Severn Sound

Environmental Association

Port Severn Walleye Spawning Shoal Habitat Survey



December 2018

Port Severn Walleye Spawning Shoal Habitat Survey

Prepared by
Severn Sound Environmental Association

for the

Trent Severn Waterway

December 2018

Table of Contents

List of Tables ii
List of Figures ii
Foreword iii
Acknowledgements iv
List of Acronyms iv
Summary v
Introduction 1
Study area 1
Study Approach 3
Methods 3
Field Sampling 3
Flow 3
Substrate 4
Temperature 7
Photo Monitoring 7
Data Sources 8
Flow 8
Water Levels 9
Elevation 9
Modelling 10
Results and Discussion 10
Flow and Velocity 10
Substrate 16
Overall Habitat Suitability 20
Temperature Conditions and Reproduction Phenology 22
Conclusions 24
Recommendations for Future Work 24
References 26

List of Tables

Table 1. Dates photo monitoring was carried out and number of photos taken. ...7
Table 2. Low flow measurements taken at Port Severn spawning shoal September 15-22 2006 12
Table 3. Summary of dates for 5°C and 11°C spawning thresholds based on continuous temperature recorded below the Bayview Dam, and date range of likely hatching period from 2002-2016 using range of 12-18 days. 23

List of Figures

Figure 1. Port Severn – Lock 45, dams and shoal 1
Figure 2. Spawning area downstream of the Bayview Dam during spring conditions....2
Figure 3. Port Severn spawning shoal flow measurement sites, showing both flow transect and approximate substrate transect ID labels 4
Figure 4. Transect and photo-monitoring locations 5
Figure 5. Example of substrate images along transect #1100. 6
Figure 6. Example of substrate measurement method using a 1 m by 0.5 m section of a transect....7
Figure 7. Bayview Dam - September 5, 2006, taken from photo monitoring location B. 9
Figure 8. Water depth modelled under low flow conditions (leakage flow of 0.3 m^3/s) 13
Figure 9. Water depth suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s) 14
Figure 10. Water velocity modelled under low flow conditions (leakage flow of 0.3 m^3/s) 15
Figure 11. Velocity suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s)....16
Figure 12. Substrate interpreted from ground photo transects (water level represents spring flow conditions)....18
Figure 13. Substrate suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s)....19
Figure 14. Relative suitability index (or Weighted Useable Area, WUA) modelled under low flow conditions (leakage flow of 0.3 m^3/s)....21
Figure 15. Daily average water temperatures from 2002-2016 recorded below the Bayview Dam 23

Foreword

This report was prepared by Severn Sound Environmental Association (SSEA) staff and provides information on several years of investigation into the factors affecting the suitability of the walleye spawning shoal at Port Severn. The document should be read as a whole, with sections or parts hereof read or relied upon in context.

Prompted by dam renovations in 2018 (Port Severn area dams and bridges project), SSEA is working with the Trent Severn Waterway (TSW) to provide the following deliverables:

- photo monitoring images coupled with flow and water level data
- substrate transect photos
- model output graphics
- summary report

Renovations to the dam are expected to be completed by Dec 2018, with bridge work complete by spring 2019.

Reference to the spawning shoal is made in the Interim Fish Habitat Management Plan for the Severn Sound (SSRAP 1993) and the Stage 3 RAP Report (2003), indicating that walleye spawning sites need to be protected from spring harvest, as well as water level fluctuations in the downstream operation of Lock 45 through partnerships between Parks Canada/Trent-Severn Waterway, MNRF and SSEA. This report lays out a series of recommendations that will facilitate the management of the walleye spawning shoal.

Although the report received some technical review, this does not necessarily mean that the contents reflect the views and policies of the SSEA or the supporting partners, Parks Canada (TSW), Environment and Climate Change Canada (ECCC), Fisheries and Oceans Canada (DFO), and the Ministry of Natural Resources and Forestry (MNRF).

While efforts have been made to ensure that the supplied information is accurate and up-to-date, complete accuracy cannot be guaranteed. The project was based on available information and data sets, and unless otherwise stated, the SSEA has not verified the accuracy or completeness of the available information.

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The following people contributed to the field work and development of the management recommendations.

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The Town of Penetanguishene provided survey equipment and a technician to collect enhanced elevation points.

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List of Acronyms

CHS – Canadian Hydrographic Service
DEM – Digital Elevation Model
DFO – Fisheries and Oceans Canada
ECCC – Environment and Climate Change Canada
GPS – Global Positioning System
masl – m above sea level
MNRF – Ministry of Natural Resources and Forestry
SSEA – Severn Sound Environmental Association
TSW – Trent Severn Waterway
WUA – Weighted Useable Area

Summary

A survey of fish habitat in the Port Severn spawning shoal area below the Bayview Dam was completed during 2006 to provide flow management and timing window recommendations to the Trent Severn Waterway (TSW). The area is known spawning grounds for walleye in Severn Sound and is used by other migratory fish species (salmon, trout). Operation of the Bayview Dam may have an adverse impact on the downstream spawning area by altering water levels over the spawning bed and reducing flows. Fluctuations of water levels and water velocity during critical spawning periods and subsequent to spawning until egg hatch may seriously affect the success of the early life-stages of walleye by rendering some of the spawning shoal dry or stagnant during the spawning and hatch period, or by flushing of the shoal during high flows carrying eggs to unsuitable hatching areas.

The hydrodynamic model River2D was used to model stream velocities and habitat conditions. Data on depth, water velocity, and substrate were collected as inputs to the model:

- **Depth** - A digital elevation model (DEM) was developed in ArcGIS for the spawning shoal using a survey of the bed and shoreline, supplemented with additional elevation measurements by level, and points from the MNRF NRVIS database.
- **Velocity** - Velocity was measured across transects that were safely wadeable during low flow conditions. Flow at the Bayview Dam was estimated using the weir formula developed by TSW for stop log dams.
- **Substrate** - The shoal substrate was surveyed using an adaptation of a pebble count protocol. Substrate was mapped by first subdividing the spawning area into dominant sediment categories (e.g. clay, sand, gravel, cobble, boulder and exposed bedrock). A visual technique was used for assessing the substrate which involved collecting digital images along transects with a reference scale in view for analysis of substrate size fractions.

Once calibrated, the model was used to estimate a relative suitability index for walleye spawning at low flow and chart datum (Georgian Bay) water level conditions. Results from the River2D model showed that the pool area downstream of the dam has the majority of suitable spawning habitat under these conditions.

Photo monitoring sites were also established and panoramas taken under varying flow conditions from 2006-2018, which can be used to determine the depth of water over substrate under different flow conditions.

Water temperature is an important factor influencing walleye spawning and egg hatching on the shoal at Port Severn. Once spawning occurs (between 5 to 11°C), the eggs incubate in the substrate. The amount of time needed for

hatching to occur is based on the growing degree days from spawning, and generally ranges from 12-18 days after spawning. Continuous temperature data has been collected from late winter to fall each year (2002 to 2016) at a location just downstream of the dam. Knowing when the optimal spawning temperature range occurs can help water managers ensure there is enough flow coming from the Severn River to cover the spawning shoals and allow the fish to reproduce successfully.

Based on the modelling using River2D for low flow conditions, and an analysis of temperature data, recommendations for inputs to a management plan for the dam to maintain optimal habitat conditions over as much of the shoal area as possible include:

- a water velocity of 0.76 to 0.91 m/s,
- a depth range of 0.73 to 1.43 m,
- cobble substrate bottom
- an appropriate amount of water through the Bayview Dam for the spawning and egg incubation period for the entire months of April and May (greater than the leakage flow of 0.3 m^3/s)

Other considerations for a future management plan should include recent dam renovations, and changes to velocity below the dam under higher Georgian Bay lake levels.

Introduction

Study area

The area downstream of the Bayview Dam at Port Severn (Figure 1 and Figure 2) is a well-known walleye (*Sander vitreus*) spawning area (SSRAP, 1988). The dam is operated by Trent-Severn Waterway as part of the Lock 45 complex of dams for flow management and water level control in Little Lake and Gloucester Pool, which forms the terminus of the Severn River. The Severn River is the major inflow to Severn Sound.



Figure 1. Port Severn – Lock 45, dams and shoal. Source: Severn Sound Environmental Association, air photo taken July 2006 for Township of Tay.

