



# Post-Watershed Restoration Stream Evaluation

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## **Abstract**

A 1993 Wisconsin Department of Natural Resources appraisal of Lake Ripley's inlet tributary found water quality to be in poor condition. Based on recommendations of the appraisal, several practices were implemented to help enhance water quality. Approximately 167 acres were removed from agricultural production and restored to natural ecosystems now called the Lake District Preserve. Additional lands were taken out of sod production and returned to wetlands, stream bank characteristics were improved to reduce erosion, and drainage ditches were plugged to help restore wetland functions. To determine the effects of these watershed practices, the Lake Ripley Management District conducted stream monitoring on three sections of the inlet tributary to Lake Ripley from May through September of 2014 and collected water samples to analyze phosphorus concentrations from May 2014 to April 2015. Phosphorus samples were submitted to the Wisconsin State Lab of Hygiene for analysis of total phosphorus. This document contains both information about the 2014 monitoring results and 2014/2015 phosphorus analysis of the stream that flows into Lake Ripley. This also provides a comparison of water quality parameters found in the 1993 appraisal to this study. While some water quality parameters seem to be improving such as dissolved oxygen and total phosphorus, the concentration of phosphorus found in the tributary is still above the State's water quality criterion for streams (WisCALM, 2015). Rain events also cause or correlate with an increase in sedimentation and nutrients in the stream that are delivered to the lake. Additional management considerations should be sought to further reduce the phosphorus and sediment loads found in the tributary. This project was funded through a small-scale lake planning grant provided by the Wisconsin Department of Natural Resources.

## **Introduction**

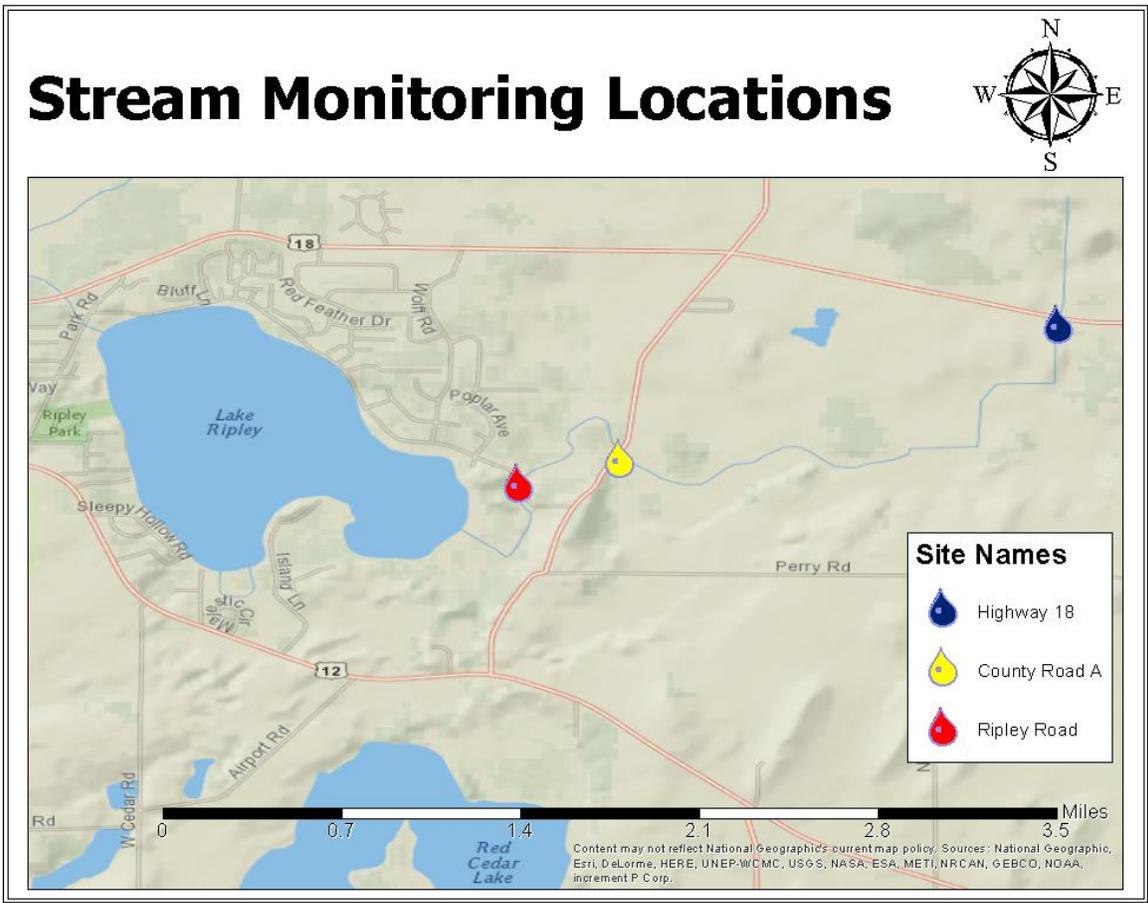
A 1993 Water Resources Appraisal was performed by the Wisconsin Department of Natural Resources (WDNR) to evaluate the condition of Lake Ripley and its inlet tributary system. Data collected from stream monitoring in 1993 was utilized to determine stream quality and classified the inlet to be in poor health largely due to the lack of oxygen in the water. The stream was described as "dark and septic" with "heterotrophic periphyton (slime growths)" that indicated very poor water quality (Wisconsin Department of Natural Resources, 1993). According to the 1993 appraisal, high phosphorus levels in the stream were estimated to contribute 72% of the lake's total phosphorus load from June through September. At one monitoring site, dissolved oxygen (D.O.) ranged from 0.8-1.8 mg/L during this timeframe. Additionally, high phosphorus concentrations of stormwater from intensive development near the lake, along with sediment and phosphorus runoff from agricultural land uses, are the main

sources of sediment and phosphorus to Lake Ripley. A D.O. level of 5 milligrams per liter (mg/L) is the minimum amount necessary to protect warm water fish and aquatic life communities that inhabit Lake Ripley and its' inlet stream. The impacts of no or low oxygen in the stream were evident based on the macroinvertebrate community that was dominated by pollution tolerant species, such as red pigmented midges, and the absence of species that require higher oxygen levels in the water. These characteristics are consistent with impacts associated with runoff containing sediment and phosphorus.

Watershed best management practices to reduce nutrients and sediments were suggested as part of the 1993 WDNR appraisal. Many projects were implemented beginning with the launch of a 13-year Priority Lake Project in 1993 to restore natural habitat and reduce erosion. Lake and stream recovery efforts following the 1993 appraisal also included the acquisition of a 167-acre agricultural area that was restored to a natural area. The restoration efforts of the natural area performed by the Lake District in partnership with the U.S. Fish and Wildlife Service included plugging two farm drainage ditches and restoring wetland habitat that was present before farming ditches were constructed. Now called the Lake District Preserve, this prior agricultural property consists of restored wetlands, woodlands, and prairie that now help absorb water and filter pollutants from farmland runoff. Ditch bank repair adjacent to a sod farm located north of the Highway 18 stream monitoring site began in 1998 and was completed in 2004. This property and the surrounding area are no longer farmed and are comprised of relatively undisturbed marshland.

### **Study Area**

Stream monitoring was conducted at three sites along Lake Ripley's only perennial inlet tributary (Figure 1). Monitoring sites were located at State Hwy 18 (Hwy 18), County Road A (CTH A) and Ripley Road (Ripley Rd.). The Hwy 18 and Ripley Road sites are located downstream of the road crossings and the CTH A site is located upstream of the road crossing. This tributary is 4.25 miles in length and is a first order stream. In 1993, monitoring stations were established and used for the stream and lake quality analysis. Data obtained from these sites during the study timeframe were also utilized for the 2014-2015 restoration analysis.



