King County Watershed Modeling Services – Green River Water Quality Assessment, and Sammamish-Washington, Analysis and Modeling Program Watershed Modeling Calibration Report

In Progress

King County

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7.1 BLACK/SPRINGBROOK RIVER WATERSHED DOMAIN

The physical domain of the HSPF model for this study is the entire Black/Springbrook River watershed above the confluence with the Green River, an area of approximately 26 square miles.

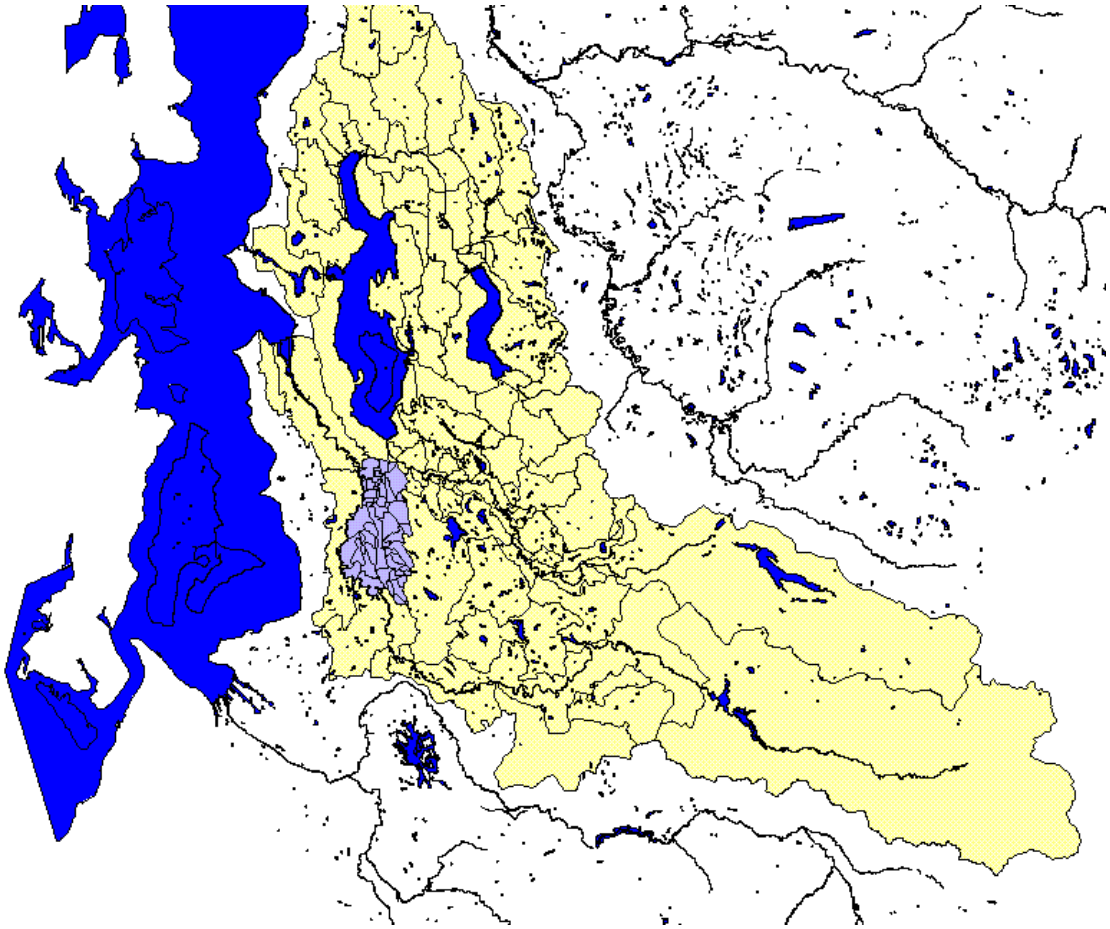


Figure 7.1-1 Black/Springbrook River Subbasin

7.2 DATA REQUIREMENTS AND AVAILABILITY

Database development is a major portion of the total modeling effort. It requires acquisition of data from a variety of sources, developing estimation procedures when needed data are not available, applying available techniques to fill-in missing data, and ensuring consistency and accuracy of the information obtained. Historical data collected by King County, the USGS and federal agencies (e.g., NOAA, NWS), supplemented with ongoing data collection efforts of these

same groups, appears to provide a sound basis for the watershed modeling effort. The purpose of this section is to identify the data needs for the various models and to present findings of the availability and sources of these data. Ultimately, the findings of this section will determine the timeframe and constituents the data are capable of supporting for model simulations.

7.2.1 OVERVIEW OF DATA NEEDS

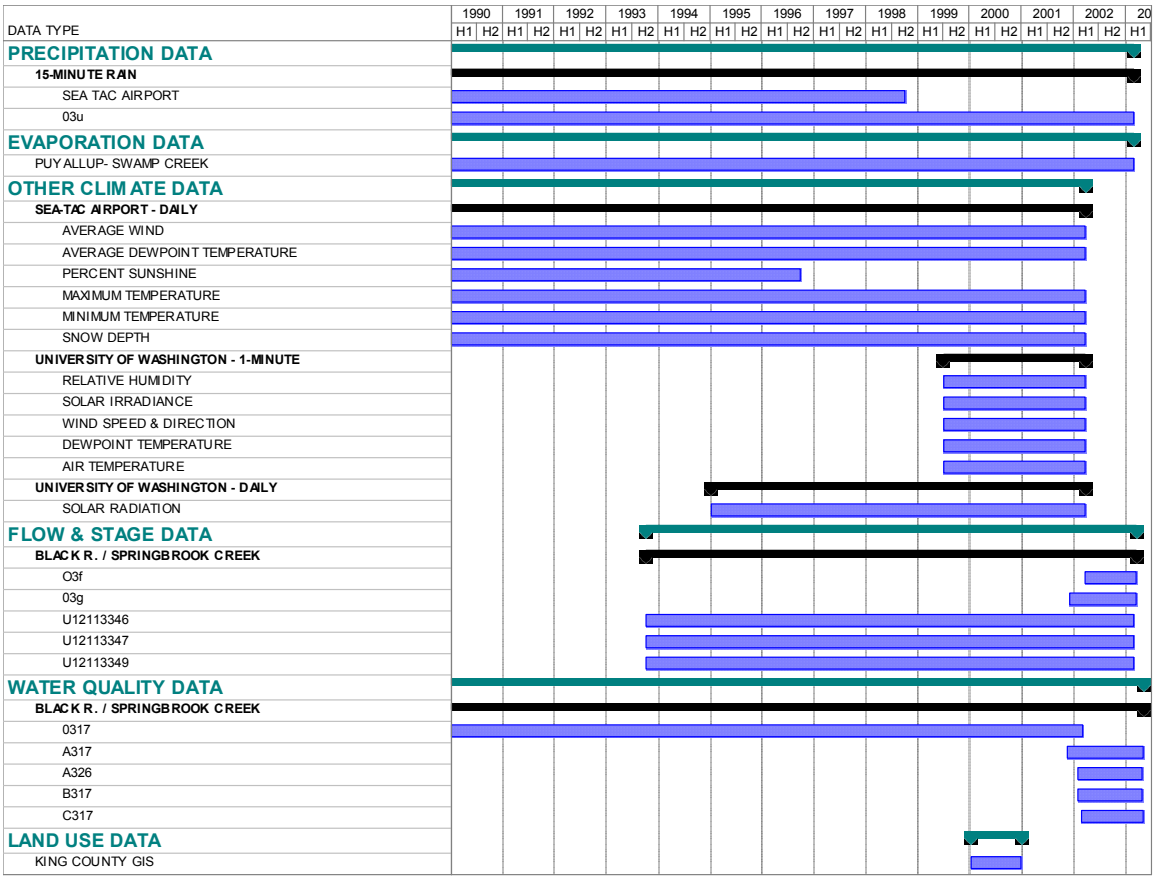
Within the modeling framework, the watershed model, HSPF, encompasses the largest spatial extent of the system and will require the most encompassing dataset for model simulations. The data requirements for HSPF are extensive, in both spatial and temporal detail, especially for an application capable of assessing the potential environmental impact of such activities as land use development in the watershed based on GMA boundaries. Typical data requirements for an HSPF application can be categorized as input/execution data, watershed/channel characterization data, and calibration/validation data.

7.2.2 INPUT / EXECUTION DATA FOR MODEL SIMULATIONS

Input / execution data includes time series data that will drive the model simulations. For this application, the watershed model will require climatic data, point, import/export, diversion, and possibly atmospheric data. The output from HSPF will provide the input to CE-QUAL-W2.

The selection of the calibration and simulation periods requires an evaluation of what field data are available and what additional data collection is needed to fully support the modeling effort. Table 7.2-1 provides a summary of the types of data that will be used as part of this modeling effort and the time periods over which they are available. These timelines are not intended to be all-inclusive but rather to provide an overall picture of available historical and current data. The references and sources used to develop the information in Table 7.2-1 include published reports (AQUA TERRA and King County, 2002b), USGS data, NOAA/NCDC data, the King County Hydrologic Information Center http://dnr.metrokc.gov/hydrodat/index.htm along with other personal communications and miscellaneous sources.

Table 7.2-1 Data Availability for Model Simulations



7.2.2.1 Calibration Data

Precipitation is the primary driving force in any watershed modeling effort. Evaporation is the other important climatic data required for hydrologic simulation.

Table 7.2-2 provides a summary of the types of data that will be used for the Black/Springbrook River hydrology calibration and the time periods over which they are available.

Table 7.2-2 Data Availability for Model Calibration

Location	Data Type	Time Step	Starting Date	Ending Date	DSN
Puyallup	Evaporation	Daily	1948/10/01	2002/09/30	1
Panther Lake	Precipitation	15-Minute	1988/10/01	2003/03/17	10
SeaTac Airport	Precipitation	15-Minute	1948/10/01	1998/09/30	8
Gage 03F	Streamflow	15-Minute	3-15-2002	3-20-2003	30

Gage 03G	Streamflow	15-Minute	12-04-2001	3-18-2003	31
U12113346	Streamflow	15-Minute	10-01-1993	6-30-2003	90
U12113347	Streamflow	15-Minute	10-01-1993	6-30-2003	91
U12113349	Streamflow	15-Minute	10-01-1993	6-30-2003	92
U12113375	Streamflow	15-Minute	10-01-1993	12-31-2000	94

7.2.2.1.1 Precipitation

The Panther Lake precipitation gage is located in the central part of the watershed on the eastern border. Other King County gages are generally located outside of the basin boundaries and are not used in this calibration effort. The locations of the respective King County gages can be seen in Figure 7.2-1.

Selection of the most applicable precipitation record to use for the calibration process was based on the length of the record, the time period of the record related to availability of recorded streamflow data, and the location of the precipitation station to the Black/Springbrook River watershed.

Individual precipitation gages were considered for the calibration based on their location, length of record, and relationship to the PRISM isohyetals shown in Figure 7.2-1. The isohyetals were used to compute a scaling factor for much of the western portion of the watershed. Two scaling factors were used. A scaling factor of 1.0 was used for the upper portion of the watershed and a scaling factor of 0.90 was used for the lower portion. Table 7.2-3 shows the breakdown of scaling factors used. Table 7.2-4 shows the annual volume summary of the Panther Creek precipitation gage.

Table 7.2-3 Precipitation Scaling Factor By Subbasin

Catchment No.	Scaling Factor
10	1.0
20	1.0
30	1.0
40	1.0

Catchment No.	Scaling Factor
50	1.0
60	1.0
70	1.0
80	1.0
90	1.0
100	1.0
110	0.9
120	1.0
130	1.0
140	0.9
150	0.9
160	0.9
170	1.0
180	1.0
190	1.0
200	1.0
210	1.0
220	1.0
230	1.0
240	1.0
250	1.0
260	0.9
270	0.9
280	0.9
290	0.9
300	0.9
310	0.9
320	0.9
330	0.9
340	0.9
350	1.0
360	0.9
370	0.9
380	0.9
390	0.9
400	0.9

Catchment No.	Scaling Factor
410	0.9
420	0.9
430	0.9
440	0.9
450	0.9
460	0.9
470	0.9
480	0.9
490	0.9
500	0.9
510	0.9
520	0.9

Table 7.2-4 Comparison of Precipitation Annual Volumes

Water Year	King Co 03U Panther Creek DSN 10
1988	38.77
1989	44.80
1990	49.47
1991	31.03
1992	34.56
1993	26.18
1994	37.57
1995	44.86
1996	52.30
1997	32.90
1998	47.95
1999	41.18
2000	37.03
2001	45.97
2002	20.49
Average	
Period of Record	39.00
2001-2003	33.23
PRISM at gage	40
Fraction of watershed	1.00

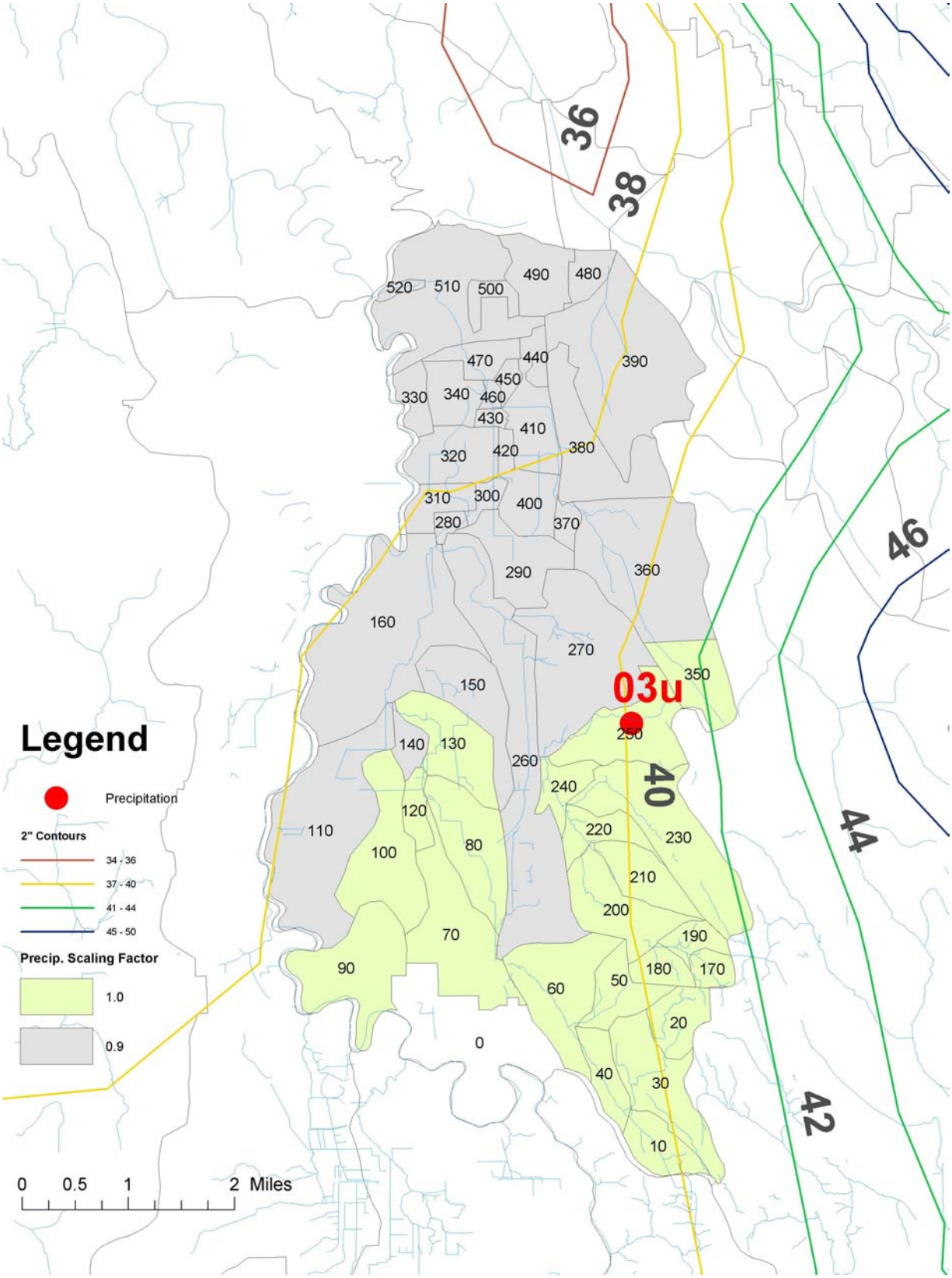


Figure 7.2-1 Nearby Precipitation Stations

7.2.2.1.2 Evaporation

The nearest evaporation data are available from Puyallup at the Washington State University Experimental Field Station. Puyallup lies approximately 60 miles to the south of the Black/Springbrook River watershed, but because evaporation does not vary greatly in the Puget Sound lowlands this distance is not considered significant (Farnsworth, et al, 1982).

As shown in Table 7.2-2, the time period of the data is not a limiting factor for model simulations. The pan evaporation time series was developed from the available daily record for water years 1960 through 1997. For the most part, this station only measured pan evaporation during the growing season. Data for winter months were filled by King County staff (Hartley, 1999) using the Jensen-Haise equation. Data for water year 1960 were transposed without change to water years 1949 through 1959 and water years 1998 through 2002 (Hartley, 1999). The selection of a single year to represent years with missing data potentially introduces error in unusually wet or dry years. Accordingly, it may be worthwhile to instead use the Jensen-Haise equation for these years for which we do not have measured pan evaporation data. This will be investigated further.

Table 7.2-5 shows representative monthly evaporation volumes for water years 1981 through 2001. The volumes are relatively consistent from one year to the next. The average monthly values for water years 1960 through 1997 are summarized at the bottom of the table and have a mean annual total of 30.71 inches. The calibration period is based on water years 1996 through 2002, and, as described above, use the 1960 data. The mean annual total for the calibration period is 30.32 inches.

The evaporation data must be adjusted to convert to an estimate of potential evapotranspiration data that are used by the models. A pan evaporation coefficient is used to convert the pan evaporation data to PET data. For the Black/Springbrook River watershed this coefficient was set to 0.78, based on the pan evaporation coefficient values shown on Map 4 of the NOAA Technical Report NWS 33, *Evaporation Atlas for the Contiguous 48 United States* (Farnsworth, et al, 1982). The pan evaporation coefficient is often adjusted in the calibration process (Donigian, 2003), but there was no need to do so in the Black/Springbrook River calibration.

Table 7.2-5 Evaporation Monthly Volumes

Water Year	Oct (in)	Nov (in)	Dec (in)	Jan (in)	Feb (in)	Mar (in)	Apr (in)	May (in)	Jun (in)	Jul (in)	Aug (in)	Sep (in)	Total (in)
1981	1.11	0.72	0.65	0.90	0.84	1.74	2.64	2.86	3.24	4.88	4.86	2.98	27.42
1982	1.10	0.74	0.65	0.91	0.84	1.74	3.67	4.61	5.18	5.21	4.75	2.83	32.23
1983	1.73	0.74	0.65	0.90	0.84	1.74	3.04	4.11	4.47	4.02	4.93	2.71	29.88
1984	1.26	0.72	0.65	0.90	0.87	1.74	2.42	4.01	4.42	6.43	5.27	3.13	31.82
1985	1.40	0.91	0.28	0.35	0.67	1.99	2.37	4.13	4.93	7.56	5.41	2.72	32.72
1986	1.71	0.37	0.23	0.87	1.13	3.35	2.08	3.24	5.81	4.59	5.87	2.88	32.13
1987	0.95	0.44	0.40	0.41	0.80	1.13	2.39	4.25	5.67	4.88	5.44	3.64	30.40
1988	1.63	0.63	0.35	0.84	0.87	1.90	2.36	3.50	4.92	5.74	5.20	3.61	31.55
1989	1.24	0.69	0.61	0.84	0.83	1.77	3.32	5.84	5.33	6.20	5.13	3.95	35.75
1990	1.58	0.69	0.61	0.84	0.83	1.77	2.53	4.48	5.40	6.76	5.45	2.88	33.82
1991	1.31	0.69	0.61	0.84	0.83	1.77	2.53	3.79	3.92	6.40	6.20	3.63	32.52
1992	1.31	0.69	0.61	0.84	0.87	1.77	2.53	5.29	2.53	5.35	6.01	4.20	32.00
1993	2.57	1.19	0.87	0.34	0.46	0.42	0.51	4.17	1.96	5.34	6.33	4.37	28.53
1994	1.28	0.69	0.61	0.84	0.86	1.79	2.58	3.68	4.12	6.63	5.86	3.58	32.52
1995	1.28	0.69	0.61	0.84	0.84	1.77	2.53	5.29	2.53	5.35	6.01	4.20	31.94
1996	2.57	1.19	0.87	0.34	0.47	0.43	0.51	4.33	1.84	5.44	6.38	4.30	28.67
1997	2.57	1.19	0.87	0.34	0.46	0.42	0.51	4.17	1.96	5.34	6.33	4.37	28.53
1998	1.27	0.72	0.65	0.90	0.84	1.74	2.49	3.94	4.59	5.67	4.68	2.82	30.31
1999	1.27	0.72	0.65	0.90	0.84	1.74	2.49	3.94	4.59	5.67	4.68	2.82	30.31
2000	1.27	0.72	0.65	0.90	0.90	1.76	2.53	3.96	4.62	5.64	4.62	2.77	30.34
2001	1.25	0.72	0.66	0.90	0.87	1.76	2.53	3.96	4.62	5.64	4.62	2.77	30.30
Average (60-97)	1.41	0.73	0.63	0.82	0.82	1.68	2.39	4.07	4.37	5.66	5.06	3.08	30.71
Average (99-01)	1.26	0.72	0.65	0.90	0.87	1.75	2.52	3.95	4.61	5.65	4.64	2.79	30.32

7.2.2.1.3 Water Quality Required Meteorological Data

The period of hydrology calibration is 10/1/1998-2/28/2003. This ending date was extended to 7/31/2003 for the water quality calibration in order to take advantage of water quality data collected by King County over that longer span. The evaporation data used in the hydrology calibration had adequate coverage, but the precipitation data had to be extended. Panther Creek precipitation gage (03U) operated by King County is the precipitation data source. The additional precipitation data were acquired from King County and appended to the existing data set.

The HSPF water quality simulation runs require five meteorological data sets in addition to the precipitation and evaporation data sets required for the hydrologic runs. These additional data are:

- Temperature
- Dew Point
- Cloud Cover
- Wind
- Solar Radiation

AQUA TERRA identified the NCDC Station 454169 at Kent as the best source for temperature data. Data were not available beyond 12/31/01 for this station; therefore, the remaining period of 1/1/02-7/31/03 was filled with data from Seattle-Tacoma International Airport (SEATAC), which is nearby and has very similar values. SEATAC was also determined to be the best source of data for the remaining four quantities. Table 7.2-6 contains selected descriptive attributes for these stations. The map in Figure 7.2-2 shows the spatial relation of these stations to the Black/Springbrook watershed.

Table 7.2-6 Additional Meteorologic Data Stations for Black/Springbrook

StationID	STATION NAME	COUNTY	LAT (dec°)	LONG (dec°)	ELEV (ft)	START	END
03U	PANTHER CREEK	KING	47.4156	122.2003	413.3	10/1/88	7/31/01
454169	KENT	KING	47.400	-122.233	400	11/1/48	12/31/01
457473	SEATTLE-TACOMA AP	KING	47.467	-122.317	30	1/1/48	7/31/03

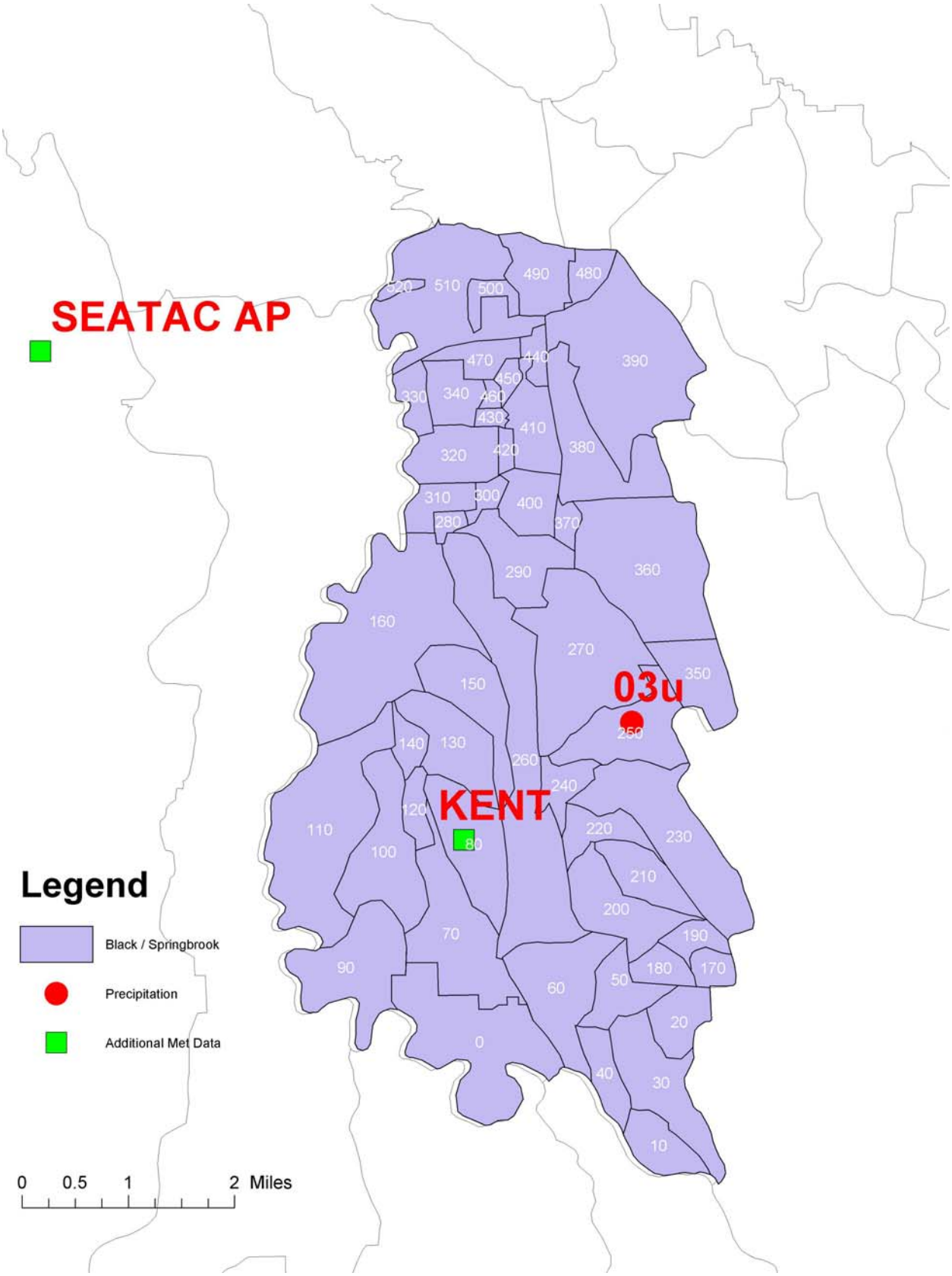


Figure 7.2-2 Map of Meteorological Data Stations Used for Black/Springbrook

Data from the Seattle Tacoma Airport were obtained from the Western Regional Climate Center (WRCC), which collects, processes, and sells data from observation stations that are part of the Automated Surface Observing System (ASOS). Since the data were delivered in "raw" format, AQUA TERRA processed the files in order to standardize the time interval and quantify the cloud cover estimations.

The time interval is hourly with the observation time in the last 10 minutes of the hour preceding that represented by the date and time labels. There were intermittent periods of missing data that were filled either by interpolation or by weighting values from nearby stations from the same time interval. For temperature and dew point, values were interpolated if there were 8 or fewer consecutive missing values (8 hours or less); whereas, for cloud cover and wind, values were interpolated if there were 24 or fewer consecutive missing values (1 day or less). When filling longer gaps using data from nearby stations, the values were weighted by a factor equal to the ratio of the means at the two stations over the period of interest. Additionally, wind values were normalized from the anemometer height to 2 feet, representing the standard height for wind data used in the model.

Cloud cover was recorded at one or more ceilings with a verbal description of CLR, FEW, SCT, BKN, or OVC. ASOS defines these terms as shown in Table 7.2-7.

Table 7.2-7 ASOS Terms

Term	Description	Equivalent in Octas	Avg Decimal Equivalent
CLR	Clear	0/8	0.0
FEW	Few	1/8 to 2/8	0.1875
SCT	Scattered	3/8 to 4/8	0.4375
BKN	Broken	5/8 to 7/8	0.75
OVC	Overcast	8/8	1.0

HSPF requires a value of 0-10 to describe the degree of cloud cover; therefore, an algorithm was used to transform the descriptions to a numeric value in this range. For the first reported ceiling, the average decimal equivalent was multiplied by 10 and taken as the total cloud coverage. If additional ceilings were reported, an incremental increase in total coverage was

calculated in the same manner, but was then multiplied by the fraction of remaining uncovered sky.

The SEATAC solar radiation dataset was developed by aggregating data from 3 different collection methods. For the period of 1/1/91-9/30/96, daily sky cover data were converted to total daily solar radiation using the solar radiation computation model implemented within the 'Compute' tool in WDMUtil. The total daily values were then disaggregated to hourly using the average daily distribution from 1960-1990, which was available at the National Solar Radiation Data Base (NSRDB) at http://rredc.nrel.gov/solar/old_data/nsrdb/. For the period of 10/1/96-7/31/99, an average annual time series was calculated as the average hourly value for that day of the year over the 30 years for which there are actual observations at SEATAC in the NSRDB. Directly observed solar radiation data were used for the final period (8/1/99-7/31/03).

7.2.2.1.4 Additional Water Quality Source Data

In addition to nonpoint loadings, other sources and losses of water quality constituents that should be represented in a model of this type are point sources, imports, diversions, and atmospheric deposition. There were six NPDES point sources and a wastewater treatment plant identified within the boundaries of the Black/Springbrook watershed. No data was available from the NPDES website for any of these stations, however, and the wastewater treatment plant has not drained to Springbrook Creek during the calibration period. Therefore, these quantities are not considered in the water quality budget of the Black/Springbrook watershed. Time series of nitrate and ammonia concentrations in rainfall (wet atmospheric deposition) were incorporated into the model using the standard methodology for specifying atmospheric deposition in HSPF. The concentrations from the two closest National Atmospheric Deposition Program (NADP) monitoring stations were averaged and combined with the rainfall data to produce loadings of nitrate and ammonia to the surface storages on land segments. The two NADP stations are LaGrande (Pierce County) and North Cascades National Park (Skagit County).

7.2.2.2 WATER QUANTITY CALIBRATION DATA

The hydrologic calibration and subsequent validation of a watershed model requires observed flow. Table 7.2-1 and Table 7.2-2 and the following sub-sections reflect knowledge of known monitoring that has been performed in Black/Springbrook River. The stations discussed in the following sections are displayed in Figure 7.2-3.

7.2.2.2.1 Streamflow

Recorded streamflow data are used to check the simulated streamflow results and evaluate the accuracy of the calibration. There are six streamflow stations in the Black/Springbrook watershed that are still actively collecting data; three gages operated by King County and three by the USGS.

There are three King County flow gages operating within the study area, two of which have been in operation long enough to develop an accurate rating curve and, therefore, will be used for calibration. These two gages are the Black/Springbrook River gage 03G at Grady Way, which is the most downstream gage, and the Black/Springbrook River gage 03F, which is located upstream of the Mill Creek (Kent) diversion structure at 76th Avenue. Gage 03G has a rating curve based on a complete period of record from December 2001 through February 2003, and will be used to calibrate the lower part of the watershed. Gage 03F has a complete period of record from March of 2002 to March of 2003, and will be used to calibrate the upper portion of the Black/Springbrook watershed. Due to the relatively short period of record for both gages, there are insufficient streamflow data to support validation of the hydrology simulation at these stations.

There are also three USGS flow gages operating within the study area. These are gage U12113346 Springbrook River at Orillia, gage U12113347 Mill River at Earthworks Park, and gage U12113349 Mill River at the confluence. All three gages contain 15-minute data, which generally exists from January 1994 to May 2003. Gage U12113347 represents the upper part of the watershed, but its data conflict with that of 03F, which represents much of the same area, so gage U12113347 will not be used in the calibration. This conflict is discussed in more depth in Section 7.3.1.3. Gages U12113346 and U12113349 are located in close proximity to each other and measure drainage from approximately the upper two thirds of the watershed.

Given the years of available streamflow data at the 4 stations used for calibration, the calibration period was selected as water years 1996-2002. Clearly, the King County stations can only be used for the portion of this period for which they have data.

Maximum flow events at gage 03G for each water year are shown in Table 7.2-8. Both maximum flood events occurred in December in response to large rainfall events.

Table 7.2-8 Black/Springbrook River Maximum Streamflows at King Co Gage 03G

Water Year	Maximum Flow (cfs)	Date of Event
2002*	355	2001/12/14
2003*	261	2002/12/16

*Dec 2001 through 28 February 2003

For this same period of record low flows at King County gage 03G were in the range of 8 to 11 cfs.

Maximum flow events for each water year are shown in Table 7.2-9. Both maximum flood events occurred in autumn (November-December) in response to large rainfall events.

Table 7.2-9 Black/Springbrook River Maximum Streamflows at King Co Gage 03F

Water Year	Maximum Flow (cfs)	Date of Event
2002	142	2002/04/14
2003*	134	2002/12/16

*October 2002 through 28 February 2003

Annual maximum events for USGS gage number U12113346 are listed in Table 7.2-10.

Table 7.2-10 Black/Springbrook River Maximum Streamflows at USGS Gage U12113346

Water Year	Maximum Flow (cfs)	Date of Event
1995	149	1995/02/19
1996	450	1996/02/09
1997	160	1996/12/29
1998	110	1997/12/16
1999	181	1998/11/25
2000	220	1999/11/12
2001	179	2000/10/20

Water Year	Maximum Flow (cfs)	Date of Event
2002	321	2001/11/14
2003	119	2003/03/12

Annual maximum events for USGS gage number U12113347 are listed in Table 7.2-11.

Table 7.2-11 Black/Springbrook River Maximum Streamflows at USGS Gage U12113347

Water Year	Maximum Flow (cfs)	Date of Event
1995	52	1994/11/30
1996	164	1996/02/09
1997	160	1996/12/29
1998	56	1997/12/16
1999	88	1998/11/25
2000	88	1999/11/12
2001	74	2000/11/26
2002	233	2001/11/14
2003	96	2003/01/03

Annual maximum events for USGS gage number U12113349 are listed in Table 7.2-12.