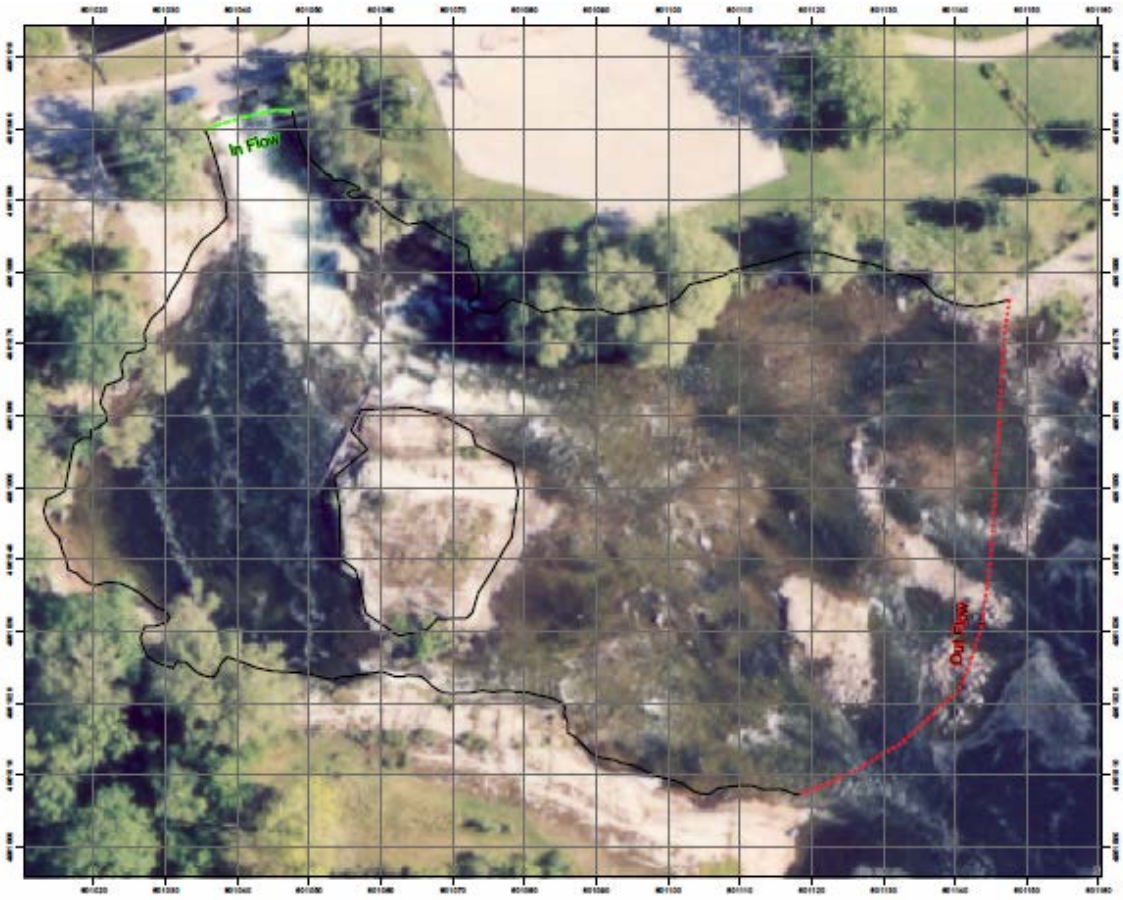


Figure 2. Spawning area downstream of the Bayview Dam during spring conditions (note 10 m grid). The black line delineates the area used for habitat modelling, with the green and red lines depicting the inflow and outflow, respectively, also used for modelling purposes.

The Port Severn dams and Lock 45 are the last water management structures on the Trent-Severn Waterway. The Severn River is a highly regulated waterway flowing into Severn Sound, Georgian Bay. The downstream sides of the dams have cascades that flow into Georgian Bay and, once the river reaches open water levels, it is subject to fluctuations in levels on Severn Sound. These can include longer-term (annual) fluctuations in static water level as well as daily or hourly seiche and wave uprush conditions caused by winds.

The spawning shoal is a series of pools and rapids that drop down in stages to the main channel flowing out into Severn Sound under the Highway 400 Bridge at Big Tug Channel. The area immediately downstream of the Bayview Dam is only accessible for conducting flow monitoring during times of low flow. During spring conditions when walleye spawning occurs, the area is inaccessible due to high flows and water levels.

Operation of the dam may have an adverse impact on the downstream spawning area by altering water levels over the spawning bed and reducing flows. Fluctuations of water levels and flow during critical spawning periods may

seriously affect the success of spawning by reducing the amount of optimal walleye spawning habitat, or by rendering some of the spawning shoal dry or stagnant during the spawning period.

Operation of the Bayview Dam by TSW influences the flow onto the shoal. Conditions on the shoal are also influenced by water level fluctuations on Georgian Bay. There have also been occasions where alteration of the shoal substrate has been carried out to enhance habitat conditions.

Study Approach

The goal of the survey was to improve understanding of the optimal fish habitat conditions (substrate, water levels and flow) in the spawning area downstream of the Bayview Dam.

The study approach taken was to measure and map key features of walleye spawning habitat (especially substrate and flow) when it was possible to access the shoal during base flow conditions. The information was assembled and used as input into a hydrodynamic model of the shoal. The model was then used to evaluate habitat under low flow and chart datum water level conditions.

Substrate, water velocity and elevation information were used as inputs to the River2D hydrodynamic model for the shoal. The model was then used to evaluate habitat under low flow and water level conditions. A weir formula developed by TSW for the Bayview Dam was used with log change records and water level data for Little Lake-Gloucester Pool to estimate high flows. High frequency temperature measurements were also made using data loggers in order to estimate the start of spawning and subsequent timing to egg hatch..

The purpose of this report is to summarize the survey methods and analysis of spawning habitat based on fieldwork from 2006/07. The model resulting from this study will provide an important technical basis for recommendations for dam operating procedures that will maximize the optimal walleye spawning habitat in the area as part of An Interim Fish Habitat Management Plan for the Severn Sound (SSRAP, 1993). This report will also estimate critical timing windows for spawning based on temperature in order to make recommendations on management actions to further maximize spawning success.

Methods

Field Sampling

Flow

Velocity measurements were made along transects during low flow conditions downstream of the dam using a Valeport EM or Marsh McBirney Flow Meter.

Cross-sectional flow measurements were calculated along transects across flowing portions of the shoal during low flow conditions (Figure 3). The velocity measurements were used to compare with River2D model predictions of habitat suitability. The flow measurements also gave a check on the amount of leakage through the dam at a time when virtually no water was overflowing the stop logs.

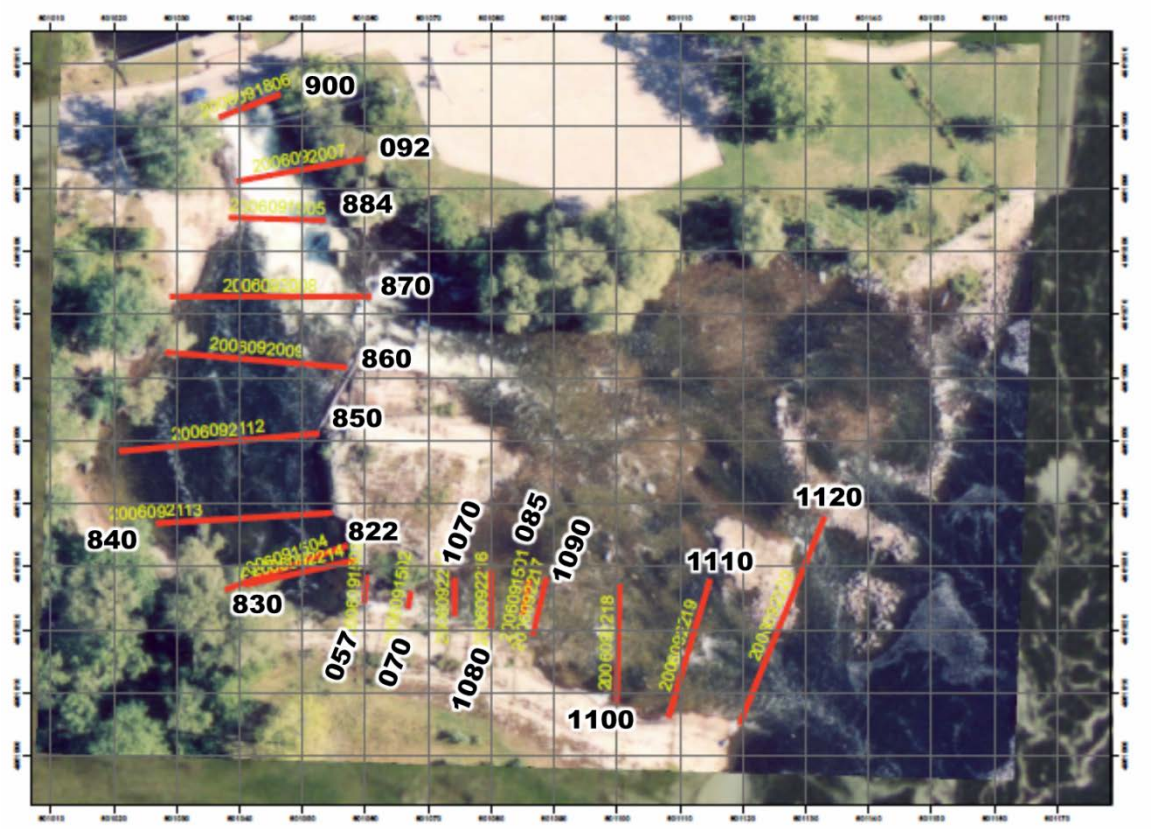


Figure 3. Port Severn spawning shoal flow measurement sites, showing both flow transect and approximate substrate transect ID labels. Flow transects roughly correspond with substrate transects. Transect 2006092111 is not shown, but is at the same location as 2006091502 (070).

Substrate

The substrate was surveyed using variations of the Wolman Method that were used in several similar studies of fish spawning substrates (Wolman 1954; Kondolf 1997; as modified by Streamkeepers of Clallam County, 2005 and Virginia Save Our Streams, 2006). Substrate was mapped by first subdividing the spawning area into dominant sediment categories (e.g. clay, sand, gravel, cobble, boulder and exposed bedrock). A visual technique for assessing the substrate was used that involved collecting digital images along transects with a reference scale in view for analysis of substrate size fractions, producing scaled images. Within cobble-dominated areas, images were sub-sampled to estimate mean particle size.

Transects were established at approximately 10 m intervals to collect the substrate data (Figure 4). A series of digital still and video images of the substrate along transects were stored for future processing. A scaled image was taken at points along each transect using a digital DVD video camera. The images from each transect were scaled digitally using ArcGIS 9.2 software and to facilitate the processing of each image. Observations through photo and video interpretation were made to determine the type of substrate found in the spawning bed (see Figure 5 for an example of images from one transect).

