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

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

U.S. Environmental Protection Agency (EPA) sponsored public domain Hydrological Simulation Program – FORTRAN (HSPF) models have been deployed (i.e., development, calibration, verification, prediction), by the Watershed Systems Group of the Hydrologic Systems Branch in the Coastal and Hydraulics Laboratory at the U.S. Army Engineer Research and Development Center, to the Sinclair and Dyes Inlet watershed in Kitsap County, Washington, USA (see Figure 1) in support of ongoing technical studies for the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Environmental Investment (ENVVEST) project

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

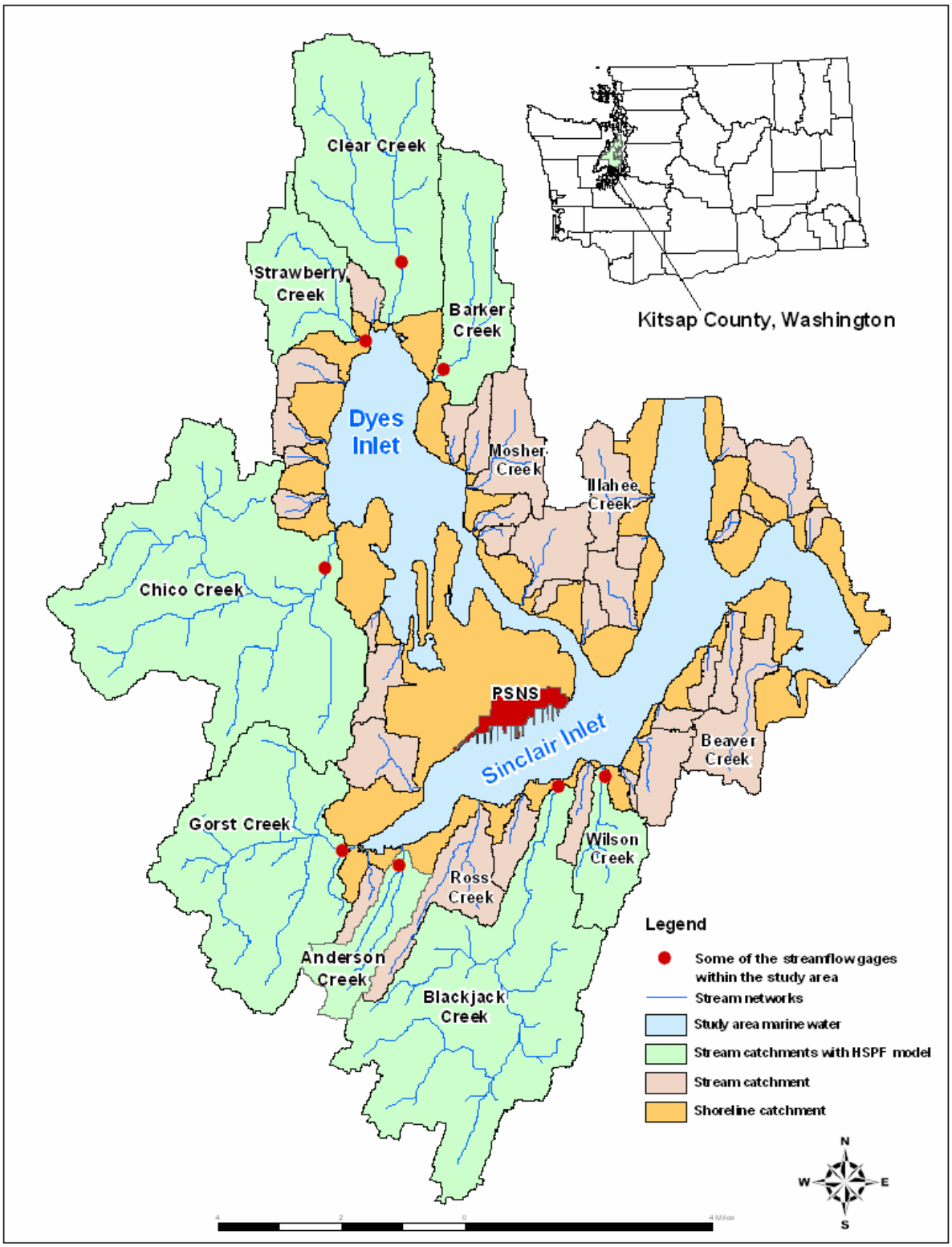

Figure 1. PSNS & IMF Project ENVVEST Study Area.

Representative HSPF hydrologic model calibration results that were obtained for the approximately 42 square kilometer Chico Creek watershed located in Kitsap County, Washington, USA. The HSPF model includes separate submodels for the drainage areas upstream of five streamflow gaging stations (Kitsap Creek, Wildcat Creek, Chico Creek Tributary at Taylor Road, Dickerson Creek, and Chico Creek mainstem) located within the watershed. The location of the Chico Creek Watershed in Kitsap County is depicted in Figure 2.

