technical memo - forest lmd

Project Name |	Shields Lake Diagnostic Study	**Date** |	7-19-2016
To / Contact info |	CLFLWD Board of Managers		
Cc / Contact info |	Mike Kinney, District Administrator		
From / Contact info |	Meghan Funke, PhD Greg Graske, PE		
Regarding |	Task 2 – Shields Lake Diagnostic Monitoring		

In 2015, the City of Forest Lake and the Watershed District were in discussions regarding the drainage through the existing neighborhood located between Harrow Avenue and Shields Lake. Future development was proposed west of Harrow Avenue. (Note that a portion of this area was permitted for construction through the District under Chestnut Creek permit 16-008 and is currently under construction). Phase 1 of the Shields Lake Diagnostic project included a review of loading and flows through the existing neighborhood to determine if there are projects that should be implemented as part of future development west of Harrow Avenue to reduce loads to Shields Lake. EOR completed a hydrological and water quality model to determine the water quality benefit of enlarging the two storage ponds at Heath/209th Street and increasing the storage capacity of the wetland south of Heath Street North and north of Holstad Trail. However, enlarging the ponds and increasing the storage capacity of the wetland did not provide any significant additional phosphorus reduction due to the large volumes of flow through these water bodies. The results from this analysis were presented to the Board at the September regular Watershed District meeting as a memo dated September 16, 2015.

At the direction of the Board during the March 26th meeting, Phase 2 of this project was added to conduct flow and water quality monitoring along tributaries to Shields Lake to determine the magnitude of phosphorus coming from the neighborhood located between Harrow Avenue and Shields Lake relative to the amount of phosphorus coming from the entire lake drainage area. The results from Phase 2 are summarized in this memo below.

Methods

Five monitoring locations were identified for flow gauging and monitoring (see Figure 1). Ditch West was located just downstream of the golf course crossing in the open ditch, downstream of the confluence of several drain tile pipes from the golf course. The 208th Street site was located at the upstream end of the 208th Street culvert. The Sump Pump West site was located inside the large sump pump shaft located near the western edge of Shields Lake. The 210th Street site was located at the outlet of the pond adjacent to 210th Street on the east side of Shields Lake. The pond outlet was a 4" PVC pipe. Lastly, the Sump Pump North site was located at the discharge point of the northern sump pump pipe that discharges into the north end of Shields Lake. It should be noted that only grab samples were collected at the Sump Pump North location.

Monitoring consisted of installation of a level logger to monitor water elevations and develop a stage-discharge relationship (rating curve). The rating curve was used to develop continuous flow records for each site (see Figure 2 through Figure 5). Note that a traditional stage-discharge relationship for the Sump Pump West site could not be developed directly from well water levels

because the well and a network of pipes upstream of the well temporarily store water between pumping events, resulting in water levels that don't directly correspond to pump discharge rates. For the Sump Pump West site, the rate of increasing water level in the well was used to determine the inflow rate of runoff into the well, and the rate of decreasing water level in the well was used to determine the pumping rate out of the well. It should be noted that inflow rates into the well are likely underestimated during periods when the pump was manually set to run continuously since it was not possible to determine the inflow rate directly and flows were simply estimated using adjacent values. Consequently there is a large amount of uncertainty in the Sump Pump West continuous flow record. However, even if the total annual flow estimated at this site was underestimated by an order of magnitude, the contribution of flow from this site compared to the rest of the watershed would still be small (~7% of the total).

Up to thirteen flow and water quality grab samples were collected at the sites, dependent on flow conditions (see Table 1). Because site establishment began in 2015 after the spring snowmelt, flow and water quality monitoring was also conducted during the 2016 spring snowmelt to collect samples over one complete year (6/4/2015 – 6/6/2016). Watershed flow volumes, and phosphorus and ortho-phosphorus flow-weighted mean concentration and load, were determined at each tributary monitoring site using FLUX (see Table 2 and Figure 6).

Results

The Ditch West site (which includes drainage from the agricultural fields located west of Harrow Avenue) contributed 234 lb TP/year (61% of the total monitored load) with a flow-weighted mean concentration of 450 µg/L (with 310 µg/L as ortho-phosphate). Undisturbed background flow-weighted mean phosphorus concentrations for this ecoregion are ~100 µg/L.

