Post-Treatment Assessment for Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek/Erie Canal

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US Army Corps of Engineers®
Buffalo District
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Prepared for:

UNITED STATES ARMY CORPS OF ENGINEERS
Buffalo District

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List of Abbreviations and Acronyms

ACT	Aquatic Control Technology, Inc.
Canal Corp.	New York State Canal Corporation
cfs	cubic feet per second
E & E	Ecology and Environment, Inc.
ERDC	Engineer Research and Development Center
ft/s	feet per second
GPS	global positioning system
hp	horsepower
µg/L	micrograms per liter
ND	non-detect
NYPA	New York Power Authority
NYSDEC	New York State Department of Environmental Conservation
ppm	parts per million
PPE	personal protective equipment
SOW	Statement of Work
USACE	United States Army Corps of Engineers (Buffalo District)
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1 Introduction

The Tonawanda Creek/Erie Canal[1] Hydrilla Demonstration Project is a field-scale demonstration of a technology developed under the U.S. Army Corps of Engineers' (USACE) Aquatic Plant Control Research Program to manage monoecious hydrilla (*Hydrilla verticillata*) in a flowing water system. This report contributes to the post-treatment monitoring and assessment of the herbicide efficacy by summarizing field conditions before, during, and after the treatment; summarizing herbicide treatment methodology and contact time; summarizing the additional spot treatment necessary following initial treatment; and identifying lessons learned to benefit future work.

1.1 Background

Hydrilla is a very aggressive, submerged aquatic plant. This invasive plant was first discovered in the Tonawanda Creek section of the Erie Canal in September 2012 by the U.S. Fish and Wildlife Service (USFWS). Hydrilla infestations have been documented from just upstream of the creek/canal's outlet at the Niagara River, in the cities of North Tonawanda and Tonawanda, upstream to the Lockport area, approximately 15 miles to the east. The total area within that reach in which hydrilla has been identified covers approximately 359 acres. Hydrilla beds are currently patchy and limited to the shallow shoreline areas outside of the main navigation channel.

There is significant concern regarding the potential spread of hydrilla to other areas of New York State and the Great Lakes as a whole because of the relative ease by which fragments of the hydrilla infestation within the creek/canal can be transported via water flow, the creek/canal's location directly adjacent to the Niagara River, and the heavy use of the canal. This concern provided the impetus for implementing this demonstration project.

The USACE – Buffalo District selected the roughly 15-mile-long infestation area for treatment under this demonstration project and established two treatment areas (see Figure 1):

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[1] The Erie Canal and Tonawanda Creek are separate waterbodies until they merge in Pendleton, just downstream of the East Canal Road/New Road bridge. From the confluence, the canal then follows the modified former channel of Tonawanda Creek.

- Primary treatment area: from the Route 265 bridge in Tonawanda near the confluence of Erie Canal/Tonawanda Creek with the Niagara River, upstream to Bear Ridge Road in Lockport for direct herbicide application.
- Secondary treatment area: from Bear Ridge Road upstream to the Pendleton Guard Gate in Lockport, located approximately 0.2 miles from Feigle/Fisk Road, for secondary treatment as the herbicide-treated water from the primary or western block moves east.

The originally identified treatment area, comprising both the primary and secondary treatment areas, shown in Figure 1, was created to be representative of the full 15-mile stretch of the canal in which hydrilla beds had been previously identified by the USFWS. The treatment area as shown in Figure 1 was the area addressed in the USACE Buffalo District's environmental assessment for this project and was subsequently modified prior to treatment to reflect updated hydrilla mapping.

Prior to treatment application, hydrilla populations within the treatment areas were delineated and mapped using hydro-acoustic surveys. In June and July 2014, the USACE Engineer Research and Development Center (ERDC) conducted supplementary mapping and plant delineation and identified additional point locations of hydrilla beds near the Route 425 bridge in North Tonawanda and just beyond Campbell Boulevard in Lockport. The updated data were used to refine the treatment areas as shown in Figure 2. As indicated in Figure 2, the western boundary of the primary treatment area was pulled in to approximately the Route 425 bridge, away from the Niagara River, and the eastern limit of the primary treatment area was extended just past Campbell Boulevard. Additionally, several supplemental areas were then added to the refined primary treatment area, as shown on Figure 2. Supplemental treatment areas were added on the western and eastern sides of the main channel primary treatment area. These changes resulted in the western boundary of the secondary treatment area beginning just east of the supplemental treatment area, labeled L4 on Figure 2, and continuing to approximately Lockport Road, as shown on Figure 1.The primary treatment area, as depicted on Figure 2, was used to guide the herbicide application.

Implementation of this project was a collaborative effort between ERDC, USACE – Buffalo District, Ecology and Environment, Inc. (E & E), the New York State Canal Corporation (Canal Corp), the New York State Department of Environmental Conservation (NYSDEC), the USFWS, and the applicator, Aquatic Control Technology, Inc. (ACT).

1.2 Purpose and Scope

The purpose of the demonstration project was to develop and implement selective control methods to manage hydrilla in a flowing water system while limiting impacts on native vegetation. Prior to implementation of this project, the use of an aquatic herbicide to manage monoecious hydrilla in a flowing water system had not been tested. Therefore, the results of this field-scale demonstration project will provide valuable information for developing future guidance on how to manage this species in other flowing water systems throughout the northeastern United States.

ERDC will use the findings in this report to support continued post-treatment monitoring that will be conducted to determine the success of the initial treatment program. Post-treatment monitoring will also be used to determine whether additional canal-wide treatments will be needed in the future or if direct targeting of individual hydrilla beds with herbicide would be more effective in removing small satellite populations that survive treatment or re-sprouted from the bank of sub-surface tubers.

This post-treatment report includes a summary of the herbicide treatment methodology, including quantity of herbicide used and total acreage treated; a discussion of herbicide contact time and dispersion through the system; and a discussion of the flow management and monitoring that accompanied the herbicide application. Lastly, the report provides some conclusions, in the form of lessons learned, to help shape future treatment projects.

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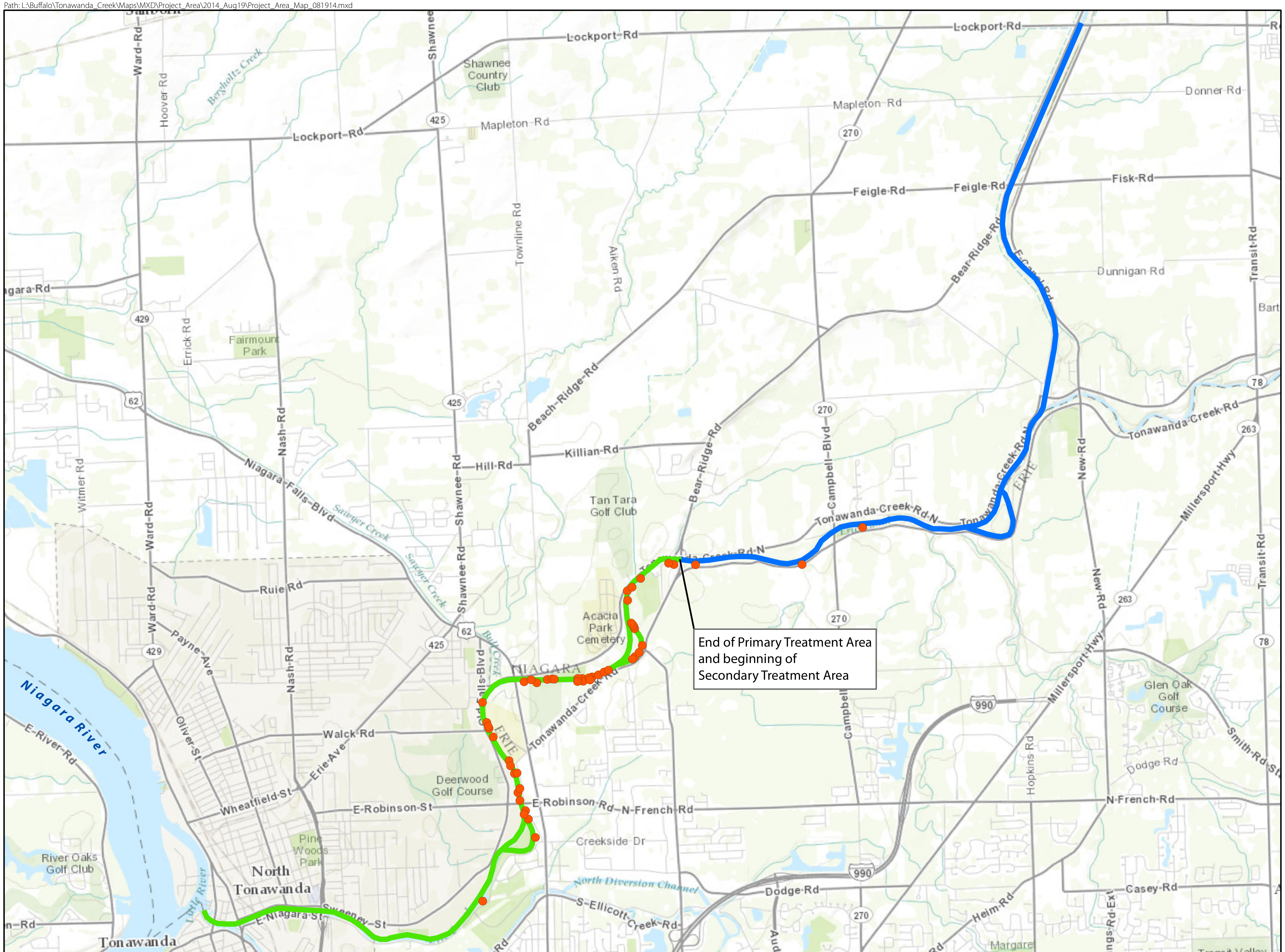


