Water Quality Monitoring and Analysis:

An investigation of the of the Eutrophication and Undesirable Algae, and Degradation of Aesthetics Beneficial Use Impairments in the Canadian St. Marys River Area of Concern (2013-2015)

Technical report prepared by: Carrie Ginou, Field Technician

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Executive Summary

The St. Marys River is an identified Area of Concern, where ongoing remedial actions have contributed towards its restoration. During this 3 year (2013-2015) water quality monitoring and analysis project, scientific data was collected to aid in the process of re-assessing the status of the Eutrophication and Undesirable Algae, and Degradation of Aesthetics beneficial use impairments. Field work, involving monitoring aesthetic, physical, and chemical parameters at 5 sites within the Canadian St. Marys River Area of Concern, was conducted on a total of 23 dates from November 2013 to October 2015. Analysis of the monitoring data confirms that the conditions that originally led to the beneficial uses being designated as impaired no longer exist. In particular, there was no evidence of oxygen stress, large quantities of algae, or high levels of nutrients typically found in culturally-eutrophic waters. In addition, there was also an absence of characteristics associated with degraded aesthetics. There were no objectionable deposits, unnatural colour, unnatural turbidity, or unnatural odour. Any human impacts could best be categorized as localized and could not be readily associated with larger-scale industrial or municipal sources. Given the weight of evidence from the 3 years of monitoring, it is suggested that both the Eutrophication and Undesirable Algae, and Degradation of Aesthetics beneficial use impairments, be re-designated as not impaired.

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Abbreviations

AOC = Area of Concern

BPAC = Bi-National Public Advisory Council for the St. Marys River Area of Concern

BUI = Beneficial Use Impairment

CCME = Canadian Council of Ministers of the Environment

CWQG = Canadian Water Quality Guidelines for the Protection of Aquatic Life

°C = Degrees Celsius

ECCC = Environment and Climate Change Canada

GLWQA = Great Lakes Water Quality Agreement

GPS = Global Positioning System

IA = Implementation Annex for the Canadian Waters of the St. Marys River Area of Concern

L = Litre

MDEQ = Michigan Department of Environmental Quality

MDL = Method Detection Limit

µg = Microgram

mg = Milligram

MOECC = Ministry of Environment and Climate Change

NA = Data Not Available

NTU = Nephelometric Turbidity Unit

PWQO = Provincial Water Quality Objectives

RAP = Remedial Action Plan

USEPA = United States Environmental Protection Agency

Introduction

Background Information

The St. Marys River is a freshwater ecosystem which connects Lake Superior to Lake Huron, and separates the twin cities of Sault Ste. Marie, Ontario and Michigan. In the 1980s, the St. Marys River was identified as one of 43 Areas of Concern (AOCs) in the Great Lakes Basin (RAP 2002). AOCs, as defined by the Great Lakes Water Quality Agreement (GLWQA) between Canada and the United States, are geographically-delineated regions where impairment of beneficial uses has occurred due to human activities (GLWQA 2012).

Remedial Action Plans (RAPs), developed in conjunction with governments, agencies, and stakeholders, guide the implementation of ecosystem restoration activities in AOCs (GLWQA 2012). The ultimate goal of the RAP process is the restoration of beneficial uses, leading to the recovery of AOCs (GLWQA 2012). Of the 14 beneficial uses identified in the GLWQA, 9 have been recognized as being impaired in the St. Marys River (RAP 2002).

Project Purpose

The purpose of this three-year (2013-2015) water quality monitoring and analysis project was to provide scientifically-defensible information to allow a re-assessment of the Eutrophication and Undesirable Algae, and Degradation of Aesthetics beneficial use impairments (BUIs) in the Canadian portion of the St. Marys River AOC.

Eutrophication refers to the nutrient enrichment of a water body (Smith & Smith 2006). This often leads to increased algal growth, especially in the presence of elevated levels of nitrogen and phosphorus (Smith & Smith 2006). This beneficial use was deemed to be impaired in the St. Marys River AOC when, in the past, high levels of nutrients discharged into the river led to noticeable and excessive algal growth (RAP 1992; RAP 2002).

Aesthetics encompasses the visual appearance of the ecosystem (RAP 1992). This beneficial use was identified as being impaired in the St. Marys River AOC when, in the past, visible debris and obvious pollution, including oil slicks, grease, floating scums, oily fibrous material, and woody debris, were observed at the shoreline, on surface waters, and sitting on bottom sediments of the river (RAP 1992; RAP 2002).

Report Objective

The objective of this technical report is to summarize the methods used, and results obtained, during the 3 years of water quality monitoring, as well as to discuss the significance of the findings with respect to the Eutrophication and Undesirable Algae, and Degradation of Aesthetics BUIs.

Methods

Monitoring Sites

Five sites, encompassing the Canadian portion of the St. Marys River AOC, were used for water quality monitoring done in 2013, 2014, and 2015 (Figure 1). The monitoring sites were chosen to be representative of the substrates, aquatic habitats, and land uses, found within the Canadian St. Marys River AOC. The sites were named for their locations: Gros Cap, Bellevue Park, Bell's Point, Echo Bay, and Richards Landing.

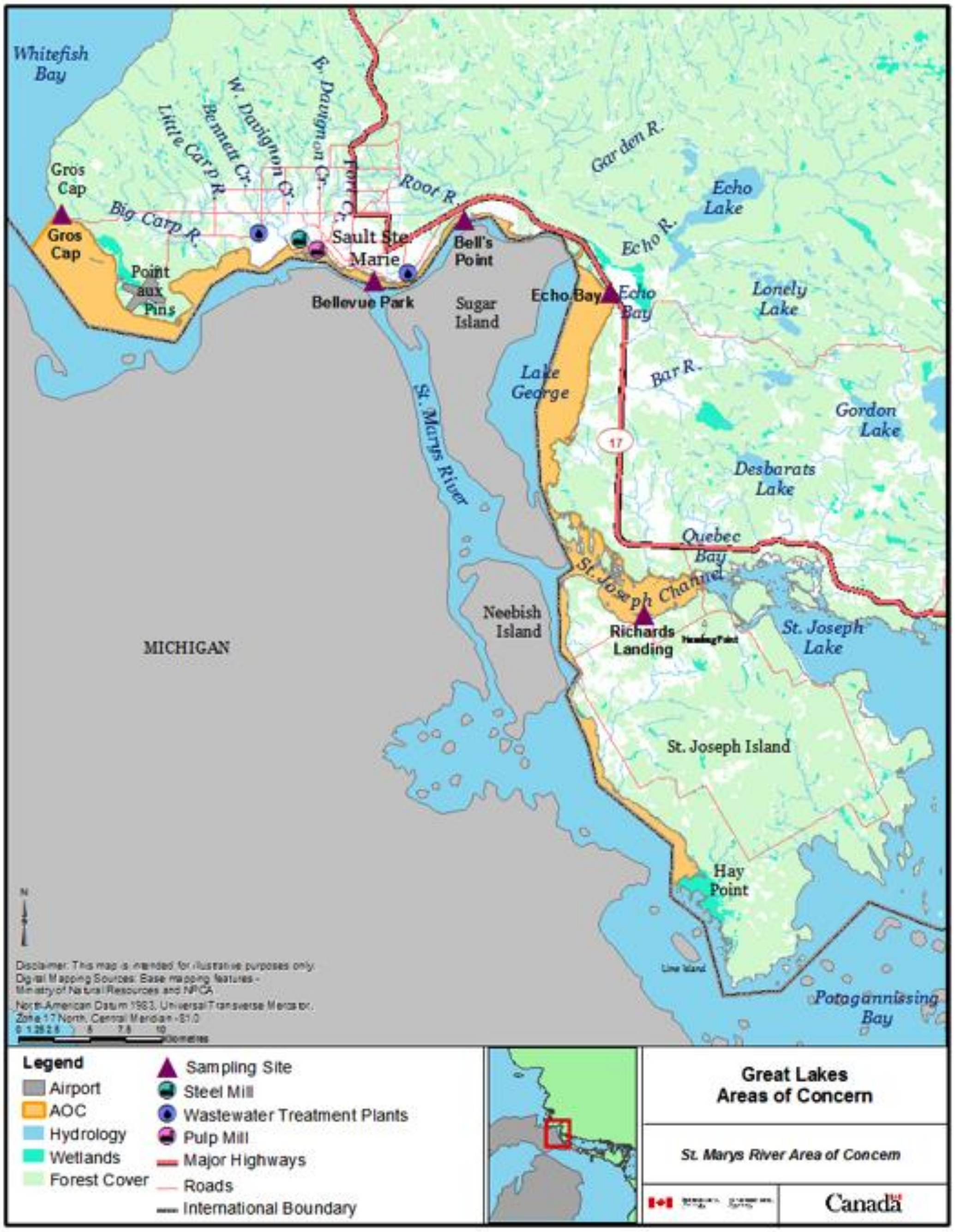

Figure 1: Canadian St. Marys River AOC showing monitoring sites (Map source: ECCC)

GPS coordinates of the monitoring sites are presented in Table 1. Due to water level changes, there were minor variations in the exact locations used throughout the field seasons. Coordinates were taken with a hand-held GPS unit (eTrex 20, Garmin).

Table 1: GPS coordinates of monitoring sites in the St. Marys River AOC (May 4, 2015)

Site	**GPS coordinates**
Gros Cap	N 46°31.736' W 084°35.179'
Bellevue Park	N 46°29.709' W 084°17.834'
Bell's Point	N 46°32.300' W 084°13.063'
Echo Bay	N 46°29.631' W 084°04.697'
Richards Landing	N 46°17.542' W 084°02.402'

Water Quality Monitoring Frequency

Water quality monitoring was conducted in November 2013, and from May to October, in both 2014 and 2015. Specific field work dates are shown in Table 2. Dates were scheduled to capture a variety of weather conditions, including rain events. In total 23 monitoring events took place. Work was done between the hours of 10:00 am and 5:00 pm.

Table 2: St. Marys River AOC water quality monitoring dates

Year	**Monitoring Dates**
2013	November 16 & 17 (monitoring over 2 days)
2014	May 14 Aug 6 May 27 Aug 26 June 10 Sept 10 June 24 Sept 22 July 14 Oct 6 July 29
2015	May 4 Aug 4 May 20 Aug 18 June 1 Sept 1 June 15 Sept 14 July 7 Oct 5 July 21

Monitoring Site Characteristics

At each monitoring site, the names of the field team members, date, start and end times, air temperature, and weather conditions were recorded. Observations of substrate type and presence or evidence of waterfowl were also made, as well as any other observations deemed relevant to the project's purpose. A copy of the field data collection sheet can be found in Appendix 1.

Field Monitoring Team

For safety purposes, the field monitoring team always consisted of a minimum of two people. Members of the field team throughout the project included the Field Technician, Assistant Field Technician, and the St. Marys River AOC RAP Coordinator.

Aesthetic Parameters

Parameters relevant to the Eutrophication and Undesirable Algae, and Degradation of Aesthetics BUIs were chosen to describe the aesthetics at each field site. These were: visual water clarity, water colour, water odour, and presence/absence of visible debris/obvious pollution. The category of visible debris/obvious pollution included any observations of algae and/or debris/pollution which was categorized as being natural, films, sheens, oil, grease, trash, solids and/or scums.

Descriptors from the MDEQ's Aesthetics Monitoring Data Sheet (MDEQ 2011), which was used to re-evaluate the Degradation of Aesthetics BUI in the American portion of the AOC, were used as the qualifiers for visual water clarity, water colour, water odour, and visible debris/obvious pollution in this study.

Water clarity and colour were determined visually (Figure 2) by looking at clear plastic bottles of river water samples against a white background (white piece of paper).

Figure 2: Visual determination of water clarity and colour using collected water samples

Visual water clarity was also quantified during all 3 study years using a Secchi disc (The Science Source) placed at a depth of 50 cm. If it was possible to see the disc at a depth of 50 cm, that was the reading. If it was not possible to see the disc, then it was raised until it could be seen and the depth measurement in cm was taken at that point.

In 2014 and 2015, a 60 cm turbidity tube (Fieldmaster, Science First) was also used to assess visual water clarity. The turbidity tube was included in the field protocol as it can be more accurate in determining water clarity than a Secchi disc when taking measurements in shallow water. At each site, the turbidity tube was filled to the top with river water. If it was possible to see the disc at the bottom of the tube, looking through the full tube of water, the measurement was 60 cm. If it was not possible to see the disc, water was removed from the tube until it was visible. Then the measurement in cm was taken from the scale on the side of the tube. Both pieces of equipment are pictured in Figure 3.

Figure 3: Determination of water clarity using a Secchi disc (left) and turbidity tube (right)

Water odour was assessed directly in the field by smelling river water collected in a plastic beaker.

Algae presence/absence and its approximate location (e.g. on rocks, floating) was determined by a visual check in the vicinity of each monitoring site.

The presence/absence of debris/obvious pollution was also determined visually by the field team.

In order to more permanently record visual observations, digital photographs were taken systematically at each field site. The photo protocol included digital photographs upstream of the monitoring site, downstream of the monitoring site, perpendicular to shoreline, a close-up into the water, and full clear plastic water sample bottles against a white background. In addition, any other relevant conditions (e.g. algae) were photographed during each field date.

Physical and Chemical Parameters

Field measurements and water samples were taken while wading at a depth of 50 cm. Measurements and samples collected during the 2014 and 2015 field seasons were taken at least 1 minute after the sampler had arrived at the sampling location, in order to negate any effect of sampler movement on the parameters investigated.

In 2013, water temperature was taken with an alcohol thermometer and pH was measured using pH test strips. During 2014 and 2015, water temperature was recorded with a digital thermometer (Traceable, Control Company) and pH was determined using a hand-held meter (pHTestr 30, Oakton). The taking of field measurements is shown in Figure 4.

Figure 4: Method used to take field measurements at monitoring sites in the St. Marys River AOC

Once the field measurements were completed, in 2013 and 2014, 3 replicates of water samples were collected from surface waters at each site. In 2015, 3 replicates were only taken at one site per field date (Table 3). The site where replicate water samples were collected was determined randomly, with each monitoring site being chosen at least twice during the field season.

Table 3: Dates when replicate water samples were taken during the 2015 field season

Monitoring Site	**Monitoring Date (3 sets of water samples taken)**
Gros Cap	May 4, July 21
Bellevue Park	June 15, Sept 15
Bell's Point	July 7, Aug 18
Echo Bay	May 20, Sept 1, Oct 5
Richards Landing	June 1, Aug 4

Water samples were collected according to the methods of the Protocols Manual for Water Quality Sampling in Canada (CCME 2011). Further procedural direction was given by Testmark Laboratories, which provided the sampling bottles and performed the chemical analysis on the collected water samples. In year 1 (2013), a procedural manual was written for the project, which was followed in years 2 and 3 (2014 and 2015).

Briefly, the sampler waded into the river at each monitoring site to a depth of 50 cm and collected surface water samples while holding sampling bottles under water facing upstream (Figure 5).

Figure 5: Water sampling method used at monitoring sites in the St. Marys River AOC

The physical and chemical parameters chosen for laboratory analysis during the project were those directly relevant to the investigation of the Eutrophication and Undesirable Algae, and Degradation of Aesthetics BUIs. Table 4 summarizes the application of each parameter measured in the collected river water samples.

Table 4: Parameters analyzed in water samples collected from the St. Marys River AOC

Parameter	**Application (what it measured)**
Total Suspended Solids	Water clarity
Turbidity	Water clarity
Chlorophyll a	Algal growth
Dissolved Oxygen	Oxygen
Total Phosphorus	Phosphorus
Dissolved Organic Carbon	Carbon
Un-ionized Ammonia (as nitrogen)	Un-ionized ammonia
Ammonium (as nitrogen)	Ammonium ion
Total Ammonia (as nitrogen)	Un-ionized ammonia and ammonium ion
Nitrite (as nitrogen)	Nitrite ion
Nitrate (as nitrogen)	Nitrate ion
Total Kjeldahl Nitrogen	Total ammonia and organic nitrogen
Total Nitrogen (as nitrogen)	Total nitrogen from all sources

The bottles used, preservation methods (where applicable), and parameters measured from each sample, are detailed in Table 5. When sulphuric acid was used as a preservative, it was added to the sampling bottles prior to the containers being shipped to Algoma University.

Table 5: Bottles used, preservation methods, and parameters measured in water samples

Sampling Bottle	Preservation	Parameter(s) Measured
1 L amber glass	None	Chlorophyll a
500 mL polyethylene terephthalate (PET) plastic	None	Dissolved Oxygen
500 mL PET plastic	None	Total Suspended Solids
500 mL PET plastic (2013-14) or 125 mL high-density polyethylene (HDPE) plastic (2015)	None	Nitrite, Nitrate, Turbidity
125 mL HDPE plastic (2013-15) or 145mL HDPE with a lock tight cap (Sept 14 & Oct 5 2015)	None (2013) Sulphuric Acid (2014-15)	Ammonia, Phosphorus, Total Kjeldahl Nitrogen
125 mL HDPE plastic	None	Dissolved Organic Carbon

Laboratory Analysis

While in the field, samples were collected and then immediately stored in coolers containing ice packs. At the end of the monitoring day, the bottles were stored in a refrigerator at 4°C. Exceptions to this include samples collected on November 16 and 17, 2013 and those taken on May 14, May 27, and June 10, 2014. These water samples were kept cool overnight but were collected before a new refrigerator was purchased and installed on June 18, 2014.

Sampling bottles were shipped in coolers with ice packs, via Purolator, to Testmark Laboratories in Sudbury, Ontario, within 24 hours of collection. The only exception to this was water samples collected on November 16, 2014, which were shipped within 48 hours of collection. Chain of custody documents, confirm that all of the samples were received at Testmark Laboratories within 24 hours of shipping.

Testmark Laboratories, Sudbury, Ontario, was chosen for this project as is it accredited by the Canadian Association for Laboratory Accreditation, and was the closest laboratory to Sault Ste. Marie, Ontario, available to perform the necessary chemical analyses.

The analytical methods used for each parameter measured and the method detection limits of each procedure are listed in Table 6. Since some of the methods and detection limits changed throughout the project, only the most recent information (as of October 2015) is shown.

Table 6: Parameters, laboratory analytical methods, and method detection limits

Parameter	Analytical Method	Method Detection Limit
Total Suspended Solids	Gravimetry using a Mettler Toledo Balance	0.7 mg/L
Turbidity	Nephelometry using a Hach 2100P	0.1 NTU
Chlorophyll a	Phillips UV/VIS Spectrophotometer	0.5 µg/L
Dissolved Oxygen	YSI BOD Meter	0.2 mg/L
Total Phosphorus	Discrete Chemistry Analyzer	0.002 mg/L
Dissolved Organic Carbon	Phoenix Analyzer	0.4 mg/L
Un-ionized Ammonia (as nitrogen)	Calculation	0.002 mg/L
Ammonium (as nitrogen)	Calculation	0.01 mg/L
Total Ammonia (as nitrogen) (un-ionized ammonia and ammonium)	Discrete Chemistry Analyzer	0.01 mg/L
Nitrite (as nitrogen)	Dionex Ion Chromatography	0.03 mg/L
Nitrate (as nitrogen)	Dionex Ion Chromatography	0.1 mg/L
Total Kjeldahl Nitrogen (ammonia and organic nitrogen)	Block Digestion and Discrete Chemistry Analyzer	0.2 mg/L
Total Nitrogen (as nitrogen) (all nitrogen sources)	Calculation	0 mg/L

Quality Control

Quality control at the field level consisted of following established sampling protocols and taking replicates of water samples. Quality control at the laboratory analysis phase included running lab controls, duplicate analyses with field samples, matrix spikes, and method blanks.

Data Entry and Analysis

Field measurements and laboratory analytical data were entered into, and organized in, Microsoft Excel spreadsheets (Microsoft Office 2013). Statistical analysis was performed on field and laboratory data using SPSS (IBM Statistics 23). Laboratory data below method detection limits was excluded from the calculations of minimum, maximum, and mean values.

Results

<u>Monitoring Site Characteristics</u>

Monitoring site characteristics are summarized in the following section. Complete details of the monitoring dates and times, air temperatures, weather conditions, the presence/absence of waterfowl, substrate type and shoreline characteristics, as well comments related to human uses and specific site conditions at the time of monitoring, for all 3 years, are available in Appendix 2.

Air Temperatures
Water quality monitoring was done in the spring, summer, and fall, with air temperatures generally ranging accordingly. Field season high and low air temperatures are shown in Table 7. Note, full field seasons (May to October) were completed in 2014 and 2015, but not 2013.

Table 7: High and low air temperatures taken at monitoring sites in the St. Marys River AOC

Year	High Air Temperature (°C)	Low Air Temperature (°C)
2013	13.5 Nov 16 at Richards Landing	7.0 Nov 16 at Bellevue Park
2014	25.8 June 10 at Bell's Point	7.5 Oct 6 at Richards Landing
2015	27.7 Aug 18 at Gros Cap	11.2 Oct 5 at Echo Bay

Weather
Monitoring dates encompassed a wide variety of weather conditions including sun, rain, cloud, and wind (Figures 6 & 7).

Figure 6: Water quality monitoring in the sun and rain

Figure 7: Water quality monitoring in cloudy and windy weather

Waterfowl

Waterfowl and their signs (scat, tracks, and feathers) were observed all 5 monitoring sites. Types included: gulls, geese, terns, ducks, loons, and cormorants. The greatest numbers of waterfowl were observed in the vicinity of the monitoring site at Bell's Point (Figure 8).

Figure 8: Waterfowl were commonly observed during water quality monitoring

Substrate Type and Shoreline Characteristics

The substrate type (river bottom) and shoreline characteristics varied considerably between monitoring sites.

Gros Cap (Figure 9) had a substrate consisting of small rocks to large boulders. The shoreline was also dominated by wave-washed rocks and boulders.

At Bellevue Park (Figure 10), the substrate consisted mainly of smaller rocks and pebbles with some large rocks within the monitoring area. The shoreline was gravelly with vegetation growing, close-to, and sometimes in the water.

Bell's Point (Figure 11), had a sandy substrate and a sand beach shoreline.

The monitoring site at Echo Bay (Figure 12) had a substrate made up of sand, silt, pebbles, and rocks. The shoreline was rocky, sandy and vegetated.

The substrate at Richards Landing (Figure 13) was sand and silt with a sand beach shoreline and an adjacent wetland.

Figure 9: The shoreline and substrate Gros Cap


Figure 10: The shoreline and substrate at Bellevue Park


Figure 11: The shoreline and substrate at Bell's Point

Figure 12: The shoreline and substrate at Echo Bay

Figure 13: The shoreline and substrate at Richards Landing

Human Uses
During all of the field seasons, a variety of human uses were observed in the vicinity of the monitoring sites. All of the sites were in public access areas, with the exception of Bell's Point, which is used by people visiting the private beach and campground.

The site at Gros Cap (Figure 14) was used frequently by hikers, sight-seers, dog walkers, and occasionally swimmers. In June 2014, the shoreline parking area was used as a base for people, equipment, and recreational vehicles involved in filming a movie in the area.

At Bellevue Park (Figure 15) the area near the monitoring site was used as an unofficial "off leash" dog park. Therefore, we usually observed, people and their dogs, in the vicinity. Occasionally we also saw dog waste and dogs swimming at the monitoring site.

Since Bell's Point (Figure 16) has an operational campground, there were campers in the area throughout the field seasons, with beach use being most frequent during July and August.

The area around the Echo Bay (Figure 17) monitoring site was used frequently as a boat launch and for fishing from shore. Until the water level increased in July 2015, there was also a fire pit, which was often full of garbage, on the shoreline. In September 2015, we observed water being pumped from the site.

Although we rarely saw swimmers, we observed many signs of recreational activity at the public beach adjacent to the Richards Landing (Figure 18) monitoring site.

Figure 14: Tire tracks at the shoreline parking area next to the Gros Cap monitoring site


Figure 15: The area next to the Bellevue Park monitoring site was used heavily by dog-walkers


Figure 16: The beach at Bell's Point was used as a recreational area


Figure 17: The Echo Bay monitoring site was most frequently used as a boat launch area


Figure 18: The monitoring site at Richards Landing was located at a public beach

Aesthetic, Physical, and Chemical Parameters

Results for aesthetic, physical, and chemical parameters (2013-2015) are summarized below. Full details are available in Appendices 3 and 4.

Visual Water Clarity

The majority of results for visual water clarity, as determined by looking at bottles of collected river water samples, showed surface waters to be clear, with some slight to moderate turbidity observed at both the Echo Bay and Richards Landing monitoring sites (Table 8).

Table 8: The range of water clarity qualifiers assigned to samples from the St. Marys River AOC

Year	Visual Water Clarity	Monitoring Site
2013 (1 monitoring event)	Clear	Gros Cap
	Clear	Bellevue Park
	Clear	Bell's Point
	Slightly turbid	Echo Bay
	Clear	Richards Landing
2014 (11 monitoring events)	Clear	Gros Cap
	Clear	Bellevue Park
	Clear	Bell's Point
	Clear, Slightly turbid	Echo Bay
	Clear, Slightly turbid, Moderately turbid	Richards Landing
2015 (11 monitoring events)	Clear	Gros Cap
	Clear	Bellevue Park
	Clear	Bell's Point
	Clear, Slightly turbid, Moderately turbid	Echo Bay
	Clear, Slightly turbid	Richards Landing

Environmental standard: free of unnatural turbidity

During all monitoring events (2013-2015) water samples collected from Gros Cap, Bellevue Park, and Bell's Point were clear.

In November 2013, on 6 dates in 2014 (May 14, May 27, June 10, August 26, September 22, and October 6), and on May 20, 2015, water samples at Echo Bay were slightly turbid. Moderate turbidity was detected in water samples taken at Echo Bay on May 4, 2015.