Watershed flow nearly doubles at the next downstream site, the 208th Street Pond (the focus of the redevelopment analysis), but the flow-weighted mean phosphorus concentration also decreases slightly to 360 µg TP/L. This decrease in flow-weighted mean phosphorus concentration suggests that some treatment of phosphorus occurs downstream of Ditch West and/or there is dilution with lower phosphorus concentration runoff from the wetlands to the south. A flow-weighted mean concentration of 360 µg/L is still much higher than undisturbed background levels, however, future treatment of high phosphorus concentration runoff from Ditch West will likely substantially reduce the phosphorus concentration and load discharged from the 208th Street Pond.

The other two sites with sufficient monitoring data to calculate phosphorus flow-weighted mean concentrations and loads were Sump Pump West and 210th Street Pond. The drainage areas contributing runoff to Sump Pump West and 210th Street Pond (38 acres and 13 acres, respectively) were considerably smaller than Ditch West and 208th Street Pond (294 acres and 704 acres, respectively) with low flow weighted mean phosphorus concentrations (283 µg/L and 209 µg/L, respectively). While flow-weighted mean phosphorus concentrations at Sump Pump West and 210th Street Pond were greater than the ~100 µg TP/L background level for this ecoregion, the total TP loads were 2 orders of magnitude lower than Ditch West and 208th Street Pond.

At the fifth monitoring site, Sump Pump North, only 4 water quality grab samples were collected during the monitoring period. The drainage area to this monitoring site is 22 acres with phosphorus concentrations ranging from 91-650 µg TP/L with 38-96% as ortho-phosphorus.

In addition, 14 composite soil samples were collected and analyzed throughout the golf course to estimate the phosphorus content of the soil (see Figure 7). Eleven of the 14 samples had high or very high phosphorus concentrations (>20 ppm), indicating that sufficient soil phosphorus exists for plant growth.

Conclusions

Overall, the 2015-2016 monitoring captured runoff from 755 acres of the total 851 acre watershed of Shields Lake. The total monitored watershed phosphorus load was 381 lb TP/year, nearly double the Six Lakes TMDL estimate of 187 lb TP/year based on literature unit area land cover values. The Shields Lake BATHTUB model was updated with 2015-2016 watershed monitoring data and recalibrated to the 2006-2015 growing season average in-lake phosphorus concentration of 241 µg TP/L. The updated BATHTUB model predicted a total lake load of 1,107 lb TP/year, with 35% of the load from the watershed and 65% of the load from lake internal loading. In contrast, the Six Lakes TMDL estimated that 18% of the total Shields lake load was from the watershed and 82% of the load was from internal loading.

In summary, the 2015-2016 monitoring data found higher than expected watershed phosphorus loads, particularly at Ditch West, compared to literature unit area land cover values which supports the need for some watershed phosphorus load reductions in addition to in-lake management of internal loads to improve the water quality of Shields Lake and ultimately reduce phosphorus loads to Forest Lake. Ditch West had the highest flow-weighted mean phosphorus concentration and highest phosphorus load for its drainage area compared to the other sites. Flows at Ditch West could be impounded to harvest stormwater for an irrigation reuse system for the golf course. Preliminary estimates for ~2 acres of pond storage and irrigation of ~100 acres of golf course greens could remove up to 50% of the annual runoff and 64% of the phosphorus load (70 lb TP/year via irrigation and 50 lb TP/year via pond sedimentation) at Ditch West. In addition, residential development of the agricultural lands west of Harrow Avenue under District rules will also reduce phosphorus loading to Shields Lake. For example, the Chestnut Creek development (permit 16-008) includes proposed treatment features that will reduce loads by approximately 32 lb TP/year.

