CHAPTER 3: WATERSHED HYDROLOGY
APPENDIX 3.M: 03-LOWER ST. JOHNS RIVER BASIN CALIBRATION

3A Crescent Lake Watershed

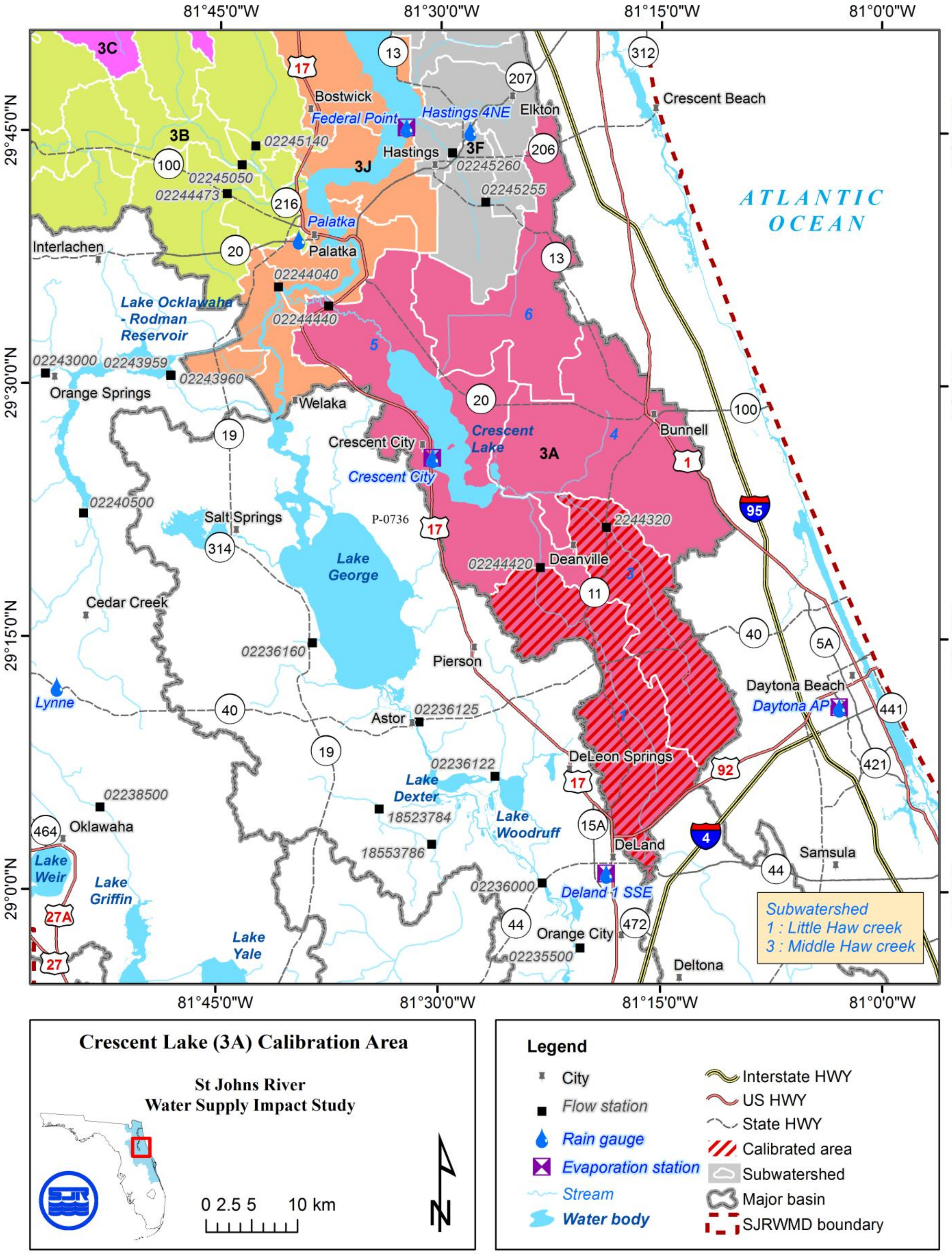

Figure 3.M.1: 3A Crescent Lake Watershed calibration areas

3A Crescent Lake Watershed. Little Haw Creek Subwatersheds

Little Haw is a 106 square miles (67,599-acre) headwater subwatershed located to the south of Crescent Lake sub-basin. Little Haw creek, a tributary of Crescent Lake, drains most part of Little Haw Creek subwatershed to Lake Disston which eventually discharges to the mouth of the subwatershed. Flow is measured at USGS gage station 02244420, located near Seville, Florida at the intersection of Little Haw creek and county road CR-305. Flow records dates from 1951 to present. Rainfall and evapotranspiration measurements for this area are recorded at a weather station in Deland, Florida. Long-term record summary (1942 – 2005) for the Deland station shows average annual precipitation to be 56.5 inches (143.5 cm). Land use distribution is predominantly forest (37%) and wetland (33%). Urbanized land uses are mainly concentrated at the southwestern portions of Little Haw Creek near the cities of Deland and DeLeon Springs.

Parameter Estimation Program (PEST) was applied to HSPF to automate the calibration of streamflow in Little Haw by tweaking 10 HSPF model parameters according to the WSI project general model parameters guidelines and ranges. Calibration period was from January 1, 1995 to December 31, 2005. Water PERLND areas were commented out in the UCI file, and added to their respective stream FTABLE surface areas. PEST was executed to obtain optimal parameters that yield minimum error between observed and simulated streamflow. Visual inspection of plots suggests reasonable agreement between observed and simulated daily flow during the calibration period. Peak flow events were overpredicted, especially for the large storm event in 2004. Over-prediction may be due to spatial variability of rainfall distribution across the large subwatershed. Flow peak was under-simulated in September 1995 in response to a large storm event. Comparison of cumulative daily observed and simulated flow plots shows good agreement at the commencement of calibration period, underprediction from 1996 to 2000, and overprediction from 2000 to 2005. In general, there is satisfactory agreement between observed and simulated daily flow-frequency duration curves. The difference between total simulated and observed flow volume is less than 2% for the calibration period. A mean daily outflows for observed of 65.18 mgd (100.90 cfs) and simulated of 63.91 mgd (98.93 cfs), monthly Nash-Sutcliffe coefficient of 0.62, and coefficient of determination of 0.64, suggest overall satisfactory model performance in predicting stream outflows in Little Haw Creek subwatershed.

Table 3.L.1: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.62	-1.94

Table 3.L.2: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02244420)	Simulated
Average	65.18	63.91
Median	20.19	16.94
Variance	11934.47	12126.06
Standard Deviation	109.25	110.12
Skew	3.41	4.14
Kurtosis	17.29	31.60
Minimum	0.00	0.00
Maximum	1169.83	1692.89
Range	1169.83	1692.89

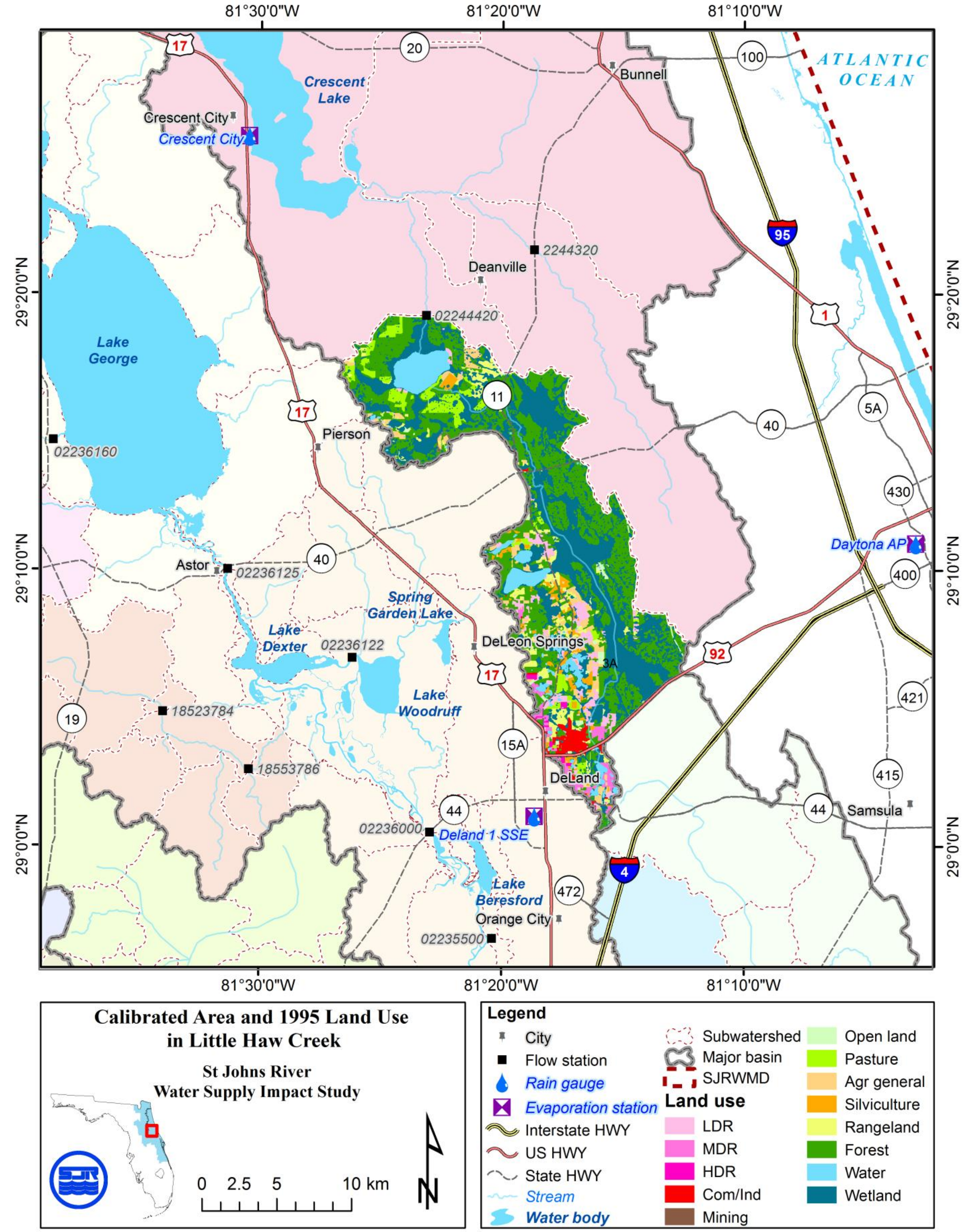

Figure 3.M.2: Little Haw Creek land use map

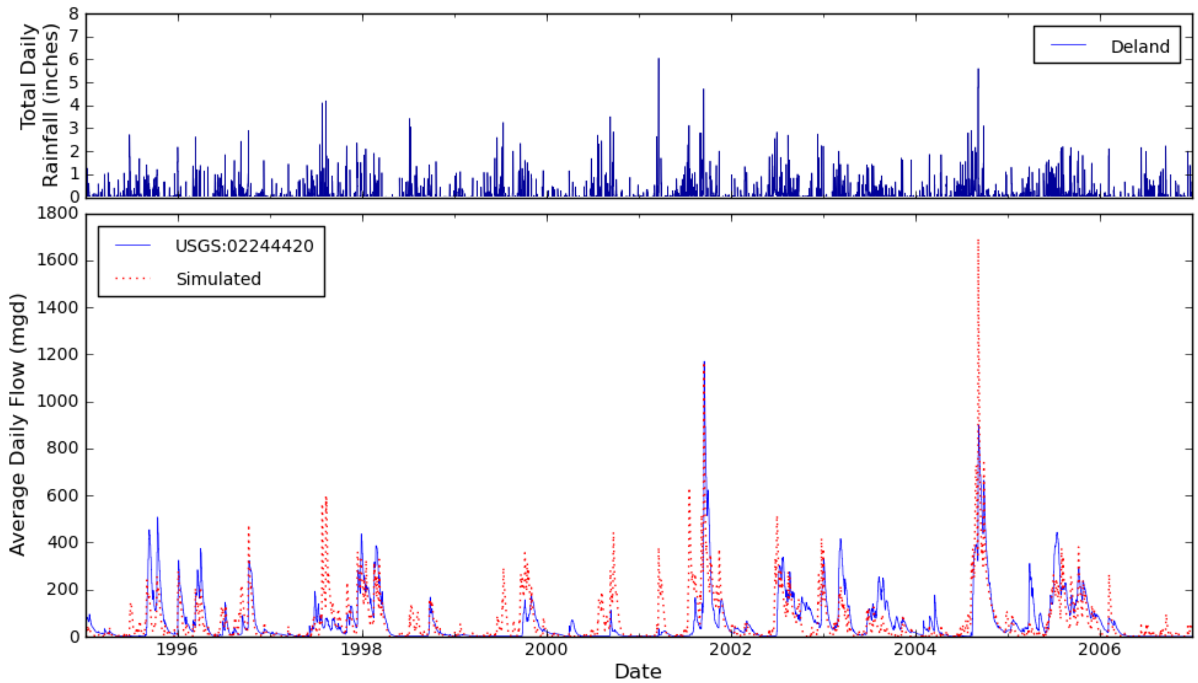

Figure 3.M.3: Little Haw Creek daily hydrograph

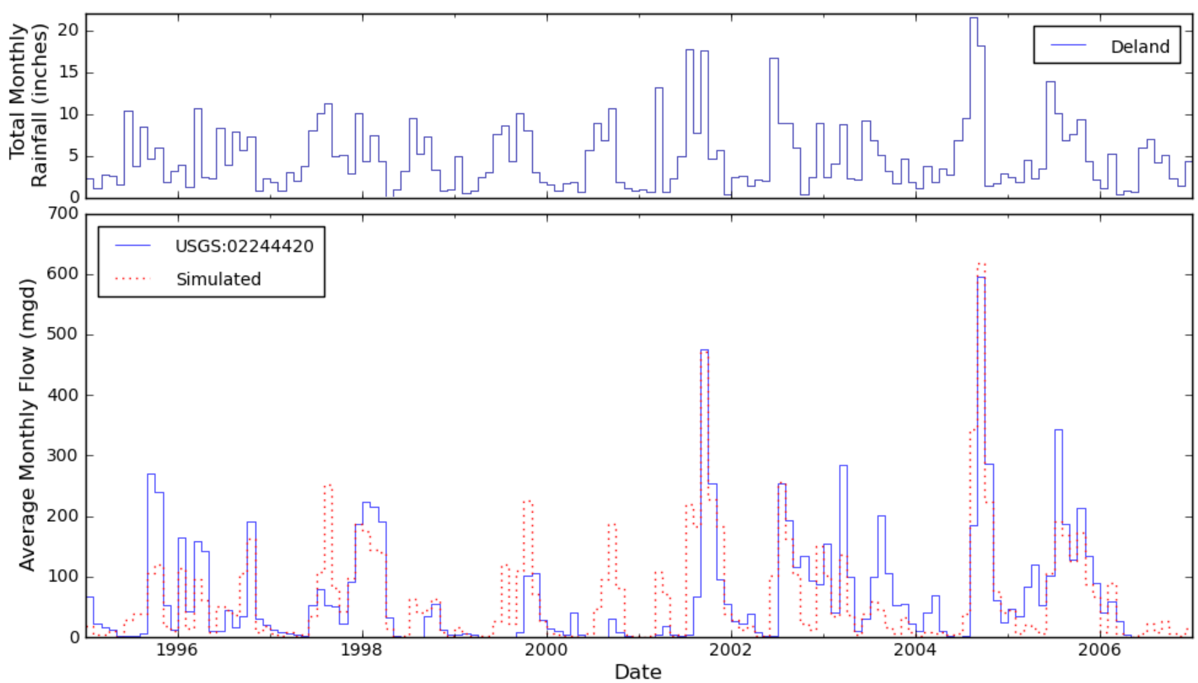

Figure 3.M.4: Little Haw Creek monthly hydrograph

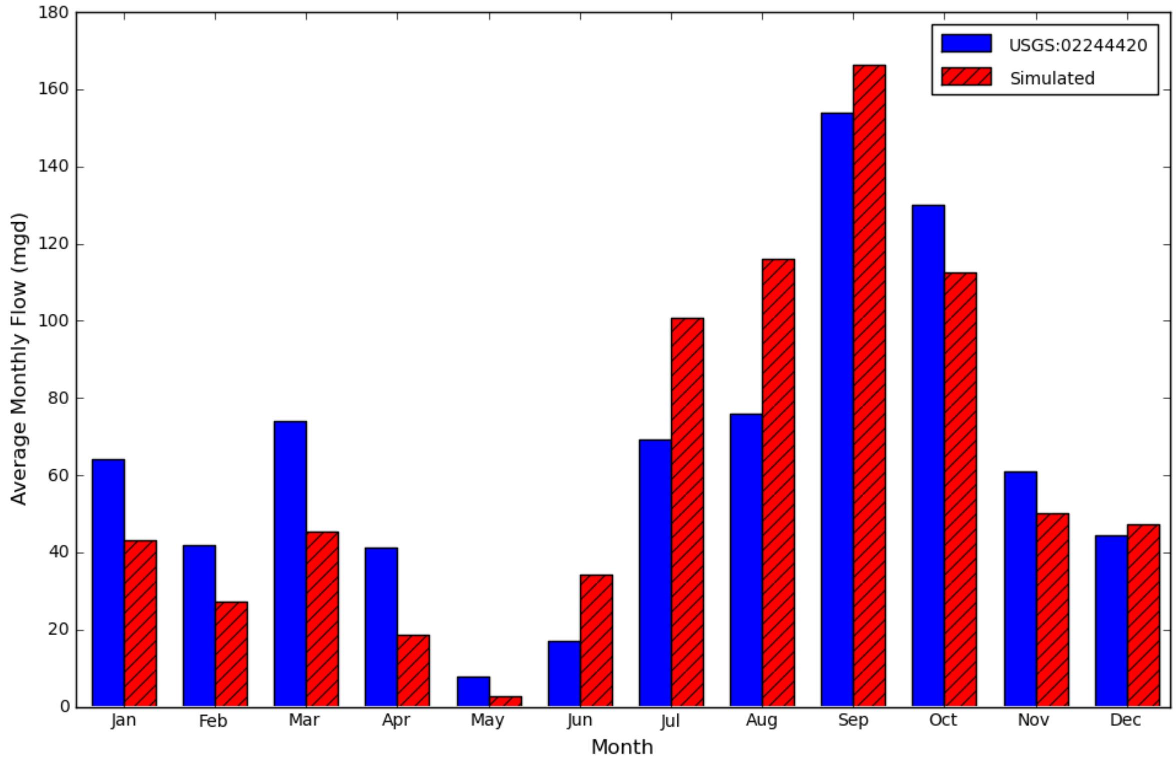

Figure 3.M.5: Little Haw Creek average monthly flow

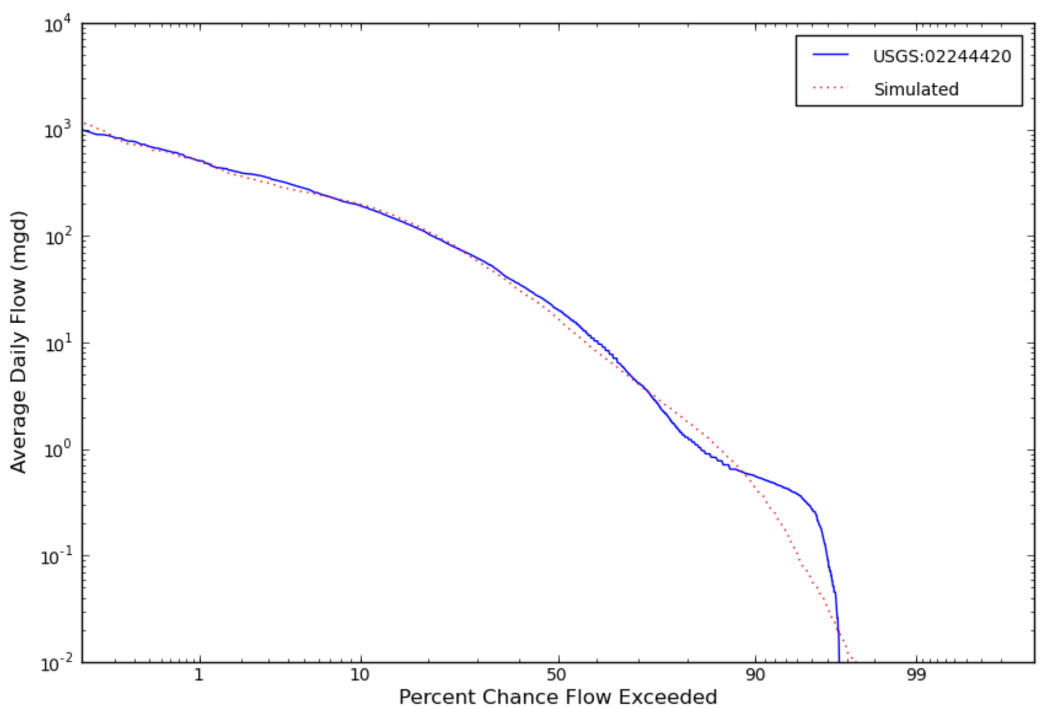

Figure 3.M.6: Little Haw Creek exceedance probability curve

3A Crescent Lake Watershed. Middle Haw Creek Subwatersheds

Middle Haw Creek is an 83-acre drainage subwatershed located in Crescent Lake sub-basin, and lies adjacent to Little Haw Creek subwatershed. The area is drained by Middle Haw creek and discharges into Haw Creek, which then flows into Crescent Lake. Land use consist of mainly forest (54%) and wetlands (34%). A USGS flow gaging station 02244320 is situated 4.5 miles upstream of subwatershed outlet at the intersection of Middle Haw creek and State Road 11, near Korona, Florida. Flow records for gaging station 02244320 are available from July 1, 1975 to present. Rainfall and evapotranspiration measurements for this area are recorded at a weather station in Daytona, Florida. Long-term record summary (1942 – 2005) for the Daytona station shows average annual precipitation to be 49.8 inches (126.5 cm).

Calibration period spans from January 1, 1995 to December 31, 2005. Parameter Estimation Program (PEST) was applied to HSPF to automate the calibration of streamflow in Middle Haw by tweaking 10 HSPF model parameters according to the WSI project general model parameters guidelines and ranges. Visual comparision between observed and simulated daily streamflow indicates that the model adequately predicted daily flow events. The model overpredicted peak flow events in 1995, 2004, and dry periods between 2000 and 2001. A couple of peak flow events in 2001 and 2003 were undersimulated. HSPF accurately predicted the rising and recession limbs of the hydrograph for the calibration period. Cumulative daily flow plots between observed and simulated data are well correlated. Inspection of daily flow-frequency duration curves shows good correlation between observed and simulated flows, except at low flow conditions where simulated values exceed the observed. The error between observed and simulated average daily streamflow is 1.02 mgd (1.59 cfs) representing only 1.7% difference. PEST calibration of Middle Haw HSPF model to the observed streamflow is deemed satisfactory based on relative difference between observed 59.55 mgd (92.18 cfs) and predicted 58.53 mgd (90.60 cfs) daily flow rates, coefficient of determination of 0.74, and monthly Nash-Sutcliffe coefficient of 0.74.

Table 3.L.3: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.74	-1.72

Table 3.L.4: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02244320)	Simulated
Average	59.55	58.53
Median	8.40	8.93
Variance	16208.82	15744.82
Standard Deviation	127.31	125.48
Skew	5.81	6.72
Kurtosis	56.64	94.64
Minimum	0.00	0.00
Maximum	2197.48	3017.34
Range	2197.48	3017.34