Table 7.2-12 Black/Springbrook River Maximum Streamflows at USGS Gage U12113349

Water Year	Maximum Flow (cfs)	Date of Event
1995	189	1995/02/19
1996	376	1996/02/09
1997	279	1996/12/29
1998	171	1997/12/16
1999	265	1998/11/26
2000	221	1999/12/15
2001	141	2000/11/26

Water Year	Maximum Flow (cfs)	Date of Event
2002	342	2001/11/14
2003	189	2003/01/26

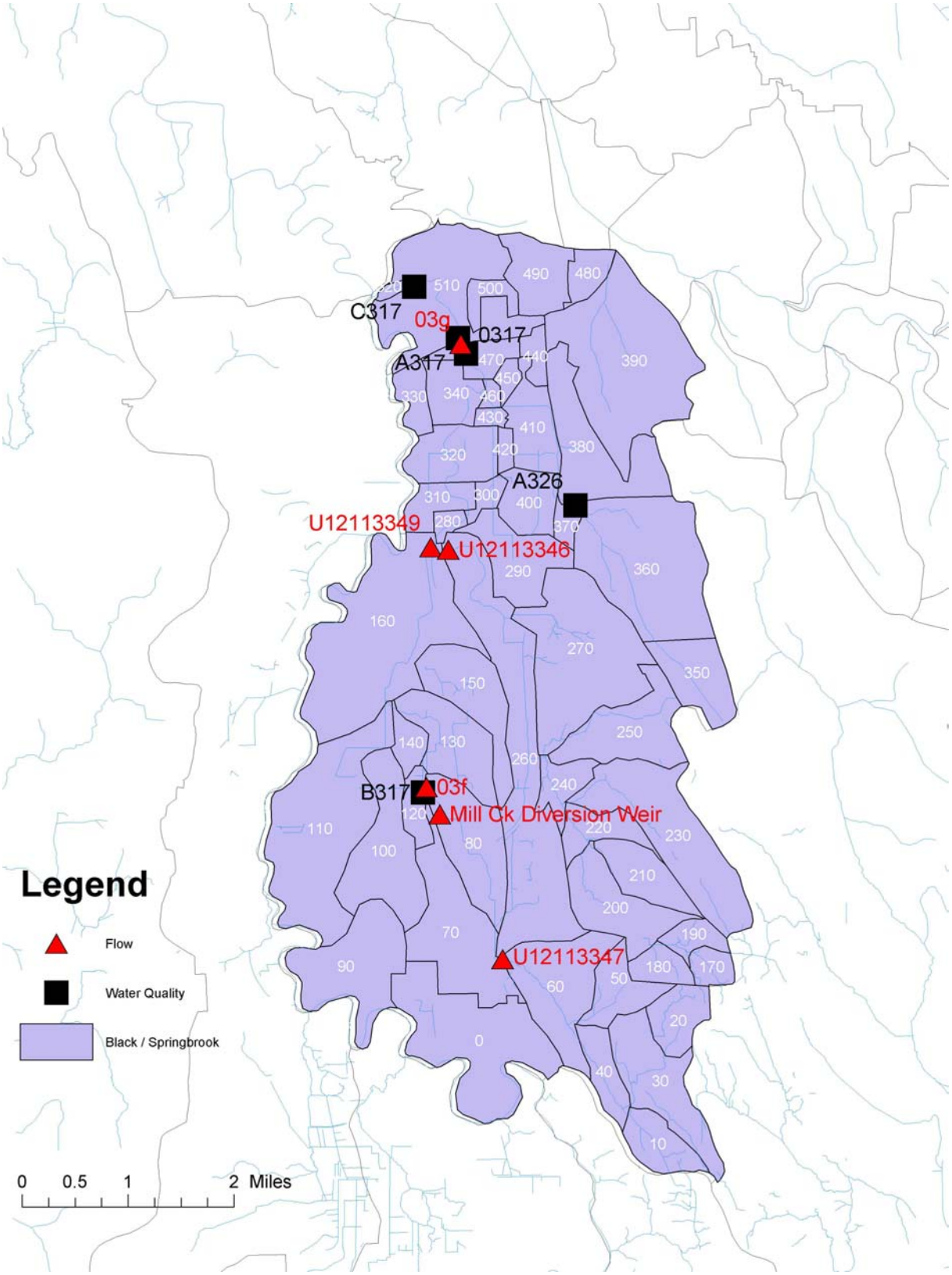


Figure 7.2-3 Map of Flow and Water Quality Gages Used for Black/Springbrook

7.2.2.3 Water Quality Calibration Data

King County maintains seven water quality sampling stations in the Black/Springbrook watershed. Two of these stations are located on lakes where the water quality varies dramatically with depth. Since the HSPF model does not account for the effects of stratified water bodies, only the five stations located on streams were used for calibration purposes. The data for the sampling stations were all provided by King County.

The preceding Figure 7.2-3 shows the location of the stations in the study area. Station C317 is near the mouth of the Black River. Due to its longer period of record, Station 0317, which is located approximately 1 mile upstream on Springbrook Creek, is the primary outlet station. Station A317 is approximately 200 feet downstream from Station 0317 on Springbrook Creek, without an intervening tributary, and is therefore at essentially the same location. Stations B317 and A326 are located upstream on two of the three major tributaries of Springbrook Creek. Station B317 is situated on Mill Creek, and Station A326 is located on Panther Creek. There are no monitoring stations on Garrison Creek, the other major tributary.

When comparing simulated and observed values, the data observed at a particular sampling station are compared to simulated results in the reach on which that station is located, unless the station is located just downstream from a reach outlet in which case the values are compared against those from the upstream reach. The resulting correspondence between sampling stations and model reaches is shown in Table 7.2-13.

Table 7.2-13 Linkage of Sampling Station to Reach Number

Station	Reach
King County Gage C317	510
King County Gage A317	470
King County Gage 0317	470
King County Gage A326	360
King County Gage B317	80

The period of record for Station 0317 includes the entire calibration period, and it has been sampled approximately on a monthly interval over the course of its history. The periods of

record for the other four stations are much shorter, going back only to approximately the beginning of calendar year 2001. The sampling schedule for these stations is approximately monthly during the dry season with more frequent samples taken during the winter rainy season. Table 7.2-14 summarizes the period of record for the various constituents at each station.

Table 7.2-14 Constituents and Periods of Record for Water Quality Monitoring Stations

	Stations				
Constituent	0317	C317	A317	A326	B317
Water Temperature	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-5/12/03	1/24/02-6/9/03	1/24/02-3/9/03
Dissolved Oxygen	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-5/12/03	1/24/02-6/9/03	1/24/02-3/9/03
BOD	12/10/02-12/10/02			11/7/02-11/7/02	11/7/02-3/9/03
Suspended Sand					
Suspended Silt					
Suspended Clay					
TSS	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Ammonia / Ammonium	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Nitrite / Nitrate	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Organic Nitrogen					
Total Nitrogen	4/13/93-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Phosphate	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Organic Phosphorus					
Total Phosphorus	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Total Organic Carbon	5/14/02-6/11/03	2/13/02-6/9/03	11/28/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Total Inorganic Carbon					
Alkalinity	12/12/95-7/13/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
pH	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-5/12/03	1/24/02-6/9/03	1/24/02-3/9/03
Silica	5/14/02-10/14/02				
E-Coli	1/20/99-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Fecal Coli	10/11/88-6/11/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Benthic Algae					
Dissolved Copper	5/27/98-1/27/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03
Total Copper	11/3/88-1/27/03	2/13/02-6/9/03	11/14/01-6/8/03	1/24/02-6/9/03	1/24/02-6/8/03

7.2.3 WATERSHED / CONVEYANCE SYSTEM CHARACTERIZATION DATA

Information describing the characteristics of the watershed, including topography, drainage patterns, meteorological variability, soils conditions, and the land use distribution are required for segmenting the watershed into individual land segments that demonstrate a similar hydrologic and water quality response. A wealth of GIS data is available from King County to describe these characteristics of the watershed. In addition, the region has been modeled extensively using HSPF for hydrology applications, which have resulted in a database of HSPF calibration parameters as they relate to watershed characteristics.

Information describing the channels, floodplain morphology, culverts, and other hydraulic features within the watershed allows for the segmentation of the conveyance system (both natural and artificial) into discrete sections with similar hydraulic and water quality behavior. Locations of dams/reservoirs, point source discharges, gages/data collectors, culverts, and diversions provides information to develop a segmentation scheme that supports modeling localized conditions within the watershed.

Table 7.2-15 documents the information, along with the respective sources, that was used in characterizing the watershed and conveyance system. The use of this information will be discussed in detail in Section 7.2.4.

Table 7.2-15 Data and GIS Coverages used to Characterize the Watershed and Conveyance System.

Data / GIS Coverage	Source	Comment
Digital Elevation Model (DEM)	USGS	Required 4 individual 10 meter resolution DEMs to be mosaiced together
Slopes	AQUA TERRA Consultants	Developed using DEM and ArcView Spatial Analyst functionality
Land Use	King County	
Soils	King County, AQUA TERRA Consultants	Coverage modified to group soils into following 4 classes: till, outwash, saturated, and bedrock
Hydrography/Stream Network	King County	Black/Springbrook River and major tributaries
Stream and Meteorological Gages	King County, NOAA, USGS	Locations of King and nearby NOAA gages
Black River Pump Station	Renton	Operated by King County, Pump Rating curves developed by NHC (1996) (see East Side Green River Watershed Hydrologic Analysis)
Green River Natural Resources Area and Mill Creek Diversion Structure	Kent	Operated by City of Kent. Stage-Storage-Discharge table derived from the Operation and Maintenance Manual/City of Kent/CH2MHill
Upper Mill Pond Diversion Weir	NHC Model	NHC HSPF model Mill_Cal.inp
Street and Watershed Boundary Map for the City of Kent	Kent	Hard copy map of streets, water features, and subbasin boundaries for the City of Kent
FTABLE's for Inclusion in the HSPF model	NHC	Existing HSPF models: Mill_Cal.inp, Garr_cur.inp, Sbrk3cur.inp, Sbrk_Cur.inp, Panth_C.inp

7.2.4 WATERSHED SEGMENTATION AND CHARACTERIZATION

Whenever HSPF, or any watershed model, is applied to an area of any significant size, the entire study area must undergo a process referred to as segmentation. The purpose of watershed segmentation is to divide the study area into individual land and channel segments, or pieces, which are assumed to demonstrate relatively homogenous hydrologic/hydraulic and

water quality behavior. This segmentation then provides the basis for assigning similar or identical parameter values or functions to where they can be applied logically to all portions of a land area or channel length contained within a segment. Since HSPF and most watershed models differentiate between land and channel portions of a watershed, and each is modeled separately, each undergoes a segmentation process to produce separate land and channel segments that are linked together to represent the entire watershed area.

The initial segmentation typically involves delineating areas (catchments) that have similar meteorological conditions, topographical features, use practices for a given land, and/or are a region of interest (e.g., NPS loads need to be quantified). Once the catchments and channel segments have been defined, these catchments must then be further characterized to: 1) develop the model categories (i.e., PERLNDs / IMPLNDs) to represent; 2) define the physical parameters (e.g., elevation, slopes, channel length) for HSPF using available data; and 3) establish initial calibration parameters for HSPF based on past applications within the region and past experience with the model.

7.2.4.1 Catchment Delineation

The initial catchment delineation was extracted from previous modeling efforts[1] conducted for City of Renton by Northwest Hydraulic Consultants, and was later revised by AQUA TERRA Consultants. The initial delineation resulted in 52 catchments ranging in size from 0.04 to 1.81 square miles (Table 7.2-16). The catchments are shown in Figure 7.2-4; the corresponding schematic is shown in Figure 7.2-5.

[1] "East Side Green River Watershed Hydrologic Analysis", 1996

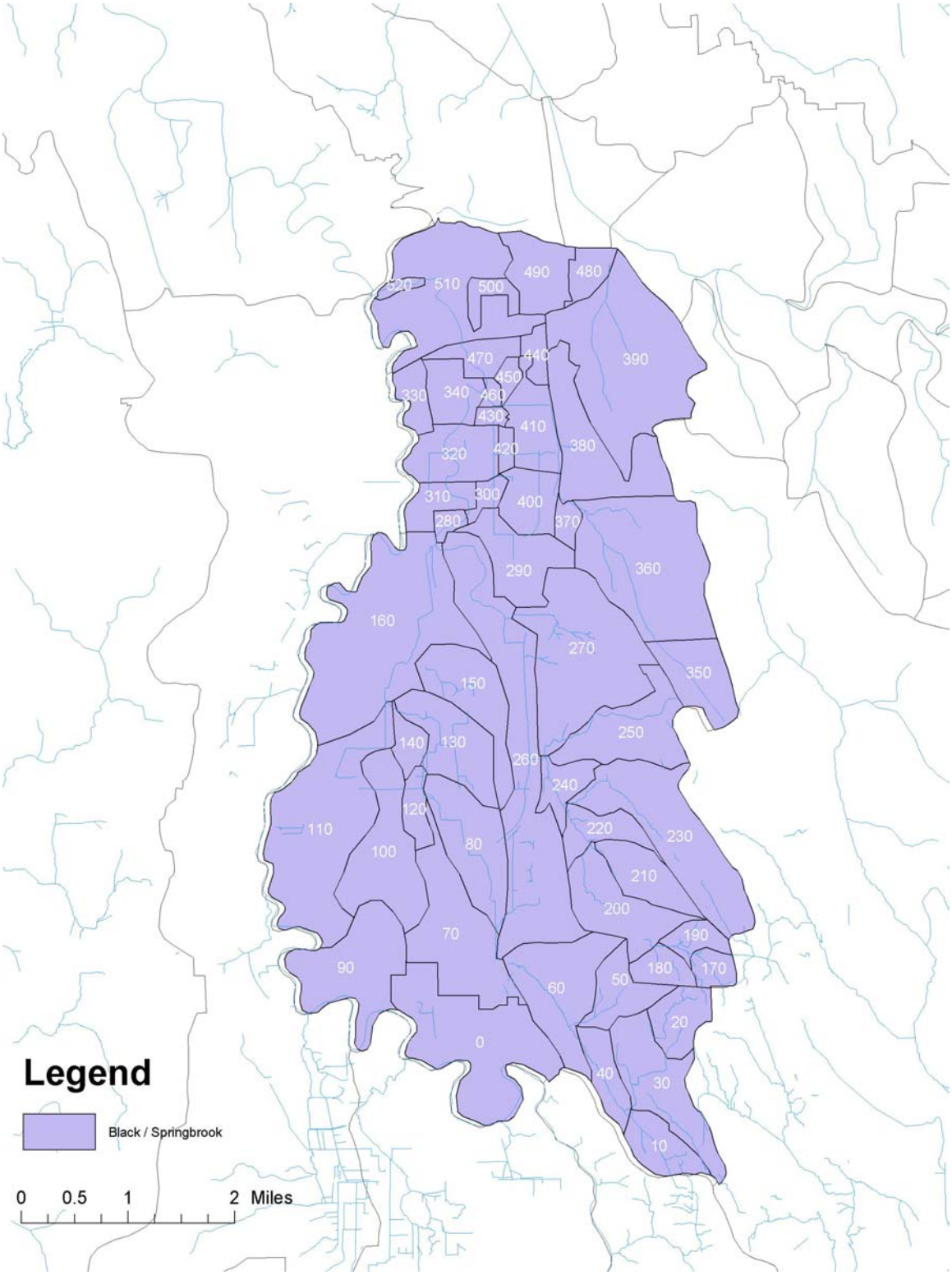


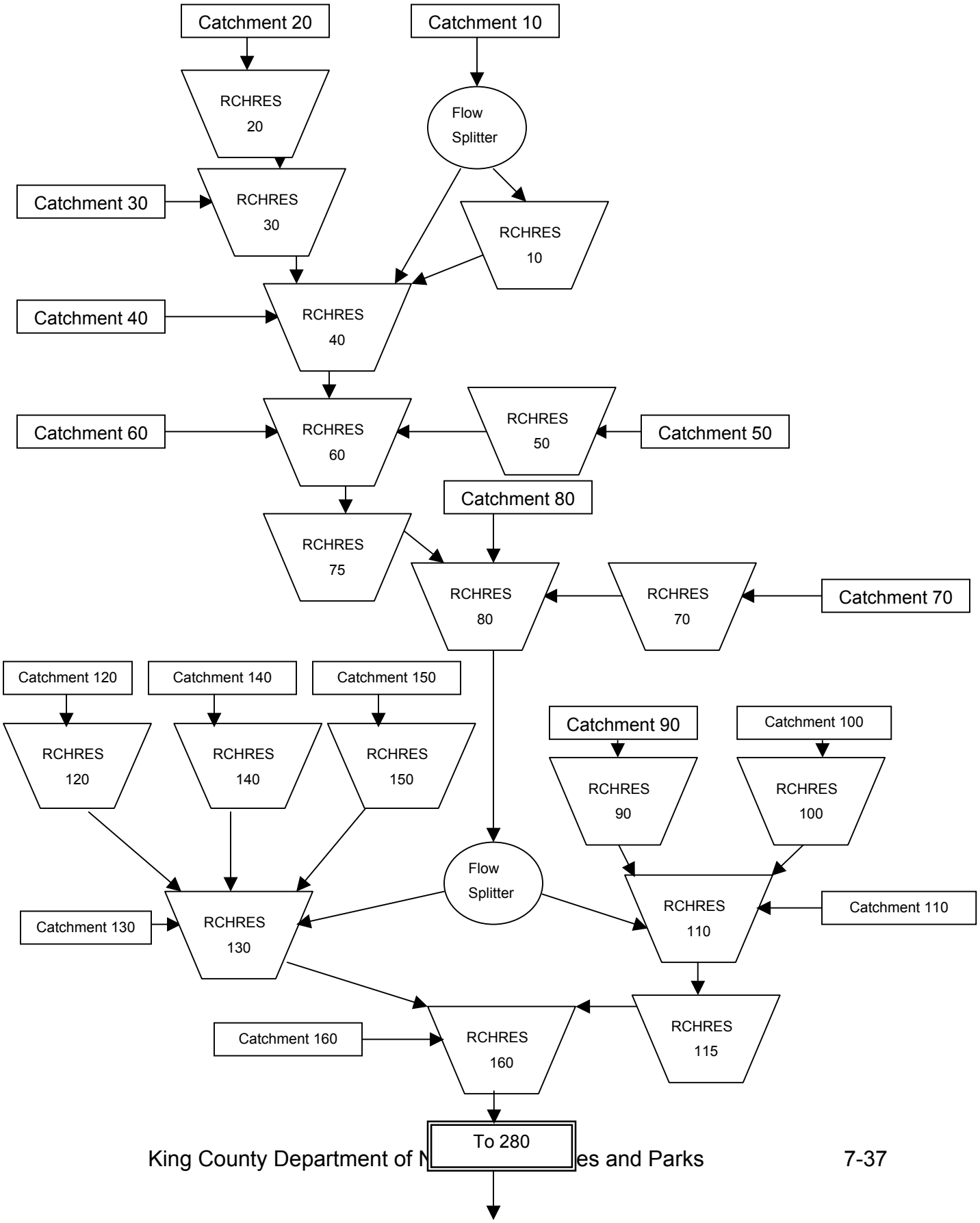
Figure 7.2-4 Black/Springbrook River Catchments

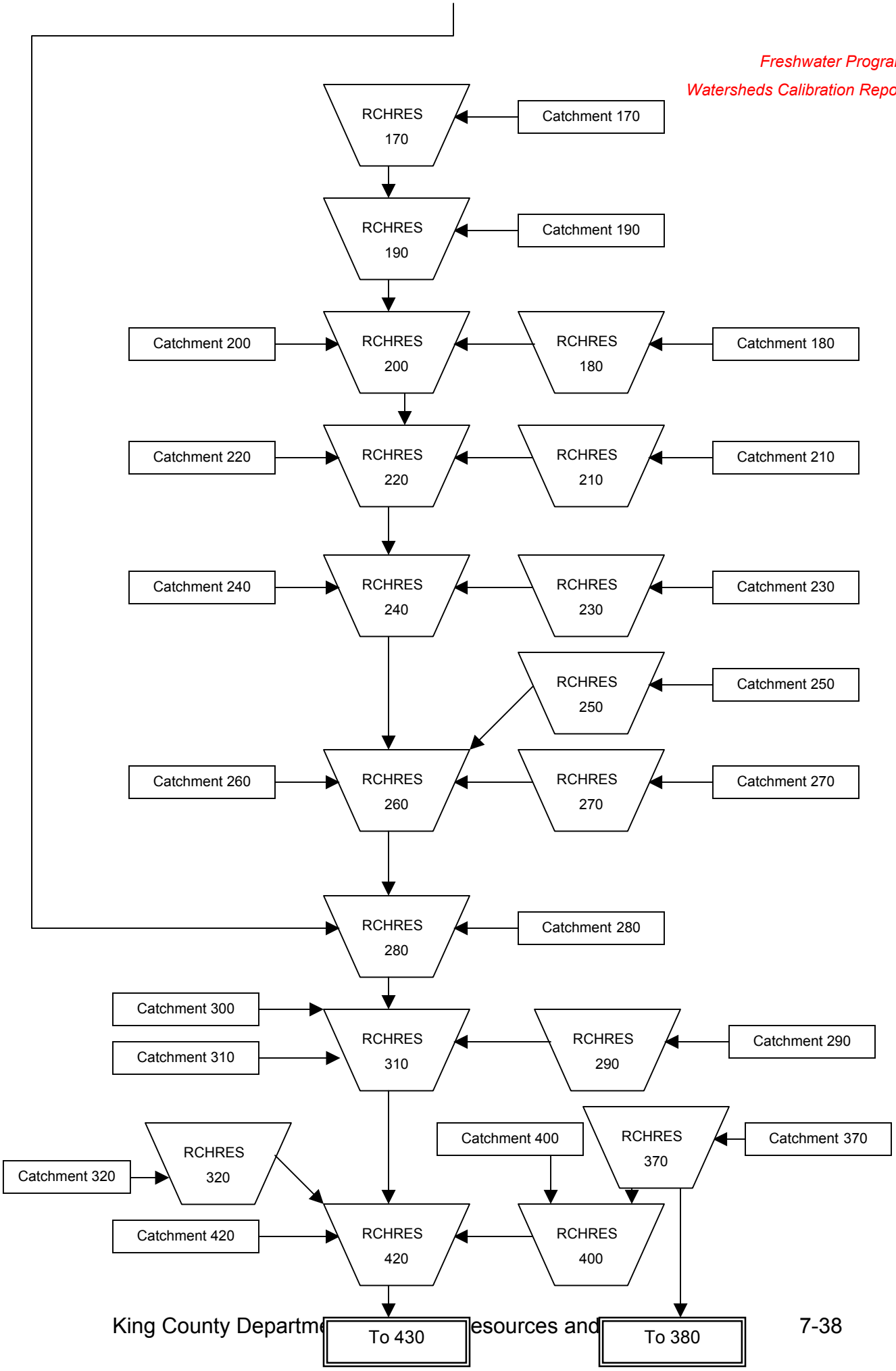
Table 7.2-16 Catchment Areas

Catchment No.	Catchment Area (acres)	Stream Reach No.
10	186	10
20	183	20
30	417	30
40	154	40
50	200	50
60	466	60
70	558	70
80	407	80
90	510	90
100	481	100
110	917	110
120	98	120
130	347	130
140	89	140
150	359	150
160	1160	160
170	84	170
180	109	180
190	98	190
200	349	200
210	219	210
220	162	220
230	676	230
240	133	240
250	396	250
260	1087	260
270	848	270
280	43	280
290	311	290
300	55	300
310	134	310
320	270	320
330	108	330
340	175	340

Catchment No.	Catchment Area (acres)	Stream Reach No.
350	272	350
360	871	360
370	55	370
380	471	380
390	1006	390
400	191	400
410	233	410
420	38	420
430	32	430
440	67	440
450	43	450
460	27	460
470	128	470
480	105	480
490	244	490
500	79	500
510	748	510
520	30	520

Figure 7.2-5 Black/Springbrook River Catchment Schematic

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RCHRES 190
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Catchment 200
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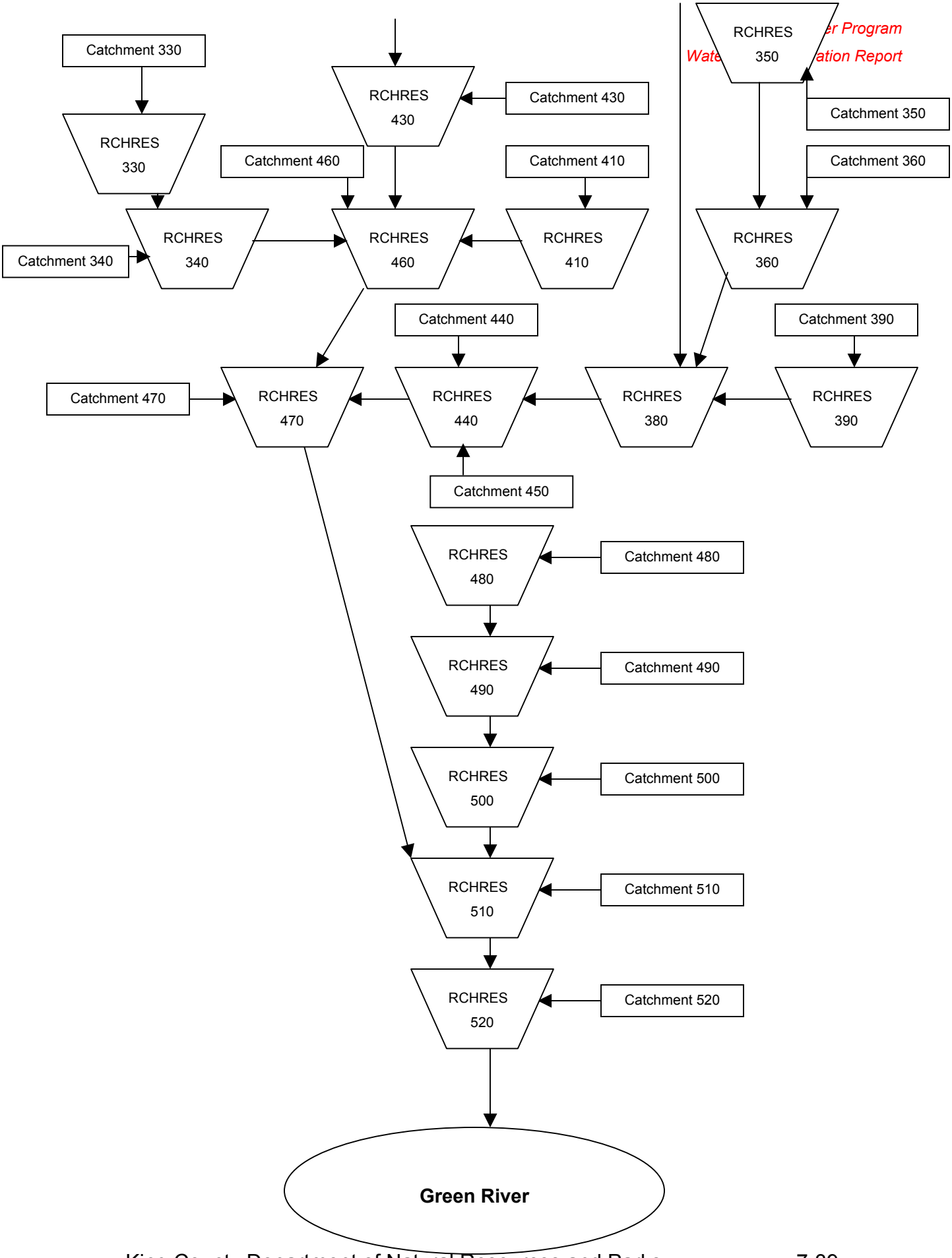
RCHRES 420
RCHRES 400
To 430
To 380


Catchment 330
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Catchment 460
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RCHRES 460
RCHRES 410
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Catchment 440
Catchment 390
Catchment 470
RCHRES 470
RCHRES 440
RCHRES 380
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Catchment 450
RCHRES 480
Catchment 480
RCHRES 490
Catchment 490
RCHRES 500
Catchment 500
RCHRES 510
Catchment 510
RCHRES 520
Catchment 520
Green River

7.2.4.2 PERLND and IMPLND Categories

After the catchment delineation was finalized, the areas of the respective PERLND (pervious land) and IMPLND (impervious land) categories were determined on a catchment-by-catchment basis. Land categories are selected so that a given set of parameters represents the hydrologic and water quality response from that land category.

For an application involving water quality simulation, such as the Black/Springbrook River application, it is also necessary to consider how the use practices for various land uses impact the nonpoint source loadings. For this application, this involves increasing the number of vegetation/land use categories that are represented by the model. The PERLND / IMPLND categories were developed based on the following revised scheme.

1. soils: till, outwash, saturated, bedrock
2. vegetation/land use: forest, pasture/agricultural, cropland, forest residential, low density residential landscaping, high density residential landscaping, commercial/industrial landscaping
3. land slope: flat (0-5%), low (5-10%), medium (10-15%), steep (>15%)

It was determined that outwash and saturated soils could be grouped for all land slope categories (i.e., flat, low, medium, and steep); the slopes for these soils are not expected to vary significantly. Thus, the hydrologic and water quality responses from these areas are not expected to be greatly impacted by slope differences.

For modeling purposes a distinction is made between total impervious area and effective impervious area. Total impervious area includes all surfaces that do not infiltrate runoff. Roofs, paved streets, sidewalks, driveways, and parking lots are all part of the total impervious area. Effective impervious area (EIA) is defined as the area where there is no opportunity for surface runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). Because it is extremely expensive and time consuming to look at every impervious surface in a watershed to determine whether or not it is an effective impervious area, average EIA values are used instead. Each average EIA value is based on the land use (forest, low density residential, high density residential, commercial, etc.) and previous experience in other Puget Sound lowland watersheds. For example, the following EIA percentages in Table 7.2-17 are representative values that have been provided by King County

(Burkey, 2002). Other continuous simulation models use similar schemes to separate out impervious areas from pervious. These land use categories in Table 7.2-17 can also be used to differentiate different land covers and pollutant sources.

Table 7.2-17 HSPF EIA Values

King County Land Use Categories	Forest	Pasture	Forest Residential	Low Density Residential	High Density Residential	Commercial/ Industrial	Road
	%	%	%	%	%	%	%
Forest	0	0	0	0	0	0	0
Recently cleared	0	0	0	0	0	0	0
Scrub/shrub	0	0	0	0	0	0	0
Grass – brown	0	0	0	0	0	0	0
Grass – green	0	0	0	0	0	0	0
Developed low	0	0	0	5	0	0	0
Developed med	0	0	0	0	25	0	0
Developed high	0	0	0	0	0	50	0
Bare ground/asphalt	0	0	0	0	0	50	0
Bare rock/concrete	0	0	0	0	0	0	50
Shadow	0	0	0	0	0	0	0
INSIDE=100	0	0	0	0	0	0	86

Corresponding pervious land divisions are shown below in Table 7.2-18.

Table 7.2-18 HSPF Pervious Land Divisions

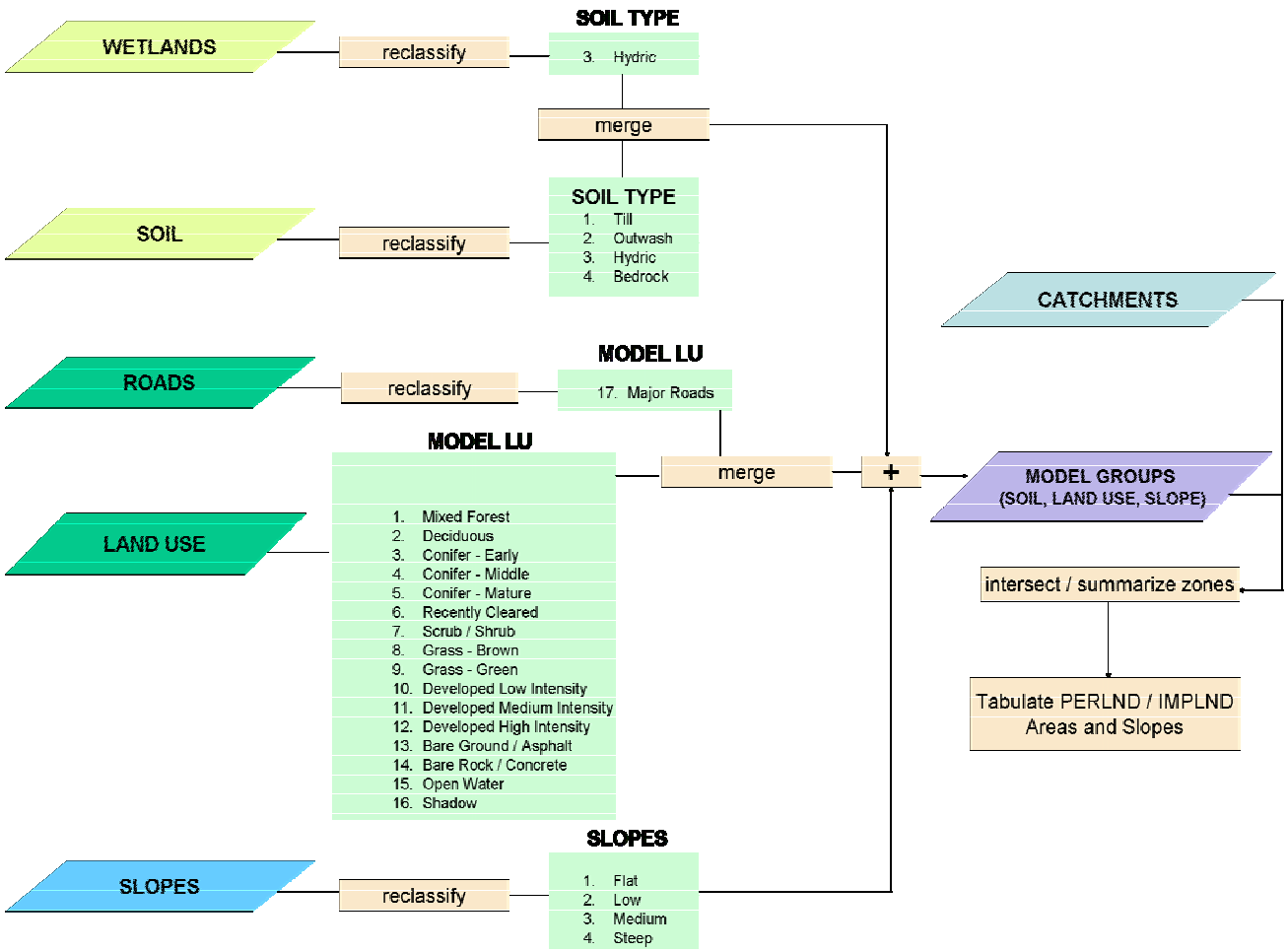
King County Land Use Categories	Forest	Pasture	Forest Residential	Low Density Residential	High Density Residential	Commercial/ Industrial	Road
	%	%	%	%	%	%	%
Forest	100	0	0	0	0	0	0
Recently cleared	0	100	0	0	0	0	0
Scrub/shrub	F*	100-F	0	0	0	0	0

King County Land Use Categories	Forest	Pasture	Forest Residential	Low Density Residential	High Density Residential	Commercial/ Industrial	Road
Grass – brown	0	100	0	0	0	0	0
Grass – green	0	0	0	100	0	0	0
Developed low	0	0	35	60	0	0	0
Developed med	0	0	0	0	75	0	0
Developed high	0	0	0	0	0	50	0
Bare ground/asphalt	0	0	0	0	50	0	0
Bare rock/concrete	0	0	0	0	0	50	0
Shadow	50	50	0	0	0	0	0
INSIDE=100	0	0	0	0	0	14	0

* The percent F (forest) is based on the percentage of forest in the catchment compared to pasture.

For the purpose of the Black/Springbrook River simulation, it is assumed that pasture is the same as agricultural animal (hobby farm) land use. The other pasture-related category of cropland may be used in other parts of the SWAMP and Green WQA study areas.

Determining the areas of the PERLNDs / IMPLNDs within the catchments is readily handled within the framework of a GIS system (ArcView) with some additional processing using Microsoft Access. Figure 7.2-6 displays a flow chart describing the methodology for spatially and quantitatively defining the PERLND / IMPLND categories. The catchment and soil coverages will be intersected in order to quantify the areas of various soil types within a given catchment. The resulting coverage will then be reclassified to group soils into till, outwash, saturated soils, and bedrock. Table 7.2-19 displays the relationship between the King County attribute geologic code to the four reclassified soil types. The land use coverage was reclassified into the vegetative/land use categories previously discussed and intersected with the modified soils coverage; creating regions with the desired combinations of soil type and vegetation characteristics (e.g., TF – Till, Forest).



Legend: **Soil Type** –Till; Outwash; Hydric; Bedrock

LU – Mixed Forest; Decidious; Conifer Early; Conifer Middle; Conifer Mature; Recently Clear; Scrub/Shrub; Grass Brown; Grass Green; Developed Low; Developed Medium; Developed High; Bare Ground Asphalt; Bare Ground Concrete; Open Water; Shadow

Slope – Flat (0 – 5%); Low (5-10%); Medium (10-15%); Steep (>15%)

Figure 7.2-6 PERLND / IMPLND Development

Table 7.2-19 King County Geologic Code to Four Soil Types

SOIL TYPE			
Till	**Outwash**	**Saturated**	**Bedrock**
Qmw	Qb	Qls	Tb
Qoal	Qal	Qw	Tdg
Qob	Qag		Teg
Qpf	Qf		Tf
Qt	Qva		Ti
Qtb	Qvi		Tmp
Qtu	Qvr		To
Qu	Qyal		Tp
Qvb			Tpr
Qvp			Tpt
Qvt			Ts
Qvu			Tsc
M			Tsg
Qom			Tv

Using the 10-meter resolution DEM, percent slopes were developed for the watershed at the same resolution. The zones established by the desired combinations of soil type and vegetation were then summarized using this slope grid (i.e., the weighted average slope for each polygon was assigned). These slopes were reclassified into flat, low, medium, and steep classifications based on the ranges discussed earlier (e.g., TFF – Till, Forest, Flat)

The final processing occurred outside the GIS within Microsoft Access. At this point, the multiple slope classes for outwash and saturated soils and the vegetation classes with an impervious component were combined into one slope class. In addition, the EIA was broken out from these vegetation classes to create four IMPLND categories (i.e., residential, commercial, industrial, and major road pollution) using the values and method previously presented in Table 7.2-17 and accompanying discussion. Table 7.2-20 presents the final potential 72 PERLND / IMPLND categories; not all categories exist in Black/Springbrook River watershed. GIS processing identified the specific categories needed.

The final processing produced a spreadsheet with the number of acres for each PERLND and IMPLND in each catchment. Within each catchment the relative size of the PERLND was checked. If the PERLND consisted of less than 5 percent of the catchment area then it was aggregated to an adjacent larger PERLND according to rules developed by AQUA TERRA Consultants. The purpose of the aggregation was to minimize the number of PERLNDs per catchment for water quality simulation linkages. Physically this also means that very small PERLNDs probably do not have a direct connection to the catchment's stream reach (RCHRES), but drain through an adjacent, larger PERLND. IMPLND areas were not changed.

