Subject: RE: Progress Update
From: "Rob Zisette"
To: "Lake Stintzi"

Hi Lake,
I attached are a couple of graphs of the water budget. They show that inputs are primarily from surface water (77%) with low groundwater input (14%), which is a good sign for phosphorus inactivation by alum or phoslock.

We will finish the phosphorus budget next week. We have the watershed phosphorus input data and I attached the report from NHC on the that and the water budget. We are still working on the internal loading and determined that we can only do that for the summer months when we have lake P data, and it is quite substantial and will be sufficient for our treatment analysis. We are looking at calculating the dose of alum and phoslock for three alternatives in decreasing order of dose and effectiveness:

1. Inactivate all sediment phosphorus to reduce internal loading and cyanobacteria blooms for about 10 years 2. Inactivate all watershed phosphorus input during the summer of 2015 to reduce cyanobacteria blooms for about two years 3. Inactivate all phosphorus present in the lake in June to reduce cyanobacteria blooms in 2015

We will then predict the effectiveness and cost of each alternative, and work with you in selection of the preferred alternative.

Rob

nhc
northwest hydraulic consultants

NHC Project No. 2000655

April 15, 2015

Herrera Environmental Consultants
2200 6th Ave #1100
Seattle, WA 98121

Attention: Rob Zisette

Via email: rzisette@herrerainc.com

Re: Black Lake Phosphorus and Algae Control Plan,
Simulated Water-Budget and External Phosphorus Loads

This memorandum and attachment provide the simulated inflows and external phosphorus loads for the Black Lake Phosphorus and Algae Control Plan project. This constitutes Northwest Hydraulic Consultant's (NHC) deliverables described in the scope of work between Herrera Environmental (Herrera) and the Black Lake Special District (BLSD). The simulations were performed using an existing hydrology and water-quality model of the Black Lake watershed developed previously by NHC under an EPA Science to Local Policy grant administered by Thurston County (NHC, 2014). The watershed model uses the Hydrologic Simulation Program Fortran (HSPF) software program to simulate watershed runoff, hydraulic routing, and pollutant loading to Black Lake.

Herrera is performing in-lake sampling, compiling NHC's simulated external phosphorus load into the overall lake phosphorus budget (which will also include estimates of internal loading from lake sediments), and designing a lake phosphorus and algae control plan.

Included in this memorandum are the following:

- Background on the Black Lake HSPF model. Specifically addressing the geographic scope of the model, model limitations, and assumptions. These include the lack of Black Lake basin-specific phosphorus loading data for model calibration or verification, and the use of data from another basin to parameterize the model's phosphorus-related algorithms..

- Summarized water-budget and external phosphorus loads simulated for calendar years 2010 – 2012. The relative surface and groundwater components of the water budget and external phosphorus loads are summarized for each month.

1 BACKGROUND ON BLACK LAKE HSPF MODEL

1.1 Model Extents

The Black Lake HSPF model extends beyond the 7.7 square miles that drain directly to the local Black Lake sub-basin to include Dempsey Creek and Fish Trap Creek tributaries that flow into a wetland at the east edge of Black Lake. That wetland is located on the basin divide between the Black River (WRIA 23) and Black Lake/Percival Creek basin (WRIA 13). The split of Dempsey Creek between the Black River and Black Lake basins was adjusted during the calibration documented by NHC (2014), ultimately ending with 40% routed to Black Lake and 60% routed to the Black River. The basin area of Dempsey Creek, Fish Trap Creek, and the Black Lake wetland is 11.5 square miles. Together with basin local to Black Lake this makes the total basin area 19.2 square miles. However, due to the flow split, only 13.1 square miles of surface runoff is effectively routed into Black Lake.

In addition to the topographic basin receiving surface runoff, the model also includes a groundwater inflow into the Black Lake basin and a groundwater loss out of the basin. The groundwater inflow comes from 1.7 square miles in the Salmon Creek basin to the southeast and the groundwater loss is to the McLane Creek basin to the northwest. The groundwater influences are documented in USGS (1999) and PGG (2001). The loss to McLane Creek was determined during model calibration, and occurs only during high lake stages. These groundwater flow patterns are documented in further detail in NHC (2014).

Sub-basin and existing land cover conditions represented in the model are shown in Figure 1 and Figure 2 below. A schematic of the HSPF model framework is also attached as Figure 3. The stage-discharge rating table of Black Lake is included as Appendix A.

1.2 Phosphorus Load Parameters and Lack of Calibration Data

At the time of the NHC (2014) study, no observed phosphorus data was available at inflow locations to Black Lake. Ideally, the model's phosphorus load parameters would be calibrated to observed data, but due to the lack of such data, the parameters were assigned based on values from the Newaukum Creek basin, located near Enumclaw in King County. This basin was selected because parameters were available and, relative to other basins where such parameters are available, the climate, development types, and densities were similar to the Black Lake basin. In addition to modeling the Black Lake Basin, the 2014 NHC study also included McLane Creek and Woodard Creek for which some total phosphorus (TP) data were available. However, these data were not sufficient for phosphorus calibration which requires both total suspended solids (TSS) and TP data due to the close association of phosphorus with sediment. Instead, the Newaukum parameters (with minor modifications required to map to land use classes not included in that basin) were used for all three basins and the TP results for Woodard Creek and McLane Creek were compared with the available data. These comparisons indicated that simulated long term average TP concentrations were 10% and 35% higher than the average concentration of collected samples from the respective creeks. These results provide an indication of the magnitude of potential error in the simulated TP inflows to Black Lake.