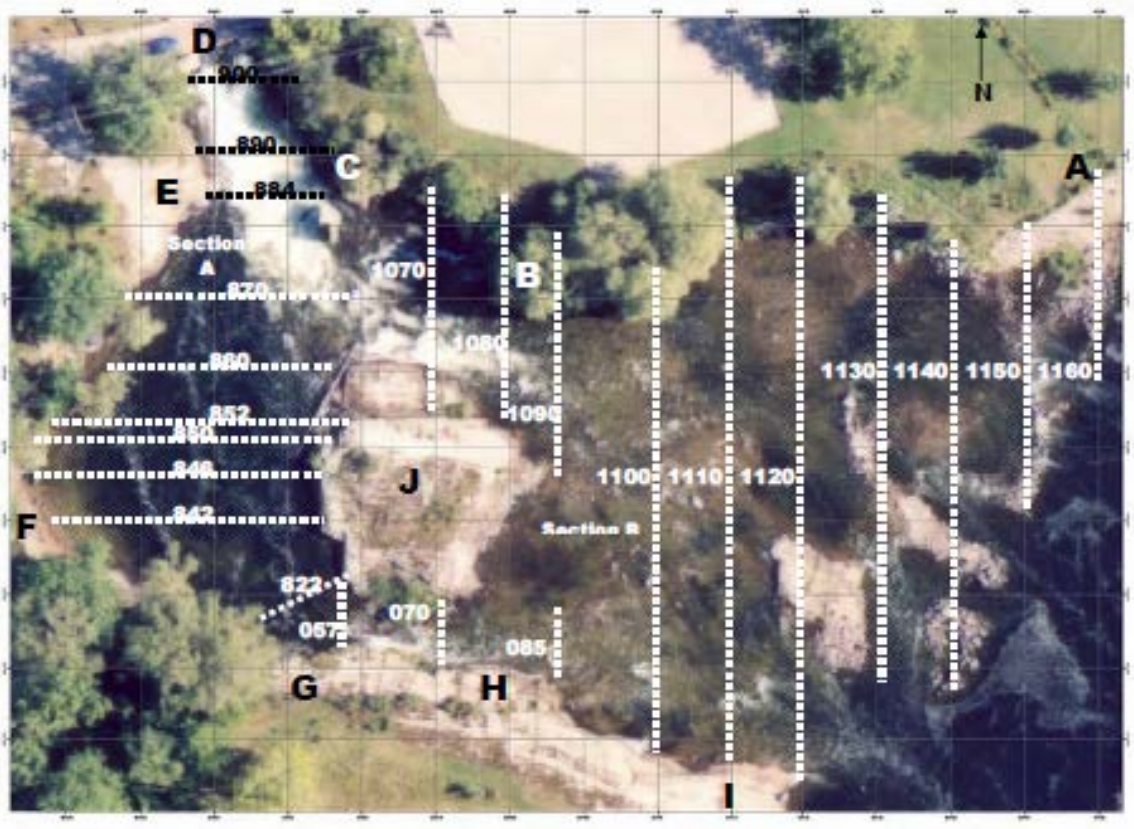


Figure 4. Transect and photo-monitoring locations. Note: Letters correspond to seasonal photo location and numbered transects correspond to substrate collection.



Figure 5. Example of substrate images along transect #1100.

The visible material in each image containing cobble (4 to 64 mm diam.) and boulder (256 mm and above) substrate was then measured on a computer screen. To facilitate a rapid estimate of the "median substrate diameter", a 10 cm grid was placed over the target image and 20% of the grid squares in the image (10 out of 50 grid squares) was randomly measured and used to represent the coarseness for that location of the bed (Figure 6). The median substrate size for each point in the transect was used to estimate Manning's roughness coefficient (Manning's *n*; Steffler and Blackburn 2002) based on the following equation:

$$n = \frac{R^{\frac{1}{6}}}{2.5\sqrt{g} \times \ln(\frac{12R}{k_s})}$$

n = Manning's roughness coefficient
R = hydraulic radius, m (*A*/*P*)
g = gravitational constant (9.8 m/s)
k_s = effective roughness height ($12R/e^m$)
A = cross-sectional area of channel, m^2
P = wetted perimeter of a cross section, m
m = correction factor for meandering of a channel ($R^{1/6}/(2.5n\sqrt{g})$)

The roughness coefficient represents the resistance to water flows in the channel and is an important input to the River2D model.

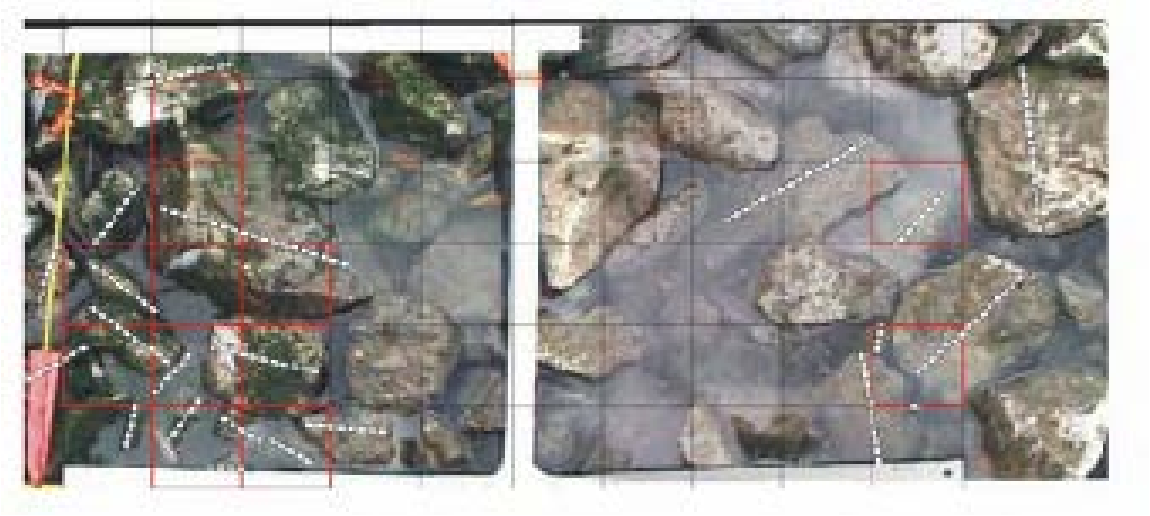


Figure 6. Example of substrate measurement method using a 1 m by 0.5 m section of a transect. The image was referenced to a grid consisting of 10 cm grid squares within ArcGIS 9.1. The red squares show the 20% random sample. Rocks that contact a red square were measured (dashed white line) using the measuring tool and recorded.

Temperature

High frequency temperature measurements were made between 2002 to 2016 using two StowAway Tidbit Temperature Loggers ® (TB132-5+37 Onset) located on the downstream side of the dam structure. Loggers were set to record temperature at 30 min intervals. In 2008 and 2011, daily temperatures were also compiled from measurements made of the raw water at the Township of Tay Rope Subdivision Water System (Township of Tay, unpublished data).

Photo Monitoring

Photo monitoring points (Figure 4) were also set up to provide a series of time-stamped panoramas and individual images of the spawning shoal under different flow and water level conditions. These images were useful in interpreting the effect of water level changes at different points within the spawning shoal. Photo monitoring was carried out from 2006-2017, dates for which are shown in Table 1.

Table 1. Dates photo monitoring was carried out and number of photos taken.

Year	Date	# Pics	Year	Date	# Pics
2006	10-Apr-06	21	2012	23-Feb-12	46
2006	01-May-06	13	2012	2-Mar-12	46
2006	13-Jun-06	44	2012	16-Mar-12	52
2006	07-Jul-06	54	2012	27-Mar-12	42
2006	09-Aug-06	50	2012	11-Apr-12	46
2006	23-Aug-06	22	2012	4-May-12	55
2006	05-Sep-06	89	2012	18-May-12	54

Year	Date	# Pics	Year	Date	# Pics
2006	11-Sep-06	78	2012	7-Jun-12	59
2006	15-Sep-06	0	2012	29-Jun-12	45
2006	18-Sep-06	2	2012	13-Jul-12	47
2006	19-Oct-06	43	2012	2-Aug-12	49
2006	30-Oct-06	76	2012	1-Oct-12	61
2006	02-Nov-06	121	2012	19-Oct-12	64
2006	19-Nov-06	78	2012	13-Dec-12	52
2006	13-Dec-06	6	2013	27-Mar-13	54
2007	14-Mar-07	62	2013	17-Apr-13	54
2007	29-Mar-07	19	2013	25-Jun-13	49
2007	03-Apr-07	30	2013	25-Oct-13	50
2007	18-May-07	60	2013	1-Nov-13	5
2007	28-Aug-07	46	2014	9-Apr-14	45
2008	10-Apr-08	79	2014	25-Apr-14	44
2008	18-Jul-08	15	2014	9-Jul-14	43
2008	27-Oct-08	24	2014	25-Nov-14	48
2009	24-Mar-09	7	2015	17-Mar-15	47
2009	1-Apr-09	64	2015	1-Apr-15	46
2009	21-May-09	17	2015	9-Apr-15	48
2010	17-Mar-10	64	2015	16-Apr-15	60
2010	25-Mar-10	11	2015	24-Apr-15	52
2010	7-Apr-10	18	2015	8-May-15	65
2011	14-Mar-11	95	2015	11-May-15	15
2011	22-Mar-11	103	2015	28-Jun-15	30
2011	31-Mar-11	109	2015	13-Jul-15	54
2011	2-Apr-11	9	2015	9-Oct-15	62
2011	8-Apr-11	84	2015	17-Nov-15	58
2011	14-Apr-11	94	2016	7-Apr-16	57
2011	20-Apr-11	71	2016	19-Apr-16	50
2011	27-Apr-11	72	2016	21-Jul-16	65
2011	3-Jun-11	64	2016	18-Oct-16	52
2011	5-Jul-11	63	2017	28-Mar-17	65
2011	25-Jul-11	59	2017	13-Jul-17	46
2011	16-Aug-11	63	2017	12-Oct-17	72
2011	7-Oct-11	46	2018	23-Oct-18	31
2011	4-Nov-11	53			

Data Sources

Flow

The Bayview Dam is a standard single sluice, 2.8 m (20 ft) stop log dam used throughout the Trent-Severn Waterway (TSW) system (Figure 7). The dam can hold a maximum of nine 305 mm (12 inch) logs and is used to augment flow and for water level management upstream of the main dam at Port Severn (Figure 1). The TSW provided a weir formula look-up table for the sluice that uses measured water level upstream of the dam and the number of logs in the dam to estimate

flow. The formula also incorporates a leakage flow, which varies depending on water level and on how well the logs fit in the sluice.