Figure 1
Hydrilla Locations and Treatment Areas

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

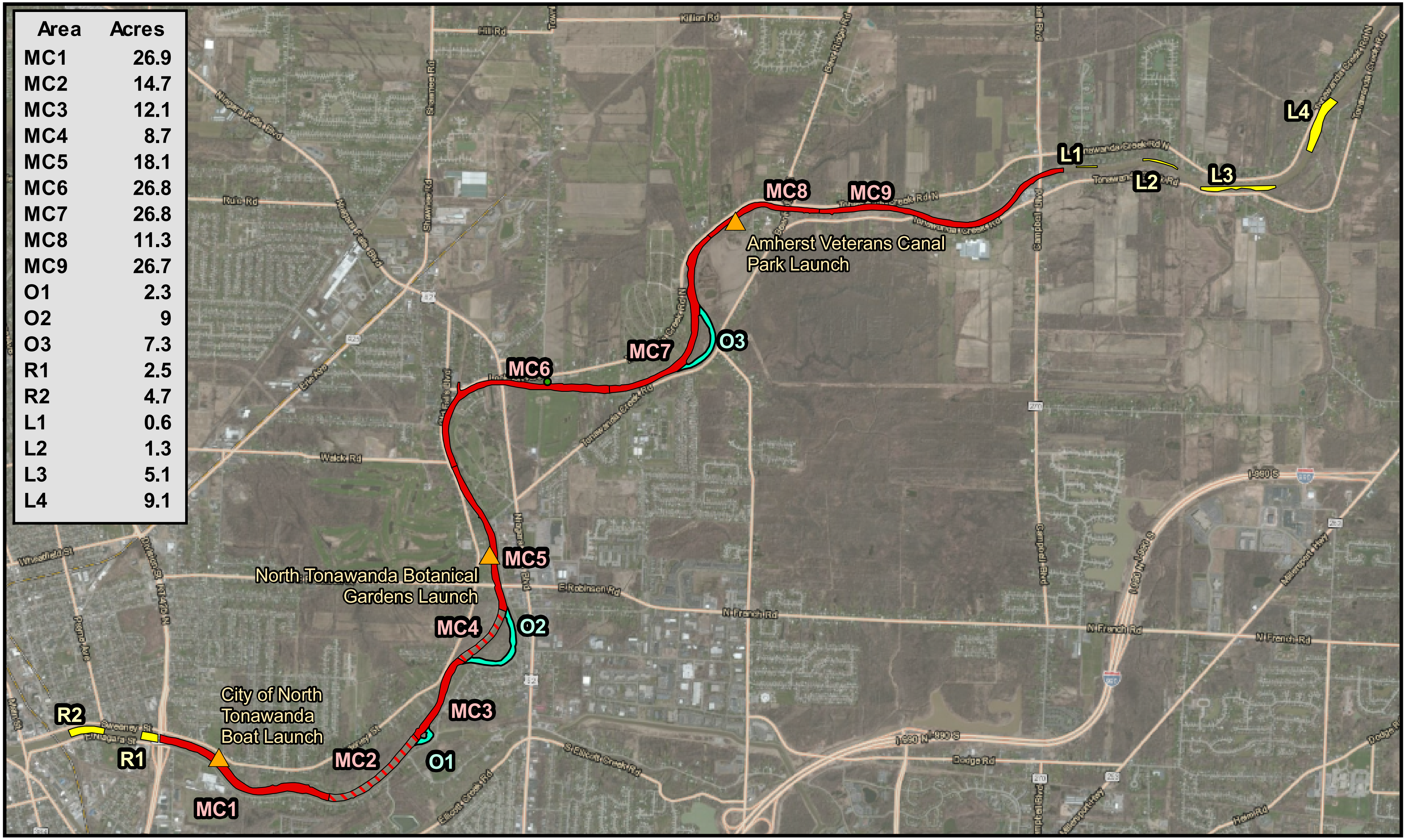
- Hydrilla Point Locations
- Primary Treatment Area
- Secondary Treatment Area

N

SCALE

0 0.5 1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2014; US Army CORPS of Engineers, 2014



Area	Acres
MC1	26.9
MC2	14.7
MC3	12.1
MC4	8.7
MC5	18.1
MC6	26.8
MC7	26.8
MC8	11.3
MC9	26.7
O1	2.3
O2	9
O3	7.3
R1	2.5
R2	4.7
L1	0.6
L2	1.3
L3	5.1
L4	9.1

Tonawanda Creek

Erie and Niagara Counties, NY

Hydrilla Treatment Areas

FIGURE:	TREATMENT DATE:	MAP DATE:
2	7/22/14	8/13/14

Legend:

- Main Channel Treatment Areas (MC1,3,5-9) - 148.6 ac
- Reduced Concentration Treatment Areas (MC2,4) - 23.4 ac
- Oxbow Treatment Areas (O1-3) - 18.5 ac
- Supplemental Treatment Areas (R1-2, L1-4) - 23.4 ac
- Loading Areas

0 0.25 0.5 1 1.5 2 Miles

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2 Overview of Herbicide Treatment

Treatment of hydrilla under this demonstration project focused on the application of the aquatic herbicide endothall (Aquathol K™) within the Tonawanda Creek section of the Erie Canal. During treatment, the objective was to minimize flow in the creek/canal while allowing for active navigation in order to achieve a minimum (or ideal) contact time at a target concentration. Minimizing flow yielded greater contact time. To minimize flow, a target flow rate of 200 cubic feet per second (cfs) or less to the east was identified.

This section discusses the public notification that preceded treatment; field conditions before, during, and after treatment; herbicide treatment methodology, quantity of herbicide used, and its dispersion; and details of the flow management and monitoring.

2.1 Public Notification

Public awareness of and understanding of the project were important to its successful implementation. Although a State of New York Permit to Use a Pesticide for the Control or Elimination of Aquatic Vegetation (Article 1, Part 327) was not required for this project, the notification requirements stipulated for the permit were adhered to (i.e., riparian owner and permitted user notification and use of warning signs). Five methods of public notification were used for the project:

1. Riparian owners and permitted users were notified via certified mail;
2. Yellow warning signs were posted along the primary treatment area at public access points;
3. Display ads were published in three local/regional newspapers (*The Buffalo News* on July 19, 2014; the *Lockport Union-Sun & Journal* on July 18, 2014; and the *Tonawanda News* on July 18, 2014);
4. Agency notification letters were distributed by mail; and
5. Project factsheets were distributed during Canal Fest by Western New York Hydrilla Task Force members.

2.2 Field Conditions

Field conditions prior to (24 hours), during, and immediately following the treatment (24 hours) are summarized in Table 2-1. As evidenced below, conditions were primarily dry around the time of herbicide application.

Table 2-1 Field Conditions Preceding, During, and Following Herbicide Application

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
July 21, 2014	Min: 65 Max: 84	0.00	Relative humidity ranged from 40% to 93% throughout the day
July 22, 2014 (treatment date)	Min: 62 Max: 85	0.00	Relative humidity ranged from 48% to 90% throughout the day
July 23, 2014	Min: 63 Max: 78	0.14	Relative humidity ranged from 57% to 82% throughout the day
July 24, 2014	Min: 58 Max: 72	0.00	Relative humidity ranged from 38% to 78% throughout the day

Source: National Weather Service – Buffalo Weather Forecast Office 2014

2.3 Herbicide Treatment Methodology

The aquatic herbicide endothall (Aquathol K™) was applied in designated sections of the creek/canal on July 22, 2014 (see Figure 2). The herbicide was applied by ACT of Sutton, Massachusetts, in accordance with the Architect-Engineer *Scope of Work (SOW) Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek /Eric Canal* dated April 24, 2014 (USACE 2014a).

Three boats were used for the herbicide application. Two large, shallow-draft work skiffs powered by conventional outboard motors were used for the majority of application in the main channel. Additionally, a 16-foot aluminum airboat was used to treat three shallow oxbows during the initial application and the supplemental areas that were added by USACE after their pre-treatment inspection on July 21, 2014. The supplemental areas are labeled on Figure 2 as River 1 (R1), River 2 (R2), Lockport 1 (L1), Lockport 2 (L2), Lockport 3 (L3), and Lockport 4 (L4).

2.3.1 Herbicide Transfer

An in-line herbicide injection system was used on the two conventional work skiffs. Each boat was outfitted with a 225-gallon polyethylene tank. The liquid herbicide was pumped from 250-gallon totes in the chemical delivery box truck located onshore into the polyethylene tanks via 1-inch-diameter tubing by electric- and gasoline-powered transfer pumps (Bellaud 2014a). Personal protective equipment (PPE) was worn by ACT staff and by the driver from the company that delivered the herbicide and assisted with the herbicide transfer to the treatment boats.

On the airboat, herbicide from the 250-gallon totes on the delivery truck was pumped into the primary 50-gallon spray tank onboard the boat. Herbicide was also pumped into 15-gallon closed tanks equipped with micro-matic valves. In addition, 105 gallons of endothall was delivered in 2.5-gallon jugs. These jugs were emptied into the 50-gallon spray tank.

2.3.2 Herbicide Application

The work skiffs were outfitted with 2-inch-diameter gasoline-powered water pumps. Water was drawn from the creek/canal and sprayed out subsurface through weighted hoses that trailed each boat. Venturi-style liquid eductors on the outflow side of the pumps were connected to the herbicide storage tanks using hoses. This connection had a gate valve that could be closed to stop flow from the tank. Herbicide was drawn from the tanks in-line at a rate of approximately 8 gallons per minute, resulting in a 10:1 dilution (Bellaud 2014a). The work skiffs were filled at the designated loading areas and applied herbicide from west to east along the creek/canal. Boat passes were made parallel to the shorelines. As requested by the USACE, the herbicide was applied in water less than 10 feet deep, which was generally within 50 feet of the shoreline. The quantity of herbicide needed for each section was initially determined by the total acreage and volume of the treatment areas; last-minute modifications by USACE prior to the start of application were necessary to account for additional treatment areas identified through the supplemental mapping discussed in Section 1.1. These modifications included the addition of six supplemental treatment areas totaling 15 acres, located outside of the previously identified primary treatment areas boundaries (i.e., Route 265 to Bear Ridge Road [see Figure 2]). These areas are denoted on Figure 2 as R1, R2, L1, L2, L3, and L4 and were added based on the pre-treatment mapping, as discussed in Section 1.1. Treatment of each section was completed before moving to the next adjacent section (Bellaud 2014a).

On the airboat, a calibrated pumping system on the stern of the boat was used to inject the herbicide concentrate below the surface through a weighted hose assembly in the three oxbow treatment areas, designated as O1 through O3 on Figure 2. The pumping system consisted of a gasoline-powered engine with a positive displacement pump. The product was applied throughout the designated treatment areas as the boat made passes parallel and then perpendicular to the shore (Bellaud 2014a). As with the conventional boats, the total quantity of product calculated for each section, as determined by the total acreage and volume of the treatment areas, was applied before moving to the next section.

ACT staff arrived at the City of North Tonawanda boat launch off Service Road at 7:30 a.m. on July 22, 2014, and launched the three boats and began assembling the treatment systems. Following on-site meetings with staff from the USACE, NYSDEC, and E & E, ACT personnel began to transfer the herbicide at approximately 9:30 a.m. (Bellaud 2014a). Each treatment crew consisted of a lead applicator and an assistant/technician. The airboat was loaded first, and it departed at approximately 9:45 a.m. to begin treatment of the River 1 (R1) and River 2 (R2) sections (see Figure 2). The two skiffs were then loaded and began herbicide application at approximately 10:15 a.m. Aside from brief breaks when the boats stopped to reload herbicide, the treatments continued uninterrupted until the operation was completed at approximately 4:30 p.m. The three boats and treatment crews spent a combined total of approximately seven hours actually applying the herbicide (Bellaud 2014a).