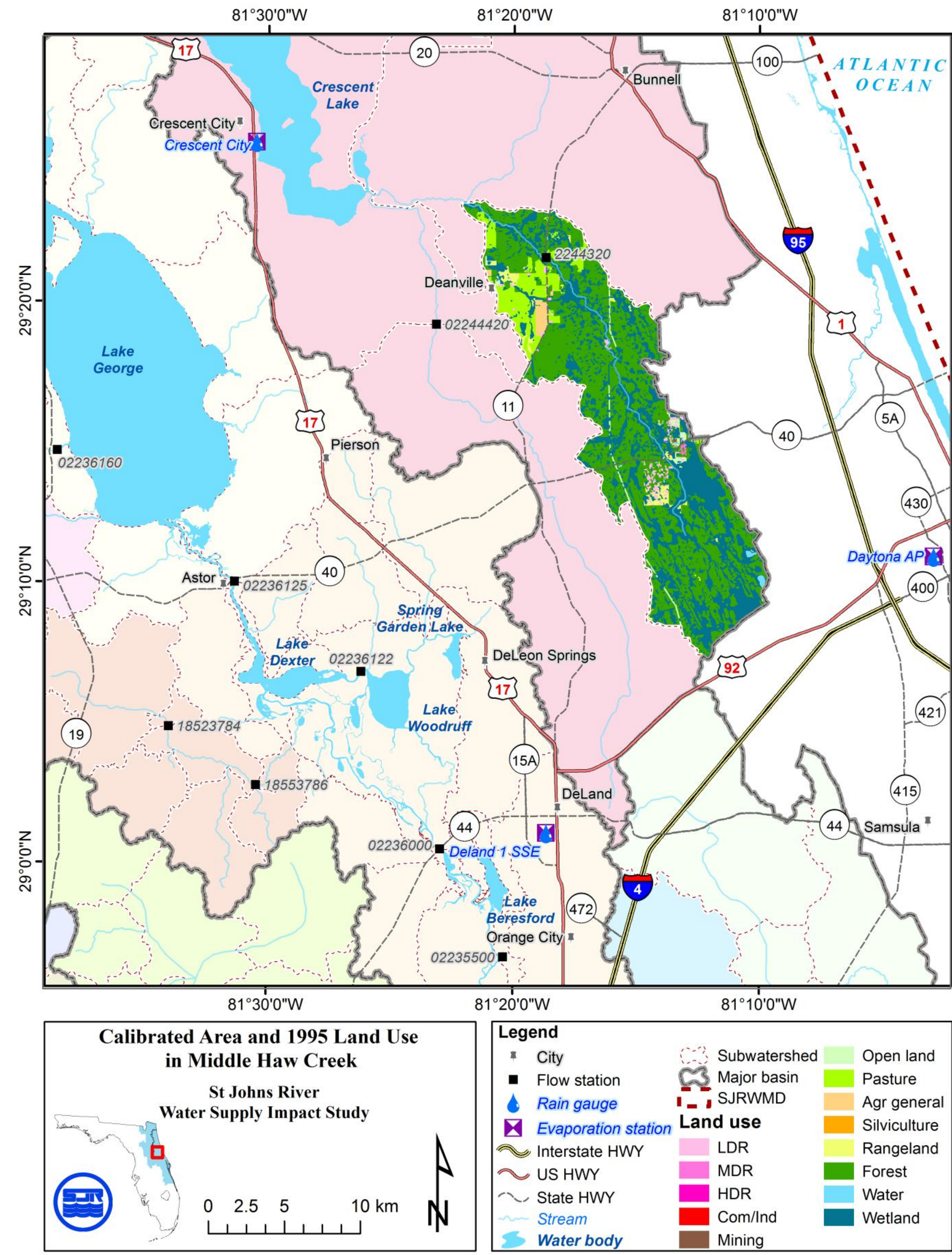

Figure 3.M.7: Middle Haw Creek land use map

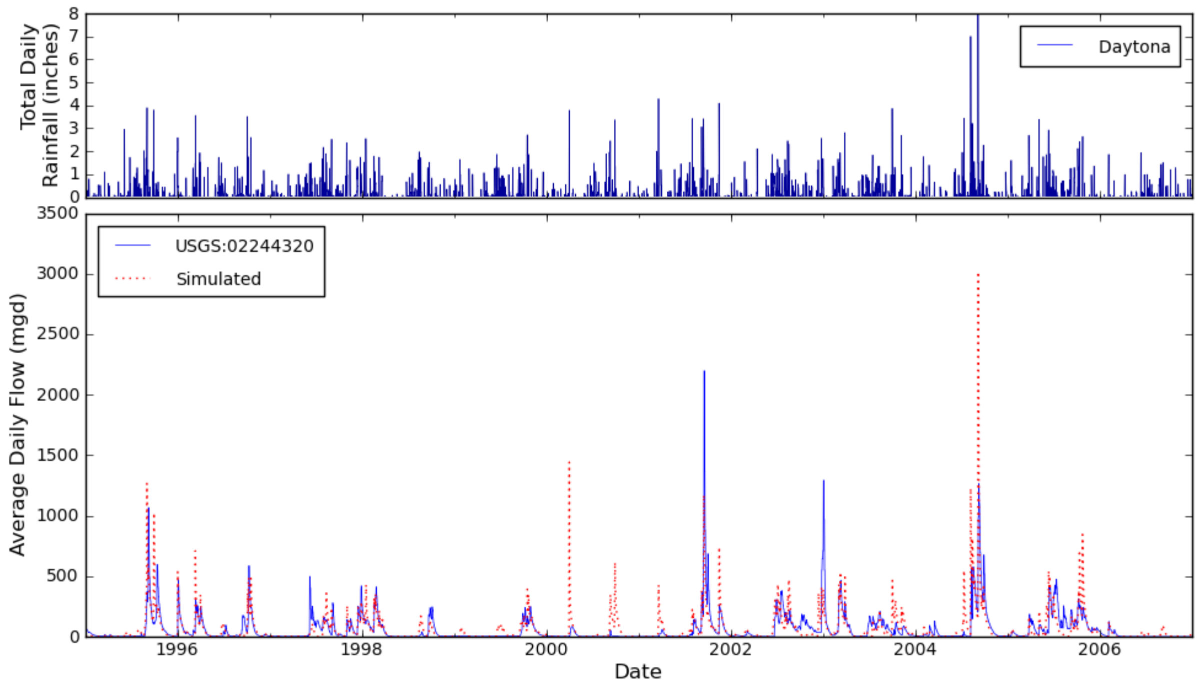

Figure 3.M.8: Middle Haw Creek daily hydrograph

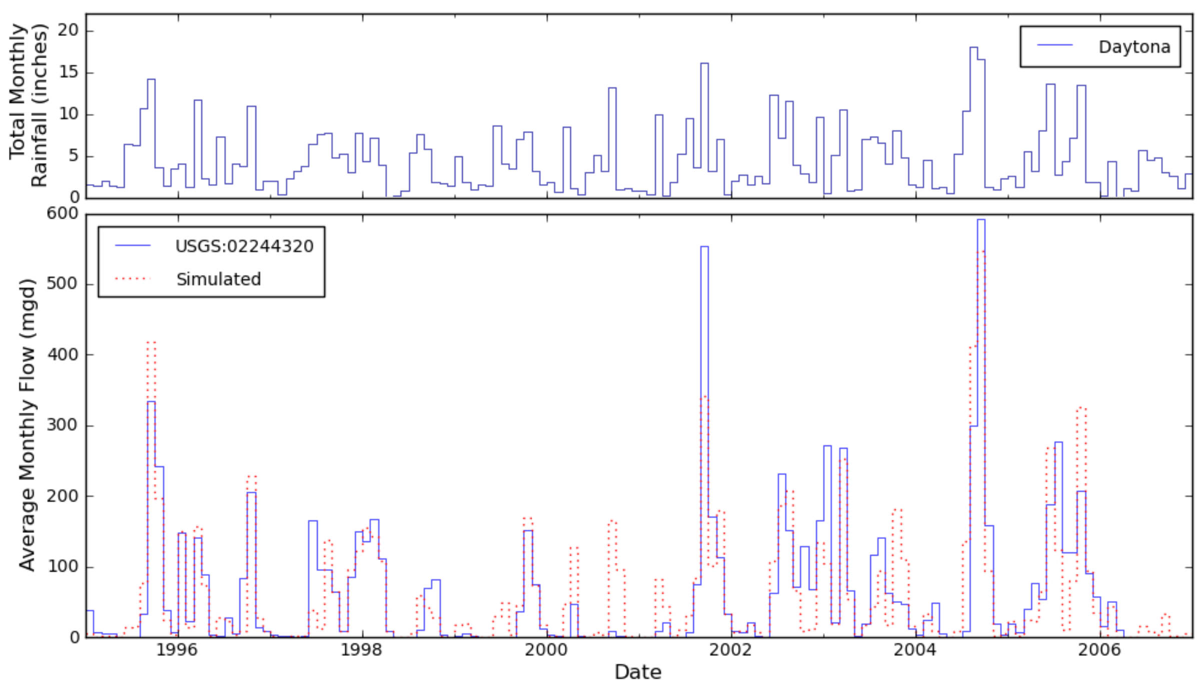

Figure 3.M.9: Middle Haw Creek monthly hydrograph

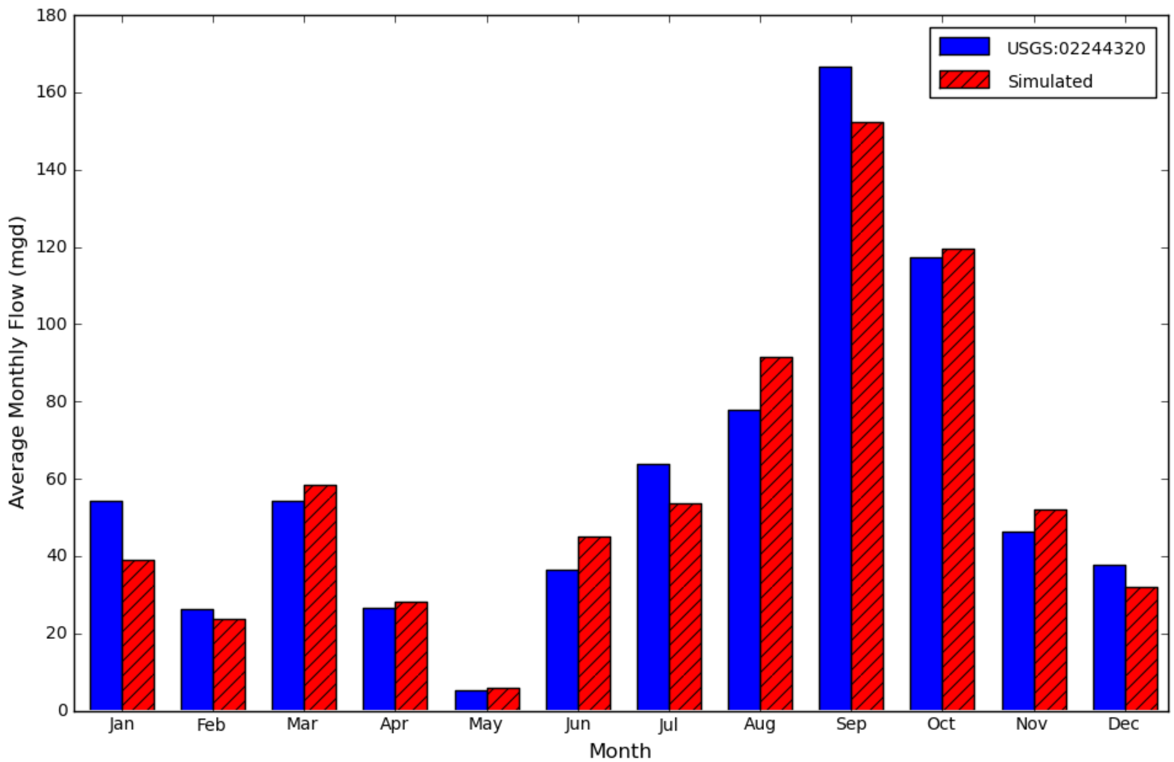

Figure 3.M.10: Middle Haw Creek average monthly flow

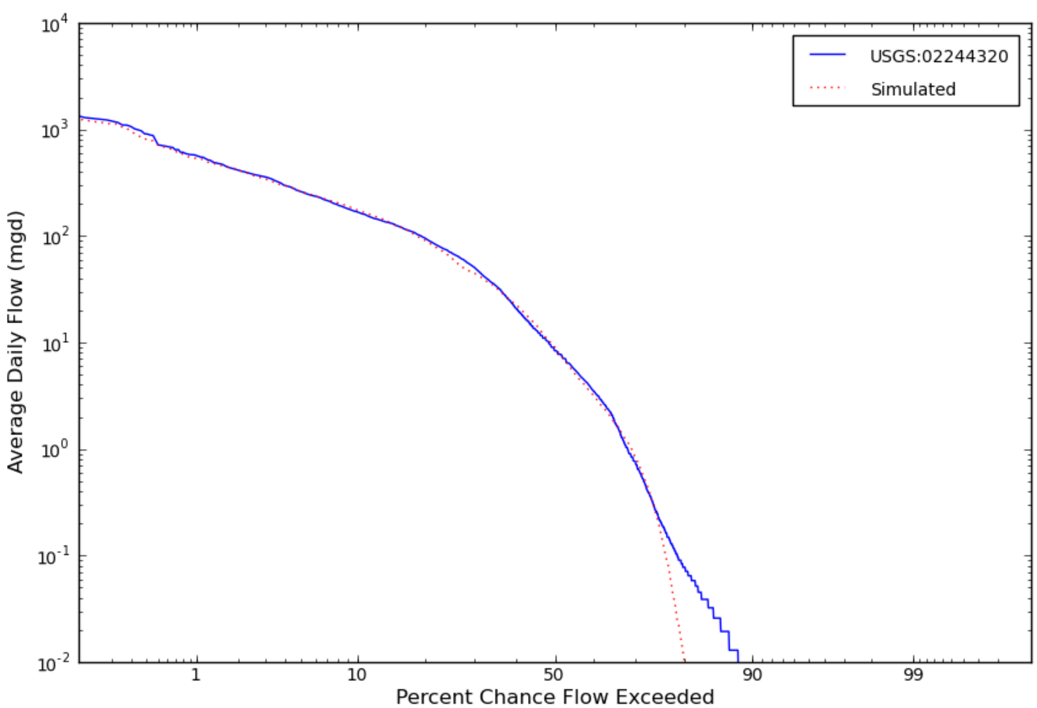

Figure 3.M.11: Middle Haw Creek exceedance probability curve

3B Etonia Creek Watershed

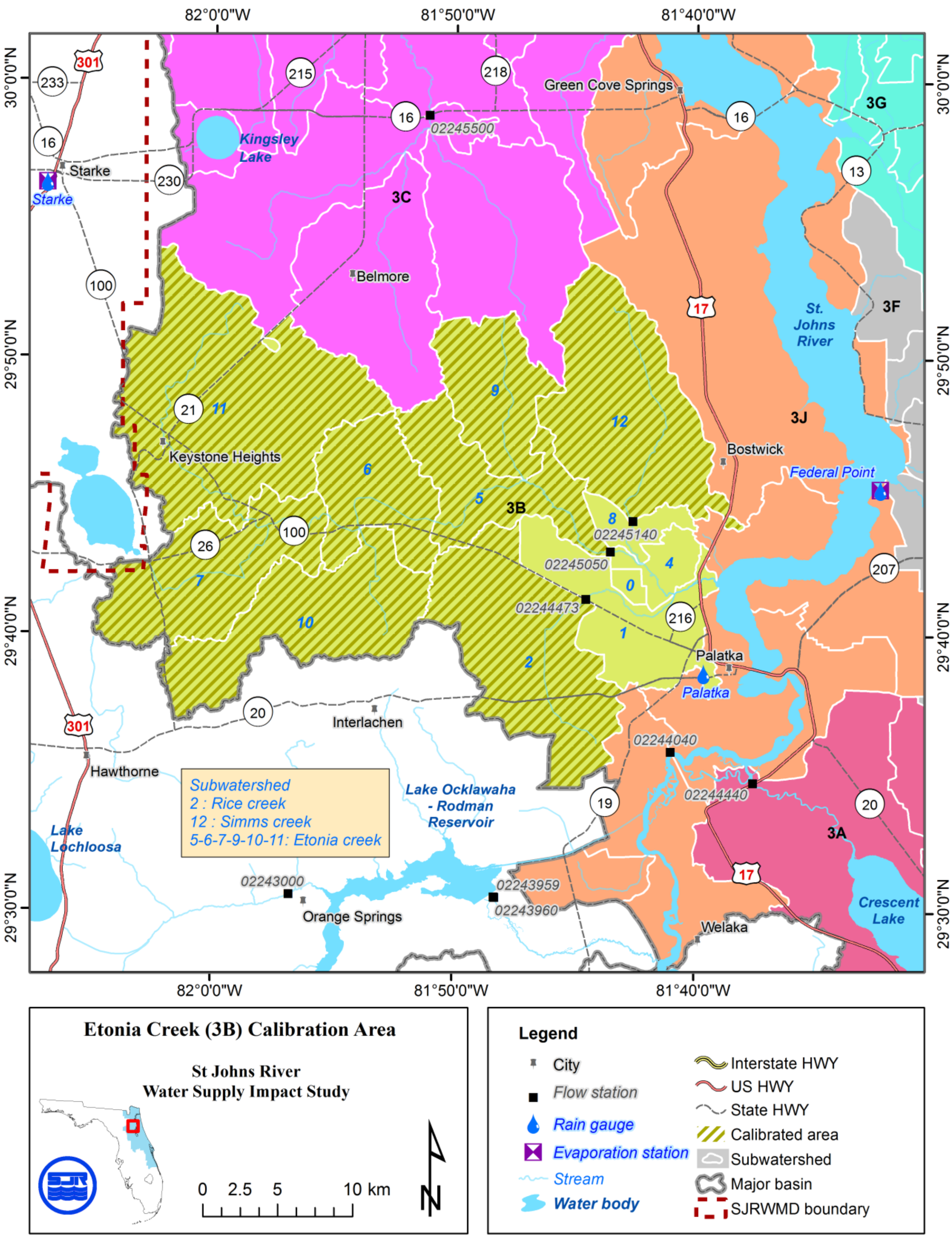

Figure 3.M.12: 3B Etonia Creek Watershed calibration areas

3B ETONIA CREEK WATERSHED. ETONIA CREEK SUBWATERSHEDS

Planning unit 3B, Etonia Creek Subbasin, is 357 square miles in size and is located on the west bank of the St. Johns River just north of Palatka. The major portion of the watershed is contained in Putnam County. Elevations range from about 240 ft above sea level, NGVD 1929, in the west to near sea level at the confluence with the St. Johns River.

Etonia Creek Subbasin is divided into 13 sub-watersheds (see Figure H-14 in Appendix H). The USGS Etonia Creek Gage Station (02245050) at Bardin has the largest drainage area, 219 sq mi. It is located 2 miles upstream of Etonia Creek's confluence with Rice Creek. (The last two miles of the river is named Rice Creek after the small tributary located there, rather than after Etonia Creek, which is much larger.) The calibration of the HSPF model at the Etonia Creek gage is described next. The calibration at two tributary USGS gaging stations (Simms Creek and Rice Creek) are discussed under their own subwatershed headings which follow this section.

There are 6 subwatershed (5, 6, 7, 9, 10, and 11) upstream of the Etonia Creek gage. Two of these only contribute during extended wet periods of above normal rainfall. For the calibration period 6/18/1996-7/5/2004, they did not contribute runoff and initially were not modeled. However after further consideration, subwatershed 10, Lake Grandin, was divided in half and the north half was made a contributing subwatershed. Rainfall data came from Starke and Palatka gages, while evaporation data came from Starke and Federal Point gages.

The Etonia Creek gage as well as the downstream area of the river has been greatly impacted by Georgia Pacific Pulp and Paper Corporation's (GP) paper mill plant. The plant is located just NW of Palatka, Florida, about 2.7 miles upstream from the St. Johns River on Rice Creek. GP has 13 water supply wells upstream of the plant that discharge into Etonia Creek or its tributaries. The river is used to transport the well water downstream to the plant where it is pumped out. The monthly well discharge data and consumptive use withdrawals from the river are accounted for in the calibration.

Error! Reference source not found. gives the water use for 1995-2000, for 2001-2008 after water conservation measures began, and the projected use for 2007-2012 obtained from the consumptive use technical staff report dated March 13, 2002. The pump totals are for two GP pumps (DSN 9007 and 9008) withdrawing water (negative discharge) from reaches 1 and 4. The last pump (DSN 9101), is a constant 1.3 mgd (2 cfs) applied as spring flow to Rice Creek, and results in a good model calibration. For the calibration period, 1995-2008, observed data was used. However, the long-term simulation period was from 1975 to 2008. Well flows for 1975-1994 were based on the 1995-2000 average observed data. The same was done for pumping rates.

For future 2030 land use conditions the well flows were reduced 87.3% by multiplying all inflows by 0.127 in the HSPF *.uci file. This is based on GP's projected 2012 ground water use of 529 MGALS versus actual Jan-Jul 2001 use of 4,167 MGALS. The projected surface water withdrawals for 2012 were 9,121 MGALS, a 29.5% increase, versus 7,045 MGALS for the same period. The increase was applied by multiplying all withdrawals by 1.295 in the HSPF *.uci file. This was the simplest way to apply the reduction in well flows and increase in surface water withdrawals until better information can be obtained. The 30 mgd wastewater discharge from GP is not addressed in the HSPF model, but instead is handled in the estuary model.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration of the 10 parameters according to the WSI project general model parameters guideline and ranges. Upstream of the gage, Etonia Creek is 50% A soils and a high recharge area. PEST chose the maximum allowable value of 10 inches for lower zone storage nominal (lzsn). It went to 15 inches when no restriction was placed on it. Likewise, deep percolation to the Floridan aquifer calibrated at 0.57. The results of the model performance (Appendix H) show the observed annual mean discharge for water year June 1996 to June 2004 was 69.8 cfs. The simulated discharge over the calibration was 70.2 cfs. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.69. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. In addition, simulated and observed stages are compared at the calibration sites. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the watershed.

Table 3.L.5: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.69	1.77

Table 3.L.6: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02245050)	Simulated
Average	45.10	45.90
Median	30.38	29.85
Variance	5019.76	4309.03
Standard Deviation	70.85	65.64
Skew	7.02	5.90
Kurtosis	68.56	47.21
Minimum	9.05	7.11
Maximum	1150.44	928.50
Range	1141.40	921.38

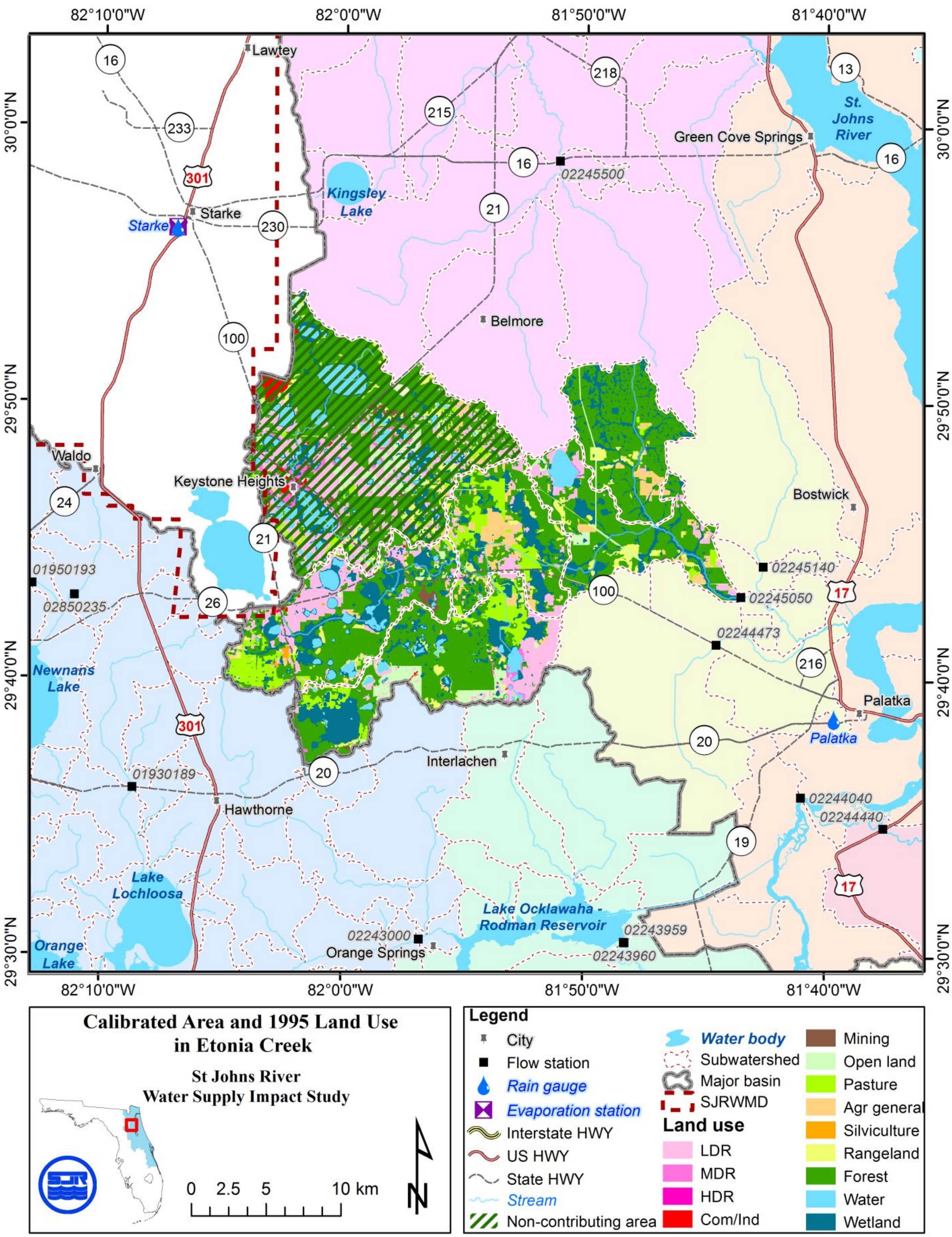

Figure 3.M.13: Etonia Creek land use map

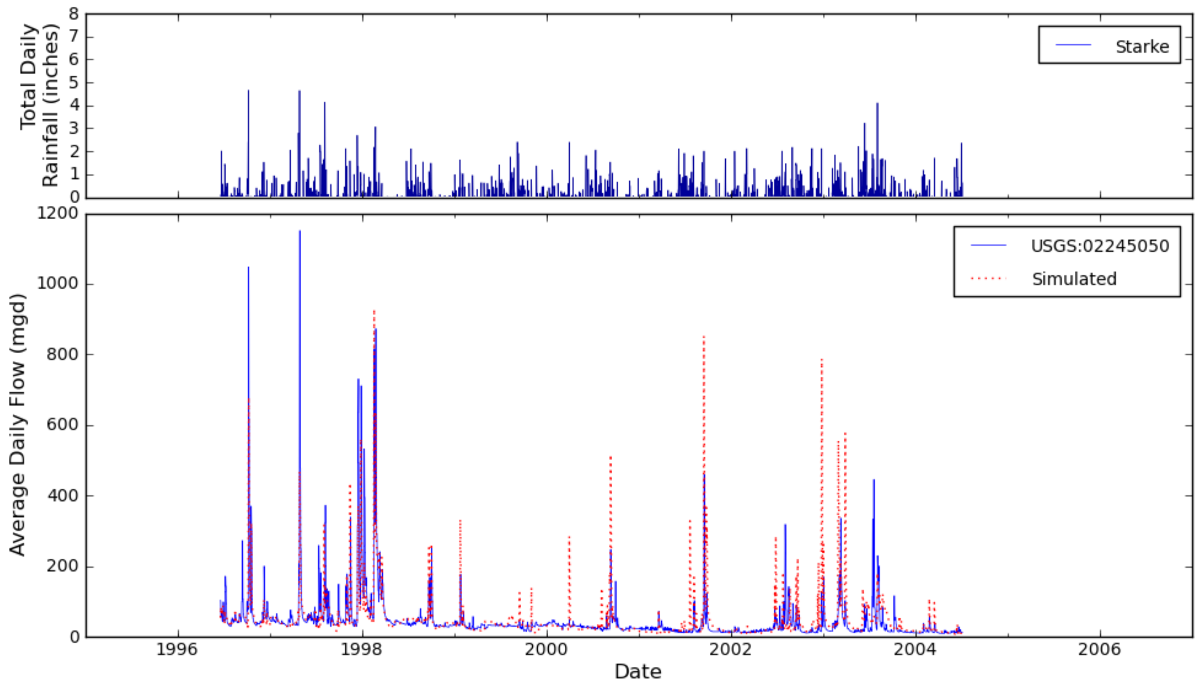

Figure 3.M.14: Etonia Creek daily hydrograph

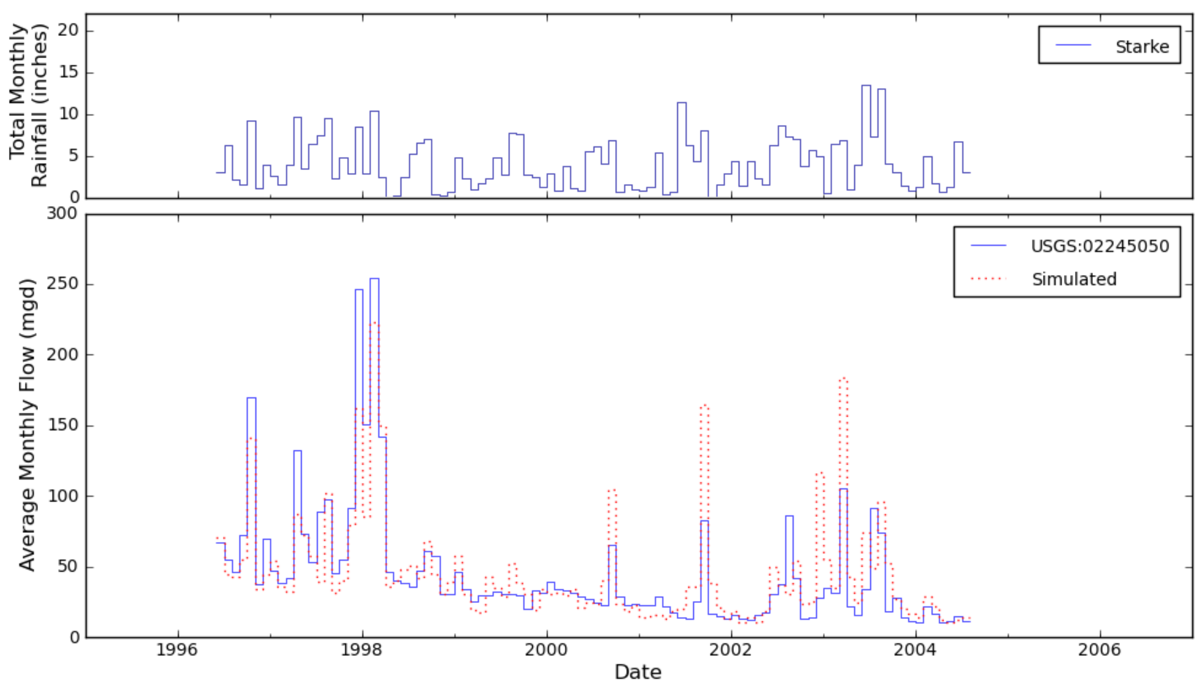

Figure 3.M.15: Etonia Creek monthly hydrograph

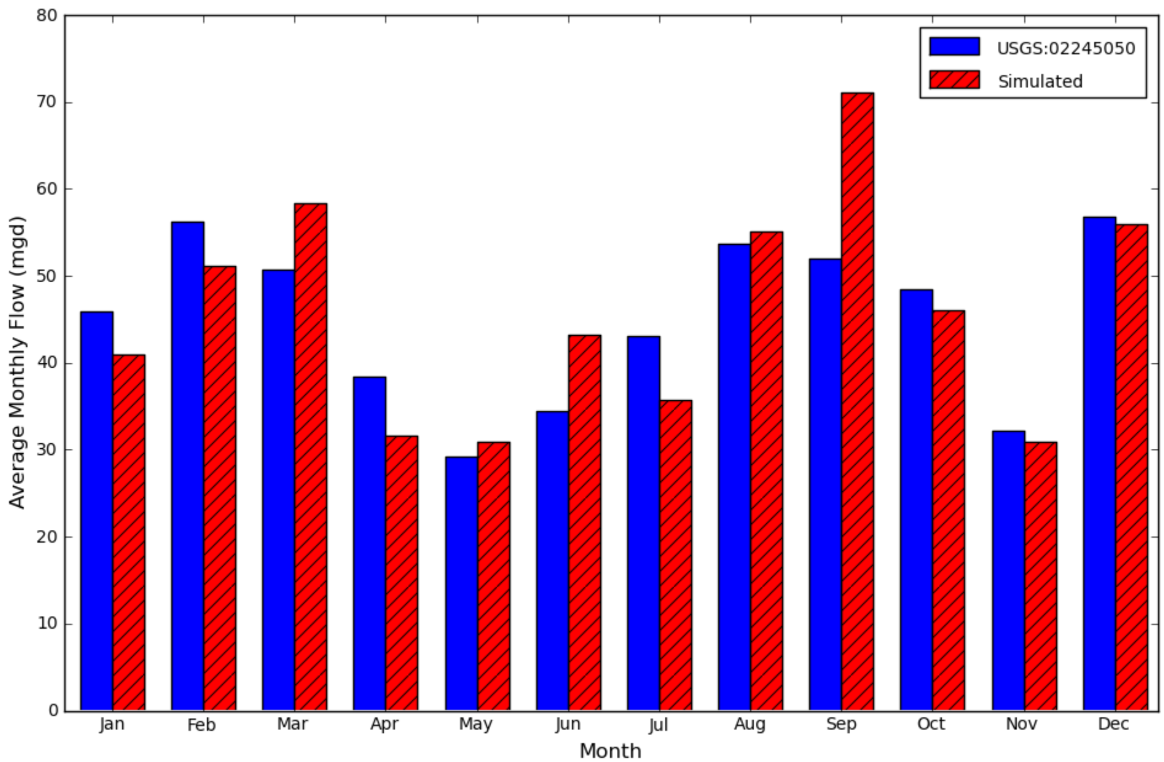

Figure 3.M.16:   Etonia Creek average monthly flow

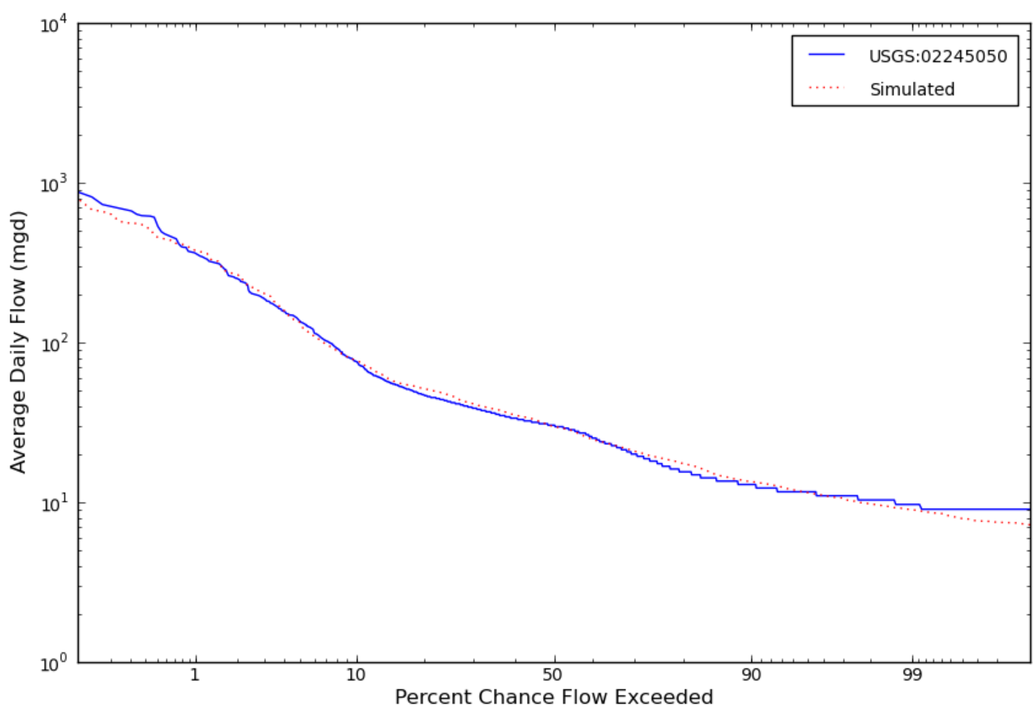

Figure 3.M.17:   Etonia Creek exceedance probability curve

3B ETONIA CREEK WATERSHED. RICE CREEK SUBWATERSHEDS

Rice Creek USGS Gage Station (02244473) is 48.2 square miles in size and is located about 4.7 miles upstream from its confluence with Etonia Creek. From there it is another two miles to the mouth of Rice Creek at the St. Johns River. The period of record is October 1973 to the current year. Records are fair. For the calibration period, 1/1/1995 – 7/5/2004, Palatka rainfall and Federal Point evaporation data were used.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration of the 10 parameters according to the WSI project general model parameters guideline and ranges. Rice Creek is a discharge area for the Floridan aquifer, so it is reasonable for it to have a low lower zone storage nominal (lzsn) value because of the high water table. For DEEPFR or the fraction of groundwater entering the deep, the minimum acceptable value of .001 was used. Despite these measures, Rice Creek was still going dry, which never occurred during the simulation period. It was necessary to add a constant spring flow of 2 cfs to calibrate the model. The results of the model performance show the observed annual mean discharge for water year 1995 to June 2005 was 42.0 cfs. The simulated discharge over the calibration was 40.9 cfs. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.80. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. In addition, simulated and observed stages are compared at the calibration sites. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the watershed.