Water samples were slightly turbid at Richards Landing on 2 occasions in both 2014 (May 14 and September 22) and 2015 (May 4 and May 20). Moderately turbid water samples were observed at Richards Landing on July 29, 2014.

Representative photographs of clear (Bellevue Park) and moderately turbid (Echo Bay) water samples are shown in Figure 19.

Figure 19: Clear (left) and moderately turbid (right) water samples collected on May 4, 2015

The results for visual water clarity, as measured directly in the river using a Secchi disc (Table 9), were similar to those for water clarity using collected water samples. Most of the data indicated clear water, with some measureable turbidity being observed at Echo Bay. Since the Secchi depths were taken in 50 cm of water, the maximum measurement possible was 50 cm, with lower numbers indicating turbidity.

Table 9: The range of Secchi depth measurements at monitoring sites in the St. Marys River AOC

Year	**Secchi Depth (cm)**	**Monitoring Site**
2013	50	Gros Cap
	50	Bellevue Park
(1 monitoring event)	50	Bell's Point
	50	Echo Bay
	50	Richards Landing
2014	50	Gros Cap
	50	Bellevue Park
(11 monitoring events)	50	Bell's Point
	50, 45, 40	Echo Bay
	50	Richards Landing
2015	50	Gros Cap
	50	Bellevue Park
(11 monitoring events)	50	Bell's Point
	50	Echo Bay
	50	Richards Landing

Environmental standard: free of unnatural turbidity

All monitoring sites in 2013 and 2015 had a Secchi depth of 50 cm, although it was noted that sometimes water was visually less clear at Echo Bay and Richards Landing.

In 2014, all Secchi depth measurements were 50 cm, with the exception of 4 dates at Echo Bay (45 cm on May 14, and 40 cm on May 27, June 10, and October 6).

Figure 20 shows photos of clear (Bell's Point) and slightly turbid (Echo Bay) surface waters.

Figure 20: Surface waters which yielded Secchi depth measurements of 50 cm (left) and 40 cm (right) on May 27, 2014

The results for visual water clarity, as measured directly in the river using a turbidity tube in 2014 and 2015 (Table 10), generally supported the results for Secchi depth, as well as the visual observations of turbidity in collected water samples. Since a 60 cm turbidity tube was used, the maximum value was 60 cm, with lower measurements indicating turbidity.

Table 10: The range of turbidity tube measurements at monitoring sites in the St. Marys AOC

Year	Turbidity Tube (cm)	Monitoring Site
2014	60, 23	Gros Cap
	60	Bellevue Park
(11 monitoring events)	60	Bell's Point
	60, 33, 30, 27	Echo Bay
	60, 56, 49	Richards Landing
2015	60	Gros Cap
	60	Bellevue Park
(11 monitoring events)	60	Bell's Point
	60, 49, 38	Echo Bay
	60, 51, 40, 47	Richards Landing

Environmental standard: free of unnatural turbidity

Maximum turbidity tube measurements were always obtained at Bellevue Park and Bell's Point. Gros Cap had one low turbidity tube measurement (23 cm) which was taken on June 24, 2014.

At Echo Bay, turbidity tube measurements below maximum were taken on 4 dates in 2014 (readings of 30 cm on May 14 and May 27, 33 cm on June 10, and 27 cm on October 6), and 3 times in 2015 (38 cm on May 4 and May 20, and 49 cm on June 1).

Turbidity tube measurements below 60 cm were taken at Richards Landing on 2 dates in 2014 (56 cm on May 14 and 49 cm on July 29) and 3 times during the 2015 season (47 cm on May 20, 40 cm on July 7, and 51 cm on July 21).

Figure 21 presents photos of clear (Gros Cap) and slightly turbid (Echo Bay) surface waters.

Figure 21: Surface waters which gave turbidity tube measurements of 60 cm (left) and 38 cm (right) on May 20, 2015

Total Suspended Solids (TSS)

The results for total suspended solids in collected river water samples are presented in Table 11.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

Table 11: Total suspended solids in water samples taken from the St. Marys River AOC

Year	**TSS (mg/L) Range (Mean)**	**Monitoring Site**
2013	2.4 - 4.4 (3.2)	Gros Cap
	2.4 - 8.0 (4.3)	Bellevue Park
(1 monitoring event, 3 replicates at all sites)	2.4 - 11.6 (5.9)	Bell’s Point
	10.0 - 12.4 (11.3)	Echo Bay
	2.8 - 6.4 (4.4)	Richards Landing
2014	<MDL – 12.4 (2.6)	Gros Cap
	<MDL – 5.2 (2.3)	Bellevue Park
(11 monitoring events, 3 replicates at all sites)	<MDL - 6.8 (2.6)	Bell’s Point
	<MDL – 19.2 (7.3)	Echo Bay
	<MDL – 37.2 (7.5)	Richards Landing
2015	<MDL – 2.3 (1.7)	Gros Cap
	<MDL – 8.3 (3.0)	Bellevue Park
(11 monitoring events, 3 replicates at 1 site)	<MDL – 3.0 (1.8)	Bell’s Point
	<MDL – 44.0 (7.5)	Echo Bay
	1.7 – 35.7 (6.9)	Richards Landing

Environmental standard: ≤ 20 mg/L

In 2013, total suspended solids in water samples, ranged from 2.4 mg/L (Gros Cap, Bellevue Park, and Bell's Point) to a high of 12.5 mg/L (Echo Bay) with the mean value being lowest at Gros Cap (3.2 mg/L) and highest at Echo Bay (11.3 mg/L).

During the 2014 field season, all monitoring sites had their lowest total suspended solids measurements below method detection limits (<0.7 mg/L). The highest values were 12.4 mg/L (Gros Cap on June 24), 19.2 mg/L (Echo Bay on May 27) and 37.2 mg/L (Richards Landing on May 14). Mean total suspended solids were lowest in water samples from Bellevue Park (2.3 mg/L) and highest in samples collected from Richards Landing (7.5 mg/L).

Measurements of total suspended solids in 2015 ranged from <MDL (all sites except Richards Landing) to high measurements of 35.7 mg/L (Richards Landing on July 7) and 44.0 mg/L (Echo Bay on May 20). Mean levels were lowest at Gros Cap (1.7 mg/L) and highest at Echo Bay (7.5 mg/L).

The overall range of measurable values (2013-2015) was from 1.7 mg/L to 44.0 mg/L with mean values from 1.7 mg/L to 11.3 mg/L. As can be seen in Figure 22, total suspended solids levels were typically greater at Echo Bay and Richards Landing.

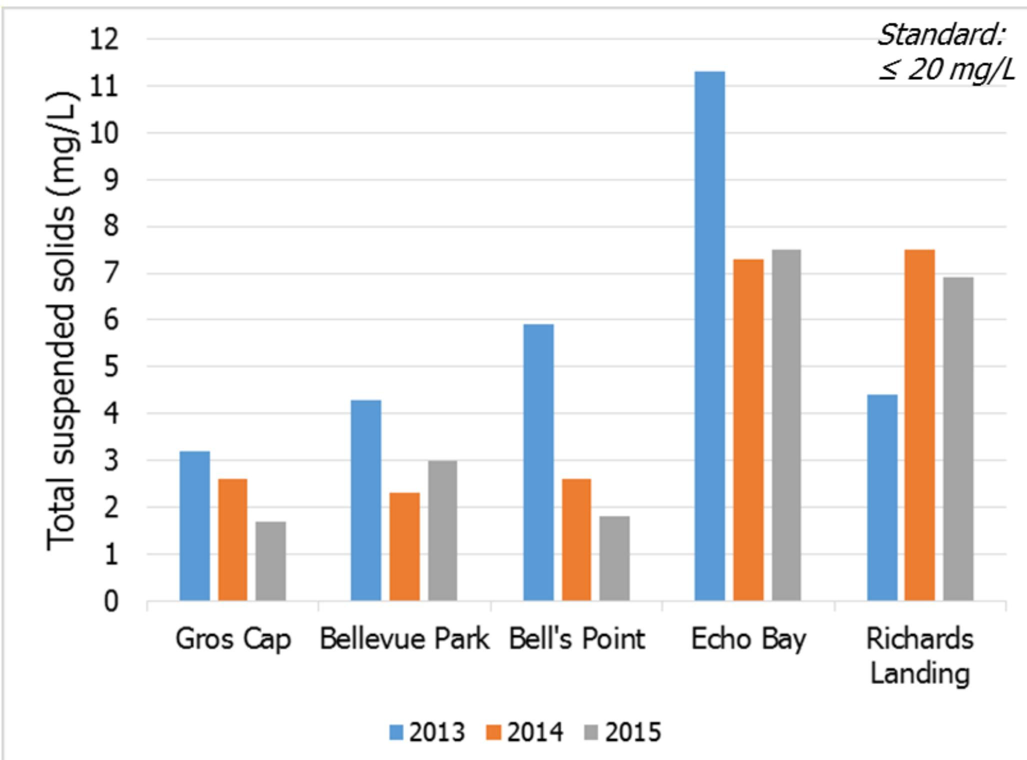

Figure 22: Mean total suspended solids in water samples from the St. Marys River AOC

Turbidity

The results for turbidity in river water samples are presented in Table 12. Range refers to the minimum and maximum values, and mean to the average of all of the data collected for that site.

Table 12: Turbidity of water samples taken from the St. Marys River AOC

Year	Turbidity (NTU) Range (Mean)	Monitoring Site
2013	0.9 - 1.3 (1.1)	Gros Cap
	1.4 – 2.8 (1.9)	Bellevue Park
(1 monitoring event,	2.1 – 2.5 (2.3)	Bell's Point
3 replicates at all sites)	15.6 – 16.6 (16.2)	Echo Bay
	4.8 – 5.2 (5.0)	Richards Landing
2014	0.3 – 12.6 (1.1)	Gros Cap
	0.9 – 3.2 (1.7)	Bellevue Park
(11 monitoring events,	0.9 – 2.5 (1.5)	Bell's Point
3 replicates at all sites)	1.7 – 23.5 (10.0)	Echo Bay
	2.4 – 9.9 (4.3)	Richards Landing
2015	0.4 – 1.8 (0.7)	Gros Cap
	0.6 – 4.5 (1.5)	Bellevue Park
(11 monitoring events,	0.8 – 1.7 (1.3)	Bell's Point
3 replicates at 1 site)	1.7 – 18.3 (7.2)	Echo Bay
	1.6 – 10.1 (4.8)	Richards Landing

Environmental standard: ≤ 20 NTU

In 2013, turbidity values ranged from 0.9 NTU (Gros Cap) to 16.6 NTU (Echo Bay). Mean turbidity was also lowest at Gros Cap (1.1 NTU) and highest at Echo Bay (16.3 NTU).

During 2014, Gros Cap again had the lowest measurement for turbidity (0.3 NTU on August 6) as well as the smallest mean value (1.1 NTU). Echo Bay retained the highest single measurement (23.5 NTU on October 6) and greatest mean value (10.0 NTU). Also of note was a turbidity level of 12.6 NTU at Gros Cap on June 24 and a high of 9.9 NTU at Richards Landing on July 29.

Turbidity levels in samples collected in 2015 continued the trend of being lowest at Gros Cap (0.4 NTU on 4 dates) and highest at Echo Bay (18.3 on May 20). A relative spike in turbidity (10.1 NTU) was also seen at Richards Landing on May 20. Mean low (0.7 NTU at Gros Cap) and high (7.2 NTU at Echo Bay) values that year were also reflective of the overall trend from the 3 years of monitoring.

The total range of turbidity (2013-2015) was from 0.3 NTU to 23.5 NTU with mean values from 0.7 NTU to 16.2 NTU. As with total suspended solids, turbidity levels were higher at the more downstream monitoring sites of Echo Bay and Richards Landing (Figure 23).

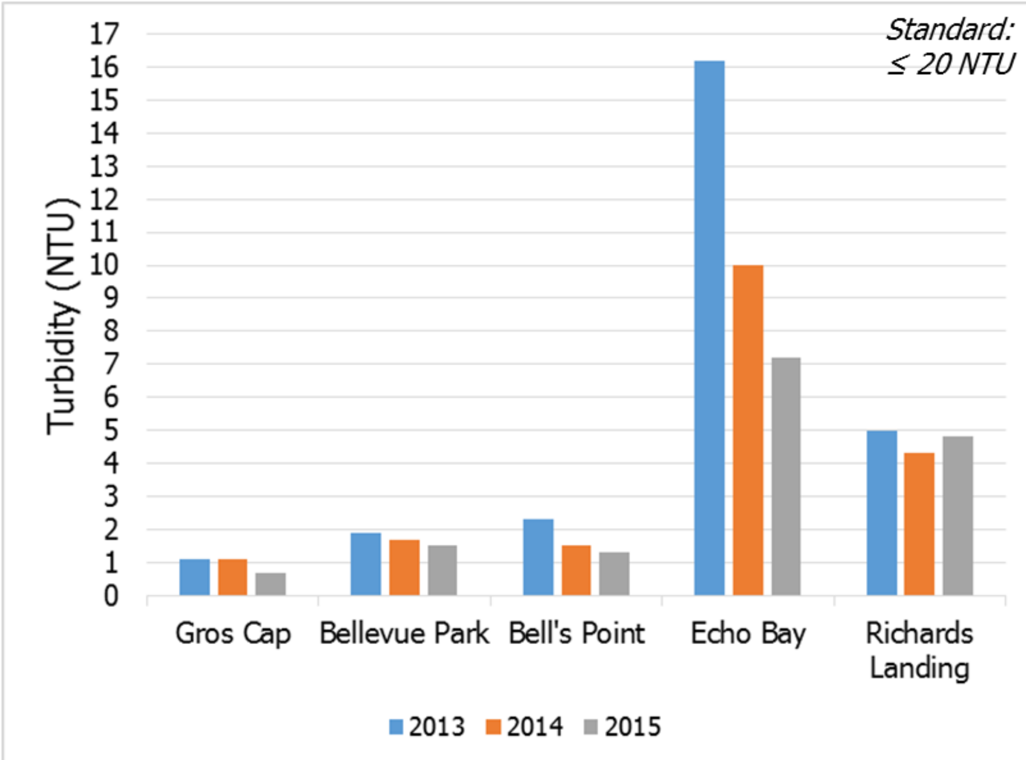

Figure 23: Mean turbidity in water samples collected from the St. Marys River AOC

Water Colour

The colours detected in bottles of collected river water samples are presented in Table 13.

Table 13: The range of water colour qualifiers from water samples collected in the St Marys AOC

Year	Water Colour	Monitoring Site
2013	Clear	Gros Cap
	Clear	Bellevue Park
(1 monitoring event)	Clear	Bell's Point
	Light yellow	Echo Bay
	Clear	Richards Landing
2014	Clear	Gros Cap
	Clear	Bellevue Park
(11 monitoring events)	Clear	Bell's Point
	Clear, Light yellow to brown	Echo Bay
	Clear, Light yellow to brown	Richards Landing
2015	Clear	Gros Cap
	Clear	Bellevue Park
(11 monitoring events)	Clear	Bell's Point
	Clear, Light yellow to brown	Echo Bay
	Clear, Light yellow	Richards Landing

Environmental standard: free of unnatural colour

During all field seasons (2013-2015) water was always described as being clear at Gros Cap, Bellevue Park, and Bell's Point.

Water samples collected at Echo Bay were light yellow in 2013. They were clear, light yellow (May 14, May 27, June 24, and September 10), light yellow-brown (June 10 and October 6), and light brown (July 29) in 2014, and clear, light yellow (June 1 and June 15), and light yellow-brown (May 4 and May 20) in 2015.

At Richards Landing, water samples taken in 2013 were clear. They were clear to light yellow (May 14) and light brown (July 29) in 2014, and clear to light yellow (May 20) in 2015.

Overall water colour was observed most often in water samples collected at Echo Bay. When comparing the 2 full monitoring seasons, fewer coloured samples were collected in 2015 (4/11 at Echo Bay, 1/11 at Richards Landing) than in 2014 (7/11 at Echo Bay, 2/11 at Richards Landing).

Examples of water colour in collected river water samples are shown in Figure 24. The clear water samples are from Bellevue Park and the light yellow-brown ones from Echo Bay.

Figure 24: Clear (left) and light yellow-brown (right) water samples collected on October 6, 2014

Water Odour

An odour was identified only once while monitoring during the entire 3 year project. A faint fishy/sewage odour was smelled in water samples collected from Bellevue Park in November 2013. On all other field dates, no unnatural odours were detected in the water.

Algae
The observations of algae at the monitoring sites is summarized in Table 14.

Table 14: Algae observed at monitoring sites in the St Marys AOC

Year	**Algae (# trips observed)**	**Monitoring Site**
2013	None	Gros Cap
	None	Bellevue Park
(1 monitoring event)	None	Bell's Point
	None	Echo Bay
	None	Richards Landing
2014	On rocks & floating (9)	Gros Cap
(11 monitoring events)	On rocks, vegetation & floating (5)	Bellevue Park
	On cement steps & floating (3)	Bell's Point
	Floating & on substrate (2)	Echo Bay
	Floating & on substrate (2)	Richards Landing
2015	On rocks (7)	Gros Cap
(11 monitoring events)	On rocks, vegetation & floating (6)	Bellevue Park
	On cement steps & vegetation (4)	Bell's Point
	On rocks (3)	Echo Bay
	None	Richards Landing

Environmental standard: free of persistent or re-occuring large algal blooms

In November 2013, algae was not noted at any of the monitoring sites. However, during the subsequent field seasons it was seen at all sites, with the exception of Richards Landing in 2015.

Algae were most frequently seen attached to rocks and submerged vegetation. When algae were floating, they were in small clumps or strands. No large mats were ever observed. Since suitable natural substrates were largely absent at Bell's Point, algae were observed attached to submerged cement steps at that monitoring site.

Algae were most often seen at Gros Cap (9/11 visits in 2014 and 7/11 visits in 2015) and least commonly observed at Richards Landing (2/11 visits in 2014 and 0/11 visits in 2015). Bellevue Park had the second most occurrences of algae in both 2014 and 2015 (5/11 dates in 2014 and 6/11 dates in 2015).

Visual quantification of algae was not systematically done. The observations were simply presence/absence. However, in 2015, definitely the largest amounts of algae were routinely seen at Gros Cap. Examples of the algae attached to rocks at Gros Cap are pictured in Figure 25.

Figure 25: Algae observed at the Gros Cap monitoring site on June 1, 2015

Chlorophyll a

The presence of algae as measured by the quantification of the photosynthetic pigment, chlorophyll a, in collected river water samples, is summarized in Table 15.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

Table 15: Chlorophyll a levels in water samples taken from the St. Marys River AOC

Year	**Chlorophyll a (µg/L) Range (Mean)**	**Monitoring Site**
2013	<MDL – 1.2 (1.0)	Gros Cap
	<MDL – 1.2 (1.0)	Bellevue Park
(1 monitoring event,	1.1 – 1.4 (1.2)	Bell's Point
3 replicates at all sites)	0.6 – 1.2 (0.9)	Echo Bay
	1.0 – 1.1 (1.1)	Richards Landing
2014	<MDL – 1.9 (1.2)	Gros Cap
	<MDL – 8.3 (1.9)	Bellevue Park
(11 monitoring events,	<MDL – 2.4 (1.2)	Bell's Point
3 replicates at all sites)	<MDL – 2.6 (1.7)	Echo Bay
	0.6 – 3.6 (1.8)	Richards Landing
2015	<MDL – 3.2 (1.2)	Gros Cap
	<MDL – 2.8 (1.5)	Bellevue Park
(11 monitoring events,	<MDL – 1.4 (0.8)	Bell's Point
3 replicates at 1 site)	<MDL – 4.3 (1.4)	Echo Bay
	<MDL – 2.2 (1.3)	Richards Landing

Environmental standard: ≤ 10 µg/L

In 2013, chlorophyll a levels varied from <MDL (<0.5 µg/L) at both Gros Cap and Bellevue Park, to 1.4 µg/L at Bell's Point. The mean chlorophyll a values were similar for all sites ranging from 0.9 µg/L at Echo Bay to 1.2 µg/L at Bell's Point.

During the 2014 field season, chlorophyll a ranged from <MDL at all sites except Richards, Landing, to a high of 8.3 µg/L at Bellevue Park on May 27. The lowest mean values were 1.2 µg/L at both Gros Cap and Bell's Point, while the highest mean chlorophyll a level of 1.9 µg/L was calculated for Bellevue Park.

In 2015, all field sites had their lowest chlorophyll a levels <MDL. The highest reading of 4.3 µg/L was taken from the water sample collected at Echo Bay on June 15. Mean chlorophyll a levels ranged from 0.8 µg/L (Bell's Point) to 1.5 µg/L (Bellevue Park).

During the 3 years of monitoring (2013-2015) measurable chlorophyll a varied from 0.6 µg/L to 8.3 µg/L with mean values ranging from 0.8 µg/L to 1.9 µg/L. The results are summarized visually in Figure 26.

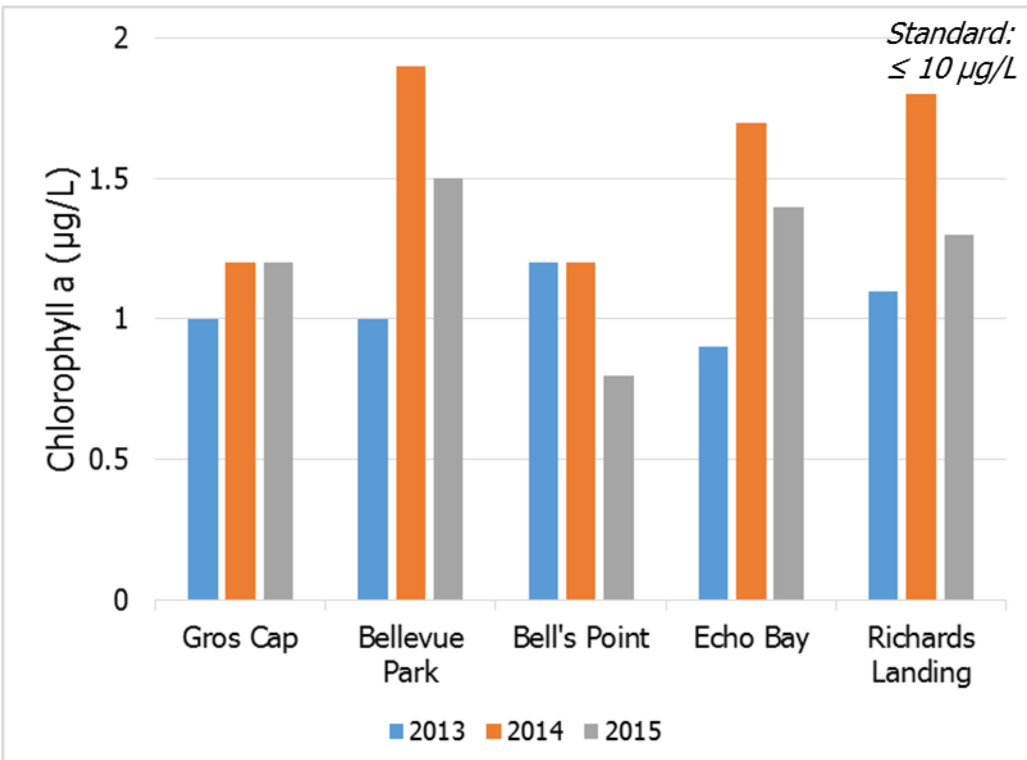

Figure 26: Mean chlorophyll a in water samples from the St. Marys River AOC

Visible Debris

During all 3 field seasons, forms of natural debris, including leaves, sticks, and plants, were observed at the monitoring sites. The presence/absence of debris is noted in Appendix 3.

There was no obvious pollution, including sheens, oil, grease, solids or scums, detected at any time. Any garbage seen was generally on the shoreline and deemed to be the result of localized human activity. Garbage is noted in the comments of Appendix 2.

Representative photographs of natural debris taken at Bell's Point on May 20, 2015 and Echo Bay on July 7, 2015, are shown in Figure 27.

Figure 27: Natural debris at Bell's Point (left) and Echo Bay (right)

Field Water pH

The range of field water pH values is summarized in Table 16. Note that the readings taken in 2013 were done with a pH strip, while the 2014-2015 results were obtained by using a pH meter.

In 2013, field water pH was determined to be 6.5 at all of the monitoring sites.

During the 2014 field season, field water pH readings ranged from 7.3 (Echo Bay on October 6) to 8.7 (Bellevue Park on May 27). Mean values varied from 7.8 at Echo Bay to 8.2 at both Gros Cap and Bellevue Park.

In 2015, field water pH ranged from 7.5 (Echo Bay on May 4 and June 1) to 8.8 (Gros Cap on October 5). Mean pH values were lowest at Bellevue Park and Bell's Point (7.9) and highest at Gros Cap and Richards Landing (8.2).

When considering only the most accurate pH measurements (those done with a pH meter in 2014 and 2015), the range of values for all monitoring sites was from 7.3 to 8.8, with mean values from 7.8 to 8.2.

Figure 28 visually presents the pH results from the 2014 and 2015 field seasons.

