



DEPARTMENT OF
ECOLOGY
State of Washington

Lake Whatcom TMDL Model – Partial Rollback Scenarios

Performed by CDM

for the Washington State Department of Ecology

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For more information contact:

Water Quality Program
Bellingham Field Office
Washington Department of Ecology
1440 - 10th St., Suite 102
Bellingham, WA 98225

Phone: (360) 715-5200

Washington State Department of Ecology www.ecy.wa.gov/

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by
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: Washington State Department of Ecology

From: CDM

Date: April 15, 2008

Subject: Lake Whatcom TMDL Model – Partial Rollback Scenarios

This technical memorandum summarizes work CDM performed under Washington State Department of Ecology (WDOE) Contract No. C0800239 with the Washington State Department of Ecology. This work includes five scenario simulations using the calibrated Lake Whatcom HSPF model for full build out and natural land use conditions (Cadmus & CDM, November 2007) and the original model for Existing conditions (Cadmus & CDM, July 2007). The five scenarios are based on a reduction of land use classes from the Existing and Full Build Out scenarios. The additional scenarios were used to develop estimates of the Total Phosphorus loading into Lake Whatcom and as inputs into WDOE's Lake Whatcom CE-QUAL-W2 lake model. A primary objective for running these additional scenarios in the HSPF model were to show what additional burden must be placed on existing development to accommodate future development.

Differences in HSPF Model Files from Previous Documents

A previous technical memorandum summarized the amendment scenarios produced for the Natural and Full Build Out conditions (Cadmus, & CDM, November 2007). Since this memo, a few notable changes have been made to the output files for the HSPF model. These include:

- Previous memos have looked at the annual results for six water years (2000 to 2005). Currently, the model reports results by calendar year for five years (2000 to 2004).
- The results shown in the following tables have been reduced to 2002 and 2003, which are the years used for the inputs into the CE-QUAL-W2 model.
- Since the previous technical memo, an error was found in the HSPF model to the assignment of runoff from Subwatersheds 35 and 45, affecting the Total Phosphorus loading results from these two subwatersheds. This error has been corrected and an updated version of the HSPF model for each of the three previous scenarios (Existing, Natural, and Full Build Out) will be sent electronically. These model files and the scenario model files are listed in **Appendix A** of this memo.

Scenario Model Runs

Partial Rollback Scenarios

Model scenario development involved reducing the developed land use classes from the Existing (or Baseline) and Full Build Out scenarios by a percentage. A zero percent reduction would represent the original scenario while a 100 percent reduction would represent a full rollback to Natural conditions. The scenarios developed in this report are called "Partial Rollback Scenarios" as they represent only a percentage reduction.

The land use for each of the Partial Rollback Scenarios was redistributed according to the percentage reduction assigned from the original scenario. Seven land use categories were used in the original HSPF model: Agriculture, Developed, Open, Evergreen Forest, Deciduous Forest, Mixed Forest, and Water/Wetlands. For each rollback scenario, the percentage of acreage was subtracted from the Agriculture, Developed, and Open land use categories in the original Existing or Full Build Out scenario and added to the Mixed Forest category. The Evergreen, Deciduous, and Water/Wetlands acreages were not changed. The rollback acreage is assigned to the Mixed Forest in order to account for a range of possible tree types. The Water/Wetlands category was not changed since it was assumed that this land use category would not be increased in a rollback situation. **Table 1** shows the changes in the acreage for each scenario by land use category and the percentage of the watershed the land use category represents.

The model was run for five different Rollback scenarios, each determined by the Department of Ecology. The rollbacks occurred from either the Full Build Out (FBO) or Existing (Baseline or BAS) conditions. Each rollback is named according to the original scenario from which the rollback occurred (Existing - BAS, Full Build Out - FBO) and the percentage of rollback to the nearest 0.01%. For example, a rollback of 74.58% from the baseline scenario would be named BAS7458.

