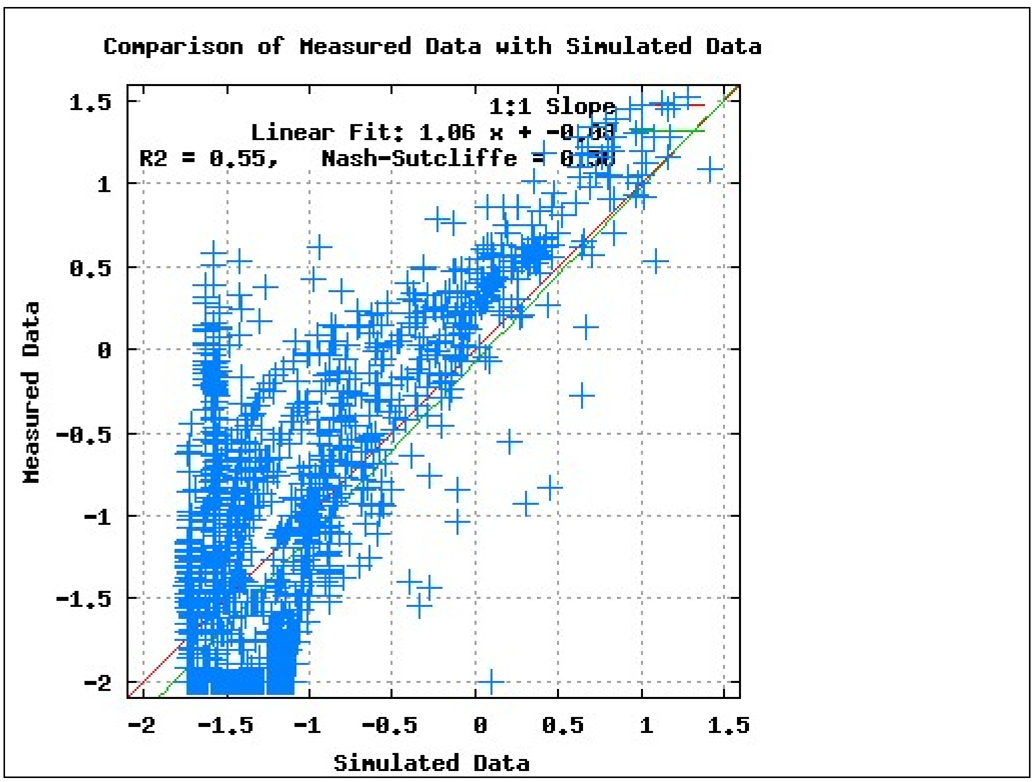

Figure 189. Comparison of simulated and observed 15 minute flow data that was used to calibrate the BST 28 HSPF hydrologic model.

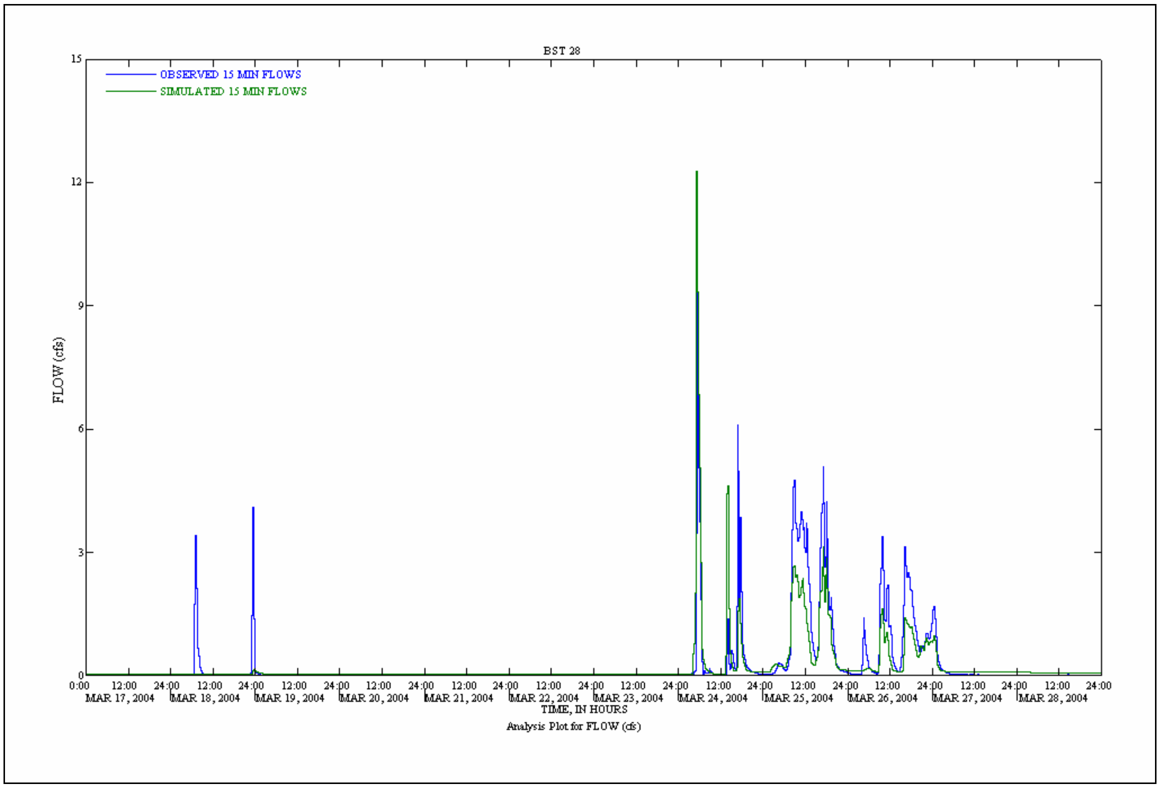

Figure 190. Comparison of simulated and observed 15 minute flow data for the BST 28 HSPF hydrologic model.

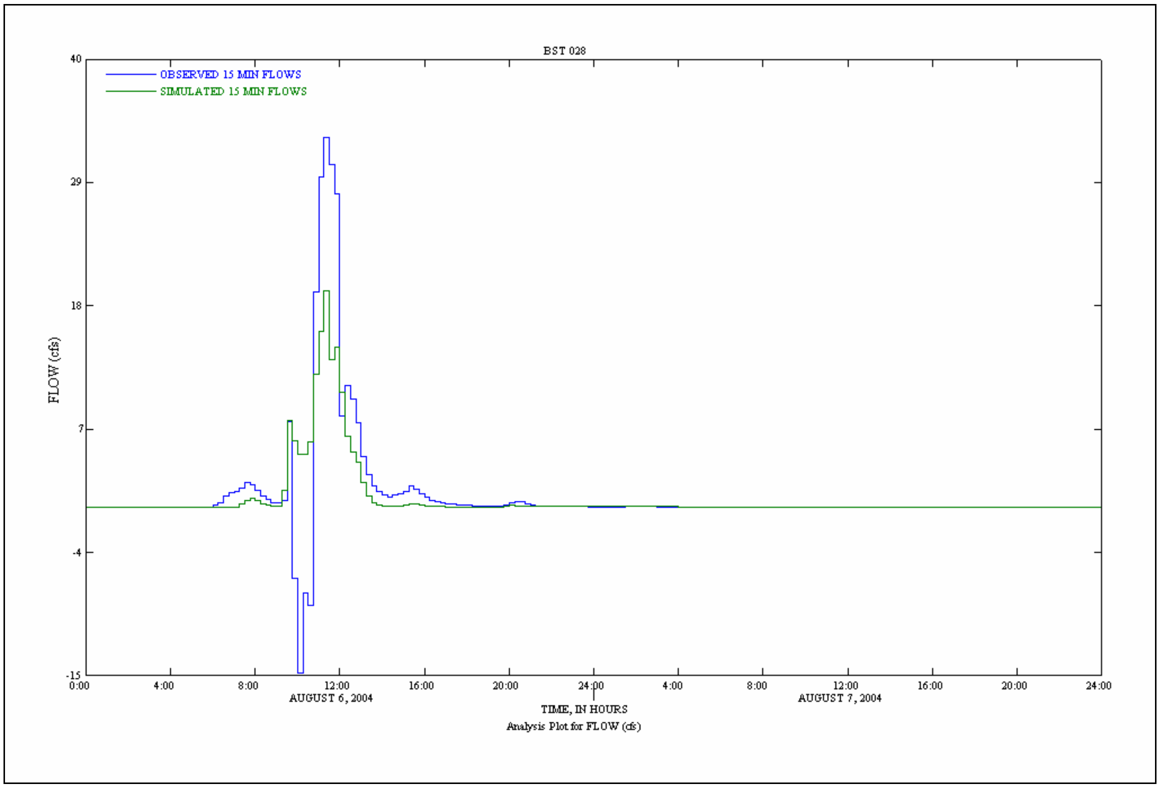

Figure 191. Comparison of simulated and observed 15 minute flow data for the BST 28 HSPF hydrologic model.

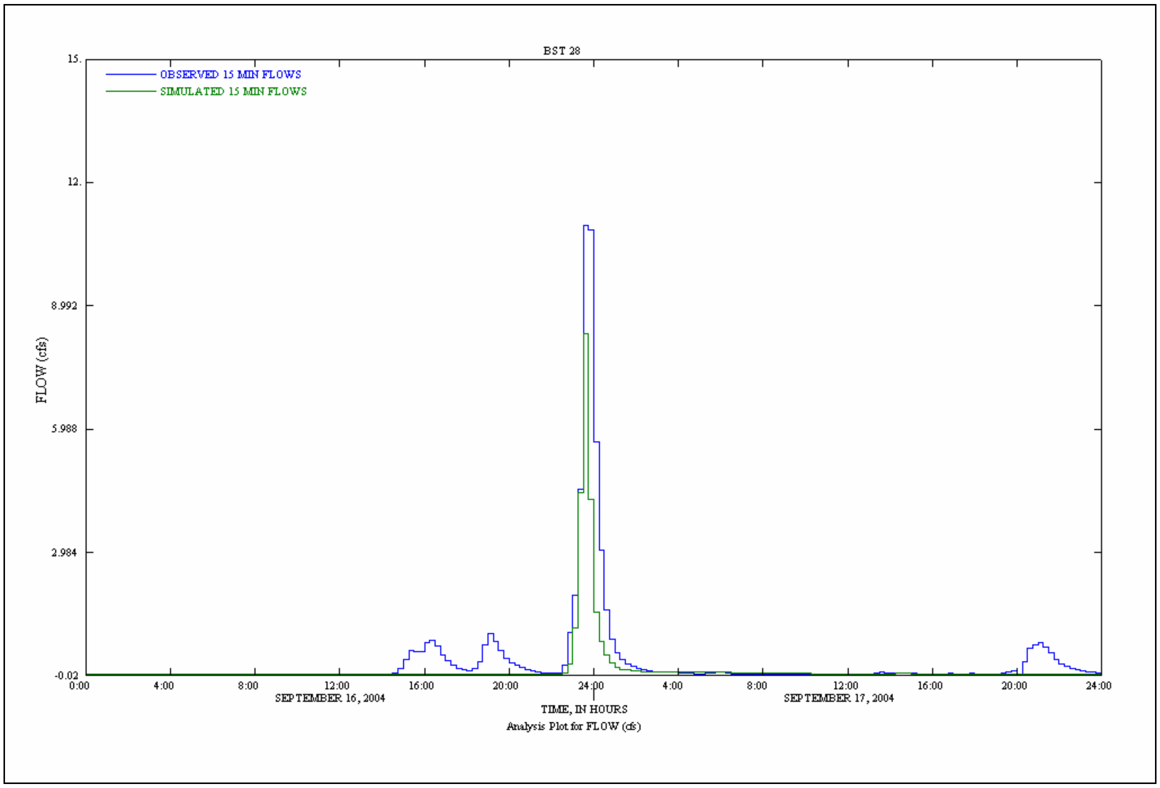

Figure 192. Comparison of simulated and observed 15 minute flow data for the BST 28 HSPF hydrologic model.

		"OBSERVED"					SIMULATED					PERCENT ERROR				
		ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET	ID	SURO	IFWO	AGWO	TAET
BST02	SUBURBAN	1	8.21	10.92	5.81	10.98	1	10.82	13.14	7.53	13.64	1	31.77	20.28	29.53	24.15
	MULTI-FAMILY	2	14.71	7.67	4.08	9.46	2	15.11	11.34	5.64	12.01	2	2.72	47.81	38.16	26.86
	COMMERCIAL	3	25.93	2.07	1.09	6.83	3	23.55	5.83	4.55	11.50	3	-9.19	182.23	315.84	68.27
	RURAL RESIDENTIAL	4	1.45	11.23	8.60	14.65	4	7.44	13.11	9.49	15.42	4	414.48	16.73	10.30	5.32
	LAWN	5	0.54	14.76	7.85	12.78	5	6.76	15.36	9.04	14.27	5	1155.27	4.05	15.15	11.65
	PASTURE	6	0.26	11.70	8.95	15.02	6	6.67	13.39	9.74	15.67	6	2506.12	14.46	8.81	4.39
	FOREST	7	0.08	7.46	11.82	16.57	7	6.94	10.69	11.54	16.27	7	8646.14	43.29	-2.34	-1.79
	BAREGROUND	10	16.28	6.89	3.66	9.09	10	16.43	10.24	6.56	12.16	10	0.92	48.75	79.05	33.76
	IMPERVIOUS - BST02	111	30.06			5.86	111	40.48			5.09	111	34.66			-13.22

Table 69. Comparison of simulated and observed targets for the partition of average annual precipitation.

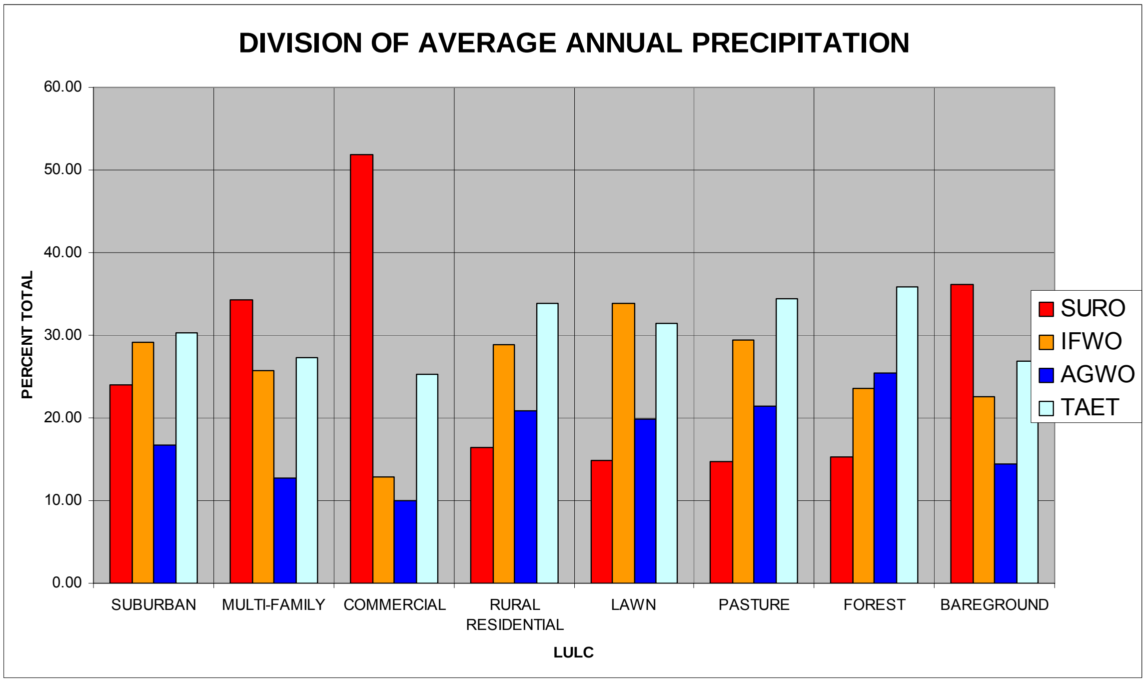

Figure 193. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at BST 28.

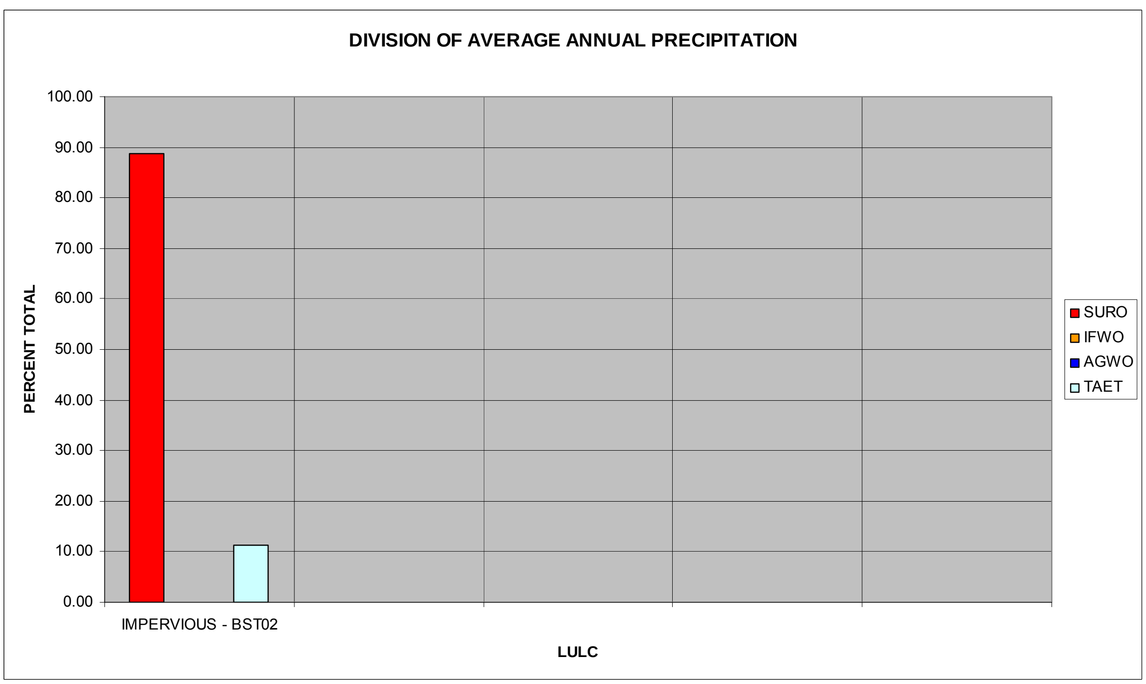

Figure 194. Simulated SURO and TAET for the impervious area for BST 28.

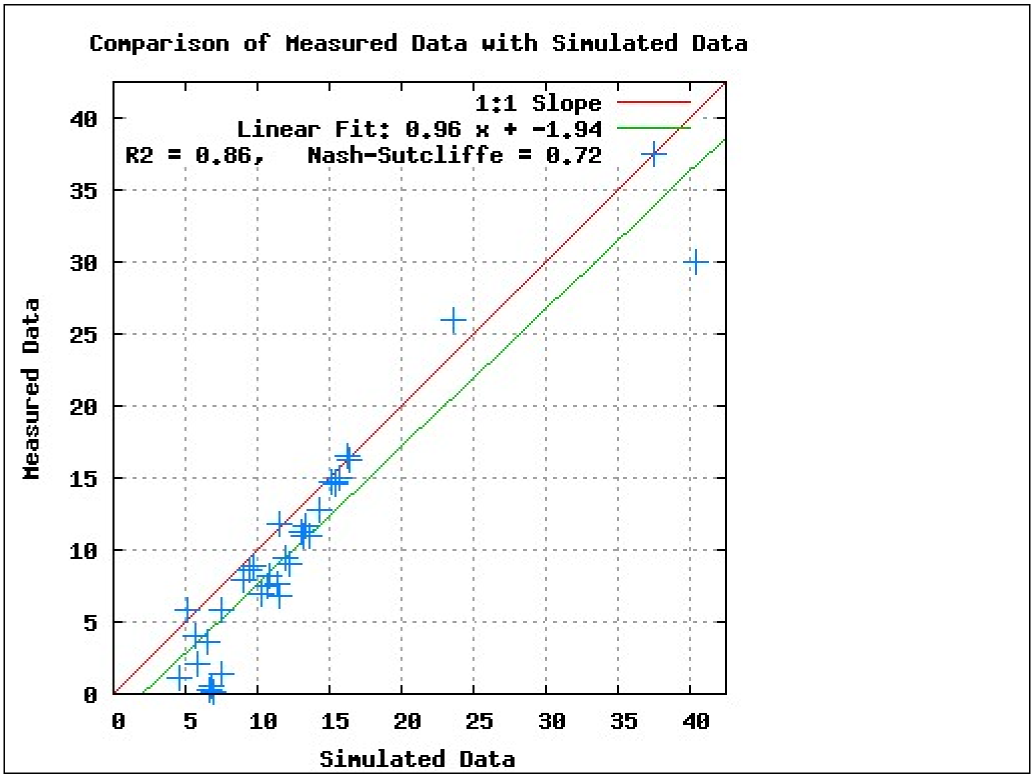

Figure 195. BST 28 - Comparison of simulated and observed targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET.

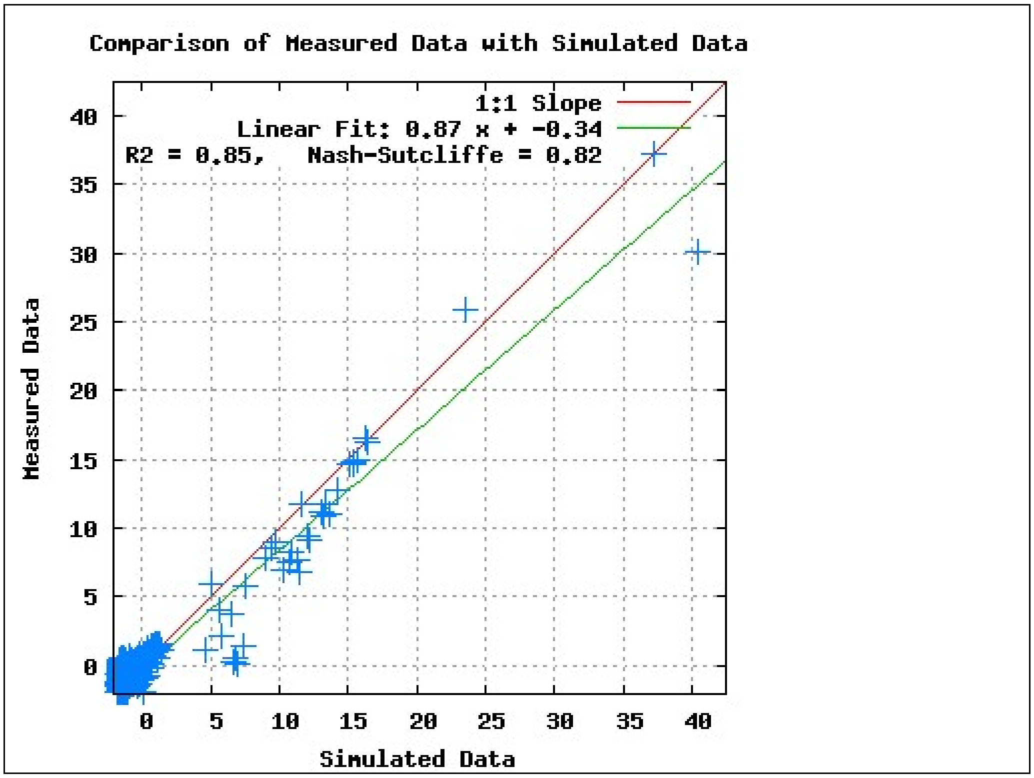

Figure 196. BST02 - Comparison of all the data, simulated and observed, (15 minute flow, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the BST 28 HSPF hydrologic model.

5.3.20 PSNS 126

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Figures 197 – 199 suggest that the calibrated PSNS 126 HSPF hydrologic model is predictive.

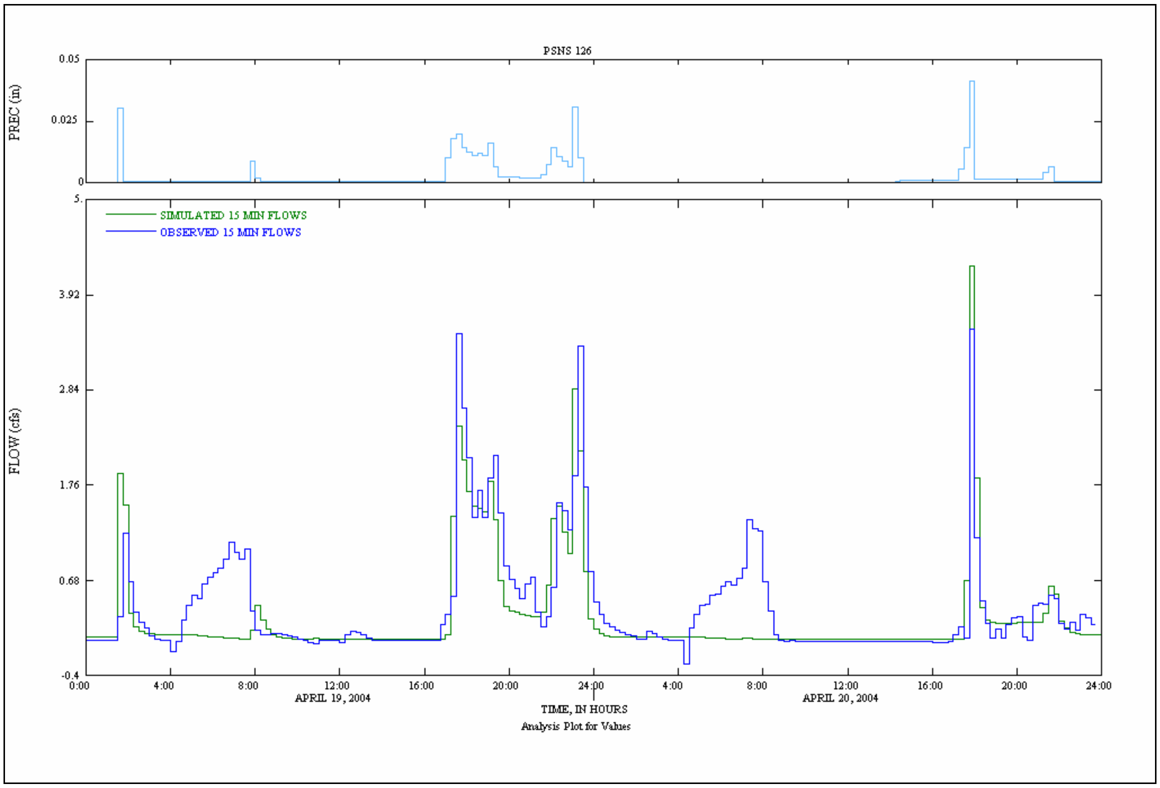

Figure 197. Comparison of simulated and observed 15 minute flow data for the PSNS 126 HSPF hydrologic model.

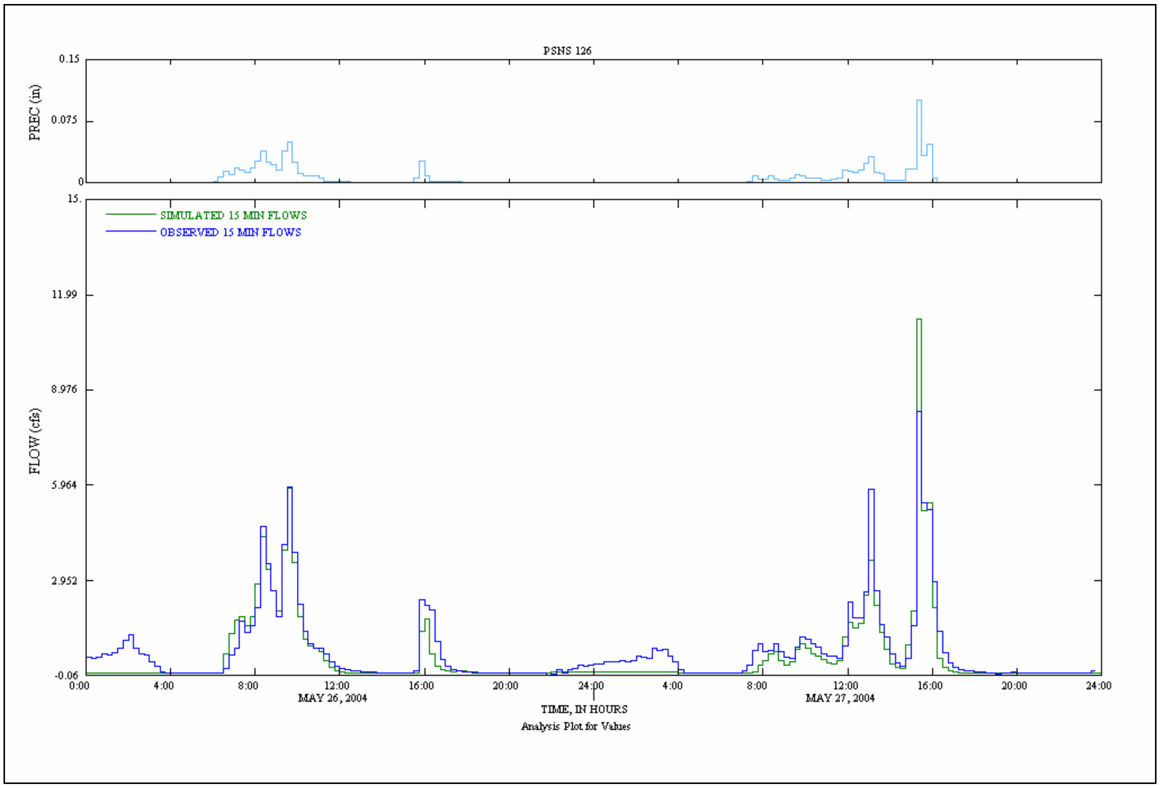

Figure 198. Comparison of simulated and observed 15 minute flow data for the PSNS 126 HSPF hydrologic model.

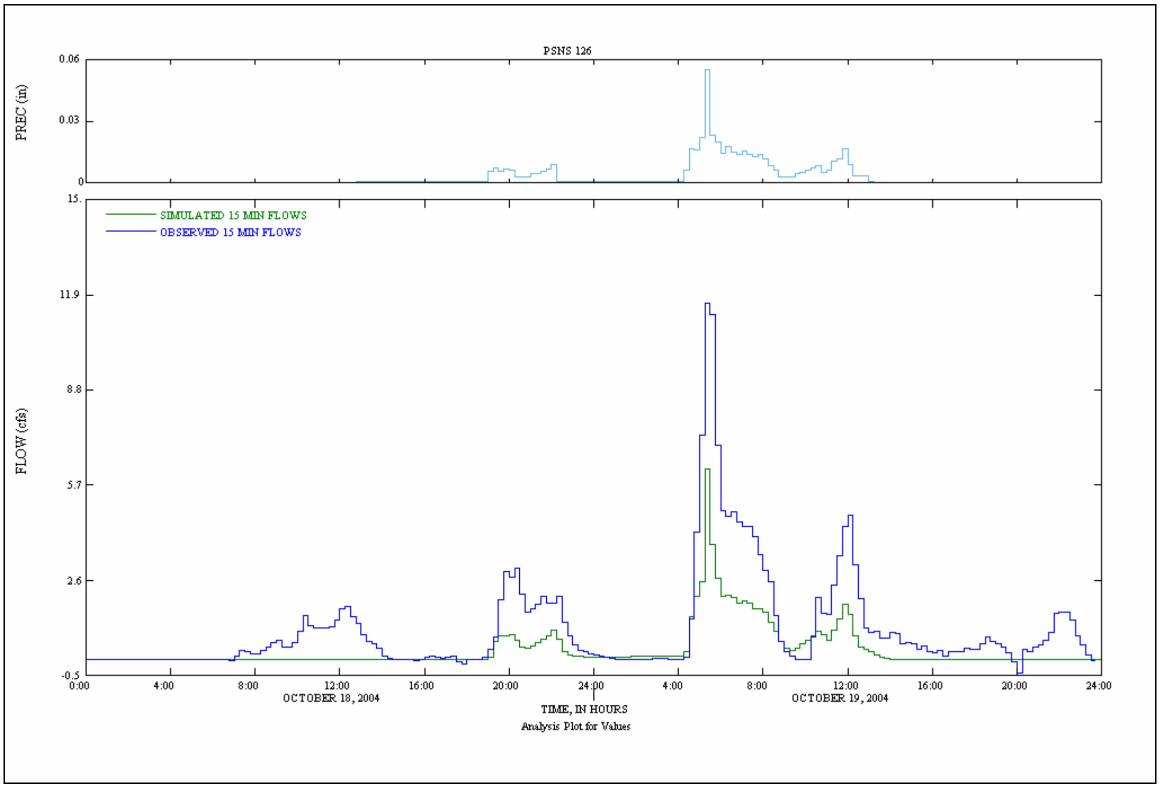

Figure 199. Comparison of simulated and observed 15 minute flow data for the PSNS 126 HSPF hydrologic model.

5.3.21 PSNS 124

There are no hydrologic model calibration results to report for PSNS 124 (see section 5.2.21).

5.3.22 PSNS 015

The limited calibration data made it difficult to mimic the conventional weight of evidence approach promulgated by Donigian (2002) for the assessment of HSPF hydrologic model performance; however, the information summarized in Figure 200 suggest that the calibrated PSNS 015 HSPF hydrologic model is predictive.

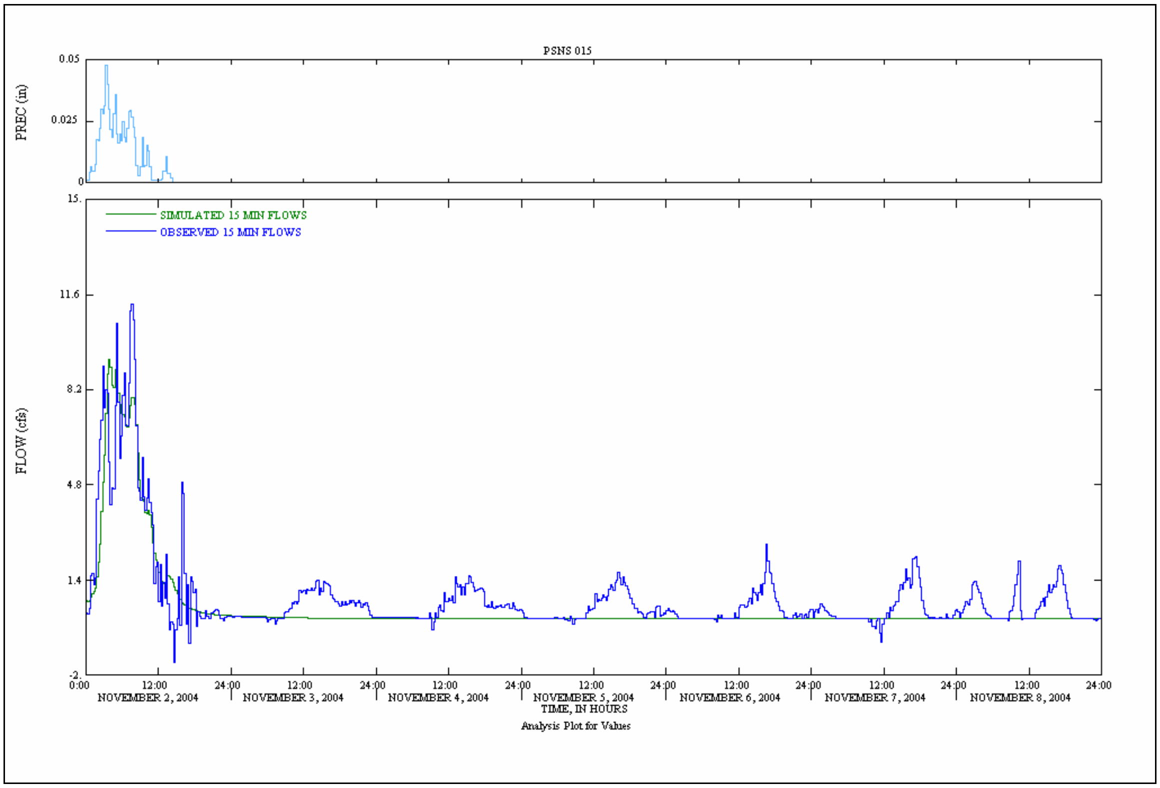

Figure 200. Comparison of simulated and observed 15 minute flow data for the PSNS 015 HSPF hydrologic model.

6.0 USLE SEDIMENT LOADING ANALYSIS

In support of continued studies for the PSNS & IMF Project ENVVEST, the HSPF hydrologic models deployed to the Sinclair and Dyes Inlet Watershed are being modified to also simulate sediment. Sediment simulation with HSPF involves the processes of accumulation, detachment, washoff, and scour followed by the instream processes of transport, deposition, and scour (See Figures 201- 203, and the HSPF manual for further details (Bicknell et al., 2001)). With HSPF sediment simulation, the initial model determination effort is focused on ensuring that the simulated aggregate sediment load from the land surface is consistent with predetermined target sediment loading rates, while also accommodating an expected balance between accumulation and washoff over the long term.

This section presents the methods, data, and results obtained from the analysis employed to determine target sediment loading rates as part of the overall process of deploying HSPF sediment models for watersheds in the Sinclair and Dyes Inlet Watershed.

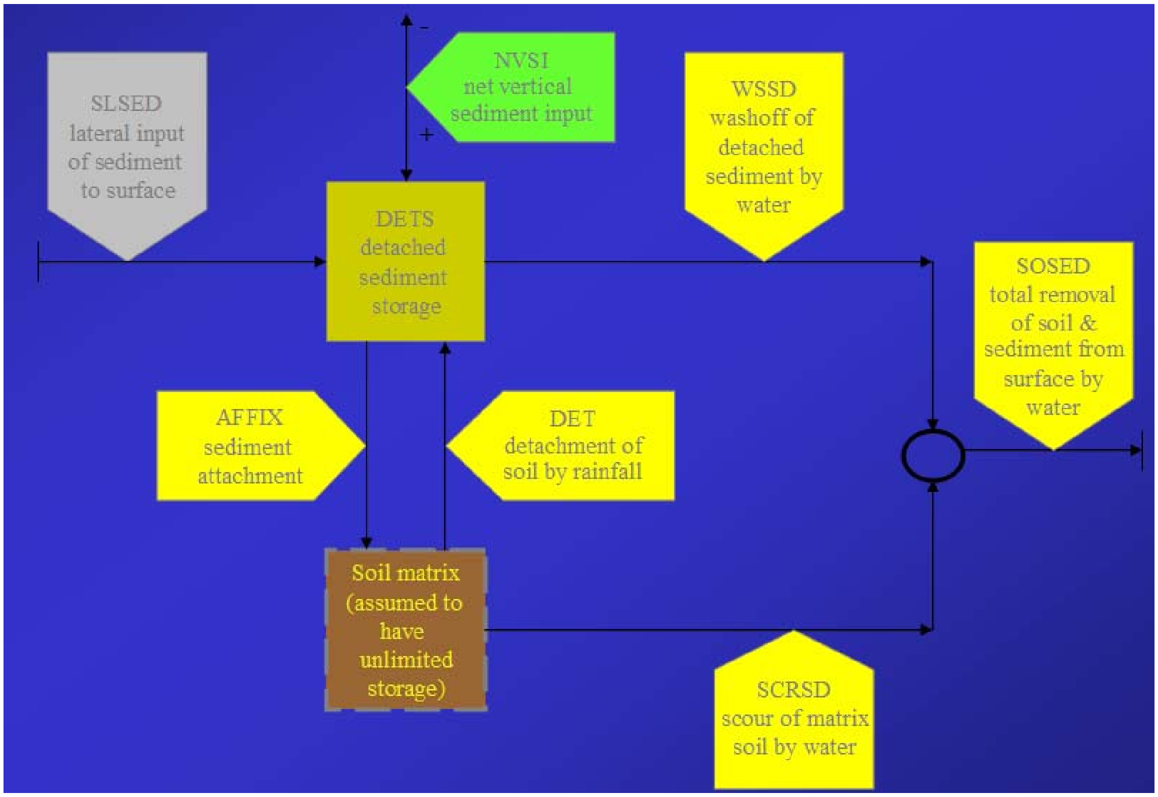

Figure 201. Sediment processes simulated within the PERLND application module of HSPF.

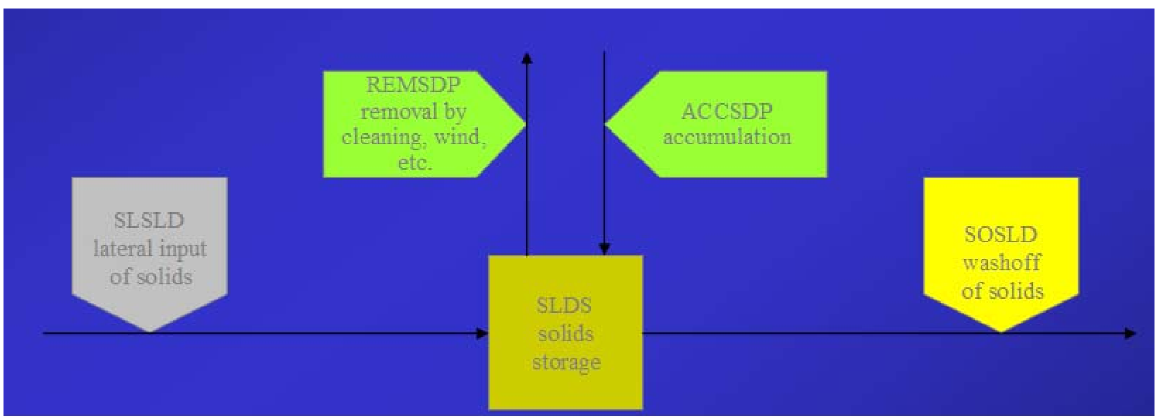

Figure 202. Sediment processes simulated within the IMPLND application module of HSPF.

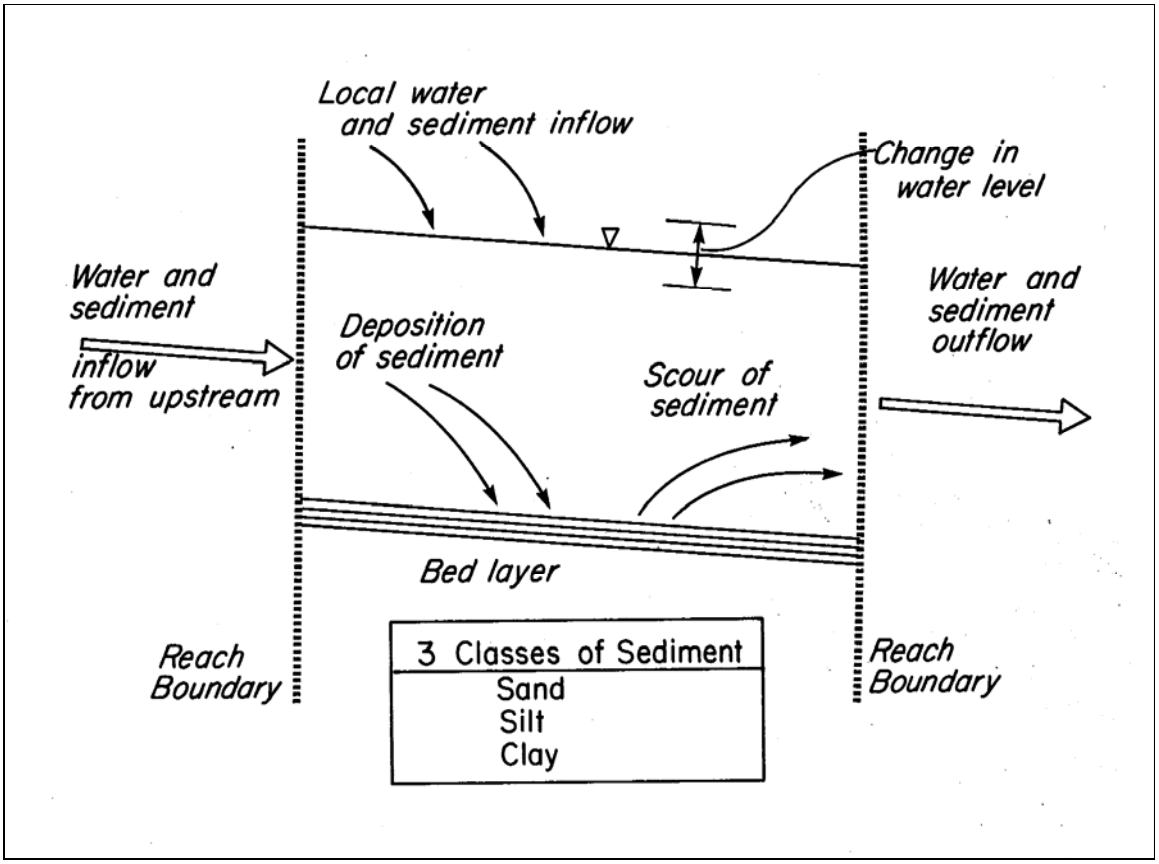

Figure 203. Sediment processes simulated within the RCHRES application module of HSPF.

6.1 METHODS

A Geographic Information Systems (GIS) based approach to application of the Universal Soil Loss Equation (USLE) was employed to determine gross annual sediment yield (See Figure 204). Based on the land use and land cover data and the GIS-based USLE analysis, for a given watershed system in the Sinclair and Dyes Inlet Watershed, sediment delivery ratios were subsequently computed to determine net annual sediment yield as a function of land use. The Universal Soil Loss Equation is given by (Shen and Julien, 1993)

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

where

A = Gross annual sediment yield in tons/acre/year
R = Rainfall erosivity factor
K = Soil erodibility factor
LS = Slope length-gradient factor
C = Crop/vegetation and management factor
P = Conservation practice factor

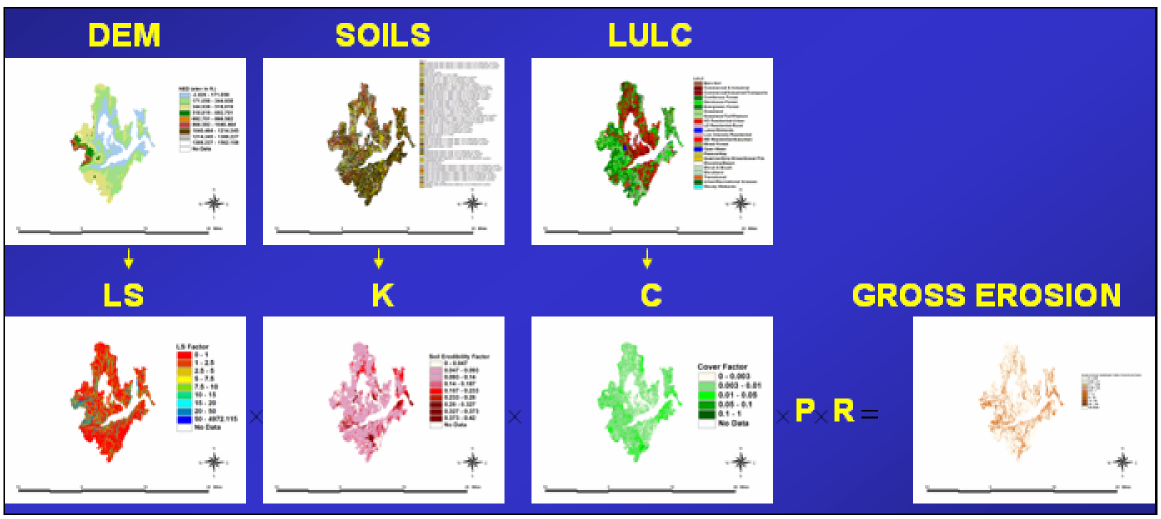

Figure 204. Schematic of GIS-based USLE analysis.

The rainfall erosivity factor, R, was estimated uniformly throughout the study area using (Lane et al., 1983)

$$R = 27.38P^{2.17}$$

where

P = two year, six hour rainfall amount in inches

As indicated in Figure 204, the parameters K, LS, and C were estimated in a spatially distributed manner using GIS soils, elevation, and land use and land cover data, respectively.

Spatially distributed values for the soil erodibility factor, K, were derived from soil texture classification data, in particular from the soil survey of Kitsap County Area, Washington (McMurphy, 1980) and published information on expected values for K as a function of soil texture classification (see for example, http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm).

The slope length-gradient factor, LS, was estimated using (Mitasova et al., 1996)

$$LS(\mathbf{r}) = (m+1)\ [\,A(\mathbf{r}) / a_0\,]^m\ [\,\sin b(\mathbf{r}) / b_0\,]^n$$

where $A[m]$ is upslope contributing area per unit contour width, b [deg] is the slope, m and n are parameters, and $a_0 = 22.1m = 72.6ft$ is the length and b_0 = 0.09 = 9% = 5.16deg is the slope of the standard USLE plot. The parameters m and n were set to 0.6 and 1.3, respectively (Mitasova et al., 1996).

Spatially distributed values for the crop/vegetation and management factor, C, were derived from land use and land cover data, in particular from proprietary thematic mapper data and the National Land Cover Data set, and published information on expected values for C as a function of land use and land cover (see for example, among others, http://www.uoguelph.ca/geography/research/geog4480_w2004/Group02/index.html; http://pasture.ecn.purdue.edu/~sedspec/sedspec/doc/usleapp.doc; http://www.css.cornell.edu/courses/620/stassign/ma.ppt; http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/T1765E/t1765e0e.htm).

The conservation practice factor, P, was assumed to be uniformly one throughout the study area.

Using the following equation (Shen and Julien, 1993), a sediment delivery ratio (SDR) was computed for each land use and land cover represented in the deployed HSPF models to determine target sediment loading rates, as a function of land use, within individual watershed systems

$$SDR = 0.31 \cdot A^{-0.3}$$

where

A = Area in square miles

6.2 DATA

The data utilized to support the GIS-based approach to application of the Universal Soil Loss Equation (USLE) in the Sinclair and Dyes Inlet Watershed included

1. National Elevation Dataset (NED) data obtained from the United States Geological Survey Seamless Data Distribution System (http://seamless.usgs.gov/website/seamless/viewer.php) (See Figure 2)
2. Soils data obtained from the United States Department of Agriculture (http://soildatamart.nrcs.usda.gov/) (See Figure 3)
3. Land Use and Land Cover (LULC) data (See Figure 4)
    a. Proprietary thematic mapper data provided to support the analysis, and
    b. National Land Cover Data obtained from the United States Geological Survey Seamless Data Distribution System (http://seamless.usgs.gov/website/seamless/viewer.php)
4. The two year, six hour rainfall amount obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu/pcpnfreq.html)
5. Published information on representative USLE parameter values (see above, for example). See Table 70 below for the data used to determine the K factor as a function of soil texture classification. See Table 71 below for the data used to

determine the crop/vegetation and management factor, C, as a function of land use and land cover.

6. The delineated watersheds within the study area (See Figure 8)

Textural Class	Average
Clay	0.22
Clay Loam	0.30
Coarse Sandy Loam	0.07
Fine Sand	0.08
Fine Sandy Loam	0.18
Heavy Clay	0.17
Loam	0.30
Loamy Fine Sand	0.11
Loamy Sand	0.04
Loamy Very Fine Sand	0.39
Sand	0.02
Sandy Clay Loam	0.20
Sandy Loam	0.13
Silt Loam	0.38
Silty Clay	0.26
Silty Clay Loam	0.32
Very Fine Sand	0.43
Very Fine Sandy Loam	0.35

Table 70. Average soil erodibility factor values as a function of soil texture classification (http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm).

LULC	C
MD Residential-Suburban	0.0100
HD Residential-Urban	0.0000
Commercial & Industrial	0.0100
LD Residential-Rural	0.0300
Grassland/Turf/Pasture	0.0500
Shrub & Brush	0.1000
Deciduous Forest	0.0090
Coniferous Forest	0.0040
Mixed Forest	0.0070
Lakes/Wetlands	0.0000
Shoreline/Beach	0.0000
Bare Soil	1.0000
Open Water	0.0000
Low Intensity Residential	0.0300
Commercial/Industrial/Transportation	0.0100
Quarries/Strip Mines/Gravel Pits	1.0000
Transitional	0.0500
Deciduous Forest	0.0090
Evergreeen Forest	0.0040
Mixed Forest	0.0070
Shrubland	0.1000
Grassland	0.0500
Pasture/Hay	0.0500
Urban/Recreational Grasses	0.0500
Woody Wetlands	0.0030

Table 71. Values assigned for the crop/vegetation and management factor, C, as a function of land use and land cover.

6.3 RESULTS

The results presented in Figures 205 - 210 below were obtained utilizing the methods and data described above.

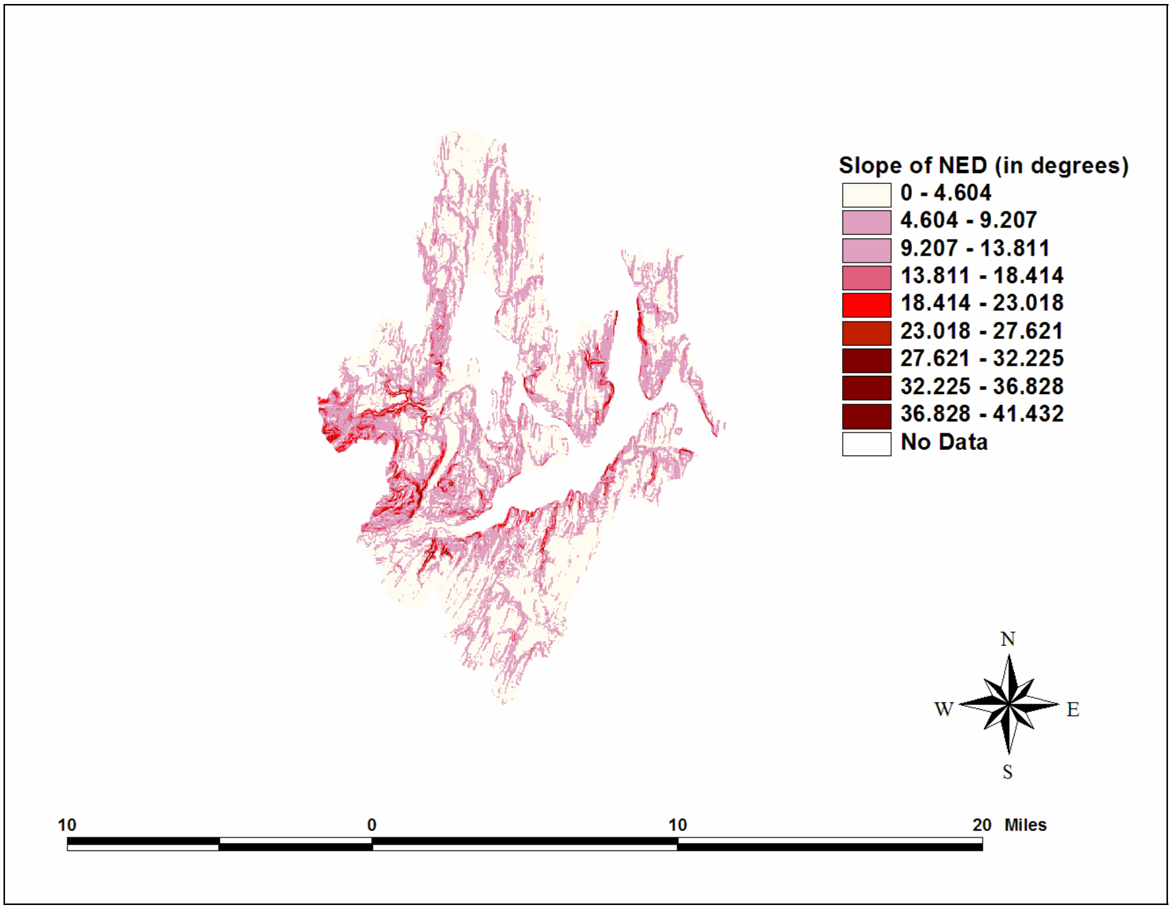

Figure 205. Slope data derived from NED data.

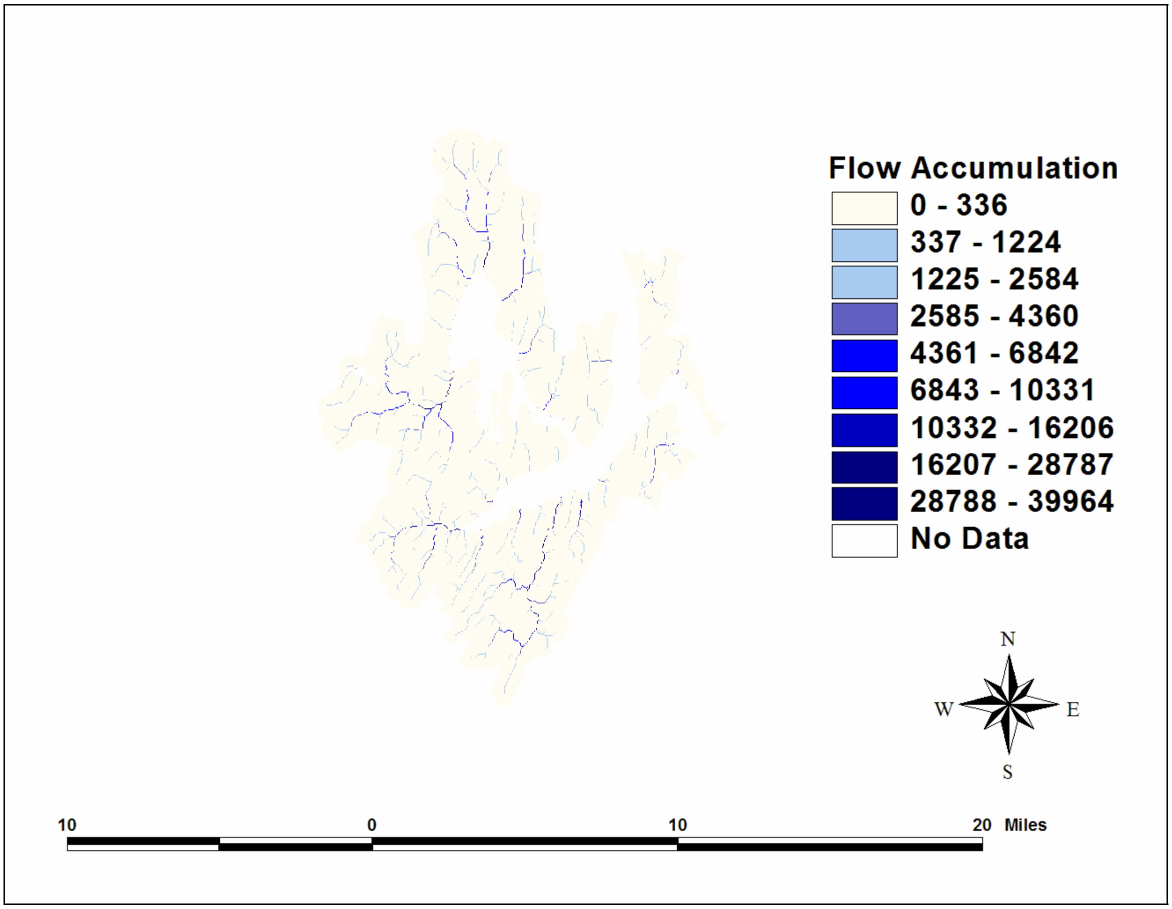

Figure 206. Flow accumulation data derived from NED data.

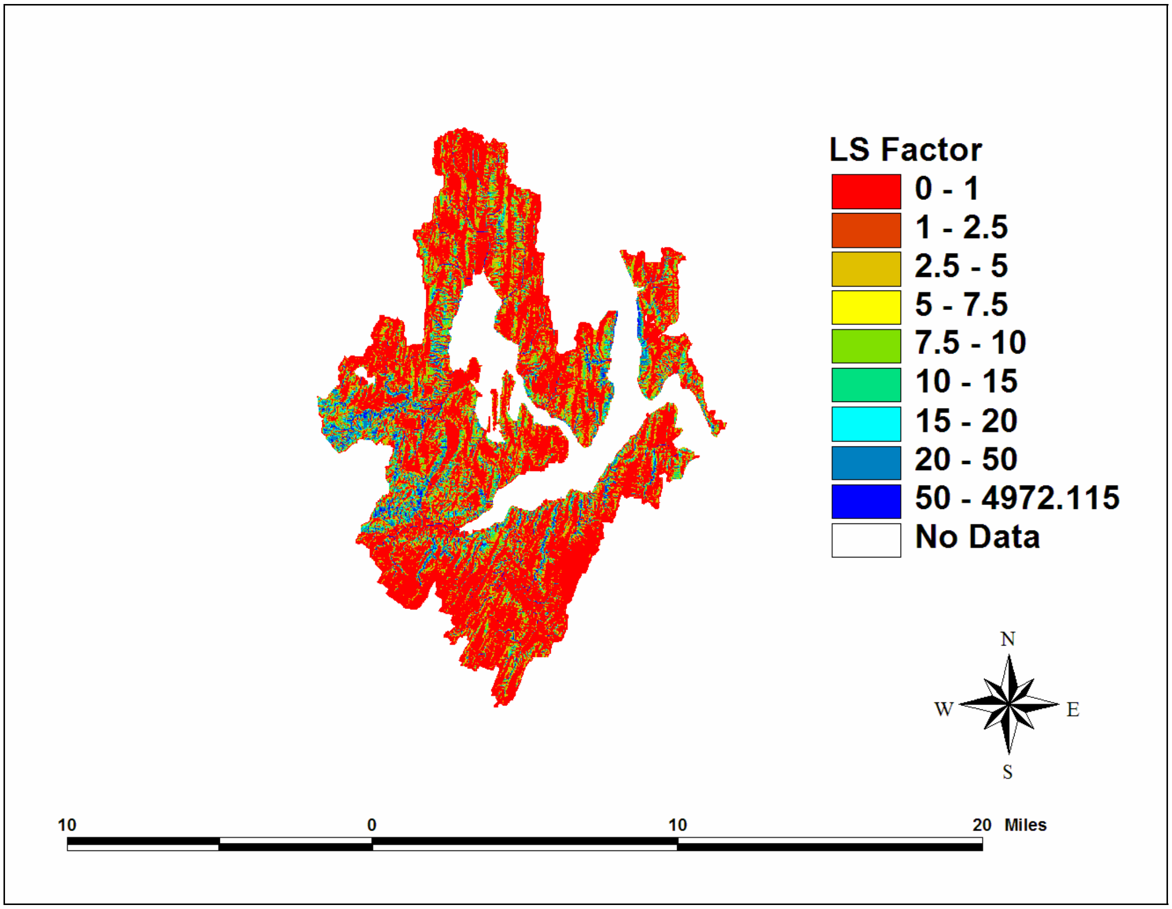

Figure 207. Computed LS factor.