Table 3.L.7: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.80	-3.08

Table 3.L.8: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02244473)	Simulated
Average	27.10	26.27
Median	7.11	7.51
Variance	3994.97	3384.00
Standard Deviation	63.21	58.17
Skew	7.69	6.41
Kurtosis	92.66	58.07
Minimum	1.10	1.29
Maximum	1137.52	904.52
Range	1136.42	903.23

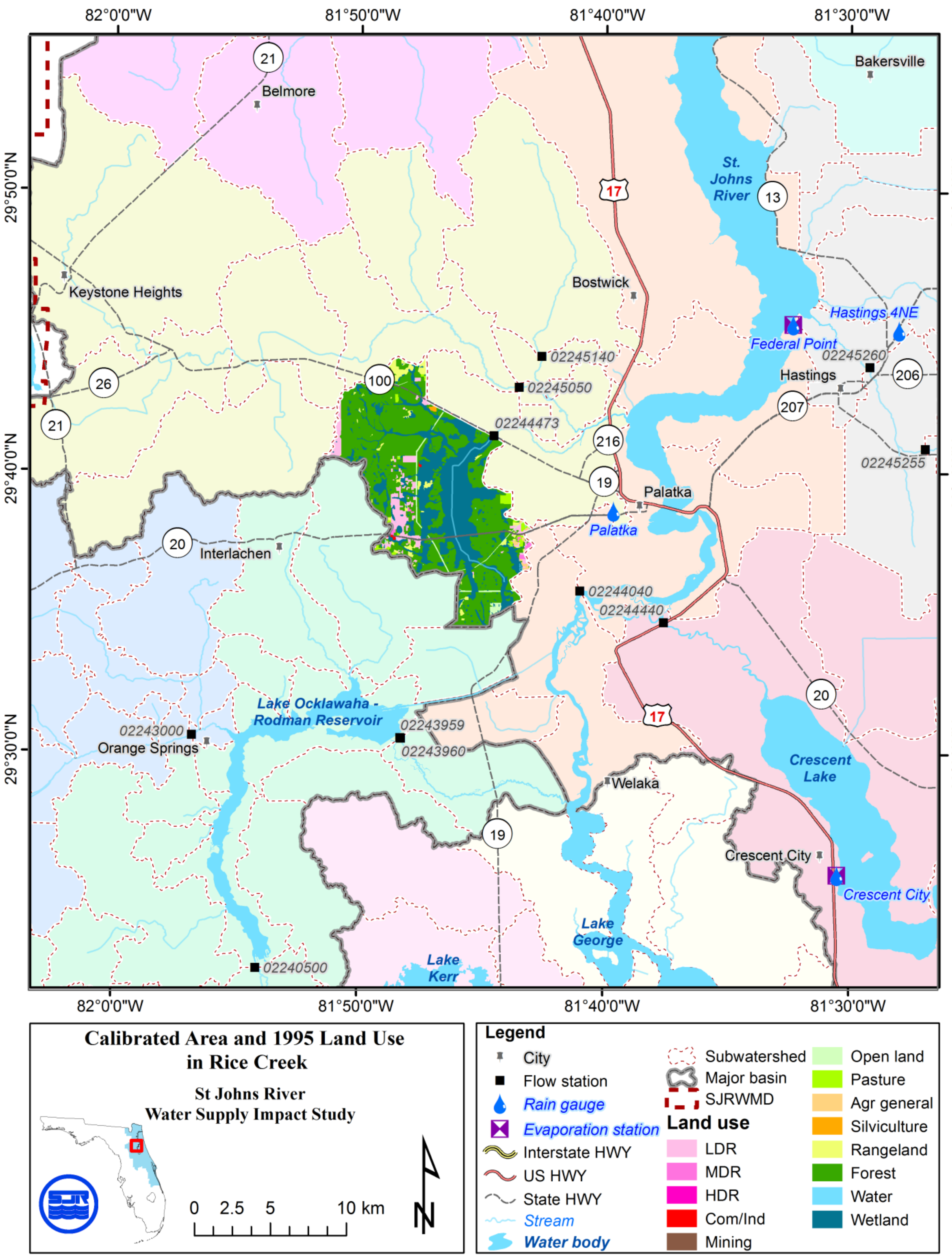

Figure 3.M.18: Rice Creek land use map

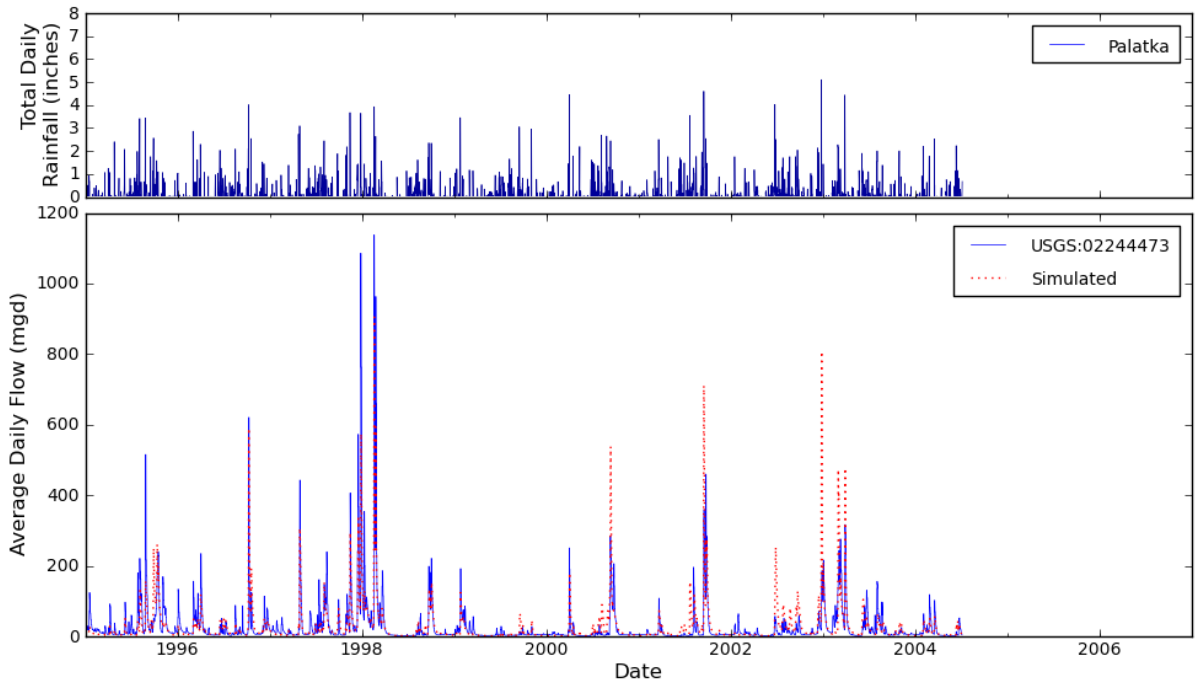

Figure 3.M.19: Rice Creek daily hydrograph

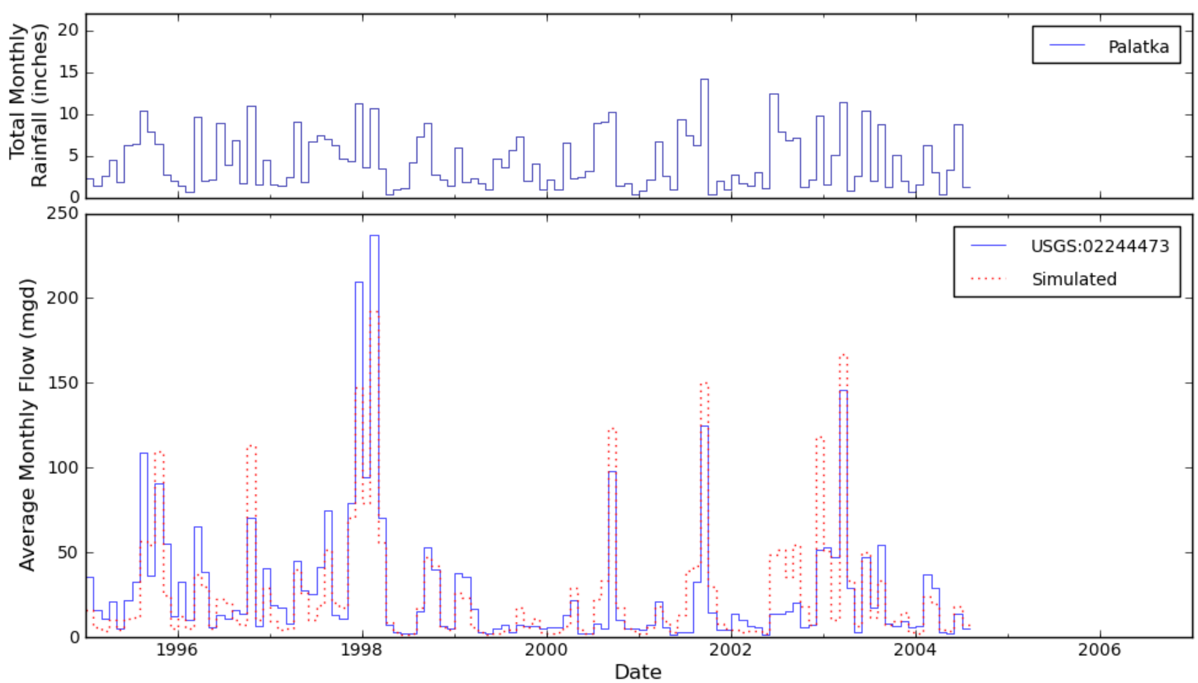

Figure 3.M.20: Rice Creek monthly hydrograph

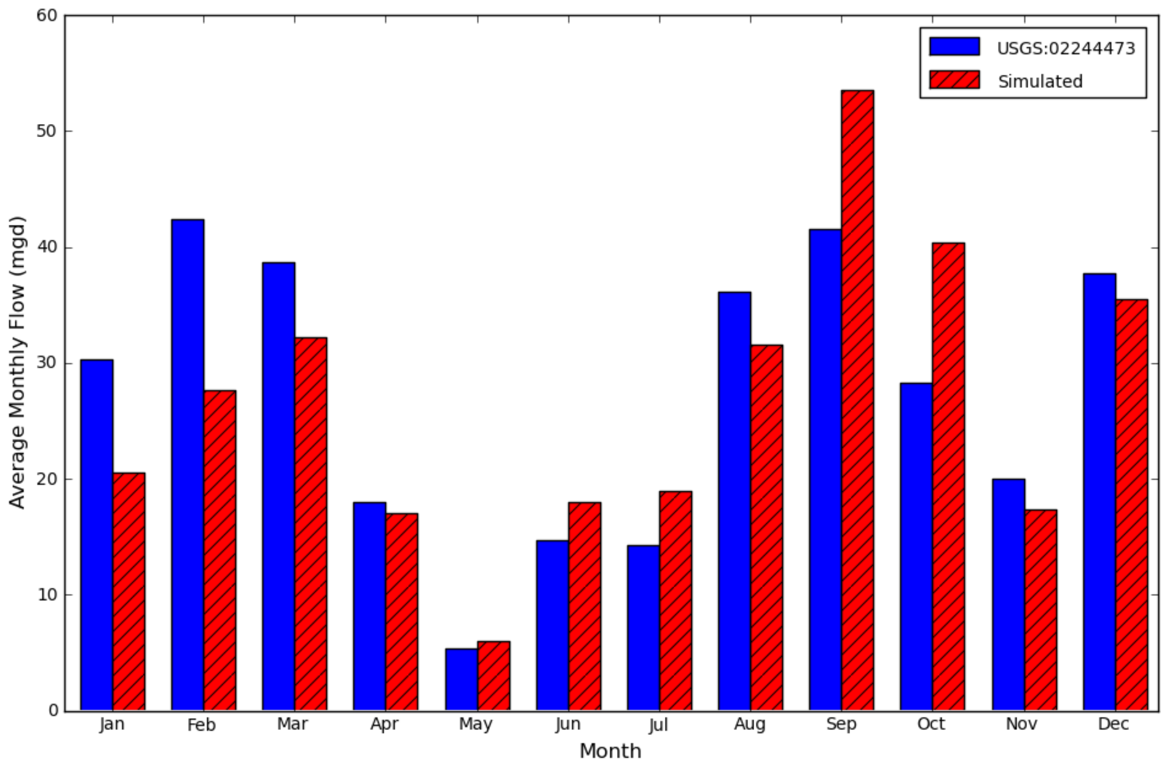

Figure 3.M.21: Rice Creek average monthly flow

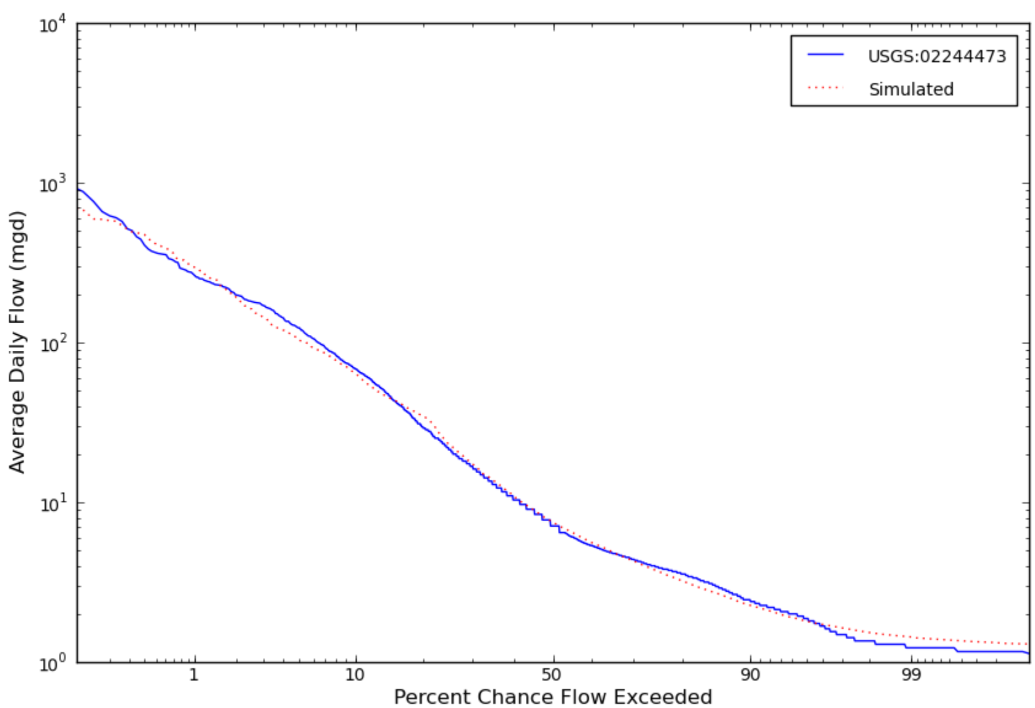

Figure 3.M.22: Rice Creek exceedance probability curve

3B ETONIA CREEK WATERSHED. SIMMS CREEK SUBWATERSHEDS

Simms Creek USGS Gage Station (02245140) near Bardin (subwatershed 12 in Figure H-14) is 48.7 square miles in size. It runs another 2.1 miles through subwatershed 8 before discharging into Etonia Creek, giving it a total drainage area of 54.6 sq mi. The confluence is 2 miles upstream of Rice Creek. The period of record is October 1973 to the current year. Records are fair. For the calibration period, 1/1/1995 – 7/5/2004, Palatka rainfall and Federal Point evaporation data were used.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration of the 10 parameters according to the WSI project general model parameters guideline and ranges. Simms Creek is a recharge area for the Floridan aquifer. PEST optimized DEEPFR at the minimal value of .001. Then was too low and was changed to 0.1, which is still on the low side of the expected amount. The results of the model performance show the observed annual mean discharge for 1995 to June 2004 was 53.5 cfs. The simulated discharge over the calibration was 51.8 cfs. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.66. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. In addition, simulated and observed stages are compared at the calibration sites. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the watershed.

Table 3.L.9: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.66	-3.11

Table 3.L.10: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02245140)	Simulated
Average	34.55	33.48
Median	13.57	16.12
Variance	4872.14	4498.33
Standard Deviation	69.80	67.07
Skew	8.16	8.08
Kurtosis	105.58	92.90
Minimum	2.91	2.55
Maximum	1454.21	1276.08
Range	1451.30	1273.53

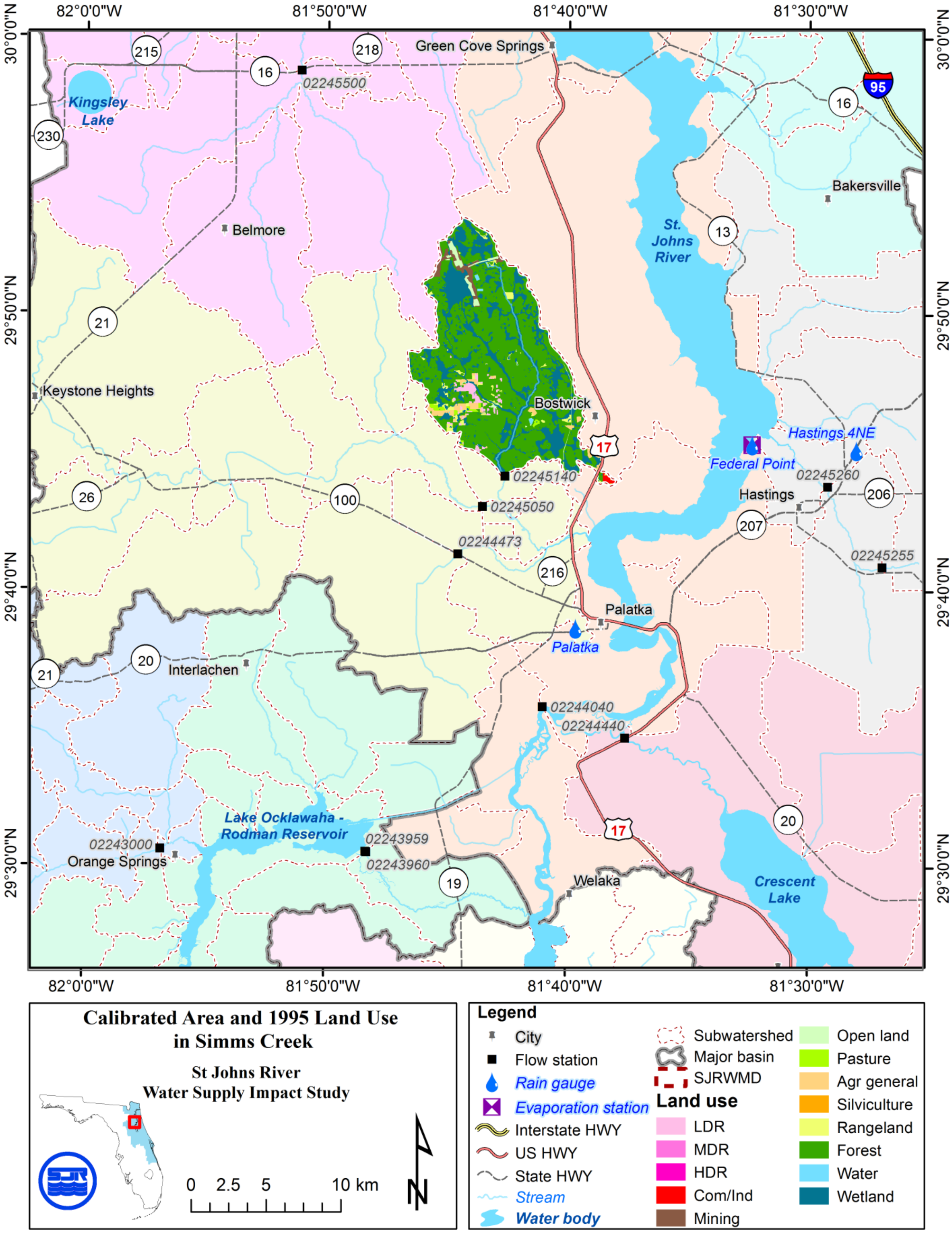

Figure 3.M.23: Simms Creek land use map

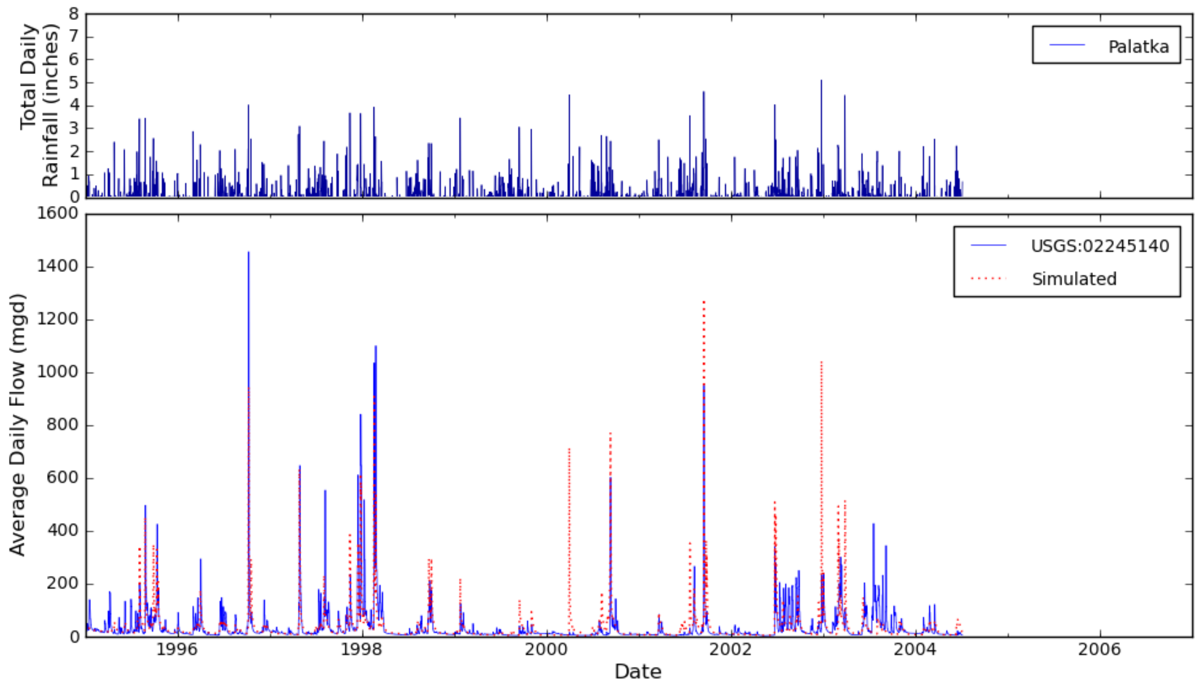

Figure 3.M.24: Simms Creek daily hydrograph

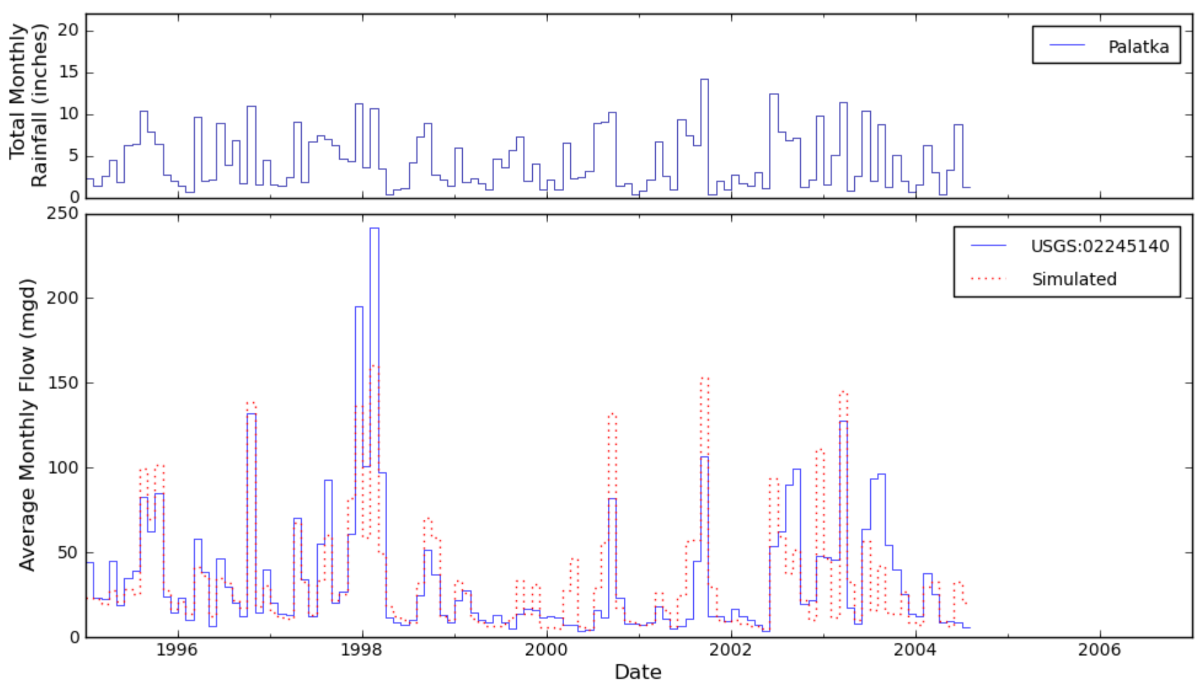

Figure 3.M.25: Simms Creek monthly hydrograph

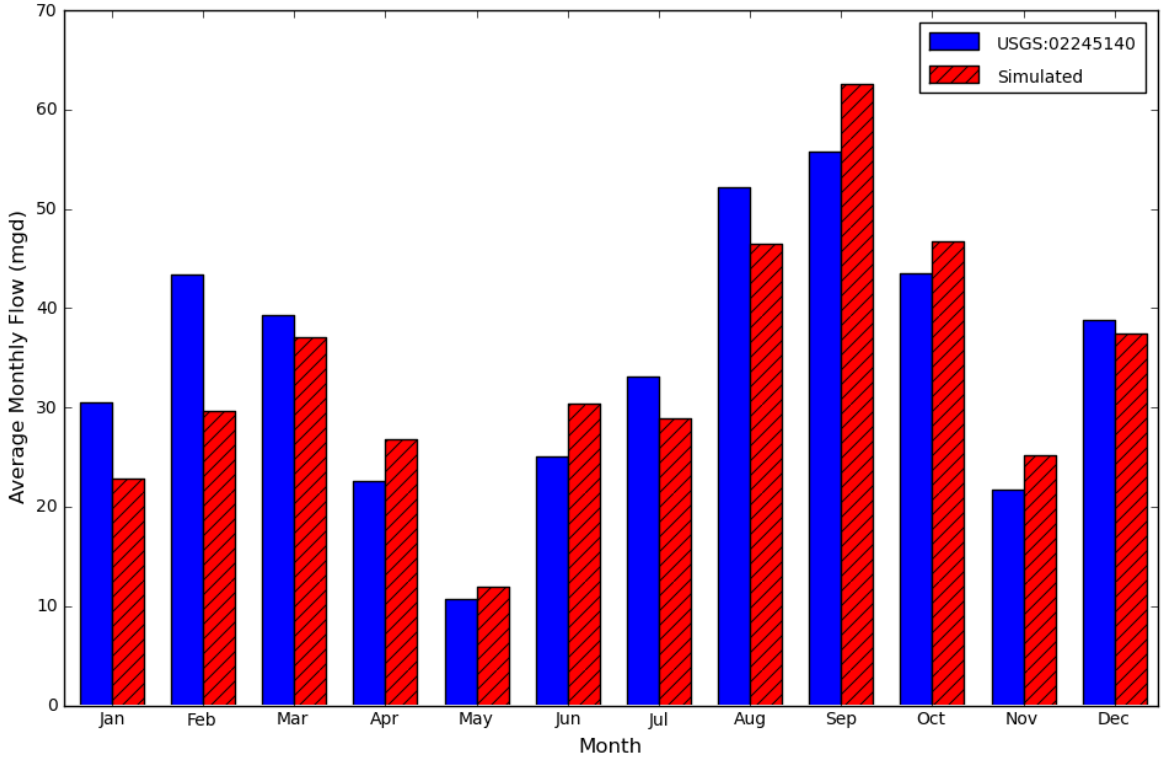

Figure 3.M.26: Simms Creek average monthly flow

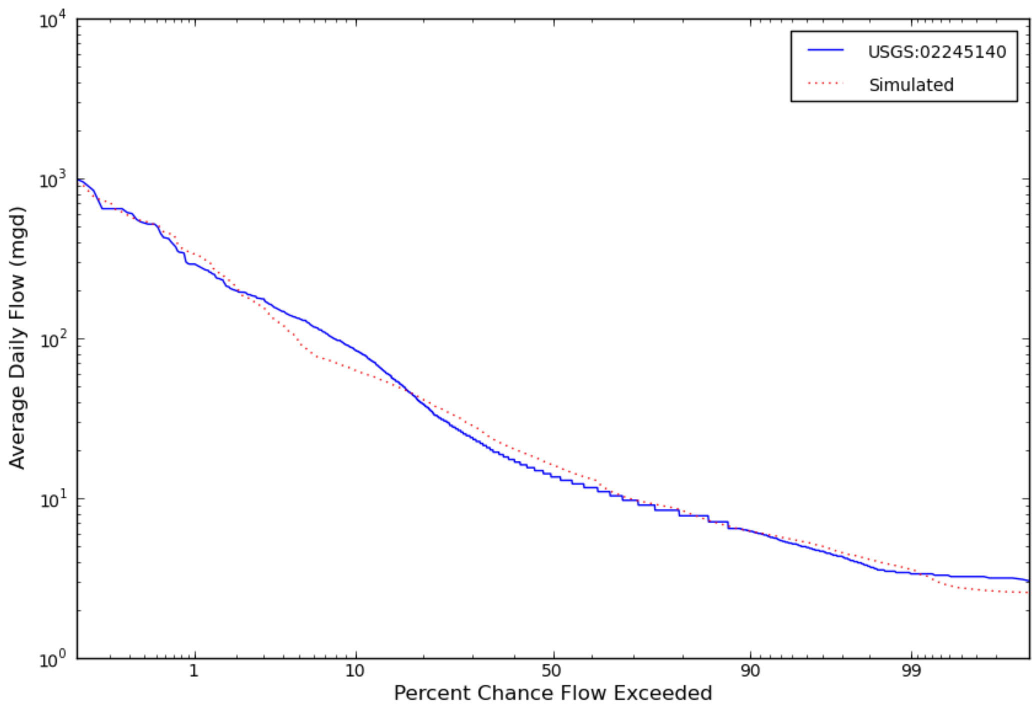

Figure 3.M.27: Simms Creek exceedance probability curve

3C Black Creek Watershed

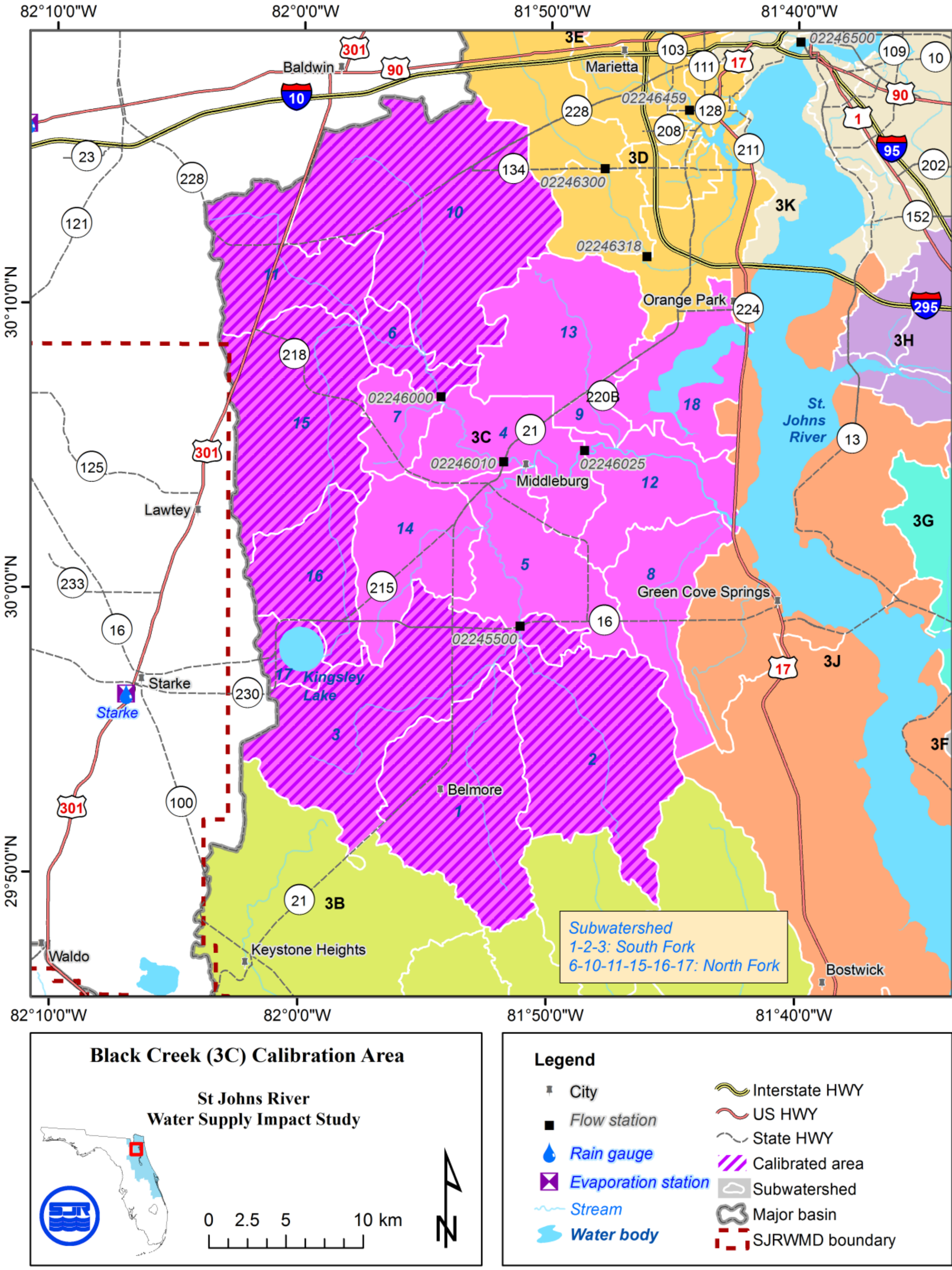

Figure 3.M.28: 3C Black Creek Watershed calibration areas

3C BLACK CREEK WATERSHED. NORTH FORK BLACK CREEK SUBWATERSHEDS

Two significant tributaries to Black Creek, the North Fork and South Fork, are gauged and used to compare with simulated discharge and calibrate the Black Creek model. North Fork Black Creek near Middleburg, USGS gage 02246000, is located 7.5 miles upstream from the confluence with South Fork. The drainage area upstream of the gage is 176 square miles. The quality of the data is good. The station was started in October 1931. The period used for calibration is from 1/1/1995 to 12/31/2006.