**Figure 1:** Stream monitoring locations of the inlet tributary to Lake Ripley.

The Hwy 18 site is the furthest distance from Lake Ripley located 3.64 miles from the lake and is just south of the road Hwy 18. Three culverts capable of transferring water from the drainage ditches on the north side of Hwy 18 to the inlet tributary and are placed at different heights along the road bank. Two out of the three culverts are known to actively transport water from the north side of Hwy 18 to the south side. The lowest of the three culverts has water flowing through it during all sampling events. This culvert enters the monitoring site at an angle and downstream of the other two culverts (Figure 2). The next higher culvert had water flowing during higher water conditions. The highest of the three culverts did not contribute to stream flow during any sampling event. The higher two culverts run perpendicular to the road. This portion of the tributary has been straightened by channeling both upstream and downstream of this monitoring site. Monitoring was conducted approximately 3 feet downstream from the bottom most culvert. A dense deposit of live and dead snails is found just downstream from the bottom culvert. Monitoring at that site included discharges from all culverts.



**Figure 2:** Two culverts of the three culverts located at the Hwy 18 site. White arrows display the presence of the two active culverts. The culvert on the left is under water and had a constant flow. A deposit of snails is located below the arrow. The culvert on the right flows when water levels north of the road reach that elevation. A third culvert is located to the right and approximately 2 feet higher in elevation to the culvert shown on the right of the image but is not visible through the grass.

Downstream of Hwy 18, the stream runs along the border of the Lake District Preserve, through wetlands owned by the Oakland Conservation Club, and then to the CTH A culvert. The CTH A sampling site is located 1.47 miles upstream of the lake and obtains water contributions from the Hwy 18 stream monitoring site and surrounding watershed. A staff gauge showing stream height elevation that was placed during the 1993 appraisal is located at this site.

The closest monitoring site to Lake Ripley is located where Ripley Road intersects with the tributary and is approximately 0.67 miles from the lake. Prior to reaching this site, the tributary meanders through wetlands that are owned by the WDNR after leaving the CTH A site. This site includes water from the previous monitoring sites and approximately two-thirds of the watershed drains through this monitoring location. Drainage of the northern, eastern and

southern portions of the watershed all flow into the inlet stream. This area is mainly comprised of agricultural uses. Drainage of the western portions of the watershed and those located north and south of Lake Ripley do not contribute flow to the inlet stream. Drainage patterns of the watershed are shown in Figure 3.

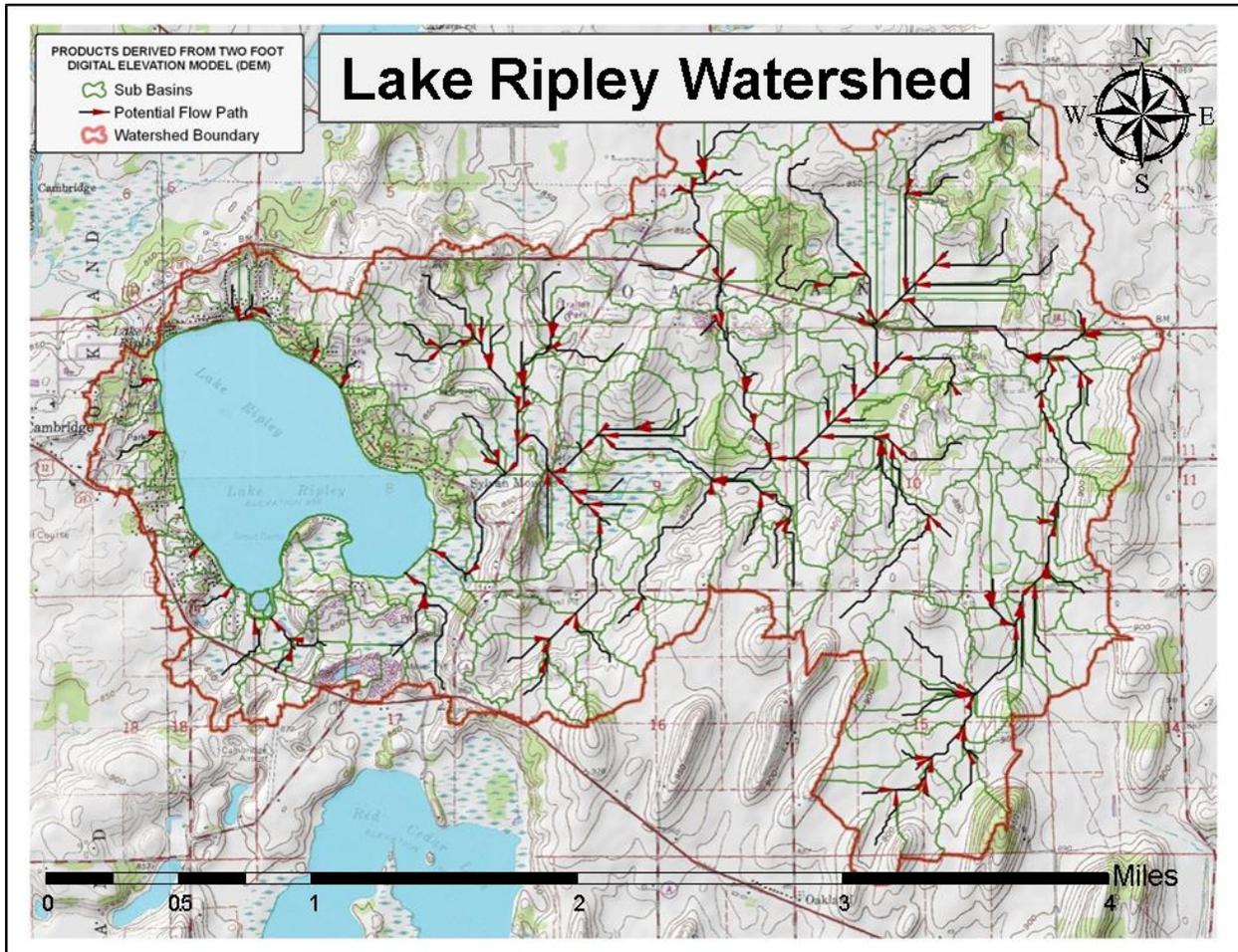


Figure 3: Lake Ripley watershed sub-basin flow path map.

## Methods

To evaluate the impacts of these large-scale watershed improvements, the Lake District conducted a short follow-up stream monitoring program in 2013 leading to the need for additional research in 2014-2015. Though not as rigorous as in the 1993 appraisal, the 2013 data revealed significant improvements to the overall stream conditions prompting for a more extensive water quality analysis.

With the assistance of David Marshall of Underwater Habitat Investigations LLC., an in depth stream health evaluation and phosphorus analysis was conducted in 2014-2015. The 2014-2015 study included chemical and physical water quality surveys, bimonthly stream monitoring, rain event sampling, fish and macroinvertebrate surveys, and phosphorus sampling. Stream

monitoring and rain event sampling was conducted on a bimonthly basis from May through September of 2014. Stream monitoring did not continue from November 2014 to April 2015 due to the challenges faced with ice conditions and the additional cost of consulting. Chemical and physical water quality surveys were conducted on May 6, May 19, June 10, June 19 (rain event), July 5, July 20, August 4, August 19, September 2 and September 4 (rain event). Fish shocking surveys and macroinvertebrate sampling were conducted once during this timeframe on May 19. All sampling events started at the furthest location from the lake at the Hwy 18 site and moved downstream to CTH A and lastly Ripley Road. Finally, monthly water samples were collected for a total phosphorus analysis on October 24, November 11, December 12, January 28, February 24, March 26, April 7, and April 10 (rain event). Data was not collected at the Ripley Road site on July 5th.

