West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

Prepared By Program Team:

Jim Sutherland, Ph.D.
New York State Department of Environmental Conservation (retired)
166 Main Street
Greenwich, New York 12834

Chris Navitsky, P.E.
Lake George Waterkeeper
PO Box 591
Lake George, New York 12845

Prepared For Program Cooperators:

The FUND for Lake George

The Lake George Association

The Lake George Land Conservancy

The Village of Lake George

Warren County

December 2018

DISCLAIMER

This report has been reviewed by representatives from The FUND for Lake George, the Lake George Association, the Lake George Land Conservancy, the Village of Lake George, Warren County, and the Lake George Waterkeeper, and approved for distribution. This approval, however, does not signify that the contents necessarily reflect the views and policies of these organizations, nor does mention of trade names or commercial products in this report constitute an endorsement of recommendation for use.

PREFACE

This report describes the results of a monitoring program conceived, designed and implemented in response to the construction of the West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex that treats stormwater runoff from a highly developed area along the Route 9 (Canada Street) corridor south of West Brook. The goal of this monitoring program was to conduct an analysis and evaluation of base-flow and stormwater conditions in the wetland and determine the extent to which the wetland was able to treat the various runoff contaminants of concern. The program objectives included the implementation of regular base-flow sampling and sampling of selected storm events. The program utilized a very basic means of assessment, i.e., the comparison of contaminant concentrations entering and exiting the wetland complex, to determine the efficiencies of the treatment chain.

ABSTRACT

The West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex is located at the south end of Lake George in the Town of Lake George (Warren County), New York. The parcel containing the wetland complex is situated on the southeast corner of the intersection of Route 9 (Canada Street) and Warren County Route 69. The wetland complex was designed and constructed to treat stormwater runoff from a highly developed subcatchment that includes Route 9 and contiguous developed areas that extend south to the intersection of Route 9 and Route 9N.

A comprehensive monitoring program that focused on base-flow and storm event conditions and the ability of the wetland treatment chain to effectively remove certain contaminants from the water column prior to the outlet of the wetland to West Brook was initiated in August 2017 and completed during September 2018. The program included collecting water samples and field measurements from different components of the wetland on a regular basis during base-flow conditions and during selected storm events. In excess of 20 field excursions and 100 water samples collected during the 13-month program period. Sample collection and sample processing were conducted according to standard US EPA protocol and samples were submitted to the Darrin Fresh Water Institute Laboratory located in Bolton Landing, New York.

The results from the monitoring program reported herein confirm that the wetland complex is able to effectively remove plant nutrients and certain other important highway runoff contaminants from storm event runoff before discharging to West Brook. On the other hand, the constituents of road salt and associated parameters pass through the wetland complex without any noticeable decrease in concentration. The report offers a series of recommendations that will enhance the performance of the wetland complex and its ability to function effectively for decades into the future.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

Page

Chapter 5 Water Quality Results – Wetland Base-flow Chemistry Characteristics (continued)

5.1 Results (continued)

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

Page

LIST OF FIGURES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The funding for this monitoring program was provided by The Lake George Land Conservancy (LGLC), The Lake George Association (LGA) and The FUND for Lake George (FUND). The FUND also provided in-kind services which allowed the participation of Chris Navitsky, The Lake George Waterkeeper, in the monitoring program.

The authors also extend their appreciation to the West Brook Conservation Initiative Conservation Easement Committee members who have participated and continue to participate in meetings that are held to discuss issues and updates regarding the wetland complex. These Committee members include, but are not limited to, Jim Lieberum and Robert Bombard (Warren County Soil and Water Conservation District), Maiken Homes, and Emma Lamy (Warren County), Randy Rath, Jeremy Farrell and Walt Lender (LGA), Jamie Brown, Monica Dore, and Alex Novick (LGLC), David Harrington (Village of Lake George), and Kevin Hajos (Director, Department of Public Works, Warren County) .

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

2018 Final Report

Chapter 1

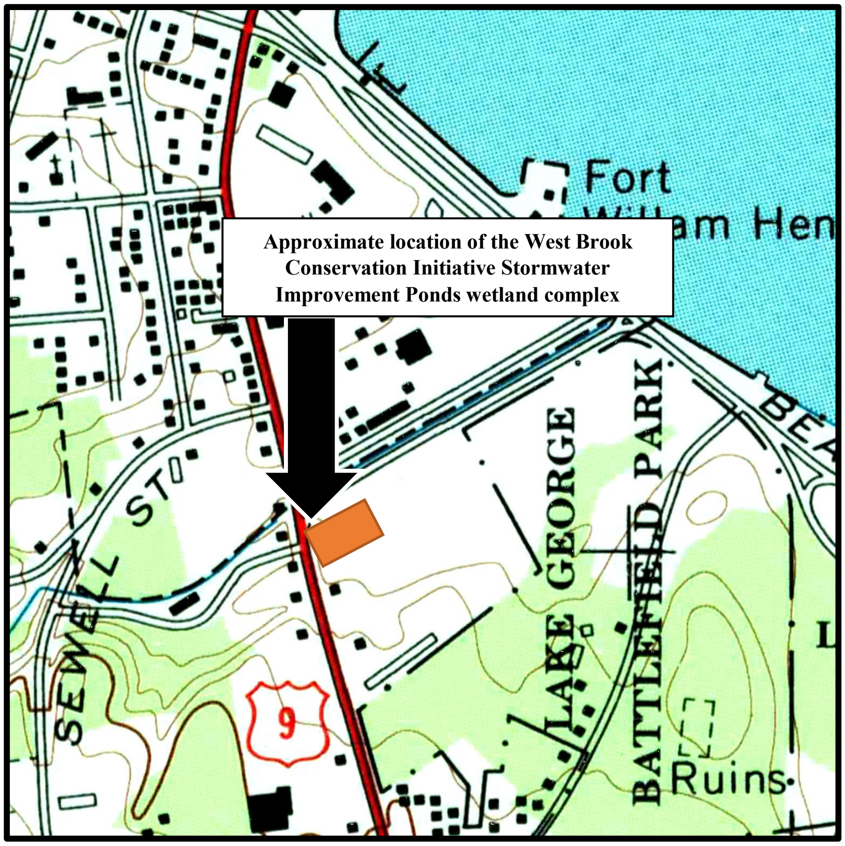
Executive Summary

This page intentionally left blank

1.0 Project Location and Boundary

The West Brook Conservation Initiative Stormwater Improvement Ponds is located at the south end of Lake George in the Town of Lake George (Warren County), New York. The parcel containing the wetland complex is situated on the southeast corner of the intersection of State Route 9 (Canada Street) and Warren County Route 69. Figure 1-1 is a portion of the USGS Lake George quadrangle 7.5-minute series topographic map showing the general location of the created wetland and its relationship to surrounding features.

Figure 1-1



The 2.0 hectare (4.9 acre) freshwater wetland is located on the properties formerly known as the Charles R. Wood Park, which include three (3) map parcels, #264.06-3-30 (3.27 acres), 264.06-3-31 (1.37 acres) and 264.06-3-32 0.25 acres) (Warren County Community Map).

The wetland complex was constructed and modified over a three-year period from 2011 through 2013. Existing buildings were demolished and the series of ponds created during June 2011. In September 2012, naturally established plants in the area were removed, original pond shape was restored, and 85 plant species were artificially introduced to the wetland complex. Plant species were introduced throughout the wetland system according to a planting scheme designed by environmental engineers to mimic natural wetland vegetation gradients (Chazen Companies 2010). Several site modifications including mowing, skimming and weir adjustments were carried out during the fall of 2013. The inlet chamber to the wetland complex was opened during October 2013 to allow the entry of stormwater runoff.

1.1 Background

Stormwater runoff from West Brook entering south Lake George has been characterized by previous scientific investigations including Fuhs (1972), Sutherland et al. (1983), Hyatt et al. (1995), and Eichler and Boylen (2012). The focus on runoff from this watershed is warranted by the high density of developed area in close proximity to the lake and the impact of emerging ground water in the form of seepage streams that result from effluent applied to infiltration beds at the Village of Lake George Wastewater Treatment Plant (Aulenbach et al 1975, Sutherland and Navitsky 2015).

The Canada Street (Route 9N) corridor south of West Brook has been recognized as a major contributor of contaminants including sand, road salt and forms of phosphorus to south Lake George for several decades (Sutherland et al. 1983, Lake 2001, Eichler and Boylen, 2012). The corridor traverses a distance of 4,500 feet within the West Brook sub-catchment and the average width of the corridor (roadway + sidewalks) is 85 feet (2 lanes in both directions plus a turning lane in the middle), which translates to a total of ~8.78 acres of impervious highway surface that drains directly to the wetland complex.

The West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) were constructed during 2011-2013 to capture and treat stormwater runoff from Canada Street and its contiguous developed areas totaling about 60 acres. The West Brook CI SIP has a surface area of 4.45 acre and consists of a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulate material and (2) support vegetation and bacterial communities that remove heavy metals, salts and excessive nutrients (Pier et al 2015). The effluent from the SIP enters West Brook and then flows into south Lake George.

During September 2012, naturally established plants growing in the SIP were removed, the original pond shapes were restored and 85 plant species were artificially introduced based upon a planting design prepared by Chazen Companies (2010) to mimic natural wetland vegetation gradients. Several modifications including mowing, skimming and weir lowering were made during the fall of 2013. The inlet to the West Brook SIP received flow beginning in October 2013.

The Darrin Fresh Water Institute (DFWI) initiated base-flow sampling of the West Brook SIP on 20 August 2013 and continued to collect base-flow samples on about a monthly basis through July 2014; 12 sets of base-flow samples were collected. Interim Reports issued by DFWI for the sampling program mention the collection of water chemistry samples for a single storm event that occurred on 27 and 28 November 2013.

With only one storm event sampled from the West Brook SIP during 2013-2014, it is not possible to evaluate the efficacy of this wetland system to treat stormwater runoff. Additional event monitoring is required before a thorough evaluation can be completed with definitive statements concerning treatment efficiency and possible recommendations associated with fine-tuning of the wetland ponds.

The Program Team (Sutherland and Navitsky) developed a work-plan to conduct an updated analysis and evaluation of the stormwater runoff in the West Brook CI SIP to determine whether the expected treatment of runoff is achieved by the construction design of the facility. The Program objectives include (1) implementation of sufficient base-flow and storm event monitoring to realize the goal of West Brook CI SIP evaluation, specifically with regard to storm event treatment, and (2) determine the amount and quality of ground water seepage that emerges from the southern slope adjacent to Pond #2 which appears to originate from higher elevations to the south along Canada Street. The summary and analysis of data collected during this study will determine the need and nature of any alternative strategies that could be recommended if fine tuning of the wetland is required.

1.2 Statement of Goal and Objectives

The data collected from the West Brook CI SIP prior to 2017 were insufficient to allow a critical evaluation of this system with regard to its ability to treat stormwater runoff from the Canada Street (Route 9) corridor before it is introduced to West Brook and, ultimately, Lake George.

The goal of the program proposed herein was to conduct an updated analysis and evaluation of the stormwater runoff in the West Brook SIP to determine whether the expected treatment of runoff has been met by the construction design of the facility.

The program objectives included the following:

(1). Implementation of sufficient base-flow and storm event monitoring to realize the goal of West Brook SIP evaluation, specifically with regard to storm event treatment of subcatchment runoff which was the basis for developing and constructing this stormwater treatment system.

With regard to the above objective, one of the report co-authors (CN) recalls that an original goal of the design and construction of the wetland was 50 percent removal of **phosphorus** and 90 percent removal of **TSS**.

Early during the Program while the work-plan was being developed, it was realized that ground water flow was moving through the wetland complex during non-event periods and was responsible for discharge from the ***Pond 7*** and ***Gravel Wetland*** outlets. Thus, a subsequent program objective was included to determine the nature of this contribution to the wetland complex.

(2). Determine the amount and quality of ground water seepage that emerges from the southern slope adjacent to Pond #2 which is believed to originate from higher elevations along south Canada Street and the Village of Lake George Waste Water Treatment Plant.

The summary and analysis of data collected during this study will determine the need and nature of any alternative strategies that could be recommended if fine tuning of the wetland is required.

1.3 2017-2018 Monitoring Program Description

During early 2017, a small Working Committee comprised of the Lake George Land Conservancy, the Lake George Association and the Fund for Lake George held a series of meetings to discuss and develop a work-plan to study the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP). The intent of the study was to determine the extent to which the wetland complex was treating stormwater runoff from the sub-catchment before releasing the water to West Brook which discharges directly into south Lake George. The co-authors of this Final Report, also known as the Program Team (Sutherland and Navitsky), developed the monitoring work-plan and budget describing the strategy that would be used to evaluate the wetland complex and reviewed said document with the Working Committee before finalizing the monitoring program.

The Program Team originally designed and implemented a 12-15 month program that included field sampling of base-flow and storm event conditions at locations within the wetland complex to examine the chemical characteristics of water passing through the series of ponds before exiting the wetland and flowing into West Brook.

1.3.1 Base-flow Sampling

This type of sampling is exactly what the term implies, i.e., water sample collection during non-storm event periods to determine the chemical composition of the water in the wetland complex which is comprised of residual water from previous storm events and ground water entering the complex from higher elevations to the south and southwest.

Early in the Program, field excursions to sample base-flow included monthly sampling of the ***Pond 7*** outlet channel and less frequent sampling of the **Gravel Wetland** outlet because this component only received storm event discharge from the wetland complex during periods of high flow when the water elevation was exceeded at the weir located in ***Pond 6***. Later, base-flow sampling was expanded to include ***Pond 1*** and ***Pond 2*** at the head of the wetland complex based upon recommendations made by Bianca Wentzell in a summary report of a vegetation survey that was conducted during August 2017.

Base-flow sampling at the wetland complex usually occurred when at least 72 hours had passed since any antecedent precipitation although this was not always the case.

1.3.2 Storm Event Sampling

A total of six (6) storm events were sampled during the Program in order to gather sufficient data to evaluate the processing of runoff through the wetland complex. Although close attention was paid to weather forecasting to help select appropriate storm events for monitoring, it was evident, particularly during the summer of 2018, that major events were very localized in nature, making storm event prediction less reliable than several decades ago during the Lake George Urban Runoff Study, even with the use of local weather radar for the south end of Lake George.

The wetland complex monitoring program was initiated on June 21st 2017 and concluded on September 19th 2018. There were a total of 27 separate field sampling excursions and a total of 108 samples collected for water chemistry and field measurements during the 13-month monitoring program.

Base-flow samples were transported immediately to the Darrin Fresh Water Institute (DFWI) laboratory in Bolton Landing for processing following collection. Storm event samples either were brought to the laboratory for processing immediately following the event or were kept on ice overnight and processed within 15-18 hours following collection.

All samples were processed in the laboratory by taking sub-samples determined by the specific analytes that comprised the base-flow and storm-water runoff *test pattern*. The primary test pattern for base-flow and event samples in this Program during the first 8 months included the following analytes:

- total phosphorus (TP),
- total filterable phosphorus (TFP),
- total nitrogen (TN),
- anions (nitrate-nitrogen (NO_3-N), sulfate (SO_4), and chloride (Cl)),
- cations (calcium (Ca), sodium (Na) and iron (Fe).)

During the last 5 months of the Program, the cation test pattern was expanded to include the metals listed above plus magnesium (Mg), copper (Cu), zinc (Zn), nickel (Ni), cadmium (CD) , and lead (PB). All of these cations are important constituents of highway runoff and adding these analytes to the test pattern occurred when seasonal traffic on the Canada Street corridor increased following the winter and spring of 2018. The expanded cation test pattern samples collected during the last 5 months of the Program were preserved and held in a refrigerator until delivery to the USGS Laboratory in Troy, NY for analysis during September 2018 when the sampling program was completed.

Total suspended sediment (TSS) was run on most samples immediately following collection and processing in the DFWI laboratory by the report co-author (JWS).

In order to obtain meaningful and accurate information concerning the amount of water processed by the wetland treatment system over a period of time, it was necessary to install water level recorders along the treatment chain to continuously collect water level data in different components of the wetland complex.

In addition to collecting continuous water level records at the ***Inlet*** chamber and the ***Pond 7*** and ***Gravel Wetland*** outlet chambers, it was necessary to manually gage different components of the system (Inlet chamber, Pond 7 and Gravel Wetland outlet chambers) to develop rating curves that would allow the conversion of water levels to discharge (either *cubic feet per second* or *million gallons per day*).

1.4 Presentation of the Final Report

The material in this final report presents, summarizes and evaluates the variety of data collected during the 13-month program and also provides conclusions and recommendations. The report is organized as follows:

Chapter 1 is an Executive Summary of the 2017-2018 study and its findings, including conclusions and recommendations based upon the evaluation of the data.

Chapter 2 provides historical background on stormwater runoff in the Lake George drainage basin including a description of the 1980-1982 Lake George Urban Runoff Study, which was the first scientific investigation to describe the impact of storm event runoff from Canada Street (State Route 9) on West Brook and Lake George.

Chapter 3 provides a description of the West Brook CI SIP, the subcatchment that drains to the wetland complex and the important constituents of stormwater runoff.