Model calibration initially consists of establishing the runoff relationships between land uses. Urban land, including impervious area, produces the most runoff, agriculture produces the next largest runoff, open land and rangeland produce less, and forest and wetland produce the least runoff. With runoff characteristics established relative to land cover, PEST is applied to adjust HSPF model parameters according to general project guidelines and model parameter ranges to achieve a satisfactory match between simulated and gauged discharge. Parameter adjustments are applied to the model section corresponding to the drainage area contributing runoff to the gauged river or tributary.

Calibration results at the North Fork gage location are overall very good. The Nash-Sutcliffe efficiency coefficient is 0.81 and the percent error of the mean discharge is -1.12. Comparison of the simulated to gauged daily flow (shown in the daily flow hydrograph) indicates that storm event generated peak flows tend to be overestimated or missed. Part of the reason for the overestimated peak discharge is due to the rainfall input. To discuss the effect of rainfall input on the ability of the model to match peak flow events three events are selected. First, the October 1996 event is closely matched; both simulated and gauged peaks are above 6000 mgd. This is a good example of a peak flow event generated by a significant rainfall event. The significant rainfall event can be characterized as having a majority of the area consisting of an intensity of about 4 inches over 4 hours and a total rainfall depth of about 7 inches over 24 hours. The two rain gauges that supply rainfall input to the North Fork portion of the Black Creek model are Starke (45% of the area) and Glen St Mary (55% of the area). The Starke rainfall is 1.9 inches in 4 hours and 4.8 inches in 24 hours; the Glen St Mary rainfall is 3.5 inches in 4 hours and 7.0 inches in 24 hours. The result of applying this rainfall amount in this proportion is to produce a peak flow event that matches the gauged peak flow.

Second, the February 1998 event is overestimated. Simulated peak flow almost reaches 7000 mgd, but the gauged peak is less than 5000 mgd. Inspection of the February 1998 rainfall event shows that the two rain gages report similar rainfall amounts previously reported during the October 1998 event. The Starke rainfall is 2.0 inches in 4 hours and 4.2 inches in 24 hours; the Glen St Mary’s gage is 5.0 inches in 4 hours and 6.8 inches in 24 hours. Similar to October 1998, the model is responsive to the Glen St Mary rainfall input. However, the rainfall recorded at Starke must better represent the rainfall over the majority of the North Fork sub-watershed. The result is that the peak discharge is overestimated.

Third, the September 1998 event is overestimated. Simulated peak flow almost reaches 4000 mgd, but the gauged peak flow is about 1000 mgd. Inspection of the September 1998 rainfall event again shows that the rainfall amounts reported between the two rain gauges are different.

The Starke rainfall is 1.1 inches over 4 hours and 1.5 inches over 24 hours; the Glen St Mary rainfall is 4.8 inches over 4 hours and 6.3 inches over 24 hours. As previously identified, the model is responsive to the Glen St Mary's rainfall input. However, again the rainfall recorded at Starke must better represent the rainfall over the majority of the North Fork sub-watershed.

The monthly hydrograph figure provides a second comparison of hydrograph trends. The monthly average flow provides a clearer comparison during the low flow period of 1999 and 2000. The simulated flow during this period generally matches the low flows, although the second half of 1999 is overestimated and the second half of 2000 is underestimated. The graph of average monthly flow shows that the seasonal trends are represented with May being the driest month and September the wettest month. However, the September average month is greatly underestimated. This significant underestimation is due to large differences occurring in September 2001 (-272 mgd), September 2000(-211 mgd), and September 2002(-141 mgd).

Comparison of the discharge exceedance probability curves shows a close match between simulated and gauged curves with a departure for flows below 10 mgd. This indicates that the discharge hydrograph produced by the model has similar characteristics to the gauged discharge hydrograph over the majority of the range of flows, but tends to overestimate low flows (10 mgd and less).

Table 3.L.11: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.81	-1.12

Table 3.L.12: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02246000)	Simulated
Average	112.68	111.42
Median	45.89	46.22
Variance	81336.76	92331.06
Standard Deviation	285.20	303.86
Skew	10.44	11.25
Kurtosis	150.01	178.42
Minimum	1.87	3.60
Maximum	6463.17	6759.82
Range	6461.29	6756.22

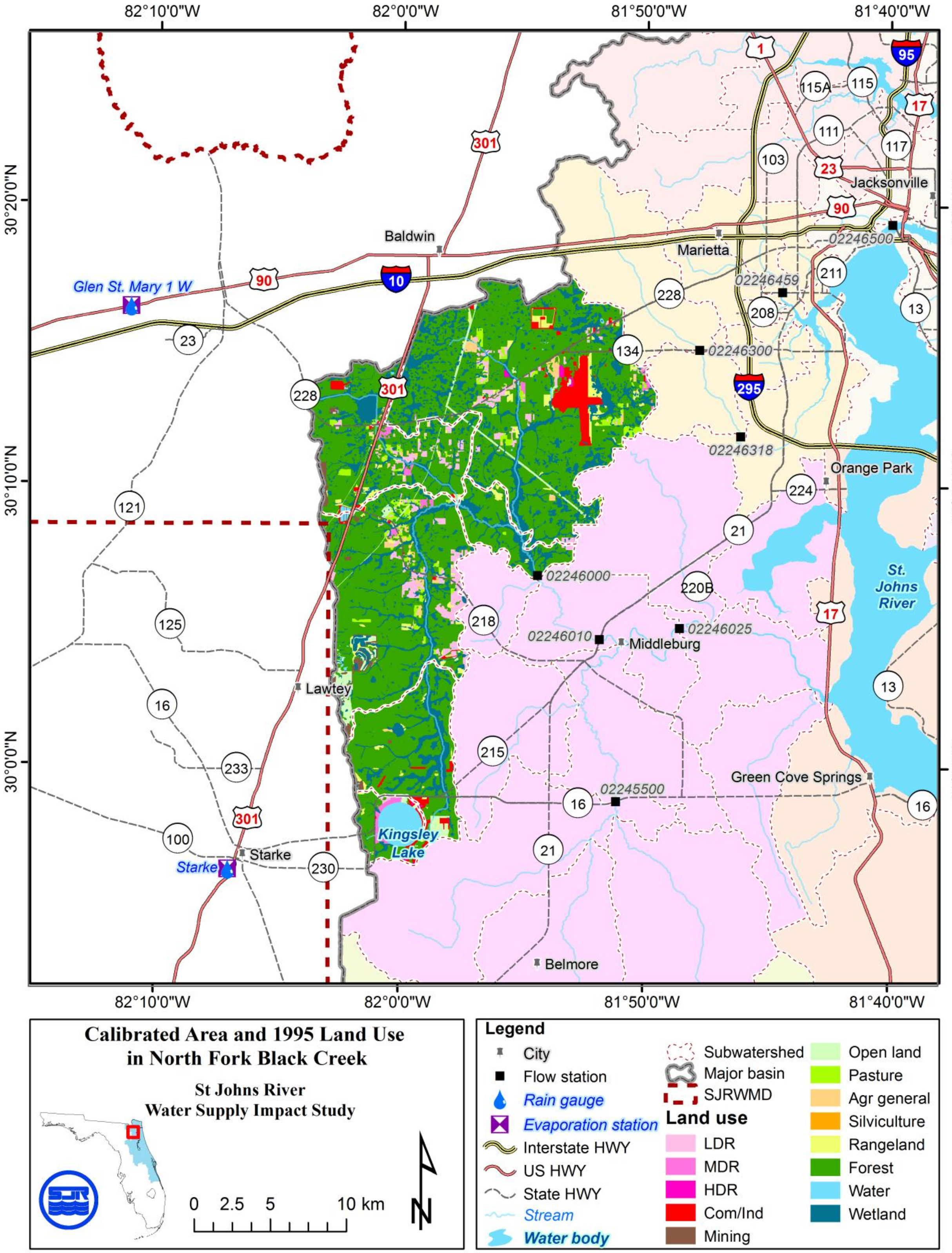

Figure 3.M.29: North Fork Black Creek land use map

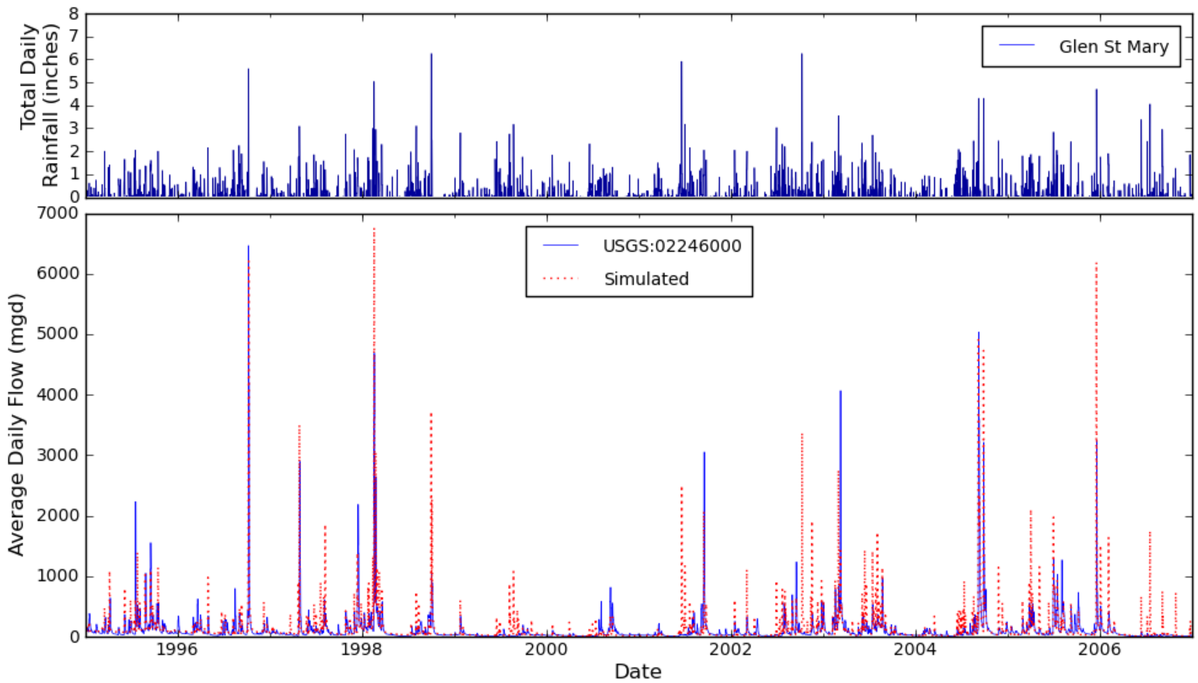

Figure 3.M.30: North Fork Black Creek daily hydrograph

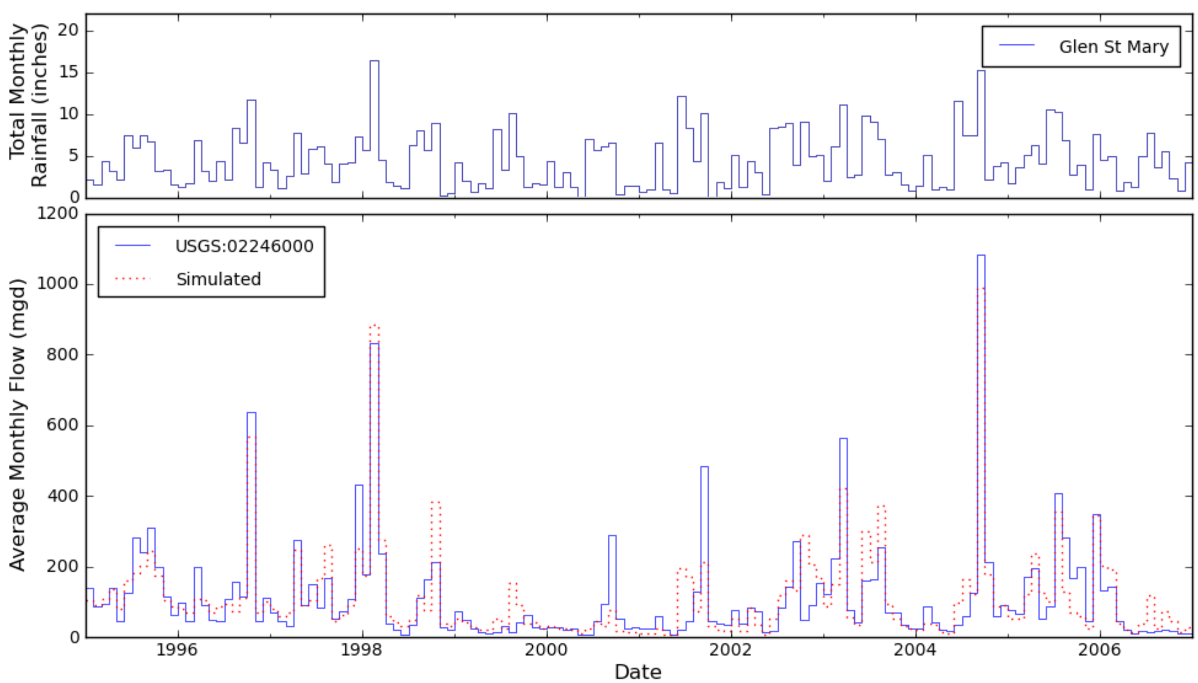

Figure 3.M.31: North Fork Black Creek monthly hydrograph

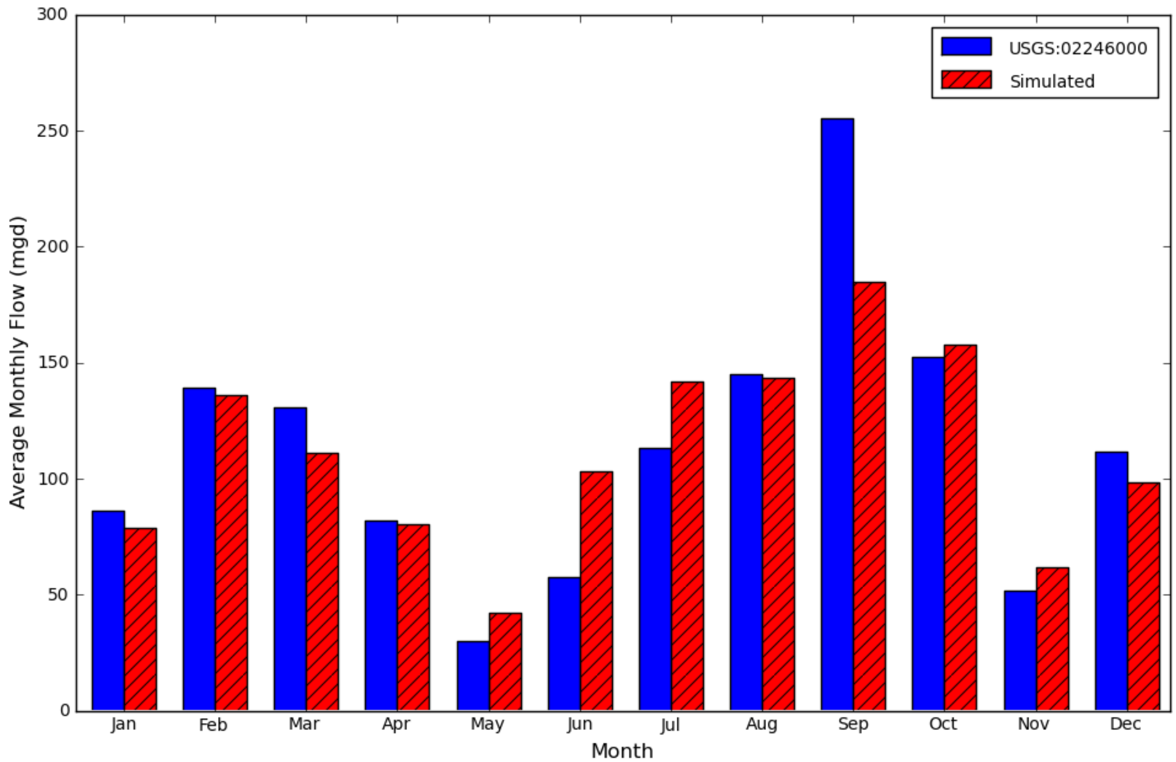

Figure 3.M.32: North Fork Black Creek average monthly flow

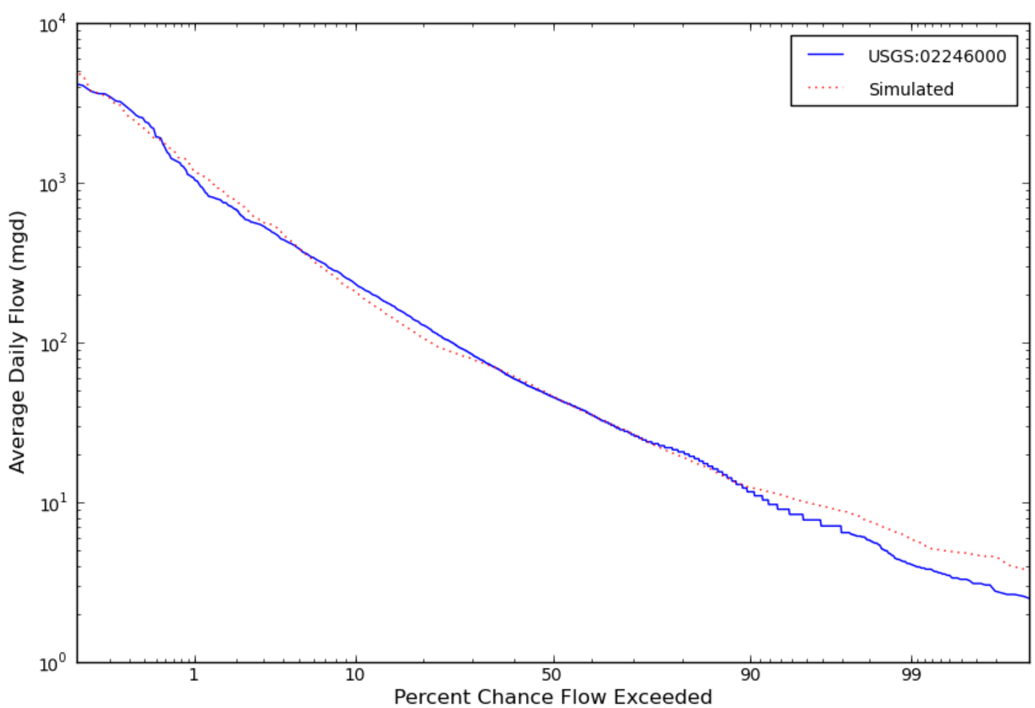

Figure 3.M.33: North Fork Black Creek exceedance probability curve

3C Black Creek Watershed. South Fork Black Creek Subwatersheds

South Fork Black Creek near Penney Farms, USGS gage 02245500, is located at the bridge of State Road 16, 24 miles upstream from the mouth of Black Creek. The drainage area upstream of the gage is 141 square miles. The quality of the data is good. The station was started in October 1939. The period used for calibration is from 1/1/1995 to 12/31/2006.

Model calibration initially consisted of establishing the runoff relationships between land uses. Urban land, including impervious area, produces the most runoff, agriculture produces the next largest runoff, open land and rangeland produce less, forest and wetland produce the least runoff. With runoff characteristics established relative to land cover, PEST is applied to adjust HSPF model parameters according to general project guidelines and model parameter ranges to achieve a satisfactory match between simulated and gaged discharge. Parameter adjustments are applied to the model section corresponding to the drainage area contributing runoff to the gauged river or tributary.

Calibration results at the South Fork gage location are overall good. The Nash-Sutcliffe efficiency coefficient is 0.75 and the percent error of the mean discharge is -2.78. The drainage area behind the South Fork gage is 141 square miles. Similar to the North Fork two rainfall stations are used for rainfall input. Starke contributes rainfall over 67% of the drainage area and the Palatka rain gauge contributes rainfall over 33% of the drainage area. Comparison of simulated to gauged flow (shown in the daily flow hydrograph) indicate that storm event generated peak flows tend to be overestimated or missed. This is similar to the North Fork calibration; the application of rainfall input may not be represent the rainfall contribution for a particular storm. However, the three example events used to discuss overestimates and mismatched peaks in the North Fork (Oct 1996, Feb 1998, and Sep 1998) are closely matched here at the South Fork gage.

The monthly hydrograph figure provides a second comparison of hydrograph trends. Again, the monthly average flow provides a clearer comparison during the low flow period of 1999 and 2000. Generally, the simulated monthly flow is able to reproduce the low flow condition. Again, the second half of 1999 is overestimated. The average monthly flow graph shows that the seasonal trends are followed with May being the driest month and September the wettest month. Winter and spring months tend to be underestimated.

Comparison of the discharge duration curve shows a close match. This indicates that the discharge hydrograph produced by the model has similar characteristics to the gauged discharge hydrograph. There is no large departure between the two curves. But, for the purpose of discussing simulated flow characteristics, three distinct departures between the curves can be identified. The simulated curve is higher than the gauged curve in low flow range indicating that the simulated discharge overestimates the low flow condition (about one mgd). In the mid range of the curve (in the range between 60 to 400 mgd) the simulated curve is lower than the gauged curve. And, in the high range of the curve the simulated is higher than gauged curve indicating that event discharge is overestimated.

Table 3.L.13: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.75	-2.78

Table 3.L.14: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02245500)	Simulated
Average	85.88	83.49
Median	36.84	36.74
Variance	39631.48	54882.03
Standard Deviation	199.08	234.27
Skew	9.89	10.53
Kurtosis	143.25	151.24
Minimum	5.04	6.27
Maximum	4394.95	4880.43
Range	4389.91	4874.16

