Lake St. Martin Emergency Outlet Channel
Assessment of Effects and Development of Offsetting

Aquatic Habitat Supporting Volume (AHSV)

May 2015

A report prepared for
Manitoba Infrastructure and Transportation
by
North/South Consultants Inc. and KGS Group

PREFACE

The following document was prepared to provide the information required under Schedule 1 of the *Applications for Authorization under Paragraph 35(2) (b) of the Fisheries Act Regulations.* As requested by Fisheries and Oceans Canada (DFO), key information from all relevant materials provided during the environmental review of the Lake St. Martin Emergency Relief Channel Project has been summarized in this document, following the subsections identified in Schedule 1 to the extent possible.

It should be noted that, because of the emergency requirement to complete this Project, it was exempted from a review under Canada's *Canadian Environmental Assessment Act (CEAA)* and *The Environment Act (Manitoba)*. In the absence of a formal screening, DFO issued *Fisheries Act* authorizations for the Project. The requirement for documentation and possible offsetting for any residual serious harm to fish that have arisen due to the Project was identified within the authorizations.

The following document is one of a series of reports listed below to address reporting requirements stipulated in the Fisheries Act authorizations. The report series is comprised of an assessment of Project-related effects determined from ongoing project monitoring, an offsetting plan in which the needs for offsetting measures are discussed, and a series of support volumes that summarize Project monitoring data collections and results by major ecosystem component (i.e., Physical Environment, Water Quality, Aquatic Habitat, and Fish). Reports and supporting volumes include the following:

- Assessment of Effects to Aquatic Habitat and Fish (AEHF)
- Offsetting Plan
- Physical Environment Supporting Volume (PESV)
- Water Quality Supporting Volume (WQSV)
- Aquatic Habitat Supporting Volume (AHSV; this volume)
- Fish Supporting Volume (FSV)

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6.0 AQUATIC HABITAT

Sections within this supporting volume are numbered to match the corresponding section within the "Effects to Aquatic Habitat and Fish" document.

6.1 INTRODUCTION

6.1.1 Project Background

Widespread record flooding throughout southern Manitoba during 2011 led to water levels in Lake Manitoba and Lake St. Martin that were several feet higher than desirable, resulting in significant damage to hundreds of properties, restricted road access to several communities, and long-term evacuation of four First Nations communities in the vicinity of Lake St. Martin. As part of emergency relief measures, the Province of Manitoba, through Manitoba Infrastructure and Transportation (MIT), constructed the Lake St. Martin Emergency Outlet Channel System (LSMEOC system), which is comprised of two emergency channels (Figure 6.1-1).

The Reach 1 Emergency Outlet Channel (Reach 1) begins at the northeast shore of the north basin of Lake St. Martin and extends approximately 6 km to the bog area surrounding Big Buffalo Lake. Water from Reach 1 inundates the bog area and then follows the natural Buffalo Creek Drainage System until flowing into the lower Dauphin River and ultimately into Sturgeon Bay (Figures 6.1-1 and 6.1-2). Water began to flow through Reach 1 on 01 November 12011 and the channel was operated until 21 November 2012.

Computer models of potential water levels at the mouth of the Dauphin River indicated that there was a significant risk of major flooding of the Dauphin River communities in spring 2012. Consequently, a second channel (Reach 3 Emergency Channel; Reach 3) was constructed during winter 2011/2012. Reach 3 was designed to divert excess flow from Reach 1 and Buffalo Creek and away from the lower Dauphin River. Due to extremely mild winter conditions in 2011/2012, ice effects on both Reach 1 and the Dauphin River were much less severe than forecasted. Consequently, the proposed operation of Reach 3 was no longer required.

Heavy precipitation during winter 2013/2014 and spring 2014 again elevated water levels in Lake Manitoba and Lake St. Martin, prompting MIT to re-open Reach 1 at the beginning of July 2014. The channel was re-opened in two stages. The first occurred during in July 2014 when approximately 35 m of the berm closing Reach 1 was removed. The second stage occurred in November 2014, when an additional 10 m of the closure berm were removed to allow additional flow into the channel. Reach 1 currently remains in operation, and will remain so until at least 15 June 2015.

Collectively, construction and operation of Reach 1, as well as construction of Reach 3, are referred to hereafter as "the Project".

Concurrent with construction of Reach 1 in summer 2011, MIT initiated studies and monitoring to help describe and assess environmental effects arising from the Project. These included studies to document changes to the physical environment (e.g., measurement of water flow through Reach 1 and the Dauphin River; sedimentation and erosion studies) and possible subsequent effects to the biological environment (e.g., possible change to fish community in Buffalo Creek). Environmental studies began in August 2011 and remain ongoing.

6.1.2 Study Area

The emphasis of aquatic monitoring is to determine what effects construction and operation of Reach 1 may have had on waterways downstream of the channel. These include the Buffalo Creek watershed (comprised of Big Buffalo Lake and the surrounding bog complex, and Buffalo Creek), the lower reach of Dauphin River, and the southwest portion of Sturgeon Bay in Lake Winnipeg. However, these waterways are also affected by conditions occurring upstream of Reach 1 and, in some instances, fish move between areas upstream and downstream of Reach 1. Consequently, some components of the aquatic monitoring program (water quality monitoring and fisheries investigations) include waterways upstream of Reach 1.

While aquatic habitat in waterbodies upstream of the Project was generally not expected to be affected by Reach 1 operation, there is a small Project footprint along the north shore of Lake St. Martin where the inlet to Reach 1 was constructed. For the aquatic habitat portion of this assessment, waterbody boundaries were defined as follows (Figure 6.1-2):

- Lake St. Martin in the vicinity of the Reach 1 inlet;
- Reach 1;
- Big Buffalo Lake and the associated bog complex;
- Buffalo Creek
- the lower reach of the Dauphin River from its confluence with Buffalo Creek to its outflow into Sturgeon Bay (hereafter referred to as "the lower Dauphin River"); and
- nearshore and offshore areas of Sturgeon Bay to the east and south of the Dauphin River mouth.

6.1.3 Phases of the Project

For the assessment of effects to aquatic habitat the phases of the Project are defined as:

- Pre-Operation - historic, up to 31 October 2011;
- 2011/2012 Operation - 01 November 2011 to 21 November 2012;
- 2011/2012 Closure - 22 November 2012 to 04 July 2014; and
- 2014/2015 Operation - began 04 July 2014 and is ongoing.

For the purposes of describing the effects of water regime changes on aquatic habitat, the Pre-Operation phase of the Project has been divided into the Pre-flood (1977-2010) and 2011 Flood (April to October 2011) periods.

6.1.4 Purpose of the Document

A diverse range of monitoring studies has been conducted annually. Aquatic habitat monitoring programs have focussed on documenting substrate composition and bathymetry, waterbody morphology, and vegetation (aquatic and riparian) in Reach 1, the Buffalo Creek watershed, the lower reach of Dauphin River to its mouth at Sturgeon Bay, and Sturgeon Bay to the east and south of the Dauphin River mouth. The outputs from hydraulic models developed to describe the physical environment were also used to characterize habitat conditions such as wetted area, water depth, and water velocity during different phases of the Project.

This volume provides a summary of available pre-Project information on aquatic habitat in study area waterbodies. It also includes a detailed description of Project monitoring, including the timing of field campaigns and the methods employed, as well as a synthesis of the results of the monitoring activities. Results are discussed by waterbody and are presented in relation to Project phase. This volume is intended to compliment the "Lake St. Martin Emergency Outlet Channel –Assessment of Effects and Development of Offsetting: Assessment of Effects to Aquatic Habitat and Fish" document.

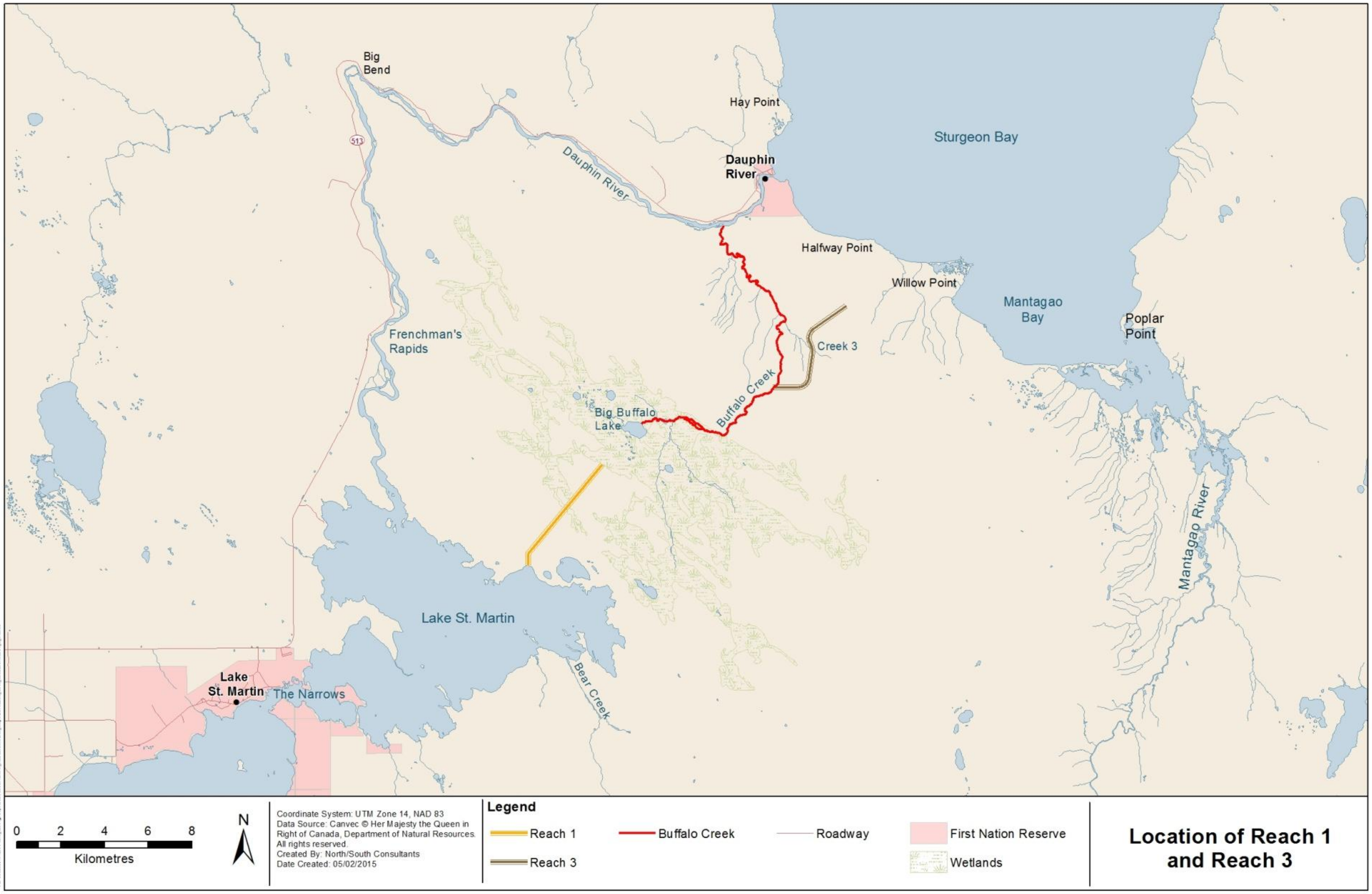


Figure 6.1-1. Location of the Reach 1 Emergency Outlet Channel, the Reach 3 Emergency Channel, and the Buffalo Creek Drainage System in relation to Lake St. Martin, the Dauphin River and Sturgeon Bay.

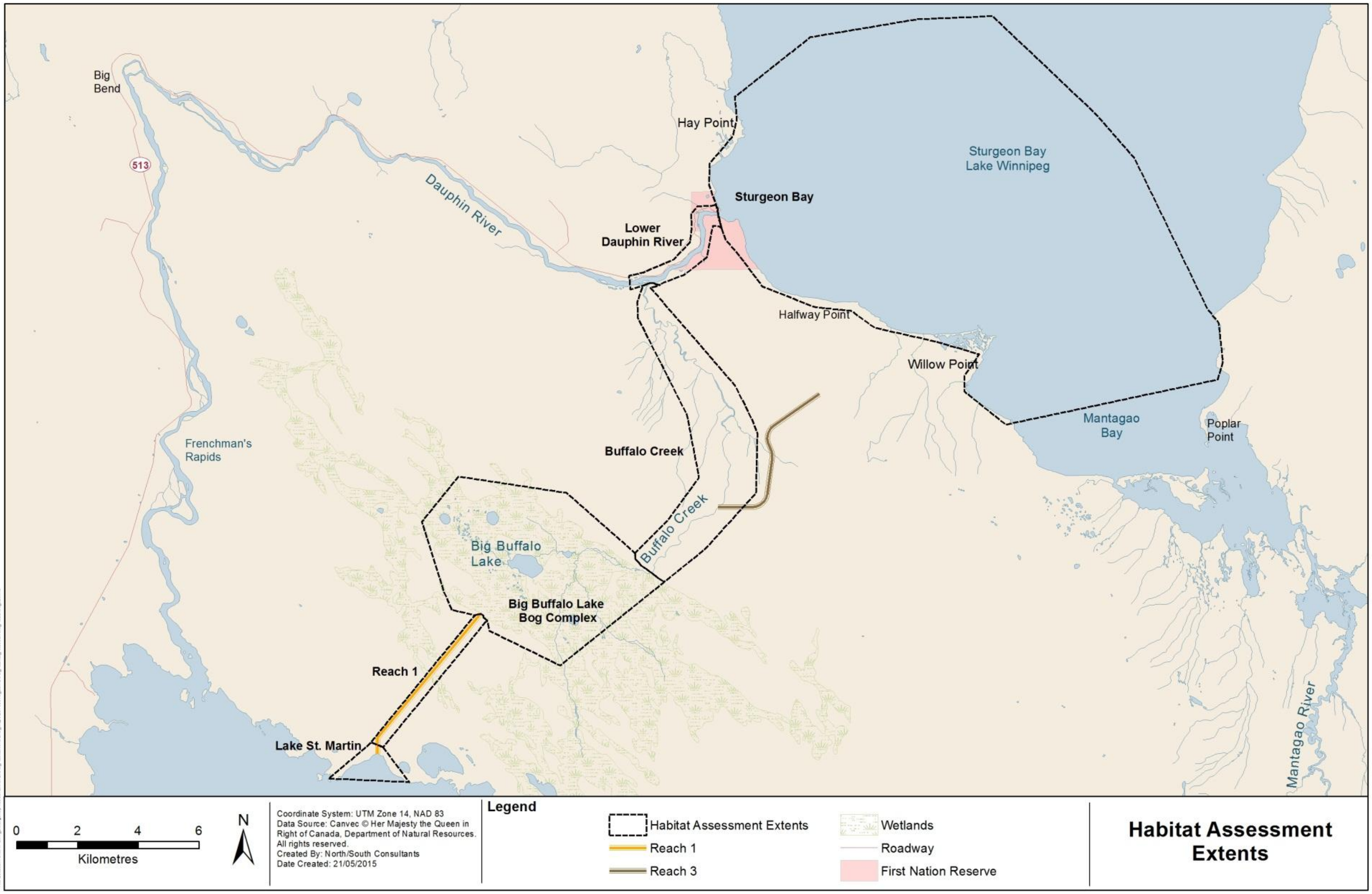


Figure 6.1-2. Waterbody extents identified for the aquatic habitat component of the effects assessment.

6.2 METHODS

Information collected during field investigations was used in conjunction with outputs from hydraulic models (see PESV) to determine habitat conditions within the study area waterbodies. In general, the aquatic habitat assessment focused on documenting changes in the quantity and type of aquatic habitat in waterbodies downstream of Lake St. Martin at 50th percentile flow or water level.

Several sampling methods were used to collect aquatic habitat data before (2011; Pre-Operation) and after (2013 and 2014; 2011/2012 Closure) Project operation. Field activities that informed the aquatic habitat effects assessment are listed below by waterbody/watershed (Table 6.2-1). As some of the data collected under physical environment monitoring were integral to assessing the effects of the Project on aquatic habitat in the study area, particular field campaigns and imagery collections belonging to that discipline are included below.

Field campaigns have not been conducted to assess aquatic habitat conditions in Lake St. Martin, although a small amount of daily water temperature data was collected from Lake St. Martin in 2013 (see Section 6.2.2). Satellite imagery was used to determine Project effects in the vicinity of the inlet to Reach 1(Section 6.2.5).

In Reach 1, field investigations included the following:

- Deployment of a water temperature logger to collect daily water temperature data during the 2014 open water season; and
- Surveys to describe the availability of suitable habitat for fish, including the measurement of water depth, ice thickness (when appropriate) and dissolved oxygen (DO) concentration, were conducted in March and May of 2013.

In the Buffalo Creek watershed, field investigations included the following:

- Deployment of a water temperature logger to collect daily water temperature data from the downstream end of Buffalo Creek during the open water season from 2011-2014, and from Big Buffalo Lake and the upstream end of Buffalo Creek during the 2014 open water season;
- Surveys to describe the availability of suitable habitat for fish in Big Buffalo Lake, including the measurement of water depth, ice thickness (when appropriate) and DO concentration, were conducted in March and May of 2013. A similar survey was also conducted in Buffalo Creek in March 2013;
- Aquatic habitat surveys to measure water depth, water temperature, and DO, and collect substrate information were conducted in Big Buffalo Lake in 2011, 2013 and 2014;
- Aquatic habitat surveys to measure water depth, wetted width, and collect stream morphology, substrate, and aquatic vegetation information, were conducted in Buffalo Creek in 2011, 2013 and 2014;
- Digital geo-referenced photographs were collected along the entire length of the Buffalo Creek watershed in 2011;

- Digital orthometric data for the entire Buffalo Creek watershed collected to support physical environment monitoring in 2011, 2013 and 2104;
- Riparian vegetation surveys conducted in support of hydraulic modeling provided information on plant species abundance and diversity along Buffalo Creek in 2011, 2013 and 2014; and
- Cross-section surveys conducted in support hydraulic modeling.

In the Dauphin River, field investigations included the following:

- Deployment of a water temperature logger to collect daily water temperature data from the Dauphin River downstream of its confluence with Buffalo Creek during the 2011 open water season, and both upstream and downstream of its confluence with Buffalo Creek during the open water season from 2012-2014; and
- Collection of bathymetric and substrate data using sonar technology in 2011, 2013 and 2014.

In Sturgeon Bay, field investigations included the following:

- Deployment of a water temperature logger to collect daily water temperature data from Sturgeon Bay during the open water season from 2011-2014;
- Collection of bathymetric and substrate data using sonar technology in 2011, 2013 and 2014;
- Visual assessment of substrate grabs; and
- Collection of substrate samples for laboratory analysis of particle size.

The following sections provide a detailed description of aquatic environment monitoring program data collection and analysis methods. Also included is a description of how data from particular components of the physical environment monitoring program were analyzed to help inform the aquatic habitat effects assessment.

6.2.1 Aquatic Habitat Assessment Parameters

A number of physical habitat parameters can be used to assess the quantity and quality of aquatic habitat. Aquatic habitat is often classified on the basis of water depth, water velocity, substrate type, and cover (including large rooted plants, terrestrial debris, riparian vegetation, and other large structures). In general, the study area waterbodies is a composite of lacustrine (Lake St. Martin, Big Buffalo Lake, Sturgeon Bay), riverine (Dauphin River), and creek (Buffalo Creek) habitats (Figure 6.2-1). These coarse habitats can be further classified according to specific habitat parameters. The following physical habitat parameters are considered for this assessment approach based on the availability of certain data sets and their importance in characterizing and assessing change to aquatic habitat.

6.2.1.1 Available Habitat Area

Areas of total habitat given for a specific water regime and inflow or water level condition provided the context to estimate overall habitat gains, alterations, and/or losses. The habitat assessment considered habitat under a range of flow conditions: low (5^{th} percentile flows); intermediate or median (50^{th} percentile flows) and high (95^{th} percentile flows). In order to abridge the assessment a median (50^{th} percentile) flow condition was used to assess change across project phases.

6.2.1.2 Water Level Habitat Zones

Water level habitat zones are defined by the water regime. The maximum available habitat area could be defined as the habitat area available under a 95^{th} percentile flow or water level. However that habitat is not sustained for the entire temporal extent or project phase and therefore habitats can be classified according to their availability to aquatic biota.

- Intermittently exposed zone (IEZ) habitats can be defined as habitats that are not sustained for a given water regime period, or the area of habitat between the 95^{th} and 5^{th} percentile flow or water levels (Figure 6.2-1).
- Predominantly wetted zone (PWZ) habitats or the areas below 5^{th} percentile water levels remain almost entirely wetted for the duration of the given water regime, providing constant habitat to biota, the quality of this habitat changes with changes to flow (Figure 6.2-1).

6.2.1.3 Water Depth

Water depth is an important aquatic habitat feature. Deep areas in water bodies can provide crucial overwintering habitat, refuge from predation or high water velocities. Shallow areas of water bodies can provide important habitat for aquatic and riparian plant species, which in turn provides important habitat for some fish species. In this assessment deep and shallow depth zones are defined as the areas above and below 2 metres (Figure 6.2-1) and are further defined as follows:

- Shallow habitats are defined as areas less than 2 metres. The 2 metre depth division was selected to indicate areas of shallow littoral habitat. Often this boundary indicates the depths to which light penetrates to the benthic zone, which has implications for the growth of rooted aquatic macrophytes and can be an indication of overall water clarity.
- Deep habitats are defined as areas that are deeper than 2 metres. Deep water habitats can provide fish with refuge from strong currents, and crucial overwintering habitat.

6.2.1.4 Water Velocity

The distribution of habitat and the biota that use them is strongly influenced by the velocities inherent within a water body. Lentic or standing water habitats, often characterize lacustrine environments and the peripheries of riverine and creek habitats (Figure 6.2-1). Lotic or flowing water habitats, typically dominate riverine and creek habitats. Certain velocities can attract some fish species to move upstream. Some fish species may find high water velocities to be a deterrent. The following water velocity classes are defined for this assessment, the classes follow those defined for other aquatic habitat assessments (Keeyask Hydropower Limited Partnership 2012):

- Lentic or standing water habitats are defined as areas of standing water which have flow below 0.2 m/s. Generally lentic habitats support organisms that avoid flowing water and are adapted to live in standing waters, including many species of aquatic plants. Some fish species tend to prefer these habitats when carrying out there life history stages (i.e., Northern Pike). During flooding riverine systems such as the Dauphin River can cause backwatering in tributary creeks (i.e., Buffalo Creek) creating a net lentic environment in a habitat that normally has flow.

- Lotic habitats having low flow are defined as areas of flowing water that have water velocities ranging from 0.2 to 0.5 m/s.
- Lotic habitats having moderate flow are defined as areas of moderately flowing water that have velocities ranging from 0.5 to 1.5 m/s.
- Lotic habitats having high flow are defined as areas of high flowing water that have velocities extending beyond 1.5 m/s.

6.2.1.5 Substrate

The benthic structure of a water body is important in sustaining various fish life history stages for different species of fish in addition to all other biota inhabiting the bottoms of water bodies. Changes to the overall composition of the benthic structure can impact the habitats of various fish species. This assessment generally classifies substrates as being hard and coarse (bedrock, boulder and cobble, and gravels), or soft and fine (sand, silt, and clay).

6.2.1.6 Vegetation and Cover

Aquatic and riparian vegetation are important features of aquatic habitat. Instream aquatic macrophytes and debris provide structure and cover from predation, temperature, and refuge from high velocities. Riparian vegetation functions to trap sediment from runoff and prevents erosion due to slope failure.

6.2.2 Water Temperature

In addition to the aquatic habitat parameters listed in Section 6.2.1, water temperature impacts fish use of aquatic habitat, so water temperature data were collected during open water periods since fall 2011.

6.2.2.1 Sampling Sites

At the beginning of fisheries investigations each year, Onset HOBO Water Temperature Pro v2 loggers (Model U22-001) were installed throughout the study area (Figure 6.2-2). The following eight locations were monitored at least once since 2011:

- Lake St. Martin approximately 1.5 km west of Reach 1, TL-05 (2012-2014);
- the downstream end of Reach 1, EC-02 (2014);
- Big Buffalo Lake, BBL-01 (2014);
- the upstream end of Buffalo Creek, BC-01 (2014);
- Buffalo Creek mouth upstream of the Dauphin River, TL-04 (2011-2014) and BC-TM (2014);
- the Dauphin River upstream of Buffalo Creek, TL-06 (2012-2014);
- the Dauphin River downstream of Buffalo Creek, TL-03 (2011-2014); and,
- Sturgeon Bay north of the Dauphin River mouth, TL-01a, -01b and -01c (2011-2014).

6.2.2.2 Field Methods

Three temperature loggers were installed at various depths at each of the two Sturgeon Bay sites in 2011 to collect vertical temperature profiles. Single loggers were deployed on all other occasions.

While deployed, temperature loggers were operated continuously and were programmed to record water temperature at one- (2011) or four-hour (2012-2014) intervals. Water temperature data were downloaded periodically from the loggers using software provided by the manufacturer (Onset HOBOware Pro ver. 2.3.1). Temperature data were collected from an additional four loggers installed by KGS in Reach 1 and the Buffalo Creek watershed during 2014. The KGS loggers recorded temperature information every 15 minutes.

6.2.2.3 Data Analysis

Daily mean water temperature was plotted to illustrate daily changes throughout the monitoring period and to compare trends between years.

6.2.3 Aquatic Habitat Field Surveys

6.2.3.1 Ice Cover Season Habitat Assessments

Sampling sites in Reach 1, Big Buffalo Lake, and Buffalo Creek were accessed by snowmobile and holes were drilled through the ice using a Stihl power auger. The location of each sampling station was recorded using a handheld Garmin GPSMap 76S GPS, and the time at which sampling occurred was noted. At each sampling location, snow cover on top of the ice was measured (± 0.1 m), ice thickness was measured (± 0.01 m), and effective water depth was measured (± 0.01 m). Effective water depth is defined as the depth of water occurring beneath the bottom surface of the ice and is determined by measuring the overall water depth (top of ice to bottom of water body) minus the thickness of ice occurring from the top of ice to the bottom of the ice surface.

Where water depth was sufficient, *in situ* measurements of water quality parameters including pH, conductivity, turbidity, and water temperature were collected using a Horiba® W22-XD water quality meter. As the DO sensor on the Horiba meter could not be correctly calibrated, all DO measurements were collected using a handheld YSI-550a DO meter.

6.2.3.2 Open Water Season Habitat Assessments

6.2.3.2.1 Big Buffalo Lake

Aquatic habitat in Big Buffalo Lake was characterized by collecting depth measurements and describing substrate compaction and size characteristics at a series of locations across the lake in both years. Location of sampling sites was recorded using a Garmin GPSMap 76S GPS receiver. Depth measurements were collected with a hand-held depth sounder.

Substrate compaction was a qualitative assessment of the firmness of the substrate completed by probing the bottom of the lake with a pole. Two compaction categories, hard or soft, were used. Substrate size classification was assessed visually (it was possible to see to the bottom of the lake at all locations). Substrate size classes were defined based on Wentworth (1922), and included the following size categories:

- Boulder > 256 mm
- Cobble 64-256 mm

- Gravel (aggregate) 2-64 mm
- Sand (aggregate) 62.5 µm – 2 mm
- Silt 3.9-62.5 µm
- Clay < 3.9 µm

6.2.3.2.2 Buffalo Creek

Habitat information was also collected from a series of locations along Buffalo Creek. Location of sampling sites was recorded using a Garmin GPSMap 76S GPS receiver. At each location, the following habitat parameters were measured, categorized, or described:

- Habitat category (riffle, pool, run; after Bisson et al. 1982);
- Wetted width (m);
- Water depth at 5 locations across the creek (m);
- Substrate composition;
- Substrate compaction; and,
- Presence/absence and type of instream vegetation.

Substrate compaction was a qualitative assessment of the firmness of the substrate underfoot. Two compaction categories, hard or soft, were used. Substrate size was assessed visually and classification was based on Wentworth (1922; see above). At each location, other habitat attributes of interest such as the occurrence of beaver dams were noted.

6.2.3.3 Water Depth Measurement and Substrate Classification

Water depth and substrate mapping studies were conducted in 2011, 2013, and 2014 (North/South Consultants Inc. 2013). Surveys focused on the lower Dauphin River and Sturgeon Bay in the immediate vicinity of the Dauphin River outflow (Figures 6.2-3 to 6.2-5). A more extensive survey of Sturgeon Bay was conducted in 2013; the survey spanned the southwest shore of Sturgeon Bay from the Dauphin River outflow to just south of Willow Point (Figure 6.2-4).

6.2.3.3.1 Sonar Data Collection

Bathymetric and bottom-typing sonar surveys in both years were conducted from a 5.5 m foot boat operated at approximately 5 to 10 km/h. In 2011, spring 2013 and spring 2014, depth, positional data, and bottom-type data were acquired concurrently using a Quester Tangent Corporation (QTC) Series 5.5 scientific-grade 50 kHz echosounder paired with a Trimble Pro-XRS real-time differential global positioning system (DGPS). In fall 2013, similar data were acquired concurrently using a BioSonics Habitat MX scientific grade echosounder with an internal differential GPS. The BioSonics Habitat MX uses a 200 kHz transducer to record Sonar echoes. Both systems recorded at 1 second intervals. Substratum distribution patterns in the Dauphin River were also interpreted in specific areas in 2013 using images produced by a Lowrance HDS Gen2 side scan sonar.

In all surveys, the echosounder transducer was positioned 0.61 m below the surface of the water, adjacent to the hull in the middle of the boat. The DGPS receiver National Marine Electronics Association (NMEA) GGA output coordinates and time stamps were logged to a notebook computer along with the sonar depth and bottom-type data, using either QTC's QTRT acquisition software (2011 and spring 2013 data) or BioSonics Visual acquisition MX software (fall 2013 data). All surveys of the river consisted of longitudinal shoreline and centre channel transects and zig-zag, bank-to-bank, transects. Transect patterns are presented in Figures 6.2-3 to 6.2-5.

6.2.3.3.2 Substrate Validation

Dauphin River

During all sonar surveys, substrate samples were collected from areas of low water velocity along the lower Dauphin River to provide information used to validate the interpretation of the sonar data. Substrate samples were collected using a petite Ponar grab. At each site, Ponar penetration depth and relative proportion (%) of each substrate type within the sample was visually estimated and recorded. Substrate size classification was based on Wentworth (1922) (see Section 6.2.3.2.1).

In areas of the Dauphin River where high water velocity or hard substrates precluded the use of a substrate sampler, bottom structure and substrate and validation were achieved through a series of rebar drags. An 18" length of steel rebar was attached to a braided nylon rope and dragged along the river bed. The vibration and movement of the rebar on the river bed provides some indication of the substrate material: soft, fine substrate areas have very little vibration and jump, whereas complicated and hard bottoms have increased levels of vibration and jump. For each rebar drag transect, aggregate size was estimated and noted (aided by visual assessment where possible).

Sturgeon Bay

During all sonar surveys, substrate samples were collected from Sturgeon Bay to provide information used to validate the interpretation of the sonar data. Substrate samples were collected using a petite Ponar grab. Rebar drags were only rarely conducted in Sturgeon Bay.

In addition to validation sites to support sonar data collection, substrate samples were collected and analysed along several transects in Sturgeon Bay (see the Ponar grab dots on Figure 6.2-4 for an indication the location of these transects). The initial transect surveys in 2011 were intended to provide information to support the incomplete fall 2011 sonar data collection. Substrate samples from fall 2013 and fall 2014 were collected to provide substrate data comparative to that collected in 2011.

Along each transect, site locations (UTM NAD 83), water depths (m), and Secchi depths (m) were recorded. One petite Ponar substrate grab was collected per site, where possible. At each site, Ponar penetration depth and relative proportion (%) of substrate type within the sample was visually estimated and recorded. Substrate size classification followed the Wentworth scale (see Section 6.2.3.2.1).

A five centimeter (outer diameter) core tube (0.002 m^2 surface area) was used to collect a 100 mL sediment sub-sample from each site's single substrate grab. Sub-samples were transferred to individually labelled polyethylene bags and kept in a cool storage container until they could be refrigerated. Samples were then submitted to a Canadian Association for Laboratory Accreditation

(CALA) certified analytical laboratory (ALS Laboratories Group, Winnipeg, MB; ALS) for particle size (PSA) and total organic carbon (TOC) analyses.

6.2.3.3.3 Digital Photography

GPS-linked digital photography was used in 2011 to document shoreline conditions in the Dauphin River and to aid in the development of the substrate map. GPS-linked digital photography allows each image taken to be imprinted with geographic coordinates so that they can be mapped and displayed accordingly post-survey.

6.2.3.3.4 Habitat Classification and Quantification

As with analysis of Buffalo Creek watershed data, a GIS-based approach was used to classify and quantify aquatic habitat in the Dauphin River during 2011, 2013 and 2014. The following sections describe the specific methods used to create detailed bathymetry and substrate maps and to make comparisons between years.

Bathymetry

Results of the depth and substrate type analysis for both years were exported to a CSV file which was then imported into Microsoft Excel for additional processing, including correction for transducer depth. The corrected sonar depths were combined with vertices extracted from the shoreline polyline file, which had been assigned zero depth values using ArcGIS 10 (2011) or 10.2 (2013 and 2014) software. The merged shapefile was imported into Surfer® 9 (2011) or 11 (2013 and 2014; Golden Software) and a Kriging spherical variogram model interpolation was used to produce a 5 m pixel resolution depth grid. The raster grid was imported back into ArcGIS for vector contouring at 0.5 m intervals and final cartographic presentation for the report. Depths were corrected further with manual editing where the depth algorithm had noticeable errors.

Substrate

The characteristics of acoustic echoes returned from a river or lake bottom are unique to each bottom type. An acoustic pulse impacting the substratum is reflected and scattered at the substratum-water interface and by the material in the sub-surface. The shape of the acoustic echo provides a means to discriminate between different bottom types and is determined mainly by the acoustic impedance of the sediment and/or the scattering characteristics of the substrate-water interface and the frequency of the acoustic pulse.

Although the acoustic data from both years were classified into groups using principal component analysis (PCA) followed by K-means clustering, the specific analysis methods and software differed between years. The following two paragraphs describe the analytical differences between the two years.

The 2011 and spring 2013 and 2014 QTC acoustic data were exported from QTC Impact and then imported to and analyzed with the statistical package SPSS. A PCA reduced the 166 acoustic waveform variables related to bed roughness and hardness down to 5 principal component variables representing over 90% of the variability within the data set. The K-means clustering approach then produced five discrete acoustic classes, representing five different substrate types. The classified acoustic tracks were imported into ArcGIS 10 to identify the acoustic classes that co-occurred with the bottom-type validation classes. In addition, the GPS-linked digital shoreline photographs were used to validate the acoustic bottom-type classes and to increase mapping resolution in the near-shore zone. Substrate classes were digitized as polygons from the classified acoustic tracks, and a final substrate data set was mapped and class areas calculated in ArcGIS 10.

BioSonics data from fall 2013 were analysed with Visual Habitat MX software. Visual Habitat MX software was first used to detect the bottom depth using a rising edge method. Analyzing hydroacoustic data in Visual Habitat MX for bottom or substrate types is a two-step process: in step 1, the software extracts features from the bottom echo signal, and in step 2, the software determines the number of types by clustering the features extracted in step 1. By defining E1 (bottom echo – first part) and E2 (bottom echo – second part), Visual Habitat MX defines where the algorithm starts to extract features for bottom classification from the first and second parts of the bottom echo. Setting a reference depth allows the algorithm to compensate for the effect the depth has on the shape of the bottom echo envelope by normalizing it to that reference depth. The user-supplied number of clusters informs the algorithm how many bottom types to sort the data into.

In order to facilitate assessment of change in substrate composition, substrate classifications were standardized into four assessment classes (Table 6.2-2). Changes in substrate composition in the Dauphin River and Sturgeon Bay were examined by comparing the area (m^2; ha) and proportion of area that each substrate class occupied within the respective surveyed areas. To conduct the analyses, substrate composition maps were standardized to spatial extent (i.e., slightly different areas were mapped during each survey) and the area of each substrate class for each survey was extracted using ArcGIS 10. Results were compared in tabular format and degree of change was expressed as change in area (m^2; ha) and proportion of each substrate class.

6.2.4 Analysis of Hydraulic Model Outputs

Two hydraulic models were used in to support the aquatic habitat assessments for study area waterbodies. These included the following:

1) MIKE 21 2D Hydraulic Model (steady state) – used to model water depth and water velocity based on flow conditions in the lower Dauphin River. Total wetted area was also derived from model outputs. Habitat parameters were modeled under a variety of flow conditions;

2) HEC RAS 1D Backwater Model – used to model water surface elevation, maximum channel depth, wetted width, and mean water velocity at cross-sections along Buffalo Creek. Habitat parameters were modeled under a variety of flow conditions.

6.2.4.1 Analysis of MIKE 21 Hydraulic Modeling Outputs

The Mike 21 2D hydraulic modeling (see PESV) modeling extent covers a small portion of the mouth of Buffalo Creek (300 m), the lower Dauphin River from 600 metres upstream of Buffalo Creek downstream to Sturgeon Bay, and the immediate area of Sturgeon Bay at the Dauphin River outflow (Figure 6.2-6). The flow parameters used to generate the MIKE 21 2D hydraulic model results are listed in Table 6.2-3. Three water regime scenarios were provided: Pre-flood (1977 – 2010), 2011 Flood (based on data from 01 April to 01 November 2011), and 2011/2012 Operation; the Pre-flood and 2011 Flood periods are two separate components of the Pre-Operation phase of the Project. In order to provide an estimate of the variation (90%) experienced for each water regime period, simulated flows for low flow (5^{th} percentile flow,) median flow (50^{th} percentile flow), and high flow (95^{th} percentile flow) were modeled.

The MIKE 21 modelling software produces a computational mesh of data points. At each modeled point in the computational mesh attributes such as UTM coordinates, bed elevation, depth, and velocity are included (Figure 6.2-7).

Depth and Velocity Rasters

The MIKE 21 computational mesh outputs were provided in Microsoft Excel format for each of the 9 model runs. Data were imported into ESRI ArcGIS 10.3 GIS software as an ESRI shapefile format. Each of the 9 model runs (Table 6.2-3) were queried for zero depths and removed in order to determine the shoreline boundary and available data points for each model run (Figure 6.2-3). A triangulated irregular network (TIN) analysis was conducted in order to interpolate velocities and depths between the modeled computational grid data points (Figure 6.2-7). ArcGIS uses Delauney criterion for the triangulation method. TINs are typically used as a digital representation of surface morphology (i.e., elevation or depth); however, the technique can be applied to other variables such as water velocity. The final processing step converted the TIN data format to a 3 m resolution raster data set. ArcGIS 10.3 Spatial Analyst was used to generate depth and velocity statistics (mean and maximum depths and velocities) for each of the 9 MIKE 21 model runs.

Shorelines (Habitat Area)

Following the triangulation processing a step was taken to delineate the TIN data area eliminating extraneous extrapolation outside of the wetted extents of the waterbodies. Vector shorelines were then produced by first executing a TIN Domain processing step, which generates a bounding vector polygon of the data points that were included in the analysis. The vector polygons were then further processed to remove internal islands and any additional geometric errors. Areas were then calculated within the GIS for all 9 MIKE 21 modeled shorelines and exported to Microsoft® Excel for tabulation and formatting.

Water Level Habitat Zones

Water level habitat zones, intermittently exposed zone (IEZ) and predominantly wetted zone (PWZ), were defined for the three water regime periods (Table 6.2-3). Intermittently exposed habitats are defined by the area of aquatic habitat that may become dewatered during a defined water regime period. The low flow (5th percentile) and high flow (95th percentile) are used to define the range of flow variation (90%) or intermittently exposed habitat. Predominantly wetted habitats are the areas that remain wetted even under low flow conditions. Water level habitat zone data sets were created in ArcGIS 10.3 using a geoprocessing technique known as a Union. Essentially the Union geoprocessing function overlays two GIS feature classes and allows the user to define the attributes for distinct areas in the overlay. In this case the 5th percentile and 95th percentile shorelines derived from the MIKE 21 model were entered as inputs to the Union. The resulting output feature class is a composite of the areas above and below the 5th percentile shoreline habitat extent, which can then be defined in the attribute tables as being intermittently exposed and predominantly wetted habitat zones.

6.2.4.2 Analysis of HEC-RAS Modeling Outputs

Buffalo Creek and Reach 1: Modeled Cross Section Variables

A HEC-RAS V.4.1.0 from the US Army Corps of Engineers backwater model was developed to simulate the hydraulic conditions on the reach of river between Big Buffalo Lake and Dauphin River and for the Reach 1 emergency channel during 2011/2012 Operation and 2011/2012 Closure.

The geometry of the HEC-RAS model utilized cross sections obtained from a combination of LiDAR and surveyed cross sections prior to the 2011/2012 Operation of the channel. A total of 30 stations were modeled using HEC-RAS hydraulic modeling software. The surveyed cross sections were located approximately 500 m apart, as shown on Figure 6.2-4. Modeled habitat parameters for the 5th, 50th, and 95th percentile flows were provided for each cross section and included:

- Wetted width;
- Mean velocity;
- Maximum channel depth;
- Water surface elevation.

These four parameters were summarized in Microsoft Excel by averaging across the 30 stations. Averages were tabulated and are included in Appendix 6A.

Buffalo Creek and Reach 1: HEC-RAS and LiDAR Shorelines

Vector shorelines of Buffalo Creek during 2011/2012 Operation were modeled. The HEC-RAS model along with the LiDAR DEM data was used to generate shoreline vectors at 5th, 50th, and 95th percentile flows during operation (Figure 6.2-8). The shoreline vectors were mapped and areas were calculated in the GIS and exported to Microsoft Excel for tabulation and formatting.

For Reach 1, wetted widths provided from the HEC-RAS model for eight cross sections under simulated 5th, 50th, and 95th percentile flows were used in concert with satellite imagery (Worldview-1 August 23, 2013) to produce shoreline vectors during 2011/2012 Operation and following 2011/2012 Closure. The GIS was used digitize vector polylines between the cross section wetted widths overlaid on the satellite imagery. Generally the satellite image and cross sections had good geometric agreement. The polylines produced for the 5th, 50th and 95th percentile shorelines were converted to polygons and areas were summarized and exported to Microsoft Excel for tabulation.

There was a minimal amount of overlap between the habitat products produced from the MIKE 21 and HEC-RAS models in the lower 300 metres of Buffalo Creek at the confluence with the Dauphin River. The GIS was used segment and remove the overlap from the HEC-RAS modeling in order to produce final habitat areas that were not 'double-counted' between the two models.

6.2.5 Analysis of Aerial and Satellite Imagery

Satellite and aerial imagery were used to quantify habitat areas for a number of locations throughout the study area. Table 6.2-4 provides an index of all satellite images used in the analysis. The sections below summarize the methods used to quantify habitat within the GIS for various study areas.

6.2.5.1 Lake St. Martin

Record construction drawings for the Reach 1 channel were provided by MIT. The drawings were compared to satellite imagery collected during closure of Reach 1 in the summer of 2013. Habitat areas created during the construction of the Reach 1 inlet at Lake St. Martin were digitized within the GIS and total habitat areas were calculated and tabulated.

6.2.5.2 Buffalo Creek Watershed

Habitat Boundary Determination

In order to quantify the composition of aquatic habitat, stream channel boundaries needed to be derived and combined with the habitat polygons to calculate habitat area and composition of the pre- and post-Project environments in the Buffalo creek watershed.

Aquatic habitat boundaries were derived from the high resolution digital orthometric aerial or satellite imagery. In 2011, the first step included a multivariate, unsupervised spectral classification of the blue green and red visible bands of the orthometric mosaic, completed using ArcGIS software. In 2013, the first step was to threshold the image band into land and water classes by selecting a digital number value (0-255) and qualitatively review the separation between land and water in the image. These classification approaches allow the user to specify the number of clustered spectral classes into which the image should be segmented. After the image has been classified, the user can then interpret the classes and assign them to a land cover type. In this case, a general classification of land and water was all that was required to delineate the land and water boundary. Once the imagery was reclassified into land and water cover types, it was converted from a raster to a vector GIS format. A smoothing algorithm (polynomial approximation with exponential kernel; PAEK) was used to remove the relic grid pattern remaining in the vector shoreline data set.

In areas where shadows were confused with the open water class, a manual interpretation of the shoreline was required, which involves 'heads up' digitization of the creek banks using ArcGIS software. After the digitization was completed the polylines representing the shorelines where converted to polygons.

The following analyses were conducted:

- The July 2011 aerial imagery (Table 6.2-4) was used to digitize a Pre-Operation shoreline for Buffalo Creek from Big Buffalo Lake to the confluence with the Dauphin River;
- The April 2012 Landsat 7 ETM+ (Table 6.2-4) image was used to delineate and estimate the maximum extent of open water in the Buffalo Lake Bog Complex during the 2011/12 operation;
- The August 2013 Worldview-1 image (Table 6.2-4) was used to digitize a shoreline for Buffalo Creek from Big Buffalo Lake to the confluence with the Dauphin River following 2012/2013 Closure.

Habitat Classification

The July 2011 aerial imagery, the high-resolution August 2013 Worldview-1 imagery, and the 07 July 2013 GAIM™ imagery (Table 6.2-4) were examined in ArcGIS to delineate polygons of discrete aquatic habitat types within the watershed. Geo-referenced digital photographs and field data were used to help validate the habitat type assigned to each polygon. Six habitat types were delineated (all adapted from Bisson et al. 1982, with the exception of Peat-Pool), including:

1) Riffle — Characterized by moderate to high gradients, stream velocities, and turbulence, below average depths, and the presence of hard substrates that range from fine to coarse, such as pebble, gravel, and cobbles;
2) Pool — Characterized by relatively low gradients, above-average depths, below-average water velocities and turbulence and substrata consisting of fine materials (i.e., silt or sand);
3) Run — Characterized by moderate gradients, average depths and velocities, controlled channel boundaries, low turbulence with an absence of any stream obstructions, and substrata consisting of small gravel and/or cobble;
4) Beaver Pool — Characterized by water impounded upstream of a complete or nearly complete channel obstruction typical of beaver dams. Pool locations reflect the current (photo date) location of beaver dams, which can shift from year to year;
5) Beaver Dam — Characterized as a full or partial obstruction of a stream consisting of woody debris and mud; and,
6) Peat-Pool — Characterized by low to stagnant velocities, organic substrates, and the absence/paucity of defined channel boundaries.

Habitat polygons were either stored in a centroid file where the boundary of each polygon was manually digitized in ArcGIS to generate a mosaic of habitat polygons (2011) or they were segmented and attributed with the matching habitat type within ArcGIS, producing a continuous polygon (2013). These polygons represented the distribution of various habitat types within the watershed. The geo-referenced digital photographs and field data were used to help validate the habitat type assigned to each polygon.

Habitat quantification in both years was conducted by calculating habitat class areas of the polygon mosaic within the GIS. The areas for each habitat type were then exported and tabulated in Microsoft Excel. The 2011 Pre-Operation habitat type classification of Buffalo Creek was tabulated along with the

2011/2012 Closure habitat classification from 2013 in Microsoft Excel. Habitat change was examined by comparing the amount of area (m^2; ha) occupied by each habitat type in 2011 (Pre-Operation) to the amount of area occupied by each habitat type in 2013 (2011/2012 Closure).

6.2.5.3 Sturgeon Bay

Selected Landsat images (Table 6.2-4) were used to show the dynamic and turbid nature of Sturgeon Bay during variable wind conditions.

Table 6.2-1. Timing of digital data collection and field campaigns in support of aquatic habitat monitoring.

Waterbody	Physical or Aquatic Environment Monitoring	Pre-operation (flood)	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation
Lake St. Martin					
Temperature Logger	Aquatic and Physical	-	14 Apr - 29 May, 2012	2013 Logger Lost	2014 Logger Lost
Reach 1					
Temperature Logger	Aquatic and Physical	-	-	18 Jun - 04 Jul, 2014	04 Jul - 22 Oct, 2014
Fish habitat surveys	Aquatic	15-17 Aug 2011	-	28 Mar 2013 28-29 May 2013	-
Cross-section surveys [1]	Physical	Oct 2011	-	03-07 July 2013	-
Big Buffalo Lake					
Temperature Logger	Aquatic and Physical	-	-	18 Jun - 04 Jul, 2014	04 Jul - 22 Oct, 2014
Atlis Geomatics [2]	Physical	Jul 2011	-	-	-
Geo-referenced photos	Aquatic	15-17 Aug 2011	-	-	-
Fish habitat surveys	Aquatic	15-17 Aug 2011	-	28 Mar 2013 28-29 May 2013 04-06 Jul 2013 18-20 Jun 2014	-
GAIM [3]	Physical	-	-	04-06 July 2013 June 2014	-

Table 6.2-1. Continued.

Waterbody	Physical or Aquatic Environment Monitoring	Pre-operation (flood)	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation
Buffalo Creek					
Temperature Logger [4]	Aquatic and Physical	19 Oct - 01 Nov, 2011	01-04 Nov, 2011 16 Apr - 08 Nov, 2012	14 May - 07 Nov, 2013 15 May - 04 Jul, 2014	04 Jul - 23 Oct, 2014
Atlis Geomatics [2]	Physical	Jul 2011	-	-	-
Geo-referenced photos	Aquatic	15-17 Aug 2011	-	-	-
Cross-section surveys [1]	Physical	Oct 2011	-	03-07 July 2013	-
Fish habitat surveys	Aquatic	15-17 Aug 2011	-	28 Mar 2013 04-06 Jul 2013 18-20 Jun 2014	-
Vegetation Survey	Physical	Oct 2011	-	03-05 July 2013 18-20 Jun 2014	-
GAIM [3]	Physical	-	-	04-06 July 2013 June 2014	-
Dauphin River					
Temperature Logger	Aquatic and Physical	19 Oct - 01 Nov, 2011	01-29 Nov, 2011 16 Apr - 08 Nov, 2012	14 May - 07 Nov, 2013 13 May - 04 Jul, 2014	04 Jul - 04 Nov, 2014
Sonar surveys - bathymetry	Physical	01-04 Jul 2011	18-20 Jun 2012	05-07, 22-24 Jul 2013 18-22 Jun 2014	18-20 Jun 2012
Sonar surveys - substrate and bathymetry	Aquatic	13-14 Oct 2011	-	09 Jun 2013 11 Sep 2013 18-22 Jun 2014	-

Table 6.2-1. Continued.

Waterbody	Physical or Aquatic Environment Monitoring	Pre-operation (flood)	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation
Sturgeon Bay					
Temperature Logger	Aquatic and Physical	19 Oct - 01 Nov, 2011	01-15 Nov, 2011 18 Apr - 07 Nov, 2012	02 Jun - 06 Nov, 2013 2014 Logger Lost	2014 Logger Lost
Sonar surveys - bathymetry and substrate	Aquatic	14 Oct 2011	-	09-13 Sep 2013 18-25 Jun 2014	-
Visual assessment of substrate composition	Aquatic	14 Oct 2011	-	09-13 Sep 2013 18-25 Jun 2014	-
Particle size analysis of sediment samples	Aquatic	14 Oct 2011	-	09-13 Sep 2013 18-25 Jun 2014	-

1 - Cross section surveys provided information on channel scour. Data also used in HEC-RAS modeling (see PESV).
2 - Digital orthometric imagery.
3 - GAIM™ = Geo-referenced Aerial Imagery and Mapping, see Appendix 6B.
4 - Data from the downstream end of Buffalo Creek (logger TL-04) in all years except 2014 when the logger was lost; data from BC-01 (upstream end of Buffalo Creek) and BC-TM (downstream end of Buffalo Creek) in 2014 (see Figure 6.2-8).