Table 16: Field water pH taken at monitoring sites in the St. Marys River AOC

Year	**Field Water pH Range (Mean)**	**Monitoring Site**
2013	6.5	Gros Cap
	6.5	Bellevue Park
(1 monitoring event)	6.5	Bell's Point
	6.5	Echo Bay
	6.5	Richards Landing
2014	7.9 – 8.6 (8.2)	Gros Cap
	8.0 – 8.7 (8.2)	Bellevue Park
(11 monitoring events)	7.7 – 8.2 (8.0)	Bell's Point
	7.3 – 8.2 (7.8)	Echo Bay
	7.8 – 8.5 (8.1)	Richards Landing
2015	7.9 – 8.8 (8.2)	Gros Cap
	7.7 – 8.5 (7.9)	Bellevue Park
(11 monitoring events)	7.7 -.8.5 (7.9)	Bell's Point
	7.5 – 8.5 (8.0)	Echo Bay
	8.0 – 8.6 (8.2)	Richards Landing

Environmental standard: pH 6.5 - 8.5

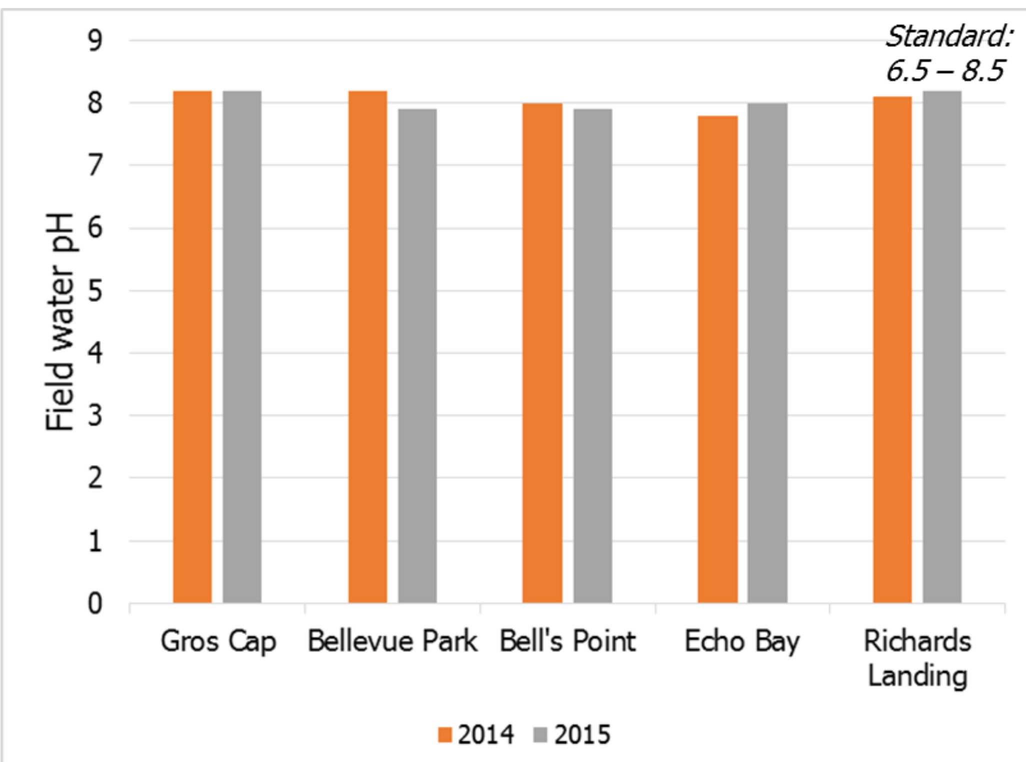

Figure 28: Mean field water pH taken at monitoring sites in the St. Marys River AOC

Field Water Temperature
Field water temperatures measured during water quality monitoring are summarized in Table 17.

Table 17: Field water temperatures taken at monitoring sites in the St. Marys River AOC

Year	**Water Temperature (°C) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event)	8	Gros Cap
	8	Bellevue Park
	8	Bell’s Point
	7	Echo Bay
	7	Richards Landing
2014 (11 monitoring events)	2.8 – 17.6 (12.0)	Gros Cap
	6.4 – 18.5 (13.5)	Bellevue Park
	8.3 – 18.6 (14.0)	Bell’s Point
	9.5 – 20.3 (16.7)	Echo Bay
	10.7 – 20.4 (16.0)	Richards Landing
2015 (11 monitoring events)	3.3 – 21.9 (13.3)	Gros Cap
	5.8 – 20.5 (14.2)	Bellevue Park
	7.9 – 20.5 (15.5)	Bell’s Point
	10.3 – 23.4 (16.7)	Echo Bay
	8.9 – 22.1 (16.2)	Richards Landing

Environmental standard: natural thermal regime unaltered (0-25 °C)

In 2013, field water temperature was measured as 7 °C (Echo Bay and Richards Landing) or 8 °C (Gros Cap, Bellevue Park, and Bell’s Point).

During the 2014 field season, the lowest field water temperature was 2.8 °C measured at Gros Cap on May 14, the first field date of that year. The highest field water temperature of 20.4 °C was measured on August 6 at Richards Landing. Mean water temperatures ranged from 12.0 °C at Gros Cap to 16.7 °C at Echo Bay.

In 2015, field water temperatures ranged from 3.3 °C at Gros Cap on May 4, the first field date of that year, to 23.4 °C at Echo Bay on August 18. Mean values of field water temperature were also lowest for Gros Cap (13.3 °C) and highest for Echo Bay (16.7 °C) in 2015.

Field water temperature for 2014-2015 ranged from 2.8 °C 23.4 °C and was typically highest at Echo Bay and Richards Landing, and lowest upstream at Gros Cap.

Since there was only one set of temperatures taken in 2013, Figure 29 shows the mean field water temperatures from the 2014 and 2015 field seasons.

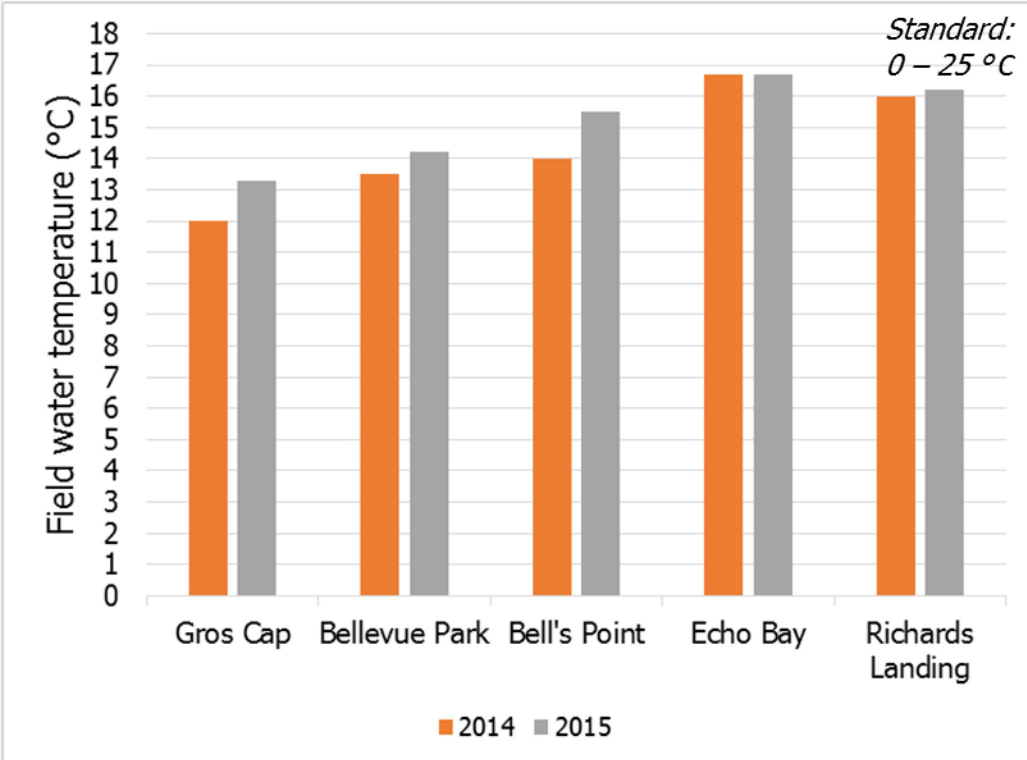

Figure 29: Mean field water temperatures taken at monitoring sites in the St. Marys River AOC

Dissolved Oxygen
Dissolved oxygen detected in collected river water samples, is summarized in Table 18.

Table 18: Dissolved oxygen in water samples taken from the St. Marys River AOC

Year	Dissolved Oxygen (mg/L) Range (Mean)	Monitoring Site
2013	9.8 – 10.1 (9.9)	Gros Cap
	9.9 – 10.1 (10.0)	Bellevue Park
(1 monitoring event, 3 replicates at all sites)	9.5 – 10.0 (9.8)	Bell's Point
	9.9 – 10.1 (10.0)	Echo Bay
	9.8 – 9.9 (9.9)	Richards Landing
2014	10.0 – 13.9 (11.2)	Gros Cap
	9.7 – 13.7 (11.1)	Bellevue Park
(11 monitoring events, 3 replicates at all sites)	9.8 – 13.8 (11.1)	Bell's Point
	8.5 – 11.8 (9.9)	Echo Bay
	8.2 – 13.5 (10.4)	Richards Landing
2015	9.2 – 12.4 (10.9)	Gros Cap
	9.4 - 12.6 (10.9)	Bellevue Park
(11 monitoring events, 3 replicates at 1 site)	9.0 – 12.4 (10.7)	Bell's Point
	8.6 – 10.5 (9.6)	Echo Bay
	8.2 – 11.1 (9.8)	Richards Landing

Environmental standard: ≥ 8 mg/L

In Table 18, range refers to the minimum and maximum values, and mean to the average measurement.

In 2013, dissolved oxygen ranged from 9.5 mg/L at Bell's Point to 10.1 mg/L in samples taken at Gros Cap, Bellevue Park, and Echo Bay. The lowest mean was 9.8 mg/L at Bell's Point, while Bellevue Park and Echo Bay shared the same highest mean of 10.0 mg/L.

During the 2014 field season, water samples from Richards Landing on July 29 had the lowest dissolved oxygen level of 8.2 mg/L. The highest dissolved oxygen reading of 13.9 mg/L was from water collected at Gros Cap on June 24. Mean dissolved oxygen values ranged from 9.9 mg/L (Echo Bay) to 11.2 mg/L (Gros Cap).

Dissolved oxygen was again lowest at 8.2 mg/L at Richards Landing (August 18) in 2015, but was highest at 12.6 mg/L in samples from Bellevue Park (June 15). Mean dissolved oxygen levels ranged from 9.6 mg/L (Echo Bay) to 10.9 mg/L (Gros Cap and Bellevue Park).

Throughout all 3 monitoring seasons dissolved oxygen ranged from 8.2 mg/L to 13.9 mg/L with mean values calculated from 9.6 mg/L to 11.2 mg/L.

Figure 30 illustrates the dissolved oxygen levels in river water samples taken from the St. Marys River (2013-2015).

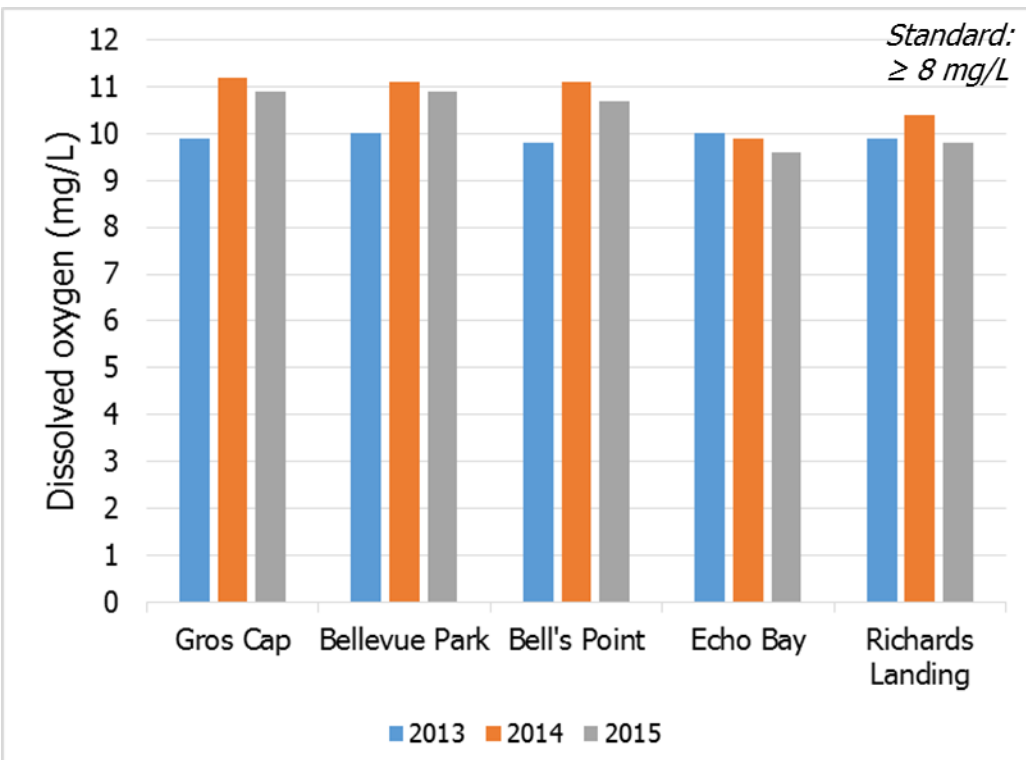

Figure 30: Mean dissolved oxygen in water samples taken from sites in the St. Marys River AOC

Total Phosphorus

Total phosphorus as measured in collected river water samples, is summarized in Table 19.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

Table 19: Total phosphorus in water samples taken from the St. Marys River AOC

Year	**Total Phosphorus (mg/L) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)	0.002 – 0.002 (0.002)	Gros Cap
	0.007 – 0.015 (0.010)	Bellevue Park
	0.005 – 0.014 (0.010)	Bell's Point
	0.019 – 0.021 (0.020)	Echo Bay
	0.007 – 0.026 (0.015)	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)	<MDL – 0.015 (0.006)	Gros Cap
	<MDL – 0.038 (0.008)	Bellevue Park
	<MDL – 0.016 (0.005)	Bell's Point
	0.003 – 0.058 (0.012)	Echo Bay
	<MDL – 0.031 (0.008)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)	<MDL – 0.011 (0.007)	Gros Cap
	<MDL – 0.013 (0.007)	Bellevue Park
	<MDL – 0.013 (0.009)	Bell's Point
	<MDL – 0.022 (0.011)	Echo Bay
	<MDL – 0.016 (0.010)	Richards Landing

Environmental standard: ≤ 0.030 mg/L

In 2013, total phosphorus ranged from 0.002 mg/L at Gros Cap to 0.026 mg/L at Richards Landing. Mean total phosphorus was lowest (0.002 mg/L) at Gros Cap and highest (0.020 mg/L) at Echo Bay.

During the 2014 field season, total phosphorus was lowest at <MDL (<0.002 mg/L) for all sites except Echo Bay, and highest in water from Echo Bay (0.058 mg/L) collected on June 10. Mean total phosphorus levels ranged from 0.005 mg/L from samples taken at Bell's Point to 0.012 mg/L in water from Echo Bay.

In 2015, all monitoring sites had water samples with total phosphorus <MDL. The highest total phosphorus was measured in water samples collected at Echo Bay (0.022 mg/L) on May 4. Mean total phosphorus varied from 0.007 mg/L (Gros Cap and Bellevue Park) to 0.011 mg/L (Echo Bay).

Total phosphorus tended to be higher at Echo Bay and Richards Landing, with the overall range of measurable values for all sites being from 0.002 mg/L to 0.058 mg/L, with mean values from 0.002 mg/L to 0.020 mg/L.

Figure 31 illustrates the trends in total phosphorus content of the collected water samples throughout the 3 field seasons of the water quality monitoring project.

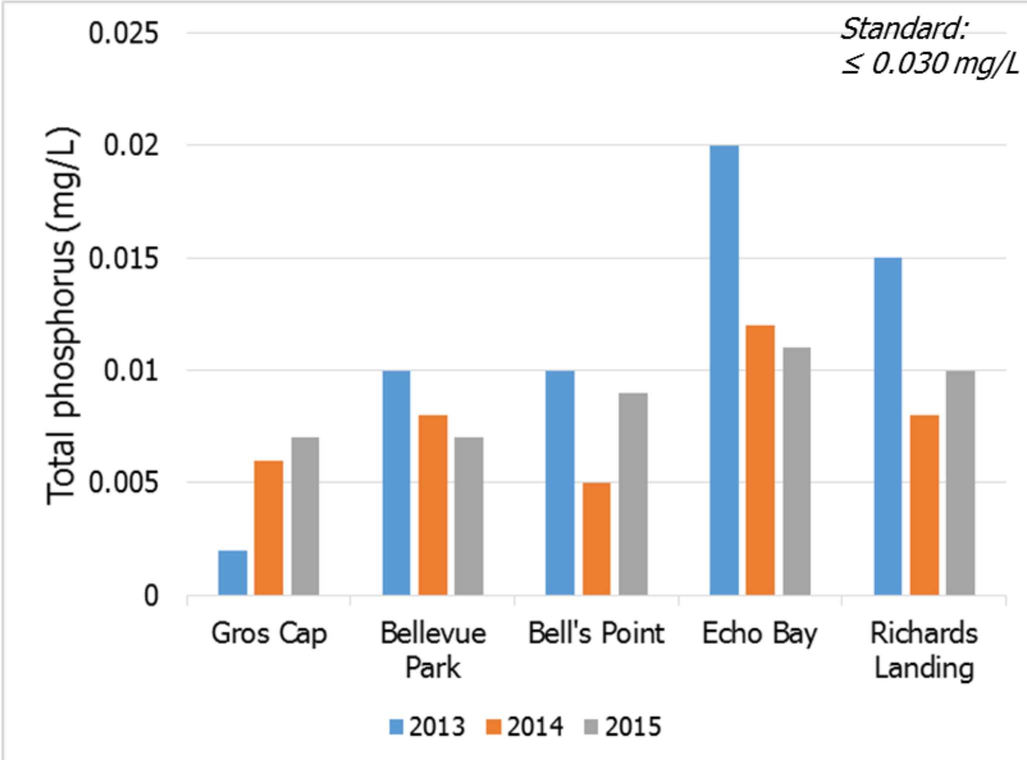

Figure 31: Mean total phosphorus in water samples taken from sites in the St. Marys River AOC

Dissolved Organic Carbon (DOC)

Dissolved organic carbon in collected river water samples, is summarized in Table 20.

Table 20: Dissolved organic carbon in water samples taken from the St. Marys River AOC

Year	**DOC (mg/L) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)	2.6 – 2.6 (2.6)	Gros Cap
	2.2 – 2.3 (2.3)	Bellevue Park
	2.2 – 2.3 (2.3)	Bell’s Point
	6.8 – 6.9 (6.9)	Echo Bay
	3.0 – 3.3 (3.1)	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)	1.5 – 10.8 (2.2)	Gros Cap
	1.6 – 2.2 (1.9)	Bellevue Park
	1.6 – 2.4 (2.0)	Bell’s Point
	1.7 – 7.5 (4.1)	Echo Bay
	1.8 – 3.9 (2.4)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)	1.6 – 2.4 (1.9)	Gros Cap
	1.6 – 2.5 (1.8)	Bellevue Park
	1.6 – 2.6 (2.0)	Bell’s Point
	1.8 – 6.2 (3.6)	Echo Bay
	1.6 – 3.0 (2.1)	Richards Landing

Environmental standard: ≤ 5 mg/L

In Table 20, range refers to the minimum and maximum values, and mean to the average measurement.

In 2013, dissolved organic carbon ranged from 2.2 mg/L, at both Bellevue Park and Bell’s Point, to 6.9 mg/L at Echo Bay. Mean dissolved organic carbon was also lowest (2.3 mg/L) at Bellevue Park and Bell’s Point and highest (6.9 mg/L) at Echo Bay.

During the 2014 field season, dissolved organic carbon concentrations were the lowest (1.5 mg/L on August 26) and the highest (10.8 mg/L on June 24) in water samples collected from Gros Cap. There were also relative spikes in dissolved organic carbon of 7.3 mg/L (June 10) and 7.5 mg/L (October 6) measured at Echo Bay. Mean dissolved organic carbon levels ranged from 1.9 mg/L at Bellevue Park to 4.1 mg/L at Echo Bay.

In 2015, the lowest dissolved organic carbon concentration of 1.6 mg/L was measured in samples from all sites except Echo Bay, which had the highest concentration of 6.2 mg/L on June 1. Mean dissolved organic carbon was lowest in samples from Bellevue Park (1.8 mg/L) and highest in water collected from Echo Bay (3.6 mg/L).

Overall (2013-2015) dissolved organic carbon ranged from 1.5 mg/L to 10.8 mg/L with mean values from 1.8 mg/L to 6.9 mg/L. As Figure 32 demonstrates, Echo Bay consistently had water samples with higher dissolved organic carbon concentrations than the other monitoring sites.

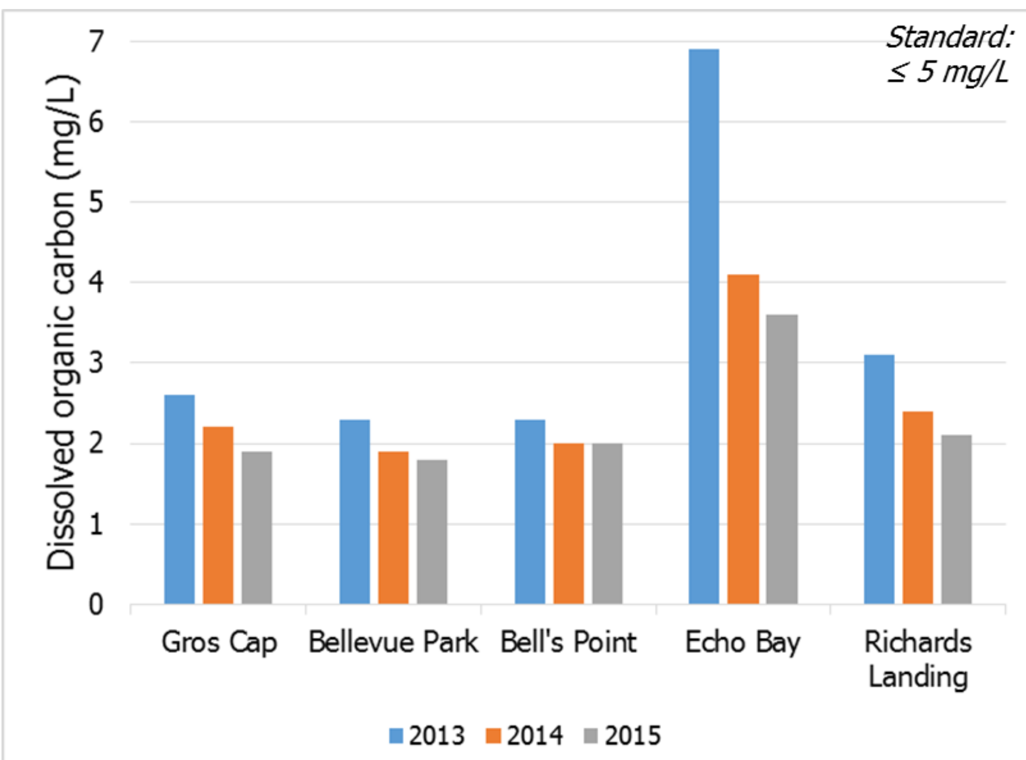

Figure 32: Mean dissolved organic carbon in samples taken from the St. Marys River AOC

Un-ionized Ammonia as Nitrogen (NH_3-N)

Un-ionized ammonia as nitrogen was found in some of the river water samples collected during the water quality project. However, in many of the samples, levels were undetectable by the analytical methods used, therefore, the results are represented by <MDL (less than the method detection limit). Since so few results for un-ionized ammonia were >MDL, all of the analytical data available is presented in Table 21.

Table 21: Un-ionized ammonia as nitrogen in water samples taken from the St. Marys River AOC

Year		**NH_3-N (mg/L) Values (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)		<MDL	Gros Cap
		<MDL	Bellevue Park
		<MDL	Bell's Point
		<MDL	Echo Bay
		<MDL	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)		<MDL, 0.005, 0.006, 0.007 (0.006)	Gros Cap
		<MDL, 0.003, 0.004 (0.004)	Bellevue Park
		<MDL	Bell's Point
		<MDL	Echo Bay
		<MDL, 0.002, 0.003 (0.002)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)		<MDL, 0.002	Gros Cap
		<MDL, 0.003, 0.003 (0.003)	Bellevue Park
		<MDL, 0.020	Bell's Point
		<MDL, 0.003, 0.004 (0.003)	Echo Bay
		<MDL	Richards Landing

Environmental standard: ≤ 0.020 mg/L

In 2013, there were no detectable (<0.002 mg/L) amounts of un-ionized ammonia found in water samples from any of the field sites.

During the 2014 field season, all monitoring sites had the lowest un-ionized ammonia levels <MDL. Un-ionized ammonia was measurable in all 3 samples (0.005 – 0.007 mg/L) taken at Gros Cap on June 10. At Bellevue Park, levels were detectable on June 10 (0.004 mg/L) and July 29 (0.003 mg/L). Samples from Richards landing had quantifiable amounts of un-ionized ammonia on both May 14 (0.003 mg/L) and August 26 (0.002). Overall the greatest levels were at Gros Cap and the lowest at Richards Landing.

In 2015, all monitoring sites again had the lowest un-ionized levels <MDL. Un-ionized ammonia was measureable in samples from Gros Cap on August 18 (0.002 mg/L), Bellevue Park on May 20 (0.003 mg/L) and August 18 (0.003 mg/L), and Echo Bay on July 7 (0.003 mg/L) and October 5 (0.004 mg/L). Samples from Richards landing never had quantifiable amounts of un-ionized

ammonia. Of particular interest was a relative spike in un-ionized ammonia (0.020 mg/L) which was measured in the sample taken from Bell's Point on October 5.

Overall the lowest detectable level of un-ionized ammonia was 0.002 mg/L and the highest 0.020 mg/L. Mean values, when available, ranged from 0.002 mg/L to 0.006 mg/L.

Figure 33 depicts the results for un-ionized ammonia in collected water samples. The bars represent either single or mean values depending on the amount of data available.