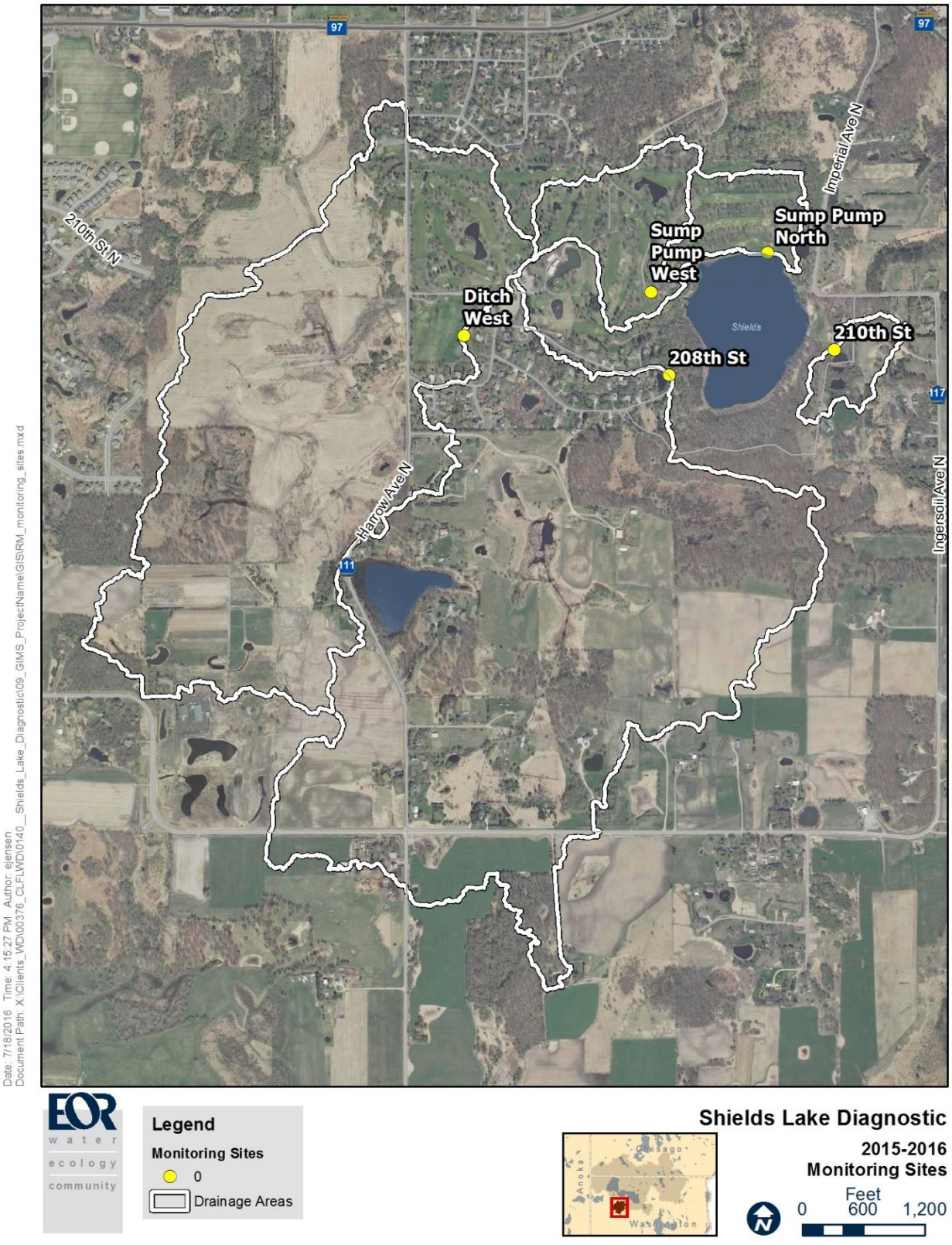

Figure 1. 2015-2016 Shields Lake Monitoring Sites

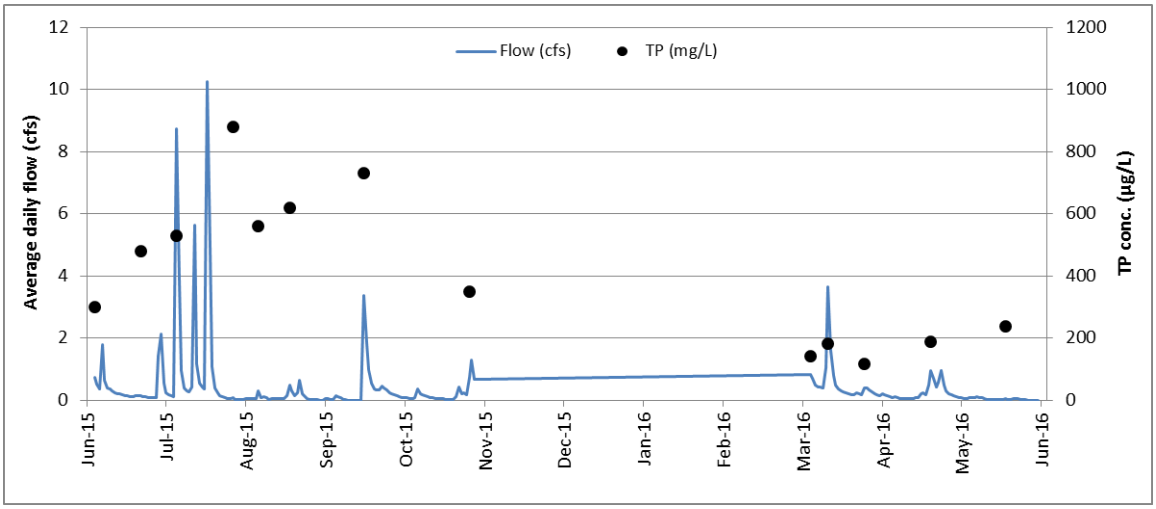

Figure 2. Continuous flow and monitored total