Table 6.2-2. Re-classification of substrates used to assess substrate change over multiple time periods prior to and after operation of Reach 1.

Original Classification	Assessment Classification
Bedrock- Limestone	Bedrock
Boulder/Cobble Cobble/Gravel	Boulder/Cobble
Compacted Gravel Gravel/Sand	Gravel
Sand Sand/Silt Clay/Silt	Fines

Table 6.2-3. Hydraulic modeling flow parameters used as inputs in Mike 21, and Lake Winnipeg water levels.

Water Regime	Flow Percentile	Percentile Date	Total Dauphin River Outflow (m^3/s)	Dauphin River Flow (m^3/s)	Buffalo Creek Flow (m^3/s)	Mean Lake Winnipeg Water Level (m ASL)
Pre-flood (1977 -2010)	5th	-	8	7	1	217.52
	50th	-	58	57	1	217.52
	95th	-	213	212	1	217.52
2011 Flood	5th	-	292	291	1	218.2
	50th	-	527	526	1	218.2
	95th	-	589	588	1	218.2
2011/2012 Operation	5th	30-Oct-12	188	142	46	217.58
	50th	16-May-12	343	221	123	217.58
	95th	12-Nov-12	521	380	141	217.66

Table 6.2-4. Summary of satellite and aerial imagery data sets used to assess aquatic habitat.

Date	Type	Platform	Resolution (m)	Area Coverage	Lake St. Martin Water Level (m)	Lake Winnipeg Water Level (m)	Dauphin River Discharge (m^3/s)	Buffalo Creek Discharge (m^3/s)	Wind Speed (km/h)	Wind Direction
19-Sep-09	Pan	Worldview-1	0.5	LSM,BC,DR	244.12	217.901	194	-	9	SSW
10-Jun-11	MS	Landsat 5 TM	30	LSM,BC,DR,SB	245.306	218.406	532	-	7	ESE
18-Jun-11	MS, RGB	Quickbird	0.5	LSM,BC,DR,SB	245.382	218.428	542	-	7	ESE
26-Jul-11	RGB	Atlis Geomatics Airphoto	0.3	LSM,BC,DR,SB	245.526	218.472	597	-	11	SSE
07-Sep-11	MS	Landsat 5 TM	30	LSM,BC,DR,SB	245.449	218.249	567	-	-	-
30-Sep-11	MS	Landsat 5 TM	30	LSM,BC,DR,SB	245.295	217.862	512	-	20	ESE
01-Apr-12	MS	Landsat 7 ETM+	30	LSM,BC,DR,SB	244.375	217.427	252	-	28	ESE
23-Aug-13	Pan	Worldview-1	0.5	LSM,BC,DR,SB	244.548	217.813	304	0.5	19	S
18-Jun-14	MS	Landsat 8	30	LSM,BC,DR,SB	244.724	218	323	4.4	-	-
22-Sep-14	MS	Landsat 8	30	LSM,BC,DR,SB	244.683	-	302	-	14	W

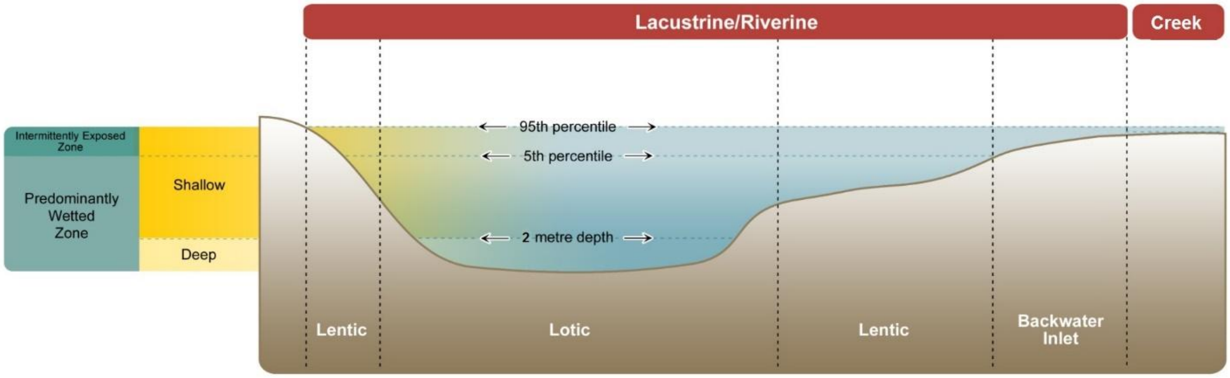


Figure 6.2-1. Schematic diagram of aquatic habitat parameters used in this assessment

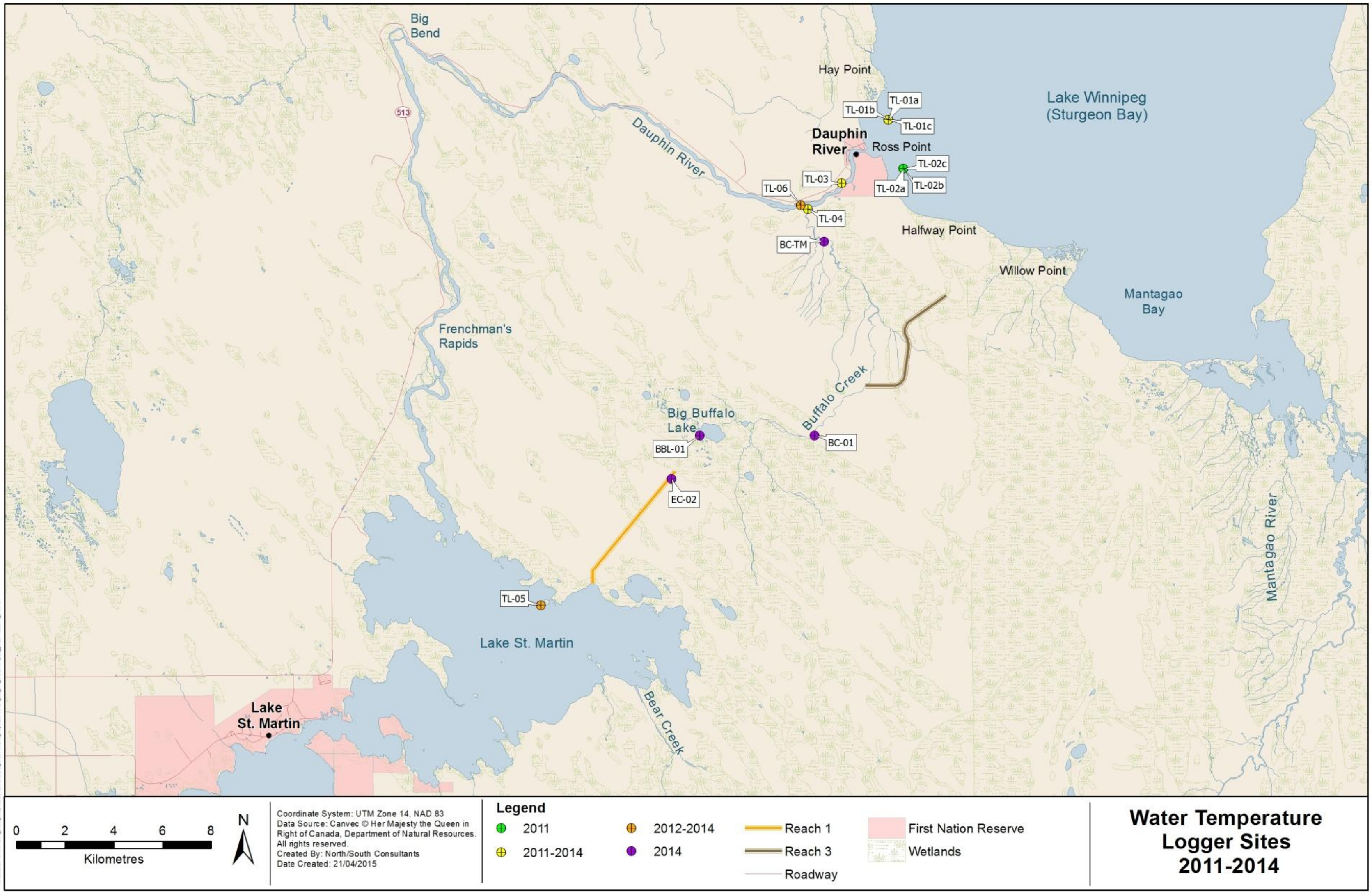


Figure 6.2-2. Locations of water temperature loggers installed in Lake St. Martin, Buffalo Creek, the Dauphin River, and Sturgeon Bay, 2011-2014.

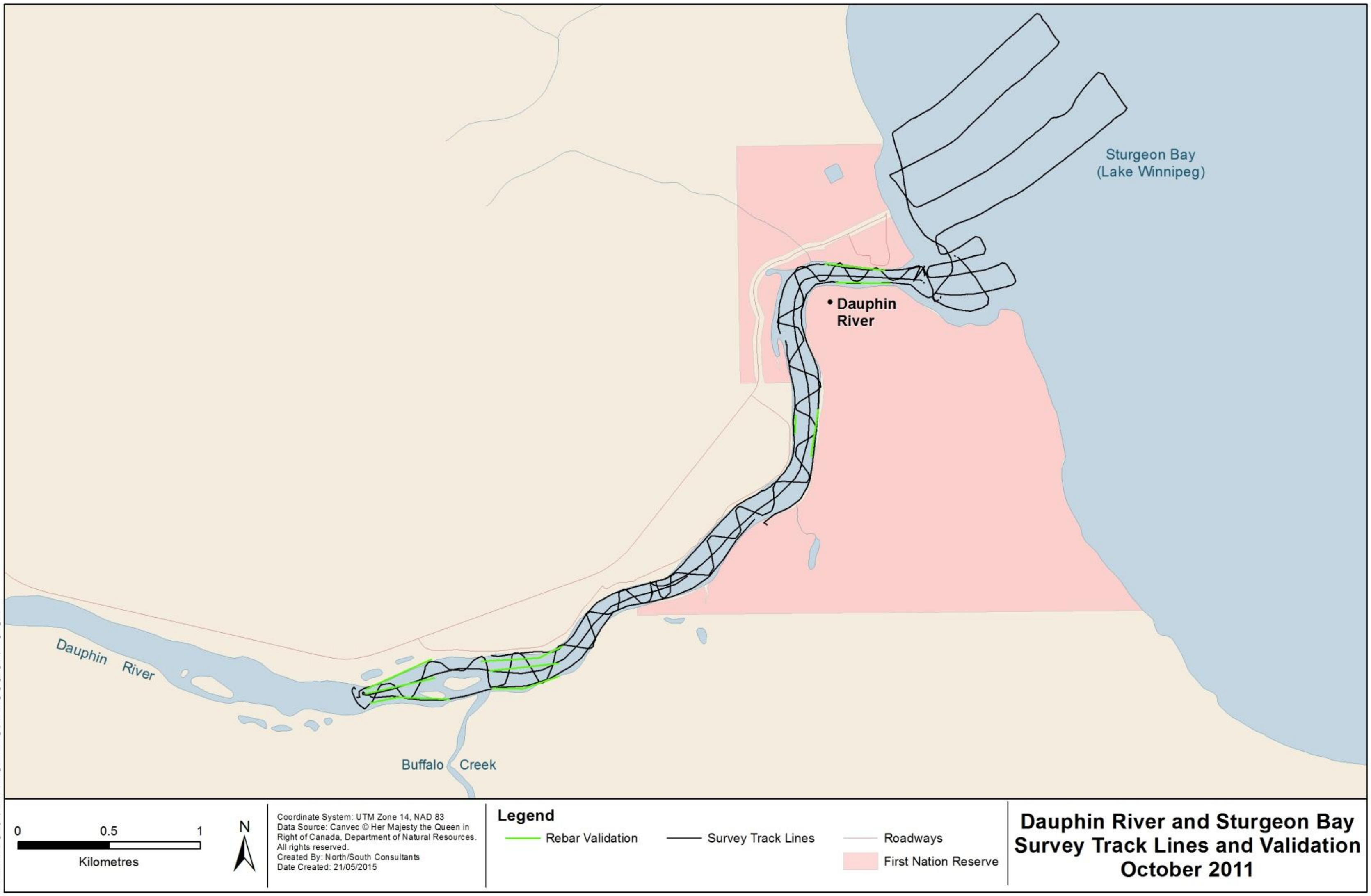


Figure 6.2-3. Map showing the pattern of transects traveled during echosounder surveys and substrate validation sites in the Dauphin River, fall 2011.

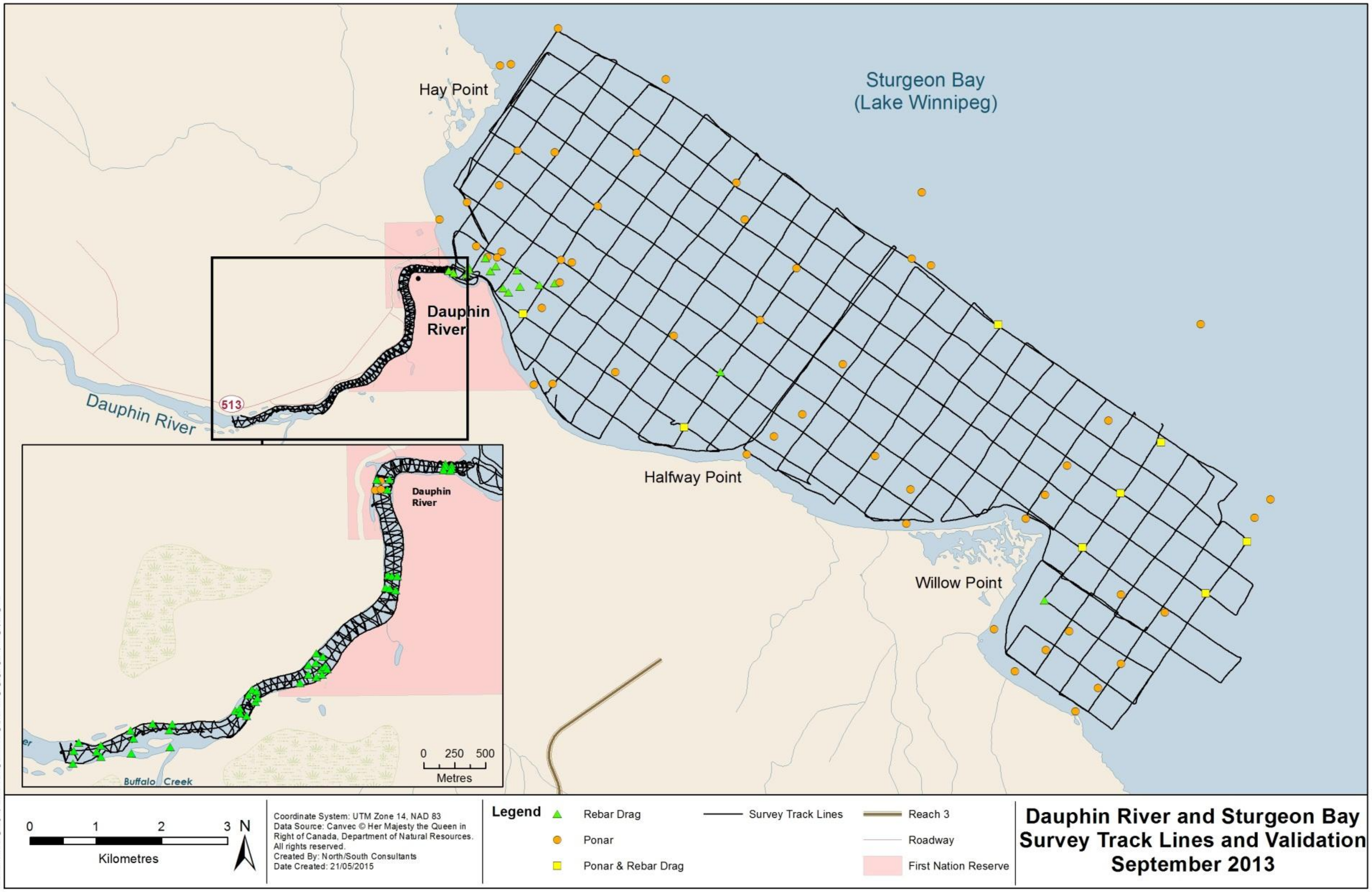


Figure 6.2-4. Map showing the pattern of transects traveled during echosounder surveys and substrate validation sites in Dauphin River and Sturgeon Bay, fall 2013.

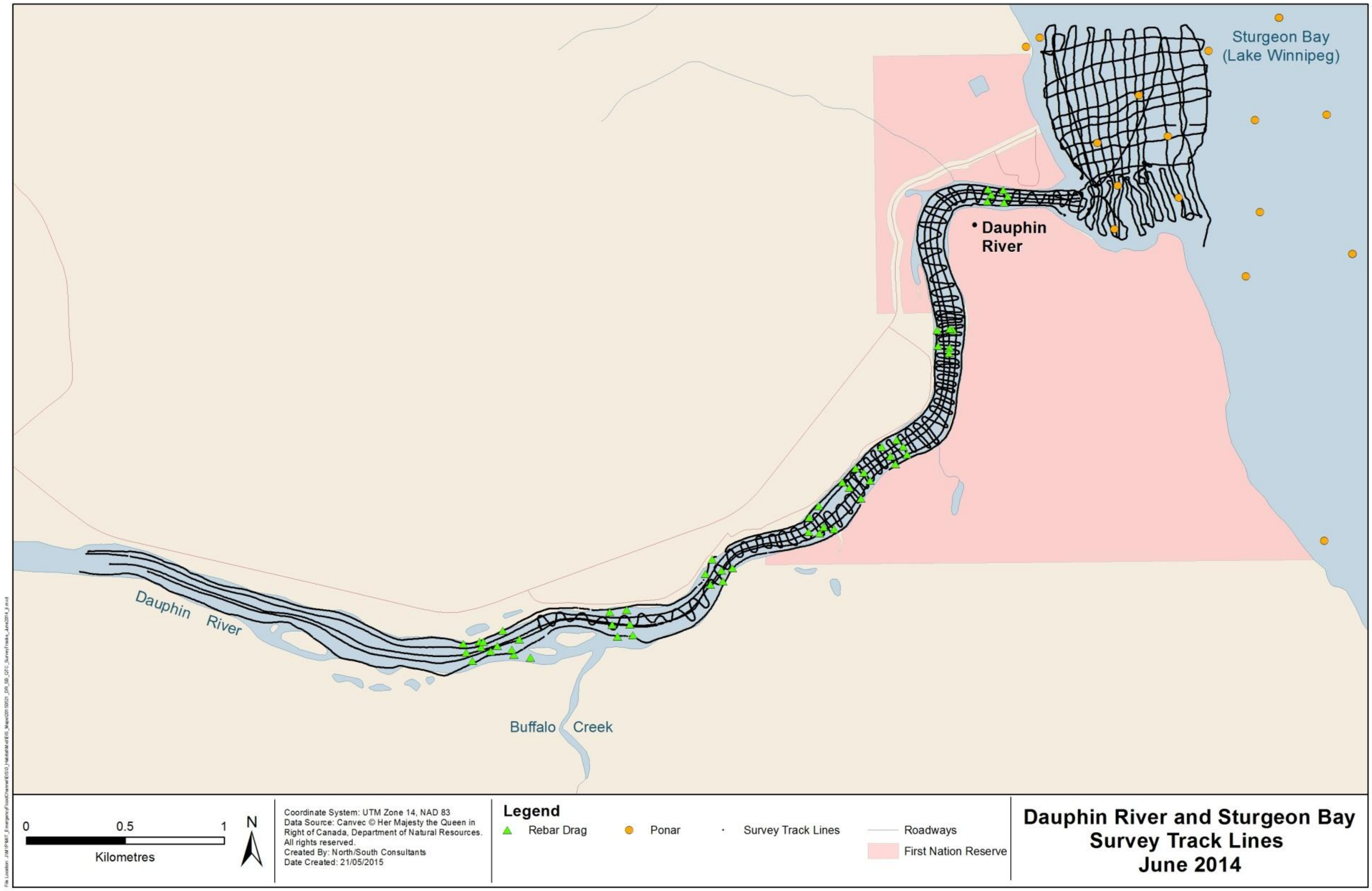


Figure 6.2-5. Map showing the pattern of transects traveled during echosounder surveys and substrate validation sites in Dauphin River and Sturgeon Bay, June 2014.

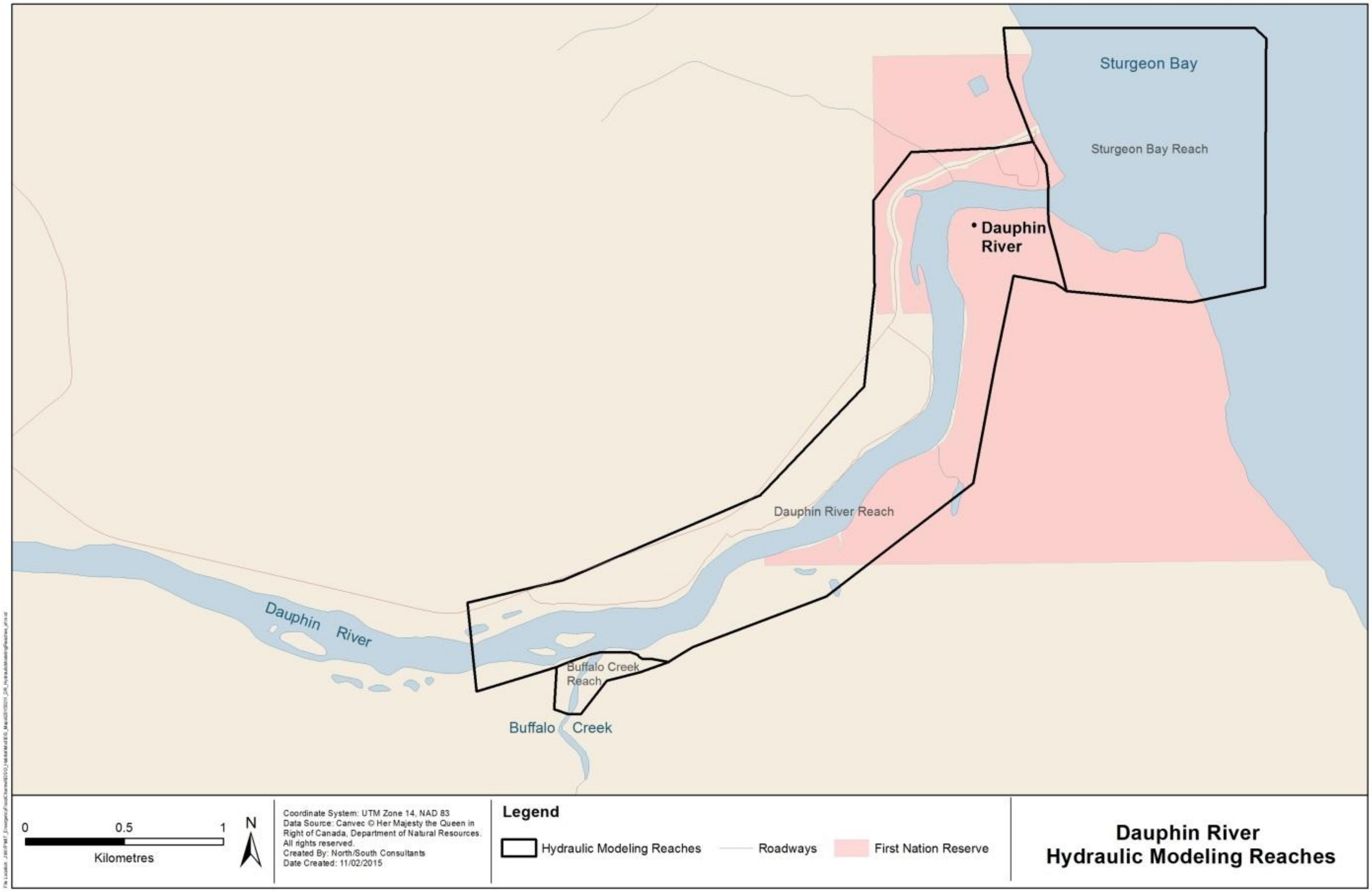


Figure 6.2-6. Reach boundaries created for the analysis of the MIKE 21 hydrodynamic model outputs.

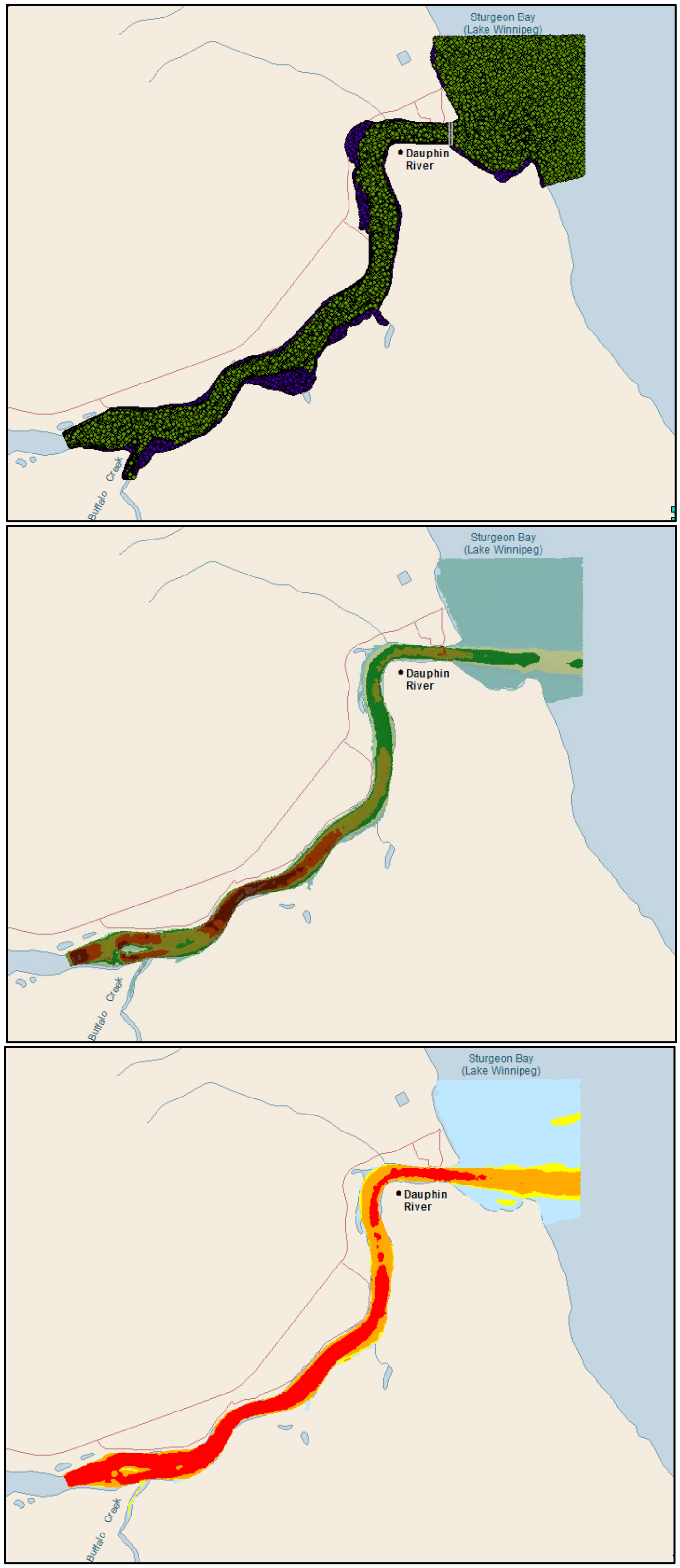


Figure 6.2-7. The MIKE 21 computational mesh output (top), productions of a TIN (middle) from the model output; and conversion and classification of the velocity raster data (bottom).

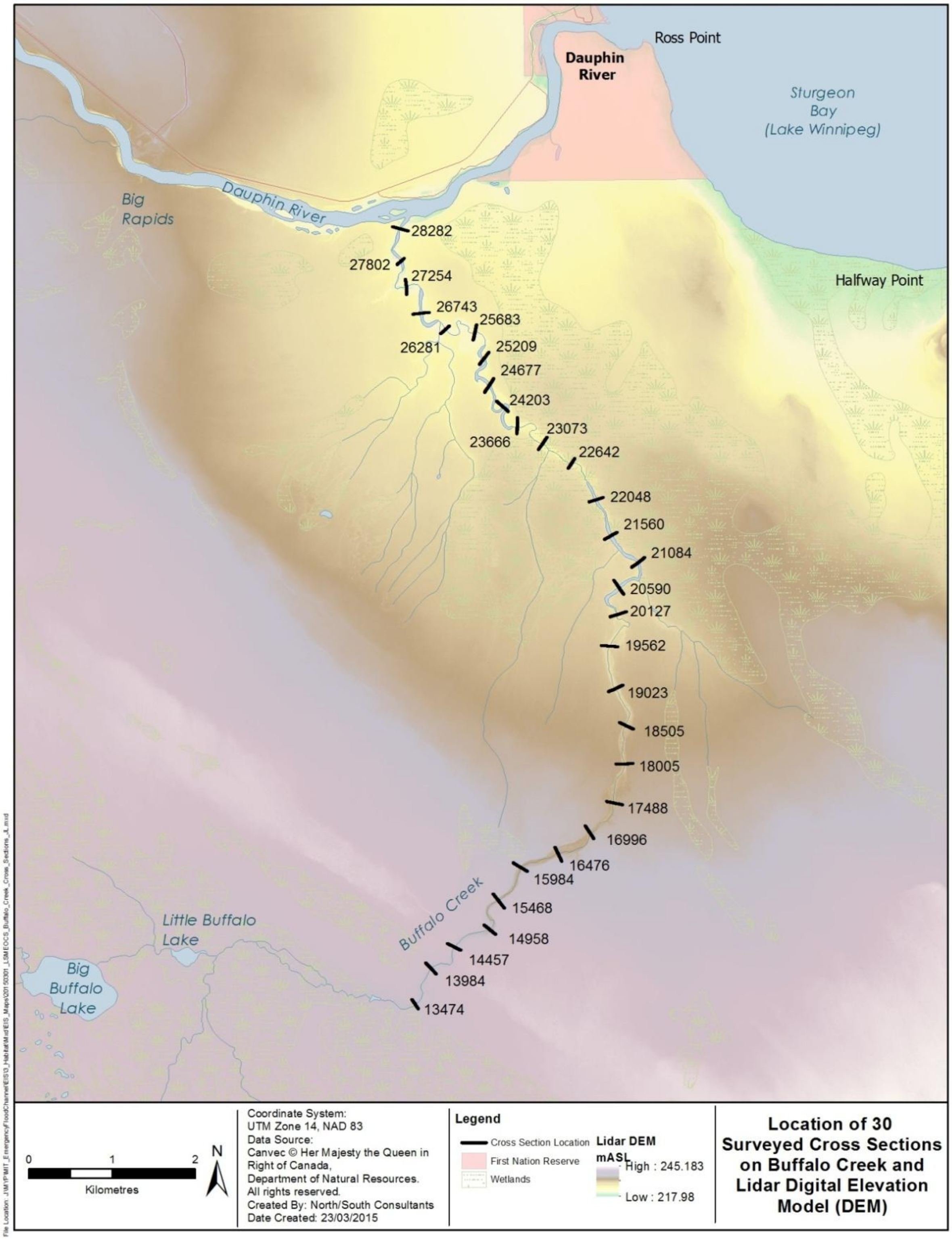


Figure 6.2-8. Map showing the location of the 30 surveyed cross sections along Buffalo Creek, the LiDAR based digital elevation model is shown in the background.

6.3 LAKE ST. MARTIN MONITORING RESULTS

6.3.1 Pre-Operation

6.3.1.1 Pre-flood

Lake St. Martin is comprised of a north and a south basin connected by a narrow constriction (Figure 6.1-1). This area is commonly referred to as the Narrows.

The substrate in Lake St. Martin is primarily composed of soft mud; however, there is an extensive area of gravel, sand, and compacted mud along the lake's western shore near the mouth of the Fairford River. Parts of the north basin and the Narrows contain large areas of bare bedrock; extensive gravel bars and boulders are also abundant, which provide suitable spawning habitat for several fish species (North/South Consultants Inc. 2013). Much of the area immediately surrounding Lake St. Martin is wetland-herb/shrub habitat.

During the open water period, water level data is collected By Water Survey of Canada (Gauge # 05LM005) at a location in the south basin approximately 5 km southeast of the Fairford River. Traverse (1999) reported that, since the construction of the Fairford River Water Control Structure (FRWCS) in 1961 and the Portage Diversion in 1970, Lake St. Martin has been repeatedly exposed to flooding which has altered the water regime and vegetation in the lake. Wardrop Engineering Inc. (2001) found that regulated maximum and minimum water levels on Lake St. Martin are 0.79 m higher and 0.66 m lower, compared conditions prior to the FRWCS.

On average, the Pre-flood water surface elevation on Lake St. Martin was 243.3 mASL and ranged from 242.7 m to 244.3 m (Table 6.3-1; PESV Section 4.3.1); which was more variable than the desirable range of 242.9 m to 243.8 m (PESV Section 4.3.1).

A solid ice cover is typical in Lake St. Martin from November until April or May (PESV Section 4.3.2).

6.3.1.2 2011 Flood

The Lake St. Martin flood stage water level is defined as 244.4 m, and 50th percentile water level on Lake St. Martin was 244.9 mASL in 2011 (Table 6.3-1; Section 4.3.1).

The Project was designed to decrease water levels within Lake St. Martin (and more upstream waterbodies including Lake Manitoba) by providing an alternate route for water to flow out of the lake into Sturgeon Bay. Construction of Reach 1 necessitated that a portion of the northeast shoreline of the north basin of Lake St. Martin, as well as surrounding wetland/aquatic vegetation, be excavated to create the Reach 1 inlet and a barge channel. As aquatic habitat surveys were not conducted in the Reach 1 inlet area of Lake St. Martin, the amount of habitat impacted by construction of Reach 1 were estimated from WorldView high-resolution satellite imagery (Figures 6.3-1 and 6.3-2).

Construction of the Reach 1 inlet resulted in an overall increase in the amount of aquatic habitat in Lake St. Martin (Table 6.3-1). Excavation of the inlet itself accounted for the majority of this increase (4.7 ha), while excavation of the barge channel led to an additional 1.5 ha of created habitat (Table 6.3-1). A total of 6.2 ha of terrestrial habitat was excavated during Reach 1 inlet construction, creating an equivalent amount of new aquatic habitat.

A total of 1.9 ha of aquatic habitat was permanently altered through the removal of wetland/aquatic vegetation. There was an assumed increase in water depth in the channel construction areas as the result of dredging, with no changes in water velocity or water surface elevation. Substrate composition likely changed due to dredging of the original benthic material, but the nature of this change is unknown.

Reach 1 construction also resulted in the loss of 200 m of Lake St. Martin shoreline habitat, but 1600 m of new shoreline habitat were created along the edges of the inlet and barge channels (each of which is 400 m long). Although not comparable to the shoreline habitat lost, the majority of the new shoreline was not armoured or stabilized and it is expected that, with time, will be modified by naturally occurring physical processes and will resemble naturally occurring shoreline conditions in the area.

6.3.2 Operation

Reach 1 operation caused water velocity to increase (not measured) in the vicinity of the Reach 1 inlet, converting habitat in this area from lentic to primarily lotic.

Operation of Reach 1 altered the ice regime in the vicinity of the Reach 1 inlet: While this area was ice-covered during the winter of 2010/2011 (Pre-Operation), open water conditions were predominant during the winter of 2011/2012 Operation (PESV Section 4.3.2). Similar to 2011/2012 Operation, open water was present at the inlet to Reach 1 during the winter of 2014/2015.

6.3.3 Closure

After Reach 1 was closed in November 2012, habitat in the vicinity of the Reach 1 inlet changed from primarily lotic to primarily lentic. With the reduction of water velocity, it is expected that the mobilization of sediments slowed and sedimentation occurred within the inlet area. Re-establishment of aquatic vegetation in dredged areas also likely resulted from the cessation of flows. During the two winters that Reach 1 was closed, (2012/2013 and 2013/2014), the inlet to Reach 1 was ice-covered (PESV Section 4.3.2).

Table 6.3-1. Aquatic habitat parameters used for assessment of effects to the Reach 1 inlet area of Lake St. Martin.

Habitat Parameters	Units	*Measured values/Observations*		
		Construction	Operation	Closure
Effect to habitat as a result of Project operation?		*yes*	*yes*	*no*
50th: Water Surface Elevation	mASL	244.9	244.2 (2011/2012) 244.7 (2014/2015)	244.4
50th: Aquatic Habitat (available wetted area)				
Reach 1 Inlet Excavation	ha	+4.7	No change	No change
Barge Channel Excavation	ha	+1.5	No change	No change
Shoreline Habitat	m	+1400	No change	No change
Water Depth	m	Increase [1]	No change	No change
Water Velocity	m^3/s	No data	Increase [1]	Decrease [1]
Wetland/Aquatic Vegetation	ha	-1.9	No change	Potential increase with removal of flow [1]
Substrate Conditions	-	No data	No data	Potential sedimentation with removal of flow [1]

1 - Not measured.

Figure 6.3-1. DigitalGlobe™ Wordview-1 Satellite image showing the area of Lake St. Martin prior to construction of Reach 1, and during 2011/2012 Closure.

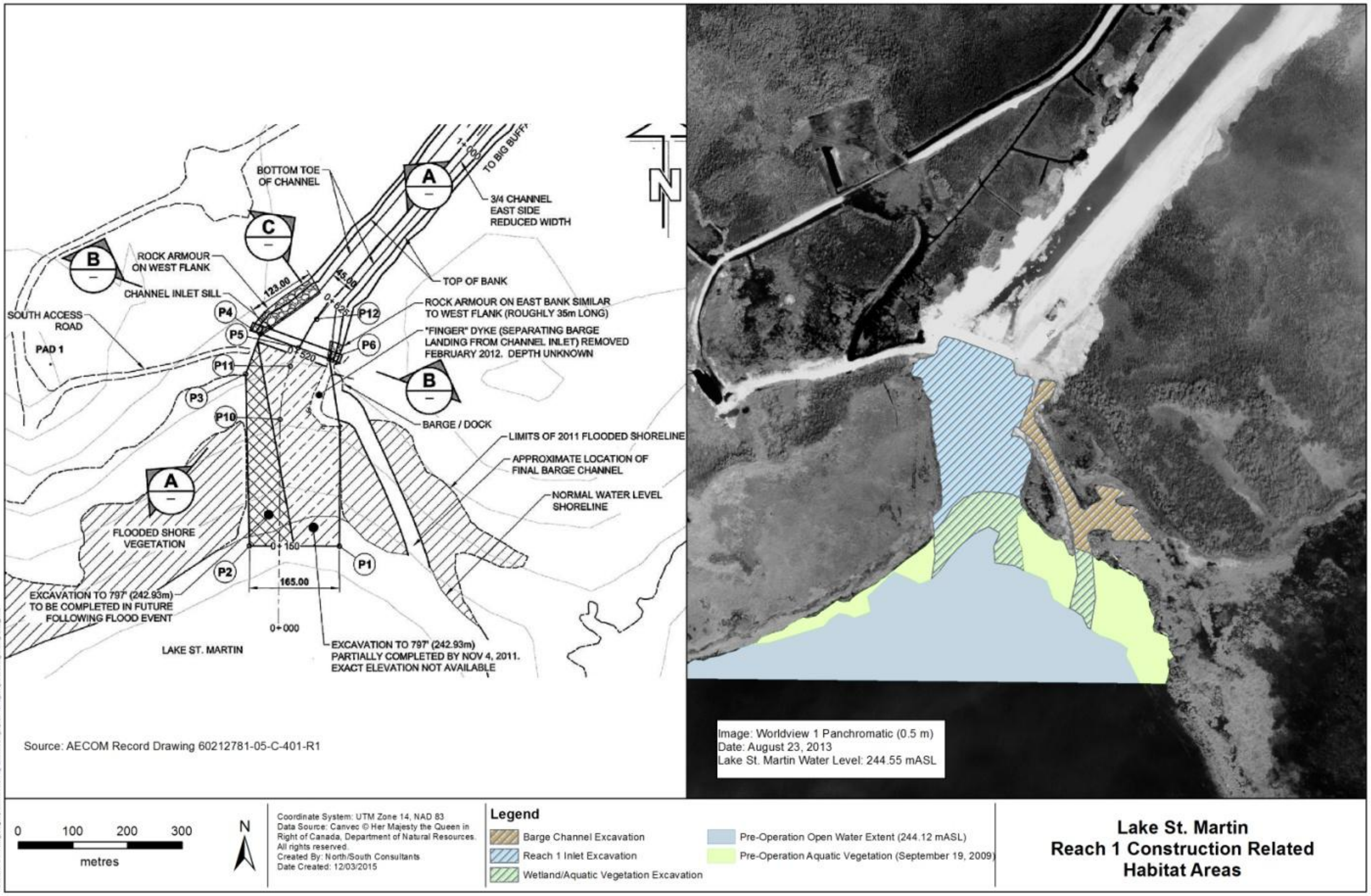


Figure 6.3-2. Detailed drawing (left) and DigitalGlobe™ Wordview-1 Satellite image (right) showing the areas where construction was conducted to create the Reach 1 inlet and barge channel.

6.4 REACH 1 AND THE BUFFALO CREEK WATERSHED MONITORING RESULTS

The Buffalo Creek watershed has a drainage area of 38,700 ha and is situated between Lake St. Martin to the south and the Dauphin River and Sturgeon Bay to the north (Figure 6.4-1). Prior to operation of Reach 1, the watershed was isolated and did not receive water from other waterways; all flow was due to local run off. The headwaters of the watershed are comprised of a bog complex including Big Buffalo Lake (55 ha) and several other ponds. Buffalo Creek originates in Big Buffalo Lake and flows for approximately 17 km to its confluence with the Dauphin River. For approximately the first 4 km downstream of Big Buffalo Lake, the creek flows through a sparsely treed wetland/bog complex before becoming a more defined creek channel with greater gradient and habitat diversity. The creek discharges into the Dauphin River approximately 4 km upstream of Sturgeon Bay.

Reach 1 allowed for the diversion of water from Lake St. Martin into the Buffalo Creek watershed. The inlet to Reach 1 is located along the northeast shore of the Lake St. Martin north basin (Figure 6.4-2). The channel extends northeast for approximately 6 km to the bog area surrounding Big Buffalo Lake. Water from Reach 1 flows through the bog complex into Big Buffalo Lake and Buffalo Creek. down Buffalo Creek into the lower Dauphin River.

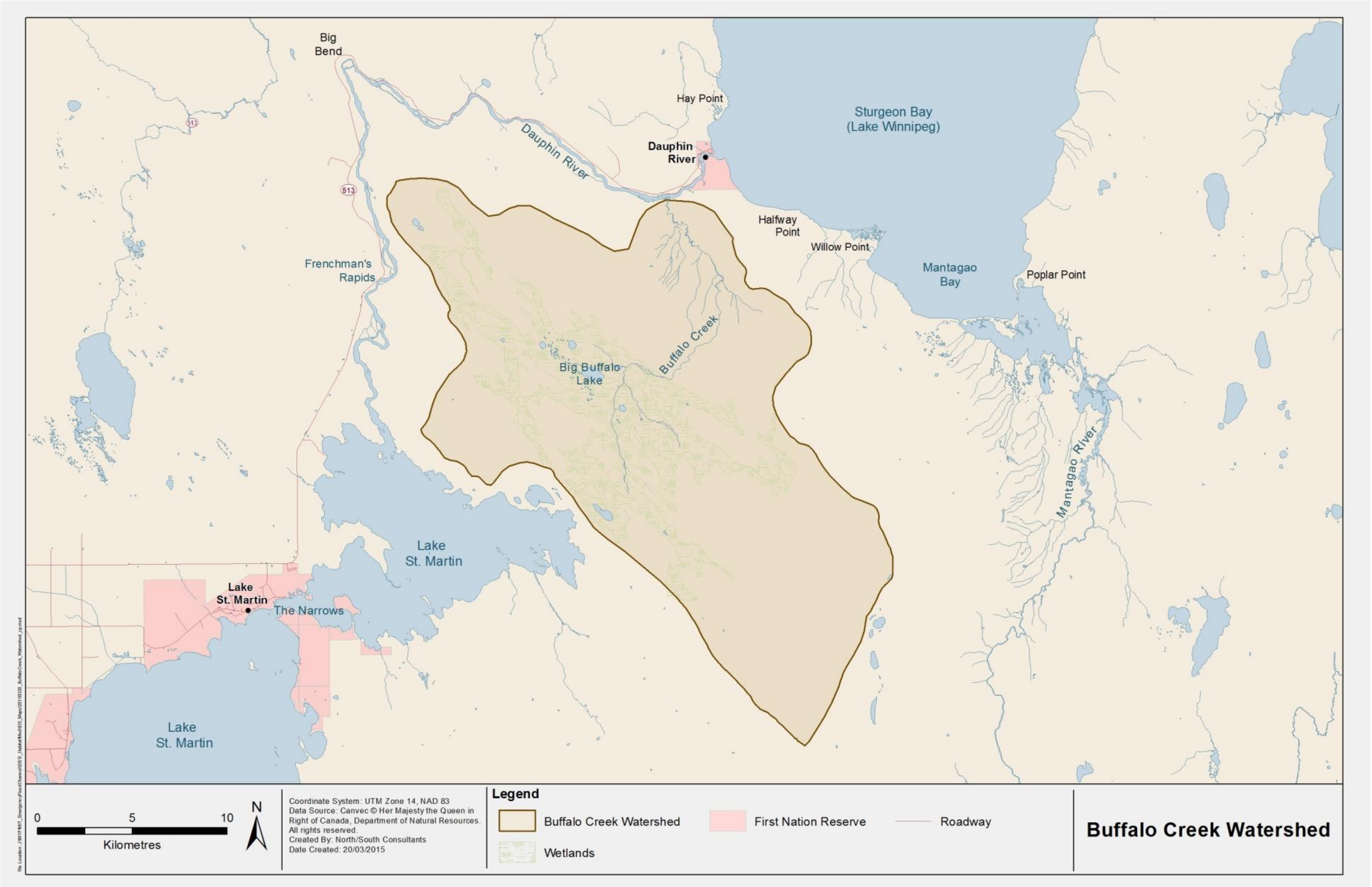


Figure 6.4-1. Pre-Operation extent and drainage area of the Buffalo Creek watershed.

6.4.1 REACH 1

6.4.1.1 Pre-Operation

Reach 1 did not exist prior to 2011.

6.4.1.2 2011/2012 Operation

As a result of Reach 1 operation, a 35.5 ha area within Reach 1 became wetted, lotic habitat with average flows of 125 m^3/s (Table 6.4-1). HEC-RAS model outputs indicate that maximum water depth and average water velocity were fairly consistent along the entire length of the channel; mean maximum water depth was 2.5 m and mean velocity was 0.97 m/s (Table 6.4-1; Figure 6.4-3). Wetted width was more variable, ranging from approximately 60-75 m throughout the upstream 5 km of the channel and then increasing to approximately 110 m within the final kilometer before its confluence with the bog complex (Table 6.4-1; Figure 6.4-3). Compact fines and exposed larger materials comprise the substrate within Reach 1.

An empirical model estimated that approximately 27,100 m^3 of sediment were eroded from Reach 1 during the 2011/2012 Operation. While erosion within Reach 1 would be not expected to affect habitat quality in the channel itself, suspended sediments were ultimately transferred to areas farther downstream.

In the winter during 2011/2012 Operation, ice conditions in Reach 1 consisted of open water with some border ice, and the production of frazil ice was observed within the channel (PESV Section 4.4.5).

6.4.1.3 2011/2012 Closure

The flow of water from Lake St. Martin into Reach 1 was halted in November 2012. This was achieved by constructing a dyke across the Reach 1 inlet in Lake St. Martin (Figure 6.4-4).

HEC-RAS modeling results indicate that the extent of aquatic habitat in Reach 1 during the open water season decreased to 30.5 ha during 2011/2012 Closure (Table 6.4-1). Mean maximum water depth decreased to 0.98 m and water flow became negligible, shifting the habitat from lotic to lentic. The wetted width of the channel also decreased, ranging from approximately 48 to 61 m along the first 5 km of the channel, and expanding to approximately 91 m at the downstream end (Appendix 6A). During winter 2012/2013, the channel was completely ice covered and DO levels in water within the channel declined to anoxic conditions. In May 2013, following the spring freshet, water remained in Reach 1 because the water level in the downstream bog had not fully receded to Pre-Operation levels.

6.4.1.4 2014/2015 Operation – Effects to December 2014

The onset of Reach 1 operation in early July 2014 re-introduced flow to the channel and re-connected waters within the channel to Lake St. Martin and the downstream bog complex. Median flows through Reach 1 between 3 July and 22 October, 2014 were 109 m^3/s (PESV Section 4.4.1); as similar flows occurred during 2011/2012 Operation (125 m^3/s), water depth and velocity conditions within the channel, as well as rates of erosion, were likely also comparable.

Ice conditions in Reach 1 during winter 2014/2015 were similar to those observed during the 2011/2012 Operation. Open water occurred through the center of the channel, with some border ice and the presence of frazil ice (PESV Section 4.4.5).

Table 6.4-1. Parameters used to describe habitat conditions in Reach 1.

Habitat Parameters	Units	*Measured values/Observations*			
		Pre-Operation	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation [1]
Effect to habitat as a result of the Project?		-	*yes*	*yes*	
50th: Discharge	m^3/s	-	125	No flow	109
50th: Aquatic Habitat (available wetted area)	ha	-	35.5	30.5	-
Water Depth					
50th: mean maximum depth	m	-	2.5	1.0	-
50th: min. maximum depth			2.3	0.5	-
50th: max. maximum depth			2.8	1.9	-
Water Velocity					
50th: mean velocity	m/s	-	0.97	0.00	-
50th: min. velocity			0.83		-
50th: max. velocity			1.05		-
Wetted Width					
50th: min. wetted width	m	-	59.9	47.6	-
50th: max. wetted width			109.7	90.7	-
Substrate Composition	ha	-	Primarily fines (sand/silt)	Primarily fines (sand/silt)	Primarily fines (sand/silt)
Dissolved Oxygen [2]	mg/L	-	8.3-14.9	0.2-12.3 < 1.00 (March) [3] 9.32-10.65 (May) [3]	Below PAL guidelines for 2 days following re-opening

1 - Conditions expected to be similar to those that occurred during the 2011/2012 Operation.
2 - Data from WQSV Section 5.4 unless otherwise noted.
3 - Data collected during 2013 fish habitat field studies.