Chapter 4 presents a detailed description of the 2017-2018 monitoring program and methodology.

Chapter 5 presents 2017-2018 water quality results that describe the base-flow chemistry characteristics of the West Brook CI SIP wetland complex.

Chapter 6 presents a detailed description of water quality results with the examination of an individual storm event.

Chapter 7 provides a detailed description of water quality results with the evaluation of 2017-2018 monitored storm events in the West Brook CI SIP and the effectiveness of the wetland complex to treat stormwater runoff.

Chapter 8 provides a summary of water movement through the wetland complex during base-flow and storm events.

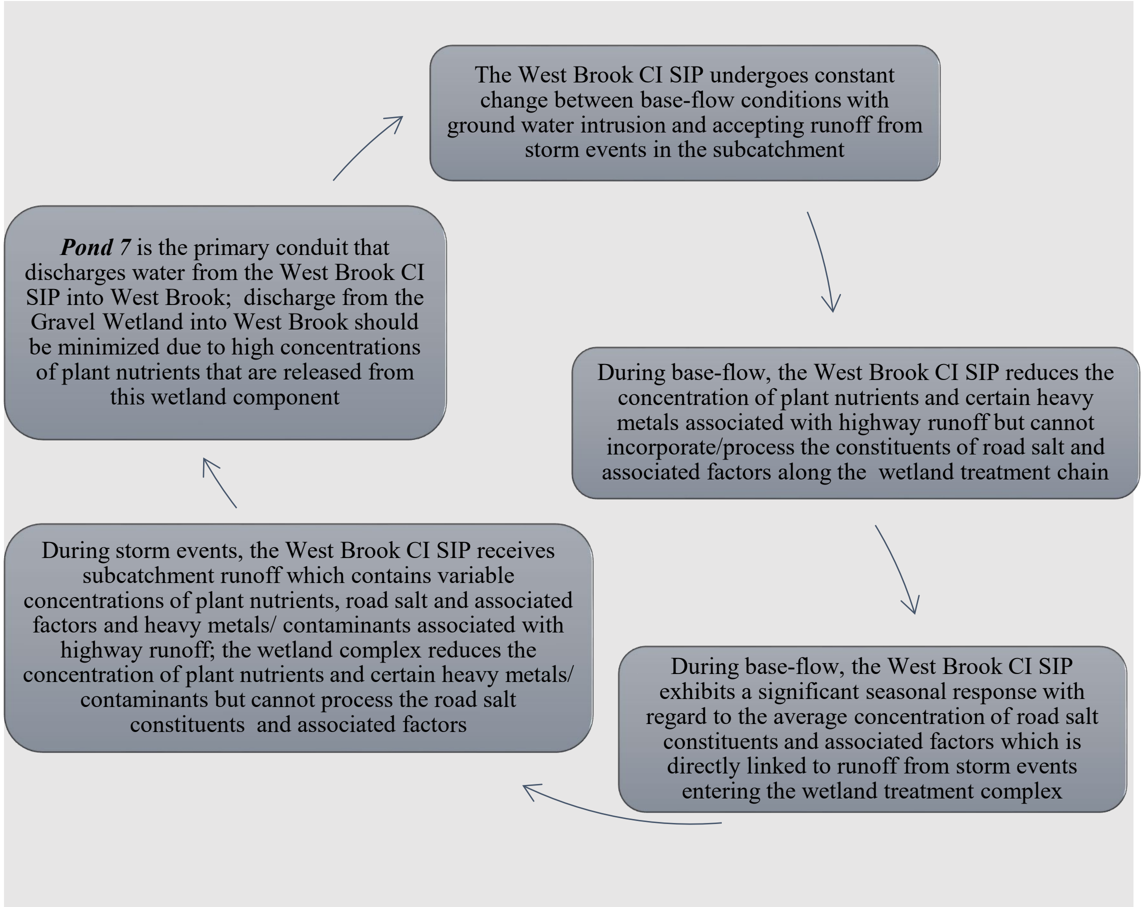
Chapter 9 presents historical background information, a description of the 2017-2018 monitoring program and methodology, results and discussion, a brief program summary, conclusions and recommendations

1.5 Summary

The West Brook CI SIP is a dynamic feature of the south Lake George landscape that functions during base-flow conditions as well as during storm events. Early during the 2017-2018 sampling program it was realized that ground water is flowing from higher elevations to the south of the wetland complex through the wetland and into West Brook via the outlets for ***Pond 7*** and the ***Gravel Wetland***.

The conceptual diagram presented in Figure 1-2 is a fairly concise summary of the West Brook CI SIP and its ability to function regarding the improvement of storm event runoff water quality from the highly developed subcatchment.

Figure 1-2



The West Brook CI SIP undergoes constant change between base-flow conditions with ground water intrusion and accepting runoff from storm events in the subcatchment

During base-flow, the West Brook CI SIP reduces the concentration of plant nutrients and certain heavy metals associated with highway runoff but cannot incorporate/process the constituents of road salt and associated factors along the wetland treatment chain

During base-flow, the West Brook CI SIP exhibits a significant seasonal response with regard to the average concentration of road salt constituents and associated factors which is directly linked to runoff from storm events entering the wetland treatment complex

During storm events, the West Brook CI SIP receives subcatchment runoff which contains variable concentrations of plant nutrients, road salt and associated factors and heavy metals/ contaminants associated with highway runoff; the wetland complex reduces the concentration of plant nutrients and certain heavy metals/ contaminants but cannot process the road salt constituents and associated factors

Pond 7 is the primary conduit that discharges water from the West Brook CI SIP into West Brook; discharge from the Gravel Wetland into West Brook should be minimized due to high concentrations of plant nutrients that are released from this wetland component

The effectiveness of the West Brook CI SIP to treat stormwater runoff from a highly developed impervious area was determined during the 2017-2018 sampling program presented in this final report. The current treatment efficiencies are best described as very satisfactory for the available plant nutrients **nitrate-nitrogen** and **total filterable phosphorus**. The overall average removal efficiency for **nitrate-nitrogen** in the wetland complex was 89 percent, while the average removal efficiency for **total filterable phosphorus** in the wetland complex was 86 percent.

The ability of the wetland treatment chain to process important **highway runoff heavy (trace) metals** and **total suspended sediments** was more variable, with **nickel** (**Ni**) completely (100 percent) removed from the water column, while the wetland complex was less able to process **iron** (**Fe**) and **cadmium** (**Cd**) with average removal efficiencies of 35 percent and 31 percent, respectively.

On the other hand, **road salt** (**Na**, **Cl**) and related parameters including **calcium** (**Ca**), **magnesium** (**Mg**), **specific conductance** (**spC**) and **Total Dissolved Solids** (**TDS**) passed through the wetland treatment chain without any uptake or processing before exiting ***Pond 7*** into West Brook.

It was not possible to achieve Objective #2 of the current study which was to characterize the water quality of the ground water entering Pond 2 due to low levels of intrusion during the 13-month period and the inability to collect sufficient volume of samples for chemistry analysis.

1.6 Conclusions

The following conclusions have been developed after careful consideration of the data collected during the recently completed 13-month study of the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) wetland:

(1) The West Brook CI SIP wetland was constructed during 2011-2013 to capture and treat stormwater runoff from Canada Street and its contiguous developed areas totaling about 63.9 acres.

(2) The West Brook CI SIP wetland has a surface area of 4.45 acres and is a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulate material and (2) support vegetation and bacterial communities that remove heavy metals, salts and excessive nutrients (Pier et al 2015); the effluent enters West Brook and then flows into south Lake George.

(3) The West Brook CI SIP wetland is a dynamic feature of the south Lake George landscape that functions during base-flow conditions as well as during storm events. Early during the 2017-2018 sampling program, it was realized that there is significant ground water intrusion into the wetland system from higher elevations to the south, which moves through the wetland and into West Brook via the outlets for ***Pond 7*** and the ***Gravel Wetland***.

(4) During base-flow conditions, the West Brook CI SIP wetland reduces the *average* concentration of **plant nutrients** and certain **other important highway runoff contaminants** through the processes of uptake and settling out of the water column, respectively, although dilution from ground water intrusion also could be a factor in the reduced *average* concentrations.

(5) During base-flow conditions, there is no definitive evidence that the West Brook CI SIP wetland is able to incorporate and/or process the **road salt (Na, Cl) constituents and associated parameters** including **calcium**, **magnesium**, **specific conductance** and **Total Dissolved Solids**.

(6) Storm event runoff from the West Brook CI SIP wetland subcatchment introduces moderate-to-high *average* concentrations of **plant nutrients** and **road salt constituents and associated parameters** and low-to-moderate *average* concentrations of **important highway runoff contaminants.**

(7) The West Brook CI SIP wetland reduces the *average* concentration of **plant nutrients** and certain **important highway runoff contaminants** between the beginning of the wetland complex (***Pond 1***) and the end of the treatment chain (***Pond 7***) through either uptake or settling or some combination of these factors.

(8) The full extent of concentration reduction of **plant nutrients** and **other important highway contaminants** is detailed in this Final Report; however, with regard to the original goal of the design and construction of the wetland complex achieving 50 percent removal of **phosphorus** and 90 percent removal of **TSS**, the system has proven to perform above expectations, with an average removal of phosphorus of ~85 percent and an average removal of TSS of 92 percent, as described in this Final Report.

(9) Storm event runoff from the West Brook CI SIP wetland subcatchment introduces low-to-high *average* concentrations of **road salt constituents and associated parameters** which exhibit a significant seasonal cycle of *average* concentration; there was no definitive evidence during the current study that the wetland system is able to process these parameters except perhaps through dilution from ground water intrusion.

(10) The ***Gravel Wetland*** is not an appropriate conduit for processing stormwater runoff because it provides fluctuating levels of *average* concentrations of **plant nutrients** and high *average* concentrations of **road salt constituents and associated parameters**, suggesting that this wetland component alternates between functioning as a 'sink' and a 'source' of analytes which discharge into West Brook.

1.7 Recommendations

The following recommendations have been developed after careful consideration of the water quality data collected during the current 13-month study of the West Brook CI SIP wetland complex reported in this final report and are presented for consideration by the West Brook CI Easement Committee (Committee).

(1) The Committee should consider continuing some level of water quality monitoring at the wetland complex to maintain an awareness of the facility and develop a long-term historic record that can be used to evaluate either any land use changes in the subcatchment or implementation of any recommendations presented in this report or developed in the future. A modest water quality monitoring program could include monthly base-flow samples collected from ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland,*** which would be submitted to the DFWI laboratory for analysis using the same test pattern presented herein, including the heavy metals and other contaminants submitted to the USGS Laboratory in Troy New York. Some very limited storm event sampling could occur, such as a sustained spring snow-melt using the automated samplers to collect water for chemical analysis. In addition, the recording and downloading of water level data to document the hydrology of the facility should be continued.

(2) The Committee should enter into discussions with the New York State Department of Transportation and encourage this agency to implement 'smart' technology road salt application along the entire State Route 9 corridor in the Lake George drainage basin but particularly the segment that discharges to the West Brook CI SIP. Any activity that would reduce the amount of road salt application on an annual basis would likewise reduce the amount of road salt constituents and associated parameters that pass through the wetland complex and enter West Brook and then south Lake George. It is suggested to implement Best Management Practices with 'smart' technology actions including the application of brine solution prior to anticipated storm events, the use of 'live-edge' plows, and installing meters and GPS systems in trucks that maintain the corridor so that actual applied amounts can be determined and recorded.

(3) The Committee should investigate the possibility of having the portion of State Route 9 (Canada Street) within the wetland subcatchment cleaned with a sweeper each spring and on a regular basis during the ice-free period of the year to remove sediment and other important highway contaminants from the road surface and minimize the concentrations of these heavy (trace) metals that enter the wetland complex.

(4) The Committee should consider temporarily adjusting the level of the weir in ***Pond 6*** to reduce the amount of water entering the ***Gravel Wetland*** during periods of heavy precipitation and high discharge (flow) through the wetland because this component of the treatment chain currently appears to be a significant source of high concentrations of plant nutrients and road salt constituents and associated parameters to West Brook which should be reduced to the extent possible. Once the amount of water flowing into the

Gravel Wetland has been reduced, maintenance, in the form of plant harvesting, should be conducted during the winter months to determine whether this strategy has any effect on the performance efficiency of this wetland component as compared with the results documented in the 2017-2018 study reported herein.

(5) The Committee should agree to continue some regular schedule of meetings each year (bi-monthly, quarterly) to keep all participants informed of any activities and/or changes that have occurred at the site and to also keep all participants active in the long-term management of this important functional component of the south Lake George landscape.

The above recommendations are not presented in any particular order of importance except for the first recommendation which proposes that a certain level of monitoring be continued beyond the period of the study that just concluded so that .

1.8 Literature Cited

Aulenbach, D.B., N.L. Clesceri, T.J. Tofflemire, S. Beyer and L. Hajas. 1975. *Water Renovation Using Deep Natural Sand Beds*. Jour. AWWA 67(9): 510-515.

Chazen Companies. 2010. *West Brook Conservation Initiative South Parcel Stormwater Improvements. Landscape Plan Plant Tables*. Chazen Job 90730.04.

Eichler, L.W. and C.W. Boylen. 2012. *West Brook Stormwater Runoff Study*. DFWI Technical Report 2012-3. Prepared for The FUND for Lake George. 28 pp. (including appendices).

Fuhs, G.W. 1972. *The Chemistry of Streams Tributary to Lake George, New York*. New York State Department of Health, Albany, New York. Environmental Health Report No. 1. 52 pp. + appendix.

Hyatt, R.M., J. W. Sutherland and J.A. Bloomfield. 1995. *Final Report: A Study of the Feasibility of Reducing the Impacts of Stormwater Runoff in Developed Areas of the Lake George Park*. New York State Parks Management and Research Institute, Saratoga Springs, New York. Lake Services Section, Division of Water, New York State Department of Environmental Conservation, Albany, New York. 115 pp. + appendices.

Lake, D.W. 2001. *West Brook Stormwater Mitigation Project*. Prepared for the Warren County Soil and Water Conservation District, Warrensburg, New York. 18 pp.

Pier, B.M., B.R. Dresser, J.J. Lee, C.W. Boylen, and S.A. Nierzwicki-Bauer. 2015. Ecological analysis before and after planting in a constructed wetland in the Adirondacks. Wetlands35: 611-624. DOI 10.1007/s13157-015-0652-4

Sutherland, J.W. and C. Navitsky. 2015. Final Report. *Village of Lake George Wastewater Treatment Plant – A Monitoring Program to Document Current Treatment Efficiencies.* Prepared for The Village of Lake George. 129 pp. + appendices.

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program***.** New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + appendices.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

2018 Final Report

Chapter 2

Historical Information

This page intentionally left blank

2.0 Introduction

Lake George is the largest body of water located entirely within the Adirondack Park in New York State. Historically, it has been called the "Queen of American Lakes" for its crystal clear waters and inherent natural beauty, and the lake has been a popular tourist attraction since the late 1800s (Farrell, personal communication).

Local concern for the preservation of water quality in Lake George has existed for many decades, primarily the result of activities initiated by the Lake George Association (LGA), the first lake conservation organization in the United States, formed in 1885. As a result of LGA efforts, the lake was classified as "AA Special" (Class AA-S) meaning (1) that water taken from the lake could be used as a public drinking water supply following treatment with chlorine and (2) that there shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters or into streams discharging to the lake (6 CRR-NY 701.3).

The construction of the Adirondack Northway, Interstate 87, in the 1960's greatly facilitated travel to the Lake George region and resulted in a surge in area tourism and recreation beginning in the late 1960s-early 1970s. The high rate and concentration of development along the southwestern shores of Lake George, particularly in Lake George Village, resulted in many environmental problems, including high sedimentation rates from streams. As the regional tourism industry rapidly grew, so did concern for the health of Lake George water quality. The late 1960s-early 1970s marked the beginning of a series of scientific investigations that focused on streams and storm-sewers and their impact on the water quality of Lake George.

2.1 Background

The U.S. Environmental Protection Agency (Agency) was created because of increasing public and government concern about environmental quality. The complexity of our environment and the interplay among its components require concentrated and integrated approaches to pollution problems.

The possible deleterious water quality effects of nonpoint sources in general, and urban runoff in particular, were recognized by the Water Pollution Control Act Amendments of 1972. Due to the uncertainties about the true significance of urban runoff as a contributor to receiving water quality problems, Congress made treatment of separate stormwater discharges ineligible for Federal funding when it enacted the Clean Water Act in 1977. To obtain information that would help resolve these uncertainties, the Agency established the Nationwide Urban Runoff Program (NURP) in 1978. This five-year program was designed to examine such issues as:

- The quality characteristics of urban runoff, and similarities of differences at different urban locations;
- The extent to which urban runoff is a significant contributor to water quality problems across the nation;
- The performance characteristics and the overall effectiveness and utility of management practices for the control of pollutant loads from urban runoff.