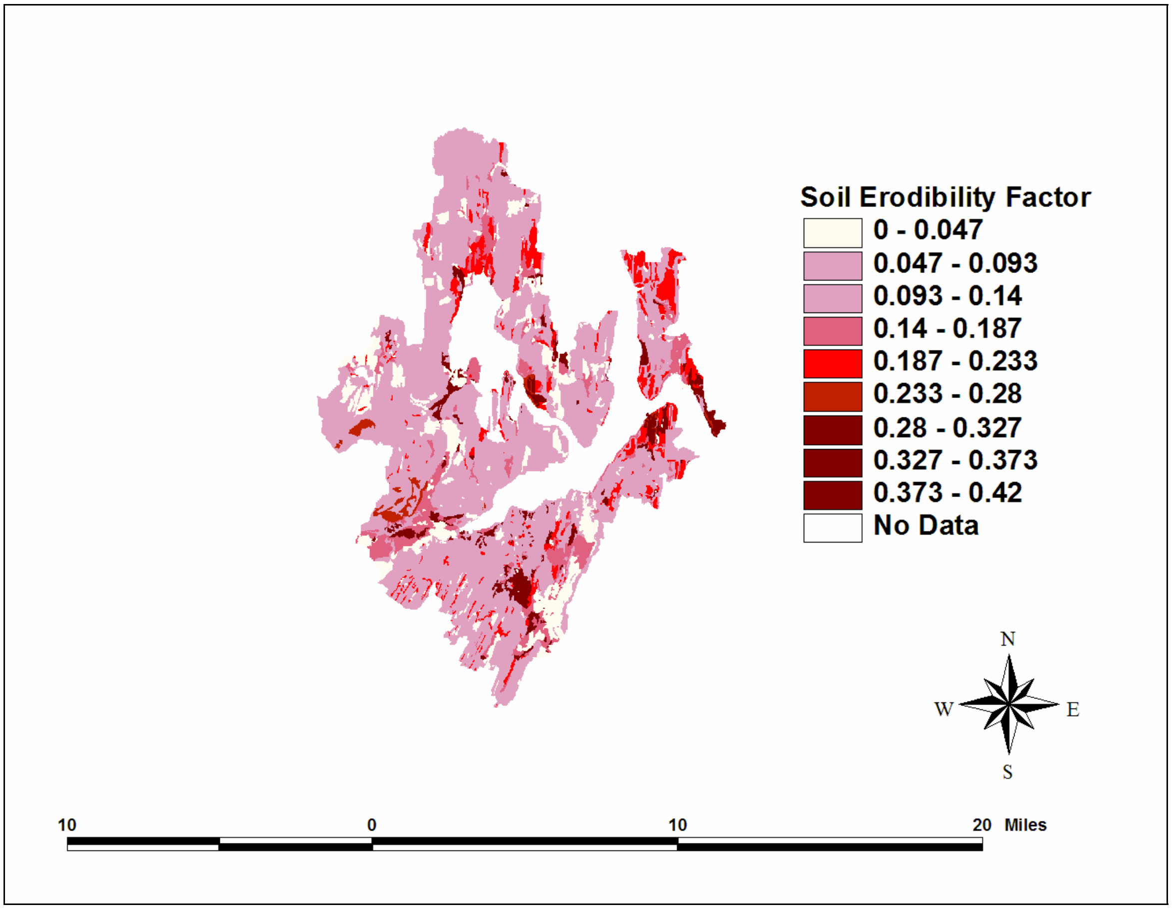

Figure 208. Soil erodibility factor derived from soils data.

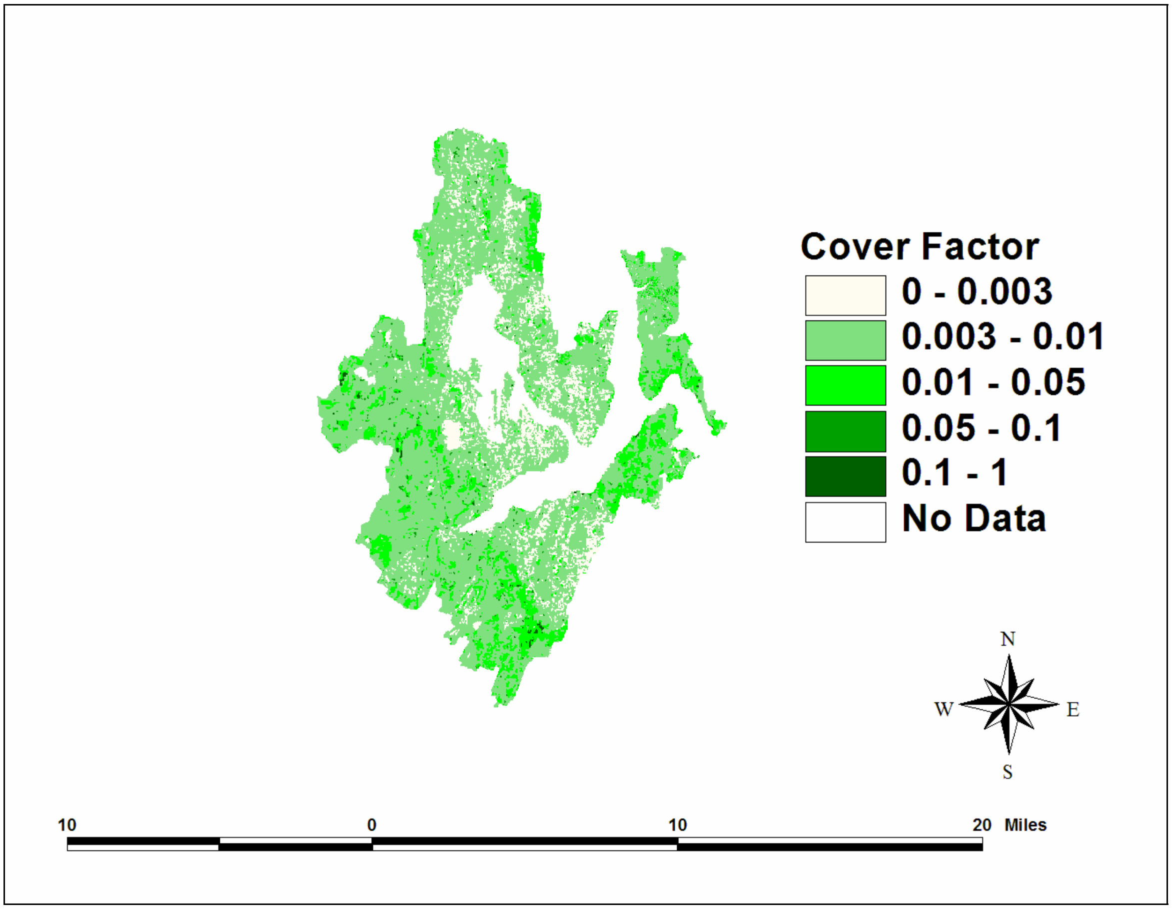

Figure 209. Crop/vegetation and management factor derived from LULC data.

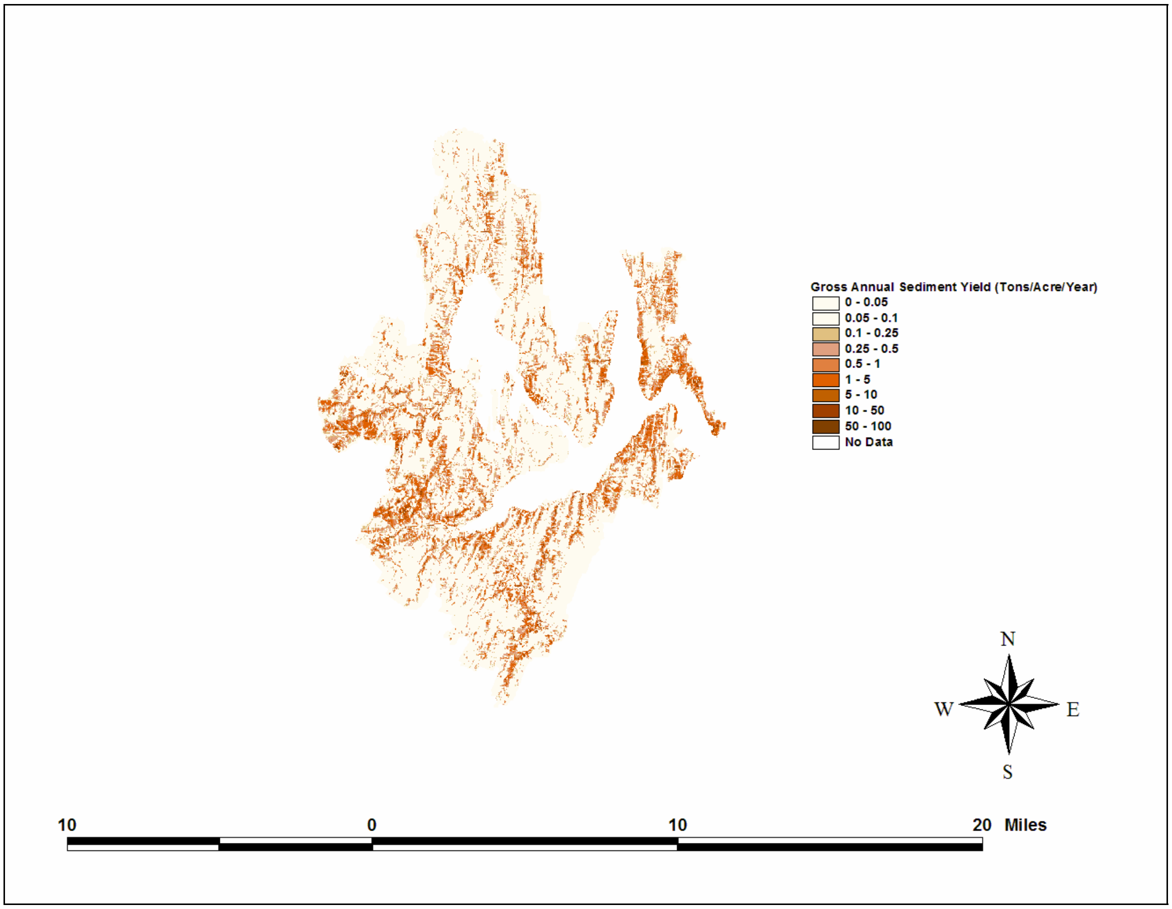

Figure 210. Gross Annual Sediment Yield (Tons/acre/year) computed using USLE.

Defining a computational mask for an individual watershed system within the study area subsequently allowed for the determination of the gross annual sediment yield and net annual sediment yield as a function of land use (through multiplication of the gross annual sediment yield for a specific land use within the defined computational mask by an appropriately determined SDR for that land use/land cover) within that defined computational mask (i.e., watershed system).

7.0 HSPF SEDIMENT LOADING CALIBRATION

The HSPF sediment loading calibration was conducted after performing the HSPF hydrologic calibration. That is, the HSPF hydrology parameters were subsequently fixed, and only those parameters pertaining to HSPF sediment loading were allowed to be adjustable.

7.1 METHODS

Enhancements (Skahill and Doherty, 2006) and adaptations (Doherty and Skahill, 2006) to the Gauss Marquardt Levenberg (GML) method of computer-based parameter estimation (Levenburg, 1944; Marquardt, 1963), and a model independent protocol (Skahill, 2006) wherein the inversion methods communicate with a model through the model's own input and output files, were utilized to calibrate the HSPF hydrologic models deployed in the Sinclair-Dyes Inlet watershed. Theory associated with these methods is presented in Appendix 5.

7.1.1 Chico Creek

The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). To account for the pervious land areas represented within each land segment, for each land segment, nine instances of all but the last four parameters listed in Table 72 required estimation. Twenty instances of the last four parameters listed in Table 72 required estimation, four instances for each subwatershed model. Thus a total of $305 = 9 \cdot 5 \cdot 5 + 4 \cdot 5 \cdot 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 31st Dec 2002. Values for the 305 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 73 and 74 with their simulated counterparts. The column of values for SOSED in Table 73 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 73 and ΔSLDS in Table 74 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 74 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 140 “observations” summarized in Tables 73 and 74, 305 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and otherwise an assumed homogeneity condition throughout Chico Creek for all of the other adjustable model parameters. This resulted in a total of 446 observations for use in the HSPF sediment loading calibration process for Chico Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Chico Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 73 and 74 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

Parameter name	Parameter function	Bounds imposed during calibration process
KRER	coefficient in the soil detachment equation	3.00000E-02 - 4.50000E-01
AFFIX	fraction by which detached sediment storage decreases each day as a result of soil compaction	3.00000E-02 - 1.00000E-01 day^{-1}
COVER	fraction of land surface which is shielded from rainfall erosion (not considering snow cover)	1.00000E-10 - 9.00000E-01
KSER	coefficient in the detached sediment washoff equation	1.00000E-02 - 1.00000E+01
JSER	exponent in the detached sediment washoff equation	1.00000E+00 - 3.00000E+00
KEIM	coefficient in the solids washoff equation	1.00000E-02 - 1.00000E+01
JEIM	exponent in the solids washoff equation	1.00000E+00 - 3.00000E+00
ACCSDP	rate at which solids accumulate on the land surface	5.00000E-04 - 3.00000E+01 tons/ac.d
REMSDP	fraction of solids storage which is removed each day when there is no runoff	1.00000E-03 - 1.00000E+00 day^{-1}

Table 72. Parameters estimated in calibration of Chico Creek subwatershed models.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Kitsap Creek	SUBURBAN	1	0.3062696	0
	MULTI-FAMILY	2	0.1497676	0
	COMMERCIAL	3	8.62E-02	0
	RURAL RESIDENTIAL	4	0.578969	0
	LAWN	5	0.6144288	0
	PASTURE	6	0.9348752	0
	DECIDUOUS FOREST	7	0.1278969	0
	CONIFEROUS FOREST	8	3.09E-02	0
	MIXED FOREST	9	6.01E-02	0
	BARE SOIL	11	0	0
Wildcat Creek	SUBURBAN	12	0.1102288	0
	MULTI-FAMILY	13	1.34E-02	0
	COMMERCIAL	14	0	0
	RURAL RESIDENTIAL	15	0.1103234	0
	LAWN	16	0.5497839	0
	PASTURE	17	0.5640477	0
	DECIDUOUS FOREST	18	0.138738	0
	CONIFEROUS FOREST	19	2.76E-02	0
	MIXED FOREST	20	8.35E-02	0
	BARE SOIL	22	10.67188	0
Chico Trib.	SUBURBAN	23	0.1985704	0
	MULTI-FAMILY	24	9.25E-02	0
	COMMERCIAL	25	0.7825	0
	RURAL RESIDENTIAL	26	0.3582029	0
	LAWN	27	0.7005017	0
	PASTURE	28	1.112036	0
	DECIDUOUS FOREST	29	0.1968329	0
	CONIFEROUS FOREST	30	3.77E-02	0
	MIXED FOREST	31	0.1515066	0
	BARE SOIL	33	46.2124	0
Dickerson Creek	SUBURBAN	34	0.560034	0
	MULTI-FAMILY	35	1.68E-02	0
	COMMERCIAL	36	0	0
	RURAL RESIDENTIAL	37	0	0
	LAWN	38	0.7859227	0
	PASTURE	39	1.373103	0
	DECIDUOUS FOREST	40	0.3929829	0
	CONIFEROUS FOREST	41	3.19E-02	0
	MIXED FOREST	42	0.1399929	0
	BARE SOIL	44	54.65508	0
Chico Creek Mainstem	SUBURBAN	45	0.8340577	0
	MULTI-FAMILY	46	0.762829	0
	COMMERCIAL	47	1.675857	0
	RURAL RESIDENTIAL	48	3.37E-02	0
	LAWN	49	0.6593091	0
	PASTURE	50	44.0005	0
	DECIDUOUS FOREST	51	0.2666531	0
	CONIFEROUS FOREST	52	0.142901	0
	MIXED FOREST	53	8.97E-02	0
	BARE SOIL	55	0	0

Table 73. Sediment loading calibration data for pervious land area in Chico Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Kitsap Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0
Wildcat Creek	SUBURBAN	21	0.3	0
	MULTI-FAMILY	22	0.3	0
	COMMERCIAL	23	0.35	0
	RURAL RESIDENTIAL	24	0.3	0
Chico Trib.	SUBURBAN	31	0.3	0
	MULTI-FAMILY	32	0.3	0
	COMMERCIAL	33	0.35	0
	RURAL RESIDENTIAL	34	0.3	0
Dickerson Creek	SUBURBAN	41	0.3	0
	MULTI-FAMILY	42	0.3	0
	COMMERCIAL	43	0.35	0
	RURAL RESIDENTIAL	44	0.3	0
Chico Creek Mainsten	SUBURBAN	51	0.3	0
	MULTI-FAMILY	52	0.3	0
	COMMERCIAL	53	0.35	0
	RURAL RESIDENTIAL	54	0.3	0

Table 74. Sediment loading calibration data for impervious land area in Chico Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.2 Strawberry Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Nine instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $40 = 9 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 40 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 75 and 76 with their simulated counterparts. The column of values for SOSED in Table 75 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 75 and ΔSLDS in Table 76 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 76 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 75 and 76, 18 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Strawberry Creek. This resulted in a total of 46 observations for use in the HSPF sediment loading calibration process for Strawberry Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Strawberry Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 75 and 76 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Strawberry Creek	SUBURBAN	1	0.1446785	0
	MULTI-FAMILY	2	0.095435	0
	COMMERCIAL	3	9.61E-02	0
	RURAL RESIDENTIAL	4	0.2333202	0
	LAWN	5	0.7189317	0
	PASTURE	6	0.7856	0
	DECIDUOUS FOREST	7	0.2872119	0
	CONIFEROUS FOREST	8	1.94E-02	0
	MIXED FOREST	9	1.71E-01	0
	BARE SOIL	11	0	0

Table 75. Sediment loading calibration data for pervious land area in Strawberry Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Strawberry Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 76. Sediment loading calibration data for impervious land area in Strawberry Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.3 Clear Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). To account for the pervious land areas represented within each land segment nine instances of all but the last four parameters listed in Table 72 required estimation for the land segment associated with the drainage area contributing to the flow monitoring location at Clear Creek West; whereas, ten instances of all but the last four parameters listed in Table 72 required estimation for the land segment associated with the drainage area contributing to the flow monitoring location at Clear Creek. Eight instances of the last four parameters listed in Table 72 required estimation, four instances for each land segment. Thus a total of 116 model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 116 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 77 and 78 with their simulated counterparts. The column of values for SOSED in Table 77 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 77 and ΔSLDS in Table 78 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 78 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 56 “observations” summarized in Tables 77 and 78, 62 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and otherwise an assumed homogeneity condition throughout Clear Creek for all of the other adjustable model parameters. This resulted in a total of 118 observations for use in the HSPF sediment loading calibration process for Chico Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Clear Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 77 and 78 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Clear Creek West	SUBURBAN	1	0.0569855	0
	MULTI-FAMILY	2	0.0457868	0
	COMMERCIAL	3	2.93E-02	0
	RURAL RESIDENTIAL	4	0.334	0
	LAWN	5	1.6950219	0
	PASTURE	6	0.3086006	0
	DECIDUOUS FOREST	7	0.2200656	0
	CONIFEROUS FOREST	8	1.47E-02	0
	MIXED FOREST	9	3.69E-01	0
	BARE SOIL	11	0	0
Clear Creek	SUBURBAN	12	0.1205219	0
	MULTI-FAMILY	13	7.19E-02	0
	COMMERCIAL	14	0.0784175	0
	RURAL RESIDENTIAL	15	0.3165946	0
	LAWN	16	0.9277868	0
	PASTURE	17	1.4051434	0
	DECIDUOUS FOREST	18	0.0998424	0
	CONIFEROUS FOREST	19	1.91E-02	0
	MIXED FOREST	20	2.54E-01	0
	BARE SOIL	22	13.2946	0

Table 77. Sediment loading calibration data for pervious land area in Clear Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		ID	"OBSERVED" SOSLD	ΔSLDS
Clear Creek West	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0
Clear Creek	SUBURBAN	21	0.3	0
	MULTI-FAMILY	22	0.3	0
	COMMERCIAL	23	0.35	0
	RURAL RESIDENTIAL	24	0.3	0

Table 78. Sediment loading calibration data for impervious land area in Clear Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.4 Barker Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Nine instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $40 = 9 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 40 adjustable model parameters were estimated by matching the "observed" data expressed in Tables 79 and 80 with their simulated counterparts. The column of values for SOSED in Table 79 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 79 and ΔSLDS in Table 80 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 80 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 "observations" summarized in Tables 79 and 80, 18 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Barker Creek. This resulted in a total of 46 observations for use in the HSPF sediment loading calibration process for Barker Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Barker Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 79 and 80 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Barker Creek	SUBURBAN	1	0.1438037	0
	MULTI-FAMILY	2	0.0604973	0
	COMMERCIAL	3	4.50E-02	0
	RURAL RESIDENTIAL	4	0.1346635	0
	LAWN	5	0.6056787	0
	PASTURE	6	1.1015	0
	DECIDUOUS FOREST	7	0.1592696	0
	CONIFEROUS FOREST	8	4.36E-02	0
	MIXED FOREST	9	3.14E-01	0
	BARE SOIL	11	0	0

Table 79. Sediment loading calibration data for pervious land area in Barker Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Barker Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 80. Sediment loading calibration data for impervious land area in Barker Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.5 Karcher Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Seven instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $32 = 7 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 32 adjustable model parameters were estimated by matching the "observed" data expressed in Tables 81 and 82 with their simulated counterparts. The column of values for SOSED in Table 81 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 81 and ΔSLDS in Table 82 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 82 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 22 "observations" summarized in Tables 81 and 82, 14 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Karcher Creek. This resulted in a total of 36 observations for use in the HSPF sediment loading calibration process for Karcher Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Karcher Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 81 and 82 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Karcher Creek	SUBURBAN	1	0.126658	0
	MULTI-FAMILY	2	2.58E-02	0
	COMMERCIAL	3	3.72E-02	0
	RURAL RESIDENTIAL	4		
	LAWN	5	0.634272	0
	PASTURE	6		
	DECIDUOUS FOREST	7	0.913614	0
	CONIFEROUS FOREST	8	5.41E-02	0
	MIXED FOREST	9	1.85E-01	0
	BARE SOIL	11		

Table 81. Sediment loading calibration data for pervious land area in Karcher Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Karcher Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 82. Sediment loading calibration data for impervious land area in Karcher Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.6 Blackjack Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Ten instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $44 = 10 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 44 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 83 and 84 with their simulated counterparts. The column of values for SOSED in Table 83 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 83 and ΔSLDS in Table 84 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 84 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 83 and 84, 20 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Blackjack Creek. This resulted in a total of 48 observations for use in the HSPF sediment loading calibration process for Blackjack Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Blackjack Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 83 and 84 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Blackjack Creek	SUBURBAN	1	7.36E-02	0
	MULTI-FAMILY	2	3.20E-02	0
	COMMERCIAL	3	4.08E-02	0
	RURAL RESIDENTIAL	4	0.187155	0
	LAWN	5	0.562273	0
	PASTURE	6	0.601483	0
	DECIDUOUS FOREST	7	0.123964	0
	CONIFEROUS FOREST	8	1.46E-02	0
	MIXED FOREST	9	7.87E-02	0
	BARE SOIL	11	22.391	0

Table 83. Sediment loading calibration data for pervious land area in Blackjack Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Blackjack Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 84. Sediment loading calibration data for impervious land area in Blackjack Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.7 Anderson Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Ten instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $44 = 10 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 44 adjustable model parameters were estimated by matching the "observed" data expressed in Tables 85 and 86 with their simulated counterparts. The column of values for SOSED in Table 85 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 85 and ΔSLDS in Table 86 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 86 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 "observations" summarized in Tables 85 and 86, 20 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Anderson Creek. This resulted in a total of 48 observations for use in the HSPF sediment loading calibration process for Anderson Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Anderson Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 85 and 86 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Anderson Creek	SUBURBAN	1	7.36E-02	0
	MULTI-FAMILY	2	3.20E-02	0
	COMMERCIAL	3	4.08E-02	0
	RURAL RESIDENTIAL	4	0.187155	0
	LAWN	5	0.562273	0
	PASTURE	6	0.601483	0
	DECIDUOUS FOREST	7	0.123964	0
	CONIFEROUS FOREST	8	1.46E-02	0
	MIXED FOREST	9	7.87E-02	0
	BARE SOIL	11	22.391	0

Table 85. Sediment loading calibration data for pervious land area in Anderson Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Anderson Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 86. Sediment loading calibration data for impervious land area in Anderson Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.8 Gorst Creek

The names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). To account for the pervious land areas represented within each land segment, for the Heins Creek land segment, six instances, for the Parish Creek land segment, nine instances, and for the Gorst Creek land segment, ten instances of all but the last four parameters listed in Table 72 required estimation. Twelve instances of the last four parameters listed in Table 72 required estimation, four instances for each subwatershed model. Thus a total of 112 model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Jan 1999 to 31st Dec 2002. Values for the 112 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 87 - 92 with their simulated counterparts. The column of values for SOSED in Tables 87, 89, and 91 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS and ΔSLDS in Tables 87 - 92 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Tables 88, 90, and 92 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 85 “observations” summarized in Tables 87 - 92, 50 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Gorst Creek. This resulted in a total of 135 observations for use in the HSPF sediment loading calibration process for Gorst Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Gorst Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 87 - 92 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

			"OBSERVED"	
		ID	SOSED	ΔDETS
Heins Creek	SUBURBAN	1		
	MULTI-FAMILY	2		
	COMMERCIAL	3		
	RURAL RESIDENTIAL	4		
	LAWN	5	2.59409	0
	PASTURE	6	2.11356	0
	DECIDUOUS FOREST	7	0.646786	0
	CONIFEROUS FOREST	8	1.26E-01	0
	MIXED FOREST	9	2.23E-01	0
	BARE SOIL	11	7.216	0

Table 87. Sediment loading calibration data for pervious land area in Heins Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Heins Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 88. Sediment loading calibration data for impervious land area in Heins Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

		"OBSERVED"		
		ID	SOSED	ΔDETS
Parish Creek	SUBURBAN	1	7.38E-02	0
	MULTI-FAMILY	2	2.98E-02	0
	COMMERCIAL	3	3.95E-02	0
	RURAL RESIDENTIAL	4	0.148303	0
	LAWN	5	0.684945	0
	PASTURE	6	1.1741	0
	DECIDUOUS FOREST	7	0.380836	0
	CONIFEROUS FOREST	8	4.61E-02	0
	MIXED FOREST	9	3.28E-01	0
	BARE SOIL	11		

Table 89. Sediment loading calibration data for pervious land area in Parish Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Parish Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 90. Sediment loading calibration data for impervious land area in Parish Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

		"OBSERVED"		
		ID	SOSED	ΔDETS
Gorst Creek	SUBURBAN	1	4.16E-02	0
	MULTI-FAMILY	2	6.63E-02	0
	COMMERCIAL	3	7.98E-02	0
	RURAL RESIDENTIAL	4	0.322011	0
	LAWN	5	1.22935	0
	PASTURE	6	1.02875	0
	DECIDUOUS FOREST	7	0.439879	0
	CONIFEROUS FOREST	8	6.48E-02	0
	MIXED FOREST	9	2.33E-01	0
	BARE SOIL	11	2.8879	0

Table 91. Sediment loading calibration data for pervious land area in Gorst Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Gorst Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 92. Sediment loading calibration data for impervious land area in Gorst Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.9 Springbrook Creek

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Seven instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $32 = 7 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 32 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 93 and 94 with their simulated counterparts. The column of values for SOSED in Table

93 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 93 and ΔSLDS in Table 94 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 94 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 93 and 94, 14 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout Springbrook Creek. This resulted in a total of 42 observations for use in the HSPF sediment loading calibration process for Springbrook Creek.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the Springbrook Creek HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 93 and 94 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
Springbrook Creek	SUBURBAN	1		
	MULTI-FAMILY	2		
	COMMERCIAL	3	4.11E-01	0
	RURAL RESIDENTIAL	4		
	LAWN	5	0.7643	0
	PASTURE	6	1.04643	0
	DECIDUOUS FOREST	7	0.214885	0
	CONIFEROUS FOREST	8	4.98E-02	0
	MIXED FOREST	9	1.29E-01	0
	BARE SOIL	11	1.6181	0

Table 93. Sediment loading calibration data for pervious land area in Springbrook Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Springbrook Creek	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 94. Sediment loading calibration data for impervious land area in Springbrook Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.10 BST 12

This model was not calibrated (see section 5.2.10).

7.1.11 BST 01

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Nine instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $40 = 9 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 40 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 95 and 96 with their simulated counterparts. The column of values for SOSED in Table 95 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 95 and ΔSLDS in Table 96 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 96 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 95 and 96, 18 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout BST 01. This resulted in a total of 46 observations for use in the HSPF sediment loading calibration process for BST 01.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the BST 01 HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 95 and 96 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

			"OBSERVED"	
		ID	SOSED	ΔDETS
BST01	SUBURBAN	1	2.44E-01	0
	MULTI-FAMILY	2	9.27E-02	0
	COMMERCIAL	3	1.08E-01	0
	RURAL RESIDENTIAL	4	0.306656	0
	LAWN	5	4.7044	0
	PASTURE	6	1.2299	0
	DECIDUOUS FOREST	7	0.188996	0
	CONIFEROUS FOREST	8	3.39E-02	0
	MIXED FOREST	9	6.09E-02	0
	BARE SOIL	11		

Table 95. Sediment loading calibration data for pervious land area in BST 01 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

			"OBSERVED"	
		ID	SOSLD	ΔSLDS
BST01	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 96. Sediment loading calibration data for impervious land area in BST 01 (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.12 LMK001

The LMK001 HSPF sediment loading model was setup to piggyback off the results obtained for the Clear Creek HSPF sediment loading model.

7.1.13 LMK002

The LMK002 HSPF sediment loading model was setup to piggyback off the results obtained for the Clear Creek HSPF sediment loading model.

7.1.14 LMK122

This model was not calibrated (see section 5.2.14).

7.1.15 PO-POBLVD

This model was not calibrated (see section 5.2.15).

7.1.16 LMK136

This model was not calibrated (see section 5.2.16).

7.1.17 LMK038

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Six instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $28 = 6 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 28 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 97 and 98 with their simulated counterparts. The column of values for SOSED in Table 97 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 97 and ΔSLDS in Table 98 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 98 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 97 and 98, 12 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout LMK038. This resulted in a total of 40 observations for use in the HSPF sediment loading calibration process for LMK038.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the LMK038 HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 97 and 98 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

			"OBSERVED"	
		ID	SOSED	ΔDETS
Manchester	SUBURBAN	1		
	MULTI-FAMILY	2		
	COMMERCIAL	3	5.95E-01	0
	RURAL RESIDENTIAL	4	1.47765	0
	LAWN	5		
	PASTURE	6	0	0
	DECIDUOUS FOREST	7	0.8121	0
	CONIFEROUS FOREST	8	4.83E-02	0
	MIXED FOREST	9	6.71E-02	0
	BARE SOIL	11		

Table 97. Sediment loading calibration data for pervious land area in LMK038 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
Manchester	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 98. Sediment loading calibration data for impervious land area in LMK038 (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.18 B-ST CSO16

The B-ST CSO16 HSPF sediment loading model was setup to piggyback off the results obtained for the BST 28 HSPF sediment loading model.

7.1.19 BST 28

With the exception of the parameter JSER, which was fixed at the value of two, the names and roles of model parameters selected for adjustment through the calibration process are provided in Table 72. Also listed are the bounds on these parameters imposed during the parameter estimation process, these being set in accordance with available guidance, for example, USEPA (2006). Four instances of all but the last four parameters listed in Table 72 required estimation. A single instance of the last four parameters listed in Table 72 required estimation. Thus a total of $20 = 4 \cdot 4 + 4$ model parameters required estimation through the calibration process. In order to better accommodate scaling issues resulting from the use of different units for different parameters, and in an attempt to decrease the degree of nonlinearity of the parameter estimation problem, the logs of these parameters were estimated instead of their native values; past experience has demonstrated that greater efficiency and stability of the parameter estimation process can often be achieved through this means (Skahill and Doherty, 2006).

The calibration period was 1st Oct 1998 to 30th Sep 2003. Values for the 20 adjustable model parameters were estimated by matching the “observed” data expressed in Tables 99 and 100 with their simulated counterparts. The column of values for SOSED in Table 99 were obtained from the GIS-based USLE analysis together with appropriately specified SDRs for each land use within each land segment. The column of values for ΔDETS in Table 99 and ΔSLDS in Table 100 were specified to be uniformly zero in attempt to enforce an equilibrium condition as mentioned previously in section 6.0. The column of values for SOSLD in Table 100 were specifed based on the GIS-based USLE analysis together with available guidance (USEPA 2006). In addition to the 28 “observations” summarized in Tables 99 and 100, 8 pieces of prior information were also included into the parameter estimation process. The prior information included specification of preferred values for the parameter KRER, and an assumed homogeneity condition for the adjustable model parameter AFFIX throughout BST 28. This resulted in a total of 36 observations for use in the HSPF sediment loading calibration process for BST 28.

The GML method together with the TPI functionality (see Appendix 5) were employed to calibrate the BST 28 HSPF sediment loading model. A weight of one was uniformly assigned to the observation data listed in Tables 99 and 100 that constituted the objective function; however, prior to initiating the parameter estimation process, weights were uniformly adjusted within each observation group such that the parameter estimation engine saw each of them as of equal importance. A weight of one was applied to each piece of prior information.

		"OBSERVED"		
		ID	SOSED	ΔDETS
BST28	SUBURBAN	1	2.57E-01	0
	MULTI-FAMILY	2	3.61E-02	0
	COMMERCIAL	3	3.83E-02	0
	RURAL RESIDENTIAL	4		
	LAWN	5		
	PASTURE	6		
	DECIDUOUS FOREST	7		
	CONIFEROUS FOREST	8	4.18E-02	0
	MIXED FOREST	9		
	BARE SOIL	11		

Table 99. Sediment loading calibration data for pervious land area in LMK038 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"		
		ID	SOSLD	ΔSLDS
BST28	SUBURBAN	11	0.3	0
	MULTI-FAMILY	12	0.3	0
	COMMERCIAL	13	0.35	0
	RURAL RESIDENTIAL	14	0.3	0

Table 100. Sediment loading calibration data for impervious land area in LMK038 (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.1.20 PSNS 126

The PSNS 126 HSPF sediment loading model was setup to piggyback off the results obtained for the BST 28 HSPF sediment loading model.

7.1.21 PSNS 124

This model was not calibrated (see section 5.2.16).

7.1.22 PSNS 015

The PSNS 015 HSPF sediment loading model was setup to piggyback off the results obtained for the BST 28 HSPF sediment loading model.

7.2 RESULTS

7.2.1 Chico Creek

The calibration inversion run was manually terminated after 3572 model calls, which resulted in reducing the objective function from a starting value of 0.50082 to a final value of 0.1385. Table 101 lists the identified parameter set that resulted from the calibration inversion run.

“Observed” data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Tables 102 and 103, respectively. The last column of Tables 102 and 103 present the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Kitsap Creek	SUBURBAN	1	0.08	0.0582	0.50	0.7033	1.8338
	MULTI-FAMILY	2	0.07	0.0647	0.72	1.1782	2.4714
	COMMERCIAL	3	0.07	0.0642	0.81	0.9889	2.2731
	RURAL RESIDENTIAL	4	0.05	0.0657	0.61	1.0705	1.1653
	LAWN	5	0.08	0.0975	0.15	1.2933	1.0000
	PASTURE	6	0.07	0.1000	0.35	1.4143	1.0000
	DECIDUOUS FOREST	7	0.09	0.1000	0.34	1.0050	1.1209
	CONIFEROUS FOREST	8	0.05	0.1000	0.79	0.9989	1.4134
	MIXED FOREST	9	0.07	0.1000	0.23	0.6499	1.3504
Wildcat Creek	SUBURBAN	12	0.06	0.0582	0.52	0.6954	1.9592
	MULTI-FAMILY	13	0.05	0.0647	0.74	1.1768	2.4964
	RURAL RESIDENTIAL	15	0.05	0.0657	0.60	1.0713	1.1592
	LAWN	16	0.04	0.0976	0.15	1.2925	1.0000
	PASTURE	17	0.05	0.1000	0.35	1.4129	1.0000
	DECIDUOUS FOREST	18	0.05	0.1000	0.34	1.0103	1.0884
	CONIFEROUS FOREST	19	0.05	0.1000	0.78	0.9994	1.4074
	MIXED FOREST	20	0.05	0.1000	0.23	0.6610	1.2900
	BAREGROUND	22	0.04	0.0650	0.90	0.9885	2.2771
Chico Trib.	SUBURBAN	23	0.06	0.0582	0.50	0.6932	2.0010
	MULTI-FAMILY	24	0.05	0.0647	0.73	1.1780	2.4786
	COMMERCIAL	25	0.09	0.0642	0.80	0.9890	2.2730
	RURAL RESIDENTIAL	26	0.04	0.0657	0.61	1.0705	1.1644
	LAWN	27	0.06	0.0976	0.15	1.2926	1.0000
	PASTURE	28	0.07	0.1000	0.35	1.4131	1.0000
	DECIDUOUS FOREST	29	0.06	0.1000	0.34	1.0136	1.0686
	CONIFEROUS FOREST	30	0.06	0.1000	0.78	0.9998	1.4036
	MIXED FOREST	31	0.06	0.1000	0.23	0.6646	1.2704
	BAREGROUND	33	0.05	0.0650	0.90	0.9885	2.2771
Dickerson Creek	SUBURBAN	34	0.26	0.0583	0.52	0.6935	1.9805
	MULTI-FAMILY	35	0.18	0.0647	0.74	1.1820	2.4166
	LAWN	38	0.05	0.0976	0.15	1.2929	1.0000
	PASTURE	39	0.06	0.1000	0.35	1.4117	1.0000
	DECIDUOUS FOREST	40	0.07	0.1000	0.34	1.0139	1.0672
	CONIFEROUS FOREST	41	0.05	0.1000	0.76	1.0023	1.3849
	MIXED FOREST	42	0.05	0.1000	0.23	0.6654	1.2647
	BAREGROUND	44	0.05	0.0650	0.90	0.9885	2.2771
Chico Creek Mainstem	SUBURBAN	45	0.12	0.0582	0.52	0.6980	1.9038
	MULTI-FAMILY	46	0.12	0.0646	0.72	1.1803	2.4386
	COMMERCIAL	47	0.17	0.0642	0.80	0.9890	2.2730
	RURAL RESIDENTIAL	48	0.03	0.0658	0.62	1.0695	1.1740
	LAWN	49	0.13	0.0976	0.15	1.2944	1.0000
	PASTURE	50	0.17	0.1000	0.35	1.4124	1.0000
	DECIDUOUS FOREST	51	0.07	0.1000	0.34	1.0111	1.0834
	CONIFEROUS FOREST	52	0.07	0.1000	0.77	1.0022	1.3878
	MIXED FOREST	53	0.04	0.1000	0.23	0.6596	1.2937

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - KITSAP CK	111	0.93	2.3726	0.0042	0.0661
	112	0.93	2.3726	0.0042	0.0661
	113	0.94	2.2941	0.0047	0.0640
	114	0.93	2.3726	0.0042	0.0661
IMPERVIOUS - WILDCAT CK	121	0.93	2.3726	0.0042	0.0661
	122	0.93	2.3726	0.0042	0.0661
	123	0.94	2.2941	0.0047	0.0640
	124	0.93	2.3726	0.0042	0.0661
IMPERVIOUS - CHICO TRIB.	131	0.93	2.3722	0.0042	0.0661
	132	0.93	2.3722	0.0042	0.0661
	133	0.94	2.2936	0.0047	0.0640
	134	0.93	2.3722	0.0042	0.0661
IMPERVIOUS - DICKERSON	141	0.93	2.3715	0.0042	0.0661
	142	0.93	2.3715	0.0042	0.0661
	143	0.94	2.2924	0.0047	0.0640
	144	0.93	2.3715	0.0042	0.0661
IMPERVIOUS - CHICO MAINSTEM	151	0.93	2.3718	0.0042	0.0661
	152	0.93	2.3718	0.0042	0.0661
	153	0.94	2.2929	0.0047	0.0640
	154	0.93	2.3718	0.0042	0.0661

Table 101. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Kitsap Creek	SUBURBAN	1	0.3062696	0	1	0.250233	7.85E-05	8.92
	MULTI-FAMILY	2	0.1497676	0	2	0.136812	-2.07E-07	4.79
	COMMERCIAL	3	8.62E-02	0	3	9.97E-02	-3.86E-05	0.44
	RURAL RESIDENTIAL	4	0.578969	0	4	0.128479	-4.71E-04	4.18
	LAWN	5	0.6144288	0	5	0.408811	-1.60E-03	25.44
	PASTURE	6	0.9348752	0	6	2.61E-01	1.09E-02	1.83
	DECIDUOUS FOREST	7	0.1278969	0	7	0.170736	1.31E-02	26.79
	CONIFEROUS FOREST	8	3.09E-02	0	8	3.28E-02	1.41E-02	4.66
	MIXED FOREST	9	6.01E-02	0	9	6.93E-02	5.96E-03	1.24
	BARE SOIL	11	0	0	11	0	0.00E+00	
Wildcat Creek	SUBURBAN	12	0.1102288	0	12	0.161251	6.42E-05	10.84
	MULTI-FAMILY	13	1.34E-02	0	13	8.41E-02	-9.87E-06	0.42
	COMMERCIAL	14	0	0	14	0	0.00E+00	0.00
	RURAL RESIDENTIAL	15	0.1103234	0	15	0.110277	-6.41E-05	6.87
	LAWN	16	0.5497839	0	16	2.00E-01	6.16E-05	25.54
	PASTURE	17	0.5640477	0	17	1.57E-01	1.35E-03	2.22
	DECIDUOUS FOREST	18	0.138738	0	18	0.117059	1.43E-02	34.75
	CONIFEROUS FOREST	19	2.76E-02	0	19	2.77E-02	1.28E-02	8.87
	MIXED FOREST	20	8.35E-02	0	20	5.44E-02	9.90E-03	5.27
	BARE SOIL	22	10.67188	0	22	2.92E-02	-1.08E-05	0.81
Chico Trib.	SUBURBAN	23	0.1985704	0	23	0.174839	6.01E-05	8.90
	MULTI-FAMILY	24	9.25E-02	0	24	8.66E-02	-2.75E-06	0.79
	COMMERCIAL	25	0.7825	0	25	1.24E-01	-4.78E-05	0.05
	RURAL RESIDENTIAL	26	0.3582029	0	26	9.56E-02	-1.14E-04	0.59
	LAWN	27	0.7005017	0	27	0.289885	2.86E-03	24.63
	PASTURE	28	1.112036	0	28	2.32E-01	1.11E-02	4.28
	DECIDUOUS FOREST	29	0.1968329	0	29	0.160008	1.16E-02	31.78
	CONIFEROUS FOREST	30	3.77E-02	0	30	4.24E-02	1.17E-02	17.40
	MIXED FOREST	31	0.1515066	0	31	1.16E-01	7.92E-03	7.73
	BARE SOIL	33	46.2124	0	33	3.13E-02	-9.51E-06	0.08
Dickerson Creek	SUBURBAN	34	0.560034	0	34	0.615131	-5.69E-06	7.58
	MULTI-FAMILY	35	1.68E-02	0	35	0.252758	4.39E-06	0.61
	COMMERCIAL	36	0	0	36	0	0.00E+00	0.00
	RURAL RESIDENTIAL	37	0	0	37	1.42E-03	7.97E-03	0.00
	LAWN	38	0.7859227	0	38	2.20E-01	7.82E-04	40.25
	PASTURE	39	1.373103	0	39	1.72E-01	1.67E-03	2.22
	DECIDUOUS FOREST	40	0.3929829	0	40	0.152043	2.65E-02	25.08
	CONIFEROUS FOREST	41	3.19E-02	0	41	3.19E-02	1.55E-02	19.98
	MIXED FOREST	42	0.1399929	0	42	7.15E-02	2.21E-02	3.43
	BARE SOIL	44	54.65508	0	44	2.79E-02	-6.65E-06	0.42
Chico Creek Mainstem	SUBURBAN	45	0.8340577	0	45	0.268258	1.53E-04	34.82
	MULTI-FAMILY	46	0.762829	0	46	0.167877	6.57E-07	8.77
	COMMERCIAL	47	1.675857	0	47	0.176266	-8.86E-05	0.70
	RURAL RESIDENTIAL	48	3.37E-02	0	48	5.07E-02	-2.30E-04	0.02
	LAWN	49	0.6593091	0	49	0.435976	-7.84E-03	7.33
	PASTURE	50	44.0005	0	50	3.51E-01	9.05E-03	1.22
	DECIDUOUS FOREST	51	0.2666531	0	51	0.156837	4.74E-03	13.38
	CONIFEROUS FOREST	52	0.142901	0	52	4.41E-02	7.92E-03	10.15
	MIXED FOREST	53	8.97E-02	0	53	6.77E-02	1.59E-02	2.07
	BARE SOIL	55	0	0	55	0	0.00E+00	0.00

Table 102. Sediment loading calibration data and results for pervious land area in Chico Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Kitsap Creek	SUBURBAN	11	0.3	0	11	0.360593	0	1.47
	MULTI-FAMILY	12	0.3	0	12	0.360593	0	5.19
	COMMERCIAL	13	0.35	0	13	0.406668	0	15.05
	RURAL RESIDENTIAL	14	0.3	0	14	0.360593	0	0.00
Wildcat Creek	SUBURBAN	21	0.3	0	21	0.339291	0	2.82
	MULTI-FAMILY	22	0.3	0	22	0.339291	0	0.00
	COMMERCIAL	23	0.35	0	23	0.382483	0	0.00
	RURAL RESIDENTIAL	24	0.3	0	24	0.339291	0	1.59
Chico Trib.	SUBURBAN	31	0.3	0	31	0.339815	0	2.14
	MULTI-FAMILY	32	0.3	0	32	0.339815	0	0.84
	COMMERCIAL	33	0.35	0	33	0.383156	0	0.72
	RURAL RESIDENTIAL	34	0.3	0	34	0.339815	0	0.08
Dickerson Creek	SUBURBAN	41	0.3	0	41	0.282646	0	0.43
	MULTI-FAMILY	42	0.3	0	42	0.282646	0	0.00
	COMMERCIAL	43	0.35	0	43	0.318687	0	0.00
	RURAL RESIDENTIAL	44	0.3	0	44	0.282646	0	0.00
Chico Creek Mainstem	SUBURBAN	51	0.3	0	51	0.301306	0	4.83
	MULTI-FAMILY	52	0.3	0	52	0.301306	0	4.71
	COMMERCIAL	53	0.35	0	53	0.33992	0	11.98
	RURAL RESIDENTIAL	54	0.3	0	54	0.301306	0	0.00

Table 103. Sediment loading calibration data and results for impervious land area in Chico Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.2 Strawberry Creek

The calibration inversion run terminated after 596 model calls, which resulted in reducing the objective function from a starting value of 0.24800 to a final value of 5.8167E-02. Table 104 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 105. The last column of Table 105 presents the percent of total load contributed from each land use.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Strawberry Creek	SUBURBAN	1	0.08	0.1000	0.69	10.0000	2.0000
	MULTI-FAMILY	2	0.09	0.1000	0.81	10.0000	2.0000
	COMMERCIAL	3	0.07	0.1000	0.78	10.0000	2.0000
	RURAL RESIDENTIAL	4	0.06	0.1000	0.03	10.0000	2.0000
	LAWN	5	0.09	0.1000	0.00	10.0000	2.0000
	PASTURE	6	0.05	0.1000	0.01	10.0000	2.0000
	DECIDUOUS FOREST	7	0.08	0.1000	0.45	10.0000	2.0000
	CONIFEROUS FOREST	8	0.06	0.1000	0.41	10.0000	2.0000
	MIXED FOREST	9	0.06	0.1000	0.29	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - STRAWBERRY CK	151	1.17	1.0000	0.0109	0.9152

Table 104. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Strawberry Creek	SUBURBAN	1	0.1446785	0	1	0.141377	9.12E-02	20.95
	MULTI-FAMILY	2	0.095435	0	2	9.47E-02	1.66E-02	6.34
	COMMERCIAL	3	9.61E-02	0	3	9.51E-02	5.15E-04	1.74
	RURAL RESIDENTIAL	4	0.2333202	0	4	0.229782	1.06E-01	5.44
	LAWN	5	0.7189317	0	5	0.282073	1.22E-01	8.79
	PASTURE	6	0.7856	0	6	8.61E-02	1.03E-01	0.34
	DECIDUOUS FOREST	7	0.2872119	0	7	1.97E-02	9.94E-02	2.36
	CONIFEROUS FOREST	8	1.94E-02	0	8	1.82E-02	9.54E-02	4.65
	MIXED FOREST	9	1.71E-01	0	9	2.43E-02	1.00E-01	0.17
	BARE SOIL	11	0	0	11	6.51E-03	4.41E-02	0.00
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Strawberry Creek	SUBURBAN	11	0.3	0	11	0.313771	-8.60E-05	10.91
	MULTI-FAMILY	12	0.3	0	12	0.313771	-8.60E-05	9.89
	COMMERCIAL	13	0.35	0	13	0.313771	-8.60E-05	27.60
	RURAL RESIDENTIAL	14	0.3	0	14	0.313771	-8.60E-05	0.82

Table 105. Sediment loading calibration data and results for pervious and impervious land area in Strawberry Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.3 Clear Creek

The calibration inversion run terminated after 1849 model calls, which resulted in reducing the objective function from a starting value of 0.62861 to a final value of 0.1404. Table 106 lists the identified parameter set that resulted from the calibration inversion run.

“Observed” data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Tables 107 and 108, respectively. The last column of Tables 107 and 108 present the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER
Clear Creek West	SUBURBAN	1	0.05	0.1000	0.73	8.3758
	MULTI-FAMILY	2	0.05	0.1000	0.85	3.5591
	COMMERCIAL	3	0.05	0.1000	0.89	2.2621
	RURAL RESIDENTIAL	4	0.05	0.1000	0.01	10.0000
	LAWN	5	0.08	0.1000	0.05	10.0000
	PASTURE	6	0.05	0.1000	0.03	10.0000
	DECIDUOUS FOREST	7	0.06	0.1000	0.19	10.0000
	CONIFEROUS FOREST	8	0.05	0.1000	0.82	10.0000
	MIXED FOREST	9	0.07	0.1000	0.21	10.0000
Clear Creek Mainstem	SUBURBAN	12	0.06	0.1000	0.71	8.3759
	MULTI-FAMILY	13	0.08	0.1000	0.84	3.5562
	COMMERCIAL	14	0.09	0.1000	0.87	2.2452
	RURAL RESIDENTIAL	15	0.07	0.1000	0.01	10.0000
	LAWN	16	0.13	0.1000	0.05	10.0000
	PASTURE	17	0.09	0.0998	0.03	10.0000
	DECIDUOUS FOREST	18	0.08	0.1000	0.19	10.0000
	CONIFEROUS FOREST	19	0.05	0.1000	0.85	9.9938
	MIXED FOREST	20	0.09	0.1000	0.21	10.0000
	BARE LAND	22	0.10	0.1000	0.00	10.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - CLEAR CK WEST	111	1.12	1.0115	0.0042	0.2334
	112	1.12	1.0115	0.0042	0.2334
	113	1.10	1.1289	0.0053	0.2267
	114	1.12	1.0115	0.0042	0.2334
IMPERVIOUS - CLEAR CK	121	1.12	1.0115	0.0042	0.2334
	122	1.12	1.0115	0.0042	0.2334
	123	1.10	1.1289	0.0053	0.2267
	124	1.12	1.0115	0.0042	0.2334

Table 106. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Clear Creek West	SUBURBAN	1	0.0569855	0	1	8.31E-02	8.65E-02	6.58
	MULTI-FAMILY	2	0.0457868	0	2	4.82E-02	1.66E-02	4.58
	COMMERCIAL	3	2.93E-02	0	3	3.55E-02	6.66E-04	0.59
	RURAL RESIDENTIAL	4	0.334	0	4	0.215858	1.04E-01	1.07
	LAWN	5	1.6950219	0	5	0.245739	1.17E-01	5.58
	PASTURE	6	0.3086006	0	6	1.04E-01	1.02E-01	1.24
	DECIDUOUS FOREST	7	0.2200656	0	7	6.78E-03	1.04E-01	0.52
	CONIFEROUS FOREST	8	1.47E-02	0	8	4.96E-03	8.42E-02	1.90
	MIXED FOREST	9	3.69E-01	0	9	7.20E-03	1.05E-01	0.07
	BARE SOIL	11	0	0	11	8.06E-03	5.92E-02	
Clear Creek Mainstem	SUBURBAN	12	0.1205219	0	12	0.106285	8.86E-02	8.27
	MULTI-FAMILY	13	0.0718915	0	13	7.10E-02	1.97E-02	5.08
	COMMERCIAL	14	0.0784175	0	14	7.22E-02	8.30E-04	0.82
	RURAL RESIDENTIAL	15	3.17E-01	0	15	2.99E-01	1.14E-01	5.63
	LAWN	16	0.9277868	0	16	0.357279	1.37E-01	17.27
	PASTURE	17	1.4051434	0	17	1.67E-01	1.02E-01	0.69
	DECIDUOUS FOREST	18	0.0998424	0	18	7.71E-02	1.12E-01	9.19
	CONIFEROUS FOREST	19	0.0190854	0	19	1.98E-02	8.35E-02	3.63
	MIXED FOREST	20	2.54E-01	0	20	7.91E-02	1.12E-01	0.45
	BARE SOIL	22	13.2946	0	22	0.589082	1.65E-02	0.44

Table 107. Sediment loading calibration data and results for pervious land area in Clear Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment).

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Clear Creek West	SUBURBAN	11	0.3	0	11	0.275311	-9.64E-03	4.01
	MULTI-FAMILY	12	0.3	0	12	0.275311	-9.64E-03	12.31
	COMMERCIAL	13	0.35	0	13	0.345882	-1.25E-02	61.55
	RURAL RESIDENTIAL	14	0.3	0	14	0.275311	-9.64E-03	0.00
Clear Creek Mainstem	SUBURBAN	21	0.3	0	21	0.275311	-9.64E-03	3.95
	MULTI-FAMILY	22	0.3	0	22	0.275311	-9.64E-03	9.04
	COMMERCIAL	23	0.35	0	23	0.345882	-1.25E-02	34.88
	RURAL RESIDENTIAL	24	0.3	0	24	0.275311	-9.64E-03	0.32

Table 108. Sediment loading calibration data and results for impervious land area in Clear Creek (SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.4 Barker Creek

The calibration inversion run terminated after 653 model calls, which resulted in reducing the objective function from a starting value of 0.18407 to a final value of 4.6025E-02. Table 109 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 110. The last column of Table 110 presents the percent of total load contributed from each land use.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Barker Creek	SUBURBAN	1	0.08	0.1000	0.66	10.0000	2.0000
	MULTI-FAMILY	2	0.06	0.1000	0.83	10.0000	2.0000
	COMMERCIAL	3	0.06	0.1000	0.88	10.0000	2.0000
	RURAL RESIDENTIAL	4	0.13	0.1000	0.72	10.0000	2.0000
	LAWN	5	0.14	0.1000	0.00	10.0000	2.0000
	PASTURE	6	0.05	0.1000	0.00	10.0000	2.0000
	DECIDUOUS FOREST	7	0.10	0.1000	0.90	10.0000	2.0000
	CONIFEROUS FOREST	8	0.07	0.1000	0.90	10.0000	2.0000
	MIXED FOREST	9	0.09	0.1000	0.90	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - BARKER CK	151	0.90	1.0481	0.0105	0.8468

Table 109. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
	ID	SOSED	ΔDETS	ID	SOSED	ΔDETS		FROM EACH LANDUSE
Barker Creek								
SUBURBAN	1	0.1438037	0	1	0.143475	4.07E-02		9.24
MULTI-FAMILY	2	0.0604973	0	2	5.98E-02	1.02E-02		5.21
COMMERCIAL	3	4.50E-02	0	3	4.45E-02	1.98E-04		3.09
RURAL RESIDENTIAL	4	0.1346635	0	4	0.132964	9.65E-02		16.01
LAWN	5	0.6056787	0	5	0.396975	1.10E-01		25.90
PASTURE	6	1.1015	0	6	1.09E-01	1.03E-01		0.50
DECIDUOUS FOREST	7	0.1592696	0	7	3.33E-03	8.45E-02		0.60
CONIFEROUS FOREST	8	4.36E-02	0	8	3.51E-03	8.31E-02		0.56
MIXED FOREST	9	3.14E-01	0	9	3.43E-03	8.40E-02		0.04
BARE SOIL	11	0	0	11	6.57E-03	4.40E-02		0.00
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
	ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS		FROM EACH LANDUSE
Barker Creek								
SUBURBAN	11	0.3	0	11	0.314413	-2.90E-04		2.71
MULTI-FAMILY	12	0.3	0	12	0.314413	-2.90E-04		9.42
COMMERCIAL	13	0.35	0	13	0.314413	-2.90E-04		22.52
RURAL RESIDENTIAL	14	0.3	0	14	0.314413	-2.90E-04		4.21

Table 110. Sediment loading calibration data and results for pervious and impervious land area in Barker Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.5 Karcher Creek

The calibration inversion run terminated after 321 model calls, which resulted in reducing the objective function from a starting value of 0.42771 to a final value of 0.2259. Table 111 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 112. The last column of Table 112 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Karcher Creek	SUBURBAN	1	0.11	0.1000	0.79	10.0000	2.0000
	MULTI-FAMILY	2	0.10	0.1000	0.90	10.0000	2.0000
	COMMERCIAL	3	0.09	0.1000	0.90	10.0000	2.0000
	LAWN	5	0.05	0.1000	0.70	10.0000	2.0000
	DECIDUOUS FOREST	7	0.15	0.1000	0.83	10.0000	2.0000
	CONIFEROUS FOREST	8	0.12	0.1000	0.83	10.0000	2.0000
	MIXED FOREST	9	0.12	0.1000	0.54	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - KARCHER CK	151	1.00	1.8000	0.0100	0.0500

Table 111. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Karcher Creek	SUBURBAN	1	0.126658	0	1	0.114433	3.39E-03	6.18
	MULTI-FAMILY	2	2.58E-02	0	2	5.09E-02	4.97E-04	9.31
	COMMERCIAL	3	3.72E-02	0	3	4.58E-02	1.96E-04	2.25
	RURAL RESIDENTIAL	4			4			0.00
	LAWN	5	0.634272	0	5	5.98E-02	4.05E-03	0.51
	PASTURE	6			6			0.00
	DECIDUOUS FOREST	7	0.913614	0	7	7.89E-02	1.27E-02	6.63
	CONIFEROUS FOREST	8	5.41E-02	0	8	5.22E-02	9.98E-03	6.34
	MIXED FOREST	9	1.85E-01	0	9	1.17E-01	2.63E-02	0.28
	BARE SOIL	11			11			0.00
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Karcher Creek	SUBURBAN	11	0.3	0	11	0.314413	-2.90E-04	3.98
	MULTI-FAMILY	12	0.3	0	12	0.314413	-2.90E-04	27.06
	COMMERCIAL	13	0.35	0	13	0.314413	-2.90E-04	37.45
	RURAL RESIDENTIAL	14	0.3	0	14	0.314413	-2.90E-04	0.00

Table 112. Sediment loading calibration data and results for pervious and impervious land area in Karcher Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.6 Blackjack Creek

The calibration inversion run terminated after 816 model calls, which resulted in reducing the objective function from a starting value of 0.36012 to a final value of 4.2765E-02. Table 113 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 114. The last column of Table 114 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Blackjack Creek	SUBURBAN	1	0.08	0.1000	0.79	10.0000	2.0000
	MULTI-FAMILY	2	0.07	0.1000	0.90	10.0000	2.0000
	COMMERCIAL	3	0.09	0.1000	0.90	3.4150	2.0000
	RURAL RESIDENTIAL	4	0.12	0.1000	0.58	8.3670	2.0000
	LAWN	5	0.16	0.1000	0.01	10.0000	2.0000
	PASTURE	6	0.11	0.1000	0.02	10.0000	2.0000
	DECIDUOUS FOREST	7	0.14	0.1000	0.13	10.0000	2.0000
	CONIFEROUS FOREST	8	0.07	0.1000	0.82	10.0000	2.0000
	MIXED FOREST	9	0.09	0.1000	0.03	10.0000	2.0000
	BARE LAND	11	0.05	0.1000	0.68	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - BLACKJACK CK	151	1.19	1.0000	0.0114	0.7807

Table 113. Identified model resulting from calibration inversion run.