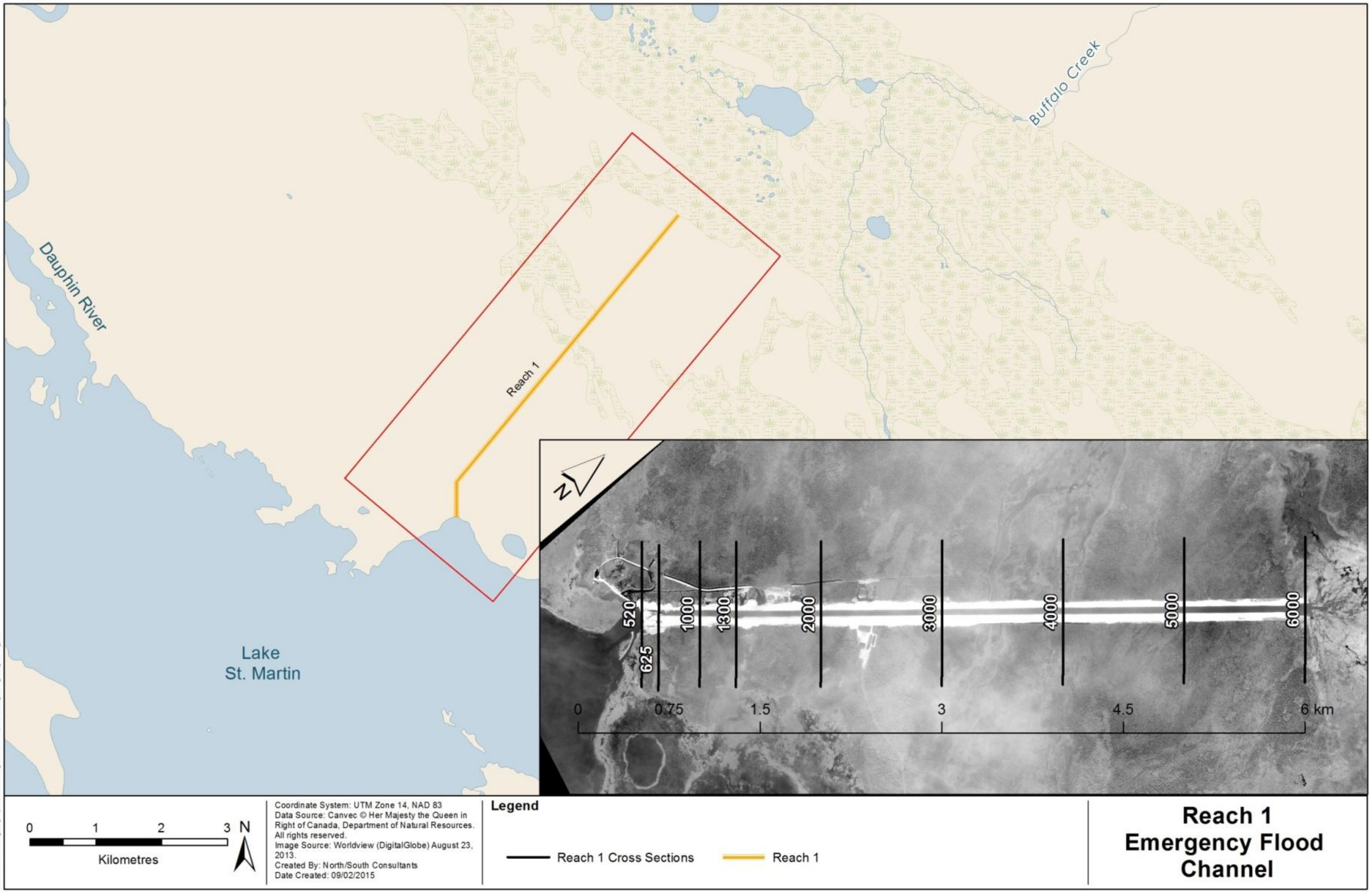


Figure 6.4-2. The location and orientation of Reach 1 relative to the north basin of Lake St. Martin and the Buffalo Creek watershed.

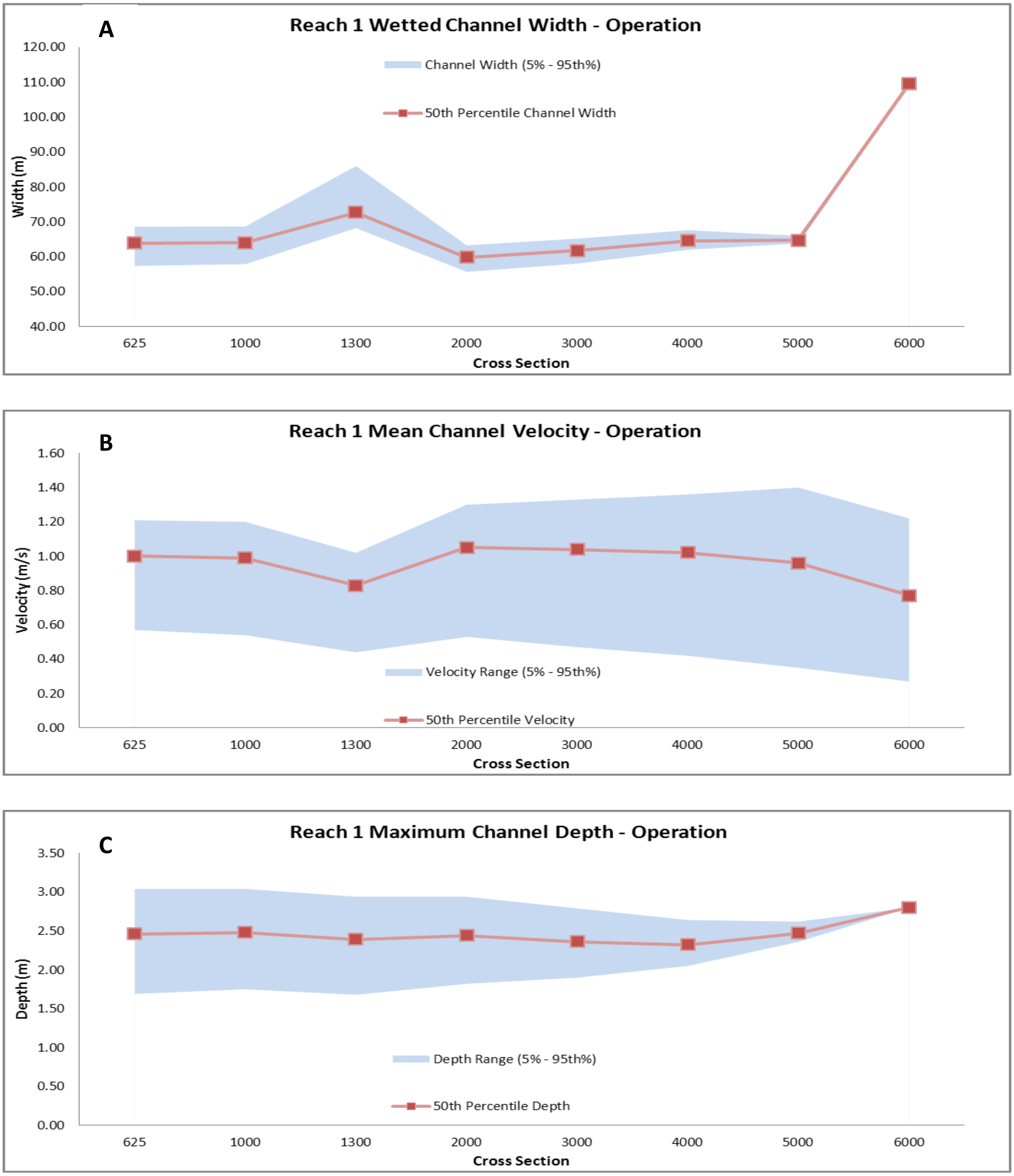


Figure 6.4-3. HEC-RAS output for Reach 1 during 2011/2012 Operation at 9 cross-sectional transects for three flow scenarios (5th, 50th, and 95th percentiles): (A) mean wetted channel width, (B) mean channel velocity, and (C) maximum channel depth.

Figure 6.4-4. Aerial photographs of the Reach 1 at the (A) inlet from Lake St. Martin, and (B) outlet into the Big Buffalo bog complex during 2011/2012 Closure.

6.4.2 BUFFALO CREEK WATERSHED – OVERVIEW

6.4.2.1 Pre-Operation

Aquatic habitat in the Buffalo Creek watershed prior to operation of Reach 1 was characterized and quantified to describe habitat conditions. Digital orthometric imagery and high-resolution satellite imagery were used to map aquatic boundaries, and classify and quantify the habitat throughout the watershed (Section 6.2.3). Habitat information collected during an August 2011 field program was used to help validate interpretations from the geo-referenced digital imagery. Aerial imagery of the Buffalo Creek watershed was also collected to provide a baseline record of riparian vegetation.

During 2011, the maximum wetted extent within the Buffalo Creek watershed was 90.20 ha (Table 6.4-2; Figure 6.4-5). Aquatic habitat was classified into six different habitat types (Table 6.4-2; Figure 6.4-6), and the majority of wetted habitat in the watershed was categorized as peat pool (70.11 ha). This habitat type occurred exclusively in the upper reaches of the watershed within the confines of the wetland/bog complex, and included Big Buffalo Lake and Little Buffalo Lake (Figure 6.4-7). Most of Buffalo Creek downstream of the wetland/bog complex was comprised of run habitat (15% of available habitat within the watershed). Twenty-one beaver dams, partial or complete obstructions of the creek, were identified from the aerial imagery (Figures 6.4-8 to 6.4-11).

6.4.2.2 2011/2012 Operation

During 2011/2012 Operation, the estimated maximum wetted area of the Buffalo Creek watershed was 1974.2 ha (at 95th percentile inflow) (Table 6.4-2; Figure 6.4-5), which corresponded to a large increase in the amount of aquatic habitat (+1884.0 ha).

6.4.2.3 2011/2012 Closure

Monitoring data collected during two field programs (July 2013 and June 2014), together with digital orthometric imagery and high-resolution satellite imagery, were used to classify and quantify the aquatic habitat throughout the watershed.

Following closure of Reach 1, the maximum wetted extent of the watershed was 98.30 ha (Table 6.4-2), indicating that approximately 8 ha of new aquatic habitat had been created by Reach 1 operation. There was a net increase in the extents of riffle, pool, and run habitats. The amount of peat pool habitat also increased slightly, while habitat losses were limited to a reduction in beaver pool (-0.70 ha) and beaver dam (-0.10 ha) habitat types.

Aerial imagery of the Buffalo Creek watershed taken during Pre-Operation and 2011/2012 Closure illustrates the changes to riparian vegetation that occurred due to increased water volumes from the operation of Reach 1 (Figure 6.4-12).

6.4.2.4 2014/2015 Operation – Effects to December 2014

Water temperature data collected from Buffalo Creek during the 2014 open water season (Figure 6.4-13) shows that when Reach 1 is closed, water temperatures in Buffalo Creek were quite variable and generally slightly higher than water temperatures in the Dauphin River. Following the re-opening of Reach 1 on 04 July, water temperatures on Buffalo Creek remained slightly higher than those measured in Reach 1 and the Dauphin River, but were less variable. Trends similar to those described for 2014 were seen during all during the open water season in all other years: Buffalo Creek water temperatures were always slightly higher than water temperatures in the Dauphin River, but they were less variable when Reach 1 was operating (as opposed to closed; Appendix 6C).

6.4.3 BIG BUFFALO LAKE AND THE SURROUNDING BOG COMPLEX

6.4.3.1 Pre-Operation

Using digital orthomethric imagery, the maximum wetted extent of Big Buffalo Lake during 2011 was determined to be 70.10 ha (Table 6.4-3; Figure 6.4-5). Results from an August 2011 field investigation indicate that habitat water depths in Big Buffalo Lake ranged from 1.2 to 2.1, with a mean depth of 1.7 m (Table 6.4-3; Figure 6.4-14). Aquatic vegetation was primarily pondweed (*Potamogeton* sp.) which was limited to the littoral zone. The riparian zone was comprised of emergent aquatic plants such as sedges (*Carex* sp.), cattails (*Typha* sp.), and bulrushes (*Scirpus* sp.). The lake and surrounding area was largely bog habitat consisting of floating peat bog mats, with few areas able to support trees (Figure 6.4-15a). Substrate compaction was soft and was almost entirely composed of organic material (Table 6.4-3).

There are no data for sediment transport or ice conditions prior to operation of Reach 1. Ice processes are assumed to resemble those observed during 2011/2012 Closure (i.e., ice cover on lake with some open water areas in bog).

6.4.3.2 2011/2012 Operation

Based on digital orthomethric imagery, Big Buffalo Lake bog complex had an estimated maximum area of 1772.0 ha during 2011/2012 Operation (Table 6.4-3), representing a 1701.9 ha increase in the amount of aquatic habitat in Big Buffalo Lake and surrounding bog complex. While HEC-RAS modeling was not completed for Big Buffalo Lake and the bog complex during 2011/2012 Operation, data collected during 2014/2015 Operation suggest that there was an approximate 1 m increase in water surface elevation with correlated increases in water depth and flow.

Changes to lake substrates were also assumed to occur within the bog complex due to sedimentation and erosion processes resulting from increased water velocities. An empirical model was used to estimate the amount of suspended sediment originating from Lake St. Martin, which combined with the estimated volume of suspended sediment from Reach 1, and ultimately deposited into the Big Buffalo Lake bog complex (PESV Section 4.4.6.1). During 2011/2012 Operation, it is estimated that 41,000 m^3 of suspended material was deposited into the lake and bog area. See Section 6.4.3.3 for a description of changes to the substrate in Big Buffalo Lake (assessed during a 2011/2012 Closure field campaign).

The amount of riparian vegetation decreased during 2011/2012 Operation due to the extent and duration of flooding (Figure 6.4-12). During winter 2011/2012, there was ice cover on Big Buffalo Lake and the bog complex, with areas of open water along the main paths of flow.

6.4.3.3 2011/2012 Closure

After the closure of Reach 1, water level within Big Buffalo Lake and the bog complex gradually receded. Big Buffalo Lake was ice-covered during the winters of 2012/2013 and 2013/2014. There were some open water areas throughout the bog but to a lesser extent than during 2011/2012 Operation. A brief field campaign in March 2013 revealed that between 0.6 and 0.7 m of ice had formed on the lake during winter 2012/2013, water depth ranged from 0.07-0.96 m, and the lake was anoxic (DO ranged from 0.12 to 0.20 mg/L). Anoxic conditions within the lake were a seasonal occurrence during 2011/2012 Closure; a survey of 16 sites in Big Buffalo Lake in May 2013 revealed DO concentrations between 9.72 and 12.52 mg/L, and water quality monitoring results indicate that DO levels were generally suitable for fish throughout the open water season (Table 6.4-3; WQSV Figure 5.4-4).

While the closure of Reach 1 resulted in an overall decrease in water surface elevation, water depth, and water velocity compared to 2011/2012 Operation, water surface elevation, on average, remained approximately 0.6 m higher than the Pre-Operation water level and average water depth was also slightly deeper (Table 6.4-3). Big Buffalo Lake and the associated bog complex also contained an additional 4.2 ha of available aquatic habitat (as compared to Pre-Operation conditions) (Table 6.4-3); the net increase in wetted habitat is related to the water storage capacity of the bog complex.

Riparian vegetation decreased as the result of the flooding that occurred during 2011/2012 Operation (Figures 6.4-12 and 6.4-15b).

Sediment and erosion processes that occurred during 2011/2012 Operation and 2011/2012 Closure altered the substrate composition within Big Buffalo Lake (Table 6.4-4). The substrate assessment conducted during June 2014 identified conditions that were more variable than those seen during Pre-Operation. In addition to the organics that were present prior to operation, fine sediments were prevalent at all sites surveyed, and coarser materials like gravel were present at a few sites, suggesting that flows through the lake may have exposed bed materials beneath the organics (Table 6.4-3).

6.4.3.4 2014/2015 Operation – Effects to December 2014

Water levels in Big Buffalo Lake and the bog complex during 2014/2015 Operation were 242.1 mASL at 50^{th} percentile flow. Water level was not measured during 2011/2012 Operation, but is assumed to have been similar; therefore the amount of aquatic habitat and effects to riparian vegetation are also expected to be similar between the two Project phases.

Just prior to the beginning of 2014/2015 Operation, DO concentrations in Big Buffalo Lake were high enough to support fish, and they were not affected by the re-opening of Reach 1 (WQSV Section 5.4.4).

A smaller volume of sediment, primarily resulting from erosional processes along Reach 1, was deposited in the Big Buffalo Lake and bog area during the first sixteen weeks of 2014/2015 Operation (15,800 m^3). There are no ice process data for 2014/2015 Operation, however ice process conditions are assumed to be similar to those observed during 2011/2012 Operation because flow magnitude is similar.

6.4.3.5 Summary

Table 6.4-5 provides a summary of aquatic habitat data from Big Buffalo Lake and the surrounding bog complex for all phases of the Project.

6.4.4 BUFFALO CREEK

6.4.4.1 Pre-Operation

Historically, flows on Buffalo Creek were low because it was isolated from other waterways and only received water from local run-off within the watershed. From satellite imagery, the median wetted area of Buffalo Creek was estimated as 20.1 ha (Table 6.4-6). Cross sections along Buffalo Creek were surveyed in order to develop a HEC-RAS hydraulic and sediment transport model for the creek (Figure 6.4-16). Model results indicate that the average wetted width of Buffalo Creek during 2011 was 12.97 m, average water velocity was 0.74 m/s, and average depth was 0.65 m (Table 6.4-6).

Aquatic habitat information was collected from sites at the upstream and downstream ends of Buffalo Creek during an August 2011 field campaign (Figure 6.4-17), and site photographs were taken to record Pre-Operation channel and riparian features (Figure 6.4-18). Wetted width was generally between 7 and 15 m and water depths were almost always less than 1.0 m; exceptions included the occasional pool upstream of a beaver dam and the extreme downstream end of Buffalo Creek, where high water on the Dauphin River was having a backwater effect (Table 6.4-7; Figure 6.4-19). As indicated by the digital orthometric and satellite imagery, a wide variety of habitat types (run, pool, riffle) existed within the creek, and while substrate type varied from site to site, softer substrates were more frequently observed in pool habitat (Table 6.4-7). Limited water quality data from the Pre-Operation phase indicate that DO levels within the creek were generally high enough to support a wide range of fish species, but DO was somewhat variable along the length of the creek (WQSV Section 5.4.1). Aquatic plants were present at all sites surveyed.

Shoreline vegetation cover surveys were also conducted. Prior to the 2011/2012 Operation, vegetation cover was described as dense, comprised of thick grasses immediately adjacent to the creek, with a substantial shrub and tree line farther up both banks.

A list of the representative aquatic and riparian plants found throughout the Buffalo Creek corridor was generated from field surveys and site photographs. Submerged aquatic plants typically found in this area are common duckweed (*Lemna minor*), pondweeds (*Stuckenia* sp.), watercelery (*Vallisneria americana*), and water plantain (*Alisma plantago-aquatica*). The vegetation covering the shoreline and banks were comprised of a variety of emergent aquatic plants such as sedges (*Carex sp.*), common spike rush (*Eleocharis palustris*), bur reeds (*Sparganium sp*.), arrowheads (*Sagittaria* sp.), cattails (*Typha sp*.), common reed grass (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*), and hard-stemmed bulrush (*Schoenoplectus acutus*).

There are no data for sediment transport or ice conditions in Buffalo Creek prior to 2011/2012 Operation. Pre-Operation ice processes are assumed to have resembled those observed during 2011/2012 Closure (i.e., mostly ice-covered except for some open water areas with flow).

6.4.4.2 2011/2012 Operation

Aquatic habitat areas during 2011/2012 Operation were estimated using the HEC-RAS and MIKE 21 model outputs (Section 6.2.2; Appendix 6A). The wetted area of Buffalo Creek increased to a maximum of 202.20 ha during this phase of the Project (Table 6.4-6; Figure 6.4-5), and was comprised of 145.5 ha of intermittently exposed habitat and 56.7 ha of predominantly wetted habitat. At 50^{th} percentile flow, wetted width, water depth and water velocity were all greatly increased compared to Pre-Operation conditions (Table 6.4-6).

Dissolved oxygen in Buffalo Creek occasionally and for short durations decreased below Manitoba Water Quality Guidelines (MWQSOGs) and Canadian Council of the Ministers of the Environment (CCME) guidelines for the protection of aquatic life (PAL) (Table 6.4-6; WQSV Figure 5.4-4). These brief decreases generally occurred during winter and rarely occurred simultaneously throughout the entire creek. As high flows had removed all the beaver dams along the creek, fish were able to move freely along its length and avoid areas of low DO.

Contrary to what was seen in Big Buffalo Lake, water entering Buffalo Creek during 2011/2012 Operation contained lower concentrations of suspended sediment than water flowing out of the creek. Comparison of 2011 and 2013 cross-section survey data confirmed that erosion occurred along most of the creek during 2011/2012 Operation, with the majority occurring along the main channel. The estimated total *in situ* volume of material that eroded from the channel between 2011 and 2013 was 86,500 m^3, and it is estimated that 17,400 m^3 of this total volume remained in suspension and was transported downstream into the Dauphin River.

Substantial hydraulic increases during 2011/2012 Operation resulted in increased suspension and transport of fine to sandy sediments, and erosion and deposition of the coarser materials, leading to shifts in the locations and extents of erosional and depositional habitats identified prior to operation of Reach 1. HEC-RAS modeling shows that flows and water velocities through Buffalo Creek during 2011/2012 Operation were sufficient to move gravel size and smaller material, and even cobble was susceptible to erosion in some areas (PESV Section 4.4.6.2). While there was a low potential for gravel size and smaller materials to deposit with the main channel, gravel size and smaller sized materials were more likely to deposit in the overbanks and there were many areas of low velocity where sand had the potential to deposit.

During the winter of 2011/2012 Operation, ice only formed along the borders of Buffalo Creek. In the middle of the creek, there was a 1 km-long ice jam and the production of frazil ice.

6.4.4.3 2011/2012 Closure

During 2011/2012 Closure, Buffalo Creek was mostly ice-covered. There was open water and frazil ice production in areas of flow, but to a lesser extent than during 2011/2012 Operation. Open areas of low flow (0.15 m deep) were observed at the upstream and downstream ends of Buffalo Creek in March 2013. Dissolved oxygen concentrations at the downstream end of the creek were higher than at the upstream end, where conditions were unsuitable for most species of fish (Table 6.4-6).

The median amount of aquatic habitat in Buffalo Creek during 2011/2012 Closure was 24.0 ha, a 3.9 ha increase from the Pre-Operation phase (Table 6.4-6). Cross section surveys were conducted along Buffalo Creek in 2013 and 2014 to characterize hydraulic conditions during 2011/2012 Closure. From the HEC-RAS model results, mean wetted width increased by 4.68 m and mean maximum water depth increased by 0.14 m, while mean water velocity decreased by 0.19 m/s (Table 6.4-6). These differences are related to the erosion and ice scour that occurred during 2011/2012 Operation and changed the morphology of the Buffalo Creek channel. Similar changes to instream habitat were observed during aquatic habitat field surveys conducted in 2013 and 2014 (Table 6.4-7).

The erosion and ice processes that occurred during 2011/2012 Operation widened banks and deepened the Buffalo Creek channel. This change in stream morphology changed the distribution of habitat types along the length of the creek. Following 2011/2012 Operation, there was an increase in the amount of run and pool habitat types, and a decrease in beaver dams (and associated pools) and partial stream obstructions (Table 6.4-2; Figures 6.4-7 to 6.4-11). A new creek channel was formed in a meander bend in Buffalo Creek where water flows or ice action caused a breach in the creek bank; the new channel cut across two bends in the creek to form a direct route channel farther downstream (Figure 6.4-10). In 2014, several beaver dams were observed, indicating that beavers were beginning to re-establish themselves in the absence of the high flows associated with Reach 1 operation.

Substrate compaction and sediment composition data collected during habitat field surveys were variable between years (Table 6.4-7). Empirical model results indicated that sediment transport in Buffalo Creek continued during 2011/2012 Closure; it was assumed that the 1,500 m^3 of suspended sediment that originated in Buffalo Creek was the result of local erosion inputs due to the gradual recession of water levels and bank slumping (PESV Section 4.4.6.1). As a result, substrate conditions within Buffalo Creek may have continued to change during 2011/2012 Closure, as HEC-RAS modeling suggested that deposition was more likely during this phase of the Project (PESV Section 4.4.6.2).

Ground survey and aerial imagery indicate that channel morphology and riparian vegetation in Buffalo Creek changed as a result of the flooding that occurred during 2011/2012 Operation (Figures 6.4-6 and 6.4-12). In July 2013, the Buffalo Creek channel was almost entirely devoid of riparian and nearshore aquatic vegetation (Table 6.4-6; Figure 6.4-20). Areas where grasses, shrubs, and trees were flooded by 2011/2012 Operation appear bright white in the satellite imagery and illustrate the extents of bare soils/ substrates, while the light to dark brown areas are dead woody shrubs and trees (Figure 6.4-12). Several areas of erosion, deposition, and bank slumping were also observed. In June 2014 (more than one growing year after the end of 2011/2012 Operation), herbaceous vegetation such as grasses and sedges were observed to have re-established along the creek margins; the extents of dead woody shrubs and trees were observed to have increased (Table 6.4-6; Figure 6.4-17e and f).

6.4.4.4 2014/2015 Operation – Effects to December 2014

Buffalo Creek discharge was estimated at 109 m^3/s during the first sixteen weeks of 2014/2015 Operation, which is similar to the modeled discharge for 2011/2012 Operation, therefore it is expected that habitat conditions within Buffalo Creek will also resemble those calculated for 2011/2012 Operation.

During the first two days of 2014/2015 Operation, DO levels in Buffalo Creek decreased below the guidelines (WQSV Section 5.4.4, Figure 5.4-4). While levels quickly returned to normal (i.e., within guidelines) at the downstream end of the creek, they remained low at the upstream end for approximately one month. From August to November 2014, DO levels throughout the creek were high enough to support a wide variety of fish species.

Empirical model results indicate that erosion within Buffalo Creek resumed during 2014/2015 Operation. Figure 6.4-21 illustrates how the turbidity of the water flowing out of Buffalo Creek increased during the first week of 2014/2015 Operation, and then decreased shortly thereafter. An estimated 9,200 m^3 of suspended sediment was transported into the Dauphin River during the first sixteen weeks of 2014/2015 Operation. This is equivalent to more than half of the total material transported out of Buffalo Creek during the year-long 2011/2012 Operation, but based on HEC-RAS model results, sediment transport processes in Buffalo Creek during 2014/2015 Operation are expected to be similar to those seen during 2011/2012 Operation.

There are limited data for ice conditions during 2014/2015 Operation, however since flow is similar to 2011/2012 Operation it is assumed that ice formation on Buffalo Creek has been minimal. Contrary to observations during 2011/2012 Operation, ice cover formed at the confluence with Dauphin River in November 2014.

6.4.4.5 Summary

Table 6.4-8 provides a summary of aquatic habitat data from Buffalo Creek for all phases of the Project.

Table 6.4-2. Aquatic habitat parameters used for assessment of effects to the Buffalo Creek watershed.

Habitat Parameters	Units	*Measured values/Observations*			
		Pre-Operation	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation [1]
Effect to habitat as a result of the Project?		-	*yes*	*yes* [2]	-
50th: Aquatic Habitat (available wetted area)	ha	90.2	-	98.3	-
95th: Aquatic Habitat (available wetted area) [3]	ha	-	1974.20	-	-
Riffle	ha	2.1	-	2.1	-
Run	ha	13.4	-	16.3	-
Pool	ha	3.7	-	5.6	-
Beaver Dam	ha	0.2	-	0.1	-
Beaver Pool	ha	0.8	-	0.1	-
Peat-Pool	ha	70.1	-	74.1	-

1 - Monitoring not yet completed for 2014/2015 Operation.
2 - Residual effects of 2011/2012 Operation.
3 - Maximum extent of the wetted area of Big Buffalo Lake and the bog complex during 2011/2012 Operation was calculated from satellite imagery, therefore the amount of aquatic habitat is only known for 95th percentile flow (not 5th or 50th).

Table 6.4-3. Aquatic habitat parameters used for assessment of effects to Big Buffalo Lake and the associated bog complex.

Habitat Parameters	Units	*Measured values/Observations*			
		Pre-Operation	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation [1]
Effect to habitat as a result of the Project?		-	*yes*	*yes*	-
50th: Water Surface Elevation	mASL	241.0	Increase [2]	241.6	242.1
50th: Aquatic Habitat (available wetted area)	ha	70.10	No data	74.3 [3]	-
95th: Aquatic Habitat (available wetted area) [4]		No data	1772.00	No data	
50th: Water Depth	m	1.71	Increase [2]	1.77 [3]	-
50th: Water Velocity	m/s	No data	Increase [2]	No data	-
Substrate Composition	ha	Soft organics	No data	Varied: silt/clay/gravel/organics	-
Dissolved Oxygen [5]	mg/L	No data	No data	0.00-12.3 0.12-0.20 (March) [3] 9.72-12.52 (May) [3]	6.2-11.7

1 - Monitoring not yet completed for 2014/2015 Operation. Dissolved oxygen measurements for July-November 2014 (see WQSV Section 5.4.4.2).
2 - Not measured.
3 - Residual effect of 2011/2012 Operation.
4 - Maximum extent of the wetted area of Big Buffalo Lake and the bog complex during 2011/2012 Operation was calculated from satellite imagery, therefore the amount of aquatic habitat is only known for 95th percentile flow (not 5th or 50th).
5 - Unless otherwise noted, DO ranges taken from Section 5.4 of the WQSV.
6 - DO during fish habitat field studies in 2013.

Table 6.4-4. Comparison of substrate in Bug Buffalo Lake during Pre-Operation (2011) and 2011/2012 Closure (2014).

2011				2014			
Site	Water Depth (m)	Substrate Compaction	Substrate Composition	Site	Water Depth (m)	Substrate Compaction	Substrate Composition
1	1.2	soft	organics	WP-25	1.3	soft	silt/organics
2	1.5	soft	organics	WP-27	1.6	medium	silt/clay
3	2.0	soft	organics	WP-28	1.9	-	-
4	2.0	soft	organics	GN-03 Start	1.6	soft	silt/organics
8	2.1	soft	organics	WP-39	2.0	-	-
9	2.1	soft	organics	WP-44	2.0	-	-
11	1.7	soft	organics	WP-32	1.8	medium	silt/clay
22	1.6	soft	organics	WP-35	1.3	medium	silt/clay
15	2.0	soft	organics	WP-41	1.8	medium	silt/clay
16	1.9	soft	organics	WP-42	1.7	medium	silt/clay
19	1.6	soft	organics	GN-01 Start	1.7	-	-
20	1.4	soft	organics	WP-52	1.7	hard	silt/clay/gravel
21	1.4	soft	organics	WP-51	1.7	hard	silt/clay/gravel
24	1.4	soft	organics	WQ-01	2.2	-	-

Table 6.4-5. A summary of habitat data collected from Big Buffalo Lake and the surrounding bog complex.

Project Phase	Flow	Water Depth & Level	Water Velocity (m/s)	Aquatic Habitat (wetted area)	Substrate Composition	Aquatic and Riparian Vegetation	Dissolved Oxygen (DO)
Pre-Operation	- No flow except at the outlet to Buffalo Creek. - Discharge not measured.	- Depths ranged from 1.2-2.1 m.	- No velocities	- 70.1 ha of peat pool habitat.	- Loosely compacted organic substrate	- No data	- No data
2011/2012 Operation	- Discharge increased during operation, but was not measured.	- No data, but based on measurements during 2014/2015 Operation, water depth likely increased by approximately 1m.	- No data, but an increase is assumed.	- Almost 1,800 ha of peat pool habitat.	- Based on observations during 2011/2012 Closure, a portion of loosely compacted surface layer was scoured away by high flows during 2011/2012 Operation, leaving patches of coarser material, and sediment deposited in off-current areas.	- Based on observations during 2011/2012 Closure, riparian vegetation decreased in areas wetted by 2011/2012 Operation but quantities were not measured.	- No data
2011/2012 Closure	- No flow except at the outlet to Buffalo Creek. - Discharge not measured.	- Depths generally ranged from 1.3-2.2 m.	- No velocities	- 74.3 ha of habitat, the vast majority of which (74.1 ha) was peat pool habitat.	- Loosely compacted organic/silt substrate with patches of gravel.	- No data	- Winter DO levels were frequently too low to support most species of fish. - Due to a lack of baseline data, it is not known whether this is a natural seasonal decrease or is a result of the Project.
2014/2015 Operation [1]	- TBD	- Based on changes to water surface elevation, water depth increased by approximately 1 m.	- TBD	- TBD	- TBD	- TBD	- TBD

1 - Data collection not yet complete for the 2014/2015 Operation phase; will be updated following closure in 2015.

Table 6.4-6. Aquatic habitat parameters used for assessment of effects on Buffalo Creek.

Habitat Parameters	Units	*Measured values/Observations*			
		Pre-Operation	2011/2012 Operation	2011/2012 Closure	2014/2015 Operation [1]
Effect to habitat as a result of the Project?		-	*yes*	*yes*	-
Discharge	m^3/s	4	125	4	109
50th: Aquatic Habitat (available wetted area) [2]	ha	20.1	128.6	24.0 [3]	-
95th: Aquatic Habitat (available wetted area) [4]	ha	-	202.2	-	-
Intermittently Exposed/ Predominantly Wetted	ha	-	145.5/56.7	-	-
Wetted Width [5]					-
50th: mean wetted width	m	12.97	96.69	17.65 [3]	
50th: minimum wetted width	m	8.06	38.36	11.13	
50th: maximum wetted width	m	23.68	205.6	27.03	
Water Depth [5]					-
50th: mean maximum depth	m	0.65	3.24	0.79 [3]	
50th: range of maximum depth	m	0.51-0.90	2.55-3.90	0.58-1.10	
Water Velocity [5]					-
50th: mean velocity	m/s	0.74	1.07	0.53	
50th: velocity range	m/s	0.45-1.14	0.50-1.70	0.31-0.82	
Substrate Composition	ha	Variable	No data	Shifted due to erosion and sedimentation [3]	-
Aquatic Vegetation	-	Present at all habitat assessment sites	No data	Present at few sites in 2013[3] Present at most sites in 2014	
Riparian Vegetation		Abundant along survey transects	No data	Absent/sparse in 2013 Grasses present in 2014	
Dissolved Oxygen [6]	mg/L	6.4-12.2	2.9-12.5	2.1-11.9 2.11 (US), 7.16 (DS) [7]	2.9-11.4

1 - Monitoring not yet completed for 2014/2015 Operation. Dissolved oxygen measurements for July-November 2014 (see WQSV Section 5.4.4.2).
2 - Pre-Operation and 2011/2012 Closure wetted area approximated from satellite imagery; 2011/2012 Operation wetted area was calculated using HEC-RAS and MIKE 21 model outputs.
3 - Residual effect of 2011/2012 Operation.
4 - Operation intermittently exposed, predominantly wetted and total water level derived from HEC-RAS and area corrected MIKE 21 models.
5 - Depth and velocity measures derived from HEC-RAS model outputs.
6 - Unless otherwise noted, DO ranges taken from Section 5.4 of the WQSV.
7 - DO measured at the upstream (US) and downstream (DS) ends of Buffalo Creek during fish habitat field studies in March 2013.

Table 6.4-7. Habitat survey data collected at sites on Buffalo Creek during Pre-Operation (2011) and 2011/2012 Closure (July 2013 and June 2014). BO = boulder; CO = cobble; GR = gravel; SA = sand; CL = clay; OM = organic matter.

	Pre-Operation (2011)						Closure (2013)						Closure (2014)					
Site	Hydraulic Habitat	Wetted Width (m)	Water Depth (m, range)	Substrate Composition	Substrate Compaction	Aquatic Vegetation	Hydraulic Habitat	Wetted Width (m, range)	Max. Water Depth (m, range)	Substrate Composition	Substrate Compaction	Aquatic Vegetation	Hydraulic Habitat	Wetted Width (m)	Water Depth (m, range)	Substrate Composition	Substrate Compaction	Aquatic Vegetation
T-1 (EF-26)	run /pool	7.2	0.1-0.2	SA/GR; CO; OM	loose OM on top of hard	present	--	--	--	--	--	--	95% run, 5% pool	15	0.7	75% SI/OM, 20% GR, 5%CO	soft	present
T-2 (EF-16)	run /pool	7.1	0.2-0.3	CL	hard	present	60% pool, 40% run	15-25	1.0-2.0	40% GR, 15% SA, 15% OM, 15% CL, 10% CO, 5% BO	upstream 80 m hard (GR/CO), downstream 20 m soft (CL)	absent	--	--	--	--	--	--
T-3 (EF-15, EF-27)	pool	7.5	> 1.0	CL	hard	present	60% pool, 40% run	9-15	1.4	45% CL, 25% BO, 15% GR, 10% CO, 5% SA	soft areas of clay along shore; otherwise hard	absent	50% run, 40% pool, 10% riffle/rapids	15	0.6	50% CO, 25% GR, 25% SI/OM	hard	present
T-4 (EF-28)	riffle/pool	12.2	0.0-0.3	riffle: CO/BO pool: GR/BO; OM	hard loose OM on top of hard	present	--	--	--	--	--	--	70% riffle/rapid, 30% pool	12	0.3-0.6	50% CO, 40% GR, 10% SI/OM	hard	present
T-5 (EF-14, EF-29)	run/pool	8.1	0.2-0.3	CO/GR/SA; BO/OM	loose OM on top of hard	present	70% run, 30% pool	5-10	0.9	40% GR, 40% CO, 10% SA, 5% BO, 5% CL	hard under organic layer	present	50% riffle/rapid, 25% pool, 25% run	12	0.3-0.5	75% CO, 20% GR, 5% SA	hard	present
EF-17 (EF-35)	--	--	--	--	--	--	60% run, 30% pool, 10% pool	6-20	0.8	75% GR, 10% SA, 10% CL, 5% CO	hard	absent	75% riffle/rapid, 20% run, 5% pool	10	0.6-0.8	90% CO, 10% SI/OM	hard	present
T-12 (Hab-14)	pool	29	< 1.0	CL/OM	hard	present	--	--	--	--	--	--	70% run, 20% pool, 10% other	20	n.r.	90% SI/OM, 10% GR	soft	present
T-11 (EF-23, Hab-15)	riffle	7	0.1-0.3	CO/BO	hard	present	60% run, 20% riffle, 20% pool	4-27	~ 1.0	50%CO, 20% GR, 15% BO, 10% CL, 5% SA	n.r.	absent	40% riffle/rapid, 30% pool, 30% run	12	n.r.	60% SI/OM, 40% CO	soft	present
T-8 (EF-22)	backwater	10	1.2	CL along stream margin GR/BO in centre of channel	hard hard	present	50% run, 30% riffle, 20% pool	5-9	> 1.0	60% CO, 20% GR, 15% BO, 5% SA	n.r.	absent	--	--	--	--	--	--
T-7 (EF-21)	backwater	22	> 1.5	GR/CO/BO	hard	present	90% run, 10% pool	11-15	> 1.0	50% BO, 25% CO, 15% CL, 10% GR	hard	present	--	--	--	--	--	--

Table 6.4-8. A summary of data collected from Buffalo Creek for key aquatic habitat parameters.

Project Phase	Flow	Water Depth & Level	Water Velocity (m/s)	Aquatic Habitat (wetted area)	Substrate Composition	Aquatic and Riparian Vegetation	Dissolved Oxygen (DO)
Pre-Operation	- Low flow habitat consisting of runs interspersed with beaver dams and associated pools. - Discharge not measured	- Depths typically less than 1.0 m.	- Modeled50th percentile velocities ranged from 0.45-1.14 /s	- Contained 20.1 ha of aquatic habitat. - Wide variety of habitat types including riffle, pool, run, beaver dam and beaver pool.	- Fines in low flow areas. - Gravel/cobble in areas of higher flow.	- Dense riparian vegetation consisting of grasses, shrubs and trees. - Aquatic vegetation present at all habitat assessment sites.	- DO levels were suitable for fish.
2011/2012 Operation	- 125 m^3/s flow.	- No data	- Modeled50th percentile velocities ranged from 0.5-1.7 m/s.	- 106.8 ha of additional wetted habitat at 50th percentile flow.	- Some fines remain in low flow areas. - Coarse material dominant in high flows.	- Observations indicate riparian vegetation to be largely absent from flooded. - Presumed loss of aquatic vegetation.	- DO levels were almost always suitable for fish. - DO levels were often lower at the upstream end of Buffalo Creek (sometimes below guidelines [2]) than at the downstream end. - Fish were able to move freely within the creek during 2011/2012 Operation and could avoid areas of low DO.
2011/2012 Closure	- Low flow (3.9 m^3/s) habitat consisting of runs, riffles and pools; beavers starting to re-establish themselves by spring 2014.	- Water depths increased by approximately 0.3 m as a result of erosion due to increased flows during 2011/2012 Operation.	- Modeled50th percentile velocities ranged from 0.3-0.8 m/s.	- Net increase of 3.9 ha of aquatic habitat. - Increases in pool and run habitat types. - Decreases in beaver dam and beaver pool habitat types as no beaver dams remained. - Beavers beginning to re-establish in the creek in spring 2014.	- Fines in low flow areas. - Gravel/cobble in high flow areas. - New areas of deposition in areas outside the banks of the creek that were flooded during 2011/2012 Operation.	- No riparian vegetation in 2013, but some grasses had re-established by 2014. - Patchy aquatic vegetation in 2014.	- DO levels in Buffalo Creek were more frequently below guidelines [2] during 2011/2012 Closure, particularly in winter. - Fish were still able to move freely within the creek during 2011/2012 Closure and could avoid areas of low DO. Some may even have moved into the Dauphin River.
2014/2015 Operation	- TBD [1]	- TBD	- TBD	- TBD	- TBD	- TBD	- TBD

1 - Data collection not yet complete for the 2014/2015 Operation phase; will be updated following closure in 2015.

2 - Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOGs) and Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (PAL).

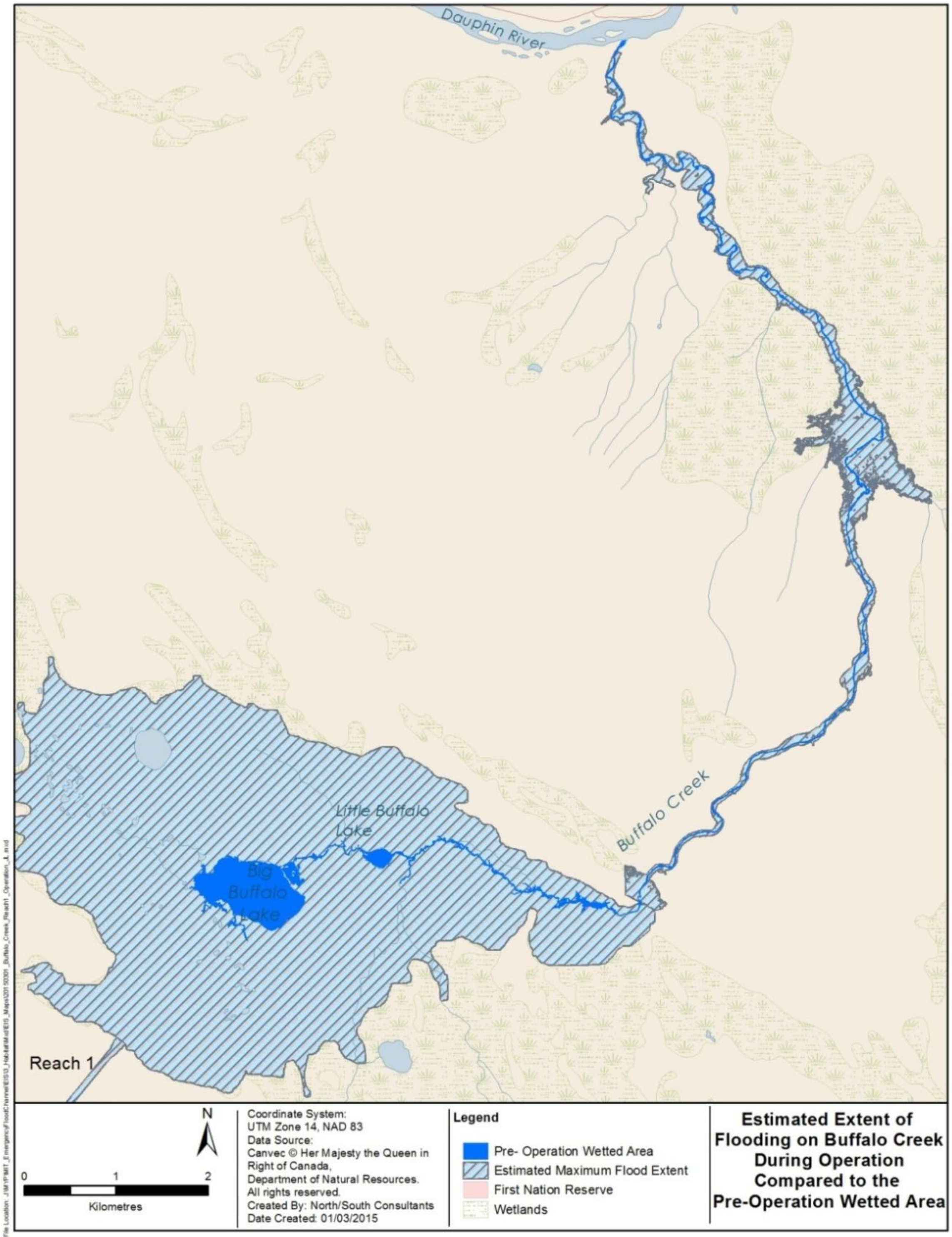


Figure 6.4-5. Maximum wetted extent (95th percentile flow) during 2011/2012 Operation compared to the estimated wetted extent of Pre-Operation conditions within the Buffalo Creek watershed.