The five scenarios selected were:

- BAS7458 - a rollback of 74.58% to 922 acres from the Existing (Baseline) conditions
- FBO8399 - a rollback of 83.99% to 1,670 acres from the Full Build Out conditions
- BAS7382 - a rollback of 73.82% to 949 acres from the Existing (Baseline) condition
- FBO9208 - a rollback of 92.08% to 826 acres from the Full Build Out conditions
- FBO8922 - a rollback of 89.22% to 1,125 acres from the Full Build Out conditions

The final bounding Partial Rollback Scenarios are FBO8922 and BAS7382. These represent two possible reductions in existing and future development land use to meet the phosphorus loading capacity for water quality standards in Lake Whatcom. Most of the developed land use categories had to be reduced in acreage from the Existing scenario to achieve the result in the FBO8922 and BAS7382 acreage. The change in acreage from the Existing (Baseline) scenario was approximately a reduction of 76% of the acreage for the Developed land use category, a reduction of 88% for the Open category, and an increase of 109% for the Agriculture category for FBO8922. These changes in acreage for each land use category can be compared to an overall reduction of 74% across all three developed categories for the BAS7382 scenario. The final acreage for both FBO8922 and BAS7382 are shown in **Table 1**.

Model Runs

The land use acreage was changed for each of the Partial Rollback Scenarios and compared to the Existing (Baseline), Natural, and Full Build Out scenarios. Model runs were performed at hourly timesteps from Date to Date in calendar years. Ecology entered the output files from each scenario into the CE-QUAL-W2 model to determine the how the changes in developed land use met the loading capacity in Lake Whatcom for each scenario.

Output Results

As expected, the decrease in developed land use acreage decreased the overall annual Total Phosphorus (TP) loading from the Existing (Baseline) and Full Build Out scenarios as shown in **Table 2**. The final scenarios, FBO8922 and BAS7382, produced an average of 5,310 lbs per year and 5,249 lbs per year, respectively, over the two years examined. This was a reduction of about 27% from the average annual TP loading for the Existing (BAS) conditions scenario of 7,271 lbs per year for the FBO8922 scenario and a reduction of about 28% for the BAS7382 scenario.

A comparison of the average annual TP loadings for all scenarios is shown in **Figure 1**. As the land use acreage is unchanged from the original scenarios for Full Build Out or Existing conditions for Deciduous Forest, Evergreen Forest, and the Water/Wetlands categories, the loadings also do not change in these categories. The high percentage change in the acreage for the developed land use categories brings the TP loadings down significantly for each of these land use categories. The TP loading from the Agriculture land use for FBO8922 remains higher than the Existing scenario since the percent of Agricultural land within the watershed is significantly higher at 13% of the watershed in the Full Build Out scenario than at 1% of the watershed in the Existing scenario as shown in **Table 1**. The Developed and Open categories are reduced significantly by the percent reductions to this category in land use acreage for both the FBO8922 and BAS7382 scenarios. The increase in the Mixed Forest category is a result of the acreage from the developed categories being transferred into this category. However, Mix Forest doesn't produce as much of a Total Phosphorus load per acre as the developed categories, thus reducing the overall TP loading in the watershed by 27%.

The change in TP loading for each subwatershed are shown by year in **Table 3** (2002) and **Table 4** (2003). The output loadings are shown for each reach as well as the corresponding subwatershed. The sixteen inflow loadings account for the subwatershed location and all subwatersheds upstream of this location. As expected, the greatest impact is on the subwatersheds which currently have the most development, as in the northern portions of the lake which have higher acreage for Developed and Agriculture categories, than compared to the southern portions of the lake which are mostly occupied with forest.

References

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

Cadmus, CDM. *Amendment to Lake Whatcom TMDL Final Modeling Report – Full Buildout and Rollback Scenarios & Translator*. November 28, 2007.

Tables

Table 1**Comparison of the Distribution of Acreage by Land Use Category for Each Scenario within the Lake Whatcom Watershed****Total Land Use Acreage for Lake Whatcom Watershed**

Scenario	HSPF Land Use Category								Subbasin
	Agriculture	Deciduous Forest	Developed (Pervious)	Developed (Impervious)	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Total Acres
Natural	-	-	-	-	-	30,542	-	643	31,185
Existing (BAS)	212	6,264	1,852	500	10,843	10,288	1,062	164	31,185
Full Build Out (FBO)	4,109	4,033	4,034	1,092	9,427	7,147	1,198	146	31,185
BAS7382 ⁽¹⁾	56	6,264	485	131	10,843	12,965	278	164	31,185
BAS7458 ⁽²⁾	54	6,264	471	127	10,843	12,992	270	164	31,185
FBO8399 ⁽³⁾	658	4,033	646	175	9,427	15,910	192	146	31,185
FBO8922 ⁽⁴⁾	443	4,033	435	118	9,427	16,455	129	146	31,185
FBO9208 ⁽⁵⁾	325	4,033	319	86	9,427	16,753	95	146	31,185

