Post-Treatment Assessment for Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek/Erie Canal 2015

Contract No. W912P4-10-D-0002

December 2015

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Prepared for:

UNITED STATES ARMY CORPS OF ENGINEERS
Buffalo District

Table of Contents

Table of Contents (cont.)

List of Tables

Table **Page**

List of Figures

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
µg/L	micrograms per liter
NYPA	New York Power Authority
NYSDEC	New York State Department of Environmental Conservation
ppm	parts per million
PPE	personal protective equipment
Project	Tonawanda Creek/Erie Canal Hydrilla Demonstration Project
RM	river mile
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 (the Project) is a field-scale demonstration of a technology developed under the United States Army Corps of Engineers' (USACE) Aquatic Plant Control Research Program to manage monoecious hydrilla (*Hydrilla verticillata;* Hydrilla) in a flowing water system.

This report contributes to the post-treatment monitoring and assessment of herbicide efficacy on Hydrilla 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 United States 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, and upstream to the Lockport area, approximately 15 miles to the east. The total area within the reach where 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 due to 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. These concerns provided the impetus for implementation of the Project.

This year, to control and eradicate Hydrilla, the USACE - Buffalo District conducted a second year of treatment for the Project within a 13.5-mile-long

[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.

stretch of creek/canal, focusing on application of the aquatic herbicide endothall (Aquathol K™). The following two areas were treated (see Figures 1-1 and 1-2):

- **Western block primary treatment area**: 5.5 miles between the Route 384 Bridge in Tonawanda, New York to West Canal Park in North Tonawanda, New York directly treated with herbicide; and
- **Eastern block secondary treatment area**: 8 miles between West Canal Park and the Pendleton Guard Gate in Pendleton, New York, which received secondary treatment from flow in the canal.

The identified treatment area, comprising both the primary and secondary treatment areas, was created to be representative of the full 15-mile stretch of the creek/canal in which Hydrilla beds had been previously identified by the USFWS. The western block contains the majority of the Hydrilla beds, thus it received direct herbicide application.

Prior to treatment application, Hydrilla populations within the treatment areas were delineated and mapped using hydro-acoustic surveys. In June and July 2015, the USACE Engineer Research and Development Center (ERDC) conducted supplementary mapping and plant delineation and identified two additional locations of Hydrilla beds near the intersection of Tonawanda Creek and the Erie Canal. These beds were isolated with limno-curtains (impermeable dividers) and received application of endothall. Additionally, the following three oxbow treatment areas were included in the primary treatment area:

- East side of the small island along Creekside Drive at Ellicott Creek Park (OX1; see Figure 1-1);
- East side of Ellicott Island Park near Creekside Drive and Niagara Falls Boulevard (OX2; see Figure 1-1); and
- East side of the island at Tonawanda Creek Road and Sweet Home Road (OX3; see Figure 1-2).

Lastly, an isolated Hydrilla bed was identified on the south bank of the canal on the east side of the River Road Bridge in Tonawanda following this Year 2 treatment effort. The newly discovered bed was treated as part of the Post-Monitoring Spot Treatment activities (see Figure 1-3).

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

1.2 Purpose and Scope

The purpose of the Project is to develop and implement selective control methods to manage Hydrilla in a flowing water system, while limiting impacts on native vegetation. Prior to the implementation of the Project in 2014, management of monoecious Hydrilla using an aquatic herbicide in a flowing water system had not been tested. Therefore, the results of this continued field-scale 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.

The ERDC will use the findings in this report to support continued post-treatment monitoring to determine the success of each successive treatment program. Post-treatment monitoring will also be used to determine whether additional creek/canal-wide treatments will be needed in the future, or if direct targeting of individual Hydrilla beds with herbicide would be a more effective way to remove small satellite populations that survive treatment or re-sprout 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, conclusions are provided, in the form of lessons learned, to help shape future treatment projects.

02:1003025.0026.04-B4394\Figure 1-1 Western Treatment Areas.ai-12/16/15-GRA

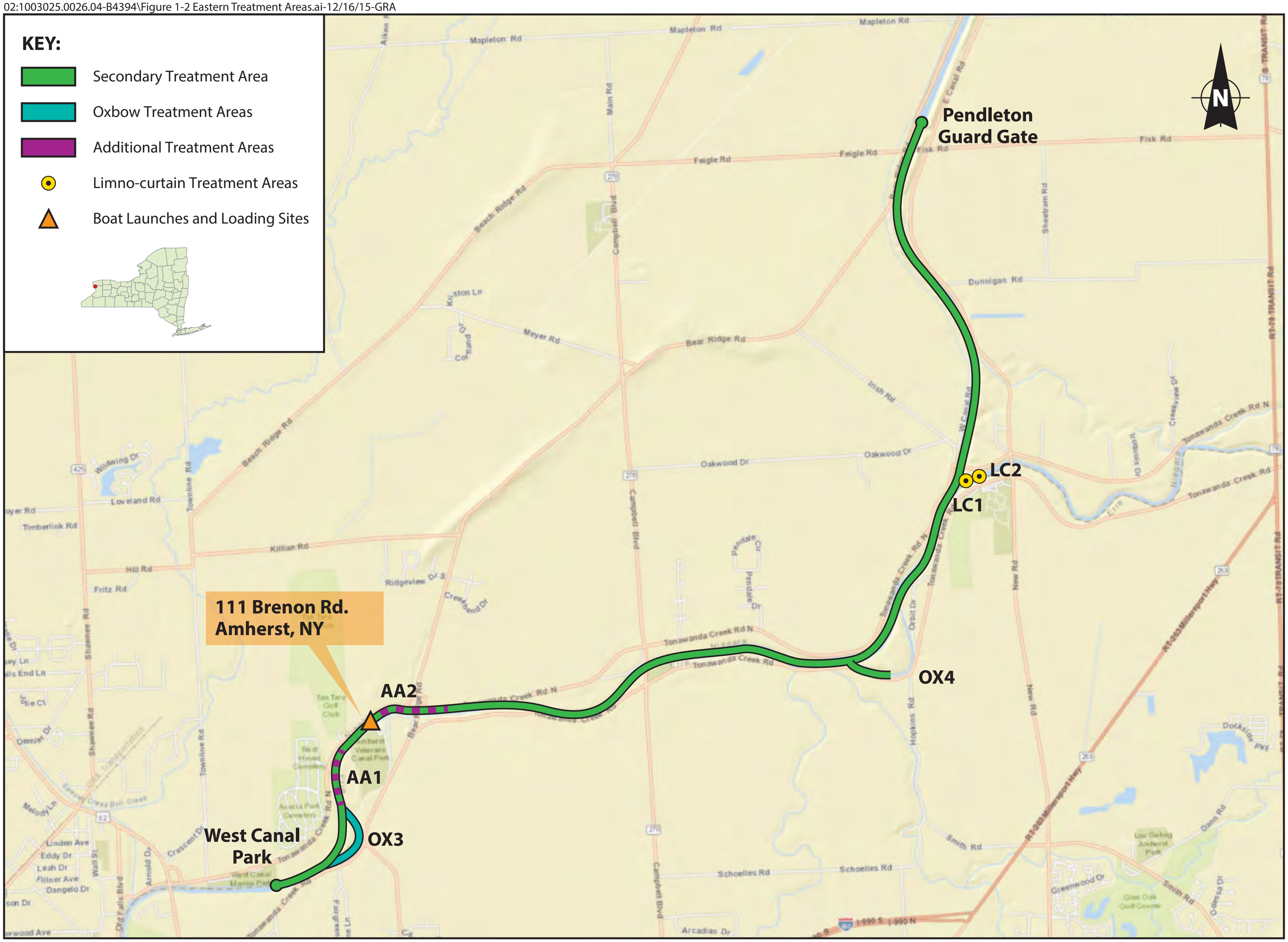
Treatment Area	Acres
MC1	12.5
MC2	15.4
MC3	11.3
MC4	9.18
MC5	10.6
MC6	6.93
MC7	13.6
MC8	15.1
SUP1	16.5
SUP2	16.2
OX1	2.26
OX2	8.99
OX3	7.25

Service Layer Credits: Sources: ESRI, HERE, DeLorme, USGS, Intermap, Increment P Corp., NRCAN, ESRI Japan, METI, ESRI China (Hong Kong), ESRI (Thailand), MapmyIndia, © OpenStreetMap Contributors, and the GIS User Community

SCALE
0 0.5 1.0 Mile

Figure 1-1 Western Block Treatment Areas Tonawanda Creek/Erie Canal

02:1003025.0026.04-B4394\Figure 1-2 Eastern Treatment Areas.ai-12/16/15-GRA



Service Layer Credits: Sources: ESRI, HERE, DeLorme, USGS, Intermap, Increment P Corp., NRCAN, ESRI Japan, METI, ESRI China (Hong Kong), ESRI (Thailand), MapmyIndia, © OpenStreetMap Contributors, and the GIS User Community

SCALE
0 0.5 1.0 Mile

Figure 1-2 Eastern Block Treatment Areas
Tonawanda Creek/Erie Canal

Insert Figure 1-3 (Color, 11 x 17) page 1 of 2

1-3 Post Monitoring Spot Treatment Location

2 Overview of Herbicide Treatment

Treatment of Hydrilla for this Project focused on the application of the aquatic herbicide endothall within the Tonawanda Creek section of the Erie Canal. During treatment, water flow in the creek/canal was minimized by Canal Corp. in order to achieve a maximum (or ideal) contact time at a target concentration. Minimizing water flow yielded greater contact time between the herbicide and Hydrilla. To minimize flow, a target flow rate of 200 cubic feet per second (cfs) or less to the east was identified.

The following sections outline 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. Photos of operations are shown in Appendix A.

2.1 Public Notification

Public awareness 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). Six methods of public notification were used for the project:

1. A public information meeting was held on June 3, 2015, at the North Tonawanda Public Library;
2. Riparian owners and permitted users were notified by E & E via certified mail;
3. Yellow warning signs identifying use restrictions of the canal following application of the herbicide were posted along the primary treatment areas at public access points;
4. Display advertisements were published in three local/regional newspapers on July 25, 2015 (*The Buffalo News*, *Lockport Union-Sun & Journal*, and the *Niagara Gazette*);
5. Agency notification letters were distributed by U.S. mail; and

6. Project factsheets were distributed during Canal Fest (July 19 through 26) by Western New York Hydrilla Task Force members.

2.2 Field Conditions

Field conditions prior to (July 23 through July 28), during (July 28 and 29), and immediately following the treatment (July 30 through August 3) are summarized in Table 2-1. Conditions were primarily dry when the herbicide was applied.

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

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
July 23, 2015	Min: 55 Max: 79	0	No significant weather observed Average wind speed 8.5 mph with gusts up to 23 mph
July 24, 2015	Min: 57 Max: 82	0	No significant weather observed Average wind speed 5 mph with gusts up to 17 mph
July 25, 2015	Min: 63 Max: 83	0.07	Fog Average wind speed 11.2 mph with gusts up to 26 mph Precipitation since June 1, 2015: 7.39 inches
July 26, 2015	Min: 68 Max: 86	0	No significant weather observed Average wind speed 4.8 mph with gusts up to 15 mph
July 27, 2015	Min: 64 Max: 89	0	No significant weather observed Average wind speed 3.8 mph with gusts up to 13 mph
July 28, 2015 Treatment Day 1	Min: 67 Max: 89	0	No significant weather observed Average wind speed 5 mph with gusts up to 16 mph
July 29, 2015 Treatment Day 2	Min: 68 Max: 91	0	No significant weather observed Average wind speed 6.9 mph with gusts up to 19 mph
July 30, 2015	Min: 72 Max: 82	0.03	Fog Average wind speed 13 mph with gusts up to 37 mph
July 31, 2015	Min: 64 Max: 82	0	No significant weather observed Average wind speed 11.6 mph with gusts up to 33 mph Total precipitation for July 2.42 inches
August 1, 2015	Min: 78 Max: 66	Trace	Light Rain Average wind speed 9.9 mph with gusts up to 32 mph
August 2, 2015	Min: 83 Max: 62	0	No significant weather observed Average wind speed 12.8 mph with gusts up to 33 mph

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

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
August 3, 2015	Min: 79 Max: 67	Trace	No significant weather observed Average wind speed 13.8 mph with gusts up to 30 mph
September 8, 2015	Min: 72 Max: 88	Trace	No significant weather observed Average wind speed 8.1 mph with gusts up to 23 mph
September 9, 2015	Min: 67 Max: 79	0.23	Fog/mist Thunder Average wind speed 9.2 mph with gusts up to 26 mph Total precipitation for August 4.39 inches; total precipitation September 1 thru 9: 0.47 inches

Source: National Weather Service 2014.

2.3 Herbicide Treatment Methodology

The aquatic herbicide endothall was applied in designated sections of the creek/canal on July 28 and 29, 2015 (see Figures 1-1, 1-2, and 1-3). 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 March 18, 2015 (USACE 2015).

Three boats were used for the herbicide application. The vessels were 18- to 24-foot, shallow-draft work skiffs powered by conventional outboard motors. The skiffs were used to treat the main creek/channel, shallow oxbows, and supplemental areas at the intersection of Tonawanda Creek and the Erie Canal. The post monitoring spot treatment area was treated from the shore by physically removing as much as the Hydrilla as possible and using a battery-powered sprayer to apply the herbicide from the shore (see photos in Appendix A).

2.3.1 Herbicide Transfer

An in-line herbicide injection system was used on the three conventional work skiffs. Each skiff 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 gasoline-powered transfer pumps. 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 skiffs.

For the smaller supplemental treatment area and the post monitoring spot treatment area, endothall herbicide was transferred into spray tanks from 2.5-gallon jugs.

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 at the water's subsurface through a boom and subsurface hose assembly mounted to the stern of each boat. Venturi-style liquid eductors on the outflow side of the pumps were connected to the herbicide storage tanks with 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. The tanks on the skiffs were filled at the designated loading areas. Herbicide was applied from west to east along the creek/canal. Boat passes were made parallel to the shorelines. 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 (see Figure 1-1); last-minute modifications by the 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 two supplemental treatment areas (AA1 and AA2; see Figure 1-2) totaling 6 acres, located outside of the previously identified primary treatment area boundaries (i.e., from Amherst Veterans Canal Park in Amherst, New York, to just west of Bear Ridge Road).

July 28, 2015: Day 1

ACT staff arrived at the City of North Tonawanda boat launch at 700 Sweeney Street at the foot of Service Road at 1300 hours, launched the three skiffs 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 1330 hours. Each treatment crew consisted of a lead applicator and an assistant/technician. Once the three skiffs were loaded, the herbicide application began at approximately 1345 hours (see photos in Appendix A). Aside from brief breaks when the skiffs stopped to reload herbicide, the treatments continued uninterrupted until the operation was completed at approximately 1815 hours. The three skiffs and treatment crews spent a combined total of approximately 4.5 hours actually applying the herbicide.

The treatment boats were launched and herbicide transfer began at the City of North Tonawanda boat launch at 700 Sweeney Street at the foot of 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 eastern sections of the creek/canal. At both locations, 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.

July 29, 2015: Day 2

The western portion of the treatment area (SUP2 and SUP1) was re-treated on Day 2 (as shown on Figure 1-1). ACT launched a single work skiff from 700 Sweeney Street at the foot of Service Road. The same herbicide transfer and application methods were used as Day 1. Treatment began at 1000 hours and was completed in approximately 2 hours.

At the same time, a second ACT crew treated two additional small patches of Hydrilla discovered by USACE staff approximately 3 miles east of the treatment area. The additional areas were located at the confluence of the Erie Canal and Tonawanda Creek in Pendleton, New York, and are designated LC1 and LC2 on Figure 1-2. Both areas were isolated using 50-foot long, floating limno-curtains that were secured to the shoreline. The limno-curtains extended from above the surface of the water to the creek/canal bed effectively isolating the Hydrilla beds from the surrounding flowing water. Endothall was diluted with water in a 50-gallon mixing tank and sprayed into the treatment areas using a 12-volt, low-pressure, hand-gun sprayer.

September 8 and 9, 2015: Post-Monitoring Treatment

During the post-treatment monitoring, USACE staff identified a small dense patch of Hydrilla located outside the treatment area to the west, immediately east of the River Road Bridge in Tonawanda, New York, on the southern shoreline (approximate location 43.021434, -78.879804) (see Figure 1-3). A 50-foot limno-curtain was installed around the patch creating an isolated area approximately 20 feet by 20 feet. The area was treated by ACT personnel on the afternoon of September 8, 2015, and again on the morning of September 9, 2015. The treatment was performed from the shore using a battery-powered backpack sprayer. Endothall herbicide was diluted with water and evenly sprayed throughout the enclosed treatment plot.

2.4 Quantity of Herbicide Used and Total Area Treated

The total quantity of endothall applied in designated sections of the creek/canal on July 28 and 29, 2015, was 2,091 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 2.3. The creek/canal section divisions were made by dividing the main channel into multiple sections to calculate the herbicide dosing.

The dosing was predetermined and calculated by the ERDC and ACT based on the total volume divided by canal sections; an equal average depth was assumed for each section. The target concentration of endothall for all of the treated sections in the main creek/canal channel was 1.5 parts per million (ppm). Again, this dose was calculated on the entire water volume of the creek/canal, but the herbicide was applied in the infested areas along the shoreline resulting in higher concentrations at the time of application. Oxbows were treated with a concentration of 3.0 ppm. Spot-treatment of the additional areas located east of the primary treatment area (areas AA1, AA2, LC1 and LC2 on Figure 1-2) targeted an in-water concentration of 4.0 ppm in order to maximize concentrations in the smaller plots. The post-monitoring treatment plot was treated on consecutive days with a concentration of 2.5 ppm each day to comply with the herbicide label requirement to not apply more than a total of 5 ppm within a seven-day interval.

Table 2-2 summarizes herbicide application for each canal section as depicted on Figures 1-1, 1-2 and 1-3.