phosphorus concentrations at Ditch West

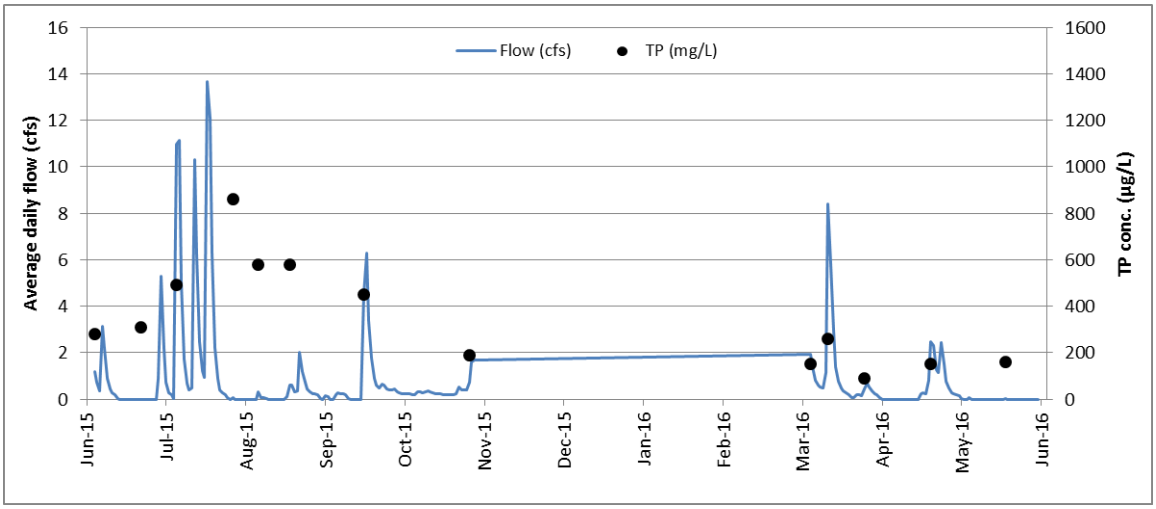

Figure 3. Continuous flow and monitored total phosphorus concentrations at 208th Street Pond