During 1979, the New York State Department of Environmental Conservation (Department) submitted an application for Federal assistance and a work-plan to the Agency for the conduct of an urban runoff study at Lake George, New York, as part of the NURP. The specific objectives of the proposed study were to:

(1) Identify and quantify (in terms of concentration and load) the major runoff contaminants transported to Lake George by streams and storm-sewers located in the developed, south portion of the drainage basin;
(2) Test the effectiveness of control measures to prevent or reduce the discharge of contaminants to Lake George;
(3) Determine the water quality response in south Lake George to the total loadings of contaminants discharged from urbanized areas under present levels of development with and without control measures;
(4) Develop a lake management program to minimize the impact of from developed areas on water quality.

The Department intended to provide a stormwater runoff strategy for developed areas and areas susceptible to development in the Lake George drainage basin and an overall lake management program which would have application in other similar situations in New York and nationwide.

2.2 The Lake George Urban Runoff Study

The Lake George Urban Runoff Study was approved for a three-year period beginning March 1 1980, for a total cost of $810,000 in Federal funds. An amount of $310,000 was committed to the first year of the study to identify and quantify the major runoff contaminants (Objective 1) and to determine the impact of runoff on water quality of the lake (Objective 3). The Department was responsible for the overall conduct of the study and the watershed sampling program. The program to determine the impact of runoff on water quality of the lake was conducted by the New York State Departments of Education and Health.

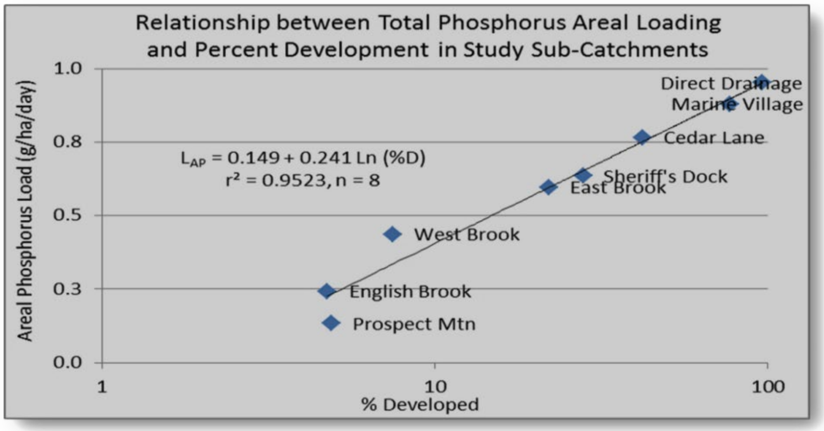
Based upon the results from the preliminary sampling, The Agency reduced the level of funding from $499,000 to $250,000 for the remainder of the study and indicated that control measure evaluation and development of a management plan should be deleted from the work-plan. In addition, the portion of the study investigating the impact of runoff on water quality of the lake was scheduled to terminate after the first year. Thus, the second and third years of the study were a continuation of the watershed sampling effort to determine loadings of various contaminants from undeveloped and developed areas to south Lake George.

The results of the NURP watershed sampling program were presented and discussed in Sutherland et al. 1983. The results of the lake sampling program were presented in Siegfried (1982) and Wood (1982). In addition, there was a final report prepared for the Phase I Clean Lakes Diagnostic Study which summarized the lake monitoring results from the urban runoff study and reviewed various structural measures for reducing surface runoff and sediment loading to Lake George (Siegfried and Quinn 1986).

More than 40 storm events were sampled at six tributary sampling stations during the Lake George NURP study. In summary, at the time that the final report was written, runoff from developed areas accounted for 14.0% of the annual phosphorus loading to Lake George, which is 15.5% of the load to the south lake and 6.6% of the load to the north lake. In addition, developed areas contributed 62.9% of the annual load to the study area at the south end of the lake. Almost one-half (45.5%) of the annual phosphorus loading to the whole lake could be attributed to the undeveloped portion of the drainage basin, with the next largest source being atmospheric deposition (31.3%).

At the time of the Lake George NURP study, approximately three quarters of the annual phosphorus loading to the lake occurred between February and June, indicating the dominant effect of snow-melt on the hydrology of the area. Furthermore, the areal phosphorus load (in grams P/hectare/day) of any sub-catchment could be directly related to the percentage of its developed area as shown in the figure below.

Figure 2-1



By use of this relationship, if the study area was 50% developed, it would have an annual phosphorus loading 1.87 times the loading at the time that the final report was written. As a consequence, the study region of the lake likely would exhibit the characteristics of a moderately eutrophic water body.

In general, the loading estimates to the lake presented in the final report corresponded closely with the observed water quality of Lake George as presented by Siegfried (1982) and Siegfried and Quinn (1986). In these studies, Siegfried showed that north-south gradients in phosphorus, chlorophyll ***a*** and Secchi depth transparency corresponded to land development patterns and drainage area-lake volume ratios.

Although annual loadings were not presented and discussed in the final report, runoff from developed areas also exhibited elevated levels of total Kjeldahl nitrogen, total suspended sediment, total organic carbon, fecal bacteria, chloride, lead, ammonia-nitrogen and total soluble phosphorus.

In summary, tributaries draining developed watersheds exhibited considerably different water quality than tributaries draining undeveloped watersheds. And because only 4.3 percent of the Lake George drainage basin was developed at that time (early 1980s), there had been little impact on the lake water quality and no identified use impairment. Given the rate of land development during that period, however, there was strong reason to believe that a significant decline in water quality would occur within the next two decades (1980s, 1990s), particularly at the south end of the lake where development already was most concentrated.

The 1983 final report for the Lake George NURP offered a series of recommendations to avert the anticipated decline, including the following recommendation:

(7) The New York State Department of Transportation should prepare a plan designed to reduce surface runoff and pollutant loadings from US Route 9 in Lake George Village (Canada Street). Such a plan could range from constructing recharge basins (marginal utility) to reducing the sidewalk and pavement areas of Canada Street by construction of a landscaped median strip (maximum utility).

While this recommendation focused specifically on the segment of Route 9 (Canada Street) within the Village of Lake George, the authors of the report also recognized that the Route 9 corridor south of West Brook was a major contributor of contaminants including sand, road salt and forms of phosphorus to south Lake George.

2.3 Chronology of Events Leading to Construction of the Wetland Complex

Circa 1995, there was some effort within the Department to move forward with design and construction of a wetland complex that would be located within the Lake George Battlefield Park and would process stormwater runoff from the segment of Route 9 south of West Brook (Sutherland, unpublished material). Unfortunately, after several years of meetings and negotiations, the process came to an abrupt halt when it was realized that the use of state land for stormwater remediation would be in violation of the New York State Constitution.

Now fast forward about 10-12 years to the time when there was renewed interest to acquire the Charles R. Wood Park located north and south of West Brook and West Brook Road (County Route 69) and east of Canada Street (Route 9) and use these parcels for the construction of an event space and a wetland complex, respectively.

The following material is a chronology of events related to the wetland complex that was compiled by Randy Rath, Lake George Association. While this material may not be complete, it does represent the most comprehensive source of information at the current time.

- 2008 – The property was closed on by the Lake George Land Conservancy, the Lake George Association, The FUND for Lake George, the Town and Village of Lake George, and Warren County.
- 2009 – An oil spill was discovered and remediated thru 2011 on south parcel
- 2010 - Demolition of the Charlie Wood Saloon (north parcel) began in December.
- 2011 - Rough grading of the north parcel began in January; demolition on the south parcel began in 2011; there were discussions about one of the buildings on north parcel and whether to keep and fix up or demolish; a snow storm collapsed the roof in February and the building was demolished; rough grading of the north parcel was completed during June; parcels were all cleared by July.
- 2012 – Topsoil was brought in and planting of the wetlands and surrounding areas was initiated during September; completed during October; over 1,800 plants, shrubs, trees and plugs were planted.

- 2013 – The wetland site was left alone so that the planted vegetation could become established; during the fall, the ***Gravel Wetland*** had about 6 inches of water in it at all times; the weir height controlling the split into ***Pond 6*** and the ***Gravel Wetland*** was too high; small channel in weir was opened to lower the level and the inlet to the ***Gravel Wetland*** was capped off so the water level could adjust.
- October 4, 2013 - The inlet under Route 9N was opened allowing stormwater to enter the site into Pond 1.
- October 7, 2013 – First rain event to provide runoff to enter the wetland complex.
- February 2014 – An old 24-inch culvert mistakenly buried along the bank of ***Pond 1*** caused an hydraulic failure, drained and eroded a portion of the pond; the inlet under Route 9N once again was capped until the ***Pond 1*** bank could be fixed and stabilized.
- June, 2014 – The 24" culvert was removed and the ***Pond 1*** bank was re-established and seeded; the cap at the inlet under 9N was once again removed so the system was now "open" again to accept runoff.
- October 2014 – Walking trails were installed on the north parcel
- 2015 – During spring-early summer, ***Pond 1*** spilled its banks during several short-term, intense events.
- 2015 - During June, the Village of Lake George Department of Public Works lowered the level of the weir located at the split between ***Pond 6*** and ***Pond 7*** to just below the invert level of the ***Gravel Wetland*** to allow any stormwater runoff entering the site to trigger flow into the ***Gravel Wetland***.
- 2015 – During August, 2 feet of clay and topsoil was added to the ***Pond 1*** bank and cattails were harvested from ***Pond 1*** at the outlet weir leading to ***Pond 2***; some rocks in the location of the weir were removed to allow easier flow into ***Pond 2*** during storm events.
- 2016 – During October, ***Pond 1*** was dredged with approximately 80 cubic yards of material removed from the pond, including cattails along the bank surrounding the pond.

The Darrin Fresh Water Institute conducted monthly base-flow sampling between August 2013 and July 2014 from various wetland components, and monitored a single storm event during November 27th-28th 2013. These data were insufficient, however, to allow a critical evaluation of the wetland complex with regard to the treatment efficiency of stormwater runoff. The need for a more critical evaluation of wetland functioning prompted discussions of the Working Committee comprised of the Lake George Land Conservancy, the Lake George Association and The FUND for Lake George to develop a work-plan to study the wetland complex (see Chapter 4).

2.4 Literature Cited

Official Compilation of Codes, Rules and Regulations of the State of New York. Title 6. Part 701. Item 701.3 Class AA-Special (AA-S) fresh surface waters. Current through August 31, 2015.

Siegfried, C.A. 1982. *Water Quality and Phytoplankton of Lake George, New York: Urban storm runoff and water quality gradients.* Technical Paper No. 66, Bureau of Water Research, New York State Department of Environmental Conservation. Albany, New York. 64 pp.

Wood, L. W. 1982. *Trophic gradients, nutrient loadings in Lake George, New York 1978-1980*. Final Report to the New York State Department of Education for work conducted under the U.S. EPA Nationwide Urban Runoff Program. Environmental Health Institute, New York State Department of Health, Albany, New York. Grant No. 20079. 66 pp.

Siegfried, C.A. and S.O. Quinn. 1986. *Lake George Clean Lakes 314 Study. Phase I – Diagnostic/Feasibility Study. Final Report*. Biological Survey, State Science Service, New York State Museum, Albany, New York and Bureau of Technical Services and Research, Division of Water, New York State Department of Environmental Conservation, Albany, New York. 407 pp. + Appendices.

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program***.** New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + Appendices.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

2018 Final Report

Chapter 3

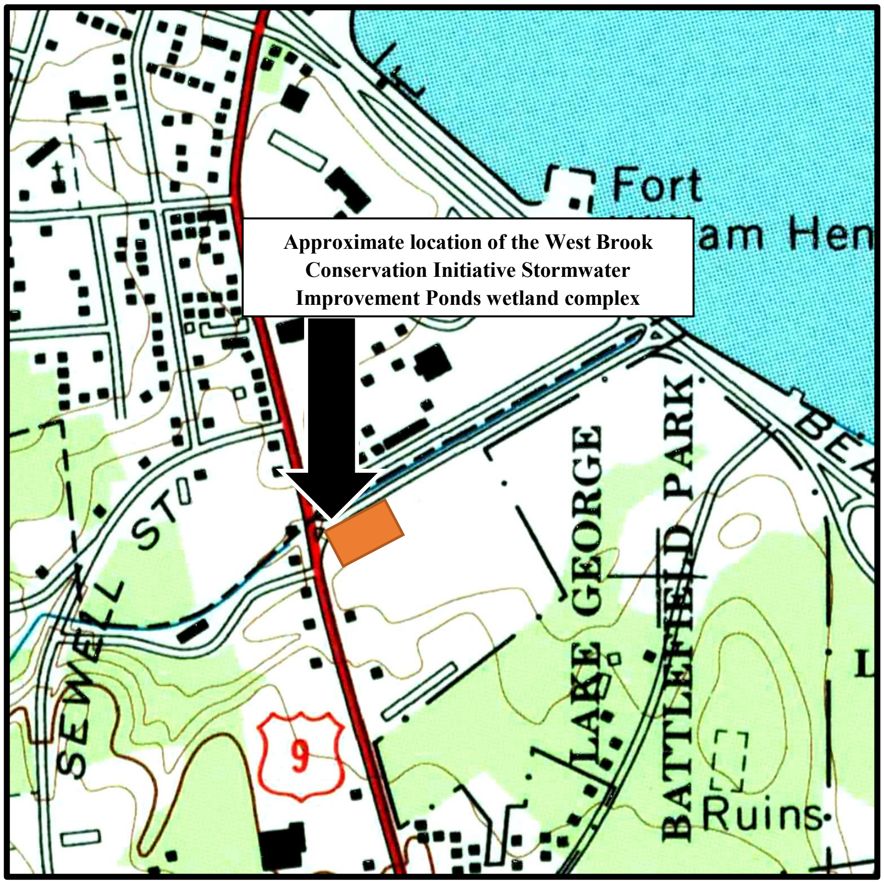
Description of the West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex, the Subcatchment that Drains to the Wetland Complex and the Important Constituents of Stormwater Runoff

This page intentionally left blank

3.0 Location

The West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex is located at the south end of Lake George in the Town of Lake George (Warren County), New York. The parcel containing the wetland complex is situated on the southeast corner of the intersection of Route 9 (Canada Street) and Warren County Route 69. Figure 2-1 is a portion of the USGS Lake George quadrangle 7.5-minute series topographic map showing the general location of the created wetland and its relationship to surrounding features.

Figure 3-1



Approximate location of the West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex

The 2.0 hectare (4.9 acre) freshwater wetland is located on the property formerly known as the Charles R. Wood Park. The wetland complex was constructed and modified over a three-year period from 2011 through 2013. Existing buildings were demolished and the series of ponds created during June 2011. In September 2012, naturally established plants in the area were removed, original pond shape was restored, and 85 plant species were artificially introduced to the wetland complex. Plant species were introduced throughout the wetland system according to a planting scheme designed by environmental engineers to mimic natural wetland vegetation gradients (Chazen Companies 2010). Several site modifications including mowing, skimming and weir adjustments were carried out during the fall of 2013. The inlet chamber to the wetland complex was opened during October 2013 to allow the entry stormwater runoff.

3.1 Owners/Operators and Design Professionals

The owners and operators of the West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex include the Village of Lake George, Warren County, the Lake George Association, The FUND for Lake George, and the Lake George Land Conservancy.

The Design Professionals for the project were The Chazen Companies, 547 River Street, Troy, New York 12180.

3.2 Description of the Wetland Complex

The West Brook Conservation Initiative is a collaborative commitment to use the Project Site for stormwater remediation, to include the redirection of storm sewer discharge through a series of stormwater treatment practices prior to being discharged into West Brook. Stormwater runoff from the Route 9 and contiguous catchment has been collected, conveyed and redirected to the stormwater treatment systems described herein.

The following material that describes the design, operation and function of the West Brook Conservation Initiative South Parcel Stormwater Improvement Ponds wetland system was excerpted from the following document: ***West Brook Conservation Initiative South Parcel Stormwater Improvements. Town of Lake George, Warren County, New York. Operation, Inspections and Maintenance Manual for Stormwater Management Facilities*** (The Chazen Companies, 2014).

3.2.1 Pond/Wetland System

Multiple cell systems such as pond/wetland systems utilize at least one pond component in conjunction with a shallow marsh component. The first cell typically is a wet pond or forebay (***Pond 1*** on Figure 3-2) which provides pretreatment of runoff by removing particulate materials. When properly designed, the permanent pool reduces the velocity of incoming water to prevent resuspension of particles and promote settling of recently introduced suspended solids. The energy-dissipating and treatment properties of the permanent pool are enhanced by aquatic vegetation which is an essential part of the stormwater design. The additional vertical storage volume also provides extra runoff detention above the normal pool elevations.

The shallow marsh wetland system (***Pond 2*** through ***Pond 5*** Shallow Marsh on Figure 3-2) receives runoff from the forebay and then filters the runoff, particularly for soluble pollutants, prior to discharge. Shallow marsh wetlands consist of aquatic vegetation with a permanent pool ranging from six to eighteen inches during normal conditions. The growing area in shallow wetlands extends from the normal pool elevation to the maximum water surface elevation. Wetland plants that tolerate intermittent flooding and dry periods have been selected for the extended detention area above the shallow marsh elevations.

Because of this system's ability to significantly reduce the velocity and rate of incoming peak flows (i.e., flow equalization or dampening), it can often achieve higher pollutant removal rates than other similarly-sized stormwater wetland systems.