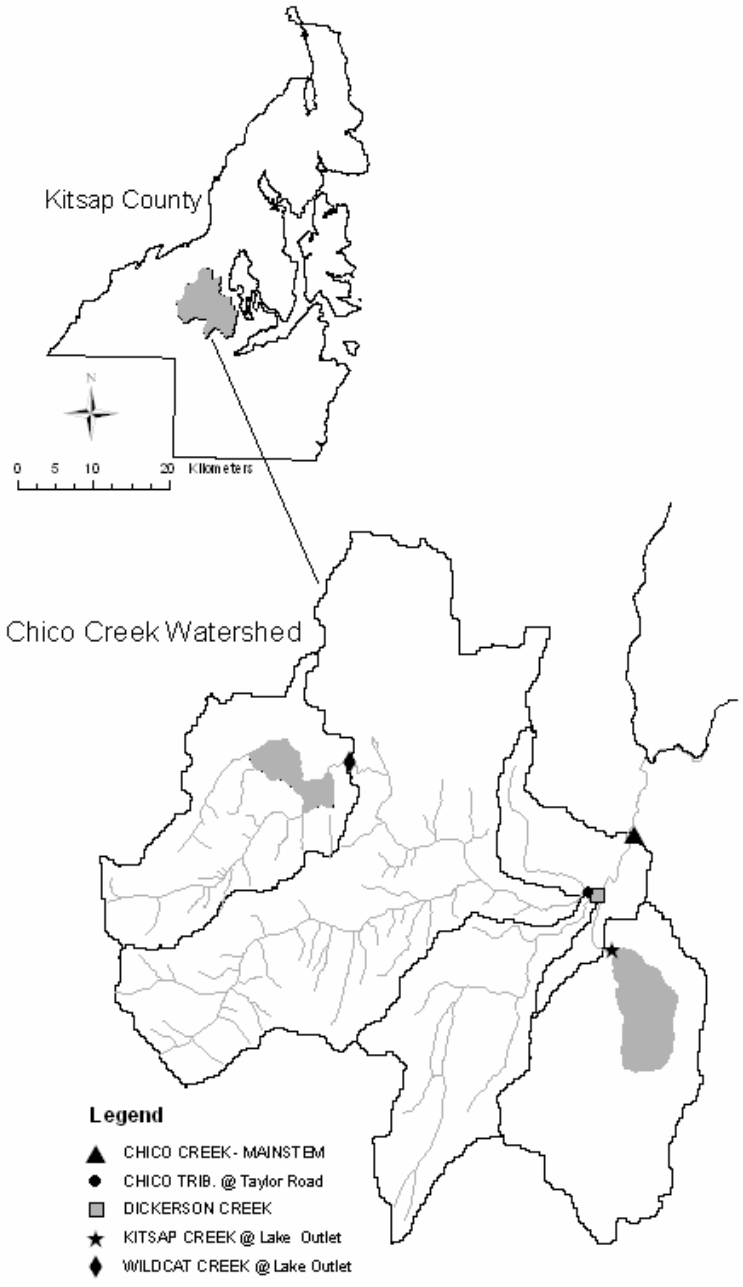

Figure 2. Location of the Chico Creek watershed in Kitsap County, Washington, USA.

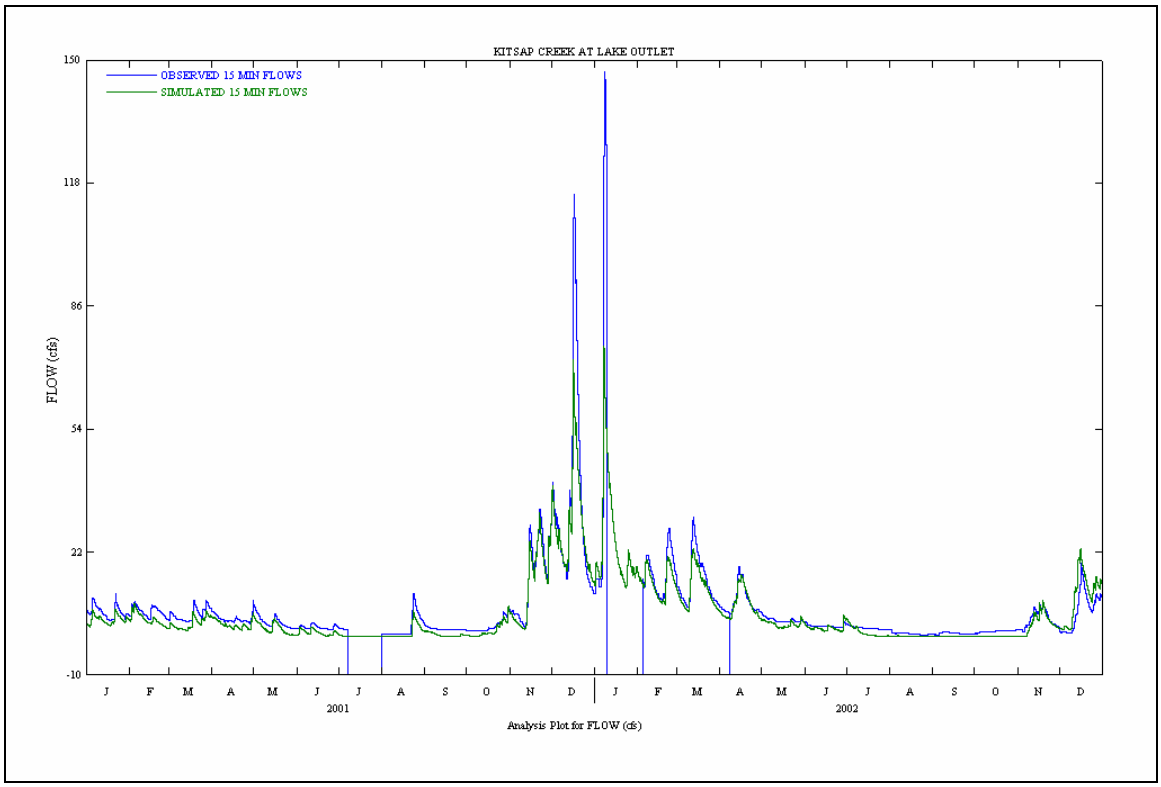

Figure 3. Calibrated model results for Kitsap Creek at Lake Outlet.

