



DEPARTMENT OF
ECOLOGY
State of Washington

Amendment to Lake Whatcom TMDL Final Modeling Report – Full Buildout/Rollback Scenarios and Translator

*Technical memorandum from The Cadmus
Group, Inc. & CDM*

to the Washington State Department of Ecology

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Amendment to Lake Whatcom TMDL Final Modeling Report – Full Buildout/Rollback Scenarios and Translator

*Technical memorandum for supplemental work under the Lake Whatcom TMDL
Contract Amendment No. 68-C-02-109*

*by
The Cadmus Group, Inc. & CDM*

Funded by the U.S. Environmental Protection Agency

Water Quality Program
Washington State Department of Ecology
Olympia, Washington 98504-7600

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Memorandum

To: U.S. Environmental Protection Agency Region 10 & Washington State Department of Ecology

From: The Cadmus Group, Inc. & CDM

Date: November 30, 2007

Subject: Amendment to Lake Whatcom TMDL Final Modeling Report – Full Buildout/Rollback Scenarios and Translator

This technical memorandum summarizes the supplemental work conducted under the Lake Whatcom TMDL Contract Amendment No. 68-C-02-109. This work included two scenario simulations using the calibrated Lake Whatcom HSPF model for full build out and natural land use conditions (Cadmus & CDM, 2007) and the development of a translator tool that converts HSPF outputs to CE-QUAL-W2 inputs. The development and results of the scenarios and translator are described below.

Scenario Model Runs

Land Use Files

Updated Land Cover/Land Use grids for the Lake Whatcom watershed were obtained from Utah State University and are comprised of data from multiple sources (Winkelaar, Utah State University). Eighteen land cover classifications (2001 National Land Cover Data) were aggregated to seven land use categories for use in the HSPF modeling. A value of 21.3% for the impervious cover was calculated in the previous modeling effort and was applied to the single developed land use class used in the model for the scenarios.

Natural Land Use

The “Natural” conditions land use grid included data interpreted from turn of the century General Land Office Surveys, 1880 land cover polygons, and potential wetlands. Hydric soils from the National Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database were used to determine native vegetations to fill gaps. All dammed water bodies were also removed from the dataset, including Lake Whatcom. These water bodies were defined as natural cover instead of water. The final product included only mixed forest and woody wetlands in the Lake Whatcom watershed and represents 1880 conditions.

The historic land use/land cover in the watershed is primarily mixed forest interspersed with wetlands. The land cover acreage is shown in **Table A-1**. **Figure A-1** shows the historic conditions from the grid.

Existing Land Use

The existing land use was used in the initial, calibration, modeling effort (Cadmus & CDM, 2007). The land cover grid constitutes the Utah State University 2001 update to the 1992 National Land Cover Dataset. **Figure A-2** shows existing conditions grid for comparison. **Table A-2** shows the existing land use acreage per sub-basin.

Full Build Out Land Use

The “Full Build Out” conditions are based on current land use designations by Whatcom County and the City of Bellingham, developed to the full extent of the current zoning. The expansion of roads was also considered and included in the forecasted land use layer.

The eighteen land use classifications based on the 2001 National Land Cover Data were aggregated into seven land use categories (same as those in the Existing Land Use dataset). The seven land use categories are shown in **Figure A-3**. **Table A-3** shows the land use acreage per each sub-basin.

The percent change in acreage for each land use designation from the existing acreage to each of the Full Build Out and Natural scenarios acreage is shown on **Table A-4**.

Model Runs

The land use acreage was changed for each model run in the Natural and Full Build Out scenarios and compared to the Existing conditions scenario. The diversion inflow of Total Phosphorus was removed from the model for the Natural scenario. The diversion inflow of Total Phosphorus was assumed to remain the same for Full Build Out conditions. Model runs were performed at hourly timesteps from Date to Date in calendar years.

Output Results

As expected, the average annual Total Phosphorus loading has decreased in the Natural scenario and increased for the Full Build Out scenario. The total annual loading by each land cover type is shown for each scenario on **Table A-5**. Excluding the loading for the diversion inflow, the Natural scenario decreased the average annual Total Phosphorus loading by 40% to 4,420 lbs per year from the Existing conditions of 7,125 lbs per year. The Full Build Out scenario increased the Total Phosphorus loading by 63% to 11,648 lbs per year.

The changes by each land cover type are also shown in the chart of **Figure A-4**. The main increase in loading to the entire watershed for the Full Build Out scenario comes from the projected increase in developed and agricultural land. **Table A-6** and **Figure A-5** show the break-out of the average annual Total Phosphorus loadings by each subwatershed. The overall trend is an increase in Total Phosphorus from Natural to Existing to Full Build Out conditions. However, in two subwatersheds, the average loading increases from the Existing to the Natural conditions. This occurs in the Anderson Creek Gage and the Brannian Creek Gage Subwatersheds. These subwatersheds have very little development in Existing conditions and consist primarily of forested land cover as shown in **Table A-2**. The expected

Natural conditions includes mostly forested land and the removal of all developed areas but also an increase in wetland land cover which provides a greater Total Phosphorus loading per acre than just forested land. This accounts for the minor increase in Total Phosphorus loadings from Existing to Natural conditions for these two subwatersheds with little development.

The average annual Total Phosphorus loadings for the inflows into the lake are also shown in **Table A-6** and **Figure A-6**. The sixteen inflow loadings account for the subwatershed location and all subwatersheds upstream of this location. The total average annual inflows are similar in value to the total subwatershed values and show the same pattern of changing Total Phosphorus loadings with each scenario as expected.

HSPF to CE-QUAL Translator

Translator Description

The translator is a VBA application run from within Microsoft Excel which reads in 22 HSPF output files: one for each HSPF subwatershed containing daily average flow and average TP mass per model time step. The translator writes out 44 files formatted for use as input to CE-QUAL-W2. The twenty two files produced by the translator are flow files and simply convert the HSPF output from units of F^3/s to units of M^3/s . The remaining 22 files comprise the phosphorus translation, which is more complex and described further below.