It is NHC's recommendation that the phosphorus loading parameters for this model should be calibrated to observed data if an accuracy higher than + or – 50% is needed. However, project resources available for the current Algae Control Plan project were not sufficient to support a calibration effort of any kind. Without a calibration, the error on the loading estimate needs to be considered as part of the control plan.

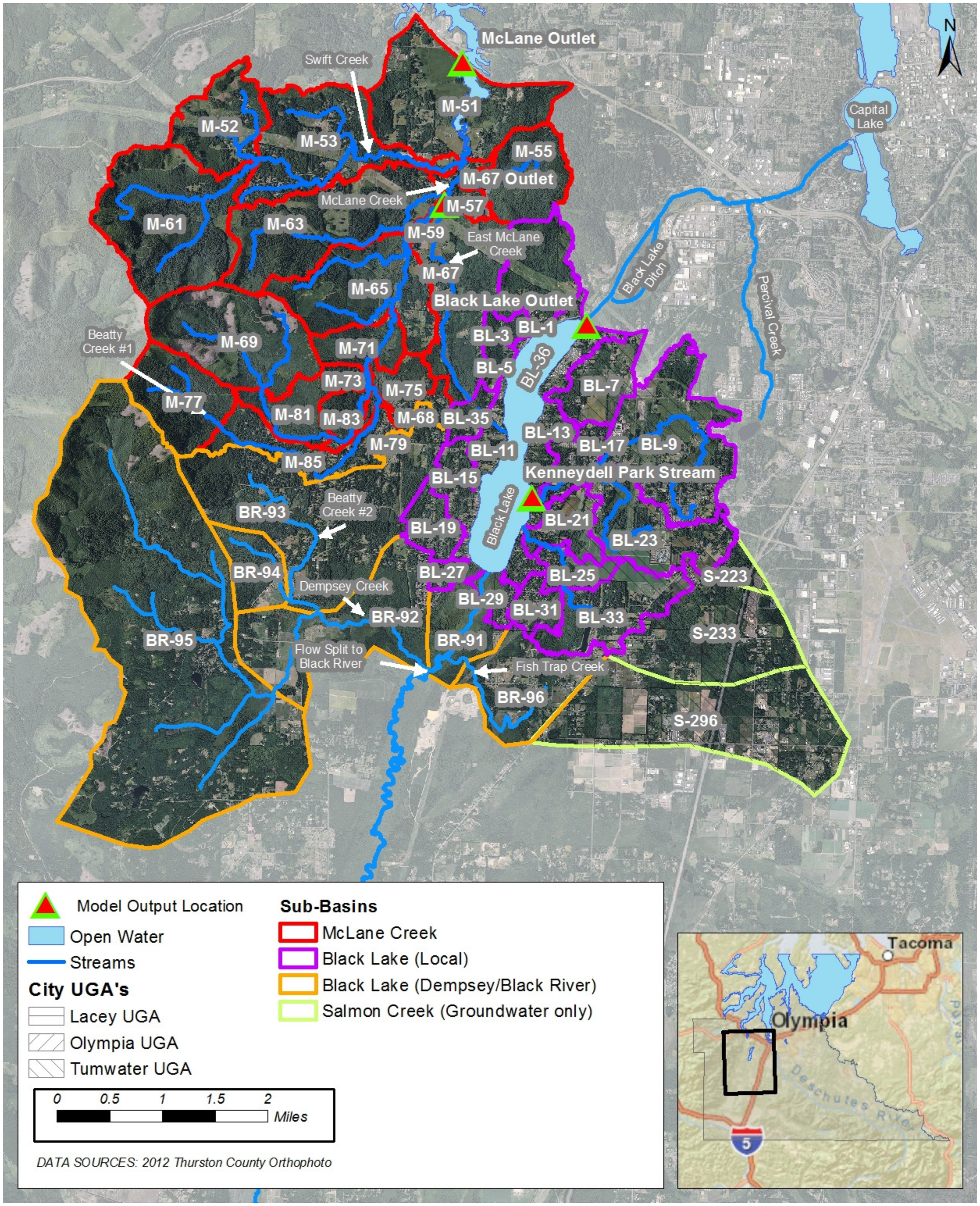


Figure 1: Black Lake HSPF Model Sub-Basins (from NHC, 2014)