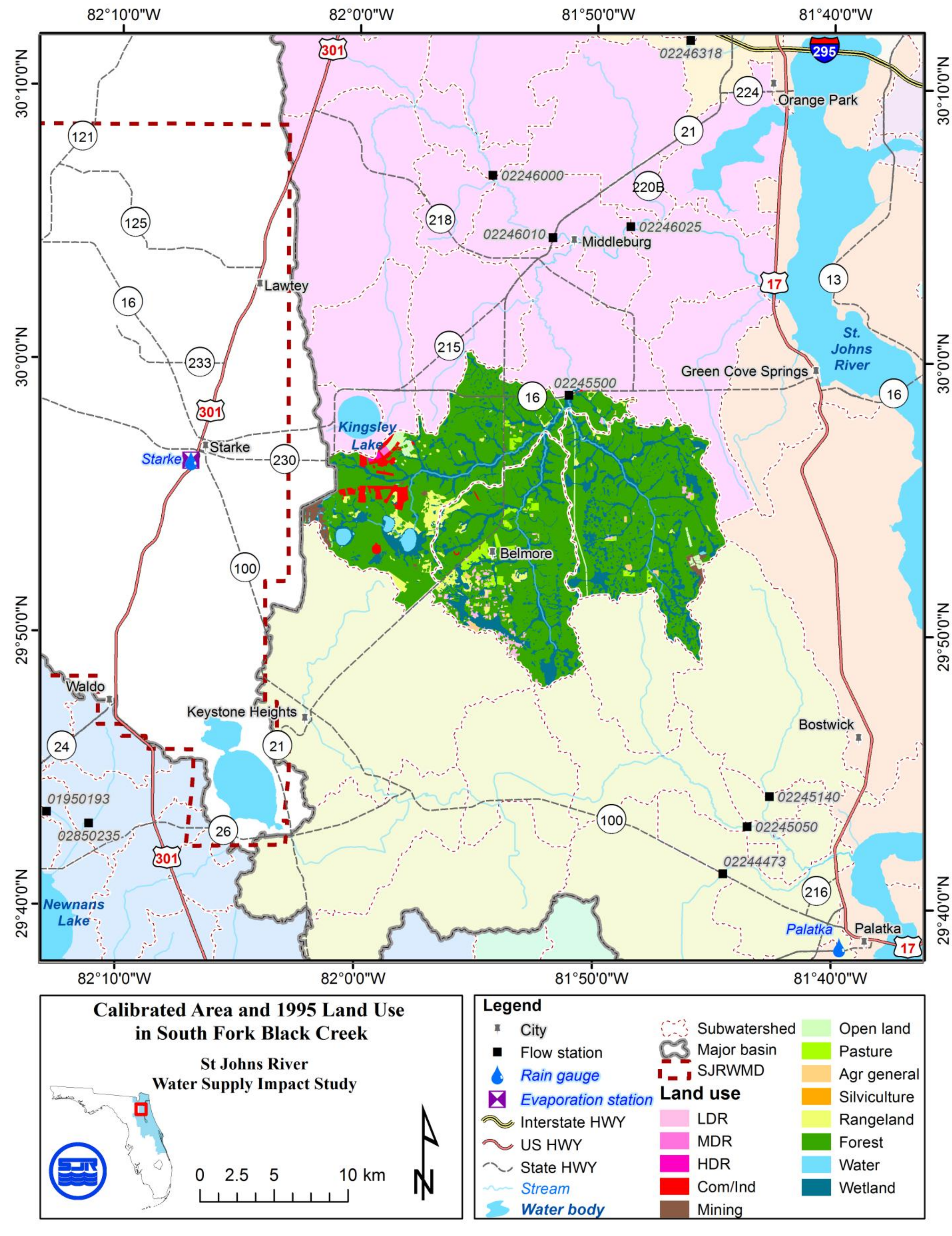

Figure 3.M.34: South Fork Black Creek land use map

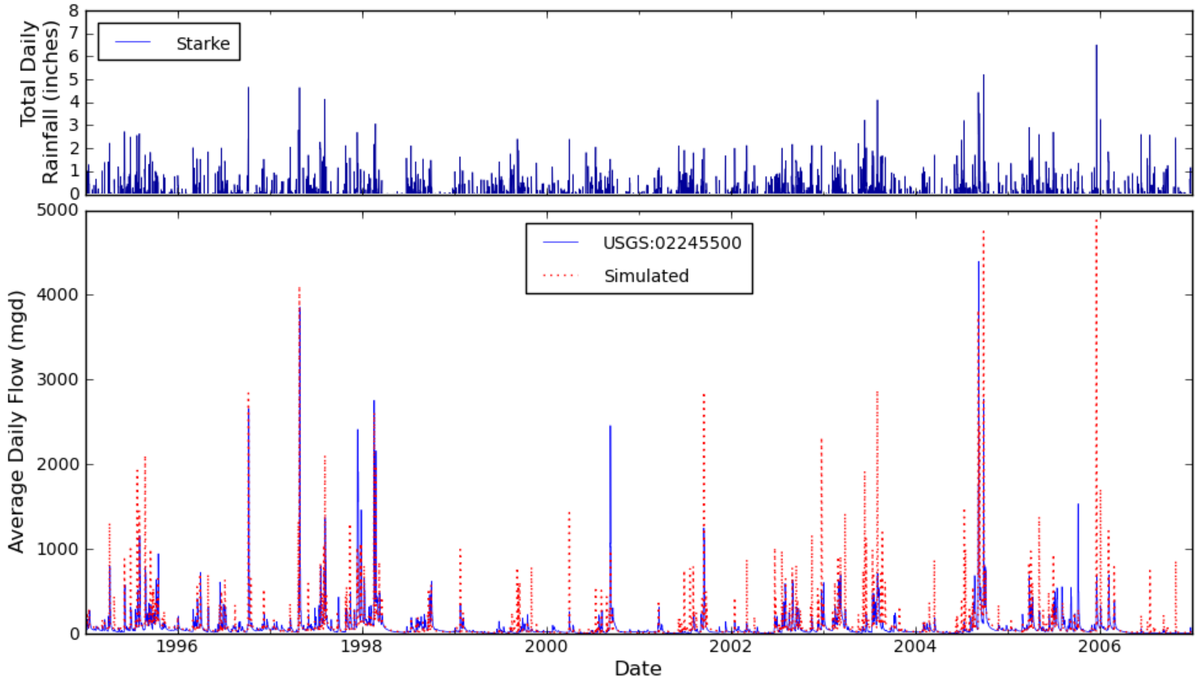

Figure 3.M.35: South Fork Black Creek daily hydrograph

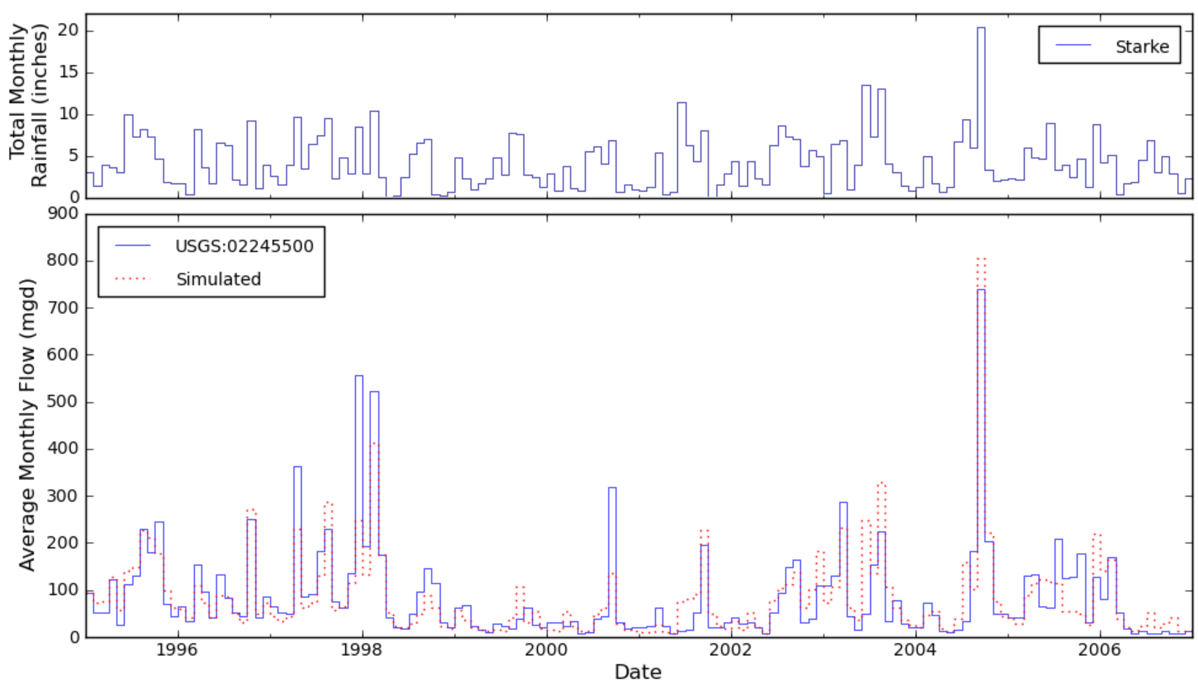

Figure 3.M.36: South Fork Black Creek monthly hydrograph

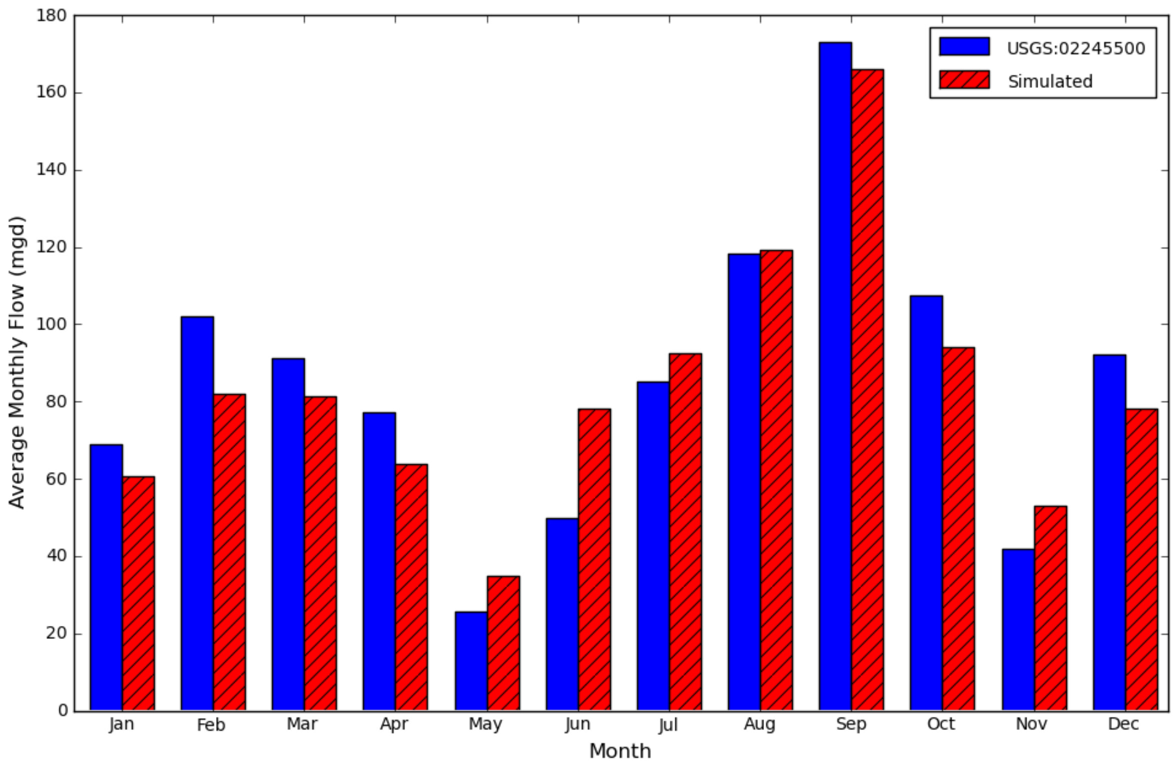

Figure 3.M.37: South Fork Black Creek average monthly flow

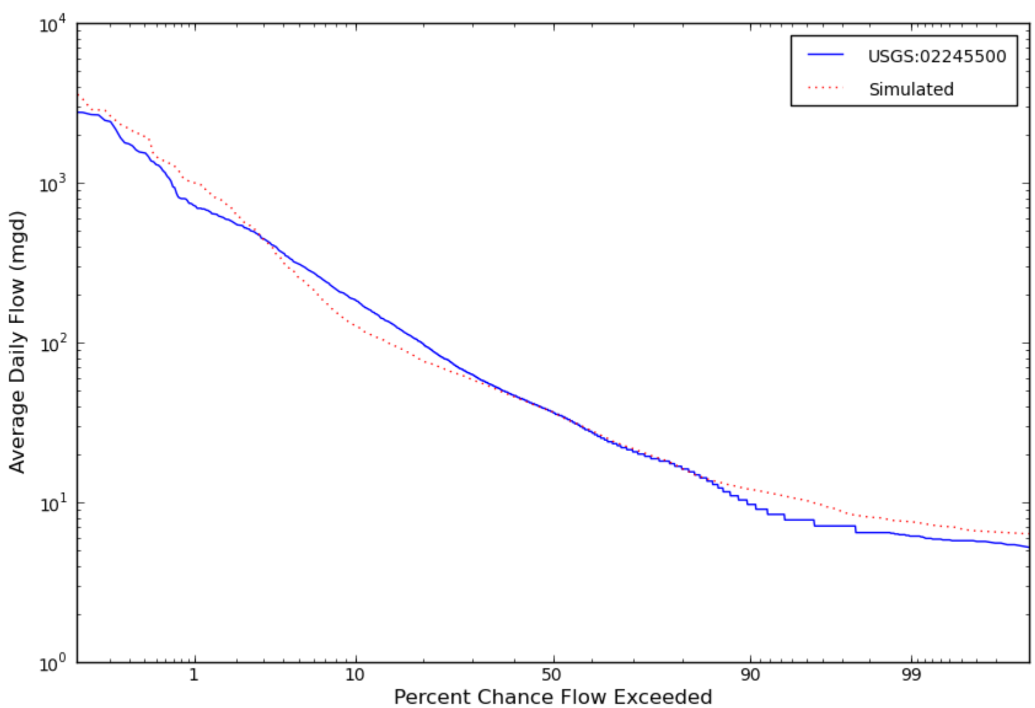

Figure 3.M.38: South Fork Black Creek exceedance probability curve

3D Ortega Watershed

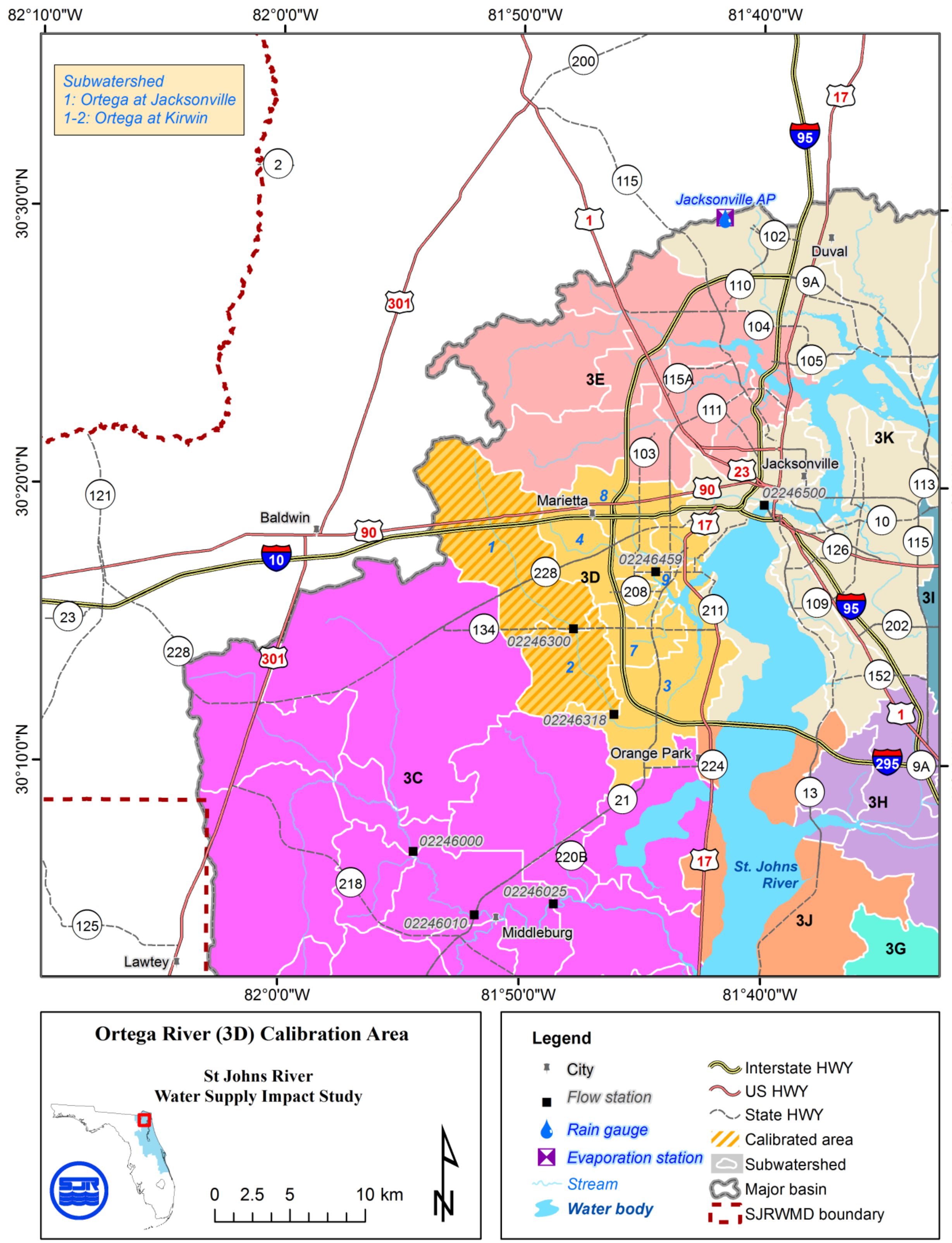

Figure 3.M.39: 3D Ortega Watershed calibration areas

3D Ortega Watershed. Ortega at Jacksonville Subwatersheds

The Ortega River watershed model is calibrated over the period from 1/1/1995 to 12/31/2006. During the calibration period one discharge gage station is discontinued and a second discharge gage station begins recording flow at a downstream location. USGS gage 02246300, Ortega River at Jacksonville located at 103rd Street Bridge started recording January 1965 and discontinued recording on 4/13/2003. The quality of the data is fair. The replacement gage is USGS gage 02246318, Ortega River at Kirwin Road, located at the Kirwin Road Bridge. The station started recording flow on 3/21/2002 at a location 4.4 miles downstream from the previous gage. The quality of the data is fair. The USGS gage 02246459, Cedar River at San Juan Avenue at Jacksonville, was not used for calibration. The discharge data consisted of extended periods (months) of negative flow.

Model calibration initially consisted of establishing the runoff relationships between land uses. Urban land, including impervious area, produces the most runoff, agriculture produces the next largest runoff, open land and rangeland produce less, and forest and wetland produce the least runoff. With runoff characteristics established relative to land cover, PEST is applied to adjust HSPF model parameters according to general project guidelines and model parameter ranges to achieve a satisfactory match between simulated and gauged discharge. In the case of Ortega River one set of model parameters are adjusted to obtain the best match between simulated and gauged flow at two gage locations. The challenge of attempting to match flow reported from two gages became apparent when comparisons of the statistics were made. Part of the challenge was to determine which gage to rely upon given the different flow characteristics at each gage. Increased weight for matching daily flow was given to the gage with the longer flow record, gage 02246300.

Calibration results at the USGS gage 02246300 are overall good. The Nash-Sutcliffe efficiency coefficient is 0.70 and the percent error of the mean discharge is -13.19. The large percent error of the mean discharge is due to trying to match two locations. As will be explained below and in the subsequent section the runoff computed from gauged flow is higher than runoff computed at the downstream gage. In an attempt to consider the flow reported at both gages a compromise was required, and the result is that there is a large positive percent error of the mean discharge at the downstream gage.

Comparison of the simulated to gauged daily flow hydrographs at USGS gage 02246300 shows that peak flow events in September 1996 and February 1998 are underestimated. The peak flow comparison in September 2001 is close. Part of the explanation for the mismatched peaks may be the accuracy of gauged data. The rainfall (recorded at the Jacksonville Airport) for the 1996 event is 6.3 and 9.3 inches for 24 and 96 hours, respectively. The recorded rainfall for the 1998 event is 4.3 and 5.0 inches for 24 hour and 96 hours, respectively. The recorded rainfall for the 2001 event is 7.0 and 11.3 inches for 24 hours and 96 hours, respectively. The largest recorded rainfall corresponds to the smallest peak of the three gauged events. The attempt to match these three events included consideration for matching events at the downstream gage, which tended to be overestimated.

Concerning the large percent error of mean discharge, there are four identified periods when the volume of simulated flow does not closely match the gauged flow volume. The four periods are summer 1995 (6/1/1995 to 9/30/1995), fall 1996 (8/1/1996 to 10/31/1996), winter 1998 (12/1/1997 to 3/31/1998), and summer 2001 (8/1/2001 to 10/1/2001). To evaluate the flow during these four periods runoff to rainfall ratios are developed. The drainage basin area upstream of USGS gage 02246300 is 19,632 acres. The respective recorded rainfall over each period is 30.1 inches, 21.3 inches, 26.8 inches, and 19.6 inches. The respective gauged runoff/rainfall ratios are 48%, 77%, 86%, and 78%. The respective simulated runoff/rainfall ratios are 27%, 41%, 52%, and 45%. Season long runoff/rainfall ratios above 70% are high in comparison to surrounding drainage areas and subsequent comparison to gauged flow at the downstream location (discussed in the next section).

Streamflow with similar characteristics should have similar flow duration curves. The simulated duration is close to the gauged duration between the percent chance exceeded of 1 to 96. The curves begin to diverge at each end. At the small percent chance exceeded, the simulated flow duration falls below the gauged flow duration. This indicates that peak discharges are underestimated (this was identified when discussing the daily flow hydrograph). At the large percent chance exceeded, the simulated flow duration again falls below the gauged flow duration. This indicates that low-flows less than 0.7 mgd are underestimated.

Table 3.L.15: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.70	-13.19

Table 3.L.16: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02246300)	Simulated
Average	27.36	23.75
Median	9.05	9.05
Variance	8253.09	4082.07
Standard Deviation	90.85	63.89
Skew	13.52	10.31
Kurtosis	253.93	163.00
Minimum	0.03	0.03
Maximum	2307.35	1514.34
Range	2307.33	1514.31

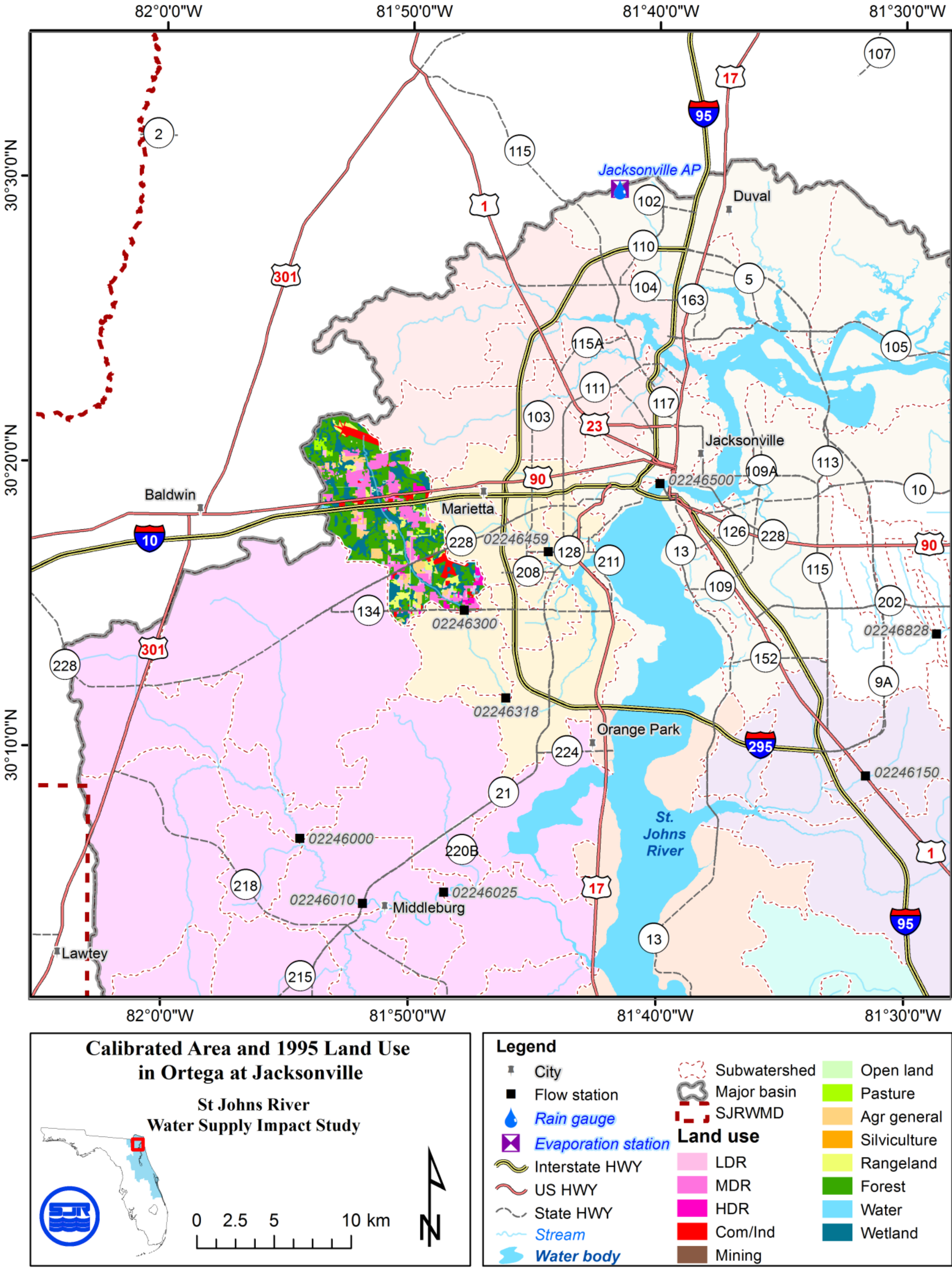

Figure 3.M.40: Ortega at Jacksonville land use map

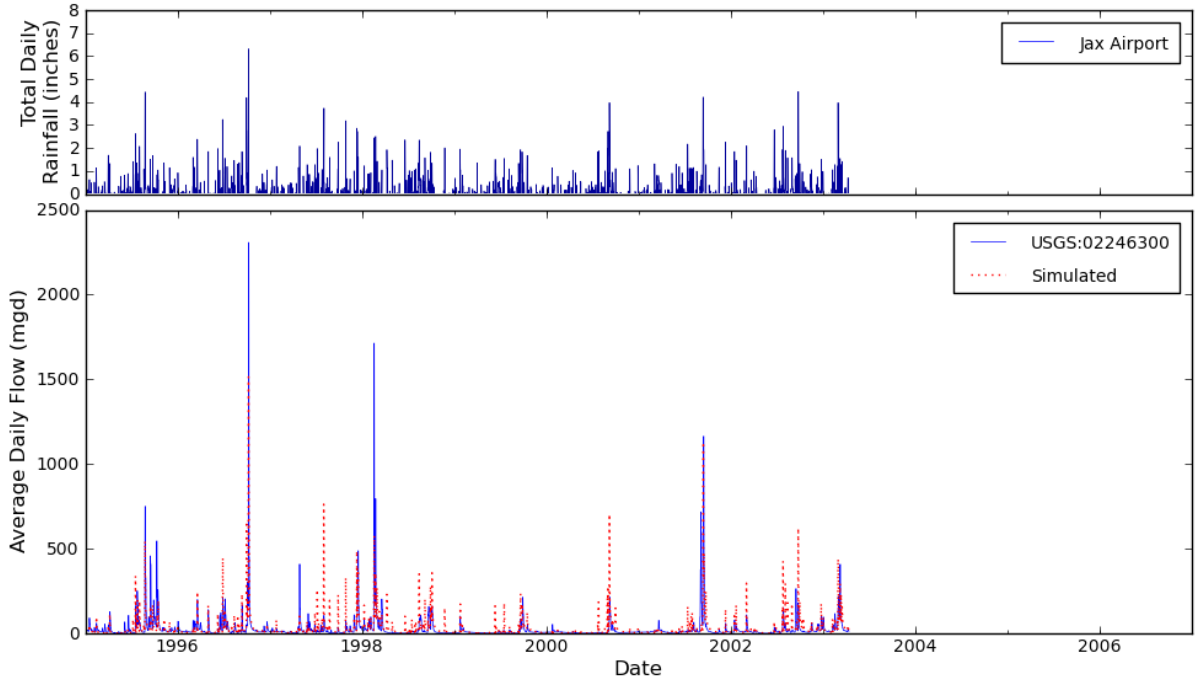

Figure 3.M.41: Ortega at Jacksonville daily hydrograph

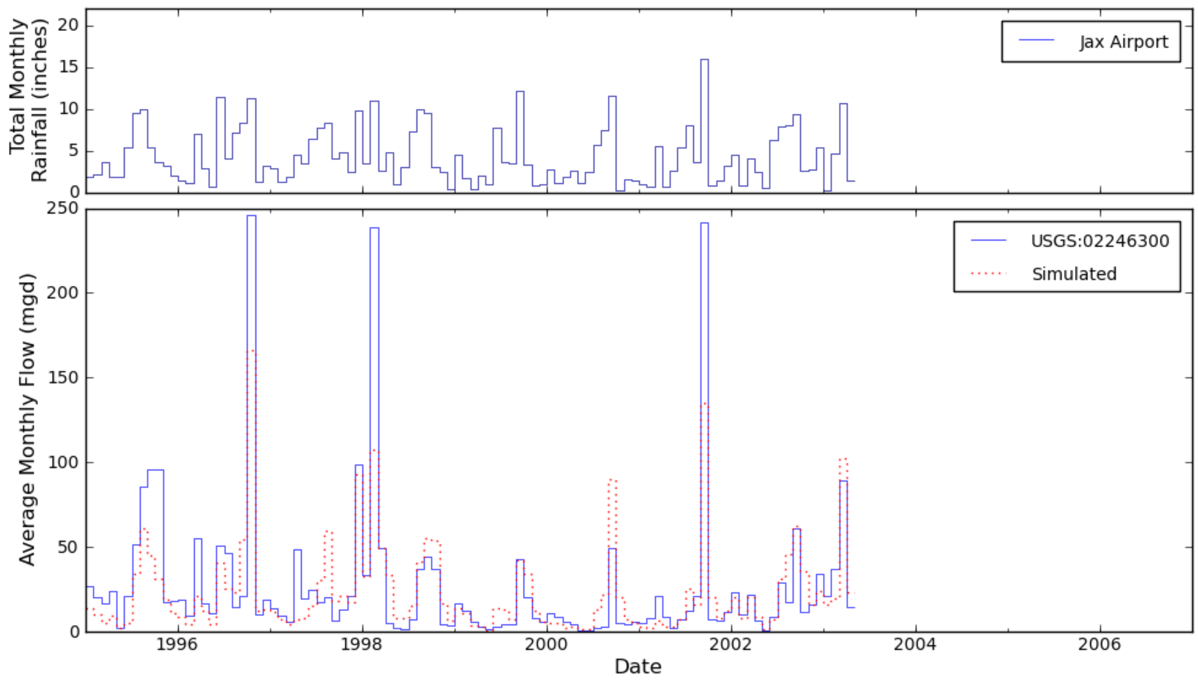

Figure 3.M.42: Ortega at Jacksonville monthly hydrograph

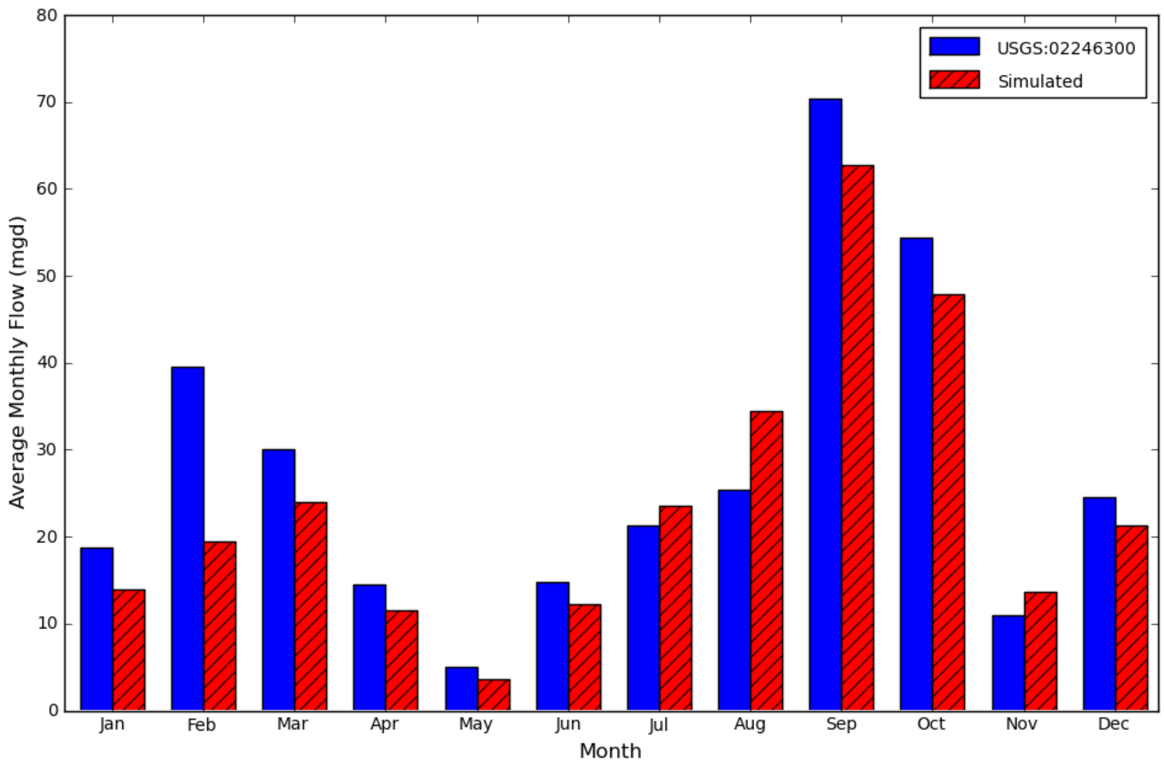

Figure 3.M.43: Ortega at Jacksonville average monthly flow

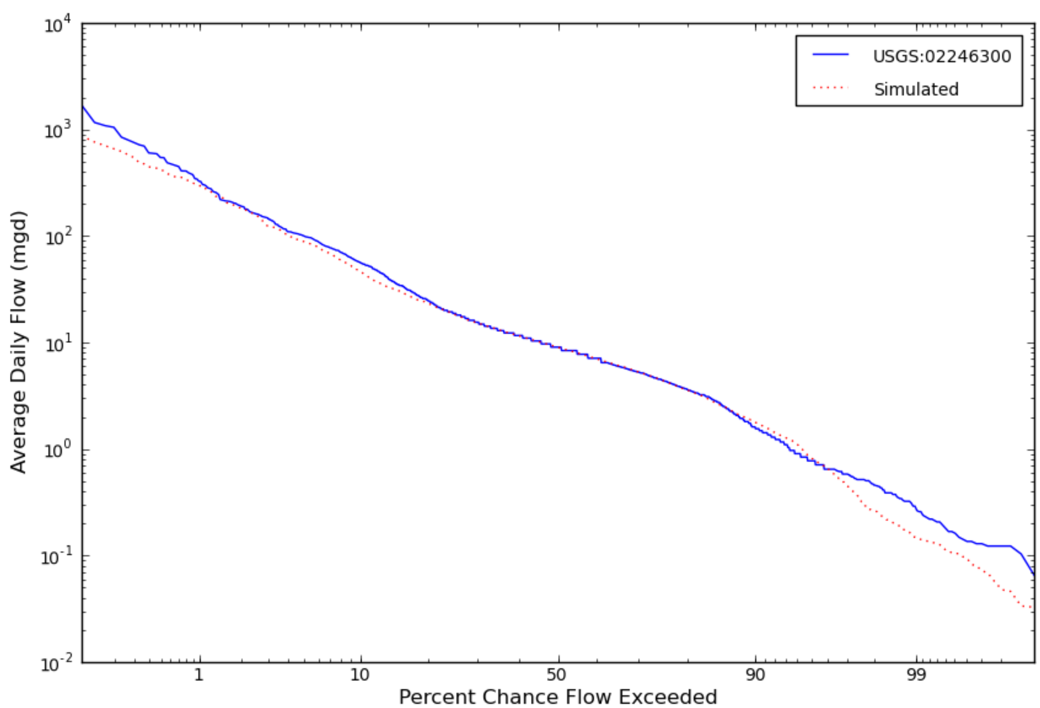

Figure 3.M.44: Ortega at Jacksonville exceedance probability curve

3D ORTEGA WATERSHED. ORTEGA AT KIRWIN ROAD SUBWATERSHEDS

As presented in the previous section, two gages on the Ortega River were used to span the calibration period. USGS gage 02246318, Ortega River at Kirwin Road, began recording flow on 3/21/2002 at a location 4.4 miles downstream of USGS gage 02246300. The quality of the data is fair. Below is a comparison of simulated to gauged flow at this location for the period from 3/21/2002 to 12/31/2006.

Calibration results at the USGS gage 02246318, with at Nash-Sutcliffe efficiency coefficient of 0.48 falls just below the satisfactory range into the unsatisfactory range. The percent error of the mean discharge is 8.73. As discussed in the previous section, emphasis was given to matching daily flow at the upstream gage and the unsatisfactory match at this gage was accepted. The large positive percent error of the mean discharge results from a compromise with the upstream gage to represent the runoff computed at each gage location.

The simulated peak flow events overestimate the gauged peak flow. This is in contrast to underestimated peak flow events at the upstream gage. The question of gauged data accuracy must still be raised to explain the mismatched peaks. For example, the June 2005 event recorded rainfall is 6.0 inches and 8.8 inches over 24 hours and 96 hours, respectively. This rainfall event is almost as great as the September 1996 rainfall event. The resulting simulated peak flow for June 2005 is approximately equivalent to the September 1996 simulated peak flow. However, the gauged peak flow in June 2005 is significantly less than the September 1996 peak flow. Because of the close proximity of these two gages it is expected that there would be more similarity between the runoff response to rainfall than is reflected by the gauged flow.

Returning to the subject of the large percent error of mean discharge, one significant period may be used as an example to help explain the difference; summer 2004 (6/1/2004 to 9/30/2004). Again, it is helpful to develop a runoff/rainfall ratio. The drainage basin area upstream of USGS 02246318 is 27,927 acres. The recorded rainfall over this period is 48.4 inches. The gauged runoff/rainfall ratio is 23%. The simulated runoff/rainfall ratio is 45%. The simulated runoff/rainfall ratio is comparable to the simulated runoff/rainfall ratios computed at the upstream gage, but the gauged runoff/rainfall ratio is much lower. Because of the differences between the gauged flows at each location it was necessary to make a comparison of rainfall/runoff ratios during the period both gages operating simultaneously (4/1/2002 to 3/31/2003). The total recorded rainfall depth during this period is 60.4 inches. The gauged runoff/rainfall ratios are 31% upstream and 36% at this location. The simulated runoff/rainfall ratios are 35% upstream and 36% at this location.