Subwatershed Partitioning to CE-QUAL-W2

For the HSPF/CE-QUAL-W2 simulations to be comparable to previous CE-QUAL-W2 simulations in aerial extent of model sub-boundaries and in the distribution of flows and TP loads, the 22 HSPF model subwatersheds had to be fit to the 22 Watershed Resource Inventory Area (WRIA) subwatersheds used by the earlier developed CE-QUAL-W2 model. For each WRAI subwatershed, the fractions of the HSPF subwatersheds corresponding to that subwatershed were tabulated for use in the translator. In the translation, both flow and TP load for each WRAI subwatershed contribution to the CE-QUAL model were taken as the sum of all fractions of the corresponding HSPF subwatersheds.

Partitioning for CE-QUAL-W2 input

The HSPF model simulates TP loads on a watershed scale using build-up and washoff. For the CE-QUAL-W2 dynamic water quality model of Lake Whatcom, a derivation of 8 phosphorous containing water quality constituents is used, based on daily HSPF TP results. The eight required CE-QUAL constituents are ortho-phosphate, 3 species of algae, and four organic constituents (ligneous and refractory dissolved; ligneous and refractory particulate).

A previous calibration run of the CE-QUAL-W2 model for calendar years 2002 and 2003 is used to calculate the daily ratio for each of the eight CE-QUAL-W2 constituents to the sum of all of those constituents (the sum of all being the simulated CE-QUAL TP). These daily ratios are applied to the HSPF daily TP output to generate eight new daily timeseries for each of the 22 CE-QUAL-W2 subwatersheds. There are nine calibration reference files for which each of the 22 CE-QUAL-W2 subwatersheds is assigned. The translator identifies which file to use for each subwatershed and then looks for it in the file directory in which the files reside.

QA/QC Process

The translator was developed with assistance from Ecology in providing the necessary setup files (CE-QUAL-W2 example files, calibration files, and GIS data) as well as in troubleshooting initial versions of the translator. Ecology and CDM identified two coding discrepancies which were resulting in translated TP loads that did not match the HSPF total loads. The final corrected version of the translator accounted for over 99% of the TP load generated in HSPF, which is consistent with the small acreage discrepancy related to the subwatershed partitioning described above. A subset of five of the 22 translated CE-QUAL-W2 files were back-checked in Excel for QA/QC purposes and found to have the same result for all days found in translated output. This, in conjunction with the 99% total load agreement, satisfied the team that all HSPF elements were properly being translated into CE-QUAL-W2 input files.

References

Cadmus, CDM. Final Model Report for Lake Whatcom Watershed TMDL Model Project
July 18, 2007

Winkelaar, Mark. *Mapping Methodology and Data Sources for Full Build Out Conditions Landuse/Landcover Within Water Resource Inventory Area 1 (WRIA 1), Washington, USA: Preliminary Draft.* Utah State University - Institute for Natural Systems Engineering.

Winkelaar, Mark. *Mapping Methodology and Data Sources for Historic Conditions Landuse/Landcover Within Water Resource Inventory Area 1 (WRIA 1), Washington, USA: Preliminary Draft.* Utah State University - Institute for Natural Systems Engineering.

Tables

Table A-1

Lake Whatcom Land Use Distribution per Subwatershed -- Natural Conditions

Total Acres per Subbasin

HFAM ID	HSPF ID	Name	HSPF Land Use Category							Subbasin	
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	Total Acres
3000	1	Mirror Lake	-	-	-	-	115	-	18	-	133
3005	5	Anderson Creek	-	-	-	-	2,437	-	142	-	2,579
3006	6	NE Lake Whatcom Inflow 1	-	-	-	-	662	-	0	-	663
3010	10	NE Lake Whatcom Inflow 2	-	-	-	-	3,240	-	1	-	3,241
3015	15	Smith Creek	-	-	-	-	3,262	-	-	-	3,262
3018	18	Smith Creek Outlet	-	-	-	-	40	-	-	-	40
3020	20	Olsen Creek	-	-	-	-	2,448	-	-	-	2,448
3025	25	Carpenter Creek	-	-	-	-	758	-	8	-	766
3030	30	North Lake Whatcom Inflow	-	-	-	-	1,156	-	-	-	1,156
3035	35	Silver Beach Creek	-	-	-	-	709	-	3	-	712
3040	40	NW Lake Whatcom Inflow	-	-	-	-	3,408	-	309	-	3,717
3045	45	Brannian Creek	-	-	-	-	2,227	-	71	-	2,297
3050	50	Brannian Creek Outflow	-	-	-	-	70	-	-	-	70
3055	55	South Lake Whatcom Inflow	-	-	-	-	2,290	-	17	-	2,307
3060	60	Upper Austin Creek	-	-	-	-	1,759	-	-	-	1,759
3065	65	Beaver Creek	-	-	-	-	2,992	-	44	-	3,036
3070	70	Austin Creek	-	-	-	-	118	-	-	-	118
3072	72	Austin Creek Outflow	-	-	-	-	433	-	-	-	433
3075	75	SW Lake Whatcom Inflow 2	-	-	-	-	925	-	25	-	950
3080	80	SW Lake Whatcom Inflow 1	-	-	-	-	582	-	-	-	582
3085	85	Euclid Creek	-	-	-	-	340	-	-	-	340
3090	90	Mill Wheel Creek	-	-	-	-	569	-	5	-	574
Total			-	-	-	-	30,541	-	643	-	31,184
Percent			0%	0%	0%	0%	98%	0%	2%	0%	100%