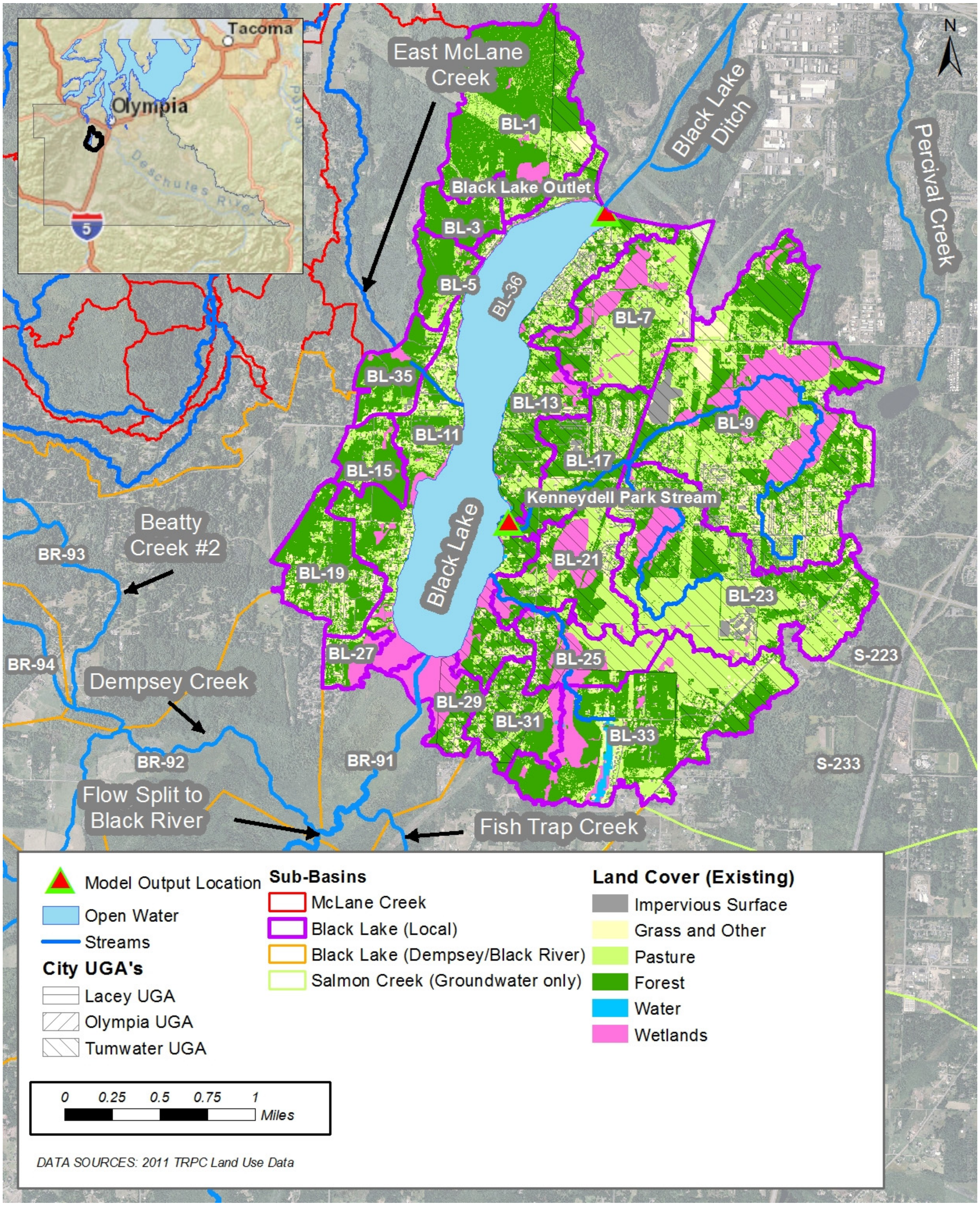
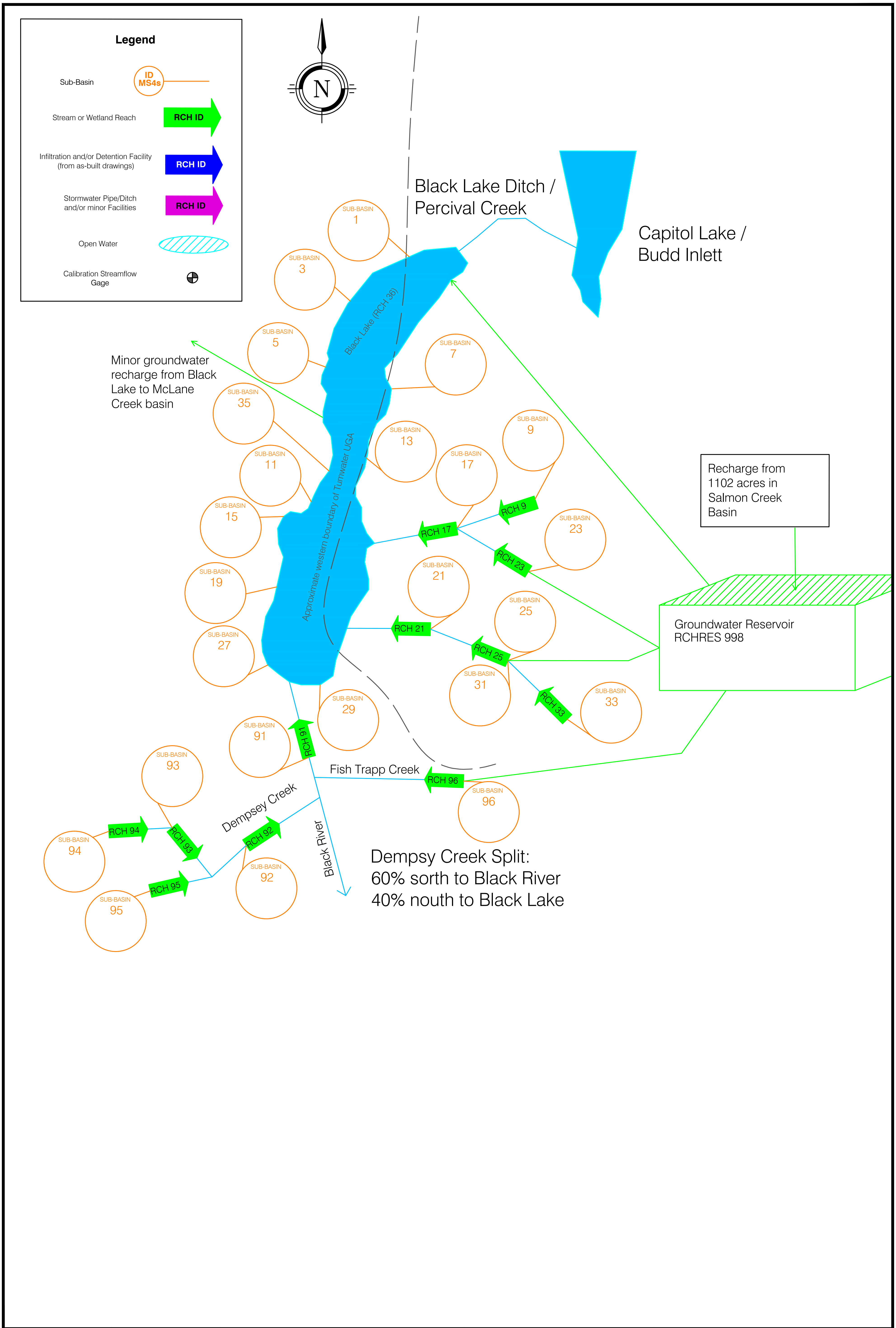


