North Lake Study

A Phased Study of Water Quality and Wave Propagation Dynamics Currently Impacting a Small Southeast Wisconsin Freshwater Lake

Carroll University
September 12, 2020

Primary Research Study Team

Carroll University

- Mike Mortensen, MSArch, Distinguished Lecturer GRC, Director of Aviation Science
- Joseph Piatt, Ph.D., M.S.C.E - Professor of Chemistry and Environmental Science
- Julio Rivera, Ph.D. - William B. Yersin Professor of Applied Business Analytics
- Katie McCarthy, Ph.D. - Assistant Professor of Applied Business Analytics, Business
- Alex Navin, Student of Chemistry
- Jenna Bales, Student of Environmental Science

Southeastern Regional Planning Commission

- Tom Slawski, Ph.D. - Chief Biologist
- Dale Buser, PE, Ph.D. - Chief of Hydrology

Terra Vigilis

- Timothy Tyre, Ph.D. - CEO
- Chuck Howard - Chief Technology Officer

North Lake Study

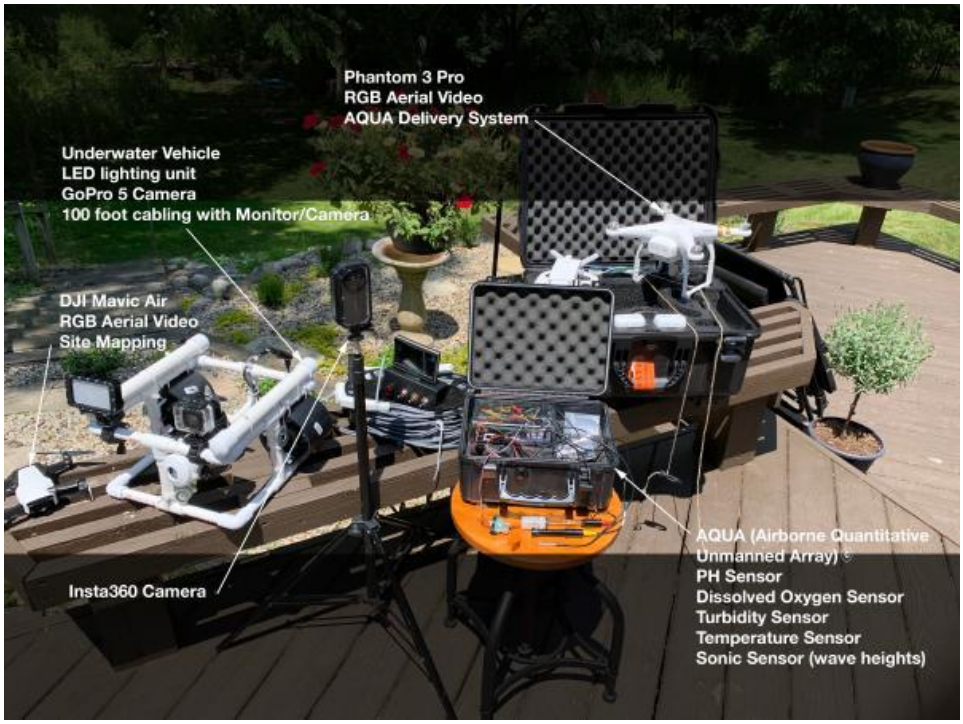
The North Lake Management District (NLMD) has requested a formal study to address water quality and wave propagation effects on shoreline, surface and subsurface areas on North Lake. North Lake is a freshwater glacial lake consisting of 438 acres. The lake is located in southeast Wisconsin in Waukesha County. North Lake has 237 property owners. The Lake has four inlets and a single outlet. The deepest portion of the Lake is 78 feet. The lake has a marl bottom and is used for recreational boating, fishing and related water sports..

Recent use of wave enhancing water craft on North Lake has become a stated concern by a majority of Lake residents due to large wave effects. The NLMD appointed a study committee (consisting of lake resident representatives) in 2017-8 to investigate these concerns. This committee was charged with producing recommendations to address the problem which resulted in a series of “Safe Boater” guidelines. The impact of the guidelines has been studied by lake resident survey in 2019 and plans are in place to repeat the resident survey again in the fall of 2020. Survey results in 2019 also highlighted strong resident concern for a comprehensive water quality study.