Streamflow with similar characteristics should have similar flow duration curves. As you might expect from the unsatisfactory Nash-Sutcliffe statistic, the comparison of discharge duration curves show considerable differences. These differences occur at the high end and low end. At percent chance exceeded less than 3 (flow greater than 200 mgd) the simulated flow overestimates the gauged flow. At percent chance exceeded greater than 85 (flow less than 4 mgd) the simulated flow underestimates the gauged flow.

Table 3.L.17: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.48	8.73

Table 3.L.18: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02246318)	Simulated
Average	37.07	40.30
Median	16.16	14.15
Variance	4958.29	10514.68
Standard Deviation	70.42	102.54
Skew	5.07	7.59
Kurtosis	31.91	75.84
Minimum	0.09	0.06
Maximum	704.49	1446.49
Range	704.39	1446.43

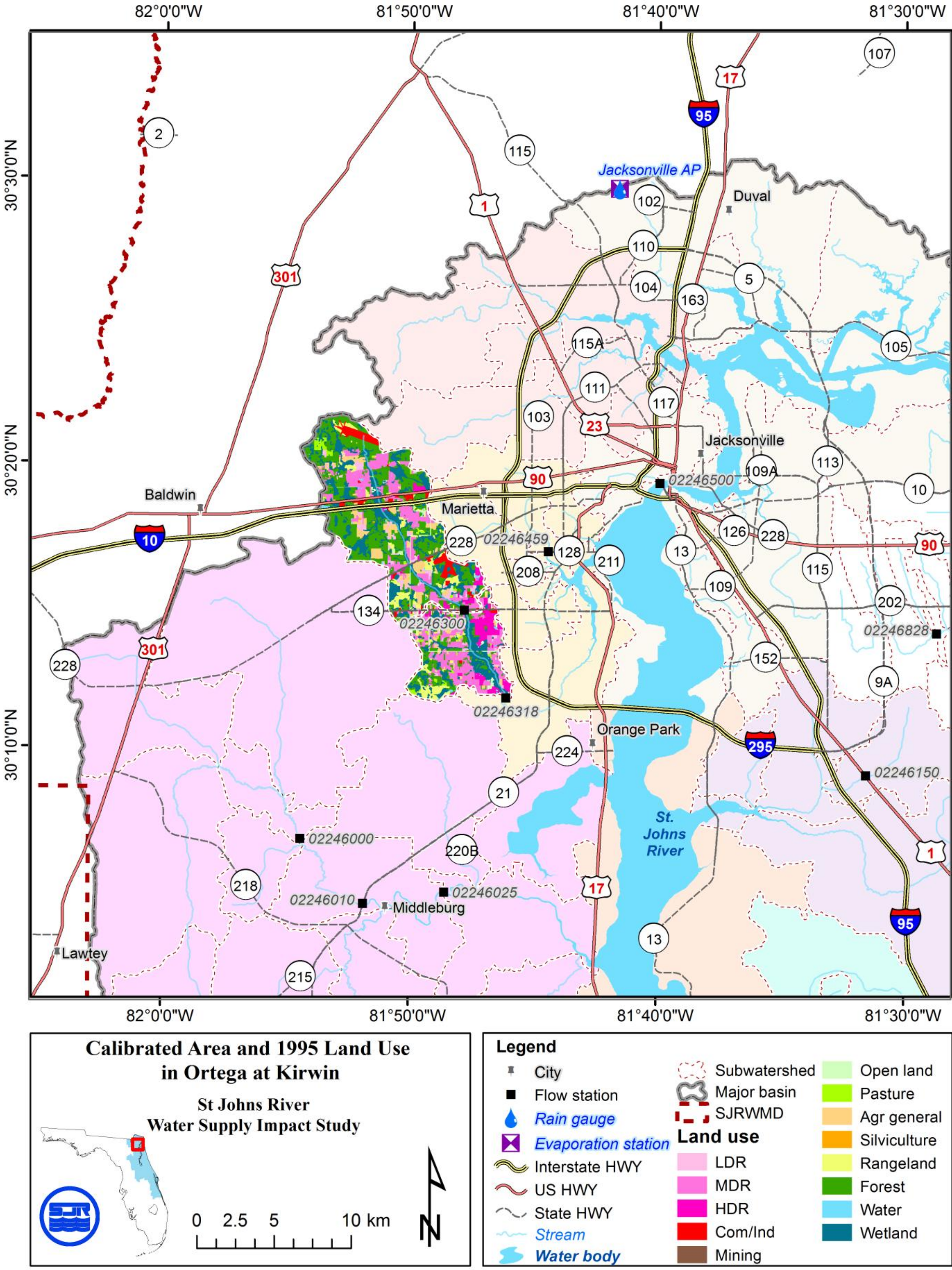

Figure 3.M.45: Ortega at Kirwin Road land use map

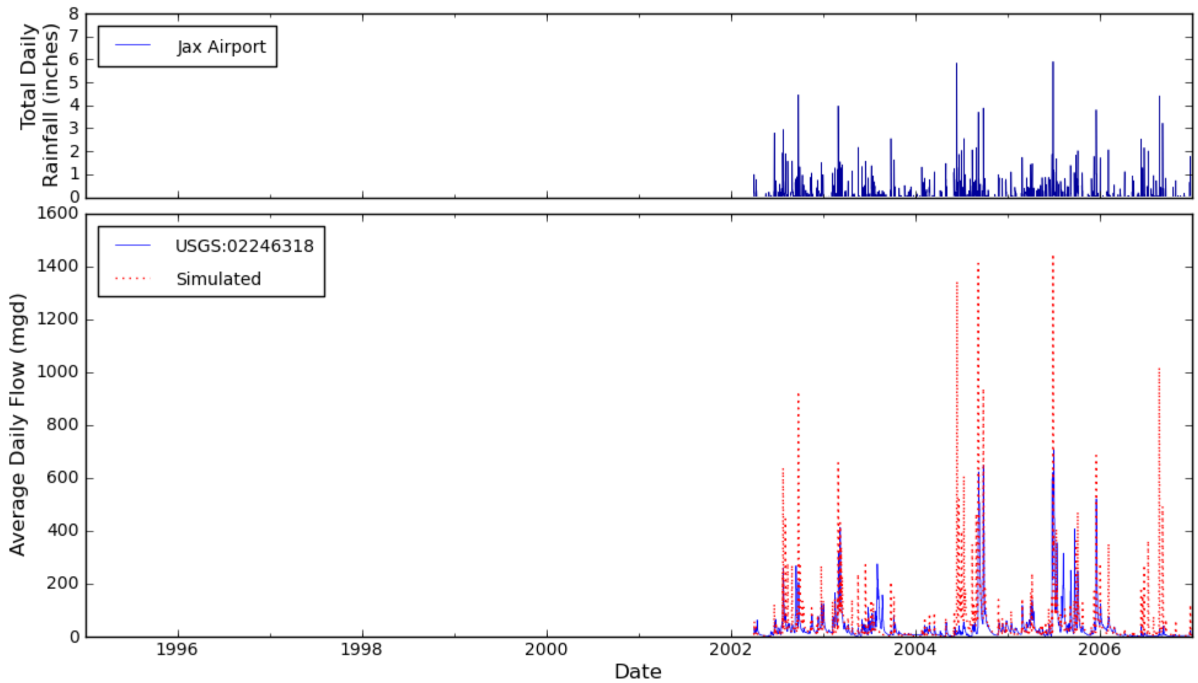

Figure 3.M.46: Ortega at Kirwin Road daily hydrograph

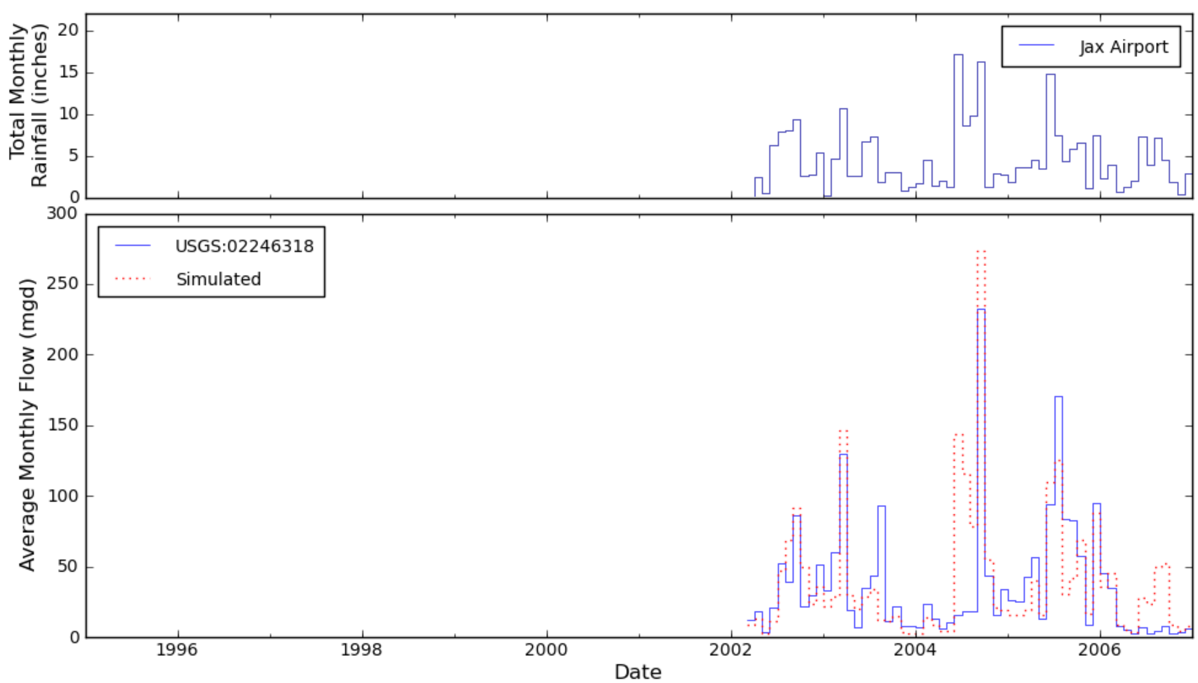

Figure 3.M.47: Ortega at Kirwin Road monthly hydrograph

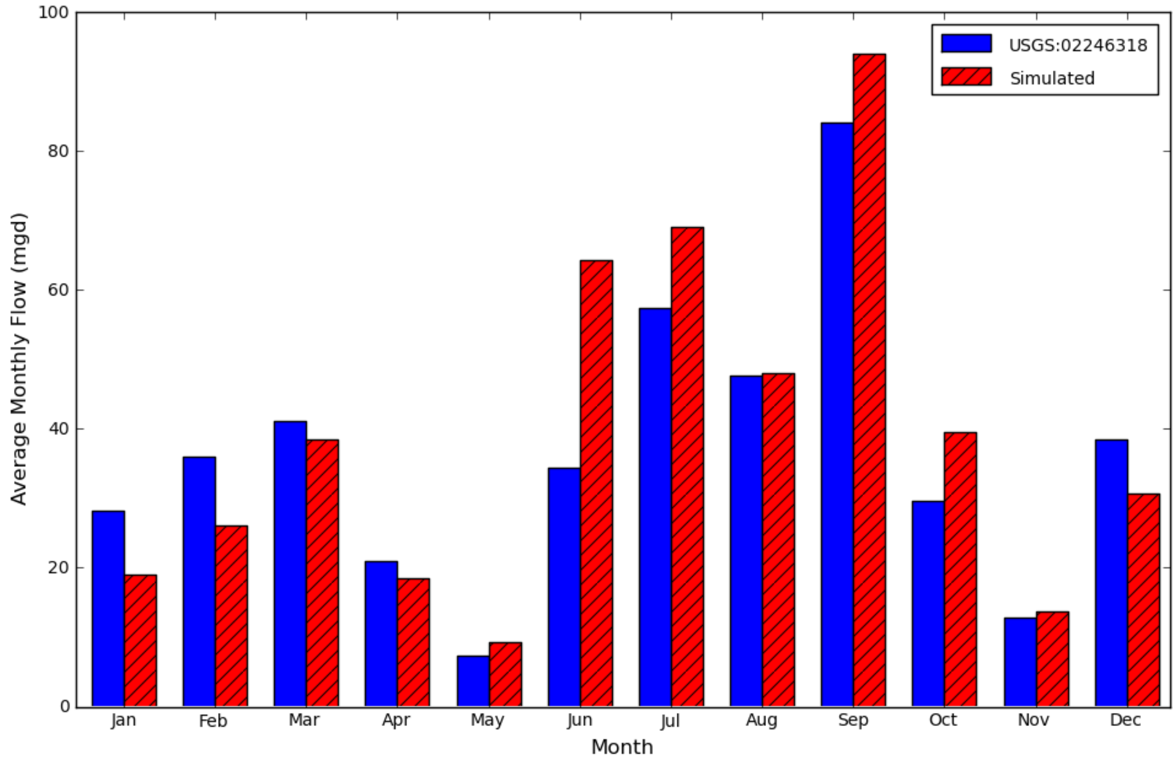

Figure 3.M.48: Ortega at Kirwin Road average monthly flow

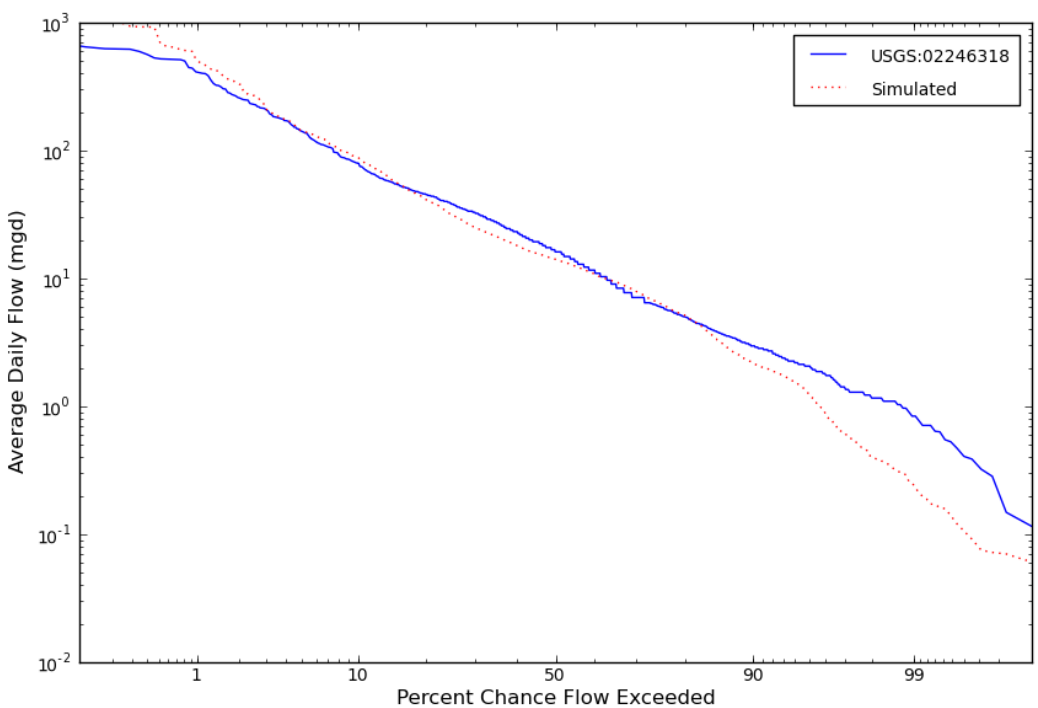

Figure 3.M.49: Ortega at Kirwin Road exceedance probability curve

3F Deep Creek Watershed

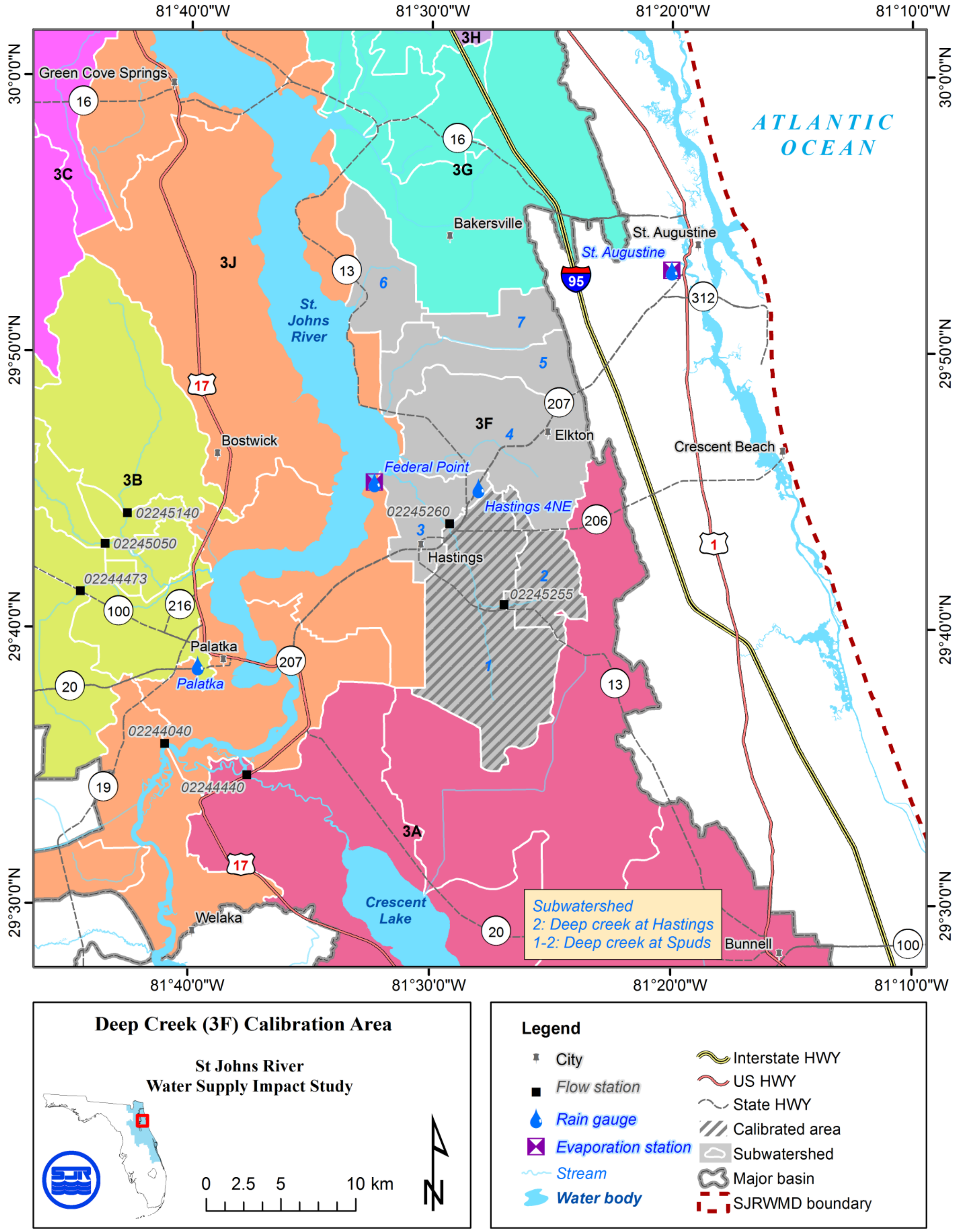

Figure 3.M.50: 3F Deep Creek Watershed calibration areas

3F DEEP CREEK WATERSHED. DEEP CREEK AT SPUDS SUBWATERSHEDS

The Deep Creek watershed model is calibrated over the period from 1/1/1995 to 12/31/2006. Two USGS gages in Deep Creek are used to compare simulated flow and adjust model parameters. The upstream gage is USGS gage 02245255, Deep Creek near Hastings, FL. The gage is located at the Cowpen Branch Road Bridge. The quality of the data is poor. The gage began recording in June 1975. The downstream gage is USGS gage 02245260, Deep Creek at Spuds, FL. The gage is located at the abandoned railway crossing. Again, the quality of the data is poor. The gage began recording in May 1992. Between the two gages, sixteen mile creek contributes significant tributary inflow.

Model calibration initially consisted of establishing the runoff relationships between land uses. Urban land, including impervious area, produces the most runoff, agricultural produces the next largest runoff, then open land and rangeland, then forest and wetland produce the least runoff. One set of model parameters are adjusted to obtain the best match between simulated and gauged flow at both gage locations. Again (as with calibration of Ortega River), it was discovered that adjusting one set of parameters to match flow reported from two gages increases the challenge of obtaining a good fit at both gage locations. Increased weight for matching daily flow and average daily flow was given to the downstream gage 02245260.

Calibration results at the USGS gage 02245255 are overall satisfactory. The Nash-Sutcliffe efficiency coefficient is 0.60 and the percent error of the mean discharge is -28.23. The large percent error of the mean discharge is due to placing more emphasis on matching the average daily flow at the downstream location.

Comparison of the simulated to gauged discharge hydrographs at both locations USGS gage 02245255 and USGS gage 02245260 shows that peak discharge is overestimated. The largest overestimates are at the downstream gage and for this reason this discussion will focus upon USGS gage 02245260. Two possible issues may contribute to overestimated peaks. First, the quality of the gauged data at both locations is rated poor and the gauged data may not closely represent the "real" discharge. Second, the recorded rainfall may not be representative of the rainfall over the drainage area. A closer look at three events may provide some explanation for the mismatched peak flows. The three events occur February 1998, September 2001, and September 2004. On February 17, 1998 at 1:00 AM, the recorded rainfall is 4.2 inches in one hour. Rainfall events of this intensity can be expected to produce a large peak simulated flow. The other two events are compared with the 10-year frequency event, 7.0 inches in 24 hours and 9.5 inches in 96 hours (Rao, 1988). The September 2001 recorded rainfall event is 7.1 inches in 24 hours and 10.7 inches in 96 hours. The September 2004 recorded rainfall event is 6.8 inches in 24 hours and 9.4 inches in 96 hours. Both rainfall events are comparable to the 10-year storm, and yet the corresponding gauged peak flow at gage 02245260 does not significantly increase over other peak flow events. It is expected that significant rainfall input should produce large simulated peak flow events.

To explain the significant percent error of mean discharge at USGS gage 02245255 it is useful to compare the runoff/rainfall ratios between the two gage locations over concurrent periods. Three periods are selected; summer 1995 (6/1/1995 to 10/31/1995), winter 1998 (9/1/1997 to

4/30/1998), and summer 2004 (6/1/2004 to 10/31/2004). The respective recorded rainfall over each period is 39.2 inches, 47.2 inches, and 43.2 inches. The drainage basin area upstream of gage 02245255 is 7,391 acres. The drainage basin area upstream of gage 02245260 is 33,789 acres. The gauged runoff/rainfall ratios at gage 02245255 in chronological order are 51%, 53%, and 72%. The gauged runoff/rainfall ratios at gage 02245260 in chronological order are 33%, 33%, and 52%. The area upstream of gage 02245255 is not more developed than the area downstream. In addition, agricultural irrigation practices are equivalent both upstream and downstream of gage 02245255 and contribute approximately equally to the runoff depths. Since no physical reason for the differences between the runoff/rainfall ratio could be found, the emphasis to match average flow at gage 02245260 resulted in underestimating the average flow at gage 02245255.

Discharge duration synthesis characterizes the flow of a creek by identifying the percent chance that a flow is exceeded. Streamflow with similar characteristics should have similar discharge duration curves. Comparison of the simulated versus gauged discharge duration curves at USGS gage 02245255 show that the simulated curve begins to drop below the gauged curve at about 90 percent. This indicates that flows of 0.4 mgd and less are underestimated. In addition, there is a range between 0.2 to 20 percent chance exceeded (7 mgd to 200 mgd) that flow is underestimated. This agrees with the underestimation of average flow at this gage. Finally, peak flows with less than 0.1 percent chance exceeded are not shown, but as previously discussed on the daily hydrograph, these infrequent peaks are overestimated.

Comparison of simulated versus gauged flow duration at USGS gage 02245260 shows that the curves are close between 0.4 to 92 percent chance exceeded (800 mgd to 0.9 mgd). Again, peak flows with 0.4 percent chance exceeded and smaller are overestimated. Low flows with 92 percent chance exceeded and greater (less than 0.9 mgd) are overestimated. The main reason for the divergence between the two curves during low flow is that the gauged flow at this location is tidally influenced resulting in negative flows that can not be emulated with HSPF’s hydrologic routing capabilities.

Table 3.L.19: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.68	0.34

Table 3.L.20: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02245260)	Simulated
Average	39.21	39.34
Median	14.87	12.51
Variance	9255.69	16883.80
Standard Deviation	96.21	129.94
Skew	7.09	14.47
Kurtosis	70.36	305.07
Minimum	-40.07	0.00
Maximum	1602.87	3686.96
Range	1642.94	3686.96