The treatment boats were launched and herbicide transfer first occurred at the City of North Tonawanda boat launch off Service Road. The base of operations was moved upstream to the North Tonawanda Botanical Gardens boat launch off Sweeney Street to handle loading for the middle sections. Finally, the base of operations was moved to the Amherst Veterans Canal Park boat launch off Brenon Road. At each location the chemical delivery box truck was able to park adjacent to or on one side of the ramp, which still enabled each ramp to be used by other boaters as necessary during the herbicide transfer operations (Bellaud 2014a).

2.4 Quantity of Herbicide Used and Total Area Treated

First applicator boat following transfer of herbicide, City of North Tonawanda Service Drive Boat Launch

The total quantity of endothall applied in designated sections of the creek/canal on July 22, 2014, was 1,855 gallons. The planned treatment area was divided into distinct sections, the total amount of endothall to be applied to each section was calculated, and the product was then applied as described in Section 2.2. The canal section divisions were made by dividing the main channel into even sections for the herbicide loads. The oxbows were an exception, as were the areas added by ERDC; these areas were addressed separately from the main channel. The dosing was calculated by ERDC and ACT based on the total volume divided by canal sections; an equal average depth was assumed for each section.

The supplemental areas added to the previously defined primary treatment area by the USACE following their July 21, 2014 survey were incorporated into the treatment plan prior to the start of work. The primary treatment area was initially defined as extending from the Route 265 bridge in Tonawanda to Bear Ridge Road in Lockport; however, as discussed in Section 1.1., that area was expanded to include the results of pre-treatment surveys, which had indicated the presence of additional hydrilla beds.

The target concentration of endothall for a majority of the treated sections was 1.5 parts per million (ppm); however, in several sections the applied rate varied from that target based on verbal direction provided by ERDC prior to treatment. Per ERDC guidance, reduced concentrations were used in areas of lower hydrilla density to save product for application in the additional areas. As indicated in Table 2-2, the canal sections in which reduced concentrations were implemented were Main Channels 1 and 4 and River 2.

In two canal sections (L1 and L2) the concentration of herbicide applied was higher than that applied in the majority of sections (see Table 2-2) because ERDC had decided to maximize concentrations in smaller plots.

Table 2-2 summarizes herbicide treatment for each canal section as depicted on Figure 2.

Table 2-2 Herbicide Application Summary, by Canal Section

Section	Acres	Endothall Applied (gallons)	Targeted Concentration (ppm)	Notes
MC 1	26.9	239	1.5	
MC 2	14.7	125	1.4	Rate reduced by ERDC
MC 3	12.1	108	1.5	
MC 4	8.7	75	1.4	Rate reduced by ERDC
MC 5	18.1	161	1.5	
MC 6	26.8	238	1.5	
MC 7	26.8	238	1.5	
MC 8	11.3	100	1.5	
MC 9	26.7	237	1.5	
O 1	2.3	11	1.5	Shallow water
O 2	9.0	40	1.5	Shallow water
O 3	7.3	65	1.5	Shallow water
R 1	2.5	22	1.5	
R 2	4.7	40	1.4	Rate reduced by ERDC
L 1	0.6	9	3.0	Higher rate, small plot
L 2	1.3	21	3.0	Higher rate, small plot
L 3	5.1	46	1.5	
L 4	9.1	80	1.5	
Total	**214**	**1,855**		

Key:

L = Supplemental treatment area
MC = Main channel treatment area
O = Oxbow treatment area
ppm = parts per million
R = Supplemental treatment area

2.5 Herbicide Contact Time and Dispersion

Herbicide was applied to sections of Tonawanda Creek/Erie Canal on July 22, 2014; these sections were determined as discussed above in Section 2.4. Water sampling, to determine the endothall concentrations and dispersion of herbicide, began on the date of application and ended on July 31, 2014, and was performed by ERDC and E & E.

2.5.1 Initial Sampling Results – First 48 Hours

ERDC completed the initial water sampling during the 48 hours following application while flows were reduced, to determine the endothall concentrations throughout the treatment areas. Sampling locations were established at 1-mile intervals along Tonawanda Creek/Erie Canal, beginning at the mouth of the creek/canal at the Niagara River (River Mile 0) to Lockport Road, approximately 15 miles upstream.

The samples were analyzed using an enzyme-linked immunoassay procedure specific for endothall. The standard operating procedures for use of the RaPID Assay® Endothall Test Kit were followed. The detection limit for this method is 7 micrograms per liter (µg/L). Samples were analyzed at either a 10:1 dilution, with a detection limit of 70, or as non-diluted samples with a detection limit of 7µg/L. The sampling results analyzed and reported by ERDC indicate the concentrations of the active ingredient, dipotassium salt of endothall, in each sample. For every 10 samples collected, duplicate and matrix spike analyses were performed to determine the percent recovery of endothall. Each sample run incorporated the use of external standards at 500, 1,000, and 2,000µg/L.

The analytical results for samples collected during the initial 48 hours following application during the reduced flow period suggest movement of endothall to the east. This resulted in less than the desired exposure between River Miles 2 and 4 at the western end of the treatment area (see Table 2-3). Endothall concentrations also declined faster than anticipated at River Miles 4 and 5; however, target endothall concentrations were maintained for 48 hours in that reach, and the highest herbicide concentrations were documented between River Miles 4 and 10 (Netherland 2014a). Therefore, that 6-mile reach of the creek/canal received the greatest exposure period. Herbicide concentrations in that reach ranged from 1,000 µg/L to more than 4,000 µg/L and were near target concentrations once the product fully dispersed (see Table 2-3). Table 2-3 summarizes results obtained through July 25, 2014 and emphasizes distribution of the treatment in relation to the target zone. Table 2-4 summarizes the results obtained on the last two days of sampling and the clearance of the herbicide from the system.

Table 2-3 Summary of Water Sample Results Showing Treatment Distribution

River Mile	Location ID [2]	Endothall Concentration (µg/L) [3]				
Sampling Date [1]		7/22/2014	7/23/2014 a.m.	7/23/2014 p.m.	7/24/2014	7/25/2014
0	H01C		ND		ND	< 70
0.2		ND	ND			
0.5	H02LB					< 70
0.7		85	ND			
1	H03RB	475	ND	ND	ND	< 70
1.1		332	ND			
1.5	H04C					< 70
2	H05LB		163	ND	ND	< 70
2	H05RB					< 70
2.5	H06RB					425
2.7	H06A	2,417	2,288		2,423	177
3	**H07C**	**2,569**	**270**	**311**	**507**	**173**
3.4	**H08A**	**2,697**	**2,528**		**2,267**	**316**
3.5	**H08LB**					**1,545**
4	**H09LB**	**2,432**	**806**	**897**	**859**	**656**
4	**H09RB**					**485**
4.5	**H10C**					**686**
5	**H11LB**	**3,041**	**1,424**	**1,260**	**1,041**	**967**
5.5	**H12RB**					**1,232**
6	**H13C**	**3,151**	**1,776**	**1,470**	**1,352**	**1,249**
6.2	**H13A**	**2,417**	**2,288**		**2,423**	**1,206**
6.5	**H14LB**					**1,411**
7	**H15LB**	**4,256**	**1,882**	**1,743**	**1,539**	**1,236**
7	**H15RB**					**1,267**
7.5	**H16C**					**1,223**
8	**H17LB**	**2,557**	**2,044**	**1,693**	**1,308**	**1,386**
8.5	**H18RB**					**1,304**
9	**H19C**	**1,433**	**2,324**	**1,749**	**1,348**	**1,495**
9.1		ND	1,931			
9.2		ND	2,235			
9.5	H20LB	ND	1,942			1,366
10	H21RB	141	2,454	1,901	1,493	1,447
10.1	H21A					1,332
10.5	H22C		1,641			1,421
11	H23LB		1,572	1,901	833	1,281
11	H23RB					
11.5	H24RB					1,219
12	H25C		727	1,998	495	1,227

Table 2-3 Summary of Water Sample Results Showing Treatment Distribution

River Mile	Location ID [2]	Endothall Concentration (µg/L) [3]				
Sampling Date [1]		7/22/2014	7/23/2014 a.m.	7/23/2014 p.m.	7/24/2014	7/25/2014
12.5	H26LB					1,342
13	H27RB		328	923	921	1,272
13.5	H28C					1,401
14	H29LB		569	976	967	912
14.5	H30RB					593
15	H31C		305		348	573
4.8	HBG1					
11.3	HBG2					

Blank cell = no sample collected
Bold text = samples taken within the primary treatment area

[1] Application occurred on July 22, 2014. Samples collected on July 22, 23, and 24 were collected by ERDC; samples collected on July 25 were collected by E & E.
[2] Location ID assigned by E & E.
[3] Endothall results provided by ERDC for all samples.

Key:
ND = Non-detect (detection limit not provided)
< = Not detected at detection limit shown

Table 2-4 Summary of Water Sample Results Showing Treatment Distribution

River Mile	Location ID [2]	Endothall Concentration (µg/L) [3]	
Sampling Date [1]		7/28/2014	7/31/2014
0	H01C	< 70	
0.2			
0.5	H02LB	< 70	
0.7			
1	H03RB	< 70	
1.1			
1.5	H04C	< 70	
2	H05LB	105	
2	H05RB	< 70	
2.5	H06RB	< 70	
2.7	H06A	102	< 7
3	**H07C**	< 70	< 7
3.4	**H08A**	< 70	< 7
3.5	**H08LB**	< 70	
4	**H09LB**	< 70	
4	**H09RB**	< 70	< 7
4.5	**H10C**	< 70	

Table 2-4 Summary of Water Sample Results Showing Treatment Distribution

River Mile	Location ID [2]	Endothall Concentration (µg/L) [3]	
Sampling Date [1]		7/28/2014	7/31/2014
5	**H11LB**	< 70	< 7
5.5	**H12RB**	< 70	
6	**H13C**	< 70	< 7
6.2	**H13A**	< 70	< 7
6.5	**H14LB**	< 70	
7	**H15LB**	< 70	
7	**H15RB**	< 70	< 7
7.5	**H16C**	< 70	
8	**H17LB**	< 70	< 7
8.5	**H18RB**	< 70	
9	**H19C**	< 70	< 7
9.1			
9.2			
9.5	H20LB	< 70	
10	H21RB	< 70	< 7
10.1	H21A	< 70	< 7
10.5	H22C	< 70	
11	H23LB	< 70	< 7
11	H23RB		< 7
11.5	H24RB	< 70	
12	H25C	< 70	< 7
12.5	H26LB	< 70	
13	H27RB	< 70	< 7
13.5	H28C	< 70	
14	H29LB	< 70	< 7
14.5	H30RB	< 70	
15	H31C	< 70	< 7
4.8	HBG1[4]		< 7
11.3	HBG2[4]		< 7

Blank cell = no sample collected
Bold text = samples taken within the primary treatment area

[1] Application occurred on July 22, 2014. Samples collected on July 28 and 31 were collected by E & E.
[2] Location ID assigned by E & E.
[3] Endothall results provided by ERDC for all samples.
4 Background sample collected July 31 only for comparison with undiluted sample results.