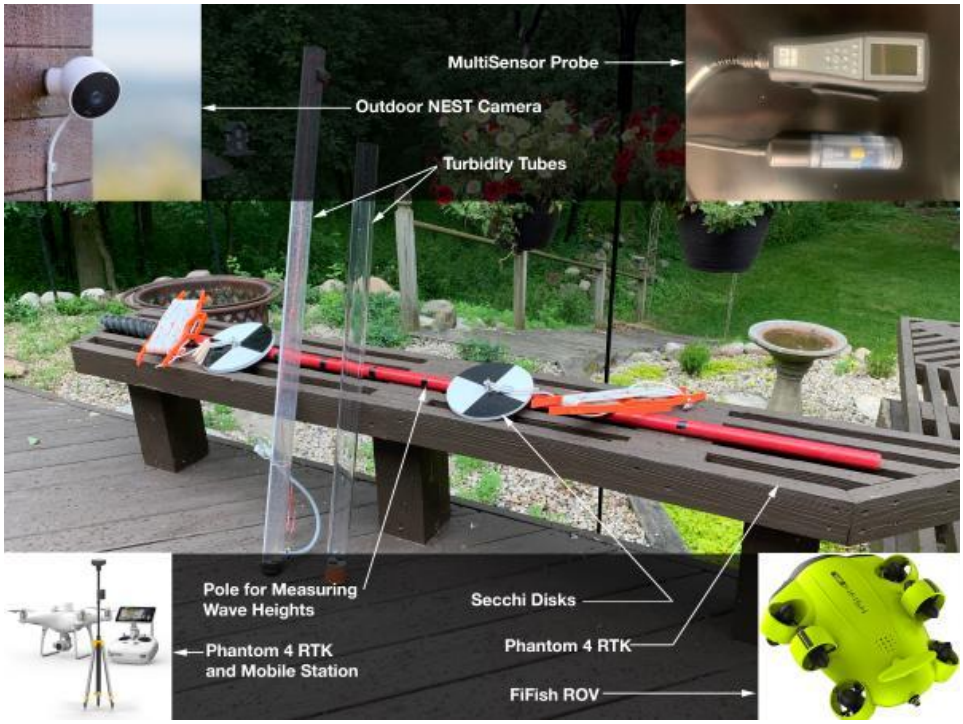
A multi-agency effort was undertaken in the spring of 2020 to combine the resources of Carroll University (Waukesha) and the Southeastern Regional Planning Commission to conduct this study. A private commercial drone firm, Terra Vigilis Security Group, was also retained to allow for measurements of wave propagation effects as a portion of this work.

Seven site locations were selected for the North Lake study.

Equipment



North Lake Equipment



North Lake Equipment

Carroll University Students: Jenna Bales with the remote underwater vehicle and Alex Navin with the DJI Mavic Air drone.

The research team has prepared a summary of preliminary results gathered in Phase 1 of this research. The purpose of the preliminary review is to allow the full research team an

opportunity to discuss the data gathered in 4 primary study domains with North Lake residents.

These domains include the following:

Domain 1

Measures have been gathered of wave heights, frequency, duration and depth (subsurface) across the primary engine powered vessels that use North Lake. These vessels include pontoon boats, personal watercraft, water ski boats and wave enhancing “wakeboard” boats.

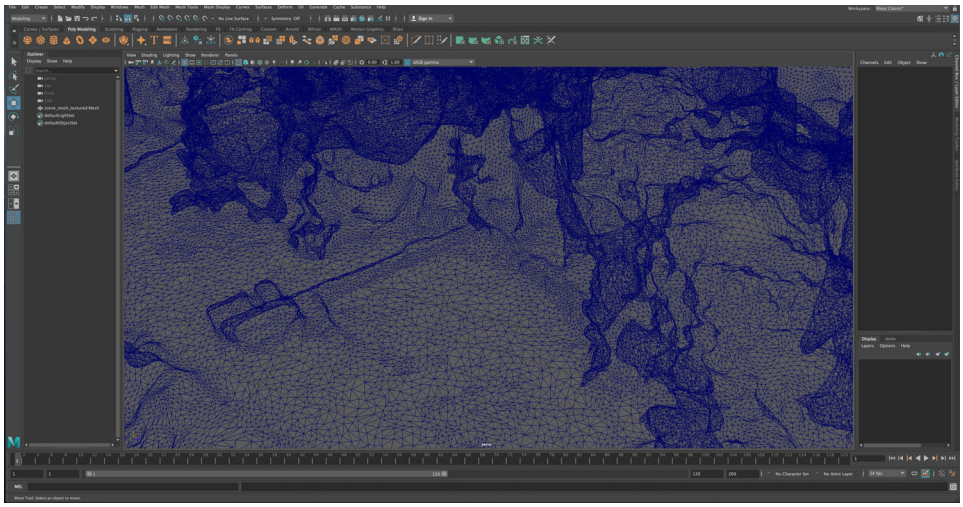
Site Mapping

Alex Navin prepares to launch the drone for aerial mapping at the North end of Wildwood Point. Mapping will allow our students to create an accurate 3D aerial map of the selected shoreline. Our students can measure shoreline erosion over time. The aerial mapping also allows our team to develop displacement maps which are used to create 3D models of waves. We determine wave heights from the 3D displacement models.

Jenna Bales prepares to launch the drone for aerial mapping at the South end of Wildwood Point. No need to worry about the rubber snake in the foreground.

Drone Mapping Plan View of Site #1

3D Textured Model of Site #1.



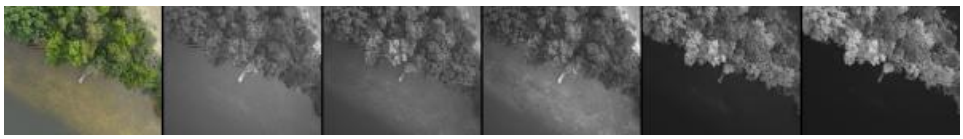
3D Wireframe Model of Site #1. Our team will analyze shoreline erosion over time. Our team has located GCP (ground control points) at two locations. The GCPs provide an accurate 3D model.