Table 2-2 Herbicide Application Summary, by Canal Section

Date	Canal Section (west to east)	Figure Number	Acres	Endothall Applied (gallons)	Targeted Concentration (ppm)	Notes
7/28/2015	SUP2	1-1	16.2	202.5	1.5	
7/28/2015	SUP1	1-1	16.5	206.25	1.5	
7/28/2015	MC 1	11-	12.5	155	1.5	
7/28/2015	MC 2	1-1	15.4	192.5	1.5	
7/28/2015	MC 3	1-1	11.3	140	1.5	
7/28/2015	MC 4	1-1	9.2	114	1.5	
7/28/2015	MC 5	1-1	10.6	132.5	1.5	
7/28/2015	MC 6	1-1	6.9	85.5	1.5	
7/28/2015	MC 7	1-1	13.6	170	1.5	
7/28/2015	MC 8	1-1	15.1	188.75	1.5	
7/28/2015	OX1	1-1	2.3	14.8	3.0	
7/28/2015	OX2	1-1	9	58.4	3.0	
7/28/2015	OX3	1-1/1-2	7.3	47.8	3.0	
7/28/2015	AA1	1-2	3	38	4.0	
7/28/2015	AA2	1-2	3	38	4.0	
7/29/2015	SUP2	1-1	16.2	152.1	1.5	Re-treatment
7/29/2015	SUP1	1-1	16.5	154.9	1.5	Re-treatment
7/29/2015	LC1	1-2	0.01	0.12	4.0	500 sq. ft. enclosed
7/29/2015	LC1	1-2	0.01	0.12	4.0	500 sq. ft. enclosed
9/8/2015	Post Monitoring Area	1-3	0.01	0.06	2.5	400 sq. ft. enclosed
9/9/2015	Post Monitoring Area	1-3	0.01	0.06	2.5	400 sq. ft. enclosed
			Total Gallons	**2,091.36**		

Key:
AA = Additional Area
LC = Limno-curtain
SUP = Supplemental treatment area
MC = Main channel treatment area
OX = Oxbow treatment area
ppm = parts per million
R = Supplemental treatment area\
sq. ft. = square feet

2.5 Herbicide Contact Time and Dispersion

Herbicide was applied to sections of the creek/canal on July 28 and 29, 2015; these sections were determined as discussed in Section 2.4. Water sampling, to determine the endothall concentrations and dispersion of herbicide, began on the date of application and ended on August 3, 2015, and was performed by ERDC and E & E.

2.5.1 Initial Sampling Results – First 48 Hours

ERDC sampled during the day of treatment (July 28, 2015) as well as portions of the creek/canal on the day after treatment (July 29, 2015) and all of the 15-mile creek/canal area July 30, 2015. E & E sampled portions of the creek/canal on July 29 as well as the entire 15-mile creek/canal area on July 31, 2015 and August 3, 2015. These sample locations and denotations are provided in Appendix B. Sampling locations were established at approximately 0.5-mile intervals along Tonawanda Creek/Erie Canal beginning at the mouth of the creek/canal at the Niagara River in Tonawanda, New York (river mile [RM] 0) to Lockport Road in Lockport, New York, approximately 15 miles upstream. Additional samples were taken at areas deemed to be significant such as oxbows and a spot treatment area. These additional locations are summarized in Table 2-3.

Table 2-3 Additional Sample Area Locations

Area Description	River Mile
400 meters west of start of treatment	0.2
Start of treatment	0.4
400 meters east of start of treatment	0.7
Twin cities memorial highway bridge	1.2
End of treatment area on7/29/15	1.7
Mayors Park	2.1
Oxbow 1	2.8
Oxbow 2	3.5
Botanical gardens	3.9
End of treatment area on 7/28/15	5.8
400 meters past end of treatment area on 7/28/15.	6.1
Oxbow 3	6.3
Oxbow 4	10.1

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 20:1 or 10:1 dilution, with detection limits of 140 or 70 µg/L, respectively, or as non-diluted samples with a detection limit of 7 µg/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 analyses were performed to determine the percent recovery of endothall. Each sample run incorporated the use of external standards at 500; 1,000; and 2,000 µg/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. The additional endothall application on July 29, 2015, was conducted to maintain adequate herbicide concentrations in the Service Drive boat ramp area. The 2014 application resulted in rapid clearance of endothall from this region (RM 1 and 2) and less than desired control. In 2015, the additional application resulted in increased endothall concentrations noted between the morning sample on July 29, 2015, and the afternoon sample in the areas near RMs 1 and 2 (see Table 2-4). While the concentrations in this zone were non-detectable by July 30, 2015, subsequent evaluations suggest complete control of the Hydrilla was achieved in the vicinity of the Service Drive boat ramp portion the creek/canal. Target endothall concentrations were maintained in the treatment area between miles 2 and 6 for 48 hours. Moreover, eastward movement of the herbicide was noted in RMs 7 through 9. RMs 10 through 12 received significant exposures to endothall on July 31, 2015. Herbicide concentrations sampled in the afternoon after application ranged from 427 to 4,134 µg/L (see Table 2-4). Table 2-4 summarizes results obtained through August 3, 2015, and emphasizes distribution of the treatment in relation to the target zone and clearance of the herbicide from the system.

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

River Mile	Location ID[2]	Endothall Concentration (µg/L)[3] Sampling Dates[1] 7/28/15 A[4]	7/28/15 B[4]	7/29/15 A[4]	7/29/15 B[4]	7/30/15	7/31/15	8/3/15
0	0.0 RB		ND	ND	ND	ND		
	0.0 C						ND	
	0.0 LB		ND	ND	ND	ND		
0.2	0.2 RB		ND					
	0.2 LB		ND					
0.4	**0.4 RB**	**534.4**	**427.2**	**ND**	**ND**			
	0.4 C	**ND**						
	0.4 LB	**ND**	**ND**	**ND**	**ND**			
0.5	**0.5 LB**						**ND**	**ND**
0.7	**0.7 RB**		**2,143.8**					
	0.7 LB		**1,495.4**					
1.0	**1.0 RB**	**3,696.0**	**2,643.8**	**637.4**	**1967.8**	**ND**	**ND**	
	1.0 C	**2,998.8**						
	1.0 LB	**2,094.8**	**2,899.6**	**581.8**	**2,324.2**	**ND**		
1.2	**1.2 RB**					**ND**		
	1.2 LB					**ND**		
1.5	**1.5 RB**					**ND**		
	1.5 C						**ND**	**ND**
	1.5 LB					**ND**		
1.7	**1.7 RB**			**1,134.4**	**3,357.8**	**ND**		
	1.7 LB			**1,470.2**	**3,160.8**	**ND**		
2.0	**2.0 RB**	**4,181.2**	**3,073.0**	**1,804.6**	**1,714.4**	**373.6**	**ND**	

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

		Endothall Concentration (µg/L)[3] Sampling Dates[1]						
River Mile	Location ID[2]	7/28/15 A[4]	7/28/15 B[4]	7/29/15 A[4]	7/29/15 B[4]	7/30/15	7/31/15	8/3/15
	2.0 C	**4,492.4**						
	2.0 LB	**2,829.2**	**2,752.2**	**1,792.8**	**1,762.8**	**334.8**	**ND**	
2.1	**2.1 RB**					**943.0**		
	2.1 LB					**670.6**		
2.5	**2.5 RB**						**ND**	**ND**
2.8	**2.8 A RB**					**1,476.8**		
	2.8 A						**ND**	**ND**
	2.8 A LB					**1,551.0**		
3.0	**3.0 RB**		**4,091.0**	**2,033.4**	**1,808.8**	**1,691.0**		
	3.0 C						**ND**	
	3.0 LB		**4,226.2**	**1,906.2**	**1,768.8**	**1,866.2**		
3.5	**3.5 A RB**					**2,029.6**		
	3.5 A						**93.9**	**ND**
	3.5 A LB					**2,045.8**		
	3.5 RB						**ND**	**ND**
	3.5 LB						**ND**	**ND**
3.9	**3.9 RB**					**1,643.8**		
	3.9 LB					**1,813.8**		
4.0	**4.0 RB**	**7,976.2**	**4,134.4**	**2,409.0**	**2,840.8**	**1,607.2**	**143.5**	
	4.0 C	**2,019.0**						
	4.0 LB	**6,343.5**	**4,066.6**	**2,356.6**	**2,644.2**	**1,749.6**		
4.5	**4.5 C**						**235.5**	**ND**
5.0	**5.0 RB**		**2,926.4**	**2,526.6**	**2,431.8**	**1,583.0**		
	5.0 LB		**2,797.6**	**2,717.0**	**2,520.8**	**1,498.4**	**567.8**	
5.5	**5.5 RB**						**1,062.4**	**ND**
5.8	**5.8 RB**			**1,276.0**	**2,410.0**	**1,571.0**		
	5.8 LB			**1,379.0**	**2,187.2**	**1,475.8**		
6.0	6.0 RB					1,663.0		
	6.0 C			1,207.2	2,231.0		976.9	
	6.0 LB					1,544.2		
6.1	6.1 RB		ND					
	6.1 LB		ND					
6.3	6.3 A			1,095.6	1,928.6		1,238.0	ND
6.5	6.5 LB						1,269.1	ND
7.0	7.0 RB					1,720.6	1,238.0	
	7.0 C			707.4	1,857.6			
	7.0 LB					1,764.2		
7.5	7.5 C						1,351.7	ND
8.0	8.0 RB					1,698.6		
	8.0 C			799.2	339.4			
	8.0 LB					1,599.6	1,139.7	
8.5	8.5 RB						1,207.5	ND
9.0	9.0 RB					1,040.4		
	9.0 C			ND	283.0		1,291.6	
	9.0 LB					1,199.0		

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

		Endothall Concentration (µg/L)[3] Sampling Dates[1]						
River Mile	Location ID[2]	7/28/15 A[4]	7/28/15 B[4]	7/29/15 A[4]	7/29/15 B[4]	7/30/15	7/31/15	8/3/15
9.5	9.5 LB						1,273.6	ND
10.0	10.0 RB					421.8	1,224.9	
	10.0 C			ND	ND			
	10.0 LB					412.2		
10.1	10.1 A			ND	ND		1,164.8	ND
10.5	10.5 C						1,211.8	ND
11.0	11.0 RB					335.2		
	11.0 C			ND	ND			
	11.0 LB					262.4	1,278.1	
11.35	Curtain Canal				ND	243.0	900.5	
	Curtain Tonawanda				3,025.6	ND	374.0	
11.5	11.5 RB						1,207.5	ND
12.0	12.0 RB					ND		
	12.0 C			ND	ND		1,156.4	
	12.0 LB					177.0		
12.5	12.5 LB						913.4	ND
13.0	13.0 RB					179.8	536.2	
	13.0 C			ND	ND			
	13.0 LB					ND		
13.5	13.5 RB						258.2	ND
14.0	14.0 C			177.6	ND			
	14.0 LB						479.8	
14.5	14.5 RB						161.4	ND
15.0	15.0 C			ND	ND		128.8	

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

[1] Application occurred on July 28 and 29, 2015. Samples collected on July 28, 29, and 30 were collected by ERDC; samples collected on July 29 and 31 and August 3, 2015, were collected by E & E.
[2] Location ID assigned by E & E.
[3] Endothall results provided by ERDC for all samples.
[4] The letter "A" denotes first sampling event of the day and "B" denotes the second sampling event of the day. For July 28, 2015 "A" was in the range of 1600-1700 hours, "B" was in the range of 1800-2000 hours. For July 29, 2015 "A" was in the range of approximately 0945-1115 hours and "B" was in the range of 1415-1530 hours.

Key:
ND = Non-detect (detection limit of 140 µg/L on 7/28, 7/29, and 7/30; 70 µg/L on 7/31; and 7 µg/L on 8/3/15)

Sampling conducted on the day of herbicide application indicated an eastward movement of the herbicide (see Table 2-5). At the eastern edge of the treatment block, the herbicide was not detectable 400 meters past the treated area by 1945 hrs.

Table 2-5 Herbicide Movement near the Western Treatment Block

Distance from Treatment Block Edge	Time Sampled on Date of Application (hours)	Average Endothall Concentration (µg/L) from east and west bank of canal
400 meters west of treatment block	1835	ND
Treatment block edge	1830	271
400 meters east of treatment block	1835	1,819

Key:
ND = Non-detect

Lateral Dispersion

To assess the lateral dispersion of endothall within the treatment areas, ERDC sampled three locations laterally across the creek/canal at RMs 1, 2, and 4. Two of the locations for each lateral were along the shorelines, and one was located in the middle of the creek/canal. 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 hours of application.

In summary, the sample results indicated relatively rapid (less than 24 hours) dispersion across the creek/canal.

2.5.2 Water Sampling Results Following Flow Resumption

As discussed in detail in Section 2.6.2, flows were managed by Canal Corp. during the 48-hour application period and immediately after. On July 28, 2015, at approximately 0900 hours, all flow within the canal system was stopped prior to herbicide application. As discussed 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 31, 2015.

Following the initial sampling effort by ERDC, E & E obtained grab water samples along Tonawanda Creek/Erie Canal on July 29, 31, and August 3, 2015 (see Table 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, New York. In addition, samples were collected in both channels where the flow is divided at the following four locations:

- East side of the small island along Creekside Drive at Ellicott Creek Park (RM 2.8);
- East side of Three Mile Island near Creekside Drive and Niagara Falls Boulevard (RM 3.5);
- East side of the island at Tonawanda Creek Road and Sweet Home Road (RM 6.3); and
- The side channel along Tonawanda Creek Road just west of Hopkins Road (RM 10.1).

The sampling locations are indicated on Figures B-1 through B-23 in Appendix B.

The samples obtained by E & E were collected as grab samples from an approximate depth of 1 foot at all locations using a peristaltic pump. A stainless-steel tube 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 each sample. Each sample was labeled with a unique sample code and immediately placed into 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 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 taken by E & E on July 29 were handed directly to the EDRC representative to be analyzed that day. Samples from July 31 and August 3 were shipped on ice to the ERDC laboratory at the University of Florida Center for Aquatic Plants for analysis. Samples from August 3 were lost in transit by UPS, but were located and delivered approximately two weeks later. Although the samples were no longer chilled, ERDC stated that the samples were still viable and results still usable because there was no breech in chain of custody and the samples were preserved with acid. All 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 three normal/duplicate pairs were collected over three days of sampling. The analytical results for two of the three pairs (both samples) were non-detect; the sample pair collected at location 6.0 C collected on July 31, 2015, had positive values and a relative percent difference of 18%, showing good correlation. Lateral sample pairs also showed good correlation.

Two sample pairs were obtained on July 31 and one sample pair was obtained on August 3. All three lateral pairs were non-detect.

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 July 29, 2015, indicated the presence of endothall from RM 1.0 through RM 9.0 (with the addition of a low detection at RM 14.0). Concentrations in this area ranged from 283.0 µg/L to 3,357.8 µg/L (see Table 2-4 and Figures B-1 through B-6 in Appendix B). On July 31, 2015, sample results indicated the presence of endothall from RM 3.5 to at least RM 15.0, which was the sample collected farthest east. All results for the final day of sampling (August 3, 2015) 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 in less than one week from initial treatment.

2.6 Flow Monitoring and Management

Flow monitoring and management were integral components of the Project. This section provides an overview of the flow monitoring methodology, management actions taken by 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 Canal Corp. manage the flows in the Erie Canal during the 48-hour treatment window. Prior to application, E & E personnel set up three flow meters on July 23 and 24, 2015, to test operations: one at Mayor's Park in Tonawanda, New York, one near the East Canal Road/New Road Bridge in Pendleton, New York, and one near the Stevens Street bridge in Lockport, New York (see photos in Appendix A).

Flow in the creek/canal was measured prior to, during, and following herbicide application. Flow was calculated for each location as a function of the cross-sectional area and average cross-sectional velocity. Prior to deployment of flow sensors, E & E obtained measurements of the stream depth and instantaneous velocity in a cross section perpendicular to the flow direction. In general, depth measurements were recorded every 10 feet across the channel, and at each location velocity measurements were recorded just below the surface and at approximately 25%, 50%, and 75% of the total stream depth. These data were used to create a depth profile and velocity profile of each stream (see Appendix B). Velocity readings were measured using a Hach FH950 Handheld Flow Meter with electromagnetic sensor with a resolution of 0.01 foot per second (ft/s), an accuracy of ±2%, and a zero stability of 0.05 ft/s.

The velocity data were then contoured using the software package Surfer version 12 by Golden Software. The Kriging method of data interpolation was used to grid the data obtained in the field and resulting grid nodes outside of the measured stream channel were removed. Surfer was used to calculate univariate statistics for the interpolated data set, including the mean cross-sectional velocity. The area within the stream that represented the mean velocity ±20% was then highlighted to indicate areas within the stream where single, continuous velocity measurements could be obtained that would represent the approximate mean cross-sectional velocity (see Appendix C).

In order to continuously measure flow during the application period, single flow sensors were deployed at each monitoring location. Flow sensors were Hach Submerged AV, 1 megahertz acoustic Doppler flow sensors connected to Hach FL900AV Flow Meter equipped with a Hach AV9000 Area-Velocity Analyzer Module. Each flow meter was equipped with a cellular modem to transmit data via Hach's Data Delivery Service for remote download and analysis. The flow sensors were positioned by E & E approximately 3 to 4 feet above the stream bed using custom-made mounting systems. The sensors had a resolution of 0.01 ft/s, an accuracy of ±2%, a zero stability of 0.05 ft/s, and were capable of sensing both positive and negative velocities. They were oriented so that positive flow was recorded for the following conditions:

- East to west in Tonawanda Creek/Erie Canal at Mayor's Park, Tonawanda, New York;
- East to west in Tonawanda Creek at New Road, Pendleton, New York; and
- South to north in the Erie Canal at Stevens Street, Lockport, New York.