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
	ID	SOSED	ΔDETS	ID	SOSED	ΔDETS		FROM EACH LANDUSE
Blackjack Creek								
SUBURBAN	1	7.36E-02	0	1	7.31E-02	2.69E-02		3.40
MULTI-FAMILY	2	3.20E-02	0	2	3.35E-02	5.53E-03		1.34
COMMERCIAL	3	4.08E-02	0	3	4.19E-02	5.19E-04		0.88
RURAL RESIDENTIAL	4	0.187155	0	4	0.186794	1.03E-01		21.95
LAWN	5	0.562273	0	5	4.05E-01	5.61E-02		39.81
PASTURE	6	0.601483	0	6	2.06E-01	1.29E-01		1.62
DECIDUOUS FOREST	7	0.123964	0	7	8.14E-02	1.38E-01		10.75
CONIFEROUS FOREST	8	1.46E-02	0	8	1.47E-02	8.59E-02		4.41
MIXED FOREST	9	7.87E-02	0	9	6.67E-02	1.20E-01		0.82
BARE SOIL	11	22.391	0	11	6.97E-02	5.86E-03		0.56
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
	ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS		FROM EACH LANDUSE
Blackjack Creek								
SUBURBAN	11	0.3	0	11	0.314334	-7.00E-04		1.80
MULTI-FAMILY	12	0.3	0	12	0.314334	-7.00E-04		2.95
COMMERCIAL	13	0.35	0	13	0.314334	-7.00E-04		6.93
RURAL RESIDENTIAL	14	0.3	0	14	0.314334	-7.00E-04		2.77

Table 114. Sediment loading calibration data and results for pervious and impervious land area in Blackjack Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.7 Anderson Creek

The calibration inversion run terminated after 708 model calls, which resulted in reducing the objective function from a starting value of 0.23817 to a final value of 5.1531E-02. Table 115 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 116. The last column of Table 116 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Anderson Creek	SUBURBAN	1	0.08	0.1000	0.81	10.0000	2.0000
	MULTI-FAMILY	2	0.07	0.1000	0.90	10.0000	2.0000
	COMMERCIAL	3	0.07	0.1000	0.89	10.0000	2.0000
	RURAL RESIDENTIAL	4	0.08	0.1000	0.40	10.0000	2.0000
	LAWN	5	0.07	0.1000	0.84	10.0000	2.0000
	PASTURE	6	0.07	0.1000	0.89	10.0000	2.0000
	DECIDUOUS FOREST	7	0.10	0.1000	0.55	10.0000	2.0000
	CONIFEROUS FOREST	8	0.08	0.1000	0.90	0.2184	2.0000
	MIXED FOREST	9	0.07	0.1000	0.58	10.0000	2.0000
	BARE LAND	11	0.07	0.1000	0.90	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - ANDERSON CK	151	1.17	1.0000	0.0120	0.9121

Table 115. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Anderson Creek	SUBURBAN	1	7.36E-02	0	1	6.29E-02	2.04E-03	5.81
	MULTI-FAMILY	2	3.20E-02	0	2	3.25E-02	2.93E-04	0.69
	COMMERCIAL	3	4.08E-02	0	3	3.46E-02	1.03E-04	0.06
	RURAL RESIDENTIAL	4	0.187155	0	4	0.160766	2.19E-02	6.95
	LAWN	5	0.562273	0	5	3.82E-02	5.33E-03	5.96
	PASTURE	6	0.601483	0	6	2.35E-02	3.59E-03	0.70
	DECIDUOUS FOREST	7	0.123964	0	7	1.18E-01	2.06E-02	53.56
	CONIFEROUS FOREST	8	1.46E-02	0	8	1.46E-02	3.86E-03	10.29
	MIXED FOREST	9	7.87E-02	0	9	7.80E-02	1.35E-02	5.60
	BARE SOIL	11	22.391	0	11	3.20E-02	2.10E-04	0.10
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Anderson Creek	SUBURBAN	11	0.3	0	11	0.315101	-1.01E-04	6.84
	MULTI-FAMILY	12	0.3	0	12	0.315101	-1.01E-04	1.57
	COMMERCIAL	13	0.35	0	13	0.315101	-1.01E-04	0.84
	RURAL RESIDENTIAL	14	0.3	0	14	0.315101	-1.01E-04	1.03

Table 116. Sediment loading calibration data and results for pervious and impervious land area in Anderson Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.8 Gorst Creek

The calibration inversion run terminated after 2719 model calls, which resulted in reducing the objective function from a starting value of 2.4267 to a final value of 1.282. Tables 117 - 119 list the identified parameter sets that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Tables 120 - 122. The last column of Tables 120 - 122 present the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Heins Creek	LAWN	5	0.09	0.1000	0.09	10.0000	2.0000
	PASTURE	6	0.10	0.1000	0.90	10.0000	2.0000
	DECIDUOUS FOREST	7	0.15	0.1000	0.77	10.0000	2.0000
	CONIFEROUS FOREST	8	0.10	0.1000	0.69	10.0000	2.0000
	MIXED FOREST	9	0.16	0.1000	0.56	10.0000	2.0000
	BARE LAND	11	0.05	0.0994	0.85	0.8307	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - HEINS CK	151	0.93	2.3726	0.0042	0.0661

Table 117. Identified model resulting from calibration inversion run

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Parish Creek	SUBURBAN	1	0.07	0.0988	0.79	1.9795	2.0000
	MULTI-FAMILY	2	0.07	0.0983	0.90	0.3585	2.0000
	COMMERCIAL	3	0.07	0.0980	0.90	0.5871	2.0000
	RURAL RESIDENTIAL	4	0.08	0.0977	0.34	0.6242	2.0000
	LAWN	5	0.07	0.0972	0.00	3.8008	2.0000
	PASTURE	6	0.05	0.0990	0.16	10.0000	2.0000
	DECIDUOUS FOREST	7	0.06	0.1000	0.47	10.0000	2.0000
	CONIFEROUS FOREST	8	0.07	0.1000	0.77	10.0000	2.0000
	MIXED FOREST	9	0.06	0.1000	0.50	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - PARISH CK	151	0.93	2.3726	0.0042	0.0661

Table 118. Identified model resulting from calibration inversion run

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
Gorst Creek	SUBURBAN	1	0.06	0.0991	0.86	1.2610	2.0000
	MULTI-FAMILY	2	0.05	0.0983	0.72	0.1997	2.0000
	COMMERCIAL	3	0.05	0.0975	0.79	10.0000	2.0000
	RURAL RESIDENTIAL	4	0.13	0.0967	0.07	1.2093	2.0000
	LAWN	5	0.16	0.0974	0.02	10.0000	2.0000
	PASTURE	6	0.14	0.1000	0.41	10.0000	2.0000
	DECIDUOUS FOREST	7	0.16	0.1000	0.58	10.0000	2.0000
	CONIFEROUS FOREST	8	0.12	0.1000	0.79	10.0000	2.0000
	MIXED FOREST	9	0.12	0.1000	0.41	10.0000	2.0000
	BARE LAND	11	0.04	0.1000	0.83	0.0489	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - GORST CK	151	0.93	2.3722	0.0042	0.0661

Table 119. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED		PERCENT OF TOTAL LOAD
	ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Heins Creek							
SUBURBAN	1			1			0.00
MULTI-FAMILY	2			2			0.00
COMMERCIAL	3			3			0.00
RURAL RESIDENTIAL	4			4			0.00
LAWN	5	2.59409	0	5	2.37E-01	7.83E-03	14.36
PASTURE	6	2.11356	0	6	3.06E-02	5.22E-03	0.57
DECIDUOUS FOREST	7	0.646786	0	7	1.04E-01	5.93E-02	36.85
CONIFEROUS FOREST	8	1.26E-01	0	8	9.35E-02	5.24E-02	26.19
MIXED FOREST	9	2.23E-01	0	9	1.84E-01	9.87E-02	21.95
BARE SOIL	11	7.216	0	11	3.77E-02	-5.69E-06	0.09
		"OBSERVED"			SIMULATED		PERCENT OF TOTAL LOAD
	ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Heins Creek							
SUBURBAN	11	0.3	0	11	0.360593	0.00E+00	0.00
MULTI-FAMILY	12	0.3	0	12	0.360593	0.00E+00	0.00
COMMERCIAL	13	0.35	0	13	0.406668	0.00E+00	0.00
RURAL RESIDENTIAL	14	0.3	0	14	0.360593	0.00E+00	0.00

Table 120. Sediment loading calibration data and results for pervious and impervious land area in Heins Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Parish Creek	SUBURBAN	1	7.38E-02	0	1	6.58E-02	3.31E-05	5.79
	MULTI-FAMILY	2	2.98E-02	0	2	3.03E-02	-3.96E-06	1.58
	COMMERCIAL	3	3.95E-02	0	3	3.48E-02	-1.61E-05	0.04
	RURAL RESIDENTIAL	4	0.148303	0	4	0.148336	-8.81E-06	10.11
	LAWN	5	0.684945	0	5	1.61E-01	-1.10E-03	8.75
	PASTURE	6	1.1741	0	6	1.04E-01	2.83E-03	0.98
	DECIDUOUS FOREST	7	0.380836	0	7	9.74E-02	4.97E-02	18.93
	CONIFEROUS FOREST	8	4.61E-02	0	8	4.66E-02	3.27E-02	18.96
	MIXED FOREST	9	3.28E-01	0	9	8.63E-02	4.56E-02	1.49
	BARE SOIL	11			11			0.00
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Parish Creek	SUBURBAN	11	0.3	0	11	0.339291	0.00E+00	3.69
	MULTI-FAMILY	12	0.3	0	12	0.339291	0.00E+00	4.51
	COMMERCIAL	13	0.35	0	13	0.382483	0.00E+00	23.43
	RURAL RESIDENTIAL	14	0.3	0	14	0.339291	0.00E+00	1.74

Table 121. Sediment loading calibration data and results for pervious and impervious land area in Parish Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Gorst Creek	SUBURBAN	1	4.16E-02	0	1	3.28E-02	2.72E-05	0.44
	MULTI-FAMILY	2	6.63E-02	0	2	6.63E-02	2.86E-07	0.86
	COMMERCIAL	3	7.98E-02	0	3	4.33E-02	-2.10E-05	0.02
	RURAL RESIDENTIAL	4	0.322011	0	4	0.304029	4.69E-04	2.32
	LAWN	5	1.22935	0	5	3.81E-01	-2.32E-03	37.51
	PASTURE	6	1.02875	0	6	1.57E-01	3.30E-02	1.08
	DECIDUOUS FOREST	7	0.439879	0	7	1.53E-01	8.69E-02	18.52
	CONIFEROUS FOREST	8	6.48E-02	0	8	6.48E-02	4.63E-02	26.01
	MIXED FOREST	9	2.33E-01	0	9	1.47E-01	8.74E-02	2.87
	BARE SOIL	11	2.8879	0	11	2.96E-02	6.01E-07	0.03

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Gorst Creek	SUBURBAN	11	0.3	0	11	0.339815	0.00E+00	0.56
	MULTI-FAMILY	12	0.3	0	12	0.339815	0.00E+00	1.12
	COMMERCIAL	13	0.35	0	13	0.383156	0.00E+00	8.47
	RURAL RESIDENTIAL	14	0.3	0	14	0.339815	0.00E+00	0.20

Table 122. Sediment loading calibration data and results for pervious and impervious land area in Gorst Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.9 Springbrook Creek

The calibration inversion run terminated after 512 model calls, which resulted in reducing the objective function from a starting value of 1.0848 to a final value of 0.3501. Table 123 lists the identified parameter set that resulted from the calibration inversion run.

“Observed” data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 124. The last column of Table 124 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

	ID	KRER	AFFIX	COVER	KSER	JSER
COMMERCIAL	3	0.16	0.1000	0.47	5.9093	2.0000
LAWN	5	0.10	0.1000	0.04	10.0000	2.0000
PASTURE	6	0.16	0.1000	0.64	10.0000	2.0000
DECIDUOUS FOREST	7	0.16	0.1000	0.58	10.0000	2.0000
CONIFEROUS FOREST	8	0.10	0.1000	0.86	1.4309	2.0000
MIXED FOREST	9	0.12	0.1000	0.69	4.4141	2.0000
BARE LAND	11	0.18	0.1000	0.01	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - SPRINGBROOK CK	151	1.21	1.0000	0.0071	0.4849

Table 123. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Springbrook Creek	SUBURBAN	1			1			0.00
	MULTI-FAMILY	2			2			0.00
	COMMERCIAL	3	4.11E-01	0	3	4.11E-01	2.13E-02	0.49
	RURAL RESIDENTIAL	4			4			0.00
	LAWN	5	0.7643	0	5	2.13E-01	1.24E-01	0.23
	PASTURE	6	1.04643	0	6	1.07E-01	1.07E-01	4.19
	DECIDUOUS FOREST	7	0.214885	0	7	2.13E-01	1.10E-01	45.82
	CONIFEROUS FOREST	8	4.98E-02	0	8	4.76E-02	8.66E-02	10.65
	MIXED FOREST	9	1.29E-01	0	9	1.29E-01	9.78E-02	24.48
	BARE SOIL	11	1.6181	0	11	8.66E-01	3.47E-02	1.51

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Springbrook Creek	SUBURBAN	11	0.3	0	11	0.312597	-3.89E-03	2.26
	MULTI-FAMILY	12	0.3	0	12	0.312597	-3.89E-03	0.00
	COMMERCIAL	13	0.35	0	13	0.312597	-3.89E-03	8.30
	RURAL RESIDENTIAL	14	0.3	0	14	0.312597	-3.89E-03	2.06

Table 124. Sediment loading calibration data and results for pervious and impervious land area in Springbrook Creek (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.10 BST 12

There are no sediment loading model calibration results to report for BST 12 (see section 7.1.10).

7.2.11 BST 01

The calibration inversion run terminated after 1237 model calls, which resulted in reducing the objective function from a starting value of 1.45928E-02 to a final value of 2.6087E-03. Table 125 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 126. The last column of Table 126 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
BST01	SUBURBAN	1	0.10	0.1000	0.54	8.4209	2.0000
	MULTI-FAMILY	2	0.09	0.1000	0.81	9.0474	2.0000
	COMMERCIAL	3	0.12	0.1000	0.83	6.5729	2.0000
	RURAL RESIDENTIAL	4	0.23	0.1000	0.71	10.0000	2.0000
	LAWN	5	0.24	0.1000	0.87	4.6870	2.0000
	PASTURE	6	0.06	0.1000	0.07	10.0000	2.0000
	DECIDUOUS FOREST	7	0.08	0.1000	0.02	10.0000	2.0000
	CONIFEROUS FOREST	8	0.09	0.1000	0.88	10.0000	2.0000
	MIXED FOREST	9	0.08	0.1000	0.76	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - BST01	151	1.22	1.0000	0.0109	0.8074

Table 125. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
BST01	SUBURBAN	1	2.44E-01	0	1	2.44E-01	2.68E-03	10.46
	MULTI-FAMILY	2	9.27E-02	0	2	9.19E-02	5.79E-03	12.16
	COMMERCIAL	3	1.08E-01	0	3	1.07E-01	3.50E-03	0.45
	RURAL RESIDENTIAL	4	0.306656	0	4	0.306546	2.43E-02	3.55
	LAWN	5	4.7044	0	5	1.05E-01	9.37E-02	0.66
	PASTURE	6	1.2299	0	6	1.47E-01	1.05E-01	0.37
	DECIDUOUS FOREST	7	0.188996	0	7	1.40E-01	1.13E-01	5.65
	CONIFEROUS FOREST	8	3.39E-02	0	8	3.38E-02	8.43E-02	1.61
	MIXED FOREST	9	6.09E-02	0	9	6.05E-02	8.88E-02	1.86
	BARE SOIL	11			11			0.00
		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
BST01	SUBURBAN	11	0.3	0	11	0.314274	-5.03E-04	1.73
	MULTI-FAMILY	12	0.3	0	12	0.314274	-5.03E-04	9.76
	COMMERCIAL	13	0.35	0	13	0.314274	-5.03E-04	51.34
	RURAL RESIDENTIAL	14	0.3	0	14	0.314274	-5.03E-04	0.40

Table 126. Sediment loading calibration data and results for pervious and impervious land area in BST 01 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.12 LMK001

There are no sediment loading model calibration results to report for LMK001 (see section 7.1.12).

7.2.13 LMK002

There are no sediment loading model calibration results to report for LMK002 (see section 7.1.13).

7.2.14 LMK122

There are no sediment loading model calibration results to report for LMK122 (see section 7.1.14).

7.2.15 PO-POBLVD

There are no sediment loading model calibration results to report for PO-POBLVD (see section 7.1.15).

7.2.16 LMK136

There are no sediment loading model calibration results to report for LMK136 (see section 7.1.16).

7.2.17 LMK038

The calibration inversion run terminated after 341 model calls, which resulted in reducing the objective function from a starting value of 1.7605 to a final value of 0.774. Table 127 lists the identified parameter set that resulted from the calibration inversion run.

“Observed” data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 128. The last column of Table 128 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

	ID	KRER	AFFIX	COVER	KSER	JSER
COMMERCIAL	3	0.10	0.1000	0.35	10.0000	2.0000
RURAL RESIDENTIAL	4	0.13	0.1000	0.28	10.0000	2.0000
PASTURE	6	0.14	0.1000	0.90	0.0174	2.0000
DECIDUOUS FOREST	7	0.13	0.1000	0.90	10.0000	2.0000
CONIFEROUS FOREST	8	0.09	0.1000	0.35	10.0000	2.0000
MIXED FOREST	9	0.07	0.1000	0.25	10.0000	2.0000

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - MANCHESTER	151	1.21	1.0000	0.0118	0.8603

Table 127. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED		PERCENT OF TOTAL LOAD
	ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
Manchester SUBURBAN	1			1			0.00
MULTI-FAMILY	2			2			0.00
COMMERCIAL	3	5.95E-01	0	3	3.52E-01	1.82E-03	1.98
RURAL RESIDENTIAL	4	1.47765	0	4	0.341908	6.06E-02	66.41
LAWN	5			5			0.00
PASTURE	6	0	0	6	7.67E-04	2.29E-02	0.01
DECIDUOUS FOREST	7	0.8121	0	7	1.75E-02	2.26E-02	2.11
CONIFEROUS FOREST	8	4.83E-02	0	8	3.00E-02	4.26E-02	0.99
MIXED FOREST	9	6.71E-02	0	9	3.57E-02	4.12E-02	0.25
BARE SOIL	11			11			0.00

		"OBSERVED"			SIMULATED		PERCENT OF TOTAL LOAD
	ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
Manchester SUBURBAN	11	0.3	0	11	0.314761	-2.69E-04	12.89
MULTI-FAMILY	12	0.3	0	12	0.314761	-2.69E-04	0.00
COMMERCIAL	13	0.35	0	13	0.314761	-2.69E-04	8.66
RURAL RESIDENTIAL	14	0.3	0	14	0.314761	-2.69E-04	6.70

Table 128. Sediment loading calibration data and results for pervious and impervious land area in LMK038 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.18 B-ST CSO16

There are no sediment loading model calibration results to report for B-ST CSO16 (see section 7.1.18).

7.2.19 BST 28

The calibration inversion run terminated after 238 model calls, which resulted in reducing the objective function from a starting value of 3.12879E-04 to a final value of

1.3631E-04. Table 129 lists the identified parameter set that resulted from the calibration inversion run.

"Observed" data, and their simulated counterparts for SOSED and ΔDETS for the pervious land areas and SOSLD and ΔSLDS for the impervious land areas are presented in Table 130. The last column of Table 130 presents the percent of total load contributed from each land use within each land segment.

ADJUSTABLE MODEL PARAMETERS

PERLND ADJUSTABLE MODEL PARAMETERS

		ID	KRER	AFFIX	COVER	KSER	JSER
BST28	SUBURBAN	1	0.07	0.1000	0.47	10.0000	
	MULTI-FAMILY	2	0.05	0.1000	0.90	10.0000	
	COMMERCIAL	3	0.05	0.1000	0.89	10.0000	
	CONIFEROUS FOREST	8	0.07	0.1000	0.90	10.0000	

IMPLND ADJUSTABLE MODEL PARAMETERS

		KEIM	JEIM	ACCSDP	REMSDP
IMPERVIOUS - BST28	151	1.13	1.0000	0.0083	0.7358

Table 129. Identified model resulting from calibration inversion run

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSED	ΔDETS	ID	SOSED	ΔDETS	FROM EACH LANDUSE
BST28	SUBURBAN	1	2.57E-01	0	1	2.57E-01	3.41E-02	5.12
	MULTI-FAMILY	2	3.61E-02	0	2	3.80E-02	1.46E-02	6.08
	COMMERCIAL	3	3.83E-02	0	3	3.76E-02	3.57E-03	0.59
	RURAL RESIDENTIAL	4			4			0.00
	LAWN	5			5			0.00
	PASTURE	6			6			0.00
	DECIDUOUS FOREST	7			7			0.00
	CONIFEROUS FOREST	8	4.18E-02	0	8	5.51E-02	6.12E-02	1.01
	MIXED FOREST	9			9			0.00
	BARE SOIL	11			11			0.00

		"OBSERVED"			SIMULATED			PERCENT OF TOTAL LOAD
		ID	SOSLD	ΔSLDS	ID	SOSLD	ΔSLDS	FROM EACH LANDUSE
BST28	SUBURBAN	11	0.3	0	11	0.309221	-7.88E-04	0.81
	MULTI-FAMILY	12	0.3	0	12	0.309221	-7.88E-04	23.29
	COMMERCIAL	13	0.35	0	13	0.309221	-7.88E-04	63.09
	RURAL RESIDENTIAL	14	0.3	0	14	0.309221	-7.88E-04	0.00

Table 130. Sediment loading calibration data and results for pervious and impervious land area in BST 28 (SOSED = total removal of soil and sediment in tons/acre/interval; DETS = storage of detached sediment; SOSLD = washoff of solids from surface in tons/acre/interval; SLDS = storage of solids on surface).

7.2.20 PSNS 126

There are no sediment loading model calibration results to report for PSNS 126 (see section 7.1.20).

7.2.21 PSNS 124

There are no sediment loading model calibration results to report for PSNS 124 (see section 7.1.21).

7.2.22 PSNS 015

There are no sediment loading model calibration results to report for PSNS 015 (see section 7.1.22).

8.0 BRIEF DISCUSSION AND CONCLUSIONS

This document summarized relevant activities that have been performed related to Hydrological Simulation Program–Fortran (HSPF) hydrologic and sediment loading model development, and associated model determination and application for the Sinclair–Dyes Inlet watershed located in Kitsap County, Washington in support of the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Environmental Investment (ENVVEST) Project (Navy, Ecology, and USEPA 2000). This report identified and described the watershed characteristics and types of data that were utilized for the model(s), and it also presented the approach that was followed for constructing, calibrating, and verifying the HSPF model(s) for the ENVVEST project study area.

As was mentioned in Section 1 of this report, for the ENVVEST project, it is required that the deployed watershed models be capable of simulating both existing and future conditions. Today, we have at our disposal, at multiple scales, digital data (e.g., elevation, soils, vegetative cover, land use, and impervious cover to name a few) assumed relevant to watershed system response, and many of these data are distributed in Geographic Information Systems (GIS) compatible data formats. Moreover, we also have readily at our disposal GIS or GIS compatible tools, often developed with the principal intent to expedite the model development/deployment process, that allow us to process and blend these data into formats consistent with the selected model structure. While GIS compatible tools have been modestly successful with this basic effort, they do not address the underlying, more fundamental, problem that upon incorporating all of this readily available highly detailed data, one has a complex (i.e., highly parameterized) model to determine through a formal calibration exercise.

Conceptual model structures, such as HSPF, for the continuous simulation of watershed hydrology are predefined, prior to modeling, by the hydrologist's understanding of the watershed system. With conceptual model structures, it is not possible to independently measure at least some of the model parameters; hence, they must be estimated through a formal model calibration exercise. Hence, the efficacy of a conceptual model structure to inform watershed management is heavily reliant upon observed system response data and the information that one can reliably “tap” from it during the calibration process. Enhancements (Skahill and Doherty, 2006) and adaptations (Doherty and Skahill, 2006) to the Gauss Marquardt Levenberg (GML) method of computer-based parameter estimation (Levenburg, 1944; Marquardt, 1963), and a model independent protocol wherein the inversion methods communicate with a model through the model’s own input and output files were employed to calibrate the HSPF models that developed for the ENVVEST project.

The availability of advanced regularization methodologies (Doherty and Skahill, 2006) and efficient global search strategies (Skahill and Doherty, 2006) does not preclude the need for data to support parameter estimation for complex watershed models, such as those that were developed for the ENVVEST project. While reliance upon a regionalization study, wherein multiple parsimonious and identifiable models are deployed and calibrated to a number of gaged systems and then the identified parameter sets from the multiple systems are subsequently used for regional complex watershed model parameter assignment, would be the preferred path, the watershed models deployed for the ENVVEST project study relied instead upon previous work for additional data to support complex watershed model parameter estimation.

Tidal influence, missing data, noisy data, date-time stamp errors, slight time shift differences between the driving precipitation data and the observed response for some systems, were all factors that complicated the HSPF hydrologic calibration for the monitored systems in the ENVVEST project study area. Tidal influence and/or noise contaminated the observed flow data for some flow monitoring locations to such an extent that no attempt was made to calibrate the HSPF model that was developed for the given watershed system. Despite these noted complications, the models match the observed flow data well in most cases and also match the predetermined targets for direct surface runoff, interflow runoff, base flow runoff, and evapotranspiration. Hence, in so far as the predetermined targets for the partition of precipitation are representative of the conditions on the ground in each system, the models are “physically-based”, and capable, likely with minimal additional alteration, of being employed to examine future conditions.

This document has also presented the methods, data, and results obtained from a Geographic Information Systems (GIS) based approach to application of the Universal Soil Loss Equation (USLE) analysis that was employed to determine target sediment loading rates as part of the overall process of deploying HSPF sediment loading models for watersheds in the Sinclair and Dyes Inlet Watershed in support of project ENVVEST. The predetermined target sediment loading rates together with an assumed balance between accumulation and washoff over the long term were employed to subsequently parameterize the previously calibrated HSPF hydrologic models for HSPF sediment simulation for the processes of accumulation, detachment, and washoff.

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APPENDIX 1 US ARMY ERDC SWRRP HSPF MODEL DESCRIPTION

The public domain Hydrological Simulation Program – FORTRAN model, known as HSPF, uses both physical and empirical formulations to simulate hydrologic and water quality processes on a continuous basis in natural and man-made watershed systems. With HSPF, a set of pervious land areas, impervious land areas, and reaches that may be open or closed channels or completely mixed impoundments constitute the land area and hydrography for a given watershed system. For pervious land areas, among others, HSPF has routines that model snow accumulation and melt; the complete land-side water budget, including interception, evapotranspiration, infiltration, surface detention, surface runoff, shallow subsurface flow (interflow), the interaction between the saturated zone and the unsaturated zone, baseflow, and percolation to deep groundwater; irrigation demand, irrigation source, and irrigation application; sediment production and removal; soil temperatures for surface and subsurface layers; water temperatures for surface, shallow subsurface, and groundwater outflows; water quality constituents in the computed outflows (i.e., overland flow, interflow, baseflow, washoff of detached sediment, and scour of the soil matrix) using relationships based on water and/or sediment yield; and detailed simulation of solute transport, pesticides, nitrogen, phosphorous, and conservatives, respectively. HSPF models the response from impervious land areas in a manner similar to that used for pervious land areas; however, infiltration and other interactions with the subsurface cannot occur. Open or closed channels or completely mixed impoundments can be modeled with routines that simulate hydraulics, water temperature, noncohesive and cohesive sediment, pesticides, nutrients, biochemical oxygen demand, phytoplankton, zooplankton, dissolved oxygen, and pH, among others. HSPF also provides the user with the capability to simulate any water quality constituent by specifying its sources, sinks, decay properties, and advective behavior. HSPF is a lumped-distributed model; hence, it is able to account for a multiplicity of landscape features assumed relevant to system response, and it can provide one with a time history of water quantity and quality at any point in the watershed. The United States Environmental Protection Agency, United States Geological Survey, and others, have developed several software programs, also in the public domain, to support the HSPF model deployment process.

APPENDIX 2 FLOW MONITORING LOCATIONS WITHIN THE SINCLAIR-DYES INLET WATERSHED

Station Name	# of Missing Values / Missing Periods	# Missing per Period	Period of Record	Location	
				Long. (DD)	Lat. (DD)
Anderson Creek - 15 Minute Flow	26332 missing of 315072;		1994/10/01 00:00 - 2003/09/25 23:45	-122.682222	47.52361111
	1994/10/01 00:00 - 1995/01/12 11:15	9934			
	1995/03/20 14:15	1			
	1995/06/20 10:45	1			
	1995/07/25 09:45 - 1995/09/27 12:00	6154			
	1996/01/05 00:00 - 1996/03/11 10:30	6379			
	1996/09/05 17:30 - 1996/09/06 11:45	74			
	1996/12/19 12:45	1			
	1997/02/12 13:00 - 1997/02/19 11:15	666			
	1997/09/09 10:15 - 1997/09/30 23:45	2071			
	1998/03/19 11:00	1			
	2002/02/21 14:30 - 2002/03/04 11:15	1044			
	2002/06/25 09:30	1			
	2002/10/01 00:15	1			
	2003/05/05 09:30	1			
	2003/05/05 11:30	1			
	2003/06/13 10:00 - 2003/06/13 10:15	2			
Karcher Creek - Daily Flow	455 missing of 1461;		1996/10/01 - 2000/09/30	-122.611667	47.54416667
	1996/10/01 - 1997/04/10	192			
	1997/10/30 - 1997/12/16	48			
	1998/01/29	1			
	1998/04/23	1			
	1998/08/28 - 1998/08/31	4			
	1998/09/29 - 1998/09/30	2			
	1999/03/01	1			
	1999/06/02	1			
	1999/08/17 - 1999/09/08	23			
	1999/10/04 - 1999/12/01	59			
	2000/02/18 - 2000/03/31	43			
	2000/04/29 - 2000/05/22	24			
	2000/08/06 - 2000/09/30	56			
Karcher Creek - 15 Minute Flow	54712 missing of 243971;		1996/10/01 00:00 - 2003/09/16 08:30	-122.611667	47.54416667
	1996/10/01 00:00 - 1997/04/10 13:00	18389			
	1997/10/30 10:15 - 1997/12/16 10:30	4514			
	1998/01/29 11:30	1			
	1998/04/23 11:15	1			
	1998/08/28 15:15 - 1998/08/31 11:15	273			
	1998/09/29 13:15 - 1998/09/30 23:45	139			

	1999/03/01 10:30	1			
	1999/06/02 11:15	1			
	1999/08/17 10:45 - 1999/09/08 13:30	2124			
	1999/10/04 14:00 - 1999/12/01 12:30	5563			
	2000/02/18 14:00 - 2000/03/31 13:00	4029			
	2000/04/29 14:00 - 2000/05/17 14:00	1729			
	2000/05/17 14:30 - 2000/05/22 13:00	475			
	2001/01/02 13:15 - 2001/01/29 16:45	2607			
	2001/09/19 12:45 - 2001/09/25 12:15	575			
	2002/01/09 12:00 - 2002/01/23 10:45	1340			
	2002/01/23 11:15 - 2002/02/01 13:30	874			
	2002/02/01 14:00 - 2002/02/04 12:00	281			
	2002/05/06 11:15 - 2002/05/09 11:00	288			
	2002/05/09 11:30 - 2002/07/31 11:00	7967			
	2003/05/19 13:00 - 2003/06/25 10:00	3541			
Dickerson Creek - 15 Minute Flow	8512 missing of 175296;		2000/10/01 00:00 - 2005/09/30 23:45	-122.713611	47.58611111
	2002/01/10 04:00 - 2002/01/24 22:30	1419			
	2002/12/30 06:30 - 2003/01/03 11:30	405			
	2003/02/05 12:00 - 2003/03/03 11:30	2495			
	2003/05/08 10:00	1			
	2003/06/02 11:15	1			
	2003/07/07 10:15	1			
	2003/09/30 11:00 - 2003/09/30 23:45	52			
	2003/11/17 12:45	1			
	2004/01/21 12:00	1			
	2004/03/11 13:45	1			
	2004/04/26 11:00	1			
	2004/05/06 18:15 - 2004/06/15 10:30	3810			
	2004/08/17 11:00	1			
	2004/10/08 08:45	1			
	2004/12/18 16:30 - 2004/12/21 19:15	300			
	2005/01/04 07:30 - 2005/01/04 12:30	21			
	2005/03/09 12:00	1			
Wildcat Creek at lake outlet - 15 Minute Flow	25902 missing of 175296;		2000/10/01 00:00 - 2005/09/30 23:45	-122.757222	47.60111111
	2000/10/01 00:00 - 2000/10/05 13:30	439			
	2000/10/05 14:00 - 2000/10/11 10:45	564			
	2001/05/27 20:30 - 2001/06/07 10:00	1015			
	2001/07/10 03:00 - 2001/08/02 10:00	2237			
	2001/09/05 09:45 - 2001/09/30 23:45	2457			
	2002/04/08 11:00	1			
	2002/04/13 01:30 - 2002/06/06 09:15	5216			
	2002/09/10 10:00 - 2002/09/30 23:45	1976			
	2002/12/09 02:30 - 2003/01/02 11:45	2342			
	2003/01/06 09:45	1			
	2003/02/04 14:00	1			
	2003/07/07 10:30	1			

	2003/09/05 11:30 - 2003/09/30 23:45	2450			
	2003/11/17 12:30	1			
	2003/11/20 20:30 - 2004/01/12 12:45	5058			
	2004/03/08 10:15 - 2004/03/08 10:30	2			
	2004/05/18 18:15 - 2004/05/22 11:45	359			
	2004/06/04 09:15 - 2004/06/14 10:00	964			
	2004/07/23 08:15 - 2004/07/23 08:30	2			
	2004/09/29 22:15 - 2004/10/08 08:15	809			
	2005/03/03 12:30	1			
	2005/05/09 11:00 - 2005/05/09 11:30	3			
	2005/07/12 13:00	1			
	2005/08/17 10:45 - 2005/08/17 11:00	2			
Kitsap Creek at lake outlet - 15 Minute Flow	12258 missing of 175296;		2000/10/01 00:00 - 2005/09/30 23:45	-122.710833	47.57972222
	2000/10/01 00:00 - 2000/10/17 23:45	1632			
	2001/07/08 00:00 - 2001/08/02 09:30	2439			
	2002/01/09 13:15 - 2002/02/04 11:00	2488			
	2002/04/08 10:30	1			
	2003/06/02 11:00	1			
	2003/07/06 00:15 - 2003/07/07 10:00	136			
	2003/08/12 10:30	1			
	2003/09/30 11:30	1			
	2003/11/17 13:15	1			
	2004/01/21 04:15 - 2004/01/21 12:00	32			
	2004/02/25 13:00 - 2004/03/22 11:00	2489			
	2004/04/26 11:30	1			
	2004/06/15 10:15	1			
	2004/07/07 08:30 - 2004/07/23 09:15	1540			
	2004/10/12 11:45 - 2004/10/12 12:00	2			
	2004/12/20 00:00 - 2005/01/04 12:45	1492			
	2005/03/09 12:30	1			
Chico Creek Tributary at Taylor Road - 15 Minute Flow	13604 missing of 105120;		2000/10/01 00:00 - 2003/09/30 23:45	-122.715278	47.58638889
	2002/01/07 17:45 - 2002/05/20 13:15	12751			
	2002/10/01 00:00 - 2002/10/01 11:30	47			
	2002/11/05 19:15 - 2002/11/13 15:15	753			
	2002/12/14 05:45 - 2002/12/14 17:30	48			
	2003/01/02 13:15	1			
	2003/02/10 15:00 - 2003/02/10 15:15	2			
	2003/04/09 09:15	1			
	2003/06/09 11:00	1			
Chico Creek Mainstem - Daily Flow	10416 missing of 43536;		1991/04/01 00:00 - 1996/03/18 23:00	-122.707500	47.59333333
	1991/04/01 00:00 - 1991/04/01 09:00	10			
	1991/04/08 08:00 - 1991/05/01 10:00	555			
	1991/09/30 23:00	1			
	1992/01/28 14:00 - 1992/01/28 22:00	9			
	1992/01/29 00:00 - 1992/02/01 22:00	95			
	1992/05/01 12:00 - 1992/05/01 13:00	2			

	1993/04/27 04:00 - 1993/09/30 22:00	3763			
	1994/08/18 10:00 - 1994/08/27 22:00	229			
	1994/09/22 09:00 - 1994/09/22 22:00	14			
	1994/09/23 07:00 - 1994/10/13 20:00	494			
	1994/11/30 07:00 - 1994/11/30 22:00	16			
	1994/12/17 06:00 - 1994/12/18 22:00	41			
	1994/12/19 11:00 - 1994/12/21 22:00	60			
	1994/12/27 04:00 - 1994/12/28 22:00	43			
	1995/02/18 16:00 - 1995/02/19 22:00	31			
	1995/02/25 10:00 - 1995/03/02 12:00	123			
	1995/04/22 11:00 - 1995/09/30 22:00	3876			
	1995/10/12 16:00 - 1995/10/13 22:00	31			
	1995/10/23 23:00 - 1995/12/05 12:00	1022			
	1996/03/18 23:00	1			
Chico Creek - 15 Minute Flow	21417 missing of 210432;		1999/10/01 00:00 - 2005/09/30 23:45	-122.707500	47.59333333
	1999/10/01 00:00 - 1999/10/06 10:00	521			
	2000/01/13 09:00 - 2000/01/24 13:15	1074			
	2000/04/19 04:00 - 2000/04/26 12:45	708			
	2000/05/16 10:00 - 2000/05/16 10:30	3			
	2000/06/26 12:00	1			
	2000/10/08 07:45 - 2000/10/18 12:00	978			
	2001/08/20 10:45 - 2001/09/20 12:45	2985			
	2001/11/06 00:00 - 2001/11/14 12:15	818			
	2002/01/02 12:00 - 2002/01/14 14:45	1164			
	2002/10/04 10:00	1			
	2002/11/12 10:45	1			
	2002/12/20 11:00 - 2002/12/20 11:15	2			
	2003/01/06 12:00	1			
	2003/01/24 15:00	1			
	2003/02/07 12:00	1			
	2003/06/09 10:45 - 2003/06/09 11:00	2			
	2003/07/14 12:00	1			
	2003/08/28 11:15	1			
	2003/11/18 12:15	1			
	2004/06/23 10:00 - 2004/06/23 11:15	6			
	2004/08/02 11:15	1			
	2004/11/15 14:15 - 2004/11/15 14:30	2			
	2005/03/03 14:15 - 2005/07/18 12:00	13144			
Clear Creek Mainstem - Daily Flow	181 missing of 2557;		1993/10/01 - 2000/09/30	-122.681111	47.66500000
	1993/12/09 - 1993/12/10	2			
	1995/03/03	1			
	1998/01/16 - 1998/01/27	12			
	1998/07/23 - 1998/09/10	50			
	1999/05/06 - 1999/05/21	16			
	1999/07/29 - 1999/08/19	22			
	1999/09/21 - 1999/09/30	10			

	1999/11/29 - 1999/12/14 2000/02/21 - 2000/03/07 2000/05/16 - 2000/06/20	16 16 36			

Clear Creek Mainstem - 15 Minute Flow	52996 missing of 315552;		1996/10/01 00:00 - 2005/09/30 23:45	-122.681111	47.66500000
	1996/12/31 18:15 - 1996/12/31 23:45	23			
	1998/01/16 12:45 - 1998/01/27 11:45	1053			
	1998/07/23 10:15 - 1998/09/10 13:30	4718			
	1999/05/06 10:00 - 1999/05/21 09:00	1437			
	1999/07/29 05:30 - 1999/08/19 10:15	2036			
	1999/09/21 09:30 - 1999/09/30 23:45	922			
	1999/11/29 05:45 - 1999/12/14 13:30	1472			
	2000/02/21 10:00 - 2000/03/07 14:00	1457			
	2000/05/16 12:30 - 2000/06/28 10:45	4122			
	2001/12/05 19:15 - 2002/01/17 12:30	4102			
	2002/02/08 10:00 - 2002/02/08 10:45	4			
	2002/04/10 12:00 - 2002/05/03 09:45	2200			
	2002/06/03 01:00 - 2002/06/07 09:45	420			
	2002/07/19 23:45 - 2002/08/08 09:00	1862			
	2002/08/28 01:15 - 2002/11/25 10:45	8583			
	2002/12/20 10:30	1			
	2003/04/09 08:45	1			
	2003/06/04 12:00	1			
	2003/07/28 10:00	1			
	2003/09/08 01:00 - 2003/09/08 23:45	92			
	2003/09/09 01:00 - 2003/09/09 23:45	92			
	2003/09/10 01:00 - 2003/09/10 23:45	92			
	2003/09/11 01:00 - 2003/09/11 23:45	92			
	2003/09/12 01:00 - 2003/09/12 23:45	92			
	2003/09/13 01:00 - 2003/09/13 23:45	92			
	2003/09/14 01:00 - 2003/09/14 23:45	92			
	2003/09/15 01:00 - 2003/09/15 23:45	92			
	2003/09/16 01:00 - 2003/09/16 23:45	92			
	2003/09/17 01:00 - 2003/09/17 23:45	92			
	2003/09/18 01:00 - 2003/09/18 23:45	92			
	2003/09/19 01:00 - 2003/09/19 23:45	92			
	2003/09/20 01:00 - 2003/09/20 23:45	92			
	2003/09/21 01:00 - 2003/09/21 23:45	92			
	2003/09/22 01:00 - 2003/09/22 23:45	92			
	2003/09/23 01:00 - 2003/09/23 23:45	92			
	2003/09/24 01:00 - 2003/09/24 23:45	92			
	2003/09/25 01:00 - 2003/09/25 23:45	92			
	2003/09/26 01:00 - 2003/09/26 23:45	92			
	2003/09/27 01:00 - 2003/09/27 23:45	92			
	2003/09/28 01:00 - 2003/09/28 23:45	92			
	2003/09/29 01:00 - 2003/09/29 23:45	92			
	2003/09/30 01:00 - 2003/09/30 23:45	92			
	2003/10/01 01:00 - 2003/10/01 23:45	92			
	2003/10/02 01:00 - 2003/10/02 11:00	41			
	2003/10/22 13:15 - 2003/11/05 18:30	1366			

	2004/02/20 11:45 - 2004/03/12 17:15 2004/08/24 13:00 - 2004/08/24 14:15 2004/10/06 06:00 - 2004/12/02 09:00 2005/07/15 13:00 - 2005/09/30 23:45	2039 6 5485 7436			
Clear Creek East Tributary - 15 Minute Flow	14852 missing of 169248; 2000/12/03 00:00 - 2000/12/30 14:15 2002/06/06 09:00 - 2002/06/07 09:15 2002/06/07 09:45 - 2002/07/29 09:45 2002/10/02 13:30 - 2002/10/02 13:45 2002/11/07 11:15 2002/11/16 19:45 2002/12/03 16:45 - 2002/12/05 10:00 2003/01/06 11:00 2003/02/07 11:30 2003/03/22 08:30 2003/04/02 09:45 2003/06/04 11:45 2003/07/11 09:00 2003/10/02 10:45 2003/11/20 13:15 2004/03/25 11:15 2004/06/17 13:45 2004/10/25 10:15 2004/11/03 04:00 - 2004/11/03 10:15 2004/11/03 18:30 - 2004/11/04 12:15 2004/11/04 18:45 - 2004/11/07 11:30 2004/11/07 19:00 - 2004/11/10 20:00 2004/11/29 00:00 - 2004/11/29 23:45 2005/01/04 07:30 - 2005/02/24 11:30 2005/08/31 07:30 - 2005/09/13 12:45	 2650 98 4993 2 1 1 166 1 1 1 1 1 1 1 1 1 1 1 26 72 260 293 96 4913 1270	2000/12/03 00:00 - 2005/09/30 23:45	-122.681667	47.66750000
Clear Creek West Tributary - 15 Minute Flow	18639 missing of 105120; 2000/10/01 00:00 - 2000/12/30 12:15 2001/04/29 09:15 - 2001/05/08 10:30 2002/02/04 15:15 - 2002/03/06 14:45 2002/10/01 00:00 - 2002/10/01 13:15 2003/02/28 14:15 2003/05/05 08:30 2003/06/18 09:15 - 2003/08/21 09:00	 8690 870 2879 54 1 1 6144	2000/10/01 00:00 - 2003/09/30 23:45	-122.690278	47.66972222
Barker Creek - Daily Flow	381 missing of 2192; 1991/10/01 1994/10/08 - 1994/10/10 1994/12/19 - 1995/02/01 1995/12/07 - 1995/12/31 1996/02/14 - 1996/02/26 1996/06/03 - 1996/06/27 1996/11/07	 1 3 45 25 13 25 1	1991/10/01 - 1997/09/30	-122.657778	47.64333333

	1996/12/31 - 1997/01/01 1997/01/08 - 1997/09/30	2 266			
Barker Creek - 15 Minute Flow	20853 missing of 175296; 2000/10/01 00:00 - 2001/01/05 14:00 2002/11/21 13:45 - 2002/12/04 12:15 2003/04/02 09:00 2003/06/04 12:45 2003/07/11 09:15 2003/10/02 11:30 2003/11/19 14:15 2004/02/20 12:00 - 2004/02/20 12:15 2004/04/08 10:15 2004/06/15 11:15 - 2004/06/15 11:30 2004/08/17 11:30 2004/10/25 10:30 - 2004/11/08 16:15 2005/02/24 12:15 - 2005/03/31 16:45 2005/07/09 06:45 - 2005/07/09 14:00 2005/07/09 18:45 - 2005/07/10 16:00 2005/07/20 12:15 - 2005/09/15 09:45	 9273 1243 1 1 1 1 1 2 1 2 1 1368 3379 30 86 5463	2000/10/01 00:00 - 2005/09/30 23:45	-122.657778	47.64333333
Strawberry Creek - Daily Flow	1103 missing of 2922; 1993/10/01 - 1995/09/30 1996/10/01 - 1997/09/30 1997/11/13 1998/12/13 1998/12/30 1999/01/18 1999/01/29 - 1999/01/30 1999/02/05 1999/02/24	 730 365 1 1 1 1 2 1 1	1991/10/01 - 1999/09/30	-122.693889	47.64638889
Strawberry Creek - 15 Minute Flow	46408 missing of 140256; 2001/10/01 00:00 - 2001/10/04 12:45 2002/10/04 11:30 2002/11/07 11:45 - 2002/12/04 12:00 2003/01/06 11:30 2003/01/24 14:30 2003/02/07 11:15 2003/04/02 09:15 - 2003/04/02 09:30 2003/06/04 12:30 2003/07/15 11:15 2003/10/01 00:00 - 2004/09/30 23:45 2004/10/25 11:00 - 2004/11/08 16:45 2005/05/11 13:15 - 2005/05/11 13:30 2005/07/20 12:00 - 2005/09/30 23:45	 340 1 2594 1 1 1 2 1 1 35136 1368 2 6960	2001/10/01 00:00 -	-122.693889	47.64638889
Gorst Creek - Daily Flows	822 missing of 2163; 1993/09/08 - 1995/09/29 1995/12/19 - 1996/02/26	 752 70	1990/10/24 - 1996/09/24	-122.713889	47.53027778

Gorst Creek - 15 Minute Flow	38824 missing of 105074; 2000/10/01 00:00 - 2000/12/30 11:15 2002/01/03 12:30 - 2002/10/01 10:45 2003/02/04 13:15 - 2003/02/04 13:30 2003/05/01 11:15 - 2003/06/13 10:00 2003/07/11 09:45 - 2003/07/11 10:00	 8686 26010 2 4124 2	2000/10/01 00:00 - 2003/09/30 12:15	-122.713889	47.53027778
Parish Creek - 15 Minute Flow	18909 missing of 70033; 2001/10/01 00:00 - 2002/02/28 11:15 2002/10/01 00:00 - 2002/10/01 10:45 2003/02/04 13:15 2003/02/28 12:30 - 2003/04/15 12:00 2003/05/01 10:30 2003/06/09 11:30 2003/07/11 09:45	 14446 44 1 4415 1 1 1	2001/10/01 00:00 - 2003/09/30 12:00	-122.712500	47.52944444
Heins Creek - 15 Minute Flow	24869 missing of 70035; 2001/10/01 00:00 - 2002/06/14 11:30 2002/10/01 11:15 2003/02/03 19:15 - 2003/02/03 20:30 2003/02/03 23:45 - 2003/02/04 00:30 2003/02/04 01:15 - 2003/02/04 12:00 2003/02/04 13:45 - 2003/02/04 15:00 2003/02/04 16:30 - 2003/02/05 13:00 2003/02/05 14:15 - 2003/02/06 14:45 2003/05/01 11:15 2003/06/09 11:45 2003/07/11 10:00	 24623 1 6 4 44 6 83 99 1 1 1	2001/10/01 00:00 - 2003/09/30 12:30	-122.715000	47.53083333
Blackjack Creek - Daily Flows	0 missing of 243;		1992/10/01 - 1993/05/31	-122.646389	47.50194444
Blackjack Creek - 15 Minute Flow	43871 missing of 175296; 2000/10/01 00:00 - 2000/12/30 10:30 2001/02/27 15:45 2002/10/01 00:00 - 2002/10/01 10:15 2002/11/04 11:30 2002/12/11 13:00 2003/02/28 12:15 2003/05/05 11:00 2003/06/13 10:45 2003/07/16 08:00 - 2003/07/16 08:15 2003/10/01 00:00 - 2004/09/30 23:45 2004/11/18 12:45 2005/02/10 10:15	 8683 1 42 1 1 1 1 1 2 35136 1 1	2000/10/01 00:00 - 2005/09/30 23:45	-122.646389	47.50194444
Steel Creek - 15 Minute Flow	25436 missing of 70080; 2000/10/01 00:00 - 2001/02/25 08:45 2002/06/05 10:00 - 2002/09/30 23:45	 14148 11288	2000/10/01 00:00 - 2002/09/30 23:45	NA	NA
PSNS 126- 15 Minute Flow	455 missing of 22889; 2004/03/17 01:45	 1	2004/03/16 14:00 - 2004/11/10 00:00	-122.628760	47.56175000

	2004/03/18 01:45 - 2004/03/18 02:15	3			
	2004/03/18 14:00	1			
	2004/03/19 02:30 - 2004/03/19 03:00	3			
	2004/03/20 03:30	1			
	2004/03/21 03:30 - 2004/03/21 03:45	2			
	2004/03/21 16:30	1			
	2004/03/22 04:00 - 2004/03/22 04:30	3			
	2004/03/24 19:30	1			
	2004/04/03 02:00 - 2004/04/03 02:30	3			
	2004/04/04 02:45	1			
	2004/04/04 14:45	1			
	2004/04/05 03:00 - 2004/04/05 03:15	2			
	2004/04/06 03:00	1			
	2004/04/07 04:00	1			
	2004/04/14 00:15	1			
	2004/04/19 04:00	1			
	2004/04/20 04:15	1			
	2004/04/21 04:45	1			
	2004/05/07 19:15	1			
	2004/05/08 05:45	1			
	2004/05/08 20:15	1			
	2004/05/14 00:15	1			
	2004/05/15 01:00	1			
	2004/05/26 21:45	1			
	2004/05/29 00:00	1			
	2004/06/04 18:15 - 2004/06/04 18:30	2			
	2004/06/04 19:00	1			
	2004/06/04 19:45	1			
	2004/06/05 20:15	1			
	2004/06/06 19:45	1			
	2004/06/13 15:00	1			
	2004/06/13 16:00	1			
	2004/06/22 20:00	1			
	2004/06/23 21:00	1			
	2004/06/27 22:45	1			
	2004/06/30 15:45	1			
	2004/07/01 16:30	1			
	2004/07/02 18:00	1			
	2004/07/02 18:45	1			
	2004/07/05 19:30 - 2004/07/05 19:45	2			
	2004/07/05 20:15	1			
	2004/07/06 19:30 - 2004/07/06 19:45	2			
	2004/07/06 20:45 - 2004/07/06 21:15	3			
	2004/07/07 20:30 - 2004/07/07 20:45	2			
	2004/07/07 21:30	1			
	2004/07/09 21:45	1			

	2004/07/10 13:30 2004/07/10 22:15 - 2004/07/10 22:45 2004/07/11 22:30 - 2004/07/11 22:45 2004/07/31 01:15 2004/08/01 01:30 2004/08/01 02:00 2004/08/02 02:30 - 2004/08/02 02:45 2004/08/02 03:15 - 2004/08/02 03:30 2004/08/02 13:30 2004/08/03 02:45 - 2004/08/03 03:00 2004/08/03 03:45 2004/08/04 03:45 2004/08/04 04:30 2004/08/05 03:45 - 2004/08/05 04:30 2004/08/05 05:00 - 2004/08/05 05:15 2004/08/06 04:45 2004/08/07 05:15 - 2004/08/07 05:30 2004/08/07 06:00 - 2004/08/07 06:45 2004/08/08 05:15 - 2004/08/08 05:45 2004/08/10 18:45 2004/08/12 18:30 - 2004/08/12 19:15 2004/08/13 18:30 2004/08/13 19:30 2004/08/14 21:45 - 2004/08/14 22:00 2004/08/15 21:15 - 2004/08/15 21:30 2004/08/15 22:15 - 2004/08/15 23:00 2004/08/16 20:45 2004/08/19 00:30 2004/08/19 02:00 2004/08/21 04:00 - 2004/08/21 04:15 2004/08/21 05:00 2004/08/22 03:45 - 2004/08/22 04:45 2004/08/22 20:45 2004/08/23 04:30 - 2004/08/23 05:30 2004/08/24 20:30 - 2004/08/24 22:15 2004/08/25 00:00 - 2004/08/25 00:45 2004/08/25 01:30 2004/08/25 03:00 2004/08/25 03:45 2004/08/25 04:15 - 2004/08/25 07:15 2004/08/25 09:15 - 2004/08/25 09:30 2004/08/25 21:45 2004/08/26 07:15 2004/08/29 00:30 - 2004/08/29 00:45 2004/08/29 11:45 2004/08/30 00:45 - 2004/08/30 01:00	1 3 2 1 1 1 2 2 1 2 1 1 1 4 2 1 2 4 3 1 4 1 1 2 2 4 1 1 1 2 1 5 1 5 8 4 1 1 1 13 2 1 1 2 1 2			

	2004/08/30 01:30 - 2004/08/30 01:45	2			
	2004/08/30 02:15 - 2004/08/30 02:45	3			
	2004/08/30 12:45	1			
	2004/08/31 02:00	1			
	2004/09/01 12:00 - 2004/09/01 12:15	2			
	2004/09/01 18:00 - 2004/09/01 18:15	2			
	2004/09/02 17:45 - 2004/09/02 18:30	4			
	2004/09/02 19:00 - 2004/09/02 19:15	2			
	2004/09/03 18:30 - 2004/09/03 19:30	5			
	2004/09/05 20:00	1			
	2004/09/11 03:30 - 2004/09/11 03:45	2			
	2004/09/11 06:00	1			
	2004/09/14 03:30 - 2004/09/14 04:00	3			
	2004/09/14 14:30	1			
	2004/09/14 15:15 - 2004/09/14 15:30	2			
	2004/09/15 04:00 - 2004/09/15 05:00	5			
	2004/09/15 10:30	1			
	2004/09/15 11:15	1			
	2004/09/15 14:15 - 2004/09/15 14:30	2			
	2004/09/15 16:15 - 2004/09/15 16:30	2			
	2004/09/16 14:00 - 2004/09/16 14:15	2			
	2004/09/16 16:45 - 2004/09/16 17:45	5			
	2004/09/17 05:30 - 2004/09/17 06:00	3			
	2004/09/17 16:00	1			
	2004/09/17 17:00 - 2004/09/17 17:45	4			
	2004/09/17 18:15 - 2004/09/17 18:45	3			
	2004/09/18 17:00 - 2004/09/18 18:15	6			
	2004/09/19 18:00 - 2004/09/19 18:45	4			
	2004/09/21 01:15 - 2004/09/21 02:00	4			
	2004/09/22 03:15 - 2004/09/22 06:00	12			
	2004/09/22 19:00 - 2004/09/22 19:15	2			
	2004/09/22 22:15 - 2004/09/22 22:45	3			
	2004/09/22 23:15 - 2004/09/22 23:30	2			
	2004/09/23 06:15 - 2004/09/23 06:30	2			
	2004/09/23 08:15	1			
	2004/09/24 23:00 - 2004/09/25 00:00	5			
	2004/09/28 15:30 - 2004/09/28 15:45	2			
	2004/10/06 02:15 - 2004/10/06 02:30	2			
	2004/10/06 05:45 - 2004/10/06 06:00	2			
	2004/10/06 07:00	1			
	2004/10/06 10:30 - 2004/10/06 10:45	2			
	2004/10/06 20:45	1			
	2004/10/06 22:00	1			
	2004/10/07 04:30	1			
	2004/10/07 08:00	1			
	2004/10/07 11:00	1			

	2004/10/07 22:15	1			
	2004/10/08 00:45	1			
	2004/10/08 12:45 - 2004/10/08 14:30	8			
	2004/10/08 23:15	1			
	2004/10/09 03:15	1			
	2004/10/09 14:00 - 2004/10/09 14:30	3			
	2004/10/10 06:00 - 2004/10/10 06:30	3			
	2004/10/10 07:00 - 2004/10/10 07:15	2			
	2004/10/10 07:45 - 2004/10/10 08:00	2			
	2004/10/10 12:15 - 2004/10/10 12:45	3			
	2004/10/10 13:15 - 2004/10/10 13:30	2			
	2004/10/11 14:15 - 2004/10/11 14:30	2			
	2004/10/12 08:45 - 2004/10/12 09:30	4			
	2004/10/12 10:30	1			
	2004/10/12 14:15	1			
	2004/10/12 15:00 - 2004/10/12 15:15	2			
	2004/10/12 22:30 - 2004/10/13 00:15	8			
	2004/10/13 01:15 - 2004/10/13 01:45	3			
	2004/10/13 11:45 - 2004/10/13 12:15	3			
	2004/10/13 13:00	1			
	2004/10/15 15:45 - 2004/10/15 16:00	2			
	2004/10/16 14:00 - 2004/10/16 14:15	2			
	2004/10/16 16:15 - 2004/10/16 16:45	3			
	2004/10/17 15:45 - 2004/10/17 17:30	8			
	2004/10/18 17:30 - 2004/10/18 17:45	2			
	2004/10/19 19:45 - 2004/10/19 20:00	2			
	2004/10/20 09:00 - 2004/10/20 09:15	2			
	2004/10/22 11:15 - 2004/10/22 12:00	4			
	2004/10/23 05:15 - 2004/10/23 05:30	2			
	2004/10/23 07:00 - 2004/10/23 09:00	9			
	2004/10/24 00:45 - 2004/10/24 01:00	2			
	2004/10/24 05:15 - 2004/10/24 05:30	2			
	2004/10/24 08:00 - 2004/10/24 08:15	2			
	2004/10/25 12:15 - 2004/10/25 12:30	2			
	2004/10/25 13:30 - 2004/10/25 13:45	2			
	2004/10/25 14:30 - 2004/10/25 15:15	4			
	2004/10/26 11:30	1			
	2004/10/26 12:45 - 2004/10/26 13:15	3			
	2004/10/26 14:15 - 2004/10/26 14:30	2			
	2004/10/26 15:15 - 2004/10/26 15:30	2			
	2004/10/27 10:45 - 2004/10/27 11:15	3			
	2004/10/27 16:15	1			
	2004/10/30 04:30 - 2004/10/30 04:45	2			
	2004/10/30 15:45 - 2004/10/30 16:30	4			
	2004/11/01 04:00 - 2004/11/01 05:45	8			
	2004/11/02 17:30 - 2004/11/02 17:45	2			

	2004/11/02 19:15 - 2004/11/02 19:30	2			
	2004/11/02 23:45	1			
	2004/11/03 00:15 - 2004/11/03 00:30	2			
	2004/11/03 02:30 - 2004/11/03 04:15	8			
	2004/11/03 04:45	1			
	2004/11/03 07:30	1			
	2004/11/03 16:15	1			
	2004/11/04 18:00 - 2004/11/04 18:30	3			
	2004/11/04 20:15 - 2004/11/04 20:30	2			
	2004/11/05 02:45 - 2004/11/05 03:00	2			
	2004/11/05 19:30 - 2004/11/05 19:45	2			
	2004/11/05 20:45 - 2004/11/05 21:15	3			
	2004/11/06 04:45 - 2004/11/06 05:45	5			
	2004/11/08 11:30 - 2004/11/08 12:30	5			
	2004/11/09 12:15 - 2004/11/09 13:00	4			
PSNS 124 - 15 Minute Flow	833 missing of 20634;		2004/03/24 11:15 - 2004/10/25 09:30	-122.629960	47.56115000
	2004/03/24 16:45	1			
	2004/03/24 17:45 - 2004/03/24 18:00	2			
	2004/03/25 02:45	1			
	2004/03/25 05:00	1			
	2004/03/25 05:30	1			
	2004/03/25 17:15 - 2004/03/25 17:30	2			
	2004/03/25 18:15 - 2004/03/25 18:30	2			
	2004/03/25 19:30	1			
	2004/03/26 18:30 - 2004/03/26 18:45	2			
	2004/03/26 19:30	1			
	2004/03/27 04:45 - 2004/03/27 05:00	2			
	2004/03/27 19:00 - 2004/03/27 19:30	3			
	2004/03/27 20:00 - 2004/03/27 20:30	3			
	2004/03/28 20:15 - 2004/03/28 20:45	3			
	2004/03/28 21:45 - 2004/03/28 22:30	4			
	2004/03/29 20:45	1			
	2004/03/29 21:30 - 2004/03/29 21:45	2			
	2004/03/29 23:00	1			
	2004/03/30 00:30	1			
	2004/03/30 22:00 - 2004/03/30 22:45	4			
	2004/03/30 23:30 - 2004/03/31 00:30	5			
	2004/03/31 01:00	1			
	2004/03/31 01:30	1			
	2004/03/31 23:15 - 2004/04/01 02:00	12			
	2004/04/01 11:00 - 2004/04/01 11:15	2			
	2004/04/02 00:00 - 2004/04/02 02:30	11			
	2004/04/03 00:30	1			
	2004/04/03 01:30	1			
	2004/04/03 02:30	1			
	2004/04/04 00:45 - 2004/04/04 01:15	3			

	2004/04/04 01:45 - 2004/04/04 02:00	2			
	2004/04/04 03:00 - 2004/04/04 03:15	2			
	2004/04/04 13:30 - 2004/04/04 13:45	2			
	2004/04/05 01:30 - 2004/04/05 02:00	3			
	2004/04/05 02:30 - 2004/04/05 03:30	5			
	2004/04/05 14:30 - 2004/04/05 14:45	2			
	2004/04/05 15:15	1			
	2004/04/06 02:00	1			
	2004/04/06 02:45 - 2004/04/06 03:15	3			
	2004/04/06 03:45	1			
	2004/04/06 04:15	1			
	2004/04/06 15:15 - 2004/04/06 16:15	5			
	2004/04/06 16:45	1			
	2004/04/07 01:45 - 2004/04/07 02:00	2			
	2004/04/07 03:30 - 2004/04/07 04:30	5			
	2004/04/07 16:15 - 2004/04/07 17:00	4			
	2004/04/08 04:15	1			
	2004/04/08 04:45	1			
	2004/04/08 17:00	1			
	2004/04/08 17:45	1			
	2004/04/09 17:45 - 2004/04/09 18:15	3			
	2004/04/10 19:00 - 2004/04/10 19:15	2			
	2004/04/10 20:00	1			
	2004/04/10 20:45	1			
	2004/04/11 19:45	1			
	2004/04/11 20:15	1			
	2004/04/11 20:45 - 2004/04/11 21:15	3			
	2004/04/12 21:15 - 2004/04/12 21:30	2			
	2004/04/12 22:45	1			
	2004/04/12 23:30	1			
	2004/04/13 08:45 - 2004/04/13 09:00	2			
	2004/04/13 22:15	1			
	2004/04/13 23:00 - 2004/04/13 23:15	2			
	2004/04/14 10:30 - 2004/04/14 10:45	2			
	2004/04/14 22:45	1			
	2004/04/14 23:15	1			
	2004/04/15 23:30 - 2004/04/15 23:45	2			
	2004/04/16 00:15	1			
	2004/04/16 01:30	1			
	2004/04/16 12:15	1			
	2004/04/17 00:30	1			
	2004/04/17 01:00 - 2004/04/17 01:45	4			
	2004/04/17 02:15	1			
	2004/04/17 03:00	1			
	2004/04/17 13:00 - 2004/04/17 13:15	2			
	2004/04/18 01:15	1			

	2004/04/18 01:45	1			
	2004/04/18 02:15	1			
	2004/04/18 02:45	1			
	2004/04/18 13:45	1			
	2004/04/18 14:15	1			
	2004/04/18 15:15	1			
	2004/04/19 01:15	1			
	2004/04/19 02:15 - 2004/04/19 02:30	2			
	2004/04/19 03:15	1			
	2004/04/19 14:45	1			
	2004/04/19 15:30	1			
	2004/04/20 00:45	1			
	2004/04/20 15:00 - 2004/04/20 15:15	2			
	2004/04/20 15:45 - 2004/04/20 16:00	2			
	2004/04/21 16:00 - 2004/04/21 16:15	2			
	2004/04/21 16:45 - 2004/04/21 17:00	2			
	2004/04/22 16:30 - 2004/04/22 17:00	3			
	2004/04/23 17:15	1			
	2004/04/23 19:00	1			
	2004/04/25 18:30 - 2004/04/25 18:45	2			
	2004/04/27 20:15 - 2004/04/27 20:30	2			
	2004/04/28 08:45	1			
	2004/04/28 21:30 - 2004/04/28 21:45	2			
	2004/04/29 22:15 - 2004/04/29 22:45	3			
	2004/05/01 11:30 - 2004/05/01 11:45	2			
	2004/05/01 23:30 - 2004/05/01 23:45	2			
	2004/05/02 12:30	1			
	2004/05/04 02:15	1			
	2004/05/04 14:30 - 2004/05/04 15:00	3			
	2004/05/05 02:30	1			
	2004/05/05 03:15 - 2004/05/05 03:45	3			
	2004/05/05 15:00 - 2004/05/05 15:30	3			
	2004/05/05 16:00 - 2004/05/05 16:30	3			
	2004/05/06 00:45	1			
	2004/05/06 03:15	1			
	2004/05/06 03:45 - 2004/05/06 04:00	2			
	2004/05/06 15:45 - 2004/05/06 17:15	7			
	2004/05/06 17:45 - 2004/05/06 18:00	2			
	2004/05/07 02:15	1			
	2004/05/07 05:15	1			
	2004/05/07 16:30 - 2004/05/07 16:45	2			
	2004/05/07 18:00 - 2004/05/07 18:30	3			
	2004/05/08 17:45	1			
	2004/05/08 18:45	1			
	2004/05/08 19:15 - 2004/05/08 19:45	3			
	2004/05/09 18:30 - 2004/05/09 19:00	3			

	2004/05/09 19:45	1				
	2004/05/09 20:15	1				
	2004/05/10 19:15 - 2004/05/10 19:45	3				
	2004/05/10 21:15	1				
	2004/05/11 20:15 - 2004/05/11 21:15	5				
	2004/05/11 22:30	1				
	2004/05/12 21:30	1				
	2004/05/12 23:15	1				
	2004/05/13 10:15	1				
	2004/05/13 22:15	1				
	2004/05/13 23:00	1				
	2004/05/13 23:30	1				
	2004/05/15 00:30 - 2004/05/15 00:45	2				
	2004/05/16 13:00 - 2004/05/16 13:15	2				
	2004/05/17 14:00	1				
	2004/05/18 14:30	1				
	2004/05/18 16:30	1				
	2004/05/19 15:00 - 2004/05/19 15:30	3				
	2004/05/19 16:00	1				
	2004/05/19 16:30 - 2004/05/19 16:45	2				
	2004/05/20 15:15 - 2004/05/20 15:45	3				
	2004/05/20 16:30	1				
	2004/05/20 17:30	1				
	2004/05/21 16:00 - 2004/05/21 16:15	2				
	2004/05/21 17:00	1				
	2004/05/21 17:30	1				
	2004/05/22 16:30 - 2004/05/22 16:45	2				
	2004/05/23 17:15 - 2004/05/23 17:30	2				
	2004/05/24 18:00 - 2004/05/24 18:30	3				
	2004/05/24 19:45	1				
	2004/05/25 18:30 - 2004/05/25 19:00	3				
	2004/05/26 19:30	1				
	2004/05/27 19:45	1				
	2004/05/27 20:30	1				
	2004/05/28 20:30	1				
	2004/05/29 21:30	1				
	2004/05/29 23:00 - 2004/05/29 23:15	2				
	2004/05/30 11:30	1				
	2004/05/30 12:00	1				
	2004/05/31 00:15	1				
	2004/05/31 12:30	1				
	2004/05/31 22:15	1				
	2004/06/01 00:45	1				
	2004/06/01 13:30 - 2004/06/01 13:45	2				
	2004/06/02 14:00 - 2004/06/02 14:30	3				
	2004/06/02 16:00	1				