North Lake Shore Line Study		North Lake Shore Line Study	
Project file data		Coordinate System	
Name:	C:\Users\0911\Documents\Survey Processed Files\North Lake Shore Line Grant.vce	Name:	United States/State Plane 1927
		Datum:	WGS 1984
Size:	47 KB	Zone:	Wisconsin South 4803
Modified:	5/26/2020 6:41:03 AM (UTC:-5)	Geoid:	Wisconsin GEOID12A
Time zone:	Central Standard Time	Vertical datum:	
Reference number:	Mike Mortsen	Calibrated site:	
Description:	North Lake Shore Line Study		
Comment 1:			
Comment 2:			
Comment 3:			

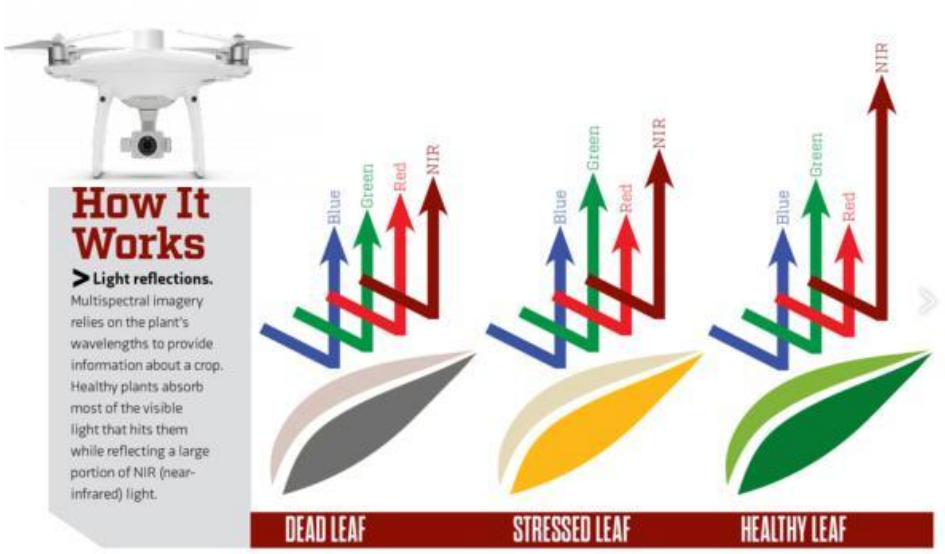
Point List

ID	Northing (US survey foot)	Easting (US survey foot)	Elevation (US survey foot)	Feature Code
100	421105.535	2430681.492	899.455	PLASTIC NAIL
101	421217.771	2430627.023	898.354	MARK ON PIER

Ground Control Point Data



Drone Multispectral Image at Wildwood Point



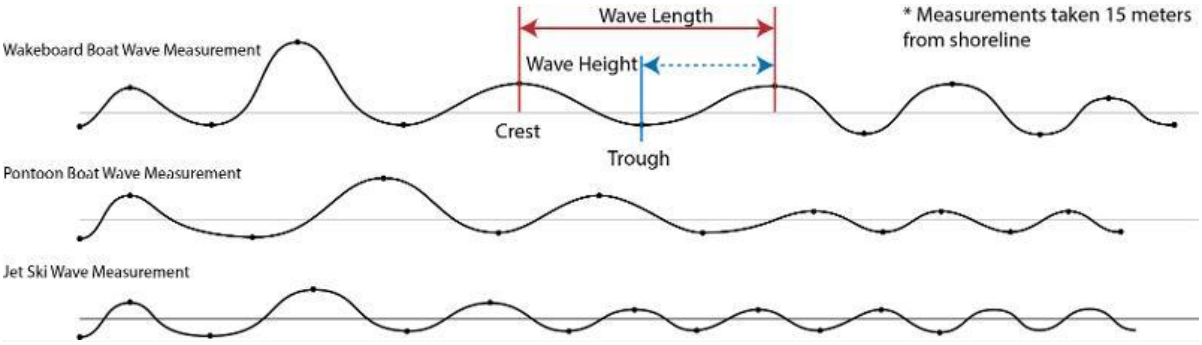
Multispectral Camera Filters: Blue(B), Green(G), Red(R), RedEdge(RE), Near Infrared(NIR). Healthier vegetation reflects more of certain types of light than unhealthy vegetation. Near Infrared light can apply the NDVI algorithm which measures the health of the vegetation.

Wave Measurements at Site 1

Wave Measurements at 15 meters from shoreline

Wakeboard Boat Wave		Pontoon Boat Wave		Jet Ski Wave	
Wavelength	Height Time	Wavelength	Height Time	Wavelength	Height Time
	-2 @ 0;00;03;17		-1 @ 0;00;31;19		-1 @ 0;00;11;19
	+2" @ 0;00;04;11		+3" @ 0;00;32;12		+2" @ 0;00;12;12
15' - 4"	-2" @ 0;00;05;21	20'-5"	-3" @ 0;00;34;10	12'-5"	-2" @ 0;00;14;16
	+8" @ 0;00;06;10		+5" @ 0;00;35;12		+3" @ 0;00;15;12
17' - 11"	-2" @ 0;00;07;21	17' - 11"	-2" @ 0;00;36;23	15' - 4"	-2" @ 0;00;16;21
	+4" @ 0;00;08;13		+3" @ 0;00;37;23		+3" @ 0;00;17;21
20'-5"	-2" @ 0;00;10;05	17' - 11"	-1" @ 0;00;39;01	17' - 2"	-1" @ 0;00;19;01
	+3.5" @ 0;00;10;28		+1.5" @ 0;00;39;22		+1.5" @ 0;00;19;18
15'-4"	-2" @ 0;00;12;18	10' - 3"	-2" @ 0;00;40;29	11' - 6"	-1" @ 0;00;20;27
	+4" @ 0;00;13;10		+1" @ 0;00;41;25		+1" @ 0;00;21;22
12'-10"	-3" @ 0;00;14;15	10' - 3"	-1" @ 0;00;42;19	11' - 3"	-1" @ 0;00;22;12
	+2" @ 0;00;15;06		+1" @ 0;00;43;10		+1" @ 0;00;23;02
	-3" @ 0;00;16;20		-2" @ 0;00;44;11		-1" @ 0;00;24;11
	+4" @ 0;00;17;10		+1" @ 0;00;45;03		+1" @ 0;00;25;00