Key:
ND = Non-detect (detection limit not provided)

Sampling conducted on the day of herbicide application and the following day at the boundaries of the originally defined treatment primary treatment area (excluding the supplemental areas added on either end [R1, R2, L1-L4]) indicated an eastward movement of the herbicide. Sampling results from the western edge of the primary treatment area, near the Route 425 bridge toward the Niagara River, are presented in Table 2-5, and sampling results from the eastern edge of the treatment block, near Campbell Boulevard toward Lockport, are presented in Table 2-6.

Table 2-5 Direction of Herbicide Movement toward the Niagara River from the Western Edge of the Treatment Block (at Route 425)

Distance from Treatment Block Edge toward Niagara River (meters)	Endothall Concentration (µg/L) Day of Treatment 7/22 (1430 – 1630)	Endothall Concentration (µg/L) 7/23 (1000 to 1200)
200	332	ND
400	475	ND
800	85	ND
1,600	ND	ND

Source: Netherland 2014a.

Key:
ND = Non-detect

Table 2-6 Direction of Herbicide Movement toward Lockport from Eastern Edge of Treatment Block (at Campbell Boulevard)

Distance From Plot Edge Towards Lockport Gates (meters)	Endothall Concentration (µg/L) Day of Treatment 7/22 (1630 – 1700)	Endothall Concentration (µg/L) 7/23 (1000 to 1200)
200	ND	1,931
400	ND	2,235
800	ND	1,942
1,600	1,062*	2,218
2,400	-	1,641
3,200	-	1,670

Source: Netherland 2014a

*This detection likely related to an extra treatment plot that was added outside of the main treatment block.

Key:
ND = Non-detect

Lateral and Vertical Dispersion

To assess the lateral dispersion of endothall within the treatment areas, ERDC sampled three locations laterally across the creek/canal at River Miles 3 through 11 on July 23 and 24, 2014. Two of the locations for each lateral were along the shorelines, and one was located in the middle of the creek/canal (Netherland 2014a). Evaluation of the relative percent difference between the shoreline and center endothall concentrations indicates that lateral dispersion of endothall occurred relatively quickly and generally within 24 hours of application. The calculated relative percent difference between the shoreline and center samples exceeded 40% (a commonly used value for evaluation of field duplicate samples) at about half of the locations on July 23, 2014, and all of the locations were below 25% on July 24, 2014 (Netherland 2014a).

The initial sample results from the day of treatment indicate that the vertical dispersion of the herbicide into the deeper waters of the creek/canal was slower than the lateral dispersion. Two sampling locations were used by ERDC to determine herbicide concentrations at three different depths. The relative percent difference between adjacent vertical samples (i.e., between surface and middle, and middle and bottom) at the same sampling site ranged from 93% to 162% on the day of application. The following day, these differences dropped to 6% to 62%, indicating much smaller differences in concentrations between the different depths that were sampled (Netherland 2014a).

In summary, the sample results indicated relatively rapid (less than 24 hours) uniform dispersion across the creek/canal. Vertical dispersion required additional time (up to 48 hours).

2.5.2 Water Sampling Results Following Flow Resumption

As discussed in detail in Section 2.6.2 below, flows were managed by the Canal Corp during the 48-hour application period and immediately after. On July 23, 2014 at approximately 4:30 p.m., all flows within the canal system were stopped. As discussed above in Section 2.5.1, flows were stopped based on the herbicide concentration rates documented in the water sampling that suggested an eastward movement of the treatment block. Flows were resumed by the Canal Corp on the morning of July 25, 2014.

Following the initial sampling effort by ERDC, E & E obtained grab water samples along Tonawanda Creek/Erie Canal on July 25, 28, and 31, 2014 (see Tables 2-3 and 2-4 for sampling results). Sampling locations were spaced approximately 0.5 miles apart, starting near the mouth of the creek/canal at the Niagara River. E & E samples were collected in the same general locations as the samples collected by ERDC. The samples were collected in an alternating fashion, beginning with the center of the channel near the mouth of the creek/canal and then alternating from the left descending bank to the right descending bank (based on "normal" downstream flow from east to west towards the Niagara River) and back to center. This alternating pattern was repeated to the end of the monitoring area at Lockport Road in Lockport, totaling 31 sampling locations. In addition, samples were collected in both channels where the flow is divided at the following four locations, bringing the total to 35 sampling locations:

- East side of the small island along Creekside Drive at Ellicott Creek Park (location H06A);
- East side of Three Mile Island near Creekside Drive and Niagara Falls Boulevard (location H08A);
- East side of the island at Tonawanda Creek Road and Sweet Home Road (location H13A); and
- The side channel along Tonawanda Creek Road just west of Hopkins Road (location H21A).

The sampling locations are indicated on Figures 3a-3t in Appendix A.

The samples obtained by E & E were collected as grab samples from an approximate depth of 1 foot at all locations using a hand-operated bilge pump. A weighted stainless steel screen was attached to vinyl tubing and suspended at the collection depth. Sample volume was then pumped directly into laboratory vials provided by ERDC. Three to four drops of hydrochloric acid were then added to preserve the sample. Each sample was labeled with a unique sample code and immediately placed in a cooler containing ice. Prior to collecting each sample, the pump and tubing system was cleaned by purging it at least 10 times with creek/canal water at the sample location.

Google Earth was used to navigate to the predetermined sampling locations. At the time of collection, a Bad Elf global positioning system (GPS) receiver was used to obtain the actual sampling location coordinates. The accuracy of this unit varied depending on availability of satellites but was typically between 8 and 14 feet.

Samples were shipped on ice to the ERDC laboratory at the University of Florida Center for Aquatic Plants for analysis. Samples were analyzed using an enzyme-linked immunoassay procedure specific for endothall (RaPID Assay® Endothall Test Kit).

Quality control samples collected in the field by E & E consisted of normal/duplicate pairs collected from the same location at the rate of approximately 5%, plus lateral sample pairs collected from opposing banks, also at the rate of approximately 5%. A total of six normal/duplicate pairs were collected over three days of sampling. The analytical results for five of the six pairs (both samples) were non-detect; the sample pair collected at location H12RB-D2 had positive values and a relative percent difference of 15%, showing good correlation. Lateral sample pairs also showed good correlation. Three sample pairs were obtained each sampling day. Two sample pairs with positive detections showed relative percent differences of 2% and 30%. Most other lateral pairs were both non-detect (one pair collected on July 28, 2014 showed mixed but correlated results of less than 70 and 105 µg/L).

The purpose of E & E's sampling effort was to determine the movement and degradation of endothall following the resumption of flow in the canal after the initial 48-hour application period (refer to Section 2.6.2 for a discussion of how flows were managed). Sample results from the first day of sampling following flow resumption (July 25) indicated the presence of endothall from River Mile 2.5 (location H06RB) through River Mile 15 (location H31C). Concentrations in this area ranged from 173 µg/L to 1,545 µg/L (see Table 2-3 and Figures 3a-3f in Appendix A). The results for samples collected between the Niagara River and River Mile 2.5 were non-detect for endothall at a detection limit of 70 µg/L. Five days after treatment (July 28, 2014), the results for samples collected from these same locations were non-detect results (at a detection limit of 70 µg/L), with the exception of samples H05LB and H06A, which had positive detections of slightly more than 100 µg/L (see Table 2-4 and Figures 3a-3t in Appendix A). Due to the lack of detections at the 70 µg/L detection limit on July 28, 2014, the sampling plan for July 31,2014 (eight days after the application window) was revised to include fewer samples (approximately every 1 mile starting at River Mile 3, plus side-channel samples). In addition, because these samples were analyzed undiluted with a detection limit of 7 µg/L, two "background" samples were collected from outside the treatment areas (at Sawyer Creek and Ellicott Creek) for comparison with the Tonawanda Creek/Erie Canal samples. All results for the final day of sampling were non-detect at an undiluted detection limit of 7 µg/L. This suggests that all of the herbicide treatment dispersed outside of the sampling area or degraded to non-detect levels by the eighth day after application.

2.6 Flow Monitoring and Management

Flow monitoring and management were integral components of the demonstration project. This section provides an overview of the flow monitoring methodology, the management actions taken by the Canal Corp, and general trends evident in the flow data collected during the monitoring period.

2.6.1 Flow Monitoring

E & E personnel programmed and installed flow meters prior to the application of the herbicide in order to help the Canal Corp manage the flows in the Erie Canal during the 48-hour treatment window. Prior to application, two flow meters were set up between June 25 and 30, 2014, to test operations: one at the Route 384 bridge in Tonawanda, New York, and one near the Stevens Street bridge in Lockport, New York. During the application and post-treatment period, a third flow meter was also established at the East Canal Road/New Road bridge in Pendleton, New York (see Figure 3).

Isco Model 2150 Area-Velocity Flow Modules were used to monitor flows. This meter uses continuous Doppler wave technology to measure mean velocity via a sensor that transmits a continuous ultrasonic wave. The meter then measures the frequency of the shift of returned echoes reflected from air bubbles or particles in the flow.

Prior to setting up the flow meters, stream cross sections were developed for all three metering sites to determine the cross-sectional area at different water heights. Cross sections were developed on June 23, 2014, by measuring the depth to water and depth to the creek bed from a reference point on each bridge (e.g., the bridge deck). Measurements were recorded every 10 feet across each creek/canal section. The cross sections were used to develop a relationship between water level and area at each location. This information was programmed into the area-velocity flow modules for calculating the flow rate in cfs by multiplying the measured velocity in feet per second (ft/s) by the area at the measured level in square feet (ft^2). Cross sections are presented in Appendix B.