In the 1993 appraisal, total phosphorus concentrations were collected at all three monitoring sites. Dates of sampling events are referenced in Table 9. Some samples were collected at each site on the same day.

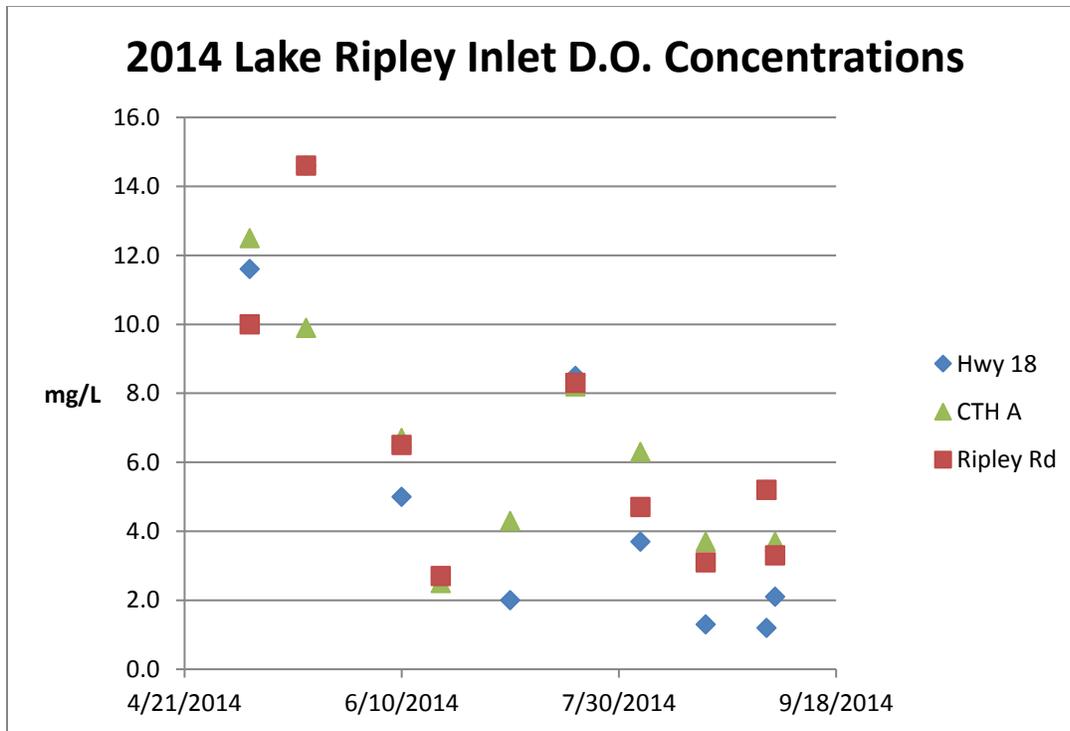
A YSI Model 52 testing meter was used to measure D.O. and temperature, while a YSI Model 63 pH/conductivity meter was used to measure pH and specific conductance. A Swiffer Model 2100 velocity meter was used to gather flow measurements along with an existing staff gauge located at the CTH A site. A rain gauge was installed on the staff meter to determine rain fall between sampling events. Water clarity was measured with a 120 cm transparency Secchi tube, and turbidity was measured with a Hach Model 2100P turbidimeter. A d-frame kick net was used in macroinvertebrate collection, and a towed direct current (DC) electroshocker was used to sample stream fish populations. Other equipment included compound and dissecting microscopes, plastic collection bottles, and sulfuric acid preservative for phosphorus analysis. Total phosphorus analysis was conducted by the Wisconsin State Lab of Hygiene.

## Results

**Dissolved oxygen (D.O.):** At Hwy 18, the average D.O. was 5.3 mg/L. Sixty percent (6 out of ten) of the water samples possess D.O. levels below 5 mg/L (the minimum amount necessary to protect warm water fish and aquatic life communities), and two of those samples were below 2 mg/L. For the most part, Hwy 18 had lower D.O. concentrations compared to the other locations. Concentrations as low as 1.2 mg/L were present approximately 1-3 feet downstream of the lowest and most active culvert. The average D.O. level at the CTH A site was 6.3 mg/L. Forty percent (4 out of 10) of the water samples possessed D.O. levels below 5 mg/L although no water samples dropped below 2 mg/L. The Ripley Road average D.O. was 6.5 mg/L and dropped below 5 mg/L 44% (4 out of 9) of the samples. Data was not collected during the July 5<sup>th</sup> monitoring event at the Ripley Road site leading to only 9 days of data collection. Dissolved oxygen data are summarized in Figure 4 and Table 1.

**Table 1:** 1993 and 2014 Dissolved Oxygen measurements at each sampling site. Yellow highlight indicates rain events.

1993 Dissolved Oxygen (mg/L)				2014 Dissolved Oxygen (mg/L)			
Date	Hwy 18	CTH A	Ripley Rd	Date	Hwy 18	CTH A	Ripley Rd
4/26/1993	12.8		8.6	5/6/2014	11.6	12.5	10.0
7/12/1993	6.1	16.0	17.3	5/19/2014	14.6	9.9	14.6
7/27/1993	9.2	1.6	0.0	6/10/2014	5.0	6.7	6.5
8/10/1993		1.6	1.3	6/19/2014	2.7	2.5	2.7
9/1/1993		0.8		7/5/2014	2.0	4.3	
10/6/1993	6.6	1.8	2.5	7/20/2014	8.5	8.2	8.3
10/19/1993		3.9	4.1	8/4/2014	3.7	6.3	4.7
11/22/1993	8.8	6.8	6.5	8/19/2014	1.3	3.7	3.1
12/14/1993		7.1	6.2	9/2/2014	1.2	5.2	5.2
				9/4/2014	2.1	3.7	3.3
<b>Average</b>	<b>8.7</b>	<b>4.9</b>	<b>5.8</b>	<b>Average</b>	<b>5.3</b>	<b>6.3</b>	<b>6.5</b>



**Figure 4:** 2014 Inlet dissolved oxygen concentrations.

**Water clarity/turbidity:** Average water clarity was highest at the Hwy 18 site at 106 cm and lowest at the CTH A site at 81 cm. Ripley Road average clarity was 101 cm. Nephelometric Turbidity Units (NTU) is a measure of the amount of light scattered by particles found in the water column and is the primary unit of measurement to describe turbidity levels. Higher amounts of particulate or sediment in a sample will scatter more light and will yield a higher