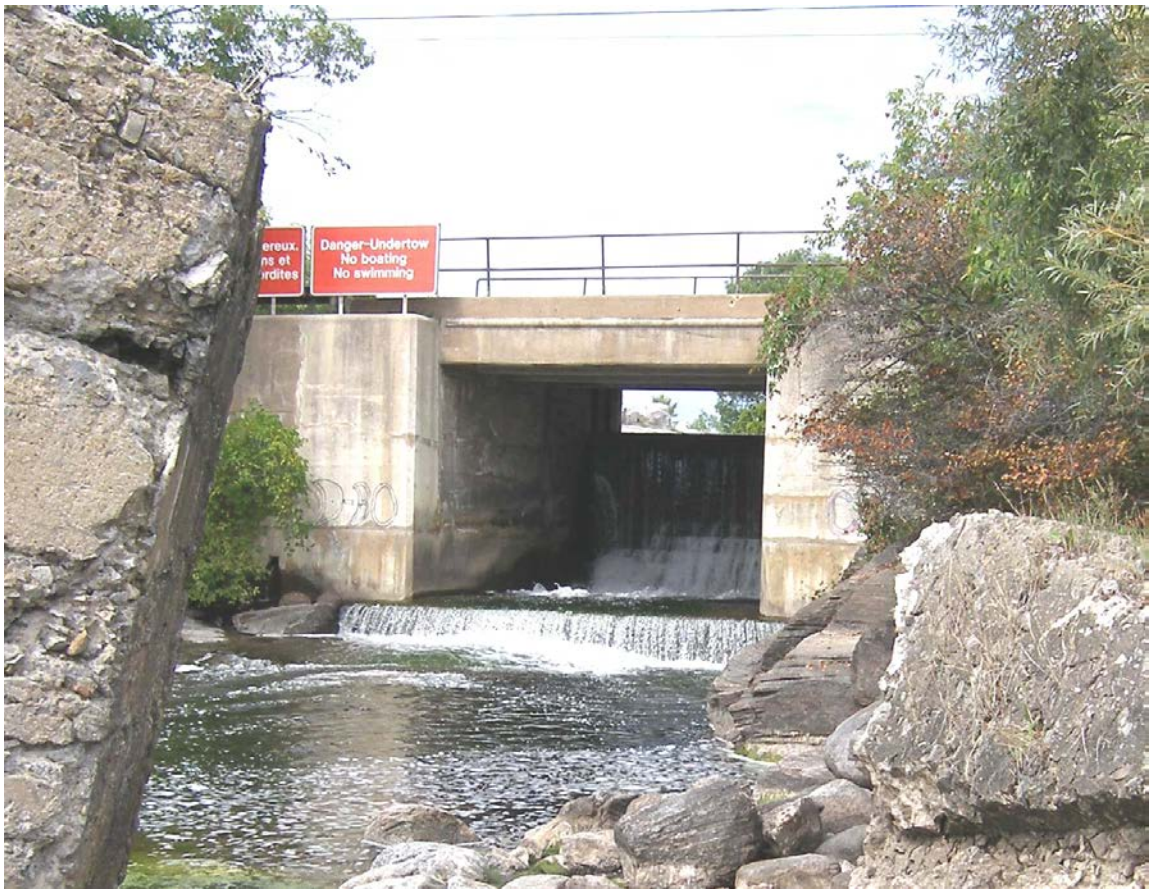


Figure 7. Bayview Dam - September 5, 2006, taken from photo monitoring location B.

For calculation purposes, the elevation of the sluice with all nine logs in and with no flow over the top log was assumed to be 180.51 masl (m above sea level - based on low flow observation of water level in Little Lake during 2006).

Water Levels

Water levels in Little Lake upstream of the dam were obtained from TSW records (provided from 2006-2017, excluding Jun 15 2009-Mar 31 2014). Water levels measured hourly by Canadian Hydrographic Service (CHS) Great Lakes water level gauges at Collingwood (2001 to 2018) and Midland (2009 to 2018) were used for the water levels downstream of the dam.

Elevation

Elevation and location data were used to generate a topographic model for input to the River2D model. Over 750 elevation data points were collected using automated survey equipment. Additional Global Positioning System (GPS) points

were collected to locate the water's edge along the spawning area. Elevation points were also provided by MNRF and the County of Simcoe from the Greater Toronto Area ortho-photo project and MNRF's Ontario Base Map data set.

The combined elevation points were entered into a Triangulated Irregular Network in order to generate a Digital Elevation Model (DEM) in ArcGIS. The elevation data was then transferred to the substrate transect points. The location and elevation are direct inputs to the River2D model.

Modelling

Optimal water velocity, depth and substrate have been described for walleye spawning (McMahon *et al*., 1984). In order to evaluate fish habitat conditions for spawning in the downstream area of the Bayview Dam a computer model developed at the University of Alberta called River2D was used (Steffler and Blackburn, 2002). This is a two-dimensional, depth-averaged model of river hydrodynamics and fish habitat that produces estimates of velocity and depth which are used to produce optimal habitat conditions for spawning. Using the model, comparisons can be made between several flow conditions, based on the number of stop logs in the dam, to determine the flow rates that provide optimal spawning habitat. The data collected for input into the model include: flow, substrate, and elevation. For the purpose of the River2D model, downstream (Georgian Bay) water levels were set to chart datum at 176.0 masl. Georgian Bay water level fluctuations were not included as an input to the model but could be considered in the future.

Results and Discussion

The model inputs were prepared using the above mentioned data. The River2D model produced various habitat suitability outputs, as discussed below. Also discussed are the results of direct measurements and analyses of habitat features (e.g. flow, temperature) in the context of the Bayview Dam and downstream shoal.

Flow and Velocity

The Severn River flows through Gloucester Pool and Little Lake before discharging through the series of dams. The navigation range for Gloucester Pool is 180.42 – 180.50 masl. Levels are drawn down in the winter to about 180.20 masl. Water level management for hydro generation at the Swift Rapids dam can also result in short-term fluctuations in the entire downstream system. Long term minimum daily flow for the Severn River at Swift Rapids during March-April (2006-2017) was 15 m^3/s, and maximum daily flow over the same period was 224 m^3/s.

The management of water levels above the dams is achieved by lifting or replacing logs from the main dam but may also involve lifting or replacing logs at the other smaller dams as necessary. Effort is made to make changes at the smaller dams, such as the Bayview Dam, in a gradual manner to maintain some flow through these smaller areas for fish habitat purposes.

Flow over the Bayview Dam ranged from measured leakage values of 0.30 m^3/s to overflows of 11.00 m^3/s during the initial photo monitoring period from spring to fall 2006 (based on the TSW weir formula). The maximum flow observed during the survey was 11.85 m^3/s over the Bayview Dam.

During low flow conditions in 2006, a ridge of exposed bedrock, including the island in the middle of the shoal, forced all flow to exit the pool through a narrow channel west of the island. Measurements collected by SSEA showed that maximum velocities during low flow were found immediately downstream of the dam and in the narrow channel west of the island (Figure 3, Table 2). Direct measurement of cross-sectional area and velocity immediately downstream of the dam was not always possible due to water turbulence, even during low flow conditions. Velocity was measured across transects that were safely wadeable (only during low flow conditions). It was not possible to obtain velocity measurements during mid to high flow conditions using flow meters.

Table 2. Low flow measurements taken at Port Severn spawning shoal September 15-22 2006. Cross sections were taken along transects shown in Figure 3, which roughly correspond with the substrate transects in Figure 4. At transect 860, mean depth, cross sectional area, mean/max velocity and flow are underestimated because a full transect could not be completed due to unsafe wading depth in the middle (total of 2 m distance missed).

Cross-section ID	Approx. Transect ID	Mean Depth (m)	Max Depth (m)	Cross-section Area (m^2)	Mean Velocity (m/s)	Max Velocity (m/s)	Flow (m^3/s)	Comments
2006091501	085	0.47	0.66	1.84	0.18	0.29	0.34	
2006091502	070	0.83	1.18	1.78	0.26	0.33	0.45	
2006091503	057	0.18	0.29	0.66	0.55	1.04	0.37	slightly E of substrate transect
2006091504	822	0.70	0.92	13.63	0.03	0.07	0.35	slightly diff. starting points than substrate transect
2006091505	884	0.70	1.80	8.34	0.06	0.10	0.45	
2006091806	900	0.55	0.95	5.81	0.05	0.19	0.34	
2006092007	092	0.63	0.91	6.82	0.11	0.51	0.51	no substrate transect equivalent
2006092008	870	0.51	1.36	10.79	0.04	0.12	0.46	
2006092009	860	*0.64	>1.40	*15.24	*0.02	*0.08	*0.67	
2006092111	070	0.80	1.20	1.74	0.27	0.48	0.44	same location as 2006091502
2006092112	850	0.67	1.19	20.54	0.02	0.23	0.67	
2006092113	840	0.50	0.92	13.36	0.03	0.07	0.49	no substrate transect equivalent
2006092214	830	0.46	0.75	7.74	0.04	0.17	0.38	no substrate transect equivalent
2006092215	1070	0.32	0.50	1.53	0.22	0.33	0.41	diff. location than substrate transect (S portion of flow)
2006092216	1080	0.26	0.45	1.95	0.14	0.29	0.41	diff. location than substrate transect (S portion of flow)
2006092217	1090	0.15	0.33	1.09	0.40	0.61	0.45	diff. location than substrate transect (S portion of flow)
2006092218	1100	0.23	0.40	3.72	0.15	0.45	0.48	only flowing portion of substrate transect
2006092219	1110	0.20	0.50	2.58	0.02	0.09	0.12	only flowing portion of substrate transect
2006092220	1120	0.24	0.66	4.87	0.03	0.29	0.41	only flowing portion of substrate transect

The model estimate of habitat suitability based on depth (Figure 8 and Figure 9) under low flow conditions indicates that the pool area has the largest area of high suitability (scale of 0-1, colour gradient of blue [0] to red [1]) while most of the remainder of the shoal has low suitability. This is understandable since water level is related, in-part, to flow over the dam.