3.2.2 Gravel Wetland System

The gravel wetland system consists of one or more flow-through constructed wetland cells, preceded by a forebay (***Pond 6*** and ***Gravel Wetland*** on Figure 3-2). The cells are filled with crushed rock or gravel, covered with an organic soil layer, and planted with wetland vegetation. During low-flow storm events, the system is designed to promote subsurface horizontal flow through the gravel media, allowing contact with the root zone of the wetland vegetation. The gravel and planting media support a community of soil microorganisms. Water quality treatment occurs through microbial, chemical, and physical processes within this media, as well as direct vegetative uptake. To accommodate higher flows, the system is designed to permit inundation of the wetland surface, and the system would function similar to other constructed wetland systems. Overflow from the wetland is provided by an outlet structure designed to keep the gravel media submerged. Following an event, remaining water on the surface of the wetland would infiltrate into the gravel media, and flow horizontally through the media as in the low flow condition.

3.2.3 Deep Pool Pond.

Water from the forebay enters this pond (***Pond 7*** on Figure 3-2) which allows or final polishing before being discharged into West Brook.

The entire wetland system can be designed to integrate some stormwater storage. With these features, the practice would not only remove pollutants, but also contribute to the attenuation of peak rates through temporary storage and reduction in runoff volume.

Figure 3-2

GENERAL OPERATION AND MAINTENANCE PROCEDURES

GENERAL SITE COVER
- MOWING AND SWEEPING: REGULARLY SCHEDULED, 2 TIMES/YEAR.
- SWEEPING: REGULARLY SCHEDULED, 2 TIMES/YEAR
- DEBRIS AND LITTER REMOVAL: REGULARLY SCHEDULED, 2 TIMES/YEAR
- STRUCTURAL REPAIR OR REPLACEMENT: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- CATCH BASIN CLEANOUT: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- GRASSED SWALE MAINTENANCE: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- RIP-RAP DISSIPATION STRUCTURE MAINTENANCE: REGULARLY MONITORED, ADDRESSED AS NEEDED.

SETTLING POND (POND 1), WET MARSH (PONDS 2, 3, 4, & 5), FOREBAY (POND 6), AND DEEP POOL (POND 7)
- MOWING: REGULARLY SCHEDULED, 2 TIMES/YEAR. NOT DESIRED NOR ALLOWED IN AQUATIC BENCHES.
- DEBRIS AND LITTER CONTROL: REGULARLY SCHEDULED, AT LEAST 2 TIMES/YEAR.
- STRUCTURAL REPAIRS AND REPLACEMENT: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- EROSION CONTROL: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- SEDIMENT REMOVAL:
    - PONDS 1 & 6: EVERY 4- 5 YEARS, OR WHEN ACCUMULATION REACHES 50% OF TOTAL CAPACITY.
    - PONDS 2, 3, 4, 5, & 7: EVERY 4- 5 YEARS, OR WHEN ACCUMULATION REACHES 12 INCHES IN DEPTH.
    - INLET AND OUTLET STRUCTURES: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- REMOVAL OF INVASIVE SPECIES: REGULARLY MONITORED, ADDRESSED AS NEEDED.

GRAVEL WETLAND
- MOWING: NOT DESIRED NOR ALLOWED.
- TREE AND SHRUB REMOVAL: BIANNUALLY.
- DEBRIS AND LITTER CONTROL: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- EROSION CONTROL: REGULARLY MONITORED, ADDRESSED AS NEEDED.
- SEDIMENT REMOVAL: ANNUALLY, OR WHEN SEDIMENT ACCUMULATION REACHES 4 INCHES IN DEPTH ACROSS THE WETLAND SURFACE.
- REMOVAL OF INVASIVE SPECIES: REGULARLY MONITORED, ADDRESSED AS NEEDED.

STORMWATER TREATMENT PROPOSED FEATURES AND PLANTINGS

SETTLING POND AND CLEANOUT AREA

SEDIMENT LADEN STORMWATER FROM ROUTE 9 ENTERS THE SETTLING POND WHERE SEDIMENT IS TRAPPED AND RETAINED. DEPOSITS ARE REMOVED ONCE A YEAR. CLEANOUT OPERATIONS TAKE PLACE ON ADJACENT REINFORCED TURF.

SHALLOW MARSH

WATER FLOWS FROM THE SETTLING POND TO THE SHALLOW MARSH WETLANDS. HERE, WETLAND PLANTINGS STORE AND TREAT RUNOFF. POLLUTION REMOVEL IS ACHIEVED THROUGH SETTLING AND BIOLOGICAL UPTAKE. THIS AREA MAY REQUIRE SEDIMENT REMOVAL OVER TIME.

FOREBAY

WATER FLOWS FROM THE SHALLOW MARSH TO THE FOREBAY. THIS AREA ALLOWS ANY REMAINING SEDIMENT TO DROP OUT BEFORE IT IS SPLIT INTO TWO DIFFERENT DIRECTIONS.

GRAVEL WETLAND

WATER FLOWS INTO THE GRAVEL WETLAND WHERE DENSE ROOT MATS, CRUSHED STONE, AND A MICROBE RICH ENVIRONMENT IMPROVE WATER QUALITY BEFORE IT IS CONVEYED TO WEST BROOK.

DEEP POOL POND

WATER FROM THE FOREBAY FLOWS INTO THE POND FOR FINAL TREATMENT BEFORE IT IS CONVEYED TO WEST BROOK.

PLANTINGS

ALL TREES, SHRUBS, MARSH PLANTS AND MEADOW SEED MIX ARE NATIVE PLANTS PLANTED IN APPROPRIATE ZONES ACCORDING TO THEIR NATIVE HABITAT.

THE Chazen COMPANIES
Engineers/Surveyors
Planners
Environmental Scientists

MUNICIPAL PARTNERS
VILLAGE OF LAKE GEORGE
TOWN OF LAKE GEORGE
WARREN COUNTY

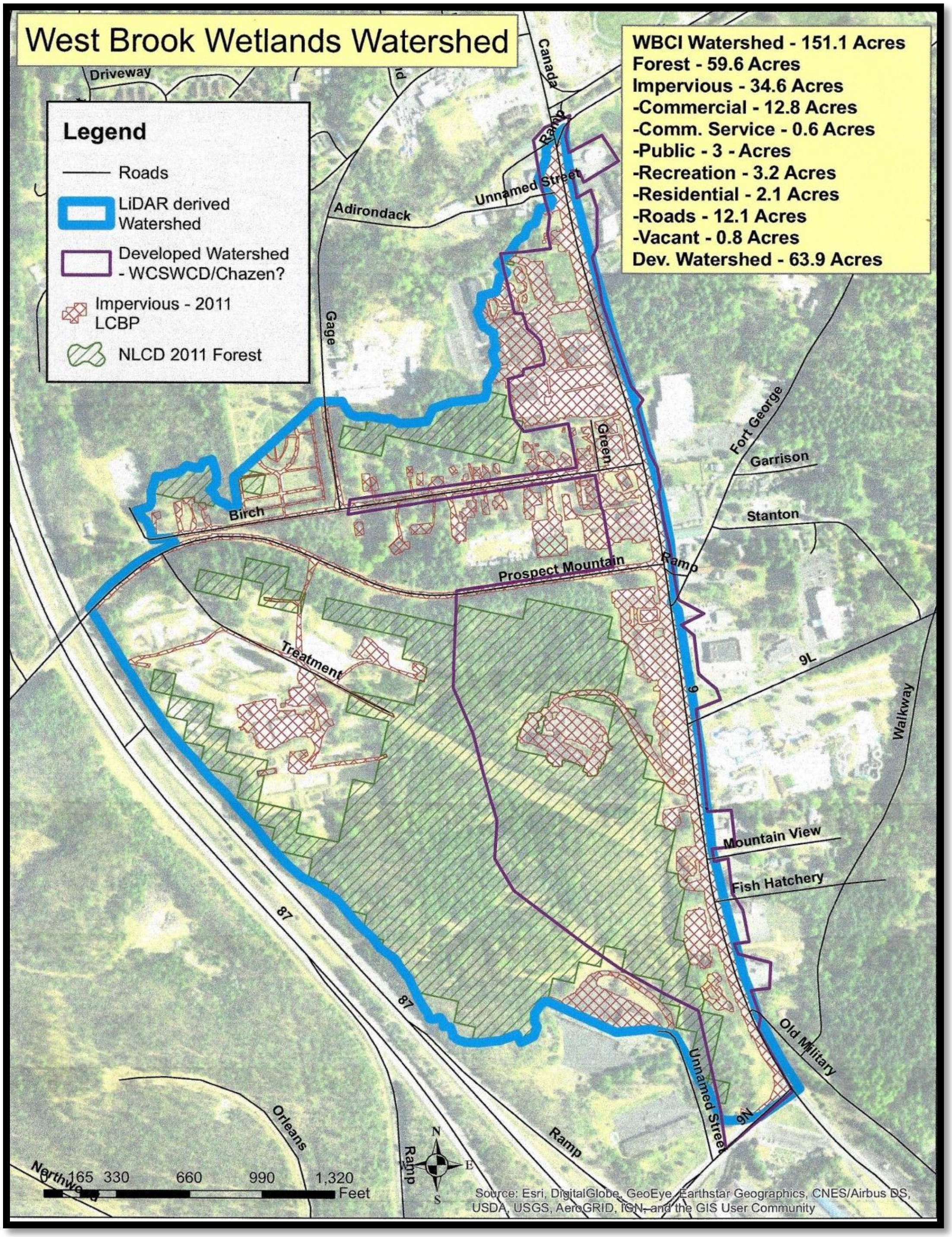
WEST BROOK CONSERVATION INITIATIVE
SOUTH PARCEL STORMWATER IMPROVEMENTS
OPERATION AND MAINTENANCE FIGURE
APRIL 22, 2014

LGA Lake George Association
LAKE GEORGE LAND CONSERVANCY
THE FUND for LAKE GEORGE

3.3 The Subcatchment that Drains to the Wetland Complex

The LiDAR (Light Detection and Ranging) derived estimated surface area of the sub-catchment that drains to the West Brook Conservation Initiative Stormwater Improvement Ponds is 151.1 acres and is shown in Figure 3-3.

Figure 3-3



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

It is likely, however, that not all of this surface area drains to the wetland complex and that the area of concern is the developed watershed which has a surface area of 63.9 acres and includes the Route 9 corridor and adjacent developed area to the west. Most of the impervious area of 34.6 acres lies within this 'developed' watershed. Much of the 'developed' watershed directly west of the Route 9 corridor is comprised of commercial businesses with sizeable parking areas.

Route 9, itself, constitutes an impressive surface area and probably contributes most of the stormwater runoff to the wetland complex. As outlined in Figure 3-3, the Route 9 (also known as Canada Street) corridor traverses a distance of 4,500 feet within the West Brook sub-catchment and the average width of the corridor (roadway + sidewalks) is 85 feet, which translates to a total of 8.78 acres of impervious highway surface that drains directly to the wetland complex. This surface area is 25 percent of the total impervious area in the LiDAR-derived watershed and an even greater proportion of the total impervious area within the developed watershed that includes the Route 9 corridor and adjacent developed areas that drain directly toward Route 9.

The entire section of Route 9 (Canada Street) that traverses the wetland complex was reconstructed prior to the beginning of the Program described herein. This portion of Route 9 now is comprised of asphalt concrete with several median areas constructed of concrete along the center of the highway and concrete sidewalks on both sides of the system.

3.4 Important Constituents of Stormwater Runoff

The following chapters in this Final Report for the sampling effort conducted in the wetland complex presents the chemistry results separately for **base-flow** and **storm events** and in groups of related analytes that comprised the Program chemistry *test pattern* including (1) plant nutrients, (2) road salt (Na, Cl), calcium, specific conductance and total dissolved solids, (3) highway contaminants, and (4) other field measurements. This grouping of analytes appears to be the most meaningful way to present wetland water chemistry and the influence of the treatment complex on chemical characteristics of water either retained in the system during base-flow, non-storm event periods or passed through the system and then discharged into West Brook during events and/or post-event periods.

3.4.1 Plant Nutrients and Total Suspended Sediments (TSS).

Nitrogen and phosphorus would be of particular concern in a sub-catchment such as the one that send stormwater runoff to the West Brook CI SIP. The primary source of nitrogen would result from atmospheric deposition on paved surfaces, fertilizer applied to vegetated areas adjacent to impervious surfaces, and organic (plant) material that gets carried into the wetland complex during runoff events. Sources of phosphorus in runoff entering the wetland could originate from atmospheric deposition on impervious surfaces, fertilizer application in the drainage area, and animal/pet feces that may occur on impervious surfaces.

Forms of nitrogen and phosphorus also could enter the wetland complex through groundwater flow at a rate dependent upon patterns and volume of precipitation that influence the level of the ground water table.

The chemistry test pattern for the wetland complex sampling program included the nutrients **total nitrogen**, **nitrate-nitrogen**, **total phosphorus**, and **total filterable phosphorus**.

Nitrogen. An important nutrient used by phytoplankton and aquatic plants to produce biomass in lakes and ponds. **Total nitrogen (TN)** is a measure of all forms of nitrogen found in water, and consists of organic forms and inorganic forms including nitrate (NO_3^-), nitrite (NO_2^-), un-ionized ammonia (NH_4), ionized ammonia (NH_3^+) and nitrogen gas (N_2). The relationships of these nitrogen forms are

Total nitrogen (TN) = Organic nitrogen (ON) + Ammonia-nitrogen (NH_3-N) + Nitrate-nitrogen (NO_3-N) + Nitrite (NO_2)

Amino acids and proteins are naturally-occurring organic forms of nitrogen. All forms of nitrogen are harmless to aquatic organisms except un-ionized ammonia and nitrite, which can be toxic to plants and fish. **Nitrite** usually is not a problem in water-bodies since it is readily converted to **nitrate** if enough oxygen is present for oxidation.

Although **TN** is an essential nutrient for plants and animals, an excess amount of nitrogen in a waterway can lead to low levels of dissolved oxygen and negatively alter various plant life and organisms. Sources of nitrogen include wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors.

Bacterial oxidation and reduction of various nitrogen compounds in lake water produces forms of nitrogen that are assimilated by aquatic plants during photosynthesis. There are several forms of nitrogen that are important to the biota of lakes and ponds including inorganic **nitrate** and **ammonia**, and the **organic nitrogen** fraction.

Nitrate-nitrogen, **NO_3-N**, is produced by the bacterial conversion of organic and inorganic nitrogenous compounds from a reduced state to an oxidized state and is readily assimilated by algae and other green plants. Collectively, n**itrate** and **ammonia** provide most of the nitrogen available for assimilation by green plants.

Ammonia-nitrogen, **NH_3-N**, is the first inorganic nitrogen product of organic decomposition by bacteria and is present in lake water primarily as NH_4^+ and NH_4OH. The relative proportions of NH_4^+ to NH_4OH in lake water depend primarily upon pH as follows (Hutchinson, 1957):

pH 6	3000:1
pH 7	300:1
pH 8	30:1
pH 9.5	1:1

At pH values ≤7.00, NH_4^+ predominates and is a good source of nitrogen for plants. At higher pH values, NH_4OH can occur in concentrations that are toxic to biological growth.

Organic nitrogen in lake water consists of dissolved and particulate forms, and represents nitrogen contained in the plankton and seston (particulate matter) suspended in the water column.

Phosphorus. Has a major role in biological metabolism and often limits the amount of productivity in lakes and ponds since it is the least abundant of the major structural and nutritional components of the biota such as carbon, hydrogen, nitrogen, etc. Although phosphorus occurs as organic and inorganic forms, more than 90 percent of the phosphorus that occurs in lake water is bound organically with living material or associated with decaying material (Wetzel, 1975).

Most important in pond metabolism is the **total phosphorus** content of unfiltered water which contains **particulate phosphorus** (in suspension as particulate matter) and the **dissolved**, or **soluble**, **phosphorus** fraction. **Particulate phosphorus** can include three forms (1) phosphorus in living organisms (e.g. plankton), (2) mineral phases of rock and soil with adsorbed phosphorus, and (3) phosphorus adsorbed onto dead particulate organic matter. The relative importance of each form seems to vary, probably as a function of allochthonous (from outside the system) material containing phosphorus, which can enter the wetland complex at different times of the year.

The 2017-2018 test pattern of analytes in the sampling Program at the West Brook CI SIP included **total phosphorus** (**TP**) and **total filterable phosphorus** (**TFP**) which is readily available for uptake in the ponds by algae and attached aquatic plants as well as other forms of biota.

Particulate phosphorus adsorbed to mineral phases of rock and soil, (2) above, can be an important source of nutrients in the West Brook sub-catchment in the form of **total suspended sediments** (**TSS**) when sand is mixed in with road salt to act as an abrasive or in the case of soil eroded from vegetated areas and carried to the wetland complex in stormwater runoff.

The 2017-2018 test pattern of analytes also included TSS which was collected from runoff entering the Inlet chamber when storm events were monitored.

3.4.2 Road Salt Constituents and Associated Parameters.

The extensive section of Route 9 and adjacent paved surfaces (sidewalks, parking lots) that provide stormwater runoff directly to the wetland complex necessitates a focus on **road salt** (**Na**, **Cl**) applied for winter deicing maintenance and other related parameters including **calcium**, **specific conductance**, and **total dissolved solids**.