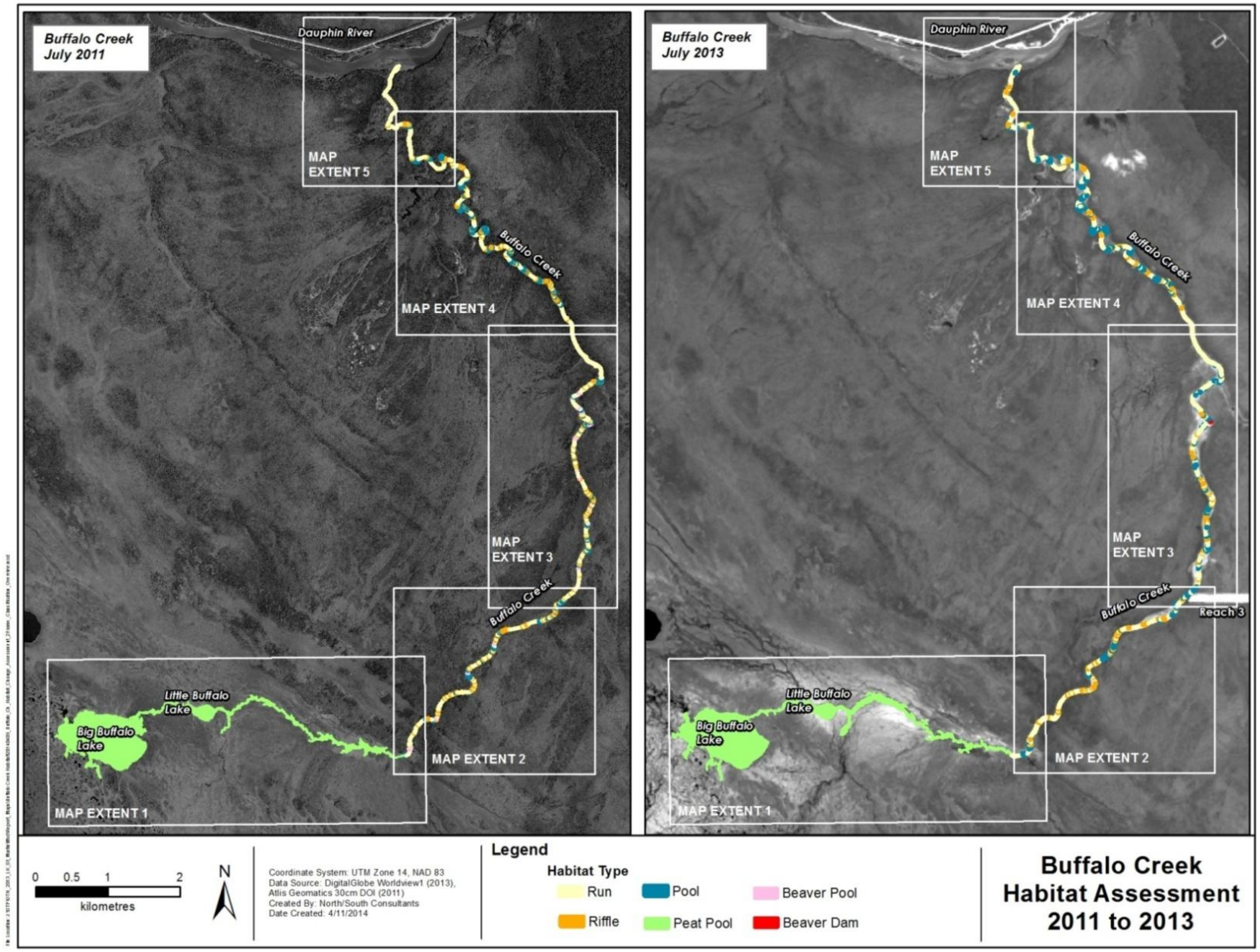


Figure 6.4-6. A comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

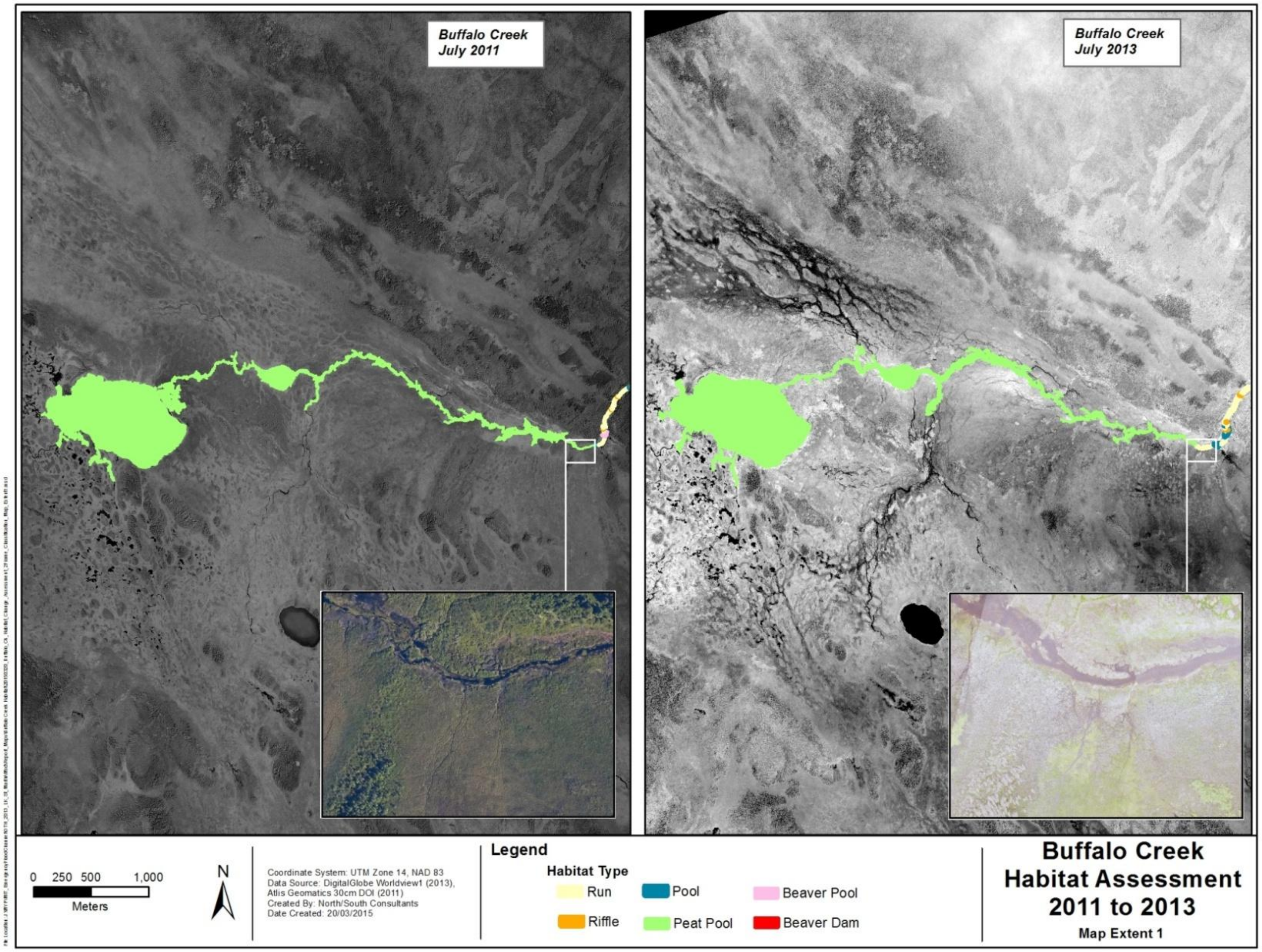


Figure 6.4-7. Extent 1: a comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

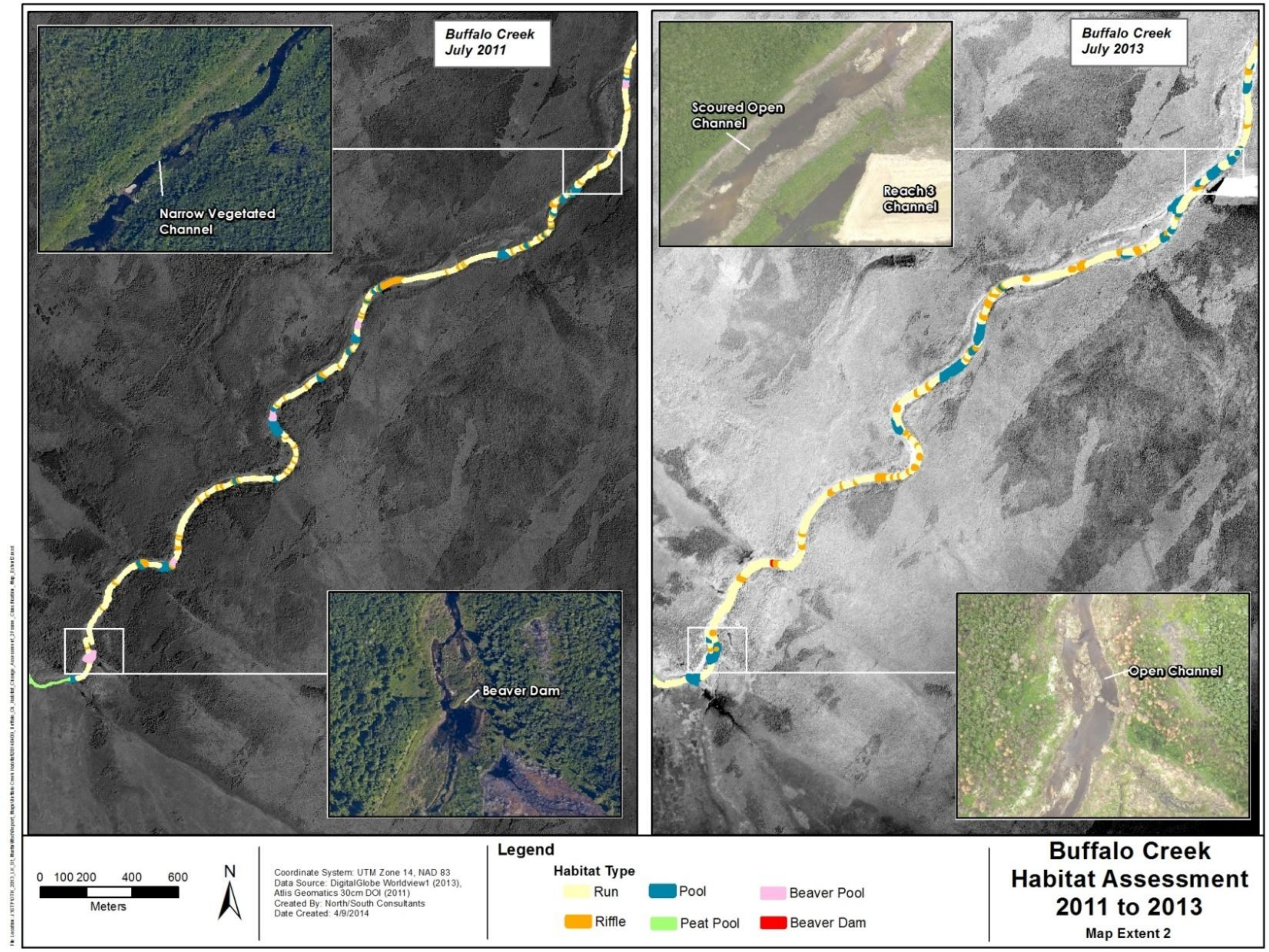


Figure 6.4-8. Extent 2: a comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

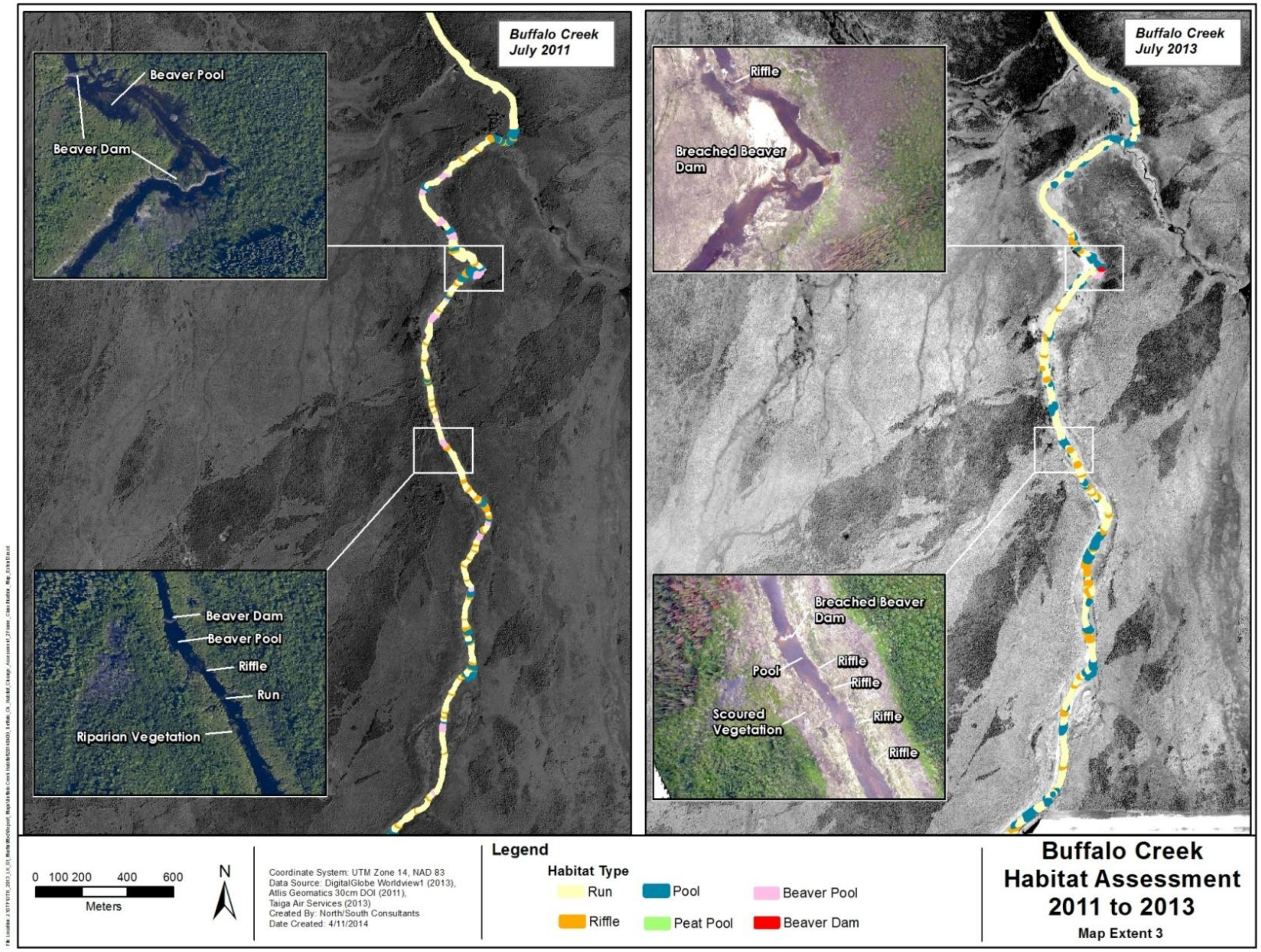


Figure 6.4-9. Extent 3: a comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

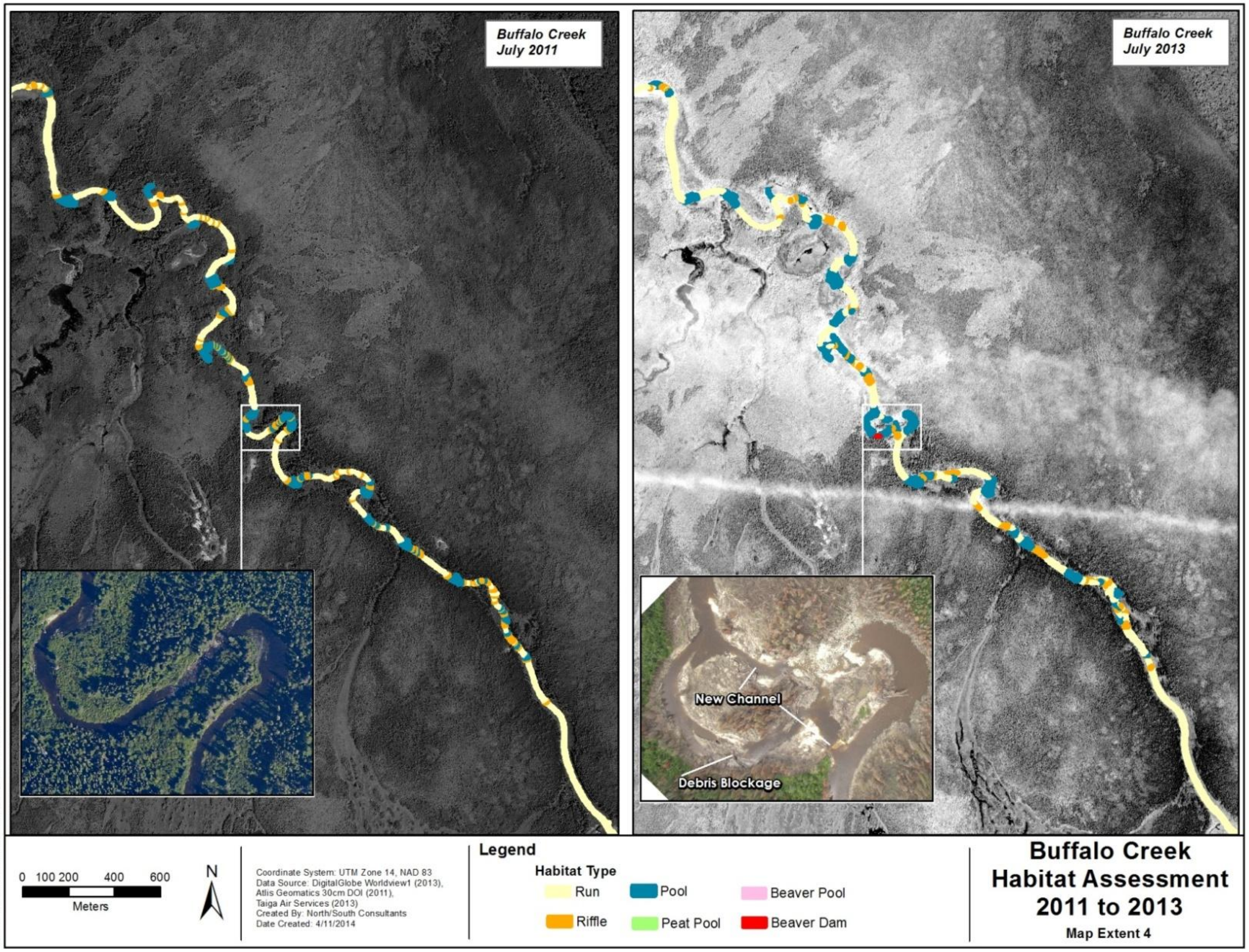


Figure 6.4-10. Extent 4: a comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

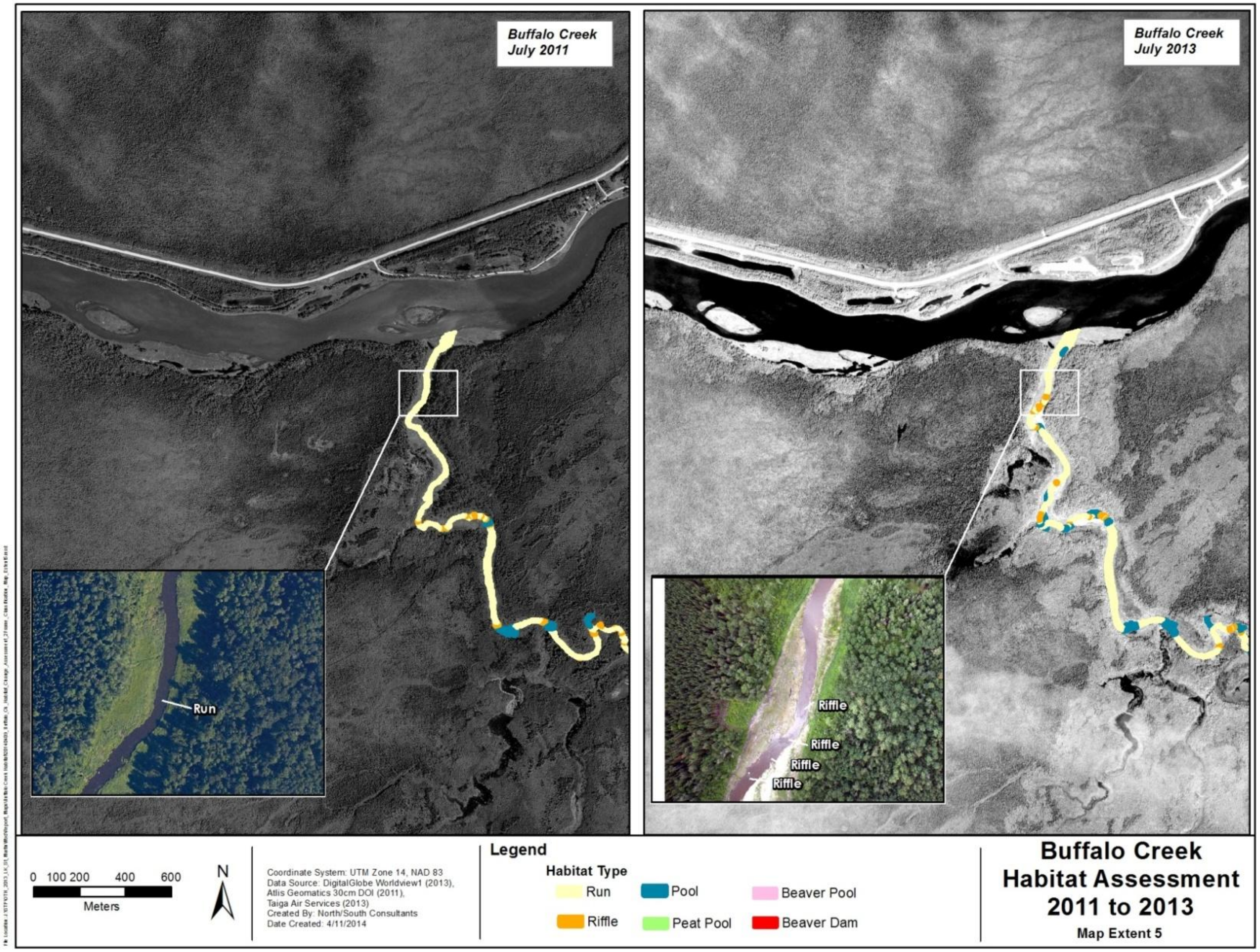


Figure 6.4-11. Extent 5: a comparison of the distribution of habitat classes within the Buffalo Creek watershed during Pre-Operation (2011) and 2011/2012 Closure (2013).

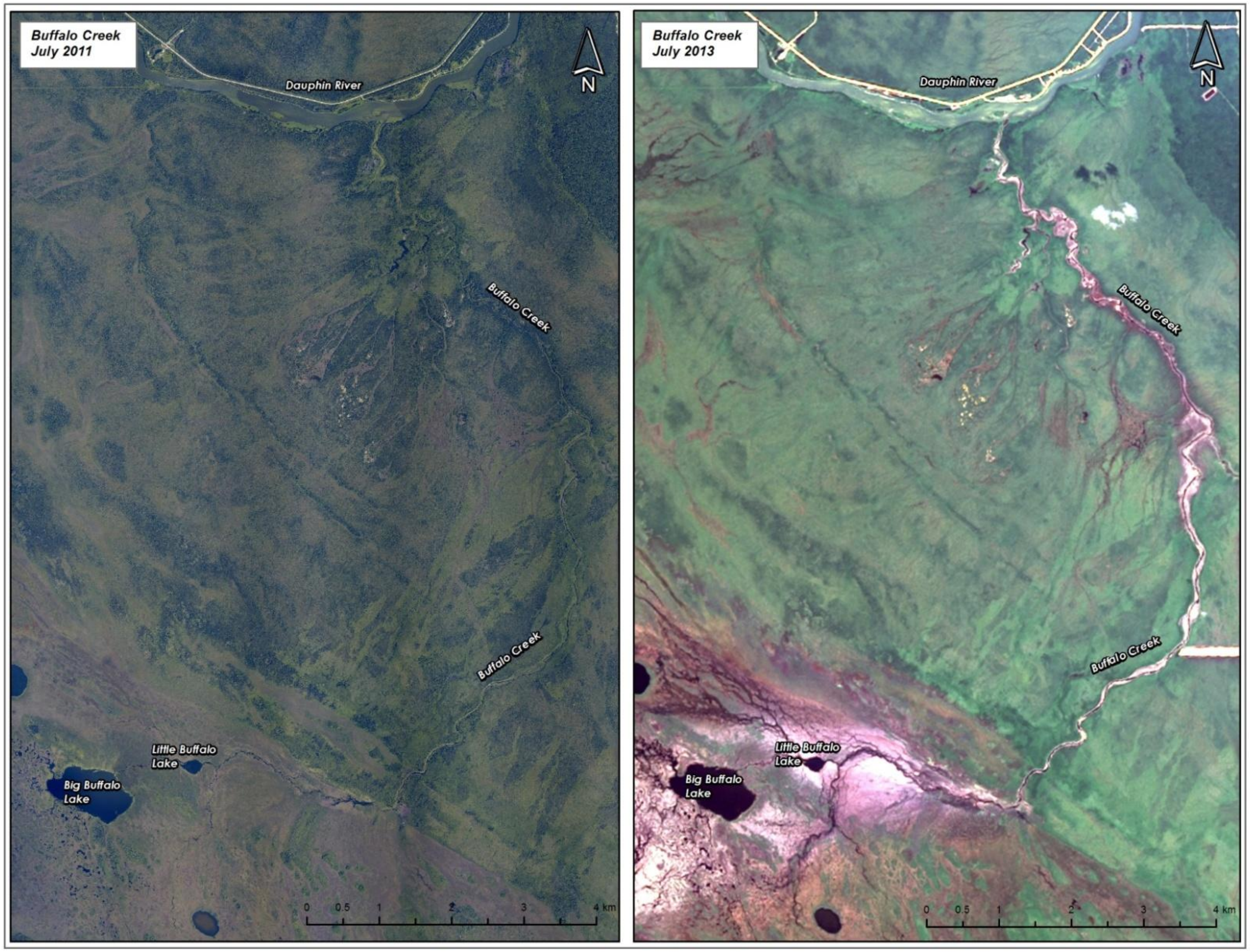


Figure 6.4-12. Satellite image overview of the Buffalo Creek watershed comparing Pre-Operation (July 2011) and 2011/2012 Closure (July 2013). Areas of bare soil resulting from flooding appear bright white, while light to dark brown areas are dead shrubs and trees.

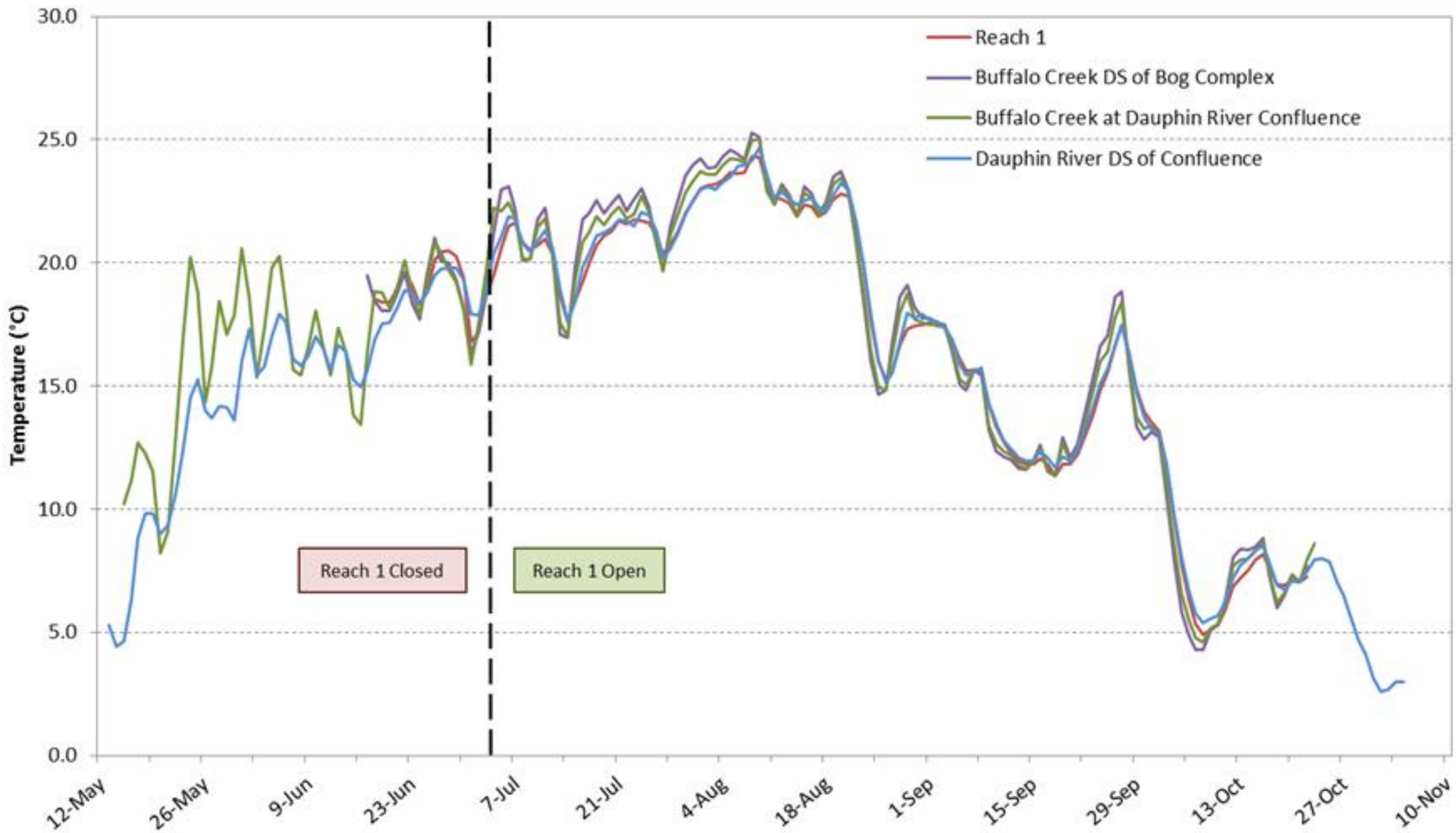


Figure 6.4-13. Water temperature data from Reach 1, Buffalo Creek, and the Dauphin River during the 2014 open water season.

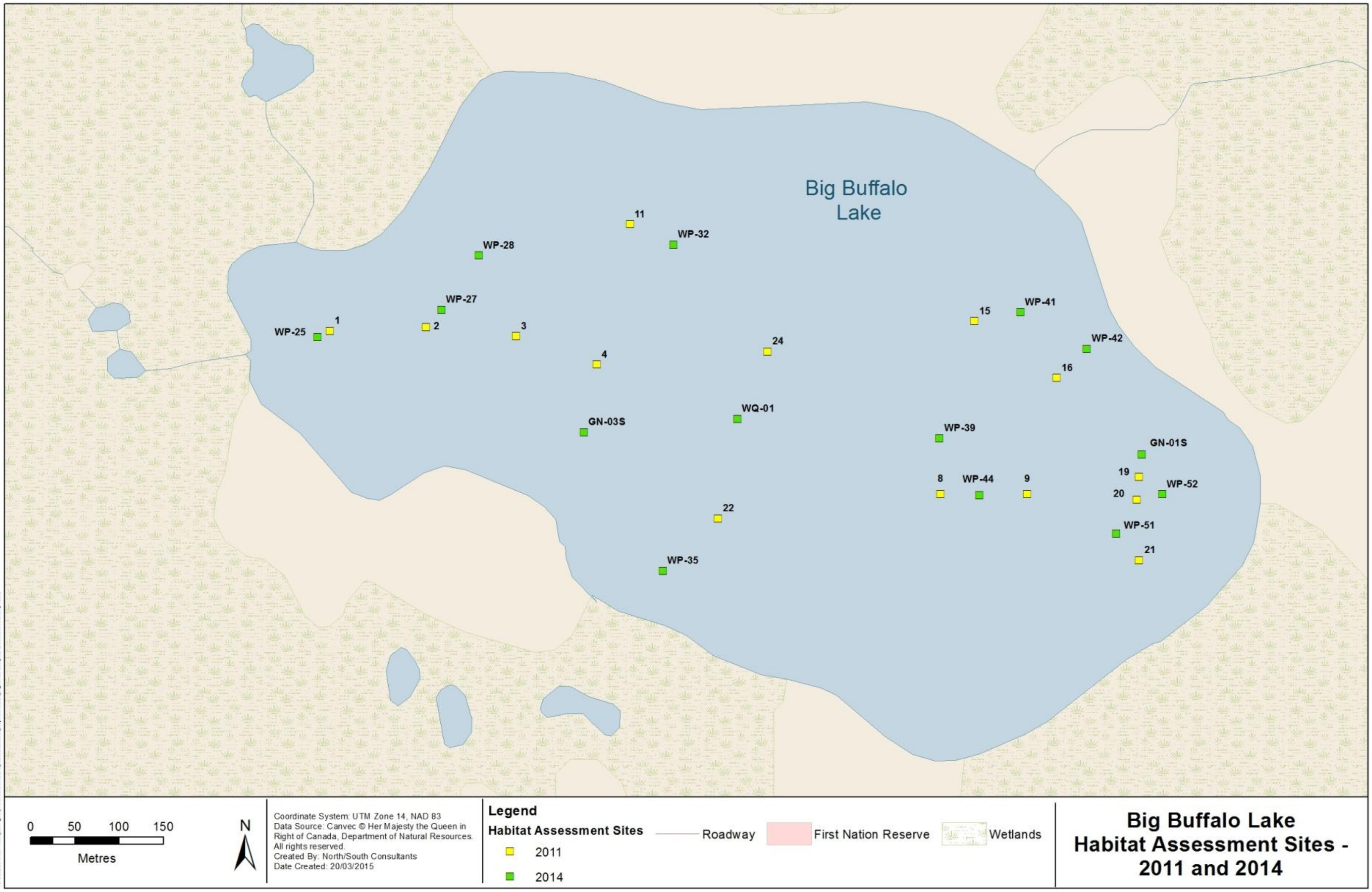


Figure 6.4-14. Aquatic habitat field survey locations in Big Buffalo Lake during Pre-Operation (2011) and 2011/2012 Closure (2014).

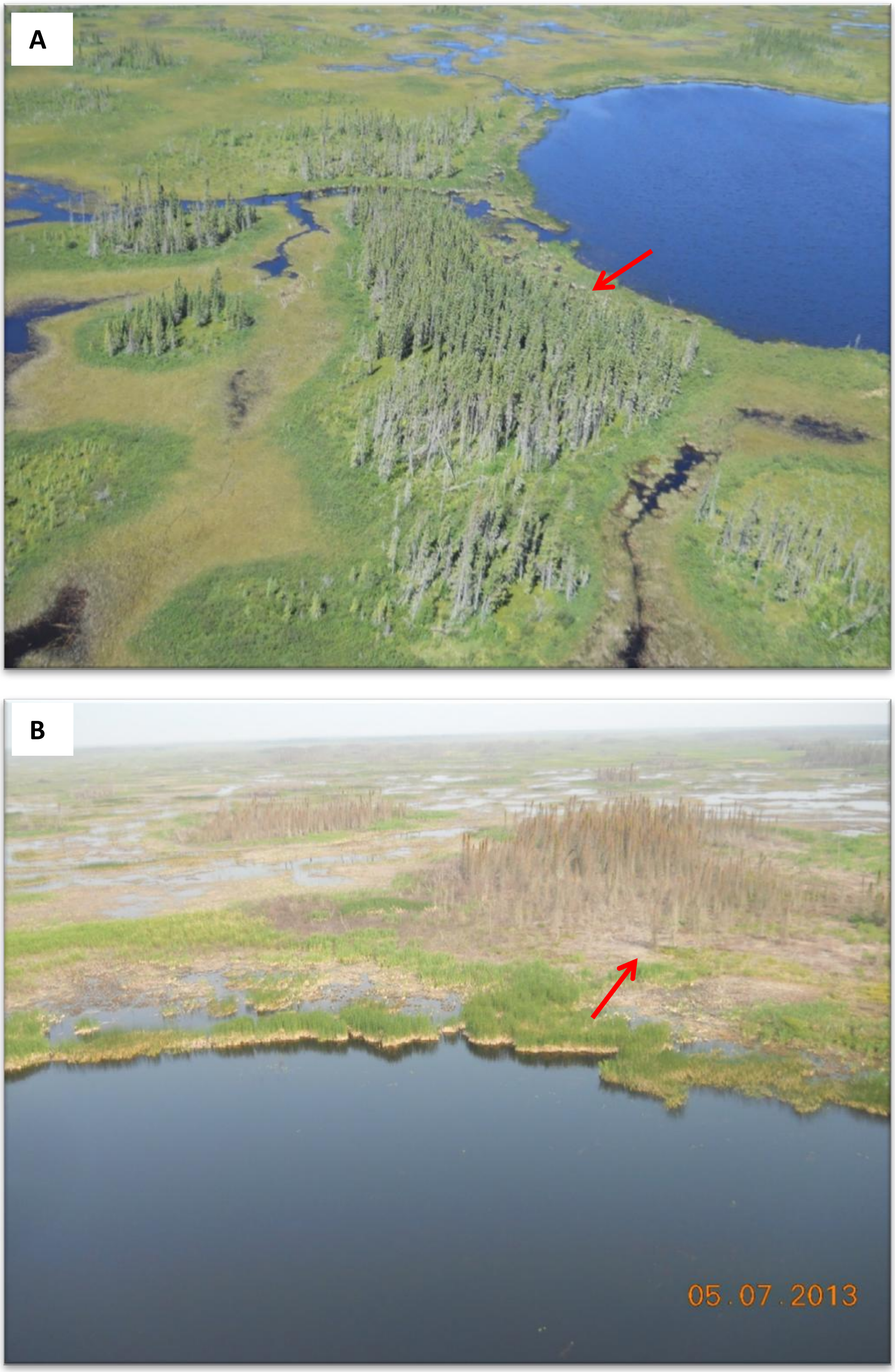


Figure 6.4-15. Aerial photographs of the shoreline vegetation in Big Buffalo Lake and its surrounding bog complex during (A) Pre-Operation and (B) 2011/2012 Closure. Red arrow points to the same cluster of trees in each photo.

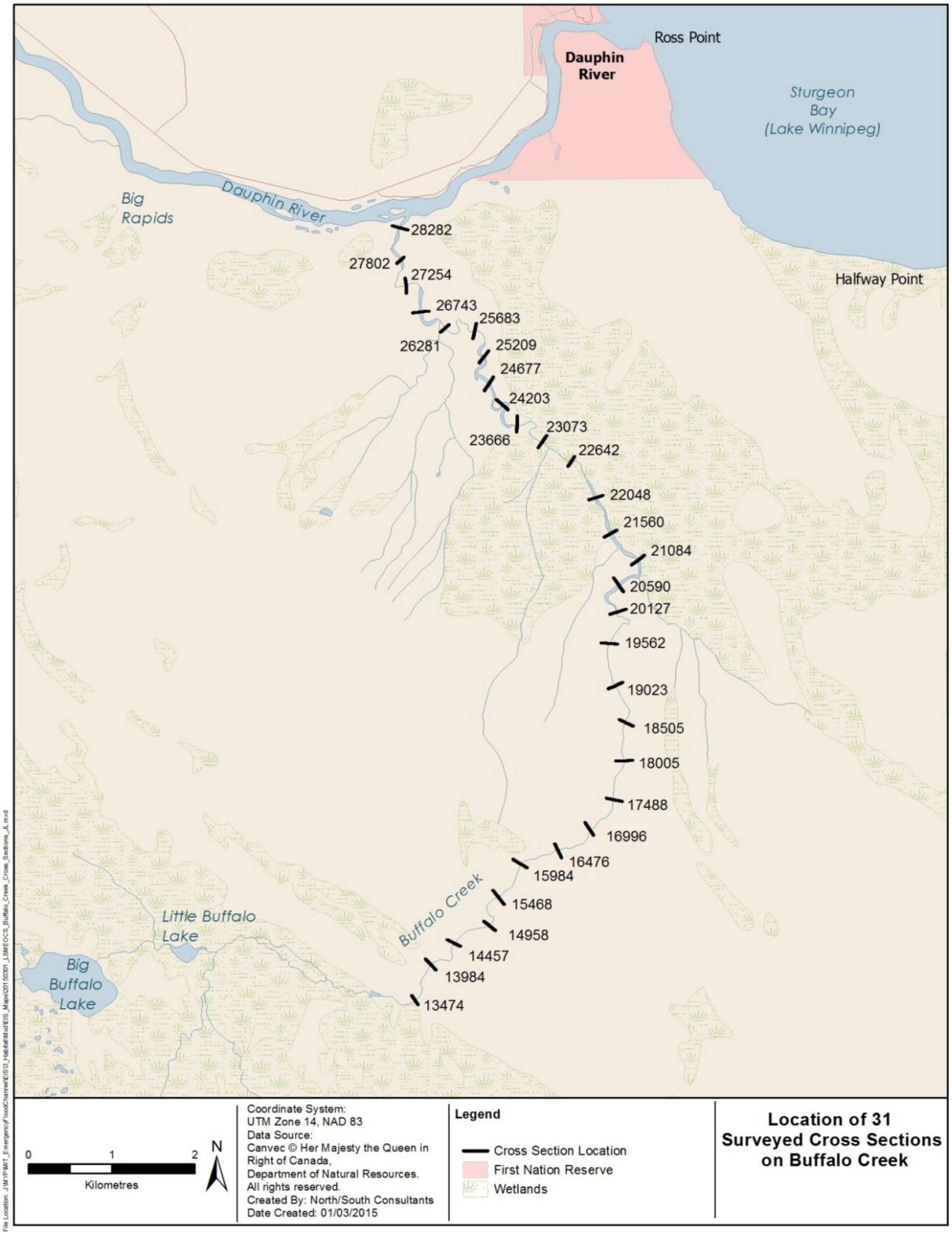


Figure 6.4-16. Cross-sectional transect locations used to measure hydraulic parameters along Buffalo Creek during Pre-Operation (2011) and 2011/2012 Closure (2013).

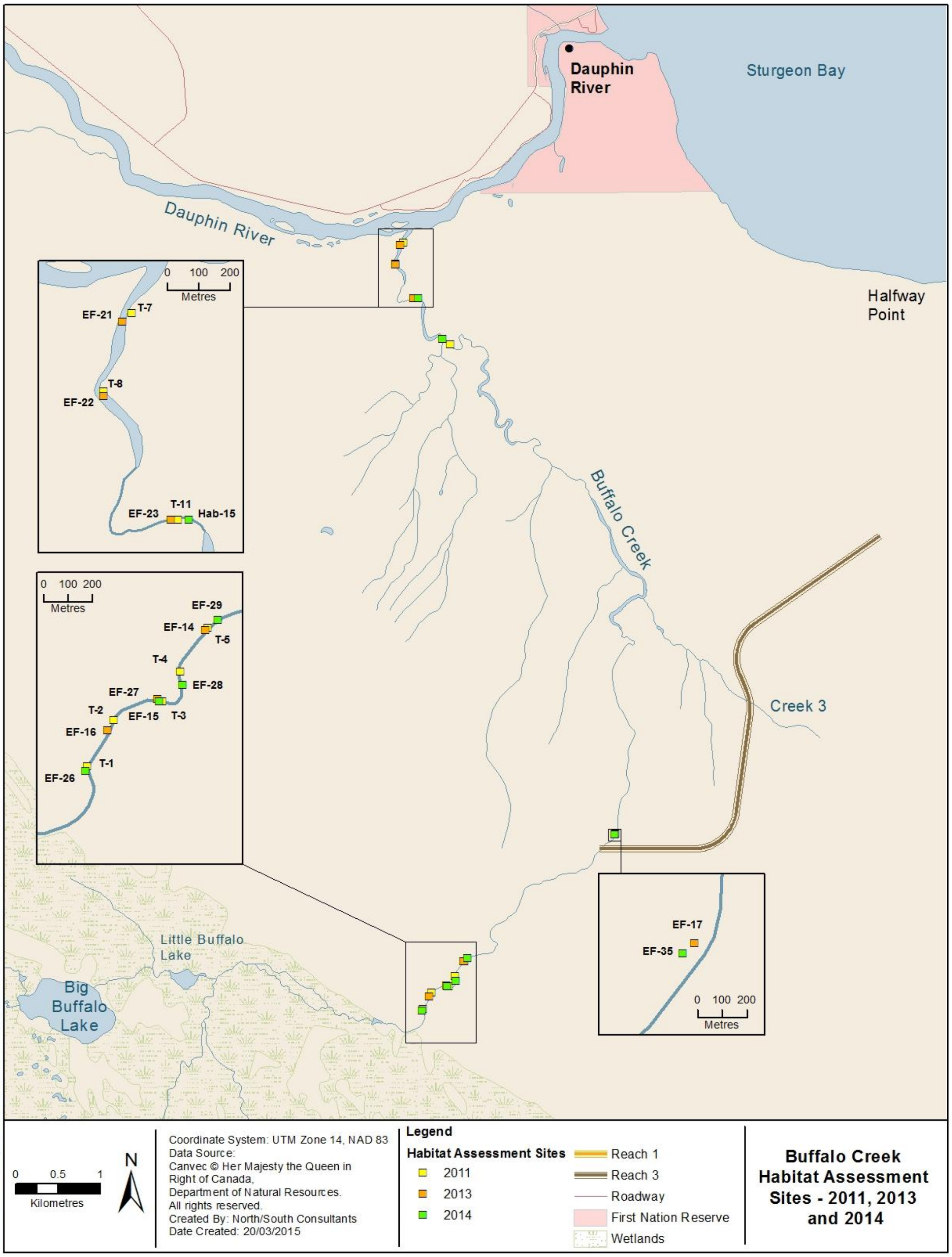


Figure 6.4-17. Aquatic habitat field survey sites in Buffalo Creek during Pre-Operation (2011) and 2011/2012 Closure (2013 and 2014).

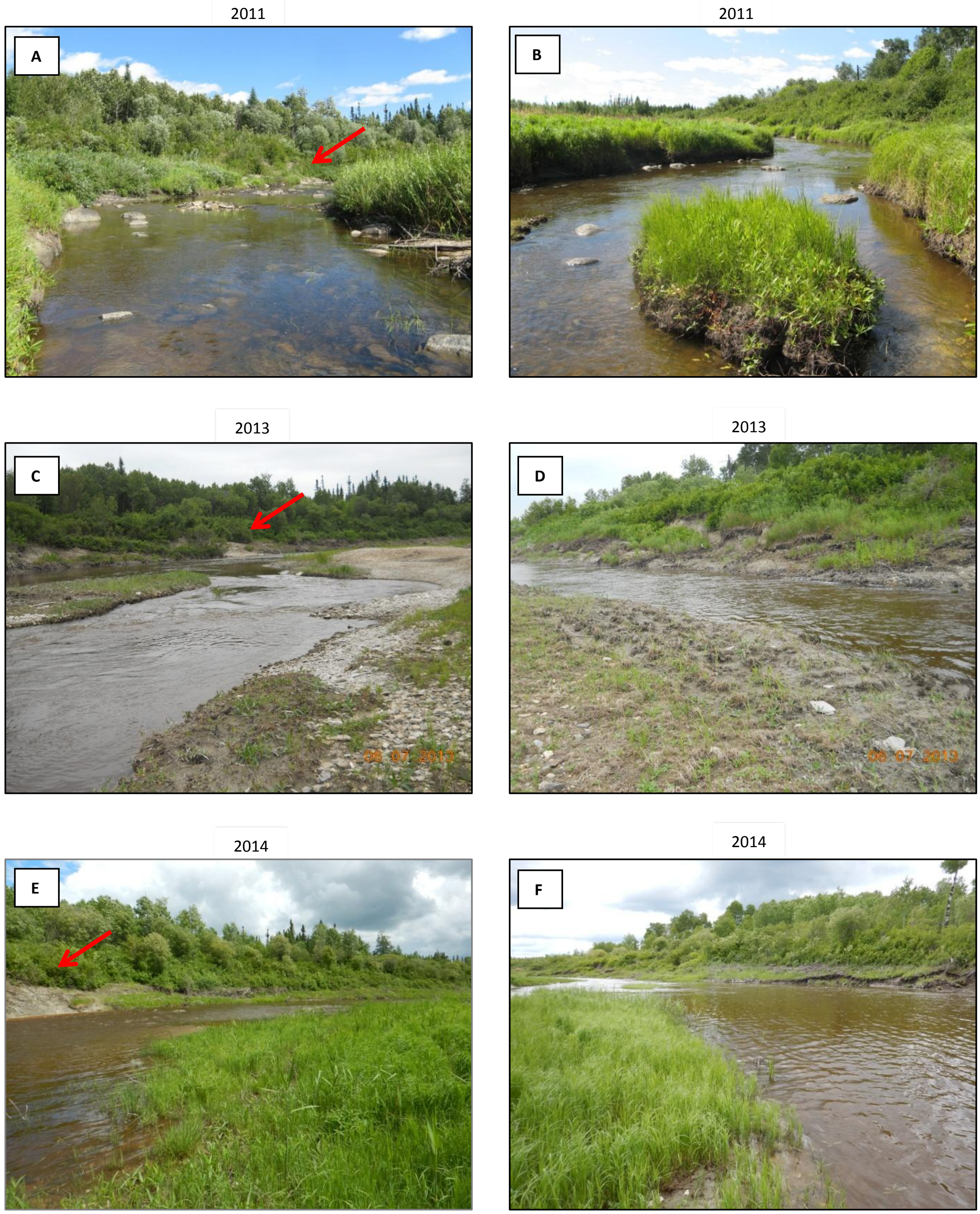


Figure 6.4-18. Aquatic habitat survey photographs taken in Buffalo Creek at site T-11 (EF-23, Hab-15) during Pre-Operation (A, B) and 2011/2012 Closure (C, D and E, F). Red arrow points to the same piece of shoreline in each photo. Note the partial stream obstruction observed during Pre-Operation (B) is absent during 2011/2012 Closure (D and F).

Figure 6.4-19. Aerial photograph of the Buffalo Creek and Dauphin River confluence during Pre-Operation.

Figure 6.4-20. Aerial photograph of the dead vegetation along Buffalo Creek during 2011/2012 Closure.

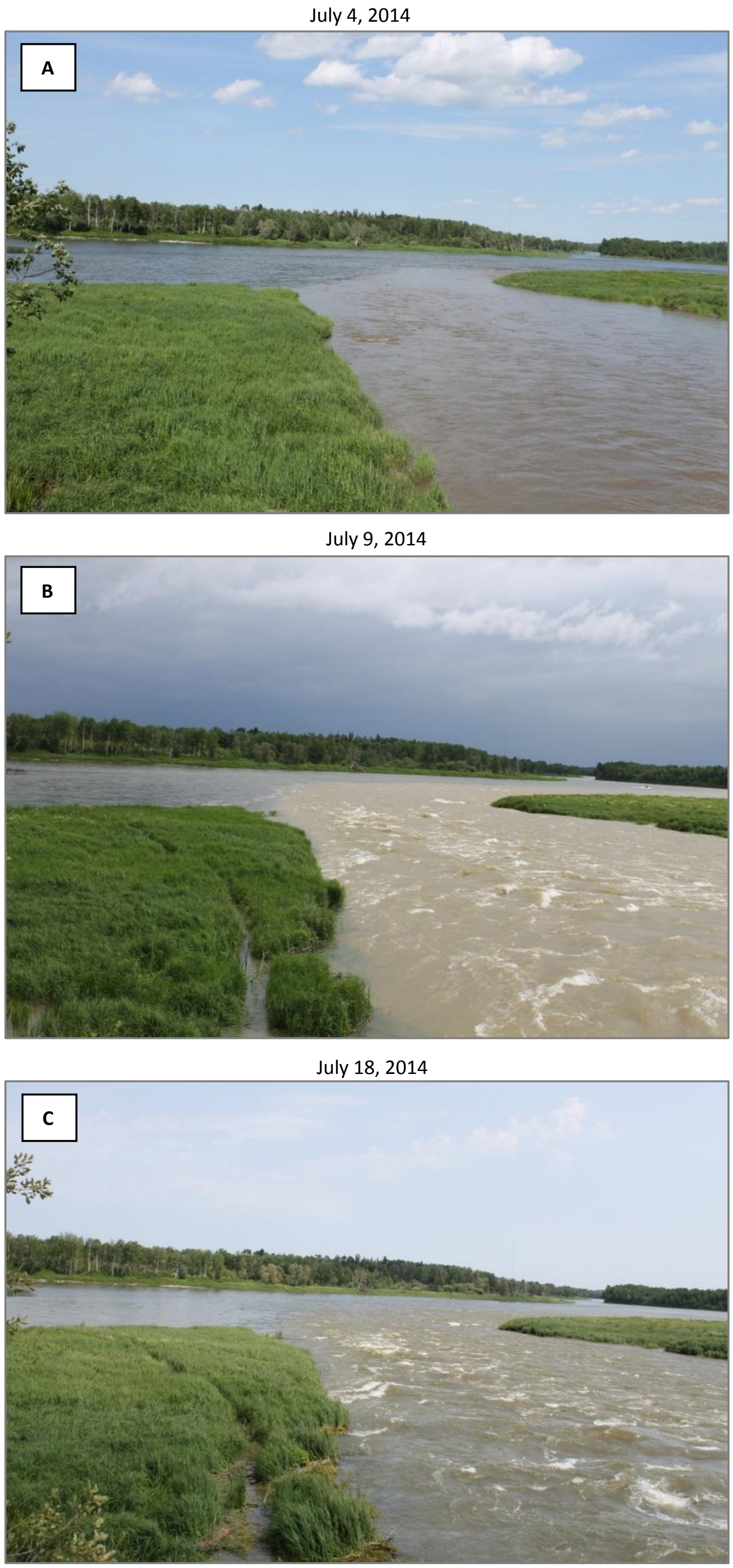


Figure 6.4-21 Time-lapse photographs of the Buffalo Creek and Dauphin River confluence during 2014/2015 Operation.

6.5 DAUPHIN RIVER MONITORING RESULTS

Reach 1 was designed to decrease flood stage water levels on Lake St. Martin by diverting water through the constructed channel into the Buffalo Creek watershed, and ultimately the lower Dauphin River. Although operation of Reach 1 reduced flow along the upper Dauphin River (i.e., between Lake St. Martin and the confluence of the Dauphin River and Buffalo creek), habitat within this portion of the river was not expected to be altered by Reach 1 operation as flows remained at the upper range of what had been recorded historically (see PESV 4.5.1). Effects to habitat within the downstream-most 4 km of lower Dauphin River are described below; modeled results pertain the habitat within this area (Figure 6.1-2).

6.5.1 Pre-Operation

6.5.1.1 Pre-flood

Water level and discharge on the Dauphin River are monitored by Water Survey of Canada (Gauge 05LM006) at a location approximately 25 km downstream of Lake St. Martin. Dauphin River discharge ranged from 8 m^3/s to 212 m^3/s and had a median discharge of 58 m^3/s (Appendix 6A) prior to the flood.

Pre-flood habitat conditions in the lower Dauphin River were derived from a spatial analysis of the MIKE 21 model (Section 6.2.2). The amount of aquatic habitat during the Pre-flood period was 61.1 ha (Table 6.5-1), average water depth was 1.2 m, and average water velocity was 0.5 m/s. The majority (78%) of the habitat was shallow, and low to moderate velocity habitat predominated (Table 6.5-1; Figures 6.5-1 and 6.5-2).

Notable habitat features within the Dauphin River include a series of rapids approximately 6 km upstream from the river mouth, where water depth is 4-5 m (0.5 m along the rapids). Sand bars are present throughout the river (McMahon and Evans 1992), and according to a report by LMRRAC (2003), gravel deposits are thought to provide spawning grounds for Lake Whitefish and Walleye.

Wide variation in slope along the Dauphin River results in diverse ice processes along its length. In the upper Dauphin River, slopes are low and the resultant slow water velocity can develop an ice cover due to border ice advancement, skim ice formation, and bridging of moving slush ice between border ice edges even before the ice cover advances from downstream. In the lower reaches of the river where slopes are greater and water velocities are higher, frazil begins to form and travels downstream to Sturgeon Bay. The area of Sturgeon Bay near the Dauphin River mouth generally ices over by early November. Ice them begins to amass and back up the Dauphin River. During spring break up, increased flow and velocity due to open water conditions at Dauphin River inlet at Lake St. Martin can lead to the formation of ice jams and elevated water levels along the Dauphin River (PESV Section 4.5.4).

6.5.1.2 2011 Flood

During the 2011 Flood period, Dauphin River discharge increased from 58 m^3/s to 527 m^3/s (Figure 6.5-2), and the amount of aquatic habitat in the lower Dauphin River increased by 9.00 ha (Table 6.5-1). At the same time, the amount of intermittently exposed habitat decreased, indicating less variation in flow conditions (Table 6.5-1).