Percent of Total Land Use Acreage for Lake Whatcom Watershed

Scenario	HSPF Land Use Category								Subbasin
	Agriculture	Deciduous Forest	Developed (Pervious)	Developed (Impervious)	Evergreen Forest	Mixed Forest	Open	Water/Wetlands	Total Acres
Natural	-	-	-	-	-	98	-	2	100
Existing (BAS)	1	20	6	2	35	33	3	1	100
Full Build Out (FBO)	13	13	13	4	30	23	4	0	100
BAS7382 ⁽¹⁾	0	20	2	0	35	42	1	1	100
BAS7458 ⁽²⁾	0	20	2	0	35	42	1	1	100
FBO8399 ⁽³⁾	2	13	2	1	30	51	1	0	100
FBO8922 ⁽⁴⁾	1	13	1	0	30	53	0	0	100
FBO9208 ⁽⁵⁾	1	13	1	0	30	54	0	0	100

Notes:

- (1) - BAS7382: 73.82% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
(2) - BAS7458: 74.58% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
(3) - FBO8399: 83.99% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
(4) - FBO8922: 89.22% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
(5) - FBO9208: 92.08% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions

Table 2
Total Phosphorus Loadings into Lake Whatcom in Pounds per Year

Scenario	Year	Land Cover Type								Total Annual Load (lbs)
		Agriculture	Deciduous Forest	Developed Pervious	Developed - Impervious	Evergreen Forest	Mixed Forest	Open	Wetlands	
Natural	2002	-	-	-	-	-	3,809	-	249	4,059
	2003	-	-	-	-	-	4,983	-	339	5,322
	Average	-	-	-	-	-	4,396	-	294	4,690
Existing (BAS)	2002	86	742	2,170	474	1,504	1,270	202	74	6,521
	2003	111	974	2,414	518	1,993	1,646	267	99	8,022
	Average	98	858	2,292	496	1,748	1,458	235	86	7,271
BAS7382 ⁽¹⁾	2002	22	742	568	124	1,504	1,518	53	74	4,605
	2003	29	974	632	136	1,993	1,961	70	99	5,894
	Average	26	858	600	130	1,748	1,739	61	86	5,249
BAS7458 ⁽²⁾	2002	22	742	552	121	1,504	1,520	51	74	4,585
	2003	28	974	614	132	1,993	1,964	68	99	5,872
	Average	25	858	583	126	1,748	1,742	60	86	5,228
Full Build Out (FBO)	2002	1,710	526	4,780	1,059	1,372	981	237	63	10,726
	2003	2,111	695	5,490	1,144	1,816	1,274	313	86	12,929
	Average	1,910	610	5,135	1,102	1,594	1,128	275	74	11,828
FBO8399 ⁽³⁾	2002	274	526	765	170	1,372	1,800	38	63	5,007
	2003	338	695	879	183	1,816	2,331	50	86	6,378
	Average	306	610	822	176	1,594	2,065	44	74	5,692
FBO8922 ⁽⁴⁾	2002	184	526	515	114	1,372	1,851	25	63	4,651
	2003	228	695	592	123	1,816	2,397	34	86	5,970
	Average	206	610	554	119	1,594	2,124	30	74	5,310
FBO9208 ⁽⁵⁾	2002	135	526	379	84	1,372	1,879	19	63	4,456
	2003	167	695	435	91	1,816	2,433	25	86	5,747
	Average	151	610	407	87	1,594	2,156	22	74	5,101

Notes:

- (1) - BAS7382: 73.82% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (2) - BAS7458: 74.58% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (3) - FBO8399: 83.99% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (4) - FBO8922: 89.22% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (5) - FBO9208: 92.08% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions

Table 3
2002 Simulated TP Load (Lbs)