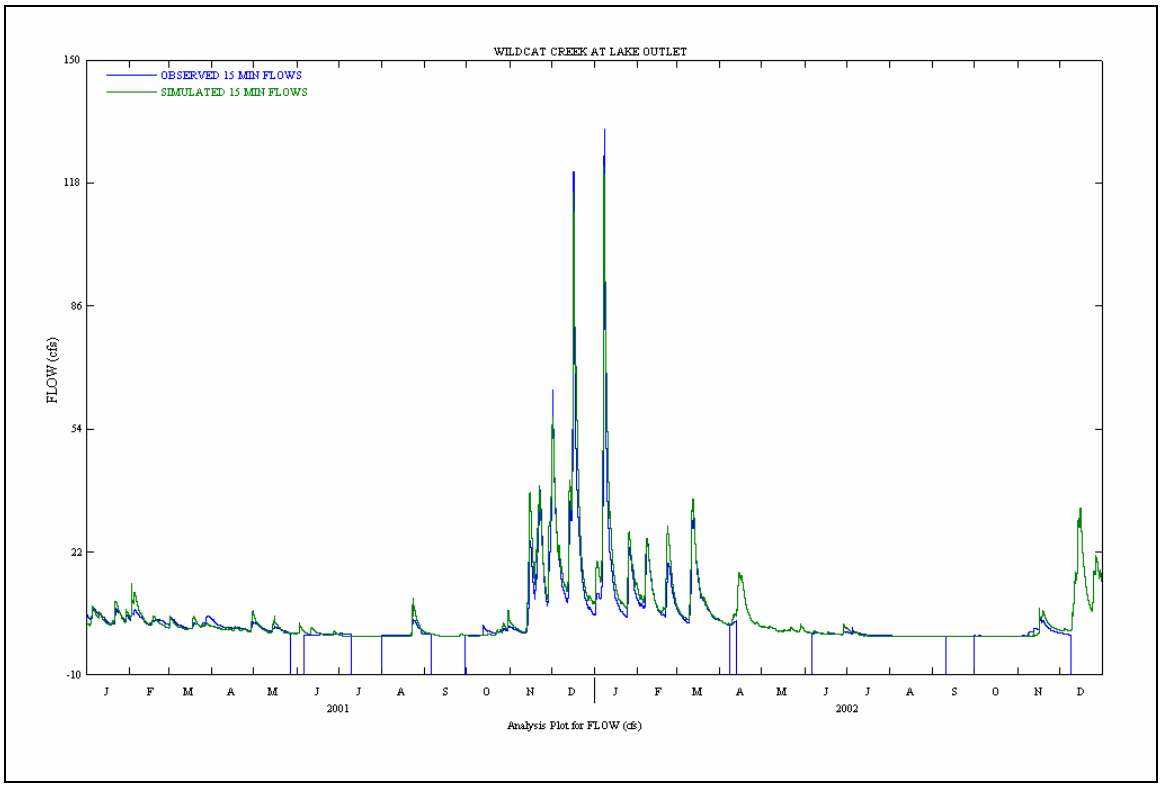

Figure 4. Calibrated model results for Wildcat Creek at Lake Oulet.