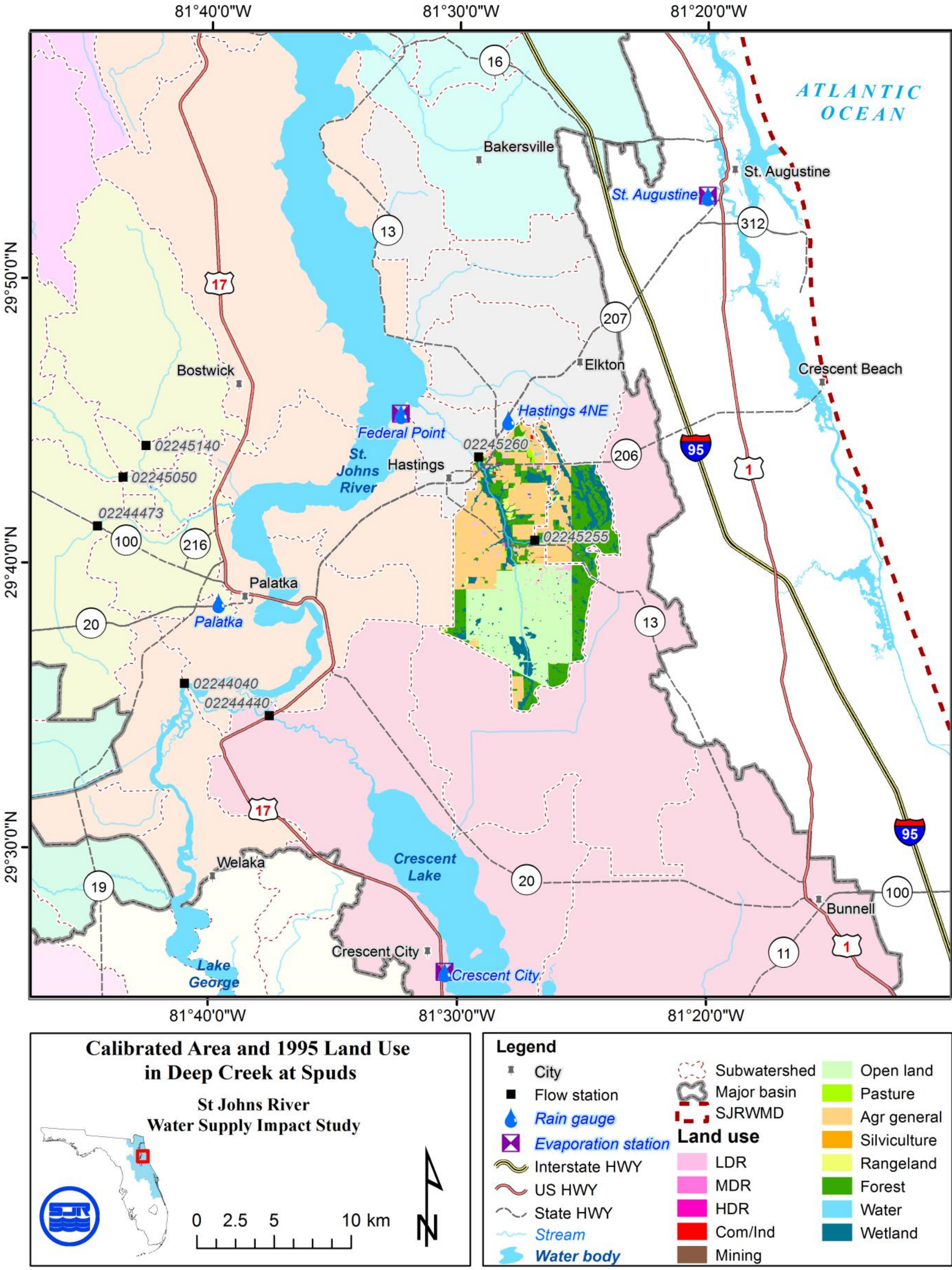

Figure 3.M.51: Deep Creek at Spuds land use map

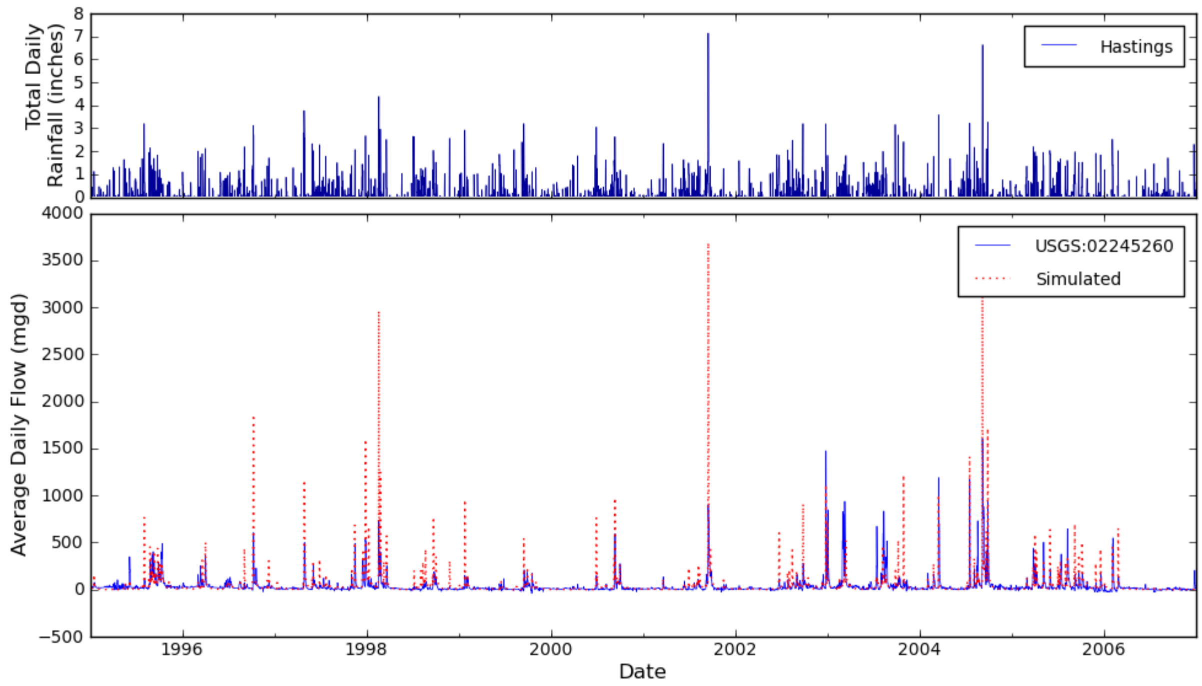

Figure 3.M.52: Deep Creek at Spuds daily hydrograph

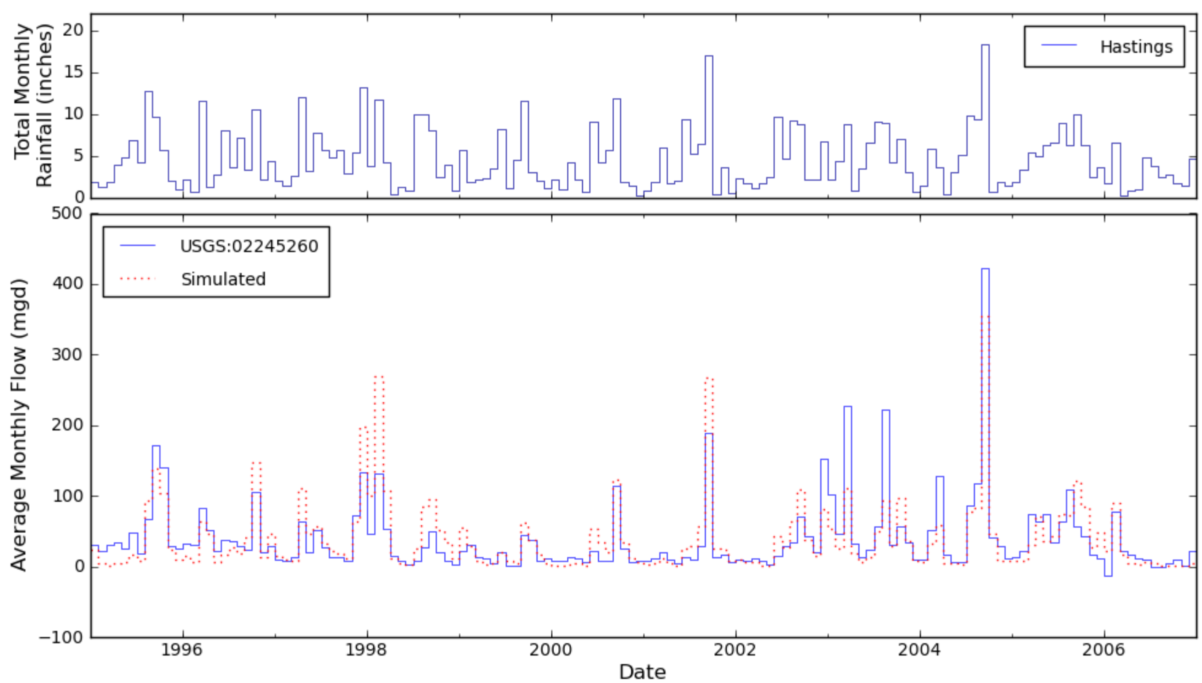

Figure 3.M.53: Deep Creek at Spuds monthly hydrograph

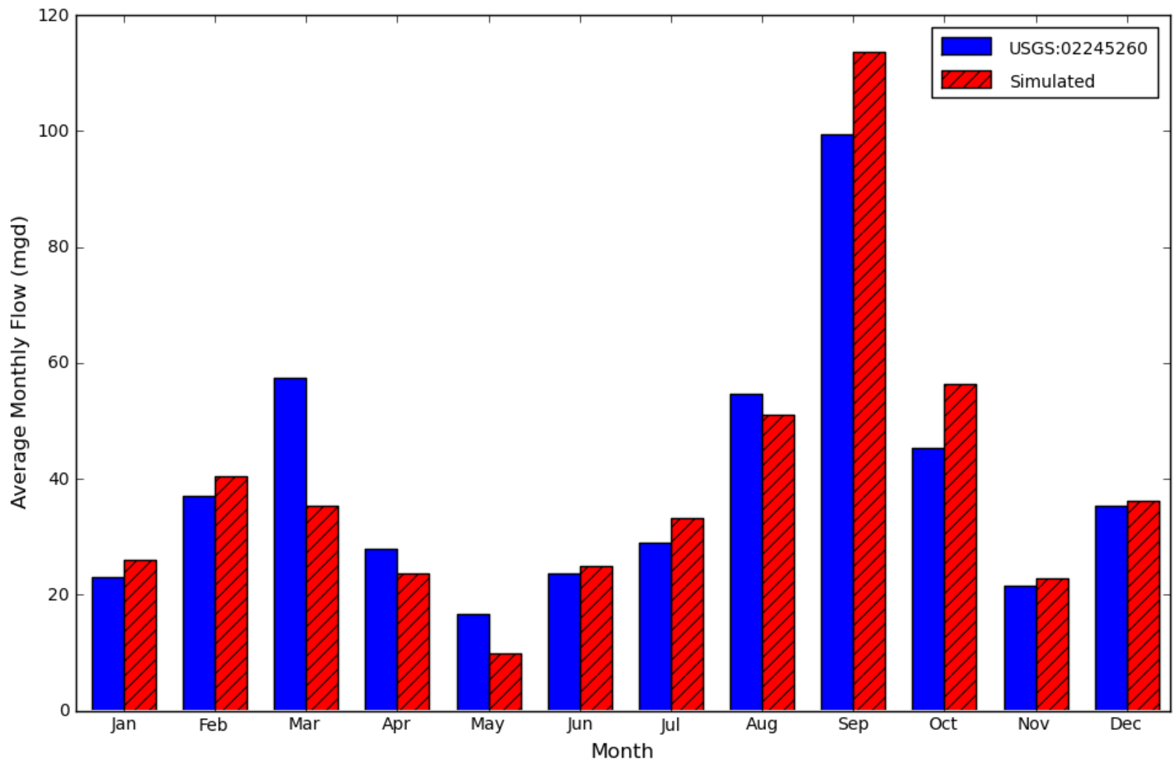

Figure 3.M.54: Deep Creek at Spuds average monthly flow

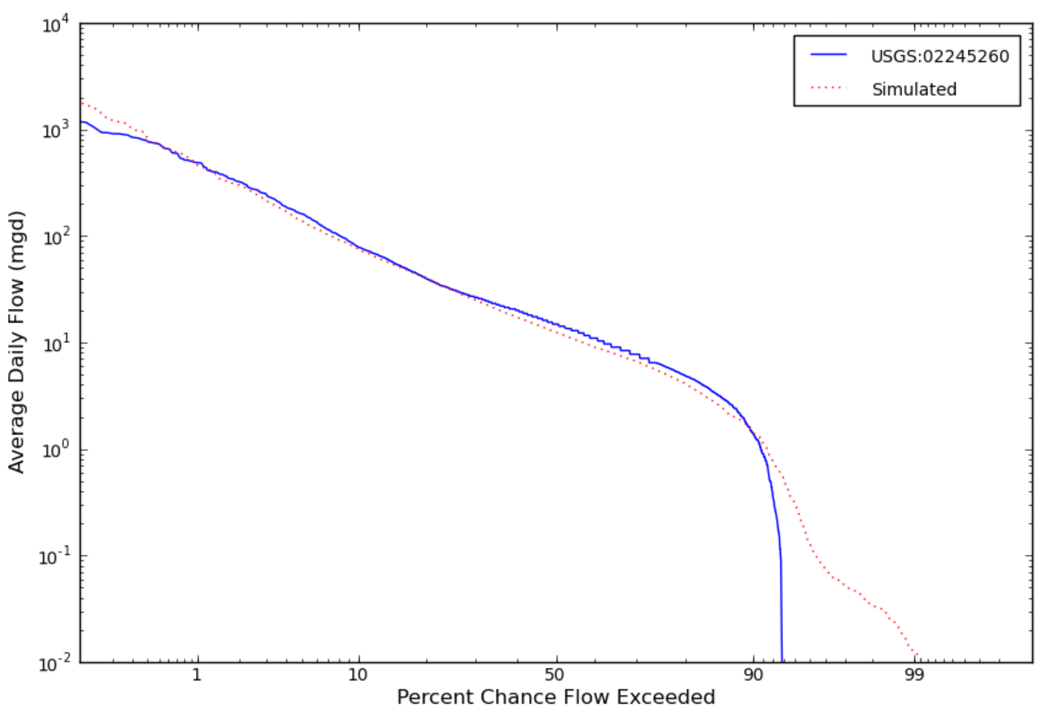

Figure 3.M.55: Deep Creek at Spuds exceedance probability curve

3F Deep Creek Watershed. Deep Creek near Hastings Subwatersheds

Please refer to the discussion in the appendix section titled ‘3F Deep Creek Watershed. Deep Creek at Spuds Subwatersheds.’

Table 3.L.21: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.60	-28.23

Table 3.L.22: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02245255)	Simulated
Average	8.91	6.40
Median	2.13	2.39
Variance	670.97	505.71
Standard Deviation	25.90	22.49
Skew	7.64	15.65
Kurtosis	90.83	348.43
Minimum	0.00	0.00
Maximum	546.14	659.29
Range	546.14	659.29

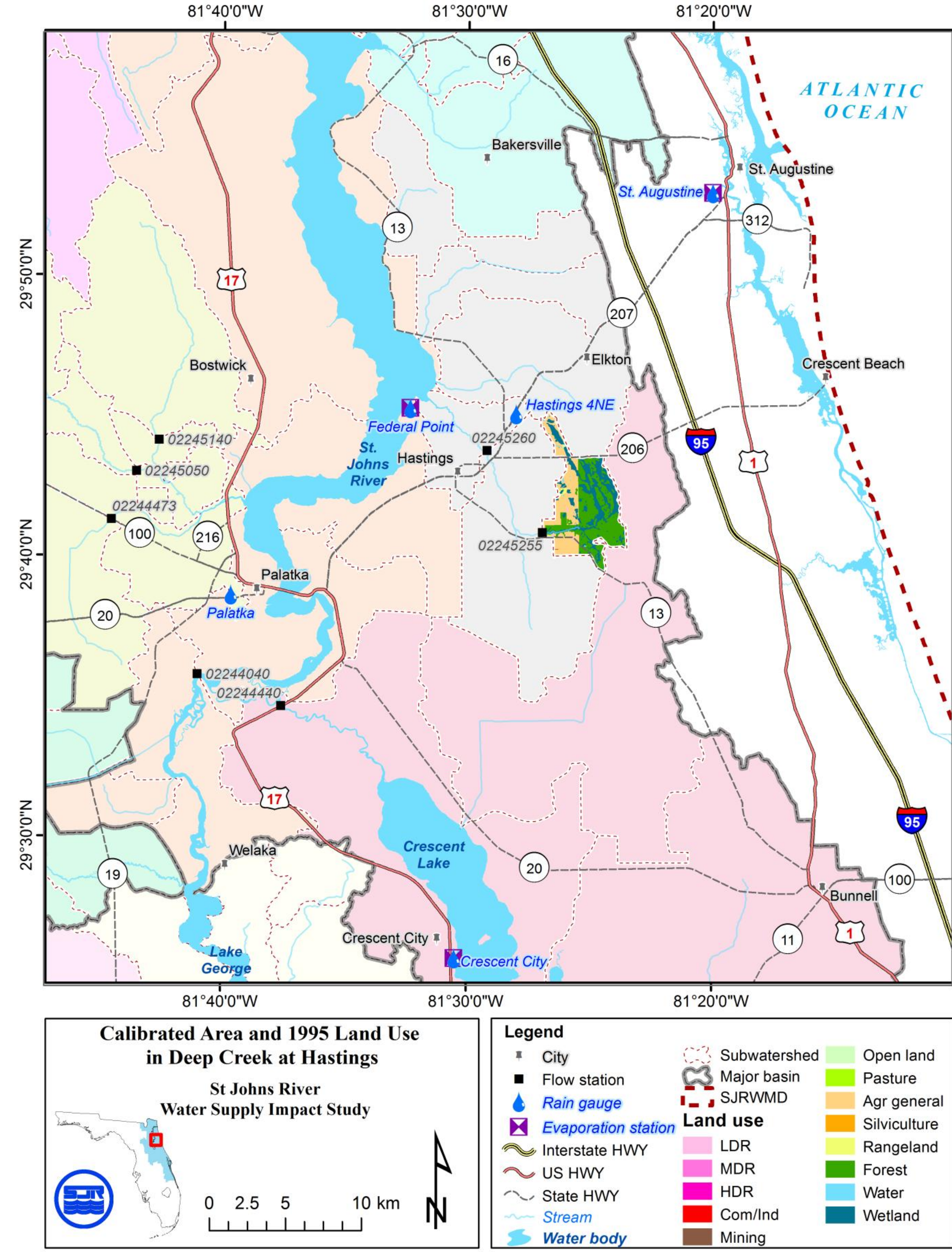

Figure 3.M.56: Deep Creek near Hastings land use map

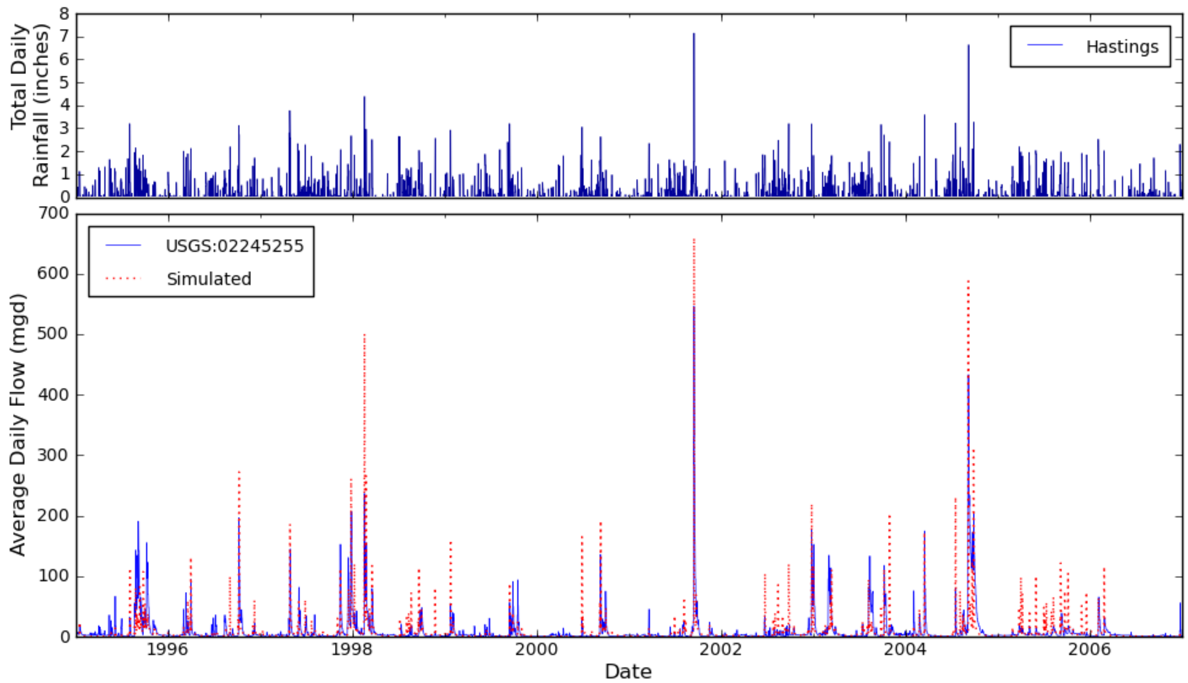

Figure 3.M.57: Deep Creek near Hastings daily hydrograph

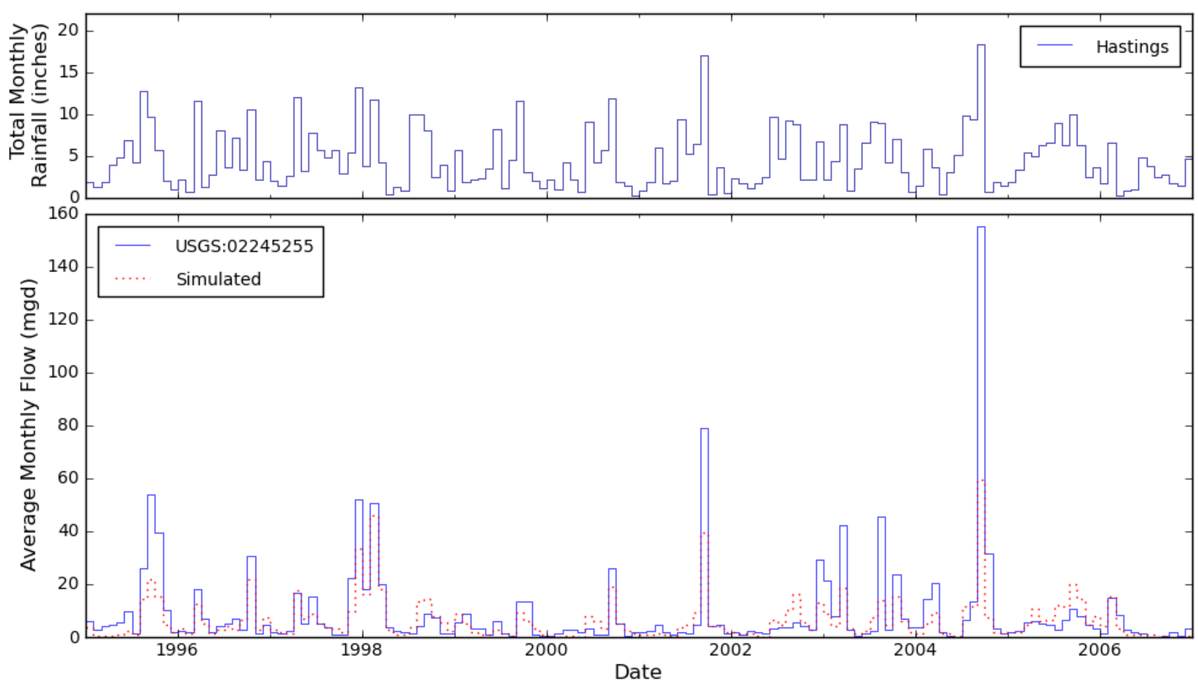

Figure 3.M.58: Deep Creek near Hastings monthly hydrograph

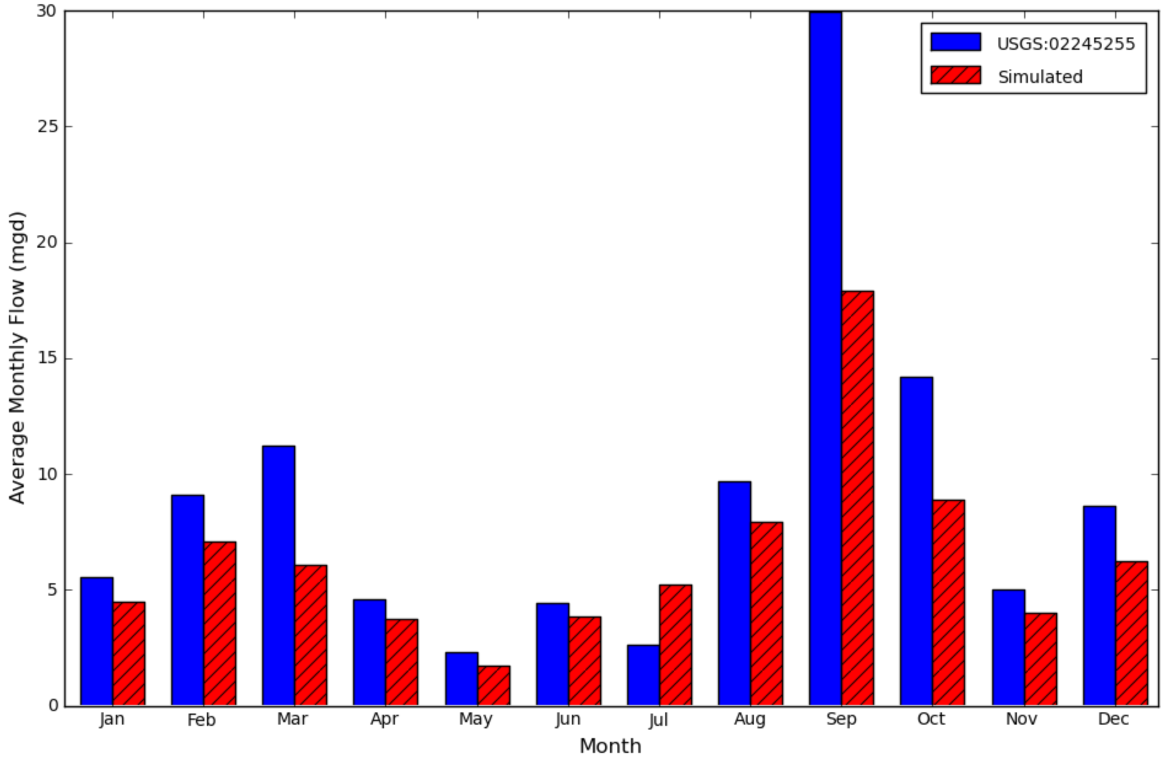

Figure 3.M.59: Deep Creek near Hastings average monthly flow

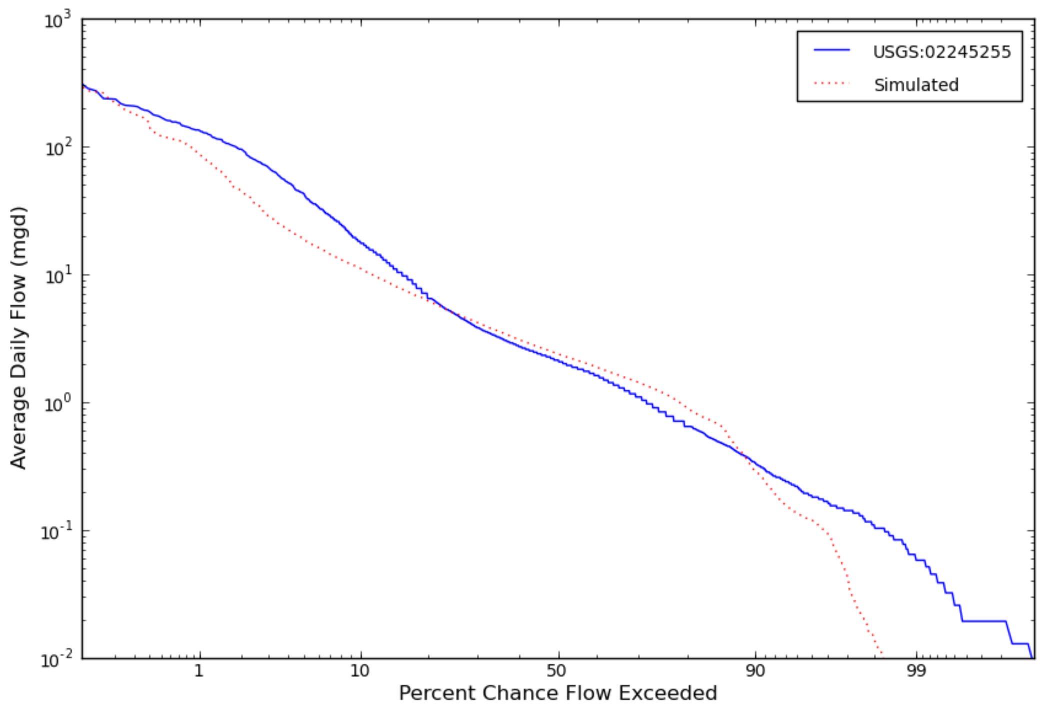

Figure 3.M.60: Deep Creek near Hastings exceedance probability curve

3H BIG DAVIS WATERSHED

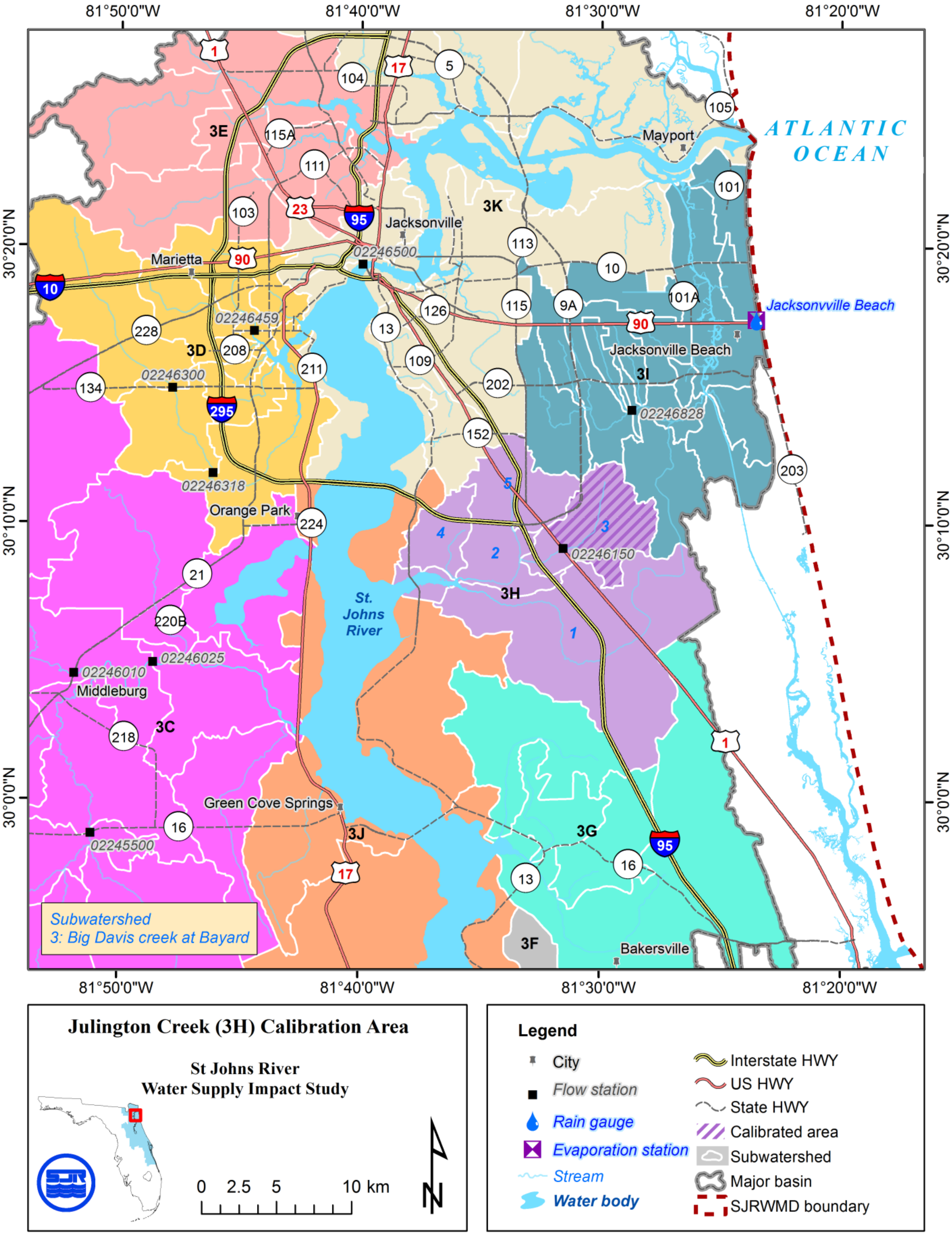

Figure 3.M.61: 3H Big Davis Watershed calibration areas

3H Big Davis Watershed. Big Davis Creek at Bayard Subwatersheds

The Julington Creek Basin (LSJR 3H) is located on the eastern bank of the St. Johns River and extends over the southern part of Duval County and the northern part of St. Johns County. The drainage area is approximately 97 square miles.   Major tributaries include Durbin Creek (sub-watersheds 5 and 2), Big Davis Creek (subwatershed 3), Oldfield Creek (subwatershed 4), and Julington Creek (subwatersheds 5 and 2). Elevations are near sea level at the conference with the St. Johns River and 30 ft NGVD inland.

The Julington Creek watershed model was calibrated at the USGS Big Davis Creek at Bayard gage station (02246150), located at the downstream end of culvert on U.S. Highway 1, 2.0 mile upstream from mouth. The total contributory drainage (upper portion of the subwatershed 3) area is 13.3 squared miles at the gage site.   St. Augustine Beach rainfall and Jacksonville Beach ET data were used for calibration of the hydrological model. The calibration period was from 1995 to 2006.

Parameters Estimation Program (PEST) was applied for the HSPF model calibration, according to the Common Logic model calibration guideline and ranges. The observed mean annual discharge during 1995 to 2006 is 17.6mgd (11.4 cfs). As the results of the model performance shows, the simulated discharge were 17.2mgd (11.1 cfs). The model monthly goodness-of-fit statistics resulted in a monthly Nash-Sutcliffe coefficient of 0.65.   During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the watershed.