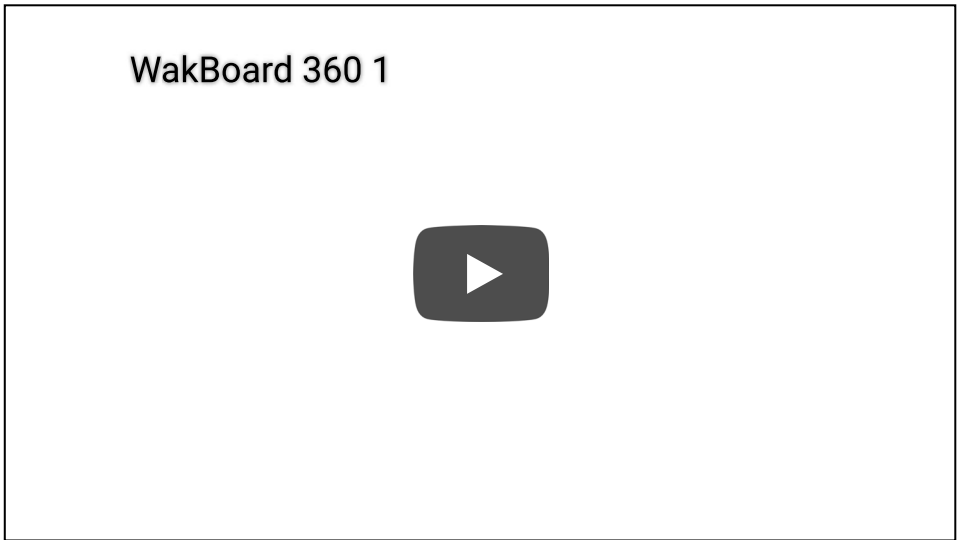
Wave Measurement Data at Site #1



Wave Measurement Graphic

Wave Propagation Video Compositions at Site 1

Video composition showing wave heights between a Jet Ski, a Speed Boat, and a Wakeboard Boat.



View of sedimentation plume caused by wave action at the shoreline

Wakeboard Boat Wave Frequency, Height and Underwater Disturbance at Site 1

Pontoon360 1

Pontoon and Jet Ski Wave Frequency, Height and Underwater Disturbance

Nearshore Sedimentation Disturbance. Left - Pontoon, Right - Wakeboard Boat

Video Recording at 71' below water surface. Wakeboard boat test.

Domain 2

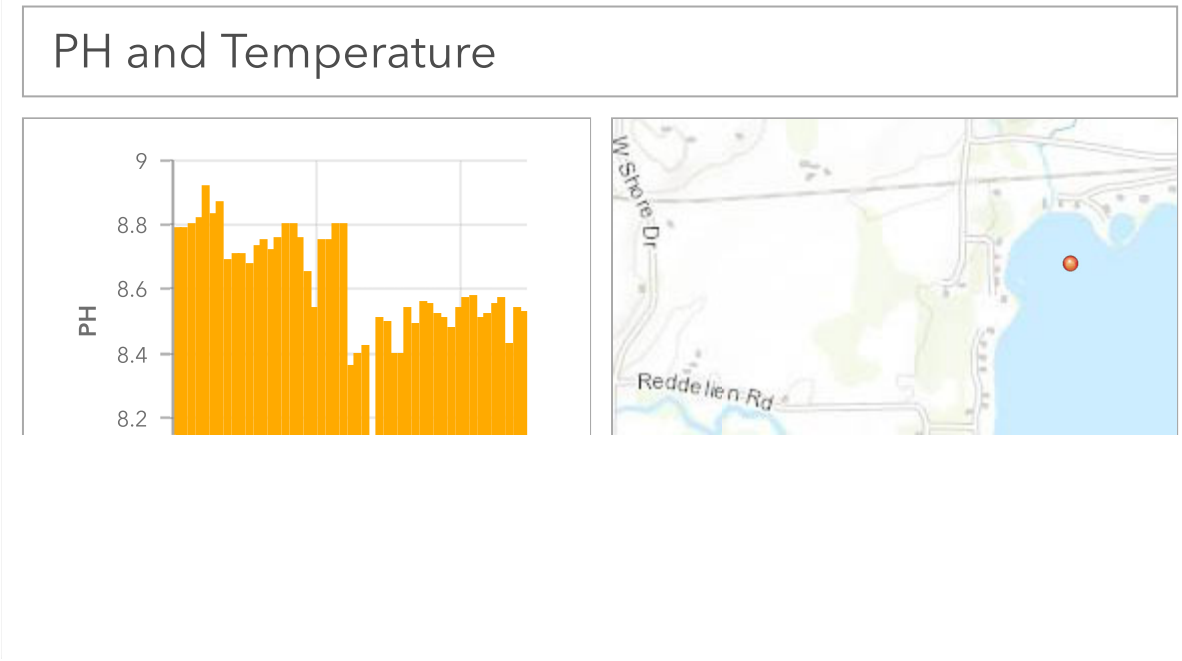
Measures of water quality as reflected by DO (dissolved O2), Ph, Turbidity and Water Temperature have been gathered. In addition, lab analysis at Carroll University using Ion Chromotography will reveal percentages of Nitrogen, Potassium and Phosphate concentrations.