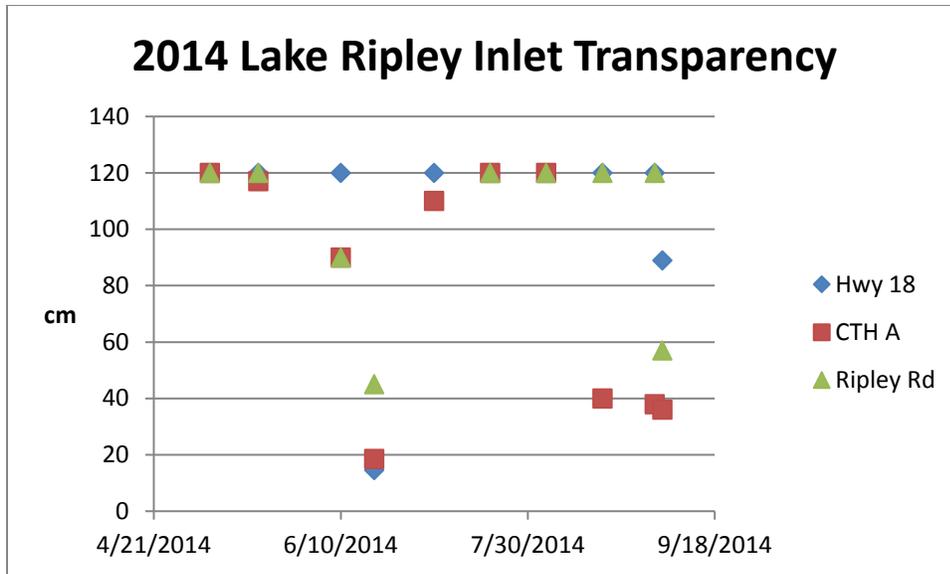
NTU reading, whereas water samples with fewer particulates will result in a lower NTU reading. Average turbidity at Hwy 18 was 10.6 NTU whereas CTH A yielded a higher average of 13.7 NTU. Ripley Road was not analyzed for turbidity.

Water clarity and turbidity measurements were typically favorable during low flow periods. As expected, water clarity declined during rain events while turbidity levels increased. The lowest water clarity measurements and highest turbidity measurements occurred after a 3.5 inch rain event on June 19, 2014.

Water clarity and turbidity data are presented in Tables 2 and 3 and Figures 5 through 7 with Figure 7 establishing the relationship between these two measurements. A non-linear log relationship between water clarity and turbidity likely reflects the truncated water clarity measurements at 120 centimeters (cm) and other factors such as color increases as organic compounds are released from wetland soils.

**Table 2:** 2014 Transparency measurements at each sampling site. Yellow highlight indicates rain events.

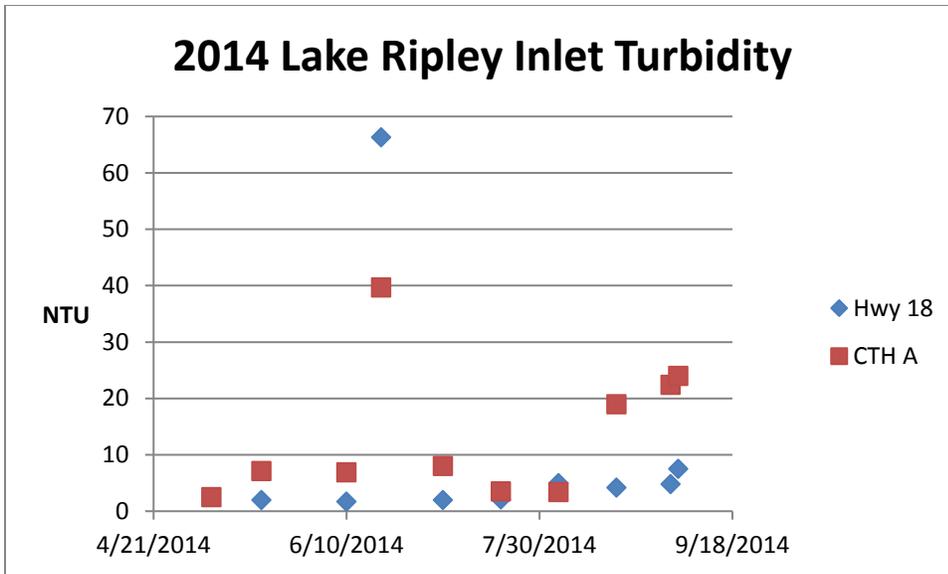
<b>2014 Transparency (cm)</b>			
Date	Hwy 18	CTH A	Ripley Rd
5/6/2014	120	120	120
5/19/2014	120	117	120
6/10/2014	120	90	90
6/19/2014	14.6	18.5	45
7/5/2014	120	110	
7/20/2014	120	120	120
8/4/2014	120	120	120
8/19/2014	120	40	120
9/2/2014	120	38	120
9/4/2014	89	36	57
<b>Average</b>	<b>106</b>	<b>81</b>	<b>101</b>



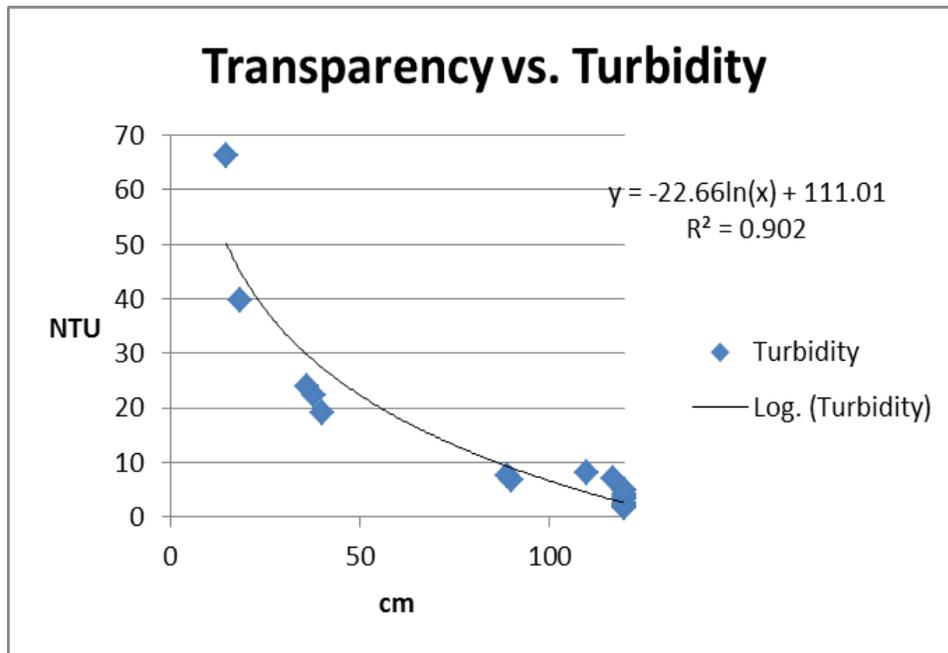
**Figure 5:** Lake Ripley transparency tube measurements.

**Table 3:** 2014 Turbidity measurements at sites Hwy 18 and CTH A. Yellow highlight indicates rain events.

2014 Turbidity (NTU)		
Date	Hwy 18	CTH A
5/6/2014		2.5
5/19/2014	2	7.1
6/10/2014	1.7	6.9
6/19/2014	66.3	39.7
7/5/2014	2	8
7/20/2014	2.1	3.5
8/4/2014	5	3.4
8/19/2014	4.2	19
9/2/2014	4.8	22.4
9/4/2014	7.5	24
<b>Average</b>	<b>10.6</b>	<b>13.7</b>



**Figure 6:** Lake Ripley inlet turbidity measurements.



**Figure 7:** Lake Ripley inlet water clarity turbidity regression

**Flow and Water Level Gage:** At the CTH A site an original stage gage was erected in 1993 and was also used to measure 2014 water levels. Generally, the higher elevation recorded on the staff gauge corresponded to a larger amount of stream flow. Average flow measured in 2014 was 6.9 cubic feet per second (cfs) (Table 4). During the June 19th rain event, we can see a dramatic increase in flow due to a 2 foot increase in water level height. The average staff height

was 7.7 ft with a flow rate of 6.9 cfs included the June 19th rain event. However, when that event is removed the average height is 7.5 ft. and the flow rate is reduced to 4.0 cfs. Flow data was not collected at Hwy 18 because the capacity of the flow output is restricted to the size of the lowest culvert during low flow conditions. Until water elevations on the north side of the road reach the elevation of the next highest culvert, flows remain the same as the maximum amount that would pass through the lowest culvert. Immediately downstream from the lowest culvert are obstructions in the stream, also reducing the ability to accurately calculate flow. Flow data was not collected at the Ripley Road site.