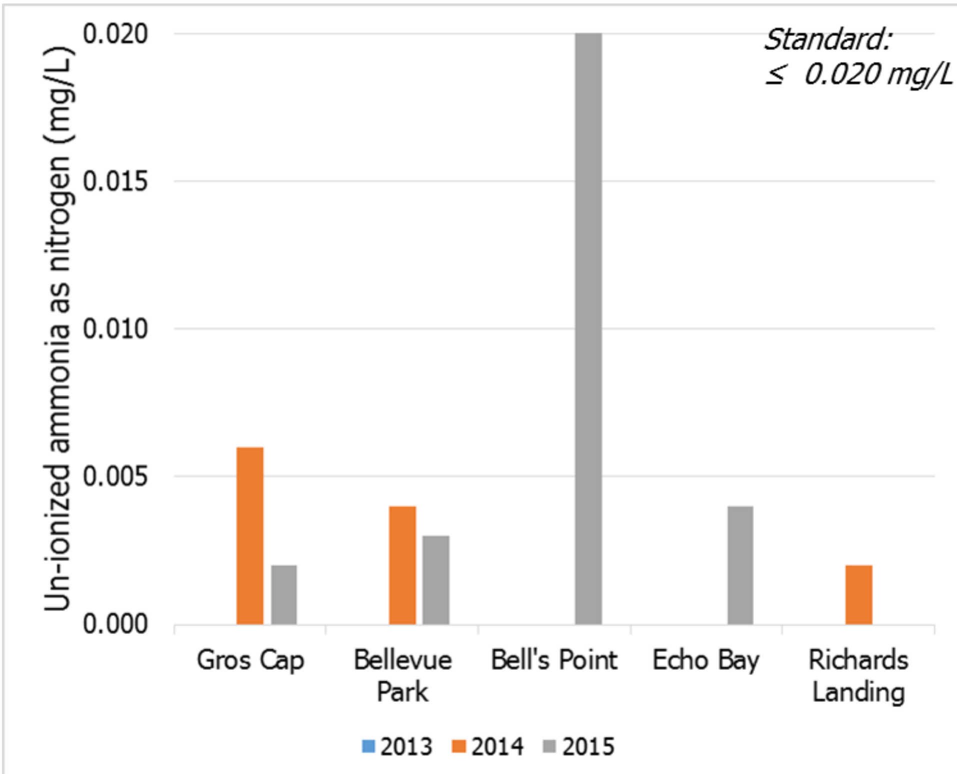

Figure 33: Un-ionized ammonia as nitrogen in samples taken from the St. Marys River AOC

Ammonium as Nitrogen (NH_4-N)

Ammonium as nitrogen measured in collected river water samples, is summarized in Table 22. The results are also illustrated in Figure 34.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

In 2013, ammonium was detected in water samples from all monitoring sites. The lowest measurement was 0.02 mg/L in water from Bellevue Park and the highest level of 0.04 mg/L was in samples from Bell's Point. Mean values for ammonium were similar between sites, being 0.02 mg/L at Bellevue Park and 0.03 mg/L at all of the other monitoring sites.

During the 2014 monitoring season, all sites had water samples with ammonium <MDL (<0.01 mg/L). The highest value for ammonium (0.14 mg/L) was measured in water collected at Gros Cap on June 10. Mean values were comparable to 2013, being 0.02 mg/l for Bell's Point and Echo Bay, and 0.03 mg/L for Bellevue Park and Richards Landing. Gros Cap had the highest mean value of ammonium at 0.04 mg/L.

In 2015, all monitoring sites again had water samples with ammonium <MDL. The highest ammonium level measured that year (0.26 mg/L) was in water taken from Bell's Point on October 5. Another relatively high measurement (0.20 mg/L) was taken from water collected at Bellevue Park on May 20. Mean ammonium was slightly higher than in previous years, being 0.03 mg/L in samples from Richards Landing, 0.04 mg/L from Gros Cap and Echo Bay, and 0.05 mg/L from Bellevue Park and Bell's Point.

Overall the range of measurable ammonium as nitrogen was from 0.02 mg/L to 0.26 mg/L with mean values from 0.02 mg/L to 0.05 mg/L.

Table 22: Ammonium as nitrogen in water samples taken from the St. Marys River AOC

Year	**NH_4-N (mg/L) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)	0.03 – 0.03 (0.03)	Gros Cap
	0.02 – 0.03 (0.02)	Bellevue Park
	0.03 – 0.04 (0.03)	Bell's Point
	0.03 – 0.03 (0.03)	Echo Bay
	0.03 – 0.03 (0.03)	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)	<MDL – 0.14 (0.04)	Gros Cap
	<MDL – 0.11 (0.03)	Bellevue Park
	<MDL – 0.04 (0.02)	Bell's Point
	<MDL – 0.04 (0.02)	Echo Bay
	<MDL – 0.08 (0.03)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)	<MDL – 0.05 (0.04)	Gros Cap
	<MDL – 0.20 (0.05)	Bellevue Park
	<MDL – 0.26 (0.05)	Bell's Point
	<MDL – 0.12 (0.04)	Echo Bay
	<MDL – 0.08 (0.03)	Richards Landing

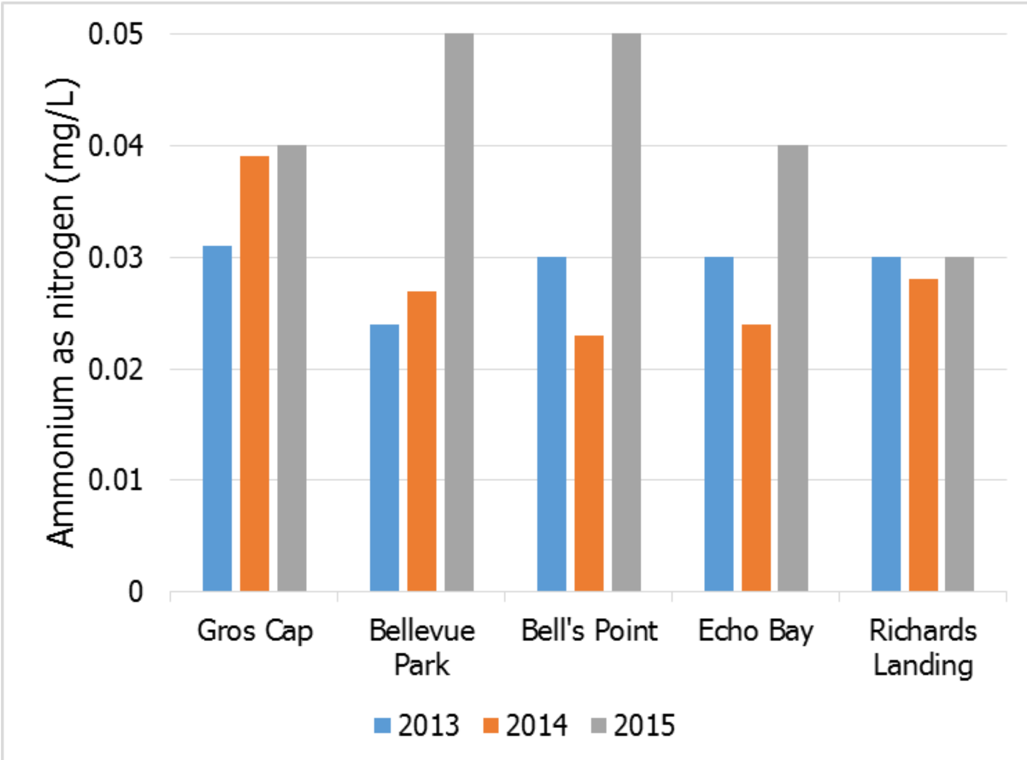

Figure 34: Ammonium as nitrogen in water samples taken from the St. Marys River AOC

Total Ammonia as Nitrogen (NH_3-N + NH_4-N)

Total ammonia as nitrogen (un-ionized ammonia and ammonium) in collected river water samples, is summarized in Table 23. Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

Since un-ionized ammonia was not detected in samples collected in 2013, the results for total ammonia are identical to those for ammonium, presented above.

In 2014, water samples from all sites had undetectable (<0.01 mg/L) amounts of total ammonia. Since un-ionized ammonia and ammonium were greatest in water samples collected from Gros Cap on June 10, the highest total ammonia measurement (0.15 mg/L) was from Gros Cap. Mean total ammonia levels were the same as those for ammonium, 0.02 mg/L for Bell's Point and Echo Bay, 0.03 mg/L for Bellevue Park and Richards Landing, and 0.04 mg/L for Gros Cap.

During monitoring in 2015, all sites again had water samples with unquantifiable (<MDL) total ammonia. The highest measurements for total ammonia, again driven by amounts of ammonium, were from water collected at Bell's Point (0.28 mg/L) on October 5 and Bellevue Park (0.21 mg/L) on May 20. Mean values were once more the same as those for ammonium, with a low of 0.03 mg/L for samples from Richards Landing, and a high of 0.05 mg/L for waters from Bellevue Park and Bell's Point.

Overall (2013-2015) measurable total ammonia as nitrogen varied from 0.02 mg/L to 0.28 mg/L with mean values from 0.02 mg/L to 0.05 mg/L (Figure 35).

Table 23: Total ammonia as nitrogen in water samples taken from the St. Marys River AOC

Year	**NH_3-N + NH_4-N (mg/L) Range (Mean)**	**Monitoring Site**
2013	0.03 – 0.03 (0.03)	Gros Cap
	0.02 – 0.03 (0.02)	Bellevue Park
(1 monitoring event, 3 replicates at all sites)	0.03 – 0.04 (0.03)	Bell's Point
	0.03 – 0.03 (0.03)	Echo Bay
	0.03 – 0.03 (0.03)	Richards Landing
2014	<MDL – 0.15 (0.04)	Gros Cap
	<MDL – 0.12 (0.03)	Bellevue Park
(11 monitoring events, 3 replicates at all sites)	<MDL – 0.04 (0.02)	Bell's Point
	<MDL – 0.04 (0.02)	Echo Bay
	<MDL – 0.09 (0.03)	Richards Landing
2015	<MDL – 0.05 (0.04)	Gros Cap
	<MDL – 0.21 (0.05)	Bellevue Park
(11 monitoring events, 3 replicates at 1 site)	<MDL – 0.28 (0.05)	Bell's Point
	<MDL – 0.13 (0.04)	Echo Bay
	<MDL – 0.08 (0.03)	Richards Landing

Environmental standard: ≤ 0.04 mg/L

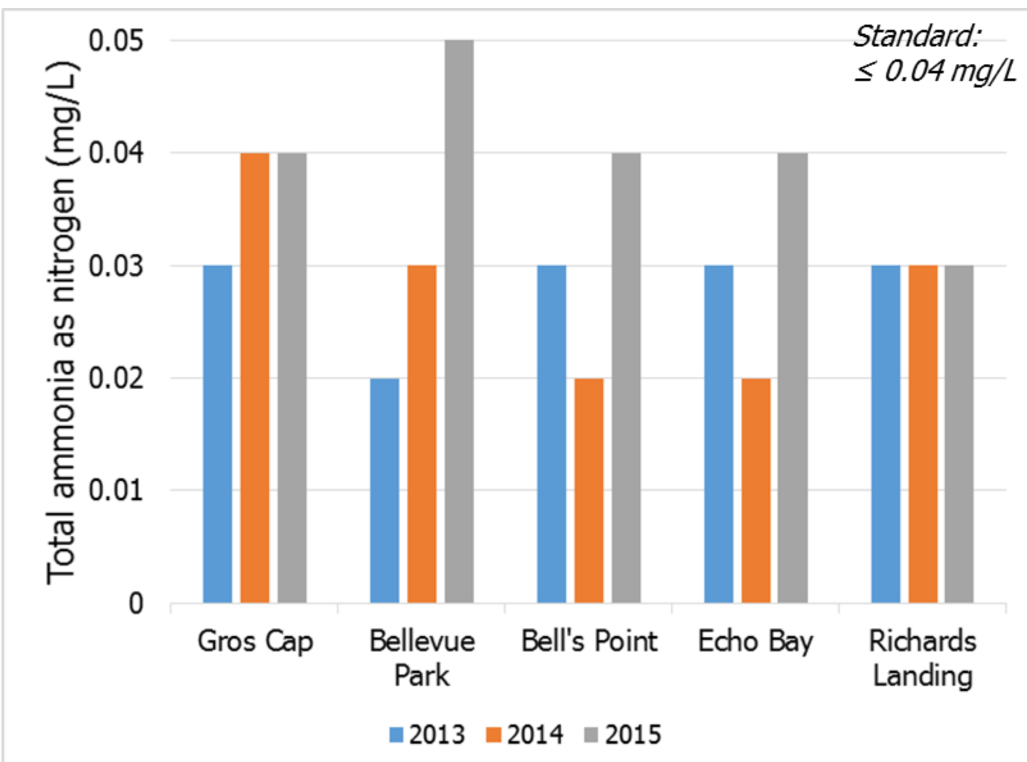

Figure 35: Total ammonia as nitrogen in water samples collected from the St. Marys River AOC

Nitrite as Nitrogen (NO_2-N)
Nitrite as nitrogen was not found at detectable levels (<0.03 mg/L) in any of the samples in 2013 or 2015. In 2014 it was found at 0.06 mg/L in a sample from Richards Landing on July 14.

Nitrate as Nitrogen (NO_3-N)
Nitrate as nitrogen concentrations in collected river water samples, are summarized in Table 24.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

In 2013, the lowest concentration of nitrate was <MDL (<0.1 mg/L) in water from Echo Bay. The highest concentration of nitrate (0.37 mg/L) was in water collected from Bell's Point. Mean readings of nitrate varied from 0.15 mg/L (Echo Bay) to 0.35 mg/L (Bell's Point).

During the 2014 field season, water samples from all sites had lowest nitrate levels <MDL. The highest amount of nitrate (0.56 mg/L) was measured in water from Bellevue Park on July 29. Mean nitrate varied from a low of 0.18 mg/L (Echo Bay) to a high of 0.30 mg/L (Bellevue Park).

Nitrate levels were lowest (<MDL) at Echo Bay on 5 dates (June 1, June 15, July 21, August 18, and September 1) in 2015. The highest nitrate measurement was (0.44 mg/L) in water collected at Bell's Point on May 20. Mean nitrate concentrations ranged from 0.22 mg/L (Echo Bay) to 0.33 mg/L (Gros Cap).

Table 24: Nitrate as nitrogen in water samples taken from the St. Marys River AOC

Year	**NO_3-N (mg/L) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)	0.25 – 0.33 (0.28)	Gros Cap
	0.29 – 0.31 (0.30)	Bellevue Park
	0.34 – 0.37 (0.35)	Bell's Point
	<MDL – 0.18 (0.15)	Echo Bay
	0.24 – 0.36 (0.28)	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)	<MDL – 0.47 (0.29)	Gros Cap
	<MDL – 0.56 (0.30)	Bellevue Park
	<MDL – 0.40 (0.29)	Bell's Point
	<MDL – 0.26 (0.18)	Echo Bay
	<MDL – 0.38 (0.22)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)	0.23 – 0.43 (0.33)	Gros Cap
	0.27 – 0.41 (0.31)	Bellevue Park
	0.25 – 0.44 (0.31)	Bell's Point
	<MDL – 0.31 (0.22)	Echo Bay
	0.18 – 0.35 (0.26)	Richards Landing

Environmental standard: ≤ 3.0 mg/L

Overall measurable nitrate as nitrogen ranged from 0.18 mg/L to 0.56 mg/L with means from 0.15 mg/L to 0.33 mg/L. As can be seen in Figure 36, nitrate concentrations were typically higher at the 3 most upstream sites (Gros Cap, Bellevue Park, and Bell's Point).

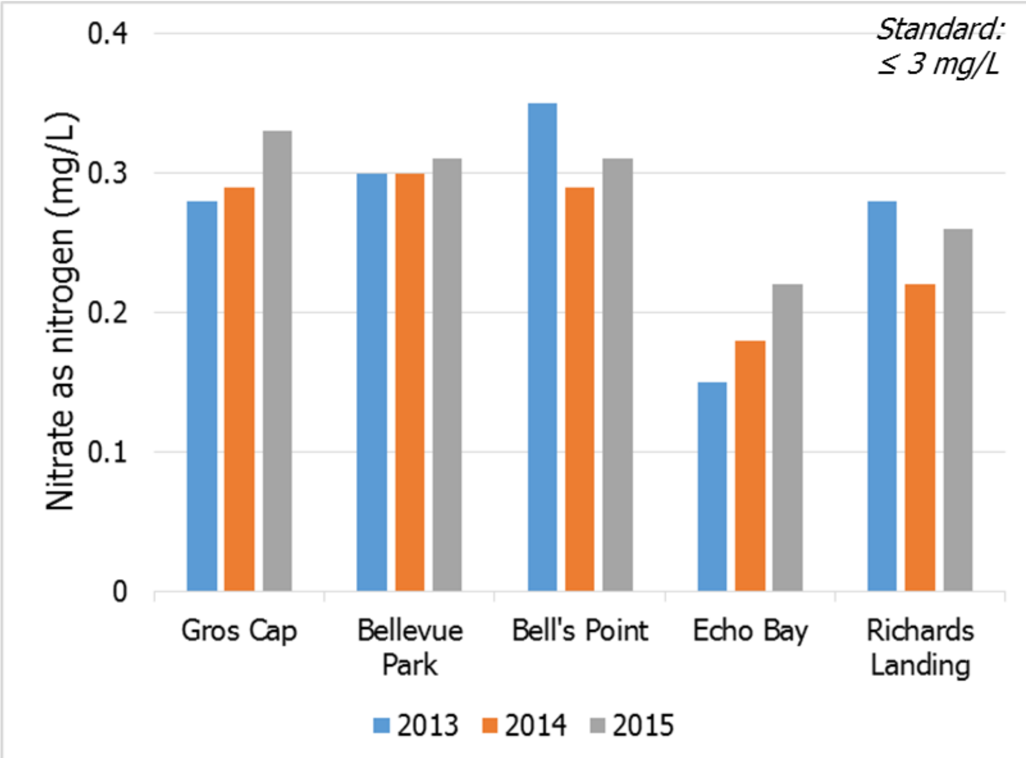

Figure 36: Mean nitrate as nitrogen in water samples collected from the St. Marys River AOC

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen (total ammonia and organic nitrogen) concentrations in collected river water samples, are summarized in Table 25.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

In 2013, TKN was <MDL (<0.2 mg/L) in samples collected from Bell's Point and Richards Landing. The greatest concentration of TKN (0.99 mg/L) was found in water collected from Echo Bay. Mean TKN was lowest (0.24 mg/L) at Richards Landing and highest (0.56 mg/L) at Echo Bay.

During the 2014 field season, all monitoring sites had TKN levels <MDL. The highest measurement of 1.30 mg/L was in water collected from Bellevue Park on May 27. Overall, mean TKN was greatest (0.64 mg/L) in samples from Echo Bay, although mean values were similar for all other monitoring sites (0.60 mg/L to 0.63 mg/L), with the exception of Bell's Point where the mean TKN was 0.53 mg/L.

In 2015, all monitoring sites again had the lowest TKN values <MDL. The greatest TKN measurement in that year (1.10 mg/L) was from water collected at Gros Cap on September 14. Mean TKN ranged from 0.42 mg/L at both Bell's Point and Echo Bay, to 0.71 mg/L at Gros Cap.

During the 3 year project (2013-2015) measurable TKN ranged from 0.30 mg/L to 1.30 mg/L with mean TKN from 0.24 mg/L to 0.71 mg/L (Figure 37).

Table 25: Total Kjeldahl nitrogen in water samples taken from the St. Marys River AOC

Year	**TKN (mg/L) Range (Mean)**	**Monitoring Site**
2013	0.42 – 0.48 (0.44)	Gros Cap
	0.40 – 0.61 (0.49)	Bellevue Park
(1 monitoring event, 3 replicates at all sites)	<MDL – 0.37 (0.34)	Bell's Point
	0.30 – 0.99 (0.56)	Echo Bay
	<MDL – 0.24 (0.24)	Richards Landing
2014	<MDL – 1.20 (0.60)	Gros Cap
	<MDL – 1.30 (0.63)	Bellevue Park
(11 monitoring events, 3 replicates at all sites)	<MDL – 0.75 (0.53)	Bell's Point
	<MDL – 0.91 (0.64)	Echo Bay
	<MDL – 0.89 (0.60)	Richards Landing
2015	<MDL – 1.10 (0.71)	Gros Cap
	<MDL – 0.90 (0.44)	Bellevue Park
(11 monitoring events, 3 replicates at 1 site)	<MDL – 0.97 (0.42)	Bell's Point
	<MDL – 0.97 (0.42)	Echo Bay
	<MDL – 1.00 (0.58)	Richards Landing

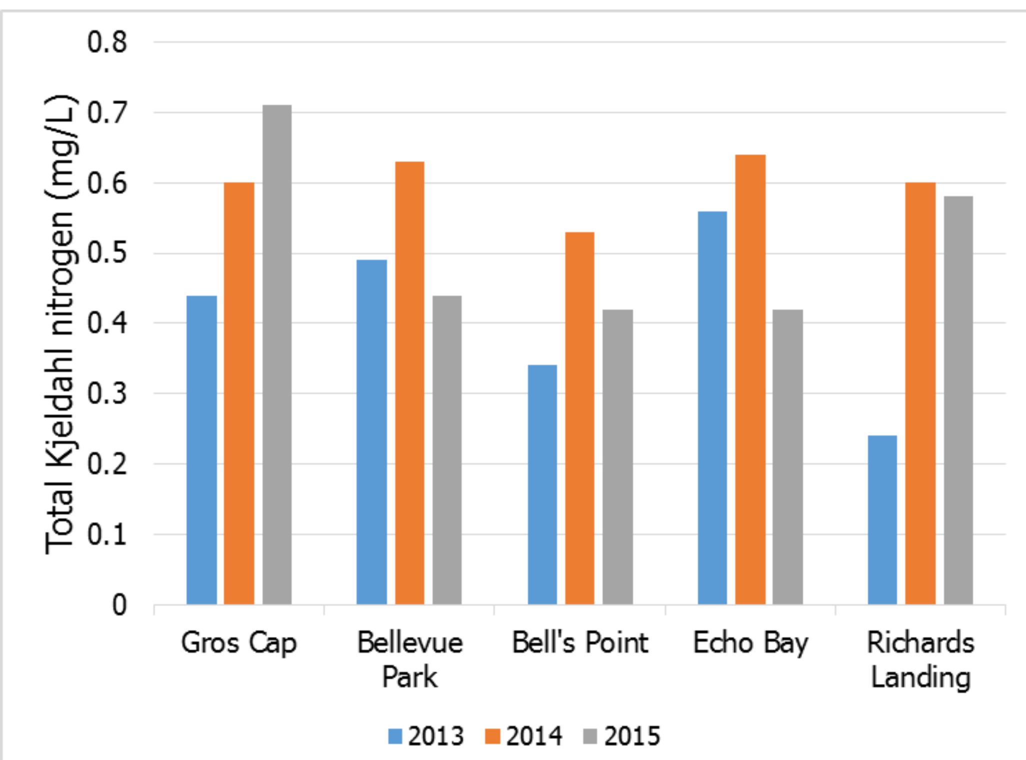

Figure 37: Mean total Kjeldahl nitrogen in water samples collected from the St. Marys River AOC

Total Nitrogen
Total nitrogen concentrations in collected river water samples, are summarized in Table 26. Total nitrogen includes all sources of nitrogen present which could include: un-ionized ammonia, ammonium, nitrite, nitrate, and organic nitrogen.

Range refers to the minimum and maximum values, and mean to the average of all of the measurable values collected for that site. If levels were undetectable by the analytical methods used, they are represented by <MDL (less than the method detection limit).

Table 26: Total nitrogen in water samples taken from the St. Marys River AOC

Year	**Total Nitrogen (mg/L) Range (Mean)**	**Monitoring Site**
2013 (1 monitoring event, 3 replicates at all sites)	0.68 – 0.75 (0.72)	Gros Cap
	0.71 – 0.92 (0.80)	Bellevue Park
	0.40 – 0.71 (0.58)	Bell's Point
	0.42 – 0.99 (0.66)	Echo Bay
	0.27 – 0.49 (0.38)	Richards Landing
2014 (11 monitoring events, 3 replicates at all sites)	0.21 – 1.63 (0.81)	Gros Cap
	0.28 – 1.63 (0.85)	Bellevue Park
	0.30 – 1.12 (0.75)	Bell's Point
	0.19 – 1.05 (0.72)	Echo Bay
	0.26 – 1.21 (0.76)	Richards Landing
2015 (11 monitoring events, 3 replicates at 1 site)	0.23 – 1.43 (0.44)	Gros Cap
	0.30 – 1.33 (0.70)	Bellevue Park
	0.27 – 1.27 (0.54)	Bell's Point
	<MDL – 1.21 (0.50)	Echo Bay
	0.19 – 1.21 (0.44)	Richards Landing

Environmental standard: ≤ 1.5 mg/L

In 2013, total nitrogen was lowest (0.24 mg/L) in water samples from Richards Landing and highest (0.99 mg/L) in water collected from Echo Bay. Mean total nitrogen ranged from 0.36 mg/L for Richards Landing to 0.80 mg/L for Bellevue Park, which had the second highest single reading of 0.92 mg/L.

During the 2014 field season, the lowest total nitrogen concentration of 0.19 mg/L was in water collected at Echo Bay on September 10. The high value for total nitrogen was 1.63 mg/L found in water samples collected at both Gros Cap and Bellevue Park on August 6. Mean total nitrogen ranged from 0.72 mg/L at Echo Bay to 0.85 mg/L at Bellevue Park.