The New York State Department of Transportation (NYSDOT) maintains the segment of Route 9 that traverses the wetland sub-catchment including application of the winter deicing product ClearLane™ Enhanced Deicer (Cargill, Lansing, NY). Numerous paved areas, parking lots and secondary access roads are adjacent to, and drain to, the Route 9 corridor, and these areas also are maintained during the winter by local government (Town of Lake George) and local contractors with application of deicing materials.

The Village of Lake George uses ClearLane™ for winter deicing whereas the product used by the Town of Lake George and local contractors for parking lots and roadways likely is Bulk Ice Control Salt (Cargill, Lansing, NY).

Table 3-1 summarizes the components included in Bulk Ice Control road salt and ClearLane™ Enhanced Deicer.

Table 3-1

Bulk Ice Control		**ClearLane™ Enhanced Deicer**	
component	**%**	**component**	**%**
sodium chloride	98.0	sodium chloride	95.9
calcium, magnesium	0.4	pre-wetting agent[1]	4.1
sulfate	0.75	[1]water	67-70 of 4.1%
water insolubles	0.75	[1]magnesium chloride	26-29 of 4.1%
acid insolubles	0.20	[1]sodium gluconate	0.25-0.35 of 4.1%
surface moisture	0.40	[1]xanthan gum	0.2-0.4 of 4.1%
yellow prussiate of soda	90 (ppm)	[1]colorant blend	0.01-0.06 of 4.1%

Sodium and chloride. The primary agent used in both of these deicing compounds is road salt or **sodium chloride** (**NaCl**), while the Bulk Ice Control product also has trace amounts of calcium, magnesium and sulfate.

Sources of **Na** and **Cl** entering the wetland complex are direct runoff from highway and other impervious surfaces that drain to the Inlet chamber, and via ground water entering the wetland as Cl moves through the soil after being applied at higher elevation.

Calcium. The presence of **calcium** in direct runoff from the sub-catchment results from winter deicing maintenance using the Bulk Ice Control product, and concrete structures within the sub-catchment may contribute small amounts of Ca^{+2} as a consequence of dissolution of Ca-rich phases in the cement. Dissolving is particularly rapid while the concrete is curing. After the more soluble portions of the concrete dissolve, the coarser-grained and less soluble surfaces contribute less Ca^{+2} to solution. There are considerable concrete surfaces along the Route 9 corridor consisting of curbs, sidewalks and highway median structures, and the entire road surface, which recently was reconstructed, is asphalt concrete which also is susceptible to dissolution of Ca^{+2}.

Calcium also can enter the wetland complex via ground water movement from higher elevations within the sub-surface drainage area. Road salt loading of soils adjacent to paved surfaces that receive winter deicing salt products will displace cations (+ charged ions) from exchange sites in soils; these desorbed cations follow a simple ion-exchange model , with lower sodium and higher calcium, magnesium and potassium fluxes in surface runoff and in ground water (Sutherland et al. 2018).

Magnesium. This element ranks eighth in order of abundance and is a common constituent of natural water. Magnesium salts are important contributors of water hardness. The **Mg** concentration may vary from zero to several hundred milligrams per liter, depending upon the source and treatment of the water.

A comprehensive survey of all Lake George tributary and stormsewer sites exhibiting flow throughout the drainage basin during 2000 determined that the average Mg concentration for all sites sampled was 2.80 mg/L^{-1} during June-July, 3.85 mg/L^{-1} during August-September, and 4.39 mg/L^{-1} during November, supporting the observation that magnesium concentration increased as flow decreased (Sutherland et al. 2001).

Aside from natural contributors/sources in the soil, the primary source of magnesium in the wetland complex would be the deicing materials that are applied in the subcatchment as summarized in Table 3-1 above.

Specific conductance. The phenomenon of **specific conductance** is a measure of water's resistance to flow of an electrical current; resistance decreases as ionized salt content of the water increases and promotes the flow of electrical current. Water with a low concentration of major ions, e.g. HCO_3 (bicarbonate), CO_3^{-2} (carbonate), K^+ (potassium), Na^+ (sodium), Ca^{2+} (calcium), Cl^- (chloride), SO_4^{-2} (sulfate) and $Mg^{=2}$ (magnesium) has the greatest resistance to electron flow, while water with a high concentration of ions, e.g. seawater, has less resistance to electron flow.

Specific conductance measured in the wetland complex would be influenced by deicing compounds (Na, Cl; Ca and SO4 to a lesser extent) carried in the stormwater runoff from Route 9 and adjacent areas that are maintained during the winter.

Total dissolved solids (TDS). **TDS** include inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, sulfates) and some small amounts or organic matter dissolved in water. In general, the total dissolved solids concentration is the sum of the cations ('+' charged ions) and anions ('**-**' charged ions).

Sodium and particularly chloride ions originating from road salt application in the sub-catchment provide a substantial component of both specific conductance and total dissolved solids and very often it is possible to demonstrate linear relationships among these parameters.

Both specific conductance and total dissolved solids are field measurements that are determined on-site when samples are collected for chemical analysis.

3.4.3 Other Important Highway Runoff Contaminants

A full list of highway runoff constituents and their primary sources was summarized by Smith and Lord (1990) and is presented in Table 3-2 below.

Table 3-2

Constituent	Primary Sources
particulates	Pavement wear, vehicles, atmosphere, maintenance
nitrogen, phosphorus	Atmosphere, roadside fertilizer application
lead	Leaded gasoline (vehicle exhaust), tire wear (lead oxide filler material), lubricating oil and grease, bearing wear
zinc	Tire wear (filler material), motor oil (stabilizing additive), grease
iron	auto body rust, steel highway structures, moving engine parts
copper	metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
cadmium	tire wear (filler material), insecticide application
chromium	metal plating, moving engine parts, brake lining wear
nickel	diesel fuel and gasoline exhaust, lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
manganese	moving engine parts
cyanide	anti-caking compounds (ferric ferrocyanide, sodium ferrocyanide, yellow prussiate of soda) used to keep deicing salts granular
sodium, calcium, chloride	deicing salts
sulphate	roadway beds, fuel, deicing salts
petroleum	spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate
PCB	spraying of highway rights-of-way, background atmospheric deposition, PCB catalyst in synthetic tires

Table from Smith and Lord (1990).

The largest component of stormwater runoff from highway surfaces is in the form of particulates, including heavy metals, which may be viewed as a priority for pollution control. Friction and vehicle deterioration as well as the deterioration of highway surfaces and structures are contributors of heavy metals. The application of highway deicing compounds, either NaCl or $CaCl_2$, may contribute to the deterioration of vehicles and highway structures and increase heavy metal concentrations. In addition, these road salts may contain trace amounts of heavy metals such as nickel, cadmium and cyanide (anti-caking compound) which can be released in solution.

While some of these constituents (e.g., nitrogen, phosphorus, sodium, calcium, chloride) have been discussed previously in other groups of runoff analytes, other constituents clearly are associated with transportation corridors and by-products of breakdown and wear.

During the final 5 months of the sampling Program, cations in the chemistry *test pattern* were expanded to include many of the constituents listed above including lead, zinc, iron, copper, cadmium, and nickel, in addition to sodium, calcium, potassium and magnesium that were part of the original cation *test pattern*.

3.5 Literature Cited

Chazen Companies. 2014. *West Brook Conservation Initiative South Parcel Stormwater Improvements. Town of Lake George, Warren County, New York. Operation, Inspections and Maintenance Manual for Stormwater Management Facilities.*

Smith, D.L., and B. N. Lord. 1990. Highway water quality control-summary of 15 years of research, in Hydrology and Environment Design 1990, National Research Council-Transportation Research Board.

Sutherland, J.W., J.A. Bloomfield, R.T. Bombard and T.A. West. 2001. *Final Report. Ambient Levels of Calcium and Chloride in the Streams and Stormsewers That Flow into Lake George (Warren County), New York.* New York State Department of Environmental Conservation, Division of Water, Albany, New York. 25 pp. + Appendices.

Sutherland, J.W., S.A. Norton, J.W. Short, and C. Navitsky. 2018. Modeling salinization and recovery of road salt-impacted lakes in temperate regions based on long-term monitoring of Lake George, New York (USA) and its drainage basin. Sci. Total Environ. 637-638, 282-294.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

Final Report

Chapter 4

Description of the 2017-2018 Monitoring Program and Methodology

This page intentionally was left blank

4.0 Background

During early 2017, a small Working Committee comprised of the Lake George Land Conservancy, the Lake George Association and The FUND for Lake George held a series of meetings to discuss and develop a work-plan to study the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP). The intent of the study was to determine the extent to which the wetland complex was treating stormwater runoff from the sub-catchment before releasing the water to West Brook which discharges directly into south Lake George. The co-authors of this Final Report, also known as the Program Team (Sutherland and Navitsky), developed the monitoring work-plan and budget describing the strategy that would be used to evaluate the wetland complex and reviewed said document with the Working Committee before finalizing the monitoring program.

4.0.1 Purpose of the 2017-2018 Monitoring Program

Data collected from the West Brook CI SIP prior to 2017 by the Darrin Fresh Water Institute were insufficient to allow a critical evaluation of this system with regard to its treatment efficiency. Base-flow samples were collected monthly from August 2013 through July 2014, while only a single storm event had been monitored during that period (November 27th-28th).

The goal of the program described in this Final Report was to conduct an updated analysis and evaluation of the stormwater runoff in the West Brook CI SIP to determine whether the expected treatment of runoff was being achieved by the construction design of the facility.

The program objectives included the following:

(1). Implementation of sufficient base-flow and storm event monitoring to realize the goal of West Brook CI SIP evaluation, specifically with regard to storm event treatment of subcatchment runoff contaminants which was the basis for developing and constructing this stormwater treatment system.

With regard to the above objective, one of the report co-authors (CN) recalls that an original goal of the design and construction of the wetland was 50 percent removal of **phosphorus** and 90 percent removal of **TSS**.

Early during the Program while the work-plan was being developed, it was realized that ground water flow was moving through the wetland complex during non-event periods and was responsible for discharge from the ***Pond 7*** and ***Gravel Wetland*** outlets. Thus, Program Objective (2) was included to determine the nature of this contribution to the wetland complex.

(2). Determine the amount and quality of ground water seepage that emerges from the southern slope adjacent to Pond #2 which is believed to originate from higher elevations along south Canada Street and the Village of Lake George Waste Water Treatment Plant.

The summary and analysis of data collected during this study would determine the need and nature of any alternative strategies that could be recommended if fine tuning of the wetland is required.

4.0.2 Monitoring Program Components

The Program Team originally designed and implemented a 12-month program that included field sampling of base-flow and storm event conditions at locations within the wetland complex to examine the chemical characteristics of water passing through the series of ponds before exiting the wetland and flowing into West Brook.

Base-flow sampling. This type of sampling is exactly what the term implies, i.e., water sample collection during non-storm event periods to determine the chemical composition of the water in the wetland complex which is comprised of residual water from previous storm events and ground water entering the complex from higher elevations to the south and southwest.

Early in the Program, field excursions to sample base-flow included monthly sampling of the ***Pond*** *7* outlet channel and less frequent sampling of the **Gravel Wetland** outlet because this component only received storm event discharge from the wetland complex during periods of high flow when the water elevation was exceeded at the weir located in ***Pond 6***. Later, base-flow sampling was expanded to include ***Pond 1*** and ***Pond 2*** at the head of the wetland complex based upon recommendations made by Bianca Wentzell in a summary report of a vegetation survey that was conducted in the wetland complex during August 2017.

Base-flow sampling at the wetland complex usually occurred when at least 72 hours had passed since any antecedent precipitation although this was not always the case.

Storm event sampling. A total of six (6) storm events were sampled during the Program in order to gather sufficient data to evaluate the processing of runoff through the wetland complex. Although close attention was paid to weather forecasting to help select appropriate storm events for monitoring, it was evident, particularly during the summer of 2018, that major events were very localized in nature, making storm event prediction less reliable than several decades ago during the Lake George Urban Runoff Study, even with the use of local weather radar for the south end of Lake George.

4.0.3 Summary of Program Sampling

The wetland complex monitoring program was initiated on June 21st 2017 and concluded on September 18th 2018. There were a total of 27 separate field sampling excursions and a total of 108 samples collected for water chemistry and field measurements during the 13-month monitoring program.

4.1 Water Chemistry, Field Measurements, and Sample Collection

This section describes the field procedures that were used to collect the water samples and the processing that occurred, following sample collection.

4.1.1 Base-flow Water Sample Collection

Base-flow sample collection was limited to ***Pond 1***and ***Pond 2***, and the ***Pond 7*** and the ***Gravel Wetland*** outlets. There was no discharge through the ***Inlet*** chamber to the wetland complex during non-storm event periods, so base-flow chemistry samples could not be collected from this sampling site.

Samples for water chemistry and field measurements were collected from ***Pond 1*** and ***Pond 2*** using an 8-foot extendable swing sampler equipped with a 500 mL bottle for water collection from the ponds. Samples for water chemistry and field measurements were collected from ***Pond 7*** and the ***Gravel wetland*** outlet at the end of the culvert where they discharged to West Brook. In cases when there was little to no discharge from the ***Pond 7*** outlet chamber, water samples were collected directly from the pond using the swing sampler.

4.1.2 Storm Event Water Sample Collection

Storm event samples were collected from the outlet of the ***Inlet*** chamber and from the ***Pond 7*** and ***Gravel Wetland*** outlets. On several occasions, storm event samples for water chemistry and field measurements also were collected from ***Pond 1*** and ***Pond 2***.

The outlet of the ***Inlet*** chamber discharges water into an open channel flowing toward ***Pond 1***; this area was accessible during storm events and this is where water samples were collected and where discharge was gaged during storm events.

Following collection, base-flow and storm event water samples were stored in 1-liter PE bottles that were labeled and dedicated to each specific site. A separate bottle of water was collected at each site for field measurements which were determined either at the wetland complex or back at the Darrin Fresh Water Institute Laboratory immediately following collection while sample processing was occurring.

4.1.3 Field Measurements

Field measurements generally were collected on-site at the time that water samples for chemistry were collected. In some instances, samples for field measurements were placed on ice following collection and measurements made at the DFWI Laboratory within a brief time following collection. Field measurements included water temperature, dissolved oxygen concentration and percent saturation, specific conductance, total dissolved solids and pH. Water temperature and dissolved oxygen measurements were made with a Yellow Springs Instrument (YSI) ProODO™ optical Dissolved Oxygen meter. Specific conductance, total dissolved solids, and pH using an Ultrameter II™ (Myron L Company).

4.1.4 Recording of Data

Important data and information gathered during sampling excursions were entered on field sheets as shown in Attachment #1 and this information was transferred to Excel files that were the repository for the Program data.

4.1.5 Summary of Program Sampling Excursions

The matrix presented in Table 3-1 below summarizes the successful field excursions to each sampling site during the 13-month monitoring program.

Table 4-1

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex						
	Summary of Samples Collected from Wetland Components for Chemical Analysis					
Date	***Inlet***	***Pond 1***	***Pond 2***	***Pond 7***	***Gravel Wetland***	Other
6/21/17			1			
7/11/17						2*
8/24/17				1	1	
9/28/17				1		
10/24/17	6			6	1	
10/25/17				1		
10/27/17				1		
11/8/17		1	1	1	1	
12/5/17	6	1	1	2	1	
12/6/17				1	1	
1/11/18				1	1	
1/12/18	5			3	2	
1/14/18				1		
2/20/18	1			1		
3/1/18		1	1	1	1	
3/16/18				1	1	
4/11/18		1	1	1	1	
5/9/18		1	1	1	1	
5/19/18	6	1		2		
5/20/18	1	1		1		
6/11/18		1	1	1		
7/10/18		1	1	1		
7/17/18	4	1	1	1		
8/7/18		1	1	1		
9/17/18		1	1	1		
9/18/18	6	1		1		
9/19/18		1		1		
total samples	35	14	11	34	12	2

4.1.6 Darrin Fresh Water Institute (DFWI) Field Station Processing

Base-flow samples were immediately transported to the DFWI laboratory in Bolton Landing for processing following collection.

Storm event samples either were brought to the laboratory for processing immediately following the event or were kept on ice overnight and processed within 15-18 hours following collection.

All samples were processed in the laboratory by taking sub-samples determined by the specific analytes that comprised the base-flow and storm-water runoff *test pattern*. The primary test pattern for base-flow and event samples in this Program during the first 8 months included the following analytes:

- total phosphorus (TP),
- total filterable phosphorus (TFP),
- total nitrogen (TN),
- anions (nitrate-nitrogen (NO_3-N), sulfate (SO_4), and chloride (Cl)),
- cations (calcium (Ca), sodium (Na) and iron (Fe).)

During the last 5 months of the Program, the cation test pattern was expanded to include the metals listed above plus magnesium (Mg), copper (Cu), zinc (Zn), nickel (Ni), cadmium (CD) , and lead (PB). All of these cations are important constituents of highway runoff and adding these analytes to the test pattern occurred when seasonal traffic on the Canada Street corridor increased following the winter and spring of 2018.