Percentages per Subbasin¹

HFAM ID	HSPF ID	Name	HSPF Land Use Category							Subbasin %	
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	Study Area
3000	1	Mirror Lake	-	-	-	-	86.4%	-	13.6%	-	0.4%
3005	5	Anderson Creek	-	-	-	-	94.5%	-	5.5%	-	8.3%
3006	6	NE Lake Whatcom Inflow 1	-	-	-	-	100.0%	-	0.0%	-	2.1%
3010	10	NE Lake Whatcom Inflow 2	-	-	-	-	100.0%	-	0.0%	-	10.4%
3015	15	Smith Creek	-	-	-	-	100.0%	-	-	-	10.5%
3018	18	Smith Creek Outlet	-	-	-	-	100.0%	-	-	-	0.1%
3020	20	Olsen Creek	-	-	-	-	100.0%	-	-	-	7.9%
3025	25	Carpenter Creek	-	-	-	-	99.0%	-	1.0%	-	2.5%
3030	30	North Lake Whatcom Inflow	-	-	-	-	100.0%	-	-	-	3.7%
3035	35	Silver Beach Creek	-	-	-	-	99.6%	-	0.4%	-	2.3%
3040	40	NW Lake Whatcom Inflow	-	-	-	-	91.7%	-	8.3%	-	11.9%
3045	45	Brannian Creek	-	-	-	-	96.9%	-	3.1%	-	7.4%
3050	50	Brannian Creek Outflow	-	-	-	-	100.0%	-	-	-	0.2%
3055	55	South Lake Whatcom Inflow	-	-	-	-	99.2%	-	0.8%	-	7.4%
3060	60	Upper Austin Creek	-	-	-	-	100.0%	-	-	-	5.6%
3065	65	Beaver Creek	-	-	-	-	98.6%	-	1.4%	-	9.7%
3070	70	Austin Creek	-	-	-	-	100.0%	-	-	-	0.4%
3072	72	Austin Creek Outflow	-	-	-	-	100.0%	-	-	-	1.4%
3075	75	SW Lake Whatcom Inflow 2	-	-	-	-	97.3%	-	2.7%	-	3.0%
3080	80	SW Lake Whatcom Inflow 1	-	-	-	-	100.0%	-	-	-	1.9%
3085	85	Euclid Creek	-	-	-	-	100.0%	-	-	-	1.1%
3090	90	Mill Wheel Creek	-	-	-	-	99.1%	-	0.9%	-	1.8%

1. Percentages > 10% in Blue

**Table A-2
Lake Whatcom Land Use Distribution per Subwatershed -- Existing Conditions**

Total Acres per Subbasin

HFAM ID	HSPF ID	Name	HSPF Land Use Category								Subbasin Total Acres
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	
3000	1	Mirror Lake	-	54	-	8	33	25	13	-	134
3005	5	Anderson Creek	77	591	6	1,015	756	126	6	2	2,579
3006	6	NE Lake Whatcom Inflow 1	11	152	2	329	161	4	2	1	663
3010	10	NE Lake Whatcom Inflow 2	2	453	15	1,436	1,106	201	24	4	3,241
3015	15	Smith Creek	-	498	-	1,486	1,174	105	-	-	3,263
3018	18	Smith Creek Outlet	-	12	1	4	18	4	0.1	0	40
3020	20	Olsen Creek	-	375	11	1,220	824	16	0.2	3	2,448
3025	25	Carpenter Creek	4	147	35	186	347	37	1	10	766
3030	30	North Lake Whatcom Inflow	1	255	88	187	484	104	14	24	1,156
3035	35	Silver Beach Creek	0.2	104	175	88	272	27	-	47	712
3040	40	NW Lake Whatcom Inflow	114	1,355	521	224	1,223	116	24	141	3,718
3045	45	Brannian Creek	-	493	1	1,071	634	97	2	0	2,298
3050	50	Brannian Creek Outflow	-	17	10	11	28	2	1	3	70
3055	55	South Lake Whatcom Inflow	0.4	698	105	489	805	153	28	28	2,307
3060	60	Upper Austin Creek	1	100	6	1,306	340	5	-	2	1,759
3065	65	Beaver Creek	0.2	598	99	1,134	1,168	8	1	27	3,036
3070	70	Austin Creek	-	9	12	62	32	0.5	-	3	118
3072	72	Austin Creek Outflow	-	26	120	110	109	9	28	32	433
3075	75	SW Lake Whatcom Inflow 2	0.4	130	197	258	287	9	15	53	950
3080	80	SW Lake Whatcom Inflow 1	-	69	258	51	122	11	1	70	582
3085	85	Euclid Creek	-	55	67	66	133	2	-	18	340
3090	90	Mill Wheel Creek	-	75	123	104	231	3	4	33	574
Total			212	6,264	1,852	10,843	10,288	1,062	164	500	31,185
Percent			1%	20%	6%	35%	33%	3%	1%	2%	100%

Percentages per Subbasin¹

HFAM ID	HSPF ID	Name	HSPF Land Use Category								Subbasin % Study Area
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	
3000	1	Mirror Lake	-	40.7%	-	5.8%	24.8%	18.9%	9.9%	-	0.4%
3005	5	Anderson Creek	3.0%	22.9%	0.2%	39.3%	29.3%	4.9%	0.2%	0.1%	8.3%
3006	6	NE Lake Whatcom Inflow 1	1.7%	23.0%	0.4%	49.6%	24.4%	0.6%	0.3%	0.1%	2.1%
3010	10	NE Lake Whatcom Inflow 2	0.1%	14.0%	0.5%	44.3%	34.1%	6.2%	0.7%	0.1%	10.4%
3015	15	Smith Creek	-	15.3%	-	45.6%	36.0%	3.2%	-	-	10.5%
3018	18	Smith Creek Outlet	-	30.7%	3.5%	9.2%	45.3%	10.1%	0.2%	1.0%	0.1%
3020	20	Olsen Creek	-	15.3%	0.4%	49.8%	33.7%	0.6%	0.0%	0.1%	7.9%
3025	25	Carpenter Creek	0.5%	19.2%	4.6%	24.2%	45.3%	4.8%	0.1%	1.2%	2.5%
3030	30	North Lake Whatcom Inflow	0.1%	22.0%	7.6%	16.2%	41.8%	9.0%	1.2%	2.1%	3.7%
3035	35	Silver Beach Creek	0.0%	14.6%	24.6%	12.3%	38.2%	3.7%	-	6.6%	2.3%
3040	40	NW Lake Whatcom Inflow	3.1%	36.4%	14.0%	6.0%	32.9%	3.1%	0.7%	3.8%	11.9%
3045	45	Brannian Creek	-	21.5%	0.1%	46.6%	27.6%	4.2%	0.1%	0.0%	7.4%
3050	50	Brannian Creek Outflow	-	24.0%	14.4%	15.1%	39.5%	2.3%	0.9%	3.9%	0.2%
3055	55	South Lake Whatcom Inflow	0.0%	30.2%	4.6%	21.2%	34.9%	6.6%	1.2%	1.2%	7.4%
3060	60	Upper Austin Creek	0.1%	5.7%	0.3%	74.2%	19.3%	0.3%	-	0.1%	5.6%
3065	65	Beaver Creek	0.0%	19.7%	3.3%	37.4%	38.5%	0.3%	0.0%	0.9%	9.7%
3070	70	Austin Creek	-	7.4%	10.4%	52.3%	26.8%	0.4%	-	2.8%	0.4%
3072	72	Austin Creek Outflow	-	6.0%	27.7%	25.4%	25.1%	2.0%	6.4%	7.5%	1.4%
3075	75	SW Lake Whatcom Inflow 2	0.0%	13.7%	20.7%	27.2%	30.2%	0.9%	1.6%	5.6%	3.0%
3080	80	SW Lake Whatcom Inflow 1	-	11.8%	44.3%	8.8%	21.0%	1.9%	0.2%	12.0%	1.9%
3085	85	Euclid Creek	-	16.0%	19.5%	19.5%	39.0%	0.7%	-	5.3%	1.1%
3090	90	Mill Wheel Creek	-	13.1%	21.5%	18.2%	40.3%	0.5%	0.7%	5.8%	1.8%