	2004/06/03 16:00	1			
	2004/06/03 16:45	1			
	2004/06/04 15:45 - 2004/06/04 16:15	3			
	2004/06/04 16:45 - 2004/06/04 17:15	3			
	2004/06/04 18:00 - 2004/06/04 18:15	2			
	2004/06/05 16:15 - 2004/06/05 17:00	4			
	2004/06/05 17:30	1			
	2004/06/05 18:00 - 2004/06/05 18:15	2			
	2004/06/05 19:30 - 2004/06/05 19:45	2			
	2004/06/06 17:15 - 2004/06/06 17:30	2			
	2004/06/06 18:30	1			
	2004/06/06 19:30 - 2004/06/06 19:45	2			
	2004/06/06 20:15 - 2004/06/06 20:45	3			
	2004/06/07 18:00 - 2004/06/07 18:30	3			
	2004/06/07 19:45	1			
	2004/06/07 21:00	1			
	2004/06/08 18:45 - 2004/06/08 19:00	2			
	2004/06/08 20:30	1			
	2004/06/08 21:45	1			
	2004/06/09 19:30 - 2004/06/09 19:45	2			
	2004/06/09 20:30 - 2004/06/09 20:45	2			
	2004/06/09 21:15	1			
	2004/06/09 22:15	1			
	2004/06/10 20:00	1			
	2004/06/10 20:30	1			
	2004/06/10 22:00	1			
	2004/06/10 22:30	1			
	2004/06/11 10:30	1			
	2004/06/12 11:30	1			
	2004/06/12 21:15	1			
	2004/06/16 14:15 - 2004/06/16 14:45	3			
	2004/06/17 15:00	1			
	2004/06/18 15:00	1			
	2004/06/18 15:30	1			
	2004/06/18 16:00	1			
	2004/06/19 15:45 - 2004/06/19 16:15	3			
	2004/06/20 16:15 - 2004/06/20 16:30	2			
	2004/06/20 17:15	1			
	2004/06/21 16:45 - 2004/06/21 17:15	3			
	2004/06/22 17:30 - 2004/06/22 17:45	2			
	2004/06/22 19:00	1			
	2004/06/23 18:00	1			
	2004/06/24 18:45	1			
	2004/06/26 22:00	1			
	2004/07/01 15:00 - 2004/07/01 15:30	3			
	2004/07/02 15:45 - 2004/07/02 16:15	3			

	2004/07/03 16:45 - 2004/07/03 17:00	2			
	2004/07/03 18:30	1			
	2004/07/04 17:15 - 2004/07/04 17:45	3			
	2004/07/04 18:30	1			
	2004/07/05 18:00	1			
	2004/07/05 19:15 - 2004/07/05 19:30	2			
	2004/07/06 18:30 - 2004/07/06 19:00	3			
	2004/07/07 19:00 - 2004/07/07 19:15	2			
	2004/07/07 20:45 - 2004/07/07 21:00	2			
	2004/07/13 14:30 - 2004/07/13 14:45	2			
	2004/07/14 14:15 - 2004/07/14 14:30	2			
	2004/07/15 15:00 - 2004/07/15 15:15	2			
	2004/07/17 15:45 - 2004/07/17 16:15	3			
	2004/07/18 16:15 - 2004/07/18 16:45	3			
	2004/07/19 17:00 - 2004/07/19 17:15	2			
	2004/07/20 17:15 - 2004/07/20 17:45	3			
	2004/07/21 18:00	1			
	2004/07/22 18:30 - 2004/07/22 18:45	2			
	2004/07/23 18:30	1			
	2004/07/23 20:30 - 2004/07/23 20:45	2			
	2004/07/24 18:30 - 2004/07/24 18:45	2			
	2004/07/25 09:45	1			
	2004/07/25 19:45 - 2004/07/25 20:00	2			
	2004/07/27 12:00	1			
	2004/07/29 13:45 - 2004/07/29 14:15	3			
	2004/07/30 14:30 - 2004/07/30 15:30	5			
	2004/07/30 16:45 - 2004/07/30 17:00	2			
	2004/07/31 15:15 - 2004/07/31 16:45	7			
	2004/08/01 16:00 - 2004/08/01 17:15	6			
	2004/08/01 18:30 - 2004/08/01 18:45	2			
	2004/08/02 16:30 - 2004/08/02 17:15	4			
	2004/08/02 18:00 - 2004/08/02 18:15	2			
	2004/08/02 19:00	1			
	2004/08/03 17:30 - 2004/08/03 19:00	7			
	2004/08/04 17:30 - 2004/08/04 19:30	9			
	2004/08/05 18:00 - 2004/08/05 18:30	3			
	2004/08/05 19:45 - 2004/08/05 20:00	2			
	2004/08/05 20:45	1			
	2004/08/06 18:00	1			
	2004/08/08 19:30 - 2004/08/08 19:45	2			
	2004/08/09 11:00	1			
	2004/08/10 12:00 - 2004/08/10 12:15	2			
	2004/08/13 14:15	1			
	2004/08/14 15:00	1			
	2004/08/15 15:15 - 2004/08/15 15:45	3			
	2004/08/16 16:00 - 2004/08/16 16:30	3			

	2004/08/16 17:15 - 2004/08/16 17:30	2			
	2004/08/17 16:15 - 2004/08/17 17:45	7			
	2004/08/19 17:00 - 2004/08/19 17:30	3			
	2004/08/20 17:30 - 2004/08/20 17:45	2			
	2004/08/21 17:00 - 2004/08/21 17:15	2			
	2004/08/21 19:15 - 2004/08/21 19:30	2			
	2004/08/22 07:45	1			
	2004/08/22 17:15	1			
	2004/08/24 10:00 - 2004/08/24 10:30	3			
	2004/08/25 11:15 - 2004/08/25 11:45	3			
	2004/08/26 12:30 - 2004/08/26 13:00	3			
	2004/08/27 13:30 - 2004/08/27 14:15	4			
	2004/08/28 14:15 - 2004/08/28 15:45	7			
	2004/08/29 15:00 - 2004/08/29 16:45	8			
	2004/08/30 15:30 - 2004/08/30 17:00	7			
	2004/08/30 17:45	1			
	2004/08/31 16:00 - 2004/08/31 17:45	8			
	2004/08/31 18:15 - 2004/08/31 18:30	2			
	2004/09/01 03:45 - 2004/09/01 04:00	2			
	2004/09/01 16:30 - 2004/09/01 17:15	4			
	2004/09/01 17:45 - 2004/09/01 18:45	5			
	2004/09/02 04:45 - 2004/09/02 05:30	4			
	2004/09/02 10:30	1			
	2004/09/02 16:30 - 2004/09/02 17:30	5			
	2004/09/02 18:00 - 2004/09/02 18:30	3			
	2004/09/03 06:30	1			
	2004/09/03 16:45	1			
	2004/09/03 17:15 - 2004/09/03 17:30	2			
	2004/09/04 07:00	1			
	2004/09/05 08:00	1			
	2004/09/07 10:00 - 2004/09/07 10:15	2			
	2004/09/08 11:15	1			
	2004/09/08 12:00 - 2004/09/08 12:30	3			
	2004/09/09 12:00	1			
	2004/09/09 12:30	1			
	2004/09/09 13:30	1			
	2004/09/10 12:45 - 2004/09/10 14:00	6			
	2004/09/10 15:30	1			
	2004/09/11 01:45 - 2004/09/11 02:30	4			
	2004/09/11 13:30 - 2004/09/11 14:00	3			
	2004/09/12 14:00 - 2004/09/12 14:45	4			
	2004/09/12 15:30	1			
	2004/09/13 00:30 - 2004/09/13 00:45	2			
	2004/09/13 14:15 - 2004/09/13 14:45	3			
	2004/09/13 15:15 - 2004/09/13 16:15	5			
	2004/09/13 17:45	1			

	2004/09/14 15:00 - 2004/09/14 15:45	4			
	2004/09/14 16:15 - 2004/09/14 16:30	2			
	2004/09/15 02:30 - 2004/09/15 03:00	3			
	2004/09/15 04:00	1			
	2004/09/15 15:00 - 2004/09/15 15:45	4			
	2004/09/15 16:15 - 2004/09/15 16:45	3			
	2004/09/15 17:15 - 2004/09/15 17:45	3			
	2004/09/16 03:15 - 2004/09/16 03:45	3			
	2004/09/16 04:15	1			
	2004/09/16 05:00 - 2004/09/16 05:15	2			
	2004/09/16 15:30 - 2004/09/16 15:45	2			
	2004/09/16 17:30	1			
	2004/09/17 04:30 - 2004/09/17 05:00	3			
	2004/09/17 05:45	1			
	2004/09/17 06:15	1			
	2004/09/17 16:00 - 2004/09/17 16:15	2			
	2004/09/17 16:45 - 2004/09/17 17:15	3			
	2004/09/17 17:45	1			
	2004/09/17 18:15	1			
	2004/09/18 05:30 - 2004/09/18 05:45	2			
	2004/09/18 06:30	1			
	2004/09/18 15:45 - 2004/09/18 16:00	2			
	2004/09/18 16:45	1			
	2004/09/18 18:15	1			
	2004/09/18 19:00	1			
	2004/09/19 06:30 - 2004/09/19 06:45	2			
	2004/09/19 07:30	1			
	2004/09/19 16:00 - 2004/09/19 16:15	2			
	2004/09/20 07:30	1			
	2004/09/20 08:00 - 2004/09/20 08:15	2			
	2004/09/21 08:45 - 2004/09/21 09:15	3			
	2004/09/22 10:00 - 2004/09/22 10:15	2			
	2004/09/23 11:00 - 2004/09/23 11:45	4			
	2004/09/23 12:30	1			
	2004/09/23 13:45	1			
	2004/09/24 12:15 - 2004/09/24 12:30	2			
	2004/09/24 13:00	1			
	2004/09/24 13:30	1			
	2004/09/25 12:45 - 2004/09/25 13:15	3			
	2004/09/25 13:45 - 2004/09/25 14:15	3			
	2004/09/25 14:45 - 2004/09/25 15:00	2			
	2004/09/25 23:45	1			
	2004/09/26 14:00 - 2004/09/26 14:15	2			
	2004/09/26 15:00	1			
	2004/09/26 15:30	1			
	2004/09/27 03:00	1			

	2004/09/27 14:15 - 2004/09/27 15:45	7			
	2004/09/27 16:45	1			
	2004/09/28 02:15 - 2004/09/28 02:30	2			
	2004/09/28 03:00 - 2004/09/28 03:30	3			
	2004/09/28 04:00	1			
	2004/09/28 14:30 - 2004/09/28 16:15	8			
	2004/09/28 17:00	1			
	2004/09/29 03:15 - 2004/09/29 03:45	3			
	2004/09/29 04:15 - 2004/09/29 04:30	2			
	2004/09/29 05:00	1			
	2004/09/29 14:45	1			
	2004/09/29 15:15	1			
	2004/09/29 15:45 - 2004/09/29 16:00	2			
	2004/09/29 16:30	1			
	2004/09/29 17:00	1			
	2004/09/30 04:00 - 2004/09/30 04:15	2			
	2004/09/30 04:45 - 2004/09/30 05:00	2			
	2004/09/30 15:30 - 2004/09/30 15:45	2			
	2004/09/30 16:15	1			
	2004/09/30 17:15 - 2004/09/30 17:30	2			
	2004/10/01 04:45 - 2004/10/01 05:00	2			
	2004/10/01 05:45	1			
	2004/10/02 05:30 - 2004/10/02 06:45	6			
	2004/10/02 15:30	1			
	2004/10/03 06:15 - 2004/10/03 06:45	3			
	2004/10/03 07:30	1			
	2004/10/04 07:30 - 2004/10/04 07:45	2			
	2004/10/05 08:00 - 2004/10/05 08:30	3			
	2004/10/05 09:15	1			
	2004/10/06 09:15	1			
	2004/10/07 10:00	1			
	2004/10/07 10:45	1			
	2004/10/20 08:00 - 2004/10/20 08:45	4			
	2004/10/20 09:15	1			
	2004/10/20 09:45	1			
	2004/10/20 11:15	1			
	2004/10/21 09:30 - 2004/10/21 10:00	3			
	2004/10/21 10:30	1			
	2004/10/21 11:45 - 2004/10/21 12:00	2			
	2004/10/22 10:30 - 2004/10/22 11:15	4			
	2004/10/22 13:45 - 2004/10/22 14:00	2			
	2004/10/23 11:15 - 2004/10/23 12:00	4			
	2004/10/23 12:30 - 2004/10/23 12:45	2			
	2004/10/23 13:15	1			
	2004/10/23 14:00	1			
	2004/10/23 14:30	1			

	2004/10/23 23:30 - 2004/10/23 23:45	2			
	2004/10/24 12:15 - 2004/10/24 12:30	2			
	2004/10/24 13:00 - 2004/10/24 15:00	9			
PSNS 015 - 15 Minute Flow	368 missing of 22881;		03/16/2004 16:00 – 11/10/2004 00:00	-122.650780	47.55817000
	2004/03/18 00:30	1			
	2004/03/18 12:00	1			
	2004/03/19 00:45 - 2004/03/19 02:15	7			
	2004/03/19 11:30 - 2004/03/19 11:45	2			
	2004/03/20 02:45	1			
	2004/03/20 13:00 - 2004/03/20 13:15	2			
	2004/03/21 02:15	1			
	2004/03/21 03:00	1			
	2004/03/22 02:00	1			
	2004/03/22 03:00 - 2004/03/22 03:15	2			
	2004/03/22 03:45 - 2004/03/22 04:00	2			
	2004/03/22 15:45	1			
	2004/03/23 02:00	1			
	2004/03/23 16:30 - 2004/03/23 16:45	2			
	2004/03/24 16:15	1			
	2004/03/24 17:30	1			
	2004/03/24 18:00 - 2004/03/24 18:45	4			
	2004/03/24 22:30	1			
	2004/03/25 00:00 - 2004/03/25 00:30	3			
	2004/03/25 01:00	1			
	2004/03/25 01:30	1			
	2004/03/25 04:15	1			
	2004/03/25 18:30	1			
	2004/03/25 19:00	1			
	2004/03/25 19:30 - 2004/03/25 19:45	2			
	2004/03/25 20:30	1			
	2004/03/26 18:15	1			
	2004/03/26 19:00	1			
	2004/03/26 20:15	1			
	2004/03/26 20:45	1			
	2004/03/27 19:00	1			
	2004/03/29 20:15	1			
	2004/03/29 21:00 - 2004/03/29 21:15	2			
	2004/03/30 21:45	1			
	2004/03/30 22:15	1			
	2004/03/31 22:45	1			
	2004/03/31 23:45	1			
	2004/04/03 00:00 - 2004/04/03 00:15	2			
	2004/04/03 01:00	1			
	2004/04/03 01:45 - 2004/04/03 02:00	2			
	2004/04/04 13:45	1			
	2004/04/05 01:15	1			

	2004/04/05 01:45 - 2004/04/05 02:00	2			
	2004/04/05 02:45 - 2004/04/05 03:00	2			
	2004/04/06 02:15	1			
	2004/04/06 15:15	1			
	2004/04/07 02:00	1			
	2004/04/07 14:15 - 2004/04/07 14:45	3			
	2004/04/07 17:00 - 2004/04/07 17:15	2			
	2004/04/08 17:45 - 2004/04/08 18:30	4			
	2004/04/08 19:00 - 2004/04/08 19:15	2			
	2004/04/09 05:30 - 2004/04/09 05:45	2			
	2004/04/09 18:45 - 2004/04/09 19:00	2			
	2004/04/10 07:00	1			
	2004/04/11 20:30 - 2004/04/11 20:45	2			
	2004/04/13 22:45 - 2004/04/13 23:15	3			
	2004/04/13 23:45 - 2004/04/14 00:15	3			
	2004/04/14 23:30 - 2004/04/14 23:45	2			
	2004/04/15 01:15	1			
	2004/04/16 01:15 - 2004/04/16 01:30	2			
	2004/04/16 12:15	1			
	2004/04/17 00:45 - 2004/04/17 01:00	2			
	2004/04/17 02:15 - 2004/04/17 02:30	2			
	2004/04/17 13:15 - 2004/04/17 13:45	3			
	2004/04/18 01:00 - 2004/04/18 01:30	3			
	2004/04/18 02:15 - 2004/04/18 02:30	2			
	2004/04/18 14:30 - 2004/04/18 15:00	3			
	2004/04/19 01:15	1			
	2004/04/19 02:15 - 2004/04/19 02:30	2			
	2004/04/19 03:30 - 2004/04/19 03:45	2			
	2004/04/19 15:00	1			
	2004/04/20 01:15 - 2004/04/20 01:45	3			
	2004/04/20 03:15 - 2004/04/20 03:30	2			
	2004/04/20 15:30 - 2004/04/20 16:00	3			
	2004/04/21 04:00 - 2004/04/21 04:15	2			
	2004/04/22 17:30 - 2004/04/22 17:45	2			
	2004/04/25 19:15 - 2004/04/25 19:30	2			
	2004/04/27 21:00 - 2004/04/27 21:45	4			
	2004/04/29 22:30 - 2004/04/29 22:45	2			
	2004/05/01 12:15	1			
	2004/05/01 23:45 - 2004/05/02 00:45	5			
	2004/05/02 13:00	1			
	2004/05/03 00:15	1			
	2004/05/03 01:30 - 2004/05/03 02:30	5			
	2004/05/03 14:30 - 2004/05/03 14:45	2			
	2004/05/04 02:15 - 2004/05/04 03:00	4			
	2004/05/04 15:00 - 2004/05/04 16:30	7			
	2004/05/05 03:00 - 2004/05/05 03:15	2			

	2004/05/05 15:45 - 2004/05/05 17:30	8			
	2004/05/06 16:45 - 2004/05/06 17:15	3			
	2004/05/07 17:30	1			
	2004/05/07 18:15	1			
	2004/05/07 18:45 - 2004/05/07 19:15	3			
	2004/05/08 18:15 - 2004/05/08 19:00	4			
	2004/05/08 20:15 - 2004/05/08 20:30	2			
	2004/05/09 19:00 - 2004/05/09 19:15	2			
	2004/05/09 20:30 - 2004/05/09 21:00	3			
	2004/05/10 22:00 - 2004/05/10 22:15	2			
	2004/05/11 21:00	1			
	2004/05/11 22:30 - 2004/05/11 22:45	2			
	2004/05/12 22:30 - 2004/05/12 22:45	2			
	2004/05/12 23:15 - 2004/05/12 23:45	3			
	2004/05/13 10:15	1			
	2004/05/13 22:15	1			
	2004/05/13 23:30 - 2004/05/13 23:45	2			
	2004/05/14 00:15 - 2004/05/14 00:30	2			
	2004/05/14 12:00	1			
	2004/05/15 00:15 - 2004/05/15 00:30	2			
	2004/05/15 01:15 - 2004/05/15 01:30	2			
	2004/05/16 14:15 - 2004/05/16 14:30	2			
	2004/05/16 22:30	1			
	2004/05/16 23:15 - 2004/05/16 23:45	3			
	2004/05/17 00:15 - 2004/05/17 00:30	2			
	2004/05/17 14:30 - 2004/05/17 15:00	3			
	2004/05/18 16:30 - 2004/05/18 16:45	2			
	2004/05/19 16:45 - 2004/05/19 17:30	4			
	2004/05/21 16:30	1			
	2004/05/21 17:45 - 2004/05/21 18:15	3			
	2004/05/22 17:00 - 2004/05/22 17:45	4			
	2004/05/22 18:15 - 2004/05/22 19:15	5			
	2004/05/24 20:15 - 2004/05/24 21:00	4			
	2004/05/25 21:30	1			
	2004/05/26 19:45 - 2004/05/26 20:00	2			
	2004/05/28 21:45 - 2004/05/28 22:30	4			
	2004/06/01 01:15 - 2004/06/01 01:30	2			
	2004/06/01 15:15 - 2004/06/01 15:30	2			
	2004/06/02 15:15 - 2004/06/02 15:30	2			
	2004/10/25 13:00 - 2004/10/25 15:00	9			
	2004/10/26 02:00 - 2004/10/26 03:30	7			
	2004/10/26 12:15	1			
	2004/10/26 12:45	1			
	2004/10/26 13:30 - 2004/10/26 15:00	7			
	2004/10/27 02:45	1			
	2004/10/27 12:00	1			

	2004/10/27 14:15 - 2004/10/27 14:30	2			
	2004/10/27 15:00 - 2004/10/27 15:15	2			
	2004/10/28 03:15 - 2004/10/28 04:45	7			
	2004/10/29 03:45 - 2004/10/29 05:30	8			
	2004/10/30 03:00	1			
	2004/10/30 03:30 - 2004/10/30 05:00	7			
	2004/10/30 16:00 - 2004/10/30 16:15	2			
	2004/10/31 04:15 - 2004/10/31 06:30	10			
	2004/11/01 04:15 - 2004/11/01 04:30	2			
	2004/11/01 05:15 - 2004/11/01 05:45	3			
	2004/11/01 06:15 - 2004/11/01 06:30	2			
	2004/11/02 13:45 - 2004/11/02 14:45	5			
	2004/11/02 15:30	1			
	2004/11/02 16:30	1			
	2004/11/02 17:00	1			
	2004/11/02 18:15	1			
	2004/11/03 06:00	1			
	2004/11/03 07:15 - 2004/11/03 07:30	2			
	2004/11/04 09:15 - 2004/11/04 09:30	2			
	2004/11/05 07:45	1			
	2004/11/05 08:30	1			
	2004/11/06 08:15	1			
	2004/11/07 09:30	1			
	2004/11/07 10:00 - 2004/11/07 10:45	4			
	2004/11/07 11:15 - 2004/11/07 11:45	3			
	2004/11/08 08:30	1			
	2004/11/08 23:00	1			
	2004/11/09 10:15	1			
	2004/11/09 11:45 - 2004/11/09 12:00	2			
	2004/11/09 12:30 - 2004/11/09 12:45	2			
B-ST CSO16 - 15 Minute Flow	11 missing of 22605;		03/19/2004 13:00 – 11/10/2004 00:00	-122.630180	47.56592000
	2004/06/12 23:15 - 2004/06/12 23:30	2			
	2004/09/15 03:15	1			
	2004/09/17 13:00	1			
	2004/09/17 13:45 - 2004/09/17 14:00	2			
	2004/09/19 14:15	1			
	2004/10/16 08:15	1			
	2004/10/16 11:45 - 2004/10/16 12:00	2			
	2004/11/01 11:45	1			
B-ST 28 - 15 Minute Flow	491 missing of 18762;		03/17/2004 13:45 – 09/29/2004 00:00	-122.653150	47.55867000
	2004/07/22 05:30 - 2004/07/22 06:00	3			
	2004/07/24 07:15	1			
	2004/07/24 18:00 - 2004/07/24 18:15	2			
	2004/07/25 05:15 - 2004/07/25 11:15	25			
	2004/07/28 12:45	1			
	2004/07/28 20:45 - 2004/07/28 21:30	4			

	2004/07/28 22:15 - 2004/07/29 06:15	33			
	2004/07/29 07:30 - 2004/07/29 08:15	4			
	2004/07/31 12:15	1			
	2004/08/04 20:30	1			
	2004/08/06 09:45 - 2004/08/06 10:30	4			
	2004/08/18 14:15	1			
	2004/08/19 11:30 - 2004/08/19 15:30	17			
	2004/08/19 16:15 - 2004/08/19 16:45	3			
	2004/08/20 11:45 - 2004/08/20 13:00	6			
	2004/08/22 06:15	1			
	2004/08/24 07:30 - 2004/08/24 18:00	43			
	2004/08/24 19:15	1			
	2004/08/24 21:30 - 2004/08/24 22:45	6			
	2004/08/24 23:45 - 2004/08/25 10:00	42			
	2004/08/25 10:30 - 2004/08/25 11:15	4			
	2004/08/25 14:15 - 2004/08/25 14:45	3			
	2004/08/25 18:00 - 2004/08/25 22:30	19			
	2004/08/26 00:00	1			
	2004/08/26 00:30 - 2004/08/26 06:45	26			
	2004/08/29 23:45	1			
	2004/08/30 00:45 - 2004/08/30 05:30	20			
	2004/08/30 08:45	1			
	2004/08/30 09:30	1			
	2004/08/30 11:30 - 2004/08/30 12:00	3			
	2004/08/30 19:00 - 2004/08/30 21:00	9			
	2004/08/30 21:45 - 2004/08/30 22:00	2			
	2004/08/30 22:45 - 2004/08/31 23:00	98			
	2004/09/01 01:45	1			
	2004/09/01 02:30 - 2004/09/01 04:30	9			
	2004/09/01 05:15	1			
	2004/09/01 05:45 - 2004/09/01 06:00	2			
	2004/09/01 06:30 - 2004/09/01 06:45	2			
	2004/09/01 07:15 - 2004/09/02 03:15	81			
	2004/09/22 23:15 - 2004/09/22 23:30	2			
	2004/09/23 18:45	1			
	2004/09/23 20:15 - 2004/09/23 20:30	2			
	2004/09/26 22:00 - 2004/09/26 22:15	2			
	2004/09/28 13:45	1			
B-ST 12 (Trenton) - 15 Minute Flow	4 missing of 22687;		03/18/2004 16:30 – 11/10/2004 00:00	-122.608530	47.56933000
	2004/04/09 09:15 - 2004/04/09 09:30	2			
	2004/06/09 04:30	1			
	2004/06/09 05:45	1			
B-ST 01 - 15 Minute Flow	703 missing of 22700;		03/18/2004 13:15 – 11/10/2004 00:00	-122.644740	47.58744000
	2004/05/18 01:15	1			
	2004/05/19 23:30	1			
	2004/05/21 01:15 - 2004/05/21 01:30	2			

	2004/06/10 14:30	1			
	2004/06/11 18:00	1			
	2004/06/12 00:45	1			
	2004/06/17 04:15	1			
	2004/06/17 09:00	1			
	2004/06/17 17:45	1			
	2004/06/19 17:00 - 2004/06/19 17:15	2			
	2004/06/19 21:45	1			
	2004/06/20 20:15 - 2004/06/20 20:30	2			
	2004/06/20 22:15	1			
	2004/06/21 13:45	1			
	2004/06/21 14:45	1			
	2004/06/21 19:45 - 2004/06/21 20:00	2			
	2004/06/22 00:00 - 2004/06/22 00:15	2			
	2004/06/22 02:30 - 2004/06/22 02:45	2			
	2004/06/22 11:45	1			
	2004/06/22 16:00 - 2004/06/22 16:15	2			
	2004/06/23 02:45	1			
	2004/06/23 09:45 - 2004/06/23 10:00	2			
	2004/06/23 12:30	1			
	2004/06/23 14:15 - 2004/06/23 14:30	2			
	2004/06/23 22:30	1			
	2004/06/24 01:30	1			
	2004/06/24 02:00 - 2004/06/24 02:30	3			
	2004/06/24 03:15 - 2004/06/24 03:30	2			
	2004/06/25 02:30	1			
	2004/06/28 20:30	1			
	2004/06/28 22:45	1			
	2004/06/29 09:30	1			
	2004/06/30 15:00	1			
	2004/07/01 15:45	1			
	2004/07/01 18:30	1			
	2004/07/07 01:00	1			
	2004/07/08 23:30	1			
	2004/07/11 22:30	1			
	2004/07/14 08:15	1			
	2004/07/14 08:45	1			
	2004/07/15 03:30 - 2004/07/15 03:45	2			
	2004/07/15 06:00	1			
	2004/07/15 08:45	1			
	2004/07/15 09:30	1			
	2004/07/15 11:15 - 2004/07/15 11:30	2			
	2004/07/15 22:45	1			
	2004/07/16 04:15	1			
	2004/07/16 04:45	1			
	2004/07/16 18:15 - 2004/07/16 18:45	3			

	2004/07/16 19:15	1			
	2004/07/16 20:30 - 2004/07/16 20:45	2			
	2004/07/17 01:30	1			
	2004/07/17 02:15	1			
	2004/07/17 09:30 - 2004/07/17 09:45	2			
	2004/07/17 10:30	1			
	2004/07/17 11:00 - 2004/07/17 11:15	2			
	2004/07/17 11:45	1			
	2004/07/17 12:45	1			
	2004/07/17 13:45	1			
	2004/07/17 14:30	1			
	2004/07/17 16:30	1			
	2004/07/17 20:15	1			
	2004/07/17 22:00	1			
	2004/07/18 00:30 - 2004/07/18 00:45	2			
	2004/07/18 03:15	1			
	2004/07/18 04:00 - 2004/07/18 04:15	2			
	2004/07/18 04:45 - 2004/07/18 05:15	3			
	2004/07/18 06:00 - 2004/07/18 06:30	3			
	2004/07/18 08:15 - 2004/07/18 08:30	2			
	2004/07/18 10:15	1			
	2004/07/18 12:15 - 2004/07/18 12:45	3			
	2004/07/18 20:00	1			
	2004/07/18 22:45 - 2004/07/18 23:15	3			
	2004/07/18 23:45	1			
	2004/07/19 06:45	1			
	2004/07/19 08:30 - 2004/07/19 08:45	2			
	2004/07/19 09:45	1			
	2004/07/19 12:15	1			
	2004/07/19 15:15 - 2004/07/19 15:30	2			
	2004/07/19 16:45 - 2004/07/19 17:00	2			
	2004/07/19 19:45 - 2004/07/19 20:45	5			
	2004/07/19 23:00 - 2004/07/19 23:30	3			
	2004/07/20 00:15	1			
	2004/07/20 01:15 - 2004/07/20 01:30	2			
	2004/07/20 02:45 - 2004/07/20 03:00	2			
	2004/07/20 04:15 - 2004/07/20 04:30	2			
	2004/07/20 05:15 - 2004/07/20 05:45	3			
	2004/07/20 06:30	1			
	2004/07/20 07:15 - 2004/07/20 07:30	2			
	2004/07/20 08:30 - 2004/07/20 09:00	3			
	2004/07/20 09:30 - 2004/07/20 10:30	5			
	2004/07/20 11:15	1			
	2004/07/20 15:45	1			
	2004/07/20 17:00 - 2004/07/20 17:45	4			
	2004/07/20 19:00 - 2004/07/20 19:30	3			

	2004/07/20 20:30	1			
	2004/07/20 23:00	1			
	2004/07/20 23:45	1			
	2004/07/21 00:45 - 2004/07/21 01:00	2			
	2004/07/21 02:30	1			
	2004/07/21 04:15	1			
	2004/07/21 05:00	1			
	2004/07/21 05:45 - 2004/07/21 06:00	2			
	2004/07/21 06:45	1			
	2004/07/21 08:30 - 2004/07/21 08:45	2			
	2004/07/21 10:45	1			
	2004/07/21 11:15 - 2004/07/21 12:15	5			
	2004/07/21 13:00 - 2004/07/21 13:15	2			
	2004/07/21 16:30 - 2004/07/21 16:45	2			
	2004/07/21 19:15 - 2004/07/21 19:30	2			
	2004/07/21 20:15	1			
	2004/07/21 20:45 - 2004/07/21 21:00	2			
	2004/07/21 21:45	1			
	2004/07/21 22:15 - 2004/07/21 22:30	2			
	2004/07/22 01:45	1			
	2004/07/22 04:00 - 2004/07/22 04:15	2			
	2004/07/22 05:00 - 2004/07/22 05:15	2			
	2004/07/22 06:30	1			
	2004/07/22 08:45	1			
	2004/07/22 10:30	1			
	2004/07/22 12:00	1			
	2004/07/22 12:45	1			
	2004/07/22 13:30 - 2004/07/22 13:45	2			
	2004/07/22 16:00	1			
	2004/07/22 16:45	1			
	2004/07/22 18:00 - 2004/07/22 18:15	2			
	2004/07/22 19:45	1			
	2004/07/22 21:15 - 2004/07/22 21:30	2			
	2004/07/23 01:15	1			
	2004/07/23 02:15 - 2004/07/23 03:15	5			
	2004/07/23 04:45 - 2004/07/23 05:00	2			
	2004/07/23 06:15 - 2004/07/23 06:30	2			
	2004/07/23 07:30	1			
	2004/07/23 08:00	1			
	2004/07/23 09:00	1			
	2004/07/23 11:45	1			
	2004/07/23 12:15	1			
	2004/07/23 14:00	1			
	2004/07/23 15:30 - 2004/07/23 15:45	2			
	2004/07/23 22:30	1			
	2004/07/24 00:15 - 2004/07/24 00:45	3			

	2004/07/24 05:30	1			
	2004/07/24 09:45	1			
	2004/07/24 10:30 - 2004/07/24 10:45	2			
	2004/07/24 13:15 - 2004/07/24 13:30	2			
	2004/07/24 14:00 - 2004/07/24 14:15	2			
	2004/07/24 15:30	1			
	2004/07/24 16:45	1			
	2004/07/24 17:30	1			
	2004/07/24 20:45 - 2004/07/24 21:00	2			
	2004/07/25 00:00 - 2004/07/25 00:15	2			
	2004/07/25 01:15 - 2004/07/25 01:45	3			
	2004/07/25 03:15	1			
	2004/07/25 06:00 - 2004/07/25 06:15	2			
	2004/07/25 08:15	1			
	2004/07/25 10:15 - 2004/07/25 10:30	2			
	2004/07/25 16:45 - 2004/07/25 17:00	2			
	2004/07/25 18:00 - 2004/07/25 18:15	2			
	2004/07/25 19:00 - 2004/07/25 19:45	4			
	2004/07/25 20:30	1			
	2004/07/25 21:15	1			
	2004/07/25 21:45 - 2004/07/25 22:00	2			
	2004/07/26 05:15 - 2004/07/26 05:45	3			
	2004/07/26 06:15 - 2004/07/26 06:30	2			
	2004/07/26 08:45	1			
	2004/07/26 10:00 - 2004/07/26 10:15	2			
	2004/07/26 12:30	1			
	2004/07/26 14:00	1			
	2004/07/26 15:30	1			
	2004/07/26 17:45	1			
	2004/07/26 19:30	1			
	2004/07/26 21:00	1			
	2004/07/26 22:00 - 2004/07/26 22:15	2			
	2004/07/27 00:15	1			
	2004/07/27 01:00	1			
	2004/07/27 07:00	1			
	2004/07/27 15:45	1			
	2004/07/27 17:15	1			
	2004/07/27 20:00 - 2004/07/27 20:45	4			
	2004/07/27 21:15 - 2004/07/27 21:30	2			
	2004/07/27 22:30 - 2004/07/27 22:45	2			
	2004/07/28 02:45	1			
	2004/07/28 05:15	1			
	2004/07/28 06:15	1			
	2004/07/28 08:15 - 2004/07/28 08:30	2			
	2004/07/28 09:30	1			
	2004/07/28 10:00 - 2004/07/28 10:15	2			

	2004/07/28 10:45	1			
	2004/07/28 12:45 - 2004/07/28 13:00	2			
	2004/07/28 13:45	1			
	2004/07/28 22:15	1			
	2004/07/29 02:30	1			
	2004/07/29 03:15	1			
	2004/07/29 05:30	1			
	2004/07/29 06:15 - 2004/07/29 06:45	3			
	2004/07/29 07:15	1			
	2004/07/29 21:45 - 2004/07/29 22:00	2			
	2004/07/29 23:15	1			
	2004/07/30 01:30	1			
	2004/07/30 04:00	1			
	2004/07/30 07:45	1			
	2004/07/30 11:15	1			
	2004/07/30 12:30	1			
	2004/07/30 15:30	1			
	2004/07/30 19:30	1			
	2004/07/31 00:00 - 2004/07/31 00:15	2			
	2004/07/31 00:45 - 2004/07/31 01:00	2			
	2004/07/31 04:30	1			
	2004/07/31 05:30	1			
	2004/07/31 07:00 - 2004/07/31 07:15	2			
	2004/07/31 08:15	1			
	2004/07/31 09:00 - 2004/07/31 09:30	3			
	2004/07/31 11:30 - 2004/07/31 11:45	2			
	2004/07/31 12:30 - 2004/07/31 13:30	5			
	2004/07/31 16:00	1			
	2004/07/31 18:45	1			
	2004/07/31 19:45	1			
	2004/07/31 21:15 - 2004/07/31 22:00	4			
	2004/07/31 23:00 - 2004/07/31 23:30	3			
	2004/08/01 01:45 - 2004/08/01 02:00	2			
	2004/08/01 04:45 - 2004/08/01 05:00	2			
	2004/08/01 06:00	1			
	2004/08/01 07:45	1			
	2004/08/01 08:30	1			
	2004/08/01 09:30 - 2004/08/01 09:45	2			
	2004/08/01 13:30 - 2004/08/01 13:45	2			
	2004/08/01 16:00	1			
	2004/08/01 18:00 - 2004/08/01 18:30	3			
	2004/08/01 19:00	1			
	2004/08/01 20:15	1			
	2004/08/02 02:00 - 2004/08/02 02:30	3			
	2004/08/02 03:30 - 2004/08/02 03:45	2			
	2004/08/02 05:15 - 2004/08/02 05:30	2			

	2004/08/02 11:30	1				
	2004/08/02 13:30 - 2004/08/02 14:00	3				
	2004/08/02 20:15	1				
	2004/08/02 22:30 - 2004/08/02 22:45	2				
	2004/08/03 00:30 - 2004/08/03 00:45	2				
	2004/08/03 02:30	1				
	2004/08/03 03:45	1				
	2004/08/03 05:45 - 2004/08/03 06:00	2				
	2004/08/03 06:45 - 2004/08/03 07:00	2				
	2004/08/03 07:45	1				
	2004/08/03 12:00	1				
	2004/08/03 12:30 - 2004/08/03 12:45	2				
	2004/08/03 15:15 - 2004/08/03 15:30	2				
	2004/08/04 00:15	1				
	2004/08/04 08:15	1				
	2004/08/04 09:30	1				
	2004/08/04 11:15	1				
	2004/08/04 11:45 - 2004/08/04 12:00	2				
	2004/08/11 00:30	1				
	2004/08/11 15:30	1				
	2004/08/11 23:00	1				
	2004/08/12 04:00	1				
	2004/08/12 11:30	1				
	2004/08/12 15:45 - 2004/08/12 16:00	2				
	2004/08/13 04:15	1				
	2004/08/13 07:30 - 2004/08/13 07:45	2				
	2004/08/13 11:15	1				
	2004/08/13 12:15 - 2004/08/13 12:30	2				
	2004/08/13 17:45 - 2004/08/13 18:00	2				
	2004/08/13 21:00	1				
	2004/08/14 01:00	1				
	2004/08/14 08:15	1				
	2004/08/14 10:15	1				
	2004/08/14 14:45	1				
	2004/08/14 15:30	1				
	2004/08/14 17:45	1				
	2004/08/14 22:45	1				
	2004/08/15 00:45 - 2004/08/15 01:00	2				
	2004/08/15 03:45 - 2004/08/15 04:00	2				
	2004/08/15 10:00 - 2004/08/15 10:15	2				
	2004/08/15 20:45	1				
	2004/08/15 23:15 - 2004/08/15 23:45	3				
	2004/08/16 01:30	1				
	2004/08/16 05:45	1				
	2004/08/16 06:45	1				
	2004/08/16 18:45	1				

	2004/08/16 21:15	1			
	2004/08/16 22:45	1			
	2004/08/17 04:30 - 2004/08/17 05:00	3			
	2004/08/17 05:30	1			
	2004/08/17 07:15	1			
	2004/08/17 10:45 - 2004/08/17 11:00	2			
	2004/08/17 11:30	1			
	2004/08/17 14:45 - 2004/08/17 15:00	2			
	2004/08/18 00:00	1			
	2004/08/18 03:00	1			
	2004/08/18 05:30	1			
	2004/08/18 11:30 - 2004/08/18 12:00	3			
	2004/08/18 18:30 - 2004/08/18 18:45	2			
	2004/08/18 20:15	1			
	2004/08/18 20:45	1			
	2004/08/19 04:45 - 2004/08/19 05:15	3			
	2004/08/19 10:30	1			
	2004/08/19 13:15 - 2004/08/19 13:30	2			
	2004/08/19 18:00	1			
	2004/08/19 18:45 - 2004/08/19 19:00	2			
	2004/08/19 22:00	1			
	2004/08/19 23:00	1			
	2004/08/19 23:30	1			
	2004/08/20 00:00	1			
	2004/08/20 04:15 - 2004/08/20 04:45	3			
	2004/08/20 06:00	1			
	2004/08/20 08:15 - 2004/08/20 08:30	2			
	2004/08/20 09:00	1			
	2004/08/20 16:15	1			
	2004/08/20 19:00	1			
	2004/08/20 21:45 - 2004/08/20 22:00	2			
	2004/08/21 00:15 - 2004/08/21 00:45	3			
	2004/08/21 04:15	1			
	2004/08/21 08:00	1			
	2004/08/21 14:30	1			
	2004/08/21 15:30	1			
	2004/08/21 17:45	1			
	2004/08/21 18:45	1			
	2004/08/21 21:00	1			
	2004/08/21 22:00	1			
	2004/08/22 06:45 - 2004/08/22 07:00	2			
	2004/08/22 07:45 - 2004/08/22 08:00	2			
	2004/08/22 09:30	1			
	2004/08/23 22:45	1			
	2004/08/27 04:15	1			
	2004/08/27 10:00	1			

	2004/08/27 18:15	1			
	2004/08/27 22:45	1			
	2004/08/28 15:15	1			
	2004/08/29 01:15	1			
	2004/08/29 03:00 - 2004/08/29 03:15	2			
	2004/08/29 04:30 - 2004/08/29 04:45	2			
	2004/08/29 09:15	1			
	2004/08/29 12:00	1			
	2004/08/29 13:45	1			
	2004/08/29 15:00 - 2004/08/29 15:30	3			
	2004/08/29 17:00	1			
	2004/08/29 18:15	1			
	2004/08/29 21:00	1			
	2004/08/30 01:00	1			
	2004/08/30 02:15	1			
	2004/08/30 03:15 - 2004/08/30 03:30	2			
	2004/08/30 04:00	1			
	2004/08/30 06:00	1			
	2004/08/30 13:30	1			
	2004/08/30 19:15 - 2004/08/30 19:30	2			
	2004/08/30 20:00	1			
	2004/08/30 20:45 - 2004/08/30 21:15	3			
	2004/08/30 22:45 - 2004/08/30 23:00	2			
	2004/08/31 01:30	1			
	2004/08/31 02:15	1			
	2004/08/31 04:00 - 2004/08/31 05:00	5			
	2004/08/31 06:30	1			
	2004/08/31 07:45 - 2004/08/31 08:30	4			
	2004/08/31 09:30	1			
	2004/08/31 11:00	1			
	2004/08/31 14:15	1			
	2004/08/31 16:00	1			
	2004/08/31 19:15 - 2004/08/31 19:30	2			
	2004/08/31 21:15 - 2004/08/31 21:45	3			
	2004/09/01 00:15	1			
	2004/09/01 02:15	1			
	2004/09/01 04:00	1			
	2004/09/01 04:30	1			
	2004/09/01 05:00 - 2004/09/01 05:15	2			
	2004/09/01 06:15 - 2004/09/01 06:45	3			
	2004/09/01 11:15	1			
	2004/09/01 11:45	1			
	2004/09/01 12:45 - 2004/09/01 13:00	2			
	2004/09/01 14:30 - 2004/09/01 15:00	3			
	2004/09/02 19:00	1			
	2004/09/03 16:30	1			

	2004/09/03 21:30 - 2004/09/03 21:45	2			
	2004/09/04 18:45	1			
	2004/09/04 22:00	1			
	2004/09/05 00:15	1			
	2004/09/05 02:15	1			
	2004/09/05 15:30 - 2004/09/05 15:45	2			
	2004/09/06 04:00	1			
	2004/09/06 13:45	1			
	2004/09/06 16:15	1			
	2004/09/06 17:45	1			
	2004/09/06 23:45 - 2004/09/07 00:00	2			
	2004/09/07 11:15	1			
	2004/09/07 13:00	1			
	2004/09/09 08:45	1			
	2004/09/09 12:00	1			
	2004/09/10 08:15	1			
	2004/09/10 17:15	1			
	2004/09/11 23:45	1			
	2004/09/12 00:30	1			
	2004/09/12 14:00	1			
	2004/09/15 22:30	1			
	2004/09/15 23:30	1			
	2004/09/16 08:00	1			
	2004/09/16 10:15	1			
	2004/09/19 22:15	1			
	2004/09/20 03:45	1			
	2004/09/20 14:45	1			
	2004/09/20 18:45	1			
	2004/09/20 21:30	1			
	2004/09/20 23:15	1			
	2004/09/21 03:45	1			
	2004/09/21 10:30	1			
	2004/09/21 16:45 - 2004/09/21 17:15	3			
	2004/09/21 18:45	1			
	2004/09/22 00:00	1			
	2004/09/23 03:45	1			
	2004/09/23 18:30	1			
	2004/09/24 02:30	1			
	2004/09/24 08:15	1			
	2004/09/24 09:30	1			
	2004/09/24 10:30 - 2004/09/24 10:45	2			
	2004/09/24 19:00 - 2004/09/24 19:15	2			
	2004/09/24 20:15 - 2004/09/24 20:30	2			
	2004/09/25 11:15	1			
	2004/09/25 19:15 - 2004/09/25 19:45	3			
	2004/09/25 20:15	1			

	2004/09/25 23:30	1			
	2004/09/26 00:15	1			
	2004/09/26 02:00 - 2004/09/26 02:15	2			
	2004/09/26 03:00	1			
	2004/09/26 23:30	1			
	2004/09/27 01:00	1			
	2004/09/27 02:45 - 2004/09/27 03:00	2			
	2004/09/27 14:00	1			
	2004/09/27 19:00	1			
	2004/09/27 20:45	1			
	2004/09/28 07:30	1			
	2004/09/28 16:00	1			
	2004/09/29 04:15	1			
	2004/09/29 17:30	1			
	2004/09/29 18:45	1			
	2004/09/30 04:30	1			
	2004/09/30 12:15	1			
	2004/10/10 14:00	1			
	2004/10/12 09:00	1			
	2004/10/12 11:45	1			
	2004/10/13 04:45	1			
	2004/10/13 05:15	1			
	2004/10/13 06:15	1			
	2004/10/13 09:30 - 2004/10/13 10:00	3			
	2004/10/13 18:00	1			
	2004/10/13 19:15	1			
	2004/10/13 20:15	1			
	2004/10/14 02:30 - 2004/10/14 02:45	2			
	2004/10/14 07:30	1			
	2004/10/14 11:00	1			
	2004/10/14 12:45	1			
	2004/10/14 20:30 - 2004/10/14 20:45	2			
	2004/10/14 21:30	1			
	2004/10/14 22:45 - 2004/10/14 23:00	2			
	2004/10/15 04:15	1			
	2004/10/15 05:00	1			
	2004/10/15 08:15 - 2004/10/15 08:30	2			
	2004/10/15 09:15 - 2004/10/15 09:30	2			
	2004/10/15 14:15	1			
	2004/10/15 16:30	1			
	2004/10/15 17:15	1			
	2004/10/15 19:15	1			
	2004/10/15 21:30	1			
	2004/10/16 00:45	1			
	2004/10/16 01:30	1			
	2004/10/16 02:15	1			

	2004/10/16 03:45 - 2004/10/16 04:00	2			
	2004/10/16 05:00 - 2004/10/16 05:15	2			
	2004/10/16 06:00	1			
	2004/10/22 02:00	1			
	2004/10/26 01:30	1			
	2004/10/27 19:00	1			
	2004/10/27 20:00 - 2004/10/27 20:15	2			
	2004/10/28 01:45	1			
	2004/10/28 11:00	1			
	2004/10/28 16:30	1			
	2004/10/29 00:15	1			
	2004/10/29 13:45	1			
	2004/10/29 16:30 - 2004/10/29 17:00	3			
	2004/10/29 18:30	1			
	2004/10/29 20:15 - 2004/10/29 20:30	2			
GORST NAVY CITY METALS - LMK122 - 15 Minute Flow	2650 missing of 20965;		04/05/2004 15:00 – 11/10/2004 00:00	-122.698310	47.52915000
	2004/04/05 17:00 - 2004/04/05 17:45	4			
	2004/04/13 02:00 - 2004/04/13 02:45	4			
	2004/04/17 04:45 - 2004/04/17 05:15	3			
	2004/04/18 05:15 - 2004/04/18 06:00	4			
	2004/04/19 05:45 - 2004/04/19 06:30	4			
	2004/04/19 13:15	1			
	2004/04/19 17:45 - 2004/04/19 19:30	8			
	2004/04/19 20:00	1			
	2004/04/19 22:30 - 2004/04/19 22:45	2			
	2004/04/20 11:15 - 2004/04/20 11:30	2			
	2004/04/20 17:45 - 2004/04/20 18:15	3			
	2004/04/20 23:45 - 2004/04/21 00:00	2			
	2004/04/21 09:45 - 2004/04/21 10:15	3			
	2004/04/21 19:00 - 2004/04/21 19:45	4			
	2004/04/22 20:00 - 2004/04/22 20:15	2			
	2004/04/24 17:30 - 2004/04/24 19:45	10			
	2004/04/25 13:00 - 2004/04/25 21:00	33			
	2004/04/25 22:30	1			
	2004/04/26 10:00 - 2004/04/26 11:30	7			
	2004/04/26 13:00 - 2004/04/26 14:00	5			
	2004/04/26 14:30 - 2004/04/26 21:30	29			
	2004/04/27 05:45 - 2004/04/27 12:30	28			
	2004/04/27 14:15 - 2004/04/27 22:45	35			
	2004/04/28 05:45 - 2004/04/29 00:15	75			
	2004/04/29 13:30 - 2004/04/29 15:30	9			
	2004/04/29 16:00 - 2004/04/29 18:00	9			
	2004/04/29 22:30 - 2004/04/30 00:45	10			
	2004/04/30 06:30 - 2004/04/30 13:45	30			
	2004/04/30 16:15 - 2004/05/01 01:15	37			
	2004/05/01 06:45 - 2004/05/01 14:45	33			

	2004/05/01 17:45 - 2004/05/02 01:45 2004/05/02 07:30 - 2004/05/02 11:30 2004/05/02 12:00 2004/05/02 12:30 - 2004/05/02 14:45 2004/05/02 19:00 - 2004/05/02 19:30 2004/05/02 23:15 - 2004/05/03 00:15 2004/05/03 21:45 - 2004/05/03 22:30 2004/05/04 08:15 - 2004/05/04 16:15 2004/05/04 22:00 - 2004/05/05 02:30 2004/05/05 08:45 - 2004/05/05 17:30 2004/05/05 23:30 - 2004/05/06 02:45 2004/05/07 18:30 - 2004/05/07 18:45 2004/05/08 10:45 - 2004/05/08 11:45 2004/05/08 13:45 - 2004/05/08 14:00 2004/05/09 04:00 - 2004/05/09 05:00 2004/05/10 12:30 - 2004/05/10 12:45 2004/05/10 23:30 - 2004/05/11 00:15 2004/05/11 05:00 - 2004/05/11 08:30 2004/05/11 16:15 - 2004/05/11 16:45 2004/05/11 22:15 - 2004/05/11 22:45 2004/05/12 06:00 - 2004/05/12 11:30 2004/05/12 13:30 - 2004/05/12 15:30 2004/05/12 16:00 - 2004/05/13 00:45 2004/05/13 07:15 2004/05/13 07:45 2004/05/13 19:45 - 2004/05/14 00:30 2004/05/14 06:15 - 2004/05/14 14:30 2004/05/14 17:15 - 2004/05/15 00:45 2004/05/15 01:45 - 2004/05/15 03:00 2004/05/15 06:45 - 2004/05/15 14:45 2004/05/15 19:00 - 2004/05/16 01:15 2004/05/16 07:00 - 2004/05/16 15:30 2004/05/16 20:30 - 2004/05/16 23:30 2004/05/17 14:00 - 2004/05/17 15:30 2004/05/22 03:00 - 2004/05/22 04:00 2004/05/22 04:45 2004/05/22 19:45 - 2004/05/22 20:15 2004/05/23 03:30 - 2004/05/23 04:15 2004/05/23 17:15 - 2004/05/23 18:00 2004/05/23 18:45 - 2004/05/23 19:45 2004/05/23 20:15 2004/05/23 20:45 - 2004/05/23 21:00 2004/05/25 08:15 - 2004/05/25 08:30 2004/05/26 04:45 - 2004/05/26 05:15 2004/05/26 21:45 - 2004/05/26 23:15 2004/05/27 23:30 - 2004/05/27 23:45	33 17 1 10 3 5 4 33 19 36 14 2 5 2 5 2 4 15 3 3 23 9 36 1 1 20 34 31 6 33 26 35 13 7 5 1 3 4 4 5 1 2 2 3 7 2			

	2004/06/02 04:45 - 2004/06/02 05:30	4			
	2004/06/03 09:15 - 2004/06/03 09:30	2			
	2004/06/03 11:00 - 2004/06/03 12:00	5			
	2004/06/03 13:00 - 2004/06/03 15:15	10			
	2004/06/03 15:45 - 2004/06/03 16:45	5			
	2004/06/04 11:00 - 2004/06/04 12:45	8			
	2004/06/04 19:45 - 2004/06/04 20:15	3			
	2004/06/06 02:45 - 2004/06/06 03:15	3			
	2004/06/06 12:00 - 2004/06/06 12:45	4			
	2004/06/06 14:15 - 2004/06/06 14:30	2			
	2004/06/06 18:45 - 2004/06/06 19:00	2			
	2004/06/07 11:15 - 2004/06/07 14:00	12			
	2004/06/07 14:30 - 2004/06/07 15:45	6			
	2004/06/07 16:45 - 2004/06/07 20:15	15			
	2004/06/07 22:30 - 2004/06/07 23:00	3			
	2004/06/08 11:30 - 2004/06/08 13:15	8			
	2004/06/08 14:30 - 2004/06/08 16:15	8			
	2004/06/09 18:00 - 2004/06/09 20:45	12			
	2004/06/09 21:30 - 2004/06/09 21:45	2			
	2004/06/10 05:00 - 2004/06/10 08:45	16			
	2004/06/10 09:45 - 2004/06/10 16:00	26			
	2004/06/10 17:45 - 2004/06/10 18:00	2			
	2004/06/10 18:30 - 2004/06/10 20:15	8			
	2004/06/11 05:00 - 2004/06/11 05:30	3			
	2004/06/11 07:45 - 2004/06/11 08:15	3			
	2004/06/11 08:45 - 2004/06/11 10:00	6			
	2004/06/11 10:45 - 2004/06/11 13:45	13			
	2004/06/11 15:00 - 2004/06/11 21:15	26			
	2004/06/11 21:45 - 2004/06/11 23:30	8			
	2004/06/12 07:15 - 2004/06/12 14:00	28			
	2004/06/13 21:15 - 2004/06/13 22:30	6			
	2004/06/13 23:15 - 2004/06/14 00:15	5			
	2004/06/14 06:15 - 2004/06/14 15:30	38			
	2004/06/14 21:30 - 2004/06/15 00:15	12			
	2004/06/15 06:30 - 2004/06/15 15:45	38			
	2004/06/15 22:30 - 2004/06/16 01:15	12			
	2004/06/16 07:15 - 2004/06/16 16:30	38			
	2004/06/16 17:45	1			
	2004/06/17 00:15 - 2004/06/17 01:45	7			
	2004/06/17 03:45 - 2004/06/17 04:00	2			
	2004/06/17 07:15 - 2004/06/17 16:30	38			
	2004/06/18 05:00 - 2004/06/18 05:45	4			
	2004/06/26 04:45 - 2004/06/26 05:15	3			
	2004/06/26 08:00 - 2004/06/26 08:30	3			
	2004/06/26 10:00 - 2004/06/26 10:30	3			
	2004/06/27 04:30 - 2004/06/27 05:45	6			

	2004/06/27 16:30 - 2004/06/27 16:45	2			
	2004/06/27 22:00 - 2004/06/27 22:15	2			
	2004/06/28 12:45 - 2004/06/28 13:15	3			
	2004/06/30 09:15	1			
	2004/06/30 14:30	1			
	2004/06/30 15:00 - 2004/06/30 15:45	4			
	2004/07/01 11:15	1			
	2004/07/01 12:00 - 2004/07/01 16:45	20			
	2004/07/02 10:30	1			
	2004/07/02 12:15 - 2004/07/02 13:30	6			
	2004/07/02 18:15 - 2004/07/02 18:45	3			
	2004/07/03 11:00 - 2004/07/03 12:45	8			
	2004/07/03 19:00	1			
	2004/07/04 18:45 - 2004/07/04 21:00	10			
	2004/07/05 01:45 - 2004/07/05 02:00	2			
	2004/07/05 19:15 - 2004/07/05 19:45	3			
	2004/07/06 20:45 - 2004/07/06 22:00	6			
	2004/07/07 20:45 - 2004/07/07 21:30	4			
	2004/07/08 21:00 - 2004/07/08 23:00	9			
	2004/07/10 23:00 - 2004/07/10 23:30	3			
	2004/07/12 15:30 - 2004/07/12 15:45	2			
	2004/07/13 15:15 - 2004/07/13 15:45	3			
	2004/07/14 09:15 - 2004/07/14 10:15	5			
	2004/07/15 12:00 - 2004/07/15 13:15	6			
	2004/07/15 15:45 - 2004/07/15 16:30	4			
	2004/07/16 07:15 - 2004/07/16 16:15	37			
	2004/07/16 18:00	1			
	2004/07/17 09:15 - 2004/07/17 09:30	2			
	2004/07/17 18:45 - 2004/07/17 19:00	2			
	2004/07/18 08:30 - 2004/07/18 14:00	23			
	2004/07/18 18:00 - 2004/07/18 20:15	10			
	2004/07/19 01:45 - 2004/07/19 03:00	6			
	2004/07/19 09:00 - 2004/07/19 15:00	25			
	2004/07/19 18:45 - 2004/07/19 19:00	2			
	2004/07/20 01:30 - 2004/07/20 02:45	6			
	2004/07/21 12:15 - 2004/07/21 18:30	26			
	2004/07/27 14:15 - 2004/07/27 14:45	3			
	2004/07/28 05:00 - 2004/07/28 07:45	12			
	2004/07/29 06:30 - 2004/07/29 06:45	2			
	2004/07/30 18:15	1			
	2004/07/31 08:30	1			
	2004/07/31 17:00 - 2004/07/31 18:00	5			
	2004/08/01 00:00 - 2004/08/01 01:45	8			
	2004/08/01 17:45 - 2004/08/01 18:45	5			
	2004/08/02 18:00 - 2004/08/02 19:30	7			
	2004/08/19 10:45 - 2004/08/19 13:15	11			

	2004/08/20 00:30 - 2004/08/20 01:30	5			
	2004/09/02 12:45 - 2004/09/02 13:45	5			
	2004/09/02 15:00 - 2004/09/02 18:00	13			
	2004/09/02 18:45	1			
	2004/09/02 23:45 - 2004/09/03 07:00	30			
	2004/09/10 11:15 - 2004/09/10 14:00	12			
	2004/09/11 12:00 - 2004/09/11 14:45	12			
	2004/09/13 10:00 - 2004/09/13 17:15	30			
	2004/09/13 22:00 - 2004/09/14 03:00	21			
	2004/09/14 22:15 - 2004/09/15 00:30	10			
	2004/09/15 09:45 - 2004/09/15 17:30	32			
	2004/09/16 01:15 - 2004/09/16 04:00	12			
	2004/09/16 14:45 - 2004/09/16 16:45	9			
	2004/09/17 03:30 - 2004/09/17 05:45	10			
	2004/09/17 11:15 - 2004/09/17 15:00	16			
	2004/09/17 23:15 - 2004/09/18 06:30	30			
	2004/09/18 12:30 - 2004/09/18 17:00	19			
	2004/09/19 00:45 - 2004/09/19 07:45	29			
	2004/09/19 14:00 - 2004/09/19 17:15	14			
	2004/09/20 01:15 - 2004/09/20 02:15	5			
	2004/09/20 06:15 - 2004/09/20 07:45	7			
	2004/09/21 05:45 - 2004/09/21 09:30	16			
	2004/09/22 04:45 - 2004/09/22 06:15	7			
	2004/09/22 08:30 - 2004/09/22 11:15	12			
	2004/09/24 22:15 - 2004/09/25 00:15	9			
	2004/09/26 15:45 - 2004/09/26 17:00	6			
	2004/09/28 12:15 - 2004/09/28 15:30	14			
	2004/09/28 16:30 - 2004/09/28 17:00	3			
	2004/09/28 21:45 - 2004/09/28 23:15	7			
	2004/10/06 05:30 - 2004/10/06 06:15	4			
	2004/10/07 06:30 - 2004/10/07 08:15	8			
	2004/10/07 22:15 - 2004/10/08 03:15	21			
	2004/10/09 03:30 - 2004/10/09 04:15	4			
	2004/10/09 05:45 - 2004/10/09 07:15	7			
	2004/10/09 20:45 - 2004/10/10 02:00	22			
	2004/10/10 04:30 - 2004/10/10 13:45	38			
	2004/10/10 20:30 - 2004/10/10 20:45	2			
	2004/10/12 14:00 - 2004/10/12 14:45	4			
	2004/10/13 08:15 - 2004/10/13 15:15	29			
	2004/10/14 16:15 - 2004/10/14 16:45	3			
	2004/10/14 17:15	1			
	2004/10/14 22:30 - 2004/10/15 05:00	27			
	2004/10/15 10:30 - 2004/10/15 12:00	7			
	2004/10/15 14:00 - 2004/10/15 15:30	7			
	2004/10/15 17:00 - 2004/10/15 18:15	6			
	2004/10/15 22:00 - 2004/10/15 23:30	7			

	2004/10/16 12:00 - 2004/10/16 12:45	4			
	2004/10/17 19:00 - 2004/10/17 19:15	2			
	2004/10/21 03:30 - 2004/10/21 04:45	6			
	2004/10/21 05:15 - 2004/10/21 06:30	6			
	2004/10/21 08:15 - 2004/10/24 09:15	293			
	2004/10/30 23:30 - 2004/10/31 04:45	22			
	2004/10/31 23:45 - 2004/11/01 00:15	3			
	2004/11/01 01:15 - 2004/11/01 04:00	12			
	2004/11/01 04:45 - 2004/11/01 05:45	5			
	2004/11/09 12:30 - 2004/11/09 12:45	2			
PO-POBLVD - 15 Minute Flow	701 missing of 20970;		04/05/2004 13:30 – 11/09/2004 23:45	-122.641470	47.53876000
	2004/05/09 01:30 - 2004/05/09 01:45	2			
	2004/05/21 05:00 - 2004/05/21 05:30	3			
	2004/05/26 10:30 - 2004/05/26 11:00	3			
	2004/05/27 13:30 - 2004/05/27 14:00	3			
	2004/07/08 18:15 - 2004/07/08 19:00	4			
	2004/07/09 01:15 - 2004/07/09 02:30	6			
	2004/08/01 07:45 - 2004/08/08 01:00	646			
	2004/08/14 09:15 - 2004/08/14 11:00	8			
	2004/08/15 06:45 - 2004/08/15 08:15	7			
	2004/08/27 13:00 - 2004/08/27 14:15	6			
	2004/09/17 00:00 - 2004/09/17 00:30	3			
	2004/11/02 10:00 - 2004/11/02 11:45	8			
	2004/11/04 00:15 - 2004/11/04 00:30	2			
ANNAPOLIS - LMK136 - 15 Minute Flow	5282 missing of 20977;		04/05/2004 12:00 – 11/10/2004 00:00	-122.618140	47.54682000
	2004/04/07 06:15 - 2004/04/07 07:30	6			
	2004/04/08 06:45 - 2004/04/08 07:30	4			
	2004/04/12 00:15 - 2004/04/12 01:00	4			
	2004/04/16 04:00 - 2004/04/16 04:15	2			
	2004/04/17 04:30 - 2004/04/17 05:00	3			
	2004/04/17 05:30 - 2004/04/17 05:45	2			
	2004/04/18 04:45 - 2004/04/18 05:45	5			
	2004/04/19 18:15 - 2004/04/19 19:00	4			
	2004/04/21 20:00 - 2004/04/21 20:45	4			
	2004/04/22 21:45 - 2004/04/22 22:15	3			
	2004/04/23 21:15 - 2004/04/23 22:30	6			
	2004/04/24 19:00 - 2004/04/24 19:45	4			
	2004/04/26 17:45 - 2004/04/26 18:00	2			
	2004/04/26 18:30 - 2004/04/26 18:45	2			
	2004/04/26 19:15 - 2004/04/26 19:30	2			
	2004/04/27 00:45 - 2004/04/27 01:00	2			
	2004/04/27 16:00 - 2004/04/27 17:00	5			
	2004/04/28 06:00 - 2004/04/28 07:30	7			
	2004/04/28 08:45 - 2004/04/28 09:15	3			
	2004/04/28 09:45 - 2004/04/30 05:30	176			
	2004/04/30 07:00 - 2004/04/30 08:45	8			