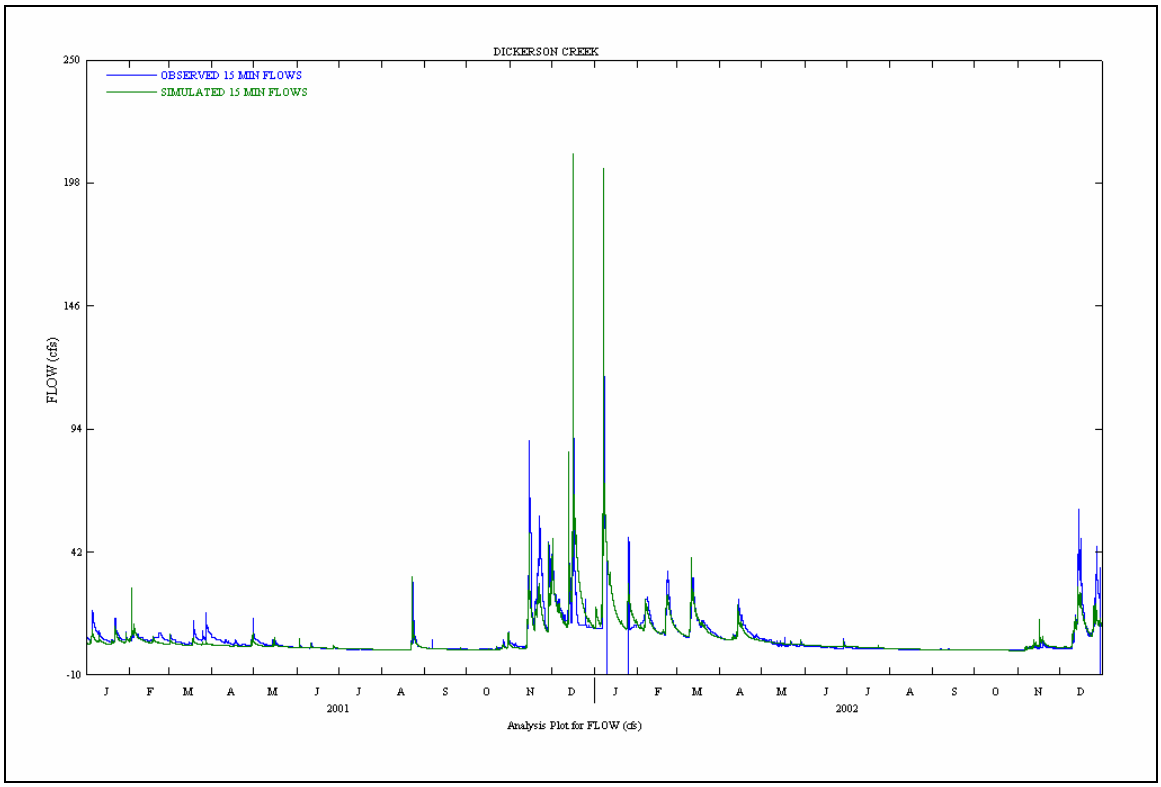

Figure 5. Calibrated model results for Dickerson Creek.

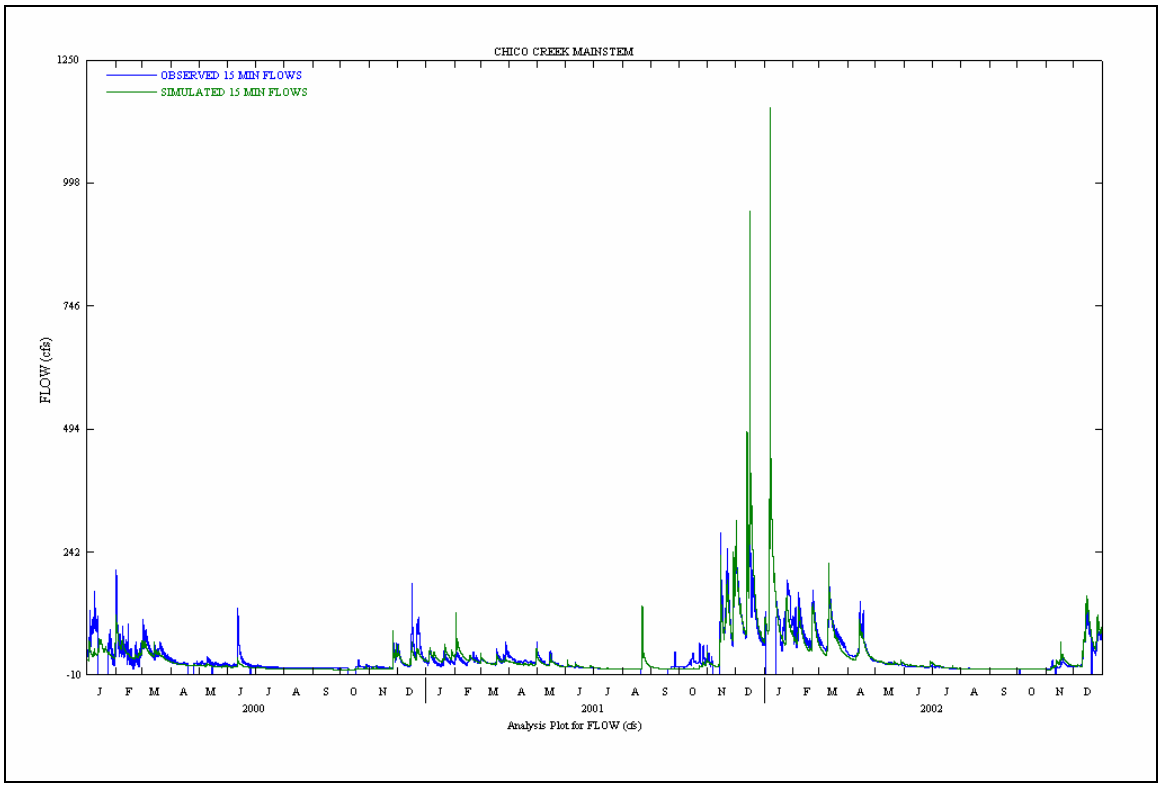

Figure 6. Calibrated model results for Chico Creek Mainstem.

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

Table 1. Comparison of simulated and observed targets for the partition of average annual precipitation (SURO = direct surface runoff; IFWO = interflow runoff; AGWO = baseflow runoff; TAET = total simulated evapotranspiration; units are in inches).