Flow meter setups are shown in Appendix C. The Route 384 bridge unit was set up near the center of the channel by attaching the sensor to the south side of the center abutment near the eastern edge. The Stevens Street bridge unit was set up on a dock on the west side of the canal, approximately 150 feet north of the cross-section location at the bridge. (There was no abutment on to which the sensor could be mounted, and the sensor could not be suspended from the bridge deck due to frequent boat traffic.) The East Canal/New Road bridge unit was suspended from the bridge deck. Following the trial period in June 2014 when sensors had been set at depths of 3 to 4 feet, it was determined through consultation with the equipment manufacturer that a shallower deployment depth (approximately 2 feet) might yield higher quality velocity measurements. Therefore, the depth of deployment during the treatment period in July 2014 was 1.7 to 2.5 feet. The deepest part of each cross section was used as a reference for recording levels (i.e., a level of 0 feet would correspond to a dry stream).

Because the level sensors could not be set up directly at the deepest part of the stream, an offset was entered into the Isco flow module program to make the level sensors read depths corresponding to the deepest part. The area-velocity relationships for each location were programmed into the flow modules (see Appendix B). The software controlling the units (Flowlink by Teledyne Isco) calculates the area based on the current level reading. When velocity measurements could not be recorded (such as during low to stagnant flow), Flowlink uses the last velocity reading to calculate flow. Because stream velocities were generally low at all three locations, the Flowlink-estimated flow rates may not be accurate when no velocity signal was recorded. Therefore, flow rates were recalculated by E & E using the instantaneous level (area) and velocity information. The data are provided in tabular format in Appendix D.

During the application period, the three meters recorded data at five-minute intervals from July 21 to 25, 2014. This included 24 hours prior to herbicide application, the day of herbicide application, and three additional days following the application. Data from the flow meters were automatically transmitted to a

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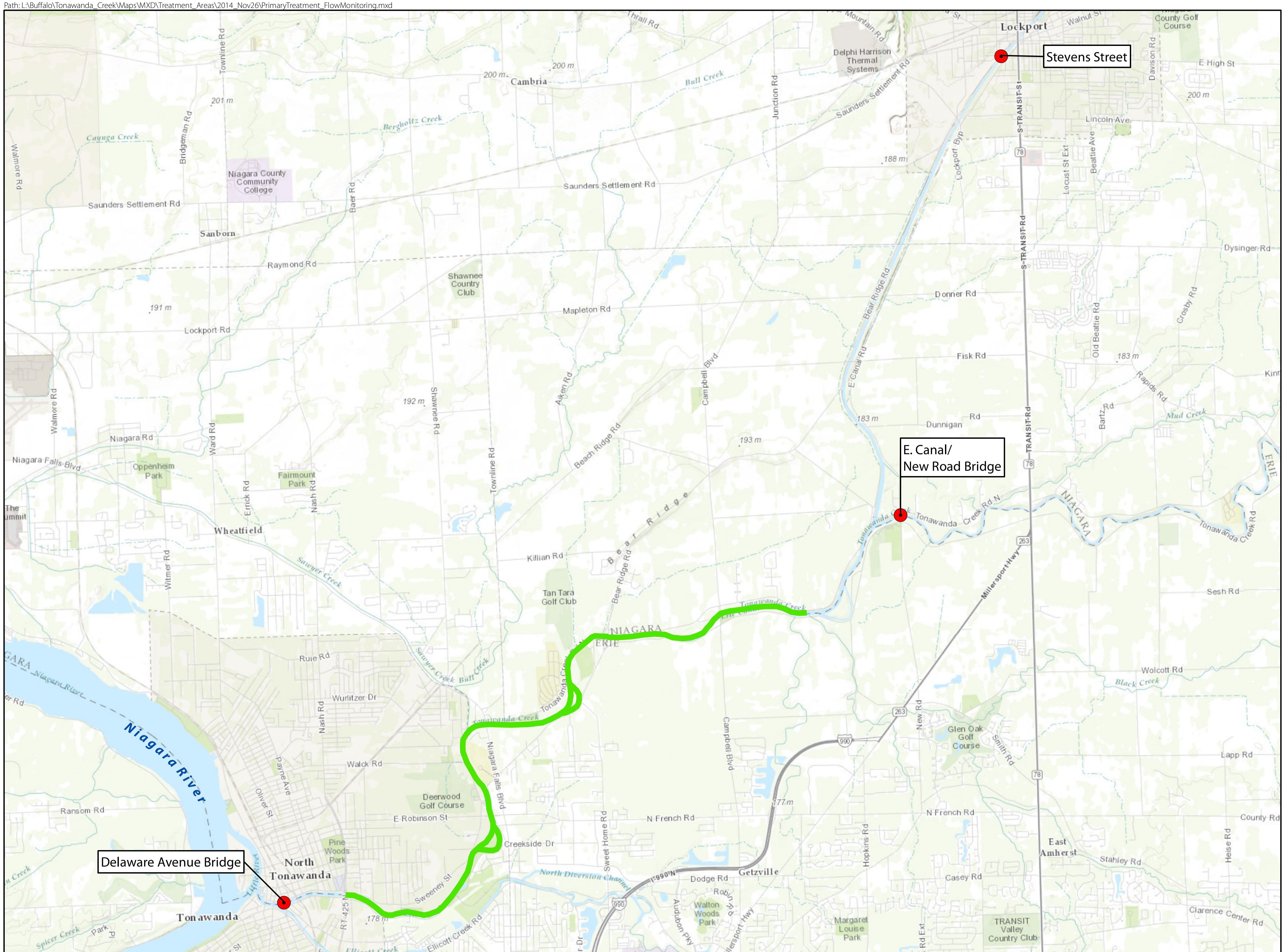

Figure 3
Primary Treatment Area and Flow Monitoring Locations

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- Flow Monitoring Location
- Primary Treatment Area

SCALE

0 1 2 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2014; US Army CORPS of Engineers, 2014 server for online access and downloading. A hand-held stream velocity meter and visual observations of surface flow were used to periodically validate the automatic readings recorded by the Isco flow modules the day prior to and during treatment. The data from the flow meters was used to determine the extent of creek/canal flow influence on herbicide dispersion.

Hourly updates were provided to the USACE – Buffalo District and the Canal Corp regarding flow conditions observed over the previous hour at each of the monitoring locations. If necessary, specific direction was provided to the Canal Corp regarding any action that may have been required with respect to flow management.

2.6.2 Flow Management

Water passes through Canal Corp Locks 34/35 in three ways: 1) through the bypass tunnel, 2) through the miter gates of Locks 34/35, and 3) through the Flight of Five gates, which are associated with Locks 67 and 71 and located immediately north of Locks 34/35 (Manns 2014a). During herbicide application, the Canal Corp closed the Flight of Five gates and operations of Locks 34/35 were kept to a minimum, leaving water to be directed through the bypass tunnel. The end of the bypass tunnel forms a "Y"— one branch of the "Y" goes to the Brookfield Power Plant gates, and the other branch goes to the Canal Corp's City Hall gates. In order for the Canal Corp to control the amount of flow through Locks 34/35, the Brookfield Power Plant was taken off-line so that that branch did not receive any water. As a result, all water was directed through the City Hall gates, which are controlled by the Canal Corp (Manns 2014a).

The Canal Corp maintained flows at approximately 20% of their typical operating levels out of Lockport (using 20% of the bypass gate opening), or 320 cfs, during the 48-hour treatment period. This was considered by the Canal Corp to be the minimum flow rate required to maintain a navigable water depth in the canal below (east of) Locks 34/35 in Lockport. This low-level flow rate represents the continuous bypass flow rate around Locks 34/35 and was maintained throughout the herbicide application period (July 22, 2014) and until approximately 4:30 p.m. the following day (July 23, 2014), when all bypass flow through the gate ceased. Based on an evaluation of endothall concentrations from samples collected by ERDC on July 22 and July 23, 2014, the eastward movement of the herbicide needed to be reduced to increase contact time between the herbicide and the hydrilla. Therefore, the Canal Corp set the bypass flow rate to zero for the remainder of July 23, 2014. The frequency of eastwardly flows observed in the canal at the Stevens Street bridge appeared to decrease slightly immediately after the bypass gate was closed on July 23. No eastwardly flows were observed at the East Canal/New Road bridge monitoring location for the remainder of July 23 once the bypass gate was closed; however, on the morning of July 24, several eastward flow recordings at the East Canal/New Road bridge monitoring location were observed. The reason for these eastward flows is unknown.

Regular lock operations continued during the treatment period. Filling Locks 34/35 caused a short-term increase in flow rate towards the locks at the Stevens Street bridge and a drop in water level of approximately 0.4 to 0.6 foot. On the day of treatment (July 22, 2014), locks were filled 13 times between the hours of 10:00 a.m. and 6:40 p.m. According to the Canal Corp, each lock fill requires approximately 3 million gallons of water. Therefore, the average flow rate of the canal towards the locks at Lockport was approximately 167 cfs during this period. Coupled with the minimal bypass flow rate of 320 cfs, the estimated total flow rate out of the canal during the day of herbicide application was 487 cfs, which was required by the Canal Corp to maintain navigation.

2.6.3 Flow Observations

As part of its relicensing studies, the New York Power Authority (NYPA) reviewed natural and man-made factors affecting water levels in the upper and lower Niagara River (URS Corp. et al. 2005a). In the upper river, it was found that regulation of the river level in the Chippawa-Grass Island Pool (downstream from the northern tip of Grand Island) has a more pronounced effect on river levels during the tourist season (April 1 to October 31) because the pool level is cycled more fully between day and night time to maintain the required flows at the Falls. During non-tourist hours (nighttime), the pool is generally maintained at a lower water level than during the day. However, the change in pool level is gradual, and on a typical day, the water level in the pool is at a maximum at 7:00 a.m.; it is drawn down during the day for power production and is generally lowest at 9:00 p.m. During the tourist season, the daily median water level fluctuation at Tonawanda Island was found to be 0.55 feet (versus 0.43 feet during the non-tourist season). Water levels were generally found to be higher in the Niagara River during the spring and summer due to generally higher natural outflow from Lake Erie.

Another study (URS Corp. et al. 2005b) looked at the effects of Niagara River water level fluctuations on tributaries. Fluctuations in Niagara River water levels were found to affect Tonawanda Creek/Erie Canal throughout the entire length of the report's study area, which extended from the confluence with the Niagara River to 10,570 feet upstream. (Modeling beyond this distance was not performed in this study.) Based on the analysis of the creek/canal profile, this study suggests that the influences from the median Niagara River level extend approximately 13.7 miles upstream in Tonawanda Creek to two riffle areas, which act as hydraulic controls limiting the river's upstream influence.