Figure 2: Existing Conditions Land-Cover for Local Black Lake (from NHC, 2014)



SCALE:N/A	PROJECT # 21881	northwest hydraulic consultants nhc 16300 Christensen Rd Ste. 350 Seattle, WA 98188-3418 phone:(206) 241-6000 fax:(206) 439-2420 www.nhcweb.com	HSPF MODEL SCHEMATIC FOR BLACK LAKE	FIGURE: 3
DESIGNED: DLS				
DRAWN: MAO	DATE: 8/1/2013			

2 BLACK LAKE WATER-BUDGET AND EXTERNAL PHOSPHORUS LOADS FOR CALENDAR YEARS 2010 – 2012

The Black Lake HSPF model was used to simulate the hydrology of Black Lake for use in establishing the water-budget and external phosphorus loads for calendar years 2010 – 2012 based on measured precipitation during this period and typical monthly values for pan evaporation. This required modifying the HSPF model to store time-series of simulated water volumes and phosphorus loads for the locations of interest. These simulated loads will be used by Herrera staff to calculate the total lake phosphorus budget. These locations included:

- Inflows to Black Lake
    - Kenneydell Park Stream
    - An unnamed stream on the east bank of Black Lake
    - Surface runoff from local drainage areas tributary to the Lake
    - Groundwater inflows from local drainage areas tributary to the Lake
    - Groundwater inflows from the Salmon Creek basin
    - Precipitation on the surface of the lake
- Outflows from Black Lake
    - Lake evaporation
    - Black Lake Ditch
    - Groundwater losses to the McLane Creek basin
- Lake volume at the end of each calendar month

2.1 Monthly Summaries

The resulting inflows and outflows are summarized for each month in calendar years 2010, 2011, and 2012 below in Table 1, Table 2, and Table 3 respectively. The relative contributions of each source are discussed briefly below in Section 2.2.

Table 1: 2010 Water Budget and External Phosphorus Loads by Month													
Month	Inflows to Black Lake									Outflows from Black Lake			
	All Surface Inflow		All Groundwater Inflows		Precipitation Inflows		Total Inflows			Evaporation from Lake	Groundwater to McLane	Black Lake Ditch	Total Outflows
	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
J-10	3192	498	497	34	364	0	4053	533		32	520	3409	3961
F-10	2080	253	432	30	217	0	2729	283		30	440	2204	2675
M-10	2143	284	432	29	240	0	2816	313		61	436	2124	2621
A-10	2017	264	432	36	158	0	2607	300		88	431	2557	3076
M-10	1128	140	319	31	151	0	1598	170		135	215	1331	1681
J-10	1309	430	279	30	166	0	1754	460		159	249	1390	1798
J-10	712	68	209	22	7	0	929	90		192	24	868	1084
A-10	532	47	149	15	3	0	684	63		160	< 1	614	774
S-10	768	231	122	13	284	0	1174	243		98	64	819	980
O-10	1307	678	151	15	282	0	1740	693		46	119	1192	1357
N-10	1998	727	304	27	278	0	2579	754		26	445	2205	2676
D-10	3987	772	501	39	471	0	4958	811		24	501	4041	4565

Table 2: 2011 Water Budget and External Phosphorus Loads by Month													
Month	Inflows to Black Lake									Outflows from Black Lake			
	All Surface Inflow		All Groundwater Inflows		Precipitation Inflows		Total Inflows			Evaporation from Lake	Groundwater to McLane	Black Lake Ditch	Total Outflows
	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
J-11	3811	609	640	48	351	0	4802	657		32	535	4367	4934
F-11	2053	233	481	34	179	0	2712	267		30	448	2320	2798
M-11	4156	687	645	49	454	0	5255	736		62	540	4445	5047
A-11	2759	352	590	52	233	0	3582	404		89	500	3163	3752
M-11	2079	452	481	49	191	0	2750	502		139	469	2404	3011
J-11	989	95	348	32	36	0	1373	127		158	186	1250	1595
J-11	753	70	283	24	66	0	1102	93		192	35	931	1158
A-11	593	51	233	18	11	0	838	68		160	< 1	756	916
S-11	504	38	152	12	73	0	730	50		98	< 1	625	723
O-11	546	42	127	11	156	0	828	52		45	< 2	759	805
N-11	1744	568	153	13	408	0	2305	580		25	144	1464	1633
D-11	1639	249	244	18	220	0	2102	266		23	281	1686	1989