In 2015, the lowest total nitrogen value was <MDL from water collected at Echo Bay on September 1. A high of 1.43 mg/L was from water samples collected at Gros Cap on September 14. Mean total nitrogen was greatest (0.70 mg/L) at Bellevue Park and lowest (0.44 mg/L) at both Gros Cap and Richards Landing.

Overall (Figure 38) total nitrogen ranged from 0.19 mg/L to 1.63 mg/L with mean values from 0.38 mg/L to 0.85 mg/L.

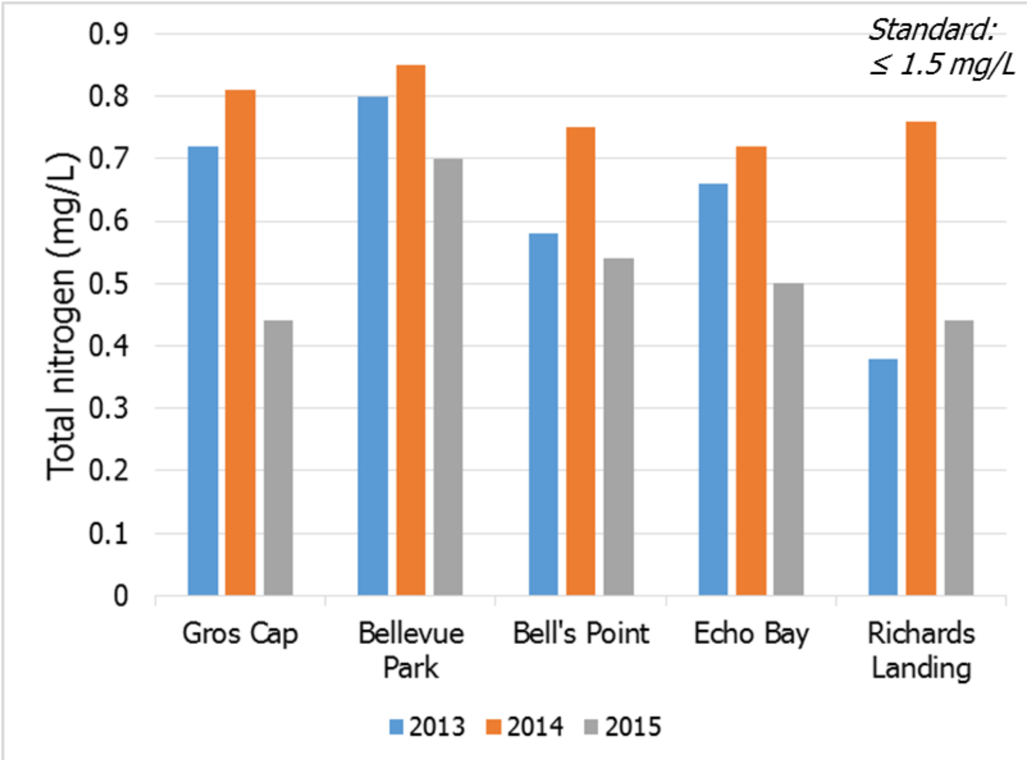

Figure 38: Total nitrogen measured in water samples collected in the St. Marys River AOC

When total nitrogen was approximately separated into its components, based on mean levels of total ammonia, organic nitrogen (TKN-total ammonia), and nitrate (Figure 39), in most cases, organic nitrogen made up the majority of the nitrogen measured.

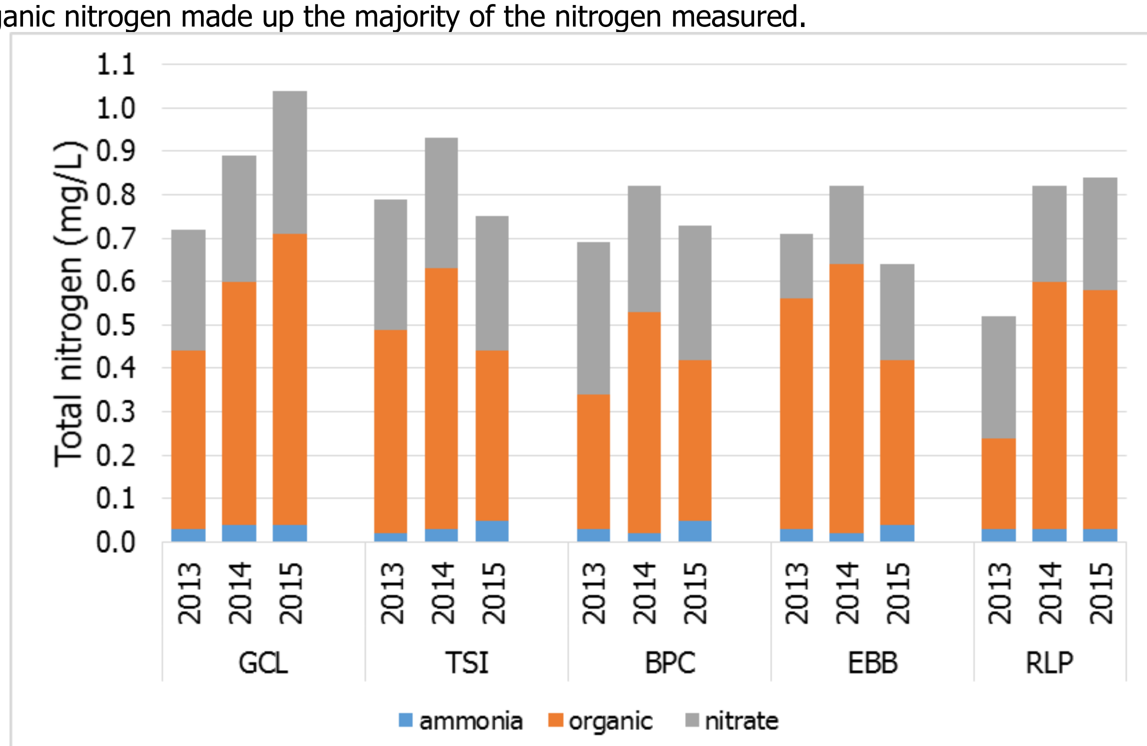

Figure 39: Total nitrogen separated by type in water samples from the St. Marys AOC

Discussion

Methods and Monitoring Site Characteristics

Water quality monitoring from 2013-2015 was successful in collecting the scientific data required to allow a re-assessment of the Eutrophication and Undesirable Algae, and Degradation of Aesthetics beneficial BUIs in the Canadian portion of the St. Marys River AOC.

The chosen monitoring sites remained accessible during the 3 years of work, and retained the characteristics appropriate for the purpose of the study. The protocols used for the collection of aesthetic, physical, and chemical parameters, worked well and yielded consistent results. Laboratory analysis of water samples was always done in a professional and timely manner.

There were few deviations from the work schedule, as set out in the progress reports submitted as required under the provincial and federal funding agreements for the project. In 2014 and 2015, monitoring did not occur in April, as anticipated, due to cold weather conditions. In addition, in both years, only one field date was possible in October, due to budgetary constraints. The final deadlines for reporting were also adjusted from fall 2015 to fall 2016 in order to accommodate a leave by the Field Technician.

Aesthetic, Physical, and Chemical Parameters

Visual Water Clarity, Total Suspended Solids, and Turbidity

Visual observations of clear water, maximum Secchi depth readings, almost exclusive maximum turbidity tube measurements, and generally lower readings for total suspended solids and turbidity, indicated that water was overwhelmingly clear and free of turbidity at the Gros Cap, Bellevue Park, and Bell's Point monitoring sites.

Higher values for turbidity and total suspended solids, lower turbidity tube readings, some Secchi depths below maximum, and visual observations of slight to moderate turbidity, showed that surface waters were relatively less clear at the Echo Bay and Richards Landing sites.

When examining the dates in which turbidity was evident and measureable, typically the weather included rain, recent rain, wind, and wave action. Previous study of water clarity in Lake Superior has shown turbidity events to be influenced by both wind and precipitation, which may act to decrease water clarity by causing shore erosion, runoff, and sediment resuspension (Stortz et al. 1976).

Both precipitation and wind can explain the uncharacteristically low turbidity tube reading (23 cm), and higher total suspended solids (12.6 mg/L) and turbidity (12.6 NTU), measured in waters from Gros Cap on June 24, 2014. While monitoring was being done, it was raining and a temporary stream was running into the river immediately upstream of the sampling location. Once particulate matter carried in the stream made it to the river, wind and wave action brought it into close proximity to the monitoring area. The intermittent nature of the runoff accounts for some of the seemingly inconsistent observations of water clarity made on that date.

Wind, wave action, rain, and runoff, can also be linked to observations of slight to moderate turbidity, lower field measurements of water clarity, and higher laboratory readings of total suspended solids and turbidity, at Echo Bay and Richards Landing. In both 2014 and 2015, the highest total suspended solids levels (37.2 mg/L at Richards Landing and 44.0 mg/L at Echo Bay) and greatest turbidity readings (23.5 NTU at Echo Bay and 18.3 NTU also at Echo Bay) were found in water samples collected on days when there was wind, and had been previous rain.

Human activities in proximity to the monitoring sites, could also help to explain the decreased water clarity at Echo Bay and Richards Landing. There is some evidence that motorboat traffic can increase turbidity through the resuspension of sediments in shallow water areas (Ailstock et al. 2002; Alexander & Wigart 2013). However, research indicates that this might account for an increase of only 1.2 NTU (Alexander & Wigart 2013) to 1.4 NTU (Ailstock et al. 2002), depending on the intensity of boating. Therefore, it is more likely that shore-based activities such as boat launching (May 20, 2015 TSS of 44.0 mg/L and 18.3 NTU at Echo Bay) and beach maintenance (July 5, 2015 TSS of 35.7 mg/L and 8.5 NTU at Richards Landing), combined with weather, led to the highest readings for the water clarity parameters.

Since all monitoring sites were at some time influenced by weather and human activity, the trend of lower visual water clarity at the two most downstream sites, can also be explained by the substrate type and shoreline characteristics. Unlike Gros Cap and Bellevue Park, where the river bottom was mainly rocky, the substrate at both Echo Bay and Richards Landing was observed to contain sand and silt. These finer types of materials are more easily resuspended in the water column, and more likely to cause turbidity, than larger particles like rocks and pebbles (CCME 2002).

The fact that water clarity was not decreased at Bell's Point, which also had a sandy substrate, can be explained by the observed higher velocity of water at that site, and the different shoreline features compared to both Echo Bay and Richards Landing. Kauss (1991) found that water velocity varied within the St. Marys River with nearshore wetland areas (more comparable to the Echo Bay and Richards Landing sites) having almost no current. Lower water velocities, combined with wetland vegetation, and a more protected shoreline, likely lead to increased fine sediment retention at Echo Bay and Richards Landing (Kauss 1991). This translates into observed and measureable turbidity when the sediments are resuspended (Stortz et al. 1976).

The relatively lower water clarity at the Echo Bay monitoring site (actually in the Lake George region of the St. Marys River) may additionally be caused by localized road runoff (water drains from the nearby bridge during rain events) and water entering the area from the adjacent Echo Bay. Kauss (1991) found that tributaries could have significant localized impacts on nearshore turbidity, especially during times of increased flow, such as following precipitation events.

The mean total suspended solids levels from this monitoring project (1.7 mg/L to 11.3 mg/L) are comparable to, but generally less than, mean concentrations of 1.0 mg/L to 52.0 mg/L measured in nearshore surface waters of southwestern Lake Huron (Howell et al. 2014). Although the actual range of values measured for total suspended solids in the St. Marys River (1.7 mg/L to 44.0 mg/L) falls within the range seen in Lake Huron, levels are probably greater in the Lake Huron study due to a larger number of eutrophic tributary inputs in the area investigated for that work (Howell et al. 2014).

When looking at the total suspended solids results, 4 values (44.0 mg/L at Echo Bay and 34.8 mg/L, 35.7 mg/L, 37.2 mg/L at Richards Landing) exceeded the 20 mg/L mark under which water is considered to be clear and free of turbidity (Michigan 2013). However, as discussed earlier, both weather and localized human activities can probably account for those values, and not industrial and municipal wastewater discharges, which were linked with increased total suspended solids and decreased water clarity in the St. Marys River in the past (CCME 2002; RAP 1992).

The range of turbidity values (0.3 NTU to 23.5 NTU) from this project falls within the published range of St. Marys River turbidity readings of <1 to 50 NTU in Kauss (1991). The mean readings (0.7 NTU to 16.2 NTU) were also comparable to, but less than, those measured in coastal wetlands (4.5 NTU to 50.6 NTU) in the St. Marys River AOC (Carpin Beach, Echo Bay, and Lake George) (ECCCCWS 2015).

When looking at water quality, although natural high turbidity occurs, levels in the range of 0-20 NTU are considered normal (CCME 2002). Less clear water may indicate higher concentrations of viruses, bacteria, and microscopic algae, some of which may have negative environmental and human health effects (Health Canada 2012).

The majority of turbidity readings taken in the present study were <20 NTU. The only exception to this were the turbidity readings from Echo Bay on October 6, 2014 (23.0, 23.3, and 23.5 NTU). Previous rain, wind, and wave action, can explain the high levels on this date. The range of mean values for turbidity (2013-2015) from 0.7 NTU to 16.2 NTU, all fall within the 0-20 NTU acceptable range. When considering aesthetics, it is also important to note that all values were under the 50 NTU aesthetic objective defined in the Canadian recreational water quality guidelines (Health Canada 2012).

If it is considered that there is naturally more turbidity at Echo Bay and Richards Landing, then the Degradation of Aesthetics beneficial use delisting criterion of river waters being free of "unnatural turbidity" has been met (RAP IA 2015).

Water Colour

Water colour was always clear at Gros Cap, Bellevue Park, and Bell's Point, with light yellow to light brown colouration noted in several samples from Echo Bay and Richards Landing. Many natural factors contribute to water colour, including minerals, plant debris, plankton, suspended sediments, and dissolved organic matter (CCME 2001; Ma & Green 2004). Sources directly attributable to human activities, such as fertilizers, eroded soil, and industrial and municipal effluents, can also influence water colour (CCME 2001).

Given that both Echo Bay and Richards Landing had relatively higher total suspended solids, turbidity, and dissolved organic carbon, as well as finer substrates and adjacent wetland vegetation, it is likely that the observed water colour can be attributed mainly to plant debris, suspended sediments, and dissolved organic matter.

The yellow-brown colour of some microscopic phytoplankton, particularly diatoms and dinoflagellates (CCME 2001), may also help to explain the yellow-brown colouration of the water samples. In their 2005 study, Reavie et al. found evidence of diverse plankton assemblages, including diatoms, in proximity to the Echo Bay monitoring site (Lake George area of the St. Marys River).

Given that the water colours detected were likely of natural origin, the river water samples investigated during this project meet the Degradation of Aesthetics beneficial use delisting criterion of being free of "unnatural colour" (RAP IA 2015).

Water Odour
Only once during the 3 year project was an odour detected in a river water sample. This was in 2013 at Bellevue Park. On all subsequent visits no unnatural odours were perceived.

Since the odour was not reproducible, it is suggested that it consisted of an isolated event. The weight of evidence indicates that the delisting criterion for the Degradation of Aesthetics beneficial use which states that the river should be devoid of substances which produce a persistent "unnatural odour" (RAP IA 2015) has been met.

Algae and Chlorophyll a
Algae were mainly observed attached to solid substrates (rocks, vegetation, and cement steps) at Gros Cap, Bellevue Park, Bell's Point, and Echo Bay. Occasionally small pieces or strands were seen floating or sitting on the river bottom. Since the substrates at Bell's Point, Echo Bay, and Richards Landing were sandier, this may be the reason why less algae were observed at those monitoring sites.

Chlorophyll a levels did not seem to be closely connected to visual observations of algae. Although the majority of visual observations of algae were made at Gros Cap, it generally had lower chlorophyll a levels than Echo Bay and Richards Landing, where algae were less often seen. Perhaps the decreased water clarity at the downstream sites, indicated increased concentrations of microscopic algae (CCME 2001). Generally warmer water temperatures (CCME 2002) combined with higher phosphorus levels (CCME 2004) at Echo Bay and Richards Landing, would allow for greater algal productivity at those sites. Observable algae, and algae floating in the water column on days of increased wind and waves, may explain the trend of higher chlorophyll a levels in water samples collected from Bellevue Park.

The range of mean values for chlorophyll a (0.8 µg/L to 1.9 µg/L) are comparable to the mean concentration of 0.9 µg/L for the St. Marys River (Kauss 1991) and levels in the nearshore surface waters of Lake Superior (0.5 µg/L) and the North Channel of Lake Huron (1.1 µg/L) (Gregor & Rast 1982). Literature chlorophyll a readings of 0.8 µg/L (Kumar et al. 2008), and 0.6 to 1.8 µg/L (Ivanikova et al. 2007), from nearshore surface waters of Lake Superior, also fall within the 0.6 µg/L to 8.3 µg/L range of values collected during this project.

All of the values for chlorophyll a were under the 10 µg/L maximum recommended in the Stage 2 Remedial Action Plan (RAP 2002). Furthermore, no large clumps or mats of algae were observed. This meets the Eutrophication and Undesirable Algae beneficial use delisting criterion of the river being free from persistent or re-occurring "large algal blooms" (RAP IA 2015).

Debris
Only natural types of debris were observed. There were no sheens, oil, grease, solids, or scums detected at any time. Any shoreline garbage could be attributed to local recreational use, not municipal or industrial sources.

These observations meet the Ontario Provincial Water Quality Objectives (PWQO), for oil and grease, of not having oil or petrochemicals present in concentrations that "can be detected as a visible film, sheen or discolouration on the surface" or "form deposits on shorelines and bottoms sediments that are detectable by site" (MOECC 1999, Appendix B, page 22). The river conditions also meet the Degradation of Aesthetics beneficial use delisting criterion of being free of "objectionable deposits" (RAP IA 2015) and support the language in the Stage 2 Remedial Action Plan which indicates that river waters should be devoid of oil slicks and surface scums (RAP 2002).

Field Water pH

When considering the years when most accurate pH measurements were taken (2014-2015) the range of mean values was from 7.8 to 8.2. These mean readings are comparable to mean literature values of 7.2 to 8.5 for coastal wetlands (Carpin Beach, Echo Bay, and Lake George) in the St. Marys River AOC (ECCCCWS 2015) and pH readings of 7.8 to 8.2 for Lake Superior (Weiler 1978). The full range of pH values collected in this study (7.3 to 8.8) was also in the range of (6.7 to 8.4) previously published pH readings for the St. Marys River (Kauss 1991).

Although 5 individual pH readings (at 8.6, 8.7 or 8.8) taken at either Bellevue Park or Gros Cap, exceeded the recommended pH range, all mean pH values were within the PWQO range of 6.5 to 8.5 which is recommended to "protect aquatic life" and avoid "irritation to anyone using the water for recreational purposes" (MOECC 1999, Appendix B, page 22).

Field Water Temperature

Field water temperature (2.8°C to 23.4 °C) varied correspondingly with air temperature (7.0°C to 27.7 °C) and typically fell within the range of expected values (0°C to 22 °C) for the St. Marys River (Kauss 1991; RAP 1992). Summer temperatures in the range of 18.0 °C to 25.7 °C measured in St. Marys River coastal wetlands (Carpin Beach, Echo Bay, Lake George), show that nearshore areas may have water temperatures greater than 22°C during the warmer months (ECCCCWS 2015).

The PWQO for temperature states that "the natural thermal regime of any body of water shall not be altered so as to impair the quality of the natural environment" (MOECC 1999, Appendix B, page 25). Given that the water temperatures taken during the 3 year investigation fell within the range of published values, it can be concluded that the thermal regime, was normal.

Dissolved Oxygen

Although dissolved oxygen levels varied somewhat between monitoring sites, the total range (8.2 mg/L to 13.9 mg/L) as well as the spread of mean values (9.6 mg/L to 11.2 mg/L) indicated that adequate dissolved oxygen was available at all of the sampling locations.

The dissolved oxygen content of surface waters can be influenced by factors such as temperature, turbulence, and biological processes (CCME 1999). Dissolved oxygen readings for all sites varied as predicted with temperature, with the greatest dissolved oxygen levels being found at the sites with the lowest temperatures. These results were expected since oxygen saturation increases with decreased water temperature (CCME 1999). Correspondingly, dissolved oxygen levels were greater at Gros Cap, Bellevue Park, and Bell's Point, compared to Echo Bay and Richards Landing.

Increased turbulence, due to wave action and greater current velocity, at the 3 most upstream sites, also helps to explain why they had higher dissolved oxygen levels. Although current velocity was not measured in this study, Kauss (1991) found that current velocities varied considerably in the St. Marys River, with water velocity being greatest in areas closer to the main channels and the least along nearshore wetland areas, the latter more representative of the Echo Bay and Richards Landing sites. Increased turbulence leads to higher dissolved oxygen concentrations through greater incorporation of oxygen into surface waters (CCME 1999).

Biological activity at Echo Bay and Richards Landing also likely accounted for the lower dissolved oxygen at these sites. Since both monitoring sites had relatively lower water clarity (which can be indicative of organic material and microbiological activity), as well as measurable chlorophyll a (phytoplankton), and visible wetland vegetation, it is likely that biological processes requiring oxygen (CCME 1991), contributed to the lower dissolved oxygen levels at those sites.

Regardless of the variability between sites, all dissolved oxygen levels were greater than the PWQO of 8 mg/L required for waters containing the most sensitive cold water species, including salmonids (MOECC 1999). Since all sites had more than adequate dissolved oxygen levels, therefore, it can be concluded that the Eutrophication and Undesirable Algae beneficial use delisting criterion of the river being free from "oxygen stress" was met (RAP IA 2015).

Total Phosphorus

Phosphorus is often the limiting nutrient in terms of productivity in aquatic ecosystems (CCME 2004). Excess inputs of phosphorus, usually of human origin, have been demonstrated to lead to dramatic increases in plant and algal biomass (CCME 20014). Undesirable effects of algal blooms include decreased ecosystem biodiversity, increased turbidity, and oxygen depletion in affected waters (CCME 2004). Degraded aesthetics, restricted recreational activities, and human health effects, are also linked to high levels of phosphorus in aquatic systems (CCME 2004).

The range of measurable values collected for total phosphorus of 0.002 mg/L to 0.058 mg/L, with mean values from 0.002 mg/L to 0.020 mg/L, were comparable to, but generally greater than, literature levels for the St. Marys River, Lake Superior, and the Lake Huron North Channel. Kauss (1991) found a mean total phosphorus concentration of 0.013 mg/L (range: 0.001 mg/L to 0.031 mg/L) in the St. Marys River. Lake Superior mean total phosphorus has been measured at 0.005 mg/L (Schelske et al. 2006), 0.006 mg/L (Gregor & Rast, 1982), and a range of 0.003 mg/L to 0.006 mg/L (Weiler 1978). Mean total phosphorus in the Lake Huron North Channel has been determined to be 0.007 mg/L (Gregor & Rast, 1982).

However, mean total phosphorus of 0.020 mg/L to 0.040 mg/L measured in St. Marys River AOC coastal wetlands (Carpin Beach, Echo Bay, and Lake George) (ECCCCWS 2015) and mean total phosphorus readings of 0.004 mg/L to 0.066 mg/L, collected in shallow nearshore areas of southwestern Lake Huron (Howell et al. 2014), do approximate the higher readings taken in water samples from the St. Marys River during this project. Since research has shown that phosphorus concentrations tend to be greater in shallower, nearshore waters (Schelske et al. 2006), is it probably best to compare the values collected in this project to those in other nearshore areas, and not as much to the more oligotrophic Lake Superior and Lake Huron North Channel.

The typically higher levels of phosphorus at Echo Bay, as compared to the other monitoring sites, may be explained by the flushing of agricultural-based inputs (e.g. fertilizers containing phosphorus) from Echo Bay into Lake George, where water samples were collected (Howell et al. 2014). This may be supported by the fact that most high readings were taken during the spring months (May and June) and usually after periods of runoff-inducing rain. Tributary inputs, often increased by precipitation (Howell et al. 2014) such as from Echo Bay to the St. Marys River, have been shown to be important sources of phosphorus in aquatic systems (Gregor & Rast, 1982).

Often when phosphorus was elevated above levels measured during other sampling dates, there was wind and wave action. Both Howell et al. (2014) and Gregor & Rast (1982) concluded that higher levels of total phosphorus were related to shore erosion and sediment resuspension, which may be increased during wind and wave events.

The majority of total phosphorus readings fell below the PWQO of 0.030 mg/L for rivers and streams (MOECC 1999). In 2014, maximum values of 0.031 mg/L (Richards Landing), 0.038 mg/L (Bellevue Park), and 0.058 mg/L (Echo Bay), fell above that number. All mean values (0.002 mg/L to 0.020 mg/L) were less than the water quality standard of 0.030 mg/L.

Phosphorus levels above 0.035 mg/L are typical of eutrophic environments while readings from 0.004 to 0.035 mg/L indicate oligotrophic to mesotrophic conditions (CCME 2004). However, although fluctuations of phosphorus levels above normal background conditions should be monitored (CCME 2004), evidence from this project, including the lack of large and persistent algal blooms, indicates that phosphorus inputs are not leading to eutrophication at the sites investigated.

Dissolved Organic Carbon

Dissolved organic carbon refers to the fraction of total organic carbon in a water sample, which has been passed through a 0.45 μM filter (personal communication 2015, Testmark Laboratories) to remove the larger particulate organic carbon (BC 2015). The amount of dissolved organic carbon in aquatic ecosystems is influenced by the amount of available organic material, which may come directly from within a water body (e.g. phytoplankton or aquatic plants) or be transported from the nearby landscape (e.g. leaves or soil) (BC 2015). Human activities such as shoreline alteration, agriculture, and the release of industrial and municipal wastewaters, may also contribute to the dissolved organic carbon fraction (BC 2015).