Table 7.2-20 Final PERLND/IMPLND Categories

TILL	OUTWASH	SATURATED	BEDROCK	EIA
TFF: till, forest, flat	OF: outwash, forest, all slopes	SF: saturated, forest, all slopes	BFF: bedrock, forest, flat	ELDR: EIA Low Density Residential
TFL: till, forest, low	OP: outwash, pasture, all slopes	SP: saturated, pasture, all slopes	BFL: bedrock, forest, low	EHDR: EIA High Density Residential
TFM: till, forest, medium	OC: outwash, cropland, all slopes	SC: saturated, cropland, all slopes	BFM: bedrock, forest, medium	ECI: EIA Commercial / Industrial
TFS: till, forest, steep	OFR: outwash, forest residential, all slopes	SFR: saturated, forest residential, all slopes	BFS: bedrock, forest, steep	ER: EIA Road
TPF: till, pasture, flat	OLDR: outwash, low density residential, all slopes	SLDR: saturated, low density residential, all slopes	BPF: bedrock, pasture, flat	
TPL: till, pasture, low	OHDR: outwash, high density residential, all slopes	SHDR: saturated, high density residential, all slopes	BPL: bedrock, pasture, low	
TPM: till, pasture, medium	OCI: outwash, commercial/ industrial, all slopes	SCI: saturated, commercial/ industrial, all slopes	BPM: bedrock, pasture, medium	
TPS: till, pasture, steep	OR: outwash, major road, all slopes	SR: saturated, major road, all slopes	BPS: bedrock, pasture, steep	
TCF: till, cropland, flat			BCF: bedrock, cropland, flat	
TCL: till, cropland, low			BCL: bedrock, cropland, low	
TCM: till, cropland, medium			BCM: bedrock, cropland, medium	
TCS: till, cropland, steep			BCS: bedrock, cropland, steep	
TFRF: till, forest residential, flat			BFRF: bedrock, forest residential, flat	
TFRL: till, forest residential, low			BFRL: bedrock, forest residential, low	
TFRM: till, forest residential, medium			BFRM: bedrock, forest residential, medium	
TFRS: till, forest residential, steep			BFRS: bedrock, forest residential, steep	

TILL	OUTWASH	SATURATED	BEDROCK	EIA
TLDF: till, low density residential, flat			BLDF: bedrock, low density residential, flat	
TLDL: till, low density residential, low			BLDL: bedrock, low density residential, low	
TLDM: till, low density residential, medium			BLDM: bedrock, low density residential, medium	
TLDS: till, low density residential, steep			BLDS: bedrock, low density residential, steep	
THDF: till, high density residential, flat			BHDF: bedrock, high density residential, flat	
THDL: till, high density residential, low			BHDL: bedrock, high density residential, low	
THDM: till, high density residential, medium			BHDM: bedrock, high density residential, medium	
THDS: till, high density residential, steep			BHDS: bedrock, high density residential, steep	
TCIF: till, commercial/ industrial, flat			BCIF: bedrock, commercial/ industrial, flat	
TCIL: till, commercial/ industrial, low			BCIL: bedrock, commercial/ industrial, low	
TCIM: till, commercial/ industrial, medium			BCIM: bedrock, commercial/ industrial, medium	
TCIS: till, commercial/ industrial, steep			BCIS: bedrock, commercial/ industrial, steep	

Note that there are no cropland categories in the Black/Springbrook River watershed.

7.2.4.3 Catchment Characterization

The location, areas, and slopes of PERLND and IMPLND categories within each catchment were determined using the methods previously discussed. Additional attributes (e.g., average elevation) were also calculated within the GIS.

7.2.4.4 Physical Parameters

The Black/Springbrook River watershed PERLND soil type and land use areas and IMPLND land use areas used in the HSPF model are summarized in Table 7.2-21. They are based on the GIS coverage and the delineation methodology described in Section 7.2.4.2.

Table 7.2-21 Black/Springbrook Watershed PERLND/IMPLND Areas

Land Use	Till (acres)	Outwash (acres)	Hydric (acres)	Bedrock (acres)	EIA (acres)	Total (acres)
Forest	874	309	126	0	0	1309
Pasture/Ag	494	414	84	0	0	993
Forest Residential	737	326	5	72	0	1141
Low Density Residential	1648	1407	127	194	192	3568
High Density Residential	2335	2063	119	144	2395	7056
Commercial/Industrial	37	672	41	0	809	1558
Roads	0	0	0	0	790	790
Total	**6126**	**5192**	**502**	**410**	**4185**	**16415**

Table 7.2-21 Black/Springbrook Watershed PERLND/IMPLND Areas (continued)

Land Use	Till (%)	Outwash (%)	Hydric (%)	Bedrock (%)	EIA (%)	Total (%)
Forest	5.32	1.88	0.77	0.00	0.00	7.97
Pasture/Ag	3.01	2.52	0.51	0.00	0.00	6.05
Forest Residential	4.49	1.99	0.03	0.44	0.00	6.95
Low Density Residential	10.04	8.57	0.77	1.18	1.17	21.74
High Density Residential	14.22	12.57	0.72	0.88	14.59	42.99
Commercial Industrial	0.23	4.09	0.25	0.00	4.93	9.49
Roads	0.00	0.00	0.00	0.00	4.81	4.81
Total	**37.32**	**31.63**	**3.06**	**2.50**	**25.49**	**100.00**

7.2.4.5 Conveyance System Segmentation and Characterization

The current segmentation scheme is primarily the result of the catchment delineation. The modeling scheme incorporates a single HSPF reach per catchment. Originally some

catchments were delineated such that they drain to the same reach as right and left contributions. These right/left catchments were combined into a single catchment for a corresponding HSPF reach.

7.2.4.6 HSPF Reach Network

The current network includes 55 reaches. Within the channel module (RCHRES) of HSPF, each stream reach is represented by a hydraulic function table, called an FTABLE, which defines the flow rate, surface area, and volume as a function of the water depth in the channel reach. The majority of the FTABLE's used in this modeling effort were extracted from previous modeling efforts. Several FTABLE's were derived as needed. These include the Green River Natural Resources area (GRNRA) and the Mill Creek Diversion Structure.

The stage-storage-discharge table for the Green River Natural Resources area was computed using generalized geomorphic information taken from the Operation and Maintenance Manual for the Green River Natural Resources area. Although the GRNRA is comprised of several different storage cells these cells were all combined into one table that is representative of the overall storage volume available. The discharge from the facility is somewhat complex in that there are several sluice gate/weir structures that can be adjusted manually to manipulate outflow from the facility. For the purposes of this model the discharge has been represented as two two-foot by four-foot gates and one 18-inch by 18-inch gate. The discharge from the three gates is then summed and used as the total discharge from the facility.

The Mill Creek Diversion Structure (MCDS) splits flows from the mainstem of Mill creek into the Green River Natural Resource Enhancement Area (GRNREA). The split of stream flow is governed by a labyrinth weir that is designed to begin splitting flows into the GRNREA when flows in Mill Creek exceed 40 cfs. Flow through the weir can also be impacted by backwater as a result of insufficient capacity in the downstream Mill Creek system. It was the goal of this approach to accurately represent common flows that are likely to be diverted into the GRNREA. For this approach backwater has not been modeled. A two outlet FTABLE has been used to represent flow through the diversion weir. All flows up to 40 cfs will continue on down Mill Creek with no diversion into the GRNREA. Above this flow level flows are split between the GRNRA and Mill Creek up to 100 cfs. Above 100 cfs, all flows are diverted into the GRNRA. The 100 cfs threshold is based on the downstream constraints of Mill Creek.

The pumping rate of the Black River Pump Station (BRPS) is based on the measured flow at the USGS gage number 12113000. This gage is for the Green River near Auburn. A Visual Basic program has been written that accesses the time series data from this gage, and based on the rules for pumping rates outlined below, a new time series of maximum flow rates has been generated. This new time series will be applied to the FTABLE that represents the BRPS. As a result, flow from the BRPS will be a maximum of the flow demand from the time series. If the maximum demand is greater than the available water supply, then only the available water supply will be extracted.

Tables 5 and 6 of the East Side Green River Watershed Hydrologic Analysis report prepared by NHC (1996) are used to determine pump operation. Table 5 of the East Side Green River Watershed Hydrologic Analysis report gives the primary basis for pump operation used for determining the demand time series. Table 5 has been summarized in Table 4.2-22.

Table 7.2-22 Black River Pump Station Discharge Rules (Table 5 of East Side Green River Watershed Hydrologic Analysis report)

Black River Pump Station Combined Discharge		
Green River Discharge	Green River Discharge	Black River Discharge
Starting Flow Level	Ending Flow Level	Discharge
(cfs)	(cfs)	(cfs)
0	10500	1700
10500	11000	1360
11000	11500	960
11500	12000	480
12000	100000	0

Table 7.2-23 shows the data used to construct the FTABLEs for Black/Springbrook River.

Table 7.2-23 Stream Reach Data

RCHRES	Total Length	RCHRES	FTABLE Origin	FTABLE Origin	FTABLE Origin

	(mi)	Length (mi)	Model Name	RCHRES Number	FTABLE Number
5	0.01	0.01	Simple Diversion Structure	No Previous Number	No Previous Number
10	0.50	0.50	Mill_Cal.inp	2	4
20	0.72	0.72	Mill_Cal.inp	31	5
30	0.20	0.68	Mill_Cal.inp	32	6
40	0.49	0.49	Mill_Cal.inp	4	12
50	0.20	1.01	Mill_Cal.inp	33	7
60	0.40	0.78	Mill_Cal.inp	4	12
70	0.52	0.10	Mill_Cal.inp	8	24
75	0.10	0.52	Mill_Cal.inp	5	14
80	1.50	0.15	Mill_Cal.inp	9	28
85	0.05	0.05	Diversion		
90	0.64	0.64	Shallow Lake		
100	1.17	1.17	Mill_Cal.inp	11	32
110	0.73	0.73	Lagoons		
115	0.73	0.73	Mill_Cal.inp	14	40
120	1.01	1.01	Industrial Pond		
130	0.30	0.30	Mill_Cal.inp	16	44
140	0.84	0.84	Mill_Cal.inp	16	44
150	1.50	1.50	Mill_Cal.inp	16	44
160	0.73	0.73	Mill_Cal.inp	19	50
170	0.80	0.10	Garr_Cur.inp	51	151
180	0.88	0.88	Garr_Cur.inp	51	151
190	0.70	0.70	Garr_Cur.inp	51	151
200	0.69	0.10	Garr_Cur.inp	52	152
210	0.69	0.10	Garr_Cur.inp	53	53
220	0.69	0.69	Garr_Cur.inp	53	53
230	0.166	0.166	Garr_Cur.inp	8	8
240	0.455	0.455	Garr_Cur.inp	10	10
250	0.417	0.417	Garr_Cur.inp	12	12
260	3.00	0.10	Sbrk3cur.inp	4	4

RCHRES	Total Length (mi)	RCHRES Length (mi)	FTABLE Origin Model Name	FTABLE Origin RCHRES Number	FTABLE Origin FTABLE Number
270	0.55	0.10	Sbrk3cur.inp	31	31
280	0.38	0.10	Sbrk_Cur.inp	5	5
290	0.30	0.10	Sbrk_Cur.inp	6	6
300	0.73	0.10	Sbrk_Cur.inp	7	7
310	0.45	0.10	Sbrk_Cur.inp	7	7
320	1.20	0.10	Sbrk_Cur.inp	92	92
330	0.20	0.10	Sbrk_Cur.inp	15	15
340	0.25	0.10	Sbrk_Cur.inp	11	11
350	0.76	0.76	Panth_C.inp	19	19
360	0.50	1.70	Panth_C.inp	20	20
370	0.20	0.20	Panth_C.inp	23	23
380	1.40	1.40	Panth_C.inp	24	24
390	0.61	0.61	Panth_C.inp	21	21
400	0.20	0.10	Sbrk_Cur.inp	8	8
410	0.40	0.10	Sbrk_Cur.inp	10	10
420	0.44	0.10	Sbrk_Cur.inp	91	91
430	0.18	0.10	Sbrk_Cur.inp	9	9
440	0.53	0.10	Sbrk_Cur.inp	13	13
450	0.10	0.10	Sbrk_Cur.inp	13	13
460	0.50	0.10	Sbrk_Cur.inp	12	12
470	0.44	0.10	Sbrk_Cur.inp	14	14
480	0.79	0.10	Sbrk_Cur.inp	162	162
490	0.60	0.10	Sbrk_Cur.inp	161	161
500	0.90	0.10	Sbrk_Cur.inp	16	16
510	0.45	0.10	Sbrk_Cur.inp	17	17
520	3.00	0.10	Sbrk_Cur.inp	18	18

7.3 MODEL CALIBRATION

The calibration of HSPF to the Black/Springbrook River watershed follows the standard model calibration procedures as described in the HSPF Application Guide (Donigian et al., 1984), in

numerous watershed studies over the past 20 years (see HSPF Bibliography [Donigian, 2002a]), and as recently summarized by Donigian (2002b).

7.3.1 WATER QUANTITY

7.3.1.1 Overview of HSPF Calibration and Validation Procedures

For HSPF, calibration is an iterative procedure of parameter evaluation and refinement, as a result of comparing simulated and observed values of interest. This approach is required for parameters that cannot be deterministically, and uniquely, evaluated from topographic, climatic, edaphic, or physical/chemical characteristics of the watershed and compounds of interest. Fortunately, the large majority of HSPF parameters do not fall in this category. Calibration is based on several years of simulation to evaluate parameters under a variety of climatic, soil moisture, and water quality conditions. Calibration results in parameter values that produce the best overall agreement between simulated and observed values throughout the calibration period. Any biases in the calibration data may affect the quality of the calibration and will be noted.

Calibration includes the comparison of both monthly and annual values, and individual storm events, whenever sufficient data are available for these comparisons. All of these comparisons are performed for a proper calibration of hydrology parameters. In addition, when a continuous observed record is available, such as for streamflow, simulated and observed values are analyzed on a frequency basis and their resulting cumulative distributions (e.g., flow duration curves) compared to assess the model behavior and agreement over the full range of observations.

A weight of evidence approach, as described above, is most widely used and accepted when models are examined and judged for acceptance. No single procedure or statistic is widely accepted as measuring, nor capable of establishing acceptable model performance. Therefore, the calibration relied on numerous statistical tests (e.g., correlation tests, Model Fit Efficiency) and graphical plots (e.g., scatter, time series, frequency) to determine the model's ability to represent the system.

Calibration is a hierarchical process beginning within hydrology calibration of both runoff and streamflow, followed by sediment erosion and sediment transport calibration, and finally calibration of water quality constituents, including water temperature.

When modeling land surface processes, hydrologic calibration must precede sediment and water quality calibration since runoff is the transport mechanism by which nonpoint pollution occurs. Likewise, adjustments to the instream hydraulics simulation must be completed before instream sediment and water quality transport and processes are calibrated. Each of these steps is discussed below with the emphasis on the key calibration parameters.

7.3.1.2 Hydrologic Calibration and Key Calibration Parameters

Calibration parameter values were initially based on past applications (i.e., regional HSPF parameter set) and the physical attributes found within the watershed. Some of these values were then modified to better represent the hydrologic processes observed in the Black/Springbrook River watershed. The final values were selected through the calibration process and a comparison of the simulated and recorded streamflow. Table 7.3-1 through Table 7.3-5 present the final PERLND and IMPLND parameter values selected for the Black/Springbrook River watershed.

Hydrologic simulation combines the physical characteristics of the watershed and the observed meteorologic data series to produce the simulated hydrologic response. All watersheds have similar hydrologic components, but they are generally present in different combinations; thus different hydrologic responses occur on individual watersheds. HSPF simulates runoff from four components: surface runoff from impervious areas directly connected to the channel network, surface runoff from pervious areas, interflow from pervious areas, and groundwater flow. Because the historic streamflow is not divided into these four units, the relative relationship among these components must be inferred from the examination of many events over several years of continuous simulation.

A complete hydrologic calibration involves a successive examination of the following four characteristics of the watershed hydrology, in the order shown: (1) annual water balance, (2) seasonal and monthly flow volumes, (3) baseflow, and (4) storm events. Simulated and observed values for reach characteristic are examined and critical parameters are adjusted to attain acceptable levels of agreement.

In addition to the input meteorologic data series, the critical parameters that govern the annual water balance are as follows:

LZSN	-	lower zone soil moisture storage (inches).
LZETP	-	vegetation evapotranspiration index (dimensionless).
INFILT	-	infiltration index for division of surface and subsurface flow (inches/hour).
UZSN	-	upper zone soil moisture storage (inches).
DEEPFR	-	fraction of groundwater inflow to deep recharge (dimensionless).

Changes in LZSN and LZETP affect the actual evapotranspiration by making more or less moisture available to evaporate or transpire. Both LZSN and INFILT also have a major impact on percolation and are important in obtaining an annual water balance. Whenever there are losses to deep groundwater, such as recharge or subsurface flow not measured at the flow gage, DEEPFR is used to represent this loss from the annual water balance.

LZETP values were adjusted monthly using the MON-LZETPARM Block in HSPF. LZETP monthly values vary by PERLND vegetation types (with forest values higher than pasture values, which in turn, are higher than residential landscaping values), by season (winter low; summer high – see Table 7.3-4), and by location in either the upper or lower watershed. For forest PERLNDs, the monthly LZETP values are relatively constant and vary from 0.42 in January in the upper watershed to 0.70 in August in the lower watershed; pasture monthly values vary from 0.14 to 0.45; and urban landscaping values vary from 0.11 to 0.45. LZSN values (Table 7.3-1) were decreased by 10 percent from their initial values in the upper watershed, and increased by 50 percent in the lower. Correspondingly, UZSN values (Table 7.3-3) were increased by 45 percent from their initial values in the upper watershed, and by 125 percent in the lower. DEEPFR was set to 0.02 for the lower watershed and represents the fraction of groundwater that bypasses the stream gage and recharges the underlying aquifer or migrates directly to the Black River.

In the next step in hydrologic calibration, after the annual water balance was obtained, the seasonal (i.e., monthly) distribution of runoff was adjusted with use of INFILT (defined above). This seasonal distribution was accomplished by INFILT by dividing the incoming moisture among surface runoff, interflow, upper zone soil moisture storage, and percolation to lower zone soil moisture and groundwater storage. Increasing INFILT reduced immediate surface runoff (including interflow) and increased the groundwater component; decreasing INFILT produced the opposite result.

The USGS regional values for till PERLNDs were used as a starting point and then varied by slope, land use, and location in either the upper or lower watershed. For INFILT, the lower watershed had relatively higher values, as did areas with milder slopes. The forest INFILT value varies from 0.055 to 7.0 (see Table 7.3-1). The pasture INFILT ranged from 0.033 to 5.25. The urban landscaping INFILT varies from 0.055 to 2.8 for the Black/Springbrook River watershed, and the residential values vary from 0.03 to 3.5. For all land uses, INFILT values for hydric soils were much higher than for other soil types.

The focus of the next stage in calibration was the baseflow component. This portion of the flow was adjusted in conjunction with the seasonal/monthly flow calibration because moving runoff volume between seasons often means transferring the surface runoff from storm events in wet seasons to low-flow periods during dry seasons. By increasing INFILT, runoff was delayed and occurred later in the year as an increased groundwater or baseflow. The shape of the groundwater recession; i.e., the change in baseflow discharge, is controlled by the following parameters:

AGWRC - groundwater recession rate (per day).
KVARY - index for nonlinear groundwater recession.

For the upper Black/Springbrook watershed, the AGWRC value was decreased from the USGS regional value of 0.996 to 0.992 for all soils except outwash, which was decreased to 0.990. Seasonal water balance calculations combined with summer low flow plots indicate that the groundwater in this portion of the watershed remains shallow and moves into the stream channel rapidly. For the lower Black/Springbrook watershed, the AGWRC value was increased slightly from the USGS regional value of 0.996 to 0.998 for all soils except outwash, which was decreased to 0.997.

In the final stage of hydrologic calibration, after an acceptable agreement was attained for annual/monthly volumes and baseflow conditions, simulated hydrographs for selected storm events were effectively altered with UZSN and the following parameters:

INTFW - Interflow inflow parameter (dimensionless).
IRC - Interflow recession rate (per day).

Both INTFW and IRC were used to adjust the shape of the hydrograph to better agree with observed values; both parameters are evaluated primarily from past experience and modeling studies, and then adjusted in calibration. Also, minor adjustments to the INFILT parameter were

used to improve simulated hydrographs; however, adjustments to INFILT were minimal to prevent disruption of the established annual and monthly water balance. Examination of both daily and short-time interval (e.g., hourly) flows were made.

In the upper watershed, INTFW was varied from 1.0 to 1.6 for all till land uses (see Table 7.3-3). Lower values were used for steeper slopes to increase surface runoff and decrease interflow. The reason for the low till INTFW values is because during the water quality calibration it was found that there was insufficient surface runoff to provide the measured loadings. Decreasing the till INTFW values produced more surface runoff (and less interflow) without significantly changing the hydrology calibration. Outwash INTFW values were adjusted upward from the regional value of 0.0 to 1.1, and saturated INTFW values were also adjusted upward from the regional value of 1.0 to 1.5. In the lower watershed, INTFW was varied from 1.5 to 2.4 for all till land uses, outwash values were set to 1.6, and saturated values were set to 2.2.

To replicate the relatively quick hydrologic response in the upper watershed, the IRC was varied from 0.24 to 0.48 for till soils (steeper slope, lower IRC), while the outwash and saturated were both set to 0.48 (Table 4.3-3). In the lower watershed, IRC values were varied from 0.3 to 0.6 for till soils, while outwash and saturated were both set to 0.6 (regional values).

Table 7.3-1 Final PERLND/IMPLND Parameter Values (Part 1)

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
11	Till Forest Flat	4.5	0.088	350	0.025	0.45	0.992
12	Till Forest Low	4.5	0.077	300	0.076	0.45	0.992
13	Till Forest Med	4.5	0.066	250	0.125	0.45	0.992
14	Till Forest Steep	4.5	0.055	200	0.251	0.45	0.992
21	Till Pasture Flat	4.5	0.066	350	0.024	0.45	0.992
22	Till Pasture Low	4.5	0.055	300	0.070	0.45	0.992
23	Till Pasture Med	4.5	0.044	250	0.119	0.45	0.992
24	Till Past Steep	4.5	0.033	200	0.193	0.45	0.992
31	Till Forest Residential Flat	4.5	0.088	350	0.025	0.45	0.992
32	Till Forest Residential Low	4.5	0.077	300	0.076	0.45	0.992
33	Till Forest	4.5	0.066	250	0.125	0.45	0.992

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
	Residential Med						
34	Till Forest Res Steep	4.5	0.055	200	0.251	0.45	0.992
41	Till Low Density Residential Flat	4.5	0.044	350	0.023	0.45	0.992
42	Till Low Density Residential Low	4.5	0.0385	300	0.072	0.45	0.992
43	Till Low Density Residential Med	4.5	0.033	250	0.123	0.45	0.992
44	Till Low Density Res Steep	4.5	0.0275	200	0.222	0.45	0.992
51	Till High Density Residential Flat	4.5	0.033	350	0.021	0.45	0.992
52	Till High Density Residential Low	4.5	0.0286	300	0.071	0.45	0.992
53	Till High Density Residential Med	4.5	0.0242	250	0.119	0.45	0.992
54	Till High Density Res Steep	4.5	0.0198	200	0.204	0.45	0.992
61	Till Commercial/ Industrial Flat	4.5	0.033	350	0.016	0.45	0.992
62	Till Commercial/ Industrial Low	4.5	0.0286	300	0.070	0.45	0.992
63	Till Commercial/ Industrial Med	4.5	0.0242	250	0.122	0.45	0.992
64	Till Commercial/ Industrial Steep	4.5	0.0198	200	0.212	0.45	0.992
71	Outwash Forest	4.5	0.26	300	0.047	0.27	0.990
72	Outwash Pasture	4.5	0.195	300	0.005	0.27	0.990
73	Outwash Forest Residential	4.5	0.26	300	0.047	0.27	0.990
74	Outwash Low Density Res	4.5	0.13	300	0.015	0.27	0.990
75	Outwash High Density Res	4.5	0.104	300	0.008	0.27	0.990

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
76	Outwash Commercial/Ind	4.5	0.104	300	0.004	0.27	0.990
81	Hydric Forest	4.0	2.2	150	0.001	0.45	0.992
82	Hydric Pasture	4.0	1.65	150	0.001	0.45	0.992
83	Hydric Forest Res	4.0	2.2	150	0.001	0.45	0.992
84	Hydric Low Density Res	4.0	1.1	150	0.001	0.45	0.992
85	Hydric High Density Res	4.0	0.88	150	0.001	0.45	0.992
86	Hydric Commercial/Ind	4.0	0.88	150	0.001	0.45	0.992
111	Rock Forest Flat	4.0	0.05	400	0.01	0.45	0.992
112	Rock Forest Low	4.0	0.05	400	0.05	0.45	0.992
113	Rock Forest Med	4.0	0.05	400	0.10	0.45	0.992
114	Rock Forest Steep	4.0	0.05	400	0.20	0.45	0.992
121	Rock Pasture Flat	4.0	0.05	400	0.01	0.45	0.992
122	Rock Pasture Low	4.0	0.05	400	0.05	0.45	0.992
123	Rock Pasture Med	4.0	0.05	400	0.10	0.45	0.992
124	Rock Past Steep	4.0	0.05	400	0.20	0.45	0.992
131	Rock Forest Residential Flat	4.0	0.05	400	0.01	0.45	0.992
132	Rock Forest Residential Low	4.0	0.05	400	0.05	0.45	0.992
133	Rock Forest Residential Med	4.0	0.05	400	0.10	0.45	0.992
134	Rock Forest Res Steep	4.0	0.05	400	0.20	0.45	0.992
141	Rock Low Density Residential Flat	4.0	0.03	400	0.01	0.45	0.992
142	Rock Low Density Residential Low	4.0	0.03	400	0.05	0.45	0.992
143	Rock Low Density Residential Med	4.0	0.03	400	0.10	0.45	0.992
144	Rock Low Density Res Steep	4.0	0.03	400	0.20	0.45	0.992

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
151	Rock High Density Residential Flat	4.0	0.03	400	0.01	0.45	0.992
152	Rock High Density Residential Low	4.0	0.03	400	0.05	0.45	0.992
153	Rock High Density Residential Med	4.0	0.03	400	0.10	0.45	0.992
154	Rock High Density Res Steep	4.0	0.03	400	0.20	0.45	0.992
161	Rock Commercial/ Industrial Flat	4.0	0.03	400	0.01	0.45	0.992
162	Rock Commercial/ Industrial Low	4.0	0.03	400	0.05	0.45	0.992
163	Rock Commercial/ Industrial Med	4.0	0.03	400	0.10	0.45	0.992
164	Rock Commercial/ Industrial Steep	4.0	0.03	400	0.20	0.45	0.992
211	Till Forest Flat	6.75	0.28	350	0.025	0.4	0.998
212	Till Forest Low	6.75	0.245	300	0.076	0.4	0.998
213	Till Forest Med	6.75	0.21	250	0.125	0.4	0.998
214	Till Forest Steep	6.75	0.175	200	0.251	0.4	0.998
221	Till Pasture Flat	6.75	0.21	350	0.024	0.4	0.998
222	Till Pasture Low	6.75	0.175	300	0.070	0.4	0.998
223	Till Pasture Med	6.75	0.14	250	0.119	0.4	0.998
224	Till Past Steep	6.75	0.105	200	0.193	0.4	0.998
231	Till Forest Residential Flat	6.75	0.28	350	0.025	0.4	0.998
232	Till Forest Residential Low	6.75	0.245	300	0.076	0.4	0.998
233	Till Forest Residential Med	6.75	0.21	250	0.125	0.4	0.998
234	Till Forest Res Steep	6.75	0.175	200	0.251	0.4	0.998
241	Till Low Density Residential Flat	6.75	0.14	350	0.023	0.4	0.998
242	Till Low Density	6.75	0.1225	300	0.072	0.4	0.998

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
	Residential Low						
243	Till Low Density Residential Med	6.75	0.105	250	0.123	0.4	0.998
244	Till Low Density Res Steep	6.75	0.0875	200	0.222	0.4	0.998
251	Till High Density Residential Flat	6.75	0.105	350	0.021	0.4	0.998
252	Till High Density Residential Low	6.75	0.091	300	0.071	0.4	0.998
253	Till High Density Residential Med	6.75	0.077	250	0.119	0.4	0.998
254	Till High Density Res Steep	6.75	0.063	200	0.204	0.4	0.998
261	Till Commercial/ Industrial Flat	6.75	0.105	350	0.016	0.4	0.998
262	Till Commercial/ Industrial Low	6.75	0.091	300	0.070	0.4	0.998
263	Till Commercial/ Industrial Med	6.75	0.077	250	0.122	0.4	0.998
264	Till Commercial/ Industrial Steep	6.75	0.063	200	0.212	0.4	0.998
271	Outwash Forest	7.5	1	300	0.047	0.24	0.997
272	Outwash Pasture	7.5	0.75	300	0.005	0.24	0.997
273	Outwash Forest Residential	7.5	1	300	0.047	0.24	0.997
274	Outwash Low Density Res	7.5	0.5	300	0.015	0.24	0.997
275	Outwash High Density Res	7.5	0.4	300	0.008	0.24	0.997
276	Outwash Commercial/Ind	7.5	0.4	300	0.004	0.24	0.997
281	Hydric Forest	6.0	7	150	0.001	0.4	0.998
282	Hydric Pasture	6.0	5.25	150	0.001	0.4	0.998
283	Hydric Forest Res	6.0	7	150	0.001	0.4	0.998
284	Hydric Low Density	6.0	3.5	150	0.001	0.4	0.998

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
	Res						
285	Hydric High Density Res	6.0	2.8	150	0.001	0.4	0.998
286	Hydric Commercial/Ind	6.0	2.8	150	0.001	0.4	0.998
311	Rock Forest Flat	6.0	0.1	400	0.01	0.4	0.998
312	Rock Forest Low	6.0	0.1	400	0.05	0.4	0.998
313	Rock Forest Med	6.0	0.1	400	0.10	0.4	0.998
314	Rock Forest Steep	6.0	0.1	400	0.20	0.4	0.998
321	Rock Pasture Flat	6.0	0.08	400	0.01	0.4	0.998
322	Rock Pasture Low	6.0	0.08	400	0.05	0.4	0.998
323	Rock Pasture Med	6.0	0.08	400	0.10	0.4	0.998
324	Rock Past Steep	6.0	0.08	400	0.20	0.4	0.998
331	Rock Forest Residential Flat	6.0	0.1	400	0.01	0.4	0.998
332	Rock Forest Residential Low	6.0	0.1	400	0.05	0.4	0.998
333	Rock Forest Residential Med	6.0	0.1	400	0.10	0.4	0.998
334	Rock Forest Res Steep	6.0	0.1	400	0.20	0.4	0.998
341	Rock Low Density Residential Flat	6.0	0.07	400	0.01	0.4	0.998
342	Rock Low Density Residential Low	6.0	0.07	400	0.05	0.4	0.998
343	Rock Low Density Residential Med	6.0	0.07	400	0.10	0.4	0.998
344	Rock Low Density Res Steep	6.0	0.07	400	0.20	0.4	0.998
351	Rock High Density Residential Flat	6.0	0.06	400	0.01	0.4	0.998
352	Rock High Density Residential Low	6.0	0.06	400	0.05	0.4	0.998
353	Rock High Density Residential Med	6.0	0.06	400	0.10	0.4	0.998

No.	PERLND	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
354	Rock High Density Res Steep	6.0	0.06	400	0.20	0.4	0.998
361	Rock Commercial/ Industrial Flat	6.0	0.06	400	0.01	0.4	0.998
362	Rock Commercial/ Industrial Low	6.0	0.06	400	0.05	0.4	0.998
363	Rock Commercial/ Industrial Med	6.0	0.06	400	0.10	0.4	0.998
364	Rock Commercial/ Industrial Steep	6.0	0.06	400	0.20	0.4	0.998

LZSN: Lower Zone Storage Nominal (inches)

INFILT: Infiltration (inches per hour)

LSUR: Length of surface flow path (feet)

SLSUR: Slope of surface flow path (feet/feet)

KVARY: Variable groundwater recession

AGWRC: Active Groundwater Recession Constant (per day)

Table 7.3-2 Final PERLND/IMPLND Parameter Values (Part 2)

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
11	Till Forest Flat	2.0	2.0	0.00	0.00	0.0
12	Till Forest Low	2.0	2.0	0.00	0.00	0.0
13	Till Forest Med	2.0	2.0	0.00	0.00	0.0
14	Till Forest Steep	2.0	2.0	0.00	0.00	0.0
21	Till Pasture Flat	2.0	2.0	0.00	0.00	0.0
22	Till Pasture Low	2.0	2.0	0.00	0.00	0.0
23	Till Pasture Med	2.0	2.0	0.00	0.00	0.0
24	Till Past Steep	2.0	2.0	0.00	0.00	0.0
31	Till Forest Residential Flat	2.0	2.0	0.00	0.00	0.0
32	Till Forest Residential Low	2.0	2.0	0.00	0.00	0.0
33	Till Forest Residential Med	2.0	2.0	0.00	0.00	0.0

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
34	Till Forest Res Steep	2.0	2.0	0.00	0.00	0.0
41	Till Low Density Residential Flat	2.0	2.0	0.00	0.00	0.0
42	Till Low Density Residential Low	2.0	2.0	0.00	0.00	0.0
43	Till Low Density Residential Med	2.0	2.0	0.00	0.00	0.0
44	Till Low Density Res Steep	2.0	2.0	0.00	0.00	0.0
51	Till High Density Residential Flat	2.0	2.0	0.00	0.00	0.0
52	Till High Density Residential Low	2.0	2.0	0.00	0.00	0.0
53	Till High Density Residential Med	2.0	2.0	0.00	0.00	0.0
54	Till High Density Res Steep	2.0	2.0	0.00	0.00	0.0
61	Till Commercial/ Industrial Flat	2.0	2.0	0.00	0.00	0.0
62	Till Commercial/ Industrial Low	2.0	2.0	0.00	0.00	0.0
63	Till Commercial/ Industrial Med	2.0	2.0	0.00	0.00	0.0
64	Till Commercial/ Industrial Steep	2.0	2.0	0.00	0.00	0.0
71	Outwash Forest	2.0	2.0	0.00	0.00	0.0
72	Outwash Pasture	2.0	2.0	0.00	0.00	0.0
73	Outwash Forest Residential	2.0	2.0	0.00	0.00	0.0
74	Outwash Low Density Res	2.0	2.0	0.00	0.00	0.0
75	Outwash High Density Res	2.0	2.0	0.00	0.00	0.0
76	Hydric	2.0	2.0	0.00	0.00	0.0

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
	Commercial/Ind					
81	Hydric Forest	8.0	2.0	0.00	0.00	0.7
82	Hydric Pasture	8.0	2.0	0.00	0.00	0.7
83	Hydric Forest Res	8.0	2.0	0.00	0.00	0.7
84	Hydric Low Density Res	8.0	2.0	0.00	0.00	0.7
85	Hydric High Density Res	8.0	2.0	0.00	0.00	0.7
86	Hydric Commercial/Ind	8.0	2.0	0.00	0.00	0.7
111	Rock Forest Flat	2.5	2.0	0.00	0.00	0.0
112	Rock Forest Low	2.5	2.0	0.00	0.00	0.0
113	Rock Forest Med	2.5	2.0	0.00	0.00	0.0
114	Rock Forest Steep	2.5	2.0	0.00	0.00	0.0
121	Rock Pasture Flat	2.5	2.0	0.00	0.00	0.0
122	Rock Pasture Low	2.5	2.0	0.00	0.00	0.0
123	Rock Pasture Med	2.5	2.0	0.00	0.00	0.0
124	Rock Past Steep	2.5	2.0	0.00	0.00	0.0
131	Rock Forest Residential Flat	2.5	2.0	0.00	0.00	0.0
132	Rock Forest Residential Low	2.5	2.0	0.00	0.00	0.0
133	Rock Forest Residential Med	2.5	2.0	0.00	0.00	0.0
134	Rock Forest Res Steep	2.5	2.0	0.00	0.00	0.0
141	Rock Low Density Residential Flat	2.5	2.0	0.00	0.00	0.0
142	Rock Low Density Residential Low	2.5	2.0	0.00	0.00	0.0
143	Rock Low Density Residential Med	2.5	2.0	0.00	0.00	0.0
144	Rock Low Density Res Steep	2.5	2.0	0.00	0.00	0.0
151	Rock High Density	2.5	2.0	0.00	0.00	0.0