Table 3: 2012 Water Budget and External Phosphorus Loads by Month													
Month	Inflows to Black Lake									Outflows from Black Lake			
	All Surface Inflow		All Groundwater Inflows		Precipitation Inflows		Total Inflows			Evaporation from Lake	Groundwater to McLane	Black Lake Ditch	Total Outflows
	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)	Volume (acre-ft)	TP (lbs)		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
J-12	2804	451	397	27	329	0	3530	477		32	500	3039	3571
F-12	2331	294	443	31	221	0	2995	325		31	466	2630	3127
M-12	3325	504	551	40	397	0	4273	544		62	520	3345	3926
A-12	2692	364	549	49	231	0	3472	413		89	503	3306	3897
M-12	1700	218	453	46	125	0	2277	265		138	401	2057	2596
J-12	1018	120	335	32	116	0	1469	152		158	180	1226	1563
J-12	738	69	256	24	51	0	1045	93		192	32	917	1142
A-12	560	49	171	16	2	0	734	65		160	< 1	674	834
S-12	436	35	121	11	< 1	0	557	47		97	< 1	509	606
O-12	602	63	102	10	319	0	1022	73		45	8	633	686
N-12	2371	1025	258	23	414	0	3044	1048		26	386	2279	2691
D-12	4442	856	600	47	534	0	5576	904		24	548	4757	5328

2.2 Annual Average Summaries and Discussion

The relative water balance inflow volumes and external phosphorus loads for each source are discussed below and are presented graphically as pie charts in Figure 4 and Figure 5.

2.2.1 Water-Balance

The water balance inflow volume chart (Figure 4, left) shows that surface water inflows make up 76% of the total inflow volume, with groundwater and precipitation making up the remaining 15% and 9% respectively. And of the surface water inflows, the Black River Wetland on the southwest end of the lake provides 42% of the total inflow volume. There is some uncertainty regarding the nature of this inflow, given that there has been no continuous monitoring of the flow split from Dempsey Creek into the Black River Wetland or the inflow from the Black River Wetland into Black Lake. However, during calibration of the HSPF model to observed flows out of Black Lake Ditch, NHC found that this volume of additional inflow to Black Lake was needed to match observed outflows from the lake. As stated previously, the HSPF model is configured to route 40% of the flows from Dempsey Creek to Black Lake and 60% to the Black River. This is the flow split needed to achieve the water balance on an annual scale, but it is likely that the flow split varies temporally throughout the year as a function of vegetation in the wetland and the stage of Black Lake. If more detailed refinement of the temporal character of inflows from the Black River wetland are needed to design lake phosphorus control measures, then additional hydraulic modeling and/or monitoring of the wetland would need to be performed.

The water balance losses chart (Figure 4, right) shows that Black Lake Ditch makes up 84% of the total outflow volume, with groundwater loss to the McLane basin and evaporation from the surface of Black Lake making up the remaining 12% and 4% respectively.

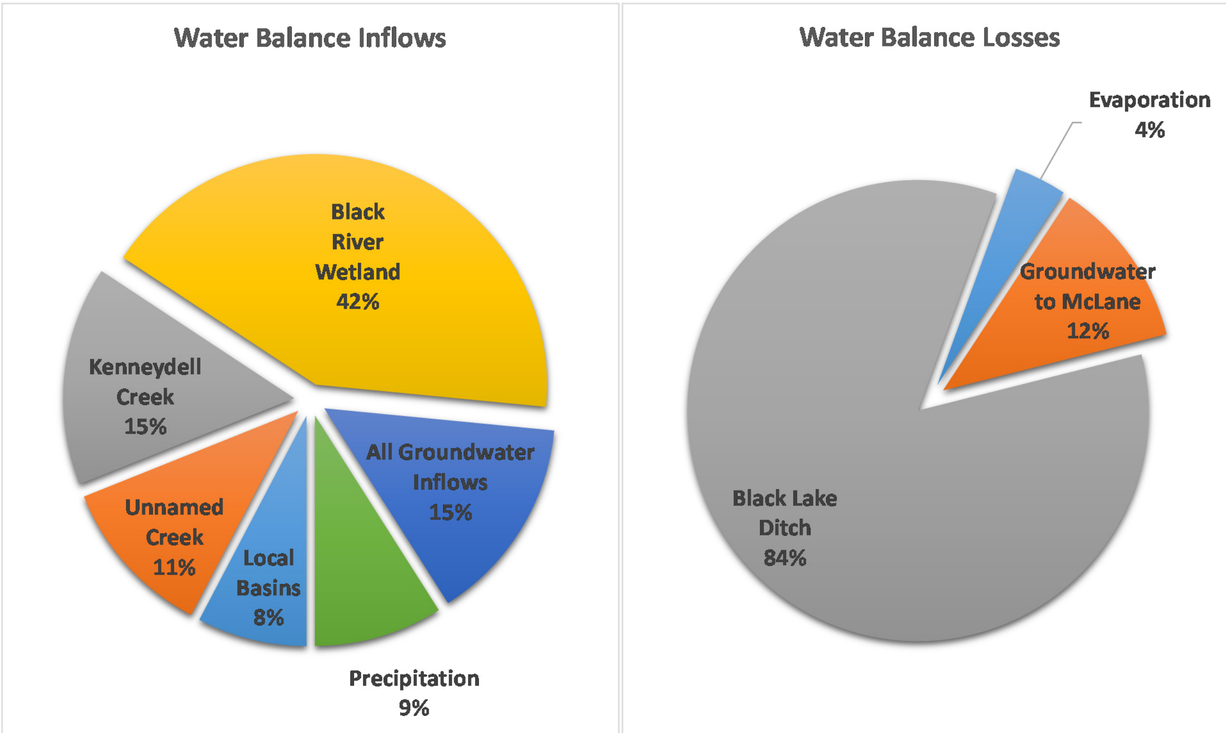


Figure 4: Water Balance Inflows (left) and Losses (right), Simulated for Calendar Years 2010 – 2012