1. Percentages > 10% in Blue

Table A-3

Lake Whatcom Land Use Distribution per Subwatershed -- Full Build Out Conditions

Total Acres per Subbasin

HFAM ID	HSPF ID	Name	HSPF Land Use Category								Subbasin Total Acres
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	
3000	1	Mirror Lake	15	41	13	2	21	25	13	3	133
3005	5	Anderson Creek	283	415	90	986	643	132	5	24	2,579
3006	6	NE Lake Whatcom Inflow 1	54	107	13	313	120	51	2	3	663
3010	10	NE Lake Whatcom Inflow 2	73	402	42	1,416	1,035	245	16	11	3,241
3015	15	Smith Creek	-	490	-	1,476	1,161	136	-	-	3,262
3018	18	Smith Creek Outlet	1	0	2	-	-	37	0.1	1	40
3020	20	Olsen Creek	137	308	25	1,205	751	15	0.2	7	2,448
3025	25	Carpenter Creek	328	26	92	107	157	32	1	25	766
3030	30	North Lake Whatcom Inflow	176	150	122	159	377	131	8	33	1,156
3035	35	Silver Beach Creek	258.1	3	328	1	16	18	0.0	89	712
3040	40	NW Lake Whatcom Inflow	1,789	439	835	11	287	106	24	226	3,717
3045	45	Brannian Creek	-	487	9	1,070	631	96	2	2	2,297
3050	50	Brannian Creek Outflow	5	9	12	7	13	20	1	3	70
3055	55	South Lake Whatcom Inflow	615.3	439	283	316	411	138	28	77	2,307
3060	60	Upper Austin Creek	-	87	98	1,239	305	4	-	26	1,759
3065	65	Beaver Creek	69.2	532	378	943	1,007	2	1	102	3,036
3070	70	Austin Creek	-	-	93	-	-	-	-	25	118
3072	72	Austin Creek Outflow	10	0	303	8	2	-	27	82	433
3075	75	SW Lake Whatcom Inflow 2	198.9	14	485	56	49	2	14	131	950
3080	80	SW Lake Whatcom Inflow 1	73	21	350	11	28	2	1	95	582
3085	85	Euclid Creek	24	31	169	34	35	1	-	46	340
3090	90	Mill Wheel Creek	-	29	292	67	98	5	4	79	574
		Total	4,109	4,032	4,034	9,427	7,147	1,198	146	1,092	31,184
		Percent	13%	13%	13%	30%	23%	4%	0%	4%	100%

Percentages per Subbasin¹

HFAM ID	HSPF ID	Name	HSPF Land Use Category								Subbasin % Study Area
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp	
3000	1	Mirror Lake	11.3%	30.9%	9.7%	1.5%	15.8%	18.9%	9.4%	2.6%	0.4%
3005	5	Anderson Creek	11.0%	16.1%	3.5%	38.2%	24.9%	5.1%	0.2%	0.9%	8.3%
3006	6	NE Lake Whatcom Inflow 1	8.1%	16.1%	1.9%	47.2%	18.1%	7.7%	0.3%	0.5%	2.1%
3010	10	NE Lake Whatcom Inflow 2	2.3%	12.4%	1.3%	43.7%	31.9%	7.6%	0.5%	0.4%	10.4%
3015	15	Smith Creek	-	15.0%	-	45.2%	35.6%	4.2%	-	-	10.5%
3018	18	Smith Creek Outlet	1.3%	0.0%	4.9%	-	-	92.2%	0.3%	1.3%	0.1%
3020	20	Olsen Creek	5.6%	12.6%	1.0%	49.2%	30.7%	0.6%	0.0%	0.3%	7.9%
3025	25	Carpenter Creek	42.8%	3.4%	12.0%	14.0%	20.5%	4.1%	0.1%	3.2%	2.5%
3030	30	North Lake Whatcom Inflow	15.2%	13.0%	10.6%	13.7%	32.6%	11.3%	0.7%	2.9%	3.7%
3035	35	Silver Beach Creek	36.2%	0.5%	46.0%	0.1%	2.2%	2.5%	0.0%	12.5%	2.3%
3040	40	NW Lake Whatcom Inflow	48.1%	11.8%	22.5%	0.3%	7.7%	2.8%	0.6%	6.1%	11.9%
3045	45	Brannian Creek	-	21.2%	0.4%	46.6%	27.5%	4.2%	0.1%	0.1%	7.4%
3050	50	Brannian Creek Outflow	7.5%	13.1%	17.1%	9.9%	18.2%	28.7%	0.9%	4.6%	0.2%
3055	55	South Lake Whatcom Inflow	26.7%	19.0%	12.3%	13.7%	17.8%	6.0%	1.2%	3.3%	7.4%
3060	60	Upper Austin Creek	-	5.0%	5.5%	70.4%	17.3%	0.2%	-	1.5%	5.6%
3065	65	Beaver Creek	2.3%	17.5%	12.5%	31.1%	33.2%	0.1%	0.0%	3.4%	9.7%
3070	70	Austin Creek	-	-	78.7%	-	-	-	-	21.3%	0.4%
3072	72	Austin Creek Outflow	2.2%	0.1%	70.1%	1.9%	0.5%	-	6.3%	19.0%	1.4%
3075	75	SW Lake Whatcom Inflow 2	20.9%	1.4%	51.0%	5.9%	5.2%	0.2%	1.5%	13.8%	3.0%
3080	80	SW Lake Whatcom Inflow 1	12.6%	3.7%	60.2%	1.9%	4.9%	0.3%	0.1%	16.3%	1.9%
3085	85	Euclid Creek	6.9%	9.2%	49.7%	10.0%	10.4%	0.3%	-	13.5%	1.1%
3090	90	Mill Wheel Creek	-	5.0%	50.9%	11.7%	17.1%	0.9%	0.7%	13.8%	1.8%