Flow measurements were paired with water level measurements to establish a flow rating curve. A linear regression with an R squared value of 0.997 proved to be a good fit down to about 2 cubic feet per second (cfs) of stream flow (Figure 8). The calculation shown in Equation 1 can be used to estimate streams flows from water levels of 7.27 feet or higher.

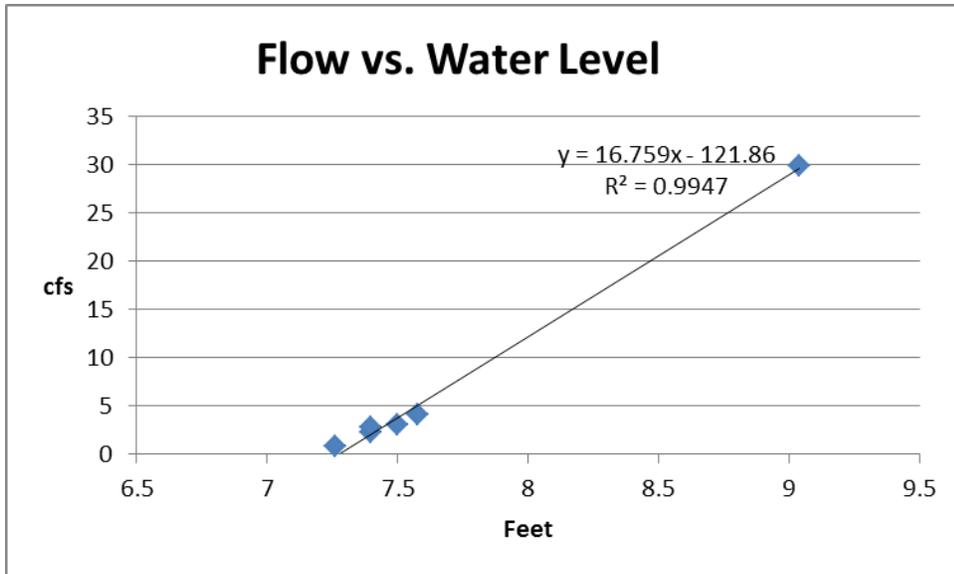
**Equation 1: Measuring flow using stream elevation**

$$y = 16.759x - 121.86 \text{ or}$$

$$\text{Flow} = 16.759 \times \text{water level} - 121.86$$

**Table 4:** 1993 and 2014 Stage height and flow of the CTH A site. Yellow highlight indicates rain events.

1993			2014		
CTH A	Stage	Flow	CTH A	Stage	Flow
Date	ft	cfs	Date	ft	cfs
5/27/1993	8	4.4	5/6/2014	7.5	3
6/29/1993	8.28	4.98	5/19/2014	7.58	4.1
7/12/1993	8.57	6.73	6/10/2014	7.4	2.2
7/27/1993	8.4	4.65	6/19/2014	9.04	29.9
8/10/1993	8.48	6.18	7/5/2014	7.95	7.8
9/1/1993	8.28	4.98	7/20/2014	7.62	5.6
<b>Average</b>	<b>8.3</b>	<b>5.3</b>	8/4/2014	7.42	2.2
			8/19/2014	7.55	4.42
			9/2/2014	7.3	<2
			9/4/2014	7.4	2.8
			<b>Average</b>	<b>7.7</b>	<b>6.9</b>
			<b>Average excluding 6/19</b>	<b>7.5</b>	<b>4.0</b>



**Figure 8:** Flow and water level regression at CTH A.

**Rain fall:** A rain gauge was installed on the staff gauge located at the CTH A site. Rain totals were recorded between sampling events. This information is useful when sampling events are held close together and after rain events. However, during longer periods of time between sampling events, these measurements may not be accurate due to possible water evaporation. Rain fall data is found in Table 5. According to the rain gauge, seven inches of rain fell between June 10 and June 19. Verifying precipitation rates from US Climate Data, rain fell in the city of Jefferson on June 17 and June 19. Jefferson lies approximately 5 miles from Lake Ripley and was the closest location with precipitation data. A LRMD Board member reported a 3.5 inch rain fall shown from their personal rain gauge from over night of June 18 into the morning of June 19.

**Table 5:** Rain fall observed in rain gauge at CTH A. Yellow highlight indicates rain events.

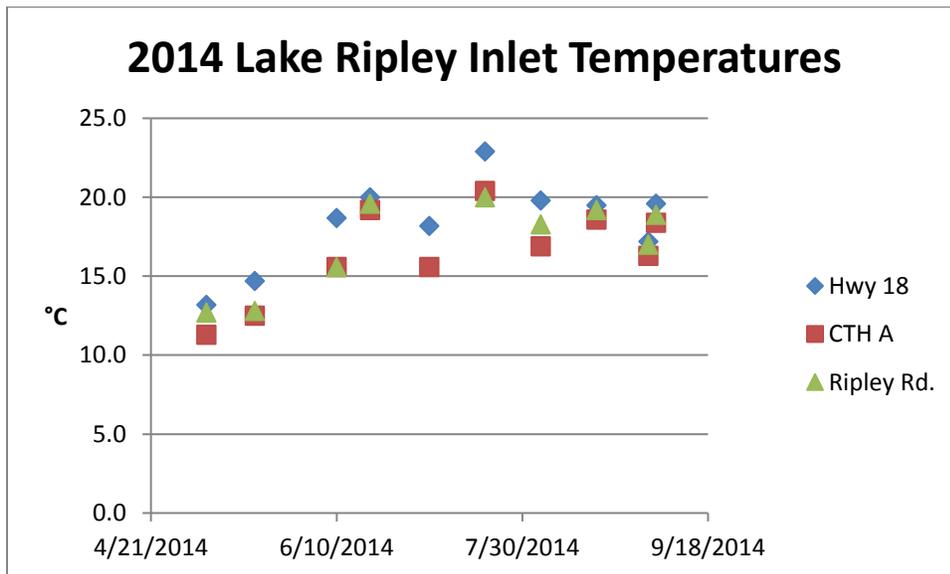
<b>2014 Rain Fall (inches)</b>	
Date	CTH A
6/10/2014	3.5
6/19/2014	7
8/19/2014	1.6
9/2/2014	1.95
9/4/2014	1.1

**Water temperature:** Water temperatures were recorded for each sampling site and found in Table 6 and Figure 9. The Hwy 18 site had the highest water temperature average at 18.4 °C , followed by Ripley Road at 17.1°C and finally CTH A at 16.5 °C. The Hwy 18 site is very shallow with slow moving water. The CTH A average is almost 2 degrees Celsius lower than Hwy 18. This could be due to ground water contribution. The Ripley Road site is also lower than Hwy 18 which could also be due to ground water contribution. During monitoring events the Hwy 18

site was routinely sampled first followed by CTH A and Ripley Road. It may be expected for temperatures to increase as sampling occurred later in the day, but this was not shown to be true at these sites.