2.2.2 External Total Phosphorus Load

The external total phosphorus load chart (Figure 5) shows that surface water inflows make up 92% of the total external phosphorus load to Black Lake, with groundwater making up the remaining 8%. It is important to re-iterate that these loads are not based on any observed data from the Black Lake basin since the HSPF model phosphorus parameters have not been calibrated to observed data. One possible adjustment that could easily be made would be that of the phosphorus load from groundwater sources. Currently the concentration of groundwater inflows specified in the model range from 8 to 66 micro g/L with the average of all land uses in the basin being 30 micro g/L. If observed data existed for the concentration of groundwater inflows into Black Lake, the total phosphorus load from groundwater sources could be re-calculated and the external load budget adjusted. An adjustment of surface water loads could also be made, but the processes involved are more complicated than those for groundwater cannot be changed by simply changing a single concentration value.

The largest single source of phosphorus to Black Lake is the Black River Wetland. This is largely due to the large volume of inflows coming from that source. Additional refinement of the Dempsey Creek flow split and its impact on this inflow source would also help refine the relative contribution of this source of phosphorus into Black Lake.

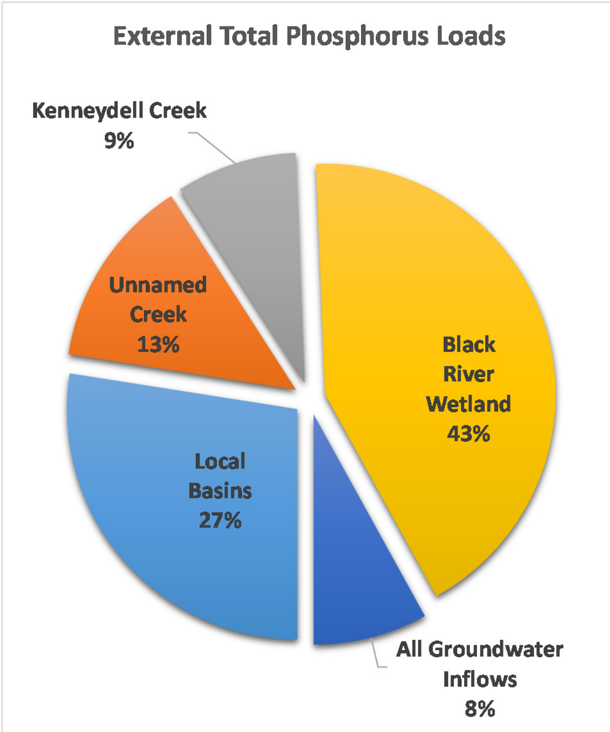


Figure 5: External Total Phosphorus Loads for Calendar Years 2010 – 2012

3 CLOSING REMARKS

The above water budget and external phosphorus load summaries, coupled with the attached EXCEL spreadsheet, should provide a planning level estimate for Herrera to use for the Black Lake Phosphorus and Algae Control Plan. As stated previously there is a significant amount of uncertainty in the external phosphorus load due to the lack of observed data or model calibration. If the designed treatment for the lake needs a level of accuracy greater than + or – 50% we recommend that the model be calibrated and the external loads be recalculated. The water-budget, while calibrated to observed outflow data from Black Lake ditch, also has some uncertainties. Specifically with respect to the flow split from Dempsey Creek into the Black River wetland at the southwest end of the lake. If the designed lake treatment is sensitive to this inflow source, we recommend that additional monitoring and/or hydraulic modeling of the flow split be performed and the water-budget be calculated with the HSPF model.

5 REFERENCES

NHC (2014). Hydrologic Modeling In Support Of Watershed Based Land Use Planning In Thurston County, Final Hydrologic Modeling Report. Prepared by Northwest Hydraulic Consultants for Thurston County Planning Department. Project No. 21881. December 2014.

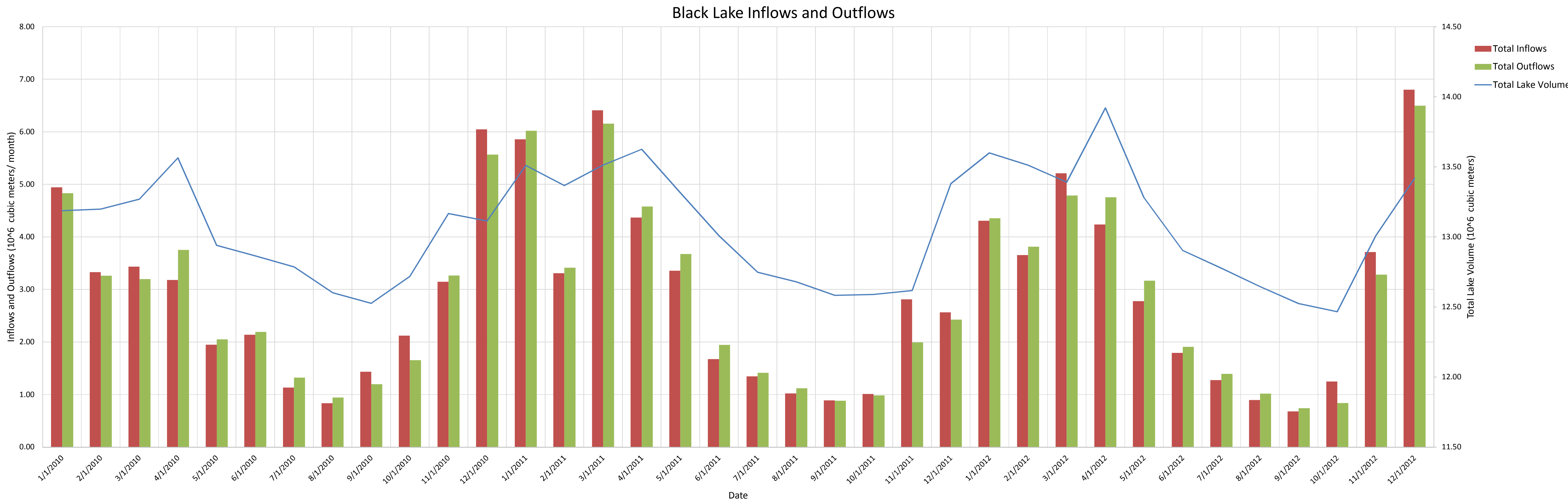
PGG (2001). Salmon Creek Drainage Basin Conceptual Hydrologic Model, Prepared by Pacific Groundwater Group for URS and Thurston County Water and Waste Management, June 2001.