		By Reach							
Reach	Name	Scenario							
		Natural	Existing (Baseline)	Full Build Out	BAS7382 (1)	BAS7458 (2)	FBO8399 (3)	FBO8922 (4)	FBO9208 (5)
1	Mirror Lake (1)								
5	Anderson Creek Gage (5)	440	433	687	403	402	439	423	415
6	Northeast Lake Whatcom Inflow (6)	116	130	185	120	120	128	125	123
10	Northeast Lake Whatcom Inflow (10)	606	665	758	630	629	637	629	625
15	Smith Creek Gage (15)								
18	Smith Creek Outlet (18)	421	432	436	425	425	425	424	423
20	Olsen Creek Gage (20)	560	584	677	566	566	579	573	570
25	Carpenter Creek Gage (25)	94	170	437	112	111	146	128	119
30	North Lake Whatcom Inflow (30)	136	321	455	189	188	190	173	164
35	Silver Beach Creek Gage (35)	35	291	559	102	100	118	91	76
40	North West Lake Whatcom Inflow (40)	304	1,112	2,061	466	460	529	434	381
45	Brannian Creek Gage (45)								
50	Brannian Creek Outlet (50)	312	313	334	295	294	296	293	292
55	South Lake Whatcom Inflow (55)	358	597	1,218	424	422	499	454	430
60	Upper Austin Creek (60)								
65	Beaver Cr trib Austin Cr (65)								
70	Austin Creek at Gage (70)								
72	Austin Creek Outlet (72)	466	671	1,379	502	501	594	545	518
75	Southwest Lake Whatcom Inflow (75)	97	344	788	159	157	204	168	148
80	Southwest Lake Whatcom Inflow (80)	26	200	266	72	70	65	52	45
85	Euclid Creek Gauge (85)	21	58	116	30	30	36	31	28
90	Mill Wheel Cr Gage (90)	23	140	301	54	53	68	53	45
TOTAL (Lbs)		4,015	6,460	10,656	4,547	4,528	4,952	4,595	4,401
TOTAL (Kg) By Calendar Year		1,825	2,936	4,844	2,067	2,058	2,251	2,089	2,001

		By Subwatershed							
Reach	Name	Scenario							
		Natural	Baseline (Existing)	Full Build Out	BAS7382 (1)	BAS7458 (2)	FBO8399 (3)	FBO8922 (4)	FBO9208 (5)
1	Mirror Lake (1)	31	30	63	29	29	34	32	31
5	Anderson Creek Gage (5)	412	406	628	376	376	407	394	386
6	Northeast Lake Whatcom Inflow (6)	116	130	185	120	120	128	124	122
10	Northeast Lake Whatcom Inflow (10)	636	695	788	660	659	667	659	655
15	Smith Creek Gage (15)	421	430	432	423	423	423	422	422
18	Smith Creek Outlet (18)	2	4	5	2	2	2	2	2
20	Olsen Creek Gage (20)	563	587	680	569	569	582	576	572
25	Carpenter Creek Gage (25)	95	170	438	112	111	147	129	119
30	North Lake Whatcom Inflow (30)	135	321	454	189	187	189	173	164
35	Silver Beach Creek Gage (35)	35	291	560	102	100	119	91	76
40	North West Lake Whatcom Inflow (40)	304	1,116	2,070	468	461	531	435	383
45	Brannian Creek Gage (45)	306	290	305	285	285	287	285	285
50	Brannian Creek Outlet (50)	7	25	31	12	12	11	10	9
55	South Lake Whatcom Inflow (55)	358	598	1,219	425	423	500	455	431
60	Upper Austin Creek (60)	204	213	344	206	206	227	219	215
65	Beaver Cr trib Austin Cr (65)	226	316	628	239	239	279	257	245
70	Austin Creek at Gage (70)	13	30	144	18	18	34	27	24
72	Austin Creek Outlet (72)	27	127	281	54	53	68	55	48
75	Southwest Lake Whatcom Inflow (75)	97	343	787	159	157	204	168	148
80	Southwest Lake Whatcom Inflow (80)	26	200	267	72	71	65	52	46
85	Euclid Creek Gauge (85)	21	58	116	30	30	36	31	28
90	Mill Wheel Cr Gage (90)	23	141	302	54	53	68	53	45
TOTAL (Lbs)		4,059	6,521	10,726	4,605	4,585	5,007	4,651	4,456
TOTAL (Kg) By Calendar Year		1,845	2,964	4,876	2,093	2,084	2,276	2,114	2,025

Notes:

- (1) - BAS7382: 73.82% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (2) - BAS7458: 74.58% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (3) - FBO8399: 83.99% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (4) - FBO8922: 89.22% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (5) - FBO9208: 92.08% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions

Table 4
2003 Simulated TP Load (Lbs)