1. Percentages > 10% in Blue

Table A-4

Percent Change in Total Acreage from Existing Conditions by Subbasin in the Lake Whatcom Watershed

Change from Existing Conditions to Natural Conditions

HFAM ID	HSPF ID	Name	HSPF Land Use Category							
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp
3000	1	Mirror Lake	-	(100.0%)	-	(100.0%)	248.6%	(100.0%)	37.1%	-
3005	5	Anderson Creek	(100.0%)	(100.0%)	(100.0%)	(100.0%)	222.3%	(100.0%)	2,155.9%	(100.0%)
3006	6	NE Lake Whatcom Inflow 1	(100.0%)	(100.0%)	(100.0%)	(100.0%)	310.4%	(100.0%)	(94.4%)	(100.0%)
3010	10	NE Lake Whatcom Inflow 2	(100.0%)	(100.0%)	(100.0%)	(100.0%)	192.9%	(100.0%)	(95.9%)	(100.0%)
3015	15	Smith Creek	-	(100.0%)	-	(100.0%)	177.9%	(100.0%)	-	-
3018	18	Smith Creek Outlet	-	(100.0%)	(100.0%)	(100.0%)	121.3%	(100.0%)	(100.0%)	(100.0%)
3020	20	Olsen Creek	-	(100.0%)	(100.0%)	(100.0%)	196.9%	(100.0%)	(100.0%)	(100.0%)
3025	25	Carpenter Creek	(100.0%)	(100.0%)	(100.0%)	(100.0%)	118.5%	(100.0%)	865.2%	(100.0%)
3030	30	North Lake Whatcom Inflow	(100.0%)	(100.0%)	(100.0%)	(100.0%)	139.0%	(100.0%)	(100.0%)	(100.0%)
3035	35	Silver Beach Creek	(100.0%)	(100.0%)	(100.0%)	(100.0%)	161.0%	(100.0%)	-	(100.0%)
3040	40	NW Lake Whatcom Inflow	(100.0%)	(100.0%)	(100.0%)	(100.0%)	178.6%	(100.0%)	1,172.0%	(100.0%)
3045	45	Brannian Creek	-	(100.0%)	(100.0%)	(100.0%)	251.0%	(100.0%)	4,315.5%	(100.0%)
3050	50	Brannian Creek Outflow	-	(100.0%)	(100.0%)	(100.0%)	153.0%	(100.0%)	(100.0%)	(100.0%)
3055	55	South Lake Whatcom Inflow	(100.0%)	(100.0%)	(100.0%)	(100.0%)	184.3%	(100.0%)	(38.9%)	(100.0%)
3060	60	Upper Austin Creek	(100.0%)	(100.0%)	(100.0%)	(100.0%)	417.0%	(100.0%)	-	(100.0%)
3065	65	Beaver Creek	(100.0%)	(100.0%)	(100.0%)	(100.0%)	156.1%	(100.0%)	3,282.8%	(100.0%)
3070	70	Austin Creek	-	(100.0%)	(100.0%)	(100.0%)	274.0%	(100.0%)	-	(100.0%)
3072	72	Austin Creek Outflow	-	(100.0%)	(100.0%)	(100.0%)	298.6%	(100.0%)	(100.0%)	(100.0%)
3075	75	SW Lake Whatcom Inflow 2	(100.0%)	(100.0%)	(100.0%)	(100.0%)	222.1%	(100.0%)	66.8%	(100.0%)
3080	80	SW Lake Whatcom Inflow 1	-	(100.0%)	(100.0%)	(100.0%)	377.3%	(100.0%)	(100.0%)	(100.0%)
3085	85	Euclid Creek	-	(100.0%)	(100.0%)	(100.0%)	156.5%	(100.0%)	-	(100.0%)
3090	90	Mill Wheel Creek	-	(100.0%)	(100.0%)	(100.0%)	146.0%	(100.0%)	25.5%	(100.0%)
Total			(100.0%)	(100.0%)	(100.0%)	(100.0%)	196.9%	(100.0%)	292.0%	(100.0%)

Change from Existing Conditions to Full Build Out Conditions

HFAM ID	HSPF ID	Name	HSPF Land Use Category							
			Agriculture	Deciduous Forest	Developed	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Developed - Imp
3000	1	Mirror Lake	n/a	(24%)	n/a	(75%)	(36%)	(0%)	(5%)	n/a
3005	5	Anderson Creek	266%	(30%)	1,459%	(3%)	(15%)	4%	(18%)	1,459%
3006	6	NE Lake Whatcom Inflow 1	380%	(30%)	435%	(5%)	(26%)	1,094%	(1%)	479%
3010	10	NE Lake Whatcom Inflow 2	3,225%	(11%)	181%	(1%)	(6%)	22%	(31%)	185%
3015	15	Smith Creek	-	(1%)	-	(1%)	(1%)	30%	-	-
3018	18	Smith Creek Outlet	n/a	(100%)	43%	(100%)	(100%)	810%	22%	35%
3020	20	Olsen Creek	n/a	(18%)	130%	(1%)	(9%)	(2%)	16%	140%
3025	25	Carpenter Creek	8,755%	(82%)	160%	(42%)	(55%)	(14%)	(29%)	162%
3030	30	North Lake Whatcom Inflow	15,913%	(41%)	39%	(15%)	(22%)	26%	(43%)	38%
3035	35	Silver Beach Creek	128,951%	(97%)	87%	(99%)	(94%)	(33%)	n/a	88%
3040	40	NW Lake Whatcom Inflow	1,466%	(68%)	60%	(95%)	(77%)	(9%)	(2%)	61%
3045	45	Brannian Creek	-	(1%)	668%	(0%)	(1%)	(1%)	(3%)	731%
3050	50	Brannian Creek Outflow	n/a	(45%)	19%	(35%)	(54%)	1,156%	6%	20%
3055	55	South Lake Whatcom Inflow	153,720%	(37%)	169%	(35%)	(49%)	(10%)	(2%)	169%
3060	60	Upper Austin Creek	(100%)	(13%)	1,674%	(5%)	(11%)	(20%)	-	1,660%
3065	65	Beaver Creek	34,496%	(11%)	282%	(17%)	(14%)	(76%)	3%	282%
3070	70	Austin Creek	-	(100%)	660%	(100%)	(100%)	(100%)	-	660%
3072	72	Austin Creek Outflow	n/a	(99%)	153%	(93%)	(98%)	(100%)	(2%)	153%
3075	75	SW Lake Whatcom Inflow 2	49,619%	(89%)	147%	(78%)	(83%)	(73%)	(8%)	147%
3080	80	SW Lake Whatcom Inflow 1	n/a	(69%)	36%	(78%)	(77%)	(86%)	(44%)	36%
3085	85	Euclid Creek	n/a	(43%)	154%	(48%)	(73%)	(63%)	-	154%
3090	90	Mill Wheel Creek	-	(62%)	137%	(36%)	(58%)	99%	(1%)	137%
Total			1,838%	(36%)	118%	(13%)	(31%)	13%	(11%)	118%

