Braddock Bay Restoration

2017 Monitoring and Adaptive Management Report

Buffalo District
U.S. Army Corps of Engineers
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Great Lakes RESTORATION

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Executive Summary

This document presents the results of the 2017 monitoring and adaptive management surveys conducted at Braddock Bay (the Bay). The purpose of this monitoring effort was to collect data that can be used to assess if the Braddock Bay restoration project has been successful in achieving its objectives, and to support local resource agencies and stakeholders in adaptive management. These monitoring results characterize the second growing season after wetland restoration activities, and the first year following near complete placement of the stone portions of the barrier beach. Construction of the barrier beach began in August of 2016 and the full length of the stone breakwater and headland breakwaters was in place by November 2016. Some sand placement occurred in late 2016 and in the summer of 2017 on the barrier beach, however this activity was not completed due to record high lake levels that persisted through the 2017 construction season.

Monitoring tasks conducted in 2017 included surveys of emergent marsh vegetation, submerged aquatic vegetation, fish, birds, anurans, water quality, aerial imagery, and bathymetry. Due to the sand placement not being complete and the navigation not achieving its design depths, assessment of impacts to navigation and littoral drift could not be fully evaluated. Additionally, because of high water present during the 2017 growing season, assessment of shoreline erosion could also not be fully evaluated.

Generally, monitoring components associated with the project objectives of improving wetland habitat diversity and improving habitat suitability were found to have been met. Some individual components associated with emergent vegetation coverage and aquatic vegetation diversity were not met. These components could have been affected by the prolonged high lake levels of the 2017 summer. The monitoring component associated with the objective to reduce erosion could not be measured due to high water levels when aerial imagery was taken, and because effective analysis of shoreline erosion rates will require longer periods of study than a single year.

Of the monitoring components associated with project constraints, those associated with littoral drift impacts and trophic state shifts were found to meet success criteria; however, both analyses were limited by the lack of longer period of data. The sub-component of the trophic state shifts consisting of submerged aquatic vegetation monitoring was not met, however, this could have been impacted by the prolonged high water levels of the 2017 summer. Impacts to navigation could not be fully evaluated as design depths were never achieved and as-built surveys were never completed.

Overall, the data suggest the Braddock Bay project is functioning well and that additional monitoring during subsequent years is warranted to fully evaluate monitoring and adaptive management components. Additional monitoring is scheduled for the 2018.

Contents

Appendices

Table of Figures

Table of Tables

1.0 Purpose and Background

This document presents the results of the 2017 monitoring and adaptive management surveys conducted at Braddock Bay (the Bay). The purpose of this monitoring effort was to collect data that can be used to assess if the Braddock Bay restoration project has been successful in achieving its objectives and to support local resource agencies and stakeholders in adaptive management.

As described in the Braddock Bay Restoration: Monitoring and Adaptive Management (Appendix A), post-restoration monitoring data is to be compared to pre-determined ecologic performance criteria to assess the status of the resource and determine if adaptive management actions are required. Data collected in 2017 was compared against baseline data, as well as, control data collected in 2015 and 2016.

1.1 Adaptive Management Approach

Adaptive Management prescribes a process wherein management actions can be changed in response to monitored system response, so as to maximize restoration efficacy or achieve a desired ecological state. Adaptive management promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood.

Adaptive ecosystem based management has become a fundamental practice being applied to a variety of environmental protection and restoration actions within New York State (NYS) Great Lakes basin. Adaptive management principles described below are consistent with, although not necessarily identical, to those principles being implemented through Bi-national Great Lakes Water Quality Act the International Joint Commission, Great Lakes Adaptive Management Committee, the US ocean policy, and NYS Great Lakes action agenda.

New York's Great Lakes action agenda includes two specific actions for monitoring and evaluating beneficial use restoration efforts in AOCs. These monitoring actions follow the steps of adaptive management outlined by the Great Lakes Action Agenda (2014) which are as follows:

1. **Conceptualize the problem** by defining the scope, vision, targets and complete situation analysis;

2. **Plan Actions and Monitoring** through development of goals strategies and assumptions. Develop an operation and monitoring plan;

3. **Implement** the Actions and Monitoring by developing a work plan and timeline;

4. **Analyze Use and Adapt the plan** through analysis of the data, and change the plan if necessary to achieve the stated goals and objectives; and

5. **Share the output** of the plan in an outreach or educational environment.

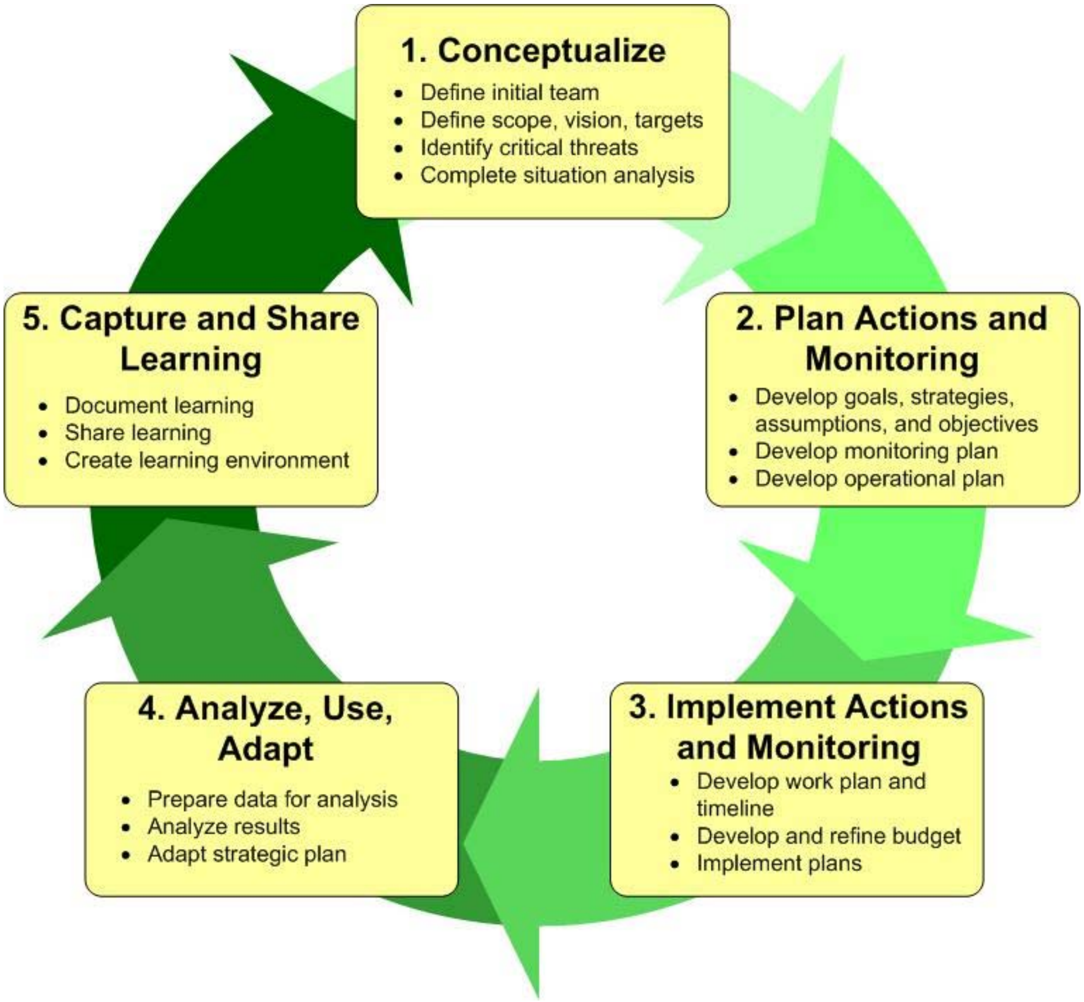

Figure 1. Adaptive management steps from New York's Great Lakes action agenda

1.2 Project Goals and Objectives

The primary purposes of monitoring efforts is to assess if the project objectives have been achieved and project constraints have been avoided. As stated in the Feasibility Report (September 2014), the planning objectives are as follows:

1. Restore wetland and habitat diversity in Braddock Bay to improve its suitability for fish and wildlife including northern pike, American mink, and the state listed black tern during the planning period of 2015 - 2065.
2. Protect Braddock Bay wetlands from erosion during planning period of 2015 - 2065.

Four critical project constraints are also being assessed through monitoring and adaptive management plan:

1. Avoid negatively impacting navigability and operation of marinas within bay.
2. Avoid impacts to nutrient dynamics of Braddock Bay that will worsen eutrophication.
3. Avoid negative impacts to Lake Ontario littoral drift system.
4. Avoid project activities that will increase extent of invasive species at project site.

1.3 Specific Monitoring Components

The adaptive management plan will focus on addressing key uncertainties associated with the proposed restoration plan. These uncertainties have potential to impact the degree to which project objectives are achieved and project constraints are avoided. In order to adequately determine if restoration outcomes have achieved the project objectives and avoided constraints, the monitoring plan will address the following components:

1. Vegetative diversity of Braddock Bay wetland (Objective 1)
2. Fish and wildlife diversity of Braddock Bay wetland (Objective 1)
3. Erosion rate of central marsh (Objective 2)
4. Navigability of bay mouth (Constraint 1, 3)
5. Water chemistry parameters specific to trophic status (Constraint 2)
6. Local littoral sediment transportation (Constraint 3)
7. Invasive species presence in restoration areas (Constraint 4)

1.4 Monitoring Framework

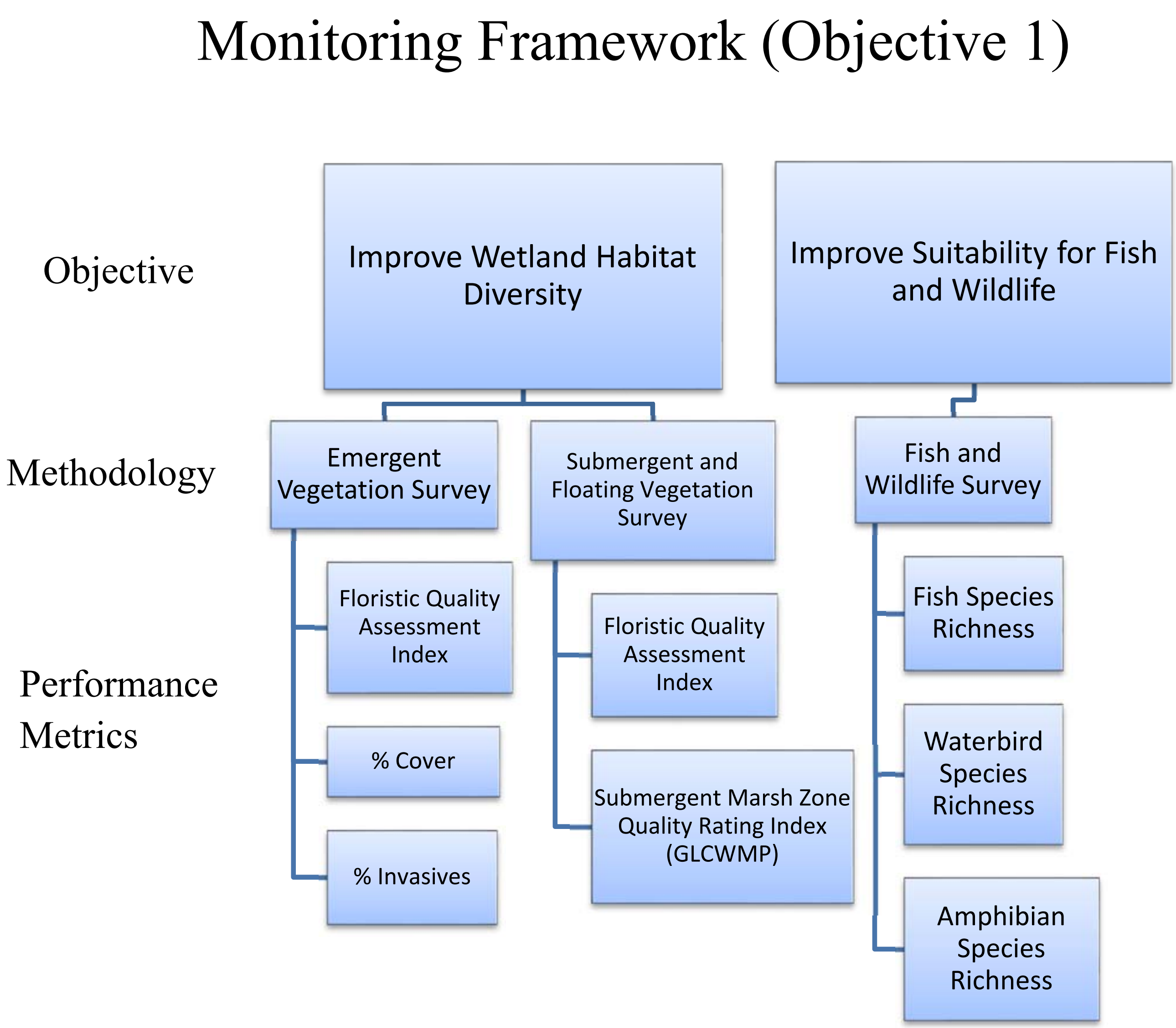

Figure 2. Monitoring Framework for Objective 1

Monitoring Framework (Objective 2)