MIKE 21 model outputs indicate that average water depth increased to 2.0 m, resulting in a 17.90 ha increase in the amount of deep water habitat (Table 6.5-1; Figure 6.5-1). Average water velocity increased to 1.6 m/s, and 56% of the modeled area was characterized by water velocities in excess of 1.5 m/s (Table 6.5-1; Figure 6.5-2).

Under normal conditions, sediment transport and distribution in the lower Dauphin River are dynamic due to its flow patterns and velocities. Finer sediments up to the size of sand typically move downstream through the Dauphin River system and settle into Sturgeon Bay; coarser materials, such as gravel and even cobble, move, erode, and shift around within the lower Dauphin River channel (PESV Section 4.5.5.2). Based on substrate data collected using sonar technology, substrate composition in the lower Dauphin River during fall 2011 was classified as predominantly boulder/cobble (Table 6.5-1; Figure 6.5-3).

There are no sediment transport data for conditions prior to operation of Reach 1, but it is assumed that because flows on the lower Dauphin River during the 2011 Flood period exceeded those seen during 2011/2012 Operation, transport processes similar to those modeled for 2011/2012 Operation (Section 6.5.2) probably also occurred during the 2011 Flood period.

6.5.2 2011/2012 Operation

Flows on the upper Dauphin River decreased as a result of Reach 1 operation but, due to the volume of water exiting Buffalo Creek, Dauphin River discharge during 2011/2012 Operation (343.0 m^3/s) was approximately the same as it would have been without the Project (337.0 m^3/s) (Table 6.5-1).

In general, habitat conditions in the lower Dauphin River during 2011/2012 Operation were intermediate to those seen during the Pre-Operation phase: water depths and velocities were higher than they were during the Pre-flood period, but they were lower than during the 2011 Flood period (Table 6.5-1; Figures 6.5-1 and 6.5-2). MIKE 21 modeling suggests an increase in wetted area during 2011/2012 Operation compared to 2011 Flood, even though flow on the Dauphin River was nearly 200 m^3/s greater during 2011 Flood. The difference in wetted area is an artefact of modeling resulting from the use of a steady state model in 2011 and a dynamic state model during 2011/2012 Operation, and the inclusion of small backwater areas in the 2011/2012 Operation model. It is expected that the differences in wetted area between 2011 Flood and 2011/2012 Operation are less than indicated by the modeling.

During 2011/2012 Operation, the amount of intermittently exposed habitat was higher than it had been during 2011 Flood but lower than Pre-flood values, indicating that water levels were more variable during 2011/2012 Operation than they has been during 2011 Flood, but less variable than under normal (i.e., Pre-flood) conditions (Table 6.5-1).

The proportions of shallow and deep water habitat in the lower Dauphin River were similar during the Pre-flood period and 2011/2012 Operation, with shallow habitat being three to four times more prevalent than deep water habitat (Table 6.5-1; Figure 6.5-1). Despite a decrease in mean velocity between 2011 Flood and 2011/2012 Operation, the majority of aquatic habitat was still within the moderate and high velocity categories (Table 6.5-1; Figure 6.5-2).

Results of empirical modeling indicate that the combined volume of suspended sediment from the upper Dauphin River and from Buffalo Creek during 2011/2012 Operation was estimated at 82,200 m^3, of which 8,900 m^3 was attributed to operation of Reach 1 (PESV Section 4.5.5.1). Due to the high velocities in the Dauphin River, suspended sediment was transported into Sturgeon Bay.

There were no evident changes in ice processes along the lower Dauphin River.

6.5.3 2011/2012 Closure

Following closure of Reach 1, flows on the Dauphin River remained elevated (205 m^3/s at 50th percentile flow) compared to Pre-flood levels, but they were within the range of historic flows (Table 6.5-1). They were similar enough to Pre-flood 95th percentile flows (212 m^3/s), that model results for that Project phase and flow condition were used as a proxy to describe habitat conditions within the lower Dauphin River during 2011/2012 Operation.

Surveys conducted in the lower Dauphin River showed changes in substrate distribution between the 2011 Flood period and 2011/2012 Closure (Table 6.5-1; Figure 6.5-3). Compared to 2011 Flood conditions, a slightly higher proportion of the surveyed area was covered in gravel substrate during 2011/2012 Operation (Table 6.5-1). The associated reduction in the area of boulder/cobble substrate suggested that the observed shifts in substrate composition likely resulted from an increased downstream transport of gravel that deposited within the boulder/cobble and bedrock areas. Substrate distributions continued to shift throughout 2011/2012 Closure (Figure 6.5-3), indicating continued transport of substrate materials. As noted in Section 6.5.1.2, of materials up to gravel and cobble size in diameter are eroded and transported under normal flow and velocity conditions in the lower Dauphin River. Results of bathymetric surveys conducted by KGS Group also indicate that changes to riverbed elevations cannot be directly attributed to operation of Reach 1 (PESV Section 4.5.3).

Results of the empirical model suggest that residual effects of Reach 1 operation (bank slumping and localized erosion resulting from the recession of flows and water levels in Buffalo Creek combined with natural drainage of Big Buffalo Lake and surrounding bog complex) led to the introduction of an additional 2,200 m^3 of suspended sediment into the Dauphin River during 2011/2012 Closure. Velocities were still sufficient (averaging greater than 0.5 m/s) to transport the majority of this material (suspended fines) into Sturgeon Bay (Table 6.5-1).

Although ice processes in the lower Dauphin River were not monitored during 2011/2012 Closure, conditions were expected to be similar to Pre-Operation conditions when the lower Dauphin River had frazil ice with some open water in paths of flow (center of channel) during winter.

6.5.4 2014/2015 Operation – Effects to December 2014

Median Dauphin River discharge during the first sixteen weeks of 2014/2015 Operation (July to October 2014) was higher than the median discharge during 2011/2012 Operation (Table 6.5-1), but it is expected that this value will decrease (and become more similar to the median discharge recorded for 2011/2012 Operation) when flows for the entire 2014/2015 Operation phase are taken into consideration. The amount of aquatic habitat present during 2014/2015 Operation is also expected to resemble that of the 2011/2012 Operation condition.

The combined volume of suspended sediment from the upper Dauphin River and Buffalo Creek was estimated at 25,400 m^3 during the first sixteen weeks of 2014/2015 Operation (PESV Section 4.5.5.1). This volume was similar in proportion to the amount of sediment transported into the Dauphin River over an equivalent duration during 2011/2012 Operation. Given that average velocities in both Buffalo Creek and the Dauphin River are greater than 0.5 m/s, transport of suspended sediment is expected to resemble 2011/2012 Operation conditions, as are the erosion and downstream movements of coarser materials within the lower Dauphin River.

There were no evident changes in ice processes along the lower Dauphin River.

Table 6.5-1. Aquatic habitat parameters used for assessment of effects in the lower Dauphin River during the Project phases.

Habitat Parameters	Units	*Measured Values/Observations*				
		Pre-Operation (Pre-flood)	Pre-Operation (2011 Flood)	2011/2012 Operation	2011/2012 Closure [1]	2014/2015 Operation [2]
Effect to habitat as a result of the Project?		-	-	*no*	*no*	-
50th: Discharge	m^3/s	58	527	343	212	430
50th: Aquatic Habitat (available wetted area)	ha	61.1	70.1	75.5[3]	64.7	-
95th: Water Surface Elevation						-
Intermittently Exposed	ha	14.78	3.56	11.87	-	
Predominantly Wetted	ha	49.93	67.38	64.60	-	
Total Water Level Zones	ha	64.70	70.93	76.47	-	
Water Depth						-
50th: Deep (> 2 m)	ha	13.68	31.60	17.31	15.16	
50th: Shallow (< 2 m)	ha	47.39	38.56	58.11	49.55	
50th: mean depth	m	1.2	2.0	1.4	1.4	
50th: max depth	m	4.2	4.9	4.5	4.2	
Water Velocity						-
50th: 0 - 0.2 (Standing - Lentic)	ha	13.33	1.83	7.60	1.99	
50th: 0.2 - 0.5 (Low)	ha	24.36	2.94	1.85	5.24	
50th: 0.5 - 1.5 (Moderate)	ha	22.23	25.91	41.62	41.67	
50th: >1.5 (High)	ha	1.15	39.48	24.40	15.81	
50th: mean velocity	m/s	0.5	1.6	1.2	1.1	
50th: maximum velocity	m/s	2.7	4.4	3.8	3.0	
Substrate Composition [4]						-
Bedrock	ha	-	2.20	-	2.30, 0.80, 0.80	
Boulder/Cobble	ha	-	58.30	-	55.00, 57.00, 57.50	
Gravel	ha	-	11.90	-	16.00, 18.50, 14.90	
Fines	ha	-	0.10	-	0.00	

1 - Due to flow similarities, 95th percentile Pre-Operation model results are provided as a proxy.
2 - Monitoring not yet completed for 2014/2015 Operation.
3 - The difference in wetted area is an artefact of modeling. It is expected that the differences in wetted area between 2011 Flood and 2011/2012 Operation are less than indicated.
4 - Substrate composition measured three times during 2011/2012 Closure. Results listed in chronological order: June 2013, September 2013, June 2014.

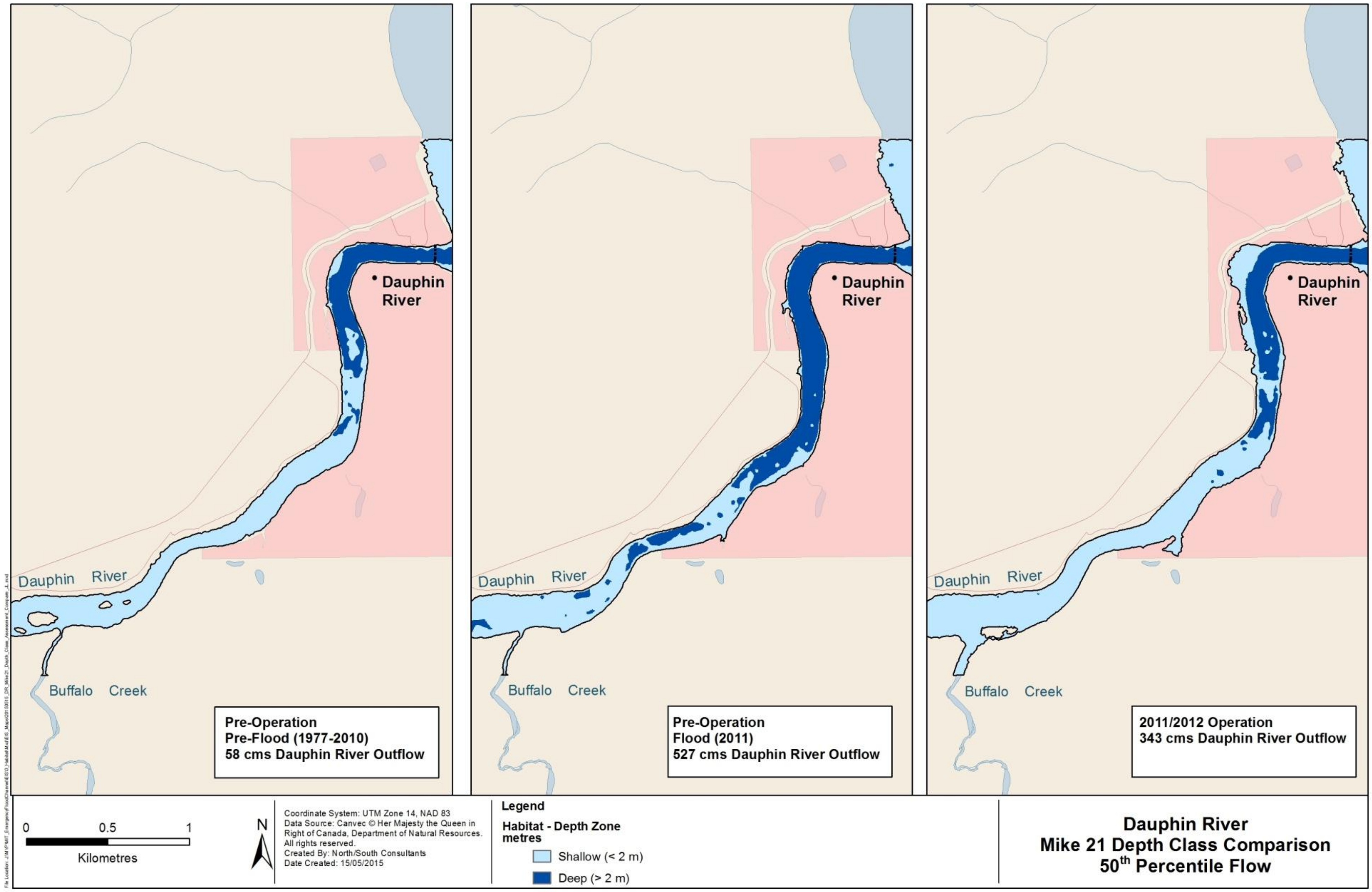


Figure 6.5-1. MIKE 21 model output for water depth (at 50th percentile flow) in the lower Dauphin River during the Pre-flood period, the 2011 Flood period, and 2011/2012 Operation phase of the Project.

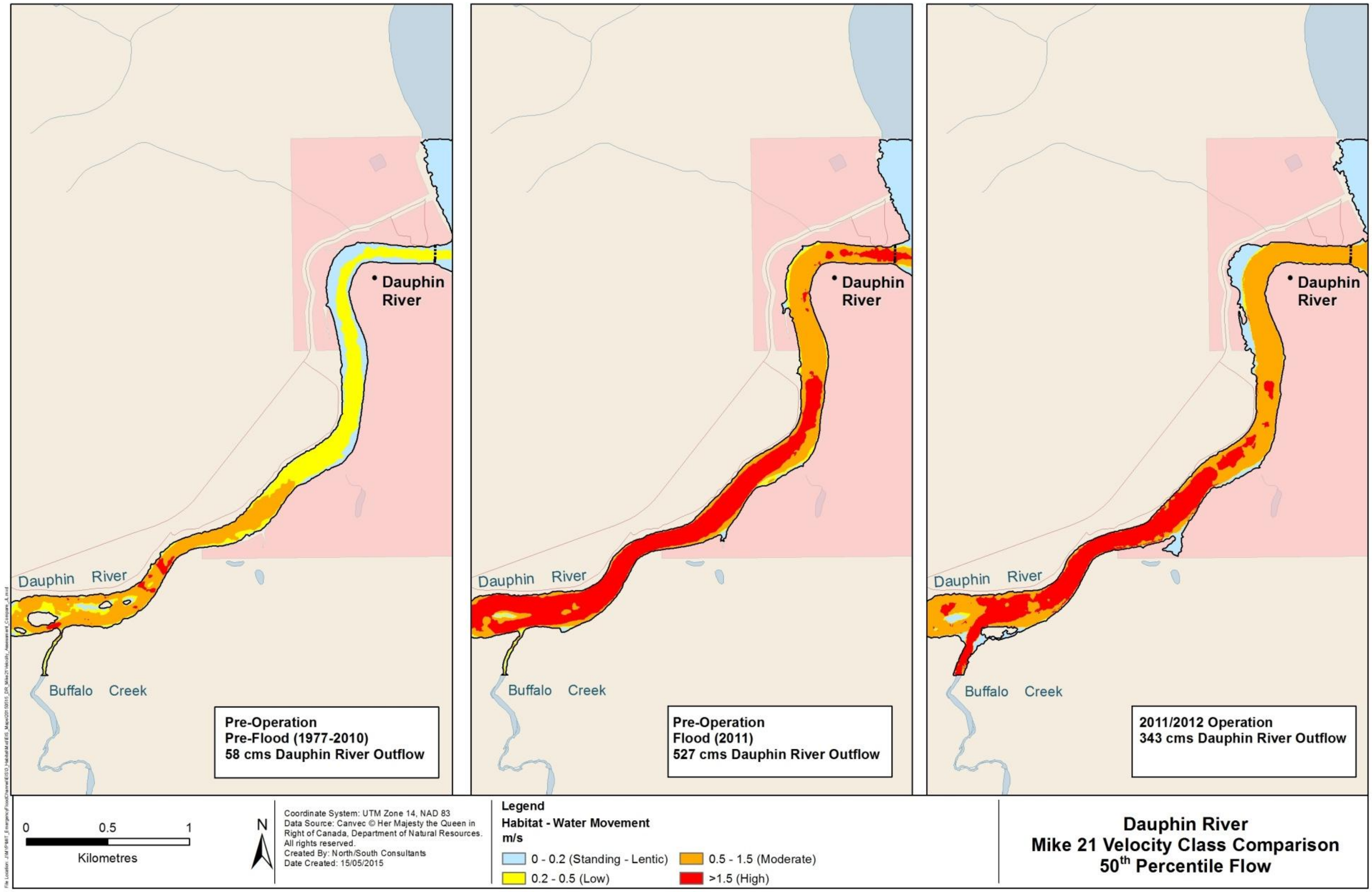


Figure 6.5-2. MIKE 21 model output for water velocities (at 50th percentile flow) in the lower Dauphin River during the Pre-flood period, the 2011 Flood period, and the 2011/2012 Operation phase of the Project.

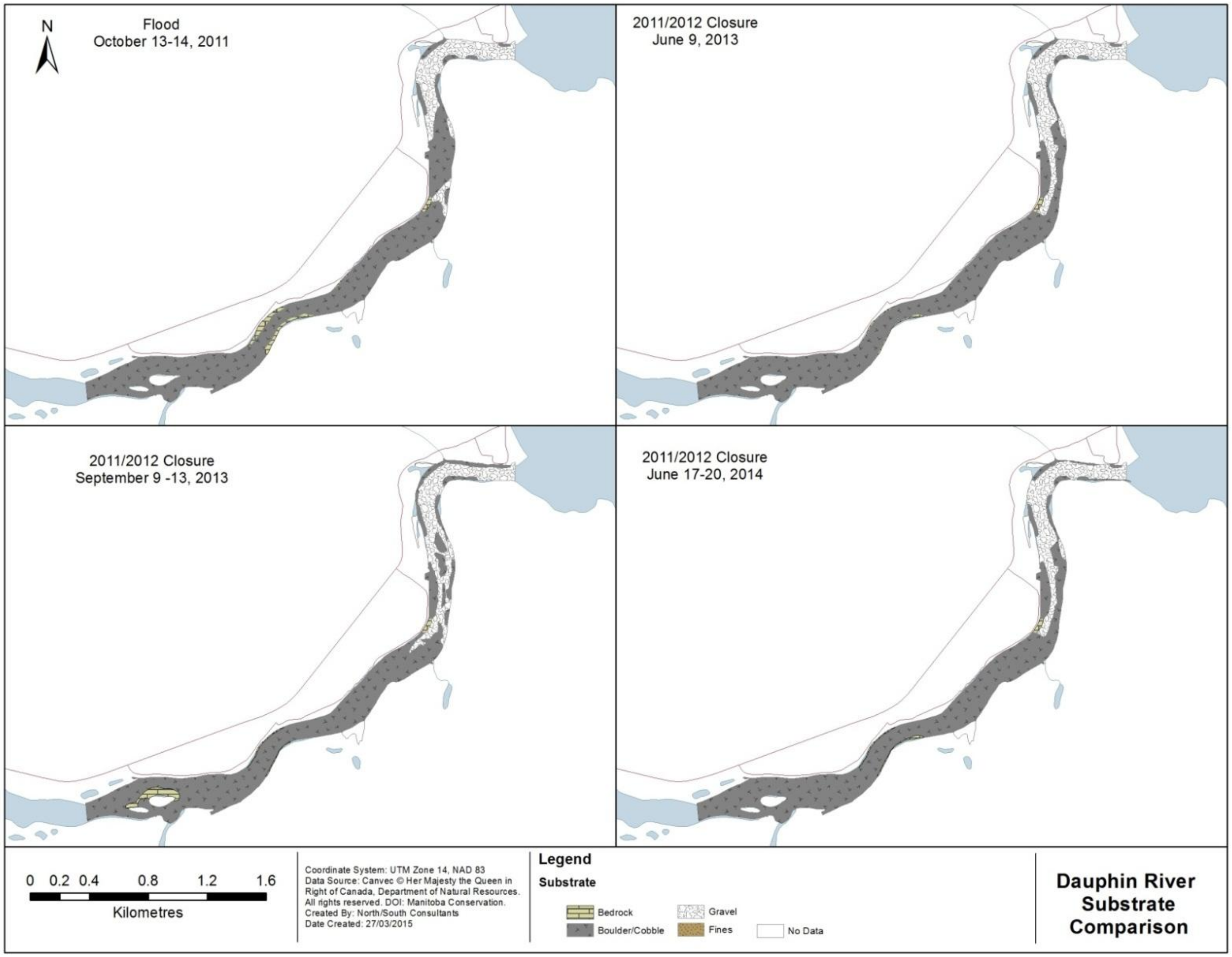


Figure 6.5-3 A comparison of the substrate distribution within the lower Dauphin River during the 2011 Flood period and three time periods during 2011/2012 Closure.

6.6 STURGEON BAY MONITORING RESULTS

6.6.1 Pre-Operation

The Partners for the Saskatchewan River Basin (2009) reported that a large proportion of the bottom terrain of Lake Winnipeg is underlain with hummocky, undulating Precambrian Shield bedrock. Lake Agassiz clays extend to approximately 50 m deep in the south basin and over 100 m deep in the north basin, while more recent sediment deposits rarely exceed 10 m in depth (Thorleifson et al. 1998; The Partners for the Saskatchewan River Basin 2009). Fine-grained sediments (sand) deposited in glacial Lake Agassiz rest directly on bedrock over most of the nearshore habitat (Figure 6.6-1), while clay/silt mud dominates the offshore sediments (Thorleifson et al. 1998; EC and MWS 2011).

A limited amount of depth information provided along a narrow transportation corridor from the north basin of Lake Winnipeg into Dauphin River (by the Canadian Hydrographic Service; mapped by the Manitoba Geological Society) suggests a maximum depth of about 10.4 m at the northern end of the bay (EC and MWS 2011). Wind-driven sediment re-suspension (through wave action) in Sturgeon Bay results in turbidity levels that are generally higher than in other areas of the north basin of Lake Winnipeg (McCullough et al. 2001).

Median flow on the Dauphin River increased from 58 m^3/s during Pre-flood to 527 m^3/s during 2011 Flood (Table 6.6-1), resulting in an increase in water depth and higher water velocity conditions at the Dauphin River mouth (Figure 6.6-2; Appendix 6A). Although water velocity within the majority of the area modeled was less than 0.5 m/s, a small portion of the area (< 0.5%) was characterized by water velocity greater than 1.5 m/s, a condition that would not have occurred under median flow conditions prior to the flood (Table 6.6-1; Figure 6.6-2).

Pre-Operation substrate conditions in Sturgeon Bay were mapped during fall 2011 (Flood 2011), but high winds occurring through much of the fall greatly restricted the extent of the survey to a small area (1.33 km^2) in the vicinity of the Dauphin River mouth. Substrate in the area was primarily cobble/boulder and gravel (Table 6.6-1; Figure 6.6-3).

Although wind conditions prevented extensive substrate mapping from being conducted, ponar grabs were collected over a broad area in fall 2011 (Figure 6.6-4). Results indicated that substrates in a band along the southwest shore of Sturgeon Bay between the Dauphin River outflow and Willow Point were generally comprised of either rock or a mixture of rock and fines (Figure 6.6-4). Areas farther offshore were entirely comprised of fines (clay, silt and/or sand), with rock and/or cobble substrates occurring infrequently in small isolated locations.

Laboratory analysis of sediment samples revealed that along each transect the proportion of sand in samples generally decreased as distance from shore increased (Table 6.6-2), while the reverse was true for silt and clay. Samples from the offshore extensive zone were predominantly clay. Total organic carbon ranged from 0.2-3.91%, and the relative proportion of organic carbon increased with distance offshore (Table 6.6-2).

6.6.2 2011/2012 Operation

Modeling conducted by Manitoba Hydro prior to operation of Reach 1 indicated that the volume of water flowing out of Reach 1 would have a negligible effect on water level in Lake Winnipeg (contributing less than 2.5 cm to water level on the lake; KGS and AECOM 2011). Water level during operation (measured by Water Survey of Canada at gauge 05RD005; Berens River) ranged from 217.4 to 218.0 mASL.

Median flow on the lower Dauphin River during the 2011/2012 Operation was 343 m^3/s (Table 6.6-1). MIKE 21 modeling indicated that maximum water velocity at the Dauphin River mouth (and extending into Sturgeon Bay) during 2011/2012 Operation was lower than it had been during 2011 Flood (Figure 6.6-2). Mean water velocity within the area modeled was characterized by low velocity conditions (< 0.5 m/s; Table 6.6-1).

An empirical model used to estimate the amount of suspended sediment mobilized as a result of Reach 1 operation indicated that between November 2011 and November 2011, an additional 8,900 m^3 of suspended sediment entered Sturgeon Bay as a result of 2011/2012 Operation, most of which entered during the first month of operation (PESV Section 4.6.2). Further discussion regarding suspended sediment introduction into Sturgeon Bay is provided in the following section.

Ice processes on Lake Winnipeg do not appear to have been affected by Project operation.

6.6.3 2011/2012 Closure

Water level on Lake Winnipeg ranged from 217.3 to 218.2 mASL and median discharge on the lower Dauphin River was 212 m^3/s during the 2011/2012 Closure period (Table 6.6-1). MIKE 21 modeling indicated that water velocities at the mouth of the Dauphin River decreased in response to lower flow on the Dauphin River, but remained higher than those estimated for historical Pre-flood conditions (Table 6.6-1; Figure 6.6-2).

It is estimated that an additional 2,200 m^3 of suspended sediment from Buffalo Creek was introduced into Sturgeon Bay during 2011/2012 Closure. Conservatively, assuming that flows in Buffalo creek would have been negligible without operation of Reach 1, the residual effects of 2011/2012 Operation contributed 2,200 m^3 of suspended sediment to the Dauphin River and, ultimately, Sturgeon Bay.

In general, the introduction of suspended sediments from the Dauphin River is a naturally occurring process. During the high flow conditions that occurred during 2011/2012 Operation and 2011/2012 Closure, approximately 11,100 m^3 of the 157,000 m^3 of suspended sediments that were introduced into Sturgeon Bay from the Dauphin River were attributed to the operation of Reach 1 (Table 6.6-3), representing a 7.6% increase in suspended sediment introduction attributed to Reach 1 operation. As would be expected, a higher percent increase (12.1%) of suspended sediment was contributed during 2011/2012 Operation.

The extent and locations where introduced suspended sediments may have deposited were examined by comparing mapped distributions of substrate types (sonar mapping), substrate composition (qualitative assessment of substrate grabs together with particle size and total organic carbon analysis of fine sediments), and sedimentation rates between years and locations within southern Sturgeon Bay.

Substrate distributions were mapped during Pre-Operation (fall 2011) and 2011/2012 Closure (fall 2013 and spring 2014). Mapping was greatly restricted in fall 2011 because of inclement weather and, consequently, only a small area to the immediate north of the Dauphin River inflow was mapped. A considerably larger portion of Sturgeon Bay was mapped during fall 2013, but only a small area near the mouth of the Dauphin River was mapped during spring 2014 as part of Dauphin River habitat mapping.

In the small area near the Dauphin River outflow where the 2011, 2013 and 2014 sonar surveys overlap, changes in substrate composition are apparent between 2011 and 2013 (Figure 6.6-3; Table 6.6-1). In 2013, substrates directly east of the river mouth did not change, but fine materials appear to have deposited over much of the coarser substrate that occurred to the north of the river mouth. Gravel and boulder/cobble persisted in the portion of the survey area to the northeast of the river mouth, but their distribution changed somewhat and the proportion of gravel increased slightly. Substrate conditions remained consistent between 2013 and 2014.

Substrate distribution was characterized over approximately 62 km^2 of Sturgeon Bay during the fall 2013 sonar survey. The survey area began at Hay Point and followed the southwest shoreline to a point about 3.5 km beyond Willow Point, extending approximately 4 km out into Sturgeon Bay along its entire length. The survey area had a maximum depth of 8 m, with shoreline water depths increasing fairly rapidly to 3 m in the vicinity of Halfway Point and Willow Point, and a more gradual gradient in areas south of Hay Point and Willow Point (Figure 6.6-5). Nearshore substrate was dominated by fines which, at a water depth of approximately 2 m, transitioned into a band of boulder/cobble that was approximately 1 km wide and ran the entire length of the survey area, except for in the vicinity of the Dauphin River mouth, where gravel replaced boulder/cobble (Figure 6.6-6). Farther offshore (> 5 m depth), fine substrates became dominant once again. Results from substrate grabs indicated that the nearshore fines were primarily sand, while the fines at offshore sites were primarily clay and silt (Table 6.6-2).

Substrate composition was examined during Pre-Operation (fall 2011) and 2011/2012 Closure (fall 2013 and spring 2014). Substrate samples were collected along pre-established transects in Sturgeon Bay were used to assess potential changes to substrate over a large area of southern Sturgeon Bay (Figures 6.6-6 to 6.6-8). Results indicated that substrate composition at sites greater than 3 km offshore was consistent between sampling seasons (i.e., years and Project phases), while sites closer to shore occasionally exhibited changes in substrate between years. Sites near to the Dauphin River outflow were no more or less likely to experience these changes, and the majority of the observed shifts in substrate composition were from fine sediments to mixed gravels and cobbles or rock.

Despite the small, dynamic changes that were seen between years, the general trends in substrate composition along each transect endured, indicating that the habitat features identified during the 2013 sonar survey (fine sediments nearshore, a strip of boulder/cobble that follows the shoreline profile, and fines again farther offshore) persisted throughout the monitoring period. Results of laboratory analyses performed on the grab samples indicated that silt content at most sites increased between the 2011 and 2013 samples (Table 6.6-2). These increases were uniform across all areas and transects sampled, and did not indicate a particular pattern of sedimentation. A small additional, and similarly uniform, increase in silt content was also detected at most sites between 2013 and 2014.

Sedimentation rates were generally uniform across Sturgeon Bay. Substantial changes in the rate of sedimentation were observed between periods of open water and when competent ice cover was formed (PESV Section 4.6.2). In general, sedimentation during periods of open water was much greater than when Sturgeon Bay was ice covered. McCullough et al (2001) reported that wind and wave driven sediment re-suspension was generally higher in Sturgeon Bay than other, deeper areas of Lake Winnipeg. Satellite imagery of Sturgeon Bay under different wind conditions, in different seasons and Dauphin River flow conditions, illustrates the extent to which wind plays a dominant role in sediment re-suspension within this part of the lake. A selection of Landsat satellite images were used to examine the re-suspension of sediments and resulting turbidity in Sturgeon Bay prior to and during operation of Reach 1 (Figure 6.6-9). For example, a wind driven event on 30 September 2011 (Figure 6.6-9, panel B) appears to have caused considerable re-suspension of nearshore sediments, visible as bright plumes oriented in the north and west directions, driven by a mid-day wind of 20 km/h out of the east-southeast direction. Re-suspension under lower wind speeds of 7km/h out of the same direction (Figure 6.6-9, panel A) do not appear to cause the same amount of nearshore sediment re-suspension. Although visually less prominent in June 2014, due to reduced contrast created by cloud cover, high wind conditions again out of the east-southeast direction appear to re-suspend sediment in the water column uniformly across the width of Sturgeon Bay (Figure 6.6-9, panel C). During 2014/2015 Operation, another Landsat image (Figure 6.6-9, panel D) shows the re-suspension of nearshore and offshore sediments aligned with the predominant west wind under moderate wind speeds.

The spatial extent over which suspended sediments from the Dauphin River may have deposited within Sturgeon Bay during the 2011/2012 Operation and Closure periods could not be determined. However, substrate sampling suggests that no large scale and apparent change occurred to substrate conditions over most of southern Sturgeon Bay. A small increase in the silt proportion of fine grained sediments (sands, silts, and clays) was noted at most locations and, in a small number of locations, substrate composition changed from predominantly fine-grained to coarser grained materials (gravel/cobbles).

6.6.4 2014/2015 Operation – Effects to December 2014

Field studies to monitor aquatic habitat in Sturgeon Bay have not been conducted since the initiation of 2014/2015 Operation. Based on monitoring during the first sixteen weeks of 2014/2015 Operation (July to October 2014), the Dauphin River outflow has been estimated at 430 m^3/s. While this value is higher than the average outflow for 2011/2012 Operation (343 m^3/s), it is likely to change after flows from October 2014 until closure are taken into consideration.

Empirical modeling estimates that 25,400 m^3 of suspended was transported into Sturgeon Bay via the Dauphin River during the first sixteen weeks of 2014/2015 Operation. This volume has not been adjusted to take into account background levels of suspended sediment in the Dauphin River because background levels are calculated based on average background over the entire 2014/2015 Operation phase. When compared to the unadjusted amount of suspended sediment that entered Sturgeon Bay during the year-long 2011/2012 Operation (82,222 m^3), the volume of sediment being transported into Sturgeon Bay appears similar between the two rounds of operation.

Table 6.6-1. Aquatic habitat parameters used for assessment of effects in Sturgeon Bay.

Habitat Parameters	Units	Measured Values/Observations				
		Pre-Operation (Pre-flood)	Pre-Operation (2011 Flood)	2011/2012 Operation	2011/2012 Closure [1]	2014/2015 Operation [2]
Effect to habitat as a result of the Project?		-	-	*no*	*no*	
Water Surface Elevation Range [3]	mASL	216.4-219.2	217.5-218.7	217.4-218.0	217.3-218.2	218.2-218.4
50th: Dauphin River Discharge	m^3/s	58	527	343	212	430
Water Depth – Dauphin River outlet [4]						
50th: mean depth	m	2.5	3.0	2.4	2.5	-
50th: max depth	m	4.2	4.9	4.2	4.2	-
Water Velocity – Dauphin River outlet [4]						
50th: 0 - 0.2 (Standing - Lentic)	ha	90.10	72.47	67.60	77.90	-
50th: 0.2 - 0.5 (Low)	ha	1.80	9.07	15.60	8.50	-
50th: 0.5 - 1.5 (Moderate)	ha	0.00	14.35	10.50	5.70	-
50th: >1.5 (High)	ha	0.00	0.40	0.00	0.00	-
50th: max velocity	m/s	0.30	1.80	1.20	1.00	-
50th: mean velocity	m/s	0.00	0.30	0.20	0.10	-
Substrate Composition - Dauphin River outlet [4]						
Boulder/Cobble	ha	-	42.33	-	17.18	-
Gravel	ha	-	28.84	-	23.78	-
Fines	ha	-	10.82	-	41.03	-

1 - 95^{th} percentile Pre-flood values were used as a proxy for 50^{th} percentile 2011/2012 Closure.
2 - Monitoring not yet completed for 2014/2015 operation, therefore all effects are predicted.
3 - Minimum and maximum water elevation on Lake Winnipeg at Berens River (Water Survey of Canada gauge 05RD005).
4 - MIKE 21 modeling results for a small area at the mouth of the Dauphin River (see Figure 6.6-2).

Table 6.6-2. Laboratory analysis of substrate samples collected from sites in Sturgeon Bay.

Site ID [1]	Laboratory Results: Total Organic Carbon (%)			Laboratory Results: Particle Size (%) Sand/Silt/Clay			Site ID	Laboratory Results: Total Organic Carbon (%)			Laboratory Results: Particle Size (%) Sand/Silt/Clay		
	2011	2013	2014	2011	2013	2014		2011	2013	2014	2011	2013	2014
T-1-1	2.89	1.62	2.39	38/49/13	39/52/9	26/62/12	T-9-1 R1	2.87	2.86	2.64	27/49/24	24/59/17	29/56/15
T-1-2	2.54	2.42	2.40	37/51/12	11/76/13	18/69/14	T-9-1 R2	-	-	2.67	-	-	19/62/18
T-1-4	0.49	-	-	20/28/52	-	-	T-9-1 R3	-	-	2.58	-	-	24/59/17
T-1-KN	-	0.98	0.26	-	55/38/7	91/8/1	T-9-2	0.73	-	0.64	9/65/26	-	17/31/51
							T-9-5	0.35	-	-	100/0/0	-	-
T-2-1	3.68	3.7	3.56	3/39/58	1/51/48	1/53/46	T-9-KN	-	-	0.25	-	-	95/4/1
T-2-2	3.79	4.17	3.27	6/45/49	1/60/39	2/61/37							
T-2-3 R1	1.07	1.74	1.46	64/28/8	33/57/10	45/45/10	T-10-1	3.12	3.51	3.52	4/59/37	2/60/38	2/67/32
T-2-3 R2	-	-	1.33	-	-	44/45/11	T-10-2	-	-	n.s.	-	-	n.s.
T-2-3 R3	-	-	1.64	-	-	43/46/11	T-10-3	-	-	n.s.	-	-	n.s.
T-2-4	0.51	-	-	87/7/6	-	-	T-10-4	0.49	-		55/11/34	-	-
T-2-KN	-	0.27	0.30	-	98/1.5/0.5	94/5/0.5	T-10-5	0.22	-	0.22	99/1/0	-	99/0.5/0.7
							T-10-KN	-	0.34	0.47	-	96/3.5/0.5	90/9/0.6
T-3-1	3.52	3.97	3.35	1/45/54	1/60/39	2/63/36							
T-3-2	0.35	-	-	-	-	-	T-11-2 R1	2.43	3.83	2.61	24/56/20	17/68/15	18/66/16
T-3-3	-	-	0.76	-	-	81/15/4	T-11-2 R2	-	-	2.83	-	-	14/67/19
T-3-KN	-	0.31	0.20	-	98.7/0.6/0.7	96/4/0.1	T-11-2 R3	-	-	2.5	-	-	17/68/15
							T-11-3	0.86	-	-	78/11/11	-	-
T-4-1	3.91	4.02	3.41	3/53/44	1/69/30	2/71/27	T-11-4	-	-	-	-	-	-
T-4-2	1.24	0.86	0.52	64/25/11	77/20/3	84/13/3	T-11-5	0.59	-	0.57	60/24/16	-	94/5/1
T-4-3	0.65	-	-	92/6/2	-	-	T-11-KN	-	0.88	0.37	-	98.5/0.5/1	95/5/0.3
T-4-KN	-	0.61	n.s.	-	35/17/48	n.s.							
							T-12-1	0.79	0.58	0.29	70/20/10	96/2/2	96/3/2
T-5-1	3.72	3.75	3.68	0/32/68	2/54/44	0.4/58/42	T-12-KN	-	0.71	n.s.	-	49/19/32	n.s.
T-5-2	2.55	2.62	2.36	36/39/25	27/58/15	37/51/13							
T-5-3	0.75	0.76	0.27	80/10/10	88/9/3	94/3/2	EZ-1 R1	2.87	2.78	2.65	1/29/70	3/42/55	2/42/56
T-5-4	0.54	0.35	<0.10	97/2/1	95/4/1	95/5/1	EZ-1 R2	-	-	2.85	-	-	1/40/59
T-5-5	0.2	0.36	-	99/0/1	97/2/1	-	EZ-1 R3	-	-	2.85	-	-	1/42/57
T-5-KN	-	0.47	0.18	-	38/44/18	84/8/8	EZ-2	3.02	3.25	2.93	3/30/67	2/39/59	5/43/51
							EZ-3	3.32	3.36	3.32	1/32/67	2/40/58	1/46/53
T-6-1	3.48	3.53	3.42	1/38/61	1/46/53	1/48/51							
T-6-2	3.74	3.81	3.47	0/38/62	0/51/49	3/57/40							
T-6-3	3.89	3.95	3.99	0/39/61	0/53/47	0.3/64/36							
T-6-4	0.57	-	-	88/9/3	-	-							

1 - See Figure 6.6-4 for site locations.

Table 6.6-3. Summary of suspended sediment introduction into Sturgeon Bay during 2011/2012 Operation and 2011/2012 Closure.

Suspended Sediment Contribution [1]	Units	2011/2012 Operation	2011/2012 Closure	Combined
Dauphin River Input including Reach 1 Operation	(m^3)	82,200	74,800	157,000
Dauphin River Input without Reach 1 Operation	(m^3)	73,300	72,600	145,900
Contribution Attributed to Reach 1 Operation	(m^3)	8,900	2,200	11,100
Percent increase in due to Reach 1 Operation	(%)	12.1	3.0	7.6

1 - Suspended sediment contributions based on empirical modeling results.

Figure 6.6-1. Shoreline of Sturgeon Bay in the vicinity of the Dauphin River, August 2011.

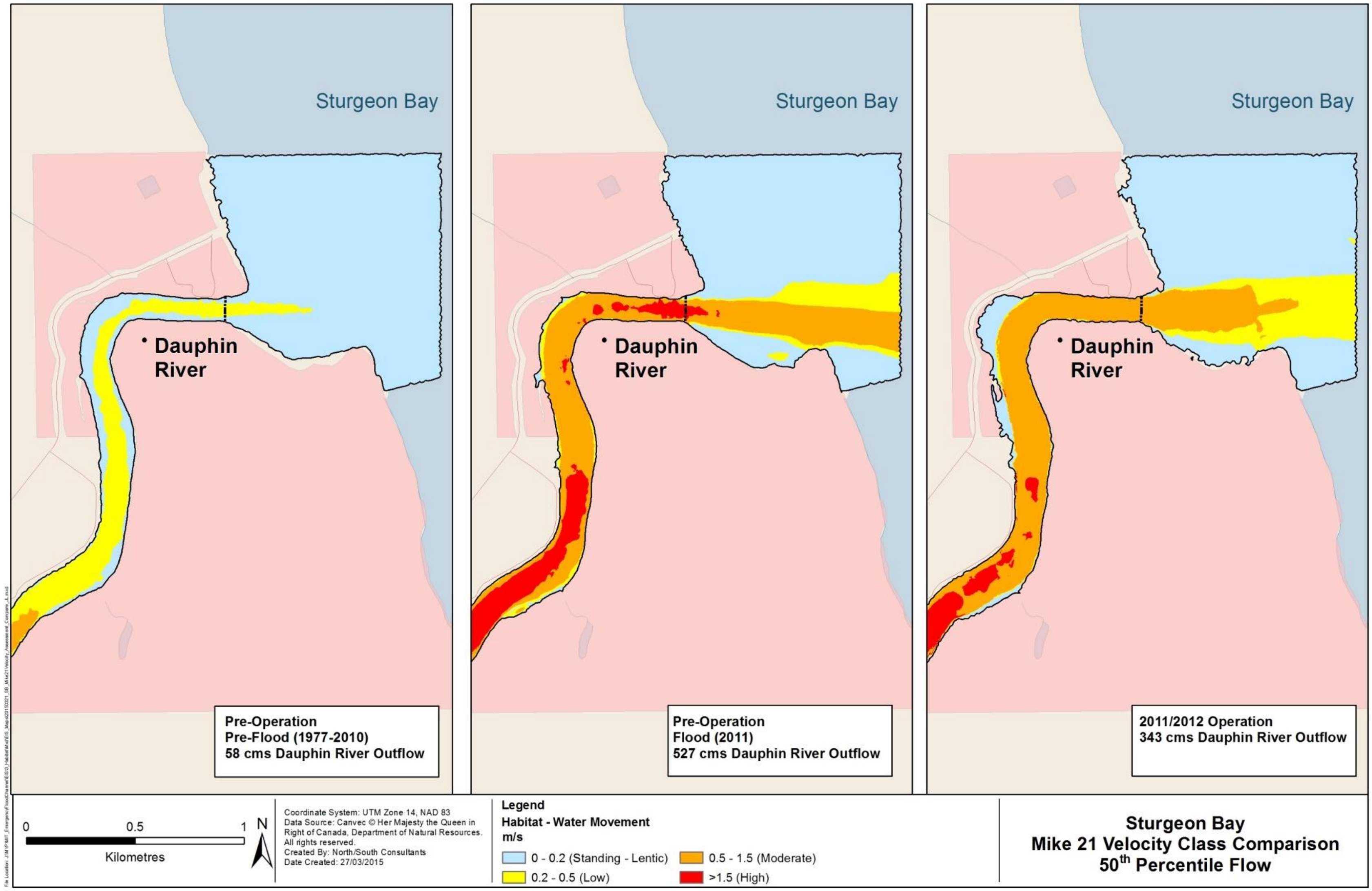


Figure 6.6-2. Comparison of 50th percentile Dauphin River outflow during the Pre-flood period, the 2011 Flood period, and 2011/2102 Operation.

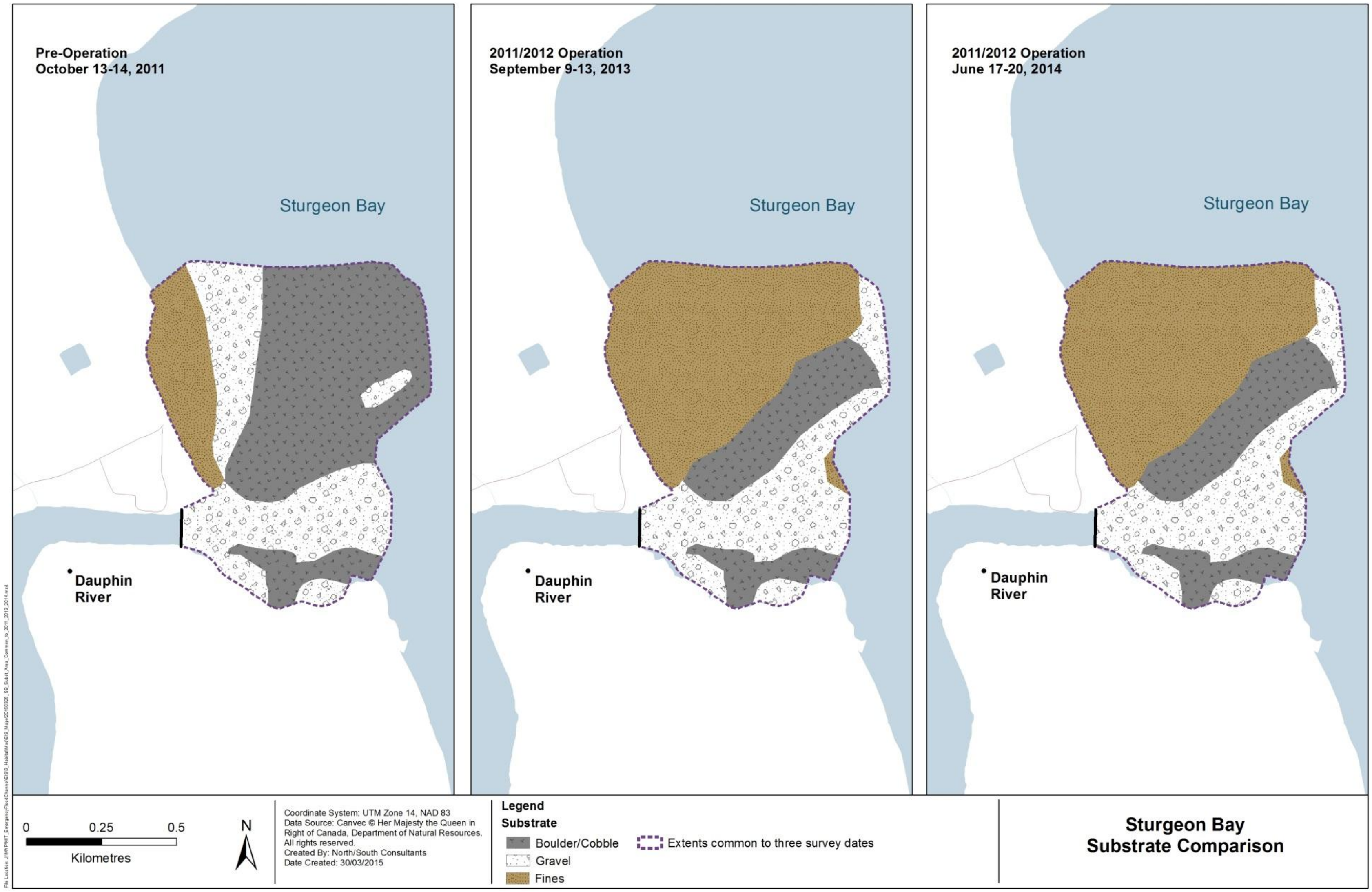


Figure 6.6-3. Comparison of Sturgeon Bay substrate near the Dauphin River outflow during Pre-Operation and Closure 2011/2012.

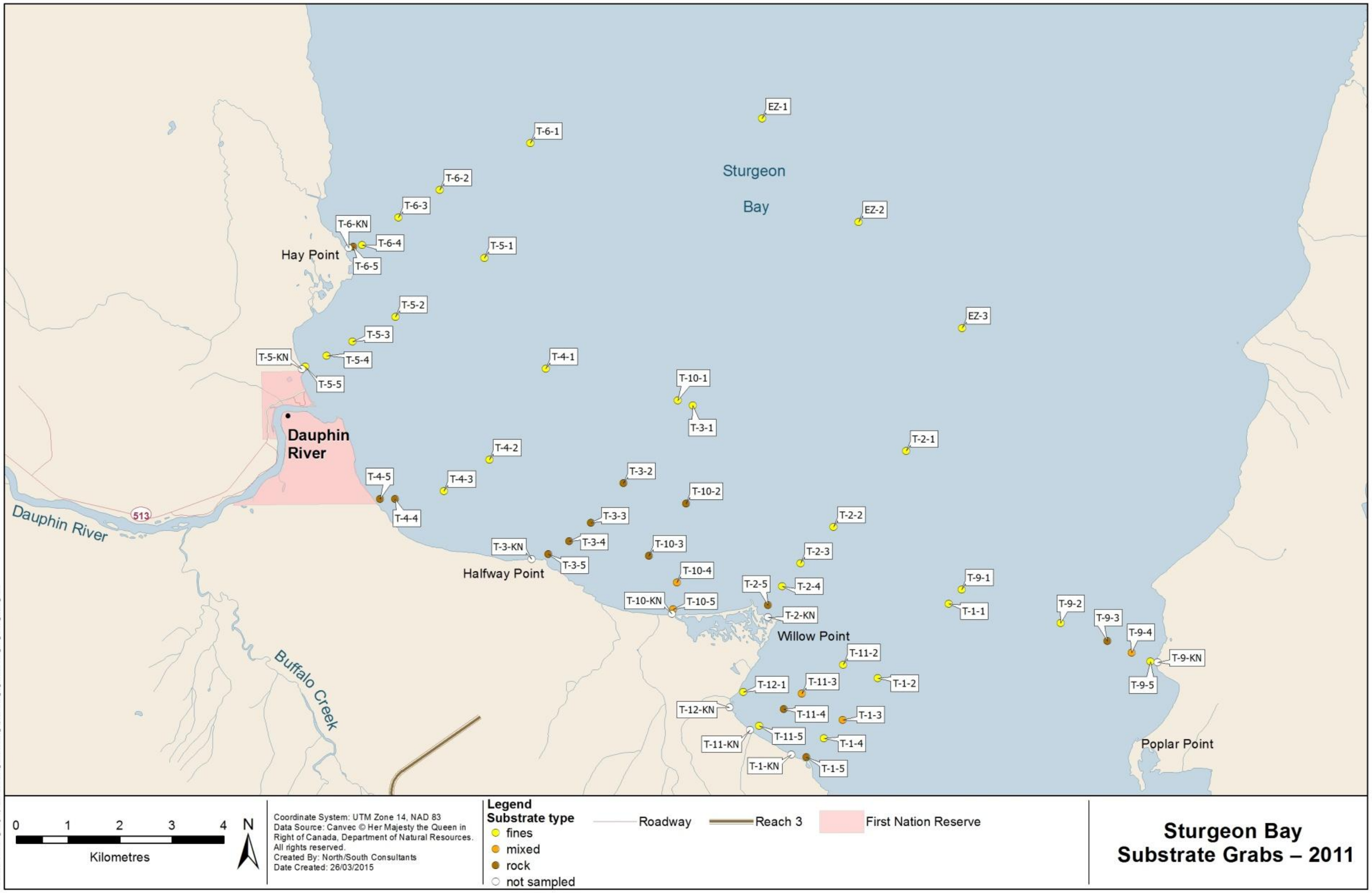


Figure 6.6-4. Substrate type classification from Ponar grab sampling conducted in Sturgeon Bay in fall 2011 (2011 Flood).