For each monitoring location, the cross-sectional area of the creek/canal was calculated using the depth measurements obtained prior to sensor deployment. The area of the stream below each sensor was calculated as a fixed area using Surfer software. The area above each sensor was calculated as a function of the water level (measured as height above the sensor) and stream bank geometry. Levels were measured using pressure transducers built into the flow sensors. The relationship between level above the sensor and cross-sectional area was determined using the depth measurements and a river profile area calculator provided by the equipment manufacturer. This calculator is based on simple trapezoidal sections of the river. The calculated areas were plotted against the levels and a line of linear interpolation was fit to the data using the basal area beneath the sensor as the intercept. The resulting formulas were used to calculate the total cross-sectional area based on the measured level. The relationships used for these calculations are depicted on the graphs in Appendix C.

Level and velocity measurements were recorded every 5 minutes. These data were saved in a spreadsheet format and the area was calculated as described herein. The product of the calculated area and measured velocity was then calculated to determine the average cross-sectional flow rate.

Some challenges were encountered with the original set up of the sensors, which allowed the sensors to tip over after being placed in the creek/canal. This challenge was realized and rectified with buoys prior to herbicide application. At the Stevens Street monitoring station, the sensor tipped shortly after it was installed due to wave action from passing boats. Based on the velocity contours that were created (see Appendix C) it was estimated that, regardless of the direction that the sensor may have tipped, it was still within an area that represented the average velocity and no corrections were required. The immediate level change at the time of sensor tipping and readjustment was approximately 3.3 feet. Raw data was corrected by this factor for the period before the sensor position was corrected on July 28, 2015, and resulting flow rates are denoted with an asterisk as estimated values (see Appendix D).

The Mayors Park location was also affected by this challenge as the sensor tipped approximately three days after installation. The data collected during the period before the sensor position was corrected on July 28, 2015, was adjusted based on the immediate changes in water level and velocity at the time it was tipped and readjusted. Flow data from this period are estimated and are denoted with an asterisk in Appendix D.

Hourly updates were provided to the USACE – Buffalo District and Canal Corp. regarding flow conditions observed over the previous hour at each of the monitoring locations. If necessary, specific direction was provided to 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 Old Locks 67 and 71 and located immediately north of Locks 34/35 (Manns 2014). During herbicide application, Canal Corp. closed the bypass tunnel and operations of Locks 34/35 were kept to a minimum, leaving water to be directed through the Flight of Five gates. In order for Canal Corp. to control the amount of flow through Locks 34/35, the Brookfield Power Plant was taken off-line. In order for the Canal Corp. to control the water level between Lockport and the Genesee River, RG&E Power Plant at Station 26 on the Genesee River was taken off-line.

Prior to the 48-hour treatment period, the Canal Corp. ceased flows out of Lockport by closing the bypass gate opening at approximately 0900 hours on July 28, 2015. Lock operations continued during the treatment period but were minimized by Canal Corp. Typically, the filling of Locks 34/35 causes a short-term increase in flow rate towards the locks at the Stevens Street bridge and a drop in water level. However, lock fills were not observed in the level data obtained near the Stevens Street bridge and therefore had minimal effects on flow rates (Manns 2015).

At the request of USACE, the bypass gates were opened minimally (approximately 50 to 100 cfs) at approximately 1900 hours on July 28, 2015, in response to a low observed flow rate away from the locks and towards the Niagara River. The flow rate at the Lockport bypass gates remained at this level until Canal Corp. resumed normal flow conditions at approximately 1700 hours. on July 31, 2015.

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, the NYPA 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 Niagara 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 0700 hours; it is drawn down during the day for power production and is generally lowest at 2100 hours. 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.

The effects of Niagara River water level fluctuations on tributaries were also studied (URS Corp. et al. 2005b). Fluctuations in Niagara River water levels affect Tonawanda Creek/Erie Canal throughout the entire length of the 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 the NYPA were not as evident in the water level data obtained during this project in 2015 compared to 2014 (see Appendix D). The water level at Mayor's Park did exhibit a cyclic behavior but not on a clear daily cycle. Previous measurements in 2014 showed that the water level in the creek/canal near the Niagara River was generally at its highest in the late morning (0900 hours to 1100 hours) and then decreased to a minimum just before midnight with a magnitude change of 0.35 to 0.6 feet. However, on July 28 and 29, 2015, the maximum water level occurred at approximately mid-day and minimum water level occurred near midnight. Fluctuations in water level did not appear to have significant effects on changes in flow rate. At Mayor's Park, the flow rate was generally of a relatively low magnitude to the west during the days prior to and the first half of the initial day of application. In the afternoon of July 28, 2015, and during the subsequent days of flow monitoring, the flow direction was to the east, also at a relatively low flow rate (see Appendix D).

At the Stevens Street monitoring location, flow rates were generally low (approximately 200 cfs) and to the east prior to and throughout the treatment period. Following resumption of flow at the locks and bypass gates on July 31, 2015, an increase in velocity and flow rate towards the locks was observed (see Appendix D).

Flow out of the natural channel of Tonawanda Creek (near East Canal/New Road) were all low. The majority of the time flow was outward from the creek to the canal, but there were periods of flow reversal likely due to backwater conditions moving up the creek/canal resulting from Niagara River level changes. During the treatment period, flow rates were generally measured to be between 50 and 100 cfs, which corroborates the United States Geological Survey (USGS) gauging station data on Tonawanda Creek in Rapids, New York (USGS Station Number 04218000). USGS data for the week of treatment showed flow rates declining throughout the week from about 65 cfs to about 48 cfs (USGS 2015).

2.7 Post-Monitoring Spot Treatment

Post-treatment monitoring conducted by the USACE during the weeks of August 10 and August 17 indicated that all areas received adequate exposure during the application in July. However, a new Hydrilla bed was identified on the south shore of the canal, on the east side of the River Road bridge (see Figure 1-3). The USACE placed a limno-curtain around the 20-ft by 20-ft area and physically removed as much of the Hydrilla as possible, and requested a two-day spot treatment of the area.

The spot treatment was conducted by ACT on September 8 and 9 using a battery-powered spray applicator. The total quantity of endothall applied in the designated spot treatment area was 0.12 gallons (see Table 2-2). The application targeted an in-water concentration of 5 ppm during each treatment throughout the 20-foot by 20-foot treatment area over the two-day period to comply with the label requirement not to apply more than a total of 5 ppm within a seven-day interval.

3 Study Improvements

The study improvements, summarized below, were based on lessons learned from the 2014 endothall application effort and coordination with the study partners during 2015 work plan development.

3.1 Herbicide Application and Analysis

Transfer of the herbicide from the shore-based areas to the skiffs and application of the herbicide in both 2014 and 2015 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.

Using an airboat for future herbicide applications was deemed unnecessary following the 2014 application. Thus, the use of airboats, which are loud and conspicuous, were eliminated from the program.

The immunoassay tests performed to determine endothall concentrations in both 2024 and 2015 were effective at detecting the herbicide and for tracking its movement and degradation.

3.2 Flow Monitoring and Management

Various improvements were implemented pertaining to flow monitoring and management as described below.

Flow Monitoring Locations

New locations for two of the three flow monitoring stations were identified at the completion of the 2014 application due to concerns regarding the proximity of public boats and security.

- **Delaware Bridge Monitoring Station.** Although the Delaware Avenue Bridge location in 2014 was initially believed to be a good flow monitoring location; the area was too heavily used by boaters and was associated with low flow rates in general. Thus, this location was replaced by the Mayors Park location. This location was not as affected by boaters; however, open-water placement of the flow sensor was challenging.
- **Stevens Street Monitoring Station.** In 2014, this location was associated with some security concerns, because people in the area use the dock for

fishing and swimming, thus there is a high potential for vandalism. Therefore, the sensor was moved to the opposite bank of the creek/canal in an area away from the dock and where there is limited shoreline access to a high, vertical rock wall. This made sensor deployment much more challenging but more secure from tampering.

Need for a Water Balance

In 2014, Canal Corp. learned that closing the bypass gates prior to treatment is necessary to hold the creek/canal 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, which is used by 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. Thus, they were included in the 2015 planning, which consisted of closing the gates the morning of the application (July 28, 2015), and reopening the gates on the morning of July 31, 2015.

Periods of No Velocity Recorded

During the 2014 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 approximately 200 cfs, more sensitive equipment would be required. Therefore, a different supplier was identified for flow sensors and monitoring equipment in 2015. Hach submerged AV, 1 megahertz acoustic Doppler flow sensors connected to Hach FL900AV flow meters equipped with Hach AV9000 area-velocity analyzer modules were deployed. The sensors had a resolution of 0.01 ft/s, an accuracy of ±2%, a zero stability of 0.05 ft/s, and were capable of sensing both positive and negative velocities. This sensitivity of instrumentation allowed for a flow rate resolution of less than 50 cfs to approximately 200 cfs (at Mayors Park where the cross-sectional area was the largest).

Canal Corp. Operations

E & E determined after the initial demonstration in 2014 that one of the most important aspects to maximize herbicide contact time was to reduce operations of the Lockport locks and bypass gate flow to the maximum extent practicable. By eliminating flow to the east through the locks, the only flow that would require management is the low input from the natural channel of Tonawanda Creek entering the canal in Pendleton, New York (less than 65 cfs during the 2015 application period [USGS 2015]). This inflow rate can be matched at Lockport by operating the bypass gate at a comparably low flow rate.

Movement of Herbicide Eastward

During the July 2014 herbicide application, eastward movement of the herbicide was observed to be relatively rapid, likely the result of continued discharge through the locks and bypass gates to maintain navigable conditions. To reduce the eastward flow of water and herbicide in 2015, operations at the locks were minimized and flow out of the bypass gates was initially shut down by Canal Corp. As a result, a slight westward flow was observed late on the first day of application and the bypass gates were reopened minimally (approximately 50 to 100 cfs) in an attempt to balance the flow and maximize herbicide contact time.

In addition to initially stopping the flow out of the bypass gates, a revision of the monitoring process was 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 were taken at the edges (eastern and western) of the herbicide application area on both application days to identify and track herbicide movement. The frequency of the edge sampling was determined by the ERDC in the field considering weather conditions and flow rates measured at the USGS gauging station on Tonawanda Creek in Rapids, New York.

3.3 2015 Lessons Learned

Buoy Deployment

Prior to buoy deployment, there was concern about potential snags by boaters/fishermen with the submerged flow monitoring equipment at each monitoring location. In order to alleviate that concern, buoy markers were placed above each sensor, and water-proof signs stating “Do Not Touch, Government Property” were placed on each buoy marker. Canal Corp. was consulted and approved the deployment of the buoys. In addition, to prevent tampering with the onshore monitoring components (wires to the sensors, datalogger, and cell phone antenna), a similar sign was placed on the data logger.

Treatment Areas

If the treatment program is going to move towards smaller treatment areas in future years, ACT recommends minimizing the use of limno-curtains except to address small outlier patches because they are cumbersome and expensive.. However, the smaller more localized areas should still be treated with open-water applications, but the application areas could focus on these localized areas rather than the entire 5.5-mile stretch. Higher application rates and back-to-back applications over a 24-hour period could be implemented to overcome dilution and insure that sufficient herbicide concentration-exposure-time is achieved.

4 References

Manns, Richard. 2014. Canal Engineer, New York State Canal Corporation. Personal communication with K. Dixon, Ecology and Environment, Inc. on October 15, 2014.

__________. 2015. Canal Engineer, New York State Canal Corporation. Personal communication with G. Florentino, Ecology and Environment, Inc. on October 26, 2015.

National Weather Service, Buffalo Forecast Office. 2014. Observed Weather Reports. http://www.nws.noaa.gov/climate/index.php?wfo=buf.

URS Corporation, Gomez and Sullivan Engineers, and E/PRO Engineering and Environmental Consulting. 2005a. *Niagara Power Project Relicensing, Niagara River Water Level and Flow Fluctuation Study Final Report*. Prepared for the New York Power Authority. http://niagara.nypa.gov/StudyReports/FinalReports.htm#WaterUseAndQuality.

__________. 2005b. *Niagara Power Project Relicensing, Upper Niagara River Tributary Backwater Study*. Prepared for the New York Power Authority. http://niagara.nypa.gov/StudyReports/FinalReports.htm#WaterUseAndQuality.

United States Army Corps of Engineers (USACE). 2015. Architect-Engineer Scope of Work Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek/Erie Canal. March 18, 2015.

United States Geological Survey (USGS). 2015. Data for USGS 04218000 Tonawanda Creek at Rapids NY. National Water Information System. http://waterdata.usgs.gov/nwis/uv?site_no=04218000.

A Photolog

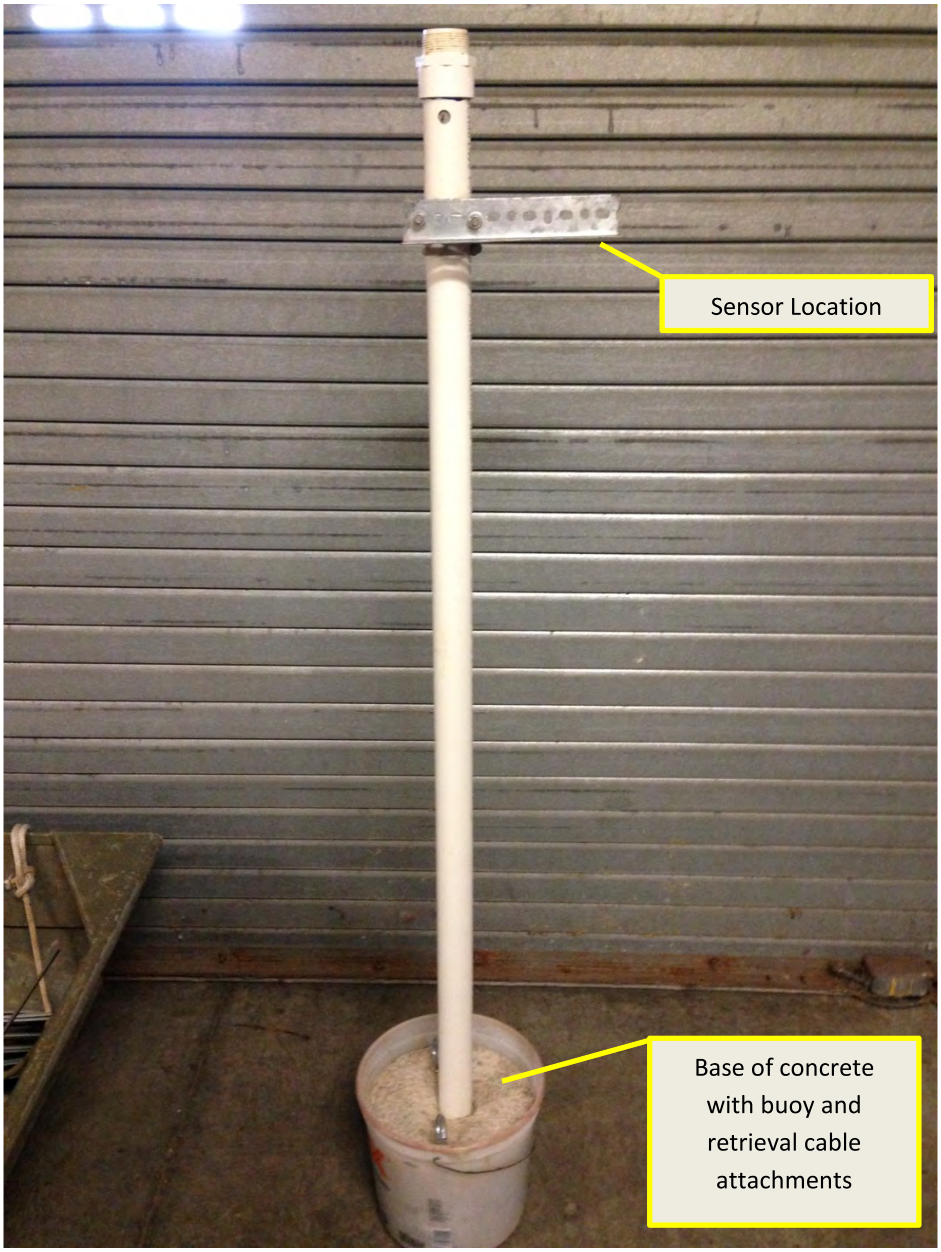


Photo A-1 Example of mount for sensor.