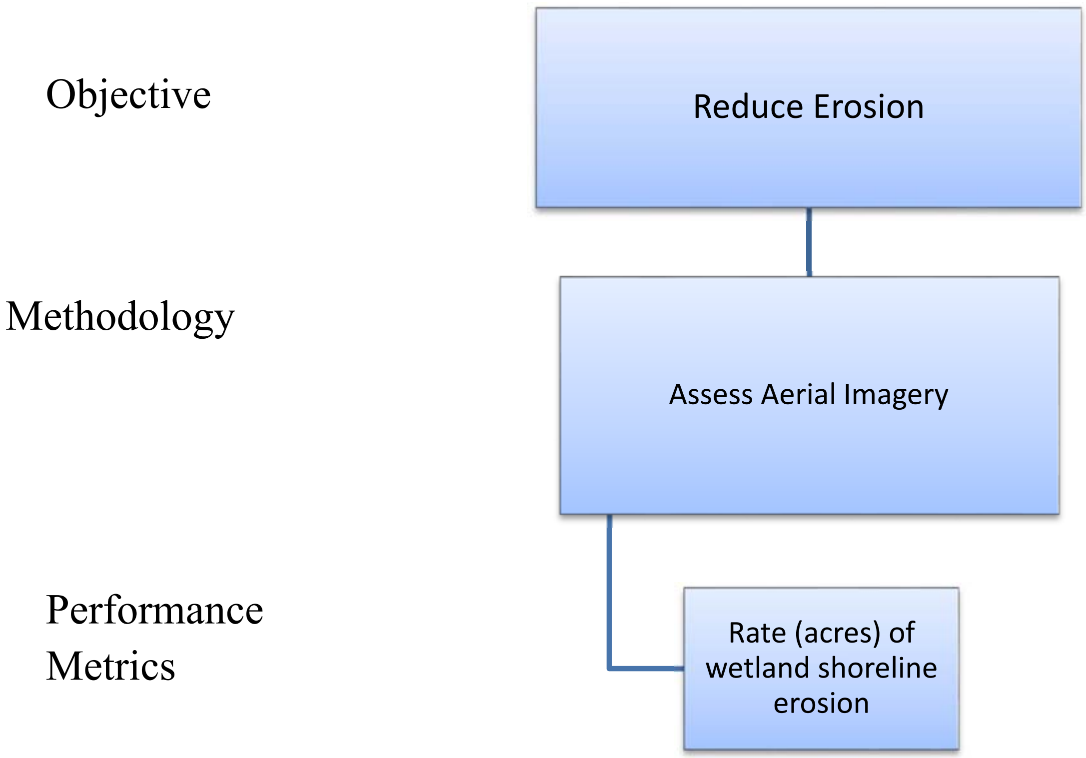

Figure 3. Monitoring Framework for Objective 2

Constraints Monitoring Framework

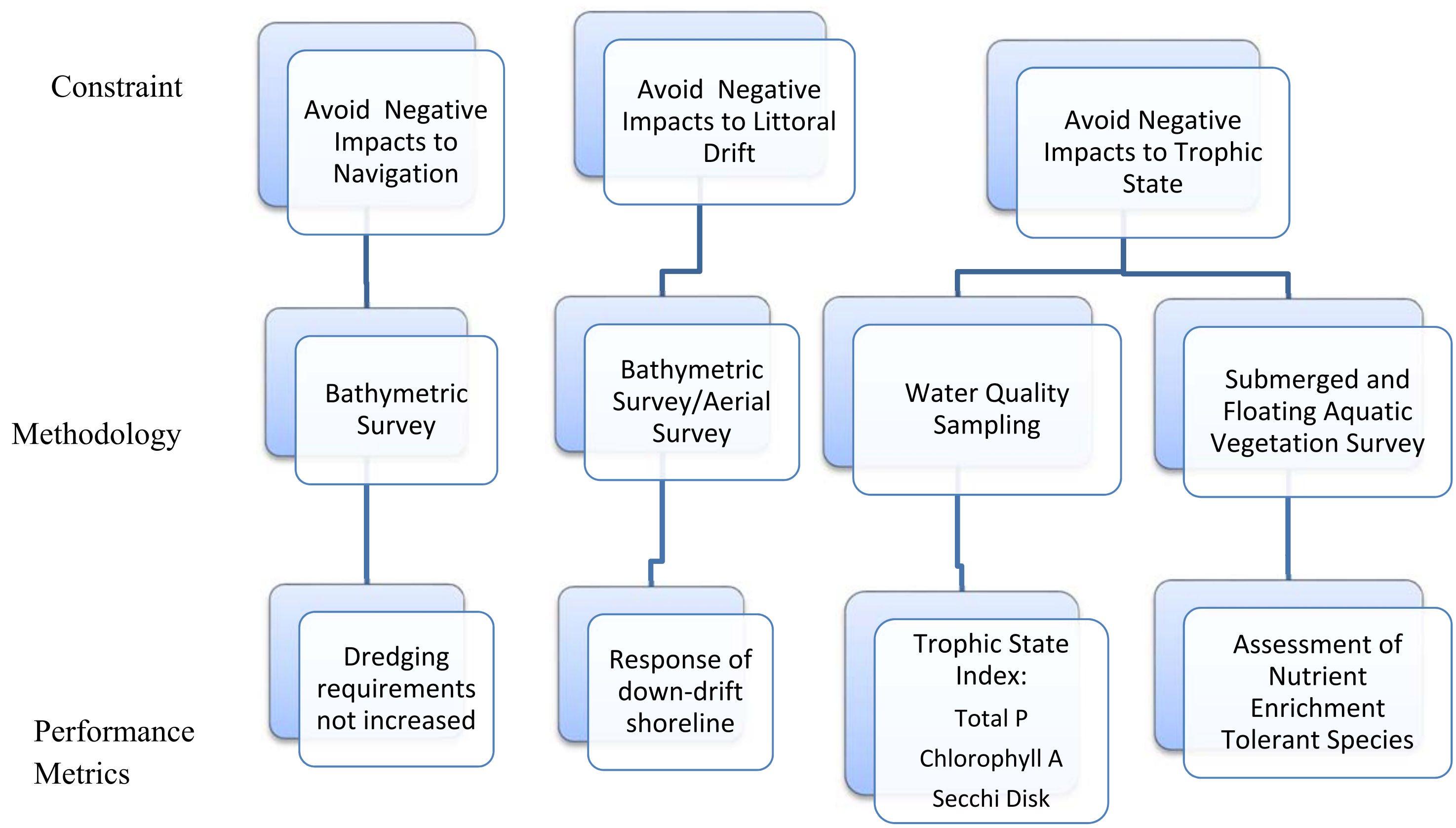

Figure 4. Monitoring Framework for Constraints

1.5 2017 Construction Progress

Implementation of the Braddock Bay Ecosystem Restoration project began in winter of 2016 with the excavation of approximately seven acres of channels and potholes within the existing marsh. Excavation began in January and concluded in March of 2016. Once completed, channel and pothole benches and habitat mounds were seeded with native seed mixes. Plugs of native wetland plants were planted in June of 2016. Cattail in the invasive species areas was mechanically removed in late July and treated chemically in late September. Phragmites stands were treated in late September and then removed mechanically in late October. Construction of the barrier beach began in August (Figure 6). Placement of the stone portions of the barrier beach were completed by December 2016.

Minimal progress was made towards completion of the project in 2017 due to record setting high water levels on Lake Ontario. At its June peak, water levels reached 248.56 feet (+5.26 feet LWD). This precluded the placement of beach sand on the barrier beach, placement of sand in the "new" emergent wetland, and treatment of cattail and phragmites. The only substantial progress made was in the placement of the low stone sill enclosing the "new" emergent marsh.

Additional work for 2018 will include sand placement on the barrier beach, installing lives stakes and plugs on the barrier beach, additional treatment of cattail and phragmites, and filling and planting the 2.7 acre of "new" emergent marsh within Braddock Bay.

Figure 5. Pothole fringe showing emergent marsh species. Photo take September 1, 2017.

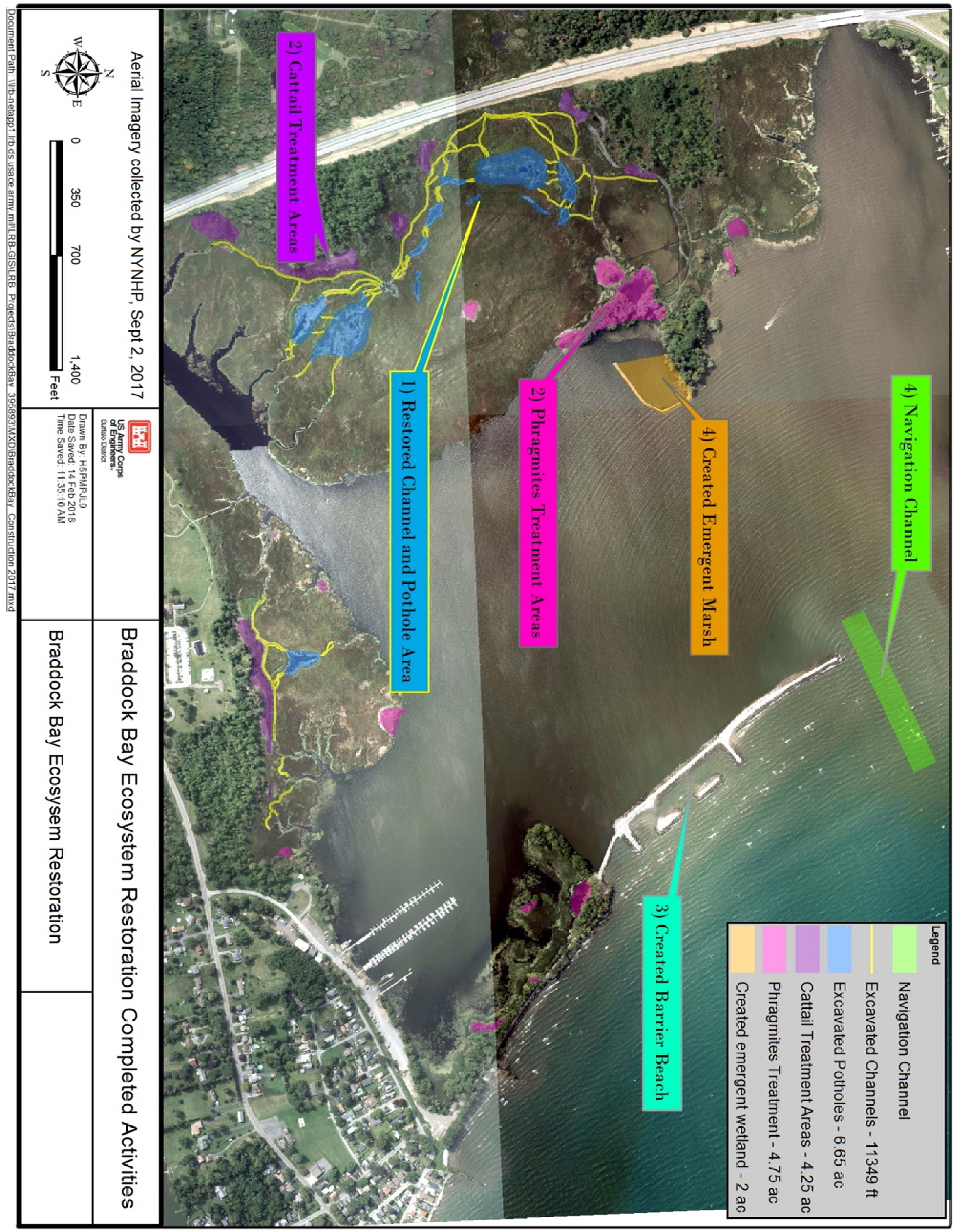

Figure 6. Braddock Bay Restoration, September 2017

2.0 Vegetation Monitoring

2.1 Emergent Marsh Monitoring

The emergent vegetative community in the areas of restoration are monitored to determine if project measures have been successful at restoring wetland and habitat diversity at Braddock Bay (Objective 1). Data collected regarding invasive species presence and absence will also help in determining if the project has adequately avoided the constraint of spreading invasive species (Constraint 4).

2.1.1 2017 Data Collection

Vegetation data was collected by State University of New York (SUNY) Brockport between the days of 7 June 2017 and 16 August 2017, 16 months after the completion of channel and pothole excavation. The full sampling methods and results can be found in (Appendix B). Only the data pertinent to the ecological performance criteria will be presented here.

2.1.2 Results

FQAI: Vegetation data from 332 quadrats (179 channel, 124 pothole, and 20 control) collected from 30 transects were compared to estimate the improvement in floristic quality as a result of restoration activities. The Floristic Quality Assessment Index (FQAI; Wilhelm and Swink, 1997) was used to evaluate quality of the area based on the plant species present. Areas with a higher FQAI score are considered to be of higher quality than areas of lower FQAI. This index is based on coefficients of conservation (C-scores) that are assigned to plants in a given region. A C-score of 0 indicates non-native taxa with a widened range of tolerance in terms of environmental limits, with a score of 10 being a very specialized native plants, with narrow range of limits associated with only undisturbed habitats. C-scores in this assessment were based off the New York State preliminary C-score list. (http://www.neiwpcc.org/nebawwg/fqaresources.asp). FQAIs were calculated using the following equation:

$$FQAI = \bar{C} * \sqrt{R}$$

Where $\bar{C}$ is the mean C-Score including all species (native and non-native), and R is the species richness of including all species (native and non-native)

To calculate average C-scores and FQAI, all survey data from different areas (channel, pothole, control) were combined to create a species list for each area. The pothole area and channel area were combined to represent all restored areas. Mean C-scores and FQAI were calculated for these species lists.

Continuing the trend from 2016, native species richness (NSR) and FQAI scores continued to increase in restored areas (Figure 7). In 2017, restored areas had an FQAI of 33.3 and a NSR of

71, compared to an FQAI of 17.5 and SR of 20 in the unrestored control areas (Table 1). This increase in species richness represents a 255% increase in native species diversity. Of the individual restoration areas, the channel areas had a higher FQAI score than pothole areas and control plots with FQAI scores of 30.1, 26.8, and 17.5 respectively (Table 1). Native species richness was also higher in channel areas (60), than in potholes (46), or control areas (20). These trends were consistent with 2016 surveys and suggest that vegetative communities in restored areas are of higher quality and higher species richness than those of unrestored (control) plots within Braddock Bay.

Table 1. 2016 and 2017 Results of Vegetation Surveys by zone type

	2016				2017			
	Control (n =30)	Channel (n=184)	Potholes (n=128)	All restored (n=312)	Control (n =20)	Channel (n=179)	Potholes (n=124)	All restored (n=303)
Total # of Species	27	68	52	74	23	70	51	81
# of Native Species	23	57	45	63	20	60	46	71
Mean C	3.6	3.5	3.5	3.6	3.7	3.6	3.8	3.7
FQAI	**18.9**	**28.6**	**25.8**	**31.1**	**17.5**	**30.1**	**26.8**	**33.3**
% natives	85%	84%	87%	85%	87%	86%	90%	88%

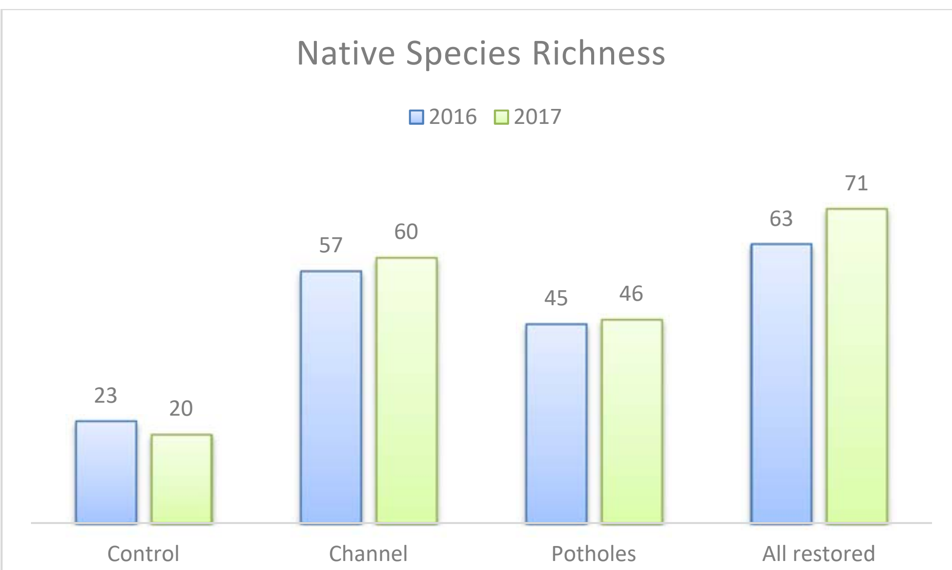

Figure 7. Native Species Richness by Restoration Area.

Percent Vegetative Cover: Percent vegetative cover was estimated during vegetation surveys along transects. The primary interest in this data is understanding if robust emergent and sedge grass meadow communities have established on channel benches, pothole benches, and adjacent habitat mounds. The target percent cover is 80% for emergent vegetation and sedge grass meadow areas. The average percent covers on habitat mounds, channel benches, or pothole benches did not achieve this goal (**Error! Reference source not found.**). The average coverage of emergent vegetation on channel benches was 49.5% and for shallow and intermediate benches respectively it was 36.8%. Average percent cover on pothole benches was 48%. Average percent cover of sedge grass meadow communities on habitat mounds adjacent to potholes was 69.7% and 61.9% for those adjacent to channels. For all locations, the variability of percent cover between survey locations was very large. For channel benches, average coverage was substantially less than 2016. This could be due to the extended high water levels that persisted through the summer of 2017. Although the target percent cover was not met, further recruitment and community establishment is anticipated in 2018, therefore no adaptive management measures are recommended this time.

Table 2. Percent Vegetation Cover: Channels vs. Potholes

Percent Vegetative Cover										
	Channel Transects						Pothole Transects			
Year	**M**		**SB**		**IB**		**B**		**M**	
	Average %	Range %	Average %	Range %	Average %	Range %	Average %	Range %	Average %	Range %
2016	62.95	10-100	66.61	30-100	68.93	25-100	48.28	<5 -100	68.54	25-100
2017	61.90	20-100	49.50	9.5-98.5	36.80	13-88	48.70	10-100	69.70	10-100

Invasive Species Cover: The coverage of invasive species was noted during vegetation surveys.