When comparing the results from this project (range: 1.5 mg/L to 10.8 mg/L, means: 1.8 mg/L to 6.9 mg/L) to published values, they are similar to, but generally greater than, dissolved organic carbon levels measured in Lake Superior (1.3 mg/L) (Ma & Green 2004) and nearshore areas of southwestern Lake Huron (1.7 mg/L to 3.0 mg/L) (Howell et al. 2014).

The highest dissolved organic carbon levels measured at the monitoring sites corresponded with rain events, as well as wind and wave action. In the case of the uncharacteristically elevated dissolved organic carbon concentration at Gros Cap on June 24, 2014 (10.8 mg/L), runoff was seen directly entering the river and increasing turbidity within the sampling area.

Generally higher levels of dissolved organic carbon at both Echo Bay and Richards Landing, compared to the other monitoring sites, were often accompanied by lower water clarity and the presence of a water colour, both characteristics which are correlated with increased dissolved organic carbon (BC 2015; Ma & Green 2004). Sources of dissolved organic carbon at the two most downstream sites may have included: phytoplankton (measurable chlorophyll a and turbidity), aquatic plants (observed), and agricultural runoff (land use within the watershed).

With the one exception at Gros Cap, dissolved organic carbon values at Gros Cap, Bellevue Park, Bell's Point, and Richards Landing, were less than the 5 mg/L considered normal in many lakes and rivers (BC 2015). However, dissolved organic carbon values may be very site-specific and vary according to seasonal inputs and short term events such as storms (BC 2015). It is suspected that weather events had an influence on the dissolved organic carbon concentrations at Echo Bay, although it appeared that they were more influential there than at the other sites. Perhaps this indicates that there are more sources of dissolved organic carbon at Echo Bay than the other monitoring sites.

There are no PWQO for dissolved organic carbon in Ontario. The recommended criterion for the protection of aquatic life in British Columbia states that concentrations should stay within seasonally-adjusted background levels (BC 2015). When looking at the 2014 to 2015 dissolved organic carbon data for Echo Bay, the minimum (1.7 mg/L in 2014 and 1.8 mg/L in 2015) and maximum (7.5 mg/L 2014 and 6.2 mg/L 2015) levels are similar for the 2 years. This could indicate that, although dissolved organic carbon is higher at Echo Bay, it is staying within regular seasonal levels. Additionally, the 2014 and 2015 mean values for dissolved organic carbon at Echo Bay, 4.1 mg/L and 3.6 mg/L respectively, are under the 5 mg/L considered normal, and demonstrate that higher peaks in dissolved organic carbon levels are not likely a regular occurrence.

Un-ionized Ammonia, Ammonium and Total Ammonia

Ammonia is readily soluble in water and can be found as un-ionized ammonia and/or the ammonium ion (CCME 2010). Sources of ammonia in aquatic environments may include, agricultural fertilizers, as well as industrial (e.g. steel mills), municipal (e.g. wastewater treatment plants), and residential releases (CCME 2010). The natural breakdown of organic wastes also leads to the production of ammonia and other forms of nitrogen (CCME 2010; Smith & Smith 2006). All ammonia levels are reported in the form of ammonia as nitrogen.

Un-ionized ammonia was the least detected analyte in St. Marys River water quality samples. When above minimum detection limits, levels were generally low (range: 0.002 mg/L to 0.020 mg/L, means: 0.002 mg/L to 0.006 mg/L). When compared to previously published values of un-ionized ammonia (0.020 mg/L to 0.046 mg/L) for the St. Marys River (RAP 1992), the concentrations measured in the current project were generally much lower.

The PWQO for un-ionized ammonia is 0.020 mg/L. Despite a project high peak of un-ionized ammonia, at Bell's Point on October 5, (0.020 mg/L) this level was not exceeded.

Since un-ionized ammonia was found in low concentrations, ammonium contributed the major part to total ammonia. Ammonium levels from this project (range: 0.02 mg/L to 0.26 mg/L, mean values: 0.02 mg/L to 0.05 mg/L), were typically higher than the maximum value of 0.02 mg/L reported by Kumar et al. (2007) for Lake Superior surface waters.

Measurable total ammonia varied from 0.02 mg/L to 0.28 mg/L with mean values from 0.02 mg/L to 0.05 mg/L. These levels were high when compared to total ammonia concentrations for Lake Superior of 0.002 mg/L to 0.006 mg/L (Weiler 1978). However, the mean values were similar to mean total ammonia levels of 0.01 mg/L to 0.04 mg/L measured in St. Marys River AOC coastal wetlands (Carpin Beach, Echo Bay, and Lake George) (ECCCCWS 2015). When compared to total ammonia levels of 0.05 mg/L to 2.85 mg/L measured in the St. Marys River in the past (RAP 1992), the values collected in this study constituted a distinct improvement in water quality.

The highest total ammonia values were gathered on dates when both un-ionized ammonia and ammonium were measurable. In 2014, the greatest levels were found in samples collected on June 10 from Gros Cap (0.15 mg/L) and Bellevue Park (0.12 mg/L). The field notes from that date do not point to weather as a major contributing factor. However, there were movie crew trailers parked at the shoreline at Gros Cap on that date and dogs in the water at Bellevue Park. This points to human activities as possibly influencing the results.

In 2015, the highest total ammonia concentrations were detected on 3 different dates. Levels were comparably high at Bellevue Park (0.21 mg/L) on May 20, Echo Bay (0.13 mg/L) on July 7, and Bell's Point (0.28 mg/L) on October 5. On both May 20 and July 7, weather may have been a factor, as there had been previous rain and wind. Both runoff and wave action have been demonstrated to contribute to higher nutrient levels in nearshore areas (Howell et al. 2014). Field notes also indicate that human activities may have played a role on both of those dates. On May 20 there were again dogs noticed in the water at Bellevue Park. On July 7 there were tire tracks leading into the water at Echo Bay, suggesting that the area was actively being used as a boat launch on that day. The reading at Bell's Point on October 5 is difficult to explain. Perhaps there was an upstream release that was captured in water samples collected on that date. However, other nutrient levels for that date are normal, and not indicative of any large scale event.

According to the CWQG for ammonia, concentrations of greater than 0.1 mg/L are indicative of organic pollution (CCME 2010). The maximum values discussed above (0.12 mg/L to 0.28 mg/L), are all greater than the 0.1 mg/L threshold.

Ammonia toxicity is pH and temperature dependent, with higher pH values and warmer temperatures increasing toxicity (CCME 2010). Using pH and temperature values closest to the highest values encountered when monitoring (pH 9, 25°C), the CWQG standard for total ammonia as nitrogen is 0.04 mg/L (CCME 2010). The mean values for total ammonia (0.02 mg/L to 0.05 mg/L) collected during the project are primarily under this level. If using the average pH and temperature values across all monitoring sites and dates (pH 8, 10°C) then the CWQG standard increases to 0.86 mg/L (CCME 2010), which is greater than all of the total ammonia results calculated for the present study.

Nitrite

Since nitrite was only found at detectable levels once during 3 years of monitoring (0.06 mg/L at Richards Landing on July 14, 2014), most of the time levels were quite low. If present on other occasions it must have been at concentrations lower than 0.03 mg/L (the method detection limit).

The low concentrations of nitrite may be explained by active nitrification or denitrification processes, which would have transformed any nitrite into either nitrate or ammonium, both of which were found at measurable concentrations (CCME 2012). It is difficult to explain the measurable level of nitrite detected once at Richards Landing. Although weather (previous rain and wind) may have been a factor in mobilizing nitrite into the water column, it is curious that this did not seem to play a role on other dates.

Given that the CWQG for nitrite as nitrogen is 0.06 mg/L (CCME 2007), nitrite levels met the water quality standard.

Nitrate

Nitrate is often the predominant form of nitrogen found in surface waters, so it is not surprising that it was detected at measurable concentrations (CCME 2012). Although there are natural sources of nitrates, such as the decomposition products of organic material, inputs are often a direct result of, or enhanced by, human activities (CCME 2012). Nitrates may enter waterways through atmospheric deposition (e.g. industrial emissions), agricultural runoff (e.g. manure and fertilizers), industrial effluents (e.g. steel and pulp and paper mills), and municipal wastewaters (CCME 2012). All nitrate levels are reported in the form of nitrate as nitrogen.

The mean measurable values collected for nitrate (range: 0.15 mg/L to 0.33 mg/L) were comparable to published nitrate levels for Lake Superior. In various studies nitrate concentrations in Lake Superior were found to be 0.30 mg/L (Weiler 1978), 0.35 mg/L (Sterner et al, 2007), 0.31 mg/L (Kumar et al. 2008), 0.30 mg/L to 0.34 mg/L (Schelske et al. 2006), and 0.31 mg/L to 0.38 mg/L (Ivanikova et al. 2007). Similar nitrate levels of 0.27 mg/L to 0.34 mg/L were also measured in Lake Huron (Schelske et al. 2006).

Lower values, especially as compared to the full range of nitrate concentrations (0.18 mg/L to 0.56 mg/L), for nitrate of 0.02 to 0.18 mg/L were found in a study of coastal wetlands (Carpin Beach, Echo Bay, and Lake George) in the St. Marys River AOC (ECCCCWS 2015). This supports the trend of the highest nitrate levels being at the 3 most upstream sites (Gros Cap, Bellevue Park, and Bell's Point), which were more lake-like, compared to the 2 most downstream locations (Echo Bay and Richards Landing), which had more characteristics of wetlands. Even though nitrates were present at all sites, biological assimilation may have been greater downstream, where vegetation was capable of using bioavailable nitrates as a primary nitrogen source (CCME 2012).

Conversely, it is likely that, given the more oligotrophic nature of the upstream monitoring sites, nitrate utilization was more limited at those locations, leading to higher nitrate concentrations. Researchers have found that in the nutrient poor waters of Lake Superior, low phosphorus (Schelske et al. 2006; Sterner et al. 2007) and low carbon (Kumar et al. 2008) levels limit nitrate utilization by phytoplankton and bacteria.

Given the land uses surrounding them, it was more probable for there to be nitrates from agricultural runoff at Echo Bay and Richards Landing. Since both showed comparatively lower concentrations, this suggests that agricultural inputs are not important at those sites, or if they are present, the processes of assimilation and sedimentation are removing nitrates from the water column (CCME 2012).

Since nitrate levels at Gros Cap, the mouth of the river, were similar to those downstream at Bellevue Park and Bell's Point, it can be expected that industrial, urban, and municipal effluent sources between those sites, are not contributing greatly to surface water nitrate concentrations, as they may have in the past. This is not completely surprising given the stronger industrial effluent regulations, closure of the pulp and paper mill, and upgrades to municipal wastewater treatment, which have led to reduced anthropogenic nutrient inputs since the St. Marys River was first designated as an Area of Concern (RAP IA 2015).

All measured values of nitrate were well below the CWQG of 3.0 mg/L for nitrate as nitrogen (CCME 2012). The concentrations also generally fell within the range (0.09 mg/L to 0.90 mg/L) for mesotrophic waters and never exceeded the 0.90 mg/L indicative of eutrophic conditions (CCME 2012).

Total Nitrogen

Total nitrogen was a calculation of all of the nitrogen sources available: ammonia, nitrite, nitrate, and organic nitrogen. In most cases, organic nitrogen (determined using total Kjeldahl nitrogen) made up the greater portion, with nitrate being the greatest part at Bell's Point and Richards Landing in 2013. Ammonia always made up the smallest fraction of total nitrogen.

When compared to previous total nitrogen levels measured in the St. Marys River of mean: 0.41 mg/L and range: 0.26 mg/L to 0.67 mg/L (Kauss 1991), the levels from the present water quality study of means: 0.38 mg/L to 0.85 mg/L, and total range: 0.19 mg/L to 1.63 mg/L, are higher.

As alluded to earlier, possible nitrogen sources include urban and agricultural runoff, atmospheric deposition, industrial and municipal effluents, and resuspension of sediments (Schelske et al. 2006; Finlay et al. 2007; Sterner et al. 2007). Research has also shown that non-point sources may contribute almost twice as much as point sources to human inputs of nitrogen into aquatic ecosystems, and that small but concentrated releases may have large localized effects (CCME 2012). Since some links between nitrogen-containing nutrients and human activities have been suggested by the results of this research, it is possible that small anthropogenic inputs do play a role in localized nutrient enrichment in the St. Marys River.

When compared to average total nitrogen levels in streams, values from this project were within the ranges expected in oligotrophic (<0.7 mg/L) or mesotrophic (0.7 mg/L to 1.5 mg/L) environments (CCME 2012). Since few values were >1.5 mg/L, this may indicate localized, but not systemic, eutrophication (CCME 2012).

Table 27 summarizes the results for all of the aesthetic, physical, and chemical parameters investigated, and displays them compared to water quality standards and historical values for the St. Marys River. Mean values for quantitative results were used for the majority of entries. NA indicates that data was not available.

Table 27: Comparison of water quality data to environmental standards and historical values

Parameter	**Year 1 (2013)**	**Year 2 (2014)**	**Year 3 (2015)**	**Environmental Standards**	**Historical Values**
Visual water clarity	Clear-slightly turbid	Clear-moderately turbid	Clear-moderately turbid	No unnatural turbidity (IA 2015)	Turbidity standards exceeded (RAP 1992)
Total suspended solids (mg/L)	3.2-11.3	2.3-7.5	1.7-7.5	≤20 normal (MI 2013)	NA
Turbidity (NTU)	1.1-16.2	1.1-10.0	0.7-7.2	≤20 normal (CCME 2002)	<1-50 (Kauss 1991)
Water colour	Clear-light yellow	Clear-light brown	Clear-light brown	No unnatural colour (IA 2015)	NA
Water odour	None-faint sewage/fishy	None	None	No unnatural odour (IA 2015)	NA
Algae	None	Floating, attached, substrate	Floating, attached	No large clumps or mats of algae (IA 2015)	Excessive amounts in bays and slow moving areas (RAP 1992)
Chlorophyll a (µg/L)	0.9-1.2	1.2-1.9	0.8-1.5	≤10 (RAP 2002)	0.9 (Kauss 1991)
Debris	Natural	Natural	Natural	Devoid of any substances that produce a persistent objectionable deposit (IA 2015)	Oil slicks, floating scum, oily fibrous material and woody debris; oil and grease (RAP 1992)
Water pH	6.5 (range)	7.8-8.2 (range)	7.9-8.2 (range)	6.5-8.5 (PWQO 1999)	6.7-8.4 (Kauss 1991)
Water temperature (°C)	7.0-8.0 (range)	2.8-20.4 (range)	3.3-23.4 (range)	Natural thermal regime should not be altered (PWQO 1999)	0-21 (Kauss 1991) 0-22 (RAP 1992)
Dissolved oxygen (mg/L)	9.8-10.0	9.9-11.2	9.6-10.9	≥8 for cold and warm water biota (PWQO 1999)	NA
Total phosphorus (mg/L)	0.002-0.020	0.005-0.012	0.007-0.011	≤0.03 for rivers (PWQO 1999)	0.001-0.031 (Kauss 1991)
Dissolved organic carbon (mg/L)	2.3-6.9	1.9-4.1	1.8-3.6	≤5 normal (BC 2015)	NA
Un-ionized ammonia (mg/L)	<0.002 (range)	<0.002-0.007 (range)	<0.002-0.020 (range)	≤0.020 (PWQO 1999)	0.020-0.046 (RAP 1992)
Ammonium (mg/L)	0.02-0.03	0.02-0.04	0.03-0.05	NA	NA
Total ammonia (mg/L)	0.02-0.03	0.02-0.04	0.03-0.05	≤0.04 (CCME 2010)	0.05-2.85 (RAP 1992)
Nitrite (mg/L)	<0.03	<0.03-0.06 (range)	<0.03	≤0.06 (CCME 2007)	NA
Nitrate (mg/L)	0.15-0.35	0.18-0.30	0.22-0.33	≤3.0 (CCME 2012)	NA
Total Kjeldahl nitrogen (mg/L)	0.24-0.56	0.53-0.64	0.42-0.71	NA	NA
Total nitrogen (mg/L)	0.38-0.72	0.72-0.85	0.44-0.70	≤1.5 (CCME 2012)	0.26-0.67 (Kauss 1991)

Conclusion

Eutrophication and Undesirable Algae

The delisting criterion for the Eutrophication and Undesirable Algae beneficial use impairment states that:

"*This beneficial use will no longer be impaired when comprehensive tests of the Area of Concern's water quality demonstrate the river is free from persistent or reoccurring problems associated with oxygen stress (eutrophication) and large algal blooms, as determined through a comparison to established guidelines for the relevant physical and chemical parameters* (RAP IA 2015)."

Results of water quality monitoring within the Canadian St. Marys River AOC, (2013-2015) indicate that, at the sites investigated, oxygen stress is non-existent, large algal blooms and high concentrations of chlorophyll a are absent, and the vast majority of nutrient measurements (phosphorus, carbon, and nitrogen) are below the recommended guidelines and within the levels typically found in either oligotrophic or mesotrophic, but not eutrophic, waters.

The data collected is consistent in showing that reduced inputs from point-sources has likely led to lower levels of cultural eutrophication in the St. Marys River. In future, smaller, non-point sources may be analyzed in order to determine their contributions to anthropogenic inputs.

Recommendation: Not impaired

Degradation of Aesthetics

The delisting criterion for the Degradation of Aesthetics beneficial use impairment states that:

"*This beneficial use will no longer be impaired when comprehensive tests of the Area of Concern's water quality demonstrate that the river is devoid of any substances that produce a persistent objectionable deposit, unnatural colour or turbidity, or unnatural odour, and is free from persistent or reoccurring problems associated with degraded aesthetics* (RAP IA 2015)."

Results of water quality monitoring within the Canadian St. Marys River AOC, (2013-2015) indicate that, at the sites investigated, there was no evidence of objectionable deposits, unnatural colour, unnatural turbidity, and/or unnatural odour, and therefore, no problems associated with degraded aesthetics as defined.

Recommendation: Not impaired

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Appendices

Appendix 1: Field Data Collection Sheet

FIELD DATA SHEET: Aesthetics Monitoring and Field Measurements

Area of Concern: St. Marys River **Site Description:**____________________________________

Field Team:____

Date:____________________________ **Start Time:** ________________**End Time:**______________

GPS: ____

Weather (check all that apply): Rain Today ☐ Clear ☐ Windy ☐

Air temp.:__________ °C Rain Yesterday ☐ Cloudy ☐ Other _________________________

WATER CLARITY (pick one)
Clear ☐
Slightly Turbid ☐
Moderately Turbid ☐
Highly Turbid ☐
Opaque ☐

WATER COLOUR (pick one colour and one qualifier)
Clear ☐ Brown ☐ Green ☐ Yellow ☐
Grey ☐ Black ☐ Milky-White ☐ Other____________
Light ☐ Medium ☐ Dark ☐

VISIBLE DEBRIS/OBVIOUS POLLUTION (pick all applicable)
None ☐ Natural ☐ (leaves, limbs, weeds)
Algae ☐ Film ☐ Sheen ☐ Oil ☐ Grease ☐
Trash:
Floating ☐ Fixed ☐ None ☐
Solids:
Floating ☐ Fixed ☐ None ☐
Scum:
Floating ☐ None ☐

Waterfowl:____

ODOUR (pick all applicable)
None/Natural ☐
Musty:
Faint ☐ Strong ☐ None ☐
Sewage/Fishy:
Faint ☐ Strong ☐ None ☐
Anaerobic/Septic:
Faint ☐ Strong ☐ None ☐

Comments:____

____

Substrate type:____

Water temperature:_____________ °C **pH:**________________

Water depth: 50 cm **Secchi Disc:**__________cm **Turbidity Tube:**___________cm

Number of replicates sampled:___________

Comments:____

____

____

At minimum the following photographs will be taken:

1. Upstream of the monitoring site
2. Downstream of the monitoring site
3. Perpendicular to the shoreline
4. Close-up looking directly into the water
5. Any other items of interest (algae, oil sheens, scum, foam, debris etc.)
6. Two full sample jars against a white backdrop

Photograph ID	**Subject/Comments**

Appendix 2: Monitoring Site Characteristics

NA = data not available

Table 1.1: Monitoring site characteristics for Gros Cap

Gros Cap	**Date/ Time**	**Air Temp (°C)**	**Weather**	**Waterfowl**
	2013			
	Nov 17 12:42-12:50 pm	12	Cloudy, rain today	NA
	Comments: culvert near water sampling location, rocks slippery			
	2014			
	May 14 11:01-11:47 am	8.5	Clear, slight wind, rain yesterday, some cloud, medium sized waves	None
	May 27 4:05 -4:40 pm	17.1	Clear and sunny, slightly windy causing constant wave action	None
	June 10 4:25 -5:05 pm	22.8	Clear, cloudy, quite a bit of cloud now, slight wind, increasing wave action	None
	Comments: movie crew trailers along adjacent shore, sampling upstream of active filming			
	June 24 3:55 -4:35 pm	13.1	Rain today, cloudy, rain moderate to heavy, fog and mist	None
	Comments: water column was occasionally visually turbid due to a temporary stream entering the river just upstream of the sampling site			
	July 14 3:19 -3:40 pm	18.7	Rain today, rain yesterday, cloudy, white-capped waves offshore, wind	None
	July 29 3:19 -3:42 pm	17.1	Clear, windy, waves, substantial rain 2 and 3 days ago	None
	Aug 6 3:31-3:51 pm	21.6	Clear and slightly windy with some wave action	None
	Comments: well-used recreational area, many people at site today			
	Aug 26 3:47-4:13 pm	23.5	Cloudy, windy, large white-capped waves	None
	Sept 10 3:35-4:00 pm	18.0	Rain with periods of HEAVY rainfall, cloudy, very windy, waves, wind direction from the EAST today	Gulls
	Sept 22 3:21-3:48 pm	17.3	Clear with sunny periods, very light wind but large waves present, rained 2 and 3 day ago	None
	Comments: 2 dogs in water upstream just prior to sampling replicate 3			
	Oct 6 3:35-4:03 pm	12	Cloudy but clearing with sunny periods, rain this morning, rain yesterday and substantial heavy rain over the last 3 days, high winds and big waves	Scat
	Comments: human garbage on shore, dog scat, 2 dogs entered the water during sampling			
	2015			
	May 4 3:47-4:11 pm	11.3	Clear, rain yesterday, windy with minimal waves, small icebergs near shore, 3 replicates	None
	May 20 2:35-3:03 pm	14.9	Clear, light rain yesterday, slight wind with no wave action	None
	Comments: 3 parked cars, hikers, runoff from road and car parking area			

	June 1 2:35-2:56 pm	15.6	Clear with light wind	None
	Comments: dog tracks along shoreline, people and cars			
	June 15 2:50-3:03 pm	23.3	Cloudy with sun, rain 2 days ago	None
	Comments: dog swimming upstream disturbing the substrate and algae, 3 people and 1 dog, 3 cars parked			
	July 7 2:20-2:35 pm	14.9	Cloudy, wind with high waves, rain yesterday	None
	Comments: small to large particles in water column, runoff into bay from last night's rain, 4 cars parked			
	July 21 2:00-2:27 pm	17.5	Clear, wind with waves	2 terns
	Comments: 3 vehicles parked, people walking along the shore, particles in water column			
	August 4 2:23-2:35 pm	18.8	Cloudy with sun, wind with moderate to high waves	None
	Comments: small floating particles in water column, 2 vehicles parked			
	August 18 2:14-2:26 pm	20.5	Rain today, rain yesterday, cloudy with sun, wind with light waves	None
	Comments: run-off from the parking area entering the river just upstream of the sampling location, boats offshore, 4 vehicles parked			
	September 1 2:17-2:31 pm	27.7	Cloudy with sun, hazy, calm	None
	Comments: sampled upstream of regular location due to recreational use, swimmers and walkers, runoff from road observed, 4 vehicles parked			
	September 14 2:19-2:33 pm	24.6	Clear, wind with high waves	1 gull
	Comments: 1 vehicle parked, strong wave action			
	October 5 1:35-1:47 pm	15.5	Clear, clouds in the distance	None

Table 1.2: Monitoring site characteristics for Bellevue Park

Bellevue Park	**Date/ Time**	**Air Temp (°C)**	**Weather**	**Waterfowl**
	2013			
	Nov 16 3:57-4:08 pm	7	Cloudy, rain yesterday	NA
	2014			
	May 14 12:40-1:15 pm	14.7	Clear, slight wind, rain yesterday, some clouds, medium-sized waves	Gull
	Comments: 3 dogs in water prior to sampling, dog scat and human garbage on shore			
	May 27 2:40 -3:11 pm	20.4	Clear and sunny, slightly windy causing small white caps	Terns, Gulls Loon Cormorant
	Comments: dogs and owners nearby, dogs in the water at site prior to replicate 3, dog scat and human garbage on shore			
	June 10 2:40-3:15 pm	24.2	Clear and cloudy, slight cloud cover has started to roll in	None nearby
	Comments: dogs playing in the water nearby			
	June 24 2:30 -3:10 pm	19.1	Rain today, cloudy, significantly less wind and wave action than usual, fog	None nearby
	Comments: human garbage on shore			