Table 3.L.23: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.65	-1.79

Table 3.L.24: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02246150)	Simulated
Average	7.32	7.19
Median	3.10	3.18
Variance	211.87	166.78
Standard Deviation	14.56	12.91
Skew	7.53	6.32
Kurtosis	90.30	68.95
Minimum	0.00	0.22
Maximum	305.71	253.14
Range	305.71	252.92

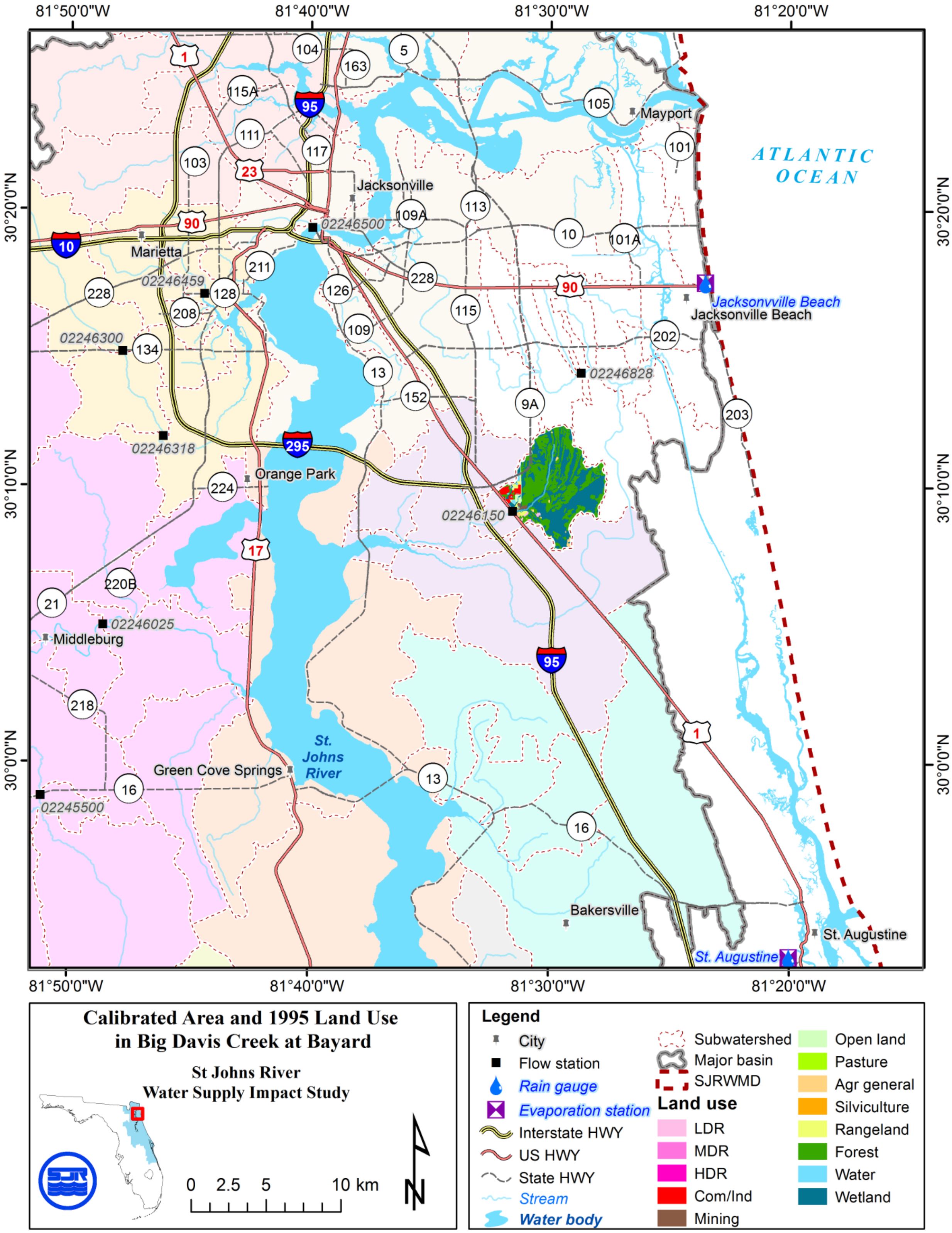

Figure 3.M.62: Big Davis Creek at Bayard land use map

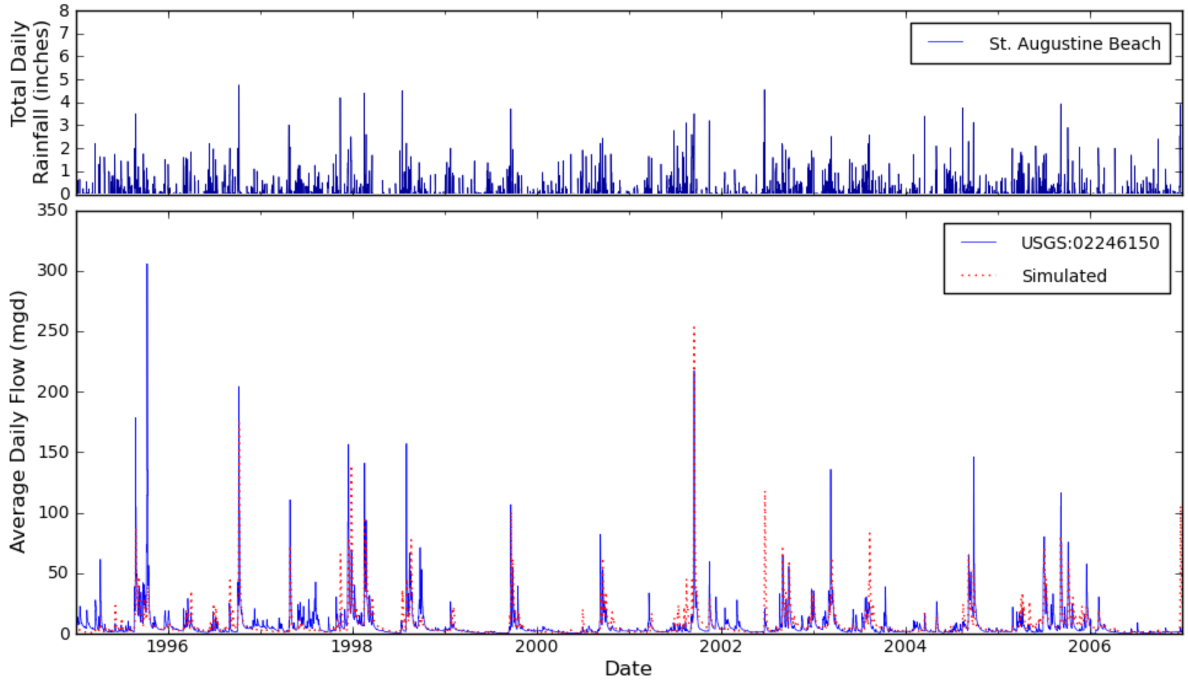

Figure 3.M.63: Big Davis Creek at Bayard daily hydrograph

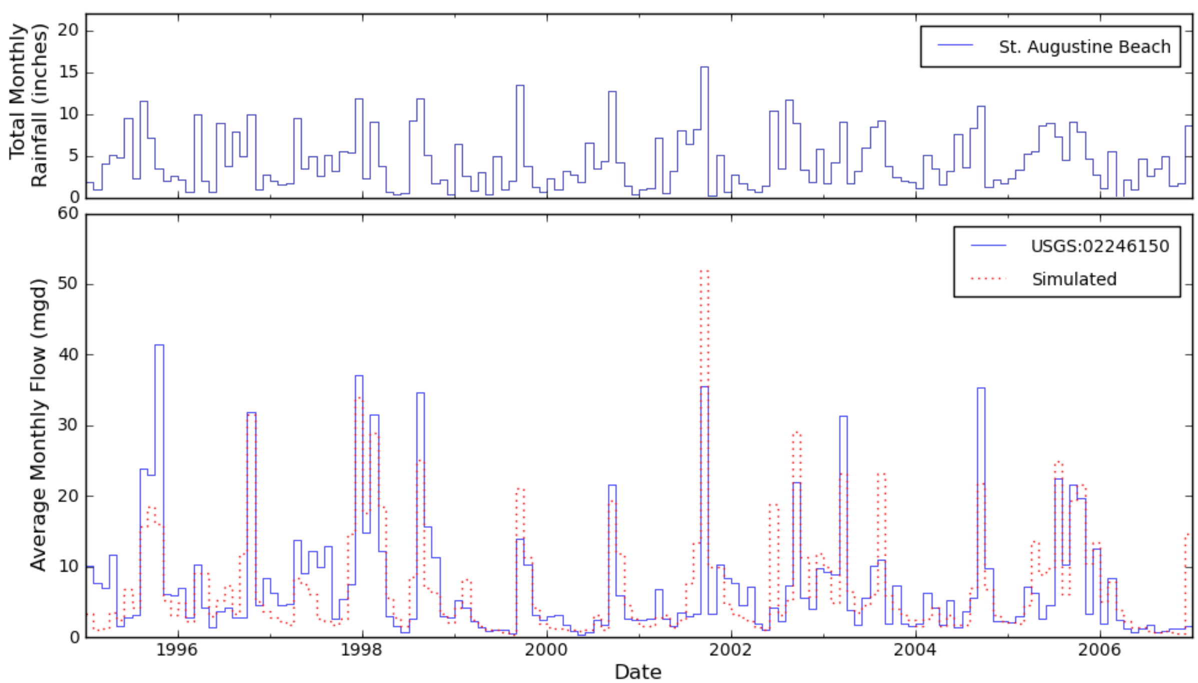

Figure 3.M.64: Big Davis Creek at Bayard monthly hydrograph

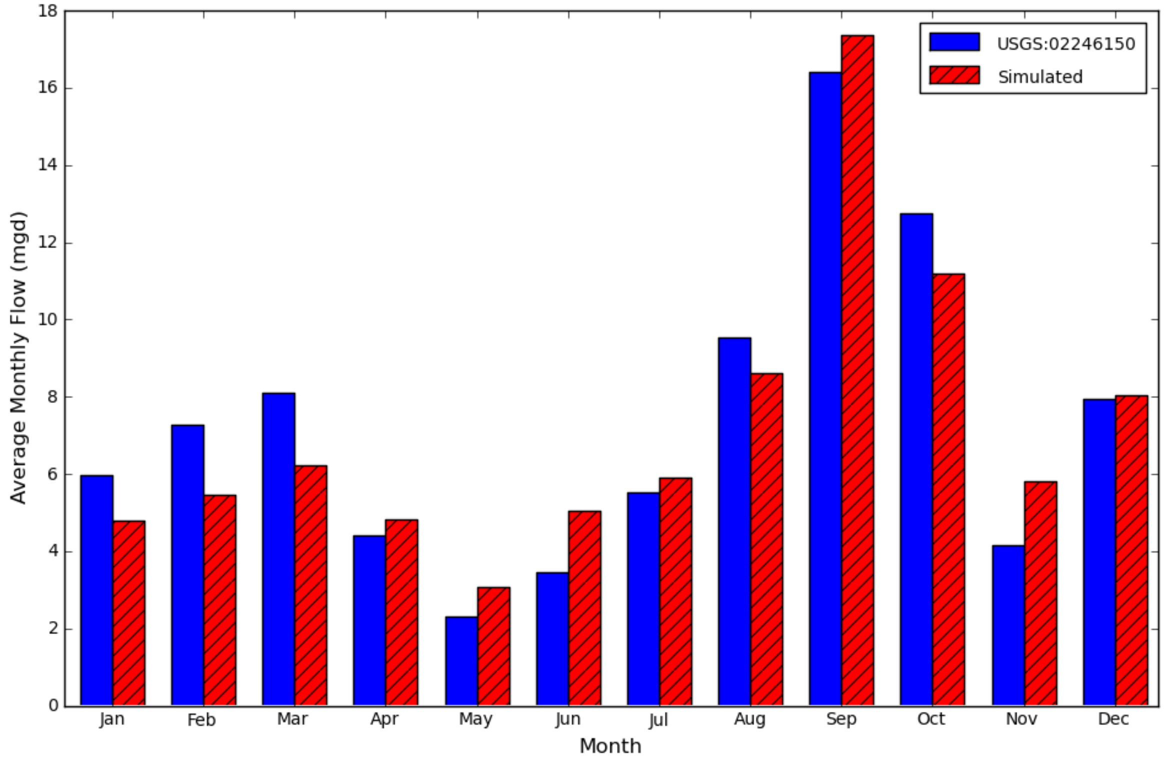

Figure 3.M.65: Big Davis Creek at Bayard average monthly flow

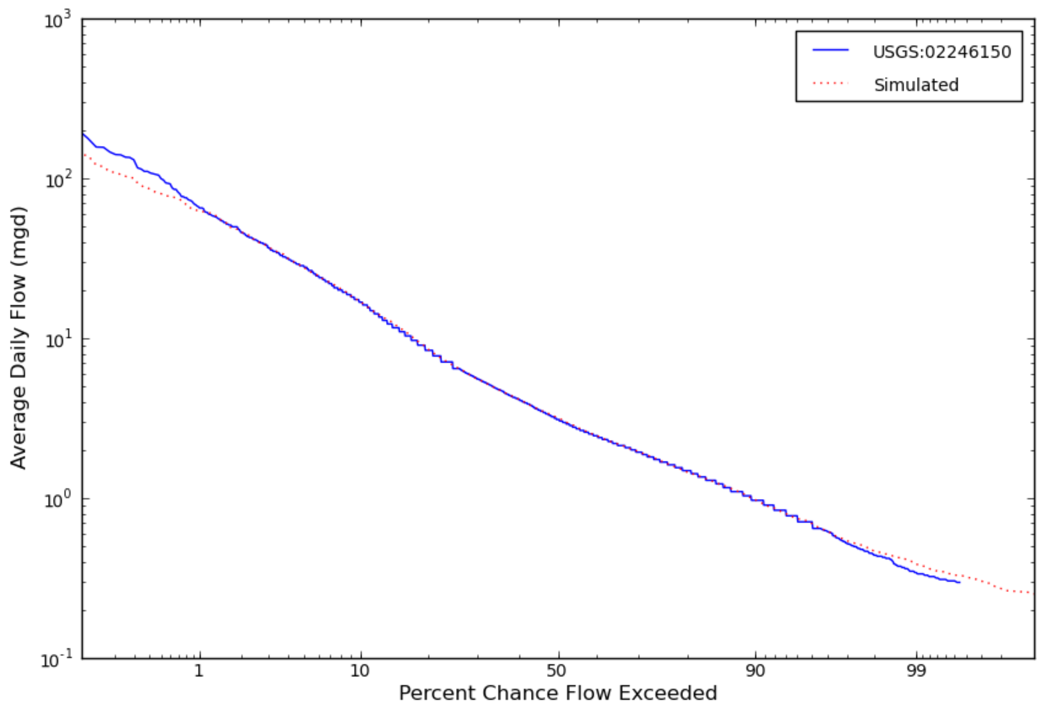

Figure 3.M.66: Big Davis Creek at Bayard exceedance probability curve

3I PABLO CREEK WATERSHED

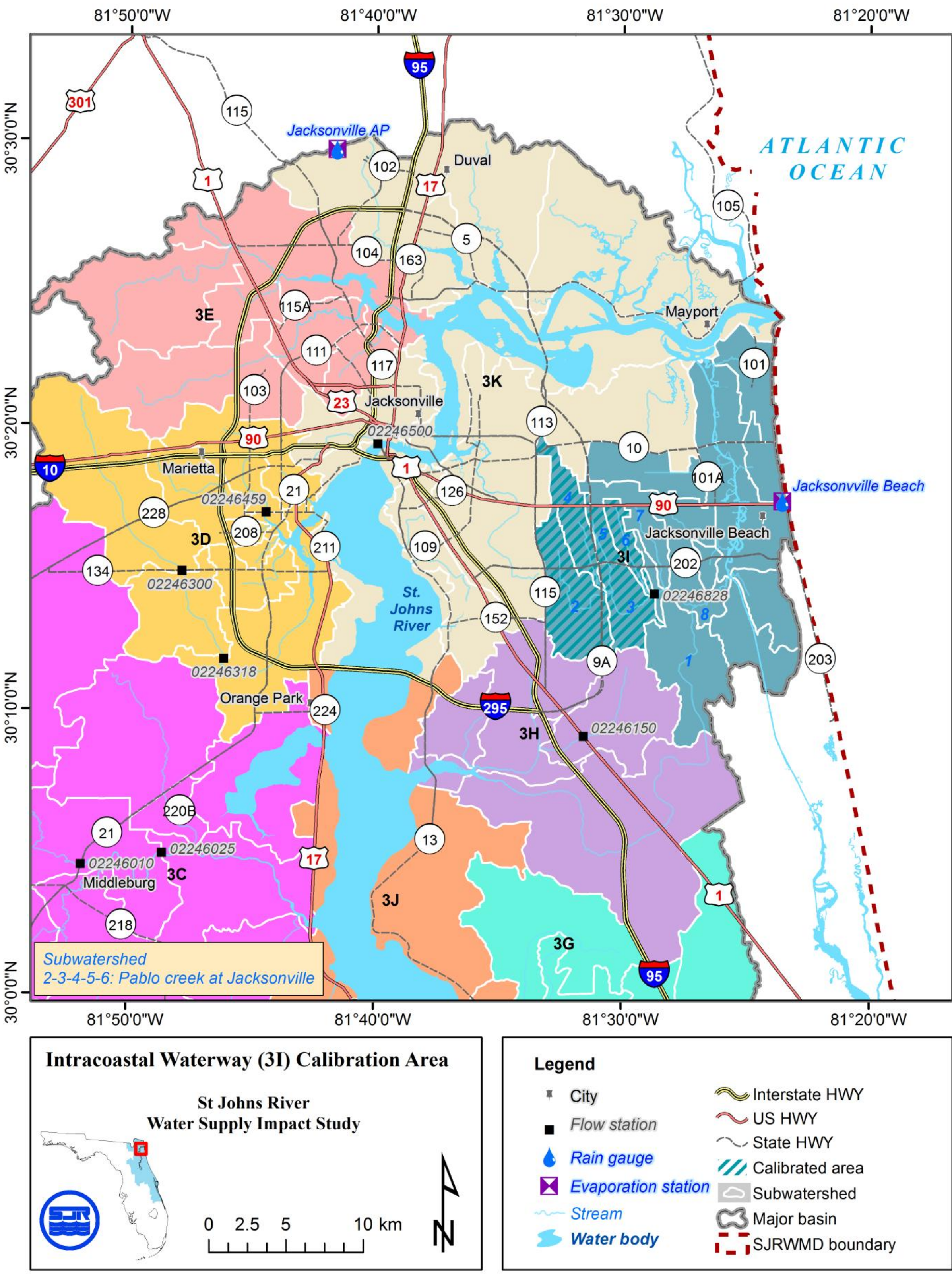

Figure 3.M.67: 3I Pablo Creek Watershed calibration areas

3I Pablo Creek Watershed. Pablo Creek at Jacksonville Subwatersheds

Pablo Creek is a dendritic tributary basin. The Pablo Creek Basin is at the western portion of the ICW with a total area of 49 square miles. The USGS Pablo Creek Gage Station (02246828) was located 0.5 mile upstream of Cedar Swamp Creek, 4.8 mile upstream from the mouth and 12.5 mile southeast of Main Street Bridge in Jacksonville. The 27 square miles contributing storm water from Puncheon Swamp Branch, Mill Dam Branch, Sawmill/Buckhead Branch, Ryals Swamp (subwatersheds 2, 4, 5, 6) were measured at this gage station in the middle of Pablo Creek (subwatershed 3). Box Branch (subwatershed 1) and Cedar Swamp (subwatershed 7) enter Pablo Creek downstream (subwatershed 8).

Jacksonville Beach rainfall and evaporation stations were used, although the coastal rainfall may not be fully representable for inland watershed. In August 1995, Jacksonville Beach had 30 inches of rainfall, which may have been from very localized storms. The calibration period for the HSPF Mode was from October 1995 to September 2002. The Pablo Creek gage station 02246828 was discontinued after that.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration according to the Common Logic model parameters guideline and ranges. As the results of the model performance shows (Appendix N), the observed annual mean discharge for water year 1995 to 2002 was 56.3 mgp (38.2 cfs). The simulated discharge over the calibration was 55.7 mgp (36.4 cfs). The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.65. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. In addition, simulated and observed stages are compared at the calibration sites. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the watershed.

Table 3.L.25: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.65	-4.93

Table 3.L.26: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02246828)	Simulated
Average	24.74	23.52
Median	12.28	11.63
Variance	1964.89	1743.96
Standard Deviation	44.33	41.76
Skew	9.61	6.09
Kurtosis	168.70	56.78
Minimum	0.52	1.19
Maximum	1079.35	690.79
Range	1078.83	689.60

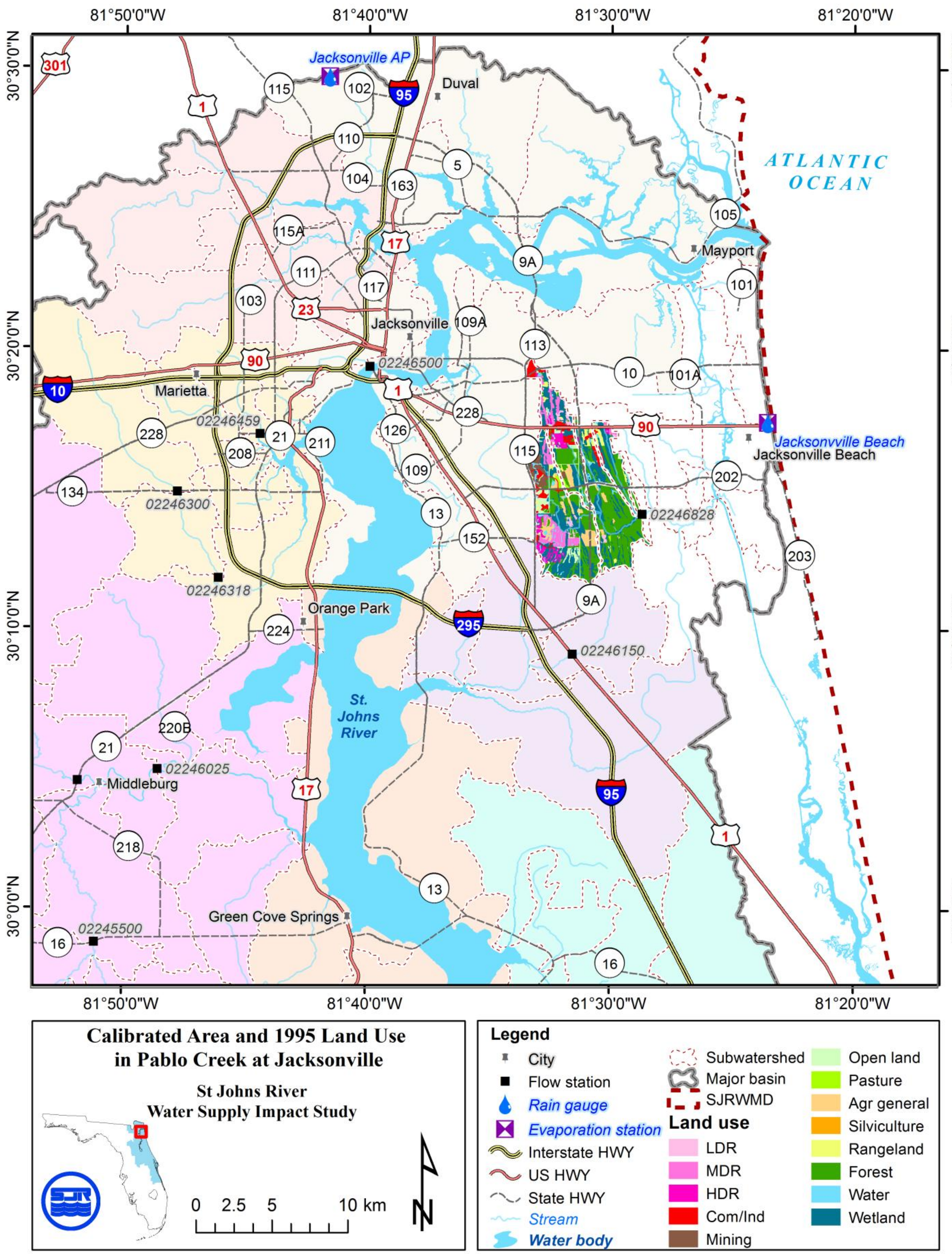

Figure 3.M.68: Pablo Creek at Jacksonville land use map

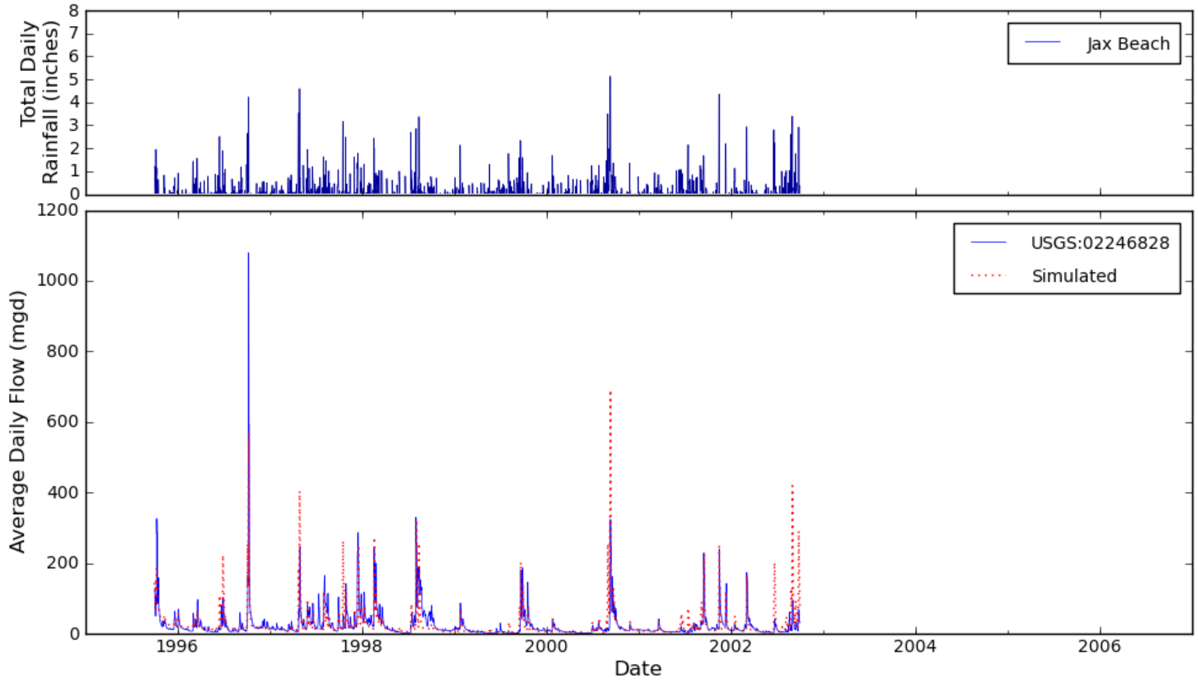

Figure 3.M.69: Pablo Creek at Jacksonville daily hydrograph

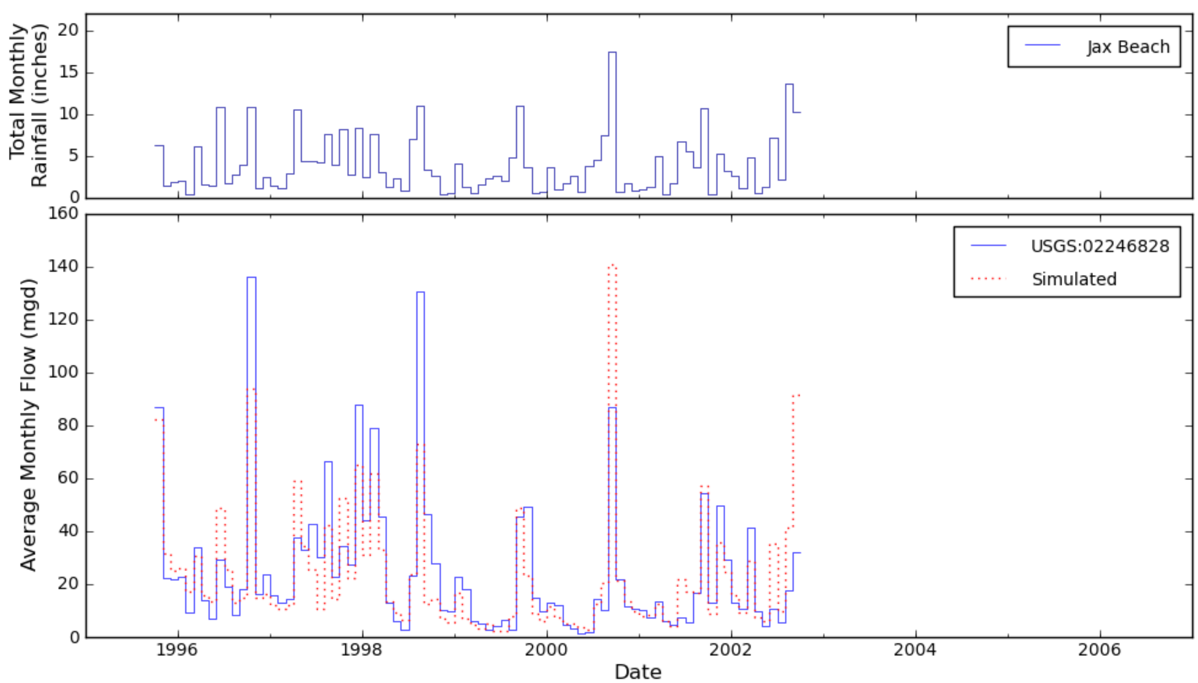

Figure 3.M.70: Pablo Creek at Jacksonville monthly hydrograph

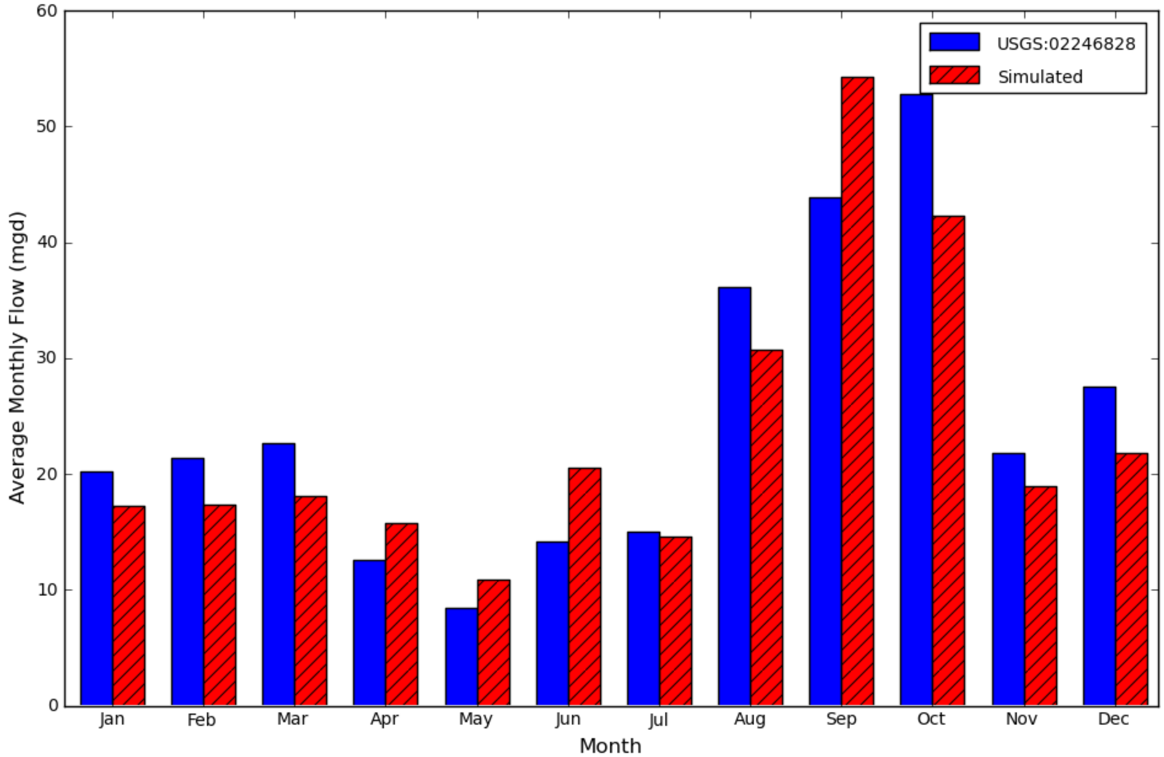

Figure 3.M.71: Pablo Creek at Jacksonville average monthly flow

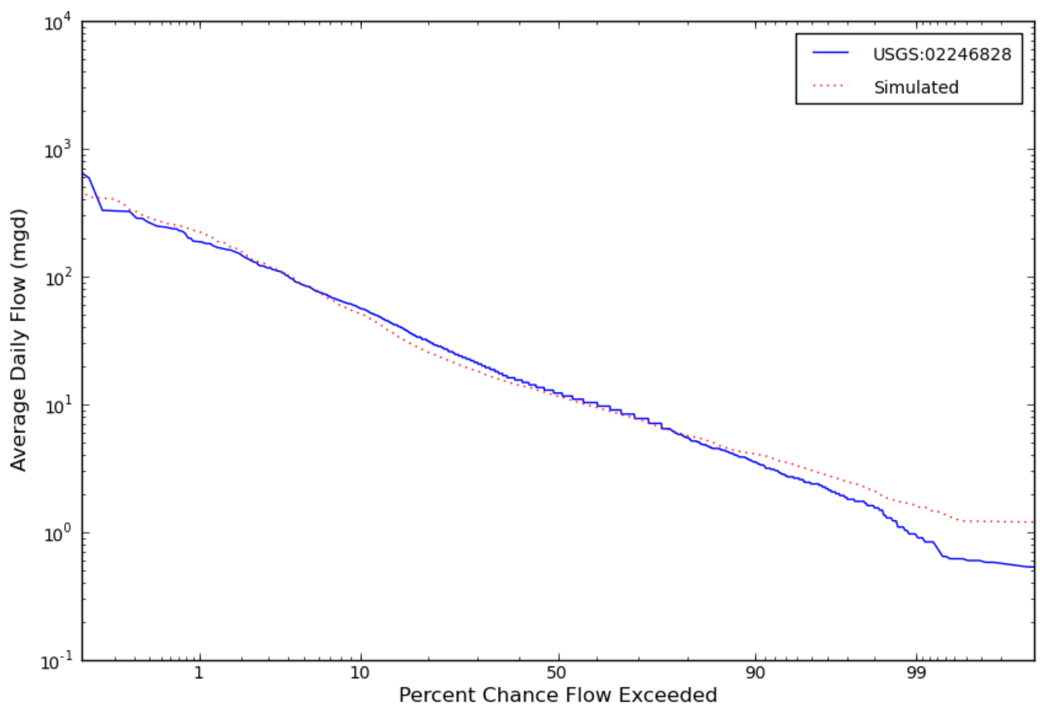

Figure 3.M.72: Pablo Creek at Jacksonville exceedance probability curve