Typha x glauca and *Hydrocharis morusus-ranae* were commonly found as co-dominant species in restored channel areas. T. glauca was most common on shallow benches, where it averaged 17.4% of vegetative coverage. *H. morsus-ranae* coverage ranged from 6-8% of shallow benches, intermediate benches, and habitat mounds. *Lythrum salicaria* coverage ranged from 1-2 % on shallow benches and habitat mounds.

The most prevalent invasive species in restored pothole areas were *T. x glauca, L. salicaria*, and Hydrocharis morsus-ranae. *T. glauca* and *L. salicaria* averaged 6.0% and 8.3 % cover on habitat mounds respectively, and 8.2% and 5.7% respectively on pothole benches.

Invasive Species Trends: Overall the coverage common invasive species within restored areas in 2017 decreased from 2016 coverages. This could be due to a variety of factors including the release of additional bio control beetles (purple loosestrife), prolonged high water levels through the 2017 growing season, and establishment of native vegetation. *Phragmites spp.* (common reed) was not observed in restoration sites.

Lythrum salicaria **-** Overall, the coverage of *L. salicaria* decreased across restored areas from 2016 to 2017. Its coverage in restored pothole areas decreased from 16% in 2016 to 5% in 2017. On restored channel benches and habitat mounds, its average coverage decreased from 5.6% in 2016 to 1.3% in 2017. This decrease may be attributed to the prolonged high water levels that occurred in 2017, as well as, a result of effective biocontrol from the purple loosestrife leaf beetle that was re-released in the Braddock Bay Wildlife Management Area in 2017. Purple loosestrife reached its highest coverage on habitat mounds adjacent to channels (2.6%) and potholes (8.3%).

Typha x glauca - The coverage of *T. x glauca* decreased across restored areas from 2016 to 2017. Its coverage in restored pothole areas decreased from 8.2% in 2016 to 5.1% in 2017. On restored channel benches and habitat mounds, its average coverage decreased from 20.5% in 2016 to 8.8% in 2017. This decrease may be attributed to the prolonged high water levels that occurred in 2017. *T. x glauca* reached its highest coverage on pothole benches (8.2%) and shallow channel benches (17.4%).

Hydrocharis morsus-ranae - The coverage of *H. morsus-ranae* decreased across restored areas from 2016 to 2017. Its coverage in restored pothole areas decreased from 16% in 2016 to 3.9% in 2017. Within restored channels, and on channel benches and habitat mounds, its average coverage decreased from 13.7% in 2016 to 6.0% in 2017. This decrease may be attributed to the prolonged high water levels that occurred in 2017. *H. morsus-ranae* reached its highest coverage on pothole benches (9.9%) and shallow channel benches (8.5%).

2.1.3 Performance Criteria and Adaptive Management

The ecologic success criteria related to this component of adaptive management are:

1. Increase in quality (FQAI) of wetland habitat

2. Cover of emergent species > 80% of channel and pothole benches; cover of sedge grass meadow species >80% on habitat mounds.

3. Invasive species cover = 0% *Phragmites,* < 50% *Typha*, <10% Other.

Floristic Quality Assessment Index (FQAI) scores of restored channels and pothole areas, 30.1 and 26.8 respectively, are higher than control areas which scored 17.5. This suggests that restoration efforts have improved the quality of emergent wetlands in Braddock Bay. The percent cover on emergent benches and habitat mounds did not achieve the target percent cover of 80%. Vegetative coverage on pothole benches remained at 48% showing little change from 2016. Vegetative coverage on channel benches decreased from 67% to 50% since 2016. The low percent coverage likely reflects the impacts of prolonged record high water levels in 2017.

Based on these results the ecologic success criteria has been met for wetland habitat quality (FQAI above baseline), but fell short of for emergent vegetation cover on benches. As such, ecologic criteria can be considered partially met for this component.

The coverage of *Typha x glauca* (5.1 % on potholes and 8.8% on channel benches and habitat mounds) and *Phragmites* (0%) in restored areas was less than predetermined criteria (50% and 0% respectively). In 2017, the coverage of other invasive species, *Lythrum salicaria* and *Hydrocharis morsus-ranae* decreased to 8.9% on pothole benches and 7.3% on channel benches and habitat mounds. These coverage percentages are below the ecologic criteria of 10%. Ecologic criteria for these species has been met for this component.

Preliminary monitoring results indicate that restoration efforts have improved the diversity of the vegetation community. Comparison of data from subsequent years will be useful in monitoring whether the trends of increased vegetative diversity continue.

It is recommended the vegetation monitoring be continued in 2018 and again within 3-5 years to determine the establishment of native vegetation communities and to track invasive species.

2.2 Submerged Aquatic Vegetation and Floating Aquatic Vegetation Beds Monitoring

The submerged aquatic vegetation (SAV) and floating aquatic vegetation communities at Braddock Bay were monitored to determine if project measures have been successful at restoring wetland and habitat diversity at Braddock Bay (Objective 1). Vegetation data will also be used to assess if changes in the trophic state of Braddock Bay are occurring (Constraint 2). Data collected regarding invasive species presence and absence will also help in determining if the project has adequately avoided the constraint of spreading invasive species (Constraint 4).

2.2.1 2016 Data Collection

Surveys of the aquatic vegetation community were conducted by USACE on 23 Aug 2017. This sampling occurred during construction of the restored barrier beach. Surveys were conducted using rake toss methods combined with acoustic sonar surveys. The Biobase® software was used to collect and interpret the acoustic sonar data.

Rake Toss Method - One hundred and nine sample locations within Braddock Bay were sampled by rake toss method. Sample locations were laid out on a 75m grid in near shore areas and 150m grid in the center of the bay. At each sample location a double headed steel garden rake (14 in. width) attached to a rope was tossed into the water at a distance of approximately 10’ from the vessel and dragged along the substrate during retrieval. All species attached to the rake upon retrieval were recorded and characterized by density using the following classification (1 – sparse, retrieval suggests presence of one plant; 2 - moderate, retrieval suggests presence of multiple plants; 3 – dense, retrieval suggests presence of dense aquatic bed).

Acoustic Sonar and Biobase – Hydroacoustic and global positioning system (GPS) data was collected using a Lowrance High Definition System (HDS) echosounder. The transducer was oriented vertically and mounted to the boat stern approximately 1.25 feet below the surface. We used the Navico BioBase settings recommended for the Lowrance unit (BioBase, 2014). The acoustic and GPS signals were logged to data storage cards in sl2 format. Data collected were analyzed with ciBioBase servers. After ciBioBase processed the data, ciBioBase generated a report for each site containing vegetation, bathymetry and substrate. Comma-separated values (CSV) files for each map layer were downloaded from the ciBioBase's website and maps were created in ArcGIS. Exported data included record number, latitude, longitude, bottom depth and biovolume (defined as percent of the water column taken up by vegetation) substrate hardness. Bottom depths and vegetation biovolume estimates were corrected for transducer depth.

2.2.2 Results

Biovolume Survey

The extent of submerged aquatic vegetation was similar to that observed in the 2016 baseline; however, the density of the vegetation was much less (Figure 8). Dense beds of submerged aquatic vegetation are present in the protected cove near the marina, the cove north of the navigation channel, and within the mouths of salmon and button wood creek. Beds of submerged aquatic vegetation become sparse and absent in deeper waters near the central portions of the bay and central channels of the tributary. The disparity in biovolume between 2016 and 2017 is likely a result of record high lake level that persisted throughout the 2017 growing season.

Aquatic Vegetation Community Makeup

A total of 17 species of aquatic vascular plants were recorded in Braddock Bay during the 2017 survey. Of the 106 sample points, 51 resulted in no return and are considered to be un-vegetated substrate (Figure 8). Fourteen of the species observed were native to the region. The most widespread species were American water celery (*Vallisneria americana*) and coon-tail (*Ceratophyllum demersum*) found in 37% and 33% sample locations respectively. *C. demersum* was a dominant species in 27% of sample locations while *V. americana* was a dominant species in 23%. This suggests that V. Americana is more widespread in the bay, but *C. demersum* tends to grow in denser patches where it is present.

Three non-native/invasive vascular species were observed in the Braddock Bay. Eurasian milfoil (Myriophyllum spicatum) and brittle water naiad (Najas minor) were observed at multiple locations in the bay and were present in 14% and 8% of sample locations respectively (Figure 9). Water chestnut (Trapa natans) was only observed behind the southern land spit near the Braddock bay marina; it was observed at 1% of sample points. An invasive algae, starry stonewort (Nitella obtussa) was observed at 4 sample locations within Braddock Bay. It was a dominant species at one location forming a dense mat.

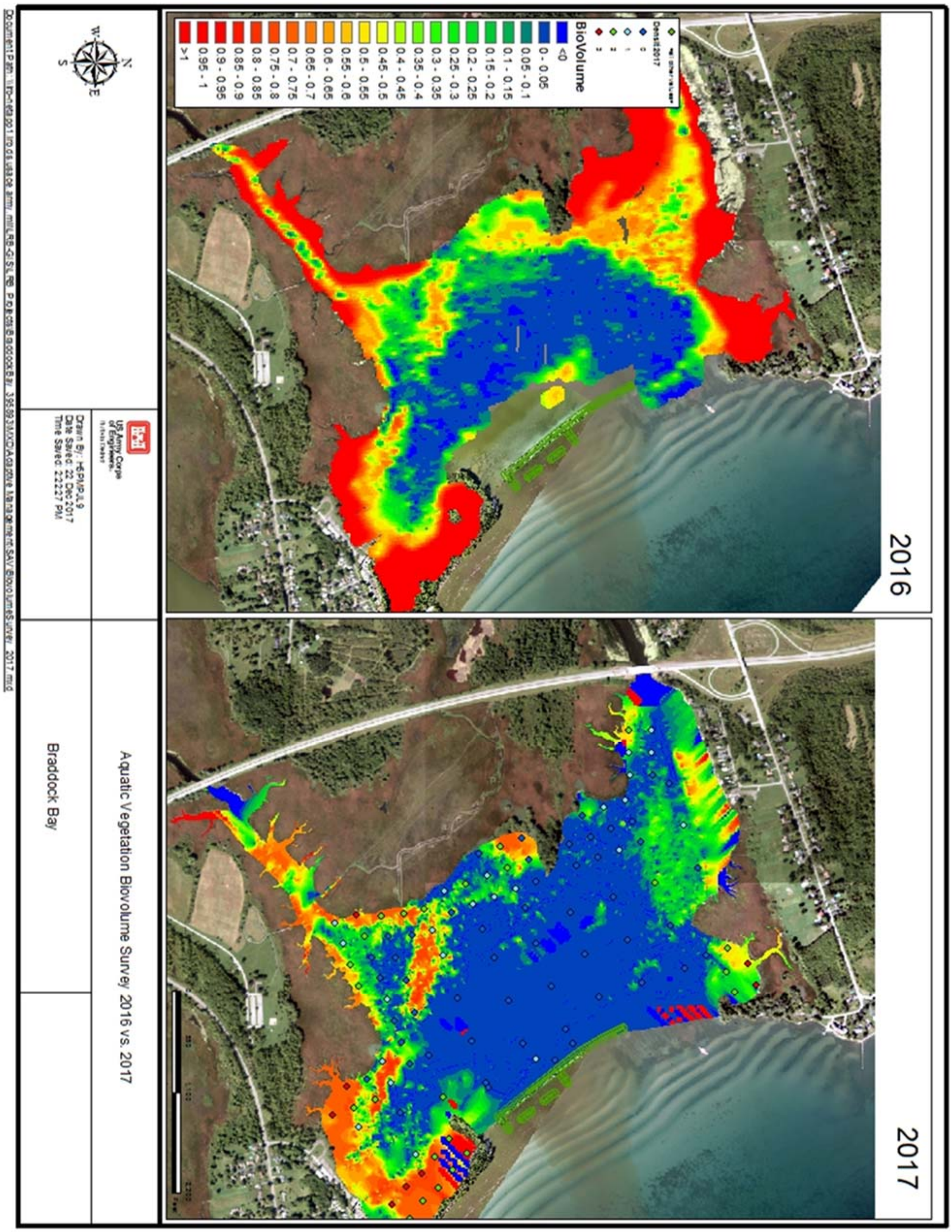

Figure 8. 2016 vs 2017 Biovolume Survey

Overall, the vegetative community in 2017 was similar to the 2016 community. Eleven native vascular species were observed in 2017 compared to the twelve that were observed in 2016. The most noticeable difference between 2016 and 2017 was the disparity in sample points without vegetation present. In 2017, 51 sample locations (48%) had no vegetation present, compared to 18 (17%) without vegetation in 2016. This is most likely a result the record high lake level that persisted throughout the 2017 growing season. This disparity is well reflected in the biovolume surveys (Figure 8).

Table 3. 2017 Aquatic vegetation survey

2017 Species Observed	# of times observed	% of all sample points	% of vegetated sample points	Dominant species sample points
Vallisneria americana	39	37%	76%	23%
Ceratophyllum demersum	35	33%	69%	27%
Elodea canadensis	15	14%	29%	3%
Myriophyllum spicatum*	15	14%	29%	8%
Heteranthera dubia (Zosteralla)	9	8%	18%	4%
Najas minor*	8	8%	16%	2%
Stuckenia pectinata	6	6%	12%	2%
Nitella obtusa*	4	4%	8%	1%
Nymphea odorata	3	3%	6%	-
Myriophyllum simbricum	3	3%	6%	-
Unk. Potamogeton	3	3%	6%	-
Chara sp.	2	2%	4%	-
Najas flexilis	3	3%	6%	-
Lemna truscala	2	2%	4%	-
Trapa natans*	2	2%	4%	-
Utricularia vulgaris	1	1%	2%	-
Native Species Richness (vascular only)	11			
Total Sample Points	106			
Sample points with no veg	51	49%		
Points with nutrient enrichment tolerant species	40	38%		
*** non-native species**	**Nutrient Enrichment Tolerant Species**			