	July 14 1:57-2:17 pm	20.9	Rain yesterday, clear and cloudy periods, increasing cloud, light wind	None nearby
	Comments: water levels up significantly, sampling at approximate shoreline of 3 weeks previous, 1 dog in water prior to replicate 1, 1 pleasure boat offshore, wave action during replicate 3, kayaker in downstream bay			
	July 29 2:00-2:27 pm	20.7	Cloudy but clearing up, substantial rain 2 and 3 days ago	Scat nearby
	Comments: dogs and owners nearby			
	Aug 6 2:13-2:36 pm	25.6	Clear and slightly windy with some wave action	None
	Comments: people and dogs in the water downstream of sampling site			
	Aug 26 2:30-2:57 pm	20.5	Cloudy, windy, waves on water	None
	Comments: water level looks high, surrounding shoreline flooded			
	Sept 10 2:03-2:31 pm	18.3	Rain with periods of HEAVY rainfall, cloudy, very windy, waves, wind direction from the EAST today	None
	Sept 22 2:03-2:28 pm	15.6	Clear with sunny periods, very light wind, feels much warmer, rained 2 and 3 day ago	None
	Oct 6 2:30-2:53 pm	17.5	Cloudy with brief sunny periods, rain this morning, rain yesterday and substantial heavy rain over the last 3 days, quite windy with wave action	None
	Comments: water level has come up substantially, downstream marsh area flooded			
	Sept 10 10:34-11:01 am	18.7	Light rain, cloudy, windy, small waves	10 gulls, scat
	Sept 22 10:25-10:56 am	10.2	Clear with clouds, windy causing small waves, rained 2 and 3 days ago	Tracks, scat
	Comments: human garbage on shore			
	Oct 6 10:49-11:25 am	7.8	Cloudy, raining currently, rain yesterday and heavy the last 3 days	Scat
	Comments: dog tracks			
	2015			
	May 4 2:05-2:22 pm	17.3	Clear, rain yesterday, windy with moderate waves	None
	Comments: dogs were in water downstream of sampling site, ice still visible near shore			
	May 20 1:24-1:46 pm	17.8	Clear, light rain yesterday, intermittent breeze with slight waves	5 gulls, 2 geese
	Comments: 1 dog and walker using the bay downstream, dogs walking on path nearby			
	June 1 1:26-1:44 pm	18.4	Clear with light wind	Heard but not seen
	Comments: dogs and people at the shoreline			
	June 15 1:30-1:55 pm	22.9	Cloudy with sun, rain 2 days ago	Gulls heard but not seen
	Comments: dogs swimming in the bay downstream, 2 dogs swam in the sampling area, frequent boat traffic throughout the sampling period			
	July 7 1:19-1:35	18.1	Cloudy with sun, wind with moderate to high waves, rain yesterday	None
	Comments: high water level, particles in water column, no dogs/dog walkers observed during sampling			

	July 21 12:59-1:12 pm	20.5	Clear, wind with waves	None
	Comments: dog playing along shore at site before sampling, particles in water column, boat traffic offshore in main channel			
	August 4 1:18-1:32 pm	16.8	Cloudy, wind with moderate waves	None
	Comments: high water level			
	August 18 1:15-1:28 pm	24.9	Rain today, rain yesterday, cloudy with sun, calm	None
	Comments: water level high, boat traffic offshore			
	September 1 1:10-1:22 pm	25.1	Cloudy with sun, hazy, calm	None
	Comments: water level slightly lower, offshore boat traffic before samples taken, some floating particles in the water column			
	September 14 1:04-1:31 pm	24.3	Clear, wind with moderate to high waves	2 mallards
	Comments: 3 replicates, 2 boats went by offshore between replicates 1 and 2, dog walkers and park users in the vicinity			
	October 5 12:37-12:49 pm	11.7	Cloudy	4 ducks, 2 gulls
	Comment: water level lower than last field date			

Table 1.3: Monitoring site characteristics for Bell's Point

Bell's Point	**Date/ Time**	**Air Temp (°C)**	**Weather**	**Waterfowl**
	2013			
	Nov 16 3:10-3:14 pm	8	Cloudy, rain yesterday	NA
	2014			
	May 14 2:30-2:58 pm	12.9	Clear, constant wind, rain yesterday, some clouds, small waves	5 geese, tracks, scat
	Comments: dog and deer tracks on beach within 1-2 m of water, campground not open			
	May 27 1:15-1:55 pm	17.7	Clear and sunny, slightly windy causing wave action	4 geese, tracks, scat
	Comments: deer tracks on beach			
	June 10 1:25-1:55 pm	25.8	clear with clouds	26 geese, tracks, scat
	Comments: canoers in the nearby bay, campers in the campground			
	June 24 1:08-1:52 pm	20.3	Rain today, cloudy, slight wind, rained heavily just prior to sampling and lightly during sampling	40 geese, 20 gulls, loon
	July 14 12:58-1:19 pm	19.4	Rain yesterday, clear and cloudy periods, increasing cloud, some wind getting stronger to windy, small waves	21+ gulls, scat
	Comments: water levels have come up significantly, pools on beach, 3 large pleasure craft (motor boats) came by before replicate 2 and created large wave action			
	July 29 12:42-1:08 pm	20.3	Cloudy, windy, small waves, substantial rain 2 and 3 days ago	20+ gulls and geese, feathers, scat, ducks
	Comments: puddles on shore, human and animal footprints, dogs on beach			

	Aug 6 12:58-1:21 pm	22.0	Clear and slightly windy just starting to cause small waves	20+ geese, 20+ gulls, feathers, tracks, scat
	Comments: children playing on the beach and in the water			
	Aug 26 1:24-1:52 pm	20.2	Cloudy, windy, wavy	Many gulls, scat
	Comments: water level looks high, kids playing at the beach			
	Sept 10 12:55-1:25 pm	18.0	Rain with periods of heavy rainfall, cloudy, windy	5 geese, scat
	Comments: puddles along beach have mostly dried up but water levels are still high, campground still full of trailers but no recreational users were observed			
	Sept 22 12:56-1:20 pm	14.0	Clear with clouds, quite windy causing waves, feels cold, rained 2 and 3 days ago	20+ gulls, tracks, scat
	Comments: deer tracks on beach			
	Oct 6 1:12-1:48 pm	10.8	Cloudy, rain this morning, rain yesterday and substantial heavy rain over the 3 previous days, quite windy with wave action	5 geese, 20+ gulls, tracks, scat
	2015			
	May 4 1:10-1:27 pm	17.5	Clear, rain yesterday, windy with slight to moderate waves	4 geese, tracks, scat
	Comments: spring water level looks lower than last year (at bottom of stone steps)			
	May 20 12:30-12:48 pm	12.9	Clear, light rain yesterday, windy with slight to moderate waves	7 geese, tracks, scat
	June 1 12:28-12:44 pm	17.6	Clear with light wind	6 gulls, 2 ducks, 2 geese, tracks, scat
	Comments: aquatic insects in sampling and nearshore area (water boatman), seasonal campers now at park, no evidence of beach use, substrate more silty than usual			
	June 15 12:36-12:50 pm	19.2	Cloudy with sun, rain 2 days ago	22 geese, tern, gulls, scat, tracks, feathers
	Comments: many trailers and people in camp, vehicle tracks on beach, water boatmen in water, aquatic vegetation in nearshore area, green frogs calling in the distance			
	July 7 12:17-12:44 pm	18.6	Cloudy with sun, very light wind with light waves, rain yesterday	33 gulls, 25 geese, scat, feathers, tracks
	Comments: high water level, campers in the park			
	July 21 12:11-12:25 pm	19.6	Clear, wind with waves	30 gulls
	Comments: 5 people on the beach, swimming and kayaking near the sampling area, campground looks full			
	August 4 12:30-12:42 pm	15.8	Cloudy with sun, wind with slight waves	Geese and gulls, scat and tracks
	Comments: high water level, campground looks full			

	August 18 12:17-12:40 pm	22.3	Rain today, rain yesterday, cloudy with sun, calm	Gulls and geese downstream
	Comments: campground busy, evidence of recent beach use, some water boatmen (aquatic insects) in nearshore area, 3 replicates			
	September 1 12:19-12:35	25.7	Cloudy with sun, fog clearing, hazy, calm	Geese and gulls downstream, scat and tracks, loons and terns offshore
	Comments: small fish, water boatmen, motor boat passed offshore causing some wave action before water samples were taken, busy campground, water level slightly lower			
	September 14 12:17-12:30 pm	21.6	Clear, wind with light to moderate waves	8 geese, 30 gulls, tracks and scat
	Comments: beach recently raked, campground still in use			
	October 5 11:53 am-12:07 pm	11.5	Cloudy	2 gulls, tracks, scat, feathers
	Comment: water level lower than last field date			

Table 1.4: Monitoring site characteristics for Echo Bay

Echo Bay	**Date/ Time**	**Air Temp (°C)**	**Weather**	**Waterfowl**
	2013			
	Nov 16 2:15-2:25 pm	9	Cloudy, rain yesterday	NA
	Comments: boat came through 10 minutes prior to sampling, trash on shore			
	2014			
	May 14 3:51-4:25 pm	12.3	Windy, rain yesterday, cloudy, small waves	Terns offshore
	Comments: human garbage on shore			
	May 27 11:50 am-2:30 pm	20.9	Clear, light wispy clouds, sunny, slight wind causing wave action	Terns, 10+ cormorants offshore
	Comments: people fishing nearby, motor boat went by just prior to sampling, human garbage on shore			
	June 10 11:50 am-12:28 pm	23.3	Clear with clouds	None
	Comments: a couple fishing nearby, cars and boat trailers parked, personal water craft went by just after sampling, human garbage on shore			
	June 24 11:50 am-12:30 pm	19.9	Rain today, cloudy, slight wind	Terns
	Comments: canoe went by just prior to sampling replicate 1, human garbage on shore			
	July 14 11:44 am-12:09 pm	20.5	Rain yesterday, clear, some big clouds on the horizon, still (no wind)	Gulls, cormorants offshore
	Comments: human garbage on shore			

	July 29 11:37 am- 12:00 pm	18.3	Cloudy but sun is coming out, windy, small waves, substantial rain 2 and 3 days ago	None
	Comments: human garbage on shore			
	Aug 6 12:00-12:22 pm	21.6	Clear	Terns, gulls, offshore
	Comments: human garbage on shore			
	Aug 26 12:28-12:50 pm	19.9	Cloudy, windy, lots of waves	Gull, cormorant
	Comments: water level looks high, human garbage on shore			
	Sept 10 11:45 am- 12:10 pm	18.1	Rain with periods of heavy rainfall, cloudy, windy	None
	Comments: runoff from the road (highway 17) entering the river from drains on the bridge adjacent to the sampling site, human garbage on shore			
	Sept 22 11:39 am – 12:05 pm	13.7	clear with clouds, windy causing waves, rained 2 and 3 days ago	12 ducks
	Comments: human garbage on shore			
	Oct 6 12:10- 12:40 pm	9.5	Cloudy, rain this morning, rain yesterday and substantial rain over the last 3 days, slight wind and waves	None
	Comments: human garbage on shore			
	2015			
	May 4 12:08-12:28 pm	15.5	Slightly cloudy, rain yesterday, windy with moderate wave action	Tern, gull, cormorant
	Comments: human garbage in fire pit on shore, culvert nearby			
	May 20 11:24-11:55	10.6	Clear, light rain yesterday, windy with slight waves and chill	1 heron
	Comments: truck parked near shoreline (tires touching water), fire pit on shore with garbage, 3 replicates, during the first replicate a motor boat went by			
	June 1 11:18-11:35 pm	17.2	Clear with no wind	None
	Comments: garbage in on shore fire pit, small fish, pigeons nesting under nearby bridge, 3 vehicles parked on roadway, boat launched immediately after sampling took place, 2 fisherman seen, water appeared slightly turbid in the river but clear in the sample jar			
	June 15 11:37-11:50 am	18.3	Cloudy, humid with fog, rain 2 days ago	Ducks heard but not seen
	Comments: garbage in shore fire pit, many small fish in the sampling area, 3 trucks parked, 1 fisherman observed, green frog calls from nearby wetland, white deposit on submerged rock, water appeared slightly turbid in the river but clear in the sample jar			
	July 7 11:20-11:35 am	16.9	Cloudy, wind with light waves, rain yesterday	None
	Comments: high water level, tiny fish, fire pit is now at the shoreline, very little garbage compared to previous visits, some floating particles in the water column but water more clear than usual, tire tracks into water			
	July 21 11:01-11:18 am	20.0	Clear, wind with waves	None
	Comments: 3 vehicles at site, people fishing under the bridge, osprey seen flying in area			

	August 4 11:37-11:48 am	17.7	Cloudy with sun, wind with moderate to high waves	None
	Comments: vehicle tracks on sand but no vehicles parked, fire pit is now in the water due to high water level			
	August 18 11:16-11:30 am	25.2	Rain today, rain yesterday, cloudy with sun, calm	Geese offshore
	Comments: many tire tracks leading into the water, natural floating debris of plant origin			
	September 1 10:58-11:23 am	20.7	Cloudy with fog, calm	None
	Comments: 3 vehicles, fisherman in boat just upstream, large water tank filled at the site just prior to sampling, mink seen upstream, leopard frog, fish, falcon, tire tracks to water			
	September 14 11:13-11:28 am	22.2	Clear, calm	None
	Comments: boat launched immediately prior to sampling causing some observed turbidity in the water column, 1 vehicle, small fish			
	October 5 11:12-11:33 am	11.2	Cloudy	None
	Comments: water level lower than last field date, boat drove by when collecting last replicate, 3 replicates			

Table 1.5: Monitoring site characteristics for Richards Landing

Richards Landing	**Date/ Time**	**Air Temp (°C)**	**Weather**	**Waterfowl**
	2013			
	Nov 16 12:33-1:06 pm	13.5	Cloudy, rain yesterday	NA
	2014			
	May 14 5:02-5:34 pm	11.8	Windy, rain yesterday, cloudy, constant small waves	4 (species unidentified)
	Comments: dog and human tracks			
	May 27 10:20 -11:07 am	18.5	Clear, light wispy clouds, sunny	5 geese, terns, scat
	Comments: docks (for swimmers) have been put into the water, the beach has been recently graded, there are dog and human tracks in the sand			
	June 10 10:20-11:05 am	21.8	Clear, very sunny with clouds	Tracks, scat
	Comments: deer tracks			
	June 24 10:25-11:05 am	20.6	Rain today, cloudy, slight wind	Feathers, scat, tracks
	Comments: deer and human tracks, tire tracks, sand castles			
	July 14 10:33-11:03 am	19.6	Rain yesterday, clear, slight wind and light clouds	5 geese, tracks
	Comment: human garbage on shore			
	July 29 10:30-10:56 am	14.4	Cloudy, light wind, some wave action, substantial rain 2 and 3 days ago	Scat
	Comments: human tracks, human garbage on shore			
	Aug 6 10:39-11:07 am	19.3	Clear	
	Comments: two humans entered the water just prior to sampling			
	Aug 26 11:11-11:40 am	19.7	Cloudy, windy, waves on water	Gulls, tracks

	Sept 10 10:34-11:01 am	18.7	Light rain, cloudy, windy, small waves	10 gulls, scat
	Sept 22 10:25-10:56 am	10.2	Clear with clouds, windy causing small waves, rained 2 and 3 days ago	Tracks, scat
	Comments: human garbage on shore			
	Oct 6 10:49-11:25 am	7.8	Cloudy, raining currently, rain yesterday and heavy the last 3 days	Scat
	Comments: dog tracks			
	2015			
	May 4 11:00-11:20 am	14.6	Cloudy, rain yesterday, windy with slight wave action	Geese calls, tracks
	Comments: wetland area has a higher water level than last spring, can hear frogs and songbirds nearby, dog tracks leading into water, deer prints on beach			
	May 20 10:15-10:38 am	8.5	Clear, light rain yesterday, windy and just a bit cool	2 geese
	Comments: 2 dogs on beach before sampling, dog tracks on shore, deer tracks further up beach, foam noticeable in adjacent wetland and some trash			
	June 1 10:02-10:32 am	13.8	Clear with very light wind	Tracks and scat
	Comments: signs of use by people (footprints), 2 people on beach, dog tracks, deer tracks, sheen on beach puddles although not visibly entering the river or adjacent wetland, small school of small fish			
	June 15 10:26-10:41 am	17.1	Cloudy, humid with fog, rain 2 days ago	4 geese, scat, tracks, feathers
	Comments: high water level, beach is flooded, dog tracks along shore, aquatic snails, tadpoles and small fish abundant in adjacent wetland and beach pools			
	July 7 10:14-10:33 am	16.5	Cloudy, wind with moderate waves, rain yesterday	None
	Comments: high water level, heavy machine tire tracks from beach maintenance			
	July 21 10:00-10:14 am	19.7	Clear, wind with waves	Tracks, scat
	August 4 10:36-10:53 am	17.8	Cloudy, wind with slight waves	Geese, 2 gulls
	Comments: high water level, 2 kayakers using beach for a boat launch, garbage on beach from beach use, maximum readings for water clarity although some turbidity visible			
	August 18 10:13-10:28 am	20.9	Rain today, rain yesterday, cloudy, humid, calm	None
	Comments: human and dog prints, some turbidity visible in the water column, Algoma Public Health has posted a risk of higher bacteria levels after rainfall sign			
	September 1 9:53-10:05 am	20.9	Cloudy with fog, calm	Geese heard nearby
	Comments: small fish, evidence of recreational beach use, bike/vehicle tracks, dog tracks, some floating particles in the water column			
	September 14 10:15-10:27 am	18.9	Clear, slight breeze with no waves	None
	Comments: small fish, floating tire, garbage due to beach use, deer and dog tracks			
	October 5 10:22-10:39 am	11.3	Cloudy with a slight breeze	2 loons
	Comments: floating tire has washed up on shore, suspended particles in the water column			

Appendix 3: Aesthetic Parameters

NA = data not available

Table 2.1: Aesthetic Parameters for Gros Cap

Gros Cap	Date	Visual Clarity	SD, TT (cm)	Visual Colour	Odour	Algae	Debris
	2013						
	Nov 17	Clear	50, NA	Clear	None	None observed	None
	2014						
	May 14	Clear	50, 60	Clear	None	None observed	None
	May 27	Clear	50, 60	Clear	None	On rocks	None
	June 10	Clear	50, 60	Clear	None	On rocks, floating	None
	June 24	Clear	50, 23	Clear	None	On rocks, floating	Natural
	July 14	Clear	50, 60	Clear	None	On rocks	Natural
	July 29	Clear	50, 60	Clear	None	On rocks	Natural
	Aug 6	Clear	50, 60	Clear	None	On rocks, floating	None
	Aug 26	Clear	50, 60	Clear	None	On rocks	None
	Sept 10	Clear	50, 60	Clear	None	None observed	None
	Sept 22	Clear	50, 60	Clear	None	On rocks	Natural
	Oct 6	Clear	50, 60	Clear	None	On rocks, floating	Natural
	2015						
	May 4	Clear	50, 60	Clear	None	On rocky substrate nearby	None
	May 20	Clear	50, 60	Clear	None	On rocks, substrate in nearshore area	None
	June 1	Clear	50, 60	Clear	None	On rocks, substrate in nearshore area	None
	June 15	Clear	50,60	Clear	None	On rocks, substrate in nearshore area, floating	None
	July 7	Clear	50, 60	Clear	None	On rocks	None

	July 21	Clear	50, 60	Clear	None	On rocks	Natural
	Aug 4	Clear	50, 60	Clear	None	None	None
	Aug 18	Clear	50, 60	Clear	None	None	None
	Sept 1	Clear	50, 60	Clear	None	On rock	None
	Sept 14	Clear	50, 60	Clear	None	None	None
	Oct 5	Clear	50, 60	Clear	None	None	None

Table 2.2: Aesthetic Parameters for Bellevue Park

Bellevue Park	**Date**	**Visual Clarity**	**SD, TT (cm)**	**Visual Colour**	**Odour**	**Algae**	**Debris**
	2013						
	Nov 16	Clear	50, NA	Clear	Faint sewage fishy	None	None
	2014						
	May 14	Clear	50, 60	Clear	None	None	Natural
	May 27	Clear	50, 60	Clear	None	Floating, on plants	Natural
	June 10	Clear	50, 60	Clear	None	On rocks	Natural
	June 24	Clear	50, 60	Clear	None	On rocks	Natural
	July 14	Clear	50, 60	Clear	None	On rocks	Natural
	July 29	Clear	50, 60	Clear	None	None	None
	Aug 6	Clear	50, 60	Clear	None	None	None
	Aug 26	Clear	50, 60	Clear	None	None	None
	Sept 10	Clear	50, 60	Clear	None	None	Natural
	Sept 22	Clear	50, 60	Clear	None	On plants	None
	Oct 6	Clear	50, 60	Clear	None	None	Natural
	2015						
	May 4	Clear	50, 60	Clear	None	Greenish-brown covering on rocks, small floating filaments	Natural
	May 20	Clear	50, 60	Clear	None	On tree and rocks	Natural

	June 1	Clear	50, 60	Clear	None	On tree and rocks	Natural
	June 15	Clear	50, 60	Clear	None	On tree, submerged branch and rocks	None
	July 7	Clear	50, 60	Clear	None	On tree	None
	July 21	Clear	50, 60	Clear	None	On tree	None
	Aug 4	Clear	50, 60	Clear	None	None	None
	Aug 18	Clear	50, 60	Clear	None	None	None
	Sept 1	Clear	50, 60	Clear	None	None	Natural
	Sept 14	Clear	50, 60	Clear	None	None	None
	Oct 5	Clear	50, 60	Clear	None	None	None

Table 2.3: Aesthetic Parameters for Bell's Point

Bell's Point	**Date**	**Visual Clarity**	**SD, TT (cm)**	**Visual Colour**	**Odour**	**Algae**	**Debris**
	2013						
	Nov 16	Clear	50, NA	Clear	None	None	Natural
	2014						
	May 14	Clear	50, 60	Clear	None	None	Natural
	May 27	Clear	50, 60	Clear	None	Floating	Natural
	June 10	Clear	50, 60	Clear	None	Floating	Natural
	June 24	Clear	50, 60	Clear	None	None	Natural
	July 14	Clear	50, 60	Clear	None	On cement steps	Natural
	July 29	Clear	50, 60	Clear	None	None	Natural
	Aug 6	Clear	50, 60	Clear	None	None	None
	Aug 26	Clear	50, 60	Clear	None	None	Natural
	Sept 10	Clear	50, 60	Clear	None	None	Natural
	Sept 22	Clear	50, 60	Clear	None	None	Natural
	Oct 6	Clear	50, 60	Clear	None	None	Natural

	2015						
	May 4	Clear	50, 60	Clear	None	None	Natural
	May 20	Clear	50, 60	Clear	None	None	Natural
	June 1	Clear	50, 60	Clear	None	Attached to cement steps	Natural
	June 15	Clear	50, 60	Clear	None	Attached to cement steps	Natural
	July 7	Clear	50, 60	Clear	None	Attached to cement steps	Natural
	July 21	Clear	50, 60	Clear	None	None	Natural
	Aug 4	Clear	50, 60	Clear	None	None	None
	Aug 18	Clear	50, 60	Clear	None	None	None
	Sept 1	Clear	50, 60	Clear	None	None	None
	Sept 14	Clear	50, 60	Clear	None	None	Natural
	Oct 5	Clear	50, 60	Clear	None	Attached to cement steps & vegetation	Natural

Table 2.4: Aesthetic Parameters for Echo Bay

Echo Bay	**Date**	**Visual Clarity**	**SD, TT (cm)**	**Visual Colour**	**Odour**	**Algae**	**Debris**
	2013						
	Nov 16	Slightly turbid	50, NA	Light yellow	None	None	Natural
	2014						
	May 14	Slightly turbid	45, 30	Light yellow	None	None	Natural
	May 27	Slightly turbid	40, 30	Light yellow	None	None	Natural
	June 10	Slightly turbid	40, 33	Light yellow brown	None	None	Natural
	June 24	Clear	50, 60	Very light yellow brown	None	Floating	Natural
	July 14	Clear	50, 60	Clear	None	On substrate	Natural
	July 29	Moderate -ly turbid	50, 60	Very light brown	None	None	Natural
	Aug 6	Clear	50, 60	Clear	None	None	None

	Aug 26	Slightly turbid	50, 60	Clear	None	None	Natural
	Sept 10	Clear	50, 60	Very light yellow	None	None	Natural
	Sept 22	Slightly turbid	50, 60	Clear	None	None	Natural
	Oct 6	Slightly turbid	40, 27	Light yellow brown	None	None	Natural
	2015						
	May 4	Moderate-ly turbid	50, 38	Light yellow brown	None	None	Natural
	May 20	Slightly turbid	50, 38	Light yellow brown	None	None	Natural
	June 1	Clear	50, 49	Very light yellow	None	None	Natural
	June 15	Clear	50, 60	Very light yellow	None	None	Natural
	July 7	Clear	50, 60	Clear	None	None	Natural, foam
	July 21	Clear	50, 60	Clear	None	None	Natural, foam
	Aug 4	Clear	50, 60	Clear	None	None	Natural, foam
	Aug 18	Clear	50, 60	Clear	None	None	Natural
	Sept 1	Clear	50, 60	Clear	None	On rocks	None
	Sept 14	Clear	50, 60	Clear	None	On rocks	Natural
	Oct 5	Clear	50, 60	Clear	None	On rocks	None

Table 2.5: Aesthetic Parameters for Richards Landing

Richards Landing	Date	Visual Clarity	SD, TT (cm)	Visual Colour	Odour	Algae	Debris
	2013						
	Nov 16	Clear	50, NA	Clear	None	None	None
	2014						
	May 14	Slightly turbid	50, 56	Very light yellow	None	Floating	Natural
	May 27	Clear	50, 60	Clear	None	On substrate	Natural
	June 10	Clear	50, 60	Clear	None	None	Natural
	June 24	Clear	50, 60	Clear	None	None	Natural
	July 14	Clear	50, 60	Clear	None	None	Natural

	July 29	Moderate-ly turbid	50, 49	Very light brown	None	None	Natural
	Aug 6	Clear	50, 60	Clear	None	None	None
	Aug 26	Clear	50, 60	Clear	None	None	Natural
	Sept 10	Clear	50, 60	Clear	None	None	Natural
	Sept 22	Slightly turbid	50, 60	Clear	None	None	Natural
	Oct 6	Clear	50, 60	Clear	None	None	Natural
	2015						
	May 4	Very slightly turbid	50, 60	Clear	None	None	Natural
	May 20	Very slightly turbid	50, 47	Very light yellow	None	None	Natural
	June 1	Clear	50, 60	Clear	None	None	Natural
	June 15	Clear	50, 60	Clear	None	None	Natural
	July 7	Clear	50, 40	Clear	None	None	Natural, foam
	July 21	Clear	50, 51	Clear	None	None	Natural, foam
	Aug 4	Clear	50, 60	Clear	None	None	Natural
	Aug 18	Clear	50, 60	Clear	None	None	Natural
	Sept 1	Clear	50, 60	Clear	None	None	Natural
	Sept 14	Clear	50, 60	Clear	None	None	Natural
	Oct 5	Clear	50, 60	Clear	None	None	Natural

Appendix 4: Physical and Chemical Parameters

Single values are expressed for pH and temperature (Temp). For 2013-14, mean values are presented for dissolved oxygen (DO), total phosphorus (Total P), dissolved organic carbon (DOC), chlorophyll a (Chloro a), total suspended solids (TSS), turbidity (Turb), un-ionized ammonia (NH_3), ammonium (NH_4), total ammonia (NH_3 + NH_4), nitrite (NO_2), nitrate (NO_3), total Kjeldahl nitrogen (TKN) and total nitrogen (Total N). In 2015, results are only <u>mean values</u> when underlined. All other results from 2015 are single measurements.