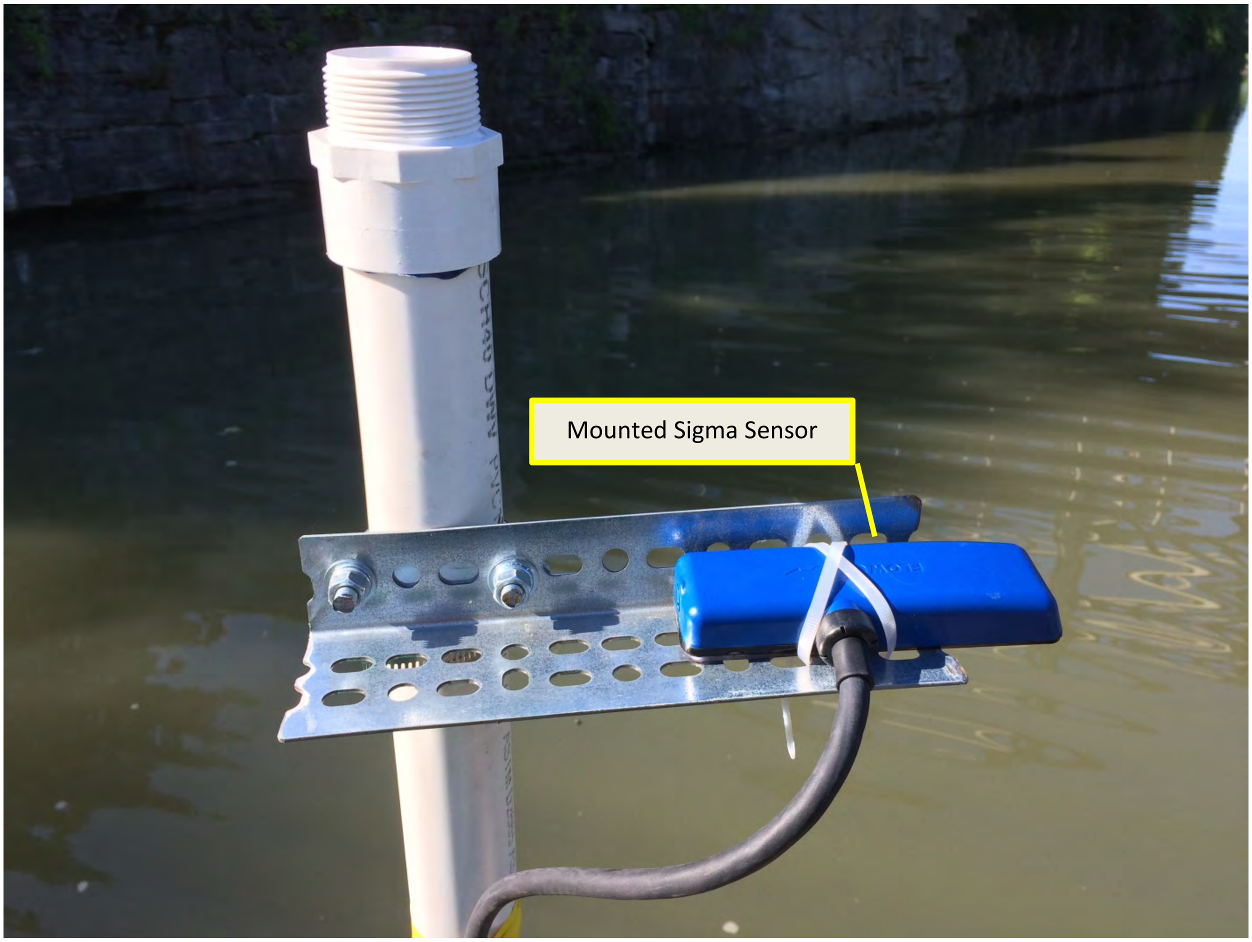


Photo A-2 Example of mounted Sigma Sensor.

Photo A-3 Application skiff set-up.

Photo A-4 Application skiffs.

Photo A-5 Application skiff.

Photo A-6 Spot treatment area.

Photo A-7 Application in Spot Treatment Area

B Water Quality Sampling Location Maps

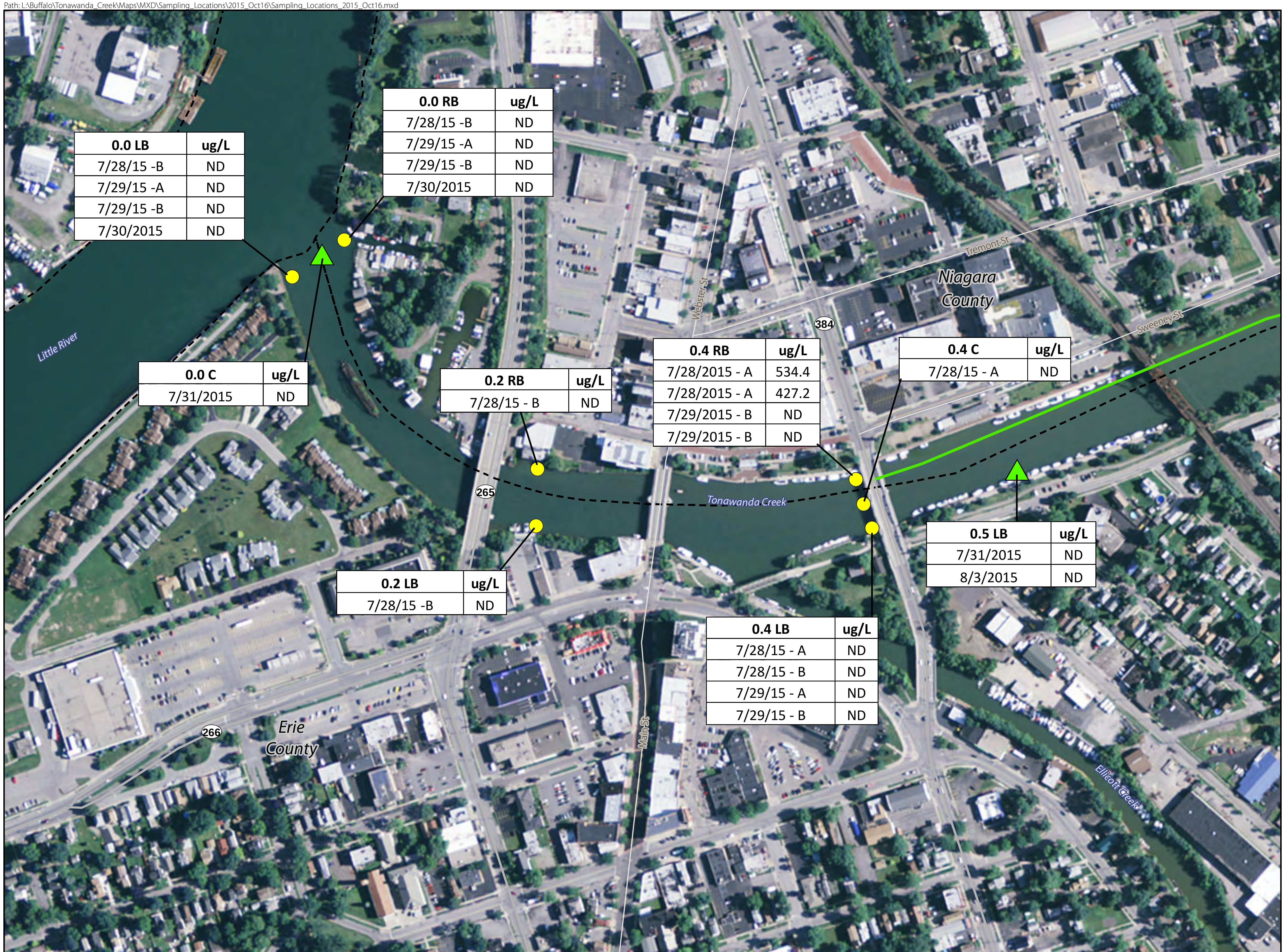
Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values

Figure B-1

Tonawanda Creek

Erie and Niagara Counties, New York



0.0 LB	ug/L
7/28/15 -B	ND
7/29/15 -A	ND
7/29/15 -B	ND
7/30/2015	ND

0.0 RB	ug/L
7/28/15 -B	ND
7/29/15 -A	ND
7/29/15 -B	ND
7/30/2015	ND

0.0 C	ug/L
7/31/2015	ND

0.2 RB	ug/L
7/28/15 - B	ND

0.2 LB	ug/L
7/28/15 -B	ND

0.4 RB	ug/L
7/28/2015 - A	534.4
7/28/2015 - A	427.2
7/29/2015 - B	ND
7/29/2015 - B	ND

0.4 C	ug/L
7/28/15 - A	ND

0.4 LB	ug/L
7/28/15 - A	ND
7/28/15 - B	ND
7/29/15 - A	ND
7/29/15 - B	ND

0.5 LB	ug/L
7/31/2015	ND
8/3/2015	ND

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Secondary Road
- Local Road

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations
and Associated Concentration Values
Figure B-2
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Secondary Road
- Local Road

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

1.5 C	ug/L
7/29/2015	2913.4
7/31/2015	ND
8/3/2015	ND

1.5 RB	ug/L
7/30/2015	ND

1.5 LB	ug/L
7/30/2015	ND

1.7 RB	ug/L
7/29/15 - A	1134.4
7/29/15 - B	3357.8
7/30/2015	ND

1.7 LB	ug/L
7/29/15 - A	1470.2
7/29/15 - B	3160.8
7/30/2015	ND

2.0 C	ug/L
7/28/2015 - A	4492.4

2.0 RB	ug/L
7/28/2015 - A	4181.2
7/28/2015 - B	3073
7/29/2015 - A	1804.6
7/29/2015 - B	1714.4
7/30/2015	373.6
7/31/2015	ND

2.0 LB	ug/L
7/28/2015 - A	2829.2
7/28/2015 - B	2752.2
7/29/2015 - A	1792.8
7/29/2015 - B	1762.8
7/30/2015	334.8
7/31/2015	ND

2.1 RB	ug/L
7/30/2015	943

2.1 LB	ug/L
7/30/2015	670.6

Sample Locations and Associated Concentration Values
Figure B-3
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

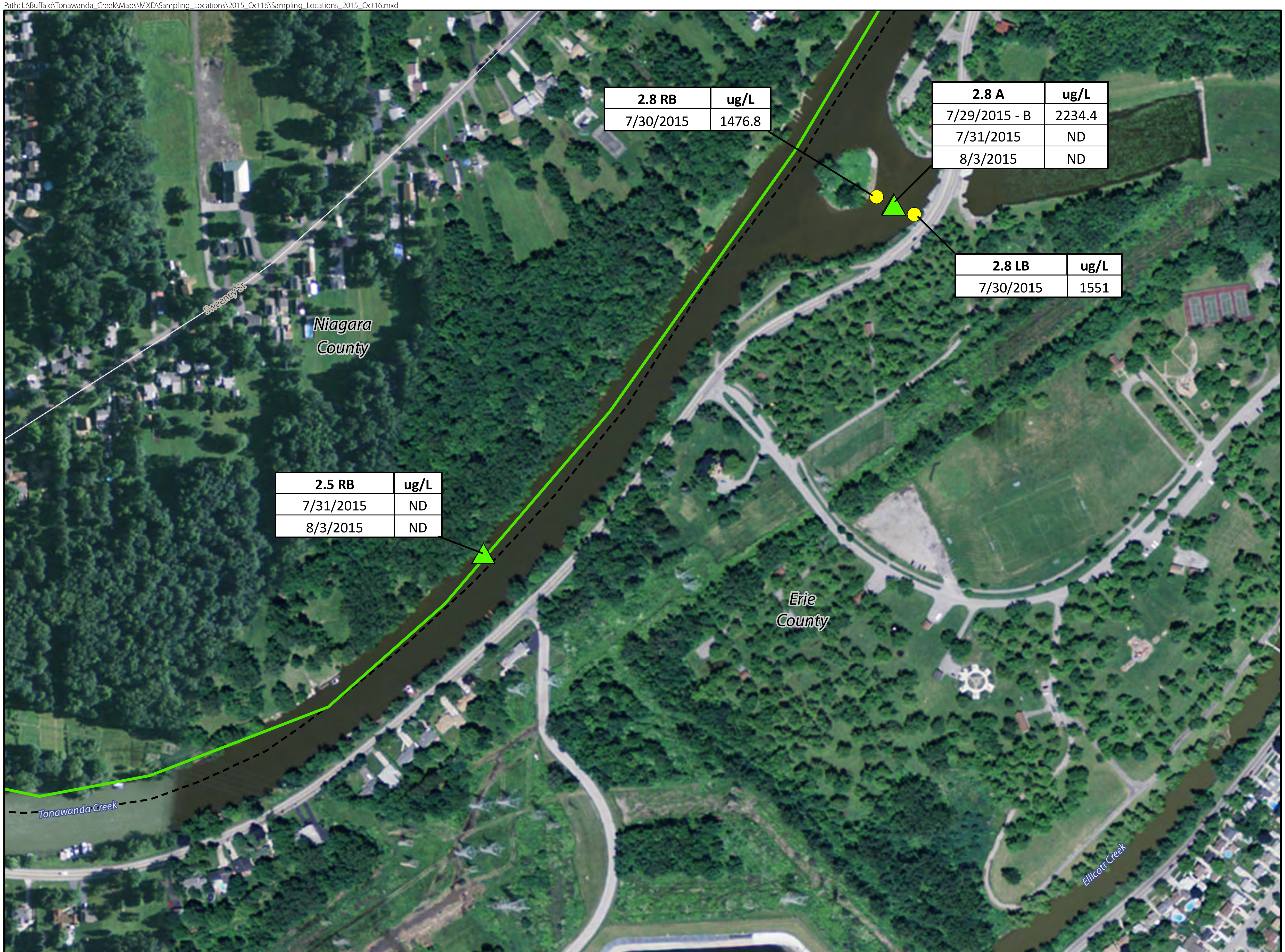
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



2.8 RB	ug/L
7/30/2015	1476.8

2.8 A	ug/L
7/29/2015 - B	2234.4
7/31/2015	ND
8/3/2015	ND

2.8 LB	ug/L
7/30/2015	1551

2.5 RB	ug/L
7/31/2015	ND
8/3/2015	ND

Sample Locations and Associated Concentration Values
Figure B-4
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

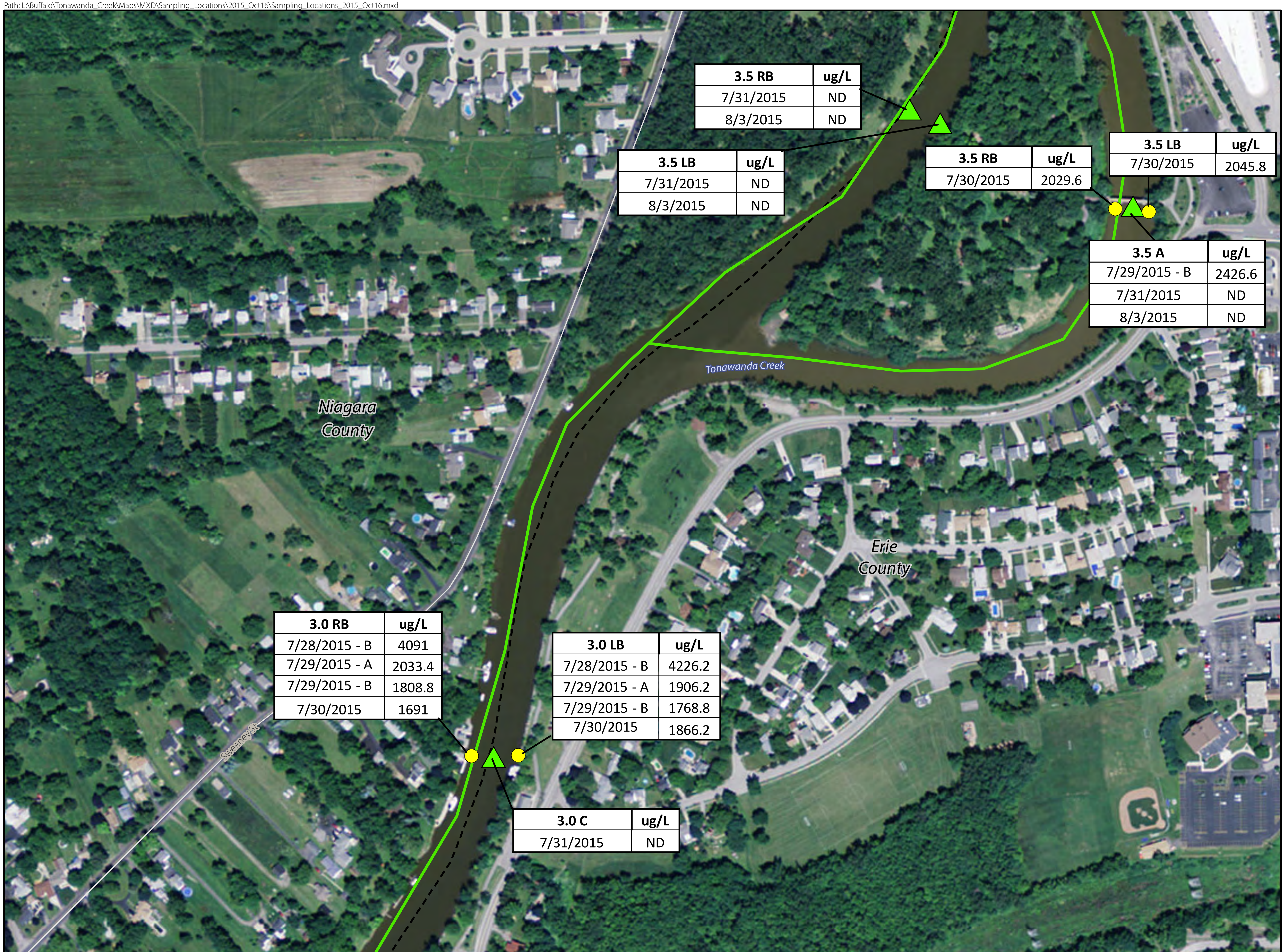
*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-5
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