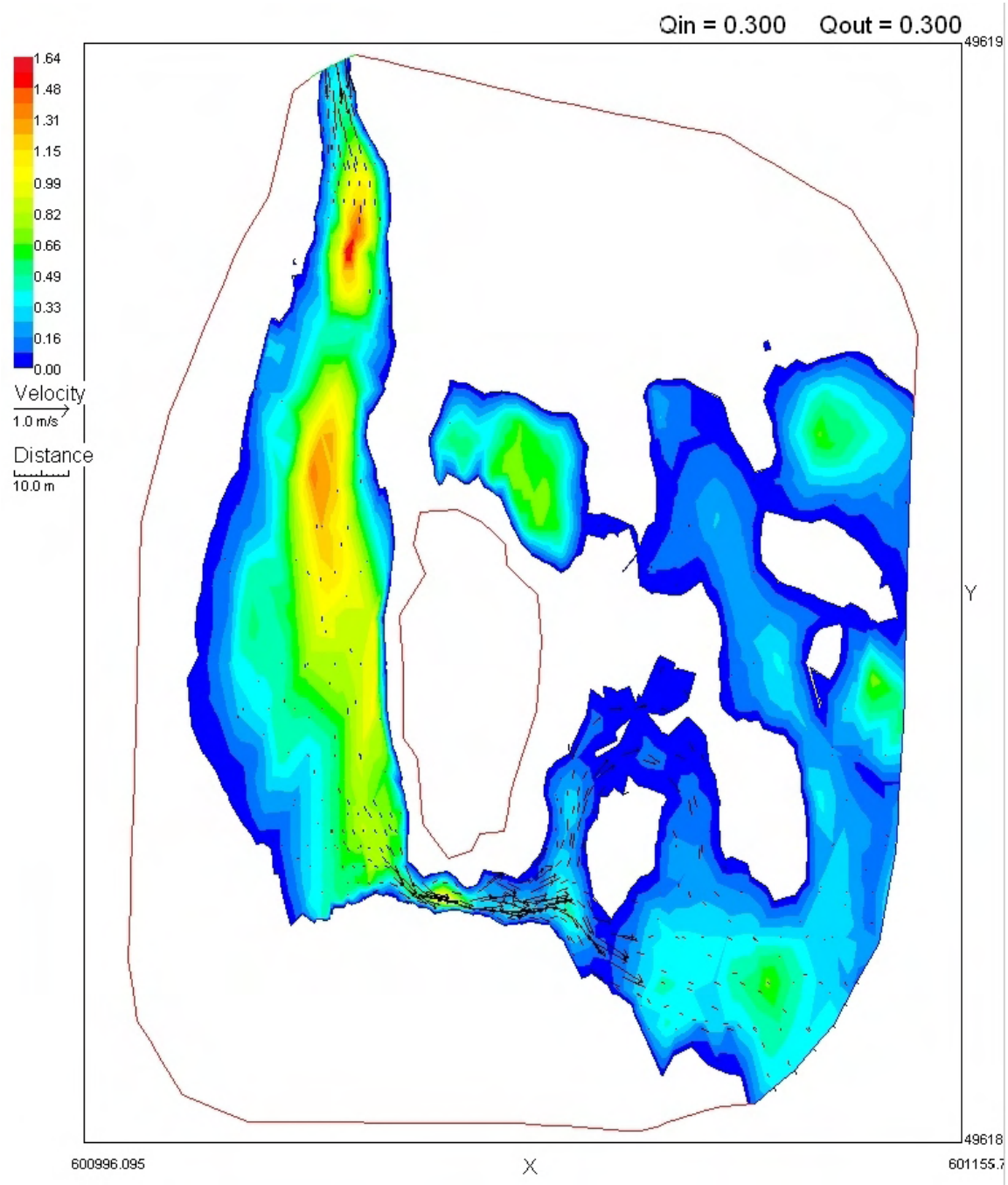


Figure 8. Water depth modelled under low flow conditions (leakage flow of 0.3 m^3/s). Shallow depth is indicated by dark blue, and increasing depth follows the colour scale, with red indicating the maximum.

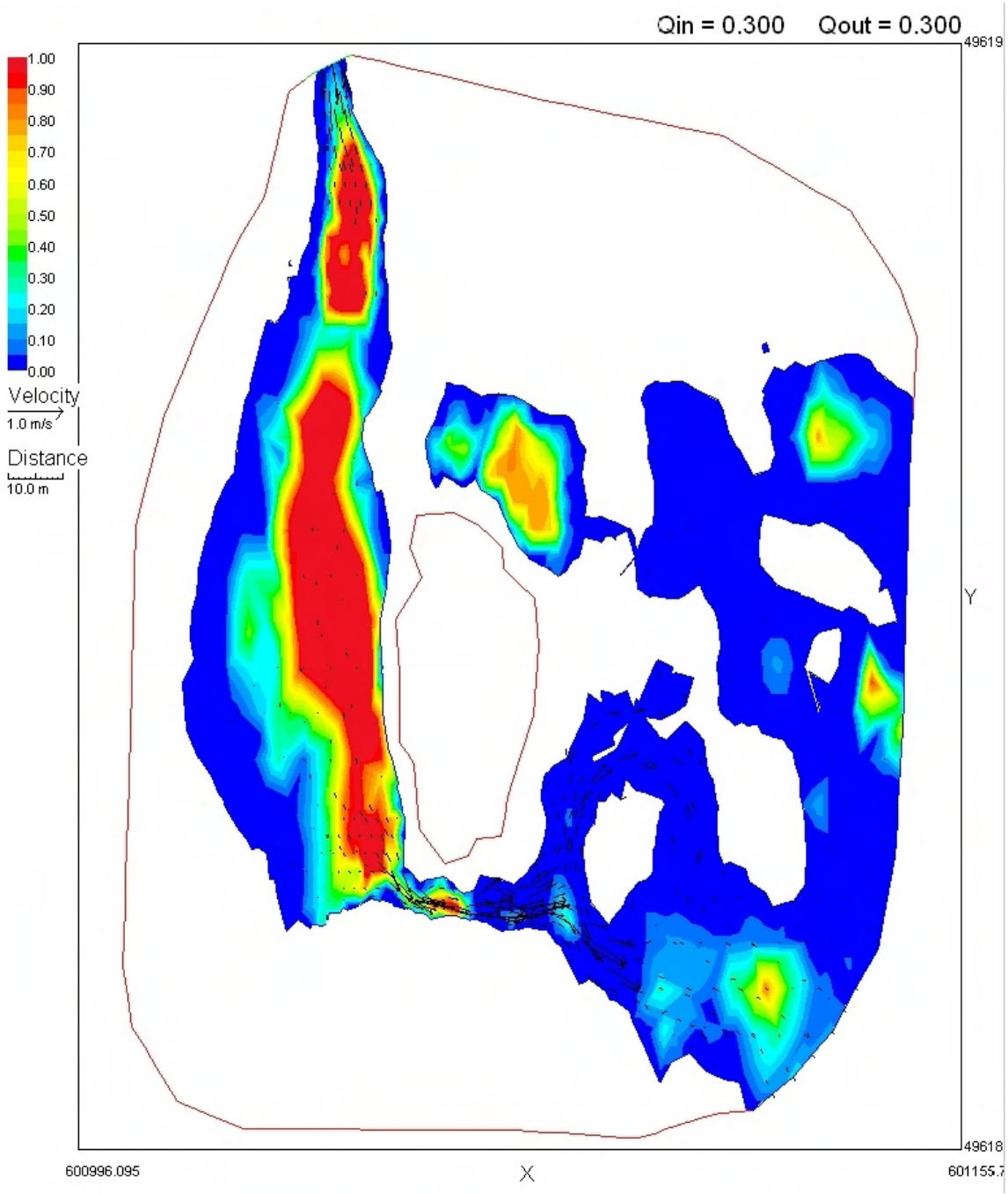


Figure 9. Water depth suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s). Low suitability is indicated by dark blue, and increases with the colour scale, with red indicating maximum suitability.

Velocity during low flow conditions (i.e. with virtually no water flowing over the sluice, only leakage – Figure 10) was similar to the observed conditions with highest velocities found downstream of the dam (shown as red/yellow) and in the channel west of the island. The model estimate of habitat suitability based on

velocity (Figure 11) was generally low (blue) throughout the shoal under these conditions.