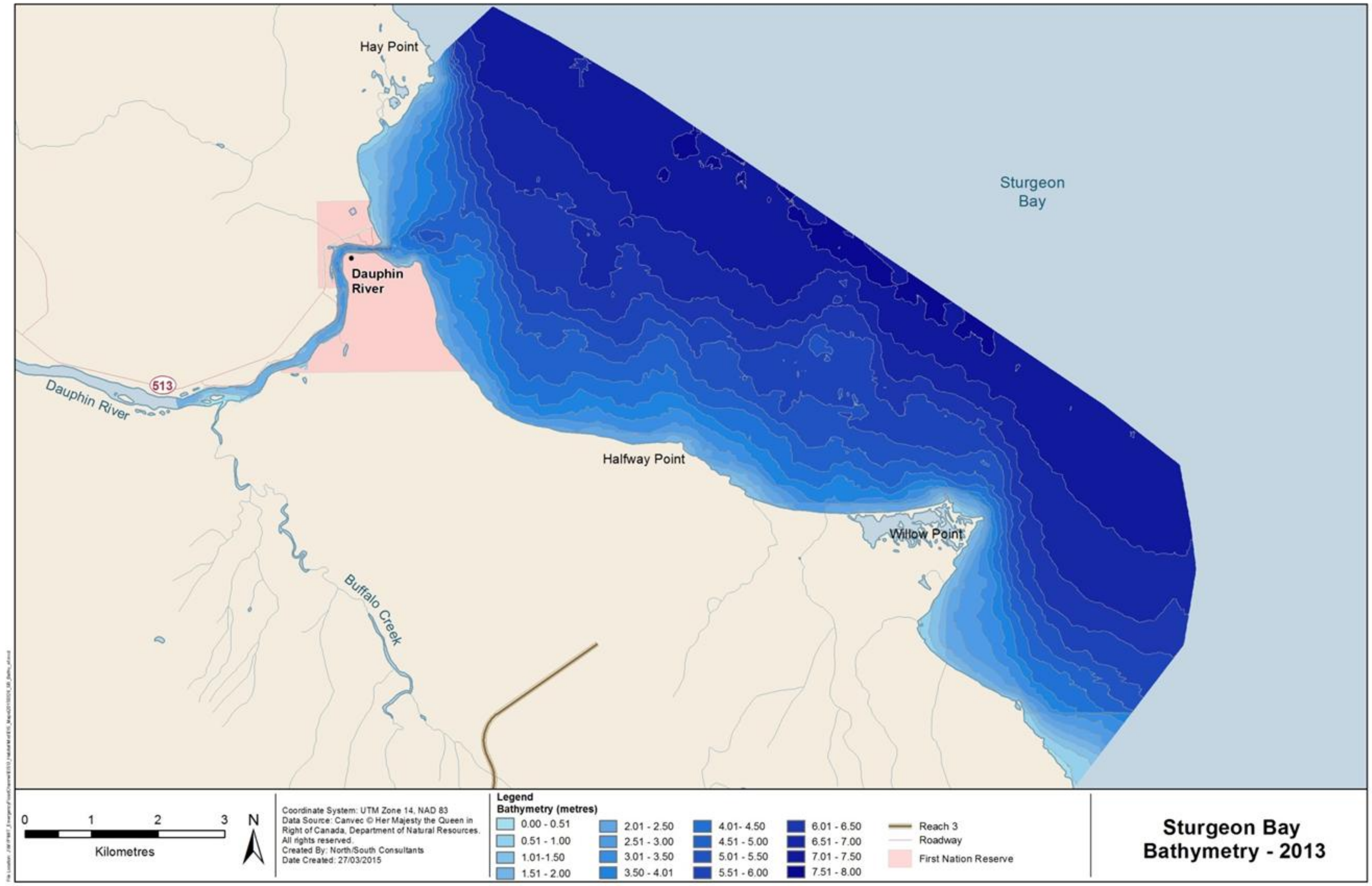


Figure 6.6-5. Results of the bathymetric survey conducted in Sturgeon Bay in fall 2013.

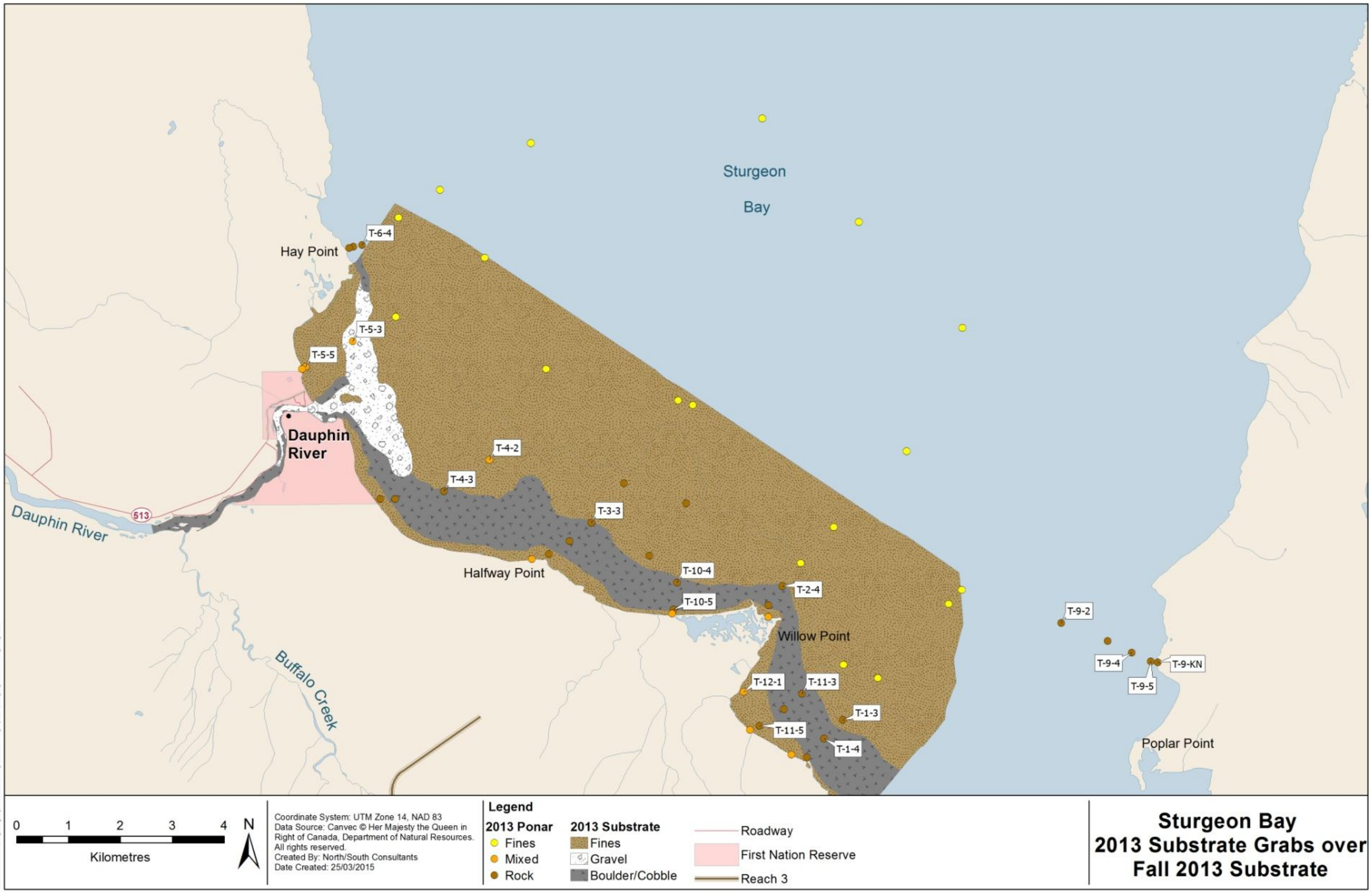


Figure 6.6-6. 2013 (2011/2012 Closure) Ponar grab sampling results superimposed on 2013 Sturgeon Bay substrate classification. Sites where Ponar grab results differ between years (2011, 2013, 2014) are marked with name labels.

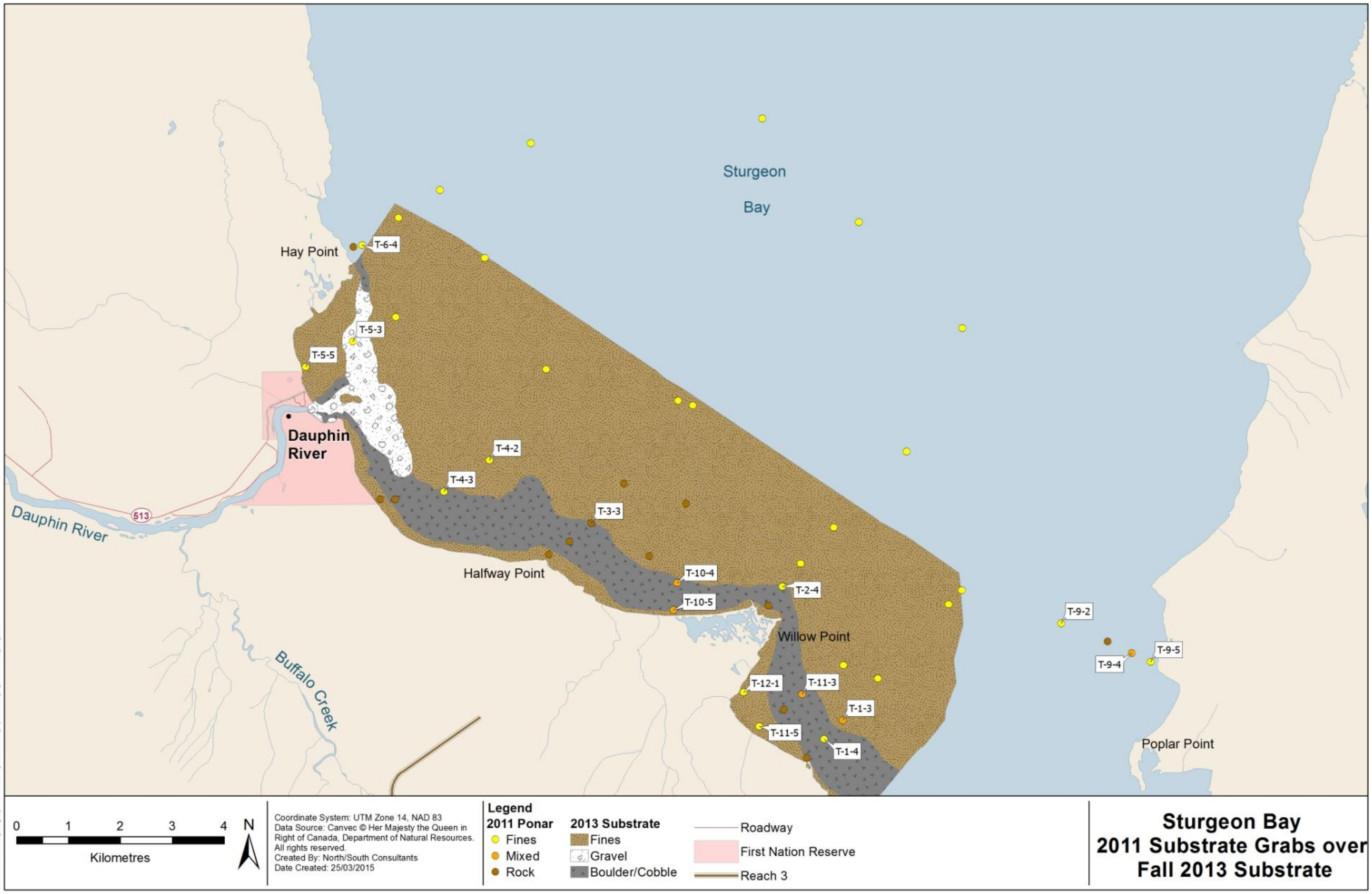


Figure 6.6-7. 2011 Flood Ponar grab sampling results superimposed on 2013 Sturgeon Bay substrate classification. Sites where Ponar grab results differ between years (2011, 2013, 2014) are marked with name labels.

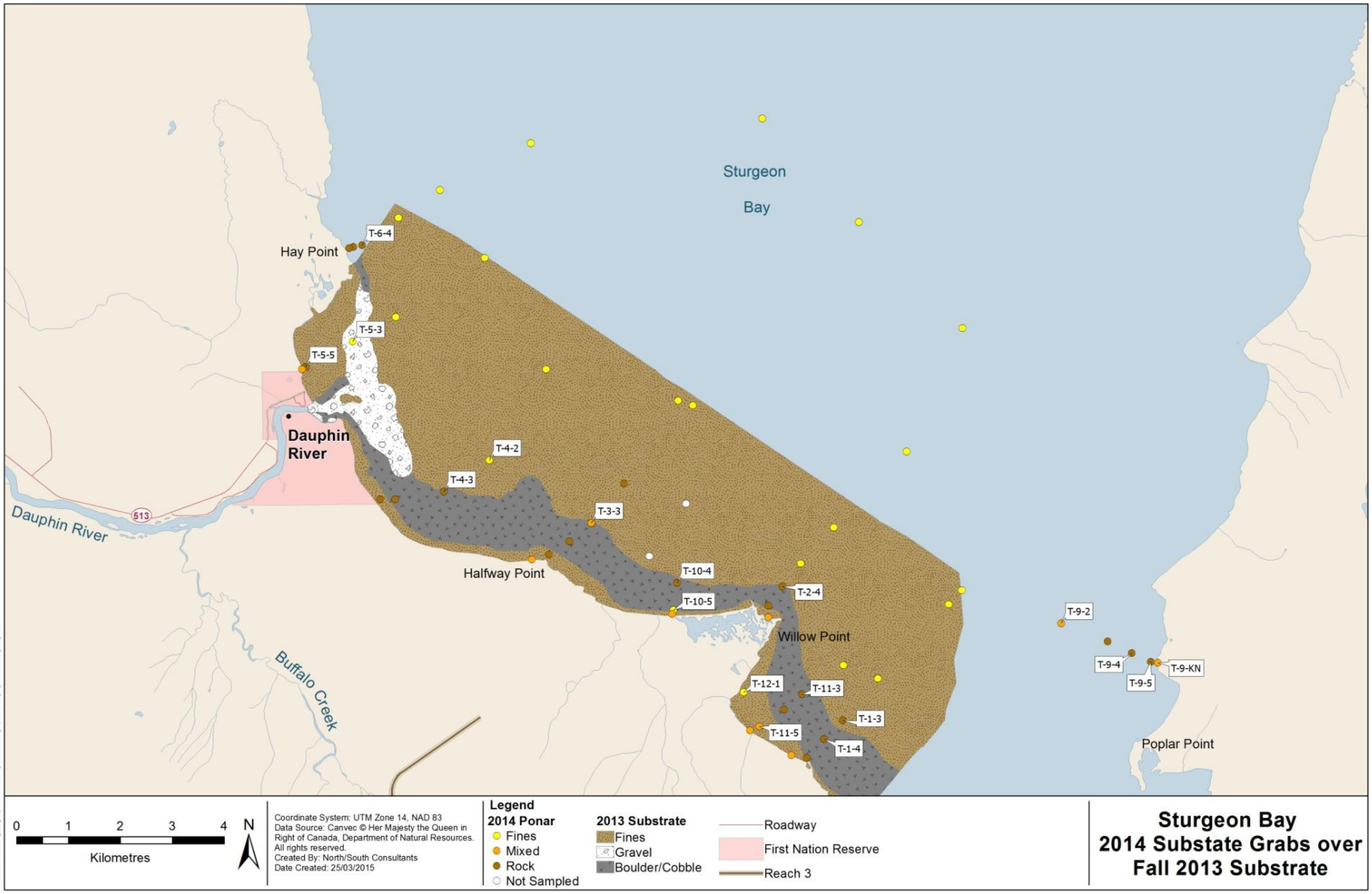
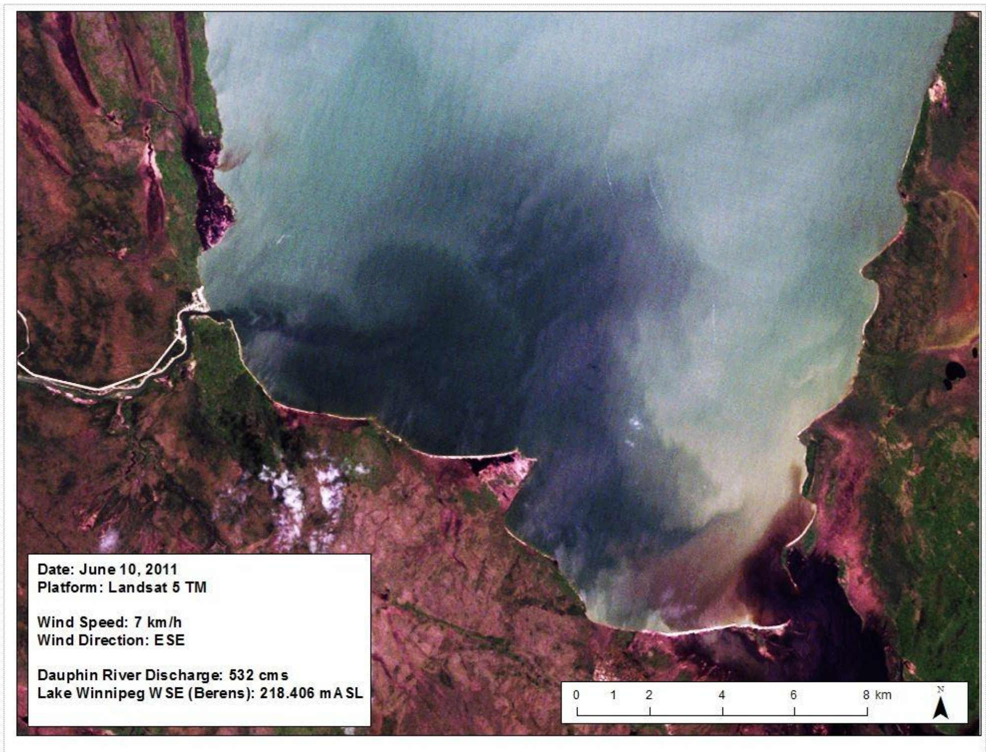


Figure 6.6-8. 2014 (2011/2012 Closure) Ponar grab sampling results superimposed on 2013 Sturgeon Bay substrate classification. Sites where Ponar grab results differ between years (2011, 2013, 2014) are marked with name labels.

A



B

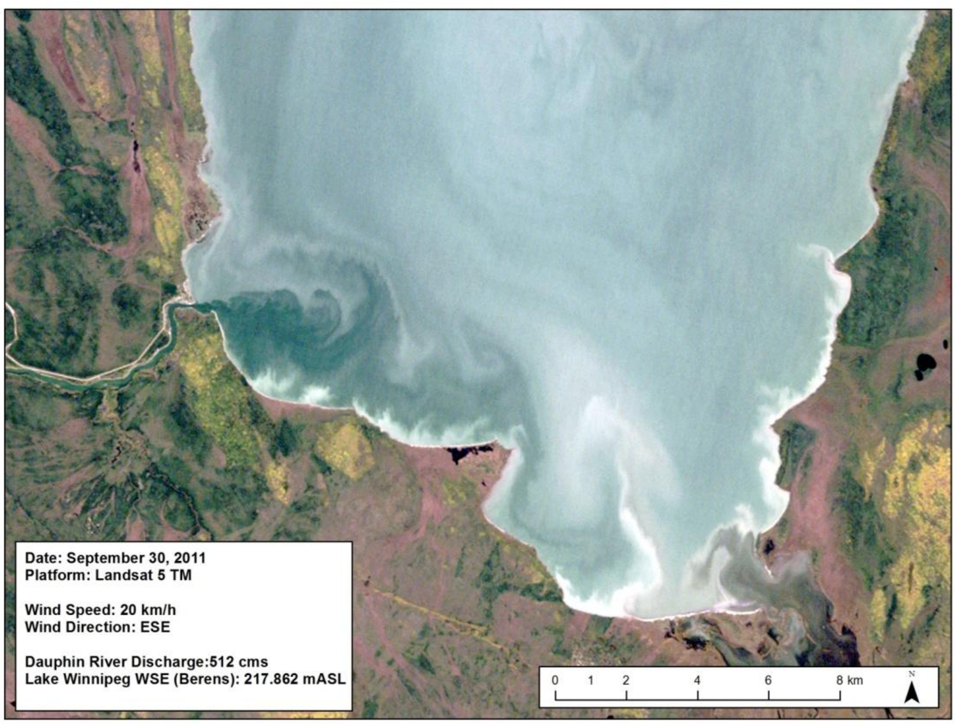
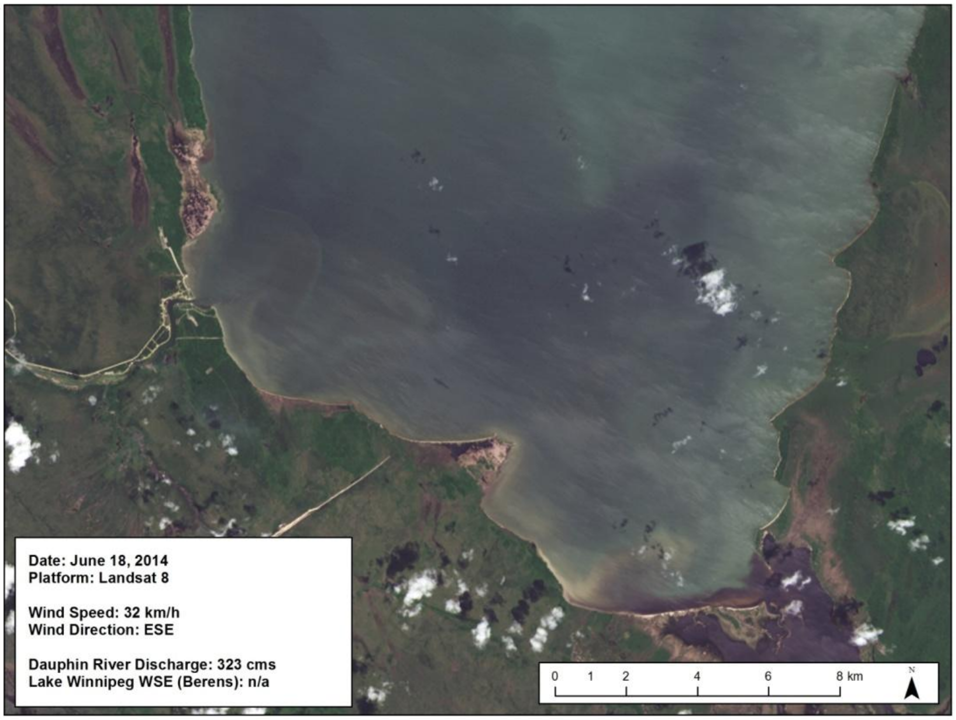


Figure 6.6-9. Satellite imagery of Sturgeon Bay under different wind conditions during the 2011 Flood period (A and B), 2011/2012 Closure (C), and 2014/2015 Operation (D).

C



D

Figure 6.6-9. Continued.

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Appendix 6A. Aquatic Habitat Assessment Analysis Results

Provided Within: Results of Aquatic Habitat Assessment Analysis

6A 1.1 MIKE 21 MODELING RESULTS

The tabular and graphical results of the MIKE 21 modeling data are presented below. Three water regime scenarios were provided: Pre-flood (1977 – 2010), 2011 Flood (based on data from 01 April to 01 November 2011), and 2011/2012 Operation, complete with simulated flows for low flow (5^{th} percentile flow,) median flow (50^{th} percentile flow), and high flow (95^{th} percentile flow). The Pre-flood and 2011 Flood periods are two separate components of the Pre-Operation phase of the Project. The AHSV presents tabular and graphical data that are derived from these data sets.

6A 1.1.1 Total Habitat Area

Tables 6A.1 – 6A.3 present total habitat areas under 5^{th}, 50^{th}, and 95^{th} percentile flow conditions for Buffalo Creek, Dauphin River, and Sturgeon Bay, respectively, for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation).

6A 1.1.2 Water Level Habitat Zones

Water level habitat zone areas for intermittently exposed habitats and predominantly wetted habitats for Buffalo Creek, the lower Dauphin River, and Sturgeon Bay for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation) are presented in Tables 6A-4 - 6A-6 and mapped in Figures 6A-1 - 6A-3.

6A 1.1.3 Water Depth and Water Velocity

Tables 6A-7 - 6A-9 present shallow and deep water depth zone areas for 5^{th}, 50^{th}, and 95^{th} percentile flow conditions in Buffalo Creek, Dauphin River, and Sturgeon Bay, respectively, for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation).

Tables 6A-10 – 6A-12 present water velocity habitat class areas for 5^{th}, 50^{th}, and 95^{th} percentile flow conditions in Buffalo Creek, the Lower Dauphin River, and Sturgeon Bay, respectively, for each of the Pre-Operation Pre-Flood (1977-2010), Pre-Operation Flood (2011), and 2011/2012 Operation project phases.

Table 6A-13 presents the mean and maximum depth statistics for 5^{th}, 50^{th}, and 95^{th} percentile flow conditions in Buffalo Creek, the Lower Dauphin River, and Sturgeon Bay, respectively, for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation).

Table 6A-14 presents the mean and maximum velocity statistics for 5^{th}, 50^{th}, and 95^{th} percentile flow conditions in Buffalo Creek, the Lower Dauphin River, and Sturgeon Bay, respectively, for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation).

Figures 6A-4 – 6A-12 present the water velocity classes and the shallow and deep water depth zone areas side by side for 5^{th}, 50^{th}, and 95^{th} percentile flow conditions in Buffalo Creek, Dauphin River, and Sturgeon Bay, respectively, for all three water regime scenarios (Pre-flood, 2011 Flood, and 2011/2012 Operation).

6A 1.2 HEC-RAS MODELING RESULTS

The tabular and graphical results of the HEC-RAS modeling data are presented below. The AHSV presents tabular and graphical data that are derived from these data sets.

6A 1.2.1 Reach 1 Total Habitat Areas

Table 6A-15 presents the total wetted habitat area under 5th, 50th, and 95th percentile flow conditions for Reach 1 during 2011/2012 Operation. Table 6A-16 presents total habitat area for Reach 1 for 2011/2012 Closure.

6A 1.2.2 Reach 1 Habitat Variables

Wetted channel width, mean cross section velocity and maximum channel depth for 5th, 50th, and 95th percentile flows during 2011/2012 Operation are presented in Table 6A-17. The habitat variable ranges are presented graphically in Figure 6A-13. Wetted channel width, mean cross section velocity and maximum channel depth for 2011/2012 Closure are presented in Table 6A-18.

6A 1.2.3 Buffalo Creek Total Habitat Areas

Table 6A-19 presents the total wetted habitat area under 5th, 50th, and 95th percentile flow conditions for Buffalo Creek and the 95th percentile flow condition for Big Buffalo Lake bog during 2011/2012 Operation.

The total wetted area for Buffalo Creek includes the modeled data output from both HEC-RAS and MIKE 21. The overlapped area was removed from the MIKE 21 data set to show a complete extent of the wetted area under all flow conditions. This was completed within the GIS by clipping and deleting the overlapping section of the HEC-RAS Lidar data, and then recalculating the area.

6A 1.2.4 Buffalo Creek Habitat Variables

Wetted channel width, mean cross section velocity, and maximum channel depth for 5th, 50th, and 95th percentile flows for 2011 Flood, 2011/2012 Operation, and 2011/2012 Closure are presented in Tables 6A-20 - 6A-22, respectively. The habitat variable ranges are presented graphically in Figures 6A-14 - 6A-22.

Table 6A-1. Total habitat areas for the lower ~300 m of Buffalo Creek under 5th, 50th, and 95th percentile flow conditions during Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh.

Flow Percentile	Pre-Operation				2011/2012 Operation	
	Pre-flood		2011 Flood			
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
5th	5665	0.6	5609	0.6	13660	1.4
50th	5666	0.6	5952	0.6	25434	2.5
95th	5677	0.6	6283	0.6	25921	2.6

Table 6A-2. Total habitat areas for the Lower Dauphin River under 5th, 50th, and 95th percentile flow conditions during Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh.

Flow Percentile	Pre-Operation				2011/2012 Operation	
	Pre-flood		2011 Flood			
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
5th	499266	49.9	673766	67.4	645970	64.6
50th	610657	61.1	701336	70.1	754900	75.5
95th	647043	64.7	709347	70.9	764675	76.5

Table 6A-3. Total habitat areas for the area of Sturgeon Bay near the mouth of the Dauphin River under 5th, 50th, and 95th percentile flow conditions during Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh. (Note: These areas do not take into account water level fluctuations on Lake Winnipeg).

Flow Percentile	Pre-Operation				2011/2012 Operation	
	Pre-flood		2011 Flood			
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
5th	918607	91.9	963492	96.3	932676	93.3
50th	919059	91.9	963493	96.3	937850	93.8
95th	921709	92.2	963493	96.3	953182	95.3

Table 6A-4. Water level habitat zone areas for the lower ~300 m of Buffalo Creek during Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Habitat Zone	Pre-Operation				2011/2012 Operation	
	Pre-flood		2011 Flood			
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
Intermittently Exposed	12	0.0	674	0.1	12262	1.2
Predominantly Wetted	5665	0.6	5609	0.6	13660	1.4
Total	5677	0.6	6283	0.6	25921	2.6

Table 6A-5. Water level habitat zone areas for the Lower Dauphin River for Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Habitat Zone	Pre-Operation				2011/2012 Operation	
	Pre-flood		2011 Flood			
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
Intermittently Exposed	147777	14.8	35582	3.6	118705	11.9
Predominantly Wetted	499266	49.9	673766	67.4	645970	64.6
Total	647043	64.7	709347	70.9	764675	76.5

Table 6A-6. Water level habitat zone areas for Sturgeon Bay for Pre-Operation and 2011/2012 Operation. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Habitat	Pre-Operation				Operation	
	Pre-flood		2011 Flood		Operation I	
	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
Intermittently Exposed	3102	0.3	0	0.0	20506	2.1
Predominantly Wetted	918607	91.9	963492	96.3	932676	93.3
Total	921709	92.2	963493	96.3	953182	95.3

Table 6A-7. Depth zone habitat areas for the lower ~300 m of Buffalo Creek during the Pre-Operation and 2011/2012 Operation periods at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Depth Habitat Class (m)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	Deep (> 2 m)	0	0.0	0	0.0	0	0.0
	Shallow (< 2 m)	5598	0.6	5562	0.6	13680	1.4
50th	Deep (> 2 m)	0	0.0	0	0.0	0	0.0
	Shallow (< 2 m)	5625	0.6	5922	0.6	25416	2.5
95th	Deep (> 2 m)	0	0.0	0	0.0	9	0.0
	Shallow (< 2 m)	5634	0.6	6273	0.6	25929	2.6

Table 6A-8. Depth zone habitat areas for the Lower Dauphin River during Pre-Operation and 2011/2012 Operation at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Depth Habitat Class (m)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	Deep (> 2 m)	239841	24.0	239886	24.0	163485	16.3
	Shallow (< 2 m)	259551	26.0	434205	43.4	482544	48.3
50th	Deep (> 2 m)	136755	13.7	316035	31.6	173088	17.3
	Shallow (< 2 m)	473877	47.4	385587	38.6	581139	58.1
95th	Deep (> 2 m)	151605	15.2	348030	34.8	254583	25.5
	Shallow (< 2 m)	495468	49.5	361584	36.2	509697	51.0

Table 6A-9. Depth zone habitat areas for Sturgeon Bay during Pre-Operation and 2011/2012 Operation at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Depth Habitat Class (m)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	Deep (> 2 m)	767889	76.8	767889	76.8	664011	66.4
	Shallow (< 2 m)	150678	15.1	195417	19.5	268704	26.9
50th	Deep (> 2 m)	629325	62.9	769914	77.0	637740	63.8
	Shallow (< 2 m)	289656	29.0	193392	19.3	299718	30.0
95th	Deep (> 2 m)	629280	62.9	766521	76.7	677853	67.8
	Shallow (< 2 m)	292392	29.2	196785	19.7	275013	27.5

Table 6A-10. Velocity class habitat areas for the lower ~300 m of Buffalo Creek during Pre-Operation and 2011/2012 Operation at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Velocity Habitat Class (m/s)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	0 - 0.2 (Standing - Lentic)	2574	0.3	2457	0.2	972	0.1
	0.2 - 0.5 (Low)	2268	0.2	2340	0.2	594	0.1
	0.5 - 1.5 (Moderate)	828	0.1	756	0.1	6903	0.7
	>1.5 (High)	0	0.0	9	0.0	5031	0.5
50th	0 - 0.2 (Standing - Lentic)	2556	0.3	2700	0.3	8424	0.8
	0.2 - 0.5 (Low)	2340	0.2	2583	0.3	369	0.0
	0.5 - 1.5 (Moderate)	729	0.1	639	0.1	2295	0.2
	>1.5 (High)	0	0.0	0	0.0	14319	1.4
95th	0 - 0.2 (Standing - Lentic)	2574	0.3	2853	0.3	6570	0.7
	0.2 - 0.5 (Low)	2340	0.2	2925	0.3	1179	0.1
	0.5 - 1.5 (Moderate)	711	0.1	495	0.0	2844	0.3
	>1.5 (High)	9	0.0	0	0.0	15345	1.5

Table 6A-11. Velocity class habitat areas for the Lower Dauphin River during the Pre-Operation and 2011/2012 Operation periods at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Velocity Habitat Class (m/s)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	0 - 0.2 (Standing - Lentic)	417879	41.8	23229	2.3	26082	2.6
	0.2 - 0.5 (Low)	49689	5.0	54054	5.4	73287	7.3
	0.5 - 1.5 (Moderate)	30105	3.0	404802	40.5	439551	44.0
	>1.5 (High)	153	0.0	192006	19.2	105120	10.5
50th	0 - 0.2 (Standing - Lentic)	133263	13.3	18261	1.8	76023	7.6
	0.2 - 0.5 (Low)	243558	24.4	29448	2.9	18459	1.8
	0.5 - 1.5 (Moderate)	222309	22.2	259146	25.9	416169	41.6
	>1.5 (High)	11502	1.2	394785	39.5	243954	24.4
95th	0 - 0.2 (Standing - Lentic)	19854	2.0	18675	1.9	64926	6.5
	0.2 - 0.5 (Low)	52434	5.2	27999	2.8	12267	1.2
	0.5 - 1.5 (Moderate)	416673	41.7	204795	20.5	248841	24.9
	>1.5 (High)	158103	15.8	458145	45.8	438516	43.9

Table 6A-12. Velocity class habitat areas for Sturgeon Bay during Pre-Operation and 2011/2012 Operation at a 5th, 50th, and 95th percentile flows. Areas are derived from the spatial analysis of the MIKE 21 hydraulic model computational mesh outputs.

Flow Percentile	Velocity Habitat Class (m/s)	Pre-Operation				2011/2012 Operation	
		Pre-flood		2011 Flood			
		Area (m^2)	Area (ha)	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
05th	0 - 0.2 (Standing - Lentic)	918468	91.8	805554	80.6	793170	79.3
	0.2 - 0.5 (Low)	0	0.0	80703	8.1	98847	9.9
	0.5 - 1.5 (Moderate)	0	0.0	77049	7.7	36252	3.6
	>1.5 (High)	0	0.0	0	0.0	0	0.0
50th	0 - 0.2 (Standing - Lentic)	901143	90.1	507555	50.8	676233	67.6
	0.2 - 0.5 (Low)	17838	1.8	271899	27.2	156312	15.6
	0.5 - 1.5 (Moderate)	0	0.0	179460	17.9	105237	10.5
	>1.5 (High)	0	0.0	4392	0.4	0	0.0
95th	0 - 0.2 (Standing - Lentic)	779031	77.9	742023	74.2	666972	66.7
	0.2 - 0.5 (Low)	85410	8.5	68652	6.9	93582	9.4
	0.5 - 1.5 (Moderate)	57231	5.7	138645	13.9	189423	18.9
	>1.5 (High)	0	0.0	13986	1.4	3231	0.3

Table 6A-13. Mean and maximum depth statistics for the lower ~300 m of Buffalo Creek, the Lower Dauphin River and the immediate area of Sturgeon Bay resulting from the analysis of MIKE 21 hydraulic model derived depth rasters.

Reach	Water Regime	Percentile	Maximum Depth (m)	Mean Depth (m)
Buffalo Creek	Pre-Operation Pre-flood	5th	0.5	0.2
		50th	0.4	0.2
		95th	0.4	0.2
	Pre-Operation 2011 Flood	5th	0.5	0.2
		50th	0.9	0.2
		95th	1.0	0.2
	2011/2012 Operation	5th	1.3	0.7
		50th	1.8	0.6
		95th	2.0	0.7
Dauphin River	Pre-Operation Pre-flood	5th	4.9	2.2
		50th	4.2	1.2
		95th	4.2	1.4
	Pre-Operation 2011 Flood	5th	4.9	1.8
		50th	4.9	2.0
		95th	4.9	2.1
	2011/2012 Operation	5th	4.3	1.4
		50th	4.5	1.4
		95th	4.5	1.7
Sturgeon Bay	Pre-Operation Pre-flood	5th	4.9	3.2
		50th	4.2	2.5
		95th	4.2	2.5
	Pre-Operation 2011 Flood	5th	4.9	3.0
		50th	4.9	3.0
		95th	4.8	3.0
	2011/2012 Operation	5th	4.3	2.5
		50th	4.2	2.4
		95th	4.3	2.5

Table 6A-14. Mean and maximum velocity statistics for the lower ~300 m of Buffalo Creek, the Lower Dauphin River and the immediate area of Sturgeon Bay resulting from the analysis of MIKE 21 hydraulic model derived velocity rasters.

Reach	Water Regime	Percentile	Maximum Velocity (m/s)	Mean Velocity (m/s)
Buffalo Creek	Pre-Operation Pre-flood	5th	1.5	0.3
		50th	1.5	0.3
		95th	1.5	0.3
	Pre-Operation 2011 Flood	5th	1.5	0.3
		50th	1.2	0.3
		95th	1.2	0.2
	2011/2012 Operation	5th	4.5	1.5
		50th	7.6	1.6
		95th	5.1	1.7
Dauphin River	Pre-Operation Pre-flood	5th	1.6	0.1
		50th	2.7	0.5
		95th	3.0	1.1
	Pre-Operation 2011 Flood	5th	2.8	1.2
		50th	4.4	1.6
		95th	4.4	1.7
	2011/2012 Operation	5th	4.9	1.0
		50th	3.8	1.2
		95th	5.7	1.5
Sturgeon Bay	Pre-Operation Pre-flood	5th	0.1	0.0
		50th	0.3	0.0
		95th	1.0	0.1
	Pre-Operation 2011 Flood	5th	0.9	0.1
		50th	1.8	0.3
		95th	2.1	0.3
	2011/2012 Operation	5th	0.8	0.1
		50th	1.2	0.2
		95th	1.8	0.2

Table 6A-15. Total wetted habitat areas of Reach 1 under 5th, 50th, and 95th percentile flows during 2011/2012 Operation.

Period	Flow Percentile	Total Wetted Area (m^2)	Total Wetted Area (ha)
2011/2012 Operation	5^{th}	336877	33.7
	50^{th}	354824	35.5
	95^{th}	374299	37.4

Table 6A-16. Total wetted habitat area of Reach 1 during 2011/2012 Closure.

Period	Flow Percentile	Total Wetted Area (m^2)	Total Wetted Area (ha)
2011/2012 Closure	n/a	305416	30.5

Table 6A-17. Reach 1 modeled HEC-RAS cross-section habitat variables for 5th, 50th, and 95th percentile flows during 2011/2012 Operation.

	5% Q = 44 m^3/s				50% Q = 125 m^3/s				95% Q = 196 m^3/s			
Cross Section Station	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Max Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Max Depth (m/s)
625	242.79	57.43	0.57	1.69	243.56	63.90	1.00	2.46	244.14	68.67	1.21	3.04
1000	242.75	57.94	0.54	1.75	243.48	64.06	0.99	2.48	244.04	68.74	1.20	3.04
1300	242.73	68.27	0.44	1.68	243.44	72.74	0.83	2.39	243.99	86.04	1.02	2.94
2000	242.67	55.74	0.53	1.82	243.29	59.93	1.05	2.44	243.79	63.32	1.30	2.94
3000	242.60	58.10	0.47	1.90	243.06	61.79	1.04	2.36	243.49	65.25	1.33	2.79
4000	242.55	62.06	0.42	2.05	242.82	64.65	1.02	2.32	243.15	67.67	1.36	2.64
5000	242.52	63.87	0.35	2.36	242.62	64.73	0.96	2.47	242.77	66.03	1.40	2.62
6000	242.50	109.65	0.27	2.80	242.50	109.65	0.77	2.80	242.50	109.65	1.22	2.80

Table 6A-18. Reach 1 modeled HEC-RAS cross section habitat variables during 2011/2012 Closure.

Cross Section Station	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)
625	241.61	47.6	0.0	0.5
1000	241.61	48.4	0.0	0.6
1300	241.61	61.2	0.0	0.6
2000	241.61	48.5	0.0	0.8
3000	241.61	50.1	0.0	0.9
4000	241.61	53.2	0.0	1.1
5000	241.61	56.1	0.0	1.5
6000	241.61	90.7	0.0	1.9

Table 6A-19. Total wetted habitat areas of Buffalo Creek under 5th, 50th, and 95th percentile flows and Big Buffalo Lake bog under 95th percentile flows during 2011/2012 Operation.

	Buffalo Creek		Big Buffalo Lake Bog	
Flow Percentile	Area (m^2)	Area (ha)	Area (m^2)	Area (ha)
5th	567077	56.7	-	-
50th	1285961	128.6	-	-
95th	2022011	202.2	17720084	1772.0

Table 6A-20. Buffalo Creek modeled HEC-RAS cross-section habitat variables for 5th, 50th, and 95th percentile flows during 2011 Flood.

Cross Section Station	5% Q = 0.5 cms				50% Q = 3.9 cms				95% Q = 6.9 cms			
	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)
13474	237.20	6.92	0.31	0.33	237.71	9.76	0.68	0.84	237.99	32.24	0.70	1.12
13984	236.87	6.57	0.48	0.23	237.25	10.39	0.93	0.61	237.43	12.14	1.10	0.79
14457	235.94	5.21	0.46	0.30	236.42	11.63	0.79	0.78	236.61	13.53	0.92	0.98
14958	235.24	4.92	0.55	0.24	235.67	9.97	0.99	0.67	235.88	18.23	0.99	0.88
15468	234.20	10.67	0.28	0.21	234.58	11.77	0.66	0.60	234.79	13.83	0.80	0.80
15984	233.71	8.22	0.33	0.32	234.15	11.61	0.68	0.76	234.38	22.45	0.73	0.98
16476	233.20	7.47	0.46	0.25	233.51	8.06	1.14	0.57	233.67	8.35	1.46	0.72
16996	232.05	7.57	0.47	0.22	232.40	8.81	1.03	0.56	232.68	23.13	0.95	0.85
17488	231.04	8.63	0.37	0.26	231.40	14.11	0.70	0.62	231.57	15.12	0.83	0.80
18005	230.44	6.91	0.43	0.23	230.81	10.57	0.87	0.60	231.00	11.46	1.05	0.79
18505	229.72	7.46	0.47	0.22	230.04	12.88	0.90	0.53	230.18	14.23	1.09	0.68
19023	228.62	9.87	0.39	0.22	228.94	15.54	0.70	0.55	229.10	17.36	0.84	0.71
19562	227.72	8.69	0.35	0.20	228.07	15.45	0.68	0.55	228.23	16.68	0.82	0.71
20127	227.16	12.90	0.31	0.22	227.45	18.32	0.63	0.52	227.61	23.54	0.73	0.68
20590	226.61	9.67	0.30	0.28	226.98	23.68	0.48	0.66	227.18	25.54	0.53	0.85
21084	226.26	7.65	0.34	0.24	226.69	10.44	0.73	0.67	226.91	11.65	0.88	0.90
21560	225.91	10.06	0.29	0.22	226.38	13.30	0.53	0.69	226.62	13.91	0.65	0.93
22048	225.62	5.68	0.38	0.31	226.09	10.73	0.73	0.78	226.29	11.38	0.91	0.98
22642	225.15	7.96	0.39	0.25	225.51	12.35	0.80	0.61	225.66	14.00	0.99	0.76
23073	224.46	7.60	0.43	0.23	224.82	13.17	0.77	0.59	224.99	16.12	0.91	0.76
23666	223.55	12.05	0.18	0.30	223.99	15.74	0.45	0.75	224.20	18.68	0.56	0.95
24203	223.37	10.23	0.38	0.19	223.69	14.52	0.74	0.51	223.85	16.08	0.88	0.67
24677	222.60	7.52	0.34	0.23	223.01	9.50	0.81	0.64	223.21	11.08	0.99	0.84
25209	222.07	7.92	0.39	0.27	222.45	13.20	0.71	0.64	222.64	14.38	0.84	0.84
25683	221.47	6.01	0.51	0.22	221.85	10.14	0.98	0.59	222.03	24.91	1.01	0.77
26281	220.39	8.98	0.20	0.43	220.87	13.30	0.52	0.90	221.07	14.72	0.66	1.10
26743	220.29	13.58	0.27	0.27	220.68	16.75	0.52	0.65	220.84	18.10	0.66	0.81
27254	219.97	8.25	0.32	0.30	220.36	21.05	0.55	0.69	220.53	25.34	0.62	0.86
27802	219.49	7.22	0.33	0.23	219.91	9.61	0.80	0.65	220.11	11.21	0.98	0.85
28282	219.03	9.70	0.36	0.25	219.36	12.59	0.76	0.59	219.54	13.64	0.92	0.76

Table 6A-21. Buffalo Creek modeled HEC-RAS cross-section habitat variables for 5th, 50th, and 95th percentile flows during 2011/2012 Operation.

Cross Section Station	5% Q = 44 cms				50% Q = 125 cms				95% Q = 196 cms			
	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)
13474	238.80	60.29	0.82	2.05	240.06	136.82	0.64	3.31	240.81	136.82	0.66	4.07
13984	238.25	32.47	1.23	1.89	239.33	39.20	1.68	2.96	240.01	46.24	1.91	3.65
14457	237.60	35.14	1.31	2.06	238.65	42.82	1.65	3.11	239.35	45.65	1.84	3.81
14958	236.55	27.88	1.43	1.75	237.60	52.83	1.70	2.80	238.28	63.85	1.71	3.48
15468	235.66	31.53	1.08	2.06	236.79	38.36	1.56	3.19	237.50	40.97	1.81	3.90
15984	235.06	41.96	1.08	1.74	236.13	54.75	1.34	2.80	236.78	59.38	1.50	3.45
16476	234.15	32.74	1.57	1.66	235.06	85.13	1.54	2.58	235.70	94.50	1.40	3.21
16996	233.09	47.73	0.77	2.06	234.26	57.98	1.05	3.23	234.97	61.09	1.21	3.94
17488	232.72	47.89	0.92	2.19	233.77	93.17	1.02	3.24	234.42	116.60	1.01	3.90
18005	232.11	53.79	1.13	2.13	233.01	64.23	1.35	3.03	233.59	94.80	1.48	3.60
18505	230.88	34.70	1.46	1.61	231.82	88.51	1.41	2.55	232.41	138.79	1.28	3.15
19023	229.89	61.34	1.10	2.01	230.93	91.44	0.98	3.05	231.50	179.80	0.97	3.61
19562	229.21	42.36	1.16	1.75	230.32	198.70	0.73	2.86	230.95	198.79	0.66	3.49
20127	228.73	74.05	0.74	2.34	229.95	204.85	0.59	3.56	230.62	204.85	0.56	4.23
20590	228.54	73.36	0.57	2.61	229.76	205.60	0.50	3.83	230.44	205.60	0.50	4.50
21084	228.24	77.59	0.78	2.32	229.47	150.82	0.63	3.55	230.15	197.66	0.61	4.24
21560	227.88	54.60	0.73	2.66	229.12	150.62	0.72	3.90	229.82	174.20	0.67	4.60
22048	227.39	32.21	1.31	2.10	228.51	96.29	1.26	3.21	229.18	152.06	1.09	3.88
22642	226.61	47.79	0.84	1.72	227.71	79.69	1.04	2.83	228.39	127.59	1.04	3.51
23073	226.02	56.69	0.83	1.97	227.24	129.37	0.75	3.18	227.96	182.80	0.69	3.90
23666	225.48	78.52	0.68	2.51	226.76	128.86	0.66	3.78	227.50	191.71	0.62	4.52
24203	224.91	42.08	1.16	1.84	226.01	51.34	1.41	2.94	226.64	60.51	1.56	3.58
24677	224.27	36.80	1.08	2.23	225.33	84.51	1.21	3.29	225.98	113.19	1.18	3.93
25209	223.76	90.72	0.78	2.40	224.78	108.98	0.77	3.42	225.46	112.20	0.83	4.10
25683	223.16	98.06	0.61	2.15	224.29	107.74	0.66	3.29	225.01	108.90	0.73	4.01
26281	222.13	70.41	0.94	2.56	223.47	81.63	0.82	3.89	224.32	142.33	0.69	4.75
26743	221.82	32.81	1.03	2.26	223.14	73.75	1.01	3.57	223.99	82.92	1.03	4.42
27254	221.50	57.64	0.80	2.02	222.90	75.30	0.87	3.43	223.77	130.91	0.85	4.30
27802	221.00	28.92	1.38	2.33	222.35	63.26	1.27	3.68	223.20	79.96	1.22	4.52
28282	220.39	29.25	1.24	1.97	221.66	64.14	1.34	3.24	222.44	87.45	1.32	4.03

Table 6A-22. Buffalo Creek modeled HEC-RAS cross-section habitat variables for 5th, 50th, and 95th percentile flows during 2011/2012 Closure.