Alex Navin and Jenna Bales preparing sediments for the baking cycle.

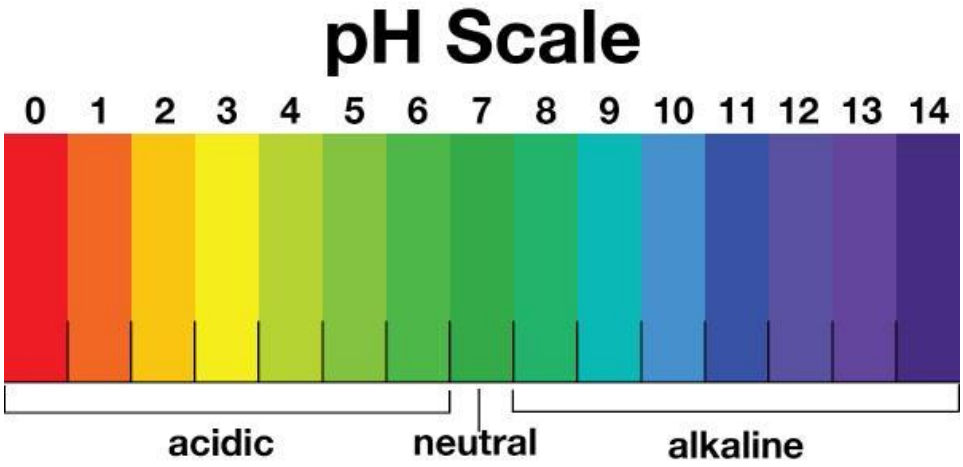
Alex Navin and Jenna Bales, Carroll University Students

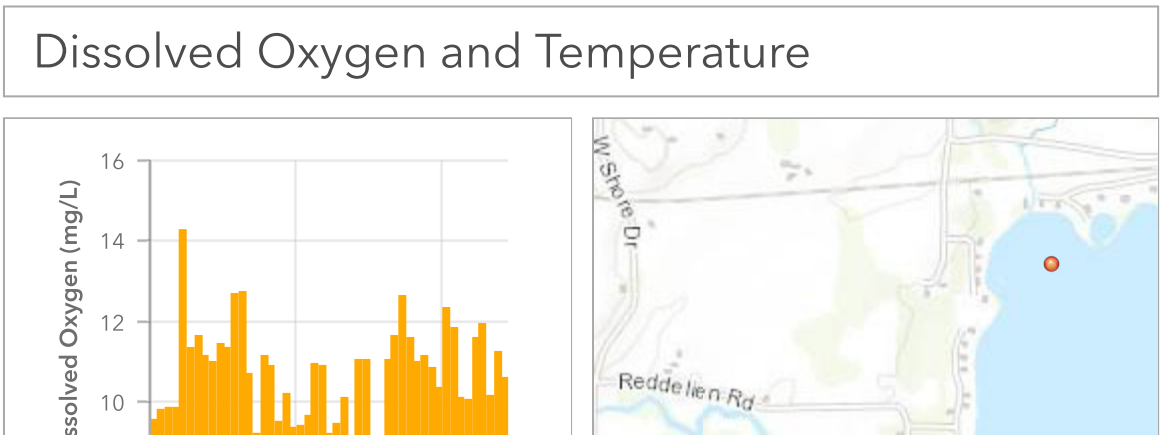
Alex Navin is preparing water samples for Ion Chromatography at the Carroll University Laboratory.