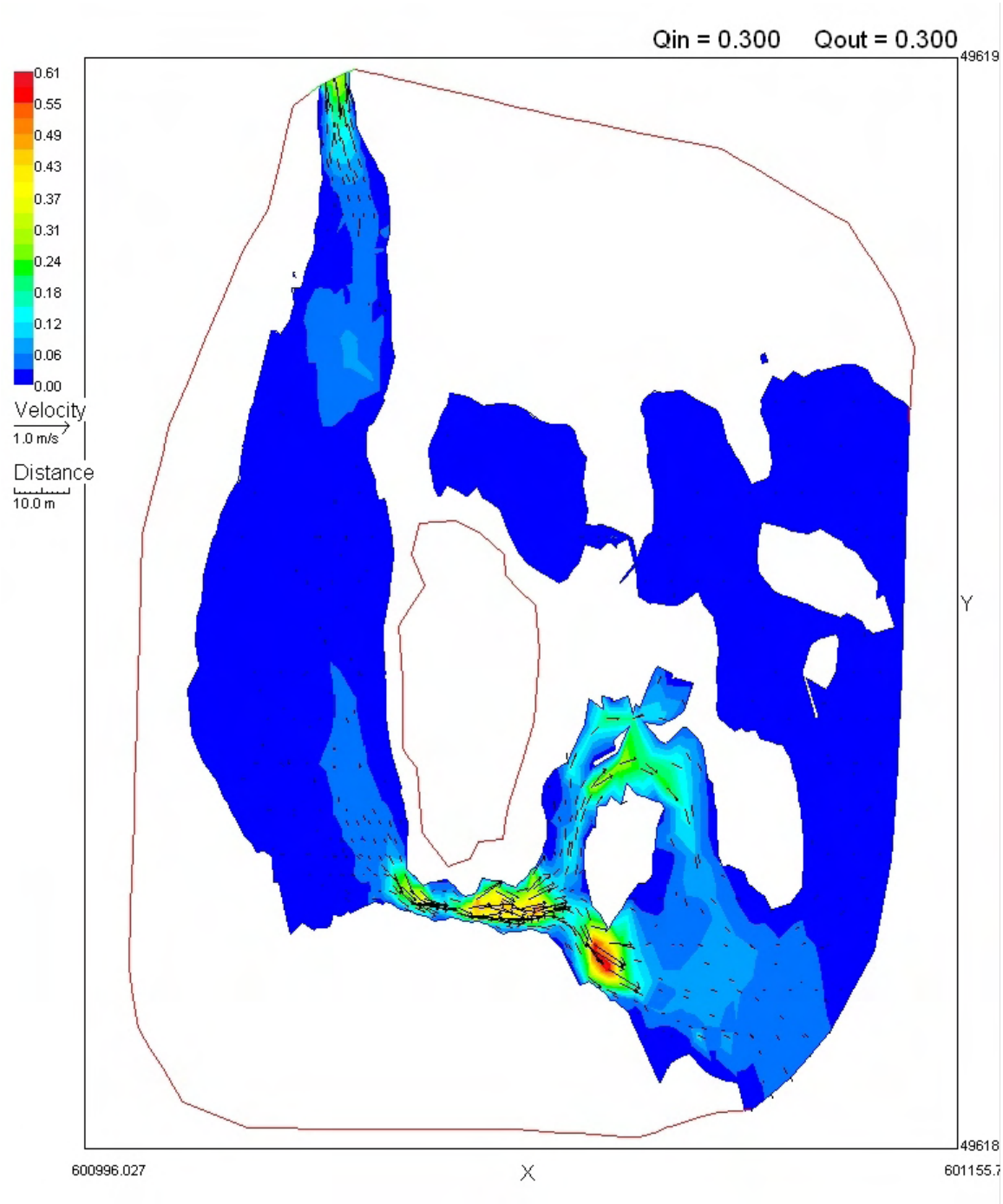


Figure 10. Water velocity modelled under low flow conditions (leakage flow of 0.3 m^3/s). Low velocity is indicated by dark blue, and increasing velocity follows the colour scale, with red indicating the maximum.

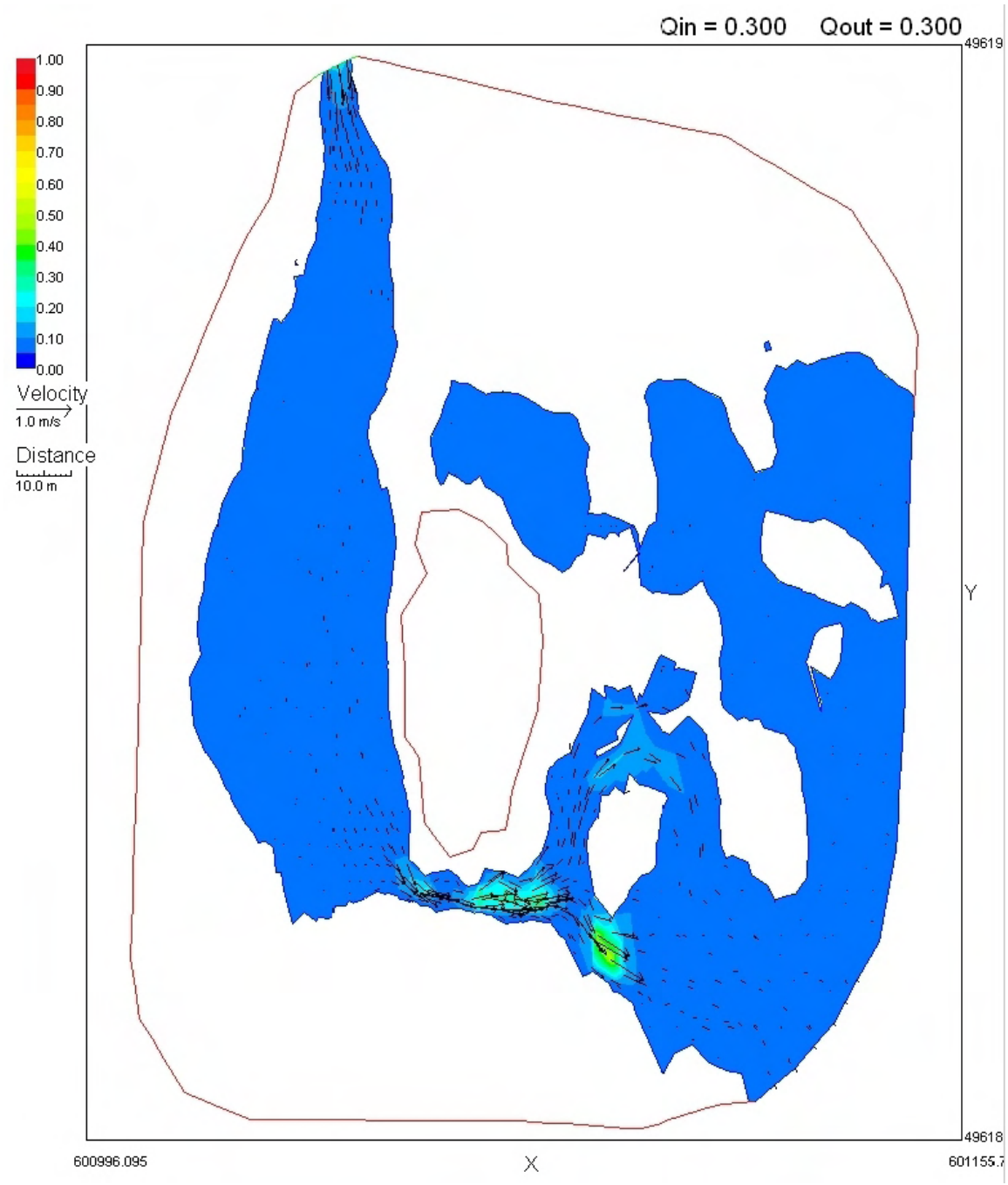


Figure 11. Velocity suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s). Low suitability is indicated by dark blue, and increases with the colour scale, with red indicating maximum suitability.

Substrate

The spawning shoal was divided into sections based on predominant substrate (Figure 12). The pool area immediately downstream of the dam is naturally reinforced by bedrock. Substrate in the pool consisted of bedrock and boulders

near the dam, sand over bedrock in the deeper areas, with sand at the western end grading to pebbles with some cobble. At the western end of the pool, the substrate was predominantly of clay.

The clay and pebble area also had a more or less continuous layer of live dreissenid (zebra and quagga) mussels and empty shells. Alteration of walleye habitat due to the impact of dreissenid mussels has been documented in other areas of the Great Lakes (Kerr *et al*. 2004). However, other studies have shown that mussel impacts on walleye survival appear to be highly variable. Fitzsimons *et al*. (1995) studied the effects of zebra mussel establishment on walleye spawning beds within Lake Erie. Despite almost complete coverage of the shoal by zebra mussels, walleye did not change their preference for spawning at these locations and no impacts to egg deposition, viability and walleye reproduction were observed (Fitzsimons *et al*., 1995). Similarly, Nienhuis *et al.* (2014) found that the presence of zebra mussels within Ontario waterbodies did not result in reduced walleye condition compared to individuals in uninvaded lakes, indicating that spawning was not directed impacted by zebra mussel establishment. The presence of zebra mussels was implicated as a factor inhibiting the feeding ecology of larval and young of the year walleye (Nienhuis *et al*., 2014). Given this evidence, it is reasonable to conclude that the presence of zebra mussels in the substrate below the Bayview Dam may have no significant effects on the spawning success of walleye at this location, but may influence larval and juvenile feeding.

The total area of the wetted shoal under spring conditions (the maximum potential wetted area, see red line in Figure 12) is estimated at 0.74 ha. Under low flow conditions, the wetted shoal area is reduced to 0.31 ha (a reduction of 58%).

The model output of substrate suitability under low flow conditions (Figure 13) indicates that more than 80% of the wetted area has substrate suitability greater than 0.40 (1 indicating perfect suitability). The areas of low substrate suitability coincide with areas of exposed bedrock.

Walleye are broadcast spawners, releasing eggs that are sticky at first, but later lose their adhesiveness and settle in to crevasses in the substrate (Scott and Crossman 1973). For this reason, fine sediments and bedrock areas are not suitable for successful spawning.