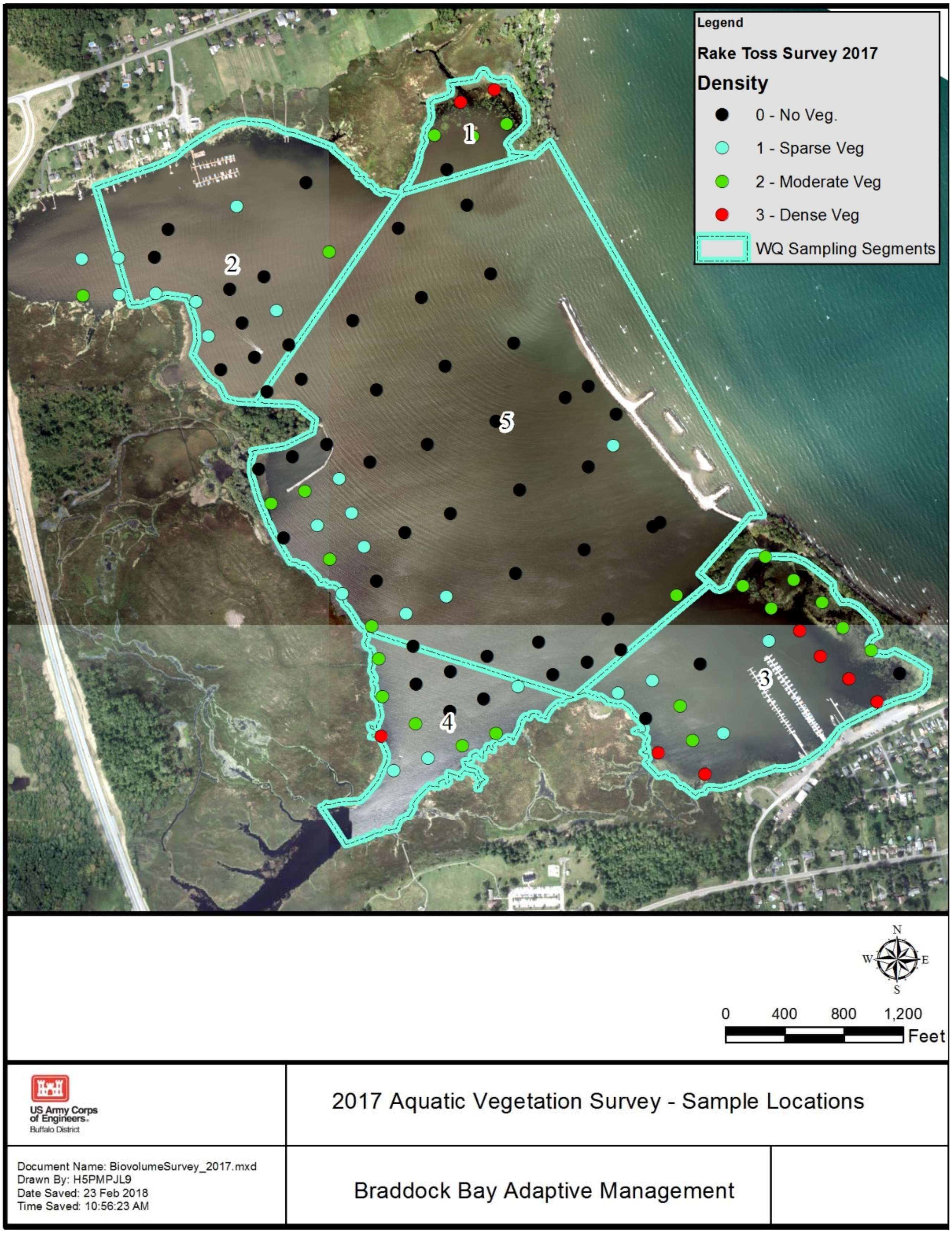

Figure 9. 2017 Aquatic Vegetation Survey - Sample Locations

Table 4. 2016 vs 2016 Vegetation Community Summary and NET Species Analysis

Entire Bay	**2016**		**2017**	
Native Species richness (vascular only)	12		11	
Total Sample Points	104		106	
Sample points with no veg	18	17%	51	48%
Points with NET species	48	46%	40	38%
NET Species Analysis Segments 3,4,5 only	**2016**		**2017**	
Total Sample Points	84		84	
Points with NET species	31	37%	31	37%
Points with NET species as Dominants	21	25%	29	35%

*NET - Nutrient Enrichment Tolerant

Nutrient Enrichment Tolerant Species

The extent of nutrient enrichment tolerant (NET) species is being used to determine if the aquatic vegetation communities of Braddock Bay are shifting toward a more eutrophic state. Nutrient enrichment tolerant species, as defined by the Great Lakes Coastal Wetland Monitoring Plan (2008) are identified in (Table 5) below.

Table 5. Nutrient enrichment tolerant (NET) species

Stress	**Species**
Nutrient Enrichment	*Ceratophyllum demersum*
	Elodea canadensis
	Lemna minor
	Myriophyllum spicatum
	Potamageton cripus
	Potamageton pectinatus
	Algae

Changes in the frequency of NET species is used as an indicator of trophic state change in Braddock Bay. Specifically, a significant increase in the frequency and extent of NET species in segments 3, 4, and 5 would result in failure to achieve the ecologic success criteria. Of the 12 vascular species observed during the aquatic vegetation survey, four were considered to be NET tolerant species: *E. canadensis*, *M. spicatum*, *C. demersum*, and *Stuckenia pectinatus* (*Potamogeton pectinatus*). Nutrient enrichment tolerant species were observed in 40 of 106 the sample points (38%) across the entire bay in 2017 (Table 4). This is a decrease in the extent of NET species from 2016 during which 48 sample points had NET species (46%). For ecologic criteria analysis only 3, 4, and 5 were considered. For these segments, no change in the frequency of NET species was observed between 2016 and 2017 with NET species observed in 31 of 84 sample locations (37%) in both years. Although the number of observations did not change between 2016 and 2017, NET species were more often dominant at sampled locations in these segments during 2017. Nutrient enrichment tolerant species were dominant in 29 of 84 sample locations (35%) in 2017 compared to 21 of 84 sample locations (25%) in 2016. *Ceratophyllum demursum* was the most widespread NET species and was primarily responsible for this change. In summary, the frequency of occurrence of NET species did not change from 2016; however, NET species became more dominant at sample locations in 2017. It is not clear if this increase in NET species dominance is due to a shift in trophic conditions in the bay, or a result of the record high lake levels in 2017. Based on the fact that water quality parameters do not show a change in the status of eutrophication, it may be more likely lake elevations influenced the 2017 vegetation community and NET species dominance.

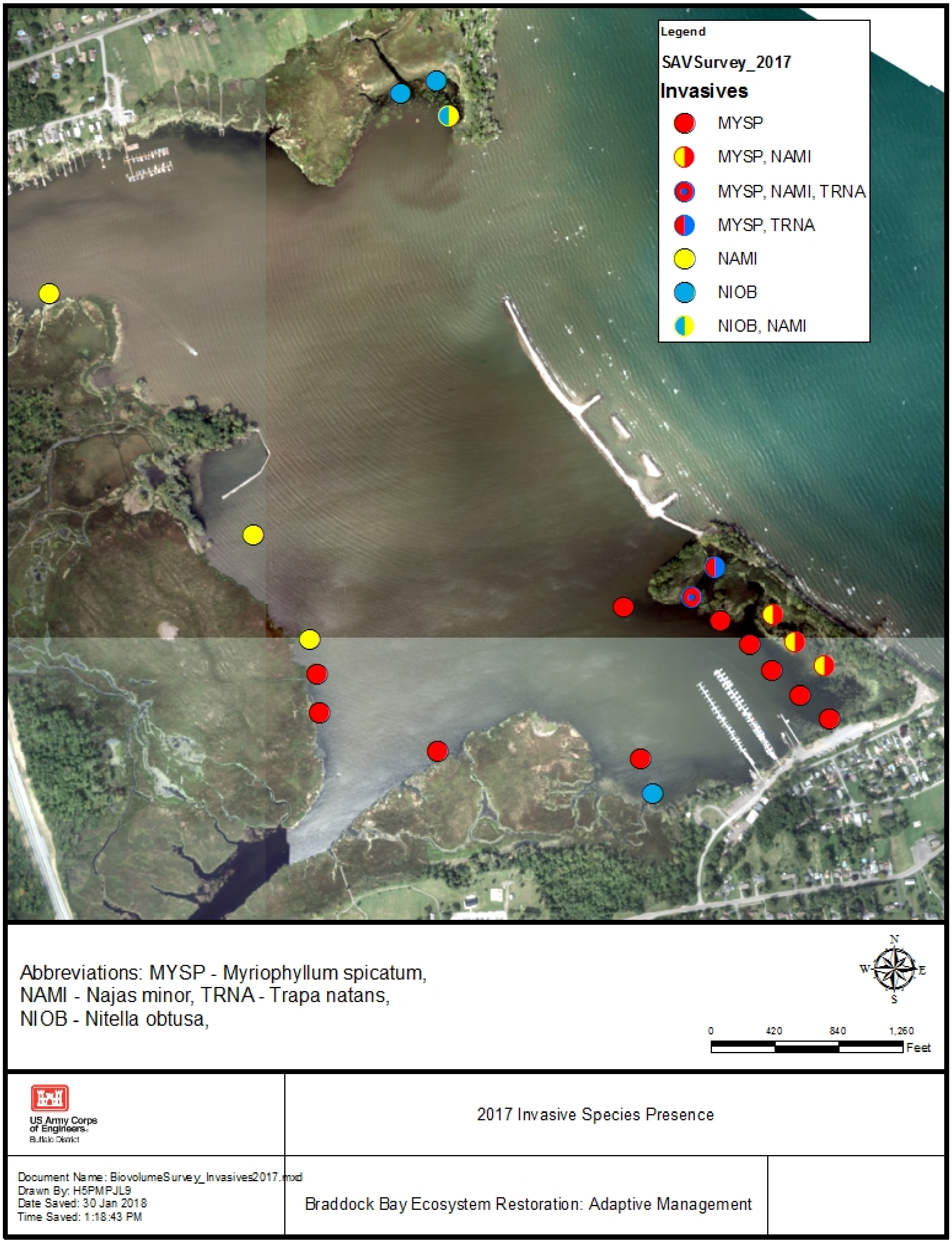

Figure 10. Braddock Bay SAV Invasive Species

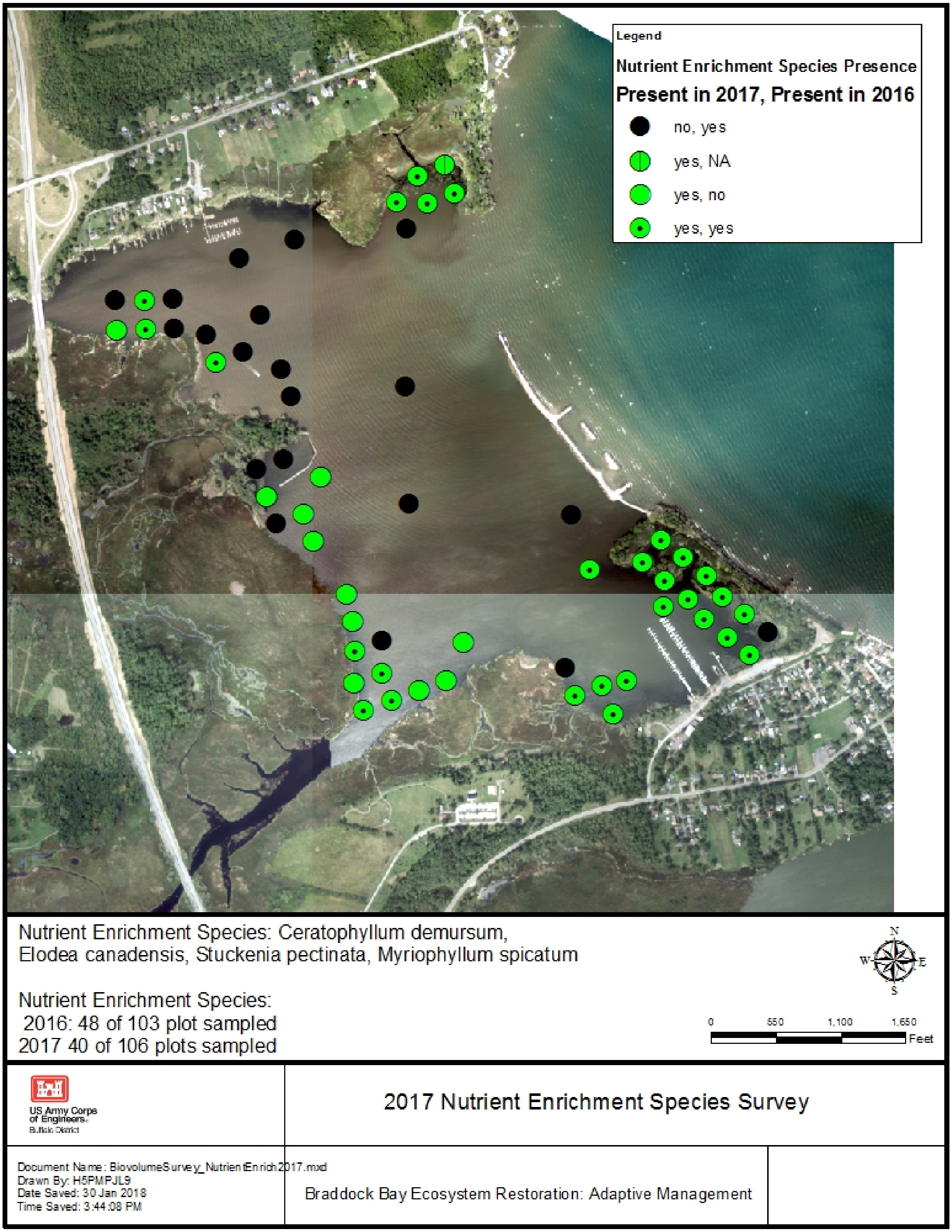

Figure 11. 2017 Nutrient Enrichment Species Survey

Submerged Aquatic Community Floristic Quality Assessment Index

The Floristic Quality Assessment Index (FQAI) score was calculated using the NY list of Coefficients of Conservatism (http://www.neiwpcc.org/nebawwg/fqaresources.asp). The FQAI of segments 4 and 5 is used as an indicator of change in the trophic state of Braddock bay, as these are the segments most likely to be affected by the construction of the barrier beach. The FQAI score for these segments of Braddock Bay was 9.8 in 2017, a decrease from the 2016 score of 13.9 (Table 6). This change in score was due to the absence of several species: *Heteranthera dubia, Lemna truscala, Myriophyllum verticillatum, Najas flexilis, Nymphea odorata, Potamogeton pusilus,and* P*otamogeton robinsii.* The absence of these species may be due to the record lake levels that persisted through the 2017 growing season. It is therefore unclear whether this disparity in FQAI scores accurately represents a change in trophic conditions in the bay. When all bay segments were included, the score for 2017 was 13.2. This score is much closer to the 2016 score for the entire bay of 13.9 (in 2016 the FQAI score for segments 4 and 5 was the same as the FQAI score for the entire bay). Additional monitoring of the FQAI in future years may be useful in determining if there has been a change in the composition of submerged aquatic vegetation community following construction of the barrier beach.

Table 6. 2017 vs 2016 FQAI comparison for aquatic vegetation communities

2017 All Vascular Species Observed (segments 4 and 5 Only)	C Score
Ceratophyllum demersum	2.5
Elodea canadensis	3
Stuckenia pectinata	5.5
Myriophyllum spicatum*	0
Najas minor	0
Vallisneria americana	4.5
Heteranthera dubia (Zosteralla)	5.5
Najas flexilis	4
Unk. Potamogeton	4.5
Total Richness	9
Native Richness	8
Average C-Score	3.28
FQAI	9.83
*** non-native species**	

2016 All Vascular Species Observed (segments 4 and 5)	C Score
Ceratophyllum demersum	2.5
Elodea canadensis	3
Heteranthera dubia	5.5
Lemna truscala	5
Myriophyllum spicatum*	0
Myriophyllum verticillatum	4.5
Najas flexilis	4
Najas minor*	0
Nymphea odorata	4.5
Potamogeton pusillus	4
Potamogeton richardsonii	4.5
Potamogeton robinnsii	4.5
Stuckenia pectinata	5.5
Vallisneria americana	4.5
Total Richness	14
Native Richness	12
Average C-Score	3.71
FQAI	13.90
*** non-native species**	

2.2.3 Performance Criteria and Adaptive Management

The ecologic success criteria for related to this component of adaptive management are:

1. Increase the quality (FQAI) of vegetation community in bay segments 4 and 5.
2. No significant increase in relative abundance of NET species in segments 3, 4, and 5.

Comparison of FQAI scores has indicated that the quality of the SAV community at segments 4 and 5 has decreased from 13.9 in 2016 to 9.8 in 2017. Therefore the ecologic criteria associated with this monitoring component has not been met. This decrease in the FQAI score was associated with the absence of several species in segment 4 and 5 that could have resulted from the record high lake levels that persisted through the 2017 season. Further monitoring will be necessary to determine if this change is part of a long term trend of SAV community quality or a short term anomaly. As such, no adaptive management activities are recommended to address this component at this time.