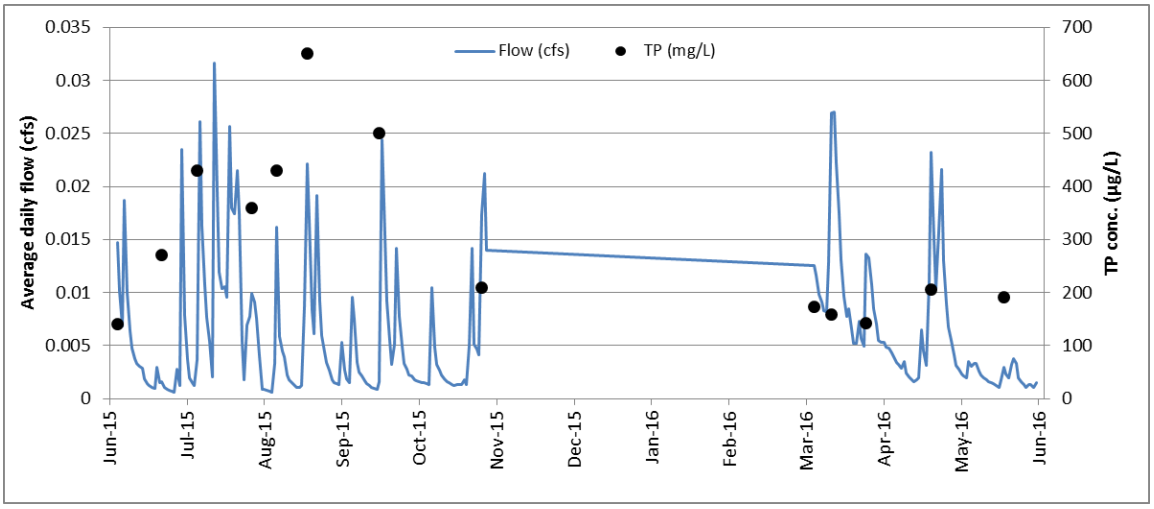

Figure 4. Continuous flow and monitored total phosphorus concentrations at Sump Pump West

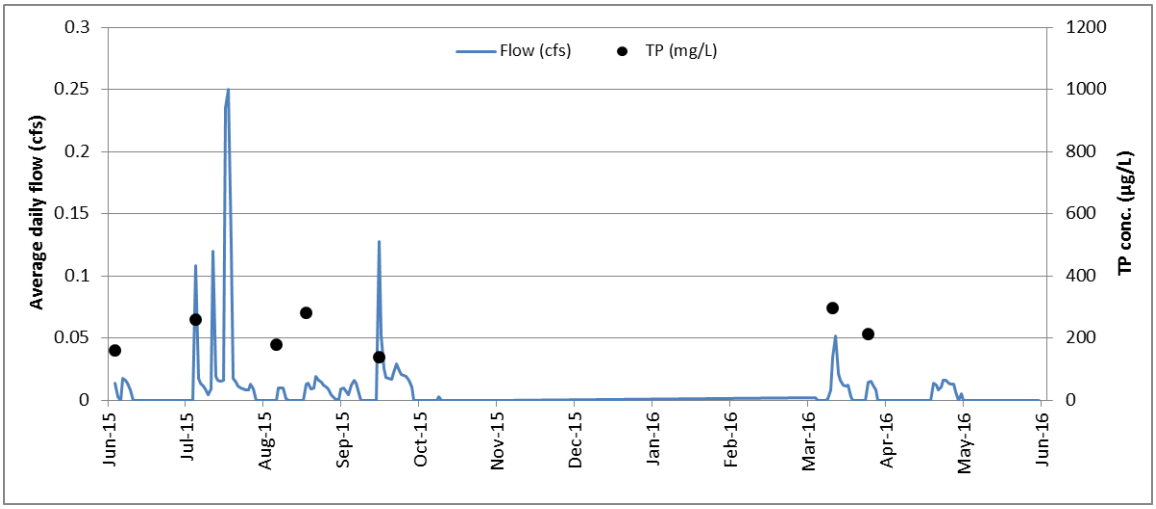

Figure 5. Continuous flow and monitored total phosphorus concentrations at 210th Street Pond

Table 1. 2015-2016 monitoring site phosphorus concentration data by sample date

Date	Ditch West		208th Street		Sump Pump W.		210th Street		Sump Pump N.	
	TP (mg/L)	Ortho-P (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TP (mg/L)	Ortho-P (mg/L)
6/4/2015	300	230	280	240	140	68	160	22		
6/22/2015	480	260	310	210	270	73				
7/6/2015	530	360	490	300	430	300	260	56		
7/28/2015	880	390	860	680	360	190				
8/7/2015	560	410	580	300	430	260	180	59		
8/19/2015	620	420	580	250	650	450	280	49		
9/17/2015	730	520	450	220	500	350	140	48	480	290
10/28/2015	350	200	190	120	210	120			480	180
3/9/2016	143	86	151	91	173	97				
3/16/2016	182	129	260	117	159	91	298	85		
3/30/2016	118	92	88	56	143	104	213	57	647	618
4/25/2016	189	152	151	114	205	140			91	123
5/24/2016	238	167	160	98	190	142				