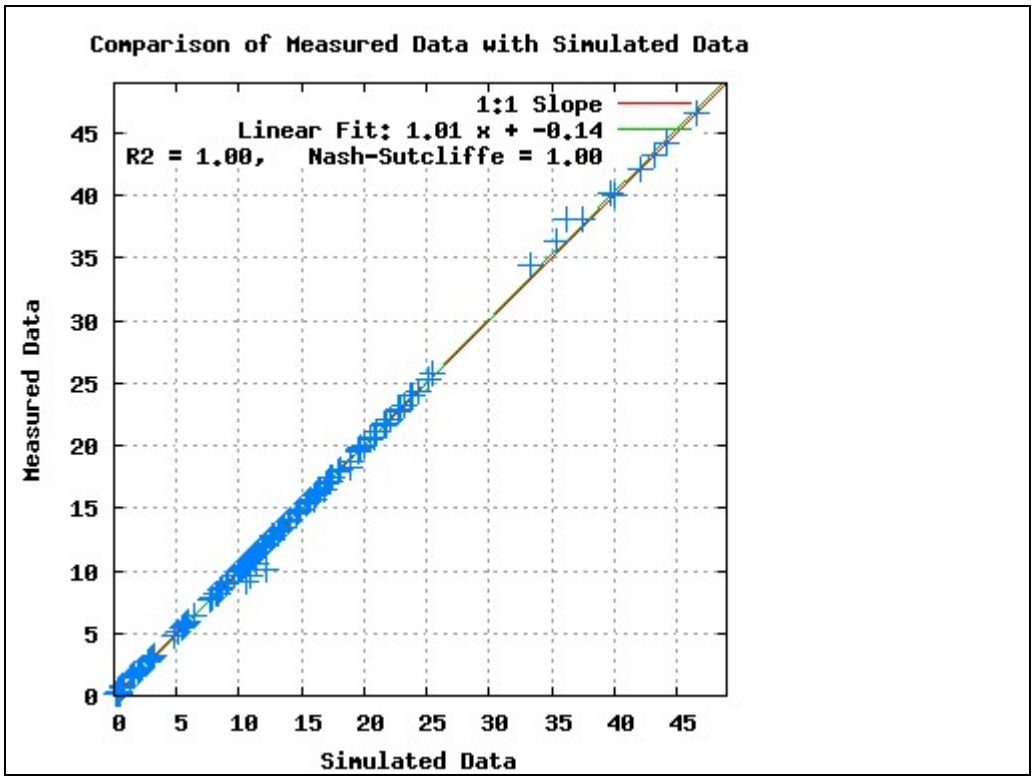

Figure 7. Comparison of simulated and observed targets for the partition of average annual precipitation.

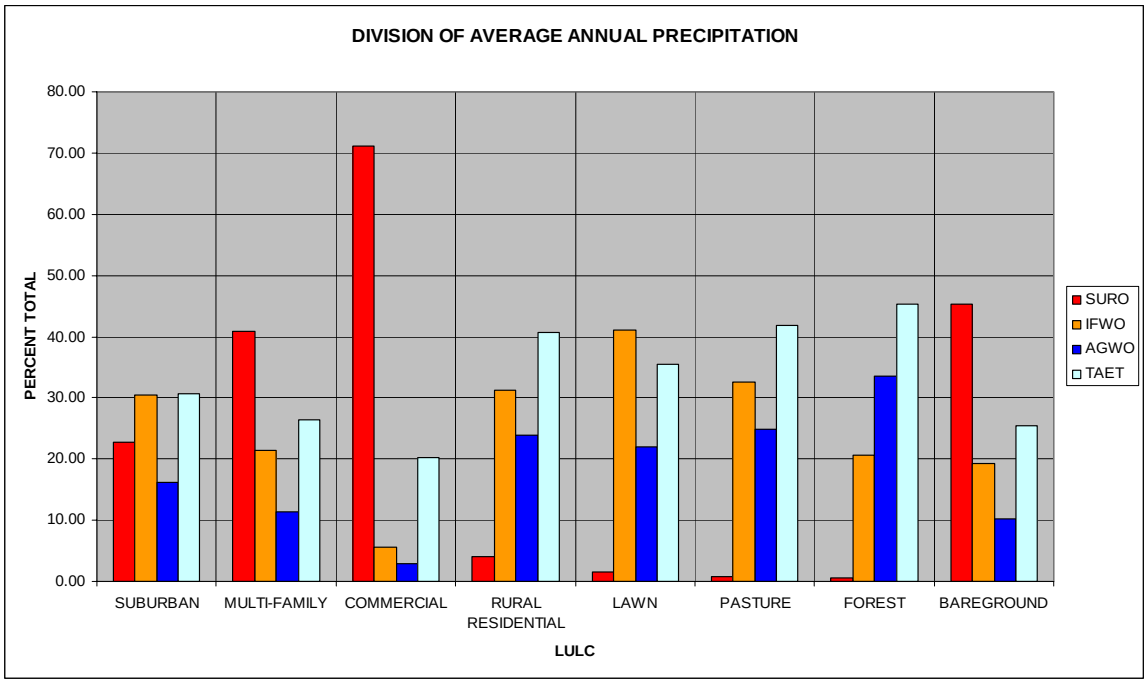

Figure 8. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Kitsap Creek at Lake Outlet.