The frequency of occurrence of NET species did not change from 2016; however, NET species became more dominant at sample locations in 2017. In other words, the extent of NET species did not change, however, NET species appeared to grow denser and more robustly where they were present in segment 3, 4, and 5. NET species were dominant in 35% of sample locations in 2017 compared to being dominant in 25% of sample locations in 2016. It is not clear if this increase in NET species dominance is due to a shift in trophic conditions in the bay, or a result of the record high lake levels in 2017. Based on the fact that water quality parameters do not show a change in the status of eutrophication, it may be more likely lake elevations influenced the 2017 vegetation community and NET species dominance. Further monitoring will be necessary to determine if this change is part of a long term trend of SAV community quality or a short term anomaly. As such, no adaptive management activities are recommended to address this component at this time.

2.3 Fish and Wildlife Monitoring

Surveys of fish, water birds, mammals and amphibian species were completed to determine if project measures have been successful at improving the suitability of the Braddock Bay wetland for fish and wildlife (Objective 1).

2.3.1 2017 Data Collection

Bird and Anuran Monitoring

The bird and amphibian community in Braddock Bay was surveyed during the spring of 2017.

Bird surveys were conducted weekly between May 20, 2017 and July 7, 2016. The bird community was surveyed with an intensified version of the Marsh Monitoring Protocol (MMP), using roughly weekly samples during the bird survey period, resulting in six surveys per point.

Surveys were conducted at three locations (Figure 12) throughout the bay. Data from an additional point count collected as part of the Great Lakes Coastal Wetland Monitoring Program were also added to the data set, raising the total to seven counts per station. Methods set forth in MMP were followed for survey weather limitations, survey timing and length, and data recording. Briefly, these include morning (half hour before to four hours after sunrise) and evening surveys (four hours before to one half hour after sunset); each survey was 15 minutes long and contained 5 minutes of passive listening, 5 minutes of marsh bird song audio playback to entice calls, and a final five minutes of passive listening; all birds detected either aurally or visually were recorded. In addition to these standardized methods, 9 non-standardized bird samples were conducted in the vicinity of the partially constructed barrier beach to examine avian use.

Anuran monitoring surveys were conducted weekly between May 20, 2017 and July 7, 2016. Surveys were conducted at three locations (Figure 12) throughout the bay during three visits using traditional MMP (BSC, 2000). In addition to the three calling amphibian surveys that were conducted as part of this project, data from an additional three point counts that were part of the Great Lakes Coastal Wetland Monitoring Program were added to the data set for a total of six point counts per station. Calling amphibian surveys were 3 minutes long, with surveyors recording all species detected in the marsh using call codes that serve as an index of abundance.

Figure 12. Amphibian and Bird Count Locations

Fish Surveys

Fish communities were surveyed by SUNY Brockport within restored and control areas for a total of 25 net nights between 13 April and 4 November 2017 (Figure 13). The timing of sampling coincided with northern pike (*Esox lucius)* spawning in early spring (13 and 20 April 2017) and northern pike young-of-year (YOY) out migration during late spring (31 May and 1 June 2017). Two mesh sizes were used (4.8 and 12.7mm) on large frame fyke nets. Dimensions for the nets include 7.6 x 0.9 m leads attached to 1.2 x 0.9 m frames, with the tram containing two mesh funnels with inside diameters of 0.17 m. Additional fish data was collected as part of a separate effort during 2017 by SUNY Brockport and is discussed in more detail in Appendix B.

Additional young-of-year (YOY) fish surveys were conducted at Braddock Bay by USACE to determine if restoration activities have resulted in suitable northern pike spawning habitat. Fish traps were deployed for 24 hour periods on 2 August and 15 August 2017. Fish nets consisted of a fyke net of four two feet diameter hoops, a one inch throat, and ten foot mesh wings made of 1/16" mesh. Nets were deployed at four restoration areas and two control areas (Figure 13). Nets in restored areas were placed at the mouth of restored channels or potholes to capture the out-migration of YOY fish. Natural channels were used as the reference locations. Dissolved oxygen and temperature were measured using a multi-parameter probe during net placement and retrieval.

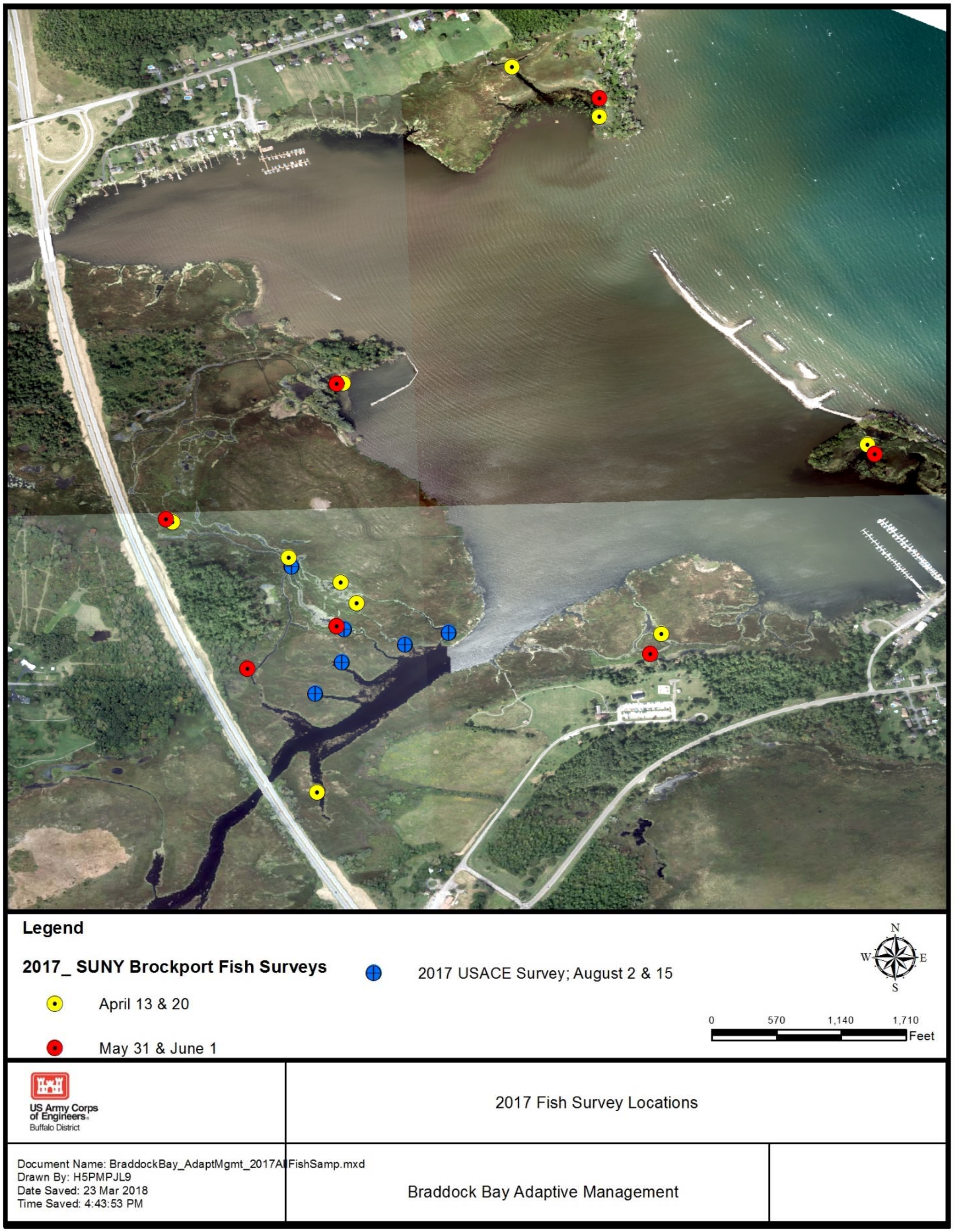

Figure 13. 2017 Fish Survey Locations

2.3.2 Results

(1) Avian Species Monitoring

A total of 28 and 34 bird species were detected in survey stations 1 and 2, respectively. These survey locations cover the cattail treatment, channel, and pothole portions of the restoration areas (Table 7). The combined number of native bird species richness for the restored sites (stations 1 and 2) is 39. This represents an increase in species observed from 2016 surveys (27). Survey station 3, the station farthest away from the cattail treatment, channel, and potholes of the restoration had 32 species present. Tree swallow (*Tachycineta bicolor*) was the most commonly detected species across all points, with a total of 269 individuals detected across the three locations and was generally more prevalent at the control point, station 3, where 200 birds were observed during one point count. Ring-billed gull (*Larus delawarensis*), red-winged blackbird (*Agelaius phoeniceus*), marsh wren (*Cistothorus palustris*), and barn swallow (*Hirundo rustica*) were the four next most commonly detected species, each with greater than 50 detections across all surveys and locations. Mute swan (*Cygnus color*), an invasive bird species, and double-crested cormorant (*Phalacrocorax auritus*), a native species that can be considered a nuisance, were detected in the surveys and were mostly observed at survey stations 1 and 3, the stations with the best view of open water is where these species are often detected. Few marsh-nesting obligate focal species were detected, with only three least bittern (*Ixobrychus exilis*) and four Virginia rail (*Rallus limicola*) present during counts. One least bittern was detected at station 1 and two at station 2, both near the restoration activities, and the four Virginia rails were detected at survey station 2, close to the restoration activities.

In additional to formal monitoring, 9 non-standardized bird surveys were conducted to examine avian use of the partially constructed barrier beach. These surveys took place between 30 August and 11 November 2017. All birds encountered on site were documented, with a special focus on birds on or near the spine of the barrier. In total, 3,699 birds of 112 species were recorded over these 9 trips (Appendix B). Highlights include a red knot (*Calidris canutus*), 3 Pied-billed Grebe (*Podilymbus podiceps*), 10 American coot, and 2 Virginia rail. Twelve different shorebird species were observed on or around the barrier, demonstrating that even though the structure is not finished, it is still providing habitat for shorebird species.

Table 7. 2017 Avian Survey Results

2017 Bird Sampling Counts by Station				
Species	Station 1	Station 2	Station 3	Total Abundance
American Crow		1		1
American Goldfinch	12	6		18
American Robin	1	1	4	6
Bald Eagle	1	2	1	4
Baltimore Oriole	2		1	3
Barn Swallow	36	8	8	52
Blue Jay		2		2
Canada Goose	20		5	25
Caspian Tern		1	1	2
Cedar Waxwing		1		1
Chimney Swift			1	1
Common Grackle			2	2
Common Yellowthroat	5	13	4	22
Double-crested Cormorant	3		4	7
Eastern Kingbird		3	18	21
Eastern Phoebe	1			1
Eastern Wood Pewee		1		1
European Starling			8	8
Gray Catbird		2	9	11
Great Blue Heron	5	2	1	8
Great-crested Flycatcher		1	1	2
Herring Gull			1	1
House Wren		1		1
Least Bittern	1	2		3
Mallard	5	2		7
Marsh Wren	47	6	10	63
Morning Dove	2		1	3
Mute Swan	3		9	12
Northern Cardinal	1	1		2
Northern Rough-winged Swallow	18	3		21
Osprey	1	2	1	4
Pileated Woodpecker		1		1
Purple Martin	5	2	1	8
Red-eyed Vireo			1	1
Red-winged Blackbird	36	51	35	122
Ring-billed Gull	31	10	82	123
Song Sparrow	5	2	8	15
Swamp Sparrow	12	14	3	29
Tree Swallow	40	11	218	269
Unidentified Gull	1100	150	90	1340
Virginia Rail		4		4
Warbling Vireo		3	3	6
Willow Flycatcher	8	6	1	15
Wood Duck	1		1	2
Yellow Warbler	5	10	17	32
Species total	**28**	**33**	**32**	
Native Species Richness*	**26**	**33**	**30**	
Marsh Obligate Species	**1**	**2**	**0**	
Non-native species		**Marsh obligate species**		
*** Native species richness does not include non-native species or unidentified species**				

(2) Amphibian Monitoring

Six anuran species were detected during the six surveys at each station in 2017 (Table 8). We report anuran abundance data using only the maximum call code recorded by species, as the maximum call code mitigates some of the issues encountered with estimating calling anuran abundance, including their sensitivity to slight weather changes affecting calling intensity and the difficulty in estimating the true abundance in the field based on calls.

American bullfrog (*Lithobates catesbeianus*) and American toad (*Anaxyrus americanus*) were the species of the lowest calling intensity, call code 1, at station 1. American toads were also recorded at call code 1 at station 3, as was the gray treefrog (*Hyla versicolor*). Northern leopard frog (*Lithobates pipiens*) and green frog (*Lithobates clamitans*) were each detected at a call code 2 at all three stations Finally, spring peeper (*Pseudacris crucifer*) was the only species to be detected in Braddock Bay with a full chorus, call code 3, and it called at this intensity at all three stations.

In 2017, Call codes from Station 1, located near the southern wetland restoration area, were unchanged from 2016 results. During both years all six species were recorded at the same intensities. At Station 2, located near the central wetland restoration area, species richness increased from four to six species as American toad and northern leopard frog were recorded in 2017 at call codes of “2”. Similar increases in species richness were observed for the station 3, the control site, where American toad and grey treefrog were observed in 2017, but not in 2016.

American toad is an upland species that utilizes wetlands to complete its life cycle, so a higher call code in the restored area indicates that these toads could be selecting the newly-constructed potholes as sites for ovipositing. The presence of Northern leopard frog at station 2 is further evidence that the habitat at Braddock Bay restoration areas has become more suitable for anurans. Compared to pre-restoration surveys from Braddock Bay conducted in 2013 only observed 4 species at location 1. Gray tree frog and American toad were not observed in the 2013 surveys.

Table 8. 2016 and 2017 Anuran Survey

Common Name	Scientific Name	Maximum call code 2016 Station 1	Maximum call code 2016 Station 2	Maximum call code 2016 Station 3	Maximum call code 2017 Station 1	Maximum call code 2017 Station 2	Maximum call code 2017 Station 3
American bullfrog	*Lithobates catesbeianus*	1	2	1	1	2	2
American toad	*Anaxyrus americanus*	1	0	0	1	2	1
Green frog	*Lithobates clamitans*	2	2	2	2	2	2
Grey treefrog	*Hyla versicolor*	2	2	0	2	2	1
Northern leopard frog	*Lithobates sylvaticus*	2	0	2	2	2	2
Spring peeper	*Pseudacris crucifer*	3	3	3	3	3	3
	Species Richness	**6**	**4**	**4**	**6**	**6**	**6**

* Data reported by call code *1=calls not simultaneous, 2 = Some calls simultaneous, 3 = full chorus

(3) Fish Monitoring

2017 SUNY Brockport Fish Sampling

Surveys targeted at capturing spawning northern pike yielded 326 fish across 22 species over the eight net nights (Table 9). All 22 species and 244 fish total were caught in the control zones, while 7 species and 82 fish in total were caught in areas that had been restored. In total, three northern pike were caught in control nets, while one was caught in a restored area. The most abundant species caught in the control nets was brown bullhead (*Ameiurus nebulosus*) (n= 123), while only four were caught in restored areas. The two most common species found in the restored areas included pumpkinseed sunfish (*Lepomis gibbosus*) (n= 33) and bowfin (*Amia calva*) (n=32).

Surveys targeted at capturing of YOY northern pike (31 May and 1 June 2017) yielded a total of 146 fish across 16 different species over the eight net nights (Table 10). In total, 13 species and a total of 116 fish were caught in the control nets, while 8 species and 30 fish total were caught in the restored areas. Eight species were found only in control zones, while only three were caught only in restored areas, including northern pike, bowfin, and banded killifish (Fundulus diaphanous). Of note, only two YOY individuals were caught over these two days. Both were northern pike, and each was caught in a restored area. The presence of these fish indicates the ecological success criteria set forth by the Adaptive Management Plan was met for 2017.

When the additional data from the Coastal Wetland Monitoring and Functional Indicators were added to the data set, a total of 566 fish across 25 species were caught in Braddock Bay during

2017 over the 28 net nights (Appendix B). Of those, 382 fish of 23 species were caught in control nets, while 184 fish of 11 species were caught in restored areas. While overall abundance and diversity appear to be greater in control areas, greater spawning success was observed in the restored sites, with 54 YOY fish of 5 species caught in those nets, versus only 3 species and 18 fish in total in control nets (Appendix B).