	2004/04/30 09:15 - 2004/04/30 09:30	2			
	2004/04/30 10:00 - 2004/05/01 00:15	58			
	2004/05/01 02:00 - 2004/05/01 04:15	10			
	2004/05/01 05:15 - 2004/05/01 06:30	6			
	2004/05/02 03:15 - 2004/05/02 05:00	8			
	2004/05/02 11:15 - 2004/05/02 23:15	49			
	2004/05/03 02:45 - 2004/05/03 06:45	17			
	2004/05/03 23:00 - 2004/05/04 02:00	13			
	2004/05/04 03:30 - 2004/05/04 05:00	7			
	2004/05/04 07:00 - 2004/05/04 20:30	55			
	2004/05/04 21:30 - 2004/05/05 05:15	32			
	2004/05/05 07:45 - 2004/05/06 04:00	82			
	2004/05/06 04:30 - 2004/05/06 06:00	7			
	2004/05/06 07:30 - 2004/05/06 08:30	5			
	2004/05/06 09:00 - 2004/05/07 03:15	74			
	2004/05/07 05:30 - 2004/05/07 08:30	13			
	2004/05/07 18:15 - 2004/05/08 00:15	25			
	2004/05/08 06:15 - 2004/05/08 14:45	35			
	2004/05/08 19:45 - 2004/05/09 03:30	32			
	2004/05/09 05:45 - 2004/05/09 08:30	12			
	2004/05/09 10:00 - 2004/05/09 10:30	3			
	2004/05/09 12:30 - 2004/05/10 07:15	76			
	2004/05/10 09:15 - 2004/05/10 09:30	2			
	2004/05/10 10:45 - 2004/05/10 11:15	3			
	2004/05/10 23:15 - 2004/05/11 03:00	16			
	2004/05/11 23:30 - 2004/05/12 03:15	16			
	2004/05/13 01:00 - 2004/05/13 03:45	12			
	2004/05/13 12:30	1			
	2004/05/13 17:30 - 2004/05/13 17:45	2			
	2004/05/13 19:00 - 2004/05/13 20:45	8			
	2004/05/14 01:30 - 2004/05/14 04:15	12			
	2004/05/15 02:30 - 2004/05/15 04:30	9			
	2004/05/16 03:15 - 2004/05/16 05:45	11			
	2004/05/16 08:00	1			
	2004/05/16 09:45	1			
	2004/05/16 10:15 - 2004/05/16 10:30	2			
	2004/05/17 03:45 - 2004/05/17 05:30	8			
	2004/05/17 17:15	1			
	2004/05/17 17:45 - 2004/05/17 20:00	10			
	2004/05/17 21:45 - 2004/05/17 22:00	2			
	2004/05/18 18:00 - 2004/05/18 20:00	9			
	2004/05/18 22:15 - 2004/05/18 22:45	3			
	2004/05/19 08:15 - 2004/05/19 09:30	6			
	2004/05/19 12:45 - 2004/05/19 15:30	12			
	2004/05/19 17:00 - 2004/05/19 21:00	17			
	2004/05/19 23:00 - 2004/05/20 00:30	7			

	2004/05/20 13:00 - 2004/05/20 13:45	4			
	2004/05/20 16:00 - 2004/05/20 16:30	3			
	2004/05/20 19:15 - 2004/05/20 22:00	12			
	2004/05/21 19:30 - 2004/05/21 22:45	14			
	2004/05/22 20:45 - 2004/05/22 23:15	11			
	2004/05/23 21:15 - 2004/05/23 23:45	11			
	2004/05/24 21:45 - 2004/05/25 00:45	13			
	2004/05/25 23:00 - 2004/05/26 01:30	11			
	2004/05/26 23:30 - 2004/05/27 02:00	11			
	2004/05/28 00:15 - 2004/05/28 03:00	12			
	2004/05/28 06:00 - 2004/05/28 07:45	8			
	2004/05/28 08:15 - 2004/05/28 12:30	18			
	2004/05/28 18:30	1			
	2004/05/29 01:00 - 2004/05/29 02:45	8			
	2004/05/29 04:15 - 2004/05/29 04:45	3			
	2004/05/29 13:00 - 2004/05/29 13:45	4			
	2004/05/29 14:30 - 2004/05/29 16:15	8			
	2004/05/29 17:45 - 2004/05/29 21:45	17			
	2004/05/30 01:15 - 2004/05/30 03:45	11			
	2004/05/30 07:15 - 2004/05/30 08:30	6			
	2004/05/30 11:45 - 2004/05/30 12:15	3			
	2004/05/30 13:15 - 2004/05/30 20:00	28			
	2004/05/31 02:15 - 2004/05/31 03:45	7			
	2004/06/01 03:15 - 2004/06/01 04:15	5			
	2004/06/01 17:15	1			
	2004/06/01 19:00 - 2004/06/01 19:15	2			
	2004/06/01 19:45 - 2004/06/03 19:45	193			
	2004/06/03 21:15 - 2004/06/04 07:00	40			
	2004/06/04 07:45 - 2004/06/04 10:30	12			
	2004/06/04 13:30 - 2004/06/04 21:15	32			
	2004/06/05 00:45 - 2004/06/05 04:00	14			
	2004/06/05 06:00 - 2004/06/05 08:45	12			
	2004/06/05 09:30 - 2004/06/05 13:45	18			
	2004/06/05 15:00 - 2004/06/05 22:30	31			
	2004/06/05 23:15 - 2004/06/06 03:30	18			
	2004/06/06 04:30 - 2004/06/06 05:15	4			
	2004/06/06 07:00 - 2004/06/06 09:00	9			
	2004/06/06 10:45 - 2004/06/06 14:45	17			
	2004/06/06 15:15 - 2004/06/06 15:30	2			
	2004/06/06 16:45 - 2004/06/06 21:45	21			
	2004/06/07 01:00 - 2004/06/07 02:15	6			
	2004/06/07 03:45 - 2004/06/07 05:00	6			
	2004/06/07 06:00 - 2004/06/07 07:30	7			
	2004/06/07 08:00 - 2004/06/07 10:45	12			
	2004/06/07 11:30 - 2004/06/08 06:15	76			
	2004/06/08 07:30 - 2004/06/08 23:30	65			

	2004/06/09 02:00 - 2004/06/10 00:15	90			
	2004/06/10 03:00 - 2004/06/12 22:30	271			
	2004/06/13 00:00 - 2004/06/13 00:30	3			
	2004/06/13 02:45 - 2004/06/16 08:00	310			
	2004/06/16 08:45 - 2004/06/16 10:30	8			
	2004/06/16 11:45 - 2004/06/16 12:15	3			
	2004/06/16 13:45 - 2004/06/16 18:30	20			
	2004/06/16 19:45 - 2004/06/16 20:45	5			
	2004/06/16 21:30 - 2004/06/16 23:30	9			
	2004/06/17 14:45 - 2004/06/18 00:15	39			
	2004/06/18 02:30	1			
	2004/06/18 04:00 - 2004/06/18 04:15	2			
	2004/06/18 05:30 - 2004/06/18 06:45	6			
	2004/06/18 12:30 - 2004/06/19 07:00	75			
	2004/06/19 08:45 - 2004/06/19 09:00	2			
	2004/06/19 10:30 - 2004/06/19 11:00	3			
	2004/06/19 13:30 - 2004/06/19 14:15	4			
	2004/06/19 15:15 - 2004/06/20 00:45	39			
	2004/06/20 01:30 - 2004/06/20 02:30	5			
	2004/06/20 03:00 - 2004/06/20 05:45	12			
	2004/06/20 12:30 - 2004/06/21 09:30	85			
	2004/06/21 10:00 - 2004/06/29 10:00	769			
	2004/06/30 01:45 - 2004/06/30 02:30	4			
	2004/06/30 17:15 - 2004/06/30 18:45	7			
	2004/07/01 02:30 - 2004/07/01 05:30	13			
	2004/07/01 17:45 - 2004/07/01 20:15	11			
	2004/07/02 03:45 - 2004/07/02 05:15	7			
	2004/07/02 18:45 - 2004/07/02 19:00	2			
	2004/07/03 04:30 - 2004/07/03 07:45	14			
	2004/07/03 19:15 - 2004/07/03 19:45	3			
	2004/07/04 05:45 - 2004/07/04 08:30	12			
	2004/07/04 19:30 - 2004/07/04 21:00	7			
	2004/07/05 20:00 - 2004/07/05 21:45	8			
	2004/07/06 00:30 - 2004/07/06 02:00	7			
	2004/07/06 05:00 - 2004/07/06 05:30	3			
	2004/07/06 21:15 - 2004/07/06 22:30	6			
	2004/07/07 01:00 - 2004/07/07 02:45	8			
	2004/07/07 04:00	1			
	2004/07/07 21:30 - 2004/07/07 22:15	4			
	2004/07/08 02:00 - 2004/07/08 03:15	6			
	2004/07/08 22:30 - 2004/07/08 23:15	4			
	2004/07/09 02:30 - 2004/07/09 03:45	6			
	2004/07/09 04:15 - 2004/07/09 04:45	3			
	2004/07/09 23:30 - 2004/07/10 00:00	3			
	2004/07/10 01:15 - 2004/07/10 02:45	7			
	2004/07/10 16:30 - 2004/07/10 16:45	2			

	2004/07/11 01:00 - 2004/07/11 02:00	5			
	2004/07/14 18:00 - 2004/07/14 19:45	8			
	2004/07/15 18:15 - 2004/07/15 20:30	10			
	2004/07/16 18:15 - 2004/07/16 21:30	14			
	2004/07/17 18:45 - 2004/07/17 21:30	12			
	2004/07/18 19:00 - 2004/07/18 22:00	13			
	2004/07/19 19:45 - 2004/07/20 00:15	19			
	2004/07/20 20:30 - 2004/07/20 21:30	5			
	2004/07/20 22:00 - 2004/07/20 23:15	6			
	2004/07/21 21:15 - 2004/07/21 23:45	11			
	2004/07/22 21:00 - 2004/07/22 22:00	5			
	2004/07/22 23:45 - 2004/07/23 00:45	5			
	2004/07/23 21:00 - 2004/07/23 22:30	7			
	2004/07/24 01:15 - 2004/07/24 02:45	7			
	2004/07/28 16:30 - 2004/07/28 17:45	6			
	2004/07/29 02:00 - 2004/07/29 05:30	15			
	2004/07/29 17:00 - 2004/07/29 19:30	11			
	2004/07/30 02:15 - 2004/07/30 05:00	12			
	2004/07/30 17:30 - 2004/07/30 21:00	15			
	2004/07/31 03:30 - 2004/07/31 04:45	6			
	2004/07/31 17:45 - 2004/07/31 19:00	6			
	2004/07/31 22:15 - 2004/08/01 00:00	8			
	2004/08/01 06:30 - 2004/08/01 07:00	3			
	2004/08/01 18:30 - 2004/08/01 19:30	5			
	2004/08/01 22:00 - 2004/08/02 00:30	11			
	2004/08/02 06:00 - 2004/08/02 07:45	8			
	2004/08/02 18:45 - 2004/08/02 20:30	8			
	2004/08/02 23:30 - 2004/08/03 00:45	6			
	2004/08/03 04:45 - 2004/08/03 05:45	5			
	2004/08/03 07:00 - 2004/08/03 08:00	5			
	2004/08/03 19:15 - 2004/08/03 21:00	8			
	2004/08/03 23:45 - 2004/08/04 05:30	24			
	2004/08/04 11:15 - 2004/08/04 11:45	3			
	2004/08/04 20:30 - 2004/08/04 21:30	5			
	2004/08/04 23:00 - 2004/08/05 02:15	14			
	2004/08/05 20:30 - 2004/08/06 07:15	44			
	2004/08/06 09:45 - 2004/08/06 10:30	4			
	2004/08/06 11:15 - 2004/08/09 17:30	314			
	2004/08/18 02:30 - 2004/08/18 02:45	2			
	2004/08/22 10:00 - 2004/08/22 10:30	3			
	2004/08/22 11:15	1			
	2004/08/22 13:00 - 2004/08/22 16:00	13			
	2004/08/24 09:00 - 2004/08/24 10:30	7			
	2004/09/11 00:00 - 2004/09/11 01:30	7			
	2004/09/17 01:45 - 2004/09/17 04:15	11			
	2004/09/17 09:15 - 2004/09/17 09:30	2			

	2004/09/17 10:15 - 2004/09/17 18:30	34			
	2004/09/17 21:45 - 2004/09/18 19:15	87			
	2004/09/18 22:00 - 2004/09/19 07:45	40			
	2004/09/19 08:45 - 2004/09/19 12:30	16			
	2004/09/19 13:00 - 2004/09/19 13:15	2			
	2004/09/19 15:15 - 2004/09/19 17:30	10			
	2004/09/19 18:00 - 2004/09/19 20:30	11			
	2004/09/19 21:00 - 2004/09/21 13:30	163			
	2004/09/21 14:30 - 2004/09/21 15:45	6			
	2004/09/21 17:00 - 2004/09/21 18:30	7			
	2004/09/21 21:00 - 2004/09/25 16:00	365			
	2004/09/25 18:00 - 2004/09/25 20:45	12			
	2004/09/26 02:15 - 2004/09/26 03:15	5			
	2004/09/26 04:15 - 2004/09/26 05:00	4			
	2004/11/02 05:30 - 2004/11/02 06:15	4			
	2004/11/02 07:30 - 2004/11/02 09:00	7			
	2004/11/02 09:30 - 2004/11/02 11:15	8			
MANCHESTER - LMK038 - 15 Minute Flow	13 missing of 22899;		03/16/2004 11:30 – 11/10/2004 00:00	-122.544090	47.55569000
	2004/05/06 09:45	1			
	2004/05/06 10:15 - 2004/05/06 10:30	2			
	2004/05/06 12:15 - 2004/05/06 13:00	4			
	2004/05/06 14:30	1			
	2004/05/07 04:15	1			
	2004/05/07 05:00	1			
	2004/10/16 02:00 - 2004/10/16 02:15	2			
	2004/10/29 14:15	1			
Silverdale West Bucklin Hill Road - LMK001 - 15 Minute Flow	1206 missing of 20792;		04/07/2004 10:15 – 11/10/2004 00:00	-122.693000	47.65133000
	2004/04/08 07:00 - 2004/04/08 08:00	5			
	2004/04/09 08:00 - 2004/04/09 08:45	4			
	2004/04/12 01:00 - 2004/04/12 01:15	2			
	2004/04/13 01:45 - 2004/04/13 02:45	5			
	2004/04/14 02:45 - 2004/04/14 03:45	5			
	2004/04/15 03:15 - 2004/04/15 04:15	5			
	2004/04/16 04:00 - 2004/04/16 04:45	4			
	2004/04/17 04:30 - 2004/04/17 05:30	5			
	2004/04/18 05:00 - 2004/04/18 06:00	5			
	2004/04/19 03:00 - 2004/04/19 04:45	8			
	2004/04/19 05:45 - 2004/04/19 06:45	5			
	2004/04/19 13:15 - 2004/04/19 13:45	3			
	2004/04/19 14:30	1			
	2004/04/20 06:15 - 2004/04/20 07:00	4			
	2004/04/20 19:45 - 2004/04/20 20:30	4			
	2004/04/21 20:15 - 2004/04/21 21:15	5			
	2004/04/22 21:00 - 2004/04/22 22:00	5			
	2004/04/23 21:30 - 2004/04/23 23:00	7			
	2004/04/24 18:30 - 2004/04/24 19:30	5			

	2004/04/24 21:45	1			
	2004/04/24 22:15 - 2004/04/24 22:45	3			
	2004/04/24 23:45 - 2004/04/25 00:15	3			
	2004/05/03 04:15 - 2004/05/03 05:15	5			
	2004/05/04 05:15 - 2004/05/04 06:00	4			
	2004/05/05 04:45 - 2004/05/05 06:00	6			
	2004/05/05 19:15 - 2004/05/05 20:00	4			
	2004/05/06 05:30 - 2004/05/06 06:45	6			
	2004/05/06 20:00 - 2004/05/06 21:00	5			
	2004/05/07 06:00 - 2004/05/07 07:00	5			
	2004/05/07 10:00 - 2004/05/07 13:45	16			
	2004/05/07 16:15 - 2004/05/07 18:45	11			
	2004/05/07 19:45 - 2004/05/07 22:00	10			
	2004/05/08 08:00 - 2004/05/08 08:15	2			
	2004/05/08 16:45 - 2004/05/08 17:45	5			
	2004/05/08 18:45 - 2004/05/08 23:15	19			
	2004/05/09 22:45 - 2004/05/10 00:00	6			
	2004/05/10 06:00 - 2004/05/10 06:30	3			
	2004/05/10 07:45 - 2004/05/10 09:00	6			
	2004/05/10 09:30 - 2004/05/10 09:45	2			
	2004/05/10 10:15	1			
	2004/05/10 11:45 - 2004/05/10 13:30	8			
	2004/05/10 18:30 - 2004/05/10 19:45	6			
	2004/05/10 20:30	1			
	2004/05/10 21:15 - 2004/05/10 22:15	5			
	2004/05/10 23:45 - 2004/05/11 01:15	7			
	2004/05/11 11:30	1			
	2004/05/11 12:45 - 2004/05/11 16:15	15			
	2004/05/11 16:45 - 2004/05/11 17:00	2			
	2004/05/11 17:30 - 2004/05/11 17:45	2			
	2004/05/11 20:15 - 2004/05/11 22:00	8			
	2004/05/11 23:00 - 2004/05/12 01:45	12			
	2004/05/13 01:30 - 2004/05/13 02:30	5			
	2004/05/14 02:30 - 2004/05/14 03:30	5			
	2004/05/14 17:15	1			
	2004/05/14 22:45	1			
	2004/05/15 02:00 - 2004/05/15 02:15	2			
	2004/05/15 02:45 - 2004/05/15 04:00	6			
	2004/05/16 00:15 - 2004/05/16 00:30	2			
	2004/05/16 04:15 - 2004/05/16 04:45	3			
	2004/05/17 04:30 - 2004/05/17 05:15	4			
	2004/05/18 22:45 - 2004/05/19 01:15	11			
	2004/05/19 06:00 - 2004/05/19 10:15	18			
	2004/05/19 19:30 - 2004/05/19 20:15	4			
	2004/05/20 20:00 - 2004/05/20 21:00	5			
	2004/05/21 20:45 - 2004/05/21 22:00	6			

	2004/05/22 21:00 - 2004/05/22 22:00	5			
	2004/05/23 22:15 - 2004/05/23 22:45	3			
	2004/05/24 23:00 - 2004/05/24 23:30	3			
	2004/05/25 23:15 - 2004/05/26 00:15	5			
	2004/05/26 08:00 - 2004/05/26 10:30	11			
	2004/05/27 00:00 - 2004/05/27 01:00	5			
	2004/05/27 08:15 - 2004/05/27 09:00	4			
	2004/05/27 12:15 - 2004/05/27 13:15	5			
	2004/05/28 06:30 - 2004/05/28 07:45	6			
	2004/05/28 09:00 - 2004/05/28 12:30	15			
	2004/05/29 01:45 - 2004/05/29 02:45	5			
	2004/05/29 08:30 - 2004/05/29 12:00	15			
	2004/05/29 13:15 - 2004/05/30 00:45	47			
	2004/05/30 02:15 - 2004/05/30 03:15	5			
	2004/05/30 18:00 - 2004/05/30 18:45	4			
	2004/05/30 20:15 - 2004/05/30 20:30	2			
	2004/05/30 21:15 - 2004/05/31 00:00	12			
	2004/05/31 01:15 - 2004/05/31 04:00	12			
	2004/06/01 03:00 - 2004/06/01 04:30	7			
	2004/06/02 03:30 - 2004/06/02 05:00	7			
	2004/06/02 18:30 - 2004/06/02 19:30	5			
	2004/06/03 04:45 - 2004/06/03 05:30	4			
	2004/06/03 19:00 - 2004/06/03 20:30	7			
	2004/06/04 02:00	1			
	2004/06/04 05:00 - 2004/06/04 06:15	6			
	2004/06/04 20:00 - 2004/06/04 21:15	6			
	2004/06/05 20:30 - 2004/06/05 22:15	8			
	2004/06/06 07:30	1			
	2004/06/06 21:30 - 2004/06/06 22:45	6			
	2004/06/07 22:15 - 2004/06/07 23:45	7			
	2004/06/08 23:00 - 2004/06/09 01:00	9			
	2004/06/09 23:45 - 2004/06/10 01:30	8			
	2004/06/11 00:45 - 2004/06/11 02:00	6			
	2004/06/12 01:45 - 2004/06/12 02:45	5			
	2004/06/13 08:45 - 2004/06/13 09:45	5			
	2004/06/13 11:15	1			
	2004/06/14 01:15	1			
	2004/06/14 19:00 - 2004/06/14 19:30	3			
	2004/06/14 21:30 - 2004/06/14 22:15	4			
	2004/06/17 19:15 - 2004/06/17 20:00	4			
	2004/06/18 19:45 - 2004/06/18 20:45	5			
	2004/06/19 20:15 - 2004/06/19 21:00	4			
	2004/06/20 20:45 - 2004/06/20 22:00	6			
	2004/06/21 21:15 - 2004/06/21 22:30	6			
	2004/06/22 21:45 - 2004/06/22 22:45	5			
	2004/06/23 22:30 - 2004/06/23 23:45	6			

	2004/06/24 23:30 - 2004/06/25 00:30	5			
	2004/06/25 23:45 - 2004/06/26 00:45	5			
	2004/06/27 00:15 - 2004/06/27 01:30	6			
	2004/06/28 00:45 - 2004/06/28 02:00	6			
	2004/06/29 01:30 - 2004/06/29 02:45	6			
	2004/06/30 02:00 - 2004/06/30 03:30	7			
	2004/06/30 18:00 - 2004/06/30 18:15	2			
	2004/07/01 03:00 - 2004/07/01 04:15	6			
	2004/07/01 18:15 - 2004/07/01 19:15	5			
	2004/07/02 04:00 - 2004/07/02 05:15	6			
	2004/07/02 19:00 - 2004/07/02 20:15	6			
	2004/07/03 05:00 - 2004/07/03 06:15	6			
	2004/07/03 19:30 - 2004/07/03 21:00	7			
	2004/07/04 06:15 - 2004/07/04 07:15	5			
	2004/07/04 20:30 - 2004/07/04 21:30	5			
	2004/07/05 21:00 - 2004/07/05 22:15	6			
	2004/07/06 21:30 - 2004/07/06 23:00	7			
	2004/07/07 22:15 - 2004/07/07 23:30	6			
	2004/07/08 22:45 - 2004/07/09 00:15	7			
	2004/07/09 23:15 - 2004/07/10 00:45	7			
	2004/07/14 17:45 - 2004/07/14 18:45	5			
	2004/07/15 18:45 - 2004/07/15 19:30	4			
	2004/07/16 19:00 - 2004/07/16 19:30	3			
	2004/07/17 19:45 - 2004/07/17 20:15	3			
	2004/07/18 19:45 - 2004/07/18 20:30	4			
	2004/07/19 20:15 - 2004/07/19 21:15	5			
	2004/07/20 20:45 - 2004/07/20 21:30	4			
	2004/07/21 21:15 - 2004/07/21 22:00	4			
	2004/07/22 21:30 - 2004/07/22 22:30	5			
	2004/07/23 22:00 - 2004/07/23 23:00	5			
	2004/07/24 22:45 - 2004/07/24 23:15	3			
	2004/07/25 23:45 - 2004/07/26 00:15	3			
	2004/07/27 00:30 - 2004/07/27 01:00	3			
	2004/07/28 01:30 - 2004/07/28 02:00	3			
	2004/07/29 02:30 - 2004/07/29 03:15	4			
	2004/07/30 03:30 - 2004/07/30 04:00	3			
	2004/07/30 18:30 - 2004/07/30 18:45	2			
	2004/07/31 04:15 - 2004/07/31 05:00	4			
	2004/07/31 19:00 - 2004/07/31 20:00	5			
	2004/08/01 05:15 - 2004/08/01 05:45	3			
	2004/08/01 19:15 - 2004/08/01 20:15	5			
	2004/08/02 06:45 - 2004/08/02 07:00	2			
	2004/08/02 19:45 - 2004/08/02 20:45	5			
	2004/08/03 20:15 - 2004/08/03 21:00	4			
	2004/08/05 21:15 - 2004/08/05 22:00	4			
	2004/08/06 10:45 - 2004/08/06 11:45	5			

	2004/08/13 18:15 - 2004/08/13 18:45	3			
	2004/08/14 18:30 - 2004/08/14 19:15	4			
	2004/08/15 19:00 - 2004/08/15 19:45	4			
	2004/08/16 19:15 - 2004/08/16 20:15	5			
	2004/08/17 19:45 - 2004/08/17 20:30	4			
	2004/08/18 20:00 - 2004/08/18 21:00	5			
	2004/08/19 20:15 - 2004/08/19 21:30	6			
	2004/08/20 20:30 - 2004/08/20 21:15	4			
	2004/08/21 21:30 - 2004/08/21 22:00	3			
	2004/08/22 21:30 - 2004/08/22 22:30	5			
	2004/08/23 23:00 - 2004/08/23 23:30	3			
	2004/08/26 16:30 - 2004/08/26 17:00	3			
	2004/08/27 17:00 - 2004/08/27 18:00	5			
	2004/08/28 17:45 - 2004/08/28 18:45	5			
	2004/08/29 18:15 - 2004/08/29 19:00	4			
	2004/08/30 06:00 - 2004/08/30 06:15	2			
	2004/08/30 18:45 - 2004/08/30 19:45	5			
	2004/08/31 19:00 - 2004/08/31 20:15	6			
	2004/09/01 06:00 - 2004/09/01 07:15	6			
	2004/09/01 18:00 - 2004/09/01 18:15	2			
	2004/09/01 19:00 - 2004/09/01 20:30	7			
	2004/09/02 20:00 - 2004/09/02 21:00	5			
	2004/09/03 20:45 - 2004/09/03 21:30	4			
	2004/09/10 17:00 - 2004/09/10 17:15	2			
	2004/09/11 17:30 - 2004/09/11 18:15	4			
	2004/09/12 17:45 - 2004/09/12 18:45	5			
	2004/09/13 17:45 - 2004/09/13 18:45	5			
	2004/09/15 06:45 - 2004/09/15 07:15	3			
	2004/09/15 18:30 - 2004/09/15 19:30	5			
	2004/09/16 18:45 - 2004/09/16 20:15	7			
	2004/09/17 18:00	1			
	2004/09/17 19:00 - 2004/09/17 20:15	6			
	2004/09/18 08:00 - 2004/09/18 08:15	2			
	2004/09/18 10:30 - 2004/09/18 11:00	3			
	2004/09/18 19:45 - 2004/09/18 20:45	5			
	2004/09/19 12:30 - 2004/09/19 12:45	2			
	2004/09/19 20:15 - 2004/09/19 21:30	6			
	2004/09/21 08:45 - 2004/09/21 09:15	3			
	2004/09/22 02:45 - 2004/09/22 03:45	5			
	2004/09/22 05:15	1			
	2004/09/22 12:15	1			
	2004/09/23 15:00 - 2004/09/23 15:45	4			
	2004/09/24 15:45 - 2004/09/24 16:30	4			
	2004/09/25 16:15 - 2004/09/25 17:15	5			
	2004/09/26 17:00 - 2004/09/26 17:45	4			
	2004/09/27 17:30 - 2004/09/27 18:30	5			

	2004/09/28 17:45 - 2004/09/28 18:45	5			
	2004/09/29 18:15 - 2004/09/29 19:15	5			
	2004/09/30 18:45 - 2004/09/30 19:45	5			
	2004/10/01 19:30 - 2004/10/01 20:15	4			
	2004/10/13 17:45 - 2004/10/13 18:30	4			
	2004/10/14 17:45 - 2004/10/14 18:45	5			
	2004/10/15 18:15 - 2004/10/15 19:15	5			
	2004/10/16 07:45 - 2004/10/16 08:45	5			
	2004/10/16 18:15 - 2004/10/16 19:30	6			
	2004/10/16 23:45 - 2004/10/17 00:15	3			
	2004/10/18 09:30 - 2004/10/18 10:45	6			
	2004/10/20 11:30 - 2004/10/20 12:45	6			
	2004/10/21 12:45 - 2004/10/21 13:45	5			
	2004/10/22 04:30 - 2004/10/22 05:15	4			
	2004/10/22 08:00 - 2004/10/22 08:45	4			
	2004/10/22 13:30 - 2004/10/22 14:45	6			
	2004/10/23 14:30 - 2004/10/23 16:00	7			
	2004/10/24 15:15 - 2004/10/24 16:30	6			
	2004/10/25 15:15 - 2004/10/25 16:30	6			
	2004/10/25 20:45 - 2004/10/25 21:00	2			
	2004/10/26 05:15	1			
	2004/10/26 16:15 - 2004/10/26 17:15	5			
	2004/10/27 16:45 - 2004/10/27 18:00	6			
	2004/10/28 06:30 - 2004/10/28 07:15	4			
	2004/10/28 17:30 - 2004/10/28 18:30	5			
	2004/10/29 07:30 - 2004/10/29 08:00	3			
	2004/10/30 06:45 - 2004/10/30 07:30	4			
	2004/10/31 07:30 - 2004/10/31 08:30	5			
	2004/11/07 13:30 - 2004/11/07 14:30	5			
	2004/11/08 14:15 - 2004/11/08 14:45	3			
	2004/11/09 14:30 - 2004/11/09 15:30	5			
Silverdale at Sandpiper - LMK002 - 15 Minute Flow	4244 missing of 20983;		04/05/2004 10:30 – 11/10/2004 00:00	-122.692830	47.65083000
	2004/04/07 07:15 - 2004/04/07 07:45	3			
	2004/04/08 07:30 - 2004/04/08 07:45	2			
	2004/04/13 01:45 - 2004/04/13 02:45	5			
	2004/04/17 04:30 - 2004/04/17 05:15	4			
	2004/04/18 05:15 - 2004/04/18 06:00	4			
	2004/04/19 05:30 - 2004/04/19 06:30	5			
	2004/04/19 17:30 - 2004/04/19 19:15	8			
	2004/04/19 20:00	1			
	2004/04/19 22:30 - 2004/04/19 22:45	2			
	2004/04/21 20:30 - 2004/04/21 21:00	3			
	2004/04/22 06:00 - 2004/04/22 07:00	5			
	2004/04/22 21:00 - 2004/04/22 22:00	5			
	2004/05/10 23:00 - 2004/05/11 00:30	7			
	2004/05/15 03:15 - 2004/05/15 04:15	5			

	2004/05/17 05:15 - 2004/05/17 09:00	16			
	2004/05/17 12:00 - 2004/05/17 12:15	2			
	2004/05/18 18:45 - 2004/05/18 19:30	4			
	2004/05/19 05:45 - 2004/05/19 06:45	5			
	2004/05/19 08:30 - 2004/05/19 11:15	12			
	2004/05/19 12:15 - 2004/05/19 14:30	10			
	2004/05/19 15:15 - 2004/05/19 18:15	13			
	2004/05/21 20:45	1			
	2004/05/22 11:00	1			
	2004/05/22 12:00 - 2004/05/22 13:00	5			
	2004/05/26 09:15 - 2004/05/26 09:30	2			
	2004/05/26 10:15 - 2004/05/26 10:30	2			
	2004/05/27 13:15 - 2004/05/27 14:15	5			
	2004/05/27 15:00	1			
	2004/05/27 16:00 - 2004/05/27 17:00	5			
	2004/05/28 07:00 - 2004/05/28 07:30	3			
	2004/06/04 20:30	1			
	2004/06/05 04:45 - 2004/06/05 06:15	7			
	2004/06/08 23:00 - 2004/06/08 23:15	2			
	2004/06/10 00:00	1			
	2004/06/13 00:15 - 2004/06/13 01:45	7			
	2004/06/13 03:15 - 2004/06/13 04:00	4			
	2004/07/03 08:30 - 2004/07/03 10:30	9			
	2004/07/03 19:15 - 2004/07/03 19:45	3			
	2004/07/14 17:45	1			
	2004/07/15 04:00	1			
	2004/07/15 04:45 - 2004/07/15 05:00	2			
	2004/07/15 09:00 - 2004/07/15 11:00	9			
	2004/07/15 13:45 - 2004/07/15 16:15	11			
	2004/07/15 17:00 - 2004/07/15 19:00	9			
	2004/07/19 17:30 - 2004/07/19 20:45	14			
	2004/07/22 15:15	1			
	2004/07/22 18:30 - 2004/07/22 19:15	4			
	2004/07/22 20:45 - 2004/07/22 21:30	4			
	2004/07/23 22:00 - 2004/07/23 22:15	2			
	2004/07/24 03:15 - 2004/07/24 03:30	2			
	2004/07/24 22:45	1			
	2004/07/25 23:45 - 2004/07/26 01:15	7			
	2004/07/27 00:00 - 2004/07/27 00:30	3			
	2004/07/30 18:00 - 2004/07/30 18:45	4			
	2004/07/30 19:30 - 2004/07/30 19:45	2			
	2004/07/31 19:15	1			
	2004/07/31 20:15	1			
	2004/08/01 19:30 - 2004/08/01 20:30	5			
	2004/08/02 20:15 - 2004/08/02 21:00	4			
	2004/08/04 07:15 - 2004/08/04 08:15	5			

	2004/08/04 15:30 - 2004/08/04 17:15	8			
	2004/08/04 19:00 - 2004/08/04 21:30	11			
	2004/08/05 21:30 - 2004/08/05 22:30	5			
	2004/08/05 23:45	1			
	2004/08/06 06:30 - 2004/08/06 06:45	2			
	2004/08/06 07:30 - 2004/08/06 07:45	2			
	2004/08/06 08:15 - 2004/08/06 17:45	39			
	2004/08/06 18:15 - 2004/08/06 18:30	2			
	2004/08/06 19:00 - 2004/08/07 05:30	43			
	2004/08/07 06:45 - 2004/08/09 01:45	173			
	2004/08/09 04:00 - 2004/08/09 04:45	4			
	2004/08/09 06:30 - 2004/08/13 19:45	438			
	2004/08/13 21:30 - 2004/08/13 22:00	3			
	2004/08/14 01:30 - 2004/08/14 02:45	6			
	2004/08/14 03:15 - 2004/08/14 04:45	7			
	2004/08/14 05:15 - 2004/08/14 07:00	8			
	2004/08/14 07:45 - 2004/08/14 10:30	12			
	2004/08/14 11:00 - 2004/08/14 13:45	12			
	2004/08/14 14:30 - 2004/08/15 00:30	41			
	2004/08/15 01:15 - 2004/08/16 01:00	96			
	2004/08/16 01:30 - 2004/08/16 07:00	23			
	2004/08/16 07:45 - 2004/08/16 10:15	11			
	2004/08/16 10:45 - 2004/08/17 00:00	54			
	2004/08/17 00:30 - 2004/08/17 13:15	52			
	2004/08/17 13:45 - 2004/08/17 14:15	3			
	2004/08/17 14:45 - 2004/08/18 02:30	48			
	2004/08/18 05:30 - 2004/08/18 07:15	8			
	2004/08/18 08:30 - 2004/08/18 14:30	25			
	2004/08/18 16:30 - 2004/08/18 20:15	16			
	2004/08/18 21:15 - 2004/08/18 23:30	10			
	2004/08/19 00:00 - 2004/08/19 03:15	14			
	2004/08/19 04:45 - 2004/08/19 20:30	64			
	2004/08/19 22:00 - 2004/08/20 02:15	18			
	2004/08/20 20:30 - 2004/08/21 00:45	18			
	2004/08/21 02:15 - 2004/08/21 03:30	6			
	2004/08/21 17:15 - 2004/08/21 21:15	17			
	2004/08/22 02:30 - 2004/08/22 06:15	16			
	2004/08/22 08:00 - 2004/08/22 21:45	56			
	2004/08/23 00:00	1			
	2004/08/23 21:45 - 2004/08/23 22:45	5			
	2004/08/24 00:15 - 2004/08/24 00:30	2			
	2004/08/24 06:30 - 2004/08/24 08:15	8			
	2004/08/24 11:30 - 2004/08/24 23:30	49			
	2004/08/25 01:30 - 2004/08/26 00:00	91			
	2004/08/26 01:45 - 2004/08/26 16:30	60			
	2004/08/27 05:15 - 2004/08/27 06:30	6			

	2004/08/27 09:00 - 2004/08/27 10:15	6			
	2004/08/27 15:30 - 2004/08/27 15:45	2			
	2004/08/27 16:15 - 2004/08/27 16:30	2			
	2004/08/27 17:00	1			
	2004/08/28 17:30 - 2004/08/28 18:15	4			
	2004/08/28 19:30 - 2004/08/28 19:45	2			
	2004/08/29 04:30 - 2004/08/29 04:45	2			
	2004/08/29 17:45 - 2004/08/29 19:15	7			
	2004/08/29 20:30	1			
	2004/08/30 18:45 - 2004/08/30 19:00	2			
	2004/08/30 20:45 - 2004/08/30 21:00	2			
	2004/08/31 06:15 - 2004/08/31 07:00	4			
	2004/09/01 07:15 - 2004/09/01 07:45	3			
	2004/09/02 19:30	1			
	2004/09/03 20:30	1			
	2004/09/04 18:45 - 2004/09/04 19:00	2			
	2004/09/04 19:30 - 2004/09/05 01:00	23			
	2004/09/05 01:30 - 2004/09/06 05:15	112			
	2004/09/06 05:45 - 2004/09/07 04:00	90			
	2004/09/07 05:30 - 2004/09/07 07:00	7			
	2004/09/07 07:45	1			
	2004/09/07 08:15 - 2004/09/07 16:30	34			
	2004/09/07 17:45 - 2004/09/07 22:45	21			
	2004/09/07 23:15 - 2004/09/08 00:45	7			
	2004/09/08 01:15 - 2004/09/08 05:15	17			
	2004/09/08 06:30 - 2004/09/08 09:15	12			
	2004/09/08 10:15 - 2004/09/08 11:30	6			
	2004/09/08 12:00 - 2004/09/09 02:30	59			
	2004/09/09 04:45 - 2004/09/09 08:45	17			
	2004/09/09 10:00 - 2004/09/10 03:30	71			
	2004/09/10 04:00 - 2004/09/10 09:00	21			
	2004/09/10 09:30 - 2004/09/10 09:45	2			
	2004/09/10 10:15 - 2004/09/10 17:45	31			
	2004/09/10 19:15 - 2004/09/10 20:00	4			
	2004/09/10 23:30	1			
	2004/09/11 02:00	1			
	2004/09/11 03:30 - 2004/09/11 17:30	57			
	2004/09/12 03:15 - 2004/09/12 03:30	2			
	2004/09/12 04:45 - 2004/09/12 18:00	54			
	2004/09/13 08:45 - 2004/09/13 18:30	40			
	2004/09/13 19:30 - 2004/09/13 20:00	3			
	2004/09/14 18:00 - 2004/09/14 18:45	4			
	2004/09/14 20:15	1			
	2004/09/14 21:00	1			
	2004/09/15 00:00 - 2004/09/15 06:30	27			
	2004/09/15 07:15	1			

	2004/09/15 07:45 - 2004/09/15 08:45	5			
	2004/09/15 09:30 - 2004/09/15 20:00	43			
	2004/09/15 20:30 - 2004/09/15 20:45	2			
	2004/09/16 07:00 - 2004/09/16 08:15	6			
	2004/09/16 14:00 - 2004/09/16 14:15	2			
	2004/09/16 15:30	1			
	2004/09/16 16:15 - 2004/09/16 17:15	5			
	2004/09/16 18:00 - 2004/09/16 20:15	10			
	2004/09/16 21:00 - 2004/09/16 21:15	2			
	2004/09/17 03:15 - 2004/09/17 05:15	9			
	2004/09/17 06:45 - 2004/09/17 16:00	38			
	2004/09/17 17:00 - 2004/09/18 13:00	81			
	2004/09/18 14:30 - 2004/09/18 22:30	33			
	2004/09/19 00:00	1			
	2004/09/19 00:30 - 2004/09/19 01:00	3			
	2004/09/19 07:00 - 2004/09/19 07:45	4			
	2004/09/19 10:00 - 2004/09/19 12:15	10			
	2004/09/19 14:00	1			
	2004/09/19 16:15 - 2004/09/19 22:30	26			
	2004/09/20 04:30 - 2004/09/20 06:30	9			
	2004/09/20 07:00	1			
	2004/09/20 07:30 - 2004/09/20 08:00	3			
	2004/09/20 08:30	1			
	2004/09/20 18:30 - 2004/09/21 02:30	33			
	2004/09/21 03:15 - 2004/09/21 04:30	6			
	2004/09/21 05:30 - 2004/09/22 12:15	124			
	2004/09/22 14:00	1			
	2004/09/22 14:45	1			
	2004/09/22 17:15 - 2004/09/23 15:15	89			
	2004/09/24 12:30	1			
	2004/09/24 14:15 - 2004/09/24 15:00	4			
	2004/09/24 15:30 - 2004/09/24 16:00	3			
	2004/09/25 16:15	1			
	2004/09/25 16:45 - 2004/09/25 18:15	7			
	2004/09/27 17:30 - 2004/09/27 18:15	4			
	2004/09/27 19:30	1			
	2004/09/28 17:00 - 2004/09/28 17:15	2			
	2004/09/28 17:45 - 2004/09/28 18:00	2			
	2004/09/28 18:30 - 2004/09/28 18:45	2			
	2004/09/29 07:00 - 2004/09/29 07:30	3			
	2004/09/29 18:45	1			
	2004/09/29 19:15 - 2004/09/29 19:45	3			
	2004/09/29 20:15	1			
	2004/09/30 18:45 - 2004/09/30 19:45	5			
	2004/10/02 17:15 - 2004/10/02 18:15	5			
	2004/10/02 20:15 - 2004/10/02 20:45	3			

	2004/10/02 21:45 - 2004/10/02 22:45	5			
	2004/10/02 23:45 - 2004/10/03 09:15	39			
	2004/10/03 09:45 - 2004/10/05 01:30	160			
	2004/10/05 02:00 - 2004/10/05 04:00	9			
	2004/10/05 05:30 - 2004/10/05 08:00	11			
	2004/10/05 08:30 - 2004/10/05 15:00	27			
	2004/10/05 16:00 - 2004/10/05 18:45	12			
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	2004/10/05 20:15 - 2004/10/05 20:30	2			
	2004/10/05 22:30 - 2004/10/06 21:45	94			
	2004/10/06 23:30	1			
	2004/10/07 01:45 - 2004/10/07 03:00	6			
	2004/10/07 05:00 - 2004/10/07 06:00	5			
	2004/10/07 17:15 - 2004/10/07 17:45	3			
	2004/10/07 20:15 - 2004/10/07 20:45	3			
	2004/10/08 12:30	1			
	2004/10/08 13:30 - 2004/10/08 16:00	11			
	2004/10/08 20:30	1			
	2004/10/08 21:30 - 2004/10/08 21:45	2			
	2004/10/08 23:00 - 2004/10/09 06:30	31			
	2004/10/09 13:00 - 2004/10/11 03:45	156			
	2004/10/11 05:45 - 2004/10/11 08:45	13			
	2004/10/11 10:45	1			
	2004/10/11 14:15 - 2004/10/11 15:45	7			
	2004/10/11 16:30 - 2004/10/11 17:15	4			
	2004/10/12 07:15 - 2004/10/12 09:45	11			
	2004/10/12 11:30 - 2004/10/12 12:15	4			
	2004/10/12 16:45 - 2004/10/12 18:15	7			
	2004/10/13 06:45 - 2004/10/13 11:30	20			
	2004/10/13 14:00 - 2004/10/13 15:15	6			
	2004/10/13 17:00 - 2004/10/13 17:30	3			
	2004/10/15 18:00 - 2004/10/15 18:30	3			
	2004/10/15 20:15	1			
	2004/10/16 08:45	1			
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	2004/10/17 08:00 - 2004/10/17 08:15	2			
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	2004/10/17 21:00	1			
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	2004/10/18 00:00 - 2004/10/18 01:15	6			
	2004/10/18 02:00 - 2004/10/18 03:00	5			
	2004/10/18 03:45 - 2004/10/18 05:45	9			

	2004/10/18 06:30	1			
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	2004/11/06 00:30 - 2004/11/06 01:00	3			
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	2004/11/06 23:00 - 2004/11/06 23:45	4			
	2004/11/07 13:00 - 2004/11/07 13:45	4			
	2004/11/09 22:15 - 2004/11/09 23:15	5			
Springbrook Creek @ New Brooklyn Rd - BI-SBC - 5 Minute Flow	25203 missing of 289568;		03/31/2004 13:20 – 12/31/2006 23:55	-122.567670	47.64300000
	2004/04/07 17:55 - 2004/04/07 18:50	12			
	2004/04/20 11:50 - 2004/05/07 10:10	4877			
	2004/05/07 18:10 - 2004/05/07 18:25	4			
	2004/07/14 09:35 - 2004/07/14 09:50	4			
	2004/11/10 09:55 - 2004/12/01 09:25	6043			
	04/07/2005 09:25 - 04/07/2005 10:25	13			
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	08/15/2005 14:50 - 08/19/2005 08:50	1081			
	10/14/2005 09:20 - 10/14/2005 09:25	2			
	01/17/2006 13:00 - 03/04/2006 06:00	13165			

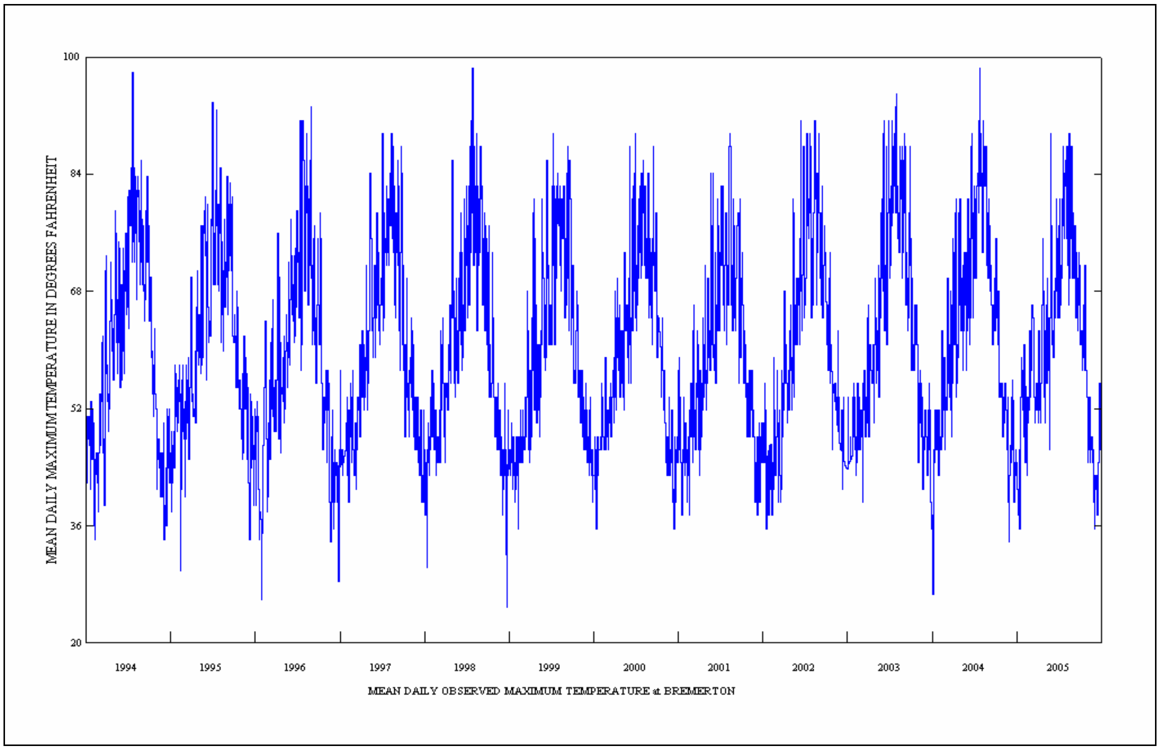

Figure A3.1. Observed mean daily maximum temperature at Bremerton, WA.

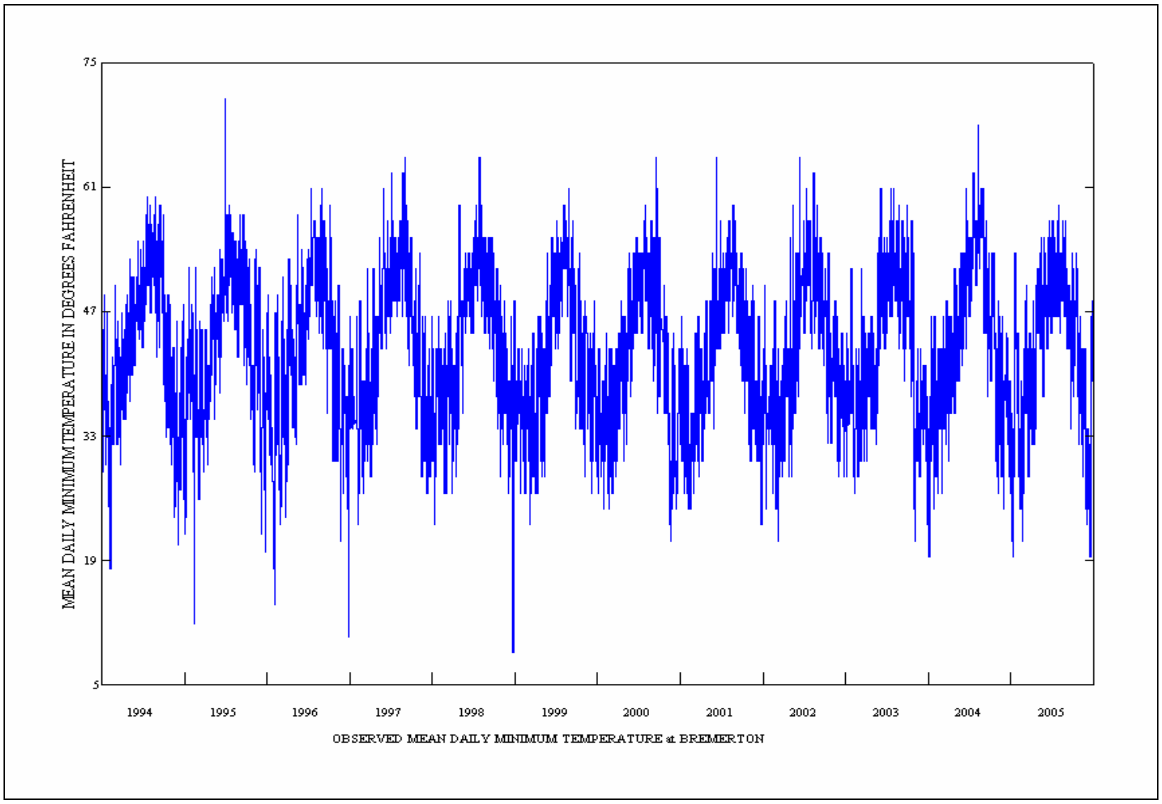

Figure A3.2. Observed mean daily minimum temperature at Bremerton, WA.

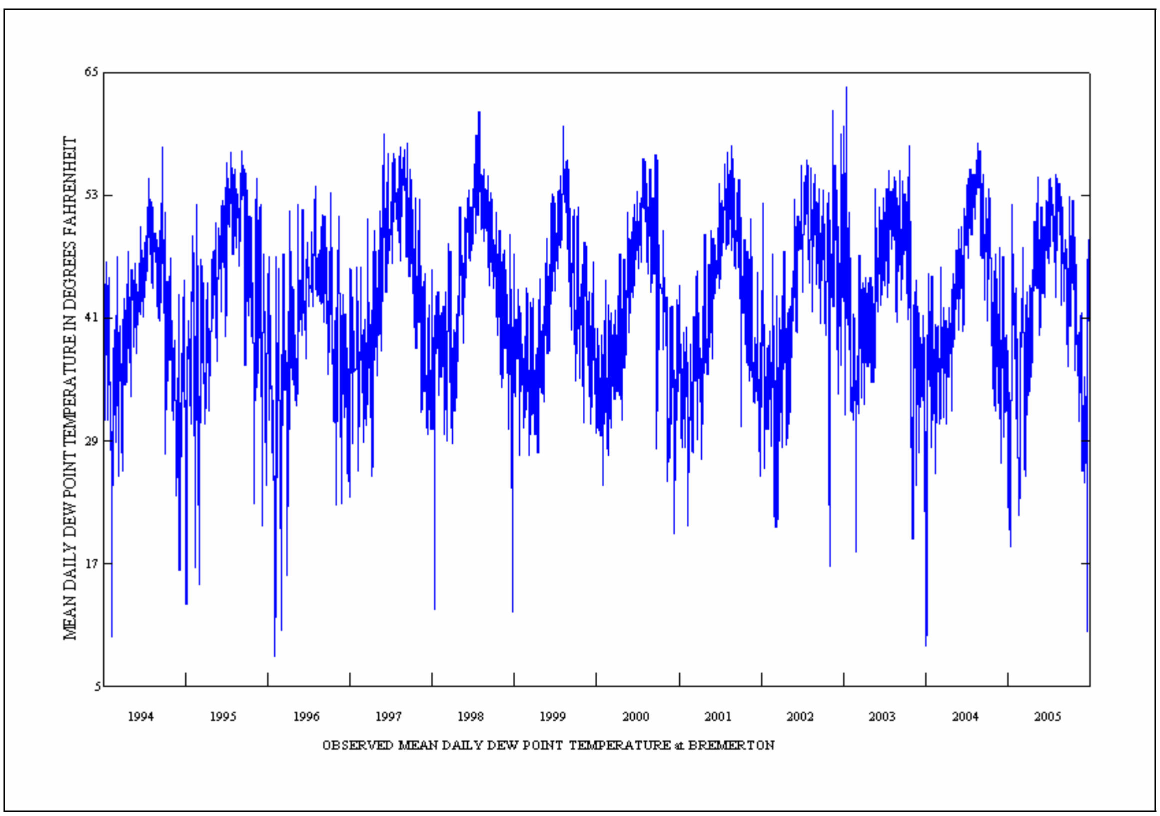

Figure A3.3. Observed mean daily dew point temperature at Bremerton, WA.

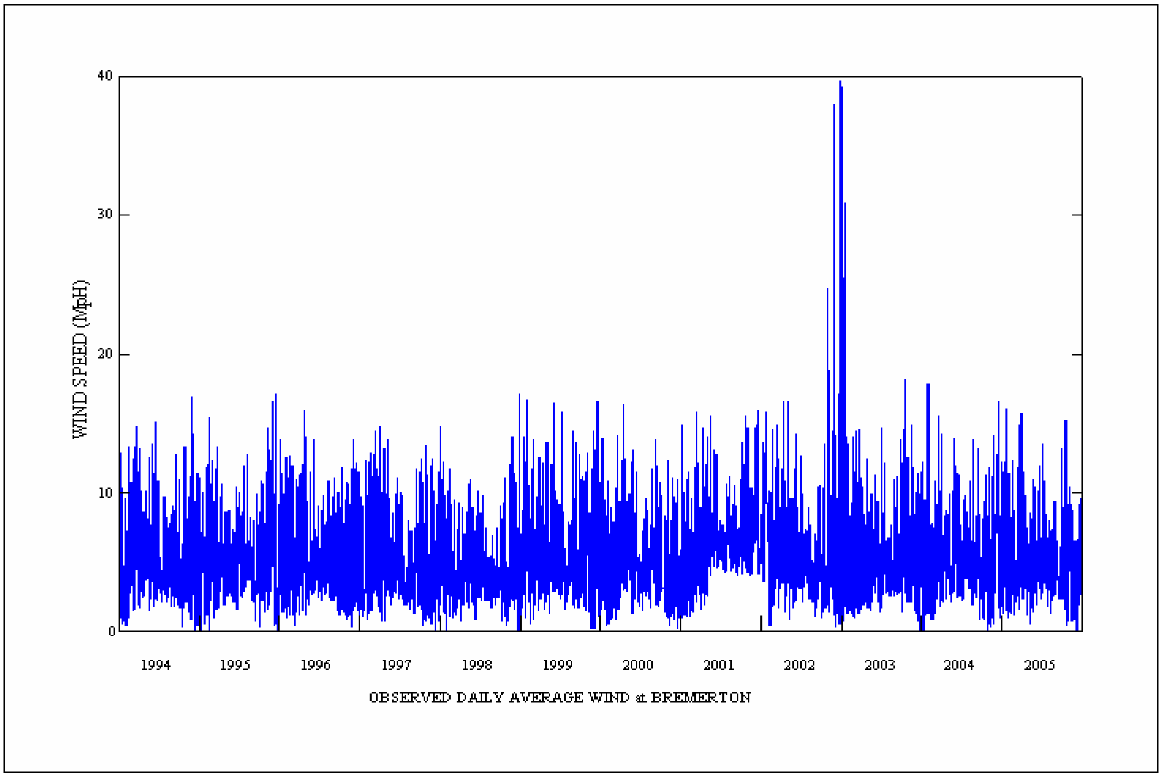

Figure A3.4. Observed mean daily average wind at Bremerton, WA.

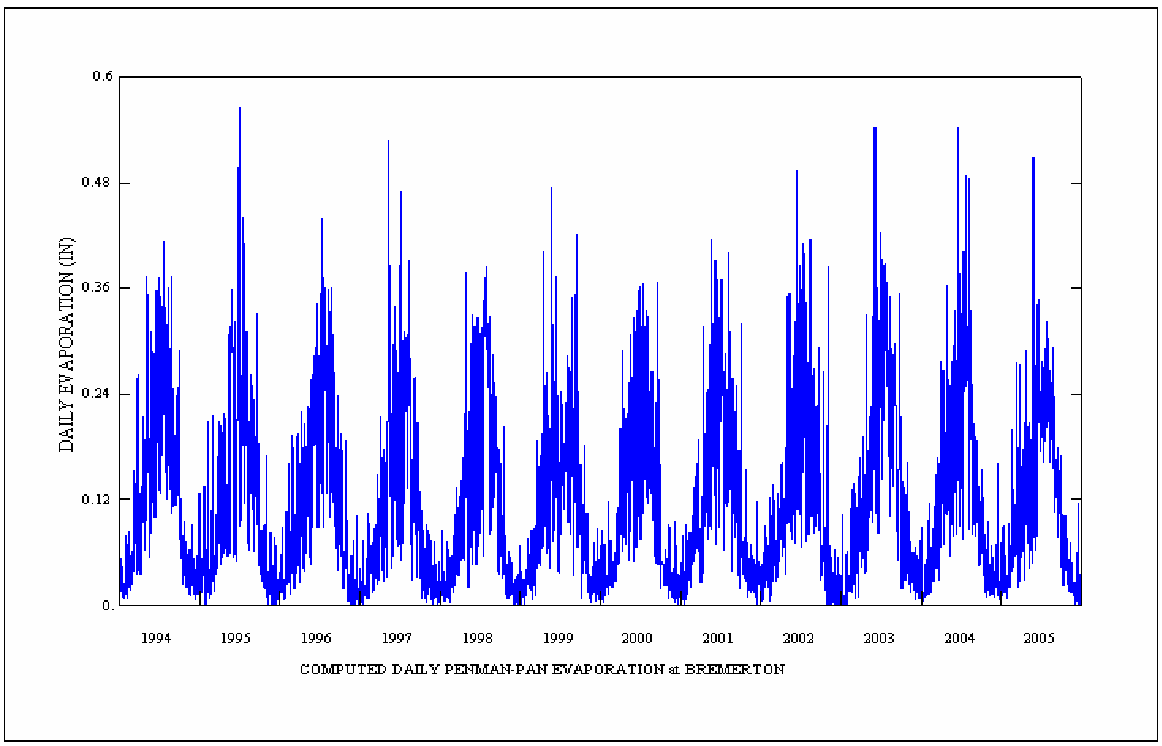

Figure A3.5. Computed daily Penman-Pan evaporation at Bremerton, WA.

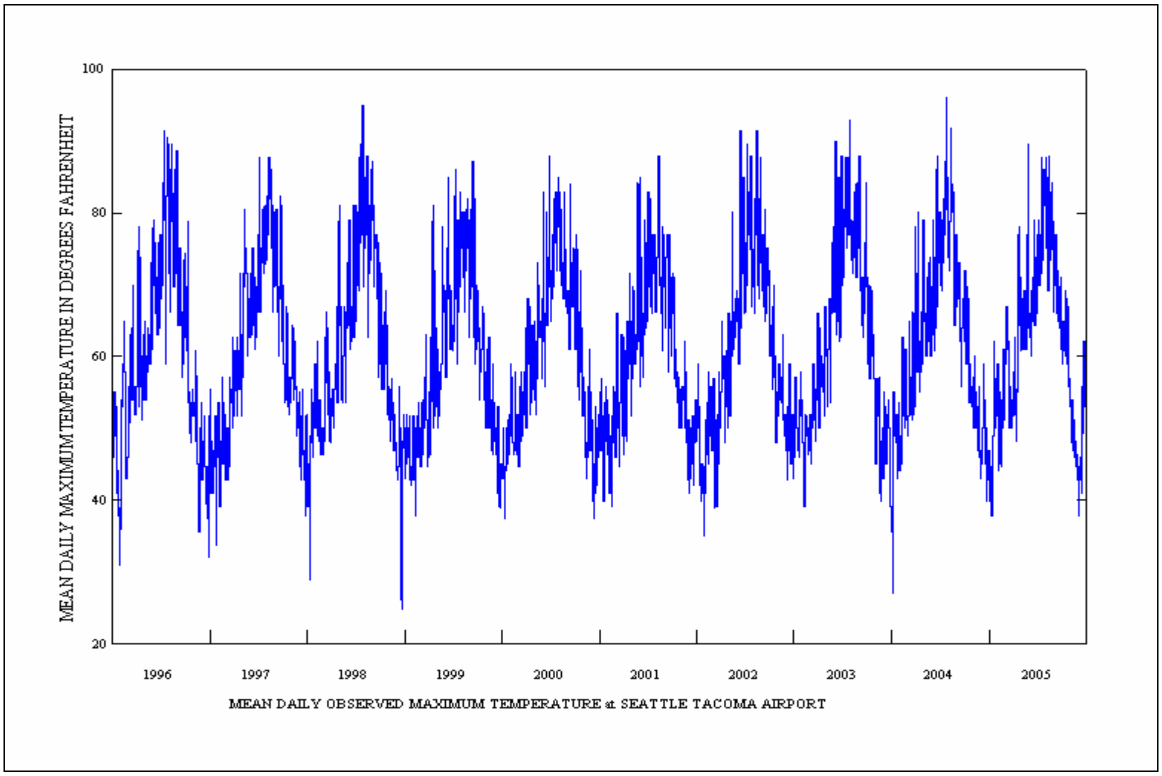

Figure A3.6. Observed mean daily maximum temperature at Seattle Tacoma Airport, WA.