Total suspended sediment (TSS) was run on most samples in the laboratory by the report co-author (JWS).

The individual base-flow and storm event samples were accessioned in a chemistry log book at the DFWI laboratory and then processed as follows:

- TP, TN – 100 mL of raw water **as is** in a 125 mL cup and chilled at 4°C,
- Anions (NO_3-N, SO_4, Cl) – 100 mL passed through a 0.45µm filter and chilled at 4°C,
- TFP - 100 mL passed through a 0.45µm filter and chilled at 4°C,
- Cations – 100 mL raw sample preserved with 1 ml 0.01 N HNO_3 and chilled at 4°C.

Samples were accessioned on a Chain of Custody form as they were processed and then delivered immediately to the DFWI laboratory chemist lab for either storage or analysis.

The expanded cation test pattern samples collected during the last 5 months of the Program were held in a refrigerator until delivery to the USGS Laboratory in Troy, NY for analysis.

4.1.7 Analytical Laboratory Techniques

The analytical techniques followed by the DFWI Lab for the analysis of the chemistry samples are summarized in Table 4.2.

Table 4-2

PARAMETER	ANALYTICAL METHOD
Specific Conductance	Wheatstone Bridge type meter (US EPA Method 20.1)[1]
Inorganic Anions (Cl, NO_3, SO_4)	Ion Chromatography (US EPA Method 300.0)[1]
Total Nitrogen	Persulfate Oxidation[2]
Phosphorus (total)	Colorimetric (US EPA Method 365.2)[1]
Ammonium	Flow Injection Analysis (Lachat)[3]
Total Metals	Atomic Absorption (US EPA Method 200)[1]

[1] US EPA. *Methods for Chemical Analysis of Water and Wastewater*; US EPA-600/4-79-020: Cincinnati, OH, 1983.

[2] Langner, C.; Hendrix, P. F. 1982. Evaluation of a persulfate digestion method for particulate nitrogen and phosphorus. *Water Res.* 1982, *16*, 1451-1454.

[3] Lachat Instruments. *Methods List for Automated Ion Analyzers*; Lachat Instruments, Loveland, CO, 2013, http://www.lachatinstruments.com/download/LL022-Rev-7.pdf

The USGS analytical procedure for the cations submitted for analysis was ICP-OES (Inductively Coupled Plasma Atomic Emission Spectrometry) as described in US EPA Method 6010.

All samples were analyzed within the prescribed holding times at the laboratories.

4.2 Measurement of Water Passing through the Wetland Complex

In order to obtain meaningful and accurate information concerning the amount of water processed by the wetland treatment system over a period of time, it was necessary to install water level recorders along the treatment chain to continuously collect water level data in different components of the wetland complex.

4.2.1 Telog Inc. WLS-31 Continuous Water Level Recorders

A series of Telog Inc. Model WLS-31 water level recorders were installed in the ***Inlet*** chamber and the ***Pond 7*** and ***Gravel Wetland*** outlet chambers to continuously record water level in these components of the treatment system.

***Inlet* chamber.** The level recorder installed at this site was a new WLS-31 unit purchased from Telog Inc. The recorder unit and associated transducer were connected by a 10-foot length of coaxial cable with heavy exterior sheathing. The transducer was installed at the end of a ~9-foot length of 1-inch PVC tubing, with the coaxial cable running inside the PVC tubing, and the recorder portion installed inside a weatherproof polycarbonate enclosure (Allied Molded Products, Inc.) with a hasp and padlock-securing mechanism. The end of the 1-inch PVC opposite the transducer was secured to the bottom of the weatherproof box to provide total enclosure and protection for the water level recording system.

The Telog unit was programmed prior to installation at the ***Inlet*** chamber to sample the water level in the outlet chamber every 10 seconds, take an average of these readings after a 1-minute interval had passed, and store that average value.

This Telog unit assembly was installed in the ***Inlet*** chamber on August 22nd 2017; Figure 4-1 shows the continuous water level recording system following installation at the wetland complex ***Inlet*** chamber.

Figure 4-1

The Telog Inc. water level recorder system assembly was secured to the grate of the outlet chamber using a Master Python cable lock system.

Prior to the installation of the Telog recorder, there was a problem detected with the accumulation of sediment in the lower level (sump) of the ***Inlet*** chamber, in a depression about 7-inches deep, below the level of the culverts that enter and exit the chamber. This sediment was removed and a plywood shelf was installed across the bottom of the chamber on a lip just below the culverts by the Village of Lake George.

***Pond 7* outlet chamber.** The Telog Inc. level recorder installed at this site was a refurbished WLS-31 unit retrieved from another project and another location. The recorder unit and associated transducer were set up according the details provided above for the Inlet chamber.

The Telog unit was programmed prior to installation at the ***Pond-7*** outlet chamber to sample the water level in the outlet chamber every 10 seconds, and then take an average of these readings after a 5-minute interval had passed, and store that average value. The Telog unit assembly was installed in the ***Pond-7*** outlet chamber on August 22nd 2017.

Figure 4-2 shows the Telog Inc. water level recorder system assembly installed at the ***Pond-7*** outlet chamber; the photograph was taken looking toward the south.

Figure 4-2

The Telog Inc. water level recorder system assembly was secured to the ***Pond-7*** outlet chamber grate using a Master Python cable lock system.

Gravel Wetland* outlet chamber.** The Telog Inc. level recorder installed at this site was a WLS-31 unit retrieved from another project and refurbished by Telog Inc. for use during the current Program. The recorder unit, coaxial cable and associated transducer were set up according the details provided above for the ***Inlet chamber (see description above).

The Telog unit was programmed prior to installation at the ***Gravel Wetland*** outlet chamber to sample the water level in the outlet chamber every 10 seconds, take an average of these readings after a 5-minute interval had passed, and store the average value. The Telog unit assembly was installed in the Pond 7 outlet chamber on August 22nd 2017.

Figure 4-3 shows the Telog Inc. water level recorder system assembly installed at the ***Pond-7*** outlet chamber; the photograph was taken looking south toward the back of the wetland complex..

The Telog Inc. water level recorder system assembly was secured to the ***Gravel Wetland*** outlet chamber grate using a Master Python cable lock system.

4.2.2 Manual Gaging of Discharge

In addition to collecting continuous water level records at the ***Inlet*** chamber and the ***Pond 7*** and ***Gravel Wetland*** outlet chambers, it was necessary to manually gage different components of the system (Inlet chamber, Pond 7 and

Gravel Wetland outlet chambers) to develop rating curves that would allow the conversion of water level data to discharge (either *cubic feet per second* or *million gallons per day*).

Figure 4-3

Description of the gaging process. Manual gaging was conducted using the cross-section technique where the total channel width was divided into equal segments (feet), and the depth (feet) and velocity (cfs) are measured at the centerline of each segment. The area, velocity profile and flow are calculated for each segment, and the segment flows are summed to determine total channel discharge (in cfs/mgd). Flow measurements were made with a top-setting wading rod and Marsh McBirney (Model 2000) Flow Meter (FlowMate).

4.2.3 Development of Discharge/Water Level Rating Curves

Following the initiation of continuous level recording at these sites, it was necessary to develop a rating curve so that water level could be converted into corresponding discharge values. This process was accomplished by gaging the ***Pond 7*** and ***Gravel Wetland*** outlet channels on different occasions so that the calculated discharge values could be used to develop an equation that would convert stored water level recorder readings into either *cubic feet per second* (cfs) or *million gallons per day* (mgd).

The outlet of the ***Inlet*** chamber only exhibited discharge during storm events and could only be gaged for discharge when actual storm events were occurring.

4.2.4 Collection of Water Level Recorder Data.

Telog water level data were downloaded from the recorders located in the ***Inlet*** chamber and ***Pond 7*** and ***Gravel Wetland*** outlet chambers on an irregular basis and saved as *csv files and then converted to Excel *.xlsx files. Data from each level recorder was transferred to a dedicated Excel file with a "read me" spreadsheet, followed by a spreadsheet with important information on the installation of the recorder, and then separate monthly spreadsheets for the water level data collected from the recorder.

4.3 Data Management and Analysis

Program data included (1) the chemistry results received from the Darrin Fresh Water Institute and US Geological Survey laboratories, (2) the field measurements collected at the wetland complex when water samples for chemistry were collected, (3) the water level recorder data downloaded from the Telog recorders installed in the Inlet chamber, and the Pond 7 and Gravel Wetland outlet chambers and (4) precipitation for the immediate area that could be integrated with water level data in the wetland complex to develop storm event hydrographs.

4.3.1 Water Chemistry Data

Chemistry data for water samples usually were received from the laboratories within a 4-6 week period following submission and the data then were entered into an electronic file according to a specific format which is shown in a section below.

4.3.2 Precipitation Data

Two sources of precipitation data were available for the current Program including daily precipitation collected at the Village of Lake George Wastewater Treatment Plant (VLG WWTP) and monthly data collected at 1-minute intervals at the Cedar Lane Atmospheric Deposition Station operated by the Jefferson Project and adjacent to Million Dollar Beach and the Battlefield State Park.

Data from the VLG WWTP were used to assess the amount of rainfall in the area as individual storms occurred, whereas the monthly data from the Cedar Lane were transferred into an Excel file and the data for individual storm events were used in conjunction with the storm event hydrographs generated by the ***Inlet*** chamber and ***Pond 7*** outlet chamber recorders.

4.3.3 Electronic Recording of Chemistry Data and Field Measurements

The data received from the DFWI and USGS Laboratories were entered into a *Master Chemistry* Excel spreadsheet file that contained all results for base-flow and storm event samples, with data for each wetland complex sampling station contained in a separate worksheet. Data were entered into the *Master* file according to the following format:

SAMPLE DATE	SAMPLE TIME	SAMPLE #	SAMPLE TYPE (BF, SE)	FLOW (cfs)	TEMP (°C)	DO (mg/l)	DO (% SAT)	TFP (µP?L)	TP (µP?L)

Cl (mg/L)	NO_3-N (mg/L)	TN (mg/L)	SO_4-S (mgS/L)	Ca (mg/L)	Na (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Cu (mg/L)

Cd (mg/L)	Zn (mg/L)	Ni (mg/L)	Pb (ug/L)	spC (µS/cm)	TSS (mg/L)

Base-flow samples collected from ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland*** outlets were summarized by calculating *minimum*, *maximum* and *average* values for each analyte during (1) the entire sampling period of the Program and also during (2) individual seasons of the 13-month period to determine if differences existed.

Storm event samples collected from these same wetland components and from the ***Inlet*** chamber were summarized by the same means as described above for base-flow samples.

4.4 Literature Cited

United State Environmental Protection Agency. 1983. *Methods for Chemical Analysis of Water and Wastewater.* US EPA-600/4-79-020. Cincinnati, OH,

Langner, C. and P.F. Hendrix. 1982. Evaluation of a persulfate digestion method for particulate nitrogen and phosphorus. *Water Res.* 1982, *16*, 1451-1454.

Lachat Instruments. *Methods List for Automated Ion Analyzers*; Lachat Instruments, Loveland, CO, 2013, http://www.lachatinstruments.com/download/LL022-Rev-7.pdf

Smith, D.L., and B. N. Lord. 1990. Highway water quality control-summary of 15 years of research, in Hydrology and Environment Design 1990, National Research Council-Transportation Research Board.

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program*. New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + appendices.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

Final Report

Chapter 5

Water Quality Results – Wetland Base-flow Chemistry Characteristics

This page intentionally left blank.

5.0 Introduction

This chapter summarizes the base-flow physical and chemical data collected during 2017-2018 from the sampling stations located within the West Brook Conservation Initiative Stormwater Improvement Ponds complex (West Brook CI SIP). As mentioned earlier in this report, there is no discharge through the ***Inlet*** chamber during non-event periods, so base-flow sampling of chemistry during the 13-month Program was limited to ***Pond 1***, ***Pond 2***, and the ***Pond*** *7* and ***Gravel Wetland*** outlets. Discharge was monitored with level recorders installed at the ***Pond*** *7* and ***Gravel Wetland*** outlets.

5.1 Results

The discharge and chemistry monitoring program reported here officially began during August 2017 and ended during September 2018; discharge and chemistry data were collected during the entire 13-month period. The results are presented and discussed in this chapter in the following categories: (1) plant nutrients and total suspended sediments, (2) road salt constituents (sodium, chloride) and associated parameters (calcium, magnesium, specific conductance, total dissolved solids), and (3) other important highway runoff contaminants.

5.1.1 Physical Characteristics

An aerial view of the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) wetland taken from Google™ Earth is shown in Figure 5-1. The view is looking from south to north and shows the different components of the wetland complex including ***Pond 1***, ***Pond 2*** and the ***Pond*** *7* and ***Gravel Wetland*** outlets which were sampled for base-flow chemistry during the Program.

Figure 5-1

Figure 5-1 traces the sequence of the wetland treatment process for storm event discharge entering the system from the Inlet to ***Pond 1*** and then through the series of succeeding ponds, with water finally discharging either to ***Pond*** *7* or to the ***Gravel Wetland***, depending upon the level of water in the area of the ***Pond 6*** weir. During dry (base-flow) conditions, however, water movement through the system is entirely dependent upon ground water flow which moves from higher elevation to the south (bottom of Figure 5-1) toward West Brook (top of Figure 5-1).

5.1.2 Chemical Characteristics of Base-flow

The chemical characteristics of base-flow were evaluated by comparing the ***Pond 1*** and ***Pond 2*** chemistry at the head of the treatment chain with the ***Pond*** *7* and ***Gravel Wetland*** outlet chemistry at the end of the complex, prior to discharge into West Brook. The chemistry values compared included *minimum*, *maximum* and *average* values

This chapter presents and discusses the chemistry results in groups of related analytes that comprised the sampling Program *test pattern* including (1) plant nutrients, (2) road salt (Na, Cl), calcium, magnesium specific conductance and total dissolved solids, and (3) other important highway runoff contaminants. It was decided that this grouping of chemistry analytes was the most meaningful way to present base-flow chemistry and the influence of the wetland complex on chemical characteristics of water retained in the system during non-storm event periods prior to discharge into West Brook. Water present in the wetland during non-storm event periods includes water retained from previous storm events and ground water continuously entering the system from higher elevations to the south.

Table 5-1 summarizes the dates that base-flow samples were collected from wetland complex components ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland***.

Table 5-1

Date	***Pond 1***	***Pond 2***	***Pond 7***	***Gravel Wetland***	# Samples Collected
August 24th 2017			x	x	2
September 28th 2017			x		1
October 24th 2017			x		1
November 8th 2017	x	x	x	x	4
December 5th 2017	x	x	x	x	4
January 11th 2018			x	x	2
March 1st 2018	x	x	x	x	4
March 16th 2018			x	x	2
April 11th 2018	x	x	x	x	4
May 9th 2018	x	x	x	x	4
May 19th 2018	x		x		2
June 11th 2018	x	x	x		3
July 10th 2018	x	x	x		3
August 7th 2018	x	x	x		3
# samples collected	9	8	14	8	39

As mentioned previously, there was an initial delay collecting base-flow samples from ***Pond 1*** and ***Pond 2*** during the early phase of the sampling Program A final report detailing an aquatic plant survey of the wetland conducted during August 2017 recommended that ***Pond 1*** and ***Pond 2*** chemistry be collected on a regular basis (Wentzell, 2017), and the sampling of those two ponds was initiated shortly thereafter.

Plant Nutrients

The chemistry sampling program for the wetland complex had a *test pattern* that included the plant nutrients **total nitrogen** (**TN**), **nitrate-nitrogen** (**NO_3-N**), **total phosphorus** (**TP**), and **total filterable phosphorus** (**TFP**). Table 5-2 presents a summary of *maximum*, *minimum* and *average* concentrations measured for these nutrients during the 13-month sampling period in ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland***.

Table 5-2

	TN (mg/L)	NO3-N (mg/L)	TP (µg/L)	TFP (µg/L)
Pond 1				
P-1 minimum	0.14	0.005	16.5	1.0
P-1 maximum	0.85	0.45	38.2	9.8
P-1 average	0.41	0.11	22.5	5.4
# of samples	10	10	10	10
Pond 2				
P-2 minimum	0.02	0.005	15.9	0.25
P-2 maximum	0.62	0.55	74.8	12.5
P-2 average	0.43	0.09	33.0	4.3
# of samples	10	9	10	10
Pond 7				
P-7 minimum	0.06	0.005	9.1	1.7
P-7 maximum	2.07	0.14	41.8	22.0
P-7 average	0.44	0.02	22.7	5.6
# of samples	16	16	16	16
Gravel Wetland				
GW minimum	0.64	0.005	42.3	0.25
GW maximum	108.7	0.02	207.3	149.2
GW average	*14.9	0.01	106.0	26.3
# of samples	8	8	8	8

0.00 = value reported is one-half the lowest detection limit

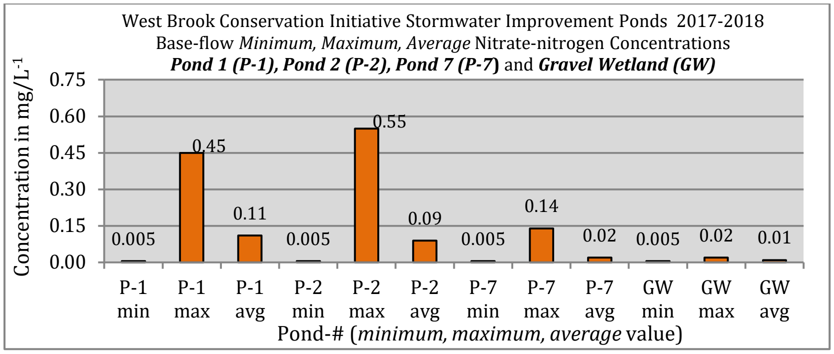
* average value skewed by reading of 108.7; otherwise, average is 1.48

Nitrogen. Some characteristics of the base-flow nitrogen dynamics in the West Brook CI SIP wetland complex during 2017-2018 that are apparent from the data summarized in Table 5-2 are as follows:

- *Average* **nitrate-nitrogen** concentrations were low among the 3 ponds and the ***Gravel Wetland***, although the ***Pond 1*** and ***Pond 2*** *average* values were higher than the ***Pond*** *7* and ***Gravel Wetland*** *average* values (see Table 4-1), indicating that nutrient metabolism was occurring along the wetland chain.
- *Average* **TN** concentrations measured in ***Pond 1***, ***Pond 2*** and ***Pond 7*** were very similar and were low (< 1.0 mg N·L^{-1}) (see Table 5-1).
- The *average* concentration of **TN** measured in the ***Gravel Wetland*** outlet (14.9 mg N·L^{-1}) was 33-fold greater than the *average* values measured in ***Pond 1***, ***Pond 2***, and ***Pond*** *7*, but was skewed by a single high reading of 108.7 mg N·L^{-1}; otherwise the ***Gravel Wetland*** *average* was 1.48 mg N·L^{-1} which reflects an abundance of **organic nitrogen** in discharge from this wetland component.
- There were no seasonal patterns of concentration exhibited by any of the major forms of nitrogen measured in the wetland complex during 2017-2018.
- The majority of the **TN** measured in the base-flow of the wetland complex during 2017-2018 was comprised of **organic nitrogen**.

The base-flow **nitrate-nitrogen** data listed in Table 5-1 are presented in Figure 5-2 to shown the similarity of *average* values between ***Pond 1*** and ***Pond 2***, and the considerably smaller *average* values measured in ***Pond 7*** and the ***Gravel Wetland***.

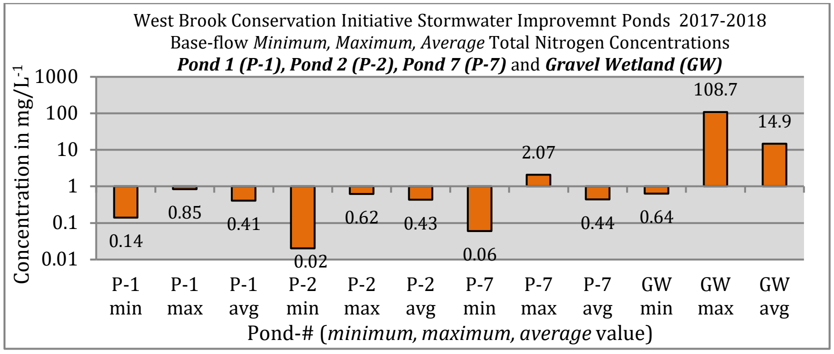
Figure 5-2



The difference between *average* **nitrate-nitrogen** values at the beginning and end of the wetland treatment chain indicate that nutrient uptake was occurring to reduce this nitrogen component that is readily available uptake and metabolism by attached plants and algae in the system.

The **TN** data summarized in Table 5-1 are presented in Figure 5-3 to show the similarity of *average* values (~0.43 mg N·L^{-1}) measured in ***Pond 1***, ***Pond 2***, and ***Pond*** *7*, compared with the *average* value of 14.9 mg **N**·L^{-1} measured in the ***Gravel Wetland*** which was skewed by the maximum value of 108.7 mg N·L^{-1}. Otherwise, the *average* value in the ***Gravel Wetland*** was 1.48 mg N·L^{-1}, which suggests a high concentration of **organic** nitrogen the discharge.

Figure 5-3



The ***y***-axis in the above figure is formatted in logarithm scale due to the wide range of **total nitrogen** concentrations and in order to properly display the relative concentration of each value with regard to all other values in the matrix.

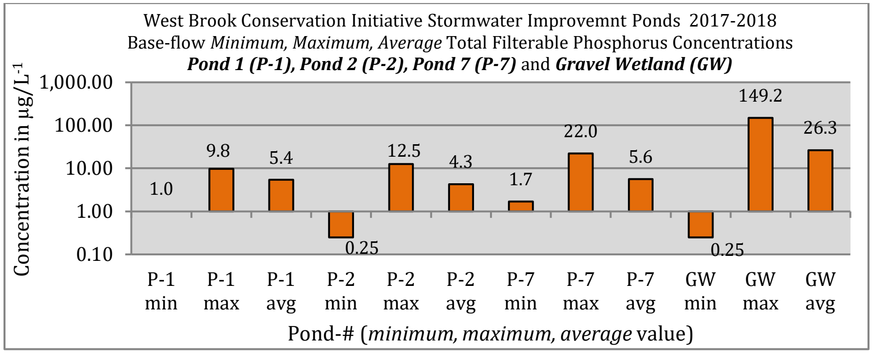
Samples collected from the wetland complex were submitted for analysis of **ammonium-nitrogen** on several occasions and the results were concentrations below the level of detection (<0.01 mg **N**·L^{-1}). Thus, if we consider that **ammonium** and **nitrite** constitute minor forms of nitrogen in the wetland system, then the major component of **total nitrogen** being measured during the 2017-2018 sampling Program would be **organic nitrogen**.

In ***Pond 1*** and ***Pond 2*** during 2017-2018, **nitrate-nitrogen** averaged about 28 percent of the **total nitrogen** average concentration while **organic nitrogen** comprised the remaining 72 percent. In direct contrast, **nitrate-nitrogen** averaged about 5 percent of the **total nitrogen** in ***Pond 7*** and < 1 percent of the **total nitrogen** in the ***Gravel Wetland***; essentially all of the nitrogen leaving the ***Gravel Wetland*** was in the form of **organic nitrogen**.

Phosphorus. The 2017-2018 test pattern of analytes in the sampling program at the West Brook CI SIP wetland complex included **total phosphorus** (**TP**) and **total filterable phosphorus** (**TFP**), which is readily available for uptake in the ponds by algae and attached aquatic plants as well as other forms of biota.

The base-flow **TFP** data summarized in Table 5-1 are presented in Figure 5-4 to highlight the similarity of *average* values among ***Pond 1*** (5.4 µg **P**·L^{-1}), ***Pond 2*** (4.3 µg **P**·L^{-1}), and ***Pond 7*** (5.6 µg **P**·L^{-1}), compared with the considerably higher *average* **TFP** value exhibited by the ***Gravel Wetland*** (26.3 µg **P**·L^{-1}).

Figure 5-4



The ***y***-axis in the above figure is formatted in logarithm scale due to the wide range of **TFP** concentrations and in order to properly demonstrate the relative concentration of each value with regard to all other values in the matrix.

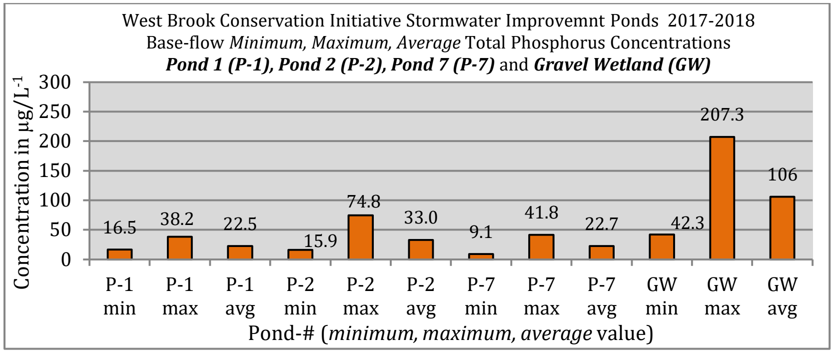
As summarized in Table 5-1, the base-flow phosphorus dynamics observed in the West Brook CI SIP wetland complex during the 2017-2018 sampling program include the following:

- The *average* concentrations of **TFP** in ***Pond 1***, ***Pond 2***, and ***Pond 7*** were very similar (4-6 µg **P**·L^{-1}), while the *average* concentration of **TFP** in the ***Gravel Wetland*** exhibited a 5-fold increase (26.3 µg **P**·L^{-1}) over the concentrations measured in the ponds.
- The *average* concentrations of **TP** in ***Pond 1***, ***Pond 2***, and ***Pond 7*** were very similar (24-30 µg **P**·L^{-1}), while the *average* concentration of **TP** in the ***Gravel Wetland*** exhibited a 4-fold increase (106 µg **P**·L^{-1}) over the concentrations measured in the ponds.
- There was no seasonal pattern of phosphorus dynamics observed in any of the wetland ponds or the **Gravel Wetland** during the period of the study (not exhibited in summary data in Table 5-1 but evaluated when considering the total base-flow chemistry data).
- With the exception of the moderate **TFP** *average* values measured throughout the wetland system, most of the **TP** present in the system occurred as particulate phosphorus contained in living organisms (e.g. plankton) and phosphorus adsorbed onto dead particulate organic matter.

The fact that the *average* concentrations of TN and TP released from the ***Gravel Wetland*** are significantly higher than the *average* concentrations of these parameters discharged from ***Pond 7*** during base-flow conditions is significant and will need to be considered in subsequent chapters when runoff from storm events is discussed.

The **TP** data summarized in Table 5-1 are presented in Figure 5-5 to show the similarity of *average* values (~26.1 µg **P**·L^{-1}) measured in ***Pond 1***, ***Pond 2***, and ***Pond 7***, compared with the value of 106.0 µg **P**·L^{-1} measured in the ***Gravel Wetland*** which is a 4-fold increase above the *average* concentrations measured in the other ponds.

Figure 5-5



As a reminder, the ***Gravel Wetland*** only receives water via the movement of ground water through the wetland treatment chain; discharge to this wetland component from the remainder of the wetland system only occurs when the water level at the ***Pond 6*** weir is exceeded during storm events.

Road Salt Constituents and Associated Parameters.

This section presents and discusses the base-flow wetland characteristics of **road salt** (**Na**, **Cl**) and related parameters including **calcium**, **magnesium**, **specific conductance**, and **total dissolved solids**. Table 5-3 summarizes the 2017-2018 base-flow characteristics of these analytes measured in the wetland complex.

Table 5-3

	Na (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	spC (µS/cm @ 25°C)	TDS (mg/L)
Pond 1						
minimum	7.3	11.8	17.0	2.0	160	102
maximum	292.9	462	69.8	8.8	1656	1214
average	106	181	38.9	4.4	775	555
n	10	10	10	5	10	10
Pond 2						
minimum	1.89	30.6	47.8	7.6	458	309
maximum	293.7	426	72.1	12.6	1673	1223
average	92.7	130	62.7	11.1	840	592
n	10	10	10	4	10	10
Pond 7						
minimum	20.8	32.8	34.2	6.5	357	236
maximum	262.2	390	117.8	10.9	1603	1188
average	84.5	125	62.4	9.0	791	566.5
n	16	16	16	5	16	16
Gravel Wetland						
minimum	28.8	42.2	55.5	nm	561	507
maximum	205.6	348	120.6	nm	2130	1593
average	112.1	188.0	93	nm	1209	912.5
n	8	8	8		8	8

n = number of samples; nm = not measured

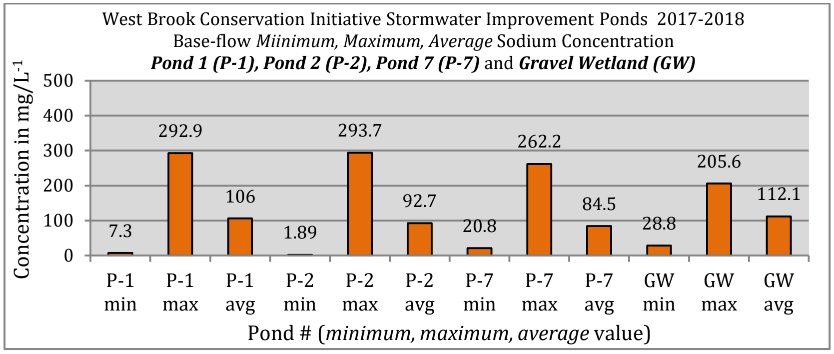
As summarized in Table 5-32, the base-flow dynamics of road salt constituents and related parameters observed in the West Brook CI SIP during the 2017-2018 sampling program include the following:

- The wide range of *minimum* and *maximum* **Na** and **Cl** values measured in ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland*** suggest a marked seasonal effect of either base-flow and/or post-storm event conditions in the wetland complex.
- A similar wide range of *minimum* and *maximum* values documented for **specific conductance** and **total dissolved solids** demonstrate the link between these parameters and **Na** and **Cl** and the existence of either a marked seasonal effect of either base-flow and/or post-storm event conditions in the wetland complex.
- The analyte **calcium** does not exhibit the wide range of *minimum* and *maximum* values demonstrated by the other parameters summarized in Table 5-3; however, there clearly is some effect that cannot be determined by the summary data provided in Table 5-3.

- The *average* value of **Na** measured in the ***Pond 7*** outlet indicates that some depletion of this analyte has occurred within the wetland complex; however, the same condition is not demonstrated by **Cl** within the treatment system.
- The ***Gravel Wetland*** exhibits the highest average values of all analytes summarized in Table 5-3 which may indicate that this portion of the wetland treatment system acts as a 'sink' for chemical analytes entering the system and that elevated concentrations of certain analytes may be released either during base-flow or high discharge conditions or during alternating conditions of oxidation-reduction in the vegetative portion of the system.

Sodium. The base-flow **Na** data summarized in Table 5-3 are presented in Figure 5-6 to highlight the wide range of *minimum* and *maximum* values and the relatively high *average* concentrations exiting the wetland complex through the ***Pond 7*** and ***Gravel Wetland*** outlets.

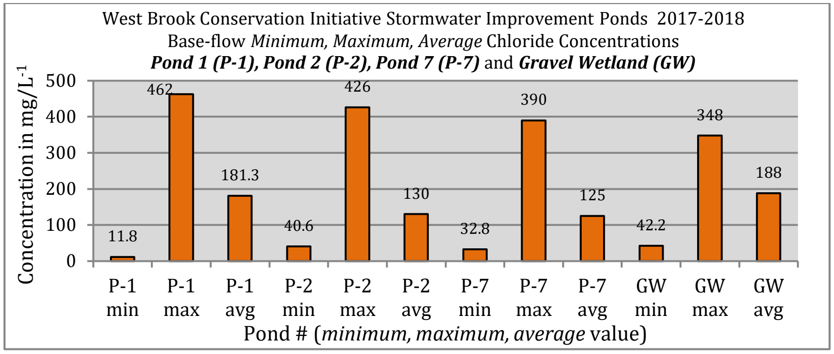
Figure 5-6



The *average* concentration of **Na** exiting the wetland complex via ***Pond 7*** (84.5 mg **Na**·L^{-1}) is below the *average* values measured in ***Pond 1*** (106 mg **Na**·L^{-1}) and ***Pond 2*** (92.7 mg **Na**·L^{-1}) and indicate some minor processing of **Na** within the treatment chain, while the *average* concentration discharged from the ***Gravel Wetland*** (112.1 mg **Na**·L^{-1}) is the highest measured. All of these *average* concentrations being discharged are considerably above 20 mg L^{-1} which is the upper limit for **Na** concentrations considered safe for drinking water.

Chloride. The base-flow **Cl** data summarized in Table 5-3 are presented in Figure 5-7 for ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland***.

Figure 5-7

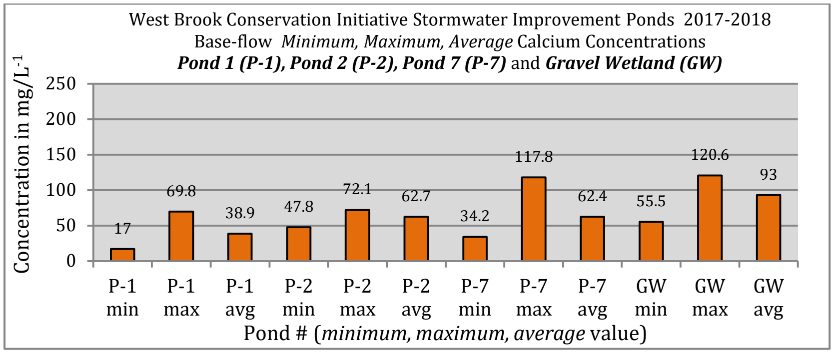


Note the wide range of *minimum* and *maximum* **chloride** concentrations measured in the ponds and ***Gravel Wetland***; often there was a 10-fold difference in these values within each component of the wetland system. In spite of the fact that the *average* value exiting the wetland complex via ***Pond 7*** (125 mg **Cl**·L^{-1}) is less than the *average* values measured in ***Pond 1*** (181.3 mg **Cl**·L^{-1}) and ***Pond 2*** (130 mg **Cl**·L^{-1}), the difference is not significant due to the wide range of values measured within each component (pond) of the wetland complex.

The wide range of **sodium** and **chloride** values measured in the treatment system during the 2017-2018 sampling program suggests that there may be a seasonal component to concentrations measured; this seasonal variation will be presented and discussed later in this chapter.

Calcium. The base-flow **calcium** values summarized in Table 5-2 are presented in Figure 5-8 for ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland***.

Figure 5-8



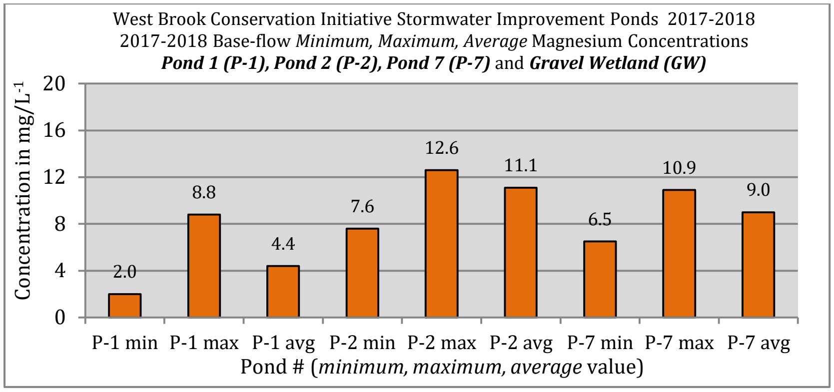
The wide range of *minimum* and *maximum* concentrations exhibited by **sodium** and **chloride** discussed above is not apparent with **calcium**, although there does appear to be a trend of increased *maximum* values in ***Pond 7*** and the ***Gravel Wetland*** at the end of the treatment chain.

Previous studies have provided average base-flow concentrations (± s.d.) of **calcium** for West Brook as follows: 28.8 (± 8.4) mg/L^{-1} (Sutherland et al. 1983), and 26.5 (± 2.1) mg/L^{-1} (Eichler and Boylen, 2012).

The *average* **calcium** concentrations listed in Table 5-2 and visually presented in Figure 5-8 are all considerably higher than the West Brook base-flow values, indicating a separate source of this element. Calcium is a component of Bulk Ice Control road salt (**calcium**, **magnesium** = 0.4%) manufactured by Cargill (Lansing, NY), which is used in some wetland complex subcatchment areas for winter deicing maintenance. This is a likely source of the high **calcium** measured in the ponds along with the dissolution and break-down of the sizeable amount of concrete-based structures associated with the Route 9 corridor including sidewalks, curbing and median structures.

Magnesium. The base-flow **magnesium** concentrations summarized in Table 5-2 are presented in Figure 5-9 for ***Pond 1***, ***Pond 2*** and ***Pond 7***. There were no **magnesium** data for the ***Gravel Wetland*** because regular sampling of this wetland component ended before the full suite of highway runoff constituents were collected, processed and stored for later analysis by the USGS Laboratory at the Rensselaer Technology Park in Troy, New York.

Figure 5-9



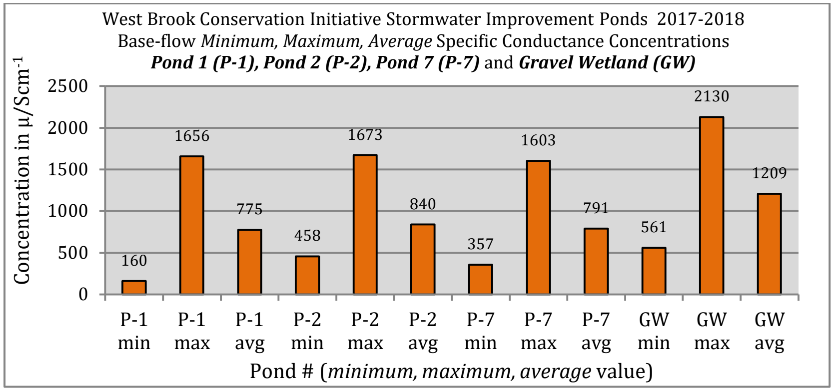
There is no distinct pattern of **magnesium** concentration among the 3 ponds when viewing the *minimum*, *maximum* and *average* values in Figure 5-9. The fact that all of the wetland ponds were sampled for highway runoff constituents beginning in May 2018 probably had some effect on the concentrations exhibited in the figure above because runoff from the winter 2017-2018 snowpack and snow-melt would accumulate in the ponds resulting in the high concentrations exhibited. It is likely that further dilution of **magnesium** would have been demonstrated if sampling of the wetland system had continued beyond September 2018.

Magnesium likely enters the wetland as a result of winter road maintenance in the subcatchment with Bulk Ice Control road salt (**calcium**, **magnesium** = 0.4%) and ClearLane™ Enhanced Deicer (**magnesium** chloride = 26-

29% of 4.1%); both products manufactured by Cargill (Lansing, New York). See Table 3-1 (page 25) for additional information.

Specific conductance. The base-flow **specific conductance** values summarized in Table 5-3 for ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland*** are presented in Figure 5-10.

Figure 5-10



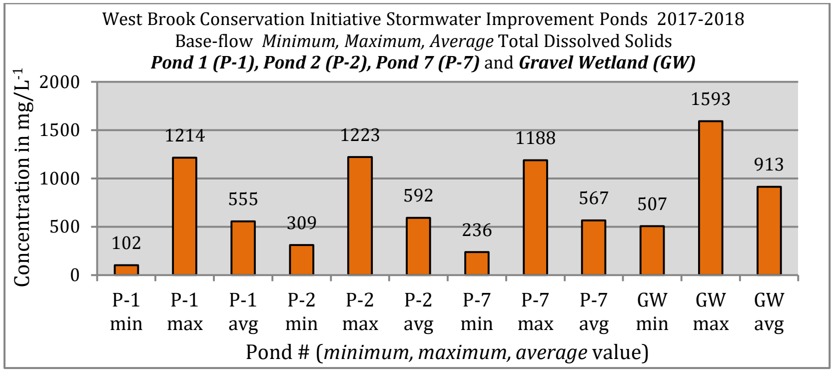
The phenomenon of **specific conductance** is a measure of water's resistance to the flow of an electrical current; resistance decreases as ionized salt content of the water increases and promotes the flow of electrical current. Water with a low concentration of major ions, e.g. HCO_3 (bicarbonate), CO_3^{-2} (carbonate), K^+ (potassium), Na^+ (sodium), Ca^{2+} (calcium), Cl^- (chloride), SO_4^{-2} (sulfate) and $Mg^{=2}$ (magnesium) has the greatest resistance to electron flow.

Water with a high concentration of ions, e.g. seawater, has less resistance to electron flow because of the ability of the ions to conduct electricity.

As demonstrated earlier in this section with **sodium** and **chloride**, there is a wide range of *minimum*, *maximum* and *average* values of **specific conductance** exhibited within each wetland component (Figure 5-10). The *average* values for ***Pond 1***, ***Pond 2*** and ***Pond 7*** were in the range of 775-840 µS/cm^{-1}, indicating that the primary constituents comprising **specific conductance** are not removed from base-flow moving through the wetland chain.

Total Dissolved Solids (TDS). The base-flow **TDS** concentrations summarized in Table 5-3 and shown in Figure 5-11 exhibit the same wide range of *minimum*, *maximum* and *average* values presented for **specific conductance**.

Figure 5-11



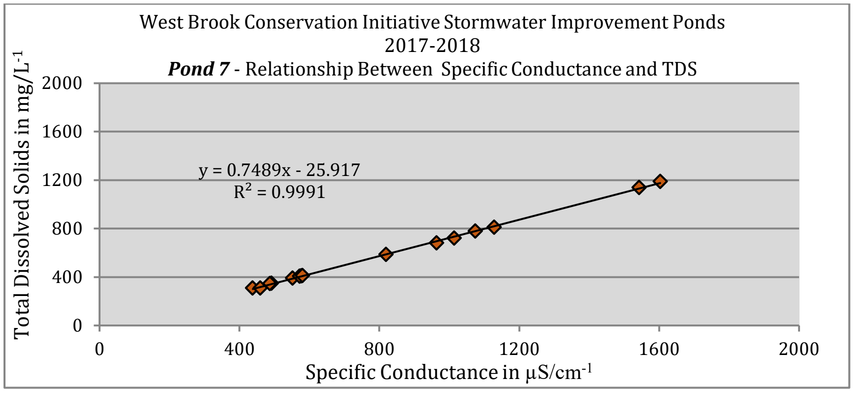
As demonstrated above for specific conductance, the *average* values of **total dissolved solids** measured in ***Pond 1***, ***Pond 2***, and ***Pond 7*** all are high and there is no indication that any reduction of constituents has occurred between the beginning and end of the wetland chain.

Figure 5-12 graphically represents the linear relationship that exists between **specific conductance** and **total dissolved solids** as well as the equation

$$(y = 0.7489x - 25.917)$$

that defines the relationship and can be used to calculate **TDS** values when only **specific conductance** values (***x*** in equation) are known.

Figure 5-12



The relationship between these two parameters is highly significant at R^2 essentially equal to 1.0 which is perfect agreement between the plotted values.

Other Important Highway Runoff Contaminants.

The movement and deterioration of automobiles, trucks and other vehicles and their parts on road surfaces and parking lots produces a sizeable number of environmental contaminants that accumulate on these impervious surfaces and are picked up by runoff during rain and snow events and carried into local bodies of water. Prior to the construction of the West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex, a large portion of Canada Street (Route 9) and contiguous impervious areas drained directly to West Brook without any prior treatment or mechanism to slow water movement to allow settling of particulate material carried in the stormwater runoff.

The impact of this stormwater runoff from Canada Street and adjacent areas on the water quality of West Brook has been well-documented previously (Sutherland et al. 1983; Eichler and Boylen 2012), which provided the basis for considering the construction of a man-made wetland to treat the runoff and improve the water quality of West brook and the south end of Lake George.

Our concern in this section is directed toward heavy metals and other cations that are produced by the wear of vehicles and the breakdown of highway surface and parking lots. More specifically, the data for heavy metals such as cadmium, copper, lead, nickel and zinc will be presented and discussed here, along with other important cations related to highway runoff including iron and sulfate.

Unfortunately, the full complement of important highway constituents were not sampled during the entire 13-month period of the wetland complex sampling program. Samples for these constituents were collected and preserved beginning in May 2018 and continuing through September 2018 when the sampling program was completed; these samples then were submitted to the USGS Laboratory for analysis at that time.

In spite of the abbreviated sampling effort for this group of constituents, there are sufficient base-flow data to evaluate the dynamics of these analytes as they enter the wetland complex via previous storm events of through base-flow from higher elevations and describe their fate prior to entering West Brook at the other end of the treatment process.

The following properties of contaminant heavy metals from highway runoff and snowmelt were summarized from Lacy (2009) who summarized the information from other literature sources:

- The majority of metals are found as particulates with pavement wear contributing 40-50 percent, tire wear contributing 20-30 percent, and the remaining particulates contributed by engine wear, brake wear and atmospheric deposition,
- The heavy metals **copper**, **lead** and **nickel** are largely bound (adsorbed) to particles associated with highway runoff,

- The heavy metals **copper**, **zinc** and **cadmium** are most likely to exist in the dissolved state when associated with highway runoff.

The highway runoff constituents analyzed for this sampling program were raw water samples collected from the ponds during dry periods and, thus, likely reflect these analytes in the dissolved state. However, extremely fine and floating clay particles could have adsorbed metals associated with them which would reflect particulate form. The data presented in this section describe the total concentration of the heavy metals and other constituents measured without any reference to their state (particulate or dissolved).

Table 5-4 summarizes the heavy metal and associated highway contaminant data collected for ***Pond 1***, ***Pond 2*** and ***Pond 7*** during 2018.

Table 5-4

	Cd (µg/L)	Cu (µg/L)	Fe (mg/L)	Pb (µg/L)	Ni (µg/L)	SO$_4$ (mg/L)	Zn (µg/L)	TSS (mg/L)
Pond 1								
minimum	nd	0.68	0.3	1.24	0.08	0.6	16.1	2.2
maximum	0.31	4.43	1.1	5.45	0.71	7.7	22.4	7.0
average	0.21	2.29	0.6	3.53	0.29	3.7	20.3	4.8
n	5	5	6	5	5	10	5	8
Pond 2								
minimum	nd	nd	2.8	2.17	nd	0.4	6.1	2.5
maximum	nd	nd	8.5	4.98	nd	8.6	19.1	13.4
average	nd	nd	4.6	3.44	nd	2.5	11.8	8.3
n	4	4	5	4	4	10	4	7
Pond 7								
minimum	0.07	0.33	0.2	0.98	nd	0.4	1.0	2.5
maximum	0.27	1.63	10.6	3.88	nd	4.0	19.4	14.3
average	0.21	0.79	2.4	2.59	nd	1.3	12.5	5.7
n	5	5	7	5	5	16	5	12
nd = not detected								

Please note in the above table that concentrations for **cadmium** (**Cd**), **copper** (**Cu**), **lead** (**Pb**), **nickel** (**Ni**) and **zinc** (**Zn**) are reported in µg/L^{-1}, while concentrations for **iron** (**Fe**), and **sulfate** (**SO$_4$**) and **Total Suspended Sediment** (**TSS**) are reported in mg/L^{-1}. Also be aware that **sulfate** is not a cation; rather, it is an anion that is included here because it is considered an important highway runoff constituent.

As summarized in Table 5-32, the base-flow dynamics of important highway runoff constituents observed in the West Brook CI SIP during the 2018 sampling program include the following:

- **Cadmium** (**Cd**) was detectable at 0.21 µg·L^{-1} in ***Pond 1*** and ***Pond 7***, but not detectable in ***Pond 2***, which may be the result of interference from other analytes in the ***Pond 2*** water column; furthermore, the **cadmium** appears to be in dissolved form and passes through the wetland complex without any appreciable reduction in this low *average* concentration; **cadmium** is a breakdown product of tire wear,
- **Copper** (**Cu**) exhibits the same pattern of interference as **cadmium** and was not detectable in ***Pond 2***; however, the *average* concentration measured in ***Pond 1*** (2.29 µg·L^{-1}) was substantially reduced at ***Pond 7*** (0.79 µg·L^{-1}); **copper** is a breakdown product of automotive metal plating, bearing and bushing wear, brake linings and moving engine parts,
- ***Pond 2*** exhibits elevated levels of **iron** (**Fe**) (4.6 mg·L^{-1}) compared with *average* concentrations measured in ***Pond 1*** (0.6 mg·L^{-1}) and ***Pond 7*** (2.4 mg·L^{-1}) which is due to high concentrations of this analyte in the soil south of ***Pond 2*** which is transported into the pond via ground water; there is some reduction of **iron** in the wetland but *average* concentrations entering West Brook from ***Pond 7*** are elevated (2.4 mg·L^{-1}) although lower than in **Pond 2**; **iron** is a breakdown product of vehicle body rust, steel highway structures, and moving engine parts,
- There is no appreciable reduction in *average* **lead** (**Pb**) concentrations between ***Pond 1*** (3.53 µg·L^{-1}) and the ***Pond 7*** (2.59 µg·L^{-1}) outflow which could be due to the fact that **lead** usually is adsorbed to soil particles (such as clay) and will not settle out of the water column if the particles are too fine in size; the primary source of **lead** is tire wear, lubricating oil and grease, and bearing wear,

- Low *average* concentrations of **nickel (Ni)** were detected in ***Pond 1*** (0.29 µg·L^{-1}) but not in the other ponds which suggests that the particles holding the **nickel** settle out of the treatment chain; sources of **nickel** are diesel fuel, regular gasoline, lubricating oil, metal plating, bushing wear, brake lining wear and asphalt paving, of which there is sufficient quantity in the subcatchment,
- The *average* **sulfate** (**SO_4**) concentration decreased by about one-half between ***Pond 1*** (3.7 mg·L^{-1}) and ***Pond*** *7* (1.3 mg·L^{-1}), although the decrease was not significant due to the variability of the individual values; the primary source of **sulfate** in the wetland subcatchment is roadway beds, fuel and Bulk Ice Control road salt.
- The *average* levels of **zinc** (**Zn**) ranged from 11.8-20.3 µg·L^{-1} in all ponds and the difference in the *average* values between ***Pond 1*** (20.3 µg·L^{-1}) and ***Pond*** *7* (12.5 µg·L^{-1}) was not significant due to variability of the individual sample readings; the sources of **zinc** in the subcatchment are tire wear, motor oil and grease.

- **TSS** is not a major problem in the West Brook CI SIP subcatchment because runoff from the subcatchment is not a driving force that delivers material during base-flow conditions; probably almost all of the **TSS** measured on filters processed from base-flow samples in the complex consists of live and dead, or decaying, organic material including algae, plant matter and zooplankton.

The heavy metal and other highway contaminant data summarized in Table 5-4 also are presented graphically in Figure 5-13 and Figure 5-14.

Figure 5-13