Table 9. Braddock Bay fish survey results April 13 and 20, 2017 (Spawning)

	Control	**Created Habitat**
Species		
Banded killifish	4	
Black crappie	2	
Blacknose shiner	2	
Bluegill Sunfish	10	5
Bowfin	13	32
Brook silverside	2	
Brown bullhead	123	4
Central mudminnow	1	
Common carp	3	
Emerald shiner	8	
Gizzard shad	1	
Golden shiner	3	
Largemouth bass	2	1
Northern pike*	**3**	**1**
Pumpkinseed sunfish	41	33
Round goby	2	
Rudd	1	
White perch	5	
White sucker	4	
Yellow Perch	14	6
Grand Total	**244**	**82**
Native Fish Richness	**17**	**7**

*Target species
Non-native

Table 10. Braddock Bay fish survey results May 31 and June 1, 2017 (YOY Surveys)

	Control	Created Habitat
Species		
Alewife	82	
Banded killifish	2	17
Bluegill Sunfish	1	1
Bowfin		3
Brook silverside	2	
Brown bullhead	7	1
Central mudminnow		3
Common carp	3	
Emerald shiner	2	
Longnose gar	3	
Northern pike*		**2**
Pumpkinseed sunfish	6	2
Rock bass	2	
Round goby	2	
White perch	1	
Yellow perch	3	1
Grand Total	**116**	**30**
Native Fish Richness	**12**	**8**

*Target species **Young of year**

Non-native

USACE Young-of-the-Year Surveys

The August 2017 YOY surveys resulted in only five YOY fish caught over the two sampling days. Despite the low catch rate, a YOY northern pike was caught in restoration area three located at outflow of one of the large central excavated potholes. Other species caught include margined mad tom, banded killi fish, and central mudminnow. The presence of a YOY northern pike in restored pothole areas is strong evidence that restoration has created spawning area for northern pike.

Table 11. Young-of-year fish species observed during 2017 USACE Surveys

Species Observed During YOY Surveys Aug 2017		
Species	Restored Area	Control
Northern pike	1	0
Margined mad tom	2	0
Banded killifish	0*	0
Central mud minnow	2	0
*Banded Killifish were not caught in any nets but were observed near trap locations in restored potholes		

2.3.3 Performance Criteria and Adaptive management

The ecologic success criteria for related to this component of adaptive management are:

- Increase in species richness of water birds
- Increase in species richness of amphibians
- Increase in species richness and abundance of YOY fish

Bird and anuran data from 2013 surveys (Brockport, 2013) at Braddock Bay provide a baseline for comparing post restoration monitoring results. These samples were collected using similar methods; however, surveys were conducted with less frequency in 2013 and also only conducted from one of the locations sampled in 2016 and 2017, "Braddock 1" in the vicinity of the restoration near the south eastern marsh (Figure 12).

The 39 different bird species in 2017 at Stations 1 and 2 represent increase in diversity from 2016 records (27 observed), and the 2013 baseline sampling (14 species observed). The greatest number of bird species was also observed at Station 2 in 2017. Marsh obligate focal species were recorded also only recorded Station 1 and Station 2 in greater numbers than in 2016. This suggests that the quality of wetland habitat for bird species at Braddock Bay restored areas continue to increase following restoration. The ecologic criteria for avian species monitoring is considered to be met. Additional monitoring will be important to demonstrating continual increases in avian diversity in restored areas.

Amphibian species richness was assessed by monitoring anuran call intensities. In 2017, call codes were recorded for six species at station 1 and 2, located near the wetland restoration areas, an increase from the four species recorded at station 1 in 2013 baseline data. Two of the species recorded at station 2 were not recorded at that location in 2016, providing further evidence that species richness has increased in restoration areas from baseline conditions. As a result the ecologic criteria associated with amphibian monitoring is considered to have been achieved. Additional monitoring will be important to demonstrating continual increases in amphibian diversity and populations in restored areas.

Nine native fish species were recorded in restored channels and potholes while 17 were recorded in control areas in Braddock Bay. Northern pike, a target species of restoration, was recorded in control and restored sites. Record high water levels that occurred in spring complicated sampling as depths often exceeded net heights, and may have reduced capture success. Young-of-the-year pike were captured in restored areas during both SUNY Brockport and USACE fish surveys. The combination of adult and YOY fish captures in restored channels and potholes is strong evidence that restoration has created spawning area for northern pike. This data demonstrates utilization of restored areas by adult and YOY northern pike and the ecologic criteria associated with fish monitoring is considered to have been achieved. Additional monitoring will be important to demonstrating continual increases in fish spawning in restored areas.

2.4 Wetland Erosion Monitoring

Aerial imagery will is used to monitor erosion of the central wetland for the purpose of determining if restoration measures have been successful at protecting the central wetland of Braddock Bay from erosion (Objective 2).

2.4.1 2017 Data Collection

Aerial imagery was not collected as part of the 2017 monitoring effort. The New York State Natural Heritage Program provided aerial imagery of Braddock Bay as part of their long term vegetation monitoring program which was collected on 2 September 2017.

2.4.2 Results

The available aerial imagery in 2017 was collected during a period when Lake Ontario water levels were still over a foot higher than average levels. This elevated water level confounds shoreline delineations and shoreline erosion estimates. As such estimates of erosion were not completed in 2017. Shoreline erosion estimates from 2009 to 2016 are provided for reference (Figure 14).

2.4.3 Performance Criteria and Adaptive Management

An evaluation of shoreline erosion was not conducted in 2017 due to the record high flooding that persisted throughout the growing season and the period when aerial imagery was collected. Aerial imagery from a 3 – 5 year period is necessary provide a meaningful estimate of shoreline erosion that is not confounded by yearly fluctuations in water levels. Therefore, it is recommended that aerial imagery and wetland erosion be evaluated in 2019, three years after the 2016 shoreline data.

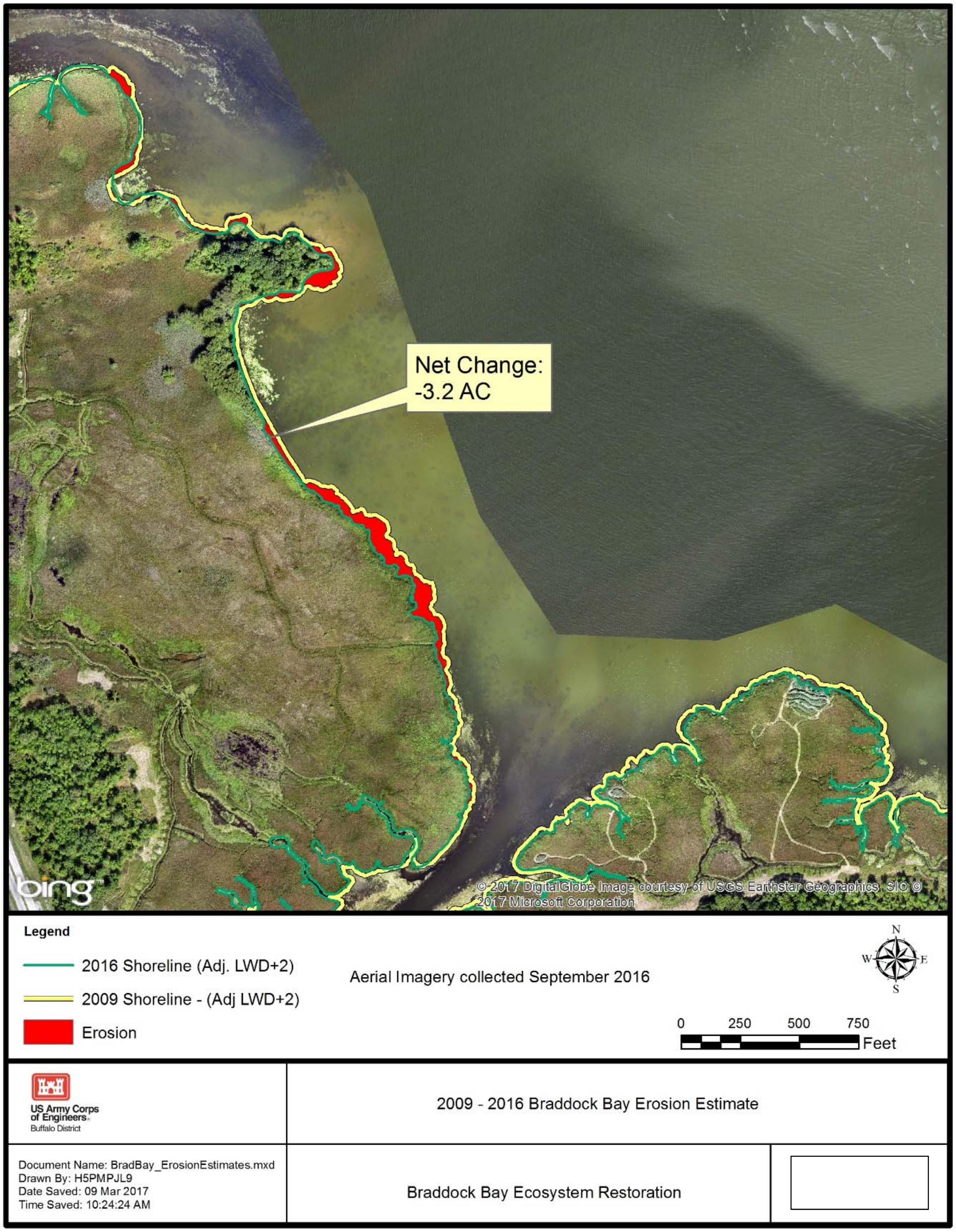

Figure 14. 2009 to 2016 Braddock Bay Erosion Estimate

2.5 Navigation Monitoring

The bathymetry of the Braddock Bay navigation channel will be monitored to determine if proposed restoration measures have successfully avoided disruptions to the navigability of the bay (Constraint 1).

2.5.1 2017 Data Collection

To date, bathymetric surveys of the mouth of Braddock Bay were completed before construction (9 August 2016) and during construction (13 April 2017 and 4 August 2017). This data was converted to digital elevation models (DEMs). Partial dredging of the borrow area and navigation channel occurred in the Fall of 2016 and the early Summer of 2017; however, final design depths were not achieved due to complications with dreading equipment and high water levels.

2.5.2 Results

Bathymetric survey data will be used to determine the rates of sedimentation and infilling in the Braddock Bay navigation channel. The navigation channel was partially excavated in the Fall of 2016, but was never excavated to its design depth due complications with dredging and high water in the 2017 construction season. Survey data from 9 August 2016 (pre-construction) was compared to data from 4 August 2017 (during construction) to analyze changes in bathymetry over this time period (Figure 15). This figure indicates some areas of the navigation channel in which bottom depths are deeper than in the pre-construction survey suggesting that infilling has not completely filled in all dredged areas over the time period. However, determination of the volumetric change and rate of infilling in the navigation channel from currently available bathymetric data is inconclusive due to incomplete dredging. An accurate survey of infill rates and depths is not possible because design depths were not achieved in 2016 and "as-built" surveys were not collected.

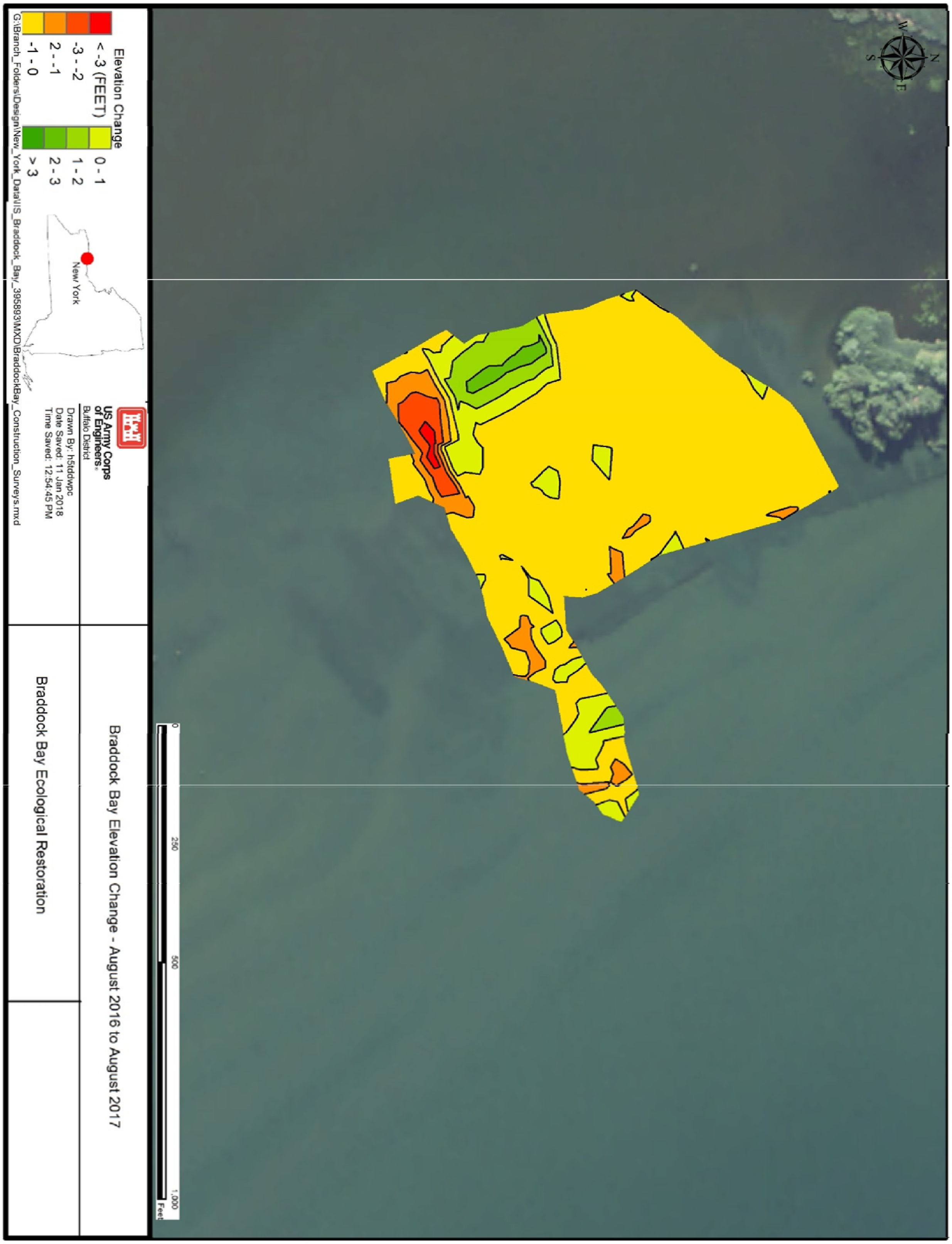

Figure 15. Braddock Bay Elevation Change - August 2016 to August 2017

2.5.3 Performance Criteria and Adaptive Management

The performance criteria related to this component is:

- The navigation channel dredging requirements shall not be increased as a result of project construction.

Pre-construction dredging requirements for Braddock Bay are uncertain because of the irregularity at which dredging was completed in the mouth of the Bay historically. Still, information about the rates of sedimentation and infilling of the navigation channel will be useful for the Town of Greece and marina operators order to manage and plan for future dredging needs.

Evaluation of infill rates of dredging areas cannot be completed until design depths are achieved, "as built" surveys are available, and post- construction data is collected. It is anticipated that dredging to the design depth will be achieved in 2018, and thus subsequent surveys in 2019 and 2020 can be used to assess the rate of channel infilling.

2.6 Littoral Sediment Monitoring

The net deposition/erosion of littoral sediment will be monitored to determine if proposed restoration measures have successfully avoided disruptions to the local littoral drift system (Constraint 3). This will be measured through aerial photography and bathymetric surveying.