Table 2. 2015-2016 Shields Lake monitoring site flows, phosphorus loads and flow-weighted mean phosphorus concentrations

Parameter	Ditch West	208th Street (incl. Ditch West flow)	Sump Pump W.	210th Street	2015-2016 Monitored Total*
Drainage Area (ac)	294	704	38	13	**755**
Flow (ac-ft)	292	590	4.5	6.5	**601**
TP Load (lb/yr)	234	377	2.3	2.4	**381**
FWMC** TP (µg/L)	449	359	283	209	**233**
*FLUX TP CV****	*22%*	*22%*	*23%*	*25%*	
Ortho-P Load (lb/yr)	161	212	1.4	0.6	**215**
FWMC** Ortho-P (µg/L)	310	202	178	54	**131**
Ortho-P (% TP)	69%	56%	63%	26%	**56%**
*FLUX Ortho-P CV****	*22%*	*29%*	*26%*	*10%*	

* The 2015-2016 monitored total is for 208th Street, Sump Pump W. and 210th Street (Ditch West is upstream of 208th Street); ** FWMC = flow-weighted mean concentration as calculated by FLUX; *** FLUX CV is a measure of uncertainty in the load and FWMC FLUX estimates

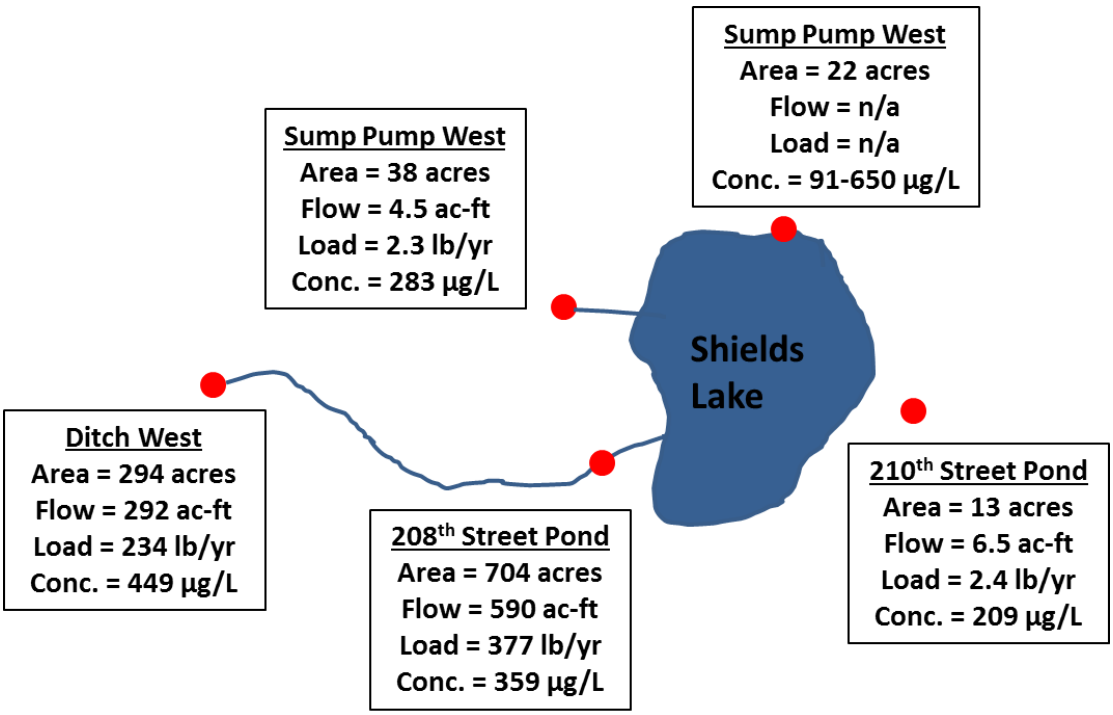

Figure 6. 2015-2016 Shields Lake monitoring site flow and total phosphorus loads and flow-weighted mean concentrations