Table A-5

Total Phosphorus Loading in Pounds per Year for Each Land Cover Type in Lake Whatcom Watershed Area

Natural

Year	Land Cover Type								Diversion Inflow ^[1]	Total Annual Load ^[2]
	Agriculture	Deciduous Forest	Developed - Pervious	Evergreen Forest	Mixed Forest	Open	Wetlands	Developed - Impervious		
2000	-	-	-	-	2,110	-	135	-	-	2,245
2001	-	-	-	-	2,821	-	184	-	-	3,004
2002	-	-	-	-	5,505	-	368	-	-	5,873
2003	-	-	-	-	3,308	-	216	-	-	3,524
2004	-	-	-	-	5,728	-	392	-	-	6,120
2005	-	-	-	-	5,376	-	377	-	-	5,754
Average	-	-	-	-	4,141	-	279	-	-	4,420

Existing

Year	Land Cover Type								Diversion Inflow	Total Annual Load ^[2]
	Agriculture	Deciduous Forest	Developed - Pervious	Evergreen Forest	Mixed Forest	Open	Wetlands	Developed - Impervious		
2000	41	410	1,403	851	695	116	35	412		3,963
2001	50	545	2,070	1,086	950	144	39	510	900	5,394
2002	111	1,078	3,048	2,182	1,843	295	96	521	512	9,173
2003	63	640	1,963	1,319	1,086	182	60	467	911	5,780
2004	117	1,121	3,130	2,259	1,907	305	103	532	859	9,474
2005	113	1,065	2,976	2,095	1,813	287	94	523	1,131	8,966
Average	83	810	2,432	1,632	1,382	221	71	494	863	7,125

Full Build Out

Year	Land Cover Type								Diversion Inflow	Total Annual Load ^[2]
	Agriculture	Deciduous Forest	Developed - Pervious	Evergreen Forest	Mixed Forest	Open	Wetlands	Developed - Impervious		
2000	971	297	3,062	782	537	140	32	896		6,717
2001	1,386	382	4,316	988	708	166	35	1,100	900	9,081
2002	2,465	762	6,629	1,960	1,375	342	85	1,160	512	14,778
2003	1,442	460	4,375	1,201	826	215	54	1,032	911	9,606
2004	2,598	792	6,837	2,039	1,431	356	92	1,163	859	15,308
2005	2,519	741	6,355	1,879	1,342	331	83	1,152	1,131	14,400
Average	1,897	572	5,262	1,475	1,037	258	63	1,084	863	11,648

Notes:

[1] - Assumes Diversion does not exist for Natural conditions.

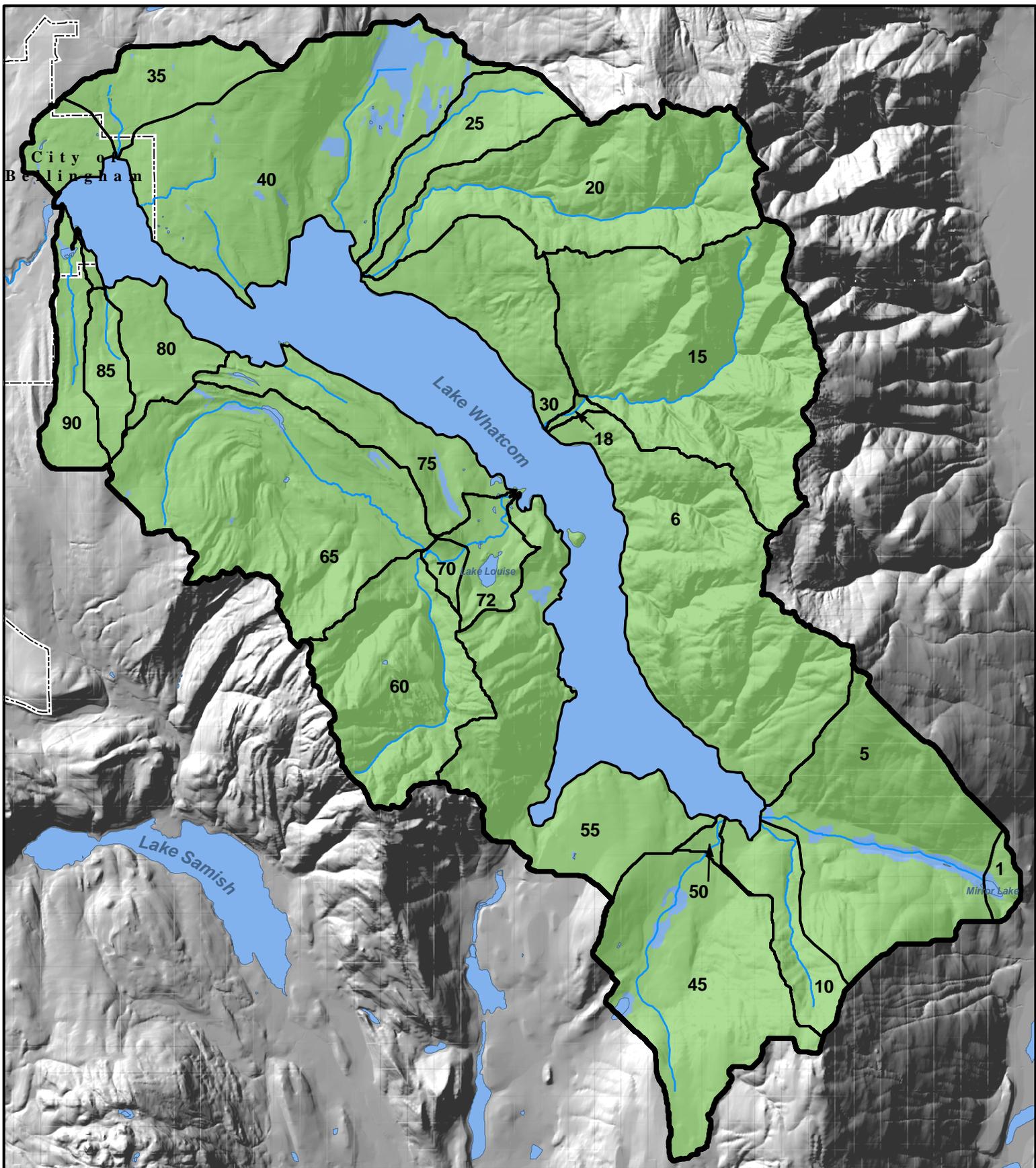
[2] - Total Annual Load does not include Diversion Inflow.