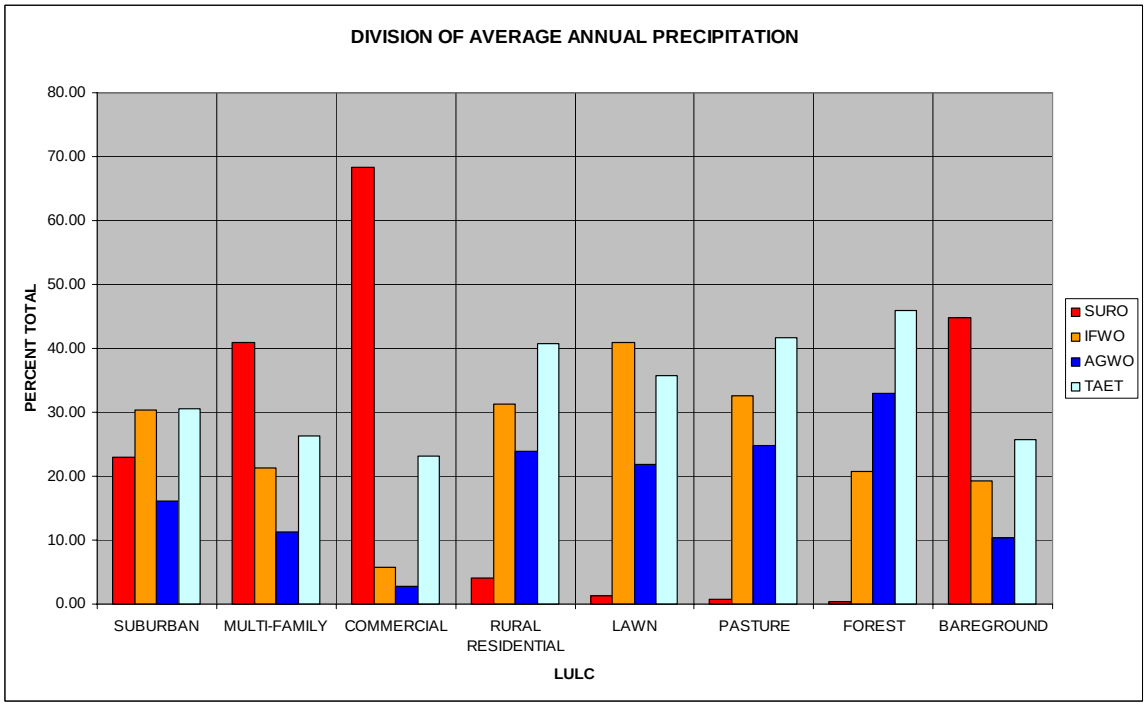

Figure 9. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Wildcat Creek at Lake Oulet.

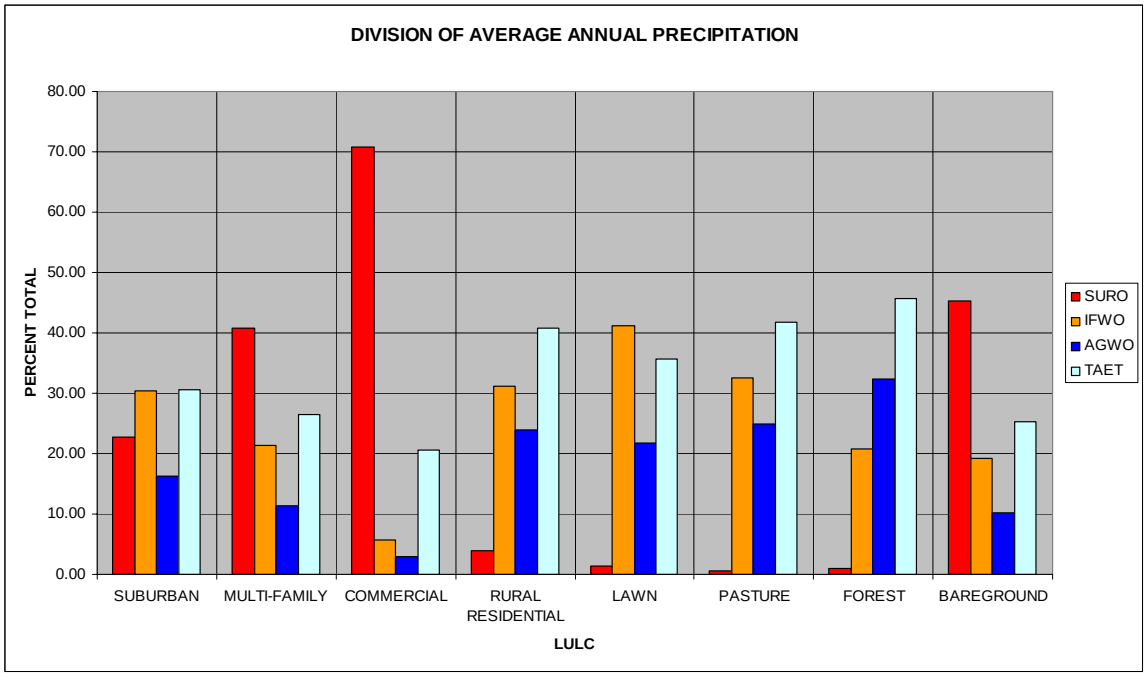

Figure 10. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Chico Tributary at Taylor Road.