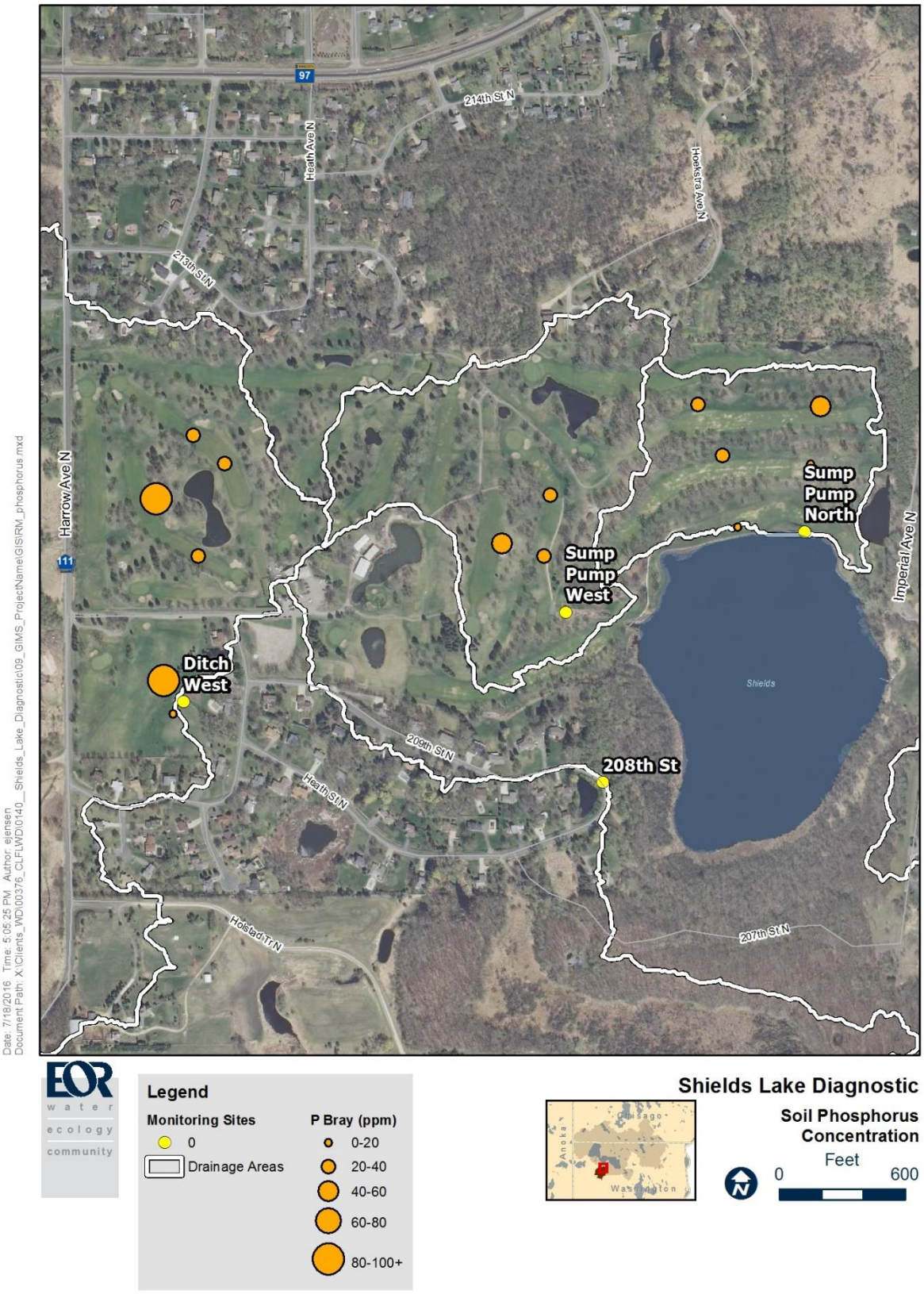

Figure 7. Shields Lake Soil Sample Phosphorus Concentrations