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
	Residential Flat					
152	Rock High Density Residential Low	2.5	2.0	0.00	0.00	0.0
153	Rock High Density Residential Med	2.5	2.0	0.00	0.00	0.0
154	Rock High Density Res Steep	2.5	2.0	0.00	0.00	0.0
161	Rock Commercial/ Industrial Flat	2.5	2.0	0.00	0.00	0.0
162	Rock Commercial/ Industrial Low	2.5	2.0	0.00	0.00	0.0
163	Rock Commercial/ Industrial Med	2.5	2.0	0.00	0.00	0.0
164	Rock Commercial/ Industrial Steep	2.5	2.0	0.00	0.00	0.0
211	Till Forest Flat	1.5	2.0	0.02	0.00	0.0
212	Till Forest Low	1.5	2.0	0.02	0.00	0.0
213	Till Forest Med	1.5	2.0	0.02	0.00	0.0
214	Till Forest Steep	1.5	2.0	0.02	0.00	0.0
221	Till Pasture Flat	1.5	2.0	0.02	0.00	0.0
222	Till Pasture Low	1.5	2.0	0.02	0.00	0.0
223	Till Pasture Med	1.5	2.0	0.02	0.00	0.0
224	Till Past Steep	1.5	2.0	0.02	0.00	0.0
231	Till Forest Residential Flat	1.5	2.0	0.02	0.00	0.0
232	Till Forest Residential Low	1.5	2.0	0.02	0.00	0.0
233	Till Forest Residential Med	1.5	2.0	0.02	0.00	0.0
234	Till Forest Res Steep	1.5	2.0	0.02	0.00	0.0
241	Till Low Density Residential Flat	1.5	2.0	0.02	0.00	0.0
242	Till Low Density Residential Low	1.5	2.0	0.02	0.00	0.0

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
243	Till Low Density Residential Med	1.5	2.0	0.02	0.00	0.0
244	Till Low Density Res Steep	1.5	2.0	0.02	0.00	0.0
251	Till High Density Residential Flat	1.5	2.0	0.02	0.00	0.0
252	Till High Density Residential Low	1.5	2.0	0.02	0.00	0.0
253	Till High Density Residential Med	1.5	2.0	0.02	0.00	0.0
254	Till High Density Res Steep	1.5	2.0	0.02	0.00	0.0
261	Till Commercial/ Industrial Flat	1.5	2.0	0.02	0.00	0.0
262	Till Commercial/ Industrial Low	1.5	2.0	0.02	0.00	0.0
263	Till Commercial/ Industrial Med	1.5	2.0	0.02	0.00	0.0
264	Till Commercial/ Industrial Steep	1.5	2.0	0.02	0.00	0.0
271	Outwash Forest	1.5	2.0	0.02	0.00	0.0
272	Outwash Pasture	1.5	2.0	0.02	0.00	0.0
273	Outwash Forest Residential	1.5	2.0	0.02	0.00	0.0
274	Outwash Low Density Res	1.5	2.0	0.02	0.00	0.0
275	Outwash High Density Res	1.5	2.0	0.02	0.00	0.0
276	Hydric Commercial/Ind	1.5	2.0	0.02	0.00	0.0
281	Hydric Forest	8.0	2.0	0.02	0.00	0.7
282	Hydric Pasture	8.0	2.0	0.02	0.00	0.7
283	Hydric Forest Res	8.0	2.0	0.02	0.00	0.7
284	Hydric Low Density Res	8.0	2.0	0.02	0.00	0.7

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
285	Hydric High Density Res	8.0	2.0	0.02	0.00	0.7
286	Hydric Commercial/Ind	8.0	2.0	0.02	0.00	0.7
311	Rock Forest Flat	2.0	2.0	0.02	0.00	0.0
312	Rock Forest Low	2.0	2.0	0.02	0.00	0.0
313	Rock Forest Med	2.0	2.0	0.02	0.00	0.0
314	Rock Forest Steep	2.0	2.0	0.02	0.00	0.0
321	Rock Pasture Flat	2.0	2.0	0.02	0.00	0.0
322	Rock Pasture Low	2.0	2.0	0.02	0.00	0.0
323	Rock Pasture Med	2.0	2.0	0.02	0.00	0.0
324	Rock Past Steep	2.0	2.0	0.02	0.00	0.0
331	Rock Forest Residential Flat	2.0	2.0	0.02	0.00	0.0
332	Rock Forest Residential Low	2.0	2.0	0.02	0.00	0.0
333	Rock Forest Residential Med	2.0	2.0	0.02	0.00	0.0
334	Rock Forest Res Steep	2.0	2.0	0.02	0.00	0.0
341	Rock Low Density Residential Flat	2.0	2.0	0.02	0.00	0.0
342	Rock Low Density Residential Low	2.0	2.0	0.02	0.00	0.0
343	Rock Low Density Residential Med	2.0	2.0	0.02	0.00	0.0
344	Rock Low Density Res Steep	2.0	2.0	0.02	0.00	0.0
351	Rock High Density Residential Flat	2.0	2.0	0.02	0.00	0.0
352	Rock High Density Residential Low	2.0	2.0	0.02	0.00	0.0
353	Rock High Density Residential Med	2.0	2.0	0.02	0.00	0.0
354	Rock High Density	2.0	2.0	0.02	0.00	0.0

No.	PERLND	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
	Res Steep					
361	Rock Commercial/ Industrial Flat	2.0	2.0	0.02	0.00	0.0
362	Rock Commercial/ Industrial Low	2.0	2.0	0.02	0.00	0.0
363	Rock Commercial/ Industrial Med	2.0	2.0	0.02	0.00	0.0
364	Rock Commercial/ Industrial Steep	2.0	2.0	0.02	0.00	0.0

INFEXP: Infiltration Exponent

INFILD: Infiltration ratio (maximum to mean)

DEEPFR: Fraction of groundwater to deep aquifer or inactive storage

BASETP: Base flow (from groundwater) Evapotranspiration fraction

AGWETP: Active Groundwater Evapotranspiration fraction

Table 7.3-3 Final PERLND/IMPLND Parameter Values (Part 3)

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
11	Till Forest Flat	0.20	0.90	0.35	1.60	0.48	Monthly
12	Till Forest Low	0.20	0.68	0.35	1.40	0.40	Monthly
13	Till Forest Med	0.20	0.41	0.35	1.20	0.32	Monthly
14	Till Forest Steep	0.20	0.27	0.35	1.00	0.24	Monthly
21	Till Pasture Flat	0.15	0.54	0.30	1.60	0.48	Monthly
22	Till Pasture Low	0.15	0.41	0.30	1.40	0.40	Monthly
23	Till Pasture Med	0.15	0.27	0.30	1.20	0.32	Monthly
24	Till Past Steep	0.15	0.18	0.30	1.00	0.24	Monthly
31	Till Forest Residential Flat	0.20	0.90	0.35	1.60	0.48	Monthly
32	Till Forest Residential Low	0.20	0.68	0.35	1.40	0.32	Monthly
33	Till Forest Residential Med	0.20	0.41	0.35	1.20	0.32	Monthly
34	Till Forest Res Steep	0.20	0.27	0.35	1.00	0.24	Monthly
41	Till Low Density Residential Flat	0.10	0.45	0.25	1.60	0.48	Monthly
42	Till Low Density Residential Low	0.10	0.27	0.25	1.40	0.40	Monthly
43	Till Low Density Residential Med	0.10	0.18	0.25	1.20	0.32	Monthly
44	Till Low Density Res Steep	0.10	0.14	0.25	1.00	0.24	Monthly
51	Till High Density Residential Flat	0.10	0.45	0.25	1.60	0.48	Monthly
52	Till High Density Residential Low	0.10	0.27	0.25	1.40	0.40	Monthly
53	Till High Density Residential Med	0.10	0.18	0.25	1.20	0.32	Monthly
54	Till High Density Res Steep	0.10	0.09	0.25	1.00	0.24	Monthly
61	Till Commercial/ Industrial Flat	0.10	0.45	0.25	1.60	0.48	Monthly

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
62	Till Commercial/ Industrial Low	0.10	0.27	0.25	1.40	0.40	Monthly
63	Till Commercial/ Industrial Med	0.10	0.18	0.25	1.20	0.32	Monthly
64	Till Commercial/ Industrial Steep	0.10	0.09	0.25	1.00	0.24	Monthly
71	Outwash Forest	0.20	0.45	0.35	1.10	0.48	Monthly
72	Outwash Pasture	0.15	0.45	0.30	1.10	0.48	Monthly
73	Outwash Forest Residential	0.20	0.45	0.25	1.10	0.48	Monthly
74	Outwash Low Density Res	0.10	0.45	0.25	1.60	0.48	Monthly
75	Outwash High Density Res	0.10	0.45	0.25	1.60	0.48	Monthly
76	Outwash Commercial/Ind	0.10	0.45	0.25	1.60	0.48	Monthly
81	Hydric Forest	0.20	2.70	0.35	1.5	0.48	Monthly
82	Hydric Pasture	0.15	2.70	0.30	1.5	0.48	Monthly
83	Hydric Forest Res	0.20	2.70	0.25	1.5	0.48	Monthly
84	Hydric Low Density Res	0.10	2.70	0.25	1.5	0.48	Monthly
85	Hydric High Density Res	0.10	2.70	0.25	1.5	0.48	Monthly
86	Hydric Commercial/Ind	0.10	2.70	0.25	1.5	0.48	Monthly
111	Rock Forest Flat	0.20	1.50	0.35	1.0	0.70	Monthly
112	Rock Forest Low	0.20	1.00	0.35	1.0	0.40	Monthly
113	Rock Forest Med	0.20	0.60	0.35	1.0	0.30	Monthly
114	Rock Forest Steep	0.20	0.45	0.35	1.0	0.20	Monthly
121	Rock Pasture Flat	0.15	0.90	0.30	1.0	0.70	Monthly
122	Rock Pasture Low	0.15	0.60	0.30	1.0	0.40	Monthly
123	Rock Pasture Med	0.15	0.45	0.30	1.0	0.30	Monthly
124	Rock Past Steep	0.15	0.30	0.30	1.0	0.20	Monthly
131	Rock Forest Residential Flat	0.20	1.50	0.35	1.0	0.70	Monthly

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
132	Rock Forest Residential Low	0.20	1.00	0.35	1.0	0.40	Monthly
133	Rock Forest Residential Med	0.20	0.60	0.35	1.0	0.30	Monthly
134	Rock Forest Res Steep	0.20	0.45	0.35	1.0	0.20	Monthly
141	Rock Low Density Residential Flat	0.10	0.75	0.25	1.0	0.70	Monthly
142	Rock Low Density Residential Low	0.10	0.45	0.25	1.0	0.40	Monthly
143	Rock Low Density Residential Med	0.10	0.30	0.25	1.0	0.30	Monthly
144	Rock Low Density Res Steep	0.10	0.15	0.25	1.0	0.20	Monthly
151	Rock High Density Residential Flat	0.10	0.75	0.25	1.0	0.70	Monthly
152	Rock High Density Residential Low	0.10	0.45	0.25	1.0	0.40	Monthly
153	Rock High Density Residential Med	0.10	0.30	0.25	1.0	0.30	Monthly
154	Rock High Density Res Steep	0.10	0.20	0.25	1.0	0.20	Monthly
161	Rock Commercial/ Industrial Flat	0.10	0.75	0.25	1.0	0.70	Monthly
162	Rock Commercial/ Industrial Low	0.10	0.45	0.25	1.0	0.40	Monthly
163	Rock Commercial/ Industrial Med	0.10	0.30	0.25	1.0	0.30	Monthly
164	Rock Commercial/ Industrial Steep	0.10	0.20	0.25	1.0	0.20	Monthly
211	Till Forest Flat	0.20	1.50	0.35	2.4	0.60	Monthly
212	Till Forest Low	0.20	1.13	0.35	2.1	0.50	Monthly
213	Till Forest Med	0.20	0.68	0.35	1.8	0.40	Monthly
214	Till Forest Steep	0.20	0.45	0.35	1.5	0.30	Monthly
221	Till Pasture Flat	0.15	0.90	0.30	2.4	0.60	Monthly

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
222	Till Pasture Low	0.15	0.68	0.30	2.1	0.50	Monthly
223	Till Pasture Med	0.15	0.45	0.30	1.8	0.40	Monthly
224	Till Past Steep	0.15	0.30	0.30	1.5	0.30	Monthly
231	Till Forest Residential Flat	0.20	1.50	0.35	2.4	0.60	Monthly
232	Till Forest Residential Low	0.20	1.13	0.35	2.1	0.50	Monthly
233	Till Forest Residential Med	0.20	0.68	0.35	1.8	0.40	Monthly
234	Till Forest Res Steep	0.20	0.45	0.35	1.5	0.30	Monthly
241	Till Low Density Residential Flat	0.10	0.75	0.25	2.4	0.60	Monthly
242	Till Low Density Residential Low	0.10	0.45	0.25	2.1	0.50	Monthly
243	Till Low Density Residential Med	0.10	0.30	0.25	1.8	0.40	Monthly
244	Till Low Density Res Steep	0.10	0.23	0.25	1.5	0.30	Monthly
251	Till High Density Residential Flat	0.10	0.75	0.25	2.4	0.60	Monthly
252	Till High Density Residential Low	0.10	0.45	0.25	2.1	0.50	Monthly
253	Till High Density Residential Med	0.10	0.30	0.25	1.8	0.40	Monthly
254	Till High Density Res Steep	0.10	0.15	0.25	1.5	0.30	Monthly
261	Till Commercial/ Industrial Flat	0.10	0.75	0.25	2.4	0.60	Monthly
262	Till Commercial/ Industrial Low	0.10	0.45	0.25	2.1	0.50	Monthly
263	Till Commercial/ Industrial Med	0.10	0.30	0.25	1.8	0.40	Monthly
264	Till Commercial/ Industrial Steep	0.10	0.15	0.25	1.5	0.30	Monthly

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
271	Outwash Forest	0.20	0.75	0.35	1.6	0.60	Monthly
272	Outwash Pasture	0.15	0.75	0.30	1.6	0.60	Monthly
273	Outwash Forest Residential	0.20	0.75	0.25	1.6	0.60	Monthly
274	Outwash Low Density Res	0.10	0.75	0.25	1.6	0.60	Monthly
275	Outwash High Density Res	0.10	0.75	0.25	1.6	0.60	Monthly
276	Outwash Commercial/Ind	0.10	0.75	0.25	1.6	0.60	Monthly
281	Hydric Forest	0.20	4.5	0.35	2.2	0.60	Monthly
282	Hydric Pasture	0.15	4.5	0.30	2.2	0.60	Monthly
283	Hydric Forest Res	0.20	4.5	0.25	2.2	0.60	Monthly
284	Hydric Low Density Res	0.10	4.5	0.25	2.2	0.60	Monthly
285	Hydric High Density Res	0.10	4.5	0.25	2.2	0.60	Monthly
286	Hydric Commercial/Ind	0.10	4.5	0.25	2.2	0.60	Monthly
311	Rock Forest Flat	0.20	0.75	0.35	1.0	0.70	Monthly
312	Rock Forest Low	0.20	0.60	0.35	1.0	0.40	Monthly
313	Rock Forest Med	0.20	0.45	0.35	1.0	0.30	Monthly
314	Rock Forest Steep	0.20	0.30	0.35	1.0	0.20	Monthly
321	Rock Pasture Flat	0.15	0.45	0.30	1.0	0.70	Monthly
322	Rock Pasture Low	0.15	0.30	0.30	1.0	0.40	Monthly
323	Rock Pasture Med	0.15	0.23	0.30	1.0	0.30	Monthly
324	Rock Past Steep	0.15	0.15	0.30	1.0	0.20	Monthly
331	Rock Forest Residential Flat	0.20	0.75	0.35	1.0	0.70	Monthly
332	Rock Forest Residential Low	0.20	0.60	0.35	1.0	0.40	Monthly
333	Rock Forest Residential Med	0.20	0.45	0.35	1.0	0.30	Monthly
334	Rock Forest Res Steep	0.20	0.30	0.35	1.0	0.20	Monthly

No.	PERLND	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
341	Rock Low Density Residential Flat	0.10	0.30	0.25	1.0	0.70	Monthly
342	Rock Low Density Residential Low	0.10	0.23	0.25	1.0	0.40	Monthly
343	Rock Low Density Residential Med	0.10	0.15	0.25	1.0	0.30	Monthly
344	Rock Low Density Res Steep	0.10	0.08	0.25	1.0	0.20	Monthly
351	Rock High Density Residential Flat	0.10	0.30	0.25	1.0	0.70	Monthly
352	Rock High Density Residential Low	0.10	0.23	0.25	1.0	0.40	Monthly
353	Rock High Density Residential Med	0.10	0.15	0.25	1.0	0.30	Monthly
354	Rock High Density Res Steep	0.10	0.08	0.25	1.0	0.20	Monthly
361	Rock Commercial/ Industrial Flat	0.10	0.30	0.25	1.0	0.70	Monthly
362	Rock Commercial/ Industrial Low	0.10	0.23	0.25	1.0	0.40	Monthly
363	Rock Commercial/ Industrial Med	0.10	0.15	0.25	1.0	0.30	Monthly
364	Rock Commercial/ Industrial Steep	0.10	0.08	0.25	1.0	0.20	Monthly

CEPSC: Interception storage (inches)

UZSN: Upper Zone Storage Nominal (inches)

NSUR: Surface roughness (Manning's n)

INTFW: Interflow index

IRC: Interflow Recession Constant (per day)

LZETP: Lower Zone Evapotranspiration fraction (see Table 4.3-4 for monthly values)

Table 7.3-4 Final PERLND/IMPLND Parameter Values (Part 4): Monthly LZETP Values

No.	PERLND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11-14	Till Forest	0.42	0.42	0.42	0.42	0.49	0.49	0.49	0.49	0.49	0.42	0.42	0.42
21-24	Till Pasture	0.14	0.14	0.14	0.18	0.21	0.25	0.28	0.28	0.28	0.32	0.21	0.14
31-34	Till Forest Residential	0.42	0.42	0.42	0.42	0.49	0.49	0.49	0.49	0.49	0.42	0.42	0.42
41-44	Till Low Density Residential	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
51-54	Till High Density Residential	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
61-64	Till Commercial/ Industrial	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
71	Outwash Forest	0.42	0.42	0.42	0.42	0.42	0.49	0.49	0.49	0.49	0.42	0.42	0.42
72	Outwash Pasture	0.14	0.14	0.14	0.18	0.21	0.25	0.28	0.28	0.28	0.32	0.21	0.14
73	Outwash Forest Residential	0.42	0.42	0.42	0.42	0.42	0.49	0.49	0.49	0.49	0.42	0.42	0.42
74	Outwash Low Density Res	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
75	Outwash High Density Res	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
76	Outwash Commercial/Ind	0.11	0.11	0.11	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
81-86	Hydric	0.35	0.35	0.35	0.42	0.49	0.53	0.56	0.56	0.56	0.49	0.42	0.35
111-114	Rock Forest	0.21	0.21	0.21	0.28	0.35	0.42	0.49	0.49	0.49	0.35	0.21	0.21
121-124	Rock Pasture	0.14	0.14	0.14	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.14
131-134	Rock Forest Residential	0.21	0.21	0.21	0.28	0.35	0.42	0.49	0.49	0.49	0.42	0.42	0.42
141-144	Rock Low Density Residential	0.11	0.11	0.14	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
151-154	Rock High Density Residential	0.11	0.11	0.14	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
161-164	Rock Commercial/ Industrial	0.11	0.11	0.14	0.14	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.11
211-214	Till Forest	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60

No.	PERLND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
221-224	Till Pasture	0.20	0.20	0.20	0.25	0.30	0.35	0.40	0.40	0.40	0.45	0.30	0.20
231-234	Till Forest Residential	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60
241-244	Till Low Density Residential	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
251-254	Till High Density Residential	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
261-264	Till Commercial/ Industrial	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
271	Outwash Forest	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60
272	Outwash Pasture	0.20	0.20	0.20	0.25	0.30	0.35	0.40	0.40	0.40	0.45	0.30	0.20
273	Outwash Forest Residential	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70	0.70	0.60	0.60	0.60
274	Outwash Low Density Res	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
275	Outwash High Density Res	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
276	Outwash Commercial/Ind	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
281-286	Hydric	0.50	0.50	0.50	0.60	0.70	0.75	0.80	0.80	0.75	0.70	0.60	0.50
311-314	Rock Forest	0.30	0.30	0.30	0.40	0.50	0.60	0.70	0.70	0.70	0.50	0.30	0.30
321-324	Rock Pasture	0.20	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.20
331-334	Rock Forest Residential	0.30	0.30	0.30	0.40	0.50	0.60	0.70	0.70	0.70	0.60	0.60	0.60
341-344	Rock Low Density Residential	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
351-354	Rock High Density Residential	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15
361-364	Rock Commercial/ Industrial	0.15	0.15	0.20	0.20	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.15

Table 7.3-5 Final PERLND/IMPLND Parameter Values (Part 5)

No.	IMPLND	LSUR	SLSUR	NSUR	RETSC
91	Low Density Residential	150	0.001	0.10	0.10
92	High Density Residential	150	0.001	0.10	0.10
93	Commercial/Industrial	150	0.001	0.10	0.10
94	Road	150	0.001	0.10	0.10

LSUR: Length of surface flow path (feet) for impervious area

SLSUR: Slope of surface flow path (feet/feet) for impervious area

NSUR: Surface roughness (Manning's n) for impervious area

RETSC: Surface retention storage (inches) for impervious area

Additional information on the HSPF model parameters and algorithms can be found in the HSPF User's Manual for Release 12 (Bicknell, et al. 2002).

7.3.1.3 Comparisons Performed

The primary hydrologic calibration was performed for the time period of water year 2001 through water year 2003 for King County gages 03F and 03G. Additional calibration has been performed for water-years 1996 through 2003 for USGS gages U12113346 and U12113349. A calibration comparison was performed for USGS gage U12113347, but the data from this gage were inconsistent with the data from King county gage 03F. Figure 7.3-1 shows the low flow data for the congruent period of record for both gages. The key issue for this figure is that the USGS gage U12113347 (1,600 acres contributing basin) is upstream of King County gage 03F (2,570 acres contributing basin), however gage 03F has the higher summer base flow of the two gages. This is particularly strange when all of the flows are viewed. Figure 7.3-2 shows the full range of flows for the congruent period of record for both gages. From this graph it is easy to see that gage 03F has significantly higher peak flows than gage U12113347. An effort to resolve the differences between the gages was unsuccessful. The changes in flow regime from gage U12113347 to gage 03F were too extreme and could not be duplicated. The combination of high low flows and very low peak flows made gage U12113347 very difficult to match simulated and observed flows; on the other hand simulated flows matched well at gage 03F. As a result gage 03F was selected for this calibration effort.

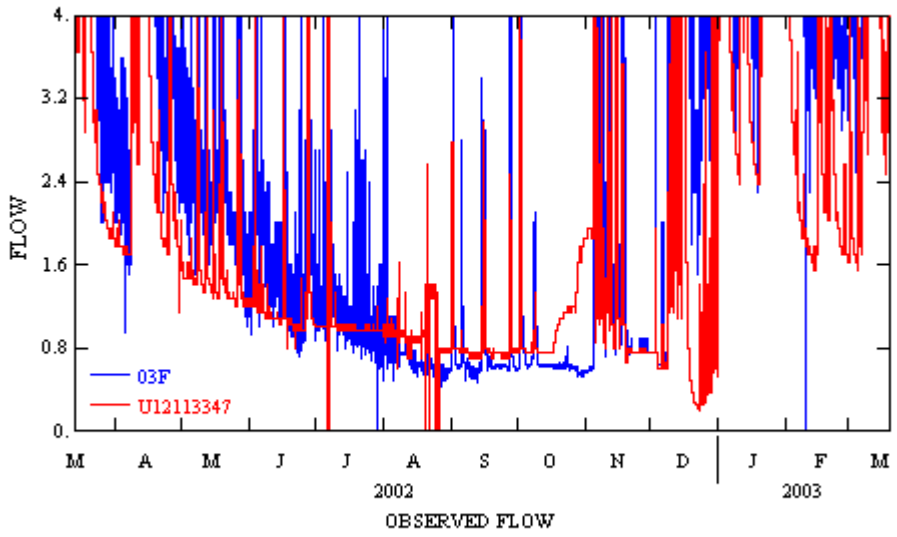


Figure 7.3-1 King Co Gage 03F vs. Gage U12113347 Low Flows

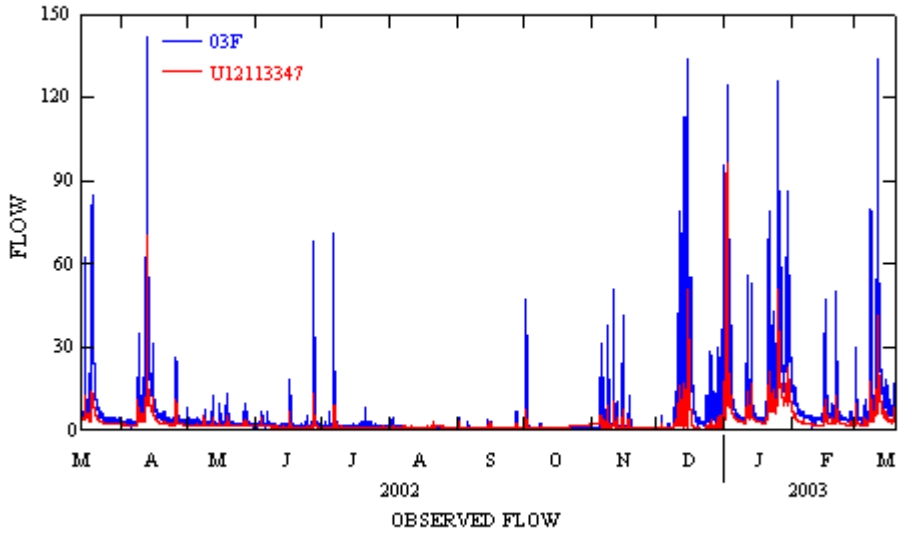


Figure 7.3-2 King Co Gage 03F vs. USGS Gage U12113347 All Flows

The following specific comparisons of simulated and observed values were performed:

Annual and monthly runoff volumes (inches)

Hourly and daily time series of flow (cfs)

Flow duration values (cfs)

Daily flow statistics for 12/4/01-3/18/03 and annual runoff volume for calendar year 2002 at Gage 03G are shown in Table 7.3-6 and Table 7.3-7, respectively. The mean daily flows and annual volumes show that the simulated results match well with the observed values, differing by 2.1 percent and 1.3 percent, respectively. The correlation coefficient is 0.96 and the model fit efficiency is 0.91. These values show a good calibration at this location.

Table 7.3-6 Flow Statistics at King County Gage 03G (Dec 2001 – Mar 2003)

	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
Mean	47.08	46.13	0.95	2.1%
Geometric Mean	30.70	29.64	1.06	3.6%
Std Deviation	50.92	51.13		
Avg Ratio of Sim:Obs	1.06			
Correlation Coefficient	0.96			
Coefficient of Determination	0.91			
Mean Error	0.94			
% Mean Error	2.05			
Mean Absolute Error	8.02			
% Mean Absolute Error	17.40			
RMS Error	15.11			
Nash Sutcliffe	0.09			
Model Fit Efficiency	0.91			
Skill Score	0.70			

With only one full year of observed data at 03G, it is impossible to analyze for annual trends. The annual volume for the single calendar year is shown in Table 4.3-7. The low percentage difference in total volume indicates a good match.

Table 7.3-7 Annual Volume at King County Gage 03G (Jan 2002 – Dec 2002)

Calendar Year	Precip (in)	Sim (in)	Obs (in)	Difference (in)	Difference (%)
2002	29.30	23.95	23.63	0.32	1.3%

Daily flow statistics for 3/15/02-3/20/03 and annual runoff volume for the year of time bounded by March 2002 and February 2003 at Gage 03F are shown in Table 7.3-8 and Table 7.3-9, respectively. The average daily flows and annual volumes show that the simulated results match very well with the observed values with no difference in the overall volumes. The correlation coefficient is 0.98 and model fit efficiency is 0.97; these statistics show a very good calibration at this location.

Table 7.3-8 Flow Statistics at King County Gage 03F (Mar 2002 – Mar 2003)

	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
Mean	6.48	6.48	0.00	0.00%
Geometric Mean	2.92	2.67	0.25	9.36%
Std Deviation	10.38	10.97		
Avg Ratio of Sim:Obs	1.12			
Correlation Coefficient	0.98			
Coefficient of Determination	0.97			
Mean Error	0.005			
% Mean Error	0.07			
Mean Absolute Error	1.023			
% Mean Absolute Error	15.80			
RMS Error	2.01			
Nash Sutcliffe	0.03			
Model Fit Efficiency	0.97			
Skill Score	0.82			

The annual volume show that the simulated results match very well with the observed values, only differing by 0.37 percent for the year.

Table 7.3-9 Annual Volume at King County Gage 03F (Mar 2002 – Mar 2003)

Year	Precip (in)	Sim (in)	Obs (in)	Difference (in)	Difference (%)
3/02 – 2/03	31.25	21.79	21.87	0.08	0.37%

Daily flow statistics for 10/1/95-3/1/03 and annual runoff volumes for water years 1996 through 2002 at gage U12113349 are shown in Table 7.3-10 and Table 7.3-11, respectively. The correlation coefficient is 0.93 and the model fit efficiency is 0.76. These statistics show a very good calibration.

Table 7.3-10 Flow Statistics at USGS Gage U12113349 (Oct 1995 – Feb 2003)

	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
Mean	17.03	17.12	-0.09	-0.53%
Geometric Mean	8.80	8.48	0.32	3.77%
Std Deviation	23.93	24.76		
Avg Ratio of Sim:Obs	1.10			
Correlation Coefficient	0.93			
Coefficient of Determination	0.86			
Mean Error	-0.090			
% Mean Error	-0.52			
Mean Absolute Error	3.995			
% Mean Absolute Error	23.33			
RMS Error	9.17			
Nash Sutcliffe	0.14			
Model Fit Efficiency	0.86			
Skill Score	0.63			

The annual volumes show some inaccuracy in matching volumes in certain years, but indicate an overall excellent match, with the simulated volume only 0.6 percent higher than the observed.

Table 7.3-11 Annual Volumes at USGS Gage U12113349 (Water Years 1995 –2002)

Water Year	Precip (in)	Sim (in)	Obs (in)	Difference (in)	Difference (%)
1996	39.15	23.91	27.50	-3.58	-13.0%
1997	47.35	28.71	28.20	0.51	1.8%
1998	32.90	16.82	16.88	-0.06	-0.3%
1999	44.91	26.15	28.74	-2.59	-9.0%
2000	36.51	20.14	22.03	-1.89	-8.6%
2001	34.75	16.52	14.01	2.51	17.9%
2002	42.67	26.13	21.96	4.17	19.0%
Average	39.75	22.63	22.76	-0.13	-0.60%

Daily flow statistics for 10/1/95-3/1/03 and annual runoff volumes for water years 1996 through 2002 at gage U12113346 are shown in Table 7.3-12 and Table 7.3-13, respectively. The correlation coefficient is 0.84 and the model fit efficiency is 0.69. With the overall simulated volume being 4.5 percent higher than the observed, these statistics show a good calibration for volumes and fair calibration for fit.

Table 7.3-12 Flow Statistics at USGS Gage U12113346 (Oct 1995 – Feb 2003)

	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
Mean	11.28	11.70	-0.42	-3.59%
Geometric Mean	6.92	7.12	0.20	2.81%
Std Deviation	15.80	17.16		
Avg Ratio of Sim:Obs	1.06			
Correlation Coefficient	0.84			
Coefficient of Determination	0.70			
Mean Error	-0.420			
% Mean Error	-3.59			
Mean Absolute Error	4.019			
% Mean Absolute Error	34.36			

	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
RMS Error	9.55			
Nash Sutcliffe	0.31			
Model Fit Efficiency	0.69			
Skill Score	0.44			

Table 7.3-13 shows the annual volumes at gage U12113346. It proved difficult to match the volumes on a year to year basis due to the fact that there is not a strong correlation between precipitation and observed flow at this station.

Table 7.3-13 Annual Volumes at USGS Gage U12113346 (Water Years 1995 –2002)

Water Year	Precip (in)	Sim (in)	Obs (in)	Difference (in)	Difference (%)
1996	39.08	10.31	11.83	-1.51	-12.8%
1997	47.27	12.58	9.67	2.91	30.0%
1998	32.84	7.79	7.32	0.47	6.4%
1999	44.84	11.53	9.95	1.58	15.9%
2000	36.44	8.91	11.40	-2.50	-21.9%
2001	34.69	7.07	7.51	-0.44	-5.8%
2002	42.60	11.57	9.05	2.52	27.9%
Average	39.68	9.97	9.53	0.43	4.5%

Mean monthly volumes for the King County 03G gage are shown in Table 7.3-14, albeit all but two of these values represent single months. The mean monthly simulated values are close to the observed values with the greatest nominal difference of 0.82 inches occurring in the month of February, which also had the largest percentage difference of 26.3 percent.

Table 7.3-14 Mean Monthly Flow Statistics at King County Gage 03G

Month	Sim	Obs	Diff	Diff

	(in)	(in)	(in)	(%)
January	3.94	4.22	-0.27	-6.5%
February	3.96	3.14	0.82	26.3%
March	2.94	2.69	0.26	9.6%
April	2.53	2.54	0.00	-0.2%
May	1.07	0.97	0.10	10.6%
June	0.96	1.10	-0.15	-13.2%
July	0.83	1.12	-0.29	-25.5%
August	0.55	0.46	0.09	18.9%
September	0.51	0.58	-0.07	-11.4%
October	0.62	0.61	0.01	2.4%
November	1.10	1.29	-0.19	-14.5%
December	4.04	3.83	0.21	5.6%
Totals:	23.06	22.53	0.53	2.4%

Monthly volumes for the King County 03F gage are shown in Table 7.3-15 (each value represents a single month of time). The overall simulated values are very close to the observed values with the greatest total difference of -0.41 inches occurring in January 2003. The largest percentage difference of 26.5% occurs in the low flow month of August 2002.

Table 7.3-15 Mean Monthly Flow Statistics at King County Gage 03F

Month	Sim (in)	Obs (in)	Diff (in)	Diff (%)
April	2.73	2.63	0.10	3.7%
May	0.76	0.86	-0.10	-11.8%
June	0.72	0.81	-0.09	-11.1%
July	0.56	0.61	-0.05	-7.5%
August	0.27	0.21	0.06	26.5%
September	0.28	0.23	0.05	19.8%

Month	Sim (in)	Obs (in)	Diff (in)	Diff (%)
October	0.39	0.39	0.00	-1.2%
November	1.04	1.00	0.04	3.7%
December	3.17	3.31	-0.14	-4.2%
January	5.87	6.28	-0.41	-6.6%
February	2.04	1.87	0.17	8.9%
March	3.97	3.59	0.38	10.4%
Totals:	21.79	21.81	-0.02	-0.1%

Mean monthly volumes for the USGS gage U12113349 are shown in Table 7.3-16. The mean monthly simulated values are close to the observed values with the greatest total difference of -0.35 inches occurring in the month of March. The largest difference of 24.6% occurs in the month of July and is generally caused by over simulating low flows. Base flows for this gage are difficult to match. As a result, the groundwater from the outwash soils in subbasins 110 and 160 are assumed to stay sub-surface until it reaches RCHRES 280 just downstream from Gage U12113349. This is a total of 1,516 pervious acres out of the entire contributing groundwater basin, which is 3,952 acres. Even with this adjustment to the contributing groundwater area the summer low flows are still somewhat oversimulated. It is possible to route more of the contributing groundwater basin around gage U12113349 but the winter base flows start to drop to levels too far below observed values.

Table 7.3-16 Mean Monthly Flow Statistics at USGS Gage U12113349

Month	Sim (in)	Obs (in)	Diff (in)	Diff (%)
October	1.17	1.07	0.11	10.0%
November	3.16	3.01	0.15	5.1%
December	3.33	3.62	-0.29	-8.0%
January	3.58	3.94	-0.35	-9.0%
February	2.79	3.10	-0.31	-10.0%

March	2.74	2.53	0.21	8.4%
April	1.85	1.68	0.18	10.6%
May	1.11	1.08	0.03	2.6%
June	0.87	0.86	0.01	1.3%
July	0.58	0.47	0.11	24.6%
August	0.41	0.40	0.01	2.8%
September	0.44	0.39	0.04	10.8%
Totals:	22.04	22.14	-0.10	-0.4%

Mean monthly volumes for the USGS gage U12113346 are shown in Table 7.3-17. The mean monthly simulated values are close to the observed values with the greatest total difference of 0.40 inches occurring in the month of March, which also has the largest percentage difference of 48.0%.