2.6.1 Data Collection

Bathymetric surveys were performed on 9 August 2016 (before commencing construction of the barrier beach), 13 April 2017, and 4 August 2017. Partial dredging of the borrow area and navigation channel occurred in the Fall of 2016 and the early Summer of 2017; however, final design depths were not achieved due to complications with dreading equipment and high water levels.

Aerial imagery for Braddock Bay was collected using an unmanned aerial vehicle on 13 to 15 September as construction of the barrier beach was occurring. Both RGB and near infrared images were collected. Additionally, aerial imagery was accessed through Digital Globe service (digitalglobe.com). Imagery covering Braddock Bay was available for 4 August 2016 (pre-construction), 3 September 2016 (beginning of construction), and 12 October 2016 (breakwater construction nearly complete), 3 June 2017 (during high water), and 17 September 2017 (water levels returning to average).

Figure 16. Braddock Bay Aerial Imagery, 17 September 2017, exhibiting strong shore parallel bar system.

2.6.1 Results

Some evidence of trends in littoral patterns can be determined from observation of aerial imagery for the site. The shore parallel bar system fronting the mouth of Braddock Bay has remained strong with the completion of the project, indicating that the breakwaters have not had a negative impact to the littoral system (Figure 16).

2.6.1 Performance Criteria and Adaptive Management

The performance criteria related to this component is:

- No impacts to the littoral drift system inferred from qualitative assessment of down drift shoreline.

The presence of the shore parallel bar system fronting Braddock Bay is evidence that the barrier beach has not had a negative impact to the littoral system. This criteria is considered to be met; however, observation and data collection to include high resolution survey data both within the footprint of the project and immediately updrift and downdrift will be required once the project is completed to fully qualify and quantify the impacts of the project. Single-beam survey multi-beam surveys are recommended to establish a relatively high resolution baseline condition. Follow-up surveys over a 5 year period will be needed to determine the rates of infilling and proved a better snapshot of coastal processes.

2.7 Trophic State Monitoring

Water quality parameters of Braddock Bay are being monitored to determine if the trophic state of Braddock Bay has been negatively impacted by project activities (Constraint 2).

2.7.1 2017 Data Collection

Water quality samples were collected from Braddock Bay, its tributaries, and Lake Ontario to determine barrier pre-, during, and post construction condition of Braddock Bay. Samples were collected from June to September over three years (2015, 2016, and 2017). In addition to barrier construction, the three years of data captured distinct lake level and water flow conditions. The years 2015 and 2017 were normal precipitation years and 2016 was a drought year. The year 2015 had normal water levels, 2016 had low water levels, and 2017 had unusually high water levels. To determine the baseline conditions of Braddock Bay, water samples were collected at five locations within Braddock Bay (SG2, SG3, SG4, SG5a, and SG5b), at the two main tributary inputs to the bay (Salmon Creek (SC) and Buttonwood Creek (BW)), and at a near shore location just outside the bay in Lake Ontario (LO; Figure 18). Samples were collected from June to September four times during 2015, and six times during 2016 and 2017. Samples collected from 6/12/2015 to 8/11/2016 were pre-barrier construction, from 8/30/2016 to 9/18/2017 were during barrier construction, and from 5/16/2017 to 9/2/2017 were post barrier construction. Water quality monitoring parameters were Secchi disc depth (feet), Turbidity

(NTU), Temperature (C), Specific Conductivity (µS/cm). Oxidation Reduction Potential (ORP; mV), Dissolved Oxygen (DO; mg/L), pH, Phosphate (PO4; mg/L), Total Phosphorus (TP; mg/L), Ammonium (NH4; mg/L), Nitrite plus Nitrate (NO2NO3; mg/L), Total Kjeldahl Nitrogen (TKN; mg/L), Total Suspended Solids (TSS; mg/L), and Chlorophyll a (CHL; µg/L).SUNY Brockport collected and analyzed water quality samples in 2016 and 2017. For additional detail, see Appendix B.

Sample collection followed the following criteria:

- Samples were not collected within five days of a major storm event, which was measured as a rain event of at least 0.5 inches within a 24 hour period.
- Sample events were spaced at least 15 days apart.
- Water samples were collected 1 to 1.5 feet below the water's surface.
- Composite samples from the bay were collected from four locations around the sampling site coordinates within the bay.
- During both years, multi-probe sensor measurements and Secchi disc depth were collected at the sampling point.
- During 2015, water samples were put on ice and shipped to an analytical lab for processing (USACE 2016).
- During 2016 and 2017, water samples for total nutrients, chlorophyll, suspended solids, and turbidity were stored on ice and filtered or digested within 36 hours of collection.
- During 2016 and 2017, dissolved nutrient samples were filtered through a 0.45 µm polycarbonate membrane filter on site, stored on ice for transport back to the lab and analyzed fully within 36 hours.
- Water quality monitoring variables were determined using standard (SM), Environmental Protection Agency (EPA) and/or American Public Health Association (APHA) methods

2.7.2 Results

2017 Results

For Braddock Bay, 2017 data represents the first year of post-construction conditions. Water quality conditions (mean and confidence intervals) for 2017 in Braddock Bay for ecosystem target criteria were 0.010 mg/L (0.000 to 0.040) for PO4, 0.071 mg/L (0.042 to 0.114) for TP, 0.030 mg/L (0.000 to 0.116) for NH4, 0.042 mg/L (0.000 to 0.146) for NO2NO3, 0.712 mg/L (0.560 to 0.833) for TKN, 34.9 µg/L (23.5 to 48.1) for CHL, 2.5 ft (1.5 to 4.0) for Secchi depth, 10.6 mg/L (4.8 to 21.1) for TSS, and 65 (59 to 70) for TSI. Ecosystem target criteria were exceeded 87%, 97%, 73%, and 87% of the time at sites within Braddock Bay for Secchi depth, TP, CHL, and TSI, respectively. P levels, turbidity, CHL, and TSI in Lake Ontario were lower than Braddock Bay conditions. Tributary P levels were higher than in Braddock Bay, N levels were variable and often similar to Braddock Bay, and CHL and TSI were similar in the tributary than in Braddock bay.

Braddock Bay water quality differed significantly between baseline (pre-construction) and post barrier construction conditions. Phosphorus and TKN concentrations were significantly lower post barrier construction than during pre-construction. Secchi disc depth was significantly deeper (i.e., greater light penetration) post construction. CHL, NH4, and NO2NO3 were exceptions and did not significantly differ pre- and post-barrier construction. These comparisons provide evidence that Braddock Bay's water quality, especially bound nutrients and non-algal suspended solids, was improved post barrier constriction. However, hydrologic conditions differed significantly between years and the water quality patterns among years need to be explored before conclusions can be drawn about the short-term impacts of the barrier to Braddock Bay's water quality.

When the annual comparisons are combined with the pre- and post-barrier construction comparisons, a consistent pattern in Braddock Bay begins to emerge. Phytoplankton biomass was similar throughout the study. Phosphorus concentrations were higher during the low water period of 2016, but similar pre-construction during 2015 and post-construction during 2017. Total kjeldahl nitrogen and suspended solids were lowest during 2017 and post-barrier construction. Ammonia and NO2NO3 were low during high and low water years. In the short-term, the barrier did not lessen phytoplankton blooms in Braddock Bay and did not clearly influence nutrient concentrations. The evidence suggests barrier construction might have helped improved suspended solid levels and water clarity, but this observation is confounded by the overlap between high water levels, low tributary inputs, and post-barrier sampling.

Pre-barrier construction, baseline conditions in Braddock Bay indicate eutrophic to hyper eutrophic conditions. Ecosystem target criteria pre-barrier were exceeded 86.1%, 80%, 85%, and 94.4% of the time at sites within Braddock Bay for Secchi depth, TP, chlorophyll a, and TSI, respectively. Similarly, post-barrier construction, ecosystem target criterial were exceeded 87%, 97%, 73%, and 87% of the time at sites within Braddock Bay for Secchi depth, TP, CHL, and TSI, respectively. Additional monitoring is needed to determine the long-term impact of the barrier on water quality conditions in Braddock Bay because the hydrological conditions varied greatly throughout the study. Part of the challenge in identifying significant effects of the barrier was due to variation among precipitation, tributary discharge, and lake levels among years. Braddock Bay significantly differed in its water quality between sampling years, but frequently exceeded target criteria in all sampling years. The effects among years tended to be stronger than the effects between baseline and post-barrier construction but there was considerable overlap between these two factors. More data need to be collected with the barrier in place to better separate the effects of barrier from year, which varied by hydrologic condition.

Phytoplankton biomass was high in Braddock Bay in all years. The evidence suggests that both nitrogen and phosphorus are important in understanding blooms in the bay and, hence, effort is needed to mitigate nutrient pollution to Braddock Bay in order to limit bloom development. Despite evidence of water exchange between the bay and lake, poor water quality conditions observed in Braddock Bay rarely caused undesirable conditions in near shore lake Ontario. Post barrier construction this pattern did not seem to change, although the high water conditions prevent over generalization of this observation. Lake Ontario was nitrate rich relative to the bay. The tributaries and the lake could both be important sources of nitrogen to the bay. For example, when tributary inputs were low in N:P ratios, phytoplankton biomass was coupled with reduced forms of nitrogen. During high water Braddock Bay N:P ratios indicated balanced nutrient conditions, which plausibly could have been supported by influx of lake nitrogen. Overall, phytoplankton blooms were most severe during low water, drought conditions when nitrogen seemed limiting and phosphorus was more abundant in dissolved form.

Overall, the results of this study are inconclusive. It is unclear from the data collected in this study how barrier construction and wetland restoration will impact water quality in Braddock Bay over the long-term. 2015 was the only normal year with respect to lake levels and hydrology. This study provides a strong dataset collected under varied weather patterns that can be used to assess how Braddock Bay responds to restoration. To account for this uncertainty, water quality should be tracked again in 2018 and periodically into the future as the restored wetland matures. The pre-restoration and current water quality conditions in Braddock Bay are poor and upstream management actions should be considered to help improve ecosystem health. Reductions in internal and external loads of phosphorus and nitrogen are likely required in this system in order to control phytoplankton blooms.

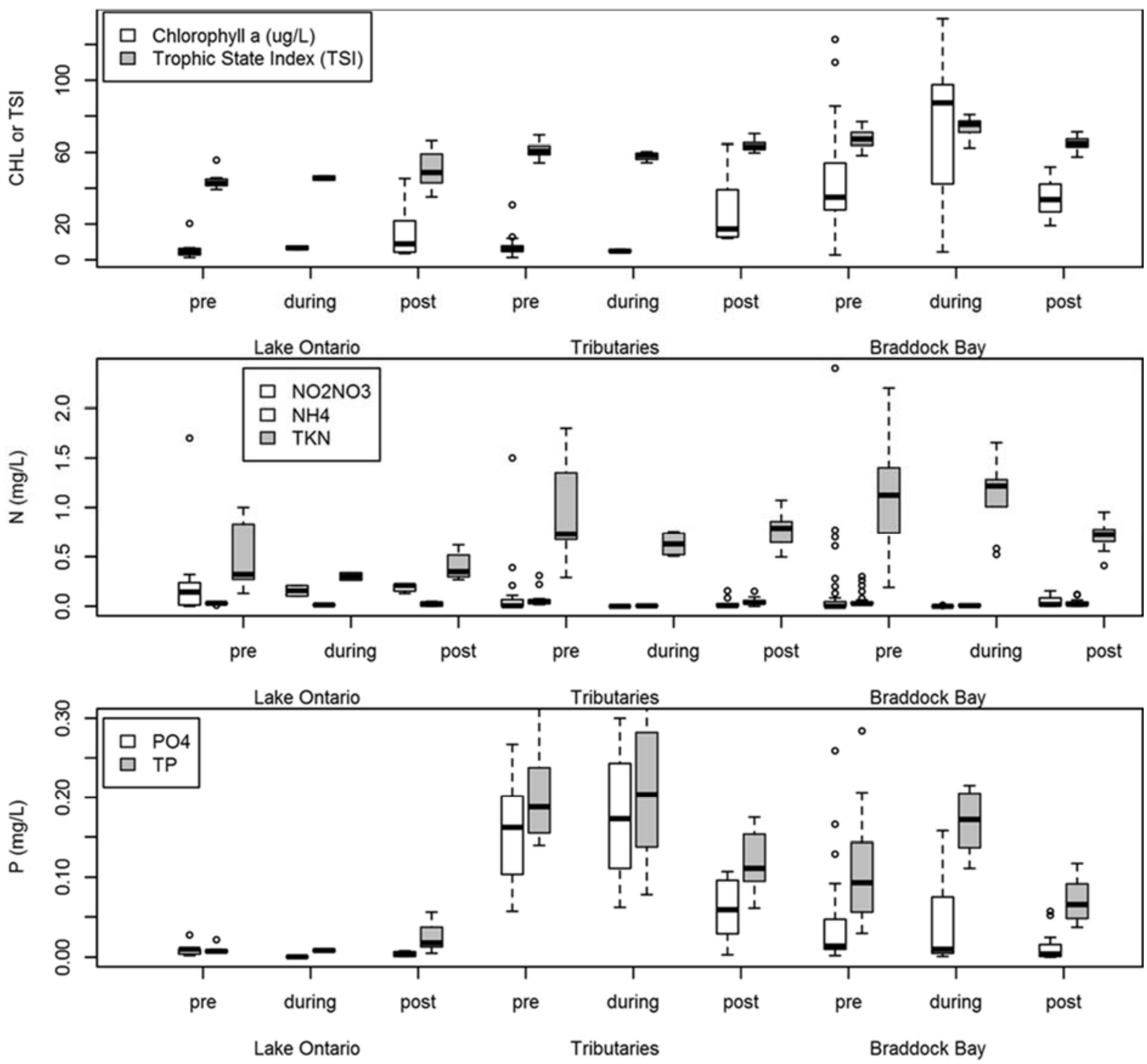

Figure 17. Box and Whisker plots of water quality by year sampled for Lake Ontario near shore, Tributary, and Braddock Bay sampling sites. Whiskers are 95% confidence interval. Boxes are the interquartile range. Bars are average values.