Alex Navin, Carroll University Chemistry Student

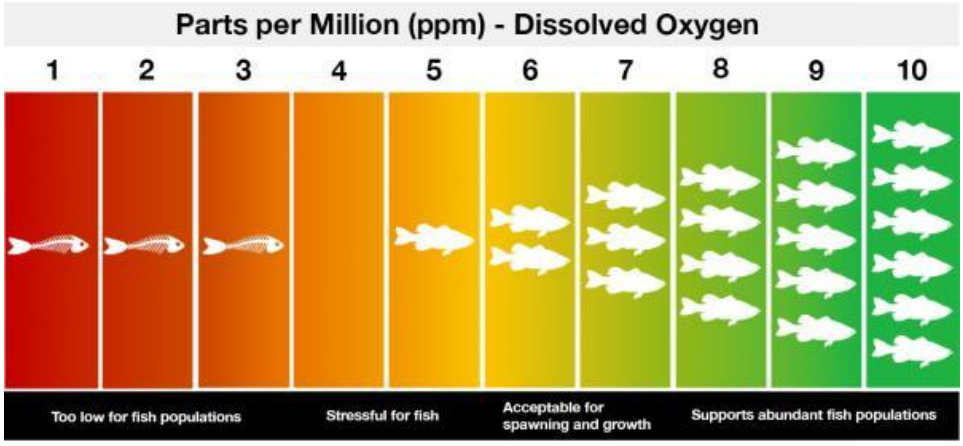


PH

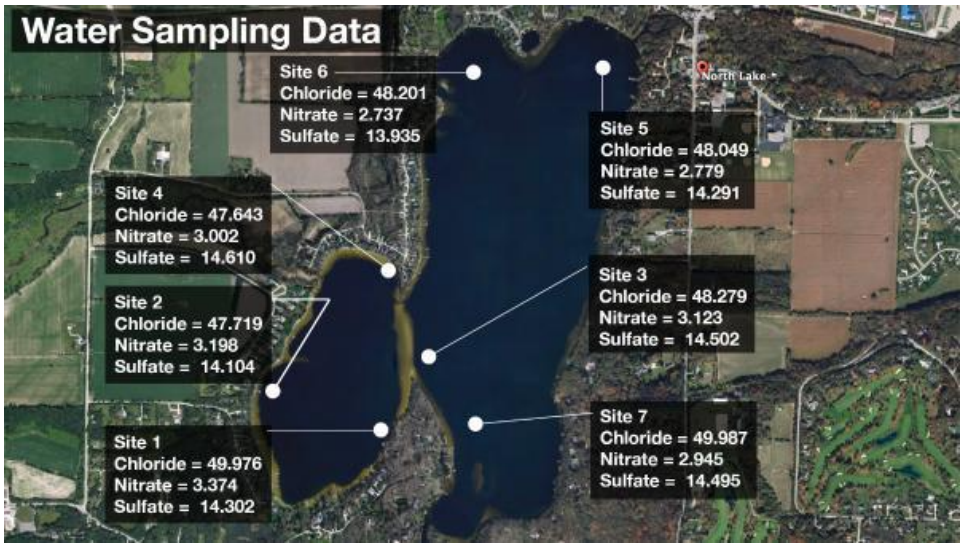




ArcGIS Dashboards

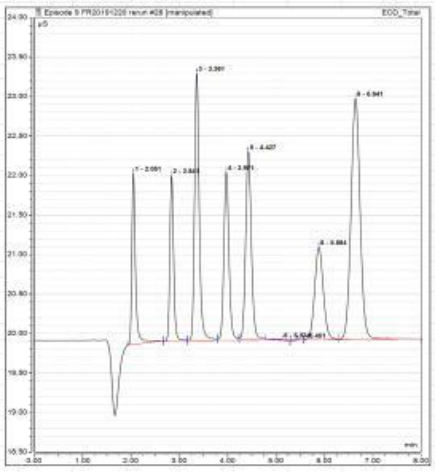


ArcGIS Dashboards



North Lake Water Sampling - Surface to 3' Below Surface - June 22, 2020

Dionex Standard 20x Dilution Example

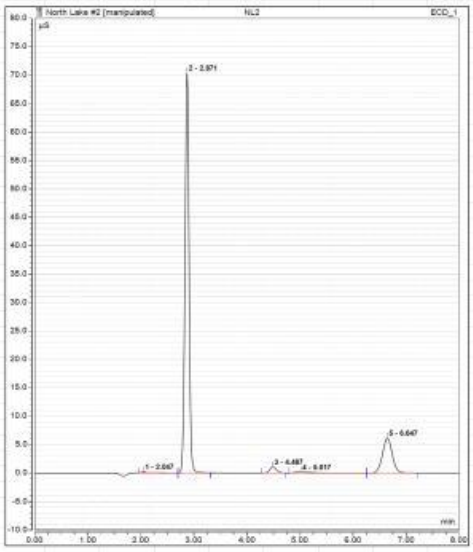


Integration Results

No.	Peak Name	Retention Time min	Area µS*min	Height µS	elative Area %	elative Heigh %	Amount n.a.
ECD_Total	ECD_Total	ECD_Total	ECD_Total	ECD_Total	ECD_Total	ECD_Total	ECD_Total
1		2.051	0.189	2.169	8.43	13.21	n.a.
2		2.841	0.185	2.094	8.22	12.76	n.a.
3		3.361	0.379	3.389	16.90	20.64	n.a.
4		3.971	0.258	2.131	11.49	12.98	n.a.
5		4.427	0.327	2.389	14.55	14.55	n.a.
6		5.134	0.003	0.013	0.15	0.08	n.a.
7		5.451	0.002	0.004	0.08	0.02	n.a.
8		5.884	0.242	1.175	10.76	7.16	n.a.
9		6.641	0.660	3.054	29.40	18.60	n.a.
Total:			2.245	16.418	100.00	100.00	

Standard Chromatogram

North Lake Shoreline Chromatogram Example



Integration Results

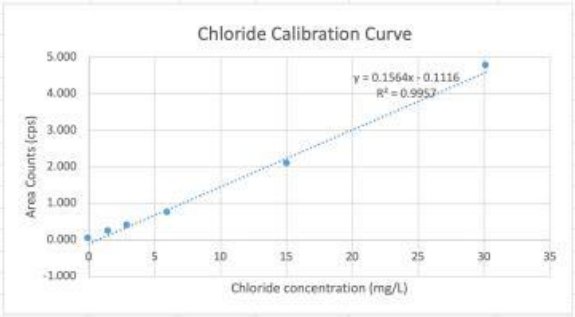
No.	Peak Name	Retention Time min	Area µS*min	Height µS	elative Area %	elative Heigh %	Amount n.a.
ECD_1	ECD_1	ECD_1	ECD_1	ECD_1	ECD_1	ECD_1	ECD_1
1		2.047	0.009	0.154	0.12	0.20	n.a.
2		2.871	6.188	70.336	80.26	90.35	n.a.
3		4.487	0.152	1.066	1.98	1.37	n.a.
4		5.017	0.063	0.178	0.82	0.23	n.a.
5		6.647	1.297	6.118	16.83	7.86	n.a.
Total:			7.709	77.851	100.00	100.00	

North Lake Chromatogram

Concentration	Cl (mg/L)	Area
0.0	0	0.000
20.0	1.51	0.185
10.0	3.02	0.366
5.0	6.04	0.729
2.0	15.1	2.071
Full	30.2	4.719