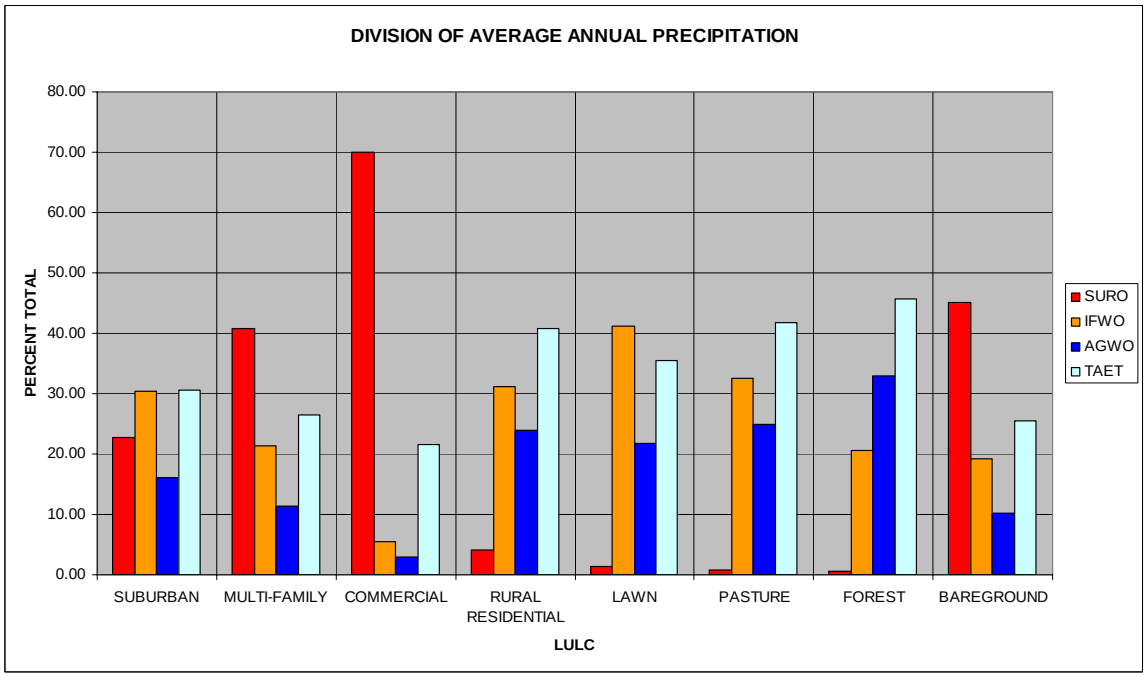

Figure 11. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Dickerson Creek.

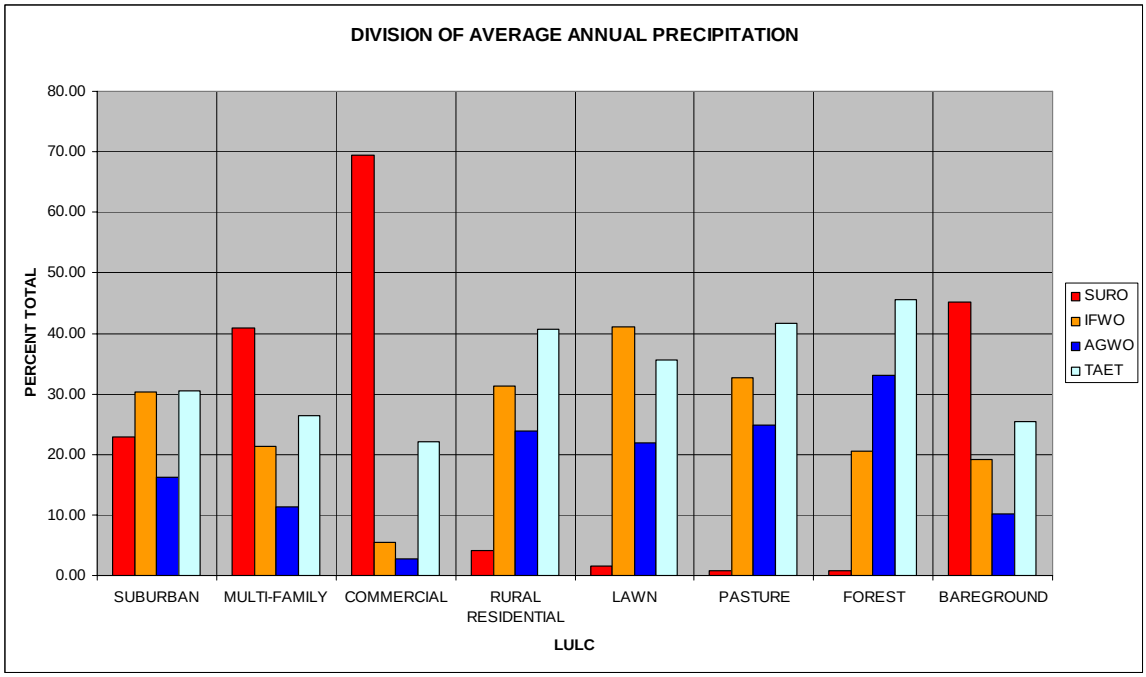

Figure 12. Simulated SURO, IFWO, AGWO, and TAET from the calibrated model at Chico Creek Mainstem.