Cross Section Station	5% Q = 0.5 cms				50% Q = 3.9 cms				95% Q = 6.9 cms			
	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)	Water Surface Elevation (m ASL)	Wetted Width (m)	Mean Velocity (m/s)	Maximum Depth (m)
13474	237.07	8.82	0.27	0.32	237.57	19.76	0.47	0.82	237.73	24.69	0.57	0.98
13984	236.63	7.73	0.34	0.27	237.06	20.41	0.55	0.70	237.24	21.27	0.62	0.88
14457	235.85	7.22	0.34	0.31	236.31	13.11	0.64	0.78	236.52	16.83	0.74	0.98
14958	235.13	9.08	0.34	0.33	235.52	16.70	0.64	0.71	235.66	18.43	0.79	0.86
15468	234.02	10.40	0.22	0.41	234.43	20.10	0.45	0.83	234.60	21.49	0.55	1.00
15984	233.63	17.43	0.25	0.30	233.93	20.27	0.51	0.61	234.09	21.64	0.62	0.77
16476	232.76	9.47	0.38	0.27	233.07	16.97	0.70	0.58	233.21	17.55	0.86	0.72
16996	231.38	6.73	0.33	0.35	231.82	27.03	0.46	0.79	231.97	32.24	0.52	0.94
17488	230.86	10.91	0.23	0.34	231.35	17.97	0.43	0.82	231.57	19.49	0.52	1.05
18005	230.35	6.50	0.36	0.37	230.82	11.13	0.68	0.83	231.04	13.35	0.81	1.06
18505	229.53	8.14	0.40	0.26	229.86	17.71	0.68	0.59	230.01	19.27	0.81	0.73
19023	228.19	9.78	0.23	0.30	228.61	16.64	0.49	0.73	228.80	17.69	0.62	0.91
19562	227.75	12.98	0.30	0.29	228.05	20.88	0.55	0.59	228.19	21.55	0.67	0.73
20127	226.76	4.79	0.37	0.37	227.38	23.25	0.51	0.99	227.55	26.51	0.57	1.16
20590	226.45	8.45	0.20	0.52	227.00	23.01	0.31	1.07	227.24	24.43	0.38	1.30
21084	226.19	8.02	0.30	0.27	226.68	11.95	0.59	0.76	226.92	12.45	0.72	1.00
21560	225.80	11.83	0.19	0.59	226.32	19.00	0.38	1.10	226.55	19.85	0.46	1.33
22048	225.61	10.33	0.23	0.31	226.05	13.85	0.54	0.75	226.26	15.45	0.66	0.96
22642	225.17	14.43	0.27	0.29	225.49	22.83	0.50	0.60	225.65	29.79	0.57	0.77
23073	224.36	9.04	0.34	0.31	224.69	15.70	0.64	0.63	224.87	17.31	0.76	0.81
23666	223.51	15.60	0.11	0.52	223.99	17.22	0.32	1.01	224.22	19.23	0.42	1.24
24203	223.36	12.05	0.31	0.30	223.69	14.68	0.67	0.62	223.85	15.43	0.83	0.79
24677	222.41	9.31	0.26	0.37	222.83	17.15	0.51	0.79	223.03	17.80	0.62	0.98
25209	221.82	11.73	0.22	0.46	222.35	16.18	0.40	0.98	222.58	16.52	0.50	1.21
25683	221.39	4.01	0.51	0.39	221.93	12.00	0.82	0.93	222.10	13.46	0.98	1.10
26281	220.15	13.03	0.10	0.58	220.64	14.98	0.34	1.07	220.87	15.31	0.45	1.29
26743	220.09	17.81	0.16	0.52	220.54	21.72	0.33	0.97	220.73	22.06	0.42	1.16
27254	219.88	8.92	0.34	0.41	220.25	18.56	0.61	0.78	220.44	22.41	0.66	0.97
27802	219.02	8.36	0.26	0.34	219.48	11.73	0.59	0.81	219.70	12.67	0.74	1.03
28282	218.62	11.59	0.27	0.20	219.01	17.08	0.55	0.59	219.18	17.74	0.68	0.77

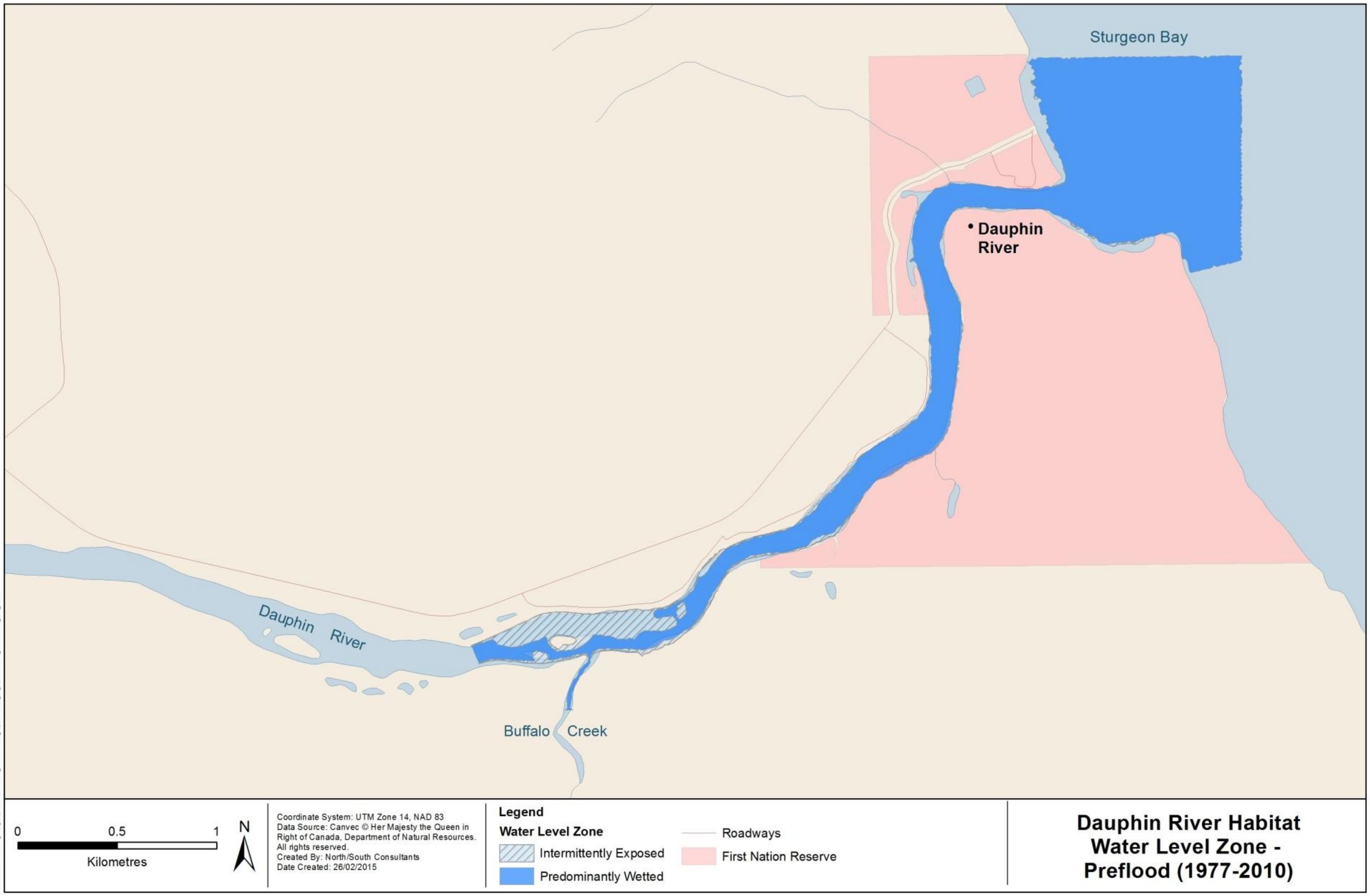

Figure 6A-1. Map showing the distribution of intermittently exposed and predominantly wetted habitat zones during the historic (Pre-flood) water regime period.

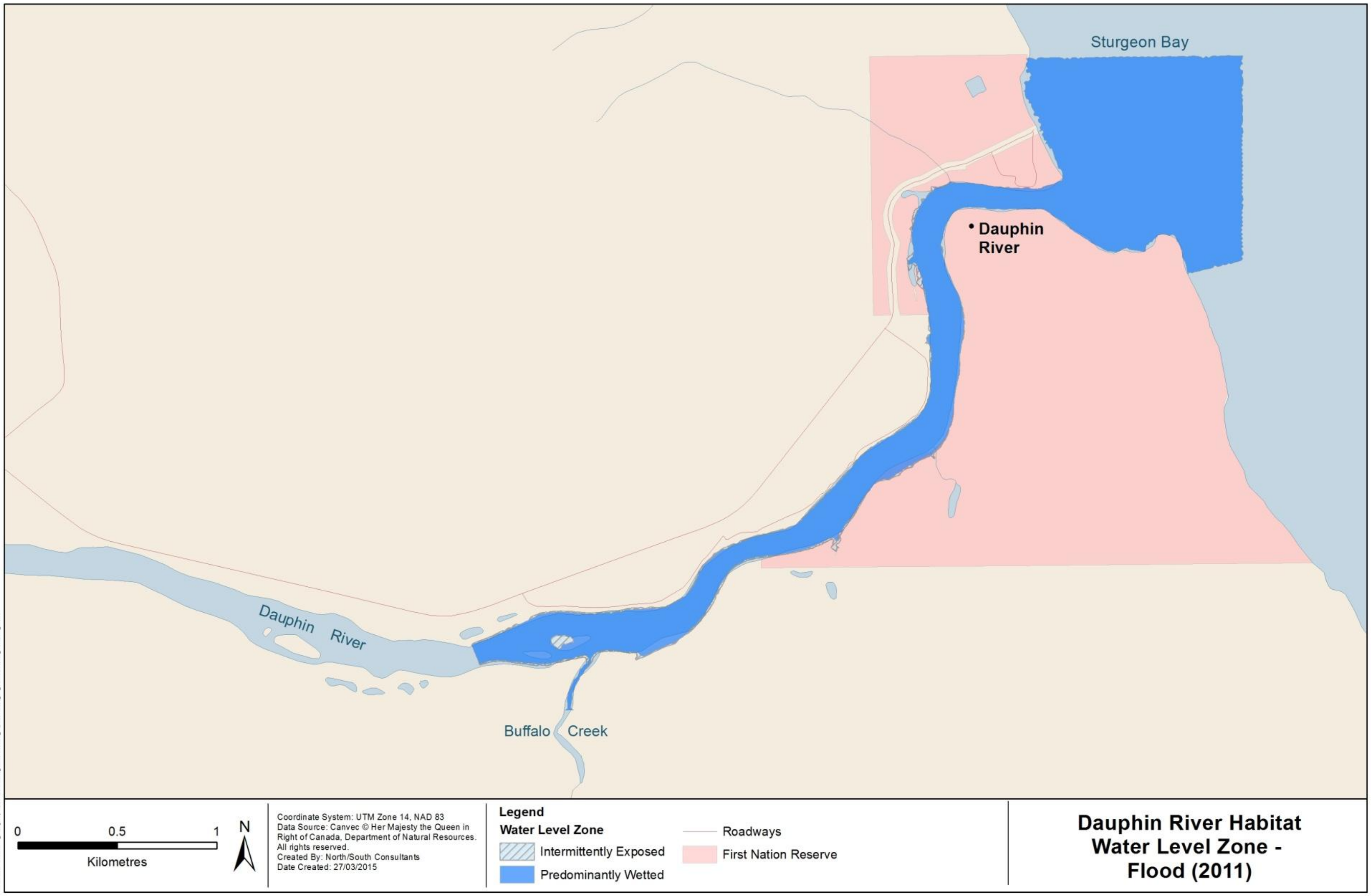

Figure 6A-2. Map showing the distribution of intermittently exposed and predominantly wetted habitat zones during the 2011 Flood water regime period.

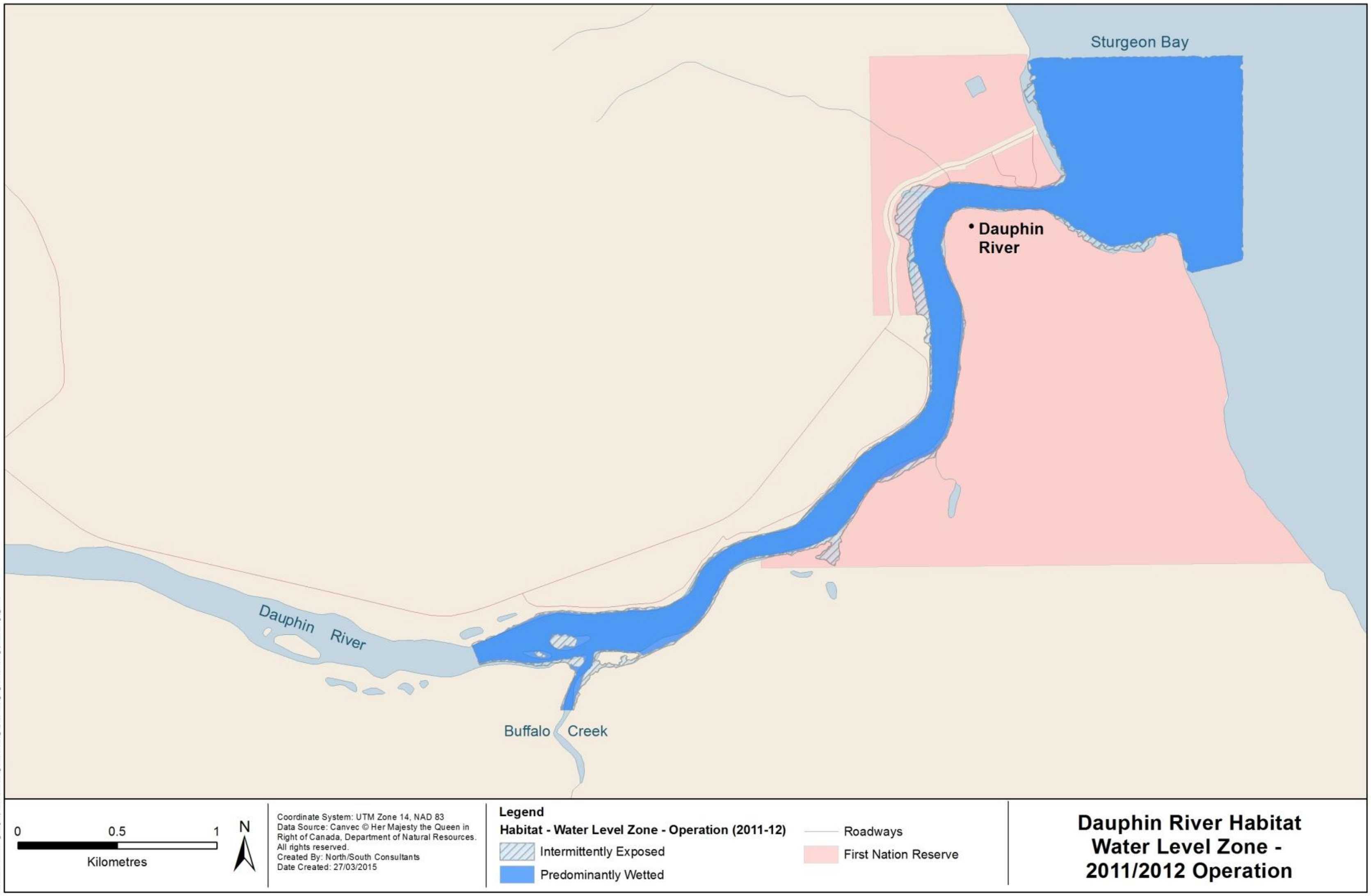

Figure 6A-3. Map showing the distribution of intermittently exposed and predominantly wetted habitat zones during the 2011/2012 Operation water regime period.

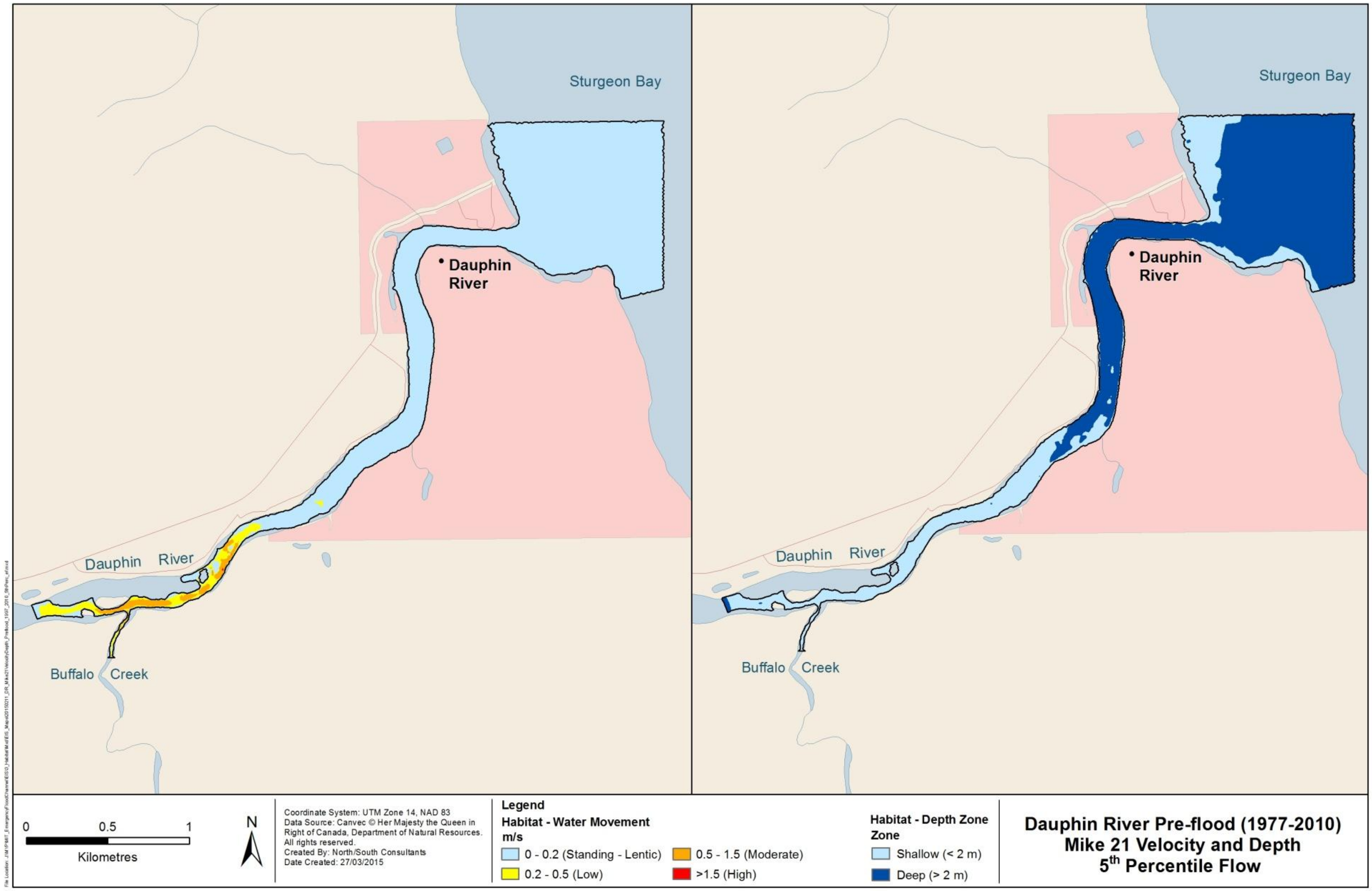

Figure 6A-4. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the historic (Pre-flood) 5th percentile (8 m^3/s) combined outflow condition.

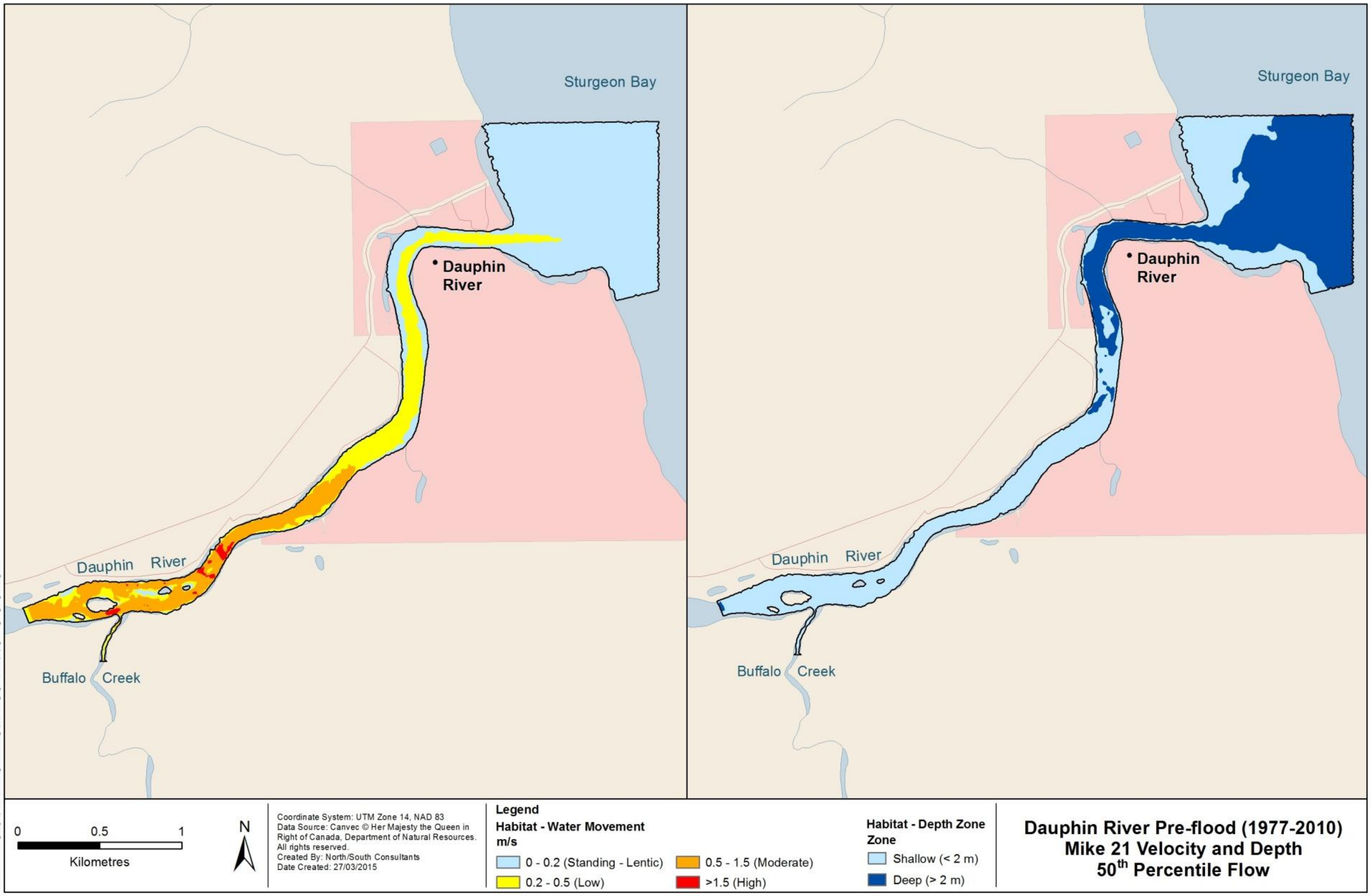

Figure 6A-5. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the historic (Pre-flood) 50th percentile (58 m^3/s) combined outflow condition.

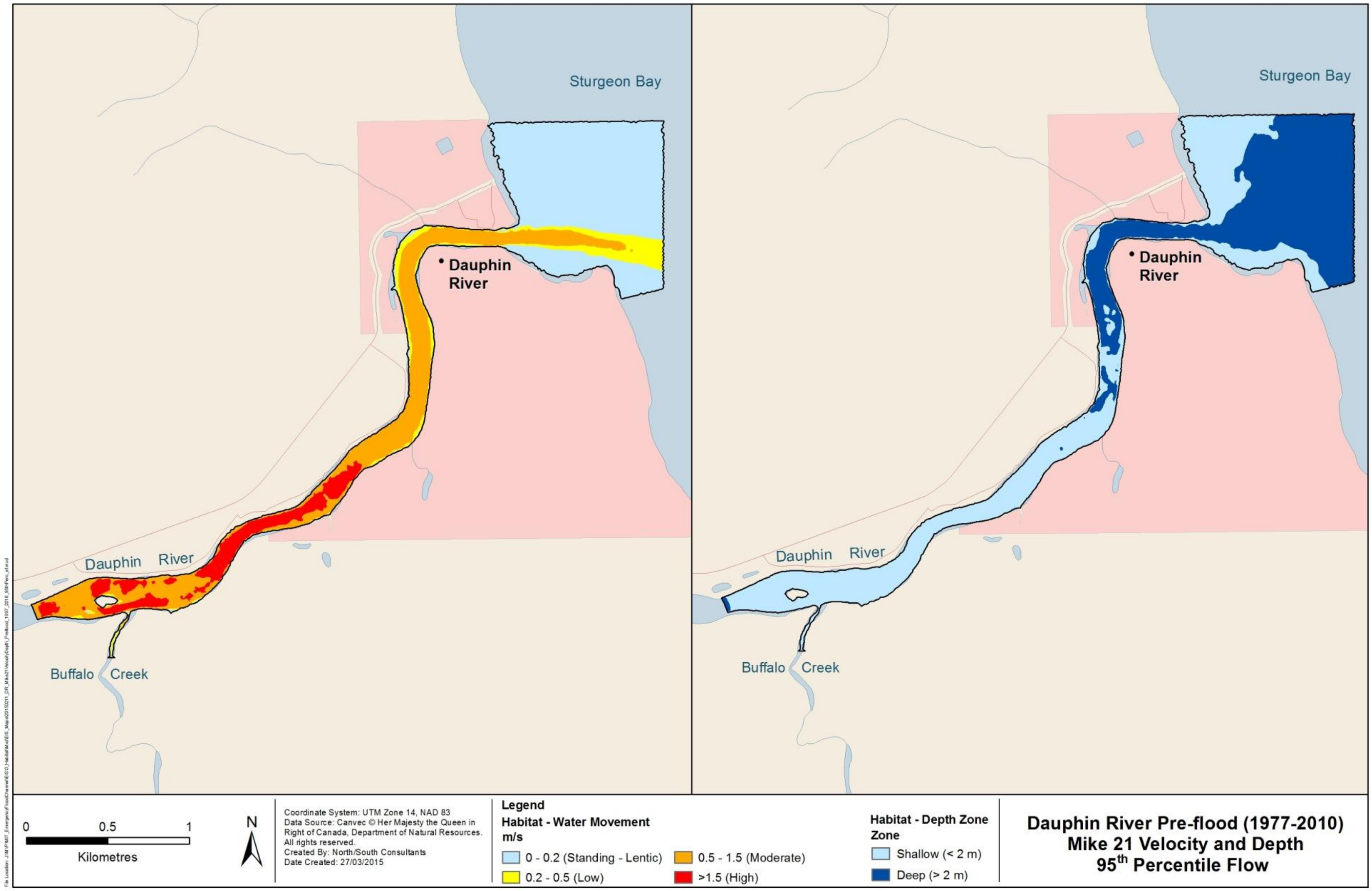

Figure 6A-6. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the historic (Pre-flood) 95th percentile (212 m^3/s) combined outflow condition.

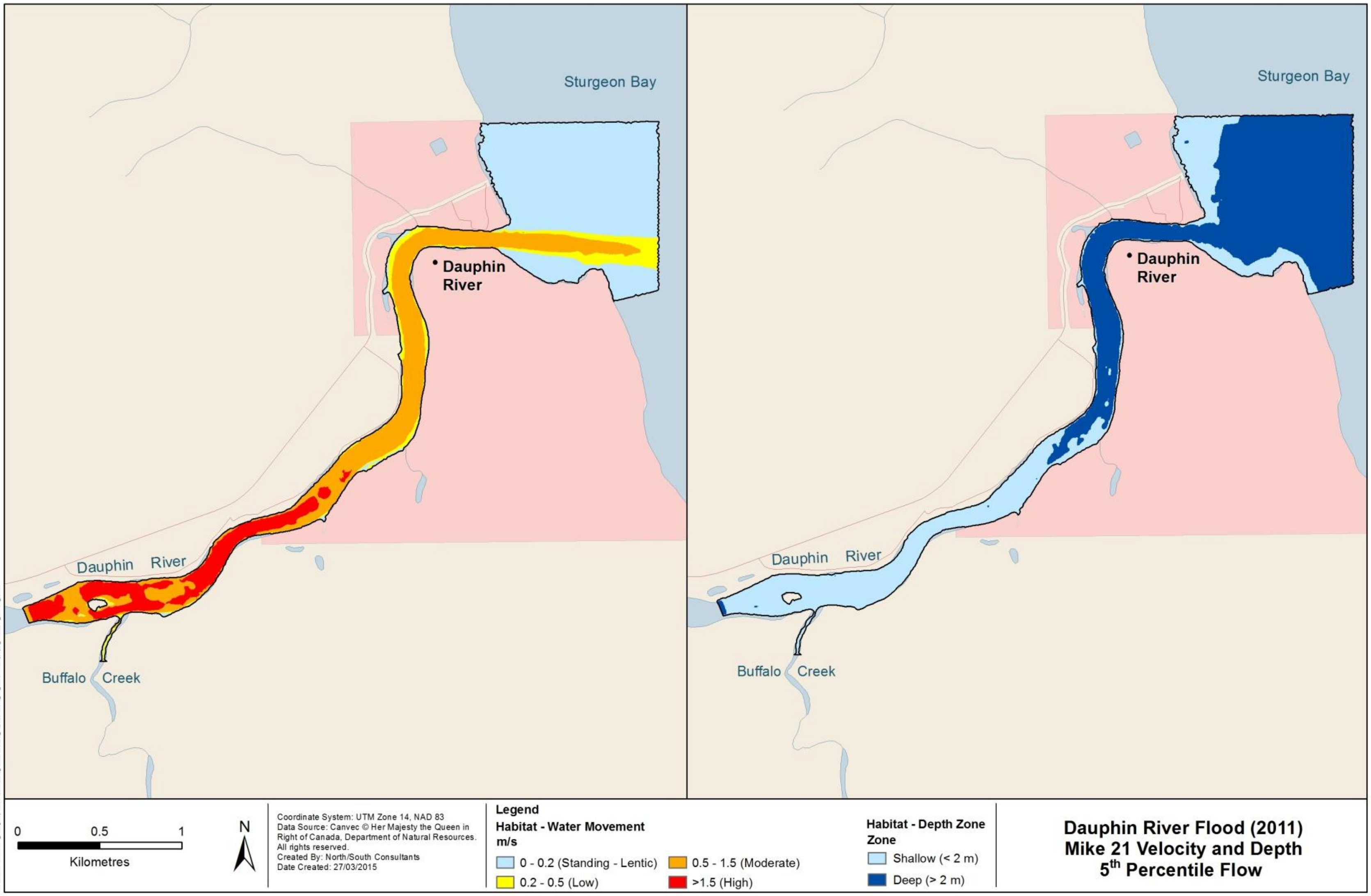

Figure 6A-7. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the2011 Flood 5th percentile (292 m^3/s) combined outflow condition.

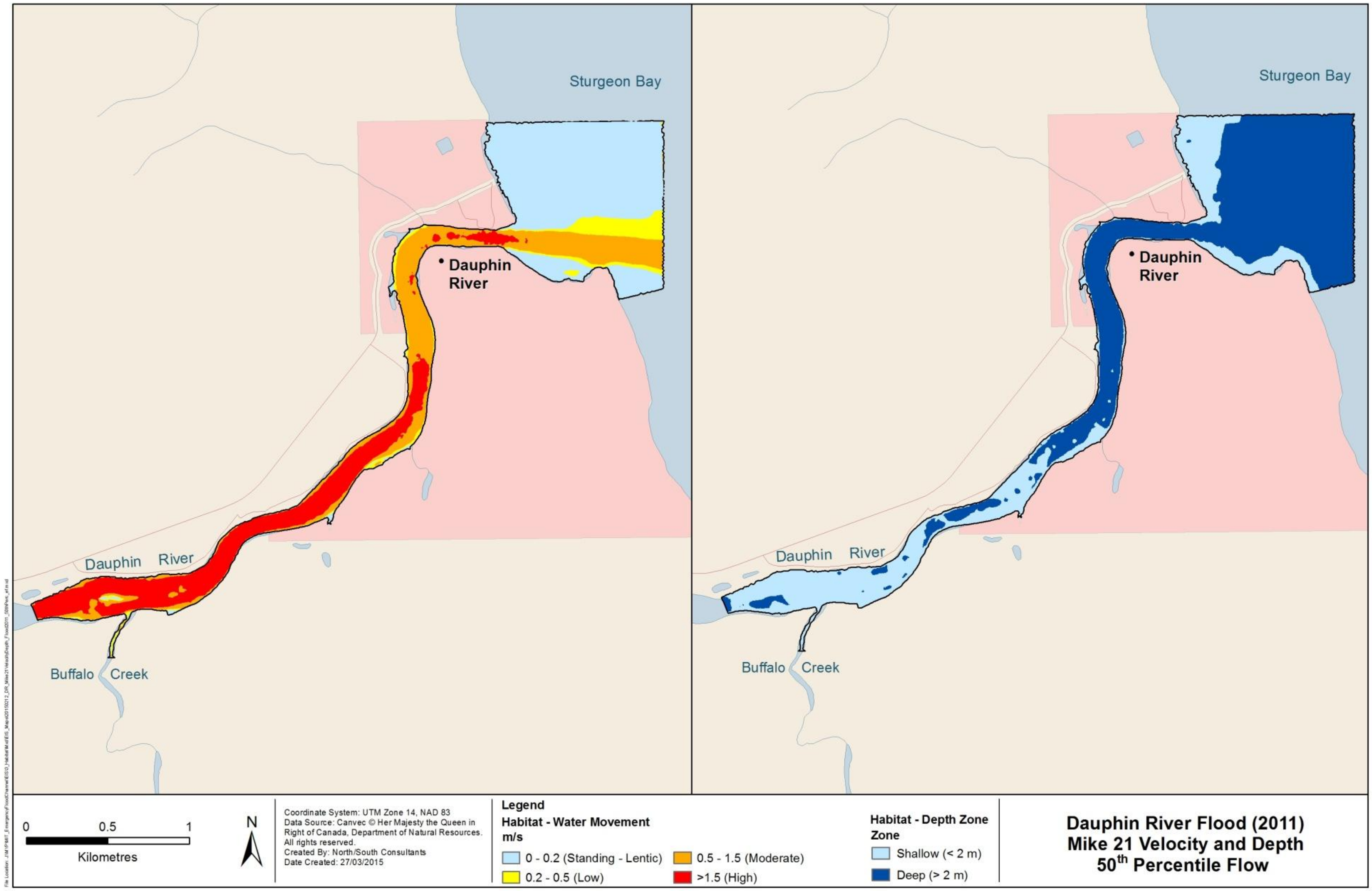

Figure 6A-8. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the 2011 Flood 50th percentile (527 m^3/s) combined outflow condition.

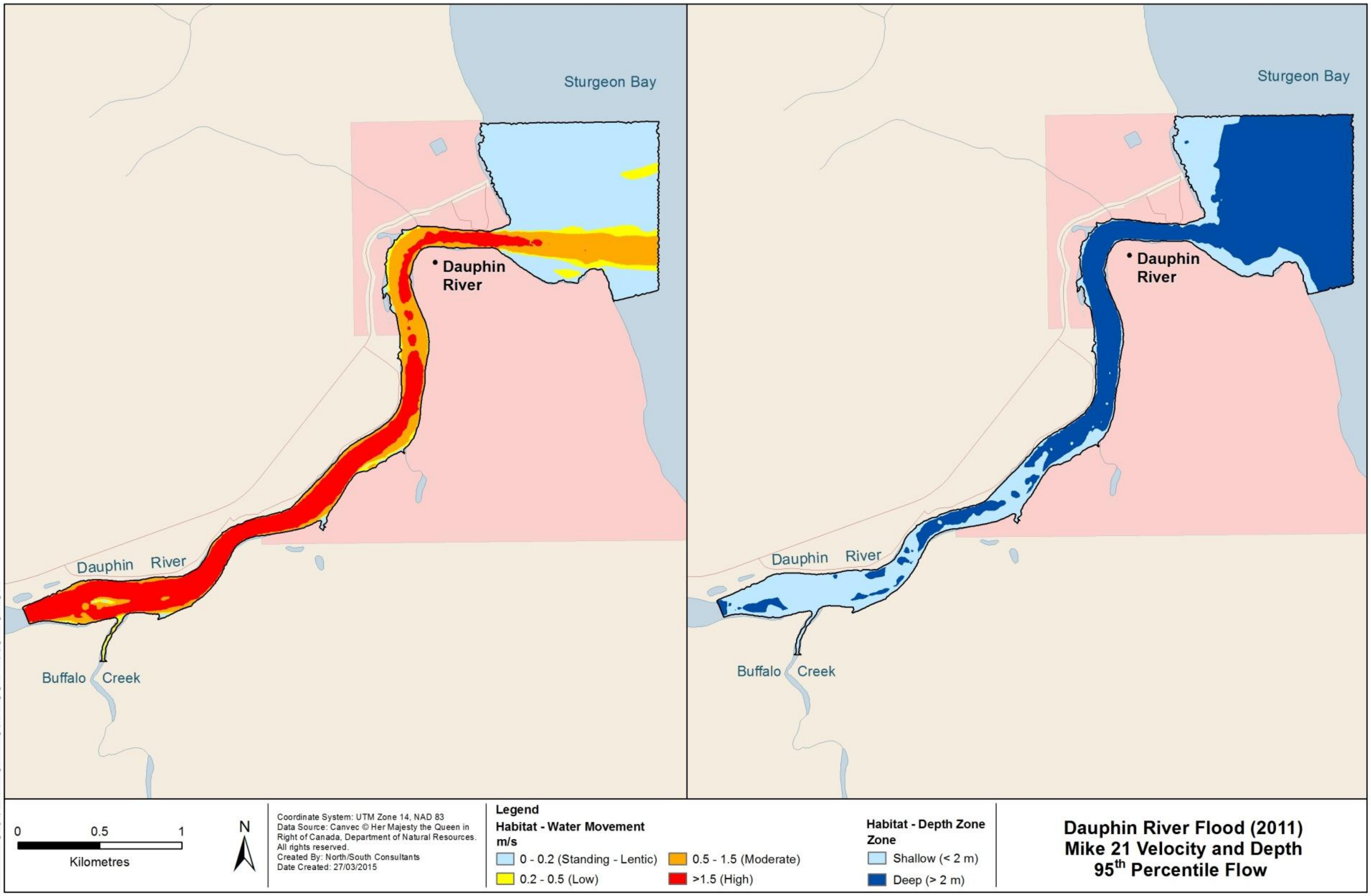

Figure 6A-9. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs under the 2011 Flood 95th percentile (589 m^3/s) combined outflow condition.

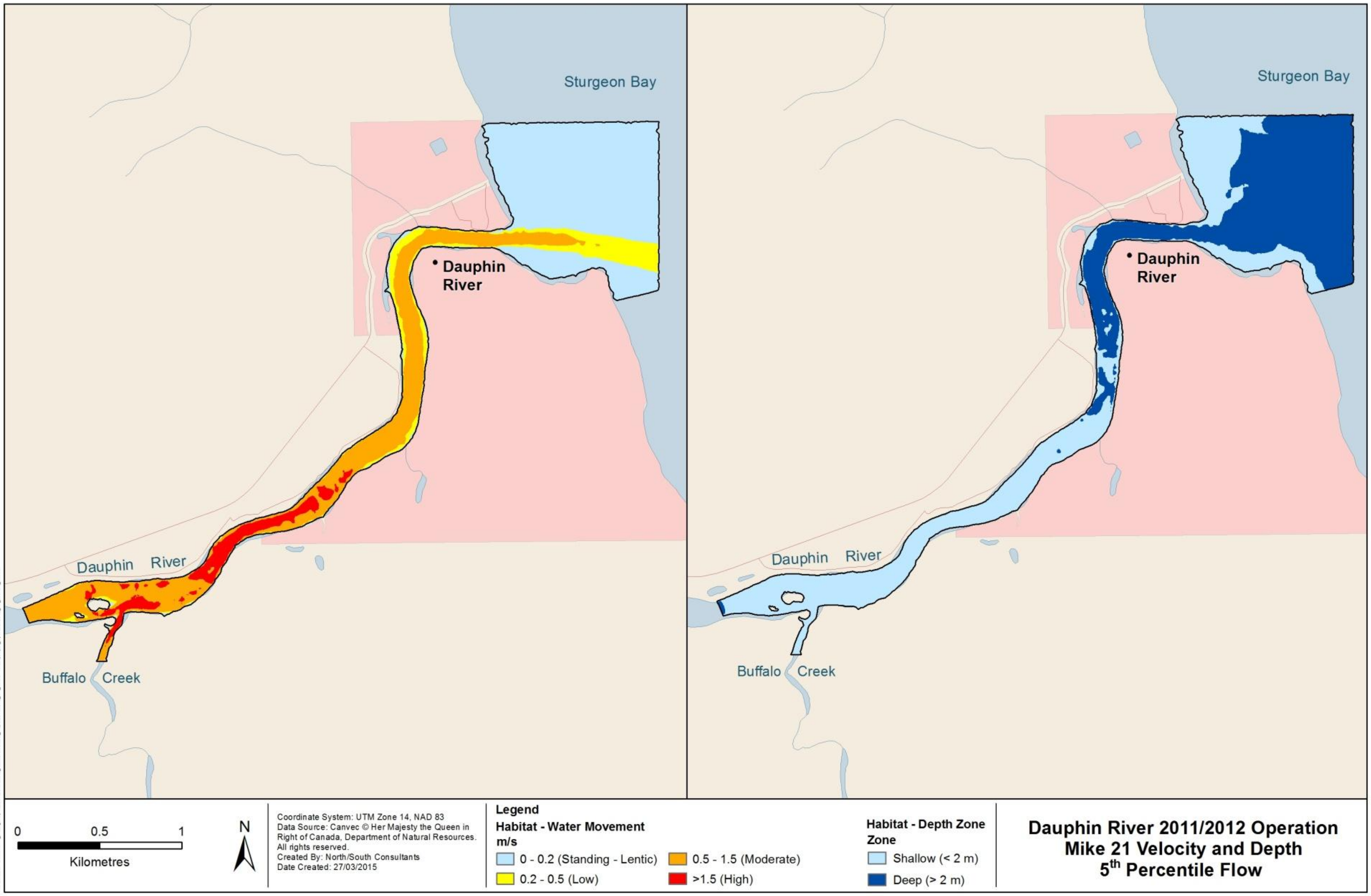

Figure 6A-10. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs during the 2011/2012 Operation 5th percentile (188 m^3/s) combined outflow condition.

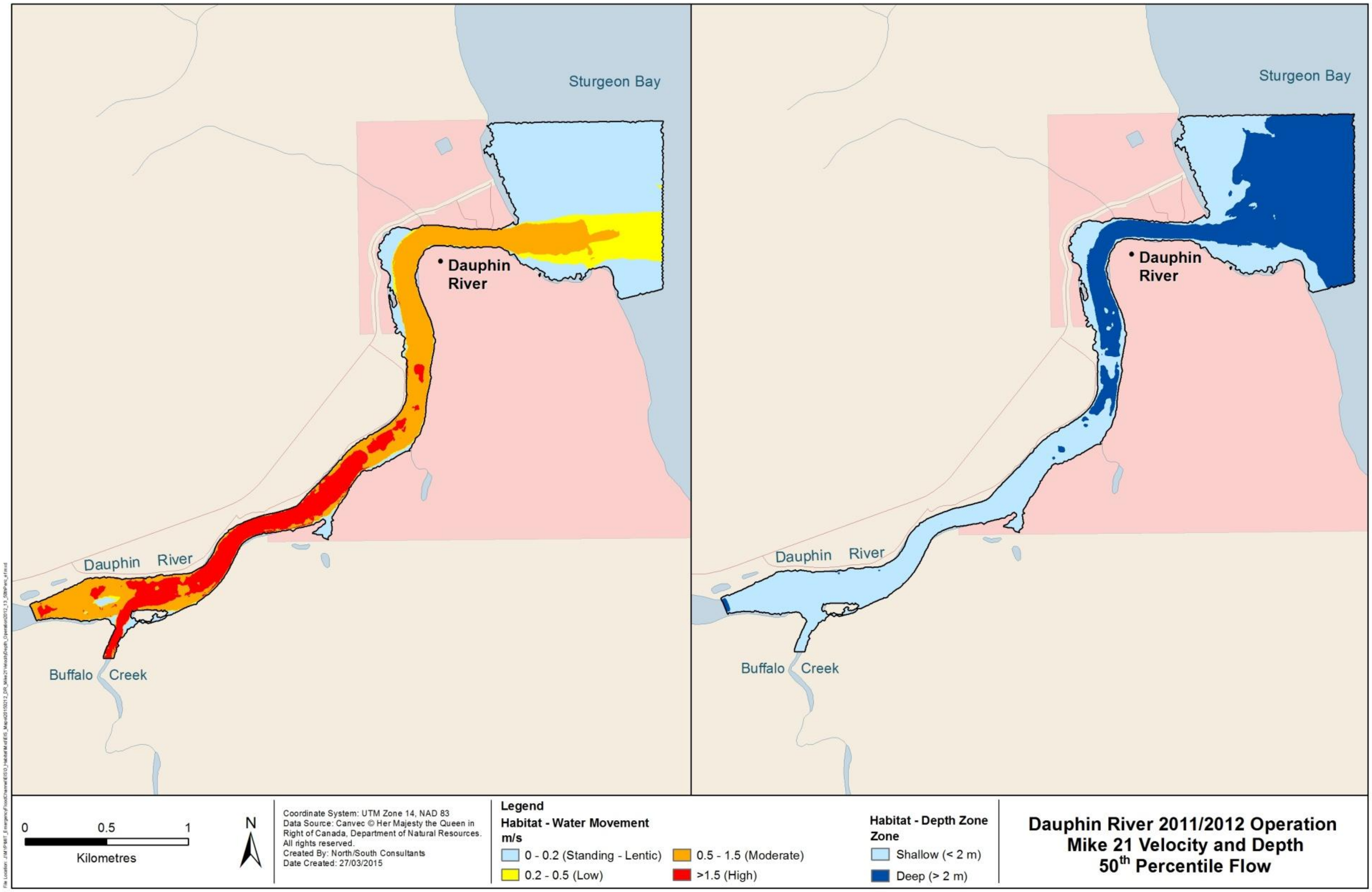

Figure 6A-11. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs during the 2011/2012 Operation 50th percentile (343 m^3/s) combined outflow condition.

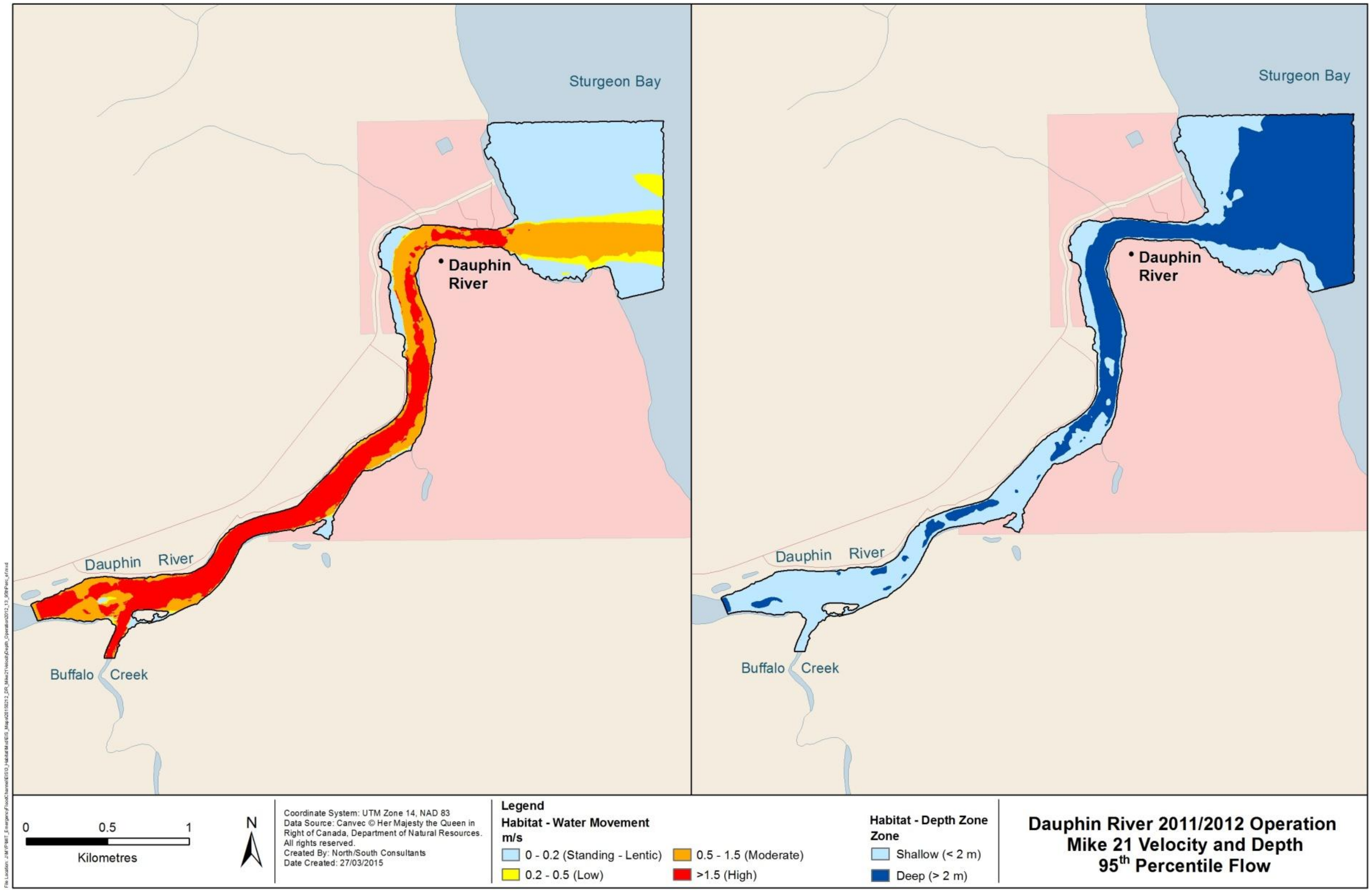

Figure 6A-12. Maps showing the distribution of velocity and depth habitat classes resulting from the spatial analysis of the MIKE 21 computational mesh outputs during the 2011/2012 Operation 95th percentile (521 m^3/s) combined outflow condition

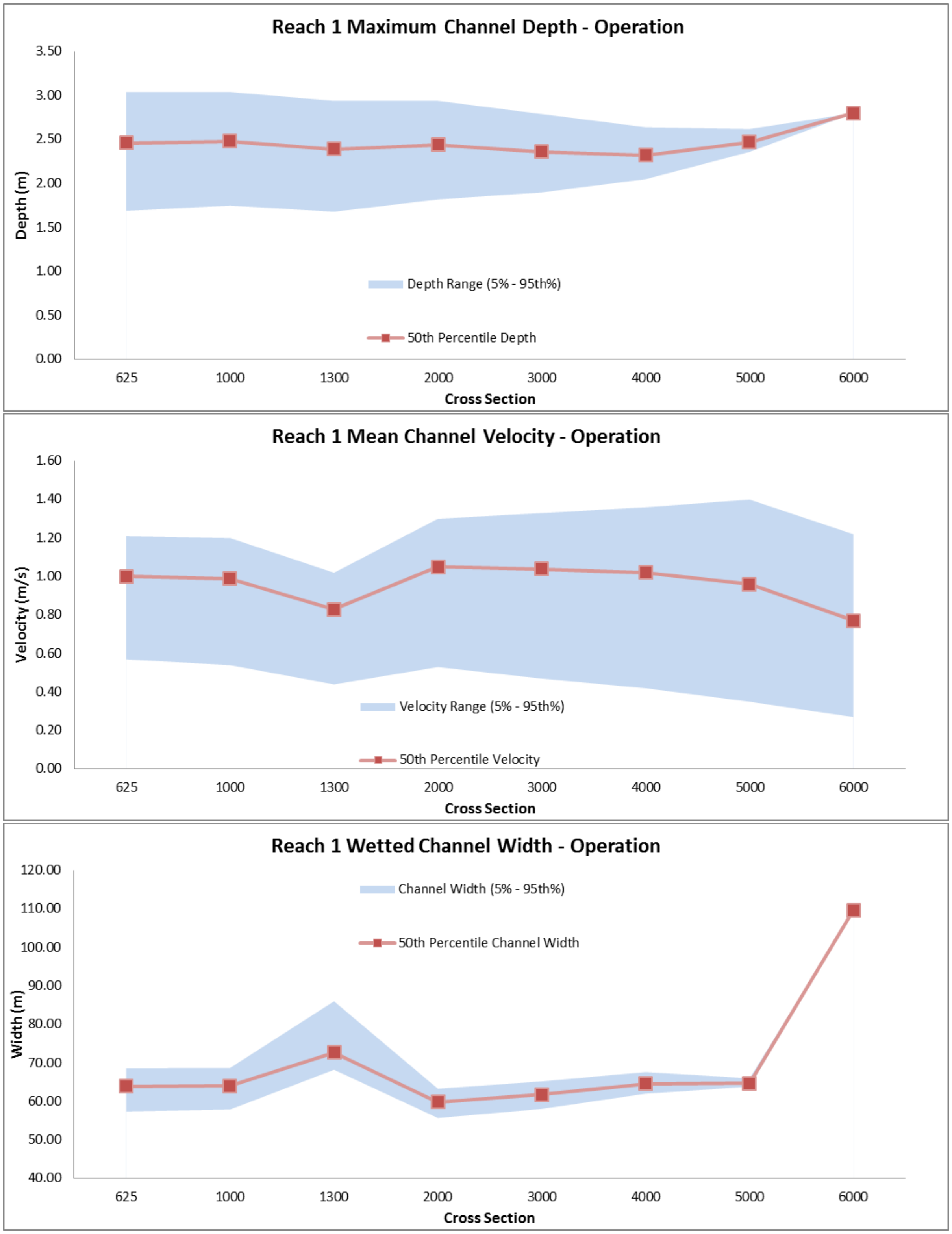

Figure 6A-13. Reach 1HEC-RAS hydraulic habitat variables showing ranges of maximum channel depth (top), mean velocity (middle), and wetted channel width (bottom) during 2011/2012 Operation.