Table A-6

Total Phosphorus Loading in Pounds per Year for Each Land Cover Type in Lake Whatcom Watershed Area

Reach	Subwatershed	Natural		Existing		Full Build Out	
		By Reach	By Subwatershed	By Reach	By Subwatershed	By Reach	By Subwatershed
1	Diversion				863		863
1	Mirror Lake (1)		29		29		60
5	Anderson Creek Gage (5)	375	391	1,231	385	1,470	594
6	Northeast Lake Whatcom Inflow (6)	112	114	125	127	179	180
10	Northeast Lake Whatcom Inflow (10)	585	584	640	639	727	726
15	Smith Creek Gage (15)		424		433		436
18	Smith Creek Outlet (18)	433	2	444	3	448	5
20	Olsen Creek Gage (20)	599	596	624	621	722	720
25	Carpenter Creek Gage (25)	92	91	168	168	429	431
30	North Lake Whatcom Inflow (30)	132	131	317	316	448	447
35	Silver Beach Creek Gage (35)	186	186	772	772	1,509	1509
40	North West Lake Whatcom Inflow (40)	303	310	1,081	1089	1,990	1996
45	Brannian Creek Gage (45)		600		565		586
50	Brannian Creek Outlet (50)	603	6	584	22	610	27
55	South Lake Whatcom Inflow (55)	337	338	559	560	1,138	1140
60	Upper Austin Creek (60)		208		217		343
65	Beaver Cr trib Austin Cr (65)		231		324		644
70	Austin Creek at Gage (70)		13		30		140
72	Austin Creek Outlet (72)	473	24	666	112	1,355	247
75	Southwest Lake Whatcom Inflow (75)	100	100	340	340	775	775
80	Southwest Lake Whatcom Inflow (80)	24	23	190	189	253	253
85	Euclid Creek Gauge (85)	19	19	54	54	110	110
90	Mill Wheel Cr Gage (90)	20	21	129	130	279	280
	TOTAL Annual TP Load (Lbs)	4,394	4,441	7,925	7,988	12,441	12,510
	Total Watershed Area	31,360	31,360	31,360	31,360	31,360	31,360
	Lbs/acre/year	0.14	0.14	0.25	0.25	0.40	0.40

Figures



Legend

-  City of Bellingham
-  Watershed Boundary
-  Sub-basin Boundary
-  Stream
-  Sub-basin ID

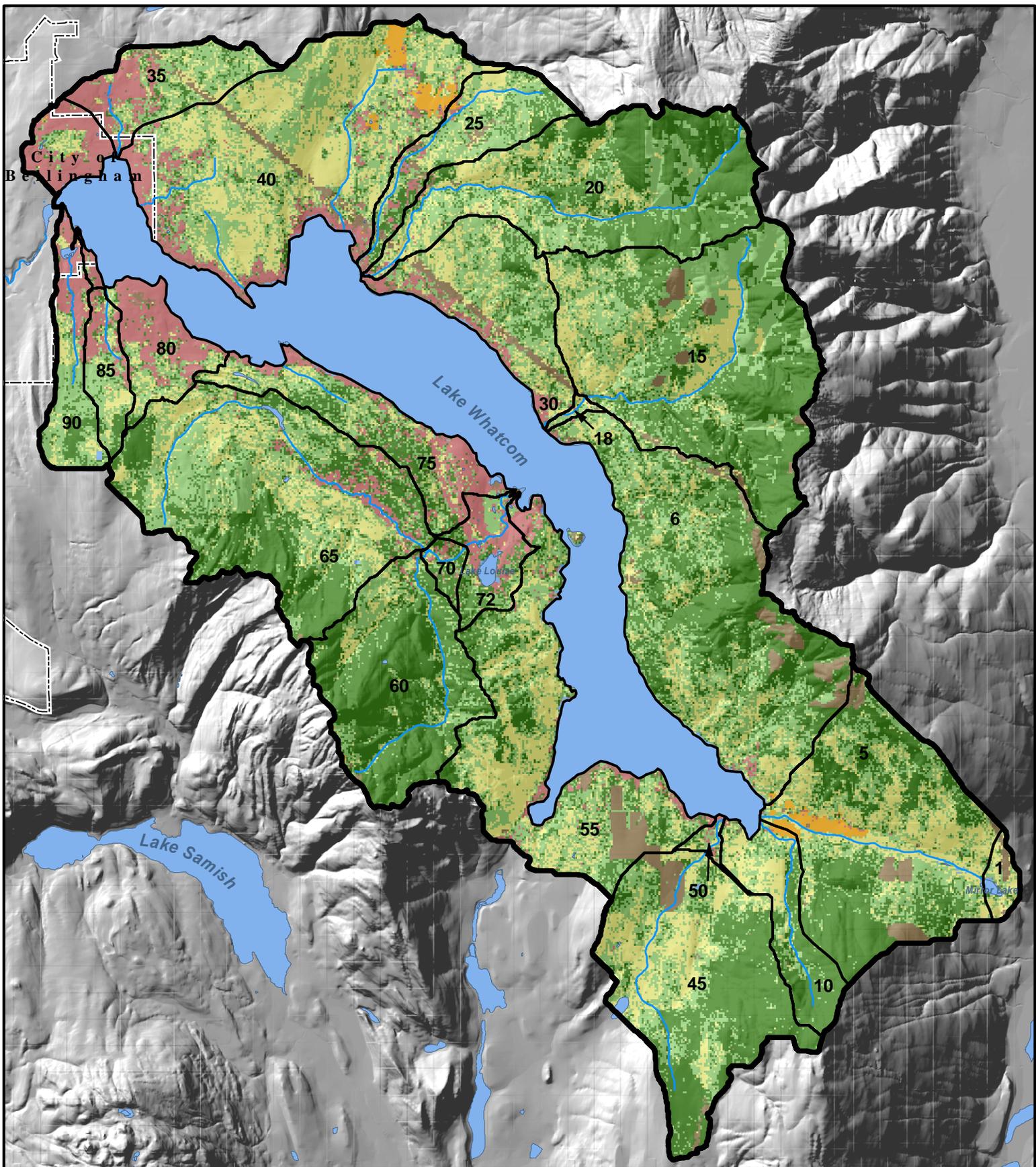
Natural Land Use (approx. Year 1880)

-  Mixed Forest
-  Water/Wetlands

Note: Lake Whatcom is considered a stream in the Natural Land Cover file.