		By Reach							
Reach	Name	Scenario							
		Natural	Existing (Baseline)	Full Build Out	BAS7382 (1)	BAS7458 (2)	FBO8399 (3)	FBO8922 (4)	FBO9208 (5)
1	Mirror Lake (1)								
5	Anderson Creek Gage (5)	604	592	923	548	547	594	574	562
6	Northeast Lake Whatcom Inflow (6)	158	175	246	163	163	173	168	166
10	Northeast Lake Whatcom Inflow (10)	796	872	988	827	827	835	826	820
15	Smith Creek Gage (15)								
18	Smith Creek Outlet (18)	518	531	536	523	523	523	522	521
20	Olsen Creek Gage (20)	698	726	837	705	705	720	713	709
25	Carpenter Creek Gage (25)	107	188	471	126	125	163	144	133
30	North Lake Whatcom Inflow (30)	154	353	497	211	210	212	195	185
35	Silver Beach Creek Gage (35)	26	290	557	95	93	111	83	68
40	North West Lake Whatcom Inflow (40)	382	1,229	2,261	546	539	617	515	459
45	Brannian Creek Gage (45)								
50	Brannian Creek Outlet (50)	491	488	515	462	462	463	460	458
55	South Lake Whatcom Inflow (55)	492	787	1,585	574	572	673	616	585
60	Upper Austin Creek (60)								
65	Beaver Cr trib Austin Cr (65)								
70	Austin Creek at Gage (70)								
72	Austin Creek Outlet (72)	664	904	1,753	703	701	813	755	723
75	Southwest Lake Whatcom Inflow (75)	152	464	1,048	230	227	290	243	217
80	Southwest Lake Whatcom Inflow (80)	24	195	260	69	68	62	50	43
85	Euclid Creek Gauge (85)	20	55	110	30	29	35	30	28
90	Mill Wheel Cr Gage (90)	19	136	296	50	49	63	49	41
TOTAL (Lbs)		5,307	7,983	12,883	5,861	5,839	6,348	5,940	5,717
TOTAL (Kg) By Calendar Year		2,412	3,629	5,856	2,664	2,654	2,885	2,700	2,599

		By Subwatershed							
Reach	Name	Scenario							
		Natural	Baseline (Existing)	Full Build Out	BAS7382 (1)	BAS7458 (2)	FBO8399 (3)	FBO8922 (4)	FBO9208 (5)
1	Mirror Lake (1)	42	41	84	40	40	46	44	42
5	Anderson Creek Gage (5)	565	553	844	511	510	551	533	523
6	Northeast Lake Whatcom Inflow (6)	158	176	247	163	163	173	169	166
10	Northeast Lake Whatcom Inflow (10)	795	872	988	826	826	834	825	820
15	Smith Creek Gage (15)	519	529	532	522	521	521	520	520
18	Smith Creek Outlet (18)	2	5	7	3	3	3	3	3
20	Olsen Creek Gage (20)	700	728	840	708	707	723	715	711
25	Carpenter Creek Gage (25)	108	189	472	127	126	163	144	134
30	North Lake Whatcom Inflow (30)	154	353	497	211	209	212	194	184
35	Silver Beach Creek Gage (35)	27	291	560	95	93	112	84	68
40	North West Lake Whatcom Inflow (40)	383	1,234	2,268	548	541	619	516	460
45	Brannian Creek Gage (45)	480	452	472	445	445	447	445	444
50	Brannian Creek Outlet (50)	12	36	44	19	18	17	16	15
55	South Lake Whatcom Inflow (55)	493	788	1,586	575	573	673	617	585
60	Upper Austin Creek (60)	306	317	478	309	309	334	325	320
65	Beaver Cr trib Austin Cr (65)	300	403	766	315	314	361	336	322
70	Austin Creek at Gage (70)	20	41	181	26	25	46	37	33
72	Austin Creek Outlet (72)	41	164	351	75	74	92	76	67
75	Southwest Lake Whatcom Inflow (75)	152	463	1,046	229	227	290	243	217
80	Southwest Lake Whatcom Inflow (80)	24	195	260	69	68	62	50	43
85	Euclid Creek Gauge (85)	20	55	110	30	29	35	30	28
90	Mill Wheel Cr Gage (90)	19	136	296	50	49	63	49	41
TOTAL (Lbs)		5,322	8,022	12,929	5,894	5,872	6,378	5,970	5,747
TOTAL (Kg) By Calendar Year		2,419	3,646	5,877	2,679	2,669	2,899	2,714	2,612

Notes:

- (1) - BAS7382: 73.82% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (2) - BAS7458: 74.58% reduction in agriculture, developed, and open land use acreage from Baseline (Existing) Conditions
- (3) - FBO8399: 83.99% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (4) - FBO8922: 89.22% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions
- (5) - FBO9208: 92.08% reduction in agriculture, developed, and open land use acreage from Full Build Out (FBO) Conditions