Site	Area counts	Cl Concentration (mg/L)
Shoreline	6.188	40.276
Heine	6.162	40.111
Wildwood Point	6.254	40.699
Luebke	6.318	41.109
Mason Creek	6.423	41.783
Oconomowac River	6.521	42.407
Cornelle	6.589	42.844

Measured Concentration of Dionex Cl: 30.2mg/L

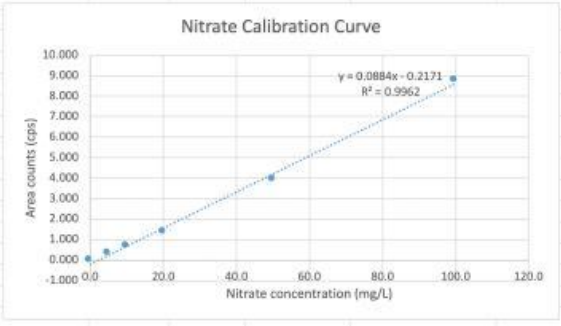


Chloride

Concentration	NO3(mg/L)	Area
0.0	0.0	0.000
20.0	5.0	0.327
10.0	10.0	0.659
5.0	20.0	1.354
2.0	50.0	3.909
Full	100.0	8.810

Site	Area counts	NO3 Concentration (mg/L)
Shoreline	0.152	4.180
Heine	0.156	4.219
Wildwood Point	0.156	4.220
Luebke	0.158	4.242
Mason Creek	0.164	4.315
Oconomowac River	0.162	4.288
Cornelle	0.126	3.886

Measured Concentration of Dionex NO3: 100mg/L



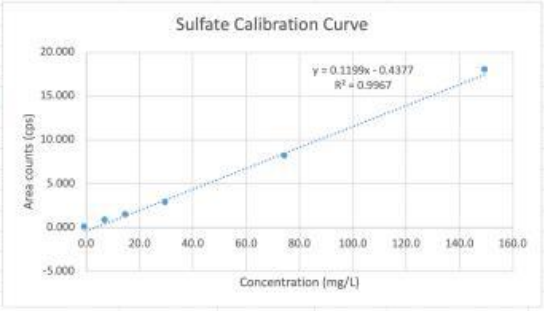
Nitrate

Concentration	SO4(mg/L)	Area counts
0.0	0.0	0.000
20.0	7.5	0.660
10.0	15.0	1.311
5.0	30.0	2.751
2.0	75.0	8.037
Full	150.0	17.875

Site	Area counts	SO4 Concentration (mg/L)
Shoreline	1.297	14.469
Heine	1.307	14.549
Wildwood Point	1.311	14.587
Luebke	1.311	14.581
Mason Creek	1.244	14.022
Oconomowac River	1.274	14.278
Cornelle	1.296	14.457

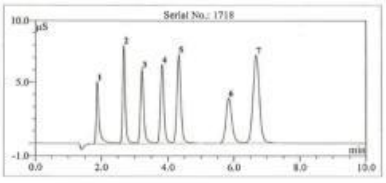
Measured Concentration of Dionex SO4: 150mg/L

Normal Range: around 20mg/L



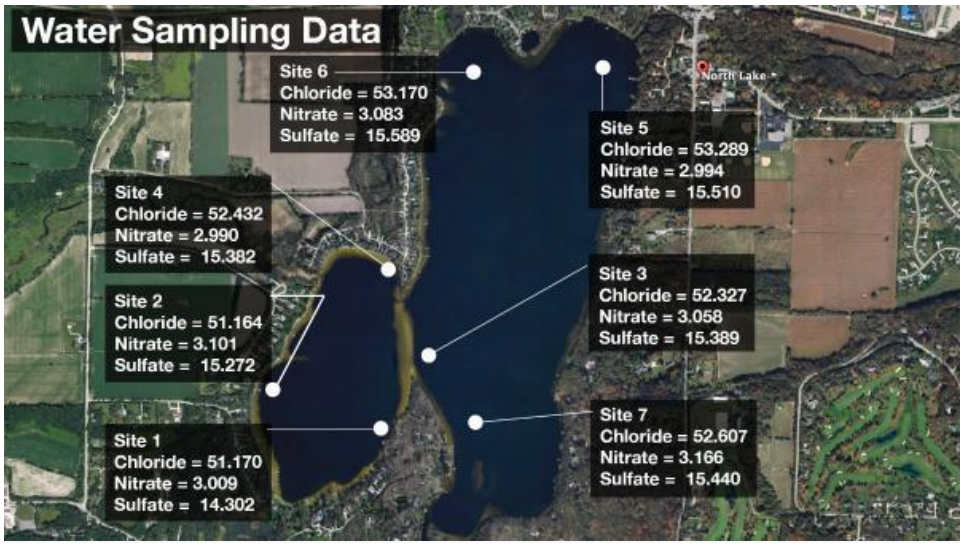
Sulfate

Eluent: 4.5 mM Na2CO3/ 1.4 mM NaHCO3
Flow Rate: 1.2 mL/min
Temperature: 30 °C
Detection: Suppressed Conductivity
Suppressor: Dionex Anion Self-Regenerating Suppressor (Dionex ASRS™ 300 4mm) AutoSuppression™ Recycle Mode
Applied Current: 31 mA
Injection Volume: 10 µL
Storage Solution: 100 mM Sodium bicarbonate



No.	Peak Name
1	Fluoride
2	Chloride
3	Nitrite
4	Bromide
5	Nitrate
6	Phosphate
7	Sulfate