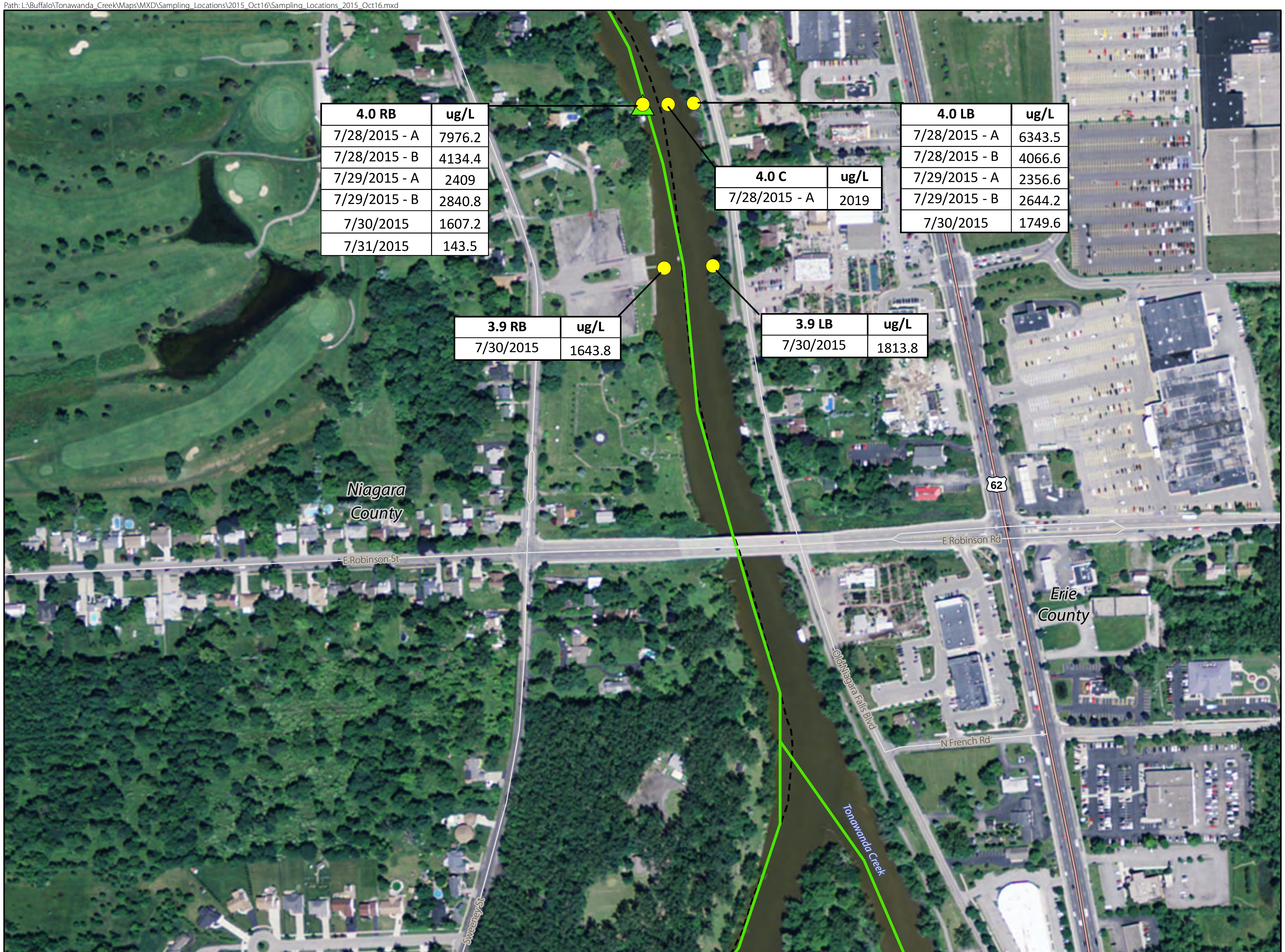
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



4.0 RB	ug/L
7/28/2015 - A	7976.2
7/28/2015 - B	4134.4
7/29/2015 - A	2409
7/29/2015 - B	2840.8
7/30/2015	1607.2
7/31/2015	143.5

4.0 C	ug/L
7/28/2015 - A	2019

4.0 LB	ug/L
7/28/2015 - A	6343.5
7/28/2015 - B	4066.6
7/29/2015 - A	2356.6
7/29/2015 - B	2644.2
7/30/2015	1749.6

3.9 RB	ug/L
7/30/2015	1643.8

3.9 LB	ug/L
7/30/2015	1813.8

Sample Locations and Associated Concentration Values

Figure B-6

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Major Road
- Local Road

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values
Figure B-7
Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Major Road
- Local Road

*Note: All Sample Locations are Approximate.

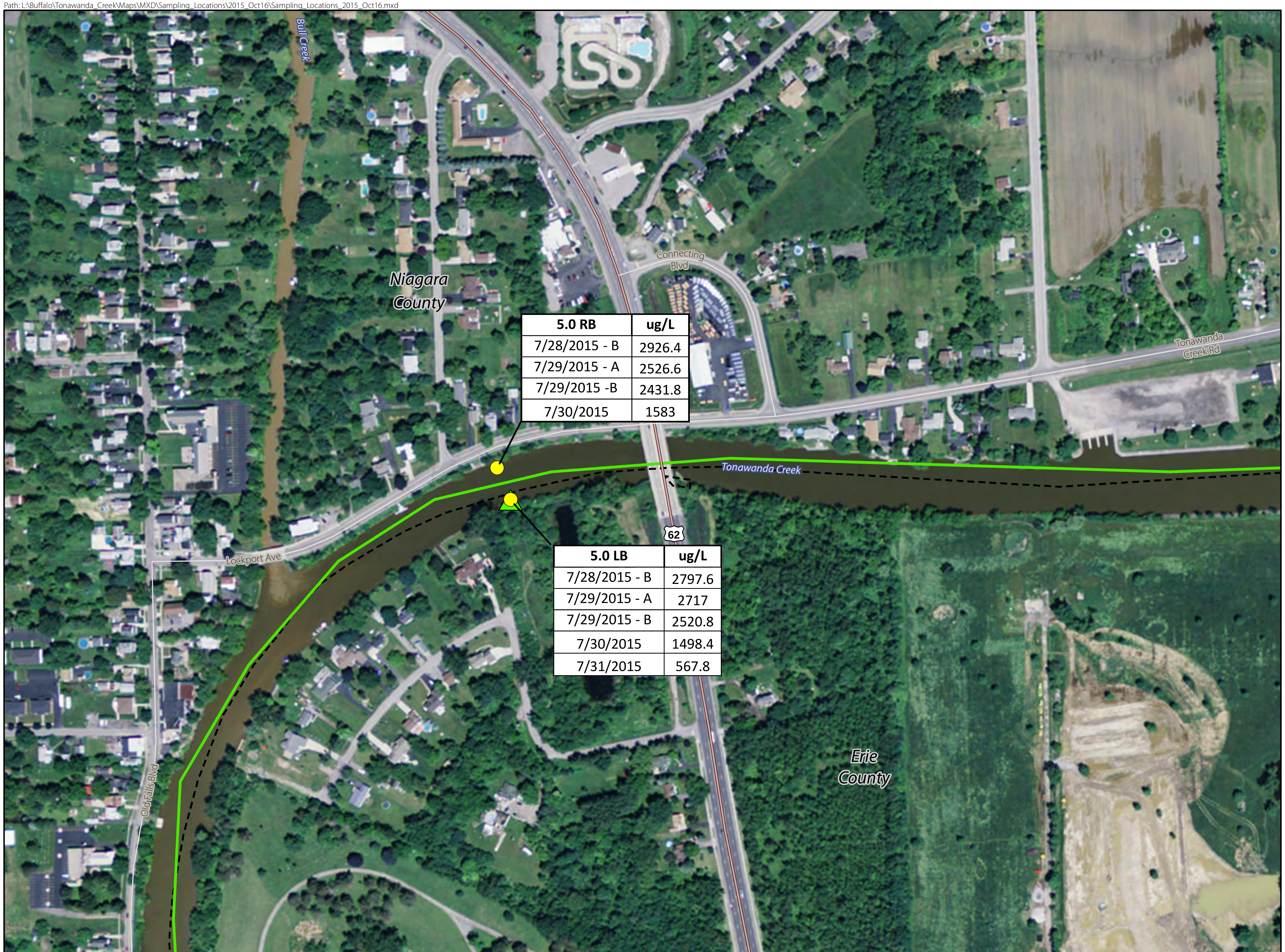
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



5.0 RB	ug/L
7/28/2015 - B	2926.4
7/29/2015 - A	2526.6
7/29/2015 -B	2431.8
7/30/2015	1583

5.0 LB	ug/L
7/28/2015 - B	2797.6
7/29/2015 - A	2717
7/29/2015 - B	2520.8
7/30/2015	1498.4
7/31/2015	567.8

Sample Locations and Associated Concentration Values Figure B-8

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Major Road
- Local Road

*Note: All Sample Locations are Approximate.

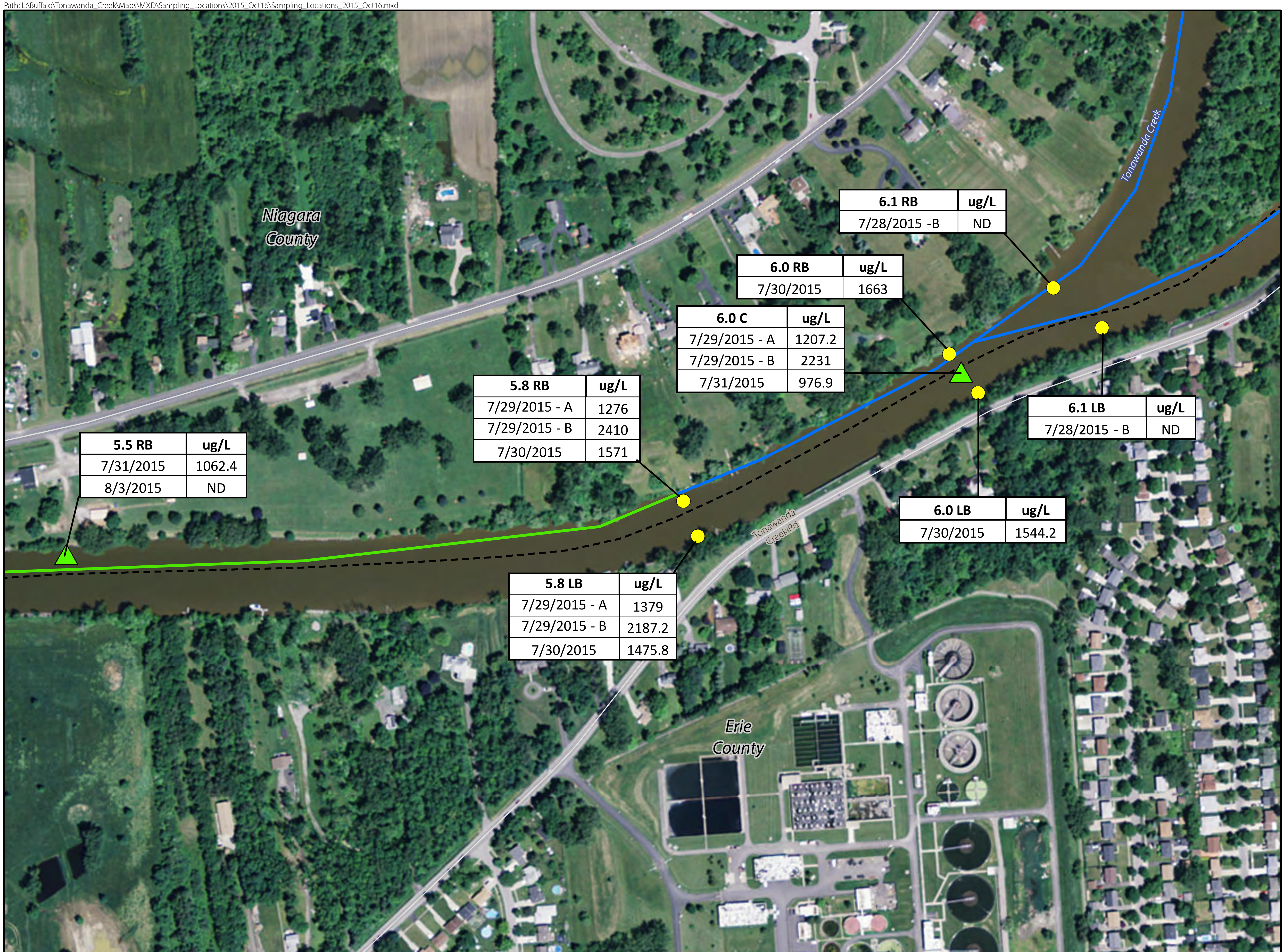
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-9

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

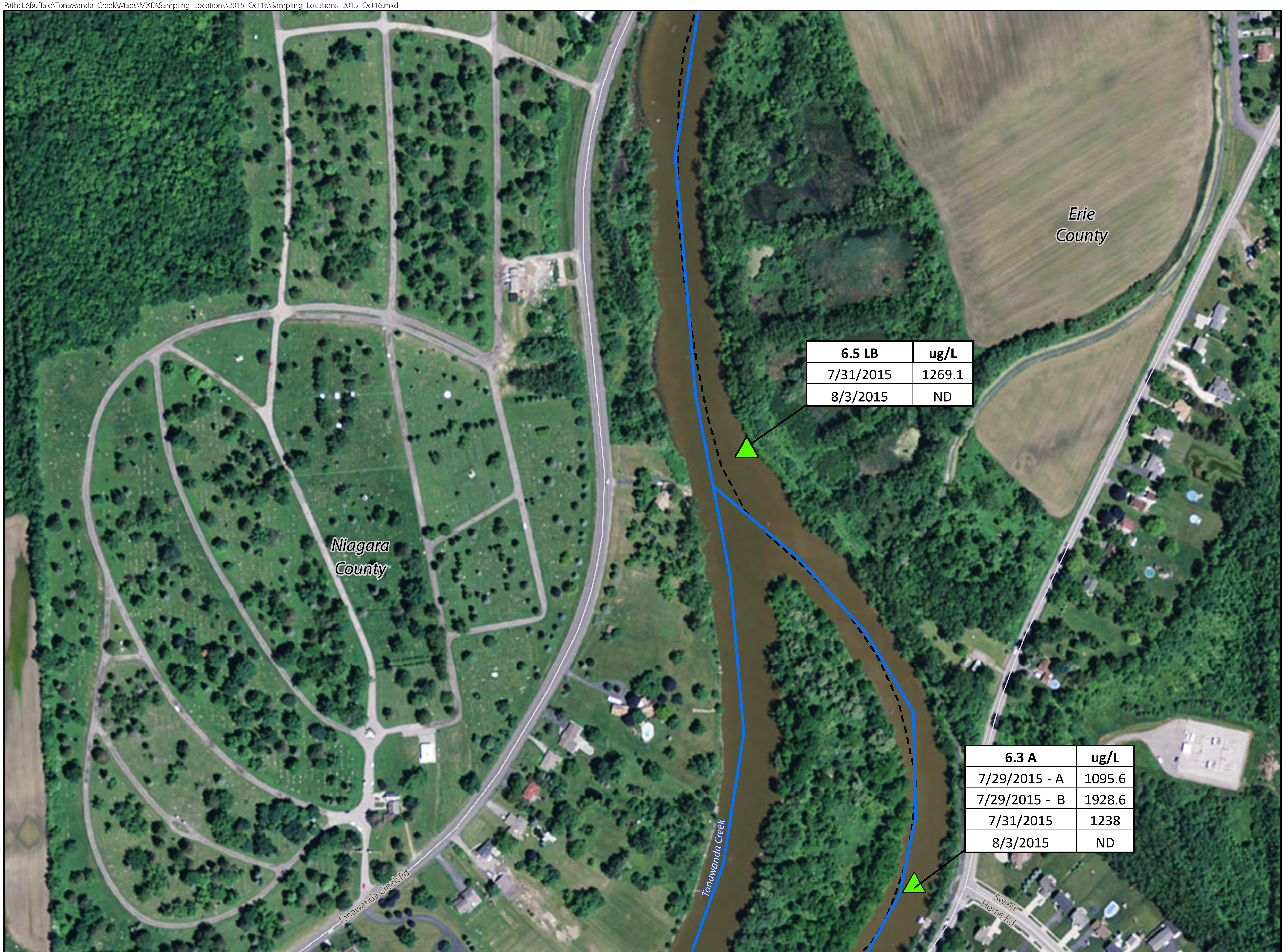
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



6.5 LB	ug/L
7/31/2015	1269.1
8/3/2015	ND

6.3 A	ug/L
7/29/2015 - A	1095.6
7/29/2015 - B	1928.6
7/31/2015	1238
8/3/2015	ND

Sample Locations and Associated Concentration Values Figure B-10

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

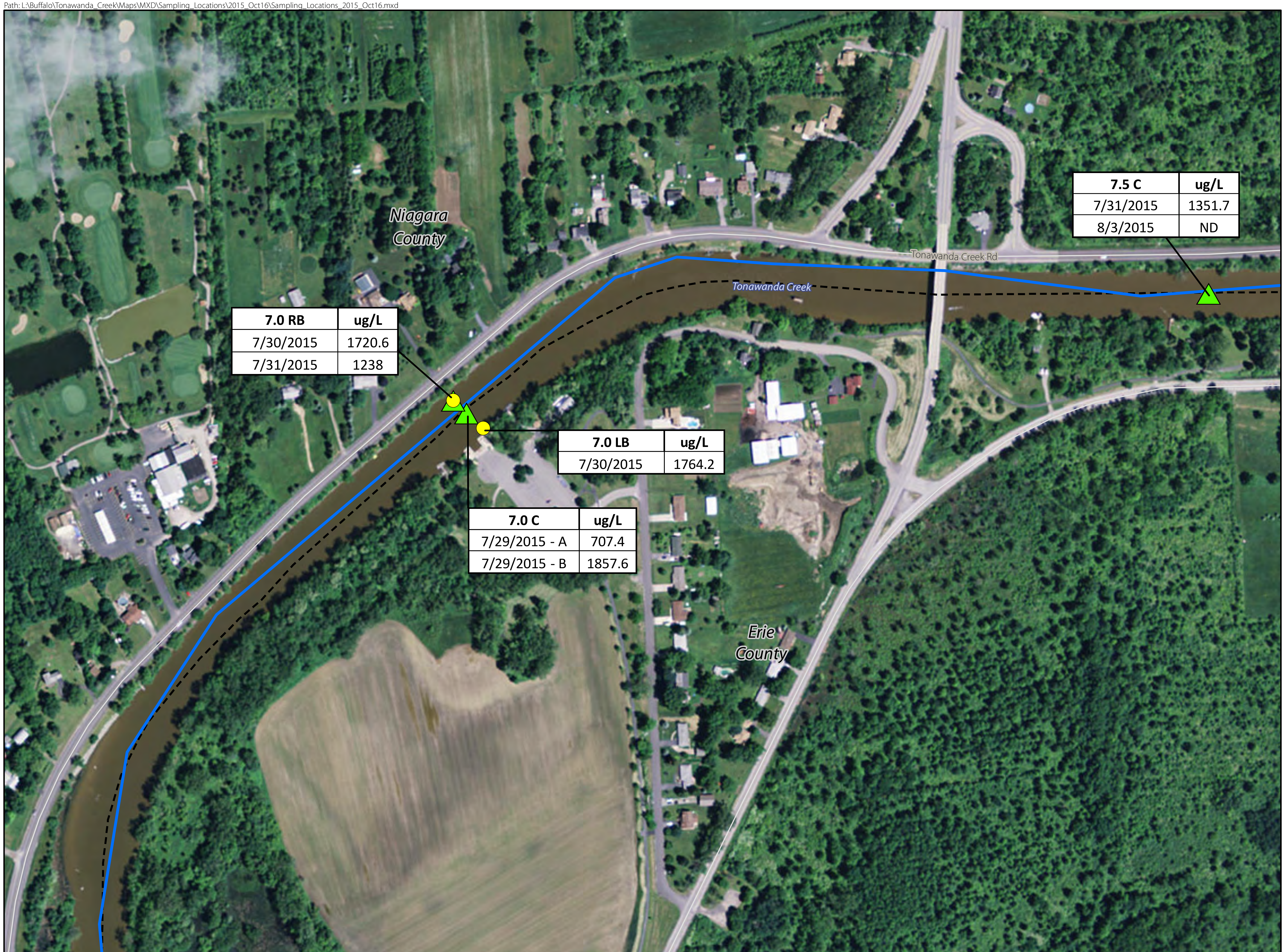
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values