**Table 6:** 1993 and 2014 temperature recorded for each sampling site. Yellow highlight indicates rain events.

1993 Temperature (°C)				2014 Temperature (°C)			
Date	Hwy 18	CTH A	Ripley Rd	Date	Hwy 18	CTH A	Ripley Rd
4/26/1993	13.0		12.5	5/6/2014	13.2	11.3	12.7
7/27/1993	25.4	21.3	27.8	5/19/2014	14.7	12.5	12.8
8/10/1993		16.5	18.2	6/10/2014	18.7	15.6	15.6
9/1/1993		18.0		6/19/2014	20.0	19.2	19.6
10/6/1993	11.5	10.0	10.6	7/5/2014	18.2	15.6	
10/19/1993		11.2	11.1	7/20/2014	22.9	20.4	20.0
11/22/1993	3.8	2.5	2.0	8/4/2014	19.8	16.9	18.3
12/14/1993		2.0	0.5	8/19/2014	19.5	18.6	19.2
				9/2/2014	17.2	16.3	17.0
				9/4/2014	19.6	18.4	18.9
<b>Average</b>	<b>13.4</b>	<b>11.6</b>	<b>11.8</b>	<b>Average</b>	<b>18.4</b>	<b>16.5</b>	<b>17.1</b>



**Figure 9:** Temperature profile of Lake Ripley inlet stream.

**pH:** Measurements in 2014 show average pH is the same for Hwy 18 and CTH A at 7.5 with slight increase to 7.7 at the Ripley Road site (Table 7). Ripley Road shows the highest average of pH compared to the other two sites. The June 19th rain event sampling date shows the lowest pH values for each site. pH values were higher in spring and reduced throughout the summer.

**Table 7:** 1993 and 2014 pH recorded for each monitoring site. Yellow highlight indicates rain events.

1993 pH			2014 pH			
Date	CTH A	Ripley Rd	Date	Hwy 18	CTH A	Ripley Rd
3/11/1993	7.5		5/6/2014	8.0	7.5	8.0
7/12/1993	7.3	7.3	5/19/2014	8.3	8.0	8.3
7/27/1993	7.3		6/10/2014	7.7	7.6	7.5
8/10/1993	7.4	7.3	6/19/2014	6.4	6.5	6.8
9/1/1993	7.4		7/5/2014	7.3	7.3	
10/19/1993	7.5	7.5	7/20/2014	7.2	7.6	7.9
			8/4/2014	7.5	7.8	7.8
			8/19/2014	7.3	7.3	7.5
			9/2/2014	7.5	7.7	7.9
			9/4/2014	7.3	7.5	7.5
<b>Average</b>	<b>7.4</b>	<b>7.4</b>	<b>Average</b>	<b>7.5</b>	<b>7.5</b>	<b>7.7</b>

**Specific Conductance:** Average specific conductance was 620  $\mu\text{ohms/cm}$  at Hwy 18, 661  $\mu\text{ohms/cm}$  at CTH A, and 665  $\mu\text{ohms/cm}$  at Ripley Road (Table 8). Specific conductance is lower at the Hwy 18 site compared to CTH A and Ripley Road. Specific Conductance is a measure of how well water can conduct an electrical current. It is highly dependent on the amount of dissolved material in the water. This slight increase in downstream sites could be due to a larger watershed area draining into those sites. The lowest values were found on June 19th rain event with values almost half the seasonal average.

**Table 8:** 2014 Specific Conductance of all three sites. Yellow highlight indicates rain events.

2014 Specific Conductance ( $\mu\text{ohms/cm}$ )			
Date	Hwy 18	CTH A	Ripley Rd
5/6/2014	686	650	715
5/19/2014	652	692	652
6/10/2014	643	714	719
6/19/2014	306	321	335
7/5/2014	655	667	
7/20/2014	661	729	732
8/4/2014	673	735	743
8/19/2014	598	662	653
9/2/2014	698	751	753
9/4/2014	624	690	680
<b>Average</b>	<b>620</b>	<b>661</b>	<b>665</b>

**Total Phosphorus Concentrations:** The total phosphorus average found in 2014 at the Hwy 18 site was 0.301 mg/L (Table 9). Two of the three samples for Hwy 18 were collected after rain events. Highest phosphorus levels (0.395 mg/L) were detected during the 3.5 inch rain event on June 19, 2014. Samples during the month of September decreased considerably with concentrations of 0.226 and 0.179 mg/L. Areas draining to the Hwy 18 site appear to be major sources for total phosphorus.

The 2014-2015 average total phosphorus for the CTH A site was 0.1435 mg/L. This average included both rain and non-rain events. Average phosphorus concentration excluding the rain events is 0.1205 mg/L. Average phosphorus concentrations for both sites are found in Table 9.

The Wisconsin water quality standard for phosphorus in the inlet stream is 0.075 mg/L (75 micrograms per liter (µg/L)). All samples taken at Hwy 18 were above the state water quality standard suggesting that lands draining to the inlet stream may require additional restoration efforts to reduce phosphorus loads. The phosphorus concentrations in this study exceeded water quality standards in all but 2 samples (both at CTH A) of the Lake Ripley inlet stream.

**Table 9:** 1993 and 2014 Total phosphorus concentration at Hwy 18 and CTH A sites. Yellow highlight indicate rain events.

1993 Phosphorus (mg/L)						2014 Phosphorus (mg/L)			
Hwy 18		CTH A		Ripley Rd		Hwy 18		CTH A	
3/11/1993	0.100	3/11/1993	0.150	4/12/1993	0.060	6/19/2014	0.395	5/19/2014	0.0828
3/25/1993	0.470	3/25/1993	0.400	4/26/1993	0.070	9/2/2014	0.226	6/10/2014	0.1490
4/12/1993	0.100	4/12/1993	0.070	5/27/1993	0.170	9/4/2014	0.281	6/19/2014	0.3280
4/26/2016	0.080	5/27/1993	0.110	6/10/1993	0.190			7/20/2014	0.0807
6/10/1993	0.240	6/10/1993	0.250	6/30/1993	0.550			8/4/2014	0.0888
6/29/1993	0.090	6/29/1993	0.180	7/12/1993	0.440			8/19/2014	0.2250
7/12/1993	0.170	7/12/1993	0.270	07/27/1993	0.560			9/2/2014	0.1830
7/27/1993	0.200	7/27/1993	0.300	8/10/1993	0.280			9/4/2014	0.2810
10/06/1993	0.180	8/10/1993	0.190	10/06/1993	0.070			10/24/2014	0.1280
11/22/1993	0.040	9/1/1993	0.270	10/19/1993	0.070			11/20/2014	0.1030
		10/6/1993	0.080	11/22/1993	0.040			12/12/2014	0.0651
		10/19/1993	0.080	12/14/1993	0.040			1/28/2015	0.0974
		11/22/1993	0.040					2/24/2015	0.0917
		12/14/1993	0.050					3/26/2015	0.0670
								4/7/2015	0.0822
								4/10/2015	0.2430
<b>Average</b>	<b>0.167</b>	<b>Average</b>	<b>0.174</b>	<b>Average</b>	<b>0.208</b>	<b>Average</b>	<b>0.301</b>	<b>Average</b>	<b>0.1435</b>

Similar to the 1993 appraisal, calculations were used to determine the amount of phosphorus delivered via the inlet stream per day. To calculate the phosphorus load in terms of pounds per day (lb/day P) the formula in Equation 2 was used. Multiply the total concentration of phosphorus determined in the sample analyzed at the state lab by the rate of flow and by a constant of 5.393 to get the total pounds per day phosphorus rate.