USGS (1999). Conceptual Model and Numerical Simulation of the Ground-Water-Flow System in the Unconsolidated Sediments of Thurston County. U.S. Geological Survey Water Resources Investigations Report 99-4165.

APPENDIX A

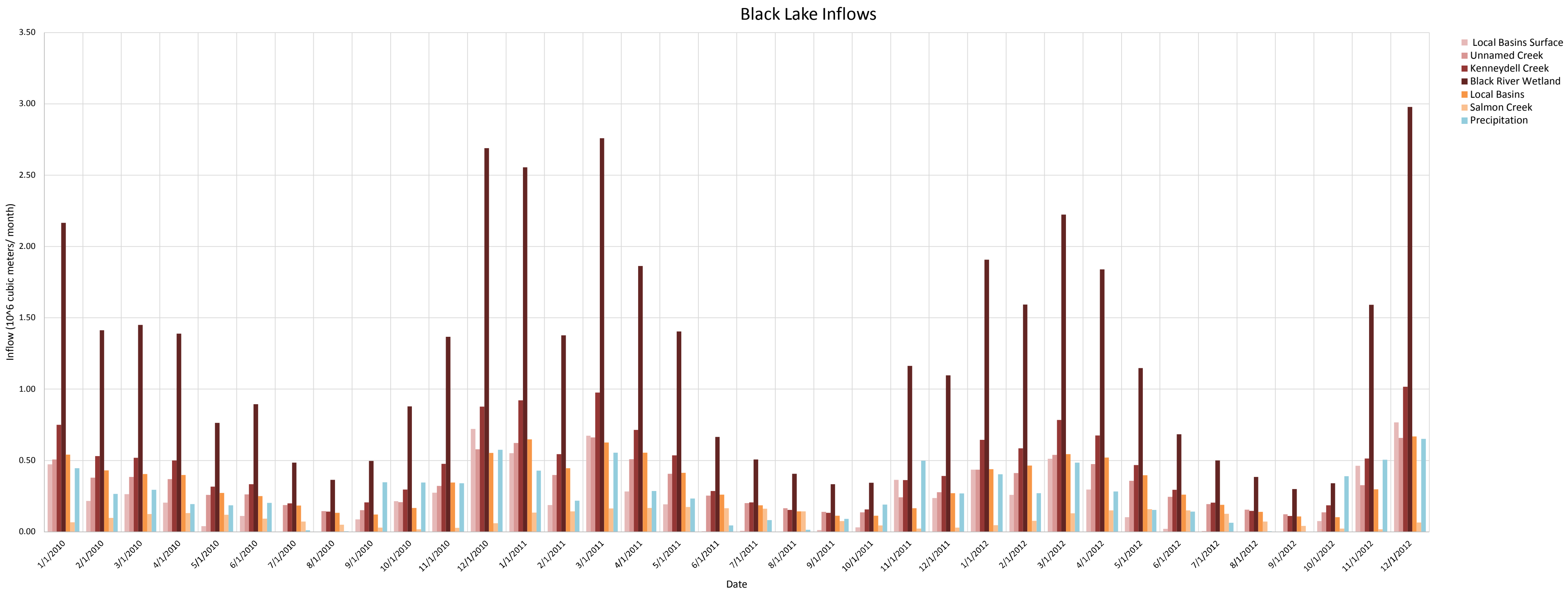
HSPF Model Representation of Black Lake Bathymetry and Outlets. Outlet #1 is a surface water discharge. Outlet #2 is volume lost to groundwater in the McLane Creek basin when lake stages are high.