Reference Information



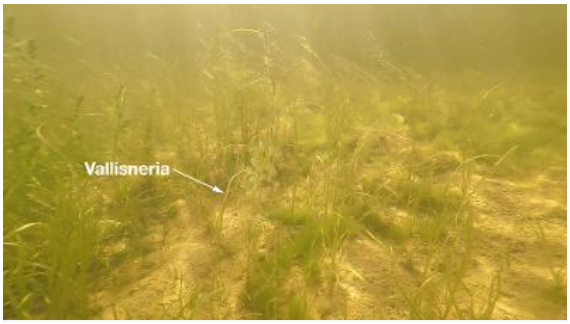
	Samples	Mass of Empty Crucible +Lid (g)	Mass of Crucible, Lid, and Soil (g)	Dry Mass (g)	Raw Combusted Mass (g)	Calculated Combusted Mass (g)	Organic Carbon Content (foc)
2	Sample 2-1	22.071	35.1591	13.0881	34.7008	12.6298	0.035016542
3	Sample 2-2	18.9547	32.3532	13.3985	31.961	13.0063	0.029271933
4	Sample 3-1	21.9032	34.0498	12.1466	31.1496	9.2464	0.238766404
5	Sample 3-2	19.7267	32.2485	12.5218	31.6547	11.928	0.047421297
6	Sample 4-1	20.5543	31.0955	10.5412	30.6899	10.1356	0.038477593
7	Sample 4-2	21.6144	35.5381	13.9237	35.0205	13.4061	0.037174027

Organic Carbon Analysis at Site #1

Domain 3

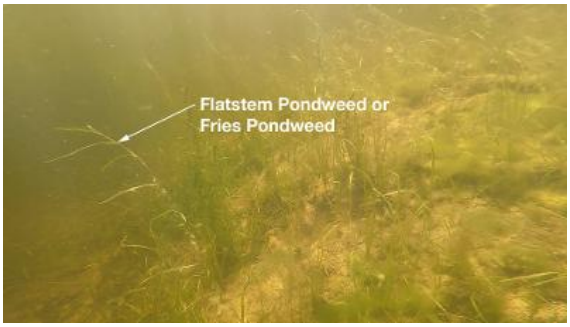
Jenna Bales preparing to launch the remote underwater vehicle. Jenna uses a head display to navigate the vehicle near the lake bottom.

Measures and sampling of surface and subsurface plant life have been gathered by the research team. This sampling will allow species identification and analyses for invasive weed risk.



Heine Residence, June 16, 2020

Vallisneria is a native plant that grows in rows and can form underwater "meadows".



Heini Residence, June 16, 2020

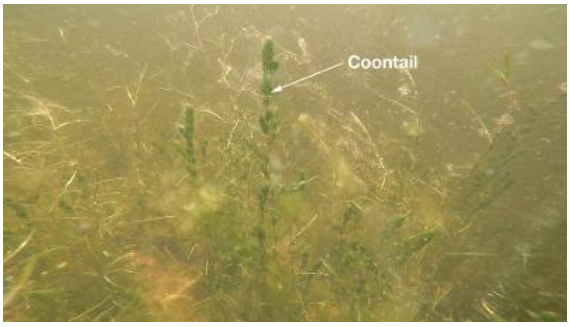
Both Flat-stem pondweed and Fries Pondweed were observed visually but it is hard to tell the difference on camera. Both are native and common in lakes and streams in this region of Wisconsin.

Heine Residence, June 16, 2020

There are two types of Water Milfoil, Eurasian Water Milfoil is highly invasive and can out compete different native species as it grows tall and will out-shade the native species below. Native Water milfoil and Eurasian Water milfoil can hybridize wich makes management of this invasive species difficult. When cut into segments it Water Milfoil can Reproduce easily by growing roots from the stem. Its makes it easy for the plant to spread.

Wildwood Point, June 16, 2020

At about 10-15 feet of water there is little to no plant growth. This trend is true for all of the points that we survey around the lake.



Cornell Inlet, June 16, 2020

Coontail is a native species. It can be identified by the rigid whorls of leaves that branch once or twice.

Cornell Inlet, June 16, 2020

Curly Leaf Pondweed if an invasive species from Eurasia and thrives in the Great Lakes Region. This species usually dies back earlier than most native plants after it fruits (early to middle July). They grow were native pondweeds do not until they grow large beds that push out native species.

Cornell Inlet, June 16, 2020

Elodea is a native to the Americans and are very common is all freshwater ways.

Oconomowoc Inlet, June 16, 2020

White Water-Crowfoot is a native plant that can grow into mats and flower above the water between June and August.

There is a great diversity of plants here in North Lake that should be protected. It was noticed near the Oconomowoc River inlet that there was a high density of Eurasian Watermilfoil and Curly Leaf Pondweed. It may be in the interest of the Lake Association to invest in a chemical or mechanical removal process.

FiFish Wildwood 480

Jenna Bales takes along the bottom of Wildwood Point utilizing the remote underwater vehicle called the FiFish. Jenna uses a head display to navigate the vehicle. This video illustrates the lack of vegetation where sedimentation is stirred up by boat activities and settles on the lake bottom.

Domain 4

Measures of plume development based upon wave propagation effects have been gathered. Imaging of plume content and spread characteristics are being analyzed relative to weed sprout areas.

Video composition of sedimentation plume development caused by boat activity

Wildwood Point Sedimentation Disruption