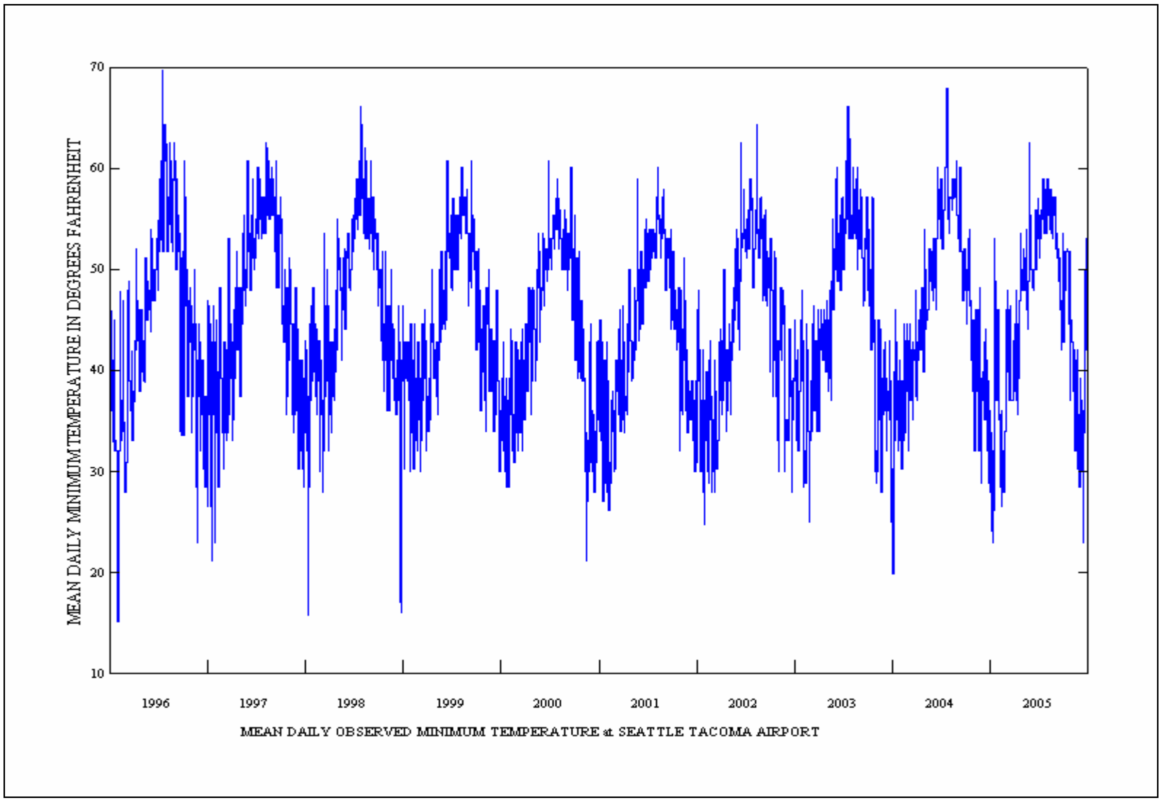

Figure A3.7. Observed mean daily minimum temperature at Seattle Tacoma Airport, WA.

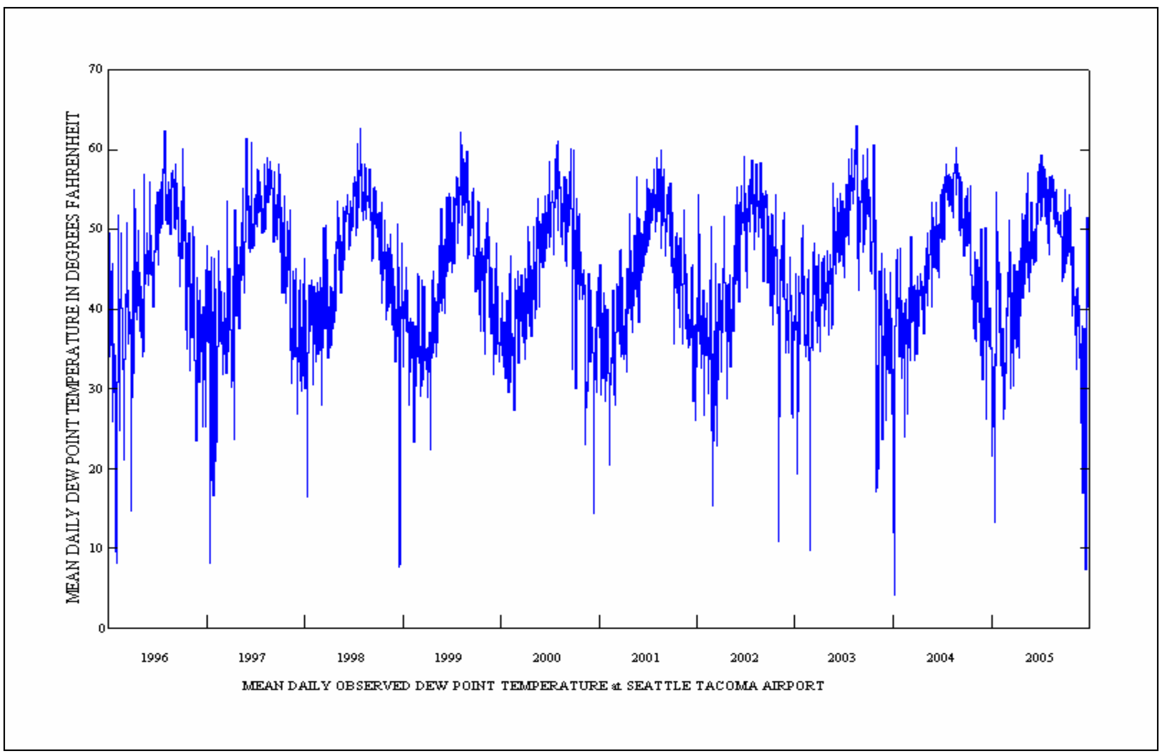

Figure A3.8. Observed mean daily dew point temperature at Seattle Tacoma Airport, WA.

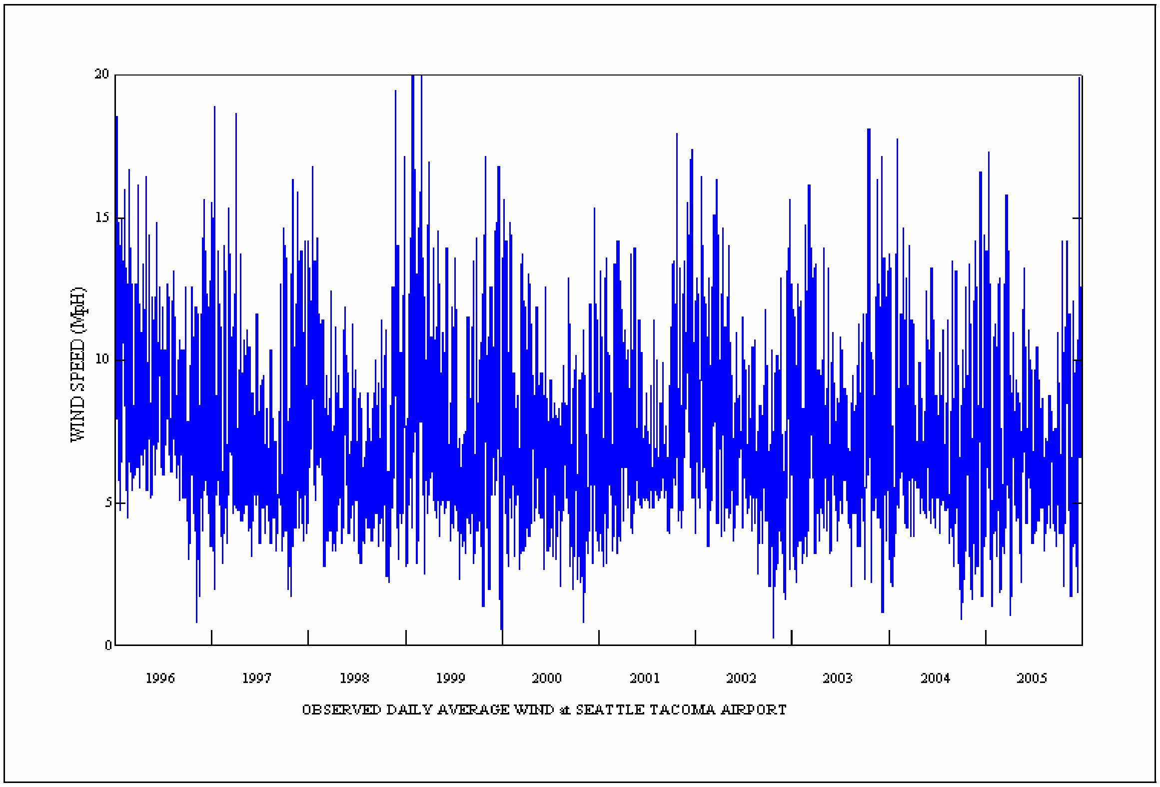

Figure A3.9. Observed mean daily average wind at Seattle Tacoma Airport, WA.

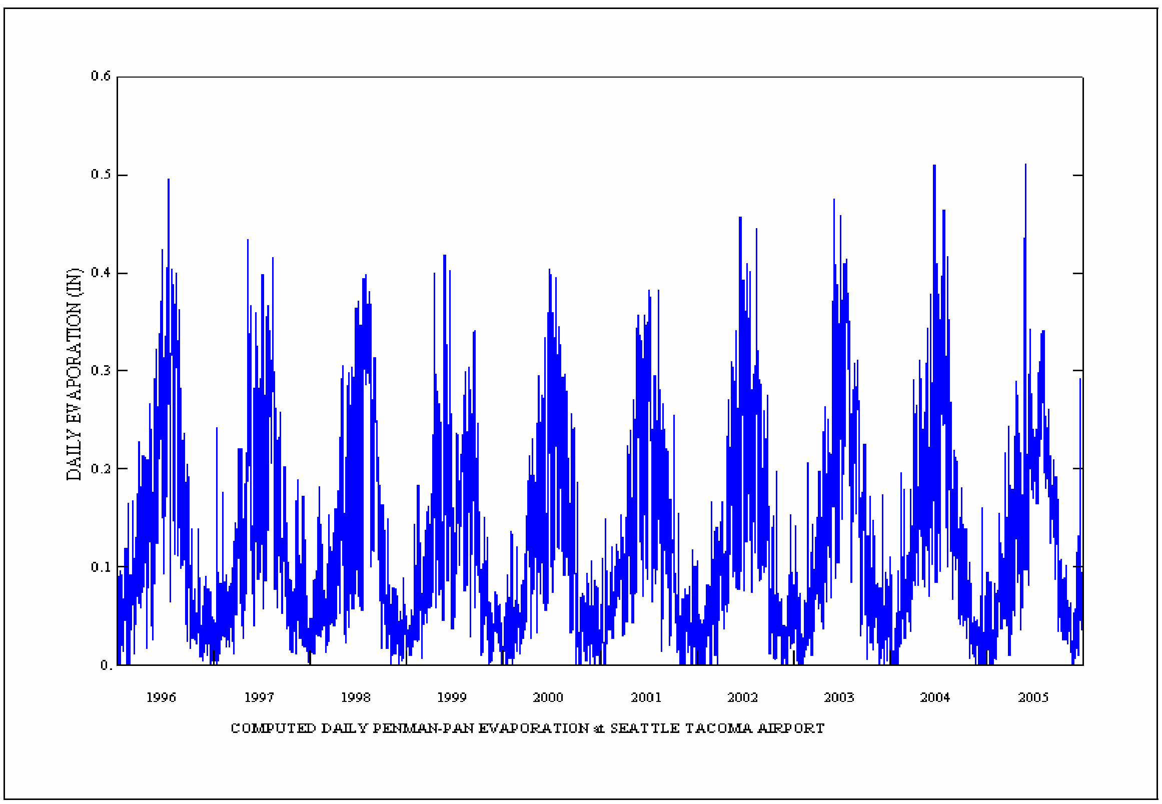

Figure A3.10. Computed daily Penman-Pan evaporation at Seattle Tacoma Airport, WA.

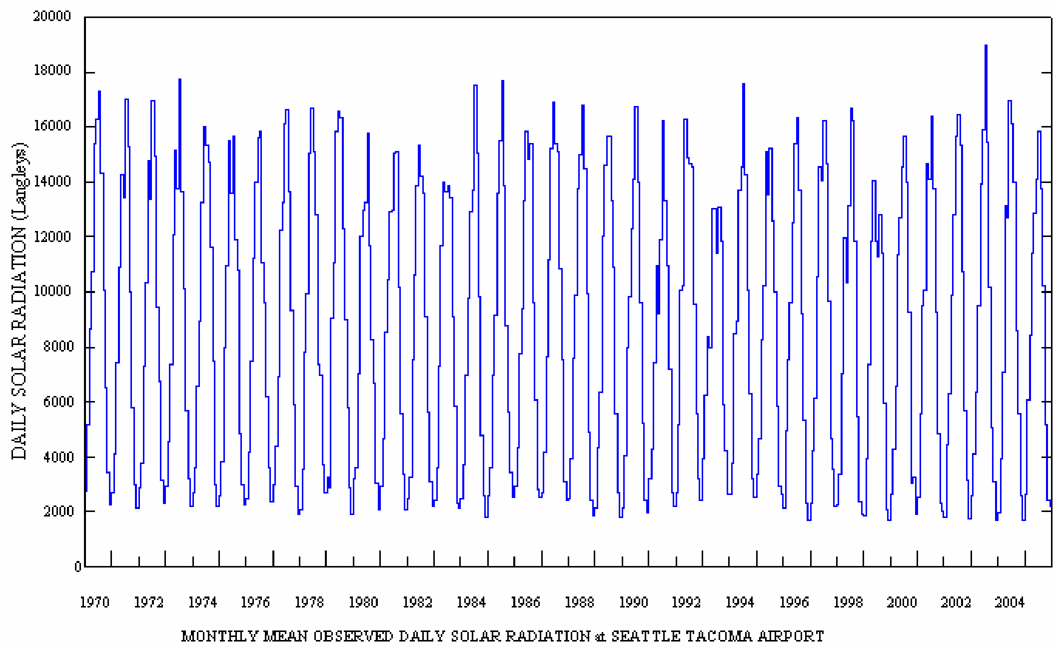

Figure A3.11. Monthly mean observed daily solar radiation at Seattle Tacoma Airport, WA.

Precipitation

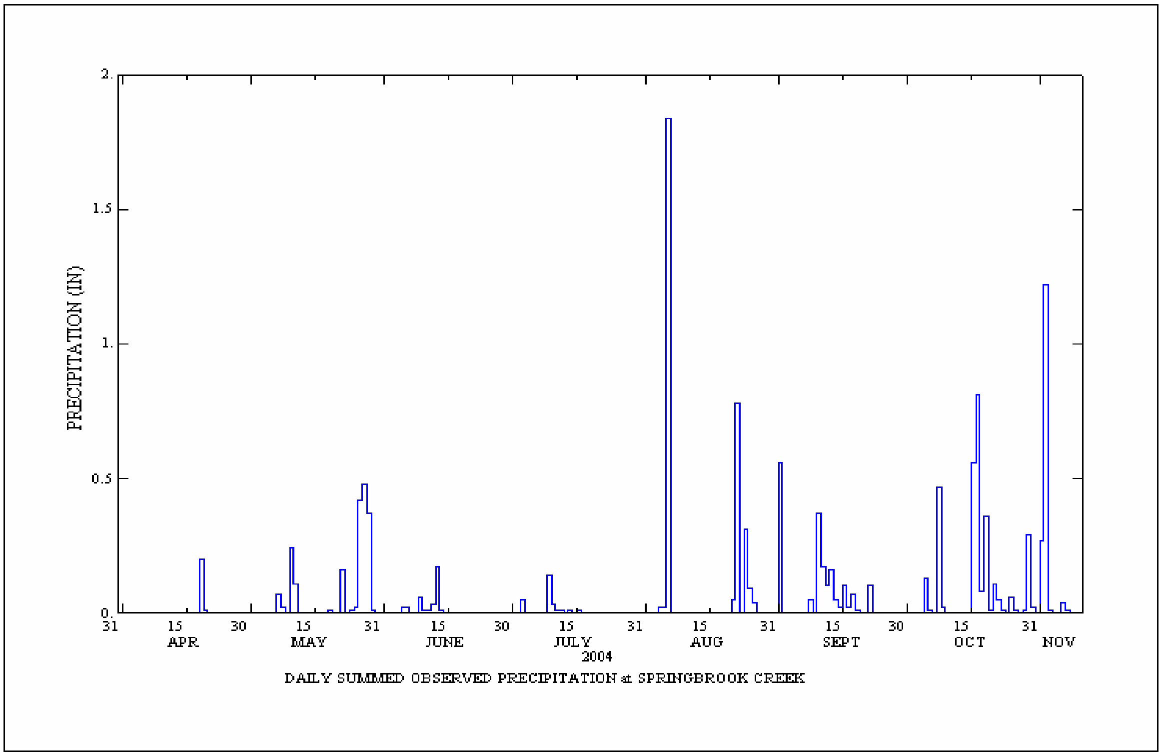

Figure A3.12. Daily summed observed precipitation at Springbrook Creek, WA.

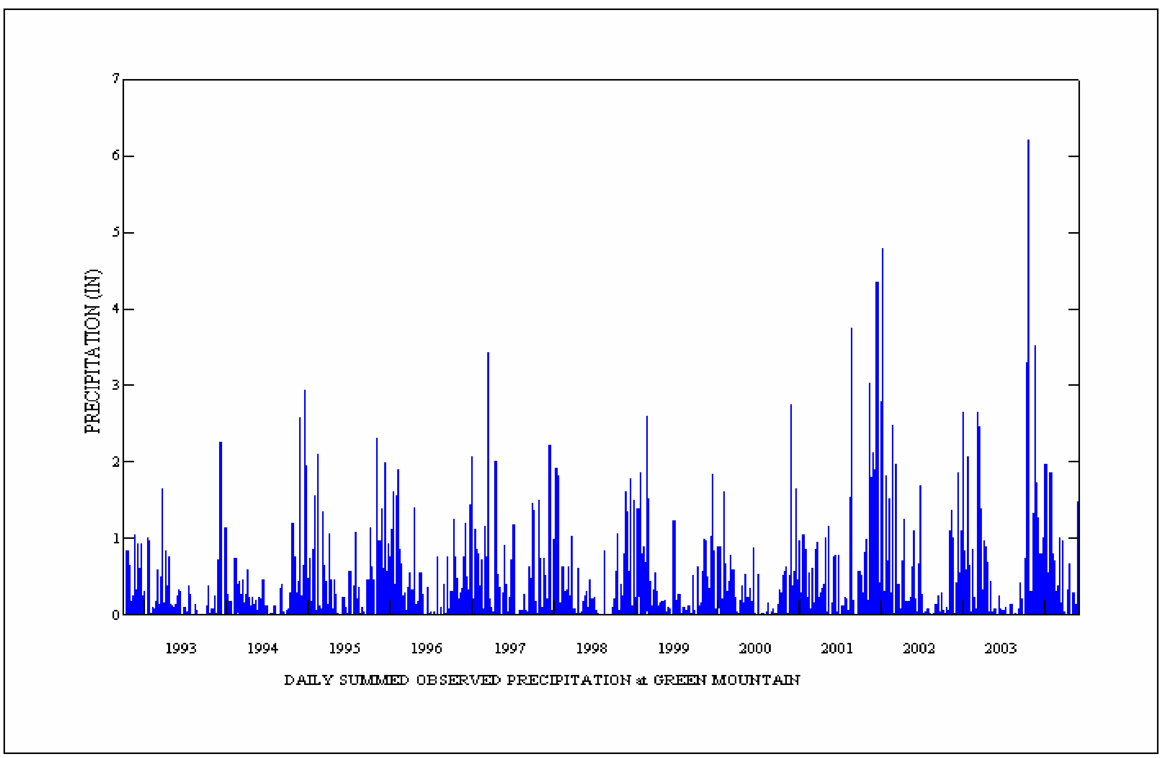

Figure A3.13. Daily summed observed precipitation at Green Mountain, WA.

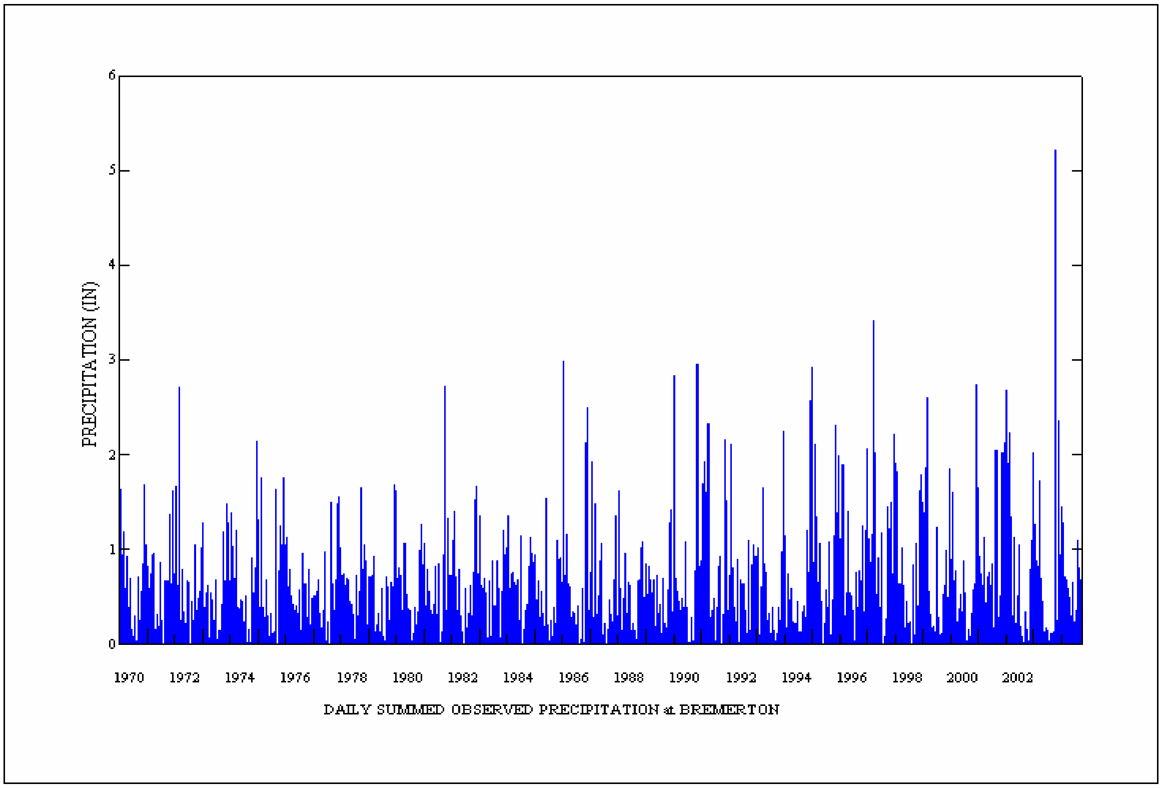

Figure A3.14. Daily summed observed precipitation at Bremerton, WA.

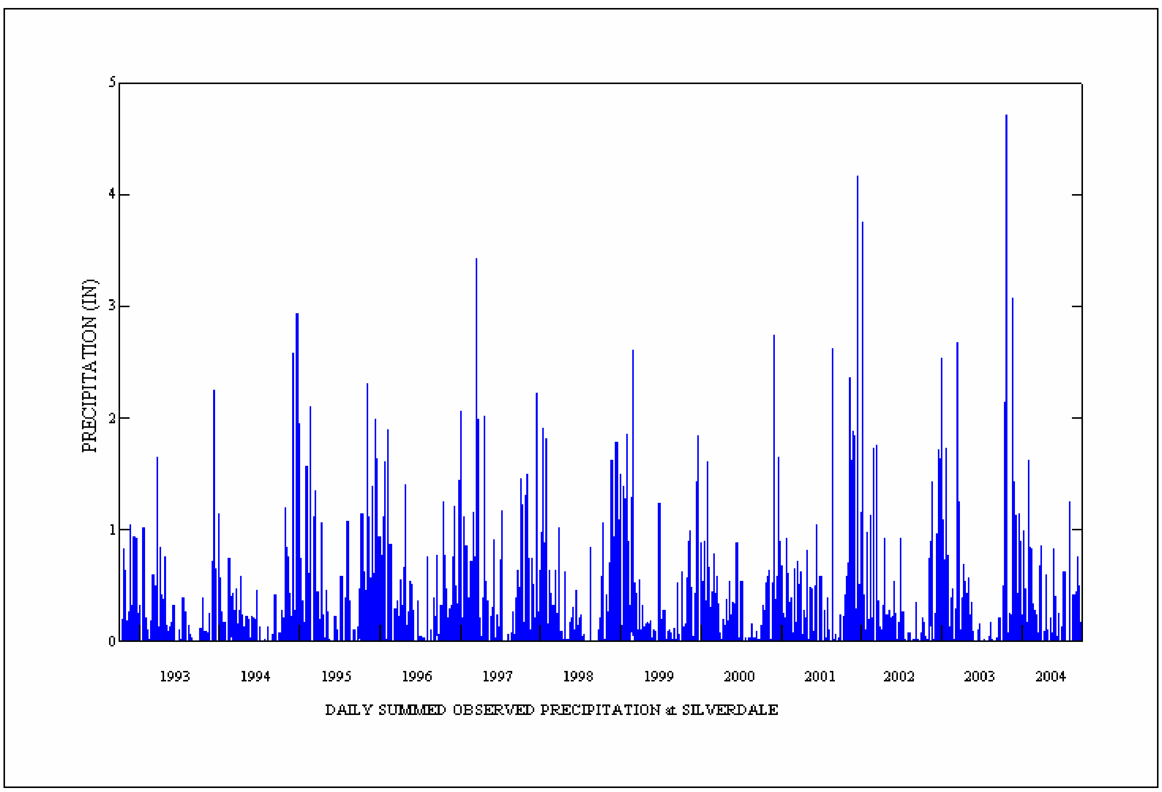

Figure A3.15. Daily summed observed precipitation at Silverdale-Wixon, WA.

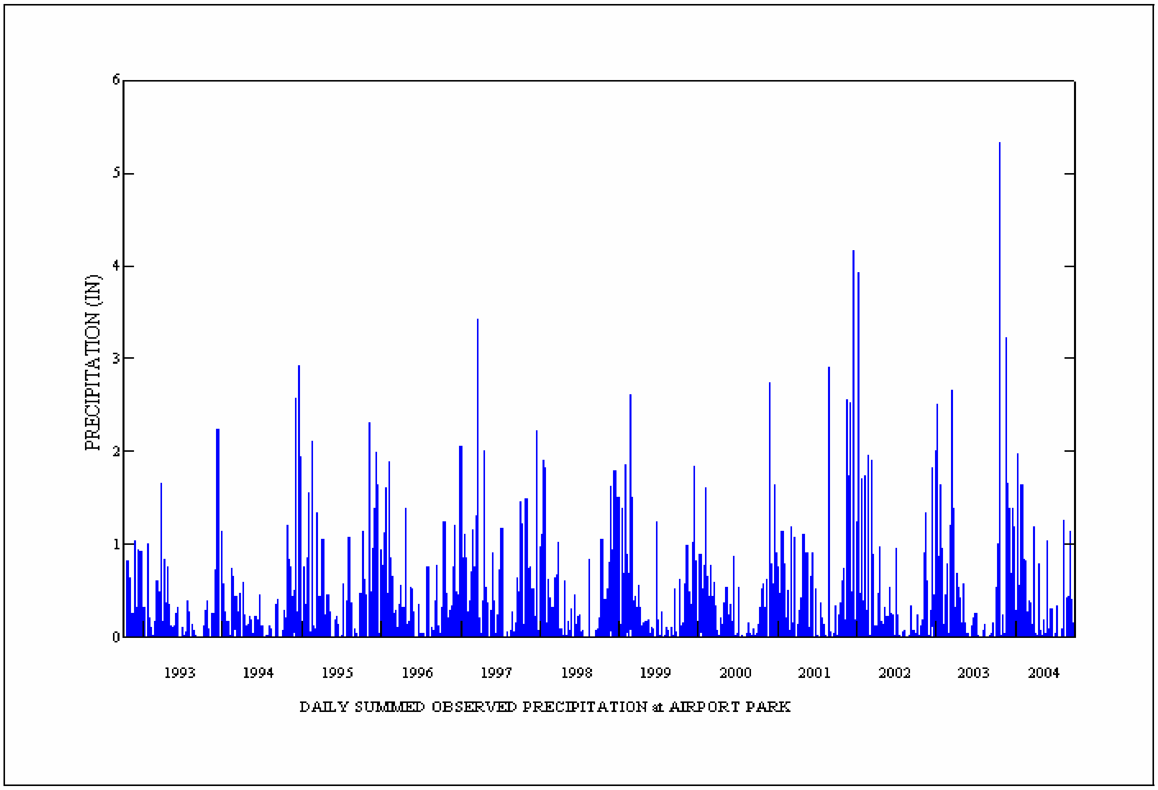

Figure A3.16. Daily summed observed precipitation at Airport Park, WA.

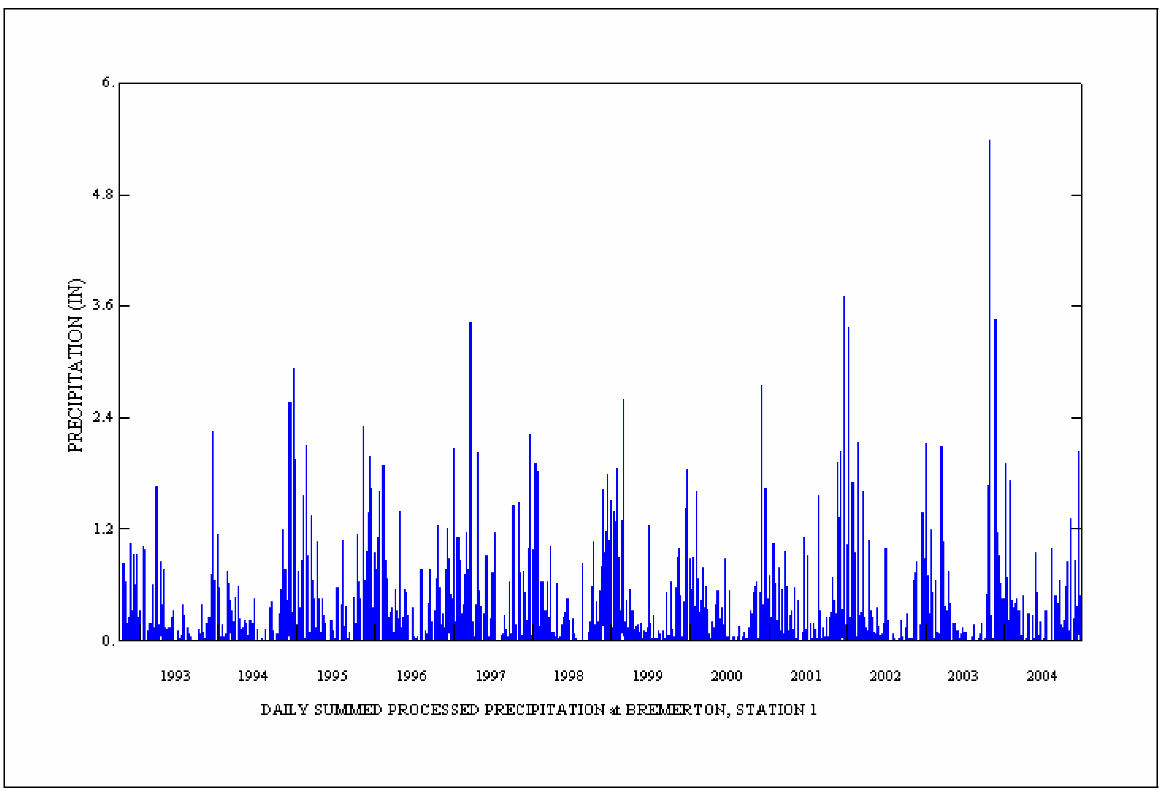

Figure A3.17. Daily summed processed precipitation at Bremerton, WA. Station 1.

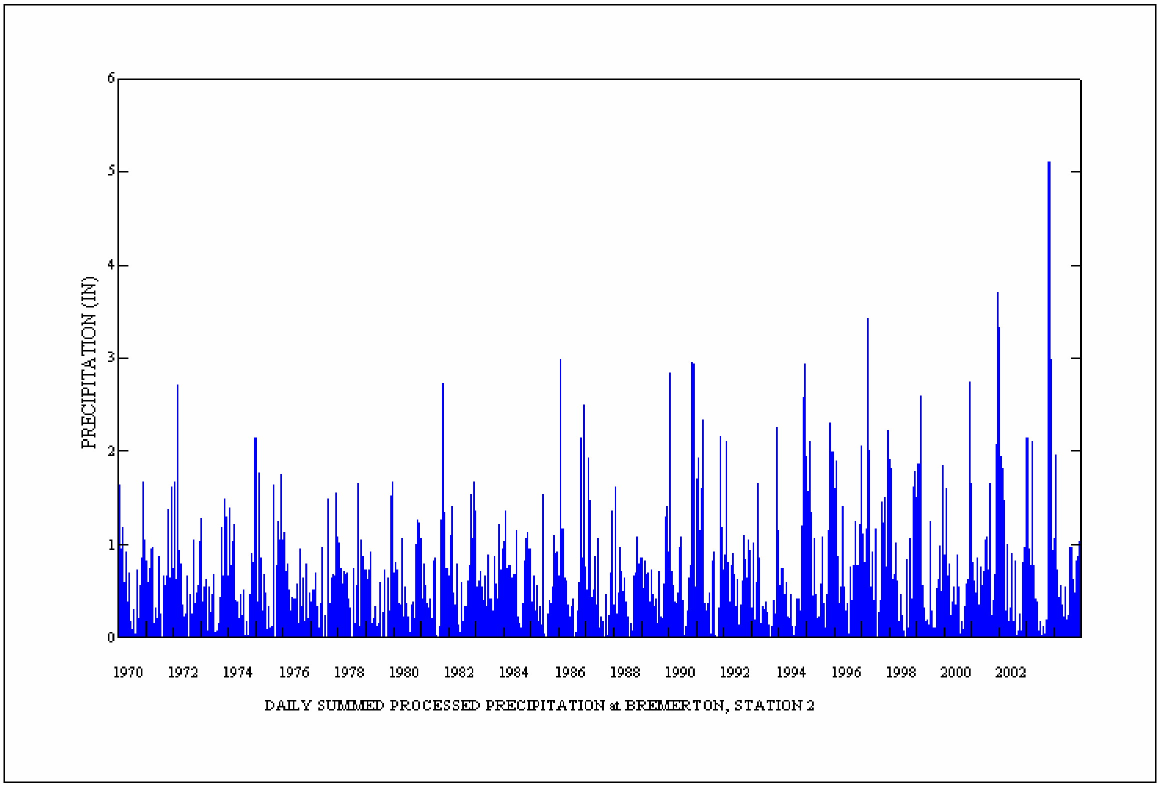

Figure A3.18. Daily summed processed precipitation at Bremerton, WA. Station 2.

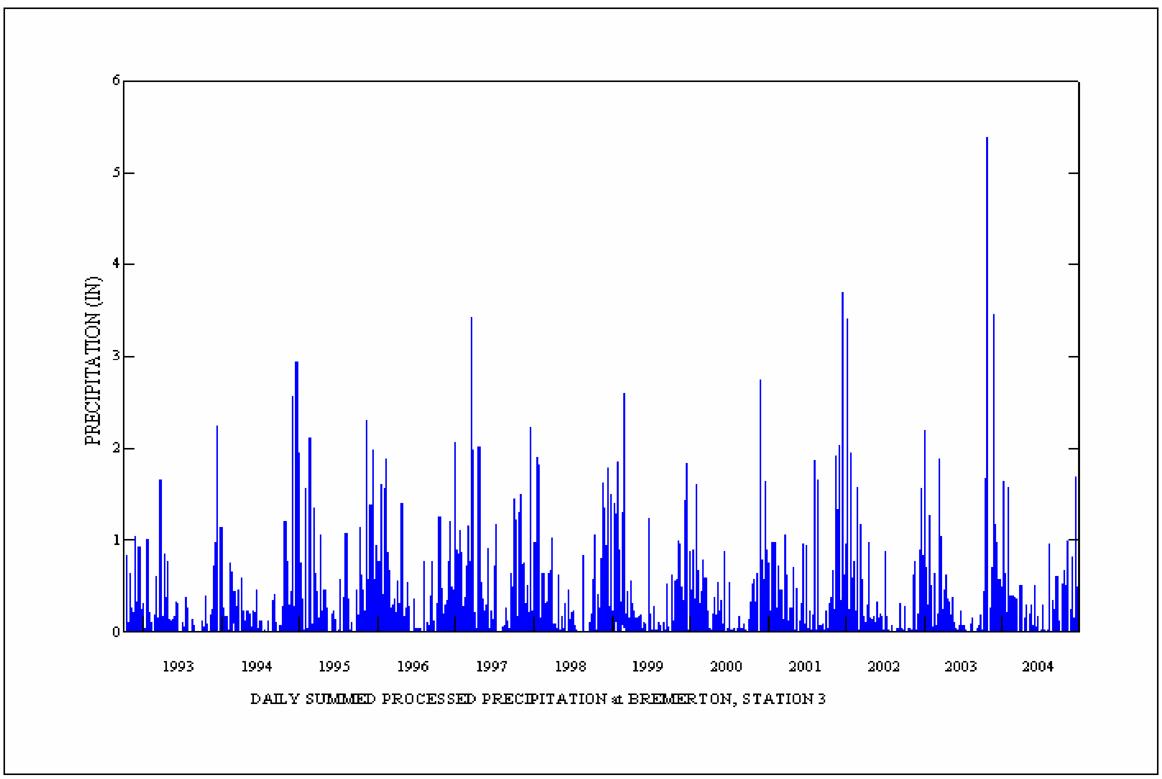

Figure A3.19. Daily summed processed precipitation at Bremerton, WA. Station 3.

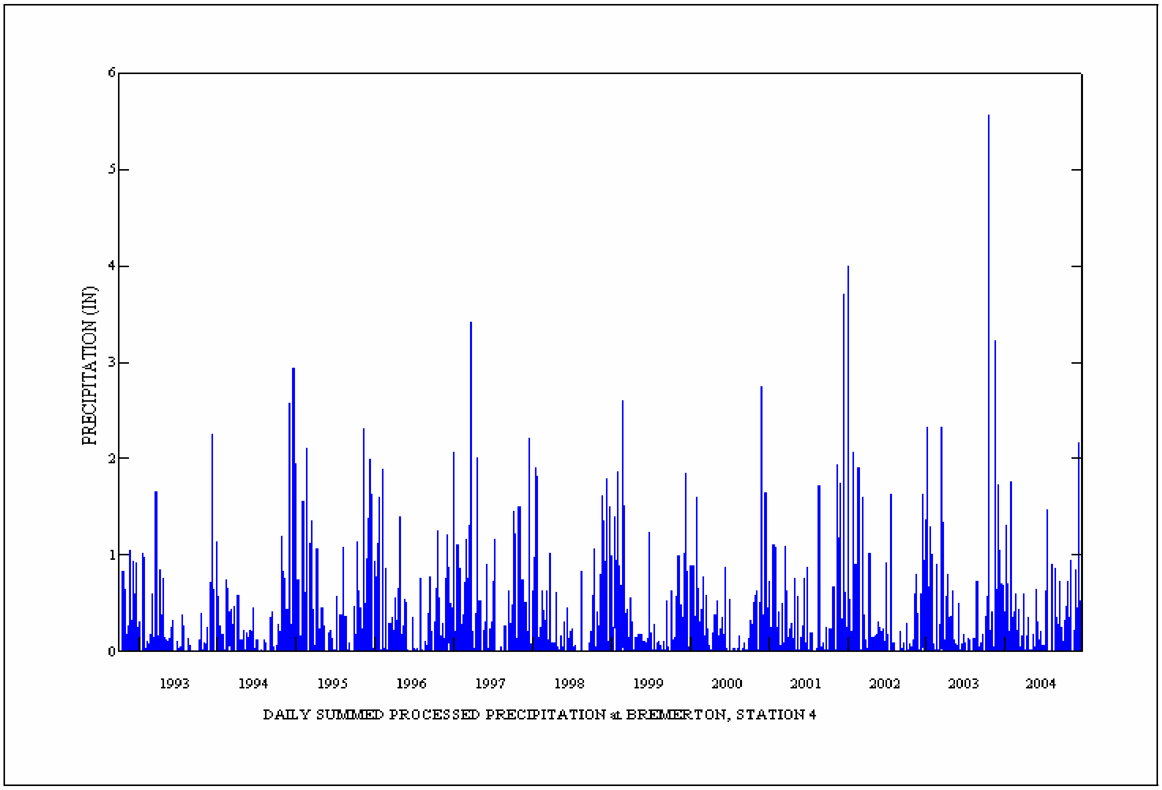

Figure A3.20. Daily summed processed precipitation at Bremerton, WA. Station 4.

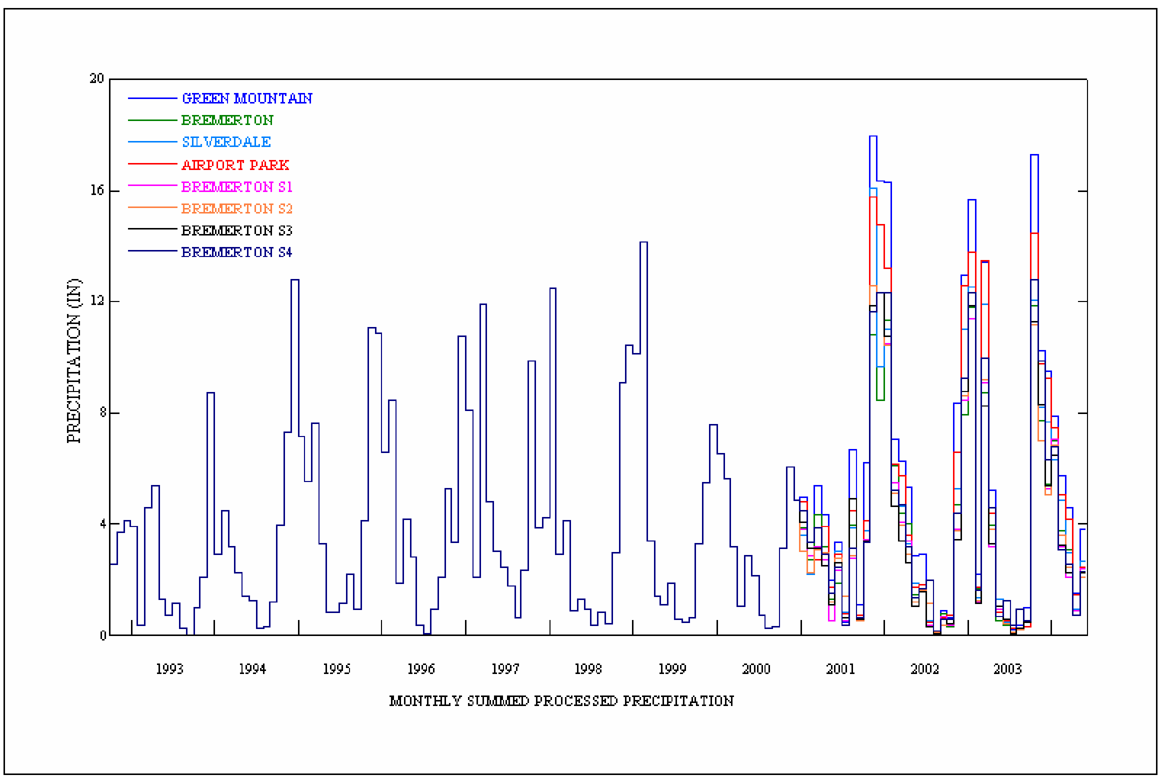

Figure A3.21. Monthly summed processed precipitation.

Flows

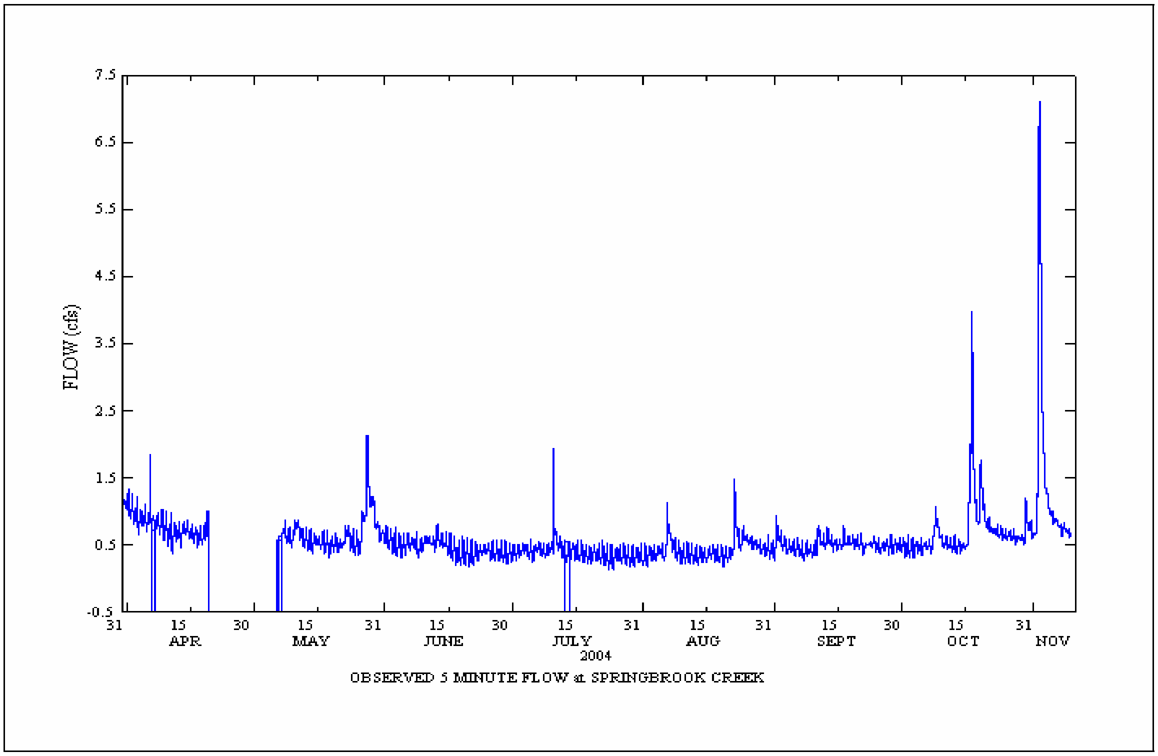

Figure A3.22. Observed 5 minute flow at Springbrook Creek, WA.

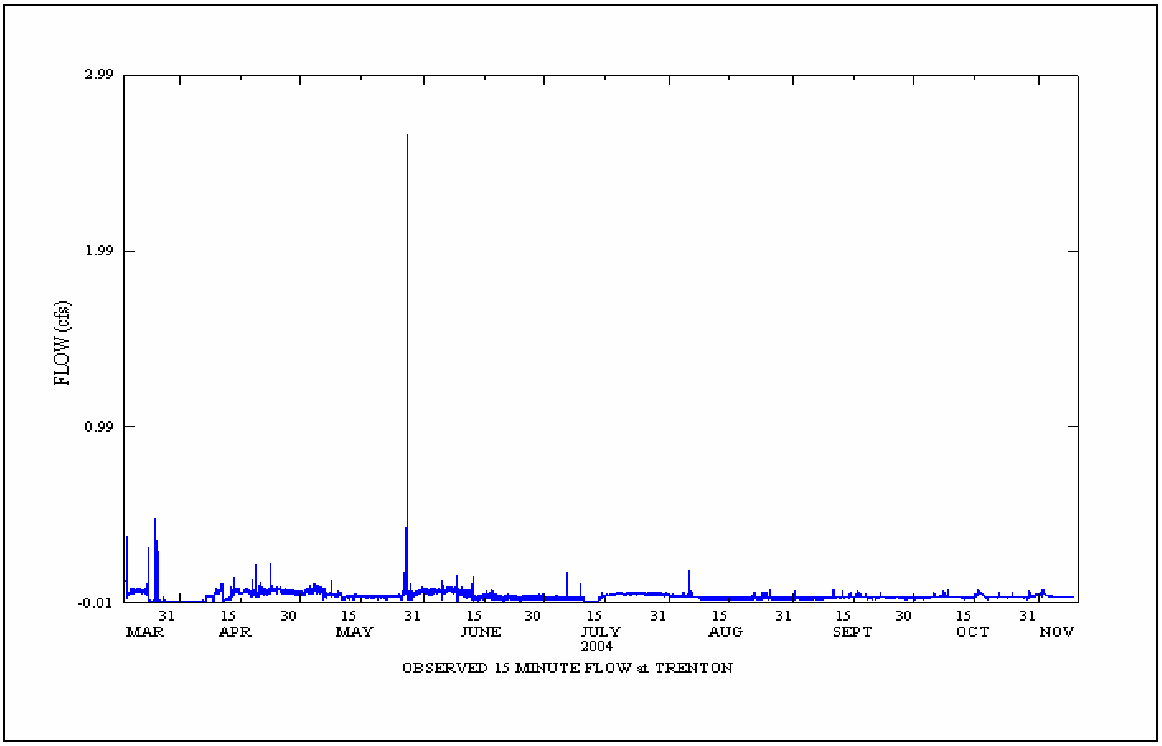

Figure A3.23. Observed 15 minute flow at Trenton, WA.

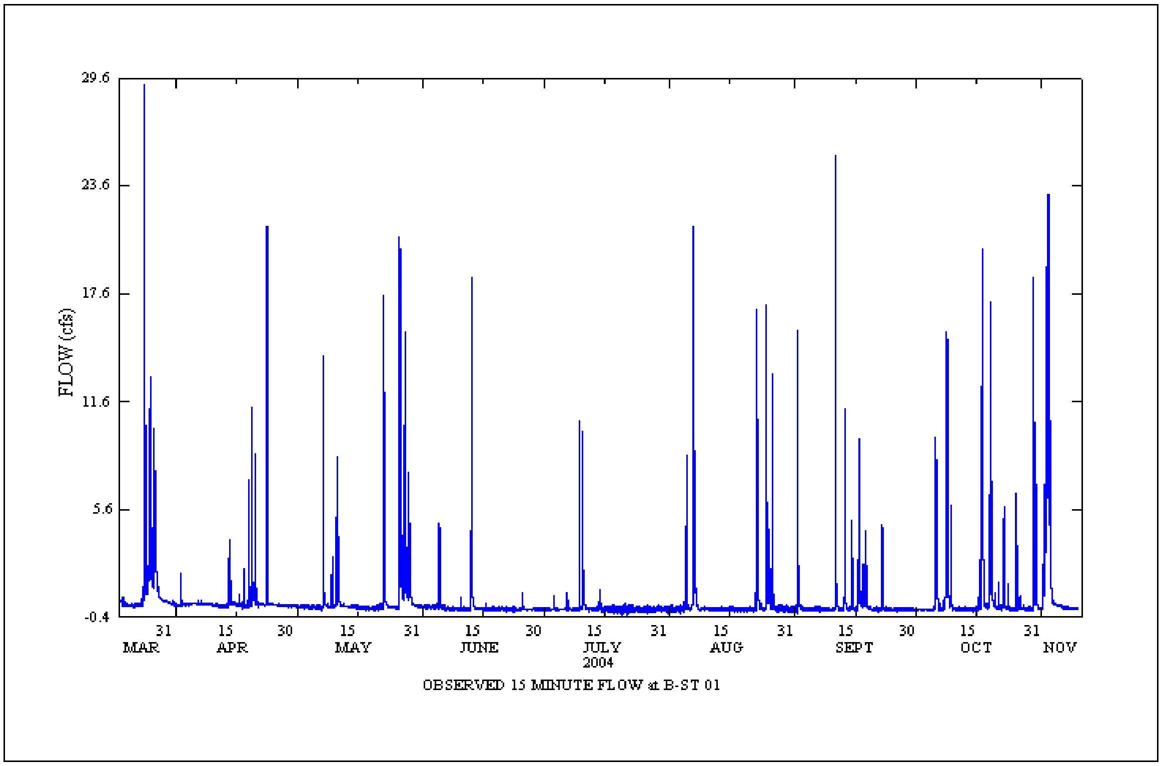

Figure A3.24. Observed 15 minute flow at B-ST 01, WA.

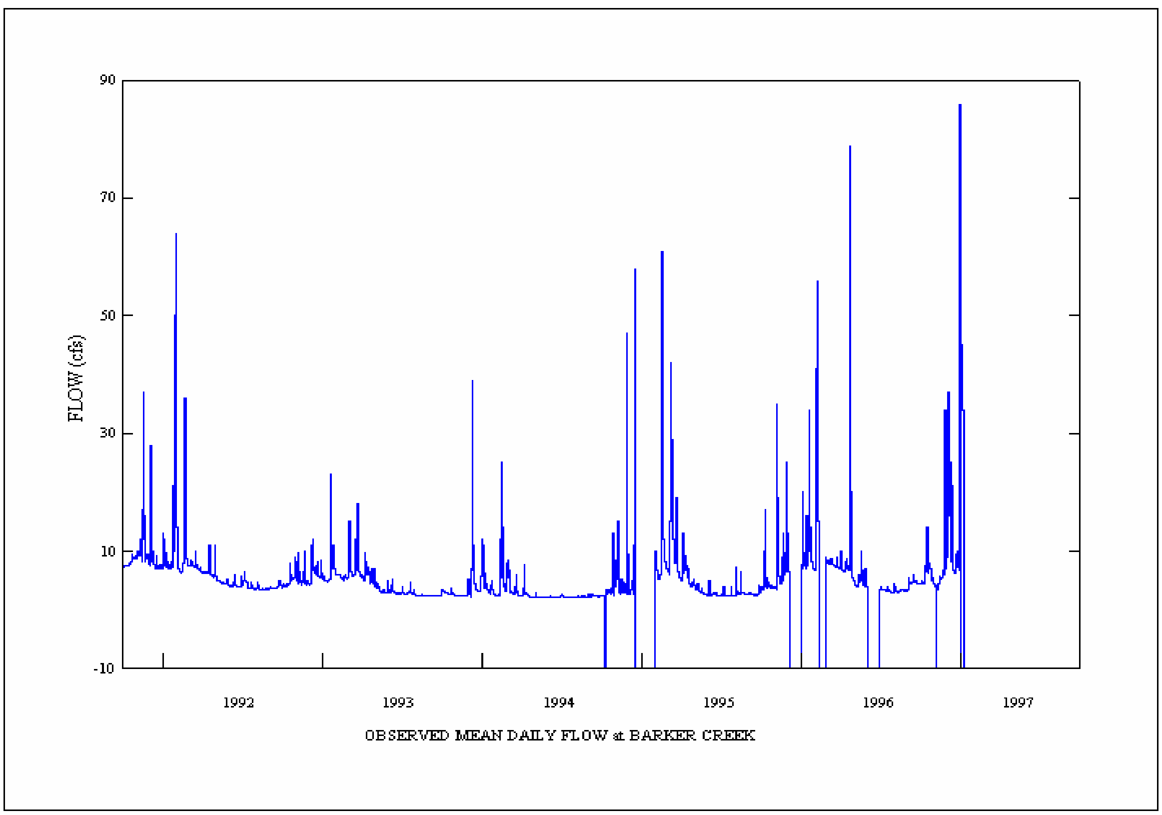

Figure A3.25. Observed mean daily flow at Barker Creek, WA.

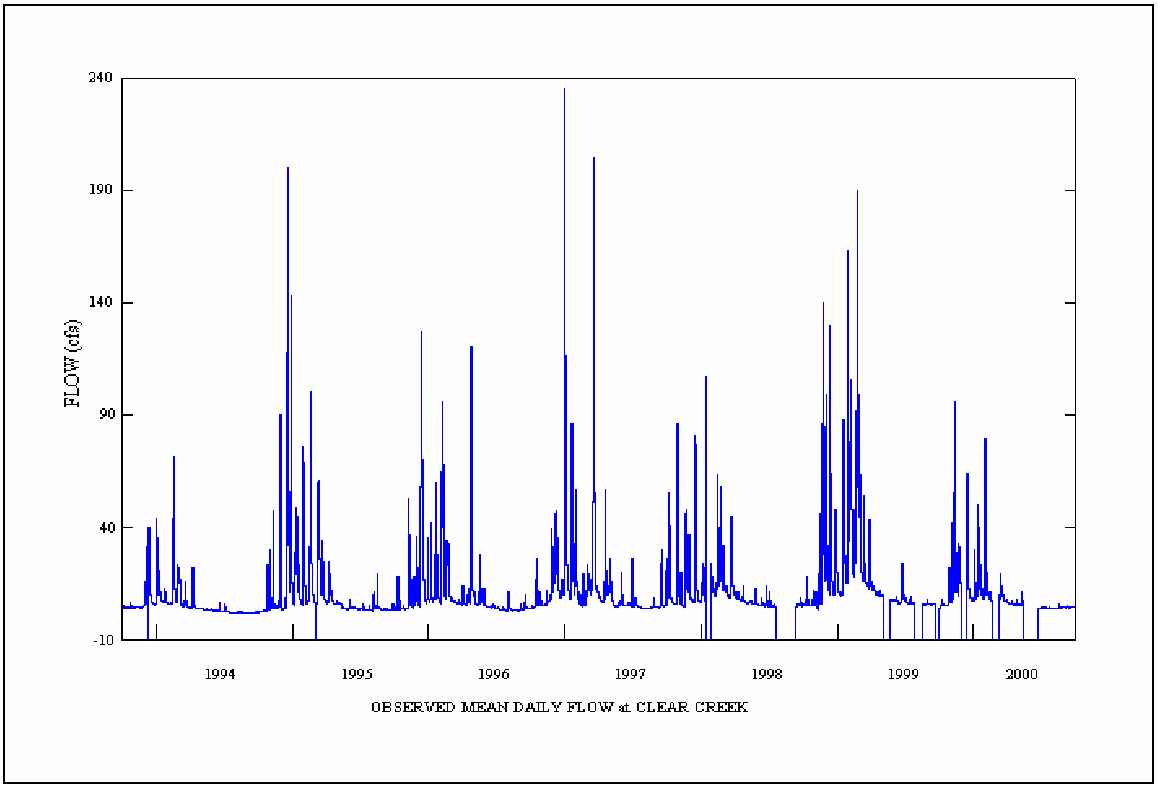

Figure A3.26. Observed mean daily flow at Clear Creek, WA.

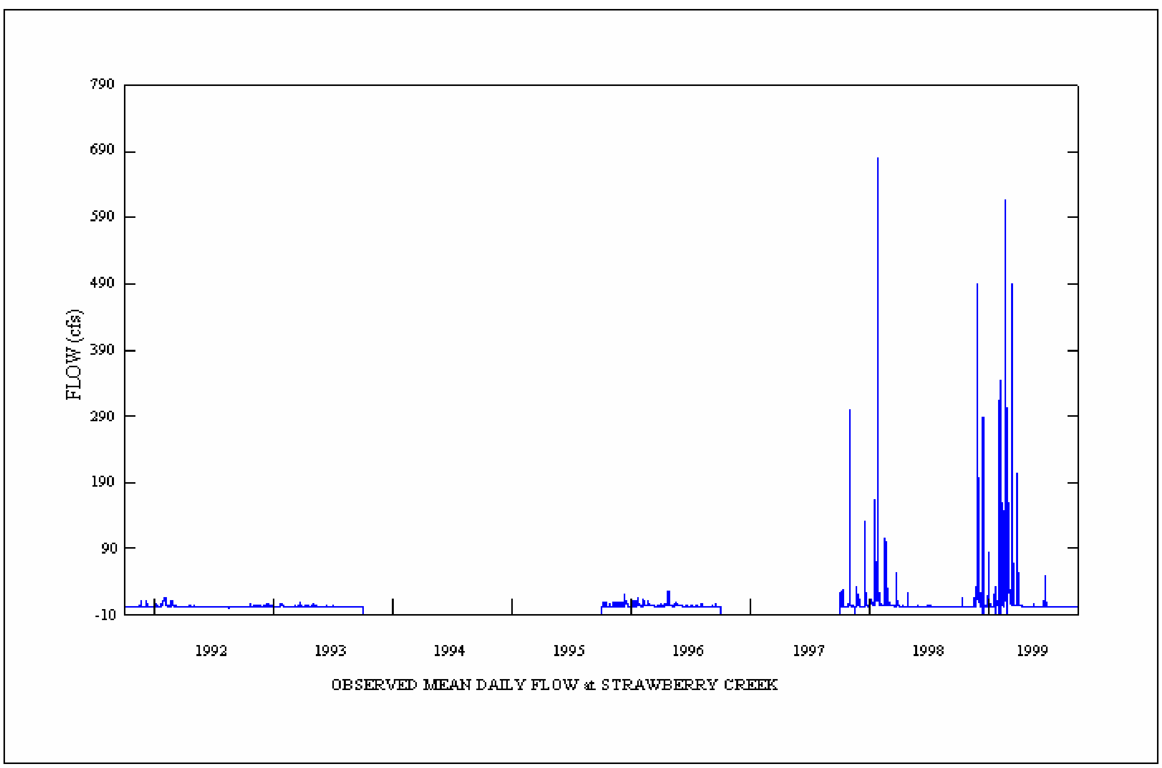

Figure A3.27. Observed mean daily flow at Strawberry Creek, WA.

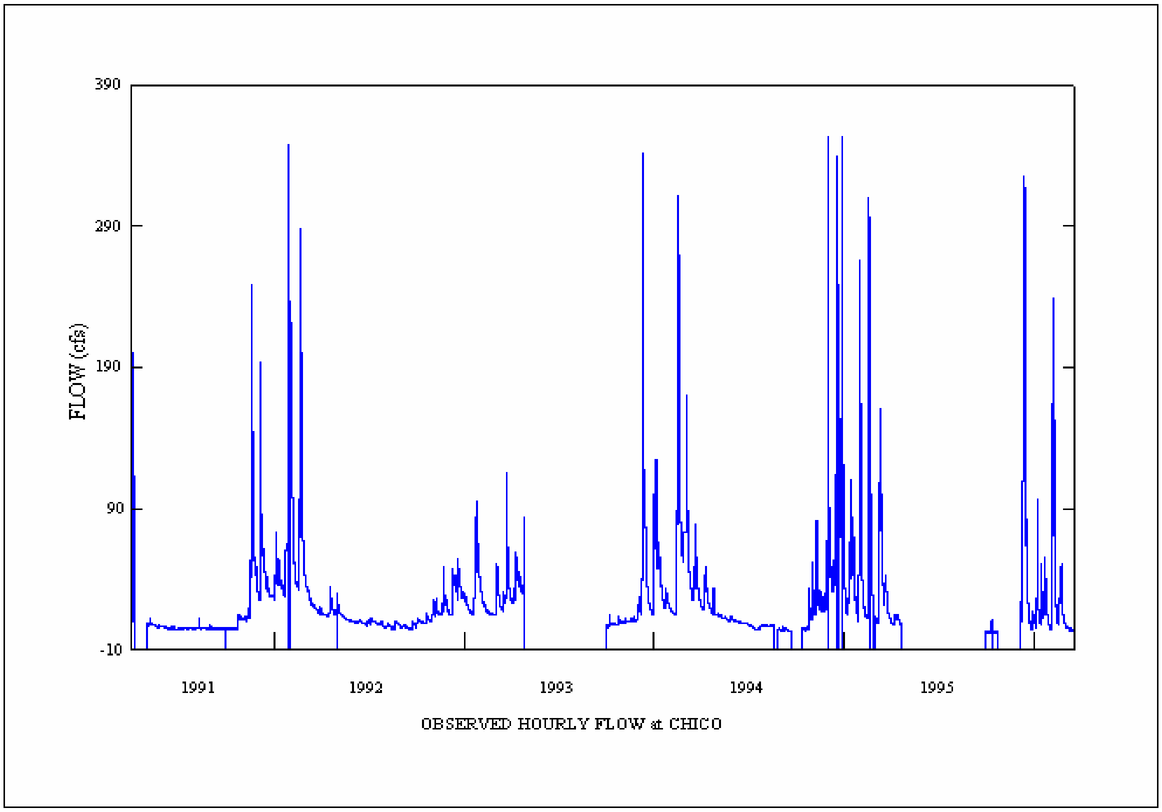

Figure A3.28. Observed hourly flow at Chico Creek, WA.