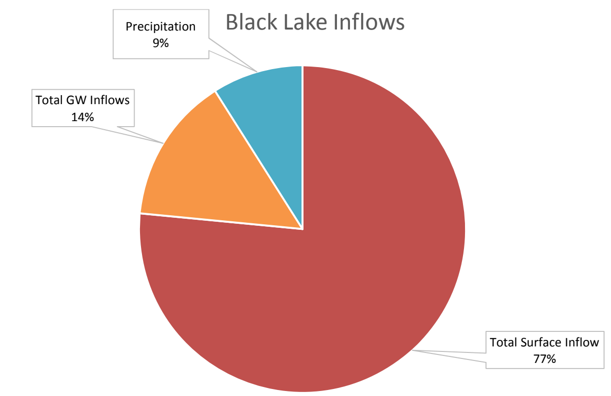
```
*******************************************************
 FTABLE     36
 ***UPDATED 8/7/2013 to include bathymetry contours
 ***depths correspond to lake depth with 30.1 being the 127.5 NAVD1988 LiDAR at lake edge
  17   5
   Depth       Area      Volume        Outflow1      Outflow2        ***
    (ft)       (acres)   (acre-ft)     (cfs)         (cfs)           ***
     0          0         0.000         0             0.00
    0.1         15        0.739         0             0.00
    5.1         107       305.4         0             0.00
    10.1        309       1345.7        0             0.00
    15.1        412       3147.5        0             0.00
    20.1        466       5341.3        0             0.00
    25.1        508       7776.8        0             0.00
    27.8        528       9175.4        0             0.00
    29.3        538       9974.7        1.2           0.00
    29.7        541       10190.6       6.6           0.00
    30.1        544       10407.6       13.9          0.00
   30.45        560       10613.0       25            5.00
    30.9        573       10826.5       37            8.00
    31.6        580       11258.9       75            9.00
    33.6        606       12444.6       220           10.00
    35.6        695       13745.9       353           12.00
***extrapolated
    40.0        891       16610         646           15.00
 END FTABLE 36
*******************************************************
```

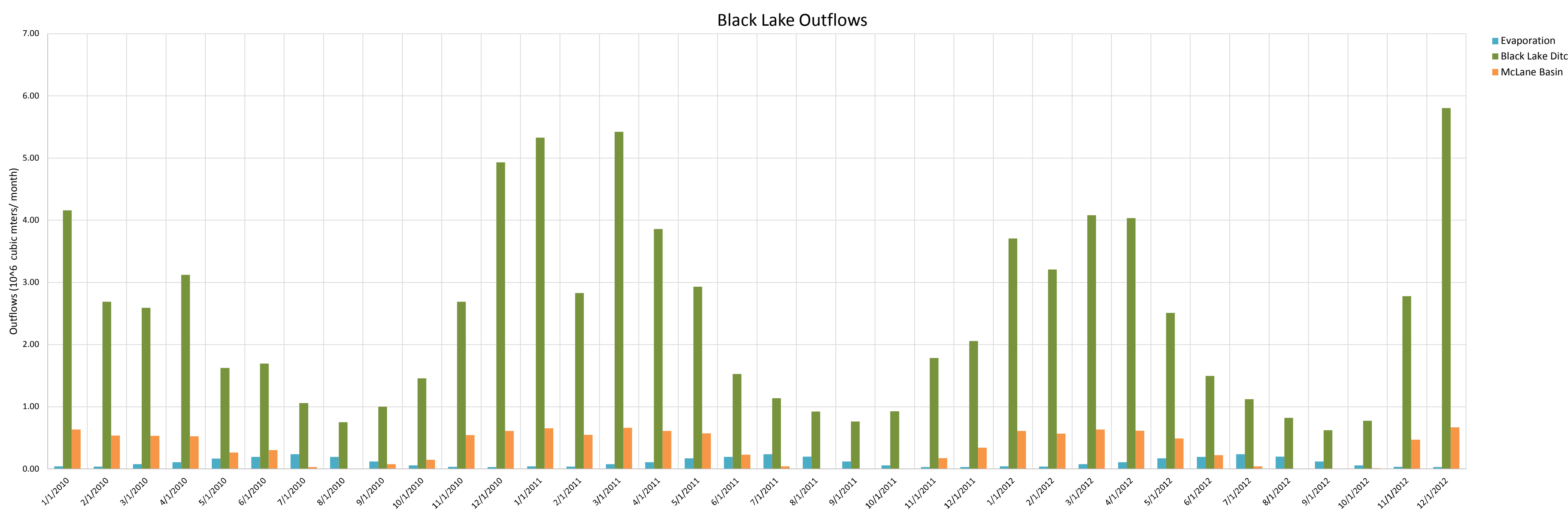


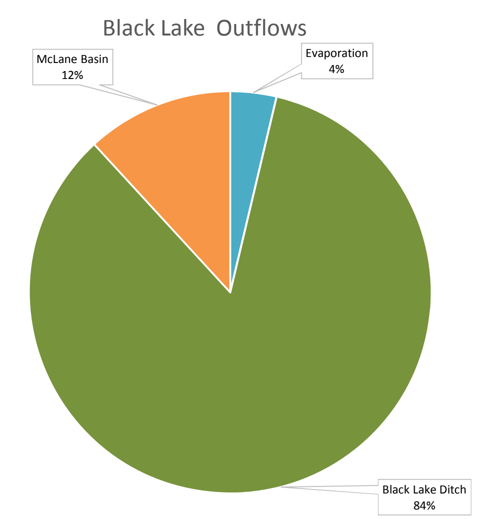
Black Lake Inflows and Outflows

Source	Total Inflow (10^6 m3)	% of Total Inflow
Groundwater	15	14%
Surface Inflows	80	77%
Precipitation	9	9%
Total	105	100%
Source	Total Outflow (10^6 m3)	% of Total Outflow
Groundwater	12	12%
Lake Outlet	88	84%
Evaporation	4	4%
Total	104	100%


Black Lake Inflows
Inflow (10^6 cubic meters/ month)
Date
Local Basins Surface
Unnamed Creek
Kenneydell Creek
Black River Wetland
Local Basins
Salmon Creek
Precipitation


Black Lake Inflows
Precipitation 9%
Total GW Inflows 14%
Total Surface Inflow 77%


Black Lake Outflows
Outflows (10^6 cubic mters/ month)
Date
Evaporation
Black Lake Ditch
McLane Basin


Black Lake Outflows
McLane Basin 12%
Evaporation 4%
Black Lake Ditch 84%