Table 7.3-17 Mean Monthly Flow Statistics at USGS Gage U12113346

Month	Sim (in)	Obs (in)	Diff (in)	Diff (%)
October	0.48	0.74	-0.26	-34.9%
November	1.22	1.40	-0.18	-12.8%
December	1.37	1.44	-0.07	-5.0%
January	1.51	1.42	0.09	6.4%
February	1.23	1.04	0.19	18.0%
March	1.24	0.84	0.40	48.0%
April	0.87	0.61	0.26	42.4%
May	0.56	0.45	0.11	23.8%
June	0.43	0.42	0.01	2.6%
July	0.33	0.30	0.03	10.9%
August	0.25	0.32	-0.07	-21.5%
September	0.24	0.28	-0.03	-12.6%
Totals:	9.72	9.24	0.48	5.2%

Table 7.3-18 uses the HSPF Expert System statistics to evaluate the calibration accuracy at Gage 03G. The simulated and observed flow values were divided into a number of categories and then evaluated according to defined criteria that allow the user to target specific flow ranges and events, such as the highest 10% of the flows, 50% low flows, summer storm volumes, etc. The criteria values range from 10 percent error to 20 percent error, depending on the type of flow range. Of the 12 criteria shown in Table 7.3-18: ten are good to excellent; one is fair; and two (average storm peak and summer storms) are poor (29.9% and –31.0%, respectively). The storm peaks and volume calculations were based on a total of 28 storms during the extremely short one-year plus calibration period; 20 Winter, 5 Spring, 2 Summer, and 1 Fall.

The calibration matches annual flow volumes and peak flood flows, overestimates the higher peak flows, and underestimates summer flows and summer storm volumes. The Expert System results, even with these differences, when viewed together with the other calibration information, shown in both tables and graphics, support the conclusion that the calibration is sufficiently accurate for the purposes of this study.

Table 7.3-18 Expert System Statistics at King Co Gage 03G (Dec 2001 – Mar 2003)

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Total (in)	23.95	23.56	0.38	1.6%	10%	Excellent
10% high (in)	9.51	9.70	-0.19	-2.0%	10%	Excellent
25% high (in)	15.21	15.27	-0.05	-0.4%	15%	Excellent
50% low (in)	3.80	3.90	-0.10	-2.6%	15%	Excellent
25% low (in)	1.44	1.36	0.09	6.4%	15%	Good
10% low (in)	0.51	0.47	0.05	9.6%	15%	Good
storm volume (in)	9.89	10.33	-0.43	-4.2%	20%	Excellent
average storm peak (cfs)	159.42	122.68	36.74	29.9%	15%	Poor
summer volume (in)	2.36	2.71	-0.35	-12.9%	15%	fair
winter volume (in)	12.73	12.14	0.59	4.9%	10%	Good
Summer storms (in)	0.35	0.50	-0.16	-26.9%	10%	Poor

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
winter storms (in)	4.49	4.27	0.22	9.3%	15%	Fair

Table 7.3-19 displays the HSPF Expert System statistics for gage 03F. Of the 12 criteria shown, ten are fair to excellent; and two (25% low flows and winter storm volume) are poor (18.0% and –30.0%, respectively). The storm peaks and volume calculations were based on a total of 29 storms during the one-year calibration period; 18 Winter, 4 Spring, 3 Summer, and 4 Fall.

The calibration produces excellent annual flow volumes and peak flood flows, estimates the higher peak flows well, and estimates summer and winter flows well, but underestimates summer storm volumes.

Table 7.3-19 Expert System Statistics at King Co Gage 03F (Mar 2002 – Mar 2003)

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Total (in)	21.79	21.81	-0.02	-0.1%	10%	Excellent
10% high (in)	11.01	11.82	-0.82	-6.9%	10%	Fair
25% high (in)	16.44	16.90	-0.46	-2.7%	15%	Excellent
50% low (in)	1.96	1.74	0.22	12.6%	15%	Fair
25% low (in)	0.64	0.54	0.10	17.9%	15%	Poor
10% low (in)	0.21	0.20	0.01	5.2%	15%	Good
storm volume (in)	14.89	15.70	-0.81	-5.1%	20%	Good
average storm peak (cfs)	71.48	72.90	-1.42	-1.9%	15%	Excellent
Summer volume (in)	1.55	1.63	-0.08	-4.8%	15%	Good
winter volume (in)	11.08	11.47	-0.39	-3.4%	10%	Good

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Summer storms (in)	0.45	0.65	-0.19	-24.8%	10%	Poor
winter storms (in)	7.15	7.72	-0.56	-2.2%	15%	Excellent

Table 7.3-20 displays the HSPF Expert System statistics for gage U12113349. Only full years of data were used to produce the statistics as to avoid seasonal bias. Of the 12 criteria shown, nine are fair or better, while three are poor. The storm peaks and volume calculations were based on a total of 37 storms during the eight-year calibration period; 20 Winter, 7 Spring, 1 Summer, and 9 Fall.

Gage U12113349 is located downstream of the GRNRA. It is believed that the GRNRA and the Mill Creek diversion structure have impacts on streamflow at this gage that are not currently being modeled. Enhanced hydraulic modeling of both features is likely to improve the calibration at this location.

Table 7.3-20 Expert System Statistics at King Co Gage U12113349 (Water Years 1995 –2002)

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Total (in)	22.63	22.70	-0.07	-0.3%	10%	Excellent
10% high (in)	9.77	9.85	-0.08	-0.8%	10%	Excellent
25% high (in)	15.66	15.75	-0.10	-0.6%	15%	Excellent
50% low (in)	2.55	2.46	0.10	4.0%	15%	Good
25% low (in)	0.78	0.66	0.12	18.0%	15%	Poor
10% low (in)	0.23	0.19	0.05	24.2%	15%	Poor
storm volume (in)	5.36	5.81	-0.45	-7.7%	20%	Good
average storm peak (cfs)	157.22	136.55	20.66	15.1%	15%	Fair

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Summer volume (in)	1.86	1.73	0.14	7.9%	15%	Good
winter volume (in)	9.86	10.79	-0.93	-8.7%	10%	Fair
Summer storms (in)	0.04	0.05	-0.01	-15.1%	10%	Poor
winter storms (in)	1.53	1.91	-0.37	-11.9%	15%	Fair

Table 7.3-21 displays the HSPF Expert System statistics for gage U12113346. As with gage U12113349, only full years of data were used to produce the statistics as to avoid seasonal bias. Of the 12 criteria shown, ten are good to excellent; and two are poor (storm volume and summer storm volume). The storm peaks and volume calculations were based on a total of 37 storms during the eight-year calibration period; 13 Winter, 5 Spring, 6 Summer, and 13 Fall.

The calibration of flow volumes is very good at this location. The model tends to undersimulate storm volumes, particularly in the summer.

Table 7.3-21 Expert System Statistics at King Co Gage U12113346 (Water Years 1995 –2002)

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
Total (in)	9.97	9.53	0.44	4.6%	10%	Good
10% high (in)	3.96	4.11	-0.15	-3.7%	10%	Good
25% high (in)	6.36	6.28	0.08	1.3%	15%	Excellent
50% low (in)	1.59	1.47	0.12	8.3%	15%	Fair
25% low (in)	0.58	0.54	0.05	8.8%	15%	Fair
10% low (in)	0.20	0.17	0.03	14.8%	15%	Fair
storm volume (in)	1.66	2.19	-0.53	-24.2%	20%	Poor

	Sim (in)	Obs (in)	Diff (in)	Diff (%)	Criteria (%)	Meets Criteria
average storm peak (cfs)	133.32	137.20	-3.89	-2.8%	15%	Excellent
Summer volume (in)	1.01	1.04	-0.02	-2.4%	15%	Excellent
winter volume (in)	4.19	4.00	0.19	4.8%	10%	Good
Summer storms (in)	0.11	0.17	-0.06	-12.0%	10%	Poor
winter storms (in)	0.354	0.466	-0.11	0.2%	15%	Excellent

Figure 7.3-3 shows the daily simulated and observed streamflow at King County Gage 03G for the period of December 2001 through February 2003. Figure 7.3-4 shows the Gage 03G flow duration for the same period, and demonstrates a good match for most of the flow ranges, especially peak flows, but does show overestimation for base flow. Figure 7.3-5 - Figure 7.3-7compare the 03G hourly simulated and observed streamflow values for the winter flow periods of December 2001, December 2002, and January 2003, respectively.

Monthly simulated and observed flow volumes are shown in Figure 7.3-8. A scatter plot of the simulated and observed daily values are presented in Figure 7.3-9. The scatter plot shows a correlation coefficient of 0.956. A residual plot of the simulated – observed flows is shown in Figure 7.3-10.

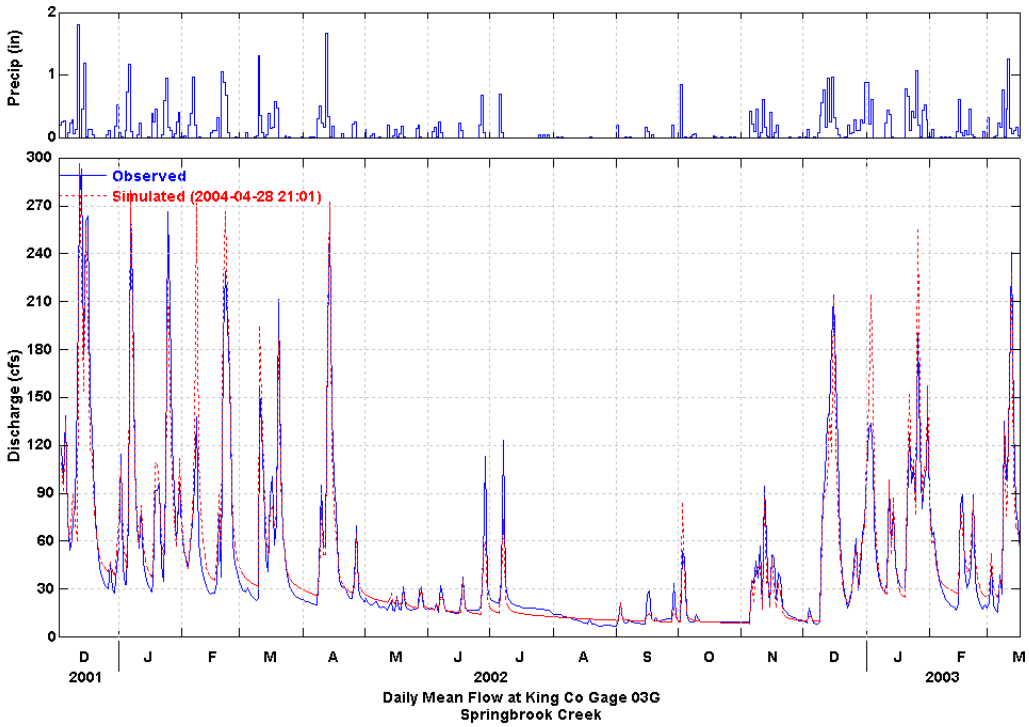


Figure 7.3-3 Simulated vs Observed Daily Flow at King Co Gage 03G

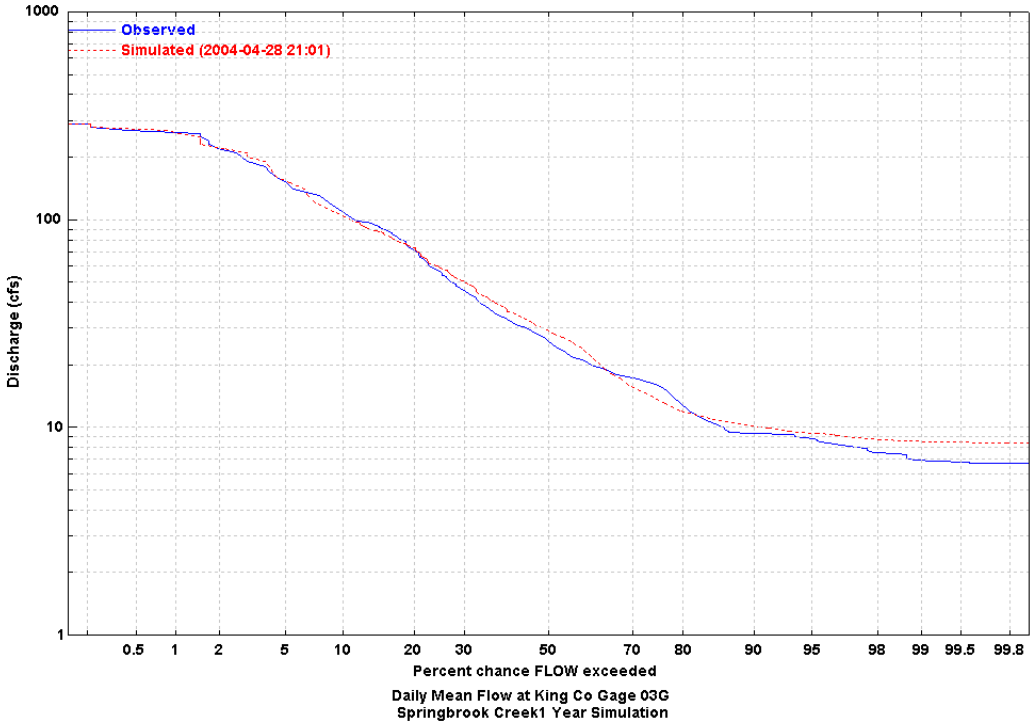


Figure 7.3-4 Daily Flow Duration Plot at King Co Gage 03G

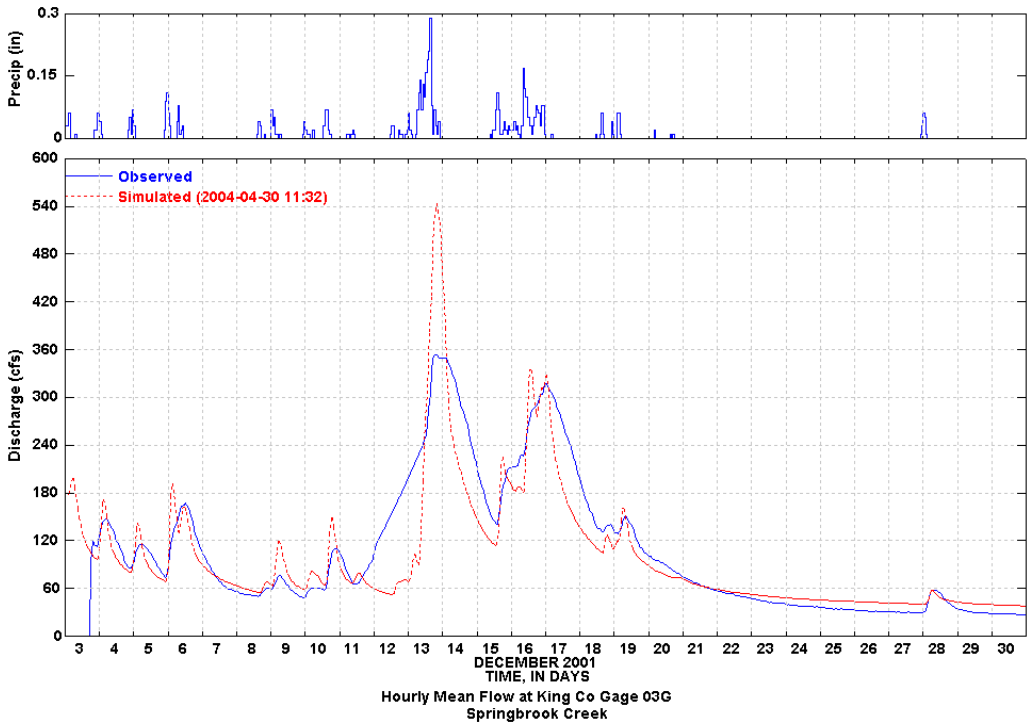


Figure 7.3-5 December 2001 Hourly Flow at King Co Gage 03G

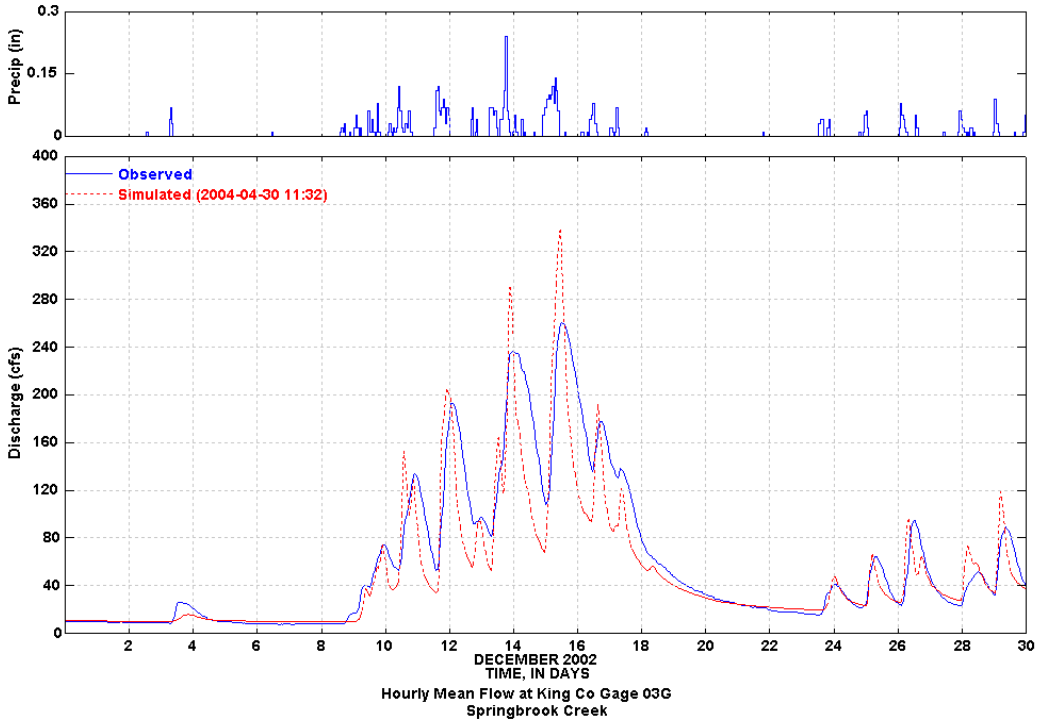


Figure 7.3-6 December 2002 Hourly Flow at King Co Gage 03G

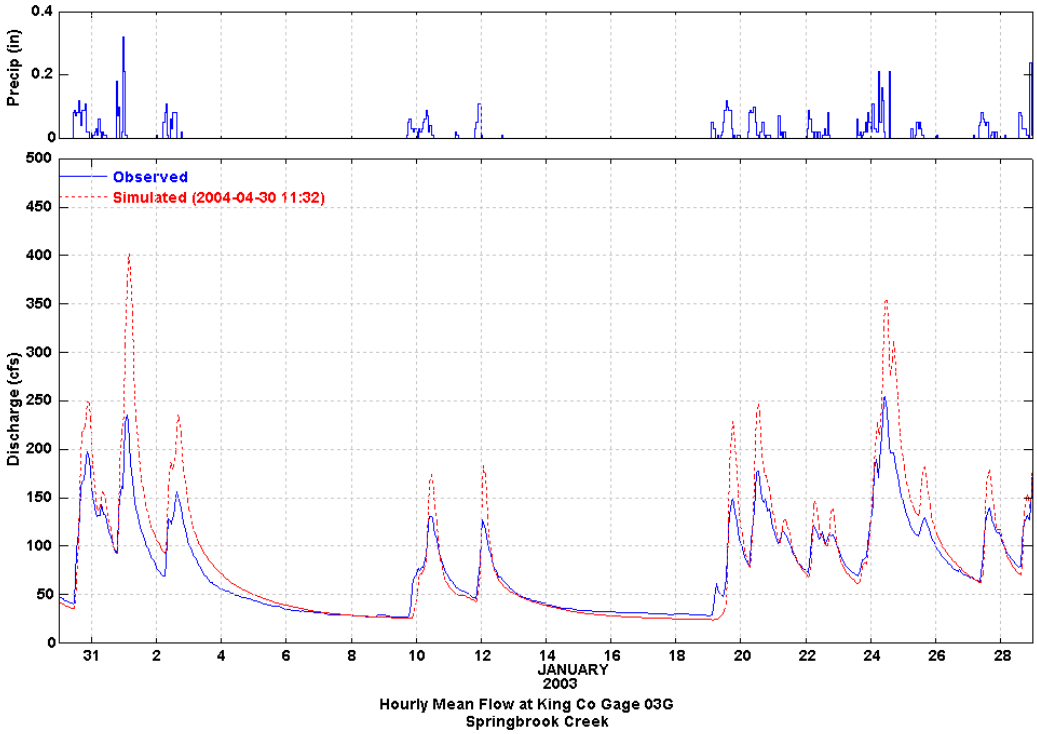


Figure 7.3-7 January 2003 Hourly Flow at King Co Gage 03G

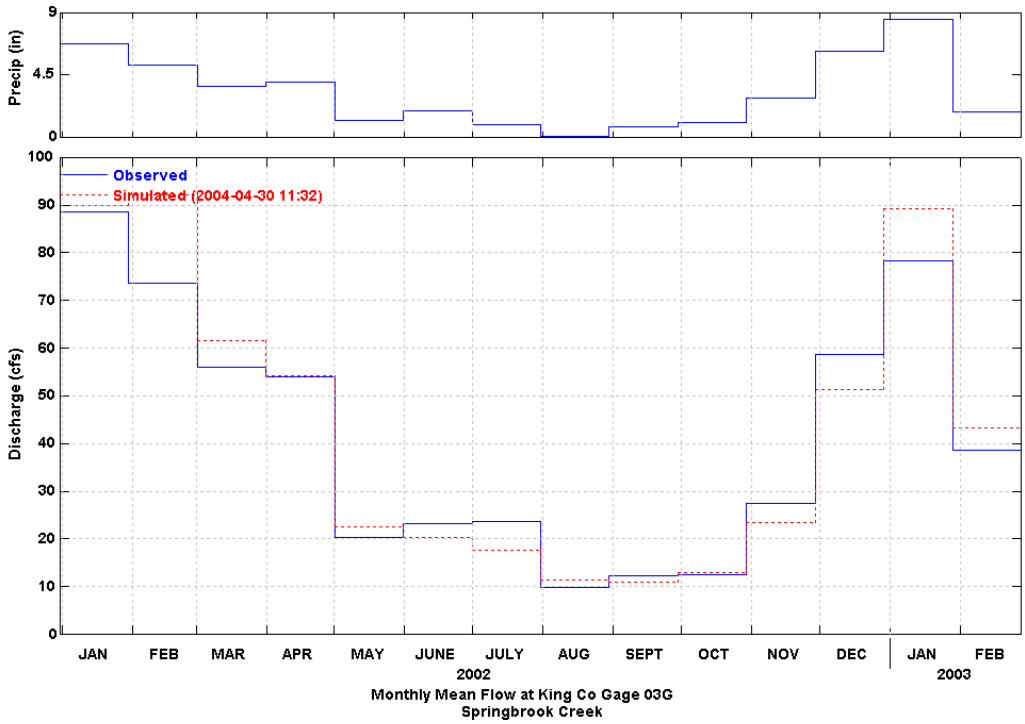


Figure 7.3-8 Monthly Flows at King Co Gage 03G

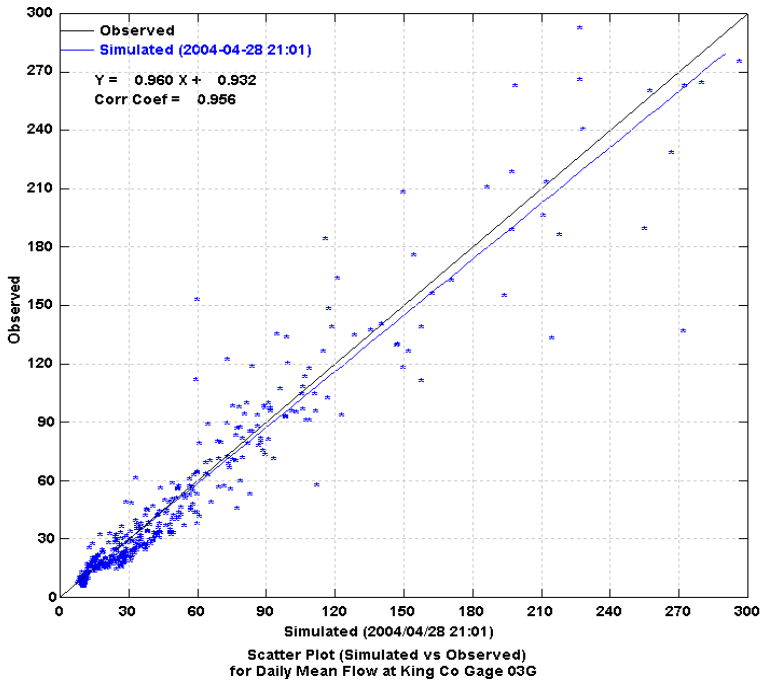


Figure 7.3-9 King Co Gage 03G Scatter Plot

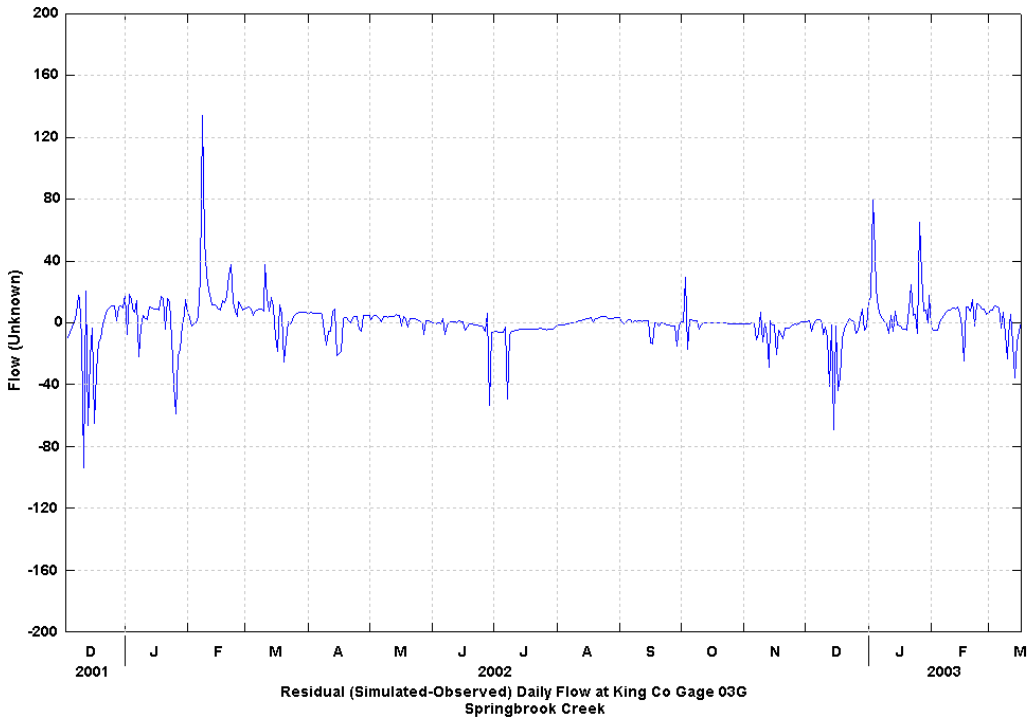


Figure 7.3-10 King Co Gage 03G Residual Plot of (Simulated – Observed) Flows

Figure 7.3-11 shows the daily simulated and observed streamflow at King County Gage 03F for the period of March 2002 through February 2003. Figure 7.3-12 shows the Gage 03F flow duration for the same period and demonstrates a good match for most of the duration ranges. Figure 7.3-13 and Figure 7.3-14 compare the 03F daily simulated and observed streamflow values for the winter flow periods of December 2002 and January 2003, respectively. Monthly simulated and observed flow volumes are shown in Figure 7.3-15. A scatter plot of the simulated and observed daily values is presented in Figure 7.3-16. The scatter plot shows a correlation coefficient of 0.984. A residual plot of the simulated – observed flows is shown in Figure 7.3-17.