Figure B-11

Tonawanda Creek

Erie and Niagara Counties, New York

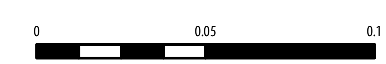
Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

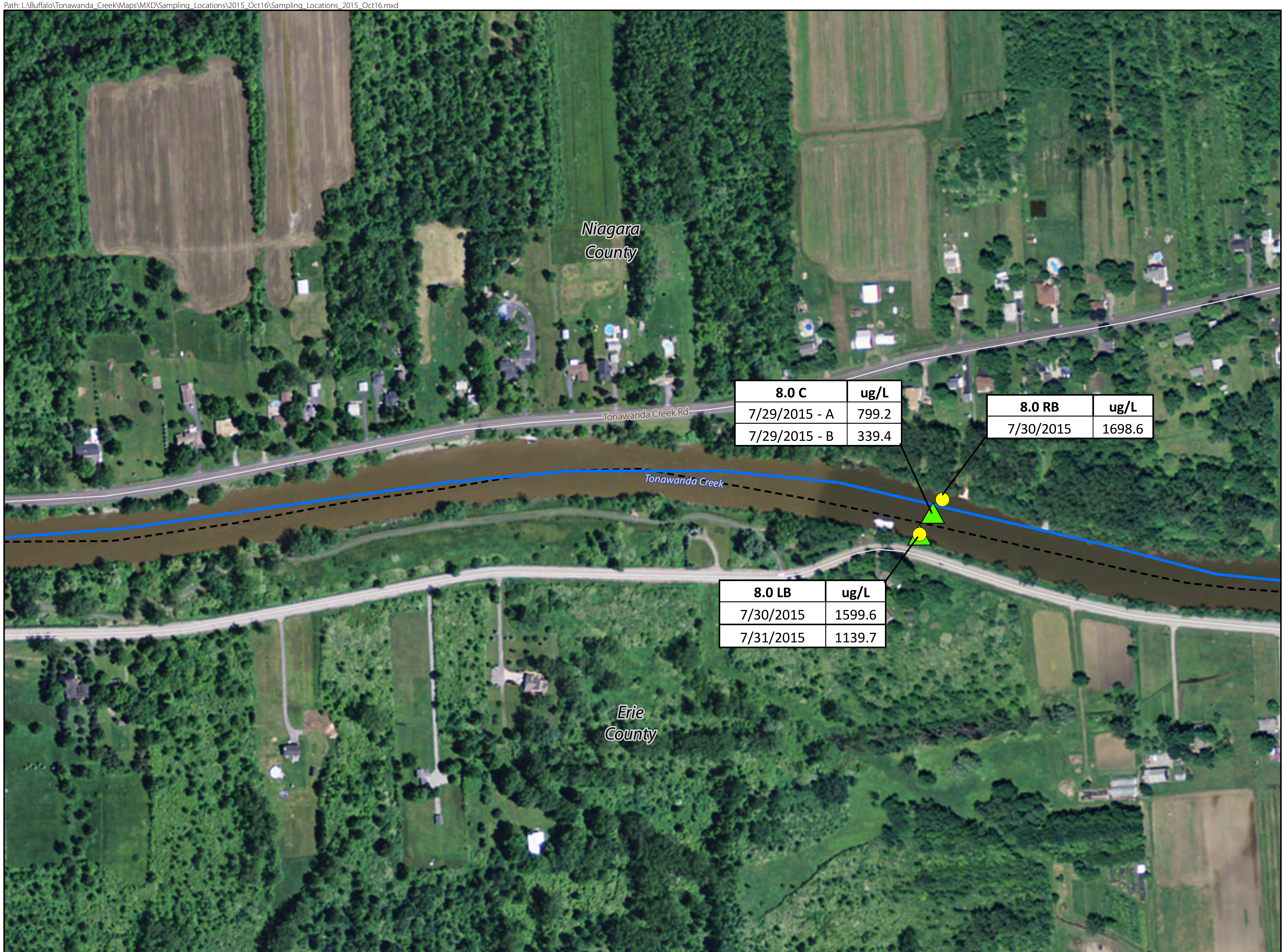
N

SCALE



SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-12
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

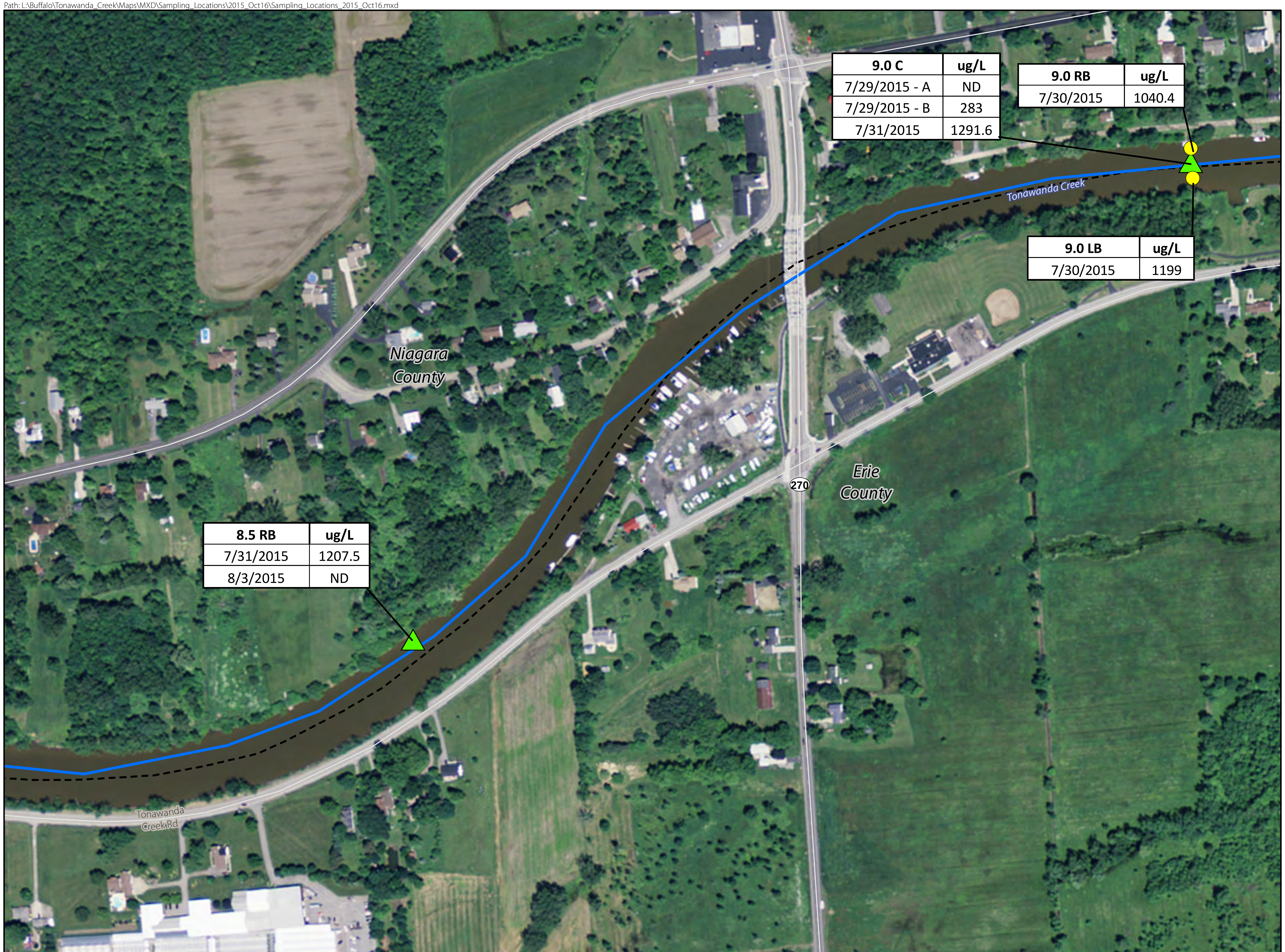
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-13
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

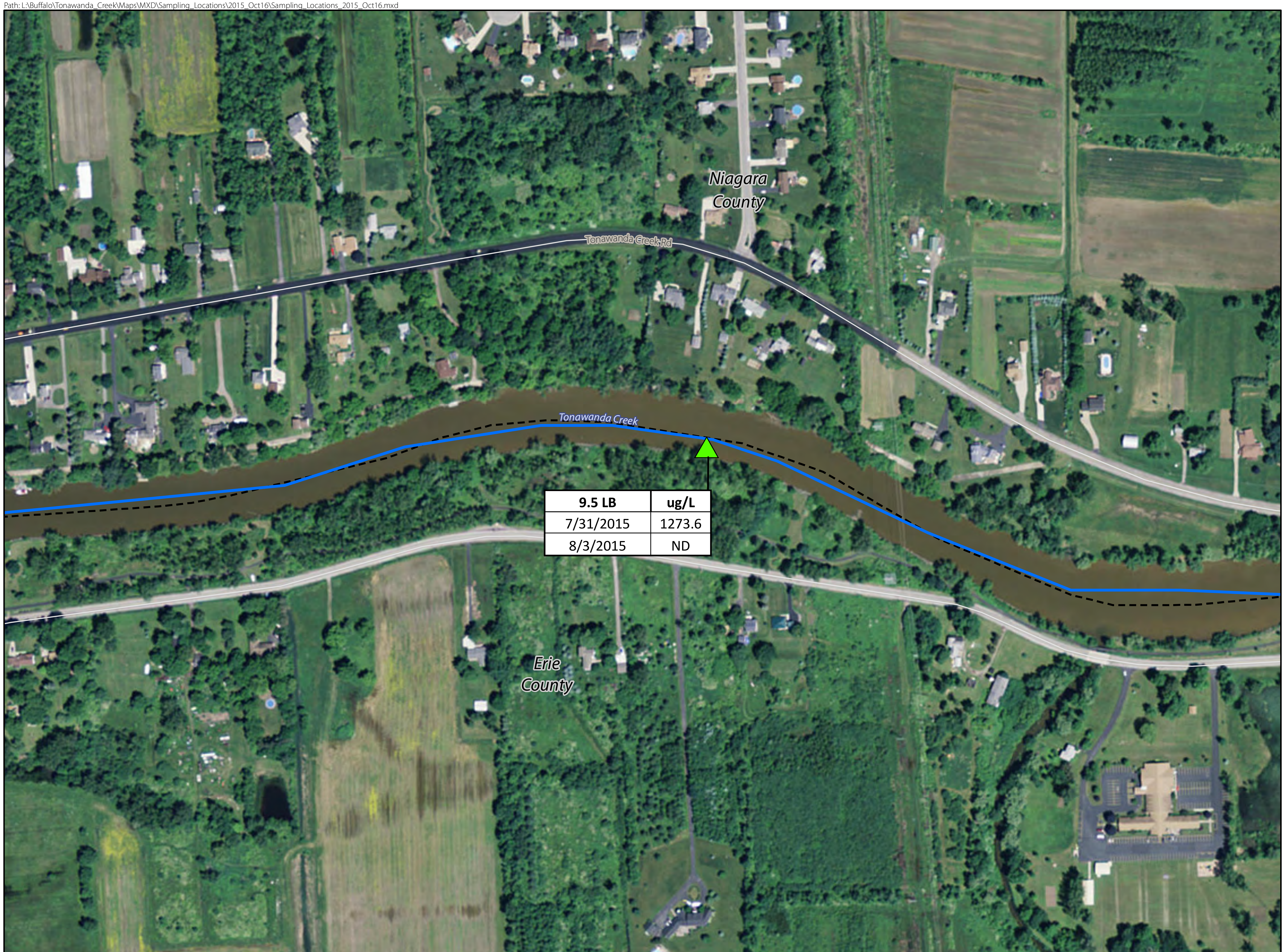
*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-14
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

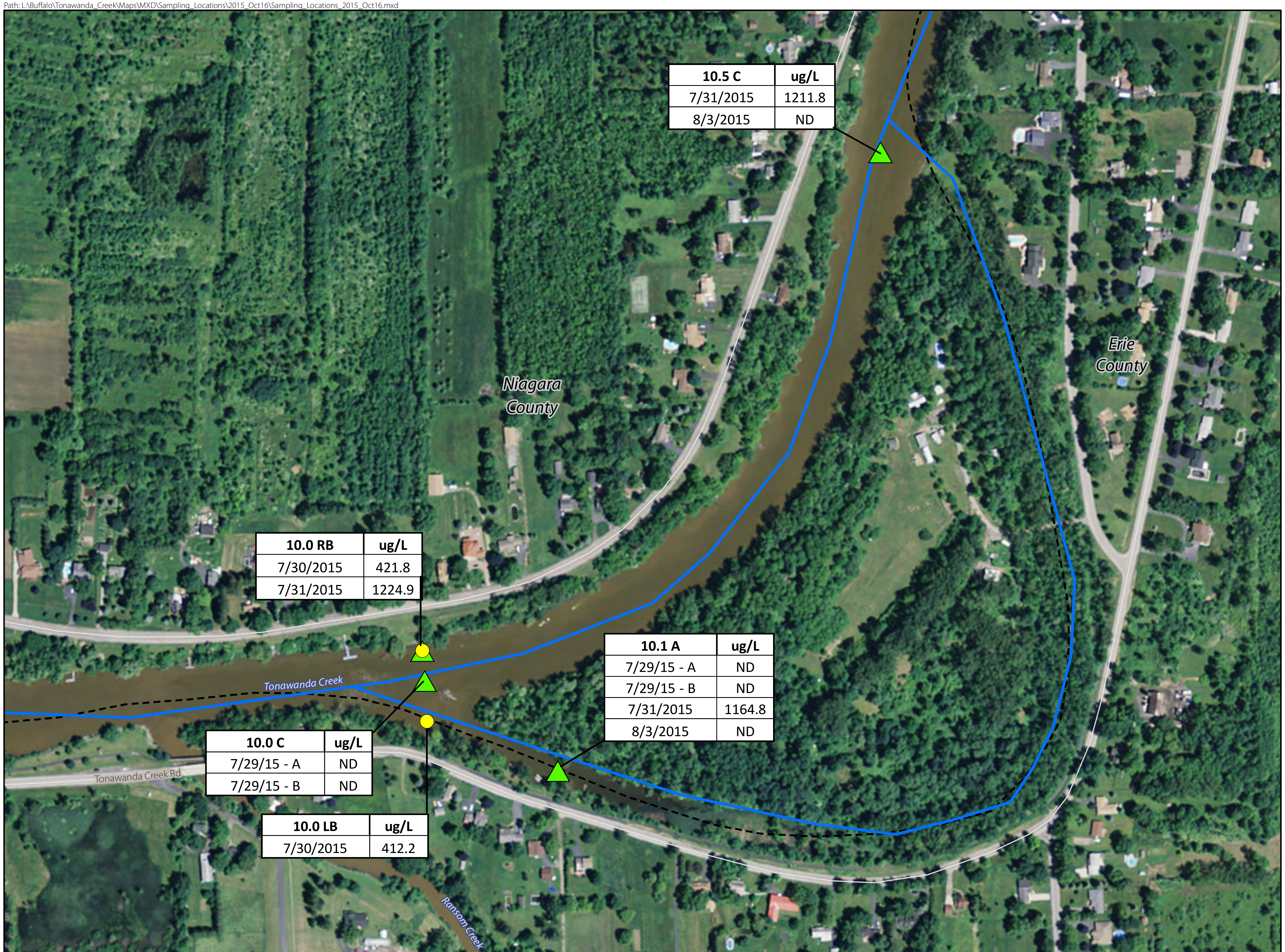
N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values Figure B-15