Figures

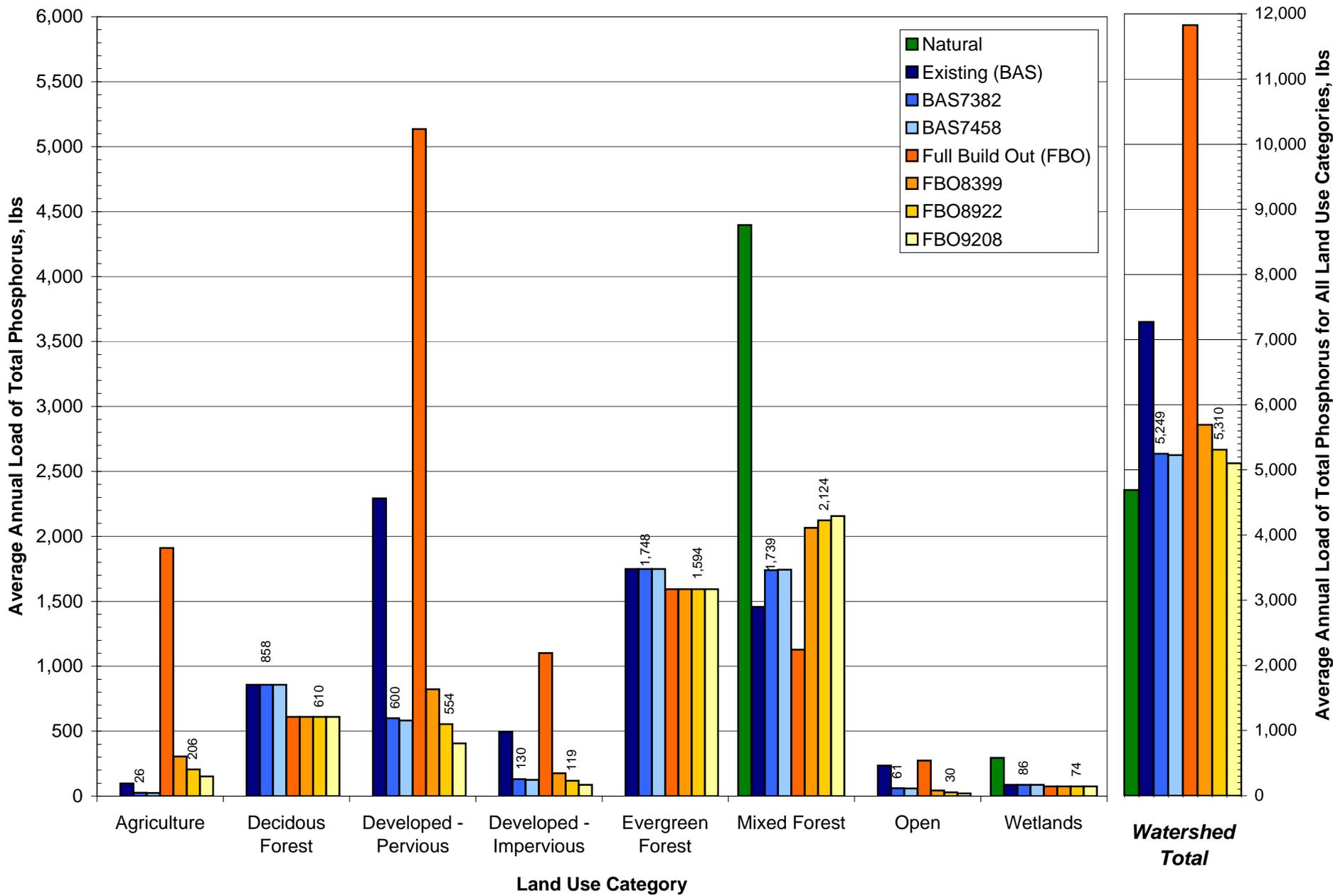


Figure 1
Average Total Phosphorus Loadings
by Land Use Category

Appendix A: Model Files Included Electronically

The HSPF model files will be distributed in “.zip” files. The files will be included for the following scenarios:

- Natural - LW_NaturalConditions.zip
- Existing - LW_ExistingConditions.zip
- Full Build Out - LW_FullBuildOut.zip
- BAS7458 - LW_BAS7458.zip
- FBO8399 - LW_FBO8399.zip
- BAS7382 - LW_BAS7382.zip
- FBO9208 - LW_FBO9208.zip
- FBO8922 - LW_FBP8922.zip