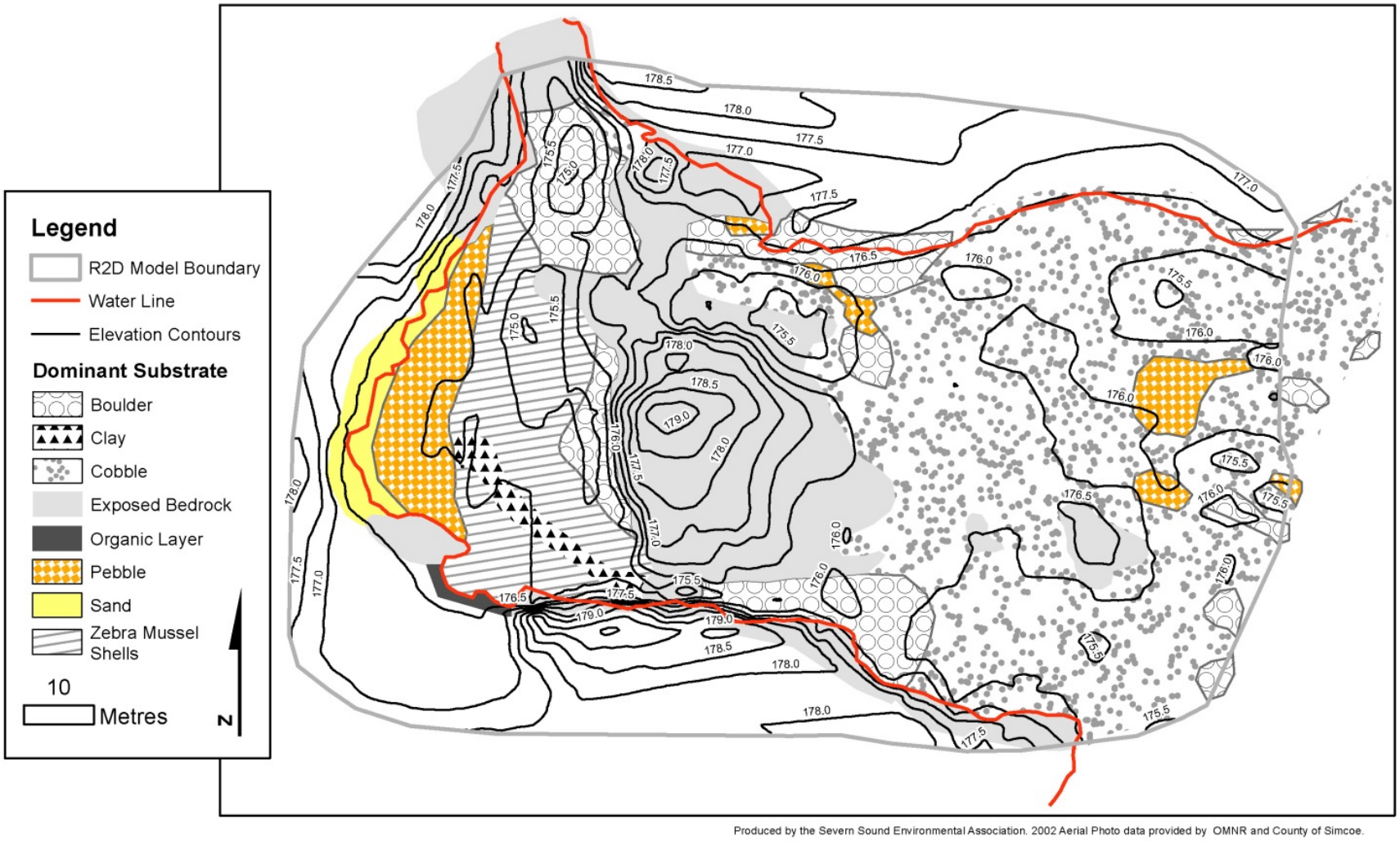


Figure 12. Substrate interpreted from ground photo transects (water level represents spring flow conditions).

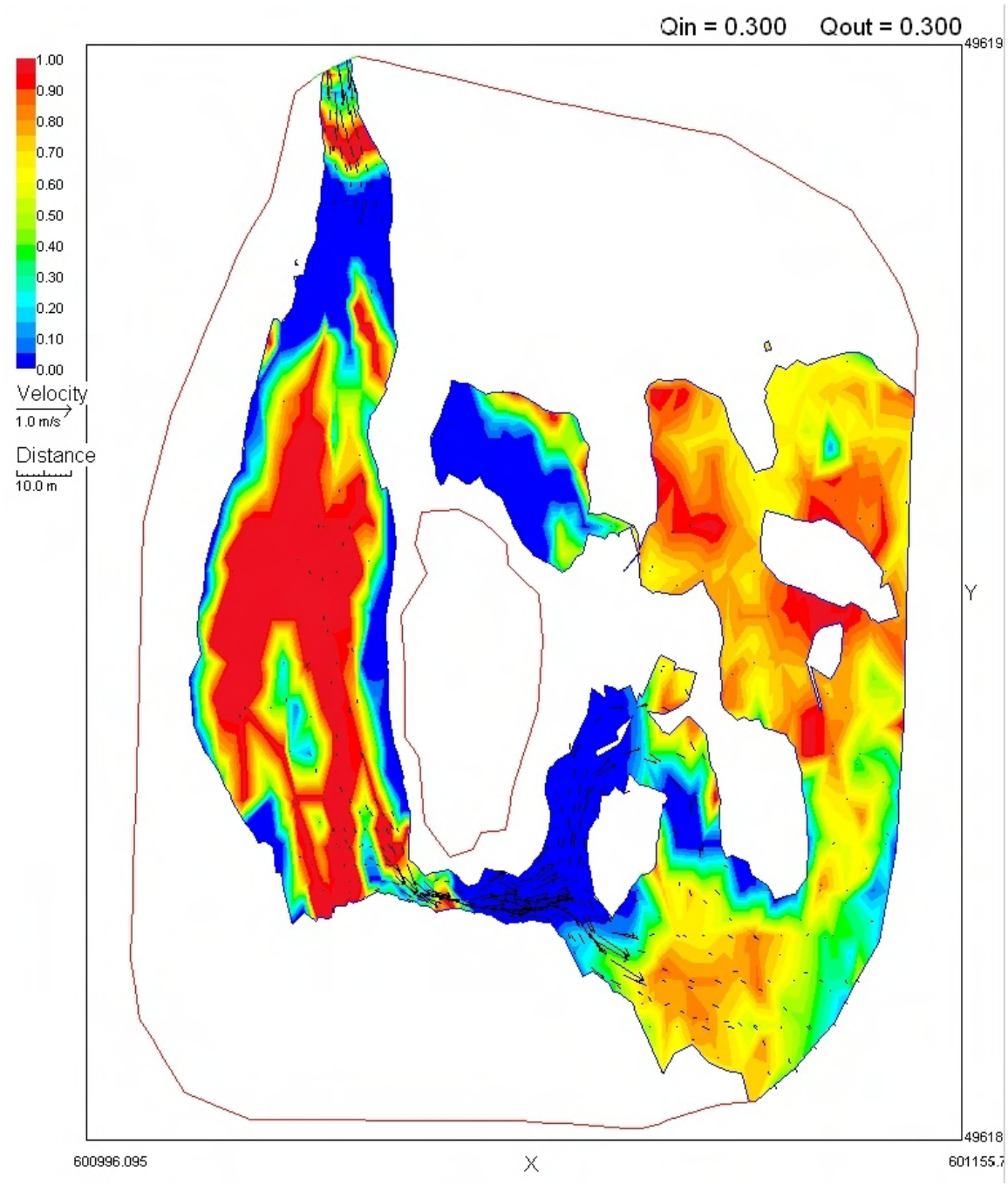


Figure 13. Substrate suitability modelled under low flow conditions (leakage flow of 0.3 m^3/s). Low suitability is indicated by dark blue, and increases with the colour scale, with red indicating maximum suitability.

Based on the substrate material, there appears to be high substrate suitability (red/yellow) over the entire potential area if water flow over the dam could be maintained to provide more water over the shoal and if the water level over the substrate could be maintained.

Overall Habitat Suitability

The combination of water depth, velocity and substrate suitability indices were used in the River2D model to provide a relative suitability index (also referred to as weighted usable area), which was equal to approximately 41 (Figure 14). The index is interpreted as the total surface area having a certain combination of conditions, multiplied by the composite probability of spawning use for that combination of conditions. This procedure gives a unitless index that roughly equates an area of marginal habitat to an equivalent area of optimal habitat (Bovee and Cochnauer 1977). The net combination of the components of habitat suitability for walleye spawning habitat under low flow conditions indicate that the pool has the majority of suitable spawning habitat. To achieve the highest suitability of walleye spawning habitat for an area, an optimal water velocity of 0.76 to 0.91 m/s, depth range of 0.73 to 1.43 m combined with a cobble substrate bottom would have to be maintained. Changes to water depths due to fluctuating Georgian Bay water levels and increased or decreased velocities due to upstream dam conditions will have an effect on the modelled habitat suitability. Changes to substrate are unlikely but could occur over time or if disturbance or enhancement to the spawning bed occurs.

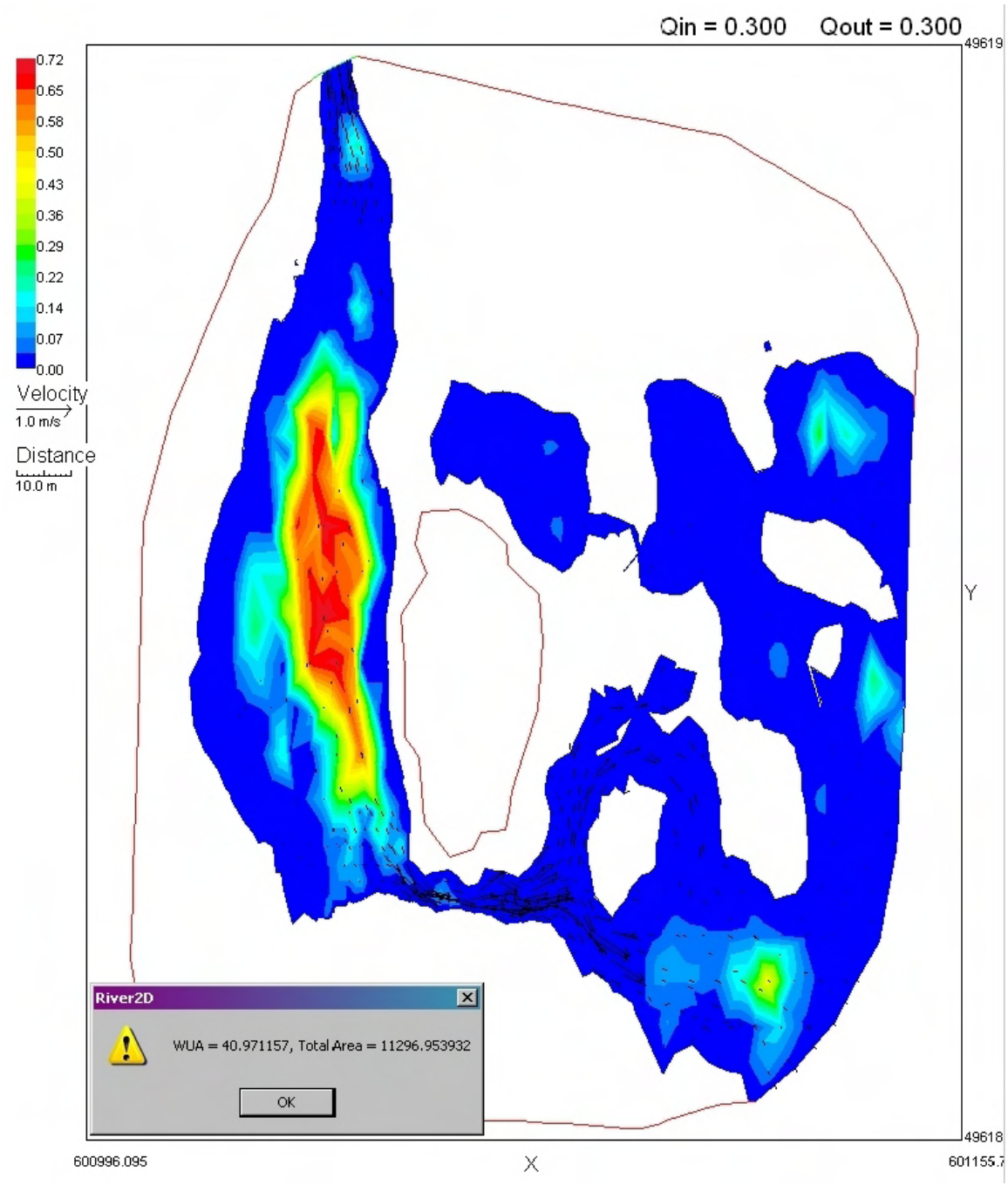


Figure 14. Relative suitability index (or Weighted Useable Area, WUA) modelled under low flow conditions (leakage flow of 0.3 m^3/s). Low suitability habitat based on depth, velocity and substrate suitability indices is indicated by dark blue, and increasing suitability follows the colour scale, with red indicating the maximum.