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

11.0 RB	ug/L
7/30/2015	335.2

11.0 LB	ug/L
7/30/2015	262.4
7/31/2015	1278.1

11.0 C	ug/L
7/29/15 - A	ND
7/29/15 - B	ND

Sample Locations and Associated Concentration Values Figure B-16

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

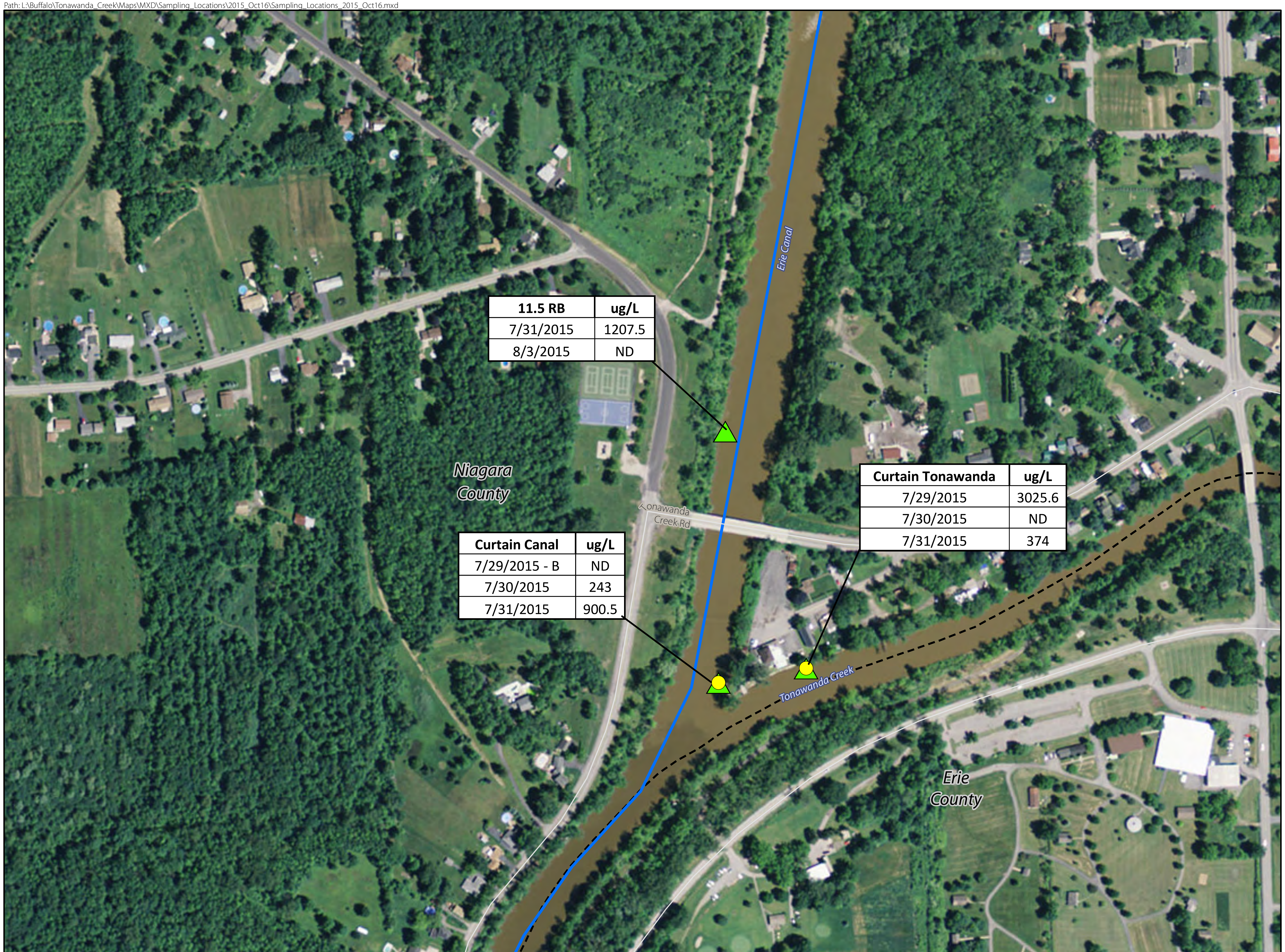
*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



11.5 RB	ug/L
7/31/2015	1207.5
8/3/2015	ND

Curtain Tonawanda	ug/L
7/29/2015	3025.6
7/30/2015	ND
7/31/2015	374

Curtain Canal	ug/L
7/29/2015 - B	ND
7/30/2015	243
7/31/2015	900.5

Sample Locations and Associated Concentration Values
Figure B-17

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary
- Local Road

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values
Figure B-18
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values
Figure B-19
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary

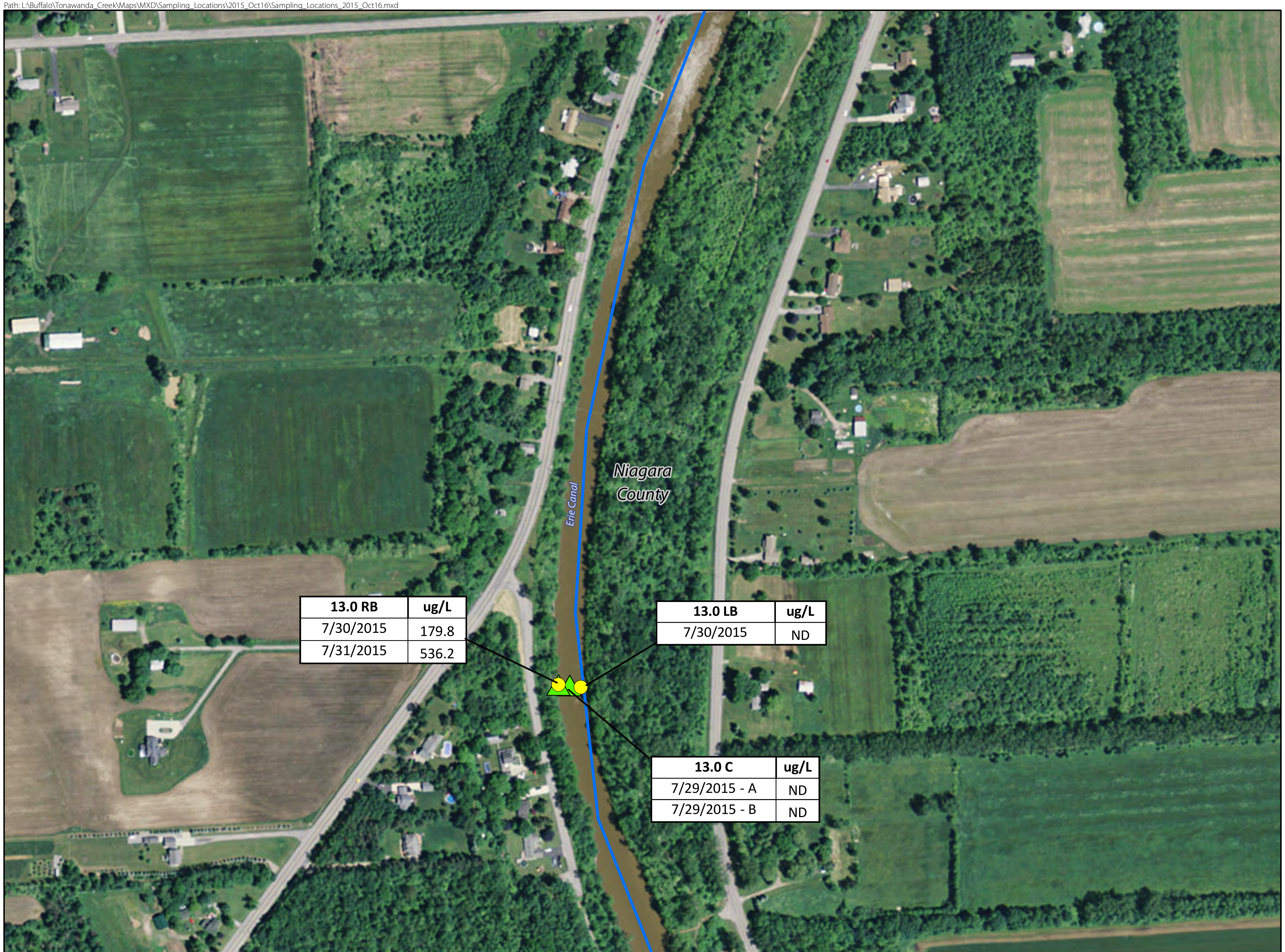
*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd



Sample Locations and Associated Concentration Values
Figure B-20
Tonawanda Creek
Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary

*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values Figure B-21

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary

*Note: All Sample Locations are Approximate.

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values Figure B-22

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

ERDC Sampling Location*

E&E Sampling Location*

Primary Treatment Area

Secondary Treatment Area

County Boundary

*Note: All Sample Locations are Approximate.

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Sampling_Locations\2015_Oct16\Sampling_Locations_2015_Oct16.mxd

Sample Locations and Associated Concentration Values Figure B-23

Tonawanda Creek

Erie and Niagara Counties, New York

Legend

- ERDC Sampling Location*
- E&E Sampling Location*
- Primary Treatment Area
- Secondary Treatment Area
- County Boundary

*Note: All Sample Locations are Approximate.

15.0 C	ug/L
7/29/2015 - A	ND
7/29/2015 - B	ND
7/31/2015	128.8

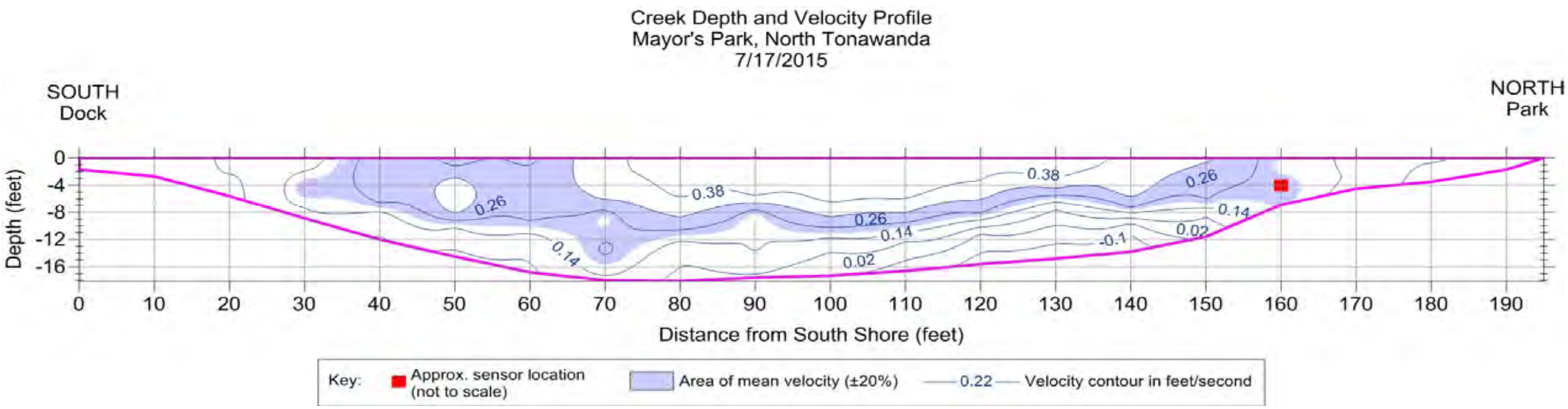
SCALE

0 0.05 0.1 Miles

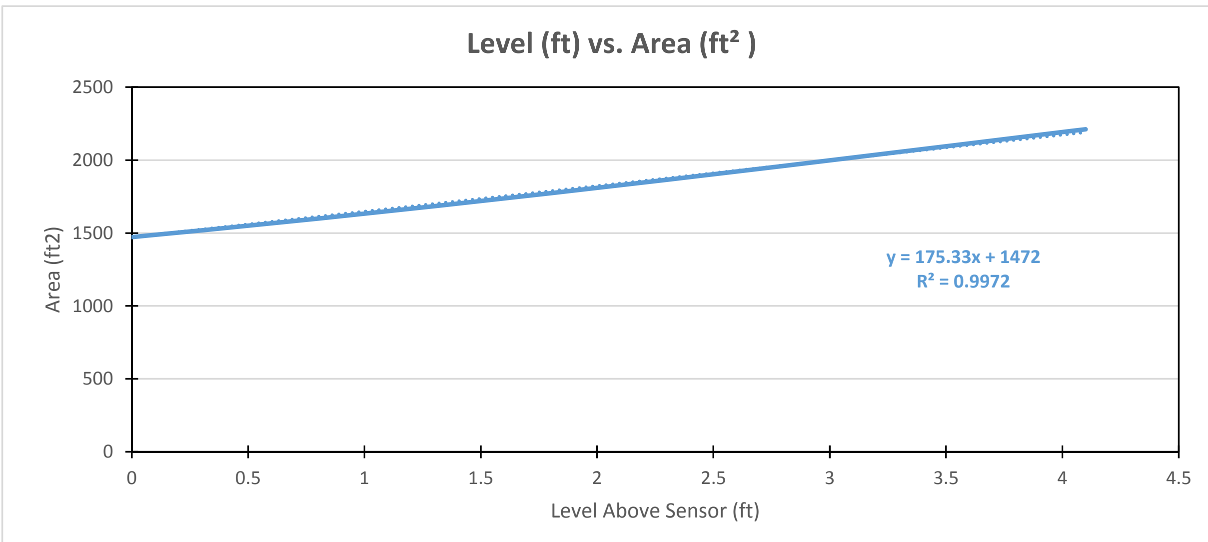
SOURCE: ESRI 2011; Ecology and Environment, Inc. 2015; US Army CORPS of Engineers, 2015

C

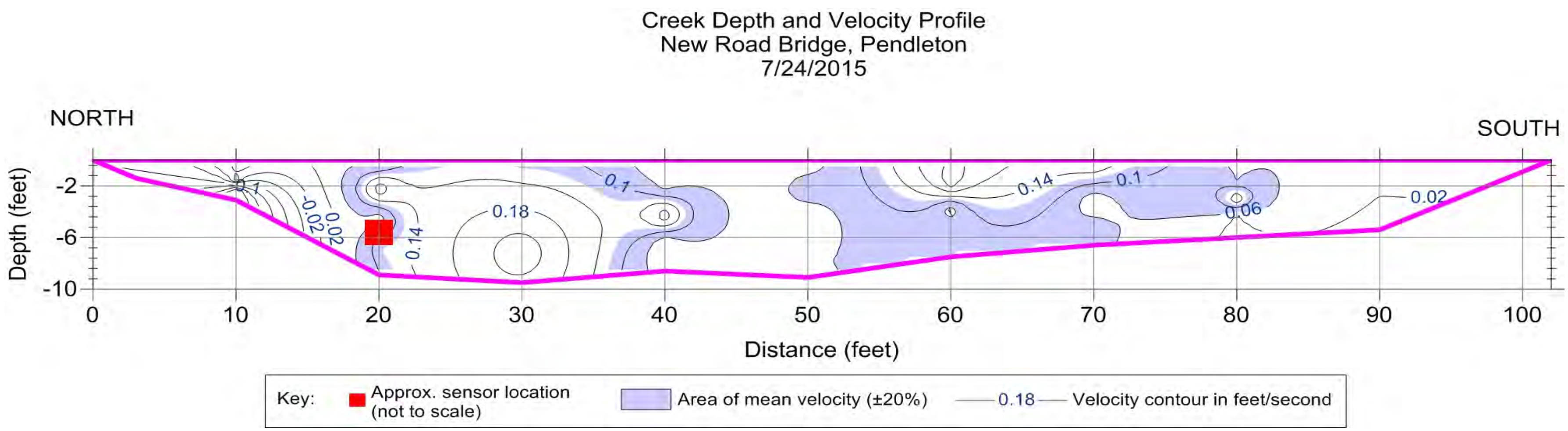
Creek Cross Sections at Monitoring Locations

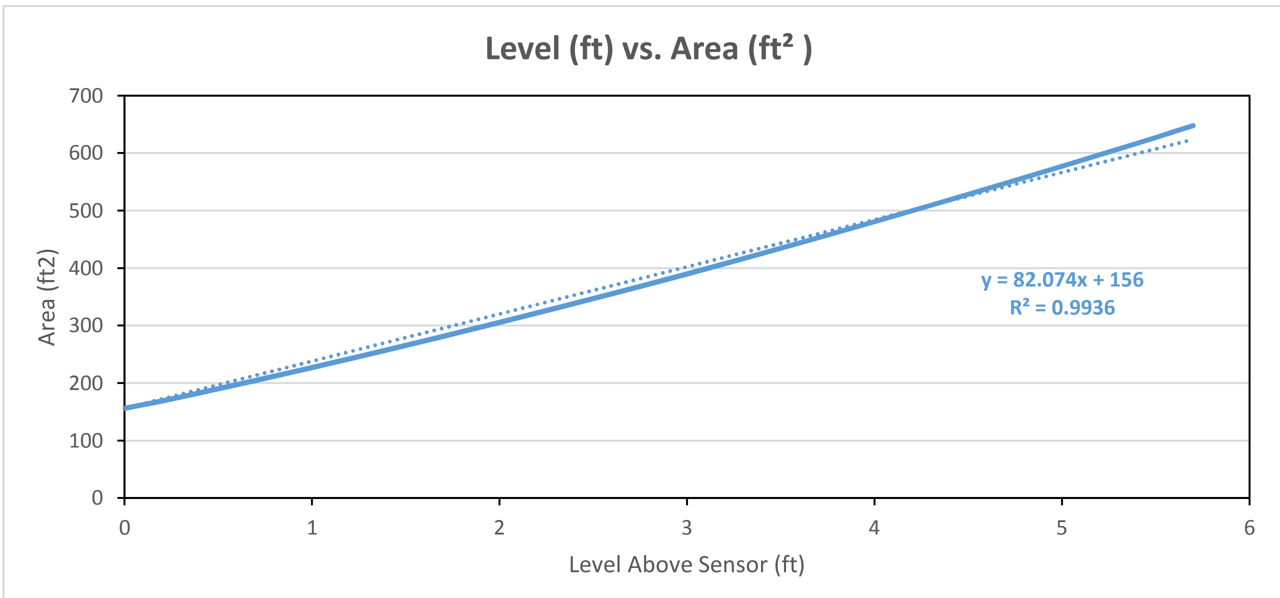


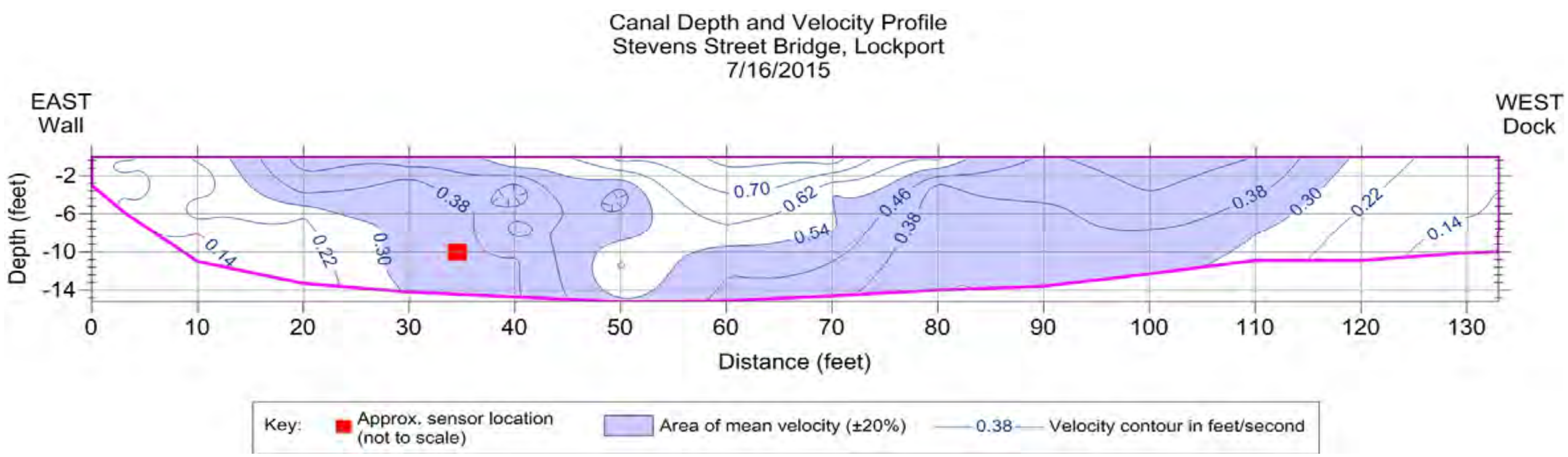
Creek Depth and Velocity Profile
Mayor's Park, North Tonawanda
7/17/2015
SOUTH
Dock
NORTH
Park
Depth (feet)
Distance from South Shore (feet)
0.38
0.26
0.14
0.02
-0.1
Key:
Approx. sensor location
(not to scale)
Area of mean velocity (±20%)
0.22
Velocity contour in feet/second