**Equation 2: Total phosphorus (lb/day).**

**Pound per day P = total P concentration (mg/L) X flow (cfs) X 5.393**

Average phosphorus loading rates in 2014 of 9.94 lb/day P. However, in 2014, a peak flow of 29.9 cubic feet per second (cfs) was measured during a rain event. This rate was the highest flow rate measured in 2014. High loading rates can be expected during major rain events affecting the results when comparing both years. Excluding this rain event from the 2014 data would significantly lower the mean loading rate to 2.78 lb/day P (Table 10).

**Table 10:** A 2014 and 1993 comparison of total phosphorus concentrations and loading rates from surveys beginning in May and ending in September in each year (mean concentrations in bold). Data from September 2, 2014 was not used as the flow rate was less than 2 cfs and therefore could not be quantified and entered into Equation 2.

	2014	2014	1993	1993
	TP	# P/day	TP	# P/day
	mg/L		mg/L	
	0.0828	1.8308	0.17	4
	0.1490	1.7678	0.55	14.8
	0.3280	52.890	0.44	16
	0.0807	2.4372	0.56	14
	0.0888	1.0535	0.28	9.3
	0.2250	5.3633	0.27	7.3
	0.2810	4.2432		
<b>Average</b>	<b>0.1765</b>	<b>9.9409</b>	<b>0.38</b>	<b>10.9</b>
<b>Average excluding 06/19/2014 event</b>	<b>0.1557</b>	<b>2.7826</b>		

**Macroinvertebrates:** The Hilsenhoff Biotic Index (HBI) characterizes water quality by the types of macroinvertebrates present in the water (Hilsenhoff, 1998). Organisms are assigned a pollution tolerance number based on their known sensitivity to pollution. Depending on what organisms are found at the site and the number of those organisms, a Family Biotic Index can be calculated. Table 11 shows the criterion and classification used to gauge water quality.

The Hwy 18 site had low species diversity. Immediately downstream from the culvert that is located under water, a collection of live and dead snails was found which is shown in Figure 2 and are several inches thick. As indicated in Table 12, low numbers of only two species were found in 2014. Due to low diversity and the number of organisms found, the HBI could not be calculated.

The CTH A site shows improvement and is listed as good water quality with an HBI of 4.36. This site had 5 different species found with multiple organisms of each species. Macroinvertebrates collected at the CTH A site reflected better environmental conditions including limited riffle

substrates and perhaps groundwater discharge via the neighboring wetlands. Otherwise, the substrate in most stretches of the stream was dominated by soft organic sediment that does not provide favorable conditions for most environmentally sensitive macroinvertebrates.

Macroinvertebrates collected at the Ripley Road site showed the water quality to be in poor condition with an HBI of 7.0. This site had 3 species found but had a similar number of organisms to those found at CTH A.

Table 12 shows the number of specimens in each macroinvertebrate family at each monitoring site for both the 1993 and 2014 assessment and calculated HBI for each site.

**Table 11:** HBI criterion and classification.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very Good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly Poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

**Table 12:** 2014 Lake Ripley inlet macroinvertebrate comparison of 1993 and 2014.

Family Name	Number of Families at Location (1993)			Number of Families at Location (2014)		
	Hwy 18	CTH A	Ripley Rd	Hwy 18	CTH A	Ripley Rd
Leptohephyphidae			1			
Hydropsychidae					18	
Limephilidae					2	
Chironomidae	7		32		23	
Talitridae						63
Crangonyctidae		1				
Gammaridae	45	19	2	9	47	12
Hyalellidae	59	149	45			
Asellidae	5	2	4	2	10	20
<b>HBI</b>	<b>6.33</b>	<b>7.56</b>	<b>7.02</b>	<b>N/A</b>	<b>4.36</b>	<b>7.0</b>
<b>Water Quality</b>	<b>Fairly Poor</b>	<b>Very Poor</b>	<b>Poor</b>	<b>N/A</b>	<b>Good</b>	<b>Poor</b>

**Fish electroshocking survey:** Two fish shocking surveys were performed on May 19, 2014 at both CTH A and Ripley Road. At the CTH A site, approximately 55 feet was surveyed upstream of the site. Deep organic sediments limited sampling further upstream. This small sample area yielded 1 mud minnow and two bluegills. The second fish shocking survey was conducted at

the Ripley Road site heading into the WDNR wetland areas. Muck substrates were also found at this site, but allowed for a more expansive distance of 264 feet. Four species were found during this survey with an increase in the amount of each species found, though none were environmentally sensitive. Total electroshocking results were limited to just four species: central mud minnow, northern pike, bluegill, and largemouth bass. Information on the fish survey is found in Table 13.

**Table 13:** 2014 Lake Ripley inlet fish electroshocking survey results.

<b>Fish Shocking: 150 V, 4 amps *</b>		
5/19/2014		
	Ripley Rd	CTH A
	264'	55'
	15 min.	4 min.
Species	Number	Number
Mud minnow	4	1
Northern Pike	3	
Bluegill	11	2
Largemouth bass	3	
Crayfish	1	
* deep water - muck limited sampling		

## Discussion

During the 1993 Lake Ripley Water Resources Appraisal, D.O. levels at Hwy 18 were higher than the two other sites (Table 1) . Average D.O. from April to December at Hwy 18 was 8.7 mg/L . There was a decrease in D.O. levels found at the Hwy 18 site during the most recent analysis. This could be due to stagnant water conditions by restricted flow on the east side of the road via culverts placed at different elevations forming an impoundment. The active culverts at this site may be draining the bottom of the confined water which may possess lower D.O.

CTH A averaged D.O. concentrations of 4.9 mg/L and Ripley Road averaged 5.8 mg/L for the same time period in the 1993 appraisal. D.O. concentration fell extremely low (0.80 mg/L) at the CTH A sampling site and Ripley Road concentrations dropped to 0.0 mg/L in July. These anoxic and near anoxic conditions were optimal for filamentous algae growth in the stream and phosphorus release from the bottom sediments. The oxic conditions found in 2014 did not stimulate heterotrophic periphyton as were found in 1993.

Forage fish such as carp can withstand a minimum of 1 mg/L, but most aquatic life requires higher D.O. concentrations to survive. When D.O. levels fall below 0.5 mg/L, phosphorus can be released from stream sediments and will contribute to the nutrient load to the lake. According to the 1993 appraisal D.O for this site ranged from 0.8-1.8 mg/L from June through September.

There is an increase in average D.O. concentrations found in the 2014 study at both CTH A and Ripley Road compared to concentrations found in 1993. This increase in D.O. could be due to

the best management practices implemented by property owners through cost-share efforts with the district, coupled with other land management practices that have been developed and the establishment of the Lake District Preserve.

Though D.O. levels fell below the criterion to protect warm water fish species and aquatic life communities on numerous events, the increase in D.O. averages is consistent with the increase of other water quality parameters.

Water clarity and turbidity were favorable during low flow events. When water flows increase due to rain events, increased turbidity and nutrients in the inlet stream were found. As rain events increase in intensity as is predicted by climate change models, a decline in clarity and increase in turbidity is likely to occur due to increased erosion and sediment delivery to the stream.