It is clear that conditions during spawning time for walleye at the shoal include significantly more water depth and velocity over the already predominantly suitable habitat than the modelled conditions. The model has been used to evaluate habitat suitability for walleye under low flow conditions (leakage flow). It was not possible to get the model to reach steady state under high flow

conditions, in part, due to inadequate data on the upper elevations of the model area. Preliminary comments from the model advisors suggest that additional measurements of velocities and water elevations under higher flow conditions would allow model runs at varying flow and water level conditions to reach steady state and allow the estimation of habitat suitability. In the future, we hope to obtain the necessary data to produce a model that can estimate habitat suitability under high flow conditions.

Temperature Conditions and Reproduction Phenology

Walleye begin spawning at water temperatures between 6.7-8.9°C, although the range has been observed as wide as 5.6-11.1°C (Scott and Crossman 1973). Egg hatching generally begins in 12-18 days, depending on water temperature, and 10-15 days after hatching, the young disperse into the open waters overlaying the spawning grounds (Scott and Crossman 1973; Kerr *et al*. 2004). In the spring, temperatures rise quickly downstream of the Bayview Dam (Figure 15), but there is wide variation among years in dates when the 5°C and 11°C thresholds are reached (Table 3). Between 2002-2016, dates when the ~5°C spawning threshold was reached ranged from Apr 1 – Apr 29, and dates when the ~11°C spawning threshold was reached ranged from Apr 16 – May 12. Between 2002-2016, the earliest date hatching is likely to have occurred is Apr 13 (based on 12 days post 5°C threshold), while the latest hatching is like to have occurred is May 30 (18 days post 11°C threshold). Therefore, in order to ensure successful reproduction of walleye, it's important that enough water comes through the Bayview Dam for the entire months of April and May. This is a conservative range based on estimates for earliest likely start of spawning and latest likely egg hatching.

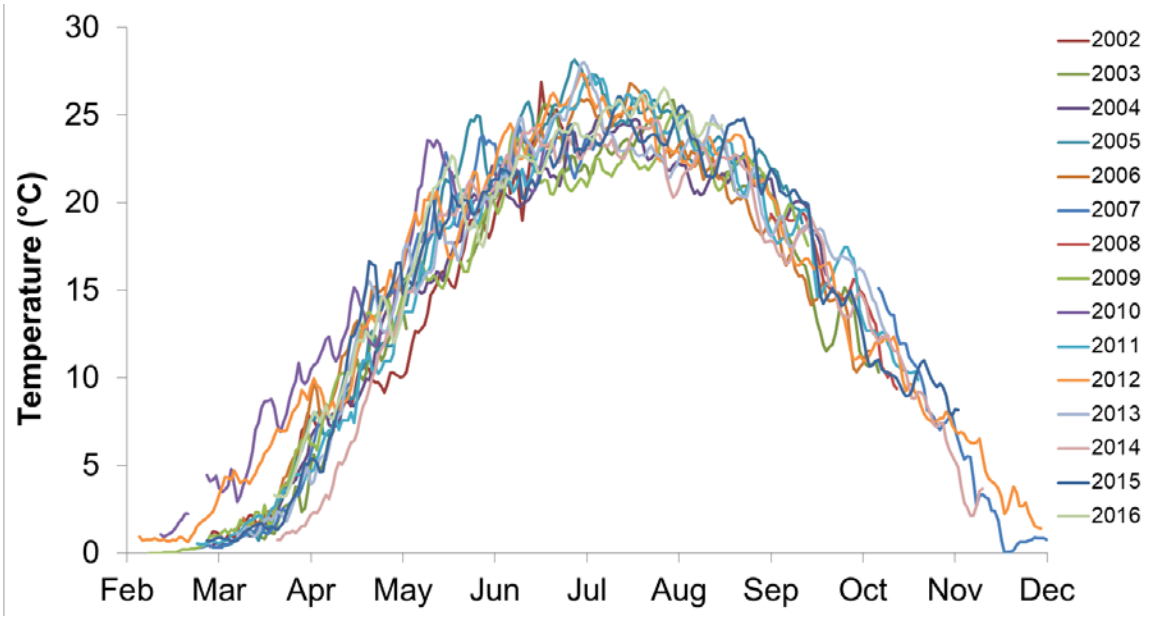


Figure 15. Daily average water temperatures from 2002-2016 recorded below the Bayview Dam. Based on continuous temperature data recorded every 30 min.

Table 3. Summary of dates for 5°C and 11°C spawning thresholds based on continuous temperature recorded below the Bayview Dam, and date range of likely hatching period from 2002-2016 using range of 12-18 days. An asterisk* indicates years where temperatures from Rope subdivision (Township of Tay) were incorporated to determine spawning threshold dates.

Year	5°C Date	11°C Date	12 Days Post 5°C Date	18 Days Post 11°C Date
2002	16-Apr-02	6-May-02	28-Apr-02	24-May-02
2003	20-Apr-03	5-May-03	2-May-03	23-May-03
2004	16-Apr-04	10-May-04	28-Apr-04	28-May-04
2005	15-Apr-05	8-May-05	27-Apr-05	26-May-05
2006	14-Apr-06	30-Apr-06	26-Apr-06	18-May-06
2007	19-Apr-07	4-May-07	1-May-07	22-May-07
*2008	16-Apr-08	11-May-08	28-Apr-08	29-May-08
2009	15-Apr-09	3-May-09	27-Apr-09	21-May-09
2010	1-Apr-10	16-Apr-10	13-Apr-10	4-May-10
*2011	22-Apr-11	7-May-11	4-May-11	25-May-11
2012	3-Apr-12	3-May-12	15-Apr-12	21-May-12
2013	23-Apr-13	3-May-13	5-May-13	21-May-13
2014	29-Apr-14	12-May-14	11-May-14	30-May-14
2015	18-Apr-15	2-May-15	30-Apr-15	20-May-15
2016	15-Apr-16	3-May-16	27-Apr-16	21-May-16
Min Date	**Apr 1**	Apr 16	Apr 13	May 4
Max Date	Apr 29	May 12	May 11	**May 30**

Conclusions

An inventory of conditions below the Bayview Dam was taken in 2006 which included elevation, velocity based on field flow measurements, and substrate conditions using a pebble count method. These data were inputs to the River2D model, which modelled suitability for walleye spawning habitat.

Results from the River2D model showed that the pool area downstream of the dam has the majority of suitable spawning habitat based on the net combination of the components of habitat suitability for walleye spawning habitat (water depth, velocity and substrate conditions) under low flow conditions.

To achieve the highest suitability of walleye spawning habitat for the area, an optimal water velocity of 0.76 to 0.91 m/s, depth range of 0.73 to 1.43 m combined with a cobble substrate bottom should be maintained.

To ensure successful reproduction of walleye, it's important that enough water comes through the Bayview Dam for the entire spawning and egg incubation period for the entire months of April and May. It is critical to bear in mind that high flow is as destructive as insufficient flow.

Walleye are a commercially, recreationally and culturally important species in Severn Sound, and recovery and maintenance of their populations is dependent on successful spawning. Positive management actions taken by the TSW in maintaining appropriate flows over the Bayview Dam for a sufficient time period will play a crucial role in ensuring spawning success and long term population viability.

Recommendations for Future Work

1. Results from the River2D model had some limitations, namely that the model could not be run at higher flows. Reassessment of higher flow scenarios as well as high downstream lake levels will help with dam/shoal management by providing a complete picture of the range of conditions that could be encountered at the shoal, which managers can take into account when creating a flow management plan for the dam. This will improve reproductive success by reducing flushing of the shoal during spring freshet and extreme weather events, and reducing the likelihood of eggs being washed away from optimal hatching areas.

2. Future work should give consideration to how flows from the dam might interact with Georgian Bay water level fluctuations to create hydrological conditions over the spawning shoal. At high downstream lake levels, high flow discharged from the dam will not result in the same water velocity as the same flow being discharged into lower downstream lake level conditions. For example, a leakage flow of 0.3 m^3/s was sufficient to maintain suitable spawning conditions

at lake level of 176 masl, however with the current higher water levels, a higher minimum flow is likely necessary.

3. Enhancements to the model could also be made by making use of newer, more robust elevation datasets than those available in 2006. It is also suggested that models other than River2D be considered for any future studies, as there have likely been refinements to this type of modelling work since SSEA's analysis was completed. With these combined model refinements, a management plan for the dam could then be developed, using the River2D model (in part) to guide the determination of minimum flows to be maintained at the dam in order to maximize optimal spawning habitat.

4. During the spawning season, it would be useful to have real-time, *in situ* water temperature data to determine when spawning may commence, and to conduct periodic water velocity and depth measurements to ensure that optimal habitat conditions are being maintained.

5. It was outside of the scope of this study to examine abiotic and biotic factors affecting the survivorship of early life stages of walleye (post-hatching). Future work could look at conditions at and near the spawning shoal for factors such as water clarity and zooplankton populations, and with consideration of the timing of infestation of Severn Sound by invasive species (dreissenid [zebra/quagga] mussels and round gobies). These data could be compared with year class strength of walleye as measured by MNRF, giving a full life-cycle assessment of the effects of spawning shoal management combined with ecological conditions in the area.

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