The effects of the drawdown of the Niagara River level by NYPA were evident in the water level data obtained during this project (see Appendix D). The water level at the Route 384 bridge was generally at its maximum in the late morning (9:00 a.m. to 11:00 a.m.) and then decreased to a minimum just before midnight. On July 21 and 22, 2014, the magnitude of the decline in level was 0.35 to 0.40 feet. On July 23, 2014, the maximum level was higher than all of the rest of the monitoring period, likely as a result of precipitation that occurred that day. The water level at this location declined more than 0.6 feet later on July 23, 2014.

Similar effects were observed at the East Canal/New Road bridge and Stevens Street monitoring locations. The minimum levels were achieved slightly later farther upstream of the Niagara River (but within 30 to 60 minutes), and the magnitude of the change was less, especially at the East Canal/New Road bridge due to the continuous inflow from Tonawanda Creek.

On July 21, 2014, incremental changes in the bypass gate opening were made to determine what effect those changes had on the flow rate within the canal. Incremental changes were made for 0%, 20%, 25%, 30%, 35%, and 45% gate openings; the corresponding Canal Corp calculated flow rate at the locks is provided in Table 2-7. The effects of changes in the bypass flow rate made by the Canal Corp were not evident in the flow data. For example, at the Route 384 bridge, flows remained fairly stagnant and negligible for the majority of the day on July 21, with the exception of spikes in the flow rates potentially due to boat traffic. Similar trends were evident at the East Canal/New Road bridge, where flow rates remained at zero from approximately 1 p.m. on July 21 through early evening on July 22.

Bypass flow rate changes appeared to have minimal effect on level and velocity and were obscured by more dramatic changes such as filling Locks 34/35 and the changes in the Niagara River water level. Lock fills had the most pronounced effect on level and flow at the closest flow monitoring station, at Stevens Street. However, lock fills were transmitted down the canal and were observed as changes in level at the East Canal/New Road bridge. Significant fluctuations in both velocity (where measurable) and water depth were observed at the East Canal/New Road bridge that coincided with opening and closing of the locks. These impacts were observed at the East Canal/New Road bridge to occur approximately 30 minutes after the operation of Lock 34/35. Impacts observed at the Stevens Street bridge monitoring location occurred approximately 10 minutes after the operation of Lock 34/35. During day-time operation of the canal, the majority of the flow at the Stevens Street bridge was eastwardly (negative), while the majority of the East Canal/New Road bridge flow data recorded was minimal (zero flow value).

No correlation was observed between the canal operations and the flows recorded at the Delaware Avenue monitoring location. The eastwardly flows at this location are also likely the result of backwater effects of the Niagara River and the NYPA's operations. Due to the lack of intermediate flow meters within the treatment area extent, it is unknown how far upstream these effects dominate the hydraulic conditions of Tonawanda Creek and where impacts transition to the Canal Corp operations..

Table 2-7 Summary of Bypass Gate Openings and Corresponding Flow Rates

Date	Time	Gate Opening (%)	Calculated Flow Rate (cfs)
July 21, 2014	8:00 am	0	0
July 21, 2014	10:00 am	30	474
July 21, 2014	1:55 pm	20	320
July 21, 2014	5:00 pm	35	550
July 21, 2014	9:30 pm	45	699
July 22, 2014	7:40 am	25	397

Source: Manns 2014b

Most velocity measurements, and thus most flow rates, were of a low magnitude. For example, at the Route 384 bridge, the measured velocities ranged from -1.0 to 1.3 ft/s (corresponding flow rates of approximately 2,300 cfs to the west and 3,100 cfs to the east); however, the majority of the measurements showed no velocity at all (see Appendix D). A trend in velocity may be observed at this location: velocities were generally higher during the day when the water level was highest. These positive velocity measurements at the Route 384 bridge indicate flow to the east.

At night, as Niagara River levels increased and Canal Corp operations were minimal (bypass flows only; no lock fills), the vast majority of velocity and flow rates were at or near zero. Data collected from four of the five monitoring days in July indicate that Tonawanda Creek and the canal have little to no measurable flow during the hours of 8:00 p.m. to approximately 8:00 a.m. (refer to the graphs at the end of Appendix D). The water elevation also appears to stabilize at the Delaware Street bridge, Stevens Street bridge, and East Canal/New Road bridge monitoring locations during this time. This implies that backwater from the Niagara River hydraulically dominates the creek when the Canal Corp is not actively operating the locks, which results in a "pool"- like state throughout the treatment area where flow is stagnant and not flowing toward the Niagara River. When the Canal Corp was operating (after about 8:00 or 9:00 a.m.) trends indicate a general eastwardly flow along Tonawanda Creek and the canal at all three monitoring stations.

The only monitoring period that showed any flow during the hours of 8:00 p.m. to 8:00 a.m. was on July 23 (the night immediately after herbicide application) at the Delaware Avenue bridge meter location. This appears to be an anomaly when compared with the other four days of recorded data during this period. An eastwardly flow rate of approximately 1,200 cfs was detected from the hours of approximately 2:30 a.m. to 6:30 a.m. Available data do not indicate the source of this early morning flow, but because canal operations were not observed during this time it is likely the result of operations of NYPA along the Niagara River. Water quality sampling at monitoring locations located between River Miles 3.0 and 6.0 (treatment zones MC3 through MC6), showed significant decreases in endothall concentrations between July 22 (p.m.) and July 23 (a.m.) (see Table 2-

3). This early morning flow disturbance likely contributed to an increased rate of eastward movement of the herbicide immediately after application, reducing the overall contact time. Similar significant decreasing trends in herbicide concentration were not observed for the following water quality sampling events conducted in the evening of July 23 and the morning of July 24 the endothall concentrations recorded for these events appear to be relatively stable compared with the July 22 (p.m.) and 23 (a.m.) event.

Flow out of the natural channel of Tonawanda Creek (near East Canal/New Road) were all generally low to stagnant. Although there was continuous flow into the canal at this location, the canal level is high enough that the flow gradient is minimal. Essentially, the water within the system acts like a pool, with low flow in both directions but primarily toward Lockport. Flow rates at the United States Geological Survey (USGS) gauging station on Tonawanda Creek in Rapids, New York (USGS 04218000) were about 105 cfs on July 21, 2014, increased to 130 cfs by midday on July 22, 2014, and then slowly decreased to about 80 cfs on July 25, 2014 (USGS 2014).

2.7 Post-Monitoring Spot Treatment

Post-treatment monitoring conducted by the USACE in August and September indicated an area in the western portion of the 7-mile primary treatment area that had not received adequate exposure during the application in July. As determined by the USACE, this approximately 1-mile area required re-treatment to effectively control hydrilla within Tonawanda Creek/Erie Canal because monitoring indicated that the plants remaining in this section were ready to put down tubers. This spot treatment area extended from the bridge east of Route 384 to just east of the Service Drive boat launch (see Figure 4) and comprised approximately 26 acres.

The spot treatment was conducted on September 16, 2014 and is discussed in detail in the following subsections.

2.7.1 Public Notification

Individual owners of riparian land, creek/canal users, and the general public were notified of the additional spot treatment.

1. Riparian owners and permitted users located along the 1-mile spot treatment area and a 0.5-mile buffer on each side were notified via certified mail; and
2. Yellow warning signs were posted along the spot treatment area at public access points.

2.7.2 Field Conditions

Field conditions prior to (24 hours), during, and immediately following the treatment (24 hours) are summarized in Table 2-8. As can be seen in Table 2-8, conditions were primarily dry around the time of herbicide application for the spot treatment.

Table 2-8 Field Conditions Preceding, During, and Following Spot Treatment Herbicide Application

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
September 15, 2014	Min: 51 Max: 66	0.64	Relative humidity ranged from 48% to 93% throughout the day
September 16, 2014 (treatment date)	Min: 53 Max: 65	0.03	Relative humidity ranged from 37% to 93% throughout the day
September 17, 2014	Min: 48 Max: 66	0.00	Relative humidity ranged from 44% to 93% throughout the day

Source: National Weather Service – Buffalo Weather Forecast Office 2014

2.7.3 Herbicide Treatment Methodology

Endothall was applied in the 26-acre spot treatment area by ACT in accordance with the SOW developed by the USACE – Buffalo District. A single boat was used for the follow-up herbicide application.

2.7.3.1 Herbicide Transfer

An in-line herbicide injection system was used in the work skiff. Due to the limited volume of product being applied, product availability, and delivery constraints, 2.5-gallon jugs of endothall were used. The jugs were transported to the project site in pick-up trucks and loaded directly onto the work skiff (Bellaud 2014b). After the jugs were emptied, they were triple-rinsed with water from Tonawanda Creek within the treatment area and were then returned to ACT's Sutton, MA office for recycling and disposal.

2.7.3.2 Herbicide Application

The work skiff was outfitted with a 2-inch gasoline powered water pump. Water was drawn from the creek/canal and sprayed out subsurface through weighted hoses that trailed the boat. A venturi-style liquid eductor was connected on the outflow side of the pump. A hose with a "stinger" was used to draw the herbicide directly out of the 2.5-gallon jugs. This connection had a gate valve that could be closed to regulate and stop the herbicide flow rate. Herbicide was drawn from the jugs, in line, at a rate of approximately 2 gallons per minute, resulting in a 40:1 dilution (Bellaud 2014b).

The work skiff was loaded at the City of North Tonawanda boat launch and herbicide was applied from west to east in the designated treatment area. Boat passes were made parallel to the shorelines. As requested by the USACE, the herbicide was applied in water less than 10 feet deep, which was generally within 50 feet of the shoreline.