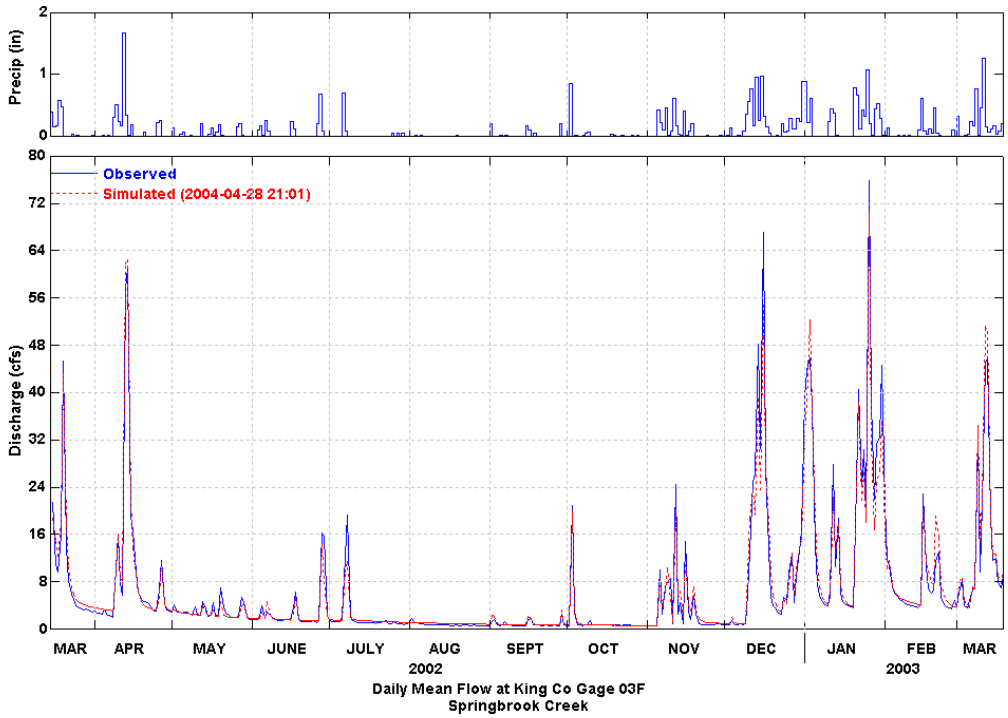


Figure 7.3-11 Simulated vs Observed Daily Flow at King Co Gage 03F

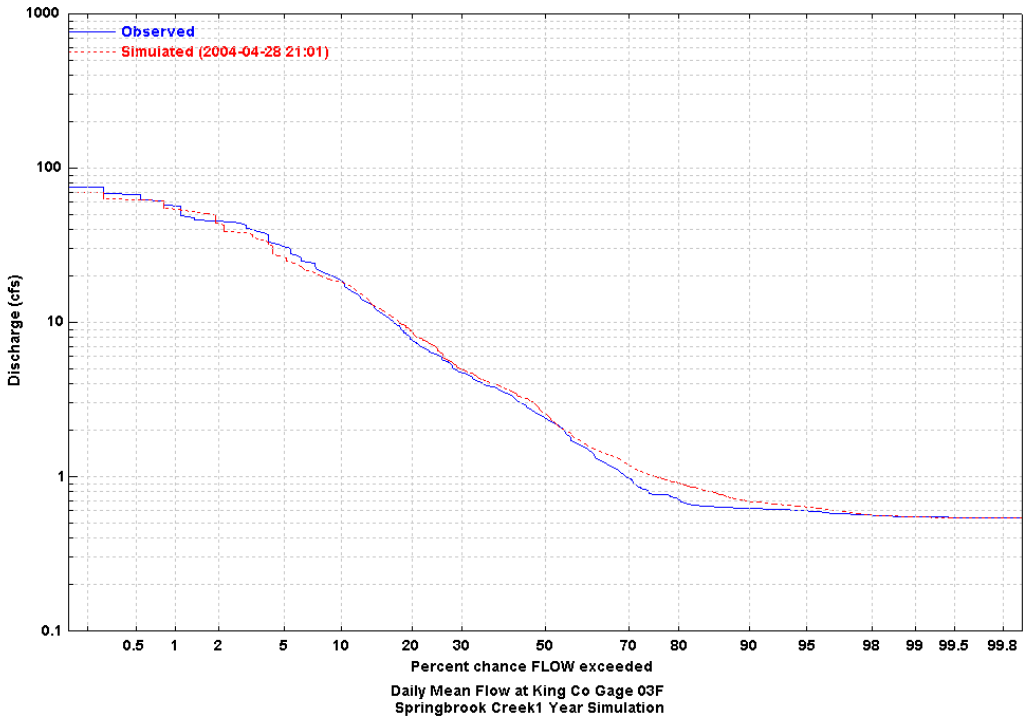


Figure 7.3-12 Daily Flow Duration Plot at King Co Gage 03F

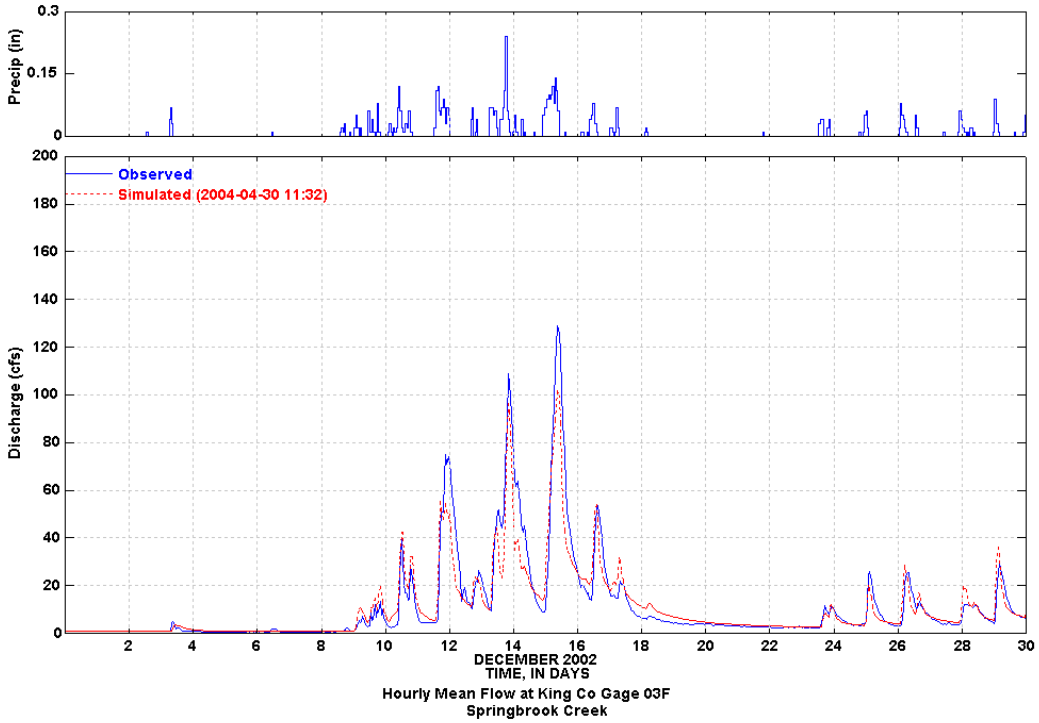


Figure 7.3-13 December 2002 Hourly Flow at King Co Gage 03F

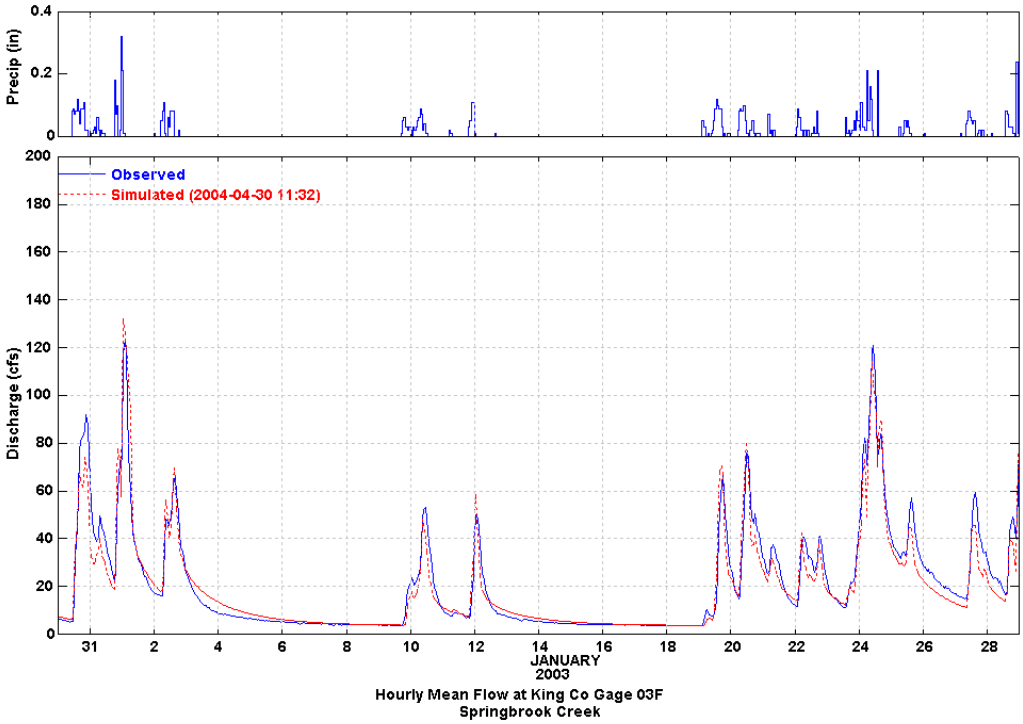


Figure 7.3-14 January 2003 Hourly Flow at King Co Gage 03F

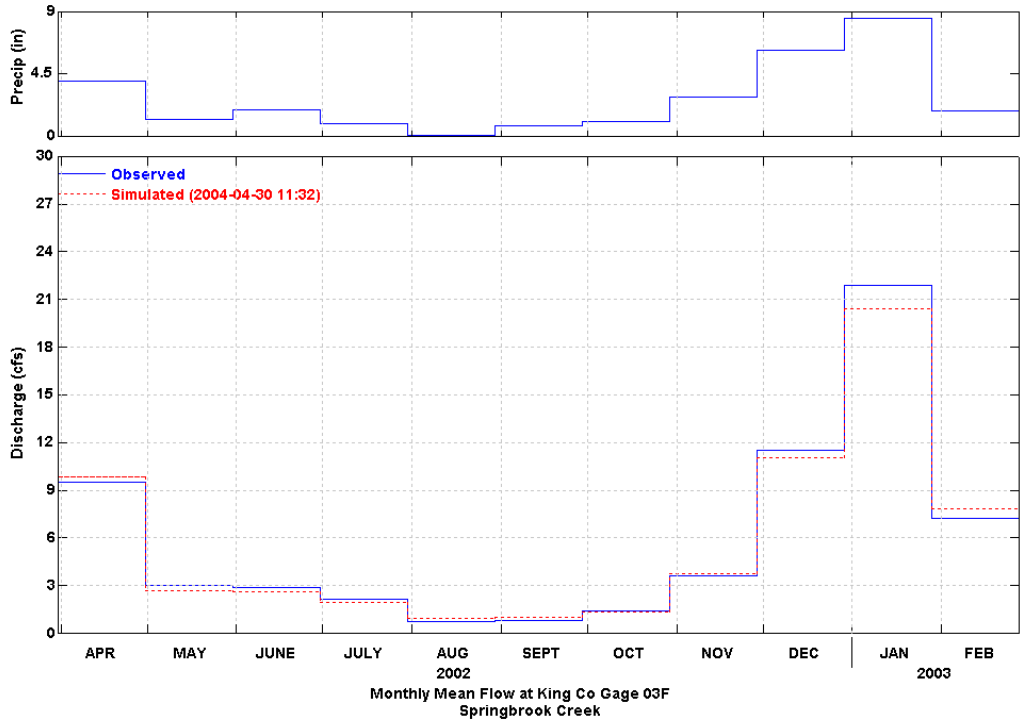


Figure 7.3-15 King Co Gage 03F Monthly Flow Time Series

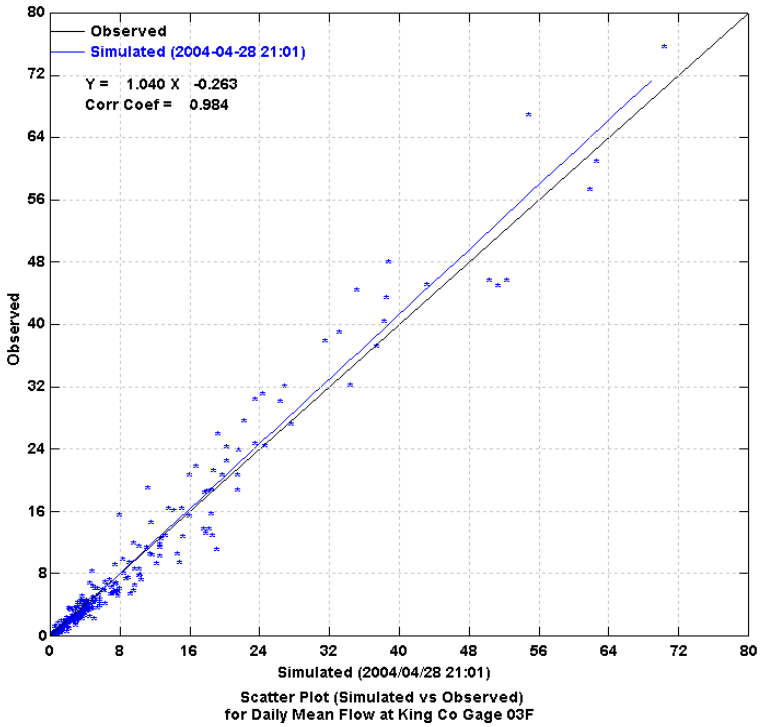


Figure 7.3-16 King Co Gage 03F Scatter Plot

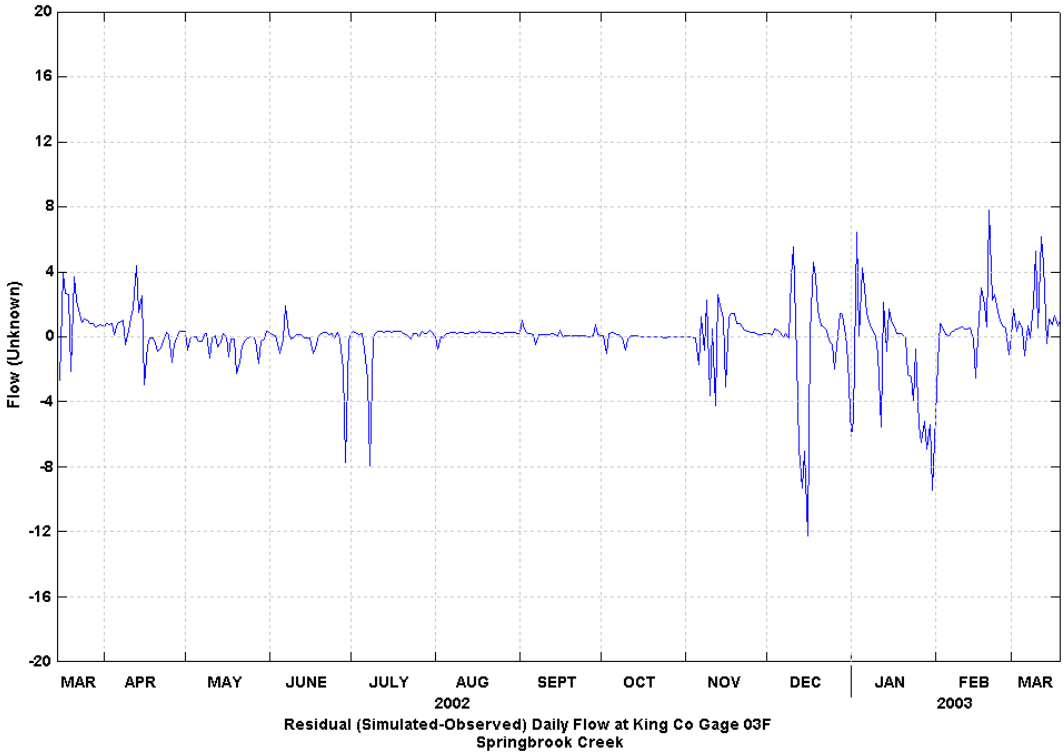


Figure 7.3-17 King Co Gage 03F Residual Plot

Figure 7.3-18 shows the daily simulated and observed streamflow at USGS gage U12113349 for the period of October 1995 through February 2003. Figure 7.3-19 shows the USGS gage U12113349 flow duration for the same period and demonstrates a good match for moderate flow ranges, but shows an underestimation of the largest events and a slight overestimation of baseflow. Figure 7.3-20 and Figure 7.3-21 compare the USGS gage U12113349 daily simulated and observed streamflow values for the winter flow periods of January and February 1996 and January and February 2002, respectively. Monthly simulated and observed flow volumes are shown in Figure 7.3-22. A scatter plot of the simulated and observed daily values is presented in Figure 7.3-23. The scatter plot shows a correlation coefficient of 0.930. A residual plot of the simulated – observed flows is shown in Figure 7.3-24.

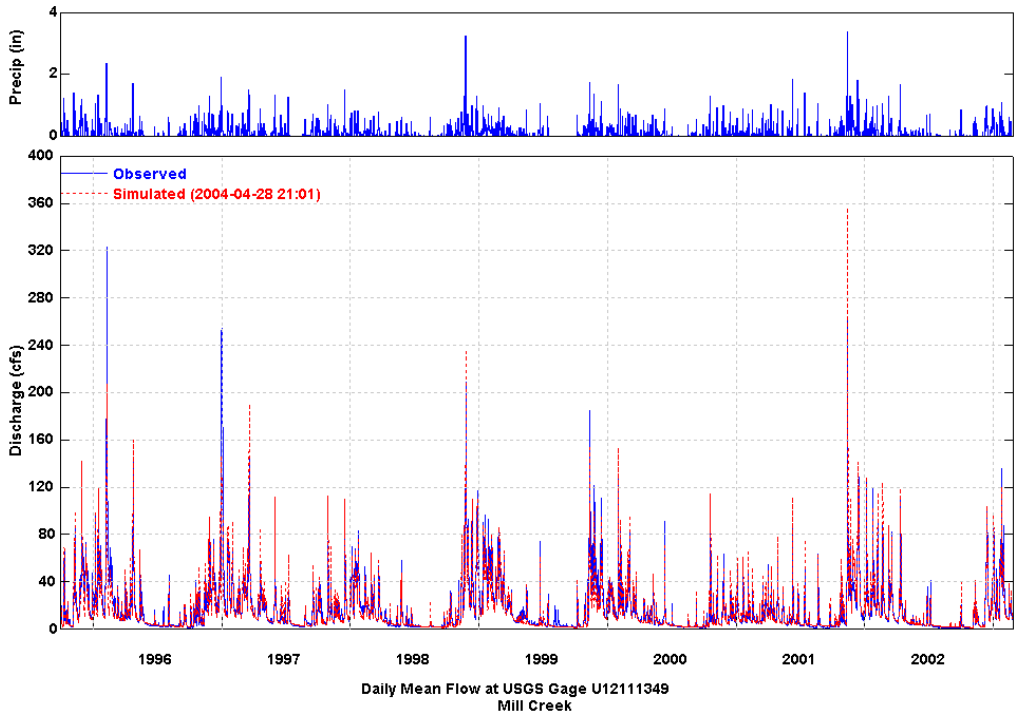


Figure 7.3-18 Simulated vs Observed Daily Flow at USGS Gage U12113349

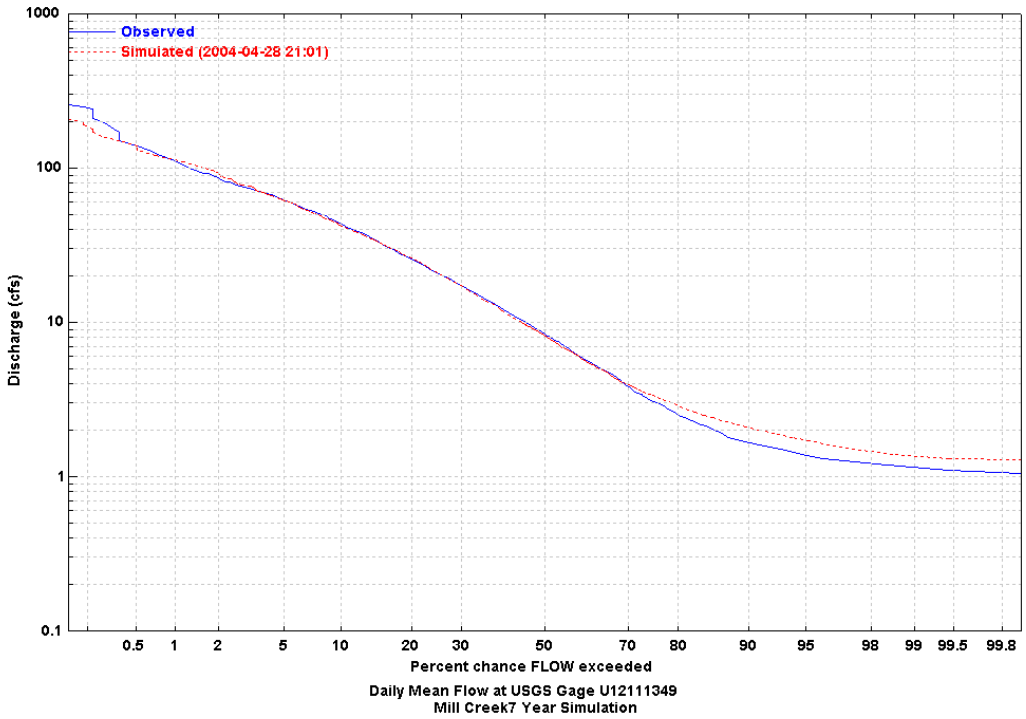


Figure 7.3-19 Daily Flow Duration Plot at USGS Gage U12113349

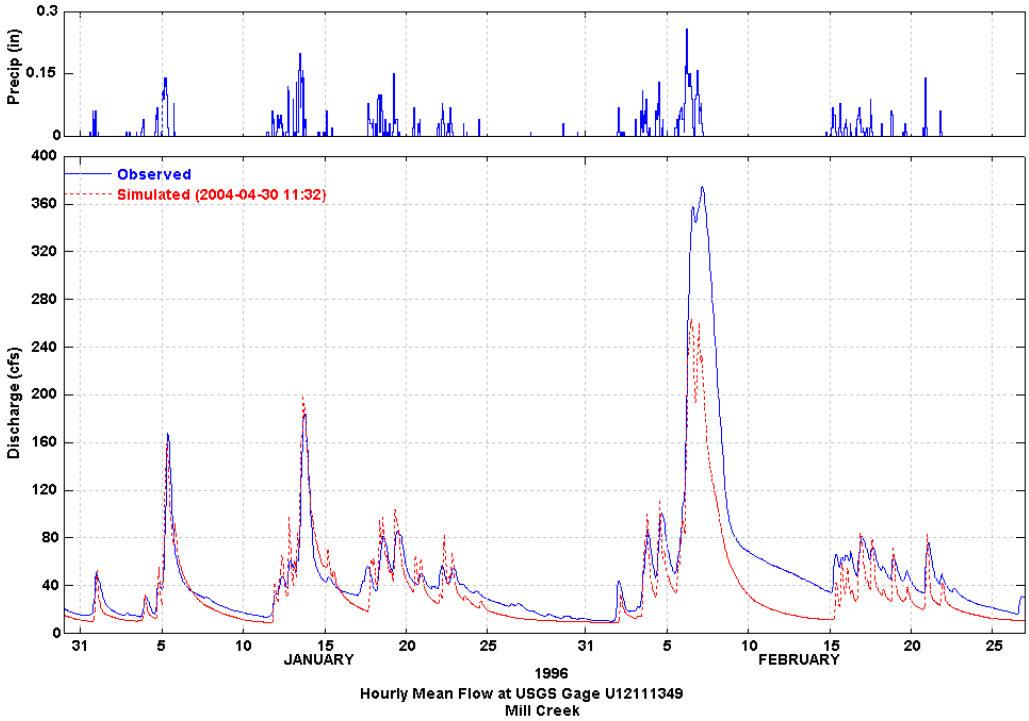


Figure 7.3-20 January – February 1996 Hourly Flow at USGS Gage U12113349

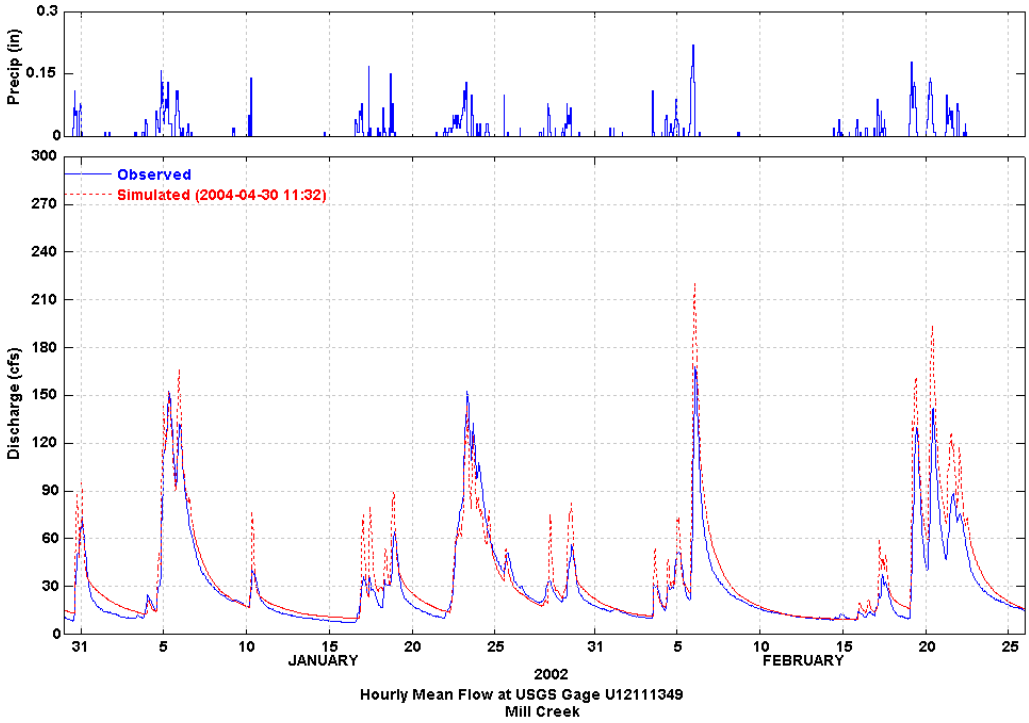


Figure 7.3-21 January – February 2002 Hourly Flow at USGS Gage U12113349

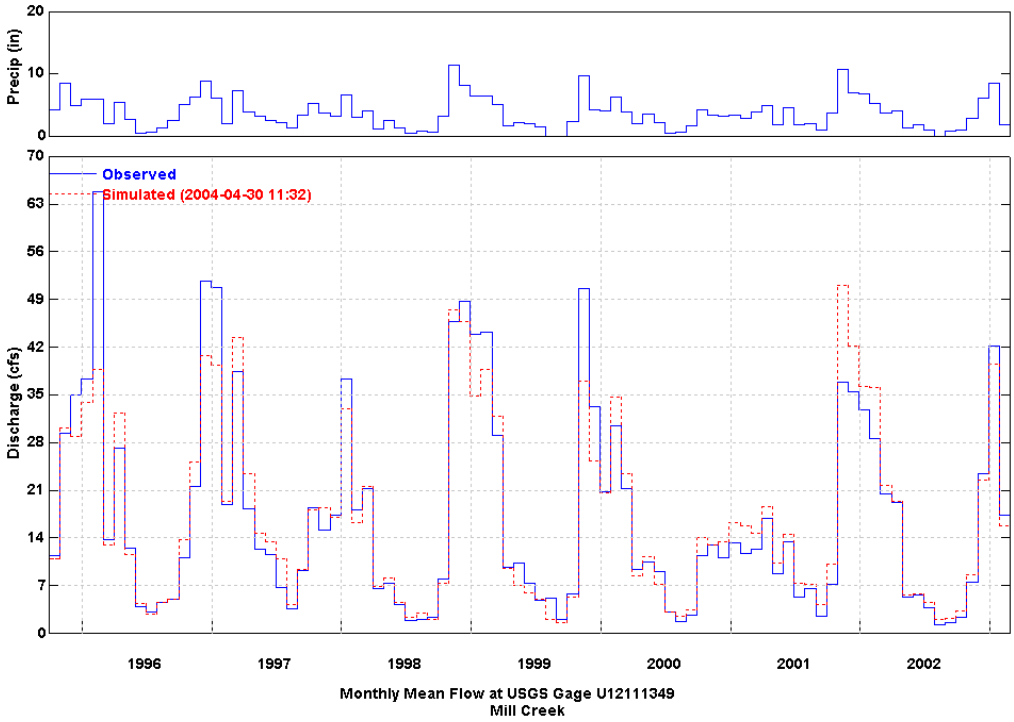


Figure 7.3-22 USGS Gage U12113349 Monthly Flow Time Series

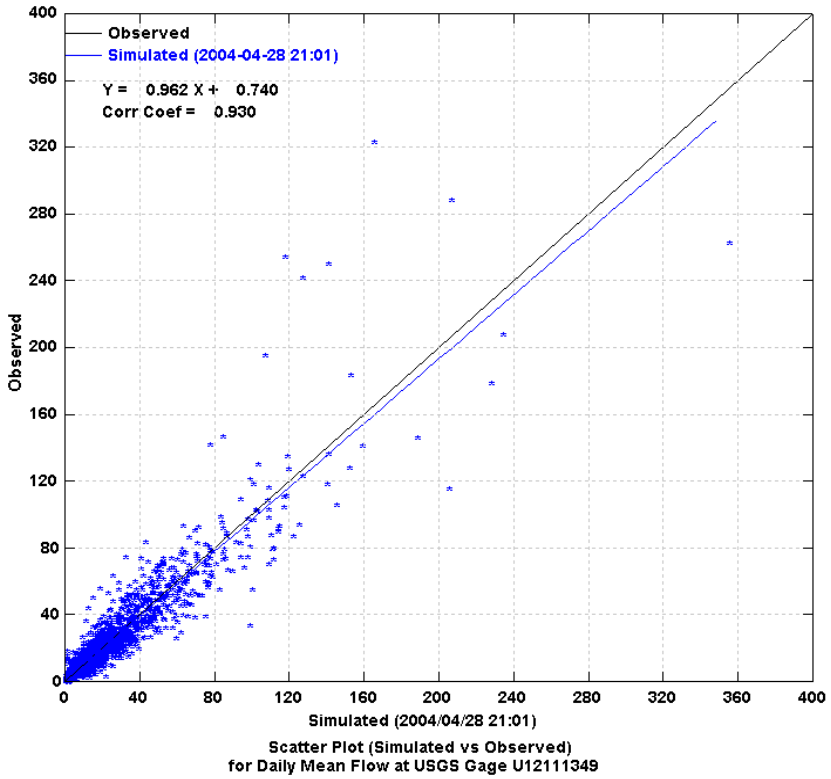


Figure 7.3-23 USGS Gage U12113349 Scatter Plot

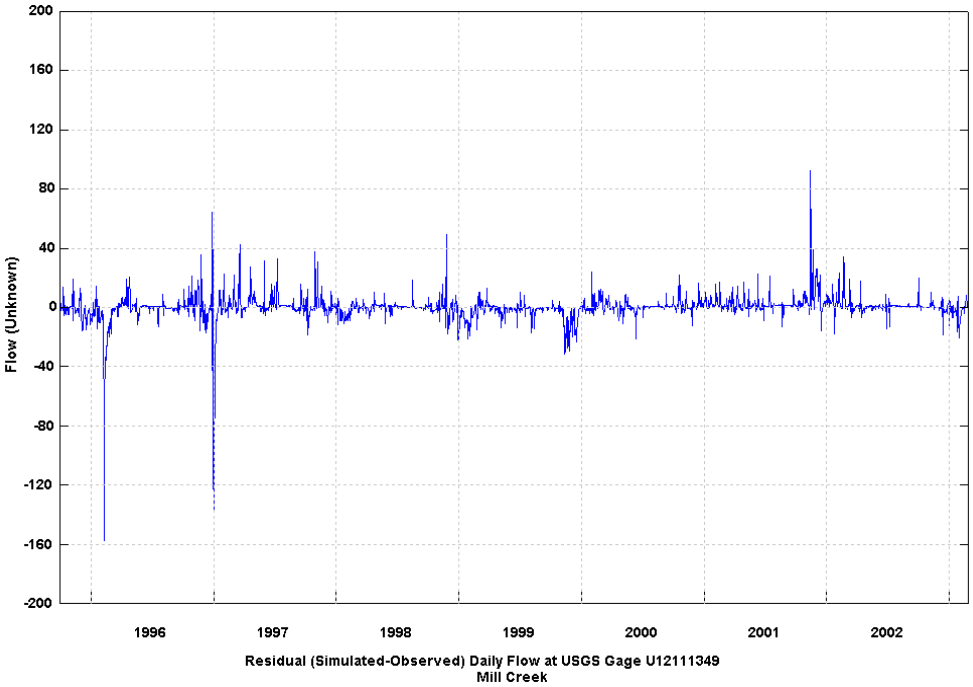


Figure 7.3-24 USGS Gage U12113349 Residual Plot of (Simulated – Observed) Flows

Figure 7.3-25 shows the daily simulated and observed streamflow at USGS gage U12113346 for the period of October 1995 through February 2003. Figure 7.3-26 shows the USGS gage U12113346 flow duration for the same period and demonstrates a good match for most flow levels. Figure 7.3-27 and Figure 7.3-28 compare the USGS gage U12113346 daily simulated and observed streamflow values for the winter flow periods of January and February 1996 and January and February 2002, respectively. Monthly simulated and observed flow volumes are shown in Figure 7.3-29. A scatter plot of the simulated and observed daily values are presented in Figure 7.3-30. The scatter plot shows a correlation coefficient of 0.836. A residual plot of the simulated – observed flows is shown in Figure 7.3-31.

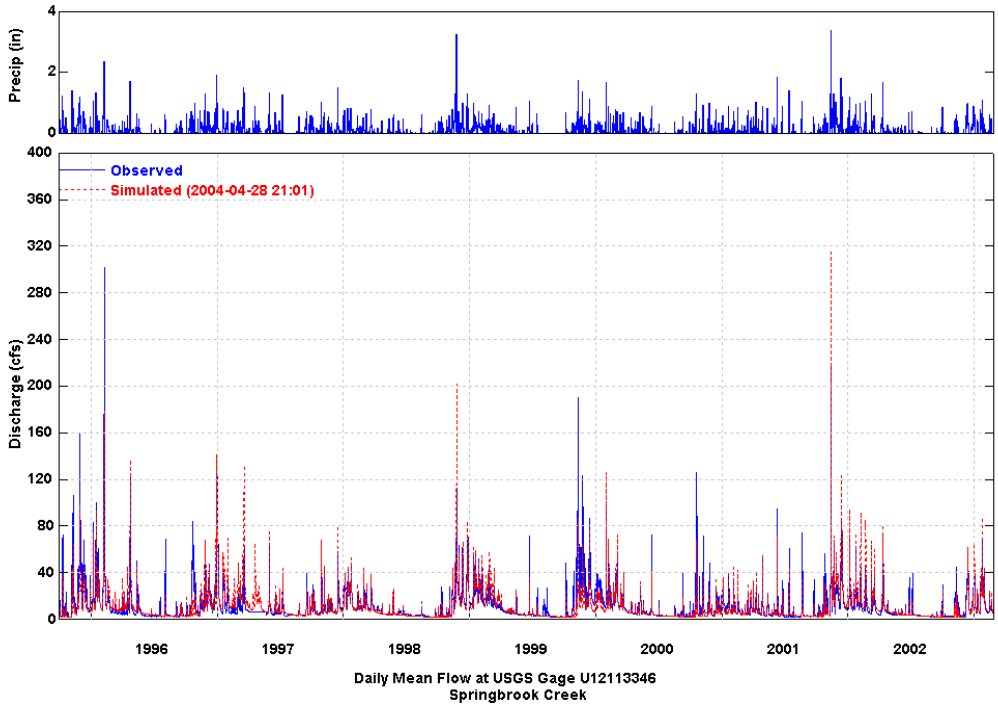


Figure 7.3-25 Simulated vs Observed Daily Flow at USGS Gage U12113346

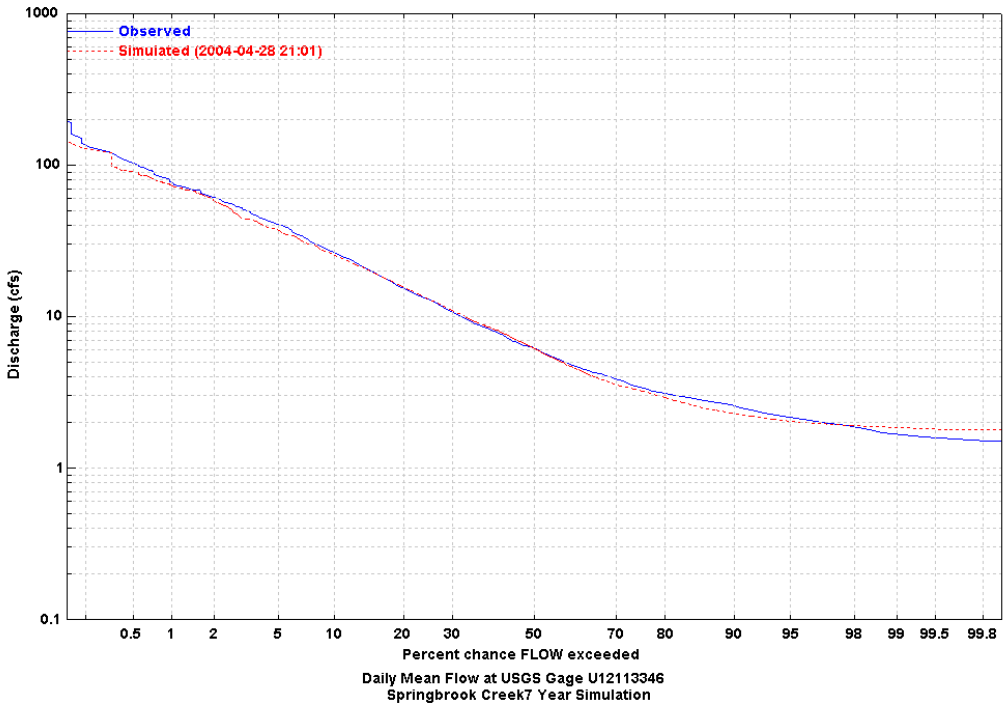


Figure 7.3-26 Daily Flow Duration Plot at USGS Gage U12113346

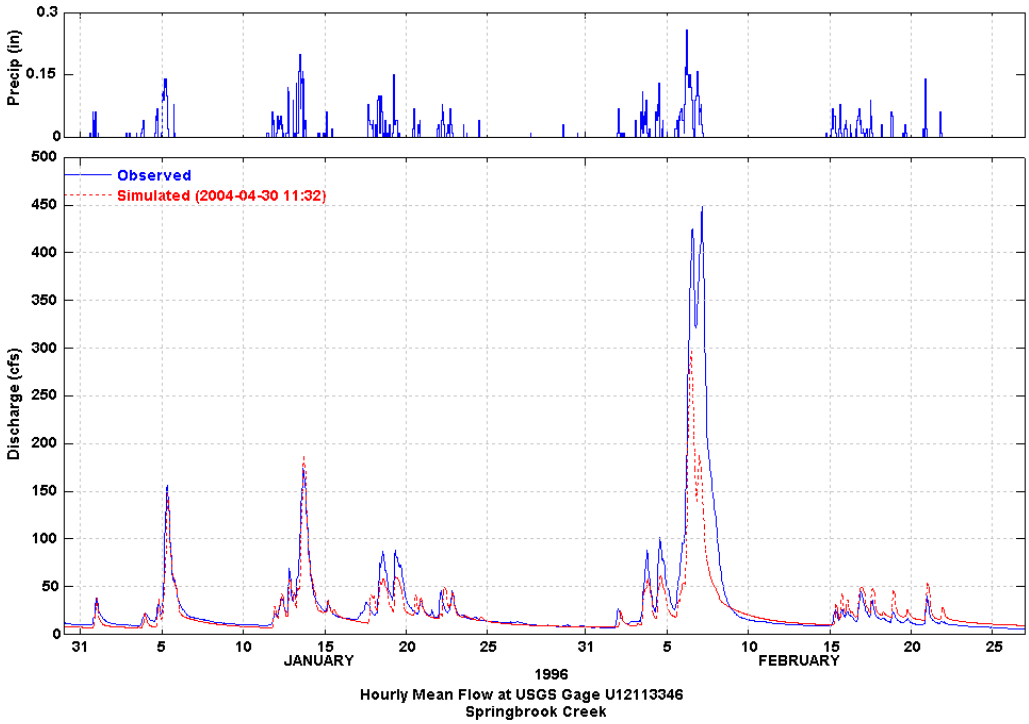


Figure 7.3-27 January – February 1996 Hourly Flow at USGS Gage U12113346

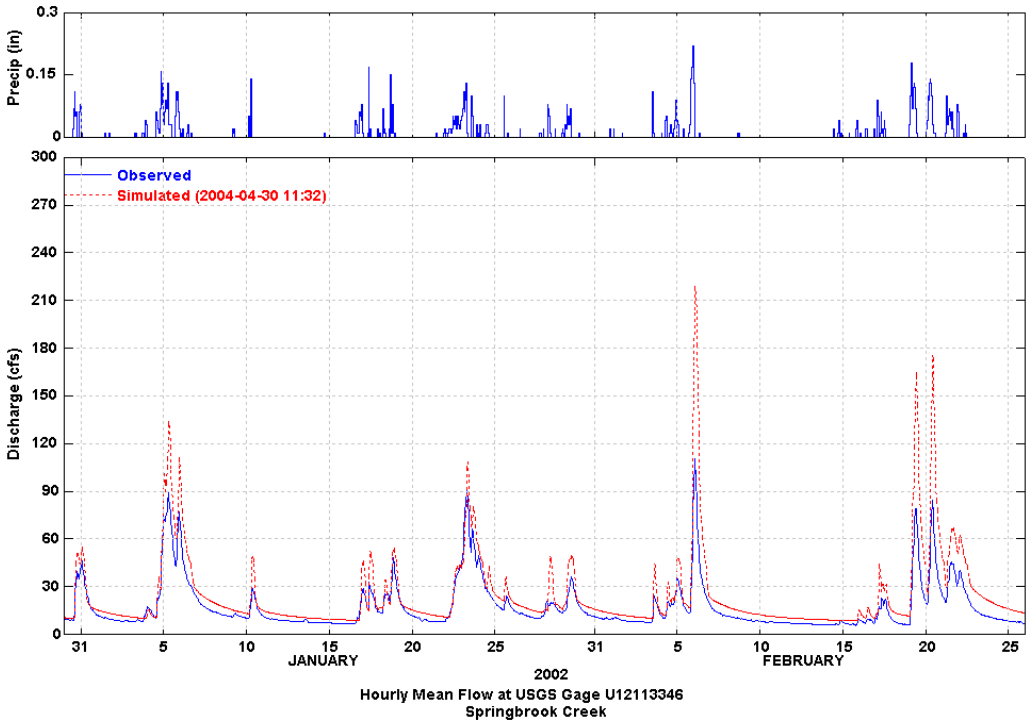


Figure 7.3-28 January – February 2002 Hourly Flow at USGS Gage U12113346

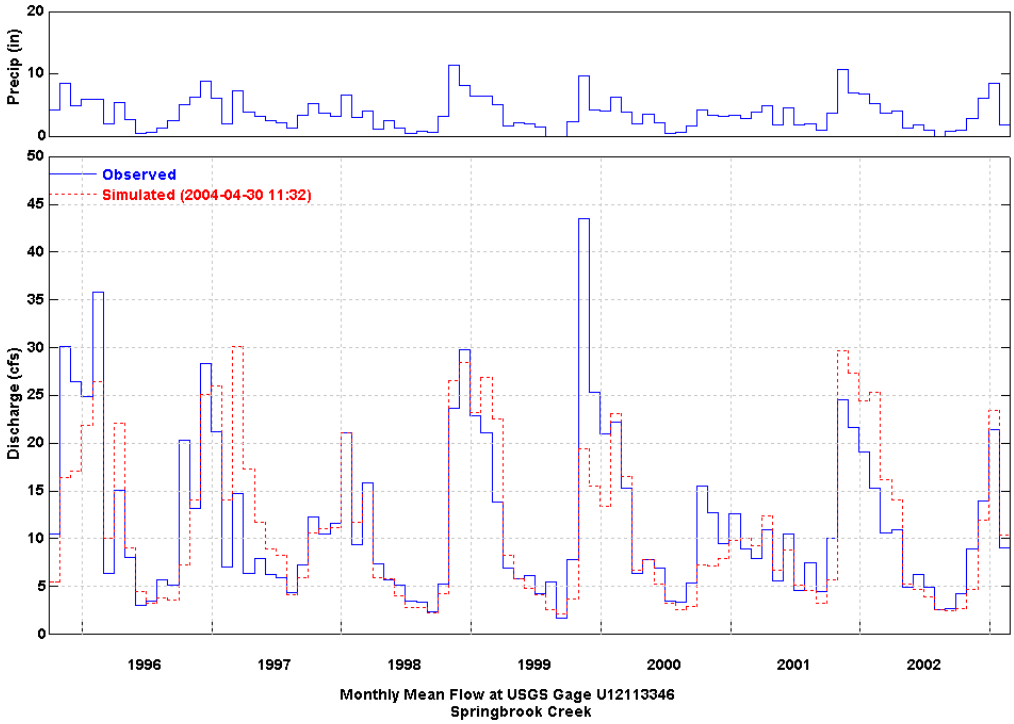


Figure 7.3-29 USGS Gage U12113346 Monthly Flow Time Series

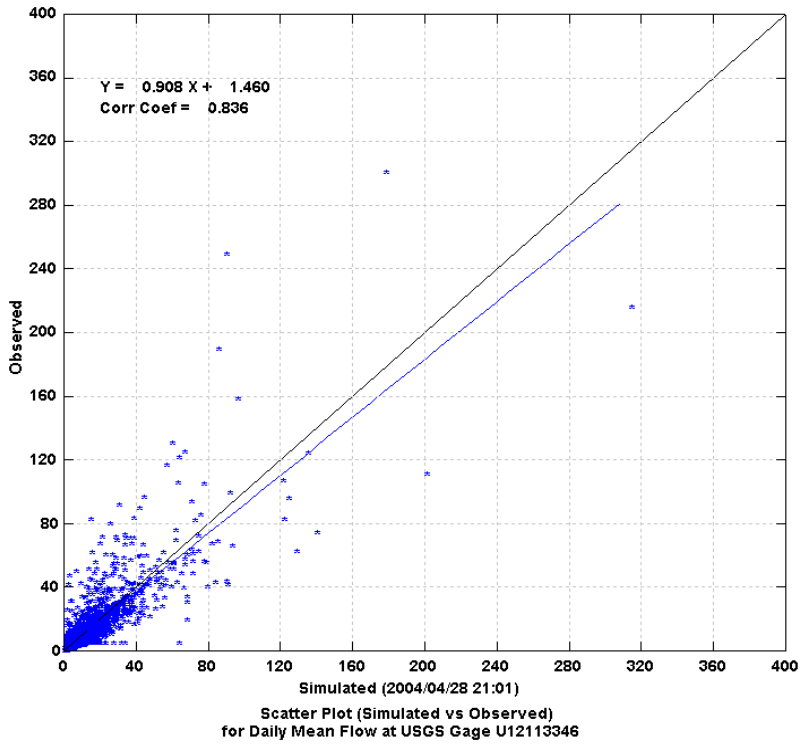


Figure 7.3-30 USGS Gage U12113346 Scatter Plot

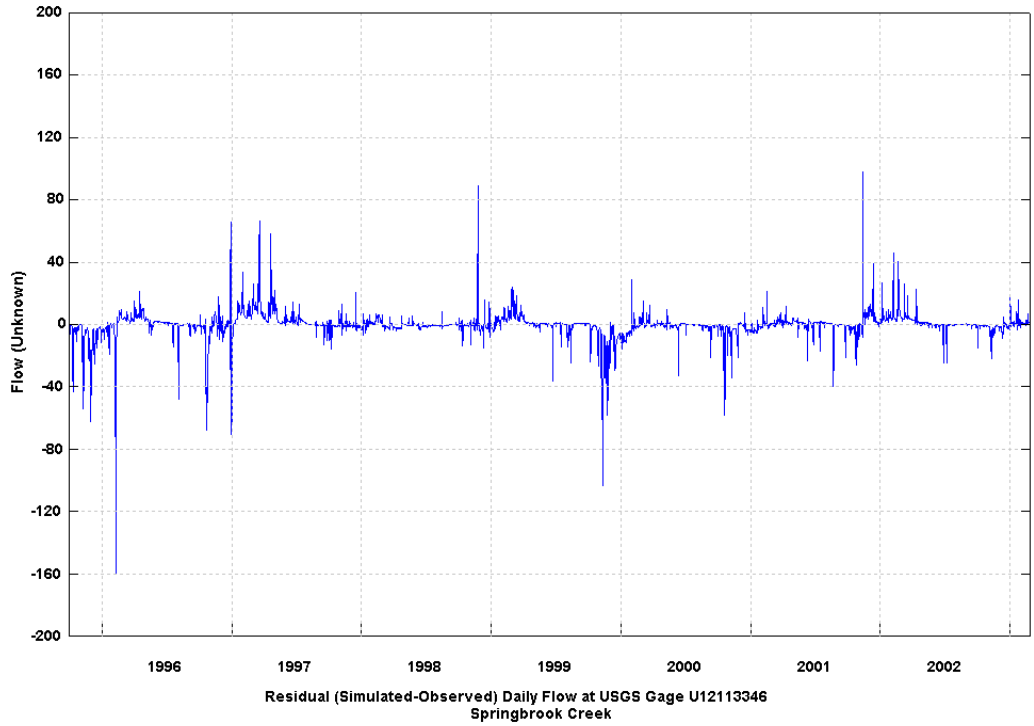


Figure 7.3-31 USGS Gage U12113346 Residual Plot of Simulated –Observed Flows

In addition to the above comparisons, the water balance components (input and simulated) were reviewed for consistency with expected literature values for the Puget Sound region. This effort included displaying model results for individual land uses for the following water balance components:

Precipitation

Total Runoff (sum of following components)
- Surface Runoff/Overland Flow
- Interflow
- Groundwater/Baseflow

Total Actual Evapotranspiration (ET) (sum of following components)
- Interception ET
- Upper zone ET
- Lower zone ET
- Baseflow ET
- Active groundwater ET

Deep Groundwater Recharge/Losses

Although observed values are not available for each of the water balance components listed above, the average annual values must be consistent with expected values for the region, as impacted by the individual land use categories. This is a separate check for consistency with data independent of the modeling (except for precipitation) to insure that land use categories and overall water balance reflect local conditions in the Black/Springbrook River watershed.

The water balance components for the entire Black/Springbrook River watershed are shown in Table 7.3-22. These values are weighed based on the contributing area of each Black/Springbrook River PERLND for 14 years (water years 1988 through 2002). For this time period the mean annual precipitation was 38.00 inches, the total runoff was 22.98 inches, the groundwater flow to the stream was 11.04 inches, the potential evaporation was 24.29 inches,

and the actual evaporation was 14.70 inches. These values are all close to or in the range of the expected values, as presented by Dinicola (1990).

Table 7.3-22 Black/Springbrook River Mean Annual Water Balance (Water Years 1988-2002)

PERLND:	Till (in)	Out-wash (in)	Saturated (in)	Bedrock (in)	EIA (in)	Watershed Average (in)	Expected (Dinicola, 1990) (in)
Influx							
Rainfall	38.45	37.68	36.98	36.29	37.95	38.00	35-50
Runoff							
Surface	1.29	0.24	0.07	1.39	30.41	8.39	
Interflow	7.18	2.94	1.80	6.40	0.00	3.81	
Baseflow	12.36	17.61	10.26	11.20	0.00	10.78	
Total	20.83	20.80	12.14	18.99	30.41	22.98	15-20
GW Inflow							
Deep	0.14	0.24	0.28	0.24	0.00	0.14	
Active	12.42	17.75	16.39	11.69	0.00	11.04	
Total	12.56	17.99	16.67	11.93	0.00	11.18	
Evaporation							
Potential	24.29	24.29	24.29	24.29	24.29	24.29	25
Interception Storage	8.07	7.81	8.10	7.80	7.54	7.85	
Upper Zone	3.51	2.49	6.40	2.32	0.00	2.36	
Lower Zone	5.77	6.04	3.47	6.40	0.00	4.31	
Ground Water	0.00	0.00	6.13	0.00	0.00	0.19	
Baseflow	0.00	0.00	2.00	0.00	0.00	0.06	
Total	17.35	16.33	24.10	16.52	7.54	14.70	18-20
Area (ac)	6125.61	5191.65	501.88	410.37	4184.95	16414.46	
Area (%)	37.32%	31.63%	3.06%	2.50%	25.50%	100.00%	

A complete listing of the water balance components by individual PERLND is presented in Appendix A.

A weight of evidence approach is most widely used and accepted when models are examined and judged for acceptance as no single procedure or statistic is widely accepted as measuring, nor capable of establishing, acceptable model performance. Therefore, the calibration relied on numerous statistical tests (e.g., correlation tests, Model Fit Efficiency) and graphical plots (e.g., scatter, time series, frequency) to determine the model's ability to represent the system.

7.3.1.4 Calibration Summary

Black/Springbrook River was calibrated at four locations: King County gage 03G at Grady Way, King County gage 03F, USGS gage U12113349, and USGS gage U12113347. Statistics and plots were produced for all four locations to demonstrate the accuracy of the calibration. Annual volumes matched well at each location, with errors of 1.26% at gage 03G, -0.09% at gage 03F, -0.32% at gage U12113349, and 4.61% at gage U12113347. The hydrology calibration is sufficiently accurate to proceed to the next step in the calibration process for the Black/Springbrook River, which is the calibration of the water quality data.

7.3.2 WATER QUALITY

7.3.2.1 Initial Water Quality Parameter Set

Initial water quality parameters for the Black/Springbrook watershed were obtained from the previously completed calibration on Newaukum Creek, which was based on the earlier calibrations on Swamp, Little Bear, and North Creeks. Additional guidance in understanding local conditions and estimating the variation of pollutant loading and subsurface pollutant concentrations by land use was developed from several local studies of nutrient loading and concentrations in streams (Brett et al., 2002; Prych and Brenner, 1983; King County, 1994) and impacts of urbanization on streams (Booth et al., 2001). Many of the initial parameters were subsequently adjusted during calibration to better represent the water quality conditions in the watershed. The final calibrated values are provided in the Black/Springbrook UCI file, in Appendix A.

7.3.2.2 Water Quality Calibration

The primary time period of the water quality calibration is October 1988 – July 2003. The calibration utilizes additional water quality data (and meteorological data) that are available at the water quality monitoring stations beginning in 1988 at one station (0317) and around the beginning of 2001 at the other four stations. Because the period of record at Station 0317 is approximately five times longer than the other four stations, and it is near the outlet of the watershed, Station 0317 is used as the primary calibration station.

The calibration of the Black/Springbrook watershed was performed similarly to the calibration of previous watersheds in King County. Subsequent to development of the initial parameter set using the previously calibrated watersheds, detailed adjustments were made to the pollutant loading parameters to fine-tune the calibration. The calibration of some constituents, such as temperature, sediment, dissolved oxygen, copper, and nutrients required instream parameter adjustments. In contrast with the previously calibrated watersheds (i.e., Little Bear, North, Swamp, and Newaukum Creeks), the impacts of instream processes on pollutant concentrations are considered significant for portions of the Springbrook/Black watershed. Specifically, the reaches located in the low-lying valley, which historically was heavily impacted by agriculture and which is now an intensive urban and industrial area, were assumed to be strongly affected by nutrient-laden bed sediments. This assumption was found to be necessary in order to achieve a reasonable calibration. However, the upland areas of the watershed in Mill Creek, Garrison Creek, and Panther Creek were generally treated as though the primary sources of nutrients are currently occurring nonpoint source loads. Therefore, the main emphasis of the calibration and parameter adjustments in these areas was the nonpoint loading values (based on land use), primarily the subsurface (interflow and baseflow) concentrations, and the surface loading associated with surface runoff and sediment.

The land use distribution is fairly uniform across the Black/Springbrook watershed. The one exception is that Station A326 on Panther Creek has no contributing commercial/industrial area. Therefore, the varying responses at the different stations are due primarily to different hydrologic responses and instream processes. Initial land use-specific parameter values for each constituent were based on those from previously calibrated watersheds, primarily Newaukum Creek where the land use draining to each of three different monitoring stations is dominated by a single major category: agricultural, residential/urban, and forest, respectively.

A key assumption of this water quality calibration is that the water quality parameters are constant within a land use category, and don't vary significantly with soils properties (i.e., till, outwash, saturated, rock) or with the four slope classes. Therefore, appropriate differences in the water quality response will be caused by the differences in hydrologic responses that occur as result of the different hydrology parameters used to characterize these soils and slope classes.

7.3.2.3 Summary of Calibration Procedures

As noted earlier, the main goal of water quality calibration is to obtain acceptable agreement of observed and simulated concentrations, while maintaining the instream water quality parameter values and processes within physically realistic bounds, and the nonpoint loading rates within the expected ranges from the literature or based on local experience and guidelines. The use of target nonpoint source loading rates is useful because the water quality concentrations measured at a particular location reflect the combined effects of contributions from multiple land uses, point sources, and instream processes. The target loading rates help to guide the calibration effort and ensure that simulated rates and fluxes from each land use category are reasonable and consistent with literature values and/or local knowledge. These nonpoint loading rates (also known as export coefficients) are highly variable with values ranging up to an order of magnitude, depending on local conditions. Therefore, AQUA TERRA compiled a set of targets with as much applicability to Puget Sound watersheds as possible. Additional data, not specific to Puget Sound were included where necessary to fill data gaps and compare with the locally derived information. These target values are presented in Section 7.3.2.4 of this document when discussing and comparing the simulated loading rates.

For most of the constituents, the calibration procedure involved an iterative series of simulations in which the following information was reviewed:

1. Comparison of land-use specific loading rates with the target export coefficients. The simulated loading rates for each land use category were computed as weighted averages based on the amount of land in each slope category of that land use.
2. Plots of simulated (average daily) and observed time series.
3. Statistics (mean, geometric mean, mean of ratio of simulated to observed, mean error, etc.) of corresponding (i.e., values on the same day) observed and simulated data points.
4. Summaries of the relative impacts and contributions of various constituent sources and processes within each stream segment.

Based on reviews of this information, the monthly variable loading rate parameters for a constituent were adjusted by land use to improve the seasonal agreement for all watersheds

and stations, with initial focus on subwatersheds where the land use is dominated by one or two categories. The adjustments were made to try to improve the agreement of concentrations (statistically and graphically) while maintaining reasonable loading rates and reasonable/ expected variation among the land use categories. When conflicts arose in the direction of adjustments, priority was given to agreement: 1) at monitoring Station 0317 due to the combination of its substantially longer period of record and its proximity to the outlet (since this model will be used primarily to evaluate impacts of total loads delivered to the Green River); 2) to agreement of concentrations/statistics over target loading rates; and 3) to maintenance of reasonable differences between land use categories. The final step involved implementing and/or adjusting instream water quality processes where necessary and reasonable to further improve the agreement. Specifically, in stream reaches satisfying certain low slope and velocity criteria, instream processes were implemented and calibrated. In particular, benthal release of N and P and benthic algae growth processes were used to elevate and seasonally calibrate the concentration of orthophosphate and ammonia in much of the lower portion of Springbrook Creek in order to achieve agreement with observations. Also, benthal oxygen demand was utilized to improve agreement of dissolved oxygen levels.

7.3.2.4 Calibration Discussion and Results

The results of the calibration are presented on the following pages. Table 7.3-23 shows the average annual (over the nearly fifteen year simulation period) loading rates in pounds/acre/ year for nitrogen species and compares them with the target rates. Table 7.3-24 shows the same information for phosphorus species and sediment. Table 7.3-25 presents the mean simulated and observed concentrations on sampling dates for the various constituents, and the ratio of the means. Table 7.3-26 shows the average (and range) of simulated/observed concentration ratios for all of the Black/Springbrook watershed stations. Finally, Figure 7.3-32 through Figure 7.3-46 show the time series plots of simulated daily and observed water quality constituent concentrations for the primary/outlet station in the Black/Springbrook watershed (i.e., Station 0317). Similar plots for the other four calibration stations are shown in Appendix B. The following discussion is focused by constituent.

Water temperature calibration is done first, so that the various instream processes that are dependent on temperature are modeled with reasonable temperature conditions. Temperature adjustments were made as follows:

- Stream shading is generally checked with any available information, and then adjusted to improve the agreement with observations; no information was available for the Black/Springbrook watershed, so shading was treated as a calibration parameter.
- The parameters that determine the temperature of runoff from pervious and impervious land areas were adjusted seasonally.
- Since many of these streams are shallow, the temperature of the ground beneath the stream was adjusted seasonally to increase the effect of heat transfers via this pathway. Generally, the average daily water temperature is well calibrated in the Black/Springbrook watershed as evidenced in Figure 4.3-32 and the statistical information presented in Tables 4.3-25 and 4.3-26, with occasional summertime oversimulations in the comparison of daily average data apparent at station 0317.

Sediment - Target sediment loadings to the stream channel were estimated for each land use category from the available literature data. Table 4.3-24 lists target loading rates that were developed for calibrating the nonpoint sediment loadings within the Black/Springbrook watershed and other Puget Sound watersheds. The model categories are a function of soil type and slope class, in addition to land use, and therefore the loading rates should also be variable within a given land use to reflect the combined erodibility of the soil matrix and slope class.

KRER and KSER are the primary sediment erosion calibration parameters in HSPF. They govern detachment of soil particles by raindrop impact on the land surface and the subsequent transport of these particles by overland flow, respectively. KRER is usually estimated as equal to the erodibility factor, K, in the USLE, and then adjusted in calibration, while KSER is primarily evaluated through calibration and past experience. During the calibration of the Black/Springbrook watershed model, KSER was adjusted upward (relative to previously calibrated watersheds) to achieve the expected range of loading rates for the various land use categories. The loading rates by slope class were primarily dictated by the overland flow rates generated by the respective class. The parameters for vegetal cover (COVER) and atmospheric fallout (NVSI) were not adjusted during the calibration process, but assumed to be constant, based on the land use.

Once the sediment loading rates were calibrated to provide reasonable loadings to the stream channel, the sediment calibration focused on the channel processes of deposition, scour, and transport. The sediment calibration involved iteratively performing several steps to determine the model parameters and appropriate adjustments needed to ensure a reasonable simulation of the sediment transport and behavior of the channel system. The steps performed during the calibration were as follows:

1. Divided the nonpoint sediment loads into sand, silt, and clay fractions. For the Black/Springbrook model, the fractionation of the sediment was assumed to be: 5% sand, 70% silt, and 25% clay.
2. Ran the model to calculate bed shear and establish scour and deposition patterns – HSPF calculates the shear stress (TAU) as a function of the reaches hydraulic radius, slope, and density of water. For the silt and clay (i.e. cohesive) fractions, shear stress calculations are compared to user-defined critical, or threshold, values for deposition and scour. Thus, knowing the range of TAU values a reach experiences is critical in establishing the expected scour and depositional patterns.
3. Estimated initial parameter values and storages for all reaches. The key sand parameters are the coefficient (KSAND) and exponent (EXPSND) in the power function equation that defines sand transport, along with the sand particle characteristics. Initial KSAND and EXPSND values were estimated, and the sand particle characteristics were set at typical values found in the literature. The key silt and clay parameters are the critical bed shear threshold values for scour (TAUCS) and deposition (TAUCD), and the associated particle characteristics. Initial values for TAUCS and TAUCD were estimated on a reach by reach basis based on the simulated TAU values in each reach. In the absence of any channel bed composition data, the initial composition of each of the channel beds was assumed to be 65% sand, 15% silt, and 20% clay. TAUCS, TAUCD, and KSAND were the primary calibration parameters.
4. Historical information was not available to describe how each of the modeled streambeds were changing over time; therefore, the primary parameters for scour, deposition and transport were mainly adjusted to achieve channels that were stable with time (i.e., over the calibration period) for each of the size fractions.
5. Calibration was performed at all five stations, with the primary focus on Station 0317, located near the outlet of the watershed. The frequency and overall number of data points did not support any rigorous statistical tests. Therefore, the comparisons primarily consisted of graphical plots and simple statistics (e.g., comparison of means, geometric means, ratio of simulated vs. observed). The primary parameters for scour, deposition and transport were further adjusted to achieve agreement between simulated and observed concentrations, while maintaining the desired bed behavior and a reasonable distribution of sand, silt, and clay within the beds and water column.

Based primarily on the loading results and the statistical summaries in Table 4.3-25, and given the limited data available (particularly the scarcity of peak flow data) and the usual difficulty in modeling sediment, we concluded that the model reasonably represents the behavior of sediment concentrations and loads in Springbrook/Black. However, the model probably over simulates the peak concentrations during the 1996-97 and 1998-99 wet seasons.

Nitrogen Species – In general, nitrogen concentrations in the Black/Springbrook watershed are similar to previously calibrated basins Little Bear, North, and Swamp, but are lower than Newaukum, which still contains a large amount of agricultural land. Calibration of nitrate and ammonia was largely done by adjusting the interflow/groundwater concentrations and ammonia surface loading factors by land use, (with consideration of the target loadings) until the errors were minimized at the Panther and Mill Creek stations. At this point, ammonia was

undersimulated at Stations 0317, A317, and C317. Assuming that bottom sediments in the Springbrook valley contain high nutrient quantities from historical agricultural activities in the valley and more recent urban/industrial nonpoint loads, releases of ammonia (and orthophosphate) were implemented in the model from the bottom muds of stream and river reaches that exhibit low longitudinal slope (less than 1%), and therefore relatively low flow velocities. These release rates are included in the model in the form of a standard rate during low flow and an increasing rate once the flow velocity exceeds a threshold. These rates, and the impacts of algal growth processes in response to the nutrient levels, were utilized to adjust the ammonia levels to improve the agreement at the downstream stations 0317, A317, and C317. The increases needed to improve the agreement of the means at the outlet station produced a baseline that was slightly high as shown in Figure 4.3-35. This balancing of baseline and overall statistical agreement was also required for orthophospahte.

While the primary calibration of nitrate was accomplished by loading adjustments, the simulated concentrations and loads in the lower Springbrook basin are strongly impacted by instream processes, specifically nitrification/denitrification and algal growth. Adjustments were made to both processes to improve nitrate agreement. The nitrate and total nitrogen results for Station 0317 are provided in Figures 4.3-36 and 4.3-37 and Tables 4.3-25 and 4.3-26. The effects of the ammonia and nitrate adjustments discussed above, plus the fact that total nitrogen concentrations are approximately 50% nitrate, which showed good statistical agreement, resulted in a similar result for total nitrogen.

Phosphorus Species – As with nitrogen, phosphorus species in the Black/Springbrook watershed are similar to previously calibrated basins Little Bear, North, and Swamp, but are lower than Newaukum due to the difference in agricultural land use. Orthophosphate concentrations were calibrated by adjusting the land use-specific interflow and groundwater concentrations and the surface parameters (potency factors) seasonally to achieve a fit at the upland stations on Mill and Panther Creeks. Additional loads were generated from the bottom sediments in the low-lying valley reaches, reflecting deposits during prior periods of agricultural activity in the watershed, in order to better match higher concentrations at the downstream stations (0317, A317, and C317). At the 0317 station, the observed data seem to show a downward trend, but since the statistics are based on the full 15 years of data, they indicate an under simulation (Sim=0.05 vs. Obs=0.07), while Figure 4.3-38 suggests a significant over simulation during the most recent 3+ years. This same phenomenon can be seen in the total

phosphorus results, where the comparison of the mean suggests an undersimulation, but Figure 4.3-39 suggests a fairly reasonable match to TP concentrations at the outlet station.

Total organic carbon – Total organic carbon data were available at all five stations in the Black/Springbrook watershed for 2002-2003. In previous watershed calibrations, excluding Newaukum which also has TOC data, the organics (N and P) were adjusted by adjusting BOD loading, and then N and P were adjusted differentially by changing multiplication factors in the MASS-LINK block, which changes the ratio between BOD loading and refractory organic N or P. Organic carbon loads are determined similarly. They are a function of the actual BOD inputs to the stream (degradable fraction) and the loading of refractory (non-degradable fraction) organic carbon, both of which are based on the same BOD loading rates and separate multiplication factors. In this case, the primary adjustment was made to the multiplication factors rather than the BOD rates, so that the organic N and P would not be negatively affected. Considering the limited data, the statistical results for TOC shown in Tables 4.3-25 and 4.3-26 suggest fair agreement; however, the time series plots suggest the upstream stations at Panther Creek is somewhat under simulated during the winter and spring.

Dissolved oxygen was calibrated to data at all five stations in the Black/Springbrook watershed. In relatively low impact streams and watersheds such as Panther Creek, the principal determining factor in DO levels is water temperature. Once the water temperature was fine-tuned, DO agreement was further improved by adjusting the seasonal DO concentration of incoming interflow and groundwater. In the higher impact streams such as lower Springbrook Creek, the algal growth/respiration cycle and organic matter decay have a large influence for much of the year. The benthal oxygen demand parameters were set at a level to depress low flow DO concentrations so that they match observed values.

Alkalinity was calibrated to data at all five stations in the Black/Springbrook watershed primarily by adjusting subsurface (interflow and groundwater) concentrations to obtain the seasonal variation exhibited at the outlet station while maintaining appropriate differences between land uses. The statistical agreement at the stations was poor, with over simulation in wet periods and both over simulation and under simulation in dry periods. Further adjustment of alkalinity, in conjunction with total inorganic carbon changes to maintain appropriate pH levels is warranted in order to improve the statistical agreement.

pH was calibrated to data at all five stations in the Black/Springbrook watershed. The calibration focused on attaining reasonable values and appropriate seasonal variation, based on experience and the monitoring data. The pH was sensitive to alkalinity, and was also sensitive to total inorganic carbon (TIC) concentration. TIC modeling was handled the same as in the previous watersheds. Based on the chemical equilibrium equations relating pH, alkalinity, and TIC, it was determined that the observed alkalinity and pH levels would necessitate concentrations of TIC in the range of 10-30 mg/L, which are unattainable with the existing CO2 formulation in HSPF. Therefore, the existing algorithm was used as an indicator or index to the TIC loading, but the actual values were adjusted upwards by a constant factor of between 30 and 70 for groundwater and between 20 and 35 for interflow (lower for the uplands and higher for the lowlands) in order to attain the necessary TIC to compute pH values that are in line with observations in Puget Sound watersheds. Considering the difficulty in modeling pH, the modeling results shown in Tables 4.3-25 and 4.3-26 and Figures 4.3-42 and B.11-1 - B.11-4 (Appendix B) are acceptable. The model predicts pH values in the same range (approximately 6.5-7.5) and with the same seasonal trends as the observed data. The model often over simulates or misses the extreme variability shown at the outlet station (0317) during dry periods.

E-Coli and fecal coliforms are extremely variable and difficult to predict. One reason for this is that many of the larger loadings of bacterial material probably occur not only during storms, but also during somewhat random but “catastrophic” events, such as failure of human (and agricultural) waste disposal facilities, which can produce large, unpredictable concentrations. Therefore, efforts were made to attain general agreement between the simulated concentrations of both species by adjusting the land use-specific loading rates via both surface and subsurface pathways. Because of the difficulty in matching actual observed values, the calibration focused primarily on agreement between the means (primarily the geometric mean, since the arithmetic mean can be strongly biased by a few extreme values) and the standard deviation. The E-Coli and fecal coliform levels in the Black/Springbrook watershed are similar to previously calibrated basins Little Bear, North, and Swamp, but are lower than Newaukum due to less intensive agricultural land use and practices (since animal waste is a major contributor to coliform loading).

Total and dissolved copper concentrations were calibrated by adjusting the land use-specific interflow and groundwater concentrations and the surface parameters (potency factors) to achieve a statistical fit with the available data. Copper is sediment-associated, so all surface

loading was modeled in the sorbed phase, and most of the data supports the association of high copper levels with storms. The instream adsorption/desorption rates and adsorption equilibrium coefficients were adjusted to achieve reasonable behavior and a good match between the dissolved and total forms of copper. Specifically, the adsorption/desorption rate coefficients were reduced slightly from those used in the Newaukum Creek model, while the equilibrium coefficients were unchanged. Adsorption rates for suspended sediment are almost 5 orders of magnitude higher than bed sediments, reflecting greater mixing and turbulence in the water column, and the lack of exposure of particles in the bed to the water column. This also helps to avoid large seasonal fluctuations in the baseline concentration caused by rapid sorption to the bed during periods of high concentration (storms) and slow desorption during periods of lower concentration. The calibrated adsorption equilibrium coefficients are the same for suspended and bed sediments.

Table 7.3-23 Average Annual Nitrogen Loadings

	Constituents (Average lbs/acre/year loadings)							
	Nitrate-N		Ammonia-N		Organic N		Total N	
Land Category	Target	Simulated	Target	Simulated	Target	Simulated	Target	Simulated
Forest	1.4	1.0	0.2	0.03	0.4	0.44	2.0	1.5
Pasture/Ag	9.0	5.6	1.3	0.14	2.5	3.14	13.	8.9
Forest Residential	4.2	1.4	0.6	0.03	1.2	0.51	6.0	1.9
Low Density Residential	4.9	2.2	0.7	0.19	1.4	0.93	7.0	3.3
High Density Residential	6.3	3.7	0.9	0.51	1.8	1.61	9.0	5.8
Commercial/ Industrial	4.9	4.2	0.7	0.80	1.4	4.41	7.0	9.4

Table 7.3-24 Average Annual Phosphorus and Sediment Loadings

	Constituents (pounds/acre/year loadings)							
	Orthophosphate-P		Organic P		Total P		Sediment (tons)	
Land Category	Target	Simulated	Target	Simulated	Target	Simulated	Target	Simulated
Forest	0.11	0.11	0.07	0.03	0.12	0.13	0.04	0.015
Pasture/Ag	0.77	0.77	0.7	0.18	1.3	0.95	0.08	0.158
Forest Residential	0.05	0.05	0.16	0.03	0.25	0.08	0.06	0.038
Low Density Residential	0.09	0.09	0.3	0.05	0.5	0.15	0.14	0.082
High Density Residential	0.21	0.21	0.45	0.09	0.7	0.30	0.16	0.230
Commercial/ Industrial	0.24	0.24	0.9	0.25	1.4	0.50	0.36	0.134

Table 7.3-25 Mean Simulated vs. Observed Concentrations on Sample Dates

	Springbrook Creek at Outlet - Station C317			Springbrook Creek at Station A317			Springbrook Creek at Station 0317			Panther Creek at Station A326			Springbrook Creek at Station B317		
Constituent	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *
Water Temperature (C)	10.53	10.89	0.95 (18)	10.14	10.19	0.99 (19)	11.40	11.03	1.03 (224)	9.58	9.63	1.02 (18)	10.79	10.62	1.02 (12)
Suspended Sediment (mg/l)	13.8	10.8	1.36 (13)	19.1	16.3	0.97 (22)	22.3	24.3	0.85 (232)	7.2	7.2	1.35 (23)	23.8	23.7	1.17 (24)
Dissolved Oxygen (mg/l)	7.65	7.66	1.06 (18)	7.37	6.36	1.20 (19)	6.96	6.40	1.11 (216)	11.44	11.79	0.97 (18)	8.18	7.62	1.10 (12)
Nitrate-Nitrite as N (mg/l)	0.43	0.38	1.16 (13)	0.48	0.43	1.17 (26)	0.44	0.49	0.97 (221)	0.49	0.47	1.19 (23)	0.53	0.58	1.11 (24)
Ammonia as N (mg/l)	0.157	0.192	1.82 (13)	0.255	0.155	4.98 (26)	0.179	0.229	2.08 (220)	0.033	0.029	1.34 (17)	0.237	0.196	2.76 (24)
Total Nitrogen (mg/l)	0.90	0.94	1.01 (13)	1.02	1.01	1.06 (26)	0.95	1.00	1.03(148)	0.77	0.84	0.94 (31)	1.08	1.24	1.03 (24)
Orthophosphate as P (mg/l)	0.040	0.029	1.91 (13)	0.066	0.032	2.63 (26)	0.050	0.071	1.62 (219)	0.029	0.030	1.37 (23)	0.053	0.021	3.25 (24)
Total Phosphorus (mg/l)	0.086	0.096	0.97 (13)	0.108	0.118	0.98 (26)	0.099	0.184	0.71 (220)	0.066	0.050	1.51 (23)	0.099	0.086	1.28 (24)
Alkalinity as $CaCO_3$ (mg/l)	91.7	85.3	1.34 (13)	80.8	71.8	1.51 (26)	96.0	94.1	1.24 (85)	75.3	59.6	1.41 (23)	76.0	50.2	1.81 (24)
pH	7.02	7.14	0.98 (18)	6.86	6.85	1.00 (19)	6.91	6.85	1.01 (218)	7.53	7.62	0.99 (18)	7.12	6.91	1.03 (12)
EColi (CFUs/100 ml)	255	550	0.70 (13)	674	902	0.86 (29)	655	642	1.35 (60)	165	304	1.39 (23)	353	1791	0.61 (23)
Fec. Coli. (CFUs/100 ml)	363	701	0.62 (13)	1315	1211	0.74 (26)	994	996	2.25 (220)	244	325	1.64 (21)	542	1691	0.95 (24)
Copper (dissolved - ug/l)	2.09	1.55	1.93 (13)	3.07	1.94	1.77 (28)	4.44	2.62	2.08 (16)	1.47	1.58	1.02 (23)	2.32	2.15	1.44 (26)
Copper (total - ug/l)	2.58	2.77	1.06 (13)	4.56	3.66	1.24 (28)	6.36	7.81	0.83 (55)	1.79	2.31	0.92 (23)	2.98	4.88	0.89 (26)
Organic Carbon (mg/l)	7.06	8.03	0.90 (14)	7.01	9.15	0.78 (25)	7.98	8.80	0.94 (13)	6.44	8.33	0.82 (23)	7.69	9.52	0.85 (24)

* Mean Daily Ratio - mean of Simulated:Observed ratios on sampling dates; sample size in parentheses

Table 7.3-26 Overall Weighted Simulated/Observed Average Values and Range of Concentration Ratios for all Stations in the Black/Springbrook Watershed

Constituent	Simulated Mean	Observed Mean	Ratio Average	Ratio Range
Water Temperature (deg C)	11.13	10.83	1.02	0.52-1.73
Suspended Sediment	20.73	21.88	0.94	0..01-27.8
Dissolved Oxygen	7.33	6.87	1.10	0.45-1.95
Nitrite-Nitrate as N	0.45	0.49	1.03	0.31-2.36
Ammonia as N (5-year run)	0.18	0.21	2.36	0.02-39.1
Total Nitrogen	0.95	1.01	1.02	0.41-4.93
Orthophosphate as P (5-year run)	0.050	0.059	1.83	0.03-15.9
Total Phosphorus	0.097	0.157	0.85	0.05-4.09
Alkalinity as $CaCO_3$	87.8	50.2	1.39	0.66-3.52
pH	6.98	6.92	1.01	0.82-1.15
E-Coli	501	811	1.09	0.02-12.3
Fecal Coliform	907	1010	1.91	0.02-37.9
Copper (dissolved)	2.62	1.97	1.58	0.23-11.2
Copper (total)	4.34	5.16	0.95	0.09-6.83
Total Organic Carbon	7.18	8.84	0.84	0.51-1.53

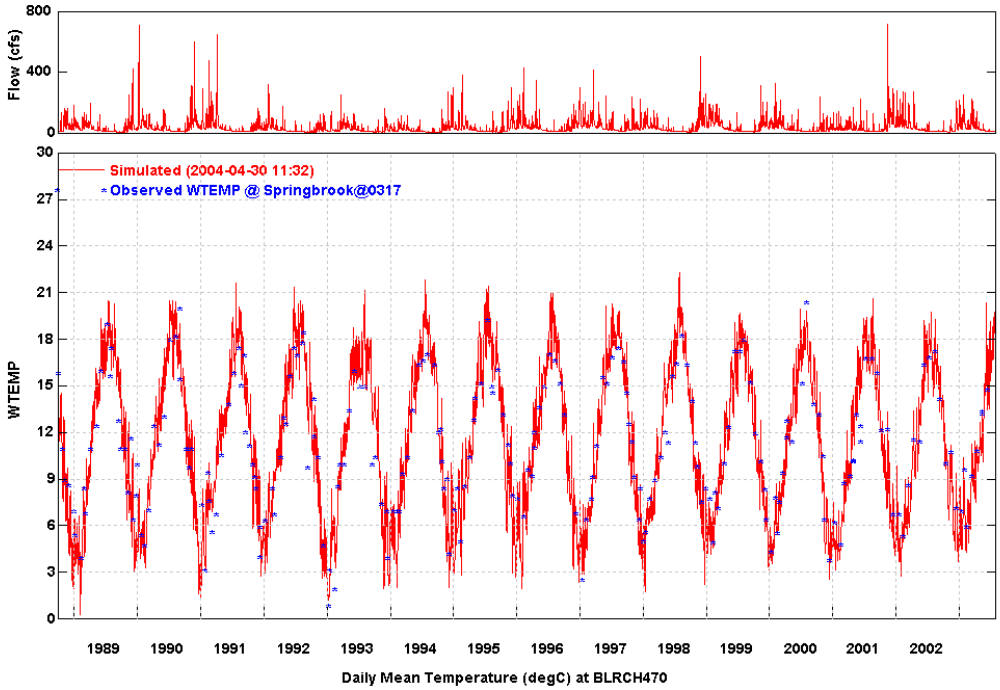


Figure 7.3-32 Observed and Simulated Daily Water Temperature for Springbrook Creek at Station 0317