Average flow measured in 1993 at CTH A was 5.3 cfs compared to 4.0 cfs found in the recent analysis. The reduction in flow found at CTH A could be due to seasonal weather conditions. It was noted in the 1993 appraisal that the inlet was monitored during a year with unusually high precipitation. Another factor could be the implementation of ditch plugs limiting direct flow to the stream. At heights above 7.27 feet on the CTH A staff gauge, flow velocities can be determined by using equation 1. By pairing flow data and water elevation levels on the staff gauge, future monitors can calculate flow rates based on a quick look at the elevation of water shown on the staff gauge and entering the data into the calculation. The LRMD does not have a velocity meter therefore by using the equation listed along with water collected for total phosphorus analysis, the LRMD can further calculate phosphorus loads per day in future monitoring.

Water temperature measurements varied by each site. As seen in the 1993 assessment the Hwy 18 site has higher water temperature than the other two sites by almost 2°C when comparing temperature averages. Higher water temperatures at the Hwy 18 site could be due to water impoundment. Lower water temperatures found at CTH A and Ripley Road could be caused by ground water recharge and more shading of the water by trees and other vegetation. Temperature can impact D.O. levels and should be included in future monitoring efforts at all three sites.

Average pH found at CTH A and Ripley Road show similar results when compared to values found in 1993. pH values show the inlet stream is slightly alkaline. Lakes in Wisconsin tend to range from 4.5 in some acid lakes to 8.4 in hard water, marl lakes (Understanding Lake Data, 2004). Acid rain can enhance the acidity of water bodies. Lake Ripley typically exhibits alkaline pH values and is somewhat buffered from acid rain impacts. Measurements were not collected for the Hwy 18 site during the 1993 appraisal.

Specific conductance levels were lower at Hwy 18 but similar at CTH A and Ripley Road. A reduction in specific conductance on 06/19/2014 show a dilution caused by the rain event. Specific conductance increases the closer the site is to the lake or further down the watershed.

This increase could be due to increased road areas or impervious surfaces. The 1993 appraisal did not include specific conductance data. Data collected in 2014 can serve as a baseline for future monitoring.

The 1993 appraisal shows the average total phosphorus concentration for Hwy 18 was 0.167 mg/L, 0.174 mg/L for CTH A, and 0.249 mg/L for Ripley Road (Table 9). The 2014 average for CTH A was 0.1765 mg/L from May to September compared to 0.38 mg/L found in 1993 for the same time period. Excluding the large rain event in June 2014, averages drop to 0.1557 mg/L. Total phosphorus concentrations continue to be higher than the state water quality standard of 0.075 mg/L and are providing additional nutrients to Lake Ripley.

Phosphorus concentrations found in 1993 and 2014 along with flow velocities are used to calculate phosphorus loads to Lake Ripley. Including the large rain event on 06/19/2014, a slight reduction in the average Phosphorus loads was shown from 10.9 lb/day P in 1993 to 9.94 lb/day P in 2014 (Table 10). However, excluding the rain event, a large decrease in average phosphorus concentration occurred from 10.9 lb/day P in 1993 to 2.7826 lb/day P in 2014. The large rain event of approximately 7 inches over the preceding two days most likely transported additional sediments and containments, leading to the large amount of total phosphorus detected on that date. As the intensity of rainfall events increase an increase in phosphorus loading could occur.

Consistent with 1993 findings, a low diversity of macroinvertebrates was found in the stream in 2014 at Ripley Road and Hwy 18 and is indicative of lower D.O. concentrations in the streams that drain extensive wetlands of various conditions, even though our D.O data show the Ripley Road site to have the highest D.O. average. At Hwy 18, 4 species of organisms were found in 1993 and only 2 species were found in 2014. Five species were found in 1993 at Ripley Road but only 3 species were found in 2014. Macroinvertebrate surveys show better water quality at the CTH A site than at the downstream Ripley Road site with 5 species found in 2014 compared to 4 found in 1993. The increase in riffle substrate, shading by trees, and decrease in water temperature could be the reason for this difference.

Fish electroshocking surveys show similar results to other indices measured. While there is some improvement to water quality, surveys showed only 4 species of fish found of which no species is environmentally sensitive. Deep organic substrates limited access to the CTH A site which may have yielded different results. The fish community of the inlet streams was not surveyed as part of the 1993 appraisal. Data collected in the 2014 analysis can serve as a baseline for future monitoring.

## **Recommendations**

Reducing phosphorus concentrations in the inlet stream should continue as a top priority for the District. Management practices should plan for increases in rain intensity when developing phosphorus reduction goals. Additional monitoring could include analysis of both total and

dissolved phosphorus. Dissolved phosphorus can be high in areas discharging from wetlands and implemented conservation practices may not address this source.

As part of the District's ongoing mission to collect stream monitoring data, monitoring could be modified to sample on both sides of the inlet stream at the Hwy 18 site. Areas north of Hwy 18 should be investigated given the high turbidity and phosphorus loading associated with the rain event in June, 2014. Persistent low D.O. at this location could be caused by the confinement of water due to the Hwy 18 road grade. The active culverts at this site may be draining the bottom of the confined water which may possess lower D.O. concentrations than water near the surface, but this hypothesis requires further investigation. Elevated water temperatures may also cause lower D.O. concentrations, but no data has been collected to measure water temperatures on the north side of the road.

Water clarity and turbidity levels showed a reduction in water clarity at the CTH A site. Further investigation is recommended to determine the source of sediments to this area. Additional management action may be needed in the Lake District Preserve or elsewhere in areas that drain to this area.

It may be useful for future monitoring efforts to include specific conductance during winter months to possibly determine if road salt applications modify these levels. This parameter should also be included with any chloride analysis of Lake Ripley.

Sampling the macroinvertebrates should continue through monitoring carried out by the District interns. A lack of species at the Hwy 18 site and the poor classification of the Ripley Road site should be noted and subsequent monitoring of species should occur to gauge changes.

The District should seek coordination with local universities who may be available for additional analysis of fish in the inlet. Specialized equipment and training is required to perform this analysis and efforts could be included in ongoing student research.

Additional solutions to reduce the impact of high intensity rain or snow melt events should also be explored. The 1993 appraisal noted that the inlet was monitored during a year with increased precipitation. That may influence the data that was collected. However, with climate change, rain intensity has increased even if the overall amount of rain is similar. The increase in intensity of rain events could cause additional erosion, increasing phosphorus concentrations, and lowering D.O levels.

## **Conclusions**

Research findings of the 2014 water quality survey of the Lake Ripley inlet stream suggests improved environmental conditions when compared to the surveys in 1993. Lack of anoxic conditions in 2014 may reflect a number of factors including improved land use management, particularly the establishment of the Lake District Preserve, ditch bank repair, and conversion of agricultural lands to natural areas. However, large rain events show an increase amount of

phosphorus and sediment detected. The intensity and frequency of seasonal rains should be considered when developing practices to reduce nutrient and sediment loads. Time of year may also play a factor in the amount of nutrients found. The exceedance of phosphorus water quality standards continues to warrant additional efforts to reduce phosphorus loads. Continued monitoring of the inlet stream should occur in the future and can remain a part of LRMD internship responsibilities. Information not available in the 1993 appraisal but obtained through these efforts can be used as a baseline for future monitoring efforts.

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### **References**

Wisconsin Department of Natural Resources and Lake Ripley Management District. 1994. Lake Ripley Water Resources Appraisal.

Wisconsin Department of Natural Resources. 2015. Wisconsin 2016 Consolidated Assessment and Listing Methodology (WisCALM) for CWA Section 303(d) and 305 (b) integrated reporting. Guidance # 3200-2015-01

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family level biotic index. *Journal of the North American Benthological Society* 7(1):65-68.

University of Wisconsin-Extension. 2004. Understanding Lake Data. G3582.

US Climate Data. November 17, 2015. [www.usclimatedata.com](http://www.usclimatedata.com)