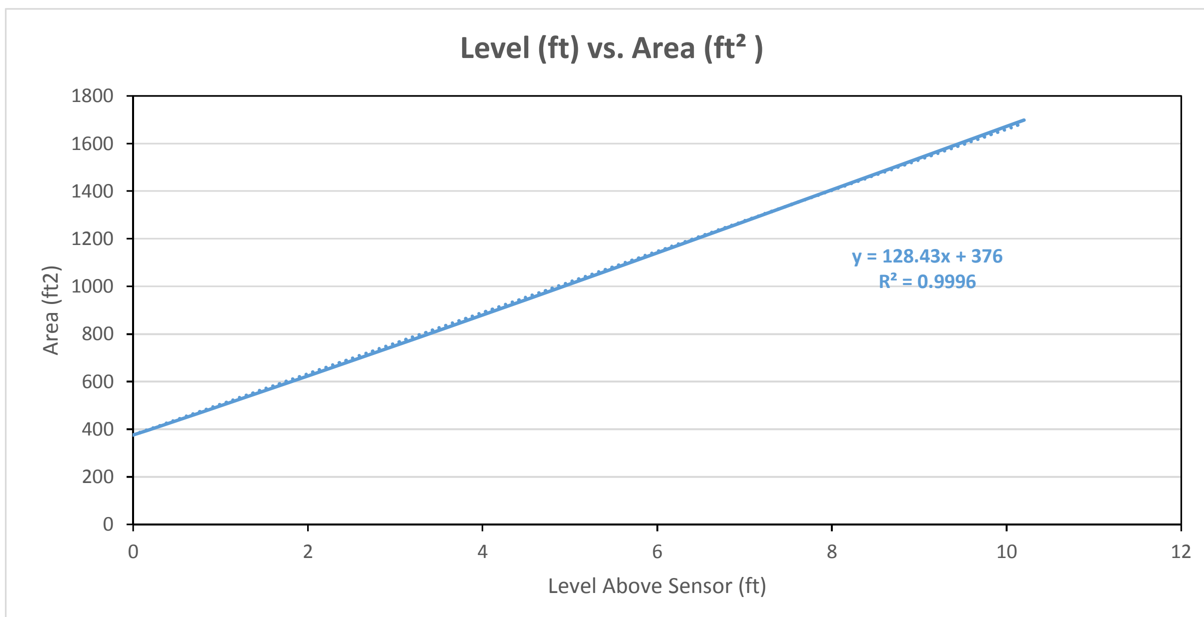


Level (ft) vs. Area (ft²)
Area (ft2)
Level Above Sensor (ft)
y = 175.33x + 1472
R² = 0.9972

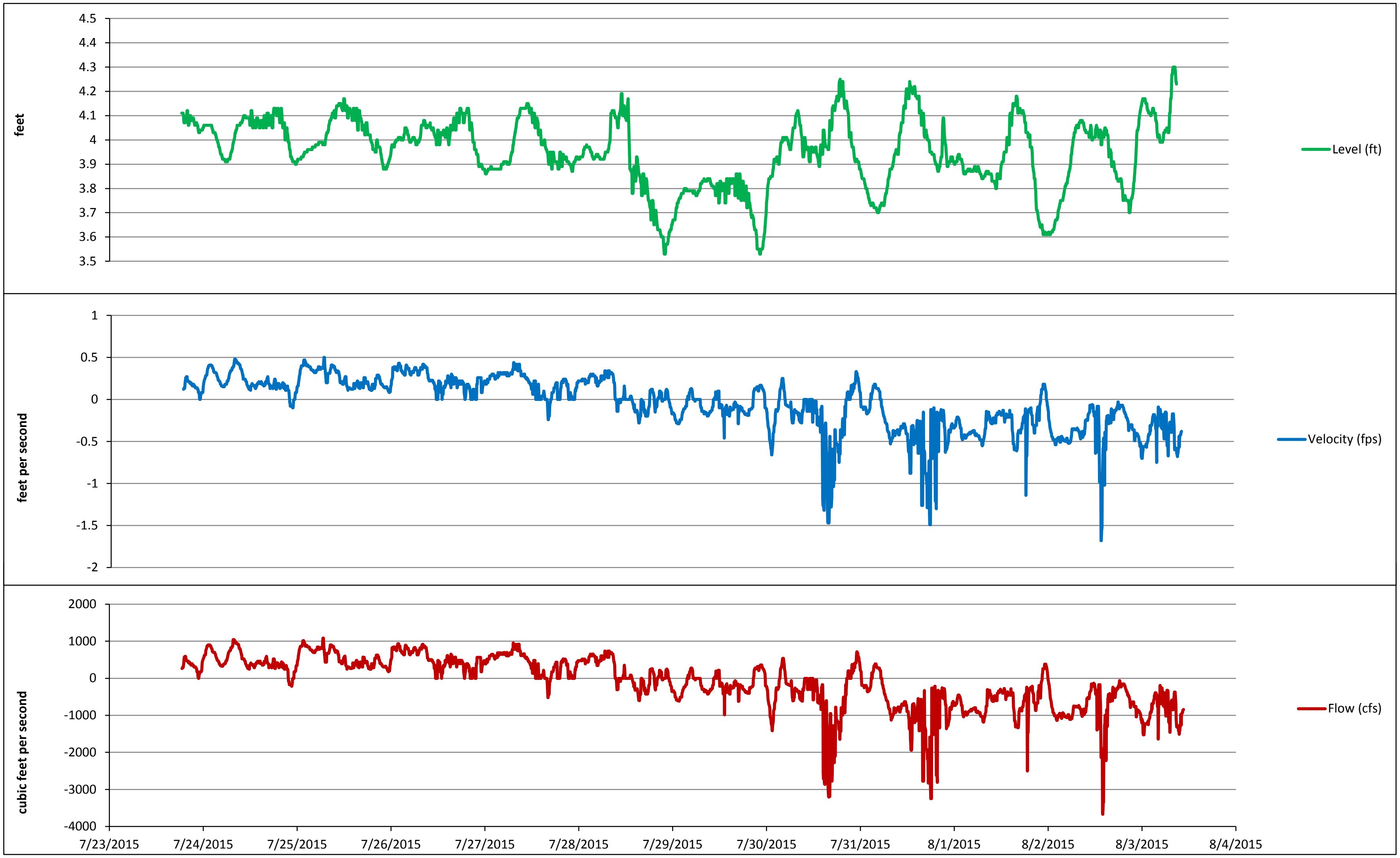

Creek Depth and Velocity Profile
New Road Bridge, Pendleton
7/24/2015
NORTH
SOUTH
Depth (feet)
-2
-6
-10
0
10
20
30
40
50
60
70
80
90
100
Distance (feet)
0.1
-0.02
0.02
0.14
0.18
0.1
0.14
0.1
0.06
0.02
Key:
Approx. sensor location (not to scale)
Area of mean velocity (±20%)
0.18
Velocity contour in feet/second


Level (ft) vs. Area (ft²)
Area (ft2)
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
Level Above Sensor (ft)
y = 82.074x + 156
R² = 0.9936

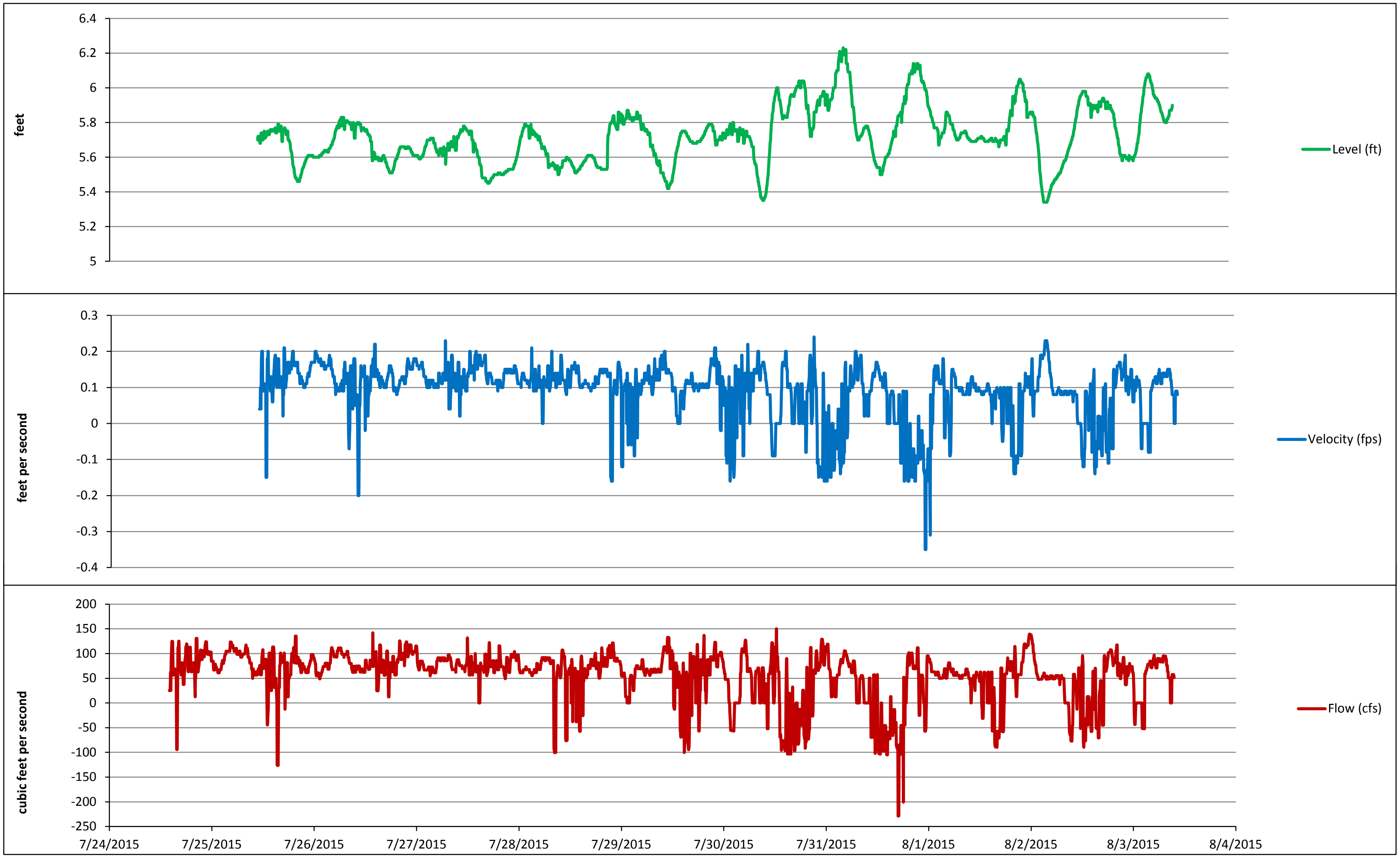

Canal Depth and Velocity Profile
Stevens Street Bridge, Lockport
7/16/2015
EAST
Wall
WEST
Dock
Depth (feet)
-2
-6
-10
-14
0.14
0.22
0.30
0.38
0.70
0.62
0.54
0.46
0.38
0.38
0.30
0.22
0.14
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Distance (feet)
Key:
Approx. sensor location
(not to scale)
Area of mean velocity (±20%)
0.38
Velocity contour in feet/second


Level (ft) vs. Area (ft²)
Area (ft2)
1800
1600
1400
1200
1000
800
600
400
200
0
y = 128.43x + 376
R² = 0.9996
0
2
4
6
8
10
12
Level Above Sensor (ft)

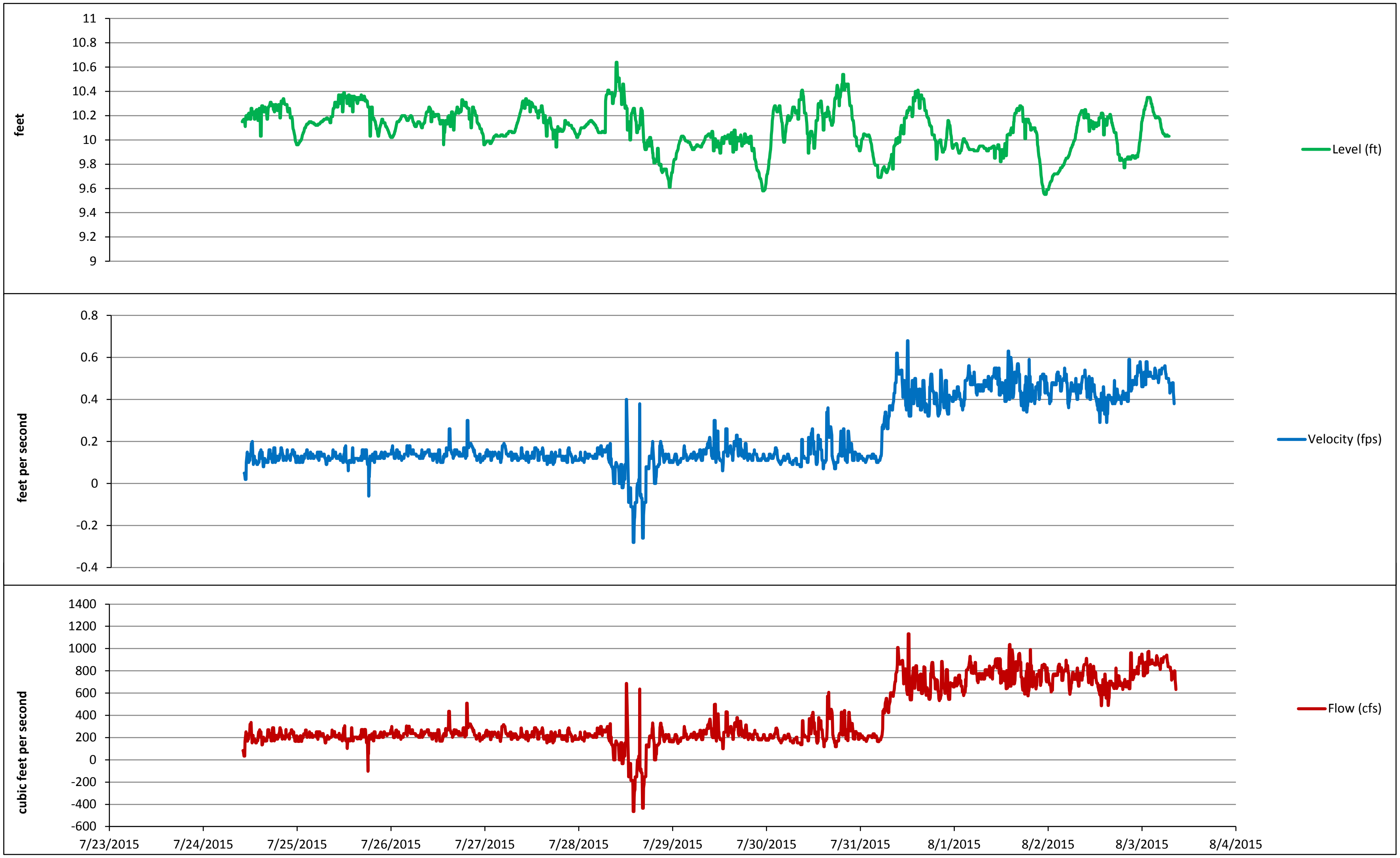
D Flow Meter Data and Water Level Graphs



Summary Flow Data and Water Levels for Tonawanda Creek at Mayor's Park (July 23rd-August 4th, 2015)



Summary Flow Data and Water Levels for Tonawanda Creek at New Road (July 23rd-August 4th, 2015)



Summary Flow Data and Water Levels for Tonawanda Creek at Stevens St (July 23rd-August 4th, 2015)