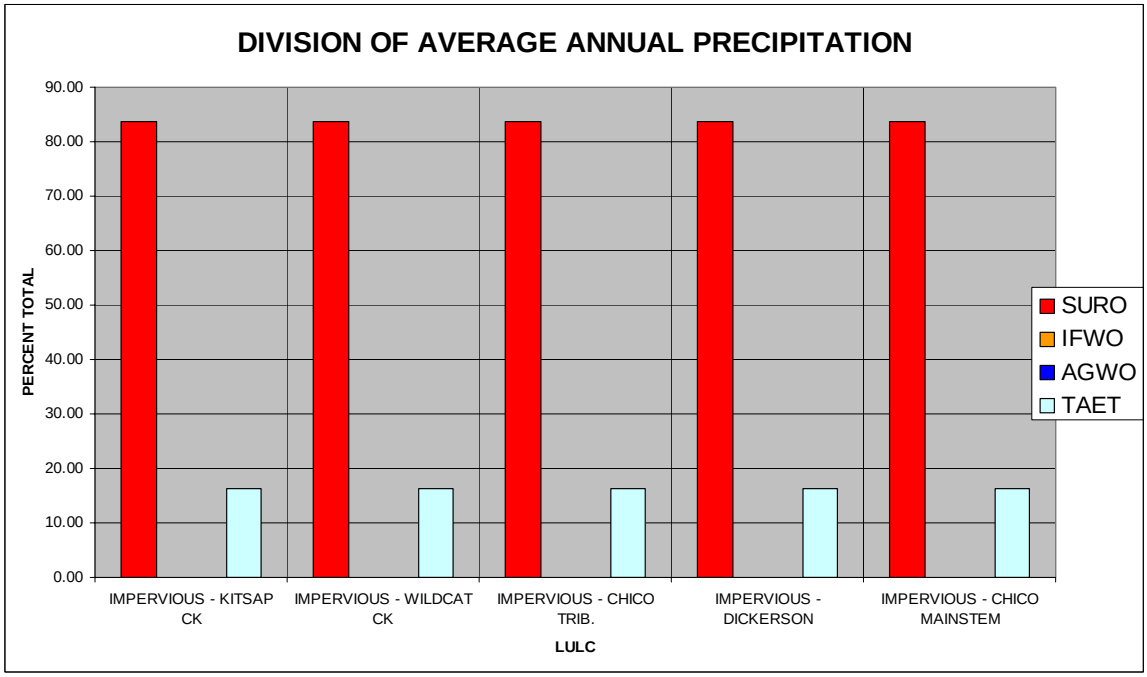

Figure 13. Simulated SURO and TAET for the impervious area for each of the five systems.

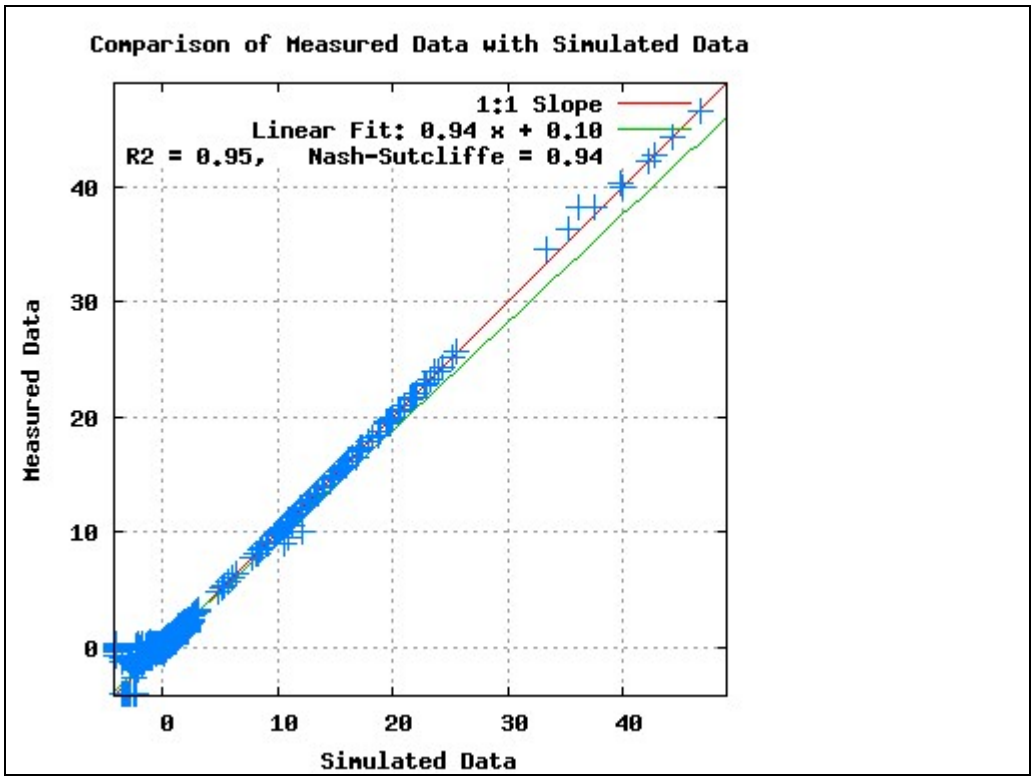

Figure 14. Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Chico Creek HSPF hydrologic model.

For more information about Project ENVVEST, please see:

http://www.ecy.wa.gov/programs/wq/tmdl/sinclair-dyes_inlets/

http://www.psmem.org/models/psns-spawar2.html