Data Sources: Watershed boundary from Whatcom County, 2002; streams and lakes from Pacific NW Hydrography Framework; Political boundaries from WA Dept. of Ecology; Land Cover from Utah State University, historic 1880 grid.



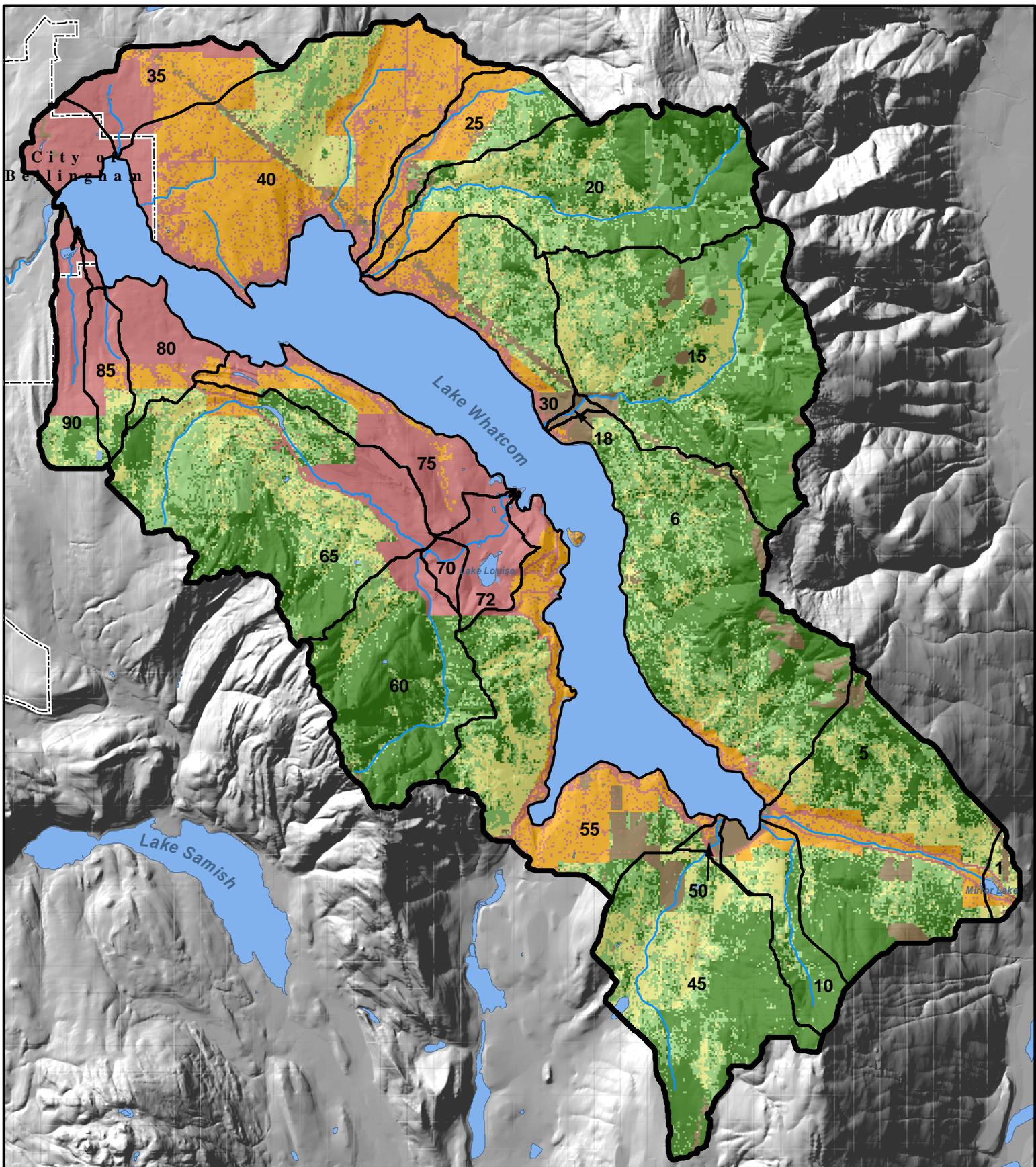
Legend

- | | | | |
|--------------------|-------------------|------------------|------------------|
| City of Bellingham | Existing Land Use | Agriculture | Evergreen Forest |
| Watershed Boundary | Open | Deciduous Forest | Water/Wetlands |
| Sub-basin Boundary | Developed | Mixed Forest | |
| Stream | | | |
| 99 Sub-basin ID | | | |



0 0.5 1 1.5 Miles

Data Sources: Watershed boundary from Whatcom County, 2002; streams and lakes from Pacific NW Hydrography Framework; Political boundaries from WA Dept. of Ecology; Land Cover from Utah State University, 2001 update of 1992 NLCD.



Legend

- | | | | | | | | |
|--|--------------------|--|---------------------|--|------------------|--|------------------|
| | City of Bellingham | | Full Build Land Use | | Agriculture | | Evergreen Forest |
| | Watershed Boundary | | Open | | Deciduous Forest | | Water/Wetlands |
| | Sub-basin Boundary | | Developed | | Mixed Forest | | |
| | Stream | | | | | | |
| | 99 Sub-basin ID | | | | | | |



Data Sources: Watershed boundary from Whatcom County, 2002; streams and lakes from Pacific NW Hydrography Framework; Political boundaries from WA Dept. of Ecology; Land Cover from Utah State University, Full Build Out.