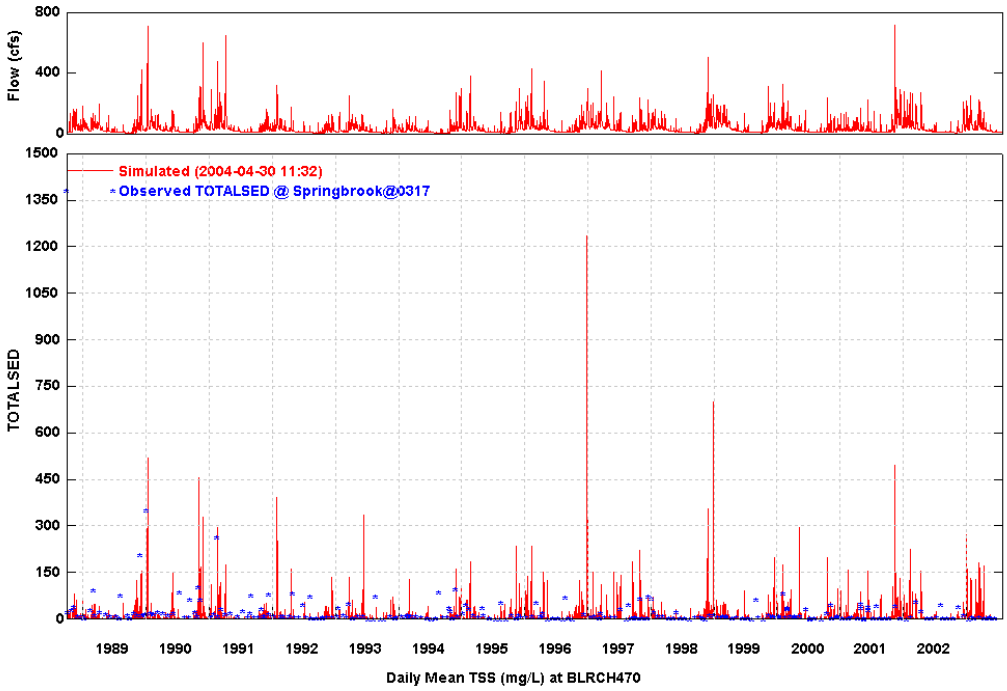


Figure 7.3-33 Observed and Simulated Daily Suspended Sediment Concentrations for Springbrook Creek at Station 0317

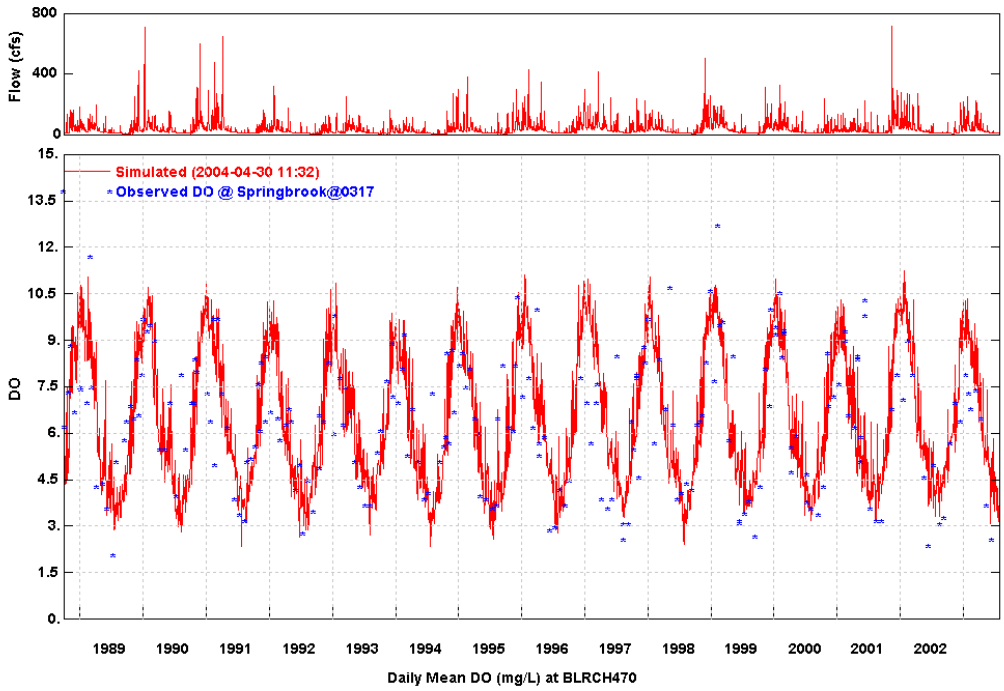


Figure 7.3-34 Observed and Simulated Daily Dissolved Oxygen Concentrations for Springbrook Creek at Station 0317

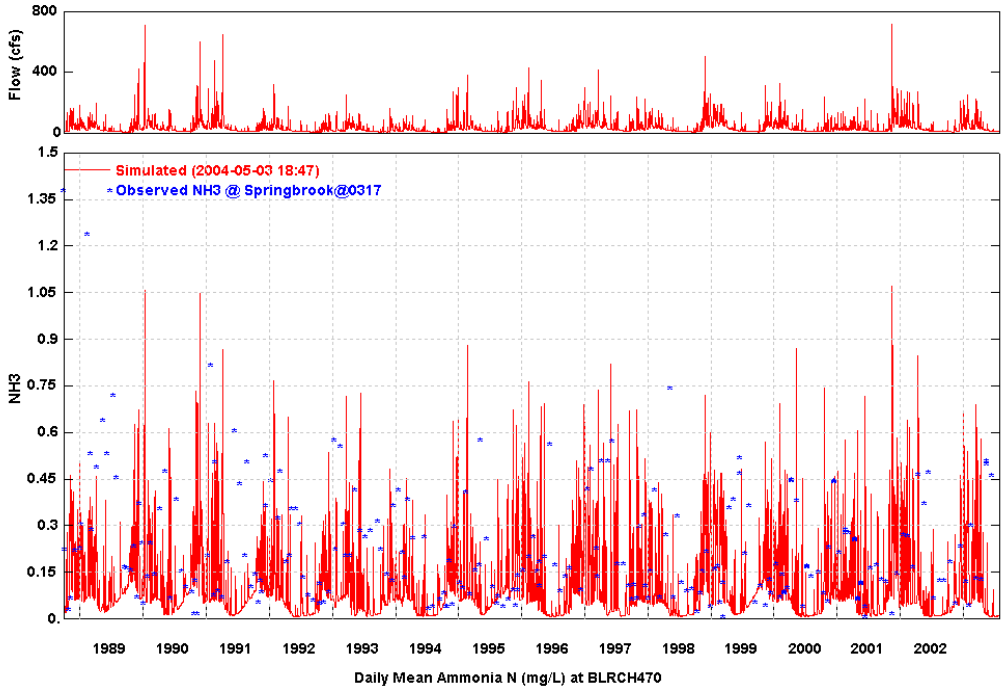


Figure 7.3-35 Observed and Simulated Daily Ammonia Concentrations for Springbrook Creek at Station 0317

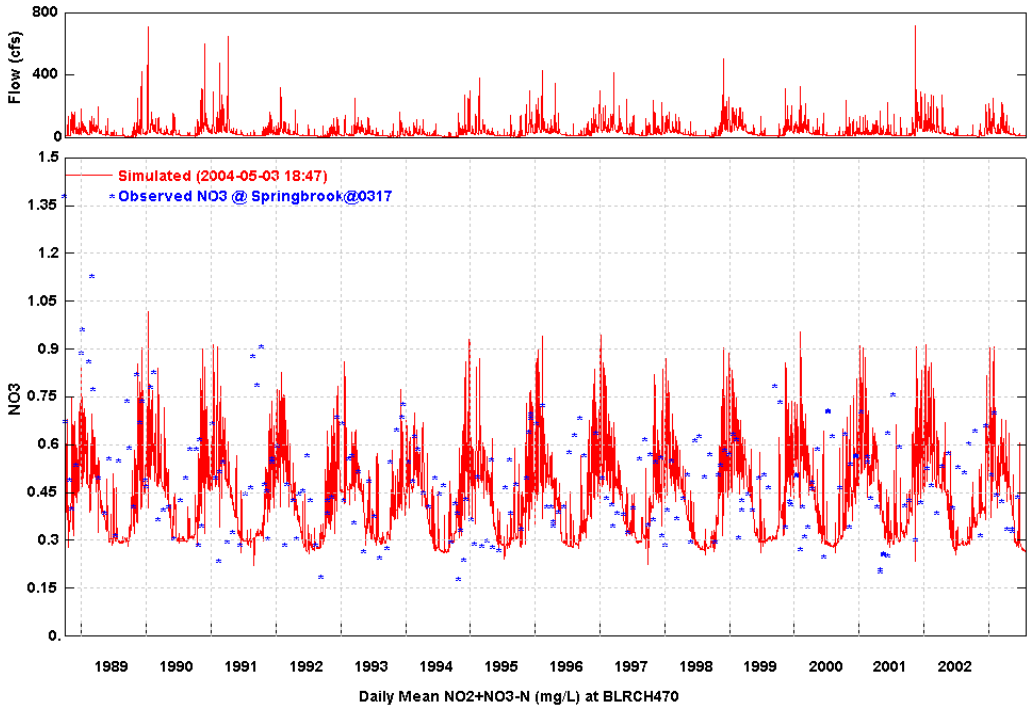


Figure 7.3-36 Observed and Simulated Daily Nitrate Concentrations for Springbrook Creek at Station 0317

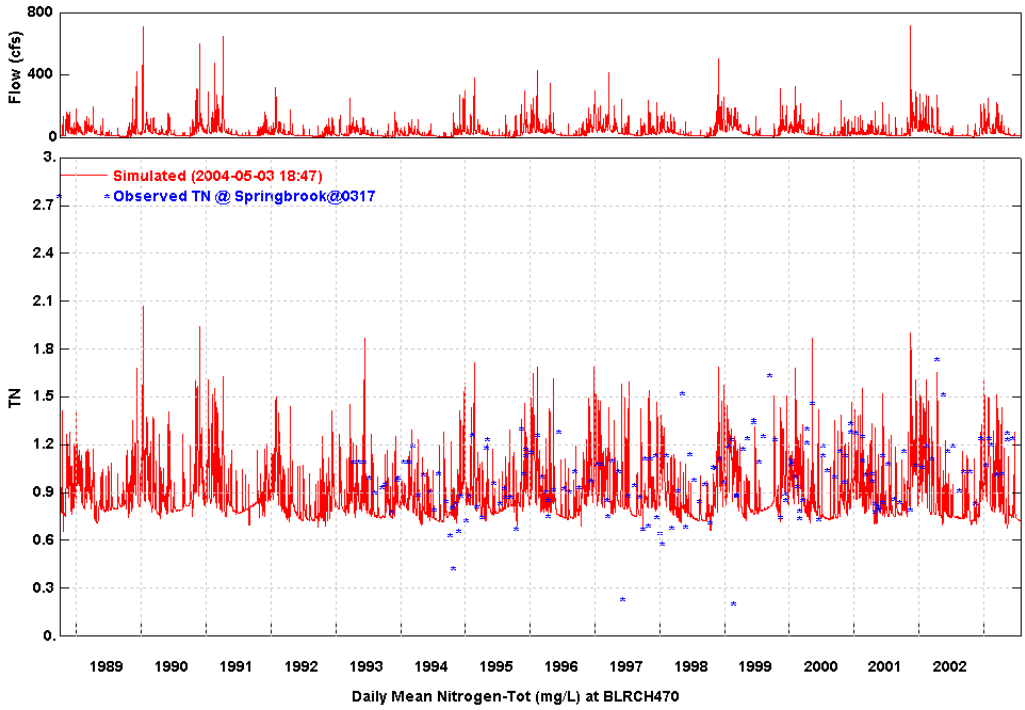


Figure 7.3-37 Observed and Simulated Daily Total Nitrogen Concentrations for Springbrook Creek at Station 0317

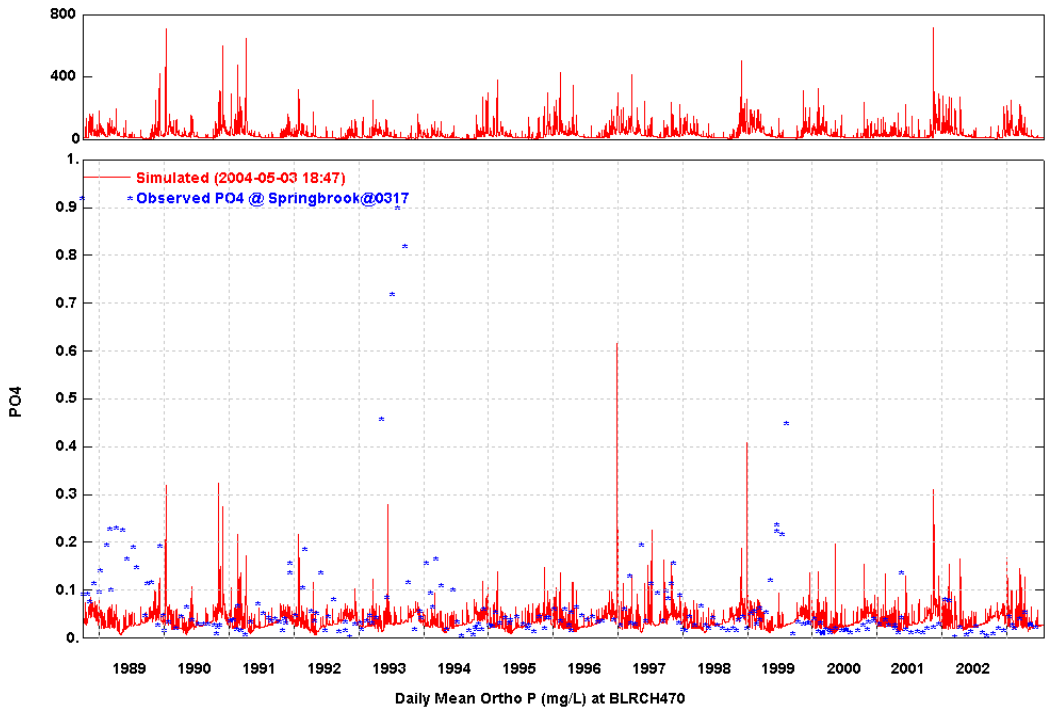


Figure 7.3-38 Observed and Simulated Daily Orthophosphate Concentrations for Springbrook Creek at Station 0317

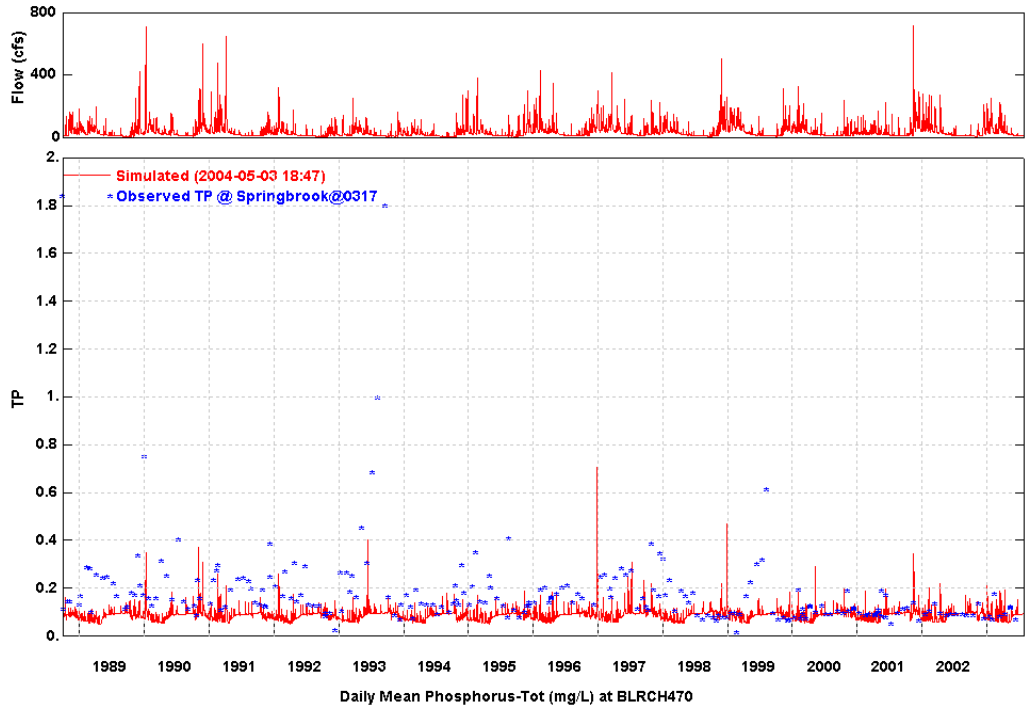


Figure 7.3-39 Observed and Simulated Daily Total Phosphorus Concentrations for Springbrook Creek at Station 0317

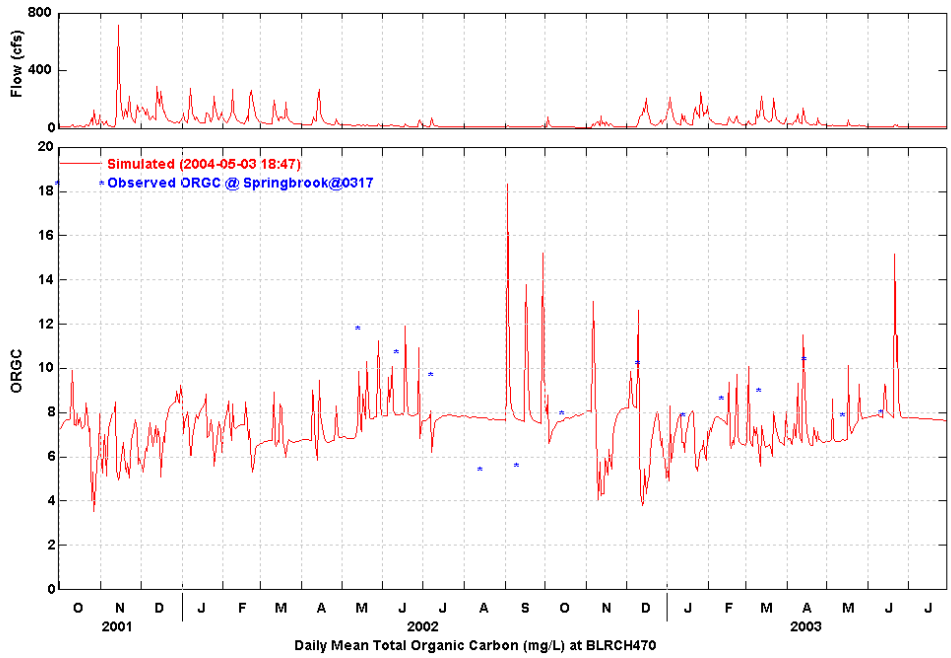


Figure 7.3-40 Observed and Simulated Total Organic Carbon Concentrations for Springbrook Creek at Station 0317

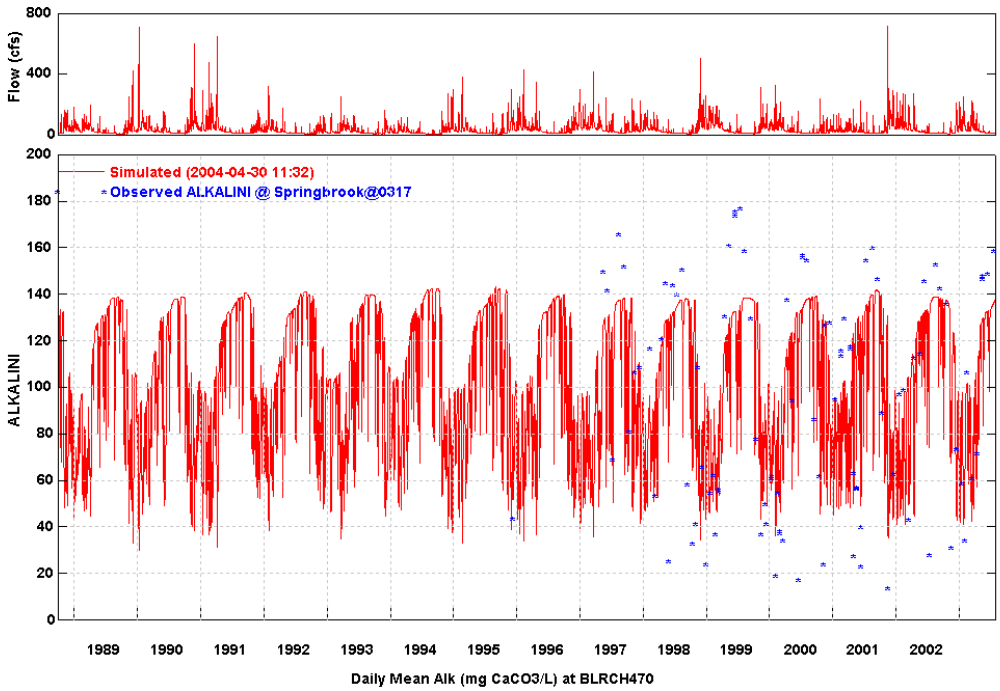


Figure 7.3-41 Observed and Simulated Daily Alkalinity Concentrations for Springbrook Creek at Station 0317

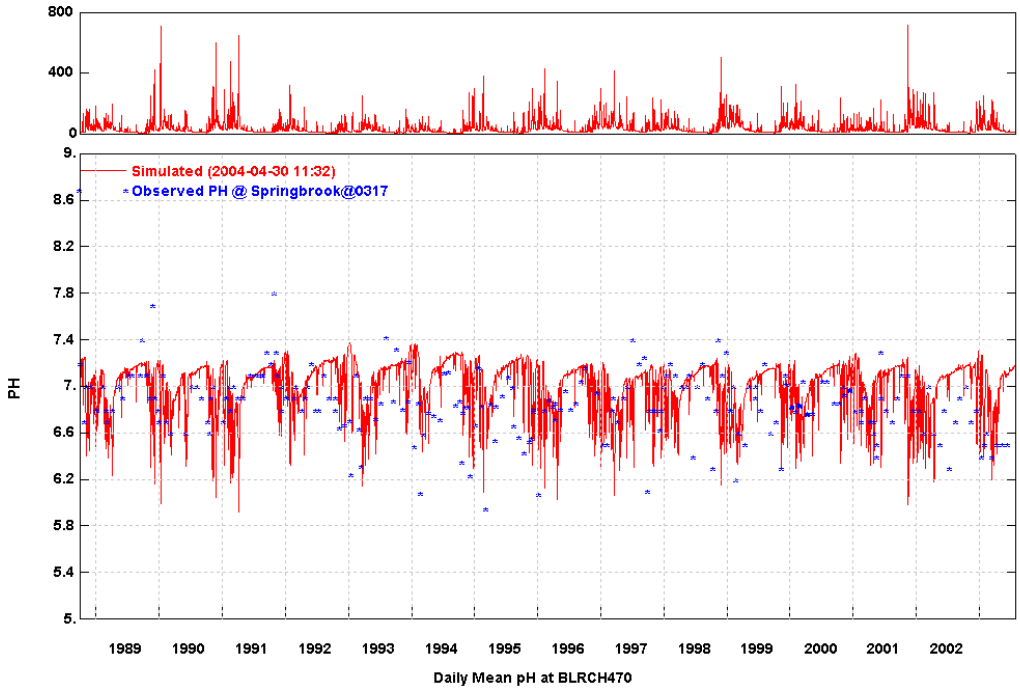


Figure 7.3-42 Observed and Simulated Daily pH Values for Springbrook Creek at Station 0317

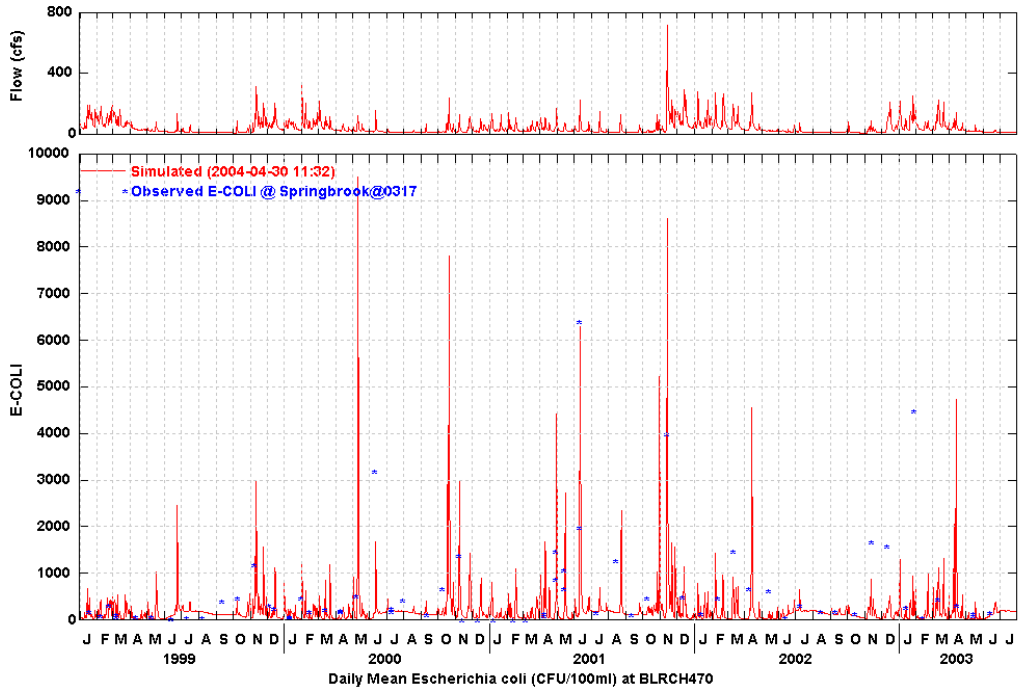


Figure 7.3-43 Observed and Simulated Daily EColi Concentrations for Springbrook Creek at Station 0317

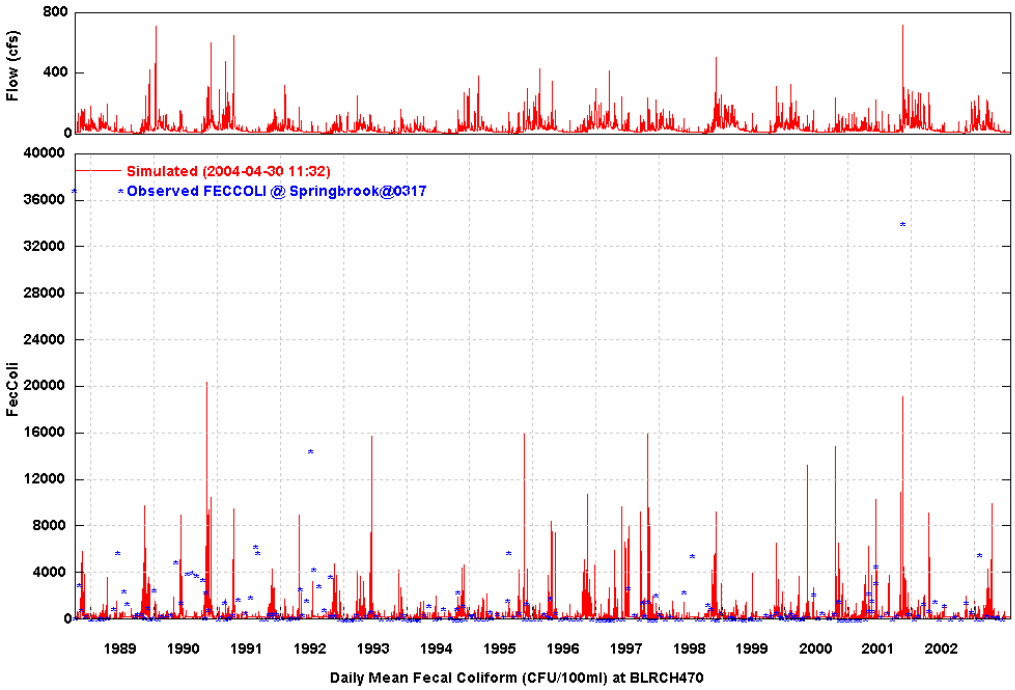


Figure 7.3-44 Observed and Simulated Daily Fecal Coliform Concentrations for Springbrook Creek at Station 0317

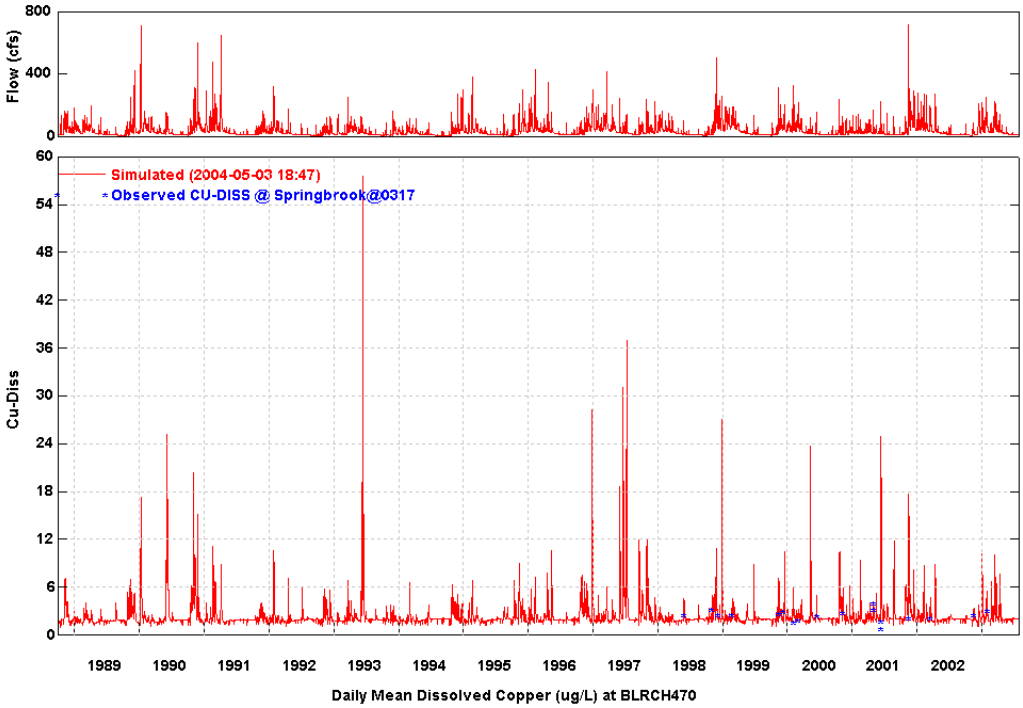


Figure 7.3-45 Observed and Simulated Daily Dissolved Copper Concentrations for Springbrook Creek at Station 0317

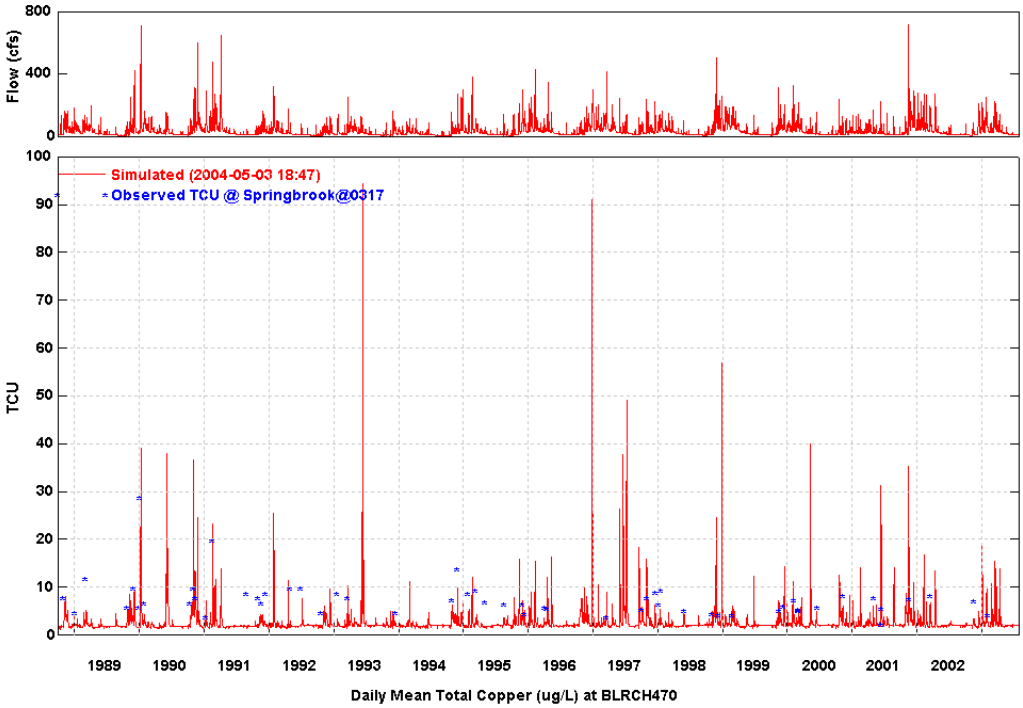


Figure 7.3-46 Observed and Simulated Daily Total Copper Concentrations for Springbrook Creek at Station 0317

7.3.2.5 Unresolved Calibration Issues

At the current time, the following issue related to this model is not complete or should at the least be investigated further.

- Point sources are not modeled in the Black/Springbrook subbasin. The watershed consists largely of urban land uses, including a significant commercial/industrial component in the lower valley area, where there historically existed agricultural land. Several NPDES facilities were identified in the subbasin, but no data on discharges were found. A large municipal wastewater treatment facility exists in the subbasin; however, the plant discharges through a pipeline to an outfall in Puget Sound. The concentrations at the outlet of the subbasin are apparently higher than are expected from current nonpoint source loadings; therefore, instream contributions from sediments contaminated by previous agricultural activities and by the intensive urban land that currently exists were implemented in the model. If point sources are contributing to the loads, the nonpoint source loading rates and the sediment sources are overcalibrated to make up the difference.

7.4 MODEL LINKAGES

The Lower Green River River Model (to be based on CE-QUAL-W2) requires a subset of the following quantities/constituents:

- Flow (m^3/s)
- Temperature (deg C)
- Sand (g/m^3)
- Silt (g/m^3)
- Clay (g/m^3)
- NO3-N (g/m^3)
- NH3-N (g/m^3)
- PO4-P (g/m^3)
- TDS (g/m^3)
- Silica-Si (g/m^3)
- Alkalinity as CaCO3 (g/m^3)
- Dissolved Oxygen (g/m^3)
- LDOM (g/m^3)
- RDOM (g/m^3)
- LPOM (g/m^3)
- RPOM (g/m^3)
- Indicator Bacteria (E-Coli) ($E6/m^3$ = #/mL = 100/100mL, etc.)

The Black/Springbrook Watershed HSPF model explicitly simulates (or can simulate) all of these except for the four organic matter quantities: LDOM, RDOM, LPOM, RPOM. (Note: at the current time the Black/Springbrook model does not include the TDS constituent, and the Silica constituent is not calibrated due to a lack of monitoring data.) The correspondence between

HSPF constituents (refractory organic N, P, & C) and the W2 organic matter constituents needs further investigation.

7.4.1 Spatial Linkage

All loadings to the Green River from Black River/Springbrook Creek effectively enter the river at a single location, i.e., the mouth of the Black River near the intersection of Benson Road and Interstate 405 in Renton, WA. Since the end of the most downstream reach (RCHRES 520) of the Black/Springbrook watershed model corresponds to this location, time series results from HSPF (for all of the required constituents) which represent the downstream outflow from this reach will provide the necessary boundary condition data to be input to CE-QUAL-W2.

7.4.2 Temporal Linkage

HSPF can generate results at any time step which is a multiple of the simulation timestep (i.e., 15 minutes). According to C. DeGasperi (Personal communication, 5/2003), the appropriate time step for the CE-QUAL-W2 model is one hour. Therefore, the data (flows, temperatures, concentrations) will be one-hour averages.

7.4.3 Linkage Formats

The model linkage output from HSPF will be generated in PLTGEN format, which is easy to generate and understand. Each PLTGEN file can contain up to 20 time series, so all of the results produced at a boundary location (e.g., a tributary stream model) contributing to CE-QUAL-W2 can be stored in a single file. It is also easy to control the time step, aggregation, and units of the data. Flow will be in units of m^3/s, temperature will be in degrees C, and all WQ constituents will be generated in the form of concentrations (g/m^3) with the possible exception of the indicator bacteria.

7.5 REFERENCES

7.5.1 Water Quantity

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7.5.2 Water Quality

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