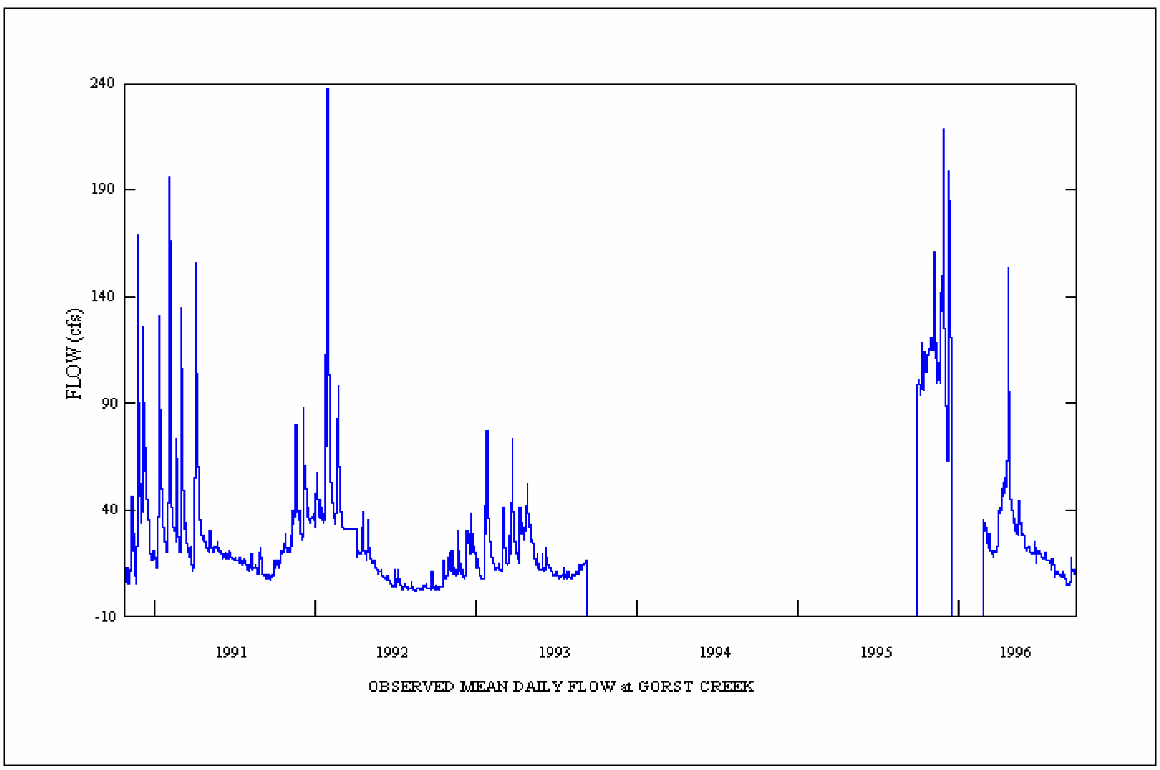

Figure A3.29. Observed mean daily flow at Gorst Creek, WA.

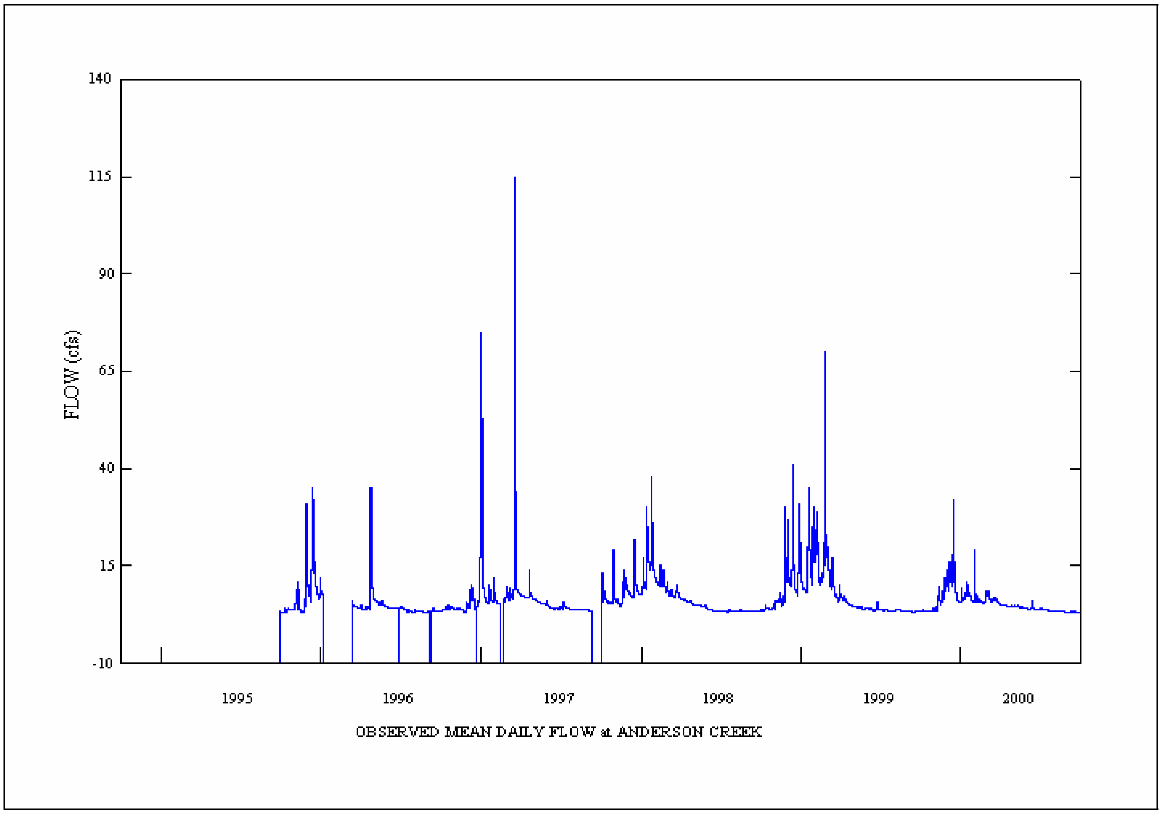

Figure A3.30. Observed mean daily flow at Anderson Creek, WA.

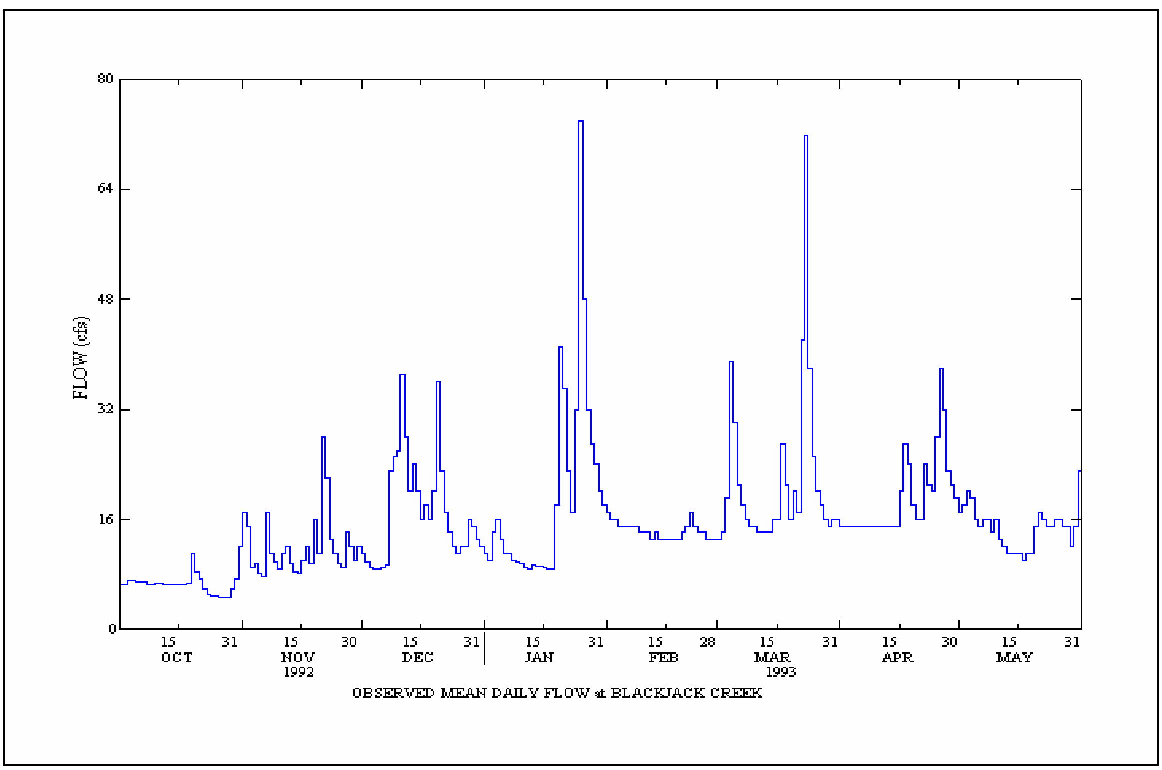

Figure A3.31. Observed mean daily flow at Blackjack Creek, WA.

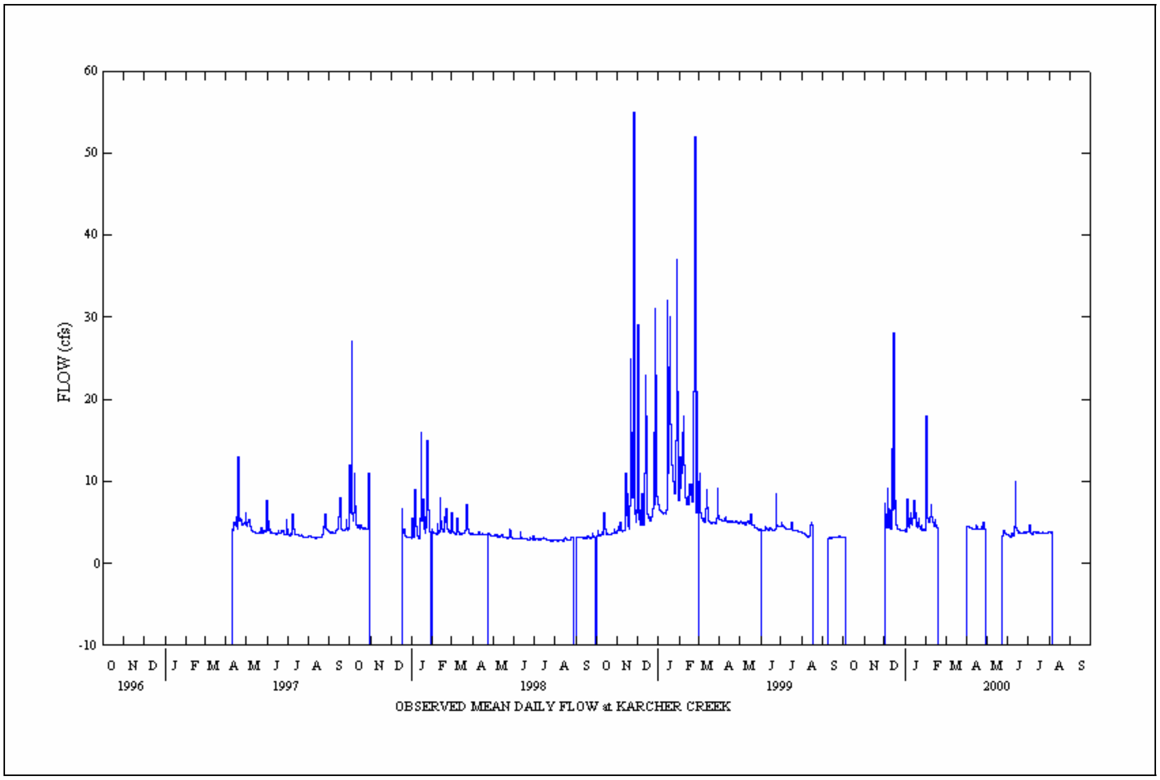

Figure A3.32. Observed mean daily flow at Karcher Creek, WA.

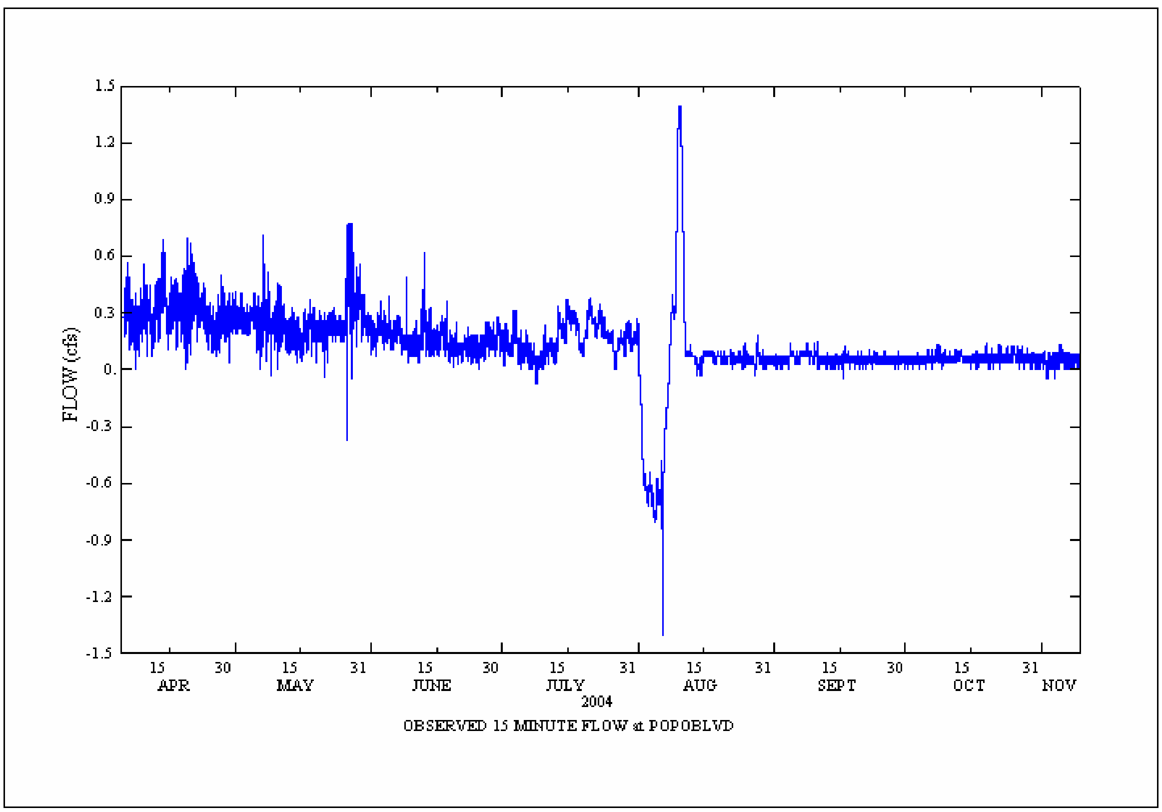

Figure A3.33. Observed 15 minute flow at POPOBLVD.

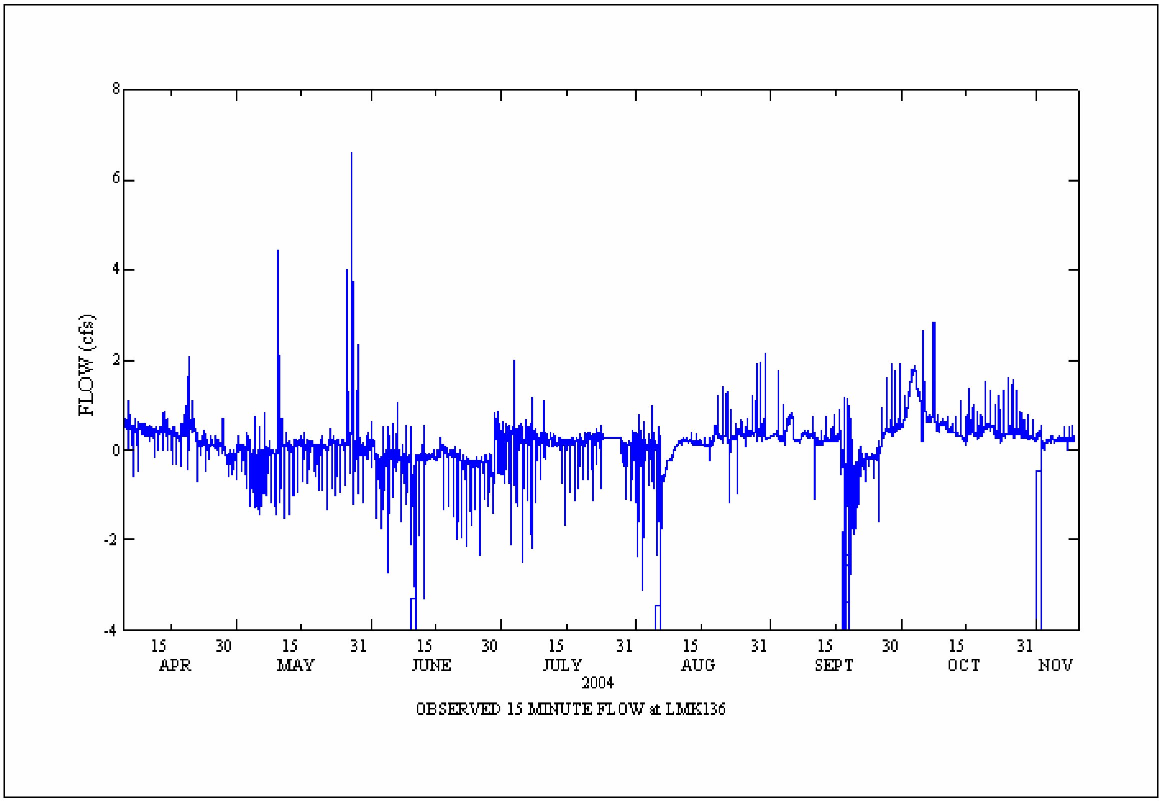

Figure A3.34. Observed 15 minute flow at LMK136.

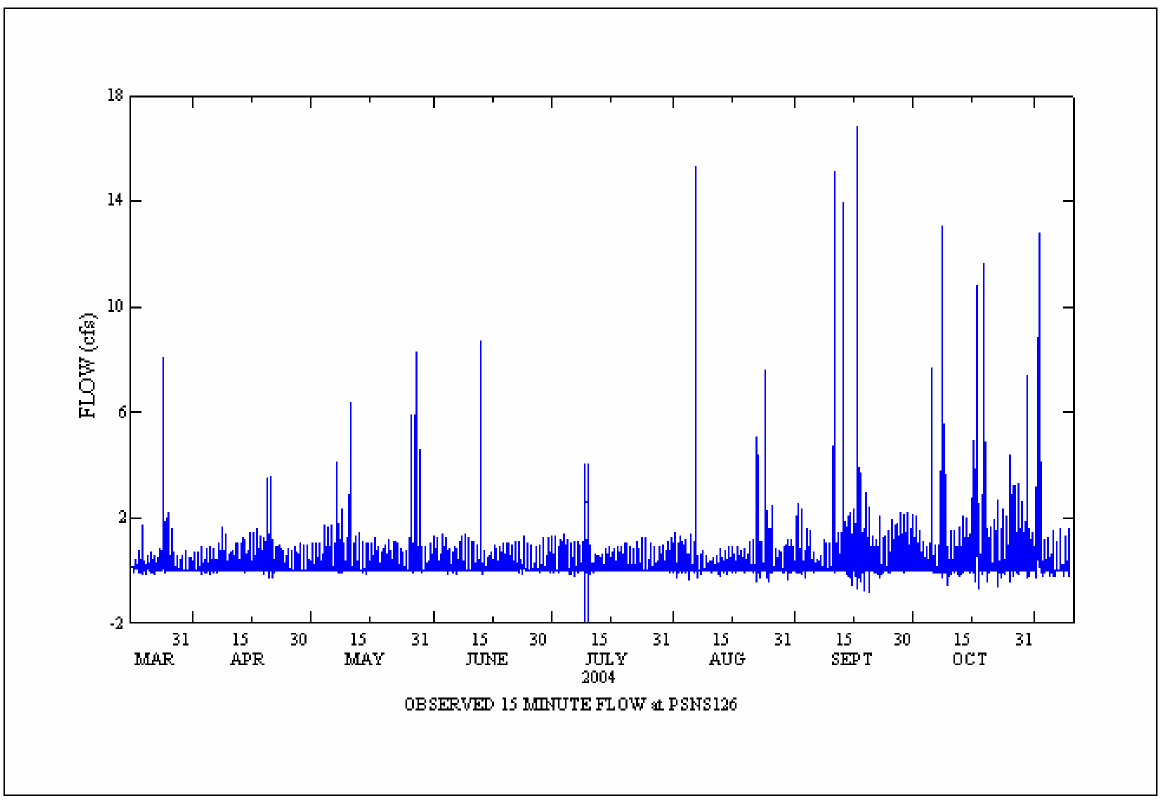

Figure A3.35. Observed 15 minute flow at PSNS126.

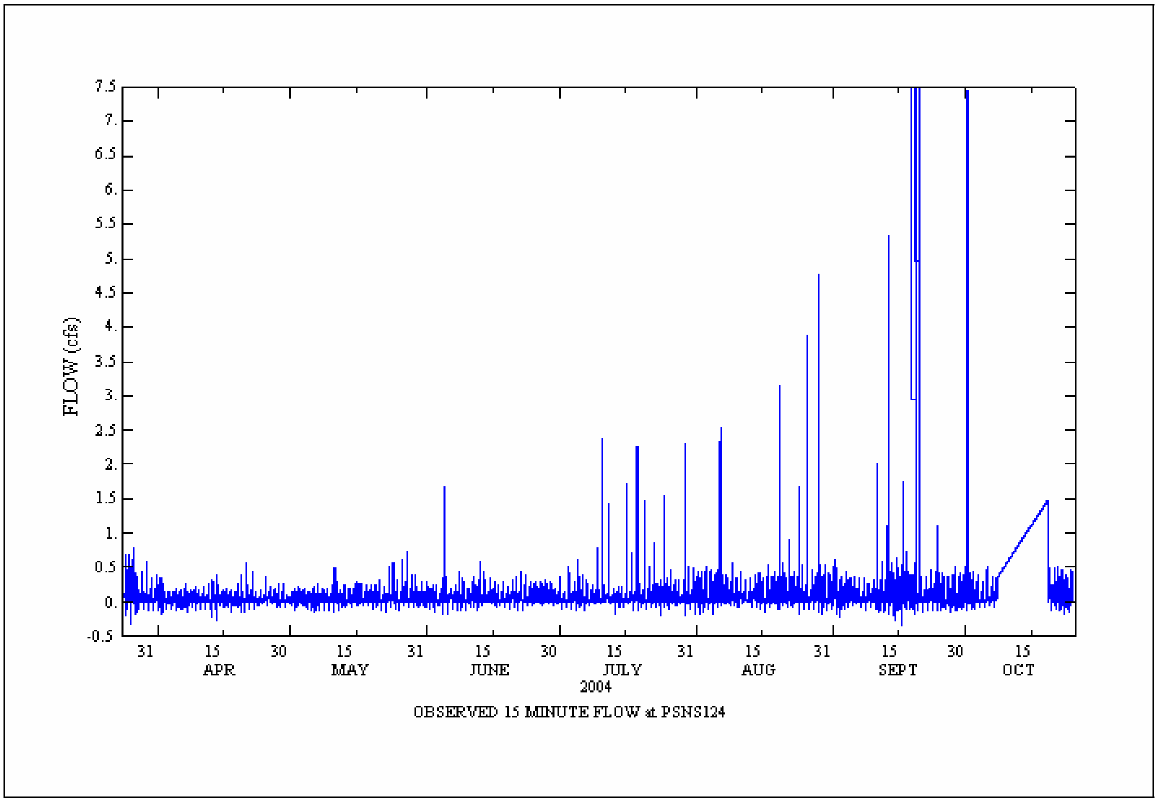

Figure A3.36. Observed 15 minute flow at PSNS124.

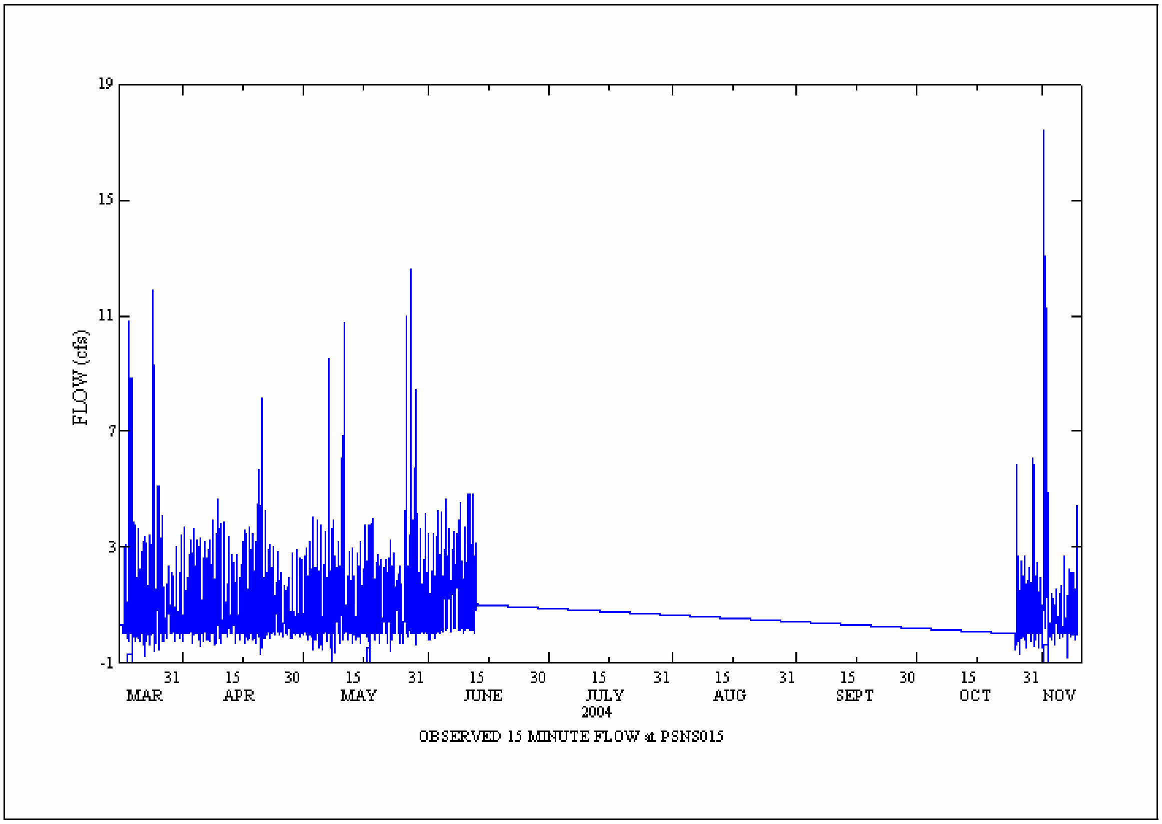

Figure A3.37. Observed 15 minute flow at PSNS015.

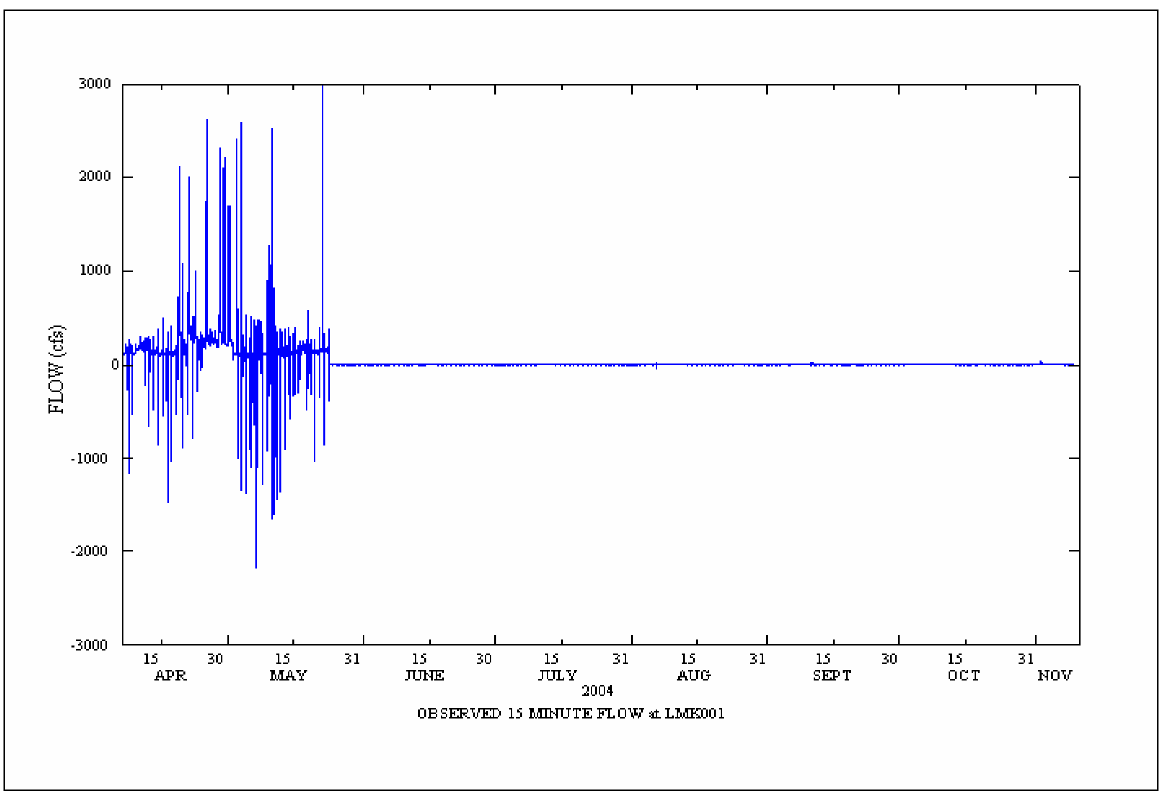

Figure A3.38. Observed 15 minute flow at LMK001.

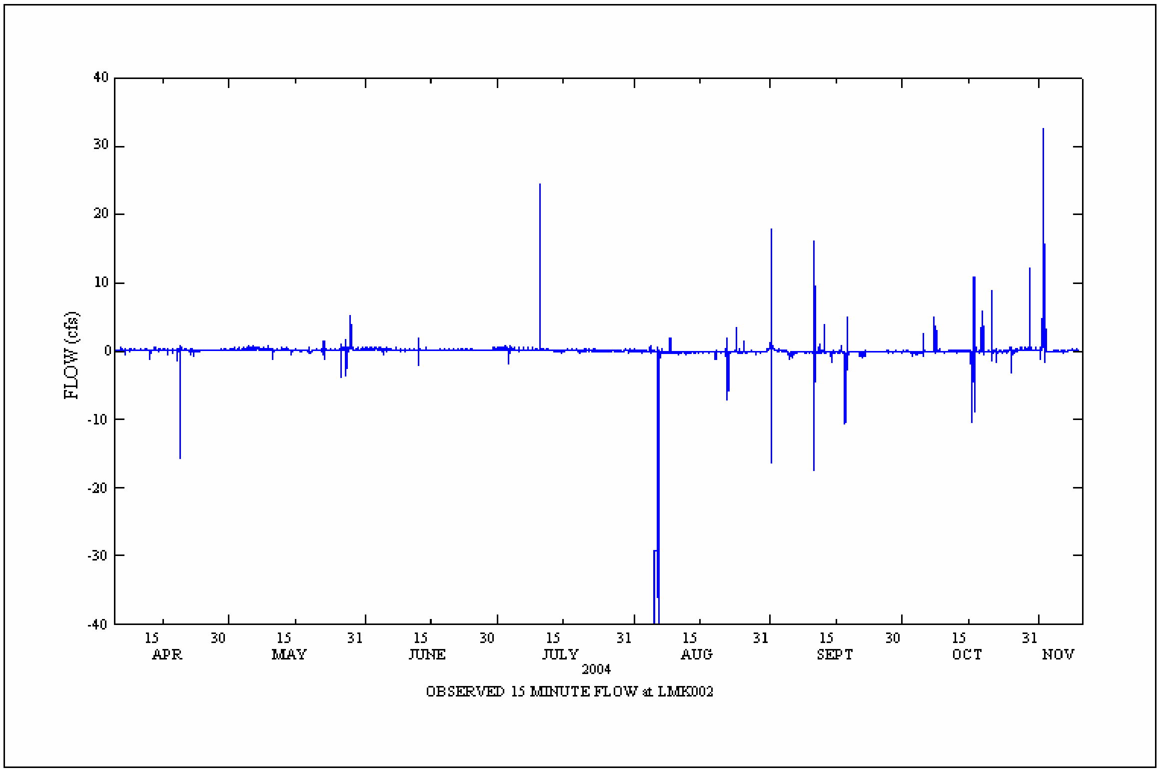

Figure A3.39. Observed 15 minute flow at LMK002.

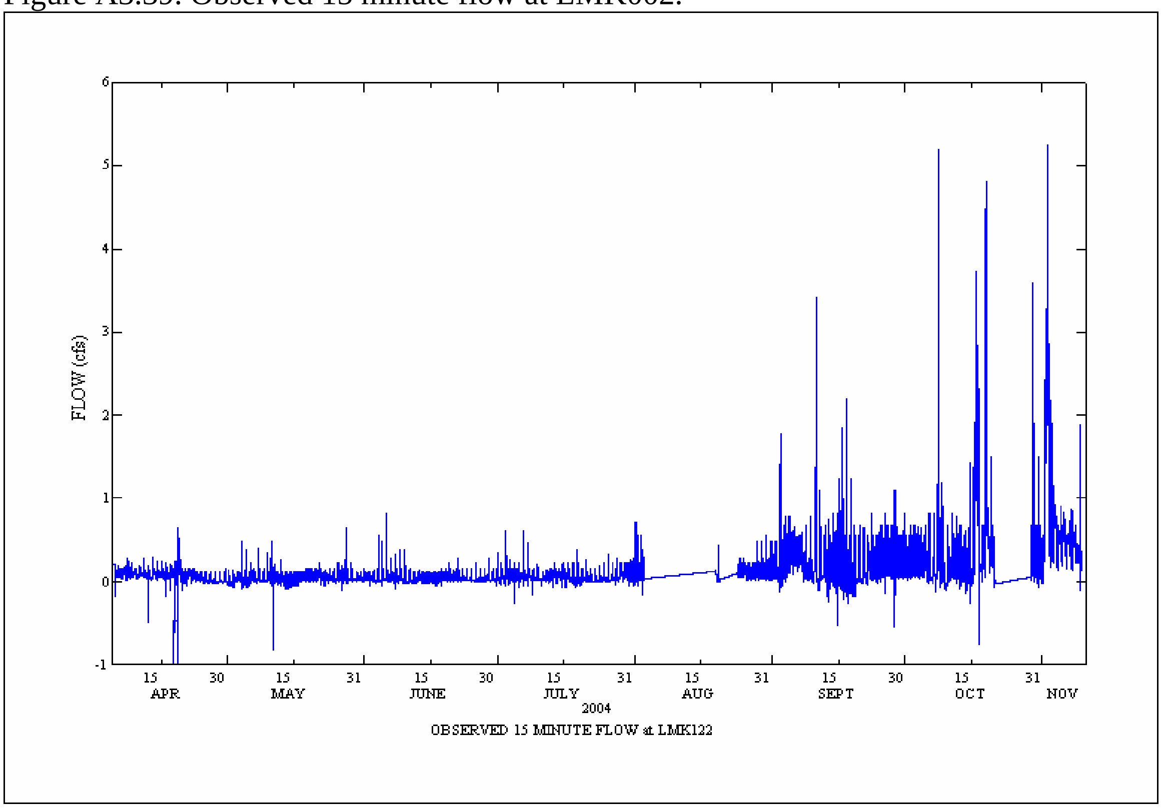

Figure A3.40. Observed 15 minute flow at LMK122.

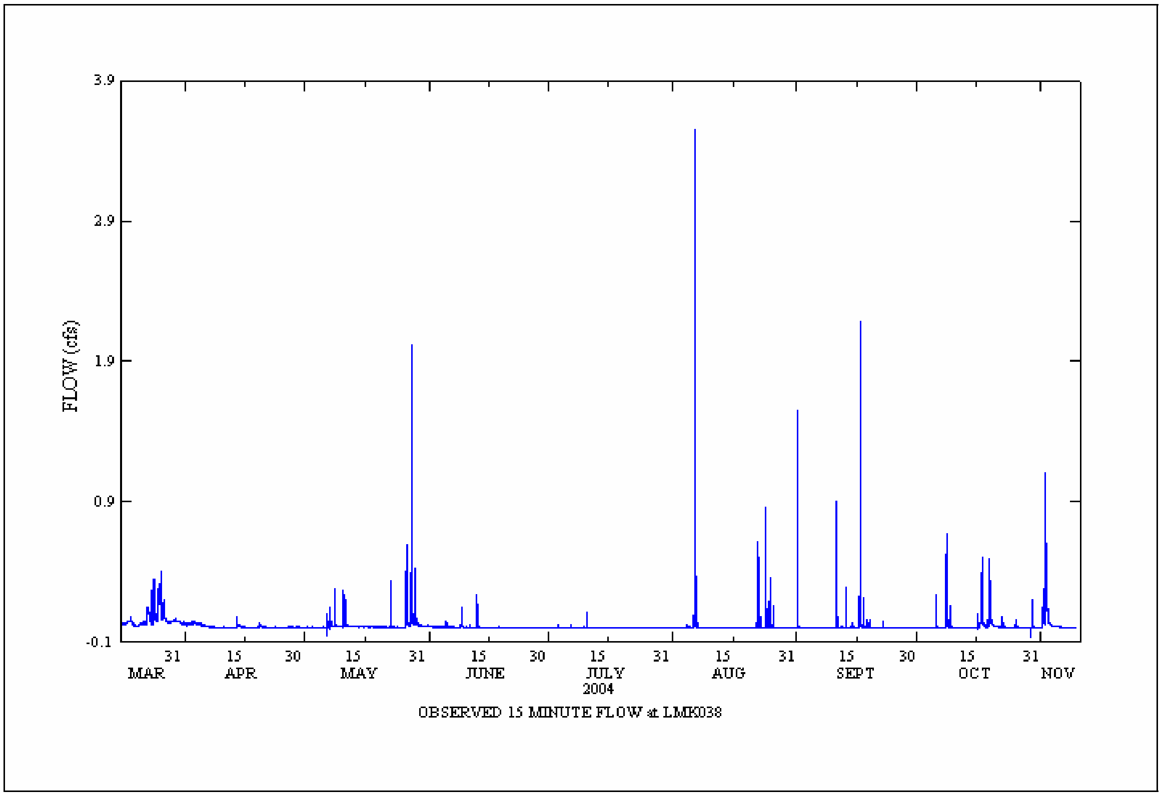

Figure A3.41. Observed 15 minute flow at LMK038.

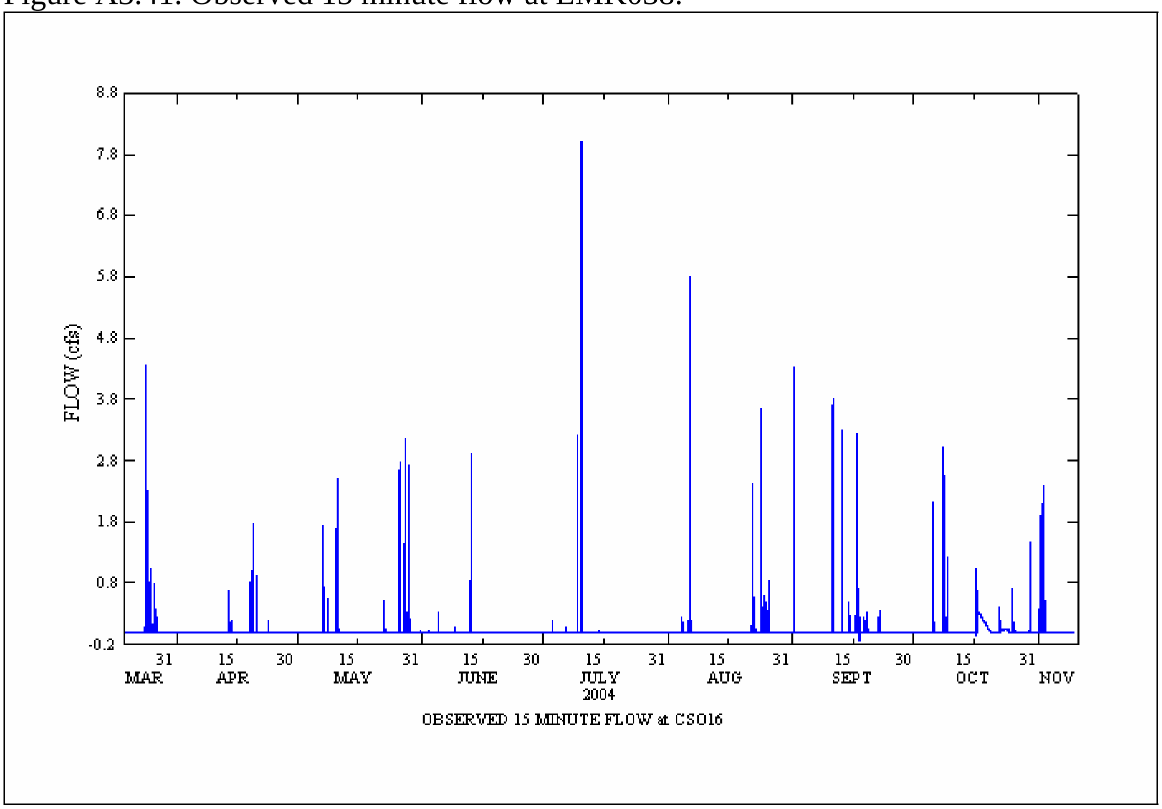

Figure A3.42. Observed 15 minute flow at CS016.

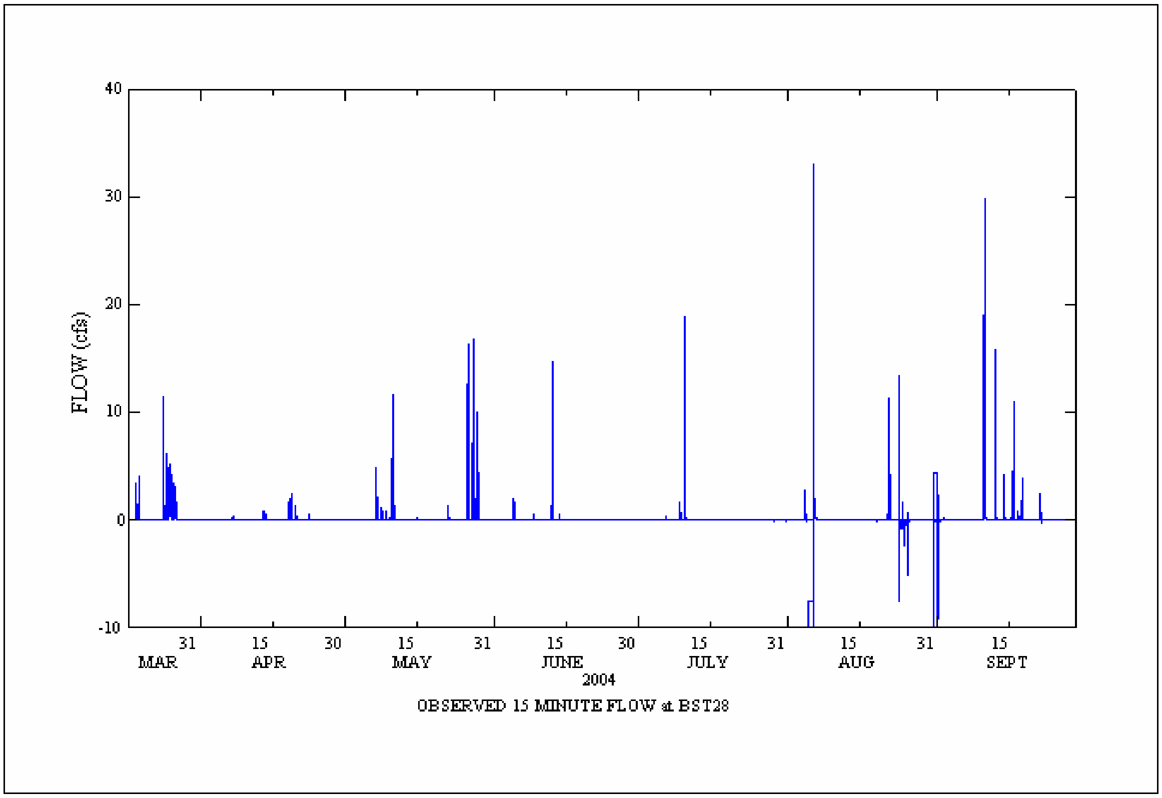

Figure A3.43. Observed 15 minute flow at BST28.

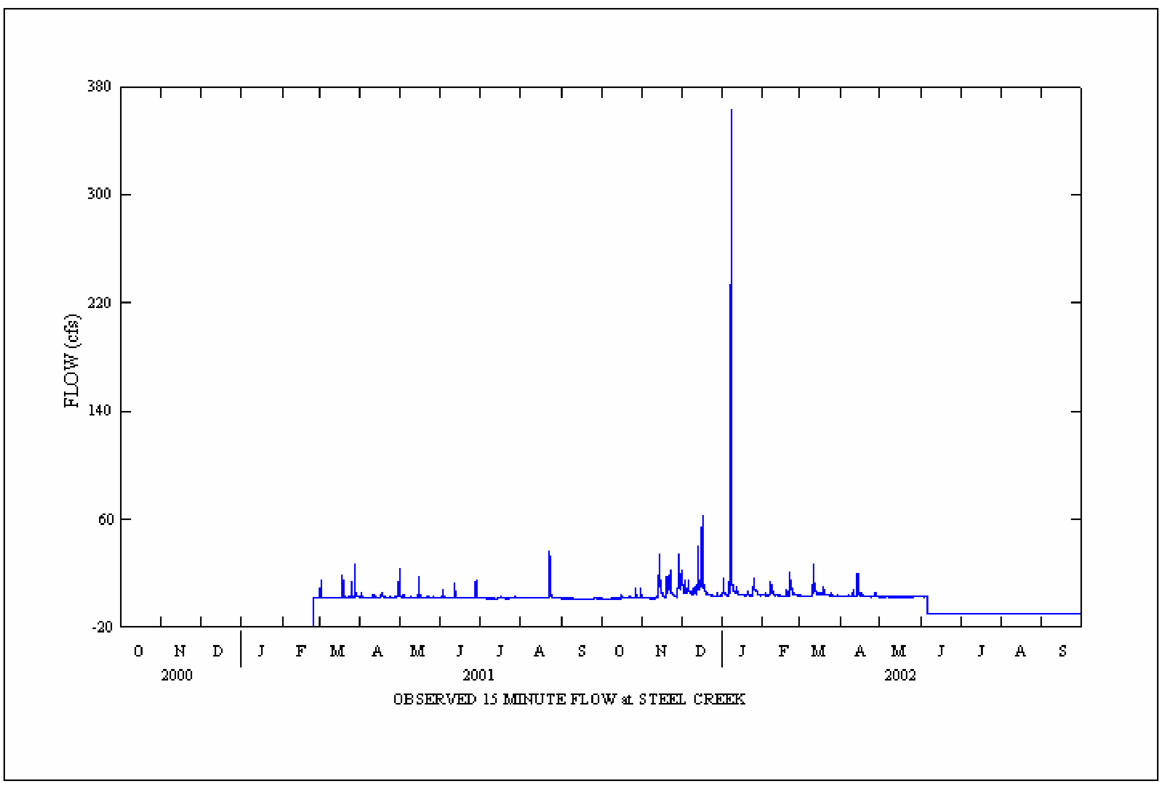

Figure A3.44. Observed 15 minute flow at Steel Creek, WA.

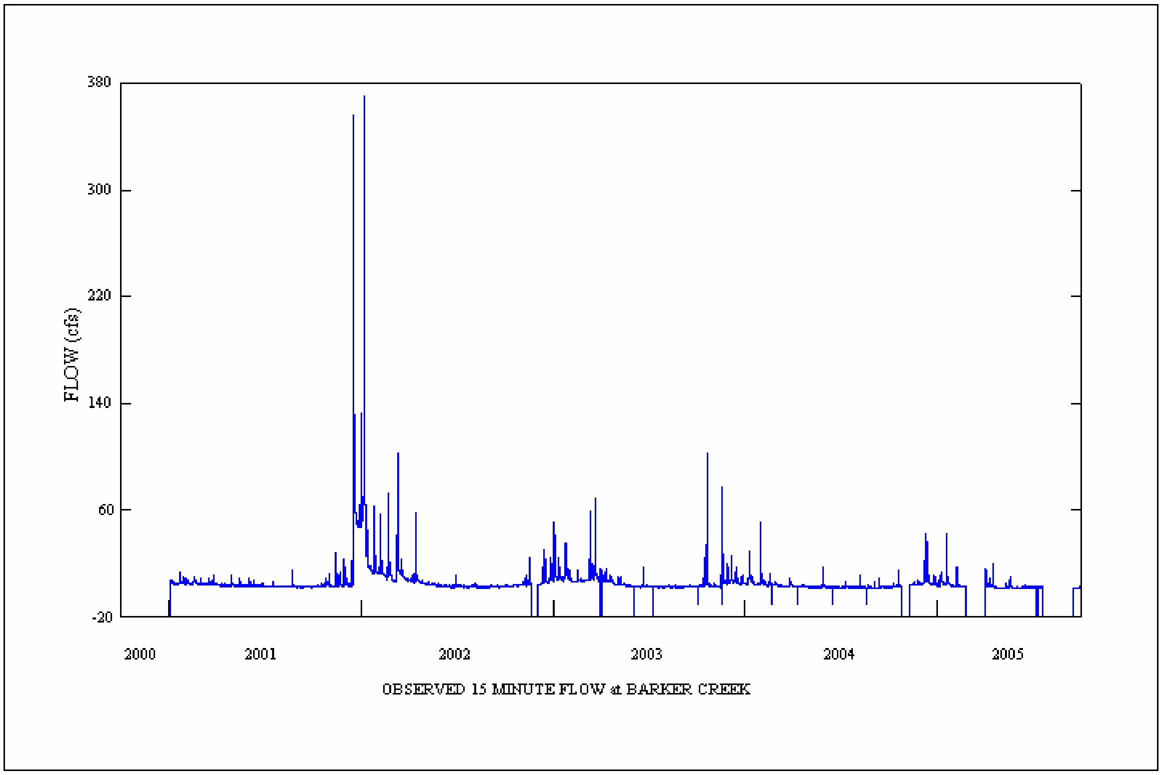

Figure A3.45. Observed 15 minute flow at Barker Creek, WA.

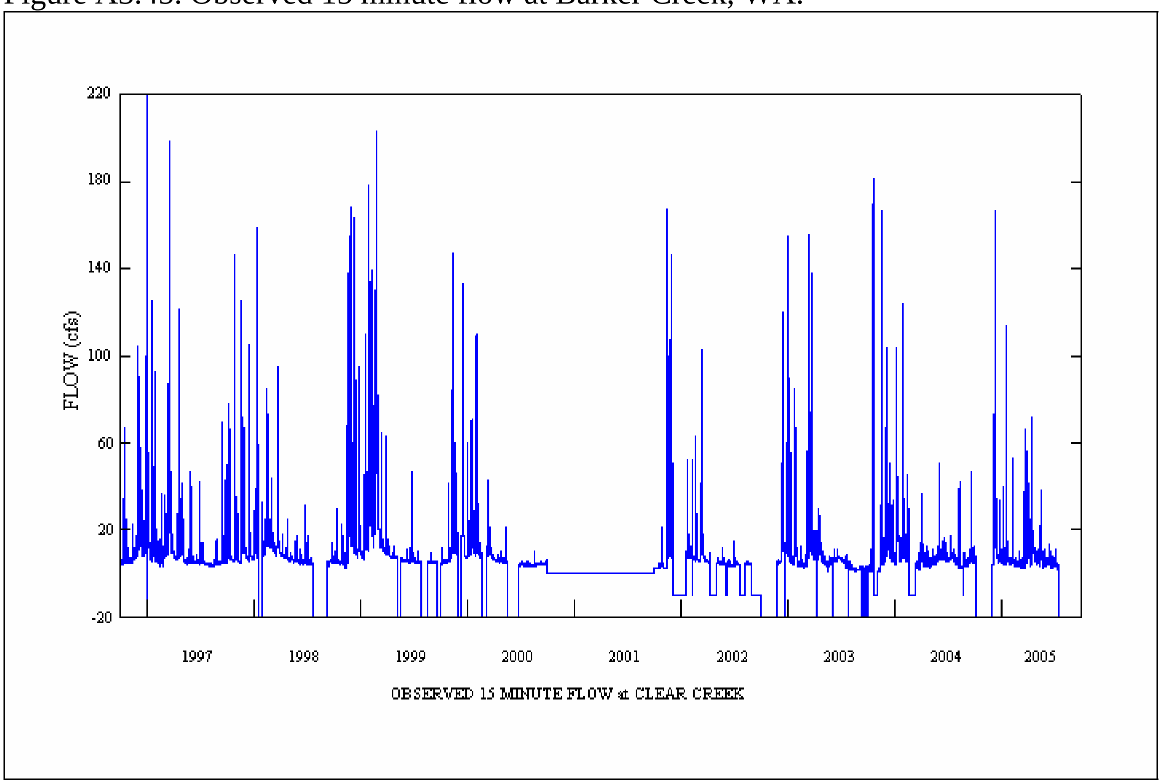

Figure A3.46. Observed 15 minute flow at Clear Creek, WA.

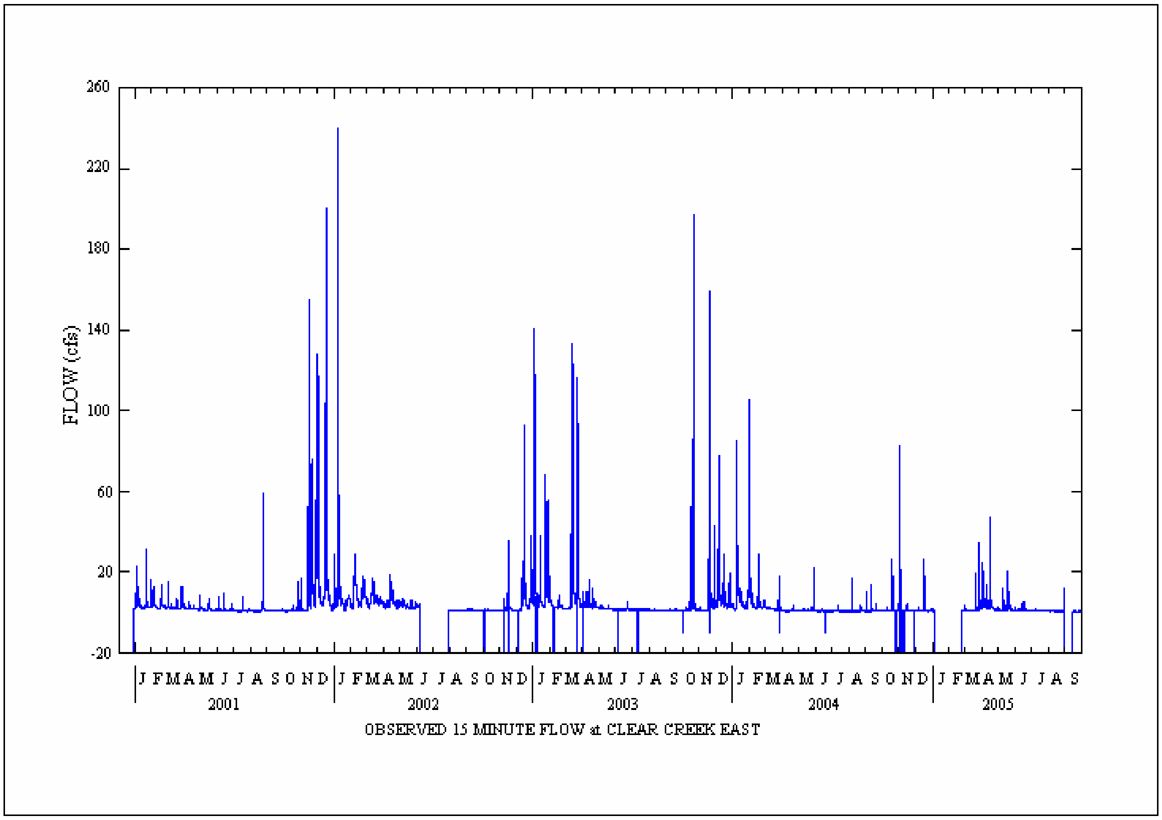

Figure A3.47. Observed 15 minute flow at Clear Creek East Tributary, WA.

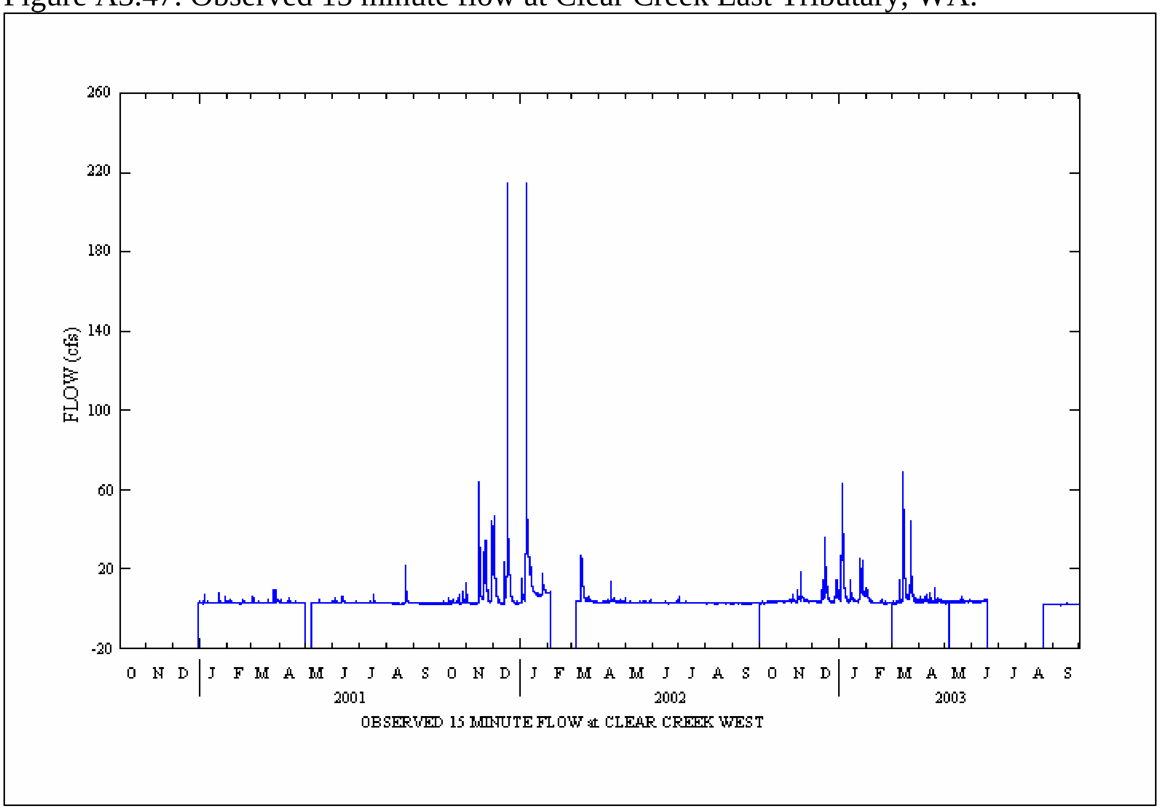

Figure A3.48. Observed 15 minute flow at Clear Creek West Tributary, WA.

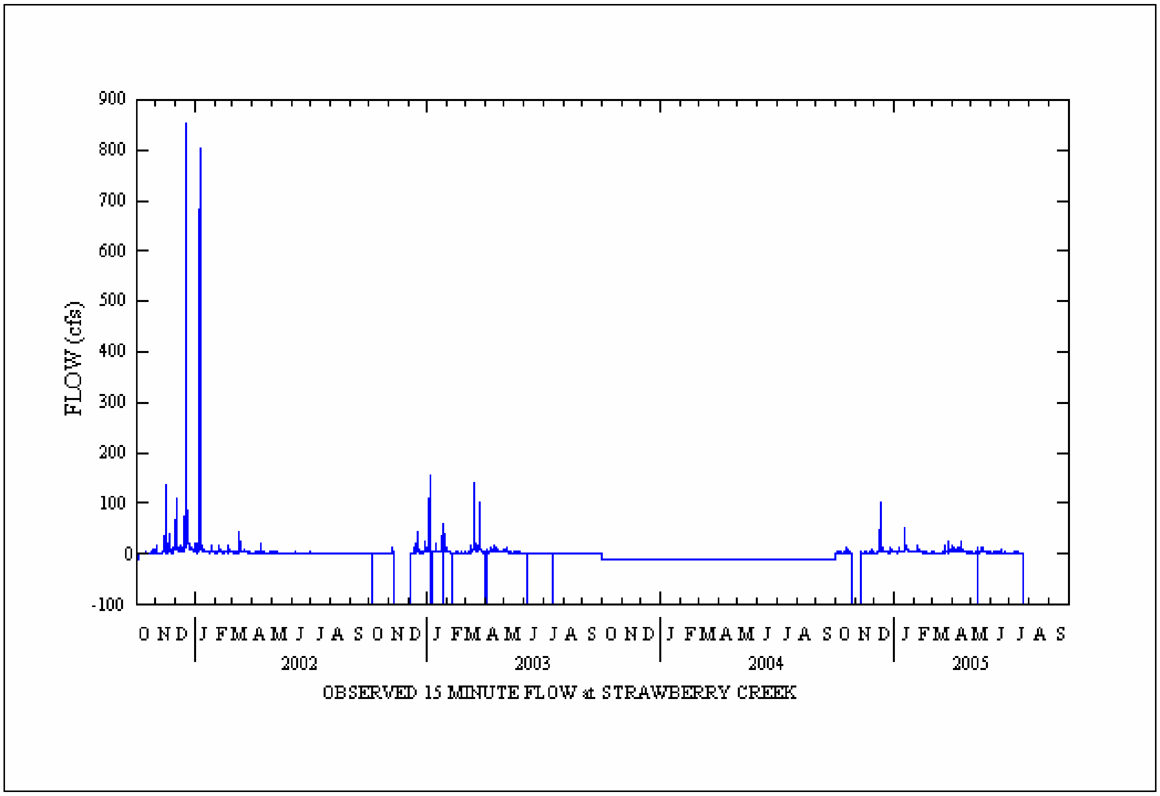

Figure A3.49. Observed 15 minute flow at Strawberry Creek, WA.

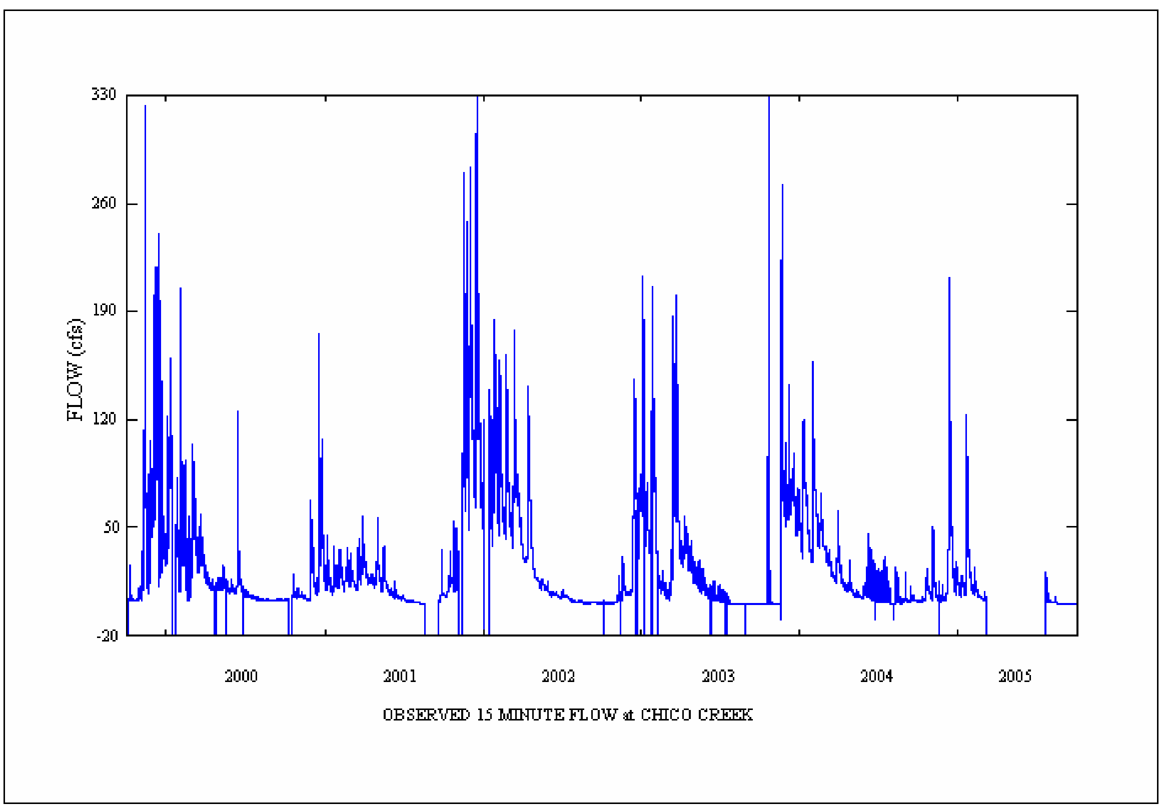

Figure A3.50. Observed 15 minute flow at Chico Creek, WA.