Readings denoted as below the method detection limits (<MDL) were not measurable using the analytical methods available. Data for chlorophyll a was not available (NA) for water samples taken on May 14, 2014.

Table 3.1: Physical and chemical parameters for Gros Cap (part I)

Gros Cap	Date	pH	Temp (°C)	DO (mg/L)	Total P (mg/L)	DOC (mg/L)	Chloro a (μg/L)	TSS (mg/L)	Turb (NTU)
	2013								
	Nov 17	6.5	8	9.9	0.002	2.60	0.75	3.20	1.09
	2014								
	May 14	8.2	2.8	13.2	0.003	1.83	NA	<MDL	0.43
	May 27	8.1	5.5	11.3	0.009	2.03	0.67	<MDL	0.99
	June 10	8.5	8.1	10.3	0.005	2.20	<MDL	<MDL	0.77
	June 24	7.9	7.5	13.5	0.008	5.47	1.67	6.53	5.83
	July 14	8.6	16.9	10.4	0.008	2.03	0.65	<MDL	0.52
	July 29	8.2	15.5	10.1	<MDL	1.80	1.37	1.03	0.96
	Aug 6	8.4	17.4	11.1	0.002	1.70	1.37	<MDL	0.52
	Aug 26	8.2	14.9	10.8	0.009	1.50	0.73	<MDL	0.62
	Sept 10	8.2	17.6	10.5	0.002	1.83	1.60	<MDL	0.76
	Sept 22	8.1	14.9	11.0	<MDL	1.80	1.12	1.67	0.44
	Oct 6	8.1	11.3	11.1	<MDL	1.73	1.20	1.10	0.77
	2015								
	May 4	7.9	3.3	<u>12.1</u>	<u>0.007</u>	<u>1.87</u>	<u><MDL</u>	<u><MDL</u>	<u>0.40</u>
	May 20	8.1	6.6	11.4	<MDL	1.80	1.20	2.00	0.74
	June 1	8.3	9.2	12.4	0.006	2.20	<MDL	<MDL	0.58
	June 15	8.2	10.3	11.7	0.009	2.40	3.20	2.00	1.77

	July 7	8.2	14.8	11.6	0.010	2.40	<MDL	2.30	1.11
	July 21	8.1	17.7	10.4	0.006	1.93	<MDL	<MDL	0.78
	Aug 4	8.2	18.6	9.6	0.011	1.60	0.59	1.00	0.41
	Aug 18	8.1	20.1	9.8	0.004	1.80	0.80	1.30	0.40
	Sept 1	8.6	21.9	10.1	0.006	1.70	1.00	<MDL	0.85
	Sept 14	8.5	19.9	9.2	<MDL	1.70	1.10	<MDL	0.82
	Oct 5	8.8	15.5	10.6	<MDL	1.80	0.53	<MDL	0.40

Table 3.2: Physical and chemical parameters for Bellevue Park (part I)

Bellevue Park	**Date**	**pH**	**Temp (°C)**	**DO (mg/L)**	**Total P (mg/L)**	**DOC (mg/L)**	**Chloro a (µg/L)**	**TSS (mg/L)**	**Turb (NTU)**
	2013								
	Nov 16	6.5	8	10.0	0.010	2.27	0.75	4.27	1.93
	2014								
	May 14	8.5	6.4	13.5	0.002	1.90	NA	1.60	2.58
	May 27	8.7	9.9	11.9	0.013	2.13	5.60	<MDL	1.56
	June 10	8.3	10.7	10.7	0.006	2.17	1.72	0.93	1.17
	June 24	8.0	9.3	13.2	0.006	2.13	1.40	1.20	1.14
	July 14	8.3	16.1	10.1	0.008	1.87	0.92	<MDL	1.09
	July 29	8.1	17.5	10.0	0.005	1.90	1.47	3.33	2.08
	Aug 6	8.2	18.5	10.4	0.005	1.67	1.32	1.50	1.75
	Aug 26	8.2	17.7	10.4	0.012	1.60	1.30	3.00	1.85
	Sept 10	8.1	17.6	9.9	0.010	1.80	2.20	3.33	1.14
	Sept 22	8.1	13.9	11.0	<MDL	1.80	1.37	1.13	1.01
	Oct 6	8.1	11.1	11.0	0.004	2.00	1.47	1.87	2.87
	2015								
	May 4	8.0	5.8	12.0	0.008	2.00	<MDL	5.00	2.71
	May 20	8.0	7.4	10.9	0.004	1.90	0.59	3.30	1.59
	June 1	8.0	8.5	11.4	0.006	1.90	<MDL	<MDL	0.66

	June 15	8.1	9.5	12.4	0.007	1.90	2.50	2.20	0.87
	July 7	8.4	16.3	11.8	0.013	2.50	<MDL	8.33	4.49
	July 21	8.1	16.5	10.9	0.007	1.90	<MDL	1.70	1.52
	Aug 4	8.2	18.3	10.7	0.012	1.60	1.20	1.70	1.18
	Aug 18	8.1	20.5	9.6	0.006	1.70	<MDL	<MDL	0.72
	Sept 1	8.2	19.8	9.9	0.006	1.60	1.00	<MDL	1.00
	Sept 14	8.4	19.1	9.4	0.004	1.73	1.37	1.50	1.57
	Oct 5	8.7	11.7	10.2	<MDL	1.70	0.80	<MDL	0.90

Table 3.3: Physical and chemical parameters for Bell's Point (part I)

Bell's Point	**Date**	**pH**	**Temp (°C)**	**DO (mg/L)**	**Total P (mg/L)**	**DOC (mg/L)**	**Chloro a (µg/L)**	**TSS (mg/L)**	**Turb (NTU)**
	2013								
	Nov 16	6.5	8	9.8	0.010	2.27	1.20	5.87	2.27
	2014								
	May 14	8.1	8.3	13.1	0.002	2.27	NA	<MDL	1.45
	May 27	8.0	10.8	11.7	0.011	2.30	0.99	4.93	0.99
	June 10	8.0	11.5	10.3	0.005	2.13	0.54	<MDL	0.99
	June 24	8.0	9.5	13.6	0.003	2.03	1.35	<MDL	1.37
	July 14	8.1	17.0	10.2	0.010	1.70	0.58	2.37	1.60
	July 29	8.1	17.3	9.9	0.003	1.90	1.23	2.43	1.76
	Aug 6	8.1	18.6	10.4	0.003	1.70	1.75	1.23	1.80
	Aug 26	8.2	18.4	10.5	0.004	1.60	0.68	<MDL	1.26
	Sept 10	8.1	17.6	10.6	0.003	1.80	1.23	2.13	1.39
	Sept 22	7.7	14.0	10.6	<MDL	2.00	1.40	2.47	1.69
	Oct 6	7.9	11.1	10.9	0.003	2.10	1.63	1.20	2.32
	2015								
	May 4	7.7	9.5	11.4	0.013	2.30	<MDL	<MDL	1.39
	May 20	7.9	7.9	11.4	<MDL	1.80	1.40	3.00	1.58

	June 1	7.9	8.7	11.2	0.006	1.80	<MDL	<MDL	1.07
	June 15	7.9	9.5	12.4	0.006	2.00	0.59	<MDL	0.82
	July 7	7.9	15.9	11.7	0.010	2.53	<MDL	1.70	1.22
	July 21	7.8	17.2	10.1	0.008	1.90	<MDL	<MDL	1.25
	Aug 4	7.9	18.4	11.0	0.013	1.60	0.64	1.00	1.26
	Aug 18	7.8	20.5	9.1	0.007	1.80	0.69	1.77	1.56
	Sept 1	8.2	19.5	10.1	0.005	1.60	0.86	<MDL	1.40
	Sept 14	8.3	18.8	9.4	<MDL	1.80	1.00	<MDL	1.35
	Oct 5	8.5	11.5	10.4	<MDL	1.70	0.96	<MDL	1.28

Table 3.4: Physical and chemical parameters for Echo Bay (part I)

Echo Bay	**Date**	**pH**	**Temp (°C)**	**DO (mg/L)**	**Total P (mg/L)**	**DOC (mg/L)**	**Chloro a (μg/L)**	**TSS (mg/L)**	**Turb (NTU)**
	2013								
	Nov 16	6.5	7	10.0	0.020	6.85	0.88	11.33	16.23
	2014								
	May 14	7.8	9.5	11.8	0.010	6.16	NA	10.67	22.97
	May 27	7.8	18.5	9.1	0.022	4.83	2.23	13.47	16.17
	June 10	7.6	19.3	8.9	0.035	7.27	1.97	11.33	18.83
	June 24	7.9	19.0	10.4	0.007	2.97	2.10	3.47	6.09
	July 14	8.1	16.9	9.5	0.004	1.93	0.58	<MDL	1.73
	July 29	7.9	18.3	9.3	0.006	3.13	1.97	3.70	5.38
	Aug 6	8.1	20.3	9.7	0.006	2.13	1.30	3.37	2.11
	Aug 26	8.2	19.7	9.8	0.010	1.70	2.03	9.17	4.63
	Sept 10	8.0	18.9	10.6	0.006	2.97	1.77	3.33	3.06
	Sept 22	7.8	12.0	10.5	0.004	4.43	1.63	2.43	5.53
	Oct 6	7.3	11.1	9.9	0.020	7.37	0.68	11.57	23.27
	2015								
	May 4	7.5	13.1	10.0	0.022	5.70	<MDL	8.33	17.70

	May 20	7.6	10.3	9.6	0.012	5.32	0.64	11.50	17.90
	June 1	7.5	15.6	9.3	0.011	6.23	<MDL	11.70	13.80
	June 15	7.6	18.6	9.6	0.016	4.34	4.30	6.00	6.90
	July 7	7.8	20.1	9.8	0.011	3.10	<MDL	3.00	2.97
	July 21	8.1	20.9	8.9	0.010	3.20	<MDL	3.30	3.45
	Aug 4	7.9	20.0	9.0	0.010	2.60	0.91	3.30	2.71
	Aug 18	7.9	23.4	9.7	0.007	3.00	1.00	2.00	1.68
	Sept 1	8.4	20.8	9.6	0.008	3.23	0.96	2.10	3.63
	Sept 14	8.0	18.4	8.6	0.005	2.20	2.00	1.70	3.04
	Oct 5	8.5	11.2	10.2	0.010	1.80	1.15	1.30	1.76

Table 3.5: Physical and chemical parameters for Richards Landing (part I)

Richards Landing	Date	pH	Temp (°C)	DO (mg/L)	Total P (mg/L)	DOC (mg/L)	Chloro a (µg/L)	TSS (mg/L)	Turb (NTU)
	2013								
	Nov 16	6.5	7	9.9	0.015	3.10	1.07	4.40	5.01
	2014								
	May 14	8.5	13.1	13.5	0.017	3.83	NA	29.33	8.16
	May 27	8.4	14.5	11.0	0.007	2.63	2.83	6.63	3.63
	June 10	8.1	15.1	9.9	0.006	2.50	1.43	<MDL	2.72
	June 24	8.3	16.8	12.0	0.005	2.23	2.30	3.33	2.61
	July 14	8.1	18.1	9.4	0.010	1.93	0.76	9.49	5.18
	July 29	8.0	17.2	8.6	0.012	2.27	2.67	10.77	9.15
	Aug 6	7.8	20.4	9.0	0.005	1.90	1.27	5.33	2.69
	Aug 26	7.8	19.5	10.0	0.005	1.80	2.30	3.57	3.05
	Sept 10	7.9	18.3	10.0	0.004	1.83	1.83	3.00	2.67
	Sept 22	8.0	11.8	10.7	<MDL	2.13	1.53	3.20	3.46
	Oct 6	8.0	10.7	10.4	0.011	2.80	1.57	2.53	4.00

	2015								
	May 4	7.8	11.7	10.5	0.014	3.00	<MDL	5.00	7.61
	May 20	8.0	8.9	10.3	0.008	2.20	<MDL	7.00	10.10
	June 1	8.0	13.0	10.7	0.006	2.30	<MDL	3.13	2.31
	June 15	8.0	14.8	11.1	0.009	2.20	0.91	1.70	1.64
	July 7	7.8	17.0	10.4	0.016	2.60	<MDL	35.70	8.49
	July 21	7.7	19.4	8.6	0.015	2.10	<MDL	5.70	7.16
	Aug 4	7.7	19.6	9.1	0.012	1.87	1.30	5.67	6.12
	Aug 18	7.7	22.1	8.2	0.011	1.80	0.53	9.00	3.78
	Sept 1	8.1	19.6	9.4	0.005	1.60	2.20	4.70	2.80
	Sept 14	8.3	18.3	9.2	0.004	1.90	1.50	5.00	2.67
	Oct 5	8.5	13.0	10.2	<MDL	1.70	1.30	4.00	2.00

Table 4.1: Physical and chemical parameters for Gros Cap (part II)

Gros Cap	**Date**	**NH_3 (mg/L)**	**NH_4 (mg/L)**	**NH_3 + NH_4 (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TKN (mg/L)**	**Total N (mg/L)**
	2013							
	Nov 17	<MDL	0.031	0.031	<MDL	0.28	0.44	0.72
	2014							
	May 14	<MDL	0.020	0.020	<MDL	0.28	0.31	0.59
	May 27	<MDL	0.026	0.026	<MDL	0.25	0.61	0.86
	June 10	0.006	0.117	0.123	<MDL	0.26	0.63	0.89
	June 24	<MDL	0.025	0.025	<MDL	0.31	0.58	0.89
	July 14	<MDL	0.011	0.011	<MDL	0.33	0.57	0.90
	July 29	<MDL	0.030	0.030	<MDL	0.16	0.59	0.75
	Aug 6	<MDL	0.010	0.010	<MDL	0.35	1.20	1.55
	Aug 26	<MDL	<MDL	<MDL	<MDL	0.33	0.35	0.68
	Sept 10	<MDL	<MDL	<MDL	<MDL	0.28	<MDL	0.28
	Sept 22	<MDL	<MDL	<MDL	<MDL	0.29	0.72	1.01

	Oct 6	<MDL	<MDL	<MDL	<MDL	0.28	0.28	0.56
	2015							
	May 4	<MDL	0.026	0.026	<MDL	0.32	<MDL	0.35
	May 20	<MDL	<MDL	<MDL	<MDL	0.43	<MDL	0.43
	June 1	<MDL	<MDL	<MDL	<MDL	0.23	<MDL	0.23
	June 15	<MDL	0.022	0.022	<MDL	0.27	<MDL	0.29
	July 7	<MDL	<MDL	<MDL	<MDL	0.35	<MDL	0.35
	July 21	<MDL	<MDL	<MDL	<MDL	0.37	<MDL	0.37
	Aug 4	<MDL	<MDL	<MDL	<MDL	0.33	<MDL	0.33
	Aug 18	0.002	0.049	0.051	<MDL	0.33	<MDL	0.38
	Sept 1	<MDL	<MDL	<MDL	<MDL	0.26	<MDL	0.26
	Sept 14	<MDL	<MDL	<MDL	<MDL	0.33	1.10	1.43
	Oct 5	<MDL	<MDL	<MDL	<MDL	0.40	0.32	0.72

Table 4.2: Physical and chemical parameters for Bellevue Park (part II)

Bellevue Park	**Date**	**NH_3 (mg/L)**	**NH_4 (mg/L)**	**$NH_3 + NH_4$ (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TKN (mg/L)**	**Total N (mg/L)**
	2013							
	Nov 16	<MDL	0.024	0.024	<MDL	0.30	0.49	0.79
	2014							
	May 14	<MDL	0.013	0.013	<MDL	0.25	0.39	0.64
	May 27	<MDL	<MDL	<MDL	<MDL	0.21	0.82	1.03
	June 10	<MDL	0.058	0.059	<MDL	0.31	0.71	1.02
	June 24	<MDL	0.027	0.027	<MDL	0.29	0.60	0.89
	July 14	<MDL	0.015	0.015	<MDL	0.22	0.53	0.75
	July 29	<MDL	0.049	0.050	<MDL	0.27	0.49	0.76
	Aug 6	<MDL	0.017	0.017	<MDL	0.33	1.27	1.60
	Aug 26	<MDL	<MDL	<MDL	<MDL	0.40	0.40	0.80
	Sept 10	<MDL	0.010	0.010	<MDL	0.29	<MDL	0.30

	Sept 22	<MDL	0.020	0.020	<MDL	0.25	0.72	0.97
	Oct 6	<MDL	<MDL	<MDL	<MDL	0.30	0.33	0.63
	2015							
	May 4	<MDL	0.017	0.017	<MDL	0.27	0.86	1.13
	May 20	<MDL	0.204	0.207	<MDL	0.41	0.31	0.72
	June 1	<MDL	<MDL	<MDL	<MDL	0.32	0.70	1.02
	June 15	<MDL	0.010	0.010	<MDL	0.31	<MDL	0.32
	July 7	<MDL	0.027	0.027	<MDL	0.37	<MDL	0.40
	July 21	<MDL	<MDL	<MDL	<MDL	0.33	<MDL	0.33
	Aug 4	<MDL	<MDL	<MDL	<MDL	0.27	0.33	0.60
	Aug 18	0.003	0.049	0.052	<MDL	0.29	0.26	0.55
	Sept 1	<MDL	<MDL	<MDL	<MDL	0.27	0.28	0.55
	Sept 14	<MDL	<MDL	<MDL	<MDL	0.30	1.23	1.53
	Oct 5	<MDL	<MDL	<MDL	<MDL	0.27	0.30	0.57

Table 4.3: Physical and chemical parameters for Bell's Point (part II)

Bell's Point	**Date**	**NH_3 (mg/L)**	**NH_4 (mg/L)**	**$NH_3 + NH_4$ (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TKN (mg/L)**	**Total N (mg/L)**
	2013							
	Nov 16	<MDL	0.030	0.030	<MDL	0.35	0.26	0.61
	2014							
	May 14	<MDL	0.025	0.025	<MDL	0.23	0.25	0.48
	May 27	<MDL	0.017	0.017	<MDL	0.20	0.69	0.89
	June 10	<MDL	0.029	0.029	<MDL	0.32	0.67	0.99
	June 24	<MDL	0.027	0.027	<MDL	0.32	0.60	0.92
	July 14	<MDL	0.016	0.016	<MDL	0.25	0.49	0.74
	July 29	<MDL	0.036	0.036	<MDL	0.17	0.53	0.70
	Aug 6	<MDL	0.021	0.021	<MDL	0.34	0.74	1.08
	Aug 26	<MDL	<MDL	<MDL	<MDL	0.30	0.37	0.67

	Sept 10	<MDL	0.018	0.018	<MDL	0.29	<MDL	0.31
	Sept 22	<MDL	0.017	0.017	<MDL	0.26	0.67	0.93
	Oct 6	<MDL	<MDL	<MDL	<MDL	0.27	0.32	0.59
	2015							
	May 4	<MDL	0.016	0.016	<MDL	0.25	<MDL	0.27
	May 20	<MDL	<MDL	<MDL	<MDL	0.44	0.23	0.67
	June 1	<MDL	<MDL	<MDL	<MDL	0.31	<MDL	0.31
	June 15	<MDL	0.012	0.012	<MDL	0.28	<MDL	0.29
	July 7	<MDL	0.025	0.025	<MDL	0.35	<MDL	0.38
	July 21	<MDL	<MDL	<MDL	<MDL	0.33	<MDL	0.33
	Aug 4	<MDL	0.012	0.012	<MDL	0.27	0.41	0.68
	Aug 18	<MDL	0.032	0.032	<MDL	0.30	0.35	0.65
	Sept 1	<MDL	<MDL	<MDL	<MDL	0.26	0.34	0.60
	Sept 14	<MDL	<MDL	<MDL	<MDL	0.30	1.30	1.60
	Oct 5	0.020	0.256	0.276	<MDL	0.27	0.32	0.59

Table 4.4: Physical and chemical parameters for Echo Bay (part II)

Echo Bay	**Date**	**NH_3 (mg/L)**	**NH_4 (mg/L)**	**NH_3 + NH_4 (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TKN (mg/L)**	**Total N (mg/L)**
	2013							
	Nov 16	<MDL	0.031	0.031	<MDL	0.12	0.56	0.68
	2014							
	May 14	<MDL	0.013	0.018	<MDL	0.13	0.48	0.61
	May 27	<MDL	<MDL	<MDL	<MDL	0.13	0.81	0.94
	June 10	<MDL	0.033	0.033	<MDL	0.08	0.90	0.98
	June 24	<MDL	0.027	0.027	<MDL	0.20	0.65	0.85
	July 14	<MDL	0.020	0.020	<MDL	0.21	0.58	0.79
	July 29	<MDL	0.033	0.033	<MDL	<MDL	0.59	0.62
	Aug 6	<MDL	0.019	0.019	<MDL	0.21	0.80	1.01

	Aug 26	<MDL	<MDL	<MDL	<MDL	0.24	0.40	0.64
	Sept 10	<MDL	<MDL	<MDL	<MDL	0.20	<MDL	0.20
	Sept 22	<MDL	<MDL	<MDL	<MDL	<MDL	0.76	0.76
	Oct 6	<MDL	<MDL	<MDL	<MDL	0.09	0.45	0.54
	2015							
	May 4	<MDL	0.020	0.020	<MDL	0.12	0.38	0.50
	May 20	<MDL	<MDL	<MDL	<MDL	0.15	0.37	0.52
	June 1	<MDL	0.018	0.018	<MDL	<MDL	0.30	0.32
	June 15	<MDL	<MDL	<MDL	<MDL	<MDL	0.31	0.31
	July 7	0.003	0.124	0.127	<MDL	0.31	<MDL	0.44
	July 21	<MDL	<MDL	<MDL	<MDL	<MDL	0.27	0.27
	Aug 4	<MDL	<MDL	<MDL	<MDL	0.14	0.37	0.51
	Aug 18	<MDL	0.027	0.027	<MDL	<MDL	0.34	0.35
	Sept 1	<MDL	0.011	0.011	<MDL	<MDL	<MDL	0.01
	Sept 14	<MDL	<MDL	<MDL	<MDL	0.24	1.20	1.44
	Oct 5	0.004	0.048	0.052	<MDL	0.25	0.47	0.72

Table 4.5: Physical and chemical parameters for Richards Landing (part II)

Richards Landing	**Date**	**NH_3 (mg/L)**	**NH_4 (mg/L)**	**$NH_3 + NH_4$ (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TKN (mg/L)**	**Total N (mg/L)**
	2013							
	Nov 16	<MDL	0.031	0.031	<MDL	0.28	<MDL	0.31
	2014							
	May 14	<MDL	0.021	0.022	<MDL	0.12	0.43	0.55
	May 27	<MDL	<MDL	<MDL	<MDL	0.18	0.71	0.89
	June 10	<MDL	0.030	0.030	<MDL	0.22	0.72	0.94
	June 24	<MDL	0.020	0.020	<MDL	0.31	0.67	0.98
	July 14	<MDL	0.018	0.018	0.06 (1 value)	0.13	0.60	0.73
	July 29	<MDL	0.035	0.035	<MDL	<MDL	0.59	0.63

	Aug 6	<MDL	0.023	0.023	<MDL	0.24	0.84	1.08
	Aug 26	<MDL	<MDL	<MDL	<MDL	0.23	0.44	0.67
	Sept 10	<MDL	0.022	0.022	<MDL	0.24	<MDL	0.26
	Sept 22	<MDL	<MDL	<MDL	<MDL	0.18	0.71	0.89
	Oct 6	<MDL	<MDL	<MDL	<MDL	0.25	0.40	0.65
	2015							
	May 4	<MDL	0.019	0.019	<MDL	0.23	0.44	0.67
	May 20	<MDL	<MDL	<MDL	<MDL	0.34	<MDL	0.34
	June 1	<MDL	<MDL	<MDL	<MDL	0.26	0.24	0.50
	June 15	<MDL	<MDL	<MDL	<MDL	0.26	<MDL	0.26
	July 7	<MDL	0.052	0.052	<MDL	0.27	<MDL	0.32
	July 21	<MDL	0.080	0.080	<MDL	0.35	0.26	0.61
	Aug 4	<MDL	0.010	0.010	<MDL	0.19	<MDL	0.20
	Aug 18	<MDL	0.030	0.030	<MDL	0.22	0.34	0.56
	Sept 1	<MDL	<MDL	<MDL	<MDL	0.27	<MDL	0.27
	Sept 14	<MDL	<MDL	<MDL	<MDL	0.31	1.20	1.51
	Oct 5	<MDL	<MDL	<MDL	<MDL	0.27	0.43	0.70