Table 12. Summary water quality conditions (minimum, maximum, mean, and 95% confidence interval) for Lake Ontario, Braddock Bay, and its Tributaries for barrier pre-construction sampling events.

	min	max	mean	95% CI
Phosphate (PO4; mg/L)				
Lake Ontario	0.002	0.028	0.010	0.003 to 0.022
Braddock Bay	0.002	0.259	0.014	0.003 to 0.131
Tributaries	0.057	0.267	0.154	0.060 to 0.237
Total Phosphorus (TP; mg/L)				
Lake Ontario	0.006	0.022	0.009	0.006 to 0.018
Braddock Bay	0.030	0.284	0.102	0.033 to 0.200
Tributaries	0.140	0.330	0.201	0.140 to 0.297
Ammonia (NH4; mg/L)				
Lake Ontario	0.010	0.047	0.030	0.015 to 0.043
Braddock Bay	0.011	0.300	0.050	0.013 to 0.213
Tributaries	0.017	0.310	0.071	0.020 to 0.243
Nitrate+Nitrite (NO2NO3; mg/L)				
Lake Ontario	0.000	1.700	0.311	0.000 to 1.217
Braddock Bay	0.000	2.400	0.136	0.000 to 0.704
Tributaries	0.000	1.500	0.142	0.000 to 0.668
Total Kjeldahl Nitrogen (TKN; mg/L)				
Lake Ontario	0.130	1.000	0.497	0.173 to 0.972
Braddock Bay	0.190	2.200	1.123	0.573 to 1.800
Tributaries	0.290	7.200	1.334	0.487 to 3.150
Chlorophyll a (CHL: µg/L)				
Lake Ontario	1.3	20.3	6.2	1.8 to 19.3
Braddock Bay	2.7	122.8	41.6	11.5 to 86.8
Tributaries	1.3	30.7	7.6	1.3 to 17.3
Secchi Disc Depth (ft)				
Lake Ontario	3.7	6.8	5.8	4.0 to 6.6
Braddock Bay	1.0	3.7	1.9	1.0 to 3.4
Tributaries	1.1	8.0	5.0	1.7 to 7.7
Trophic State Index (TSI)				
Lake Ontario	39	56	44	40 to 52
Braddock Bay	58	77	67	61 to 75
Tributaries	54	69	61	54 to 67

Table 13. Summary water quality conditions (minimum, maximum, mean, and 95% confidence interval) for Lake Ontario, Braddock Bay, and its Tributaries for barrier post construction sampling events.

	min	max	mean	95% CI
Phosphate (PO4; mg/L)				
Lake Ontario	0.001	0.008	0.004	0.001 to 0.008
Braddock Bay	0.000	0.057	0.010	0.000 to 0.040
Tributaries	0.003	0.107	0.060	0.006 to 0.105
Total Phosphorus (TP; mg/L)				
Lake Ontario	0.005	0.056	0.025	0.007 to 0.051
Braddock Bay	0.037	0.117	0.071	0.042 to 0.114
Tributaries	0.061	0.175	0.120	0.074 to 0.173
Ammonia (NH4; mg/L)				
Lake Ontario	0.000	0.049	0.024	0.000 to 0.047
Braddock Bay	0.000	0.120	0.030	0.000 to 0.091
Tributaries	0.000	0.151	0.048	0.000 to 0.120
Nitrate + Nitrite (NO2NO3; mg/L)				
Lake Ontario	0.129	0.221	0.190	0.135 to 0.221
Braddock Bay	0.000	0.155	0.042	0.000 to 0.146
Tributaries	0.000	0.156	0.026	0.000 to 0.116
Total Kjeldahl Nitrogen (TKN; mg/L)				
Lake Ontario	0.268	0.620	0.400	0.275 to 0.594
Braddock Bay	0.410	0.952	0.712	0.560 to 0.833
Tributaries	0.497	1.072	0.773	0.568 to 0.976
Chlorophyll a (CHL: µg/L)				
Lake Ontario	3.5	45.4	15.5	3.7 to 39.5
Braddock Bay	19.1	51.8	34.9	23.5 to 48.1
Tributaries	12.0	64.5	26.2	12.0 to 56.6
Secchi Disc Depth (ft)				
Lake Ontario	1.8	bottom	4.0	1.9 to 6.5
Braddock Bay	1.3	4.2	2.5	1.5 to 4.0
Tributaries	2.5	6.0	4.0	2.8 to 5.4
Trophic State Index (TSI)				
Lake Ontario	35	66	50	37 to 64
Braddock Bay	57	71	65	59 to 70
Tributaries	60	70	64	60 to 69

2.7.3 Performance Criteria and Adaptive Management

The ecologic success criteria related to this component of adaptive management are:

- No increasing trends of TP, CHL, or TSI following construction of barrier beach

Comparison of 2017 data with 2015 and 2016 data suggests that construction of the barrier has not negatively impacted water quality in Braddock Bay. However, water levels and rainfall conditions were highly variable among the sampling years, which makes it difficult to draw firm conclusions about long term impacts. Furthermore, 2017 is the first full year of post construction data, limiting the ability to infer trends in the data. Additional data will be needed to determine if there are trends in the concentration of TP, CHL, and TSI following construction of the barrier beach. Additional monitoring is needed to determine the long term impact of the barrier on water quality conditions in Braddock Bay.

Overall, it is unclear from the data collected in this study how barrier construction and wetland restoration will impact water quality in Braddock Bay over the long term. 2015 was the only normal year with respect to lake levels and flow conditions. This study provides a strong dataset collected under varied weather patterns that can be used to assess how Braddock Bay responds to restoration. To account for this uncertainty, water quality should be tracked again in 2018 and periodically into the future as the restored wetland matures. The pre-restoration and current water quality conditions in Braddock Bay are poor and management actions should be taken to help improve ecosystem health. Reductions in internal and external loads of phosphorus and nitrogen are likely required in this system in order to control phytoplankton blooms.

As recommended in the 2015 and 2016 water quality monitoring report, determinations about the necessity of adaptive management actions related to water quality should be based on an analysis of the trends in TP and chlorophyll α data while also considering changes in the aquatic vegetation community. Increasing trends of TP and chlorophyll a concentrations with an observed shift in the aquatic vegetation community to a more eutrophic composition would be strong evidence that the trophic state of the Bay is shifting and adaptive management actions are necessary. Additional sampling is scheduled for 2018.

2.8 Barrier Beach Monitoring

Placement of stone for the barrier beach was substantially completed in Fall of 2016. Sand placement and completion of the barrier beach was interrupted by record high water levels throughout the 2017 construction season. The stone portions of the barrier beach were observed to be in good condition. Sand placed at the end of 2016 was mobilized due to the high water levels in the 2017 season resulting in loss of sand from some of the beach areas. Construction activities will proceed with additional sand placement in 2018 and completion of the barrier beach.

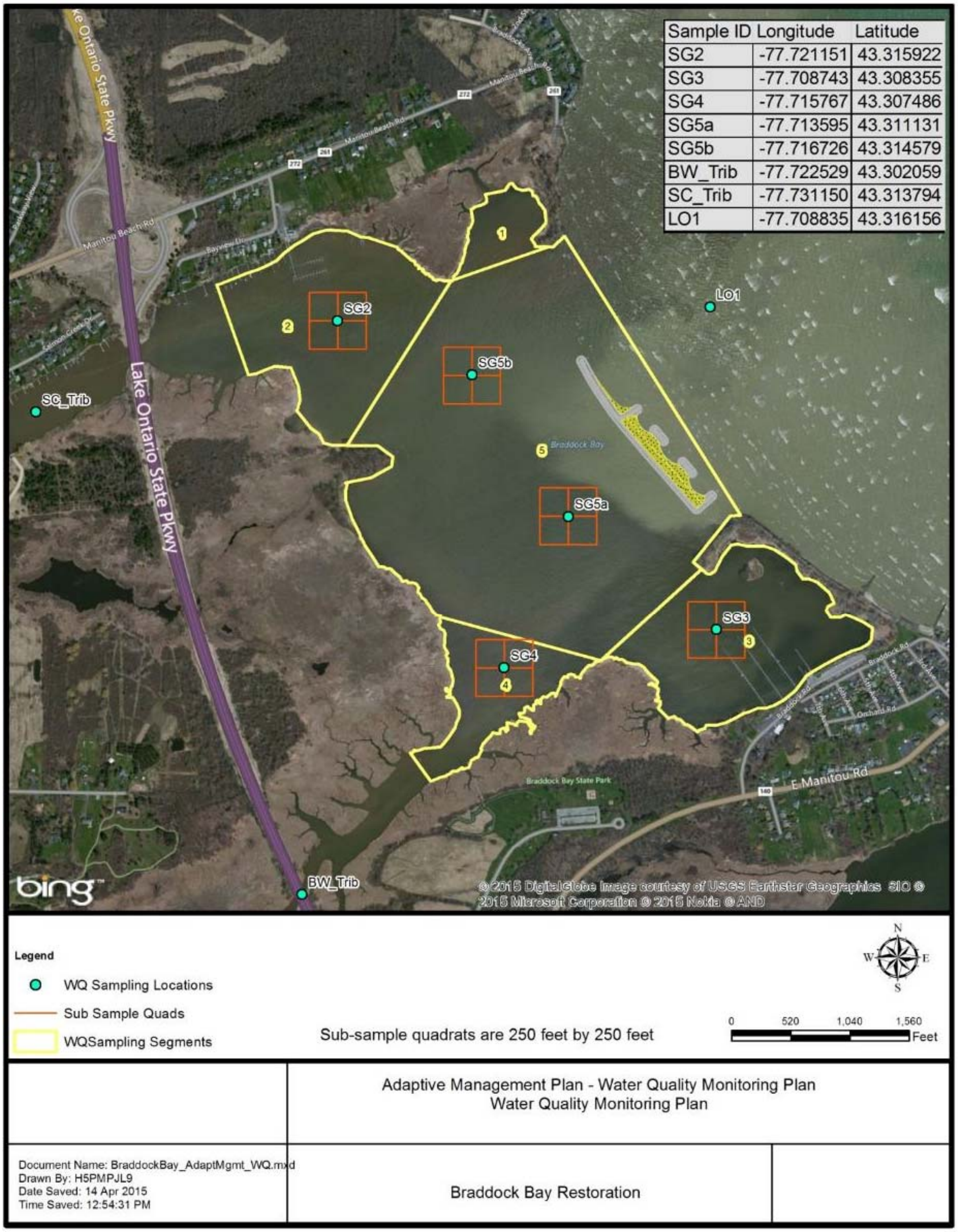

Figure 18. Water Quality Monitoring

3.0 Performance Criteria Summary

Monitoring Components Related to Project Objectives

The majority of success criteria were achieved in 2017. For the monitoring components associated with the project objectives, only three of nine components did not achieve the performance criteria. The percent cover of emergent and sedge grass meadow in restoration areas and the FQAI of the SAV community were not achieved. Both of these components may have been affected by the record high lake levels that persisted through the 2017 growing season. The component associated with monitoring wetland erosion could not be adequately addressed due to the need for more, longer term data. It is recommended that monitoring for all components continue into 2018.

Monitoring Components Related to Project Constraints

For the monitoring components associated with the project objectives, only one of four components did not achieve the performance criteria. The component associated with the dominance of nutrient enrichment tolerant species was determined to not be met, however, this may be a result of the record high lake levels that persisted through the 2017 growing season. The monitoring components associated with avoiding littoral impacts and avoiding trophic state impacts are considered to have been met based on existing data; however, data from subsequent years will be needed to confirm these conclusions. The component associated with impacts to navigation could not be fully evaluated due to the structure having not been completed and as-built drawings not being available.

Table 14. Monitoring and Adaptive Management Plan

Objectives	Monitoring Methodology	Ecologic Success Criteria	2016 Results	2017 Results	Criteria Met
Wetland Habitat Diversity	Emergent Vegetation	$FQAI_{control}$= 20.4	$FQAI_{control}$= 18.9 $FQAI_{channels}$= 28.6 $FQAI_{potholes}$= 25.8	$FQAI_{control}$= 17.5 $FQAI_{channels}$= 30.7 $FQAI_{potholes}$= 27.0	**Yes**
		% Cover >= 80% of emergent and sedge grass meadow.	% Cover = 48% – 69% benches 63% habitat mounds	% Cover = 36%-49% 62% habitat mounds	**No.** Continue monitoring.
		% Invasive Cover = *0% Phragmites*, < 50% *Typha* species, <10% of other invasive species	% Phragmites Cover = *0%* *% Typha Cover = 48.9%* % other invasive species = 37.1%	% Phragmites Cover = *0%* *% Typha Cover = 5.1% potholes and 8.8% in channel benches and habitat mounds* % other invasive species = 8.9% on potole benches 7.3% on channel benches and mounds	**Yes**
	SAV and Floating Vegetation Survey – Rake and sample plots (Bay segments 2-5)	SAV FQAI increases	FQAI $baseline_{2016}$ = 13.9	FQAI baseline2016 = 9.8	**No**. Continue monitoring.
Habitat Suitability	Fish surveys	Native fish species richness increase. Abundance of YOY northern pike increase	Control = 9; restored areas = 10. No northern pike YOY recorded	Control = 17; restored areas = 9 YOY northern pike recorded in restored areas	**Yes**
	Bird Surveys	Bird Species Richness > $14_{(2013)}$	Restored areas = 27	Restored Areas = 39	**Yes**
	Amphibian Surveys	Amphibian species richness > $4_{(2013)}$	Amphibian species richness = 6	Amphibian species richness = 6	**Yes**
Reduce Erosion	Shoreline erosion evaluation	Shoreline erosion within range of 0.23 to 0.55 acres per year	Not evaluated in 2016, structure not complete	Not evaluated in 2017.	Not evaluated

Constraints					
	Monitoring Methodology	Success Criteria	2016 Results	2017 Results	Criteria Met
Avoid Navigation Impacts	Bathymetric Survey	Navigation channel dredging requirements shall not be increased as a result of project construction	Not evaluated in 2016, structure not complete	Not evaluated in 2017, structure not complete	**Not evaluated**
Avoid Littoral Drift Impacts	Aerial Imagery & Bathymetric Survey	No impacts to the littoral drift system inferred from qualitative assessment of down drift shoreline.	Not evaluated in 2016, structure not complete	Preliminary analysis determines criteria is met, but future monitoring and analysis is needed	**Met**
Avoid Shift in Trophic State	Total Phosphorus, Chlorophyll a, and Secchi Disk. Calculate TSI using Chl-a for segments 2-5 in Braddock Bay.	No increasing trends of TP, Chl a, or TSI following construction of barrier beach	Baseline conditions frequently exceed ecosystem target criteria. Success criteria should be based on the occurrence of increasing trends in TP, Chl a, or TSI in years after barrier beach is created.	No significant impact from barrier beach as indicated by 2017 data, future year data needed to analyze trends	**Met**
	SAV and Floating Vegetation Survey – Rake and visual Surveys(Bay segments 3-5)	No significant increase in relative abundance of "nutrient enrichment tolerant" species	2016 Baseline Nutrient enrichment tolerant species dominance – 25%	2017 Nutrient enrichment tolerant species dominance - 35%	**Not met.** Likely due to high lake levels in 2017
Other	Barrier Beach Structural Monitoring	-	Not evaluated in 2016, structure not complete	Structure not complete in 2017	**Not evaluated**

4.0 Monitoring Time Frames and Adaptive Management

USACE has completed monitoring for 2015, 2016, and 2017. The majority of future monitoring will be undertaken by NYSDEC and SUNY Brockport. The exception is the USACE will collect and analyze water quality data in 2018, and will also contribute to the assessment of littoral drift, erosion, and navigation in future years as funding allows.

Table 15. Adaptive Management and Future Monitoring

Objectives				
	Monitoring Methodology	Criteria Met	Adaptive Management	Next Sampling
Wetland Habitat Diversity	Emergent Vegetation	Partial	Monitor in 2018	2018
	SAV and Floating Vegetation Survey – Rake and sample plots (Bay segments 2-5)	Not Met	Monitor in 2018 (USACE)	2018
Habitat Suitability	Fish surveys	Yes	Monitor in 2018	2018
	Bird Surveys	Yes	Monitor in 2018	2018
	Amphibian Surveys	Yes	Monitor in 2018	2018
Reduce Erosion	Shoreline erosion evaluation	Not Evaluated	Monitor in 2019 or 2020 to provide a 3 year analysis of erosion	2019
Constraints				
Avoid Navigation Impacts	Bathymetric Survey	Not Evaluated	Monitor in 2018 (USACE)	2018
Avoid Littoral Drift Impacts	Aerial Imagery & Bathymetric Survey	Yes	Monitor in 2018 (USACE)	2018
Avoid Shift in Trophic State	Total Phosphorus, Chlorophyll a, and Secchi Disk.	Tentatively Met	Monitor in 2018 (USACE)	2018
	SAV and Floating Vegetation Survey – Rake and visual Surveys(Bay segments 2-5)	Not Met	Monitor in 2018 (USACE)	2018
Other	Barrier Beach Structural Monitoring	Met	Monitor in 2018 (USACE)	2018

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APPENDIX A: BRADDOCK BAY RESTORATION: ADAPTIVE MANAGEMENT PLAN

APPENDIX B: SUNY BROCKPORT RESTORATION MONITORING REPORT - 2017

APPENDIX C: USACE VEGETATION ANALYSIS AND NORTHERN PIKE SURVEY DATA

APPENDIX D: COASTAL ASSESSMENT

APPENDIX E: 2017 PHOTO LOG