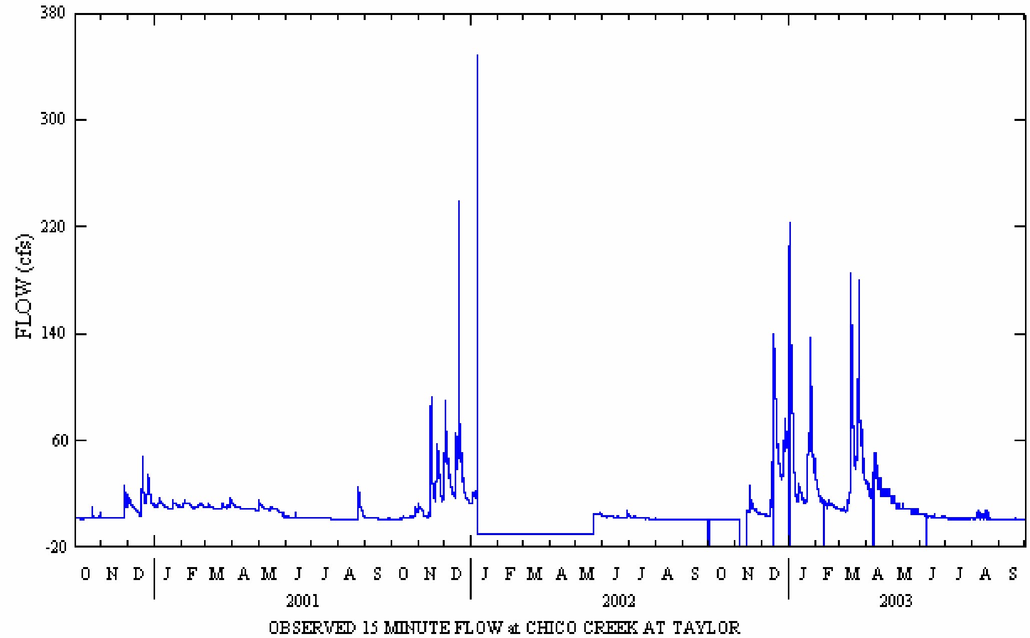

Figure A3.51. Observed 15 minute flow at Chico Creek at Taylor Tributary, WA.

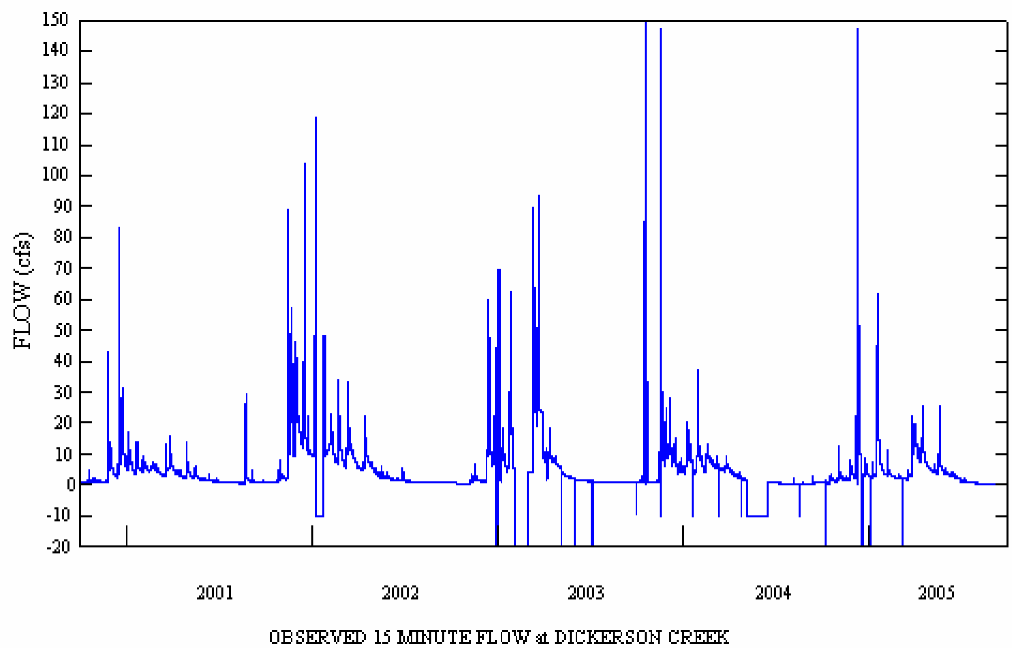

Figure A3.52. Observed 15 minute flow at Dickerson Creek, WA.

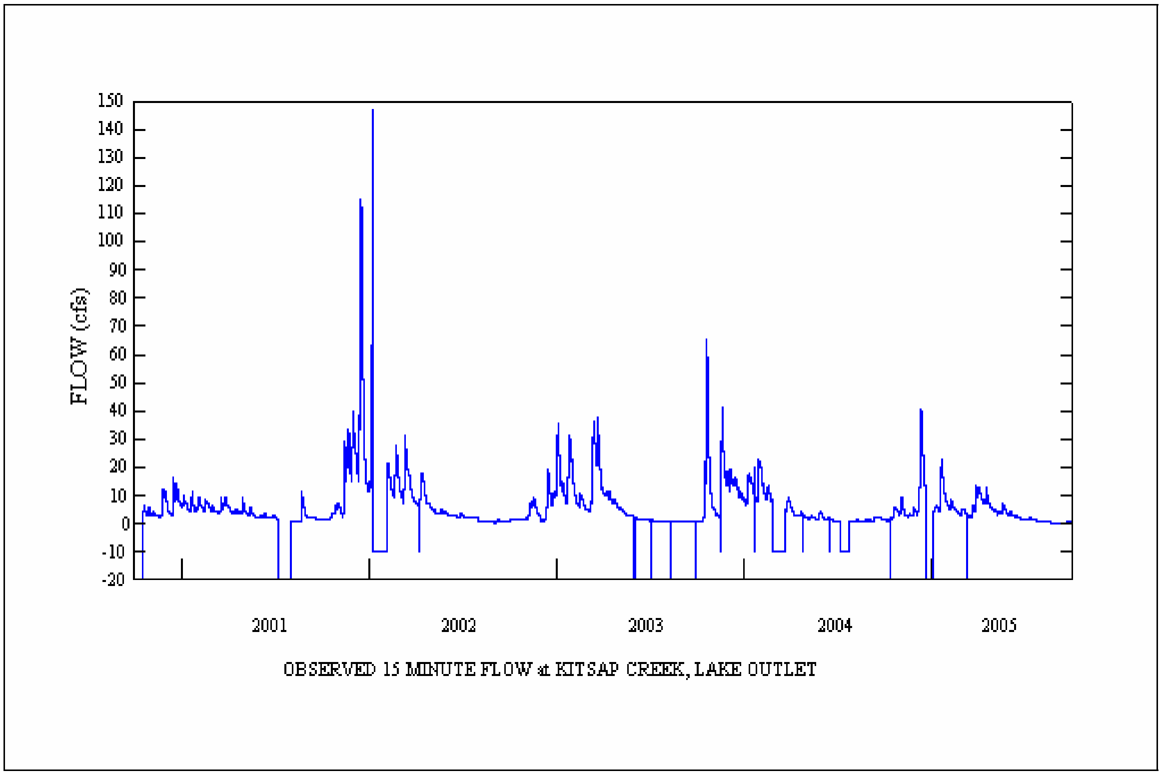

Figure A3.53. Observed 15 minute flow at Kitsap Creek, WA, lake outlet.

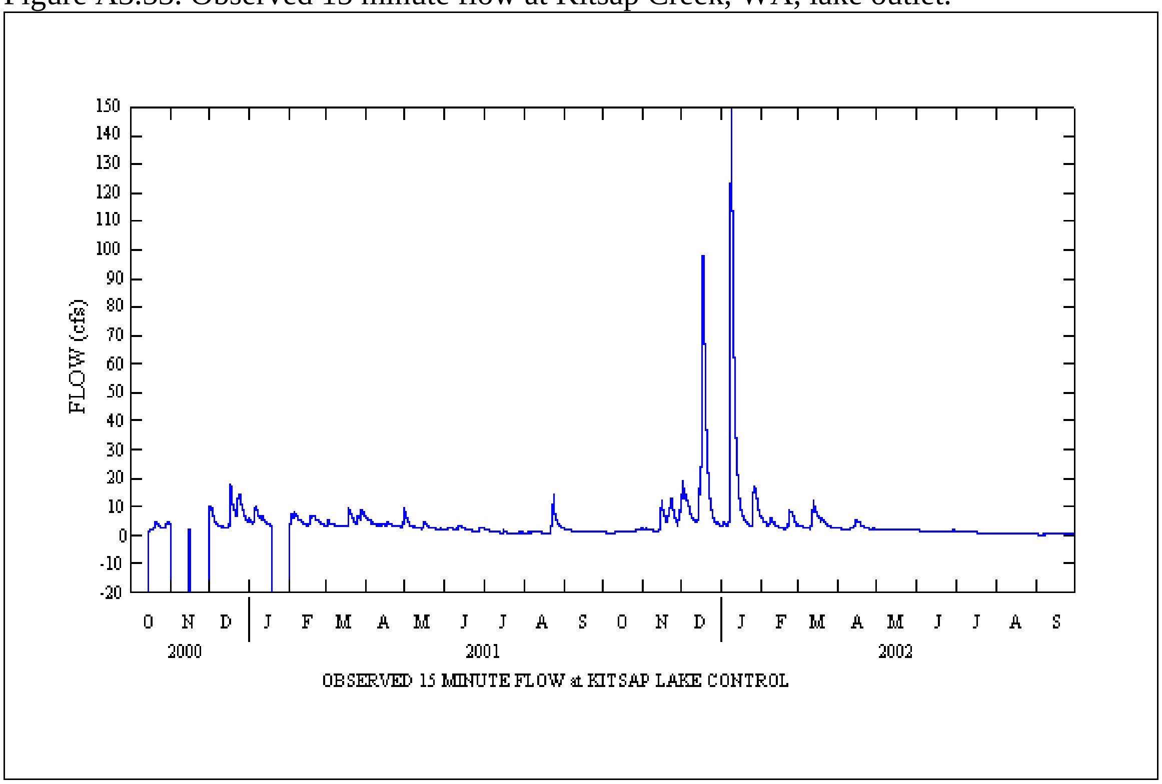

Figure A3.54. Observed 15 minute flow at Kitsap Creek, WA, lake control.

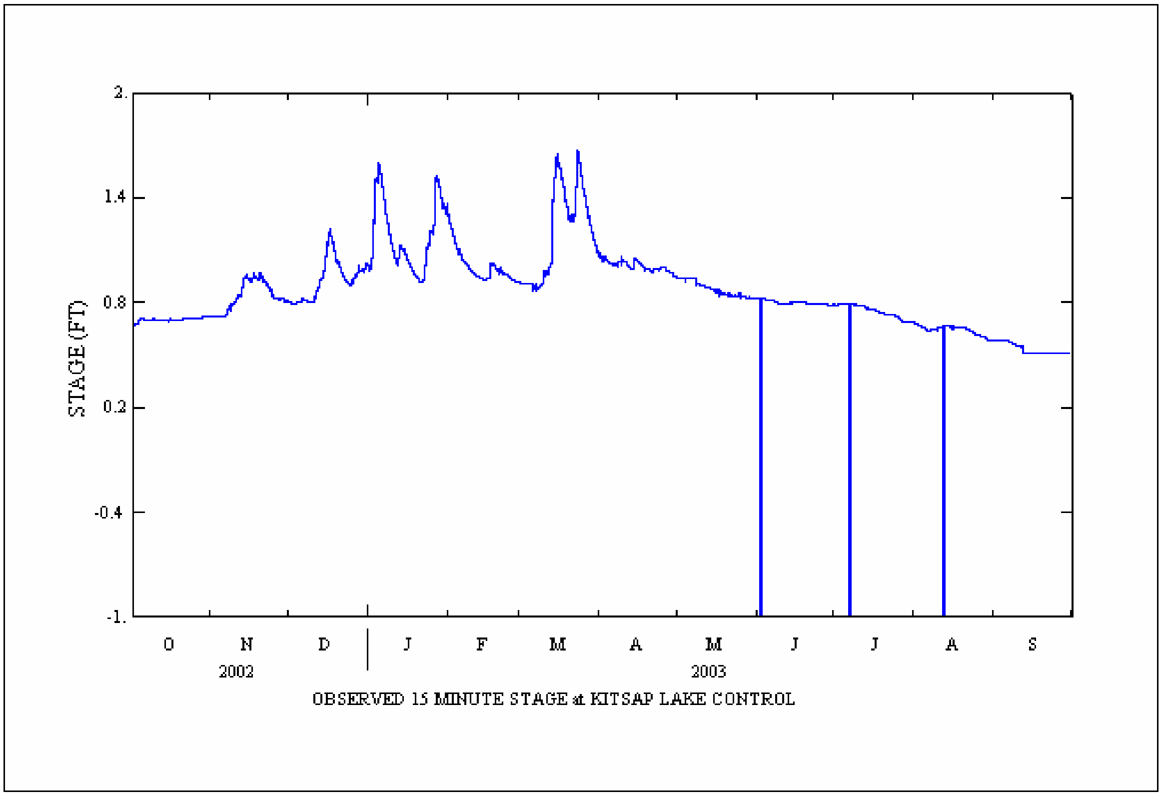

Figure A3.55. Observed 15 minute stage at Kitsap, WA, lake control.

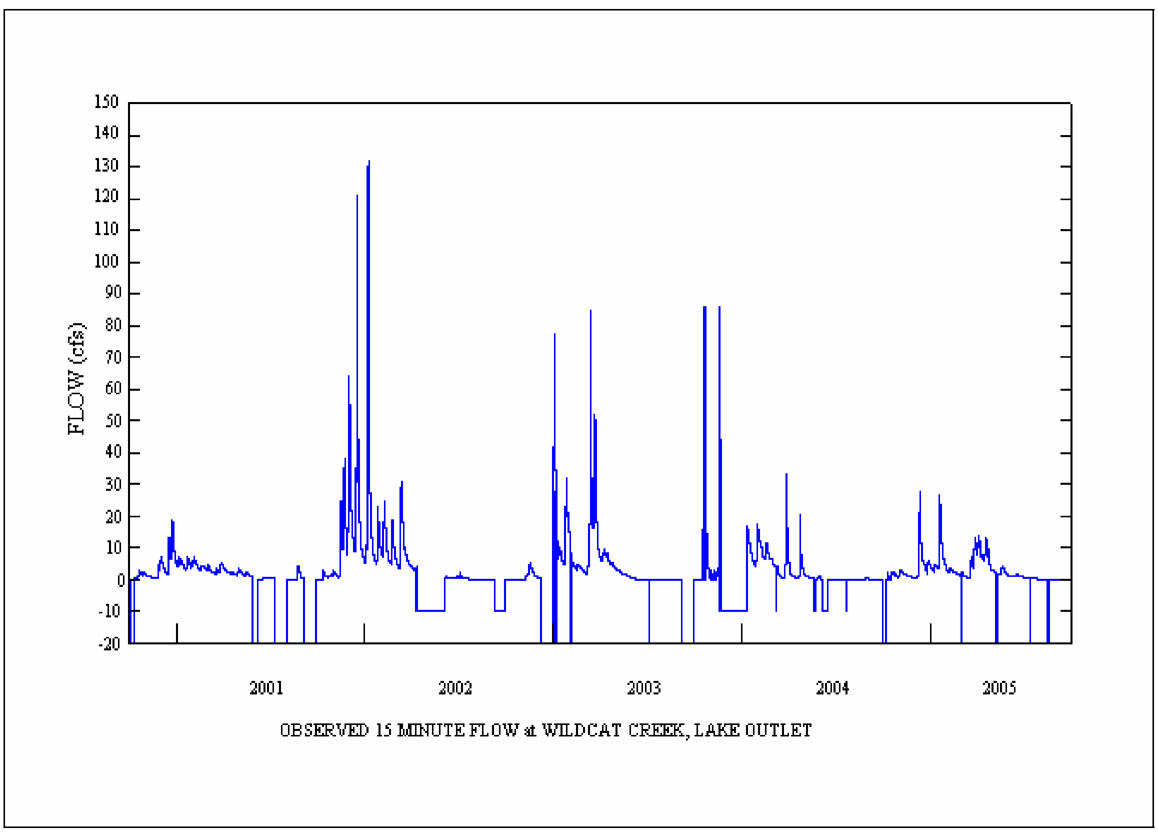

Figure A3.56. Observed 15 minute flow at Wildcat Creek, WA, lake outlet.

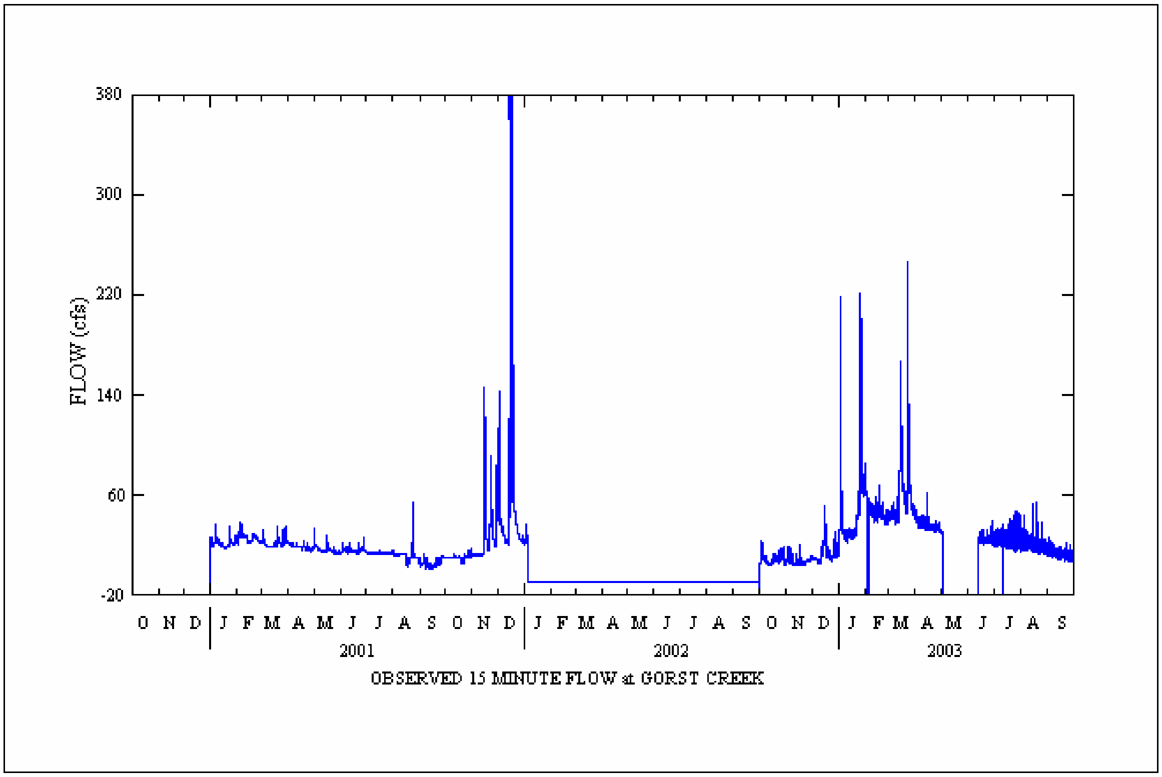

Figure A3.57. Observed 15 minute flow at Gorst Creek, WA.

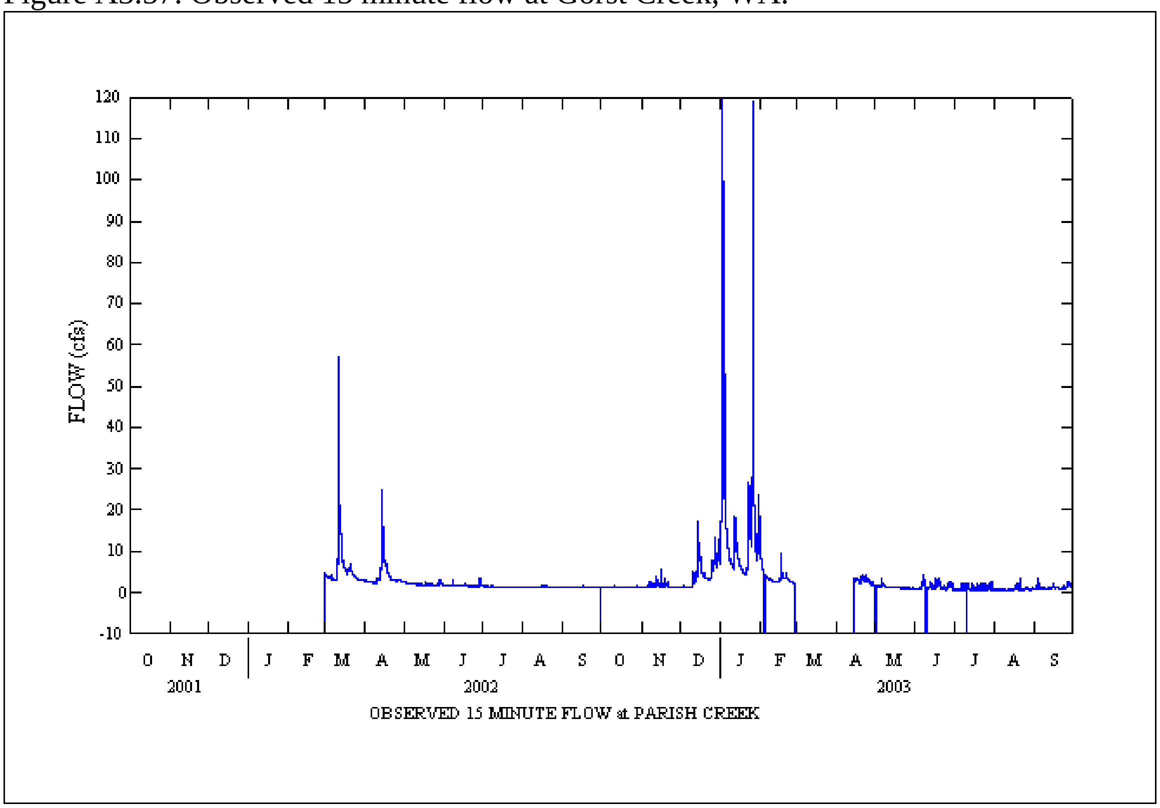

Figure A3.58. Observed 15 minute flow at Parish Creek, WA.

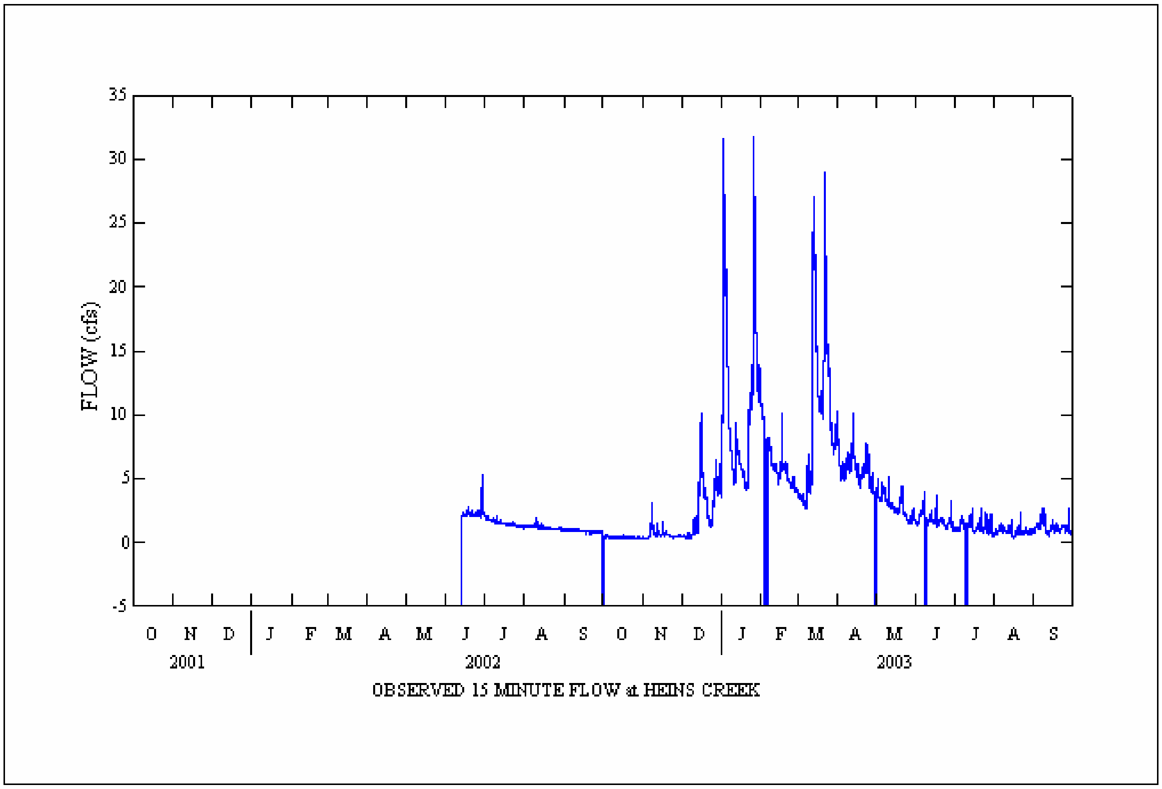

Figure A3.59. Observed 15 minute flow at Heins Creek, WA.

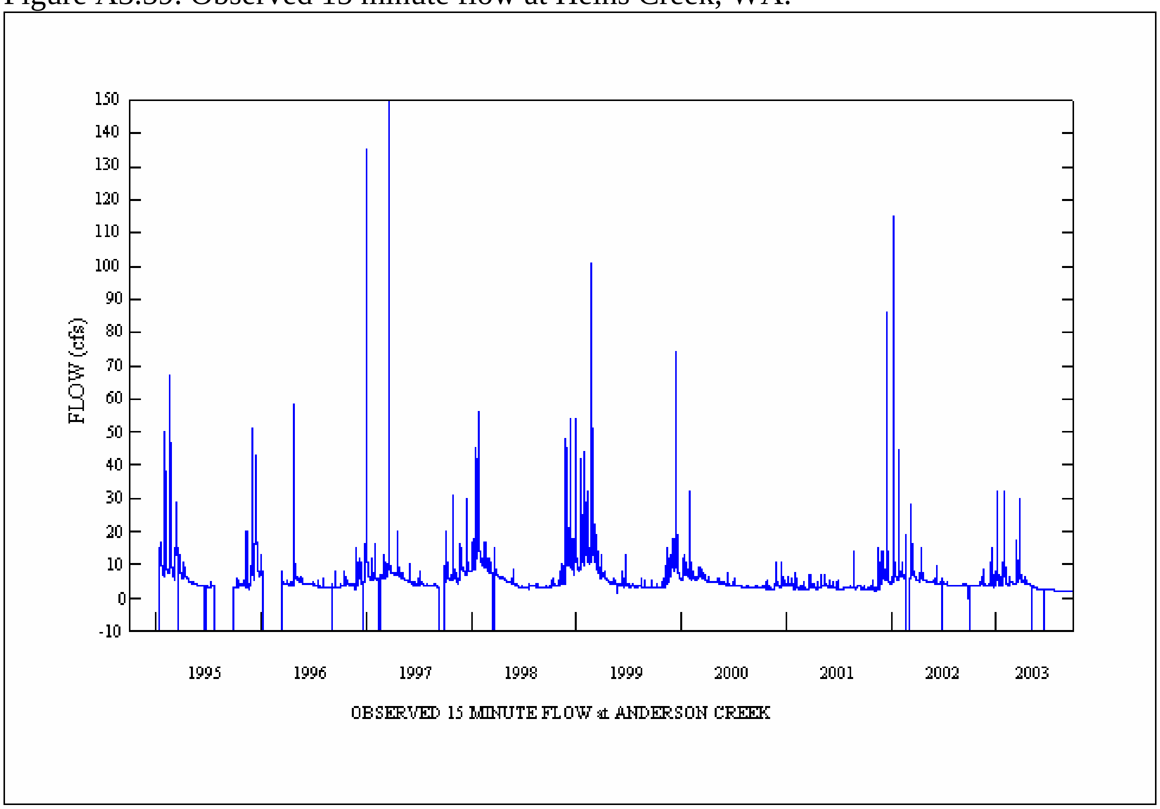

Figure A3.60. Observed 15 minute flow at Anderson Creek, WA.

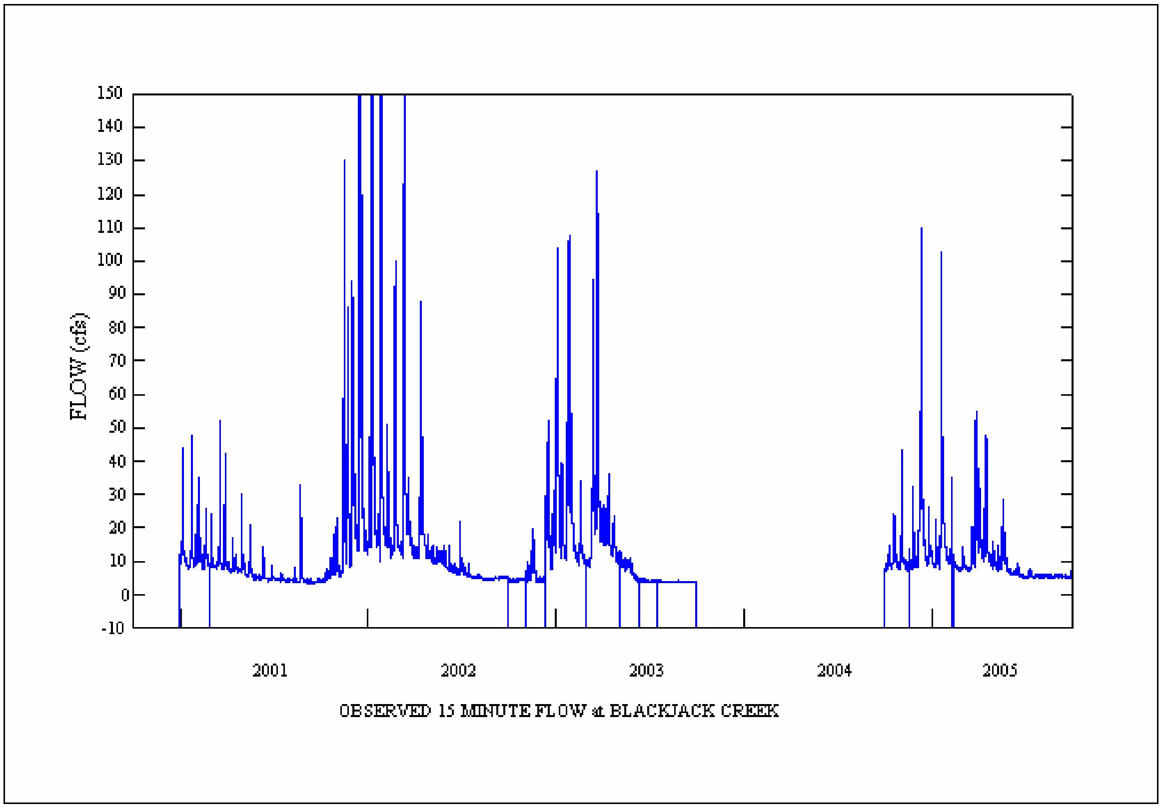

Figure A3.61. Observed 15 minute flow at Blackjack Creek, WA.

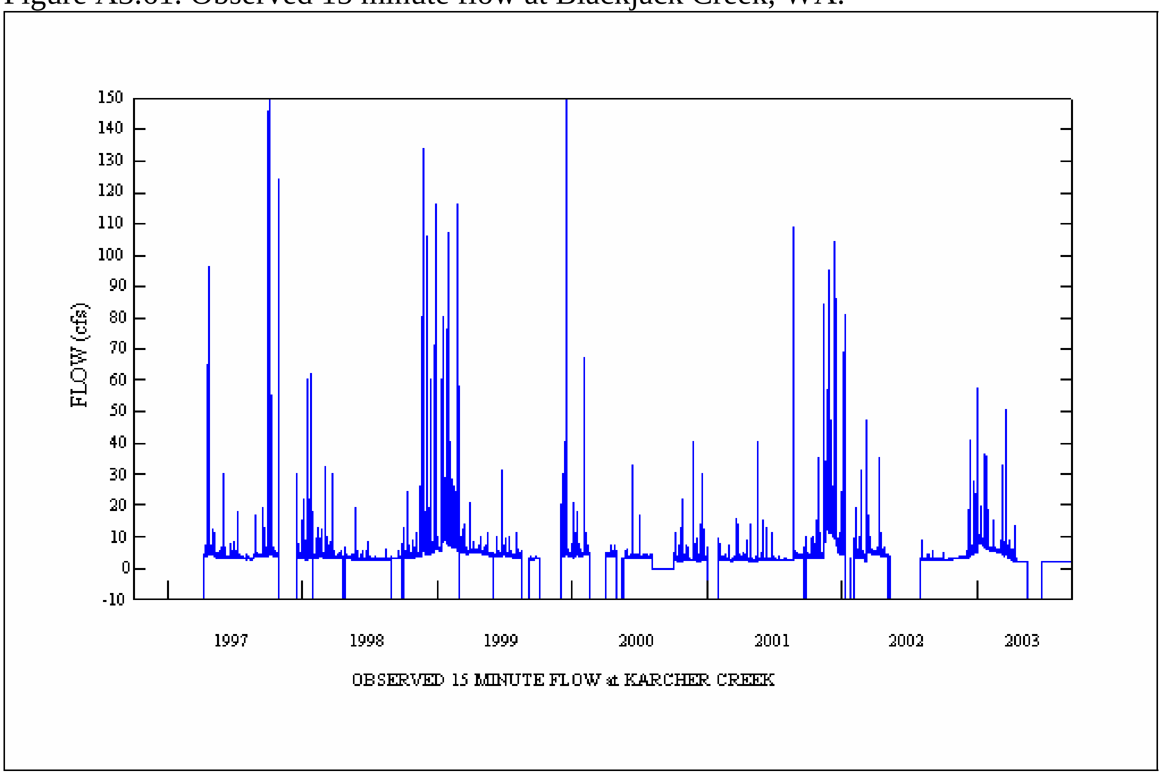

Figure A3.62. Observed 15 minute flow at Karcher Creek, WA.

APPENDIX 4 MODEL TOPOLOGY INFORMATION

from	to	from	to	from	to	from	to	from	to
56	57	8	MW	95	MW	177	MW	217	MW
57	MW	9	MW	97	MW	162	MW	216	MW
28	MW	11	MW	139	MW	161	MW	104	MW
30	MW	12	MW	145	MW	223	MW	78	81
61	ISLAND LAKE	13	MW	149	MW	144	MW	81	MW
ISLAND LAKE	60	10	MW	105	108	146	MW	213	MW
60	59	18	MW	108	113	147	MW	46	MW
59	62	17	MW	106	113	148	MW	211	MW
62	58	19	MW	113	114	150	MW	212	MW
72	MW	6	MW	114	128	165	MW	196	MW
73	MW	156	157	107	128	166	MW	182	MW
92	MW	157	224	121	120	167	MW	209	210
100	MW	224	221	122	120	168	MW	210	MW
101	MW	221	158	109	112	169	MW	21	MW
102	MW	155	154	110	112	170	MW	23	MW
103	MW	158	MW	111	112	171	MW	24	MW
70	2	154	MW	120	117	172	MW	74	MW
2	200	140	MW	112	117	173	MW	75	MW
69	200	141	MW	115	116	174	MW	203	MW
200	194	142	MW	116	119	175	MW	204	MW
191	194	143	MW	117	126	176	MW	205	MW
194	193	151	MW	119	126	178	MW	206	MW
192	185	152	MW	118	126	49	55	207	MW
190	189	153	MW	123	124	51	55	208	MW
193	MW	53	89	124	126	52	55	40	MW
185	MW	89	KITSAP LAKE	128	1	55	MW	41	MW
189	MW	KITSAP LAKE	54	1	126	27	MW	42	MW
31	MW	225	WILDCAT LAKE	126	127	29	MW	43	MW
32	MW	WILDCAT LAKE	226	127	125	215	MW	44	MW
93	MW	226	26	129	132	214	MW	45	MW
202	MW	88	90	132	134	63	64	82	MW
188	MW	47	90	134	136	64	MW	83	MW
183	MW	90	91	125	133	33	MW	84	MW
186	MW	50	91	130	133	34	MW	85	MW
187	MW	54	91	131	133	35	MW	86	MW
3	4	91	87	133	135	36	MW	94	MW
4	7	87	MW	135	136	37	MW	66	MW
5	9	22	MW	136	MW	38	MW	67	MW
15	14	201	MW	220	218	39	MW	68	MW
14	17	25	MW	218	177	76	MW	96	MW
7	MW	26	MW	222	219	77	MW	98	MW
195	MW	65	MW	219	162	79	MW	99	MW
199	MW	71	MW	160	161	80	MW	137	MW
								20	16
								16	MW

Table 4.1. Model topology for the Sinclair-Dyes Inlet HSPF models (MW = Marine Water).

APPENDIX 5 THEORY

Gauss-Marquardt-Levenberg Parameter Estimation

Let the action of a model under calibration conditions be described by the model operator $\mathcal{M}$ that maps *m*-dimensional parameter space to the space of the *n* observations that are available for use in the calibration process. Let the *m*-dimensional vector **p** represent model parameters and the *n*-dimensional vector **h** represent observations. In many instances of watershed hydrologic model calibration these observations will represent stream discharges which have been "processed" in some way in order to achieve homoscedascity, and statistical independence of measurement "noise". The former is often achieved through a Box-Cox transformation (Box and Cox, 1964), while the latter is often attempted through fitting residuals to an ARMA model, often as part of the parameter estimation process itself (Box and Jenkins, 1976; Kuczera, 1983). The observations **h** can be comprised of a single observation type, multiple observation types, and/or a single observation type processed in different ways in order to ensure that the information content associated with different aspects of the calibration dataset exercise sufficient influence in the estimation of a final set of model parameters (Madsen, 2000; Boyle et al, 2000; Doherty and Johnston, 2003).

Model calibration seeks to minimize some measure of model-to-measurement misfit encapsulated in a "measurement objective function", herein designated as Φ_m. In the present instance this is defined as:-

$$\Phi_m = [\mathcal{M}(\mathbf{p}) - \mathbf{h}]^t\mathbf{Q}[\mathcal{M}(\mathbf{p}) - \mathbf{h}] \qquad (3)$$

where **Q** is a "weight matrix" which, in the context of watershed model calibration where *n* is large, is mostly comprised of diagonal elements only. Ideally, each diagonal element of **Q** is proportional to the inverse of the squared potential error associated with the corresponding processed measurement.

Where **p** is estimable (i.e. where minimization of Φ_m results in a unique parameter set), it is calculated as:-

$$\mathbf{p} - \mathbf{p}_0 = (\mathbf{X}^t\mathbf{QX})^{-1}\mathbf{X}^t\mathbf{Q}(\mathbf{h}-\mathbf{h}_0) \qquad (4)$$

where **X** is the model Jacobian matrix, each row of which is comprised of the derivatives (i.e. sensitivities) of a particular model output (for which there is a corresponding field measurement) with respect to all elements of **p**. These sensitivities are calculated at current parameter values, represented by $\mathbf{p}_0$, for which corresponding model outputs are $\mathbf{h}_0$. Where the model is nonlinear, **p** calculated through equation 4 is not optimal (i.e. it does not minimize Φ_m) unless $\mathbf{p}_0$ is close to optimal. Hence, after equation 4 is used to calculate an improved parameter set, a new set of sensitivities (i.e. **X**) is calculated on the basis of the new parameter set, and the process is repeated until convergence to the objective function minimum is achieved.

In practice, the $\mathbf{X}^t\mathbf{QX}$ matrix of equation 4 is supplemented by addition of a diagonal term – the so-called "Marquardt lambda". Thus, equation 4 becomes:-

$$\mathbf{p} - \mathbf{p}_0 = (\mathbf{X}^t\mathbf{QX} + \lambda\mathbf{I})^{-1}\mathbf{X}^t\mathbf{Q}(\mathbf{h}-\mathbf{h}_0) \qquad (5)$$

Normally λ is adjusted during each iteration of the parameter estimation process such that its current value results in maximum parameter improvement during that iteration. When λ is high it is easily shown that the direction of parameter improvement is the negative of the gradient of Φ_m and under these conditions equation 5 becomes equivalent to the "steepest descent" method of parameter estimation. While this method can result in rapid parameter improvement when parameters are far from optimal, its performance is disappointing in the vicinity of the objective function minimum, especially where that minimum occupies a long valley in parameter space as a result of excessive parameter correlation or insensitivity. In these circumstances "hemstitching" is likely to occur, where successive parameter improvements result in oscillations across the objective function valley, which is never actually penetrated. Hence, ideally λ should commence the parameter estimation process with a moderate value, and then be reduced as the process progresses. However, if $\mathbf{X}^t\mathbf{QX}$ is ill-conditioned, reducing the value of λ will incur numerical instability as $\mathbf{X}^t\mathbf{QX} + \lambda\mathbf{I}$ of equation 5 is inverted. Hence, the Marquardt lambda has a secondary role, this being that of a de facto regularization device, with its value often being raised in order to prevent instability in the calculation of the parameter upgrade vector $\mathbf{p}–\mathbf{p}_0$. However, while the use of a high Marquardt lambda can prevent a relatively ill-posed parameter estimation problem from foundering, it achieves this at a cost in efficiency, for parameter upgrades become smaller at higher values of λ as an inspection of equation 5 suggests. Furthermore, as stated above, the ability of the calibration process to penetrate an elongate valley in parameter space may be severely compromised.

The predisposition of a matrix to stable inversion is often measured by its “condition number”. High condition numbers result in amplification of numerical noise during the inversion process (Conte and de Boor, 1972) while low condition numbers indicate that inversion should be possible with little numerical difficulty. In general, condition numbers for $\mathbf{X}^t\mathbf{QX}$ greater than about 10^4 are to be avoided, for at this level the numerical noise incurred through finite difference-based derivatives calculation for filling of the $\mathbf{X}$ matrix is amplified to the extent that parameter upgrades may lack integrity. While a raised Marquardt lambda can often rescue such a damaged process from total failure as described above, efficiency of the parameter estimation process is likely to be seriously degraded.

Another problem that can be encountered when parameter estimation is accomplished by iterative calculation of $\mathbf{p}\text{-}\mathbf{p}_0$, using (5), is that this process can converge to a parameter set $\mathbf{p}$ that corresponds to a local, rather than the global, minimum of the objective function. “Gradient methods”, such as the Gauss-Marquardt-Levenberg method described above, that rely on equations such as (5) have been criticized for this reason, and so-called “global search” methods such as SCE-UA (Duan et al, 1992) are often used instead. While a well-designed and robust global search method can indeed be guaranteed to minimize the objective function in spite of the existence of local minima, such robustness comes at a price, this being the high number of model runs that is normally required for completion of the parameter estimation process. To make matters worse, the number of model runs increases dramatically as the number of parameters requiring estimation increases. Use of equation 5, on the other hand, is very run-efficient. Fortunately, its propensity to find local minima can be mitigated through the use of schemes such as that described by Skahill and Doherty (2006) which combine the efficiency of gradient methods with the benefits of introducing a small degree of randomness to the parameter estimation process, together with an ability to "learn from past mistakes". In addition, equation 5 can be enhanced by the inclusion of a regularization term (much more powerful than the Marquardt lambda as will be described shortly) that greatly increases the propensity for robust and efficient behavior when the dimension m of $\mathbf{p}$ is large, and the shape of the objective function surface in parameter space becomes a valley (or series of valleys) rather than a bowl (or series of bowls).

Gradient-based methods such as the Gauss Marquardt Levenberg (GML) method have been criticized for poor performance in the face of local optima (Gupta et al, 2003). Use of such methods can lead to the determination of a parameter set that corresponds to a local, rather than global, objective function minimum, leaving the user with no idea of whether another location exists within parameter space for which the objective function is lower. However certain features of the GML method make it difficult to reject outright as a serious contender for use in watershed model calibration. These features include the following.

1. In calibration contexts where local optima are rare or nonexistent, the GML method can normally find the objective function minimum in far fewer model runs than any other method.
2. Estimates of parameter uncertainty, correlation and (in)sensitivity are readily available as a by-product of its use.

3. In cases of high parameter insensitivity and correlation, the method can be readily modified by the inclusion of various regularization devices to maintain numerical stability and robustness.
4. Various enhancements can be made to the GML method that allow it to carry out linear or nonlinear post-calibration predictive uncertainty analysis, with run efficiencies that far exceed those of MCMC methods (Vecchia and Cooley, 1987).

It follows that if a methodology can be found that retains the advantages of the GML method, while eradicating its propensity to be trapped in local optima, such a method would deserve serious consideration for use in watershed model calibration.

The Trajectory Repulsion Scheme

The robust performance of the SCE-UA method, as well as that of most other global search methods, is based on two principals. These are as follows.

1. The injection of a certain degree of randomness into the parameter estimation process allows it to go in directions that may eventually prove fruitful, even if the attractiveness of a new direction may be shielded by the promise of local, more immediate, rewards.
2. The benefits of randomness are partly offset by the cost of making mistakes. Hence by incorporating into a global optimization process an ability to learn from mistakes, the likelihood of incurring large run-time penalties through repeatedly making the same (or a similar) mistake is minimized.

Based on these principals, a modified form of the GML method was developed in order to increase the capacity of this method to work well in contexts where local minima occur. The package takes the form of a driver, in which GML parameter estimation is still conducted, but in which successive inversion runs are undertaken under intelligent control. The package is presently named “PD_MS2” (Skahill and Doherty, 2006).

PD_MS2 commences execution by running the model that it must calibrate *N* times, where *N* is set by the user. Experience has shown that between the square and the cube of the number of parameters requiring estimation is a suitable value for *N*. PD_MS2 employs random parameter values for these runs; these are sampled from a uniform or log-uniform distribution defined between user-supplied upper and lower parameter bounds.

PD_MS2 next ranks the outcomes of the *N* random runs in order of increasing objective function value. It then disregards all runs for which the objective function is above the median. Next it initiates an inversion run, with initial values for this run being equal to the random parameter sample for which the objective function was lowest. PD_MS2 monitors this run, recording optimized parameter values, as well as parameter values calculated during every iteration of the nonlinear GML method which it implements. Normally between 5 and 15 such iterations are required to reach an objective function minimum. Each such iteration requires that at least as many model runs be undertaken as there are parameters requiring estimation, plus a few more.

After completion of the first inversion run, another inversion run is initiated. For this run it is desired that the chances of finding the same objective function minimum as that which was encountered on the first inversion run be minimized. Hence from among the *N*/2 retained pre-calibration samples of parameter space, a starting point is chosen that is maximally distant from any point on the parameter trajectory taken by the initial inversion run. Selection of such a starting point is based on the rationale that the closer is a point in parameter space to the previous parameter trajectory, the more likely it is to lie in the “catchment area” of the previously-encountered objective function minimum.

After the next inversion run is complete, another parameter set is selected from the *N/2* potential starting points. The parameter set selected is that which is maximally distant from all previous points on all previous trajectories. The process is then repeated.

A number of criteria can be used to terminate the PD_MS2 global optimization process. Where model run efficiency is an issue, PD_MS2 can be instructed to cease execution if the objective function has not been lowered over the last M_1 inversion runs. Alternatively, PD_MS2 can be asked to undertake M_2 inversion runs regardless of the outcomes of these runs. If M_2 is moderate to large, this enables PD_MS2 to find the locations of many local optima in parameter space (should these exist), thus providing the user with powerful insights into the structure of the objective function surface.

It is worth noting that, as well as providing insights into the “broadscale” structure of the objective function response surface, PD_MS2 provides insights into the structure of this surface in the vicinity of the global objective function minimum as well. As has already been mentioned, the GML method can provide parameter sensitivities and can calculate a linear approximation to the parameter covariance matrix, as well as statistics derived from this matrix including correlation coefficients and eigenvectors/eigenvalues of the covariance matrix. Information of this type is forthcoming only with difficulty from global search methods, this difficulty increasing with the number of parameters being estimated and with the degree of correlation between them (which, unfortunately, is the very situation in which such information is of most value).

Temporary Parameter Immobilization

“Temporary parameter immobilization” can be used as both a regularization device and as a device for conducting ordered attempts to break out of local pits in parameter space. This scheme is implemented only if the objective function improvement attained during a particular iteration of the GML process is less than a user-supplied threshold (normally 10%). In implementing this scheme, the most insensitive parameter is selected, and temporarily removed from the optimization process. With the dimensionality of estimable parameter space thus reduced (and with the most troublesome parameter being temporarily removed from the parameter estimation process), the parameter upgrade vector (which now has no component in the subspace of parameter space occupied by the temporarily frozen parameter) is re-calculated using equation 5. A model run is then conducted on the basis of the trial parameter set thus calculated in order to compute the objective function associated with this parameter set. Unless the objective function has fallen by a significant amount, the next most troublesome parameter is temporarily frozen (in addition to the first), and the parameter upgrade calculation procedure is repeated. After a number of parameters have been successively frozen in this manner (with already frozen parameters maintained in their frozen state), the process is abandoned, and then re-commenced using a different value of the Marquardt lambda. For a parameter estimation problem involving m parameters, up to half of these parameters may be progressively frozen for up to three Marquardt lambdas, this requiring $3m/2$ model runs for that iteration for the testing of parameter upgrade vectors in addition to the (depending on whether forward differences or central differences are employed) m or $2m$ model runs required for filling of the Jacobian matrix. (Note however that the process is immediately abandoned if a suitable objective function improvement is obtained.) Thus, implementation of the TPI process may lead to the requirement that between twice and three times (at the very most) the number of model runs be carried out compared to normal GML operations. However, experience has demonstrated that on most occasions in which the TPI method is employed about fifty percent extra model runs need to be carried out, and that this is generally a small price to pay for the benefits that it brings in terms of increased numerical stability in situations of parameter nonuniqueness, and for a dramatic reduction in the risk of becoming trapped in local objective function pits.

The decreased probability of ensnarement in local optima that attends use of the TPI scheme has its roots in a number of properties of this scheme. One obvious reason for a heightened probability of success in finding its way out of small regions of attraction of limited extent in parameter space is the sheer number of parameter upgrades that are attempted by this scheme, together with the fact that the directions pertaining to these upgrade attempts tend to be maximally different with respect to each other. This maximality of difference is a result of two factors. The first is the fact that the upgrade direction tends to be dominated by insensitive parameters where all parameters are involved in the computation of this direction; this is a direct result of the fact that, because of their insensitivity, the GML parameter estimation algorithm calculates that these parameters require larger movement than other parameters to affect the objective function. As dimensions of parameter space are progressively closed to the parameter upgrade vector through the temporary immobilization of insensitive parameters, and new upgrade directions are accordingly computed in spaces of lower dimensions, these new directions will tend to be orthogonal to the original upgrade vector which was dominated by the now-omitted dimensions. The penchant for orthogonality is further increased as a result of the fact that the entire dimensionality reduction process is repeated for widely different Marquardt lambda values. As documented in works such as Bard (1974), computed upgrade directions can vary between that of steepest descent down the objective function surface when the Marquardt lambda is high, to a direction that can be almost orthogonal to this when the Marquardt lambda is low.

Another important factor behind the success of the TPI scheme is that it lowers the chances of upgraded parameters finding local optima in the first place. Unless objective function improvement during a particular iteration is acceptably large without the help of the TPI scheme (which often occurs in the early stages of the parameter estimation process), use of the TPI scheme requires that model runs be carried out specifically to test the ability of different upgrade vectors (often with very different directions as discussed above) to lower the objective function. The upgrade vector that results in the largest objective function decline is that which is selected as the basis for the next linearization of the inverse problem. Of all the upgrade vectors tested, this is the one least likely to lead to a local objective function minimum, for the encroachment of global or local optimality (for which derivatives of the objective function with respect to all model parameters is zero) is normally marked by smaller and smaller declines in the objective function per iteration as the GML method ensures that a parameter set is found from which all directions lead uphill. In fact, the more nonlinear is the problem, the less likely it is that a parameter upgrade vector resulting in a large objective function decline will lead directly to the bottom of an objective function minimum (due to the fact that the equations upon which this upgrade vector are calculated are based on an assumption whose inapplicability grows with increasing parameter movement, and/or increasing changes in model outputs on account of this movement).

An additional factor that contributes to the success of the TPI scheme in both avoidance of local minima of small lateral extent, and in extricating itself from such minima, is use of finite differences for parameter derivatives calculation. As was mentioned above, parameter increments of one percent are often employed for forward difference derivatives calculation and two percent for central difference derivatives calculation. These increments are large enough to "see" outside of a small pit in which it may be currently trapped. Alternatively, if current parameter values lie just outside of a small pit, these increments are large enough for the effect of the pit to exert a smaller influence on calculated derivatives than would be the case if derivatives were exact. Thus, the use of finite-difference-based parameter derivatives provides a kind of filtering mechanism through which finer details of the objective function surface are prevented from concealing the broader features of that surface.

So, through a combination of the fact that many upgrade vectors are tested, that a parameter upgrade selection procedure is adopted that minimizes the chances of being trapped in a local minimum in the first place, and maximizes the chances of escaping from that minimum if ensnarement does indeed occur, and because parameter upgrades possess some immunity to the effects of pits because their calculation is based on finite-difference derivatives rather than point derivatives, use of the TPI method in calibration of surface water models has consistently resulted in good performance in estimating parameters for those models.

(Note that selection of a TPI activation threshold of 10% improvement in the objective function is somewhat arbitrary. However experience has demonstrated that this normally results in efficient implementation of the method. If the threshold is set too high, TPI-based parameter upgrade re-computation will be undertaken on most GML optimisation iterations, irrespective of proximity, or otherwise, to an objective function minimum. This can result in wasted model runs if rapid objective function improvement is taking place without the need for TPI upgrade repetitions. On the other hand, if the improvement threshold is set too low, then needless "struggling" of the GML method in the face of difficulties incurred through problem ill-posedness or proximity to a local minimum, resulting in only small improvements in the objective function in successive iterations, can be avoided).

Regularized Inversion

Conceptually, singularity or near-singularity of $\mathbf{X}^t\mathbf{QX}$ (as occurs when large numbers of parameters require estimation and/or when the information content of the calibration dataset with respect to estimated parameters is poor) can be remedied through the addition of extra "observations" to the parameter estimation process which pertain directly to the parameters requiring estimation. For example, it may be "observed" that each parameter is equal to a certain, user-supplied value; presumably this value will have been chosen to be realistic in terms of the system property which the parameter represents. Alternatively (or as well), it may be "observed" that certain pairs of parameters are equal, or have values which observe a certain ratio or difference.

Let these "regularization relationships" be represented by the operator $\mathcal{Z}$ acting on the parameter set $\mathbf{p}$, and let the "observed" values of these relationships be represented by $\mathbf{j}$. Then the regularization relationships (also referred to as "regularization constraints" herein) can be represented by the equation:-

$$\mathcal{Z}(\mathbf{p}) = \mathbf{j} \tag{6a}$$

the linearized form of which is:-

$$\mathbf{Zp} = \mathbf{j} \qquad (6b)$$

where **Z** is the Jacobian of the $\mathcal{Z}$ operator. Note that, as is discussed below, it is not essential that (6a) and (6b) be exactly observed, only that they be observed to the maximum extent possible in calibrating the model.

If the regularization constraints are given sufficient weight in comparison with the observation weights encapsulated in **Q**, a well-posed inverse problem will have been formulated. Mathematically, this problem is then iteratively solved for the parameters **p** using the equation:-

$$\mathbf{p}\text{-}\mathbf{p}_0 = (\mathbf{X}^t\mathbf{QX}+ \beta^2\mathbf{Z}^t\mathbf{SZ} + \lambda\mathbf{I})^{-1}(\mathbf{X}^t\mathbf{Q}[\mathbf{h}\text{-}\mathbf{h}_0]+ \beta^2\mathbf{Z}^t\mathbf{S}[\mathbf{j}\text{-}\mathbf{j}_0]) \qquad (7)$$

In equation 7 $\mathbf{j}_0$ represents the right side of (6a) when current parameter values $\mathbf{p}_0$ are substituted for **p** in this equation. **S** is a "relative weight matrix" assigned to the regularization observations **j**; it has the same role for regularization observations as **Q** does for field observations. All of the relative regularization weights encapsulated in **S** are multiplied by a "regularization weight factor" β^2 in equation 7 prior to calculation of $\mathbf{p}\text{-}\mathbf{p}_0$.

Selection of an appropriate value for β^2 is critical. If its value is too high the parameter estimation process will ignore the measurement dataset **h** in favor of fitting the regularization observations **j**. If it is too small, the regularization observations will not endow the parameter estimation process with the numerical stability which it needs in order to obtain estimates for the parameters **p**.

Equation 7 can be shown to constitute a constrained minimization problem in which a "regularization objective function" Φ_r defined as:-

$$\Phi_r = [\mathcal{Z}(\mathbf{p})\text{-}\mathbf{j}]^t\mathbf{S}[\mathcal{Z}(\mathbf{p})\text{-}\mathbf{j}] \qquad (8)$$

is minimized subject to the constraint that Φ_m of equation 3 rises no higher than a user-specified value, referred to herein as the "target measurement objective function". Thus the user informs the regularized inversion process of the level of model-to-measurement misfit required; this process then enforces the regularization constraints defined through equation 6a to the maximum extent that it can by minimizing Φ_r subject to the constraint that Φ_m rises no higher than the target level. If the target measurement objective function cannot be achieved, the regularized inversion process simply minimizes Φ_m; however, where minimization of Φ_m would otherwise be an unstable process due to parameter nonuniqueness, stability of this process is maintained by seeking that set of parameters lying within the elongate Φ_m valley that also minimizes Φ_r. In either case, the regularization weight factor β^2 can be viewed as a Lagrange multiplier associated with the constrained minimization problem, and it is re-calculated during every iteration of the regularized nonlinear parameter estimation process using a bisection algorithm based on local linearization of the constrained minimization problem about current parameter values.

Note the continued inclusion of the Marquardt lambda in equation 7. Its value is adjusted as needed from iteration to iteration as a practical measure to enhance optimization efficiency and to ensure stability of the parameter estimation process should $\mathbf{X}^t\mathbf{Q}\mathbf{X}+\beta^2\mathbf{Z}^t\mathbf{S}\mathbf{Z}$ become ill-conditioned through use of an inappropriately low value for β^2. This can occur where regularization constraints are poorly formulated, or where too a good a fit is sought between model outputs and field measurements, requiring that regularization constraints be abandoned in pursuit of this fit. Often it occurs for a combination of these reasons, where weights on some regularization constraints must be lowered for attainment of a good fit between model outputs and field measurements, but where the relaxation of regularization constraints then leads to unestimability of those model parameters whose estimation is not realized through attainment of this fit.

Formulation of the inverse problem as a constrained minimization problem through use of equation 7 allows many more parameters to be estimated than would otherwise be possible, thereby ensuring that maximum information is extracted from the calibration dataset. If the relationships of equation 6 are realistic, the fact that estimated parameters are such as to ensure minimal deviation from these relationships heightens the probability that estimated parameters will themselves be realistic. However, a practical problem that is often encountered when using the Tikhonov method is that the regularization weight matrix **S** must be supplied ahead of the regularized inversion process; furthermore, it is not adjusted through this process except for global multiplication by β^2. Ideally, individual regularization constraints described by the rows of equation 6 should be more strongly enforced where the information content of the calibration dataset is insufficient to require their contravention for the sake of obtaining an appropriate level of model-to-measurement fit. However because it is almost impossible to know ahead of the calibration process the extent to which this should occur for each of the different relationships encapsulated in $\mathcal{Z}$, it is often very difficult to supply an **S** matrix that is an appropriate complement to the current calibration dataset.

Adaptive Regularization

An "adaptive regularization" methodology is now presented which overcomes this problem in many modeling contexts. The set of regularization constraints described by equation 6 is subdivided into groups; if desired, each constraint can be assigned to its own group. The set of model parameters **p** is then supplemented by an additional parameter set $\mathbf{p}_r$, with one new parameter being defined for each new regularization group. Each such parameter is, in fact, the inverse of a group-specific regularization weight multiplier; this group-specific weight multiplier is applied in addition to the global weight multiplier β^2 depicted in equation 7, the latter being adjusted as part of the constrained minimization process as described above. Regularization constraints are then provided for the elements of $\mathbf{p}_r$ so that these too can be estimated as part of the regularized inversion process. Each such constraint comprises the "observation" that the respective element of $\mathbf{p}_r$ is zero.

The re-formulated regularized inversion problem remains a constrained minimization process, and thus still seeks to find a parameter set that either minimizes the measurement objective function Φ_m, or reduces it to a user-specified target level, while ensuring that the regularization objective function Φ_r is conditionally minimized. Because conditional minimization of the regularization objective function now requires maximization of weights assigned to individual or groups of regularization constraints, these weights are applied as strongly as possible, thereby maximizing the extent to which the corresponding regularization relationships encapsulated in equation 6 are adhered. However, with the calculation of the overall regularization weight factor β^2 by the constrained minimization process being such as to allow minimization of the target measurement objective function, or achievement of a user-specified target for this function, these regularization constraints are not so strongly enforced that model-to-measurement fit is compromised. Thus, the regularized inversion process itself ensures that the strength of enforcement of regularization constraints on parameter values or relationships complements the information content of the calibration dataset in relation to these parameters. As a result, regularization constraints are automatically applied more strongly where the attainment of a satisfactory level of model-to-measurement fit does not require otherwise, thus overcoming a disadvantage of the Tikhonov method. The outcome is a numerically stable regularized inversion process that achieves a desired level of model-to-measurement fit with impressive run economy, and that yields sensible values for model parameters.

Like all numerical strategies, this adaptive regularization methodology is more suitable for use in some contexts than in others. It is certainly not the only means by which numerical stability of a regularized inversion process can be achieved, for so-called "subspace methods" (Aster et al, 2005) are very effective in this regard. However, use of the present methodology can be beneficial in those modeling contexts where the means by which numerical stability is achieved is just as important as the achievement of that stability itself. In general, where the necessity for parameters to observe key values or relationships to the maximum extent possible without compromising fit between model outputs and field measurements is a critical part of the calibration process, then the adaptive regularization methodology described herein will serve that calibration process well; such a case is demonstrated in the following section. However, the need to introduce extra parameters into the calibration process in order to guarantee enforcement of desired parameter relationships does place some restrictions on the method. Where such relationships fall into a relatively small number of distinct groups, and/or where the number of parameters requiring estimation is not such as to introduce vastly different levels of “estimability” between them (thus requiring the introduction of many new parameters in order to accommodate the differential strengths with which regularization constraints must be applied), the above method has proven very successful. However, where large numbers of parameters require estimation, and where differences in estimability between them are likely to cover a broad range, recourse to subspace methods becomes a necessity. Unfortunately, in this case, the guarantee of numerical stability that accompanies use of such methods is attained at the cost of loss of ability on the part of the modeler to insist on the observance of specified parameter relationships in attaining that stability.