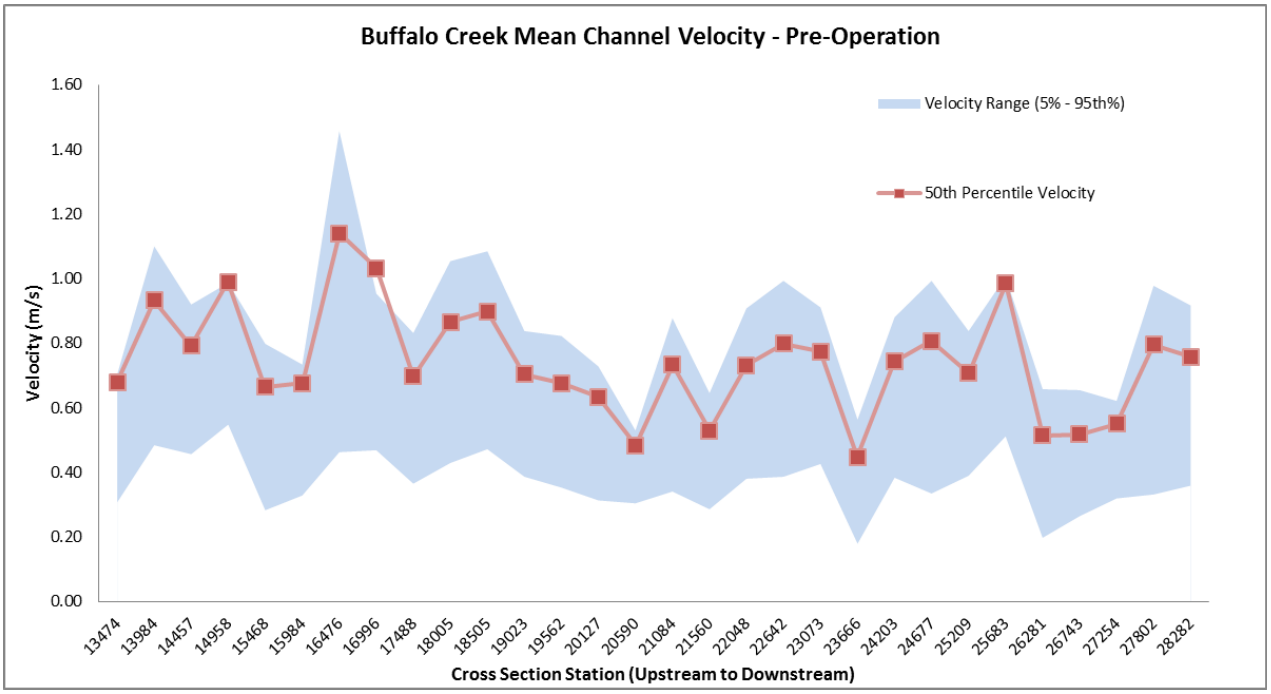

Figure 6A-14. Buffalo Creek HEC-RAS modeled Pre-Operation mean channel velocity at 30 cross section stations under simulated 5th, 50th and 95th percentile flows during.

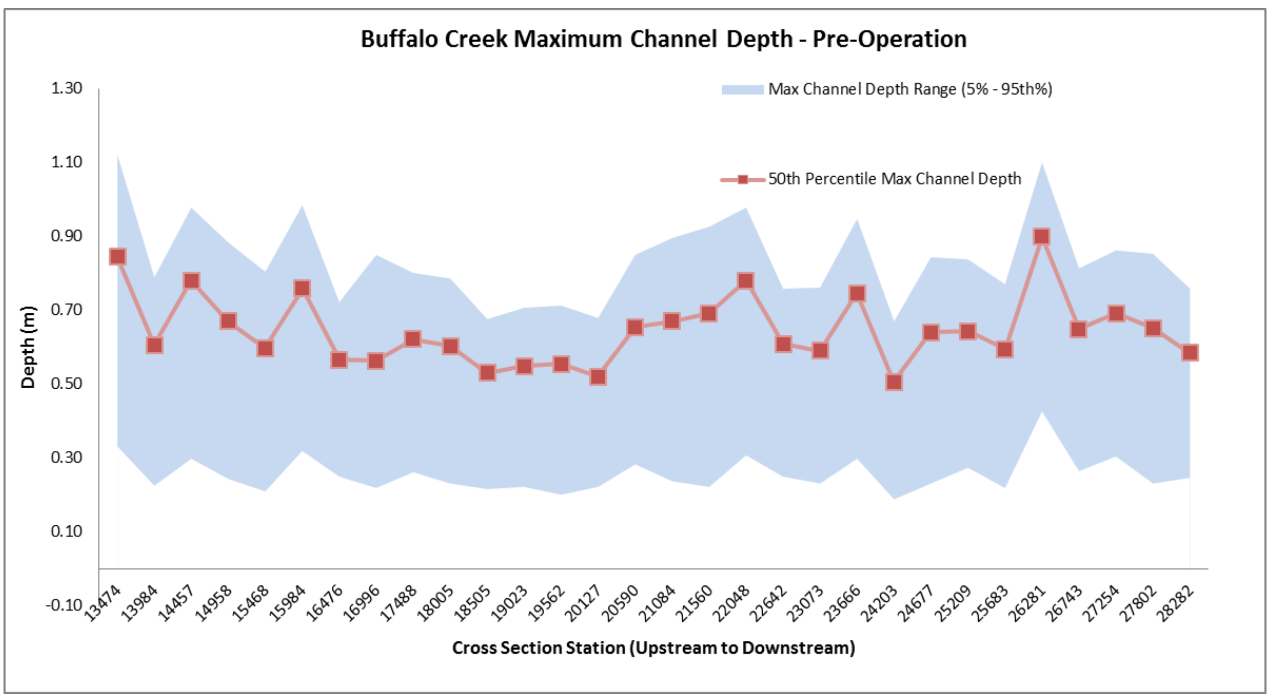

Figure 6A-15. Buffalo Creek HEC-RAS modeled Pre-Operation maximum channel depth at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

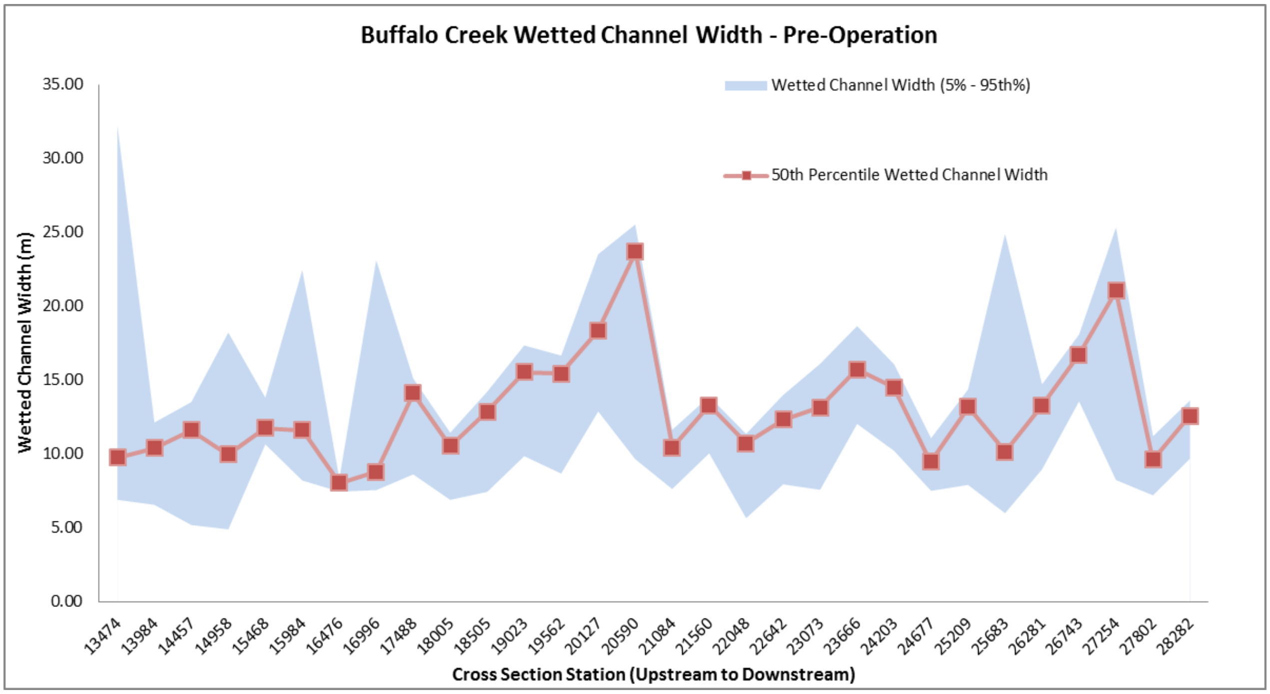

Figure 6A-16. Buffalo Creek HEC-RAS modeled Pre-Operation wetted channel width at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

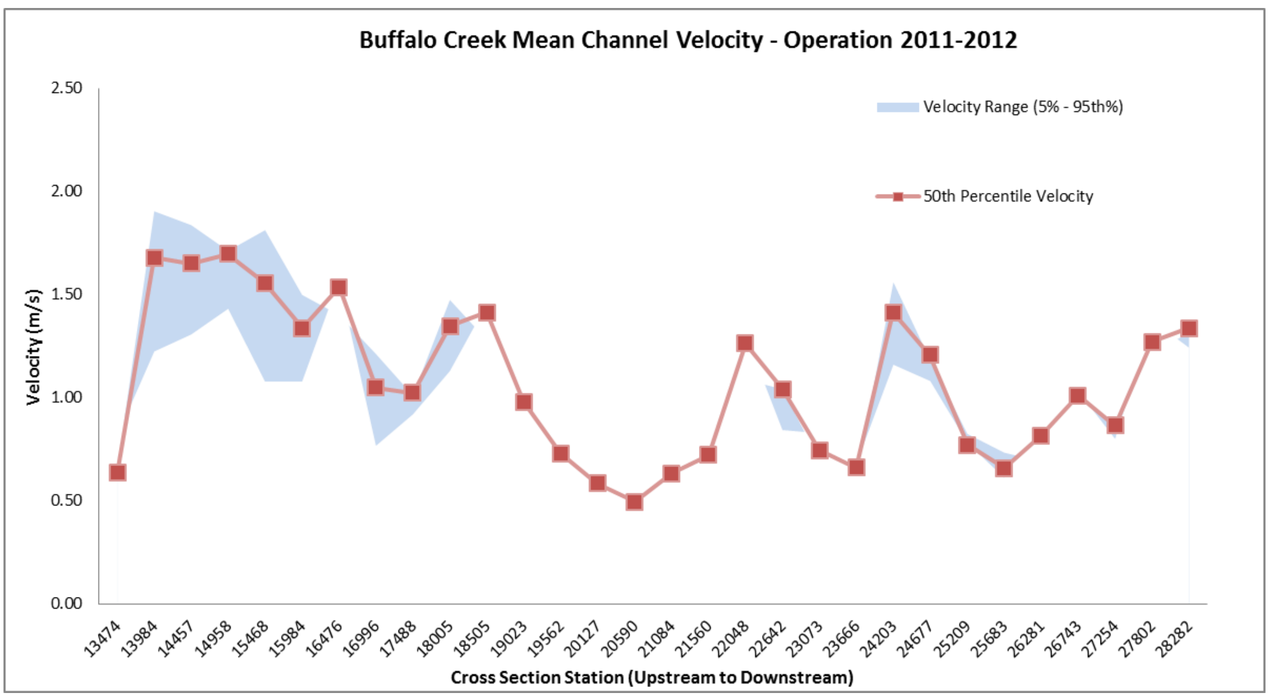

Figure 6A-17. Buffalo Creek HEC-RAS modeled 2011/2012 Operation mean channel velocity at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

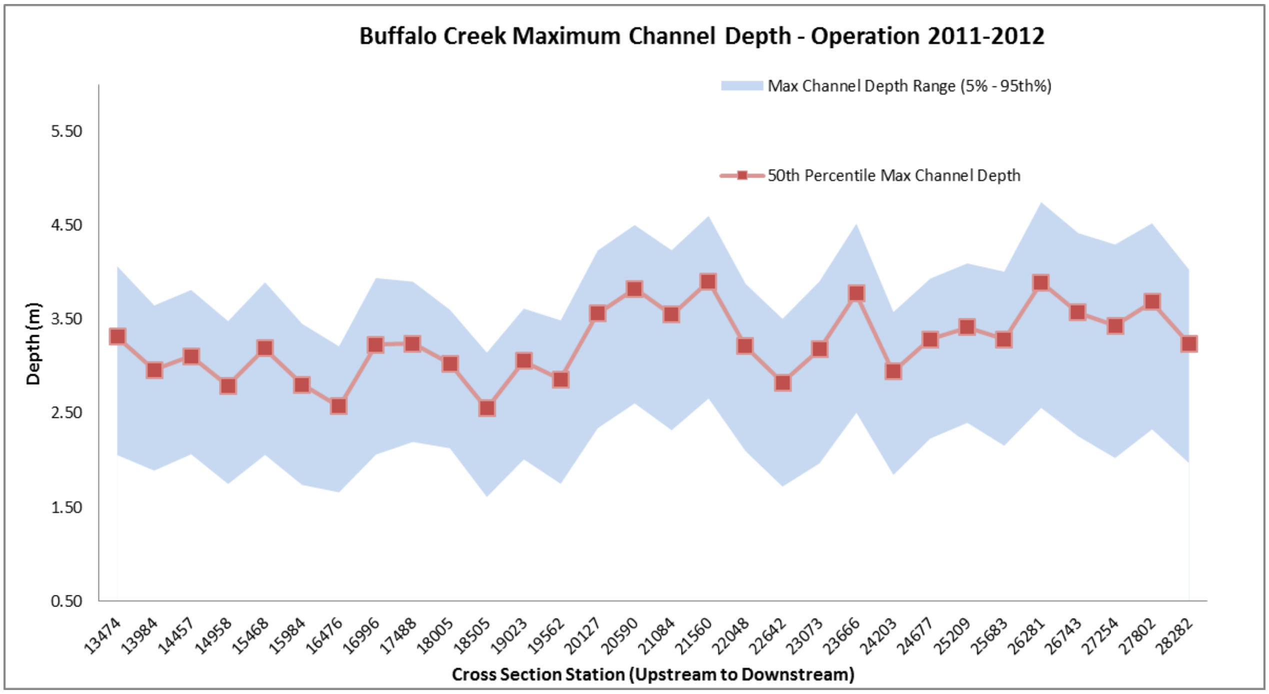

Figure 6A-18. Buffalo Creek HEC-RAS modeled 2011/2012 Operation maximum channel depth at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

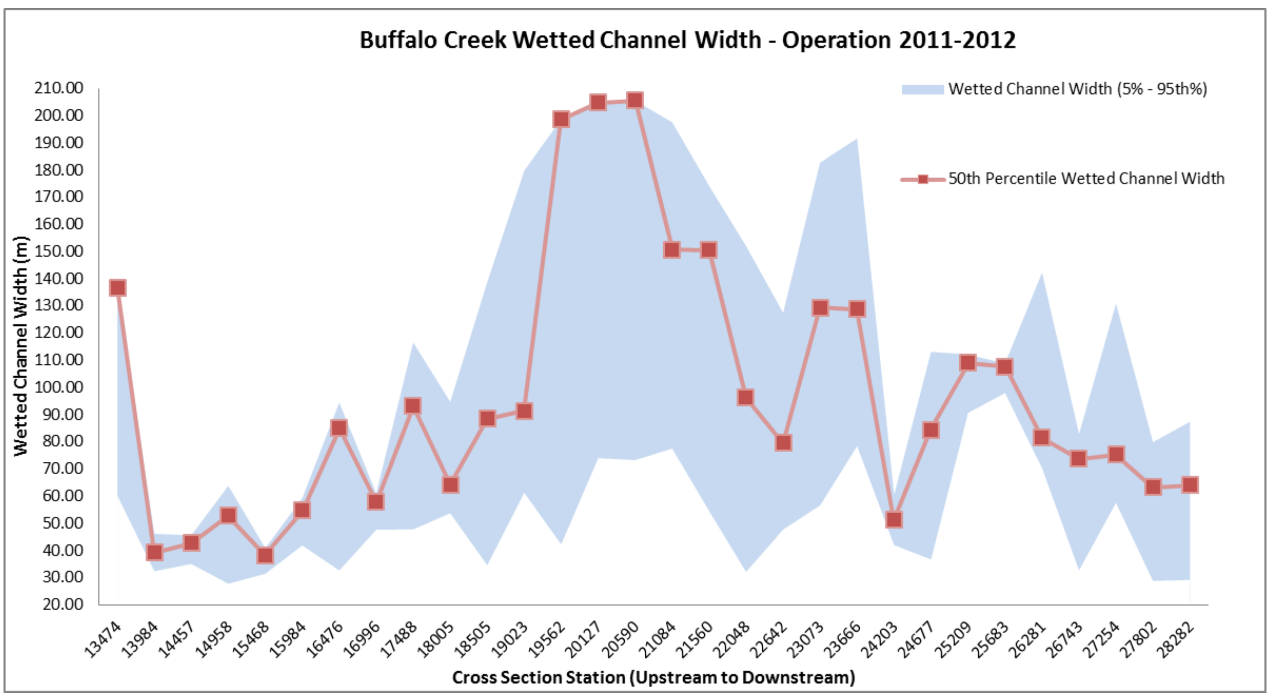

Figure 6A-19. Buffalo Creek HEC-RAS modeled 2011/2012 Operation wetted channel width at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

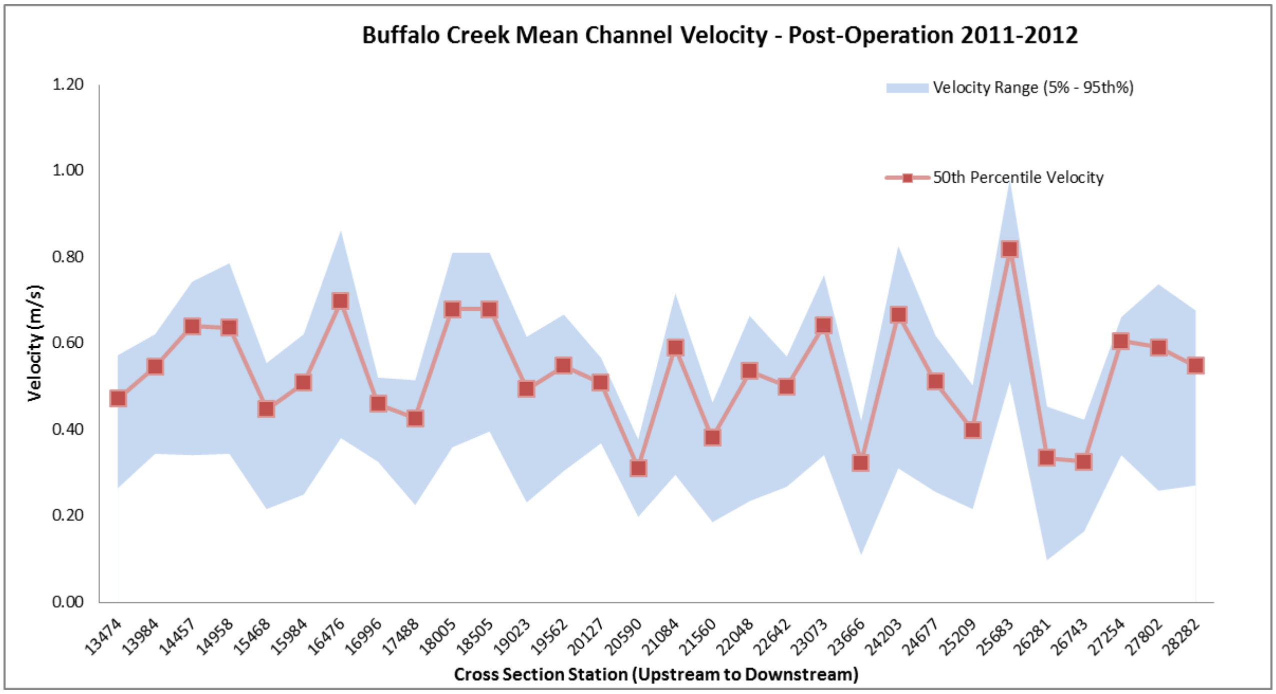

Figure 6A-20. Buffalo Creek HEC-RAS modeled 2011/2012 Closure mean channel velocity at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

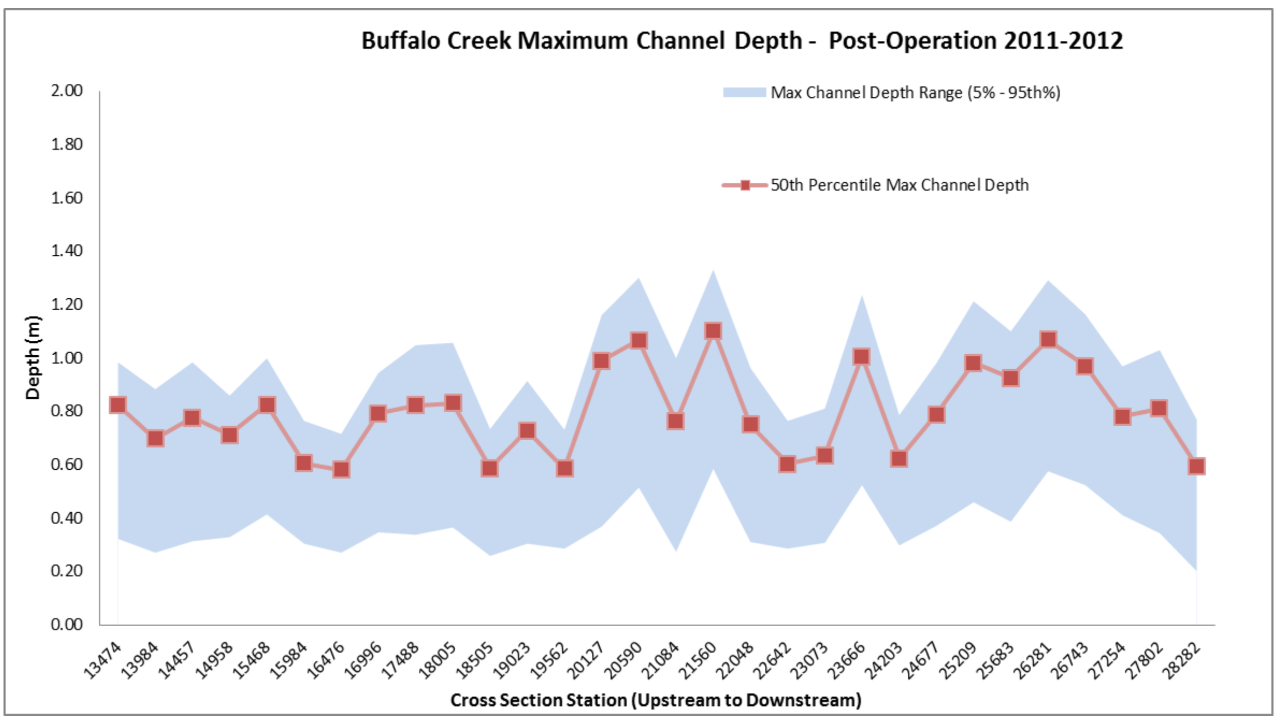

Figure 6A-21. Buffalo Creek HEC-RAS modeled 2011/2012 Closure maximum channel depth at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

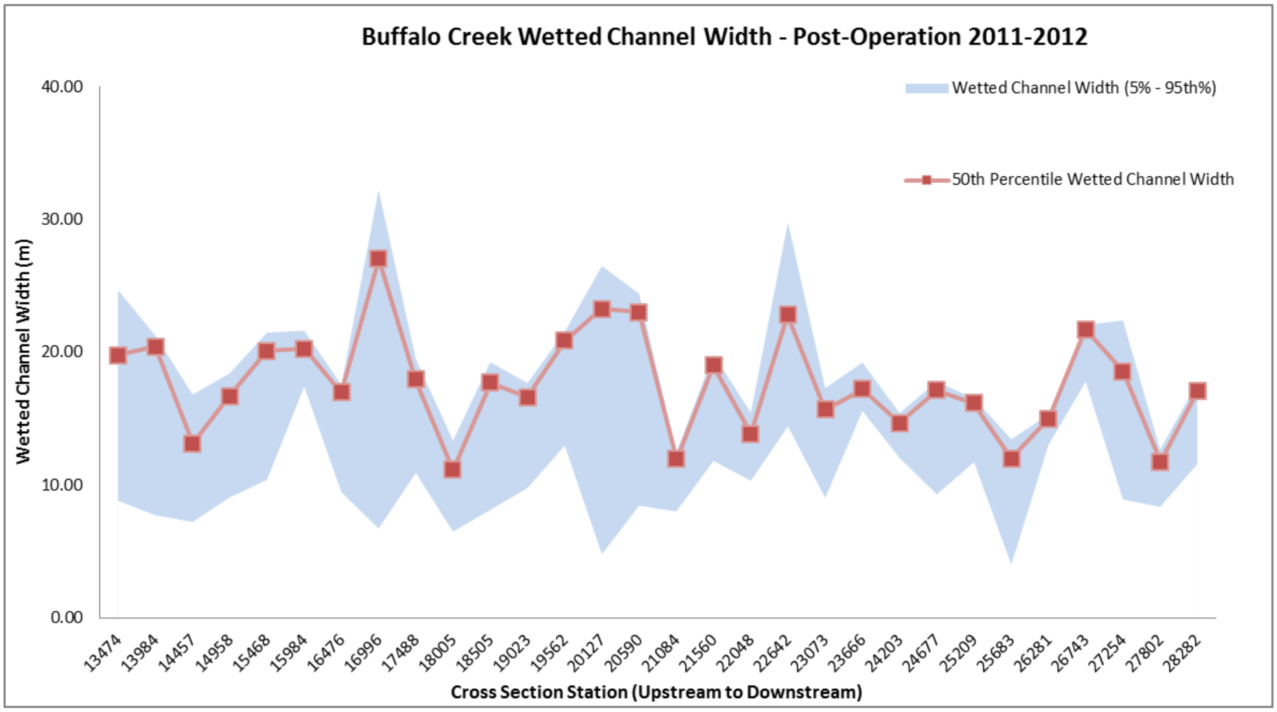

Figure 6A-22. Buffalo Creek HEC-RAS modeled 2011/2012 Closure wetted channel width at 30 cross section stations under simulated 5th, 50th and 95th percentile flows.

6A 4.0 REFERENCES

Bisson, P. A., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. Pages 62-73 IN: N. B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland.

North/South Consultants Inc. 2013. Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation: Volume 4 Fish Habitat. A draft report prepared for Manitoba Infrastructure and Transportation. xxii + xx pp. in prep

Appendix 6B. Geo-Referenced Aerial Imagery (GAIM™)

Provided Within: Details of the GAIM™ imagery used.

Geo-Referenced Aerial Imaging and Mapping (GAIM) is a system, used by Taiga Air Services LTD., that can collect geo-referenced high resolution imagery and video concurrently using a helicopter mounted sensor. The imagery captured for the Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation project (Table 6B-1) was acquired at an altitude of between 200 and 300 metres above ground level depending on the specific flight and tasks required. The helicopter imagery was captured at a speed of approximately 80 kilometers per hour as a requirement to provide clear and high resolution imagery. Typical resolution of the imagery is 7 cm to 10 cm ground pixel resolution.

GAIM data, specifically high resolution imagery, were collected in 2011 and 2012 as part of the Emergency Reduction of Lake Manitoba and Lake St. Martin Water Levels Project, which was the precursor to the current project (Figures 6B-1 and 6B-2). The imagery was initially requested by MIT for the purpose of documenting conditions at the site prior to and after construction of the emergency outlet channels. KGS Group and NSC repurposed the data to use support routing, biological surveys, sediment transport analysis, habitat assessments, etc. As part of the on-going monitoring in the project study area, MIT requested the GAIM be included in the current project. GAIM flights were conducted in July 2013 and June 2014 (Figures 6B-3 and 6B-4). Once again, the project team repurposed the imagery captured to support studies required to determine potential impacts from the development, operation, and post-operation of the LSMEOC system.

Three types of imagery products were captured for the project as follows:

- Hyperlinked geo-centered imagery;
- Georeferenced individual images placed; and
- Strip mosaicked Digital Ortho Imagery (DOI).

The imagery captured using GAIM are available as hyperlinked geo-centered imagery. The 2013 imagery was also produced as individual image georeferenced, and ortho strip imagery has been completed in select areas along Buffalo Creek and Reach 3. The complete 2014 imagery has been mosaicked into an ortho-strip.

Table 6B-1. GAIM Flight Data for Lake St. Martin Area Captured For KGS Group 2011–2014.

Year	Month	Area of Cover	Status	Submitted
2011	June	See image F01	Processed	Yes
2011	July	See image F01	Processed	Yes
2012	January	See image F02	Processed	Yes
2013	July	See image F03	Processed	Yes
2014	June	See image F04	In Progress	No

Figure 6B-1. Flight path for June/July 2011 GAIM data collection.

Figure 6B-2. Flight path for January 2012 GAIM data collection.

Figure 6B-3. Flight path for July 2013 GAIM data collection.

Figure 6B-4. Flight path for June 2014 GAIM data collection.

Appendix 6C. Water Temperature Logger Data by Year

Provided Within: Graphs summarizing annual water temperature data

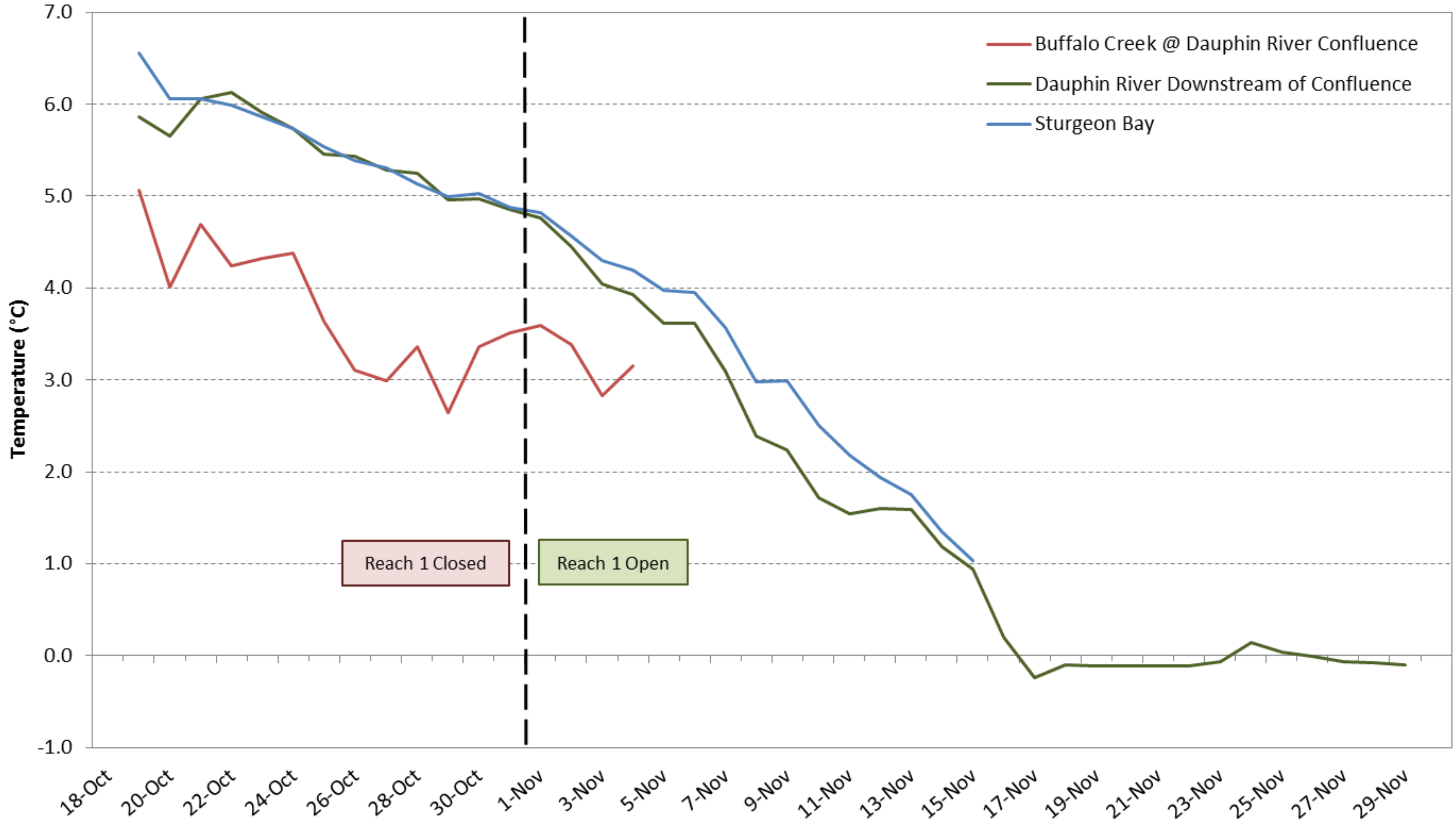

Figure 6C-1. Daily mean water temperature in Project waterbodies during fall 2011.

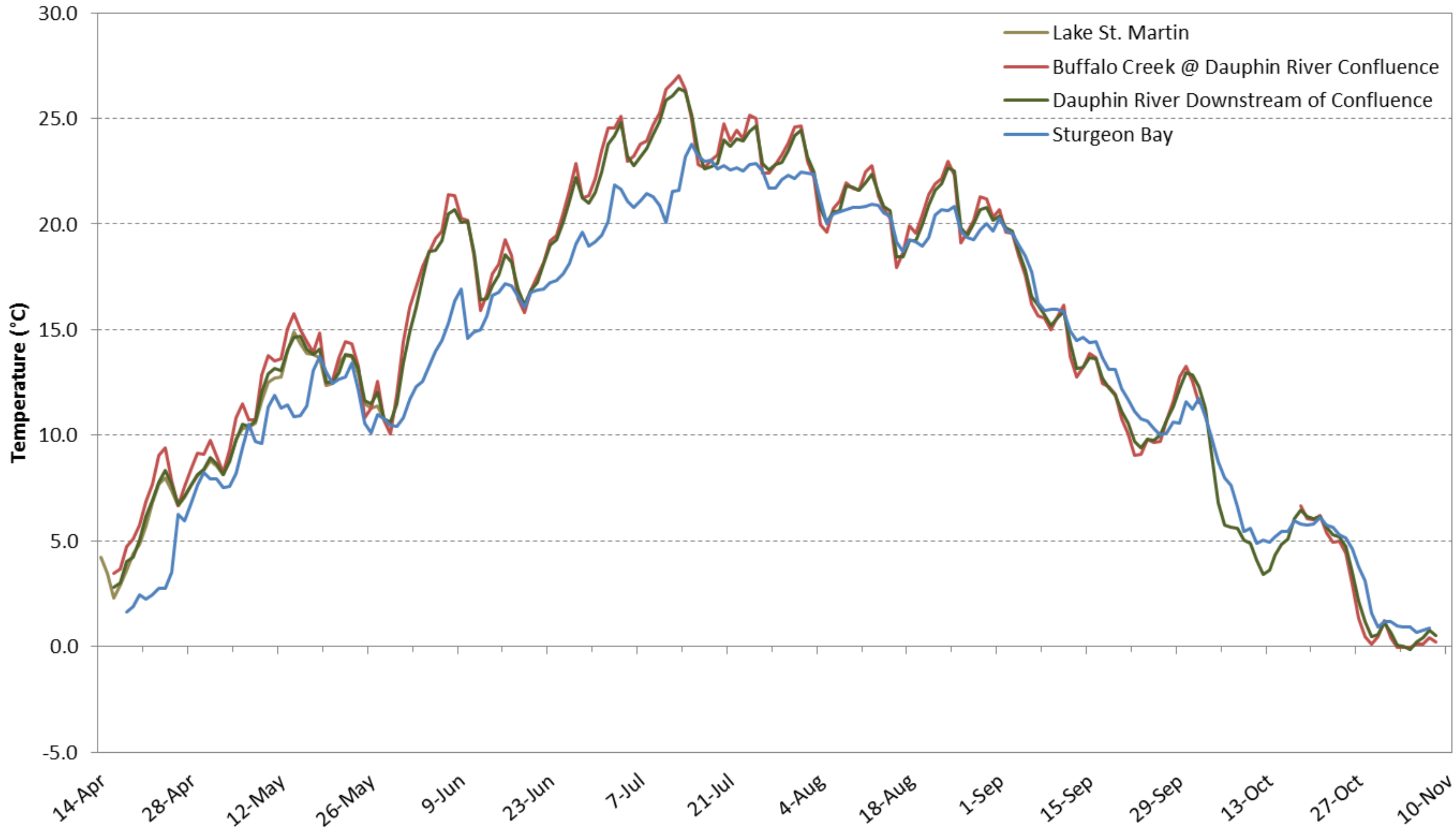

Figure 6C-2. Daily mean water temperature in Project waterbodies during the 2012 open water season.

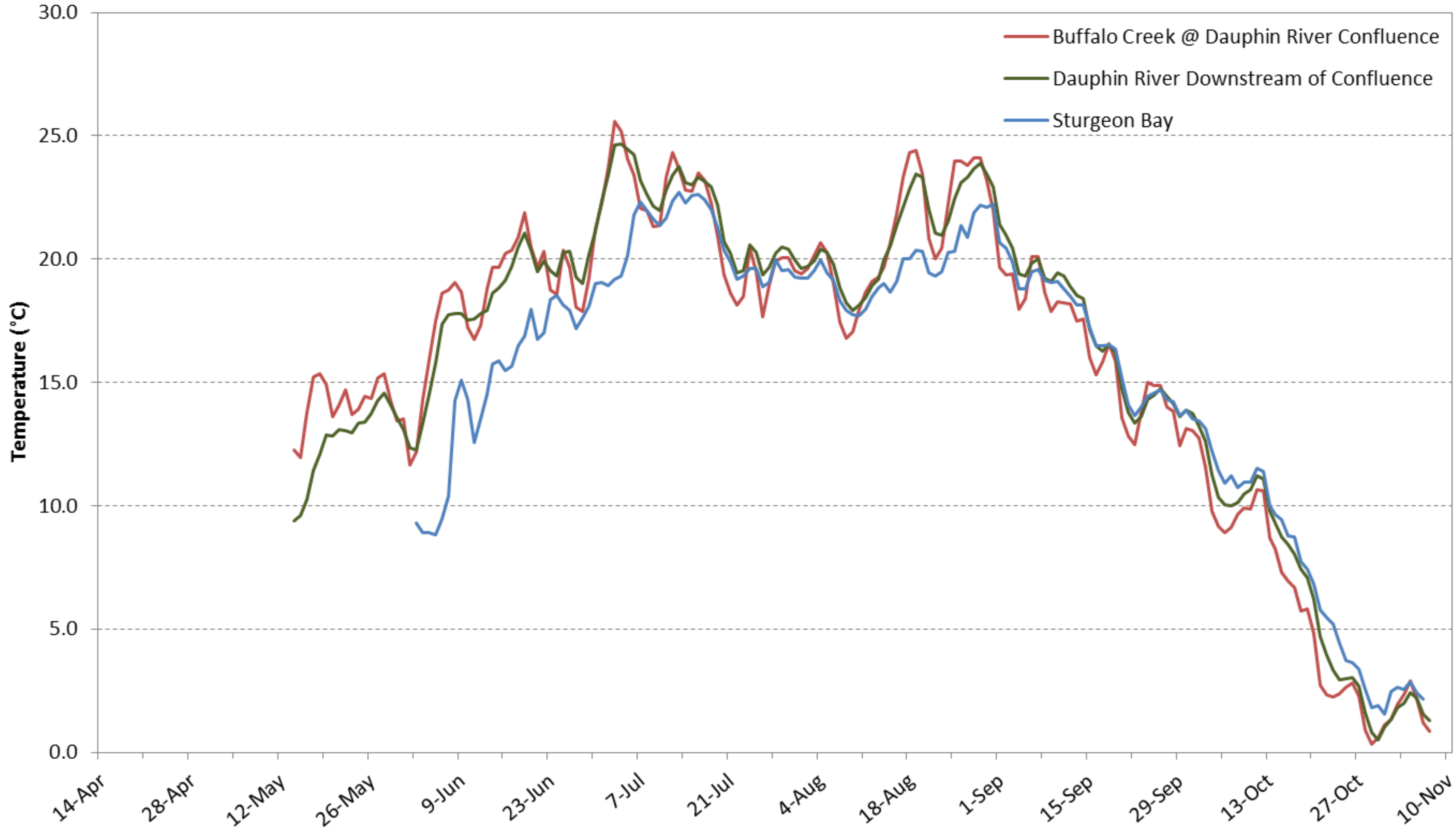

Figure 6C-3. Daily mean water temperature in Project waterbodies during the 2013 open water season.

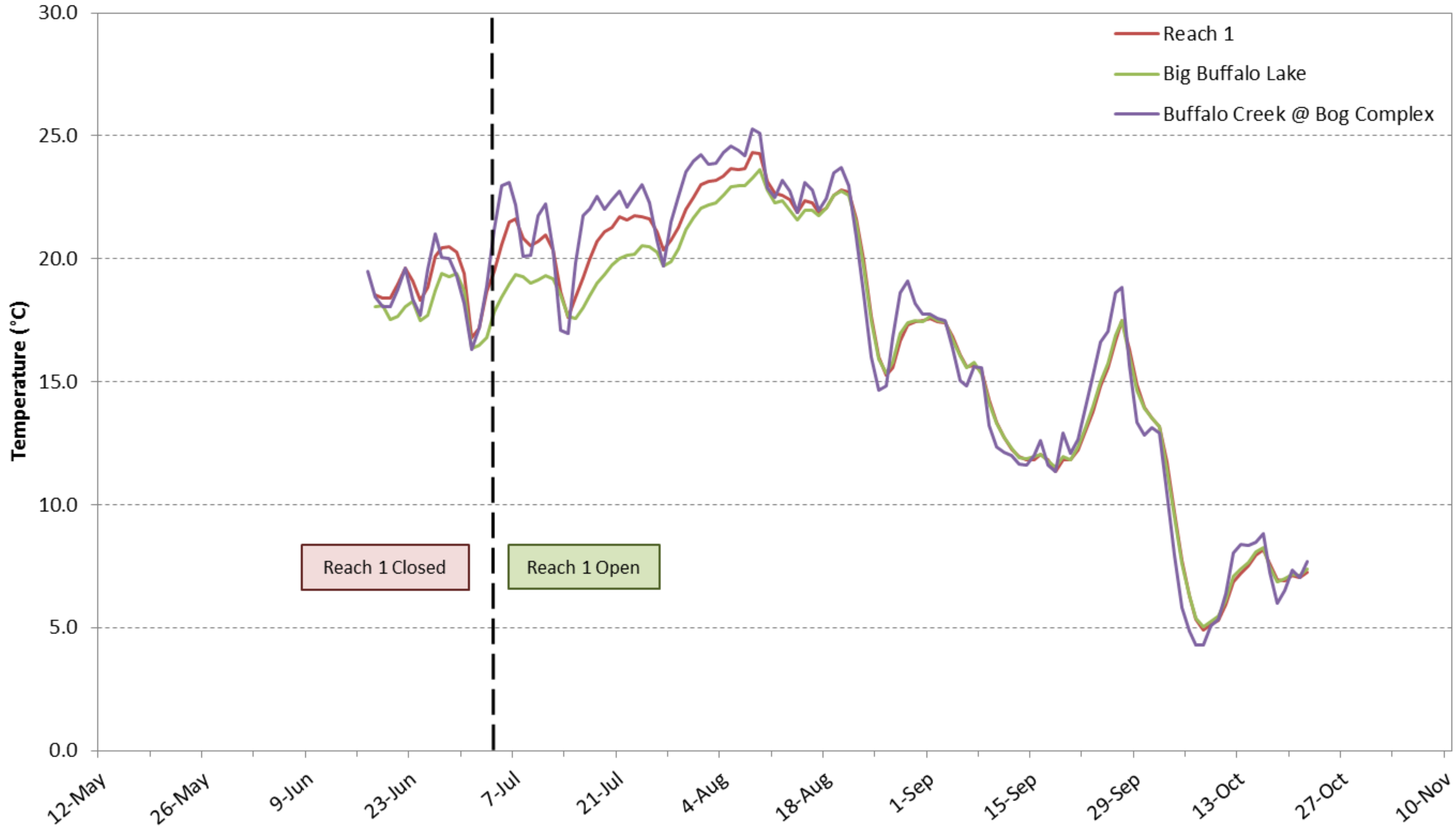

Figure 6C-4. Daily mean water temperature in Project waterbodies from Reach 1 downstream to the upper end of Buffalo Creek, 2014 open water season.

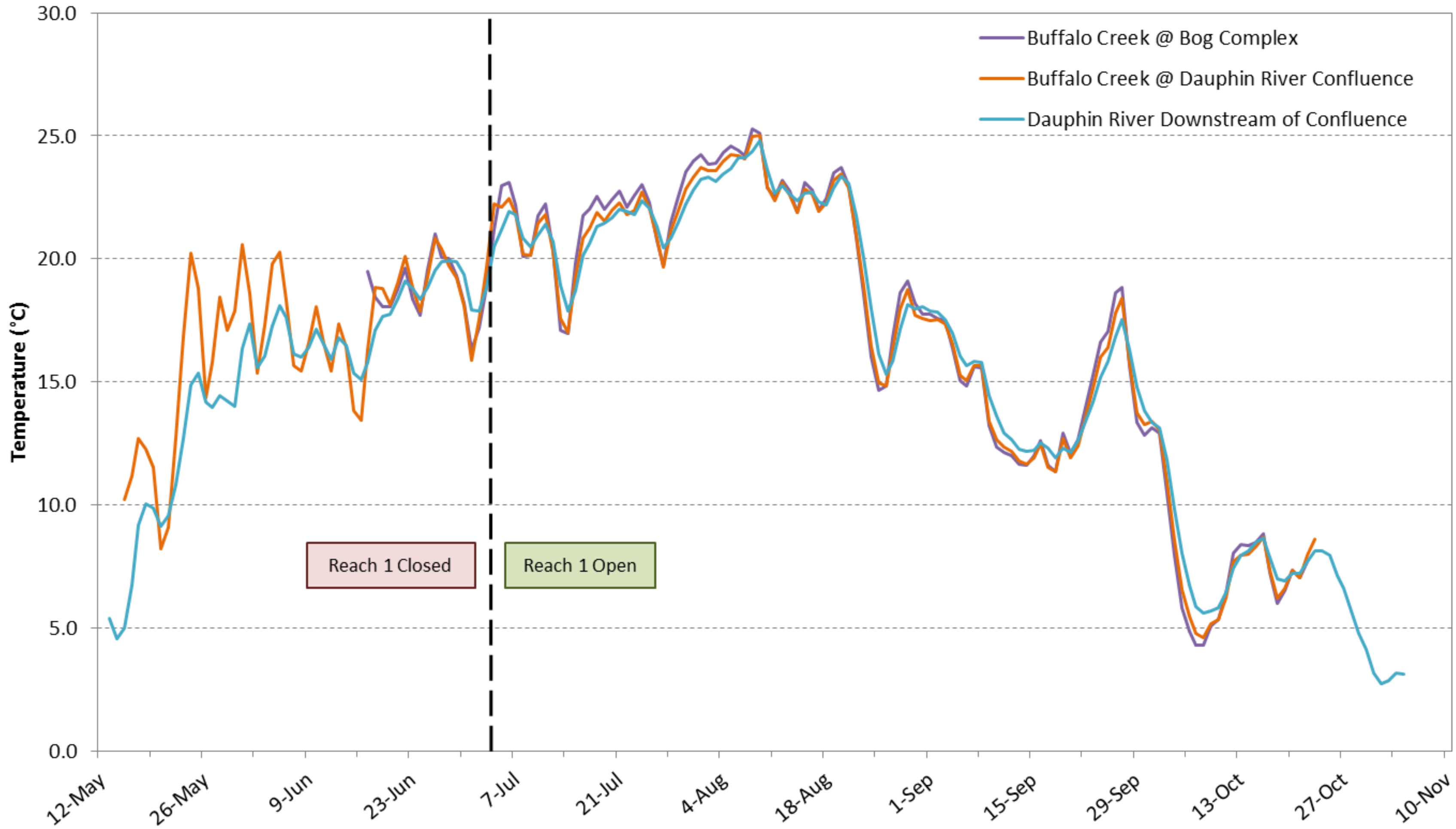

Figure 6C-5. Daily mean water temperature in Project waterbodies from the upper end of Buffalo Creek to the lower Dauphin River, 2014 open water season.