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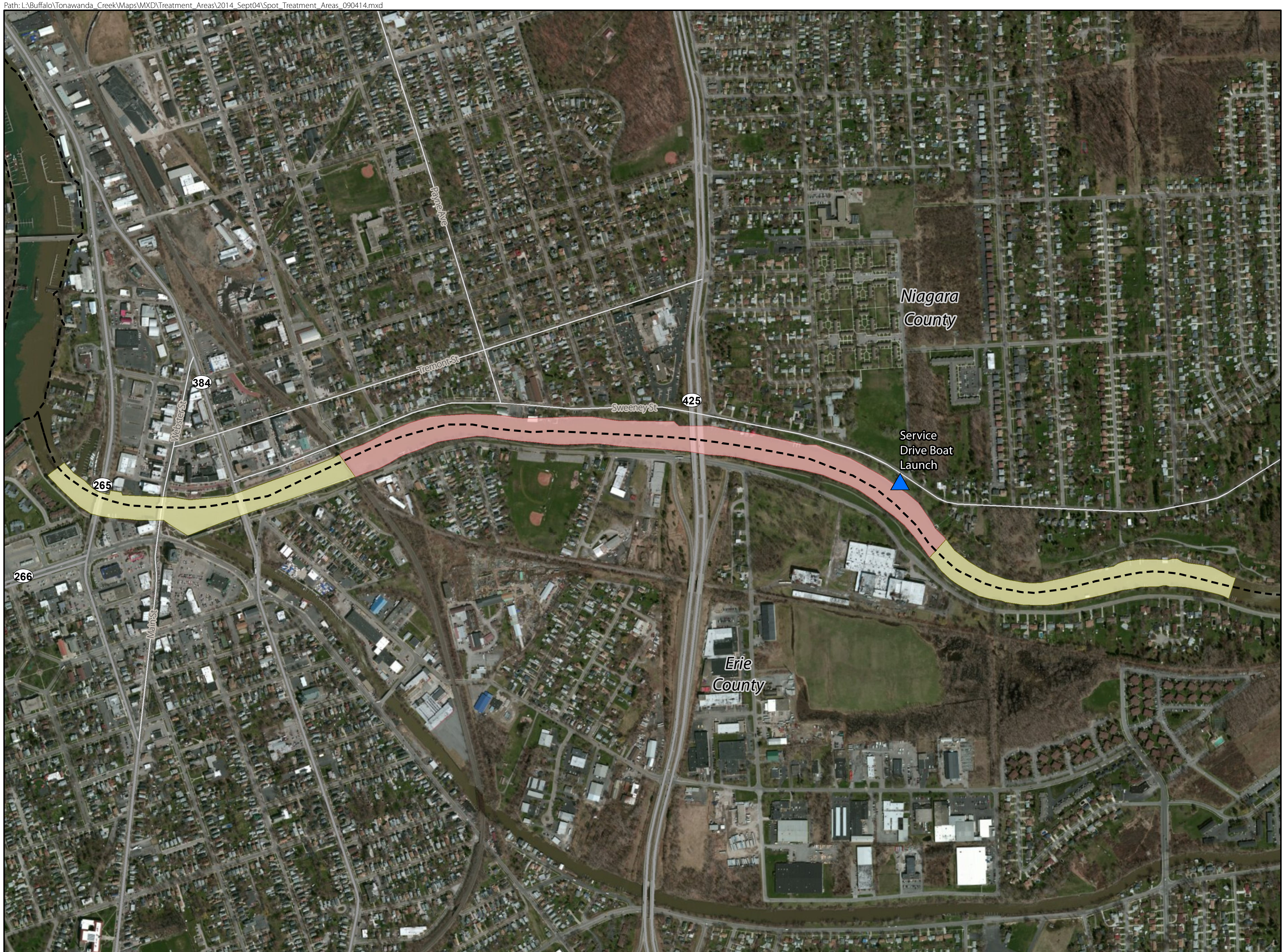

Figure 4
Spot Treatment Area and One-Half Mile Buffer
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- Boat Launch
- Spot Treatment Area
- One-Half Mile Buffer
- County Boundary
- Secondary Road
- Local Road

SCALE

0 0.125 0.25 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2014; US Army CORPS of Engineers, 2014

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

The 26-acre area was divided into four sections that were each approximately 6.5 acres (see Figure 5). The quantity of herbicide needed for each section was determined by the total acreage and volume of the area to be treated. All of the herbicide was applied to each section before moving to the next section.

ACT staff arrived at the City of Tonawanda Launch at Service Road at 8:00 a.m. on September 16, 2014, launched the work skiff, and began assembling treatment systems. After a brief on-site meeting with staff from NYSDEC and the USACE, the herbicide application began at approximately 9:00 a.m. Aside from brief breaks when the boats stopped to re-load herbicide, the treatment continued uninterrupted until the operation was completed at approximately 11:30 a.m. (Bellaud 2014b). The actual duration of the application was approximately 2.5 hours.

2.7.3.3 Quantity of Herbicide Use and Total Area Treated

The total quantity of endothall applied in the designated spot treatment area was 261 gallons. The application targeted an in-water concentration of 1.5 ppm throughout the 26-acre treatment area (Bellaud 2014b).

2.7.3.4 Herbicide Concentration Time and Dispersion

To determine the endothall concentrations and dispersion of herbicide, ERDC sampled water at locations both within and outside the treatment area at 2, 5, 21, and 17 hours post-application. A total of 14 sampling sites were established (see Figure 6). Two sampling sites (REF 0 and REF 1) were west of the treatment area, and nine sampling sites (REF 2 through 10) were located east of the treatment area (see Table 2-9). Additionally, three sampling sites were located within the treatment area.

Samples were analyzed using the same procedure as described in Section 2.5.1.

Table 2-9 Summary of Post-Treatment Water Sampling Results

Sample Site (with distance from edge of treatment area in parentheses)	Endothall Concentration (µg/L)			
	2 Hours Post-Application (9/16/2014)	5 Hours Post-Application (9/16/2014)	21 Hours Post-Application (9/17/2014)	27 Hours Post-Application (9/17/2014)
TRT 1	1605, 1620, 1636	781, 1007, 776	103, 67, 87	ND, ND, ND
TRT 2	1355, 953, 1914	1198, 1401, 1306	349, 456, 388	ND, ND, ND
TRT 3	1172, 2140, 1463	1324, 2218, 1273	1244, 1566, 1644	ND, ND, ND
REF 0			ND	ND
REF 1	ND, ND, 208	105, 216, ND	192	ND
REF 2 (200 m)	1737, 305, 304	1401, 966, 1730	1251	ND

Table 2-9 Summary of Post-Treatment Water Sampling Results

Sample Site (with distance from edge of treatment area in parentheses)	Endothall Concentration (µg/L)			
	2 Hours Post-Application (9/16/2014)	5 Hours Post-Application (9/16/2014)	21 Hours Post-Application (9/17/2014)	27 Hours Post-Application (9/17/2014)
REF 3 (400 m)	ND, ND, ND	1033, 986, 1129	1414, 775, 1137	ND, 333, 299
REF 4 (800 m)	ND, ND, ND	523, ND, 280	322	296
REF 5 (1600 m)	ND, ND, ND	ND, ND, ND	273, 226, 404	433, 249, 319
REF 6	-	-	202	ND
REF 7	-	-	243	ND
REF 8	-	-	-	ND
REF 9	-	-	-	ND
REF 10	-	-	-	ND

Source: Netherland 2014b

Notes:
Sample sites with three values represent samples collected along the two shorelines and one collected in the center of the canal.
Sample sites with one value represent one sample collected in the middle of the canal.

Key:
ND = Non-detect
Ref = Sampling sites outside of the treatment area
TRT = Sampling sites inside the treatment area

Although the herbicide was applied to the near-shore areas, rapid lateral movement of the herbicide was noted within hours of application. Endothall concentrations at sampling sites TRT1 and TRT2 within the treatment area were significantly lower by 5 and 21 hours post-treatment (see Table 2-9). Sampling location TRT3 at the east end of the treatment area maintained endothall concentrations near the target rate throughout 21 hours post-application (Netherland 2014b). During the post-treatment application, flows were shut down for slightly more than 24 hours (see Section 2.7.3.5 below). Following resumption of normal flows in the canal, rapid loss of herbicide from the treatment area and significant dilution of the herbicide concentrations in downstream locations east of the treatment area were noted (see Table 2-9, 27-hours post-application).

Vertical movement of the herbicide was also monitored at the three sampling sites within the treatment area (TRT1 – TRT3) at three different depths. The relative percent difference between adjacent vertical samples (i.e., between surface and middle, and middle and bottom) at the same sampling site were greatest between the middle and bottom sites (Table 2-10). The relative percent differences decreased over time (from two hours post-application to 21 hours post-application) for both TRT1 and TRT2. TRT3 did not evidence the same pattern of

Tonawanda Creek

Erie and Niagara Counties, NY

Hydrilla Spot-Treatment Areas

FIGURE:	TREATMENT DATE:	MAP DATE:
5	9/16/14	9/30/14

Legend:

Follow-Up Treatment Areas (S1-4) - 26.0 ac

Loading Areas

0 0.035 0.07 0.14 0.21 0.28 Miles

N

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Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2014_Nov04\Water_Sampling_Locations_110414.mxd

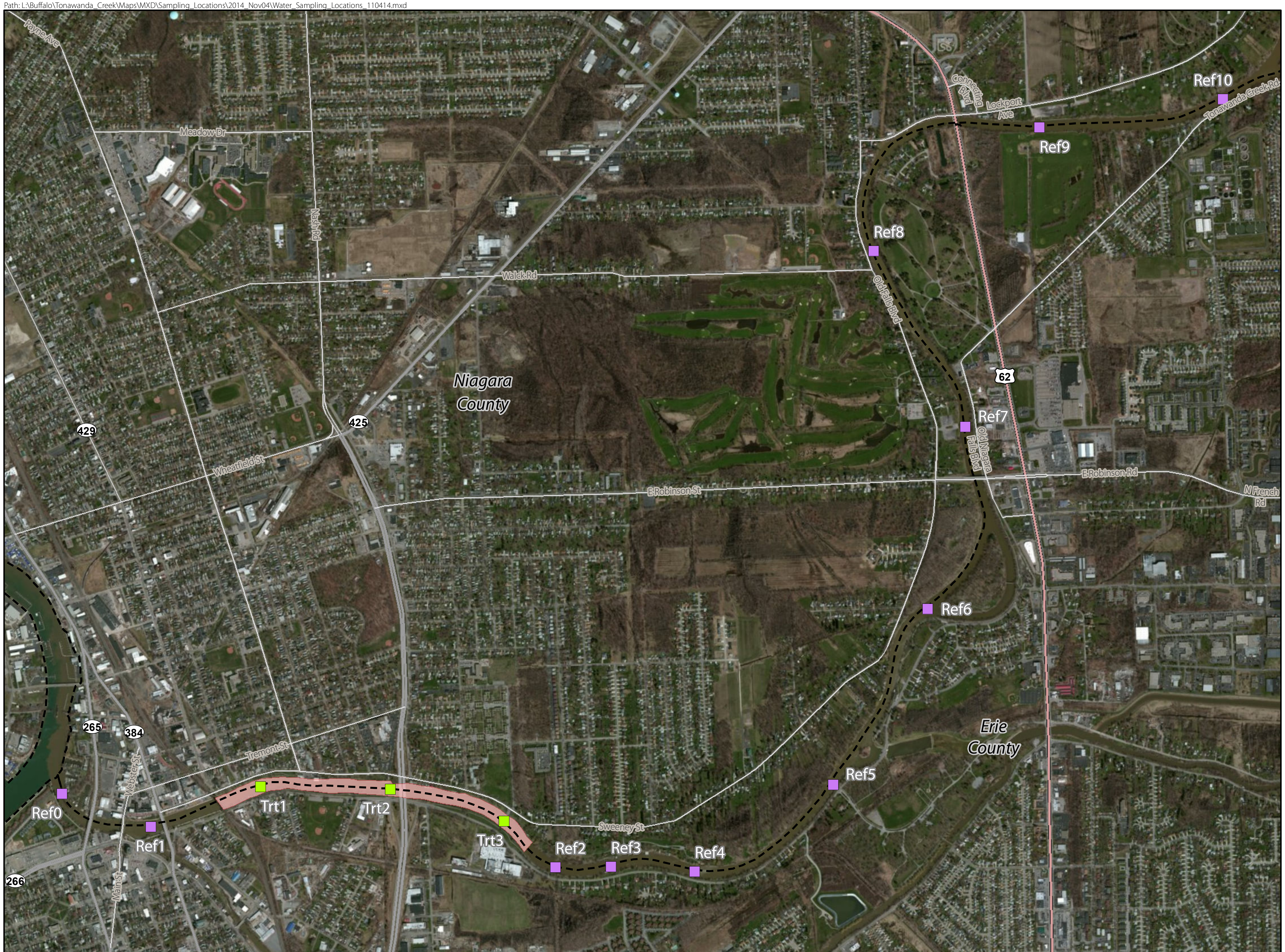

Figure 6
Spot Treatment
Water Sampling Locations
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- Samples collected outside of the treatment area
- Samples collected within the treatment area
- Spot Treatment Area
- County Boundary
- Major Road
- Secondary Road
- Local Road

N

SCALE

0 0.25 0.5 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2014; US Army CORPS of Engineers, 2014

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community decreasing percent differences but instead showed an increase in relative percent increase from two hours to five hours post-application and a decrease from five hours to 21 hours post-application (Table 2-10).

Table 2-10 Vertical Distribution of Endothall within Three Treatment Sites

Sample Site	Depth	Endothall Concentration (µg/L)			
		2 Hours Post-Application (9/16/2014)	5 Hours Post-Application (9/16/2014)	21 Hours Post-Application (9/17/2014)	27 Hours Post-Application (9/17/2014)
TRT 1	Surface	1605	581	103	ND
	Middle	932	460	100	ND
	Bottom	ND	ND	ND	ND
TRT 2	Surface	1355	1198	377	ND
	Middle	ND	578	333	ND
	Bottom	ND	ND	ND	ND
TRT 3	Surface	1072	1324	1606	ND
	Middle	1168	711	1497	ND
	Bottom	ND	ND	ND	ND

Source: Netherland 2014b

Key:
ND = Non-detect

2.7.3.5 Flow Monitoring and Management

The Canal Corp shut down their flows out of the bypass gates around 8:00 a.m. on September 16, 2014 and held the flows at zero until approximately 10:00 a.m. on September 17, 2014. Based on the issues noted above with reducing flow rates in the canal for 48 hours, the target for flow reduction for the spot treatment was reduced to 24 hours. The ability to demonstrate a decrease in the amount of contact time required for hydrilla control and the ability to reduce the amount of time required to reduce flow rates in the canal can inform future management decisions.

In-stream flow was not monitored during the spot treatment; flows were monitored prior to the herbicide application using the USGS Rapids, NY gauging station.

3 Lessons Learned

The lessons learned, summarized below, were based on feedback provided by the interagency project team during a team conference call held on August 25, 2014, and through other team communications.

3.1 Herbicide Application and Analysis

Transfer of the herbicide from the shore-based areas to the boats and application of the herbicide was smooth and efficient. The locations and number of staging areas adequately supported operations along the creek/canal. Public access to the boat ramps during use by the applicators was uninterrupted.

Any improvements to the herbicide application process would be limited to simple, operational improvements. For example, a larger transfer pump could be used in the future to yield additional time efficiencies as a whole. The use of a larger boat that could accommodate a larger tank for herbicide could also yield additional time efficiencies.

Using an airboat during future herbicide applications may be revised if channel conditions allow. Airboats are conspicuous and if not needed to complete the job, an additional prop boat would be preferred.

The immunoassay test performed to determine endothall concentrations was effective at detecting the herbicide and for tracking its movement and degradation.

3.2 Flow Monitoring and Management

Various lessons learned pertaining to flow monitoring and management were identified. Each of these is summarized below, by topic area.

Flow Monitoring Locations

New locations for two of the three flow monitoring locations should be identified because of concerns regarding the proximity of public boats and security. The Delaware Avenue bridge was a good flow monitoring location; however, the area was too heavily used by boaters and was associated with low flow rates in general. The number of boats that turn around near the Delaware Avenue bridge may have affected readings; a new location farther east along the canal should be identified for future treatments. The additional flow meter should be installed approximately at the bridge at Route 425 in order to help identify the transition between the backwater impacts observed at the downstream Delaware Avenue monitoring location and the impacts resulting from canal operations observed at the Stevens Street and East Canal/New Road monitoring locations.

The Stevens Street flow monitoring location was associated with some security concerns, because people in the area use the dock and there is a potential for vandalism. While no such incidents occurred in July, the potential does exist.

Need for a Water Balance

The Canal Corp learned that closing the bypass gates prior to treatment is necessary to hold the pool level within the system. They also reported that it would be beneficial to understand flows and the potential adjustments at the outset of the treatment, instead of being asked for an adjustment to flow management mid-treatment: for example, users farther east in the canal system, e.g., the Mount Morris Dam and Rochester Gas & Electric, had not anticipated changes in flow management. The Canal Corp suggested that the Mount Morris Dam and Rochester Gas & Electric be notified, as other stakeholders are notified, before any future large-scale treatments take place.

These concerns illustrate the need to develop a water balance that includes all inputs and outputs to the canal system before implementing another large-scale treatment in the Tonawanda Creek/Erie Canal Once those inputs/outputs are identified and quantified what can be stopped and what cannot be stopped can be determined. The Canal Corp can then control the “faucet” as necessary.

Periods of No Velocity Recorded

During flow monitoring, there were many lengthy periods when no velocity measurements were recorded. It was determined that these represented periods of no flow, low velocity, or changing conditions (e.g., changes in flow direction) when flow was essentially stagnant. Typically, velocity measurements less than 0.2 ft/s were not recorded. Assuming that this is the approximate detection limit of the area-velocity flow modules, this velocity equates to flow rates of 85 to 475 cfs for the three monitoring locations, depending on the cross-sectional area used. Therefore, in order to manage flows of less than about 400 cfs, more sensitive equipment may be required. It is not known whether such automated equipment is available at this time; stream velocity measurements are typically only measurable manually at flows above 0.1 to 0.2 ft/s, and manual measurements are more prone to operator error. Thus, manual measurements are not the solution, although they can be useful for verifying automated readings. Alternative meters, including other types of current meters, should be evaluated to see if they would be more appropriate for monitoring the water flow along Tonawanda Creek. Additionally, the placement of the flow meters along the creek cross-section should be reviewed to identify if the meters could be placed at locations better suited to measuring creek flow.

Measuring such low velocities with the sensitive Doppler flow meters is further complicated by outside conditions such as wind and boat traffic. For example, at times when the flow at the Route 384 bridge was visually observed to be stagnant and most flow-module velocity readings were zero, isolated positive velocities were recorded. On multiple occasions this was observed to occur when boat traffic passed by. The "noise" recorded in the water level data for this location is also likely due to wave action caused by weather and boat traffic.

Canal Corp Operations

Perhaps most important to managing flows in the Tonawanda Creek/Erie Canal to maximize herbicide contact time would be to temporarily cease operations of the Lockport locks. If bypass flow can be eliminated before, during, and after treatment, and lock fills stopped, then the only flow that would require management is the low input from the natural channel of Tonawanda Creek (less than 130 cfs during this study). This inflow rate could be adjusted at Lockport by operating the bypass gate at a comparably low flow rate. Maintaining navigable conditions in the canal during herbicide application requires a maintaining a certain flow rate out of the system (estimated to be less than 500 cfs during this study), which can negatively impact movement of the herbicide.

Movement of Herbicide Eastward

During the July herbicide application, eastward movement of the herbicide was rapid. The flow resulting from lock movements and the bypass gates may have been the biggest contributor to the eastward movement of the herbicide. To reduce this contribution to water movement in the future, if additional large-scale treatments are necessary, operations at the locks and flow out of the bypass gates should be shut down to the maximum extent possible. However, during the August spot treatment, the bypass gates were closed and eastward movement of the herbicide still occurred (see Section 2.7.3.4).

In addition to stopping the flow out of the bypass gates, a revision of the monitoring process has been recommended to improve the understanding of herbicide contact time and dispersion. Instead of relying solely upon flow monitoring to manage the movement of the herbicide, an enhanced water sampling process in addition to flow monitoring is recommended. Additional samples should be taken at the edges (eastern and western) to identify and track herbicide movement. This monitoring process would result in the ability to "see," via analytical results, the herbicide moving within the system. The frequency of the edge sampling should be based on weather conditions and flow conditions at the USGS gauging station on Tonawanda Creek in Rapids, New York, with minimum sampling completed on the day of herbicide application and the day following application. This methodology was employed during the August spot treatment, and sampling sites were chosen on the eastern and western edges of the treatment area (see Figure 6).

Additionally, the flow monitoring data indicate that the flow rate to the east along the entirety of Tonawanda Creek was 200 cfs or less immediately prior to the 8:00 p.m. to 8:00 a.m. duration. This time period provides the most hydraulically stable period along Tonawanda Creek and would allow for the longest contact time.

Also, further evaluation of the NYPA operations should be conducted to determine if actions can be taken to mitigate potential influence from the Niagara River during this period. Flow management for the western portion of the treatment area is dependent on the Niagara River water levels and flows. Logistically it may be impractical to treat the water during this optimal timeframe. If the herbicide is applied during normal canal operational hours (i.e., 8:00 a.m. to 6:00 p.m.), in order to compensate for the eastwardly flow that will likely occur, the use of the locks should be kept at a minimum during and after treatment to increase the contact time in the area of concern. Additionally, consideration should be given to applying the herbicide at a location downstream of the treatment area to account for migration.

Lastly, , although the hydrilla plant density within River Mile 2 to River Mile 4 may be lower, it may be more appropriate to increase the concentration of the herbicide because eastwardly migration is likely unavoidable, given the hydraulics within the treatment area.

3.3 Interagency and Stakeholder Coordination

During a project interagency team call on August 25, 2014, team members provided feedback regarding how the coordination process was conducted. The primary area identified for improvement was the need for clear communication after the treatment had been completed to notify stakeholders that conditions were back to normal. The City of North Tonawanda expressed uncertainty regarding when the canal water was safe for use for irrigation. Other than improving communication, the remainder of the coordination among interagency team members and stakeholders, e.g., pre- and post-treatment planning and communications, was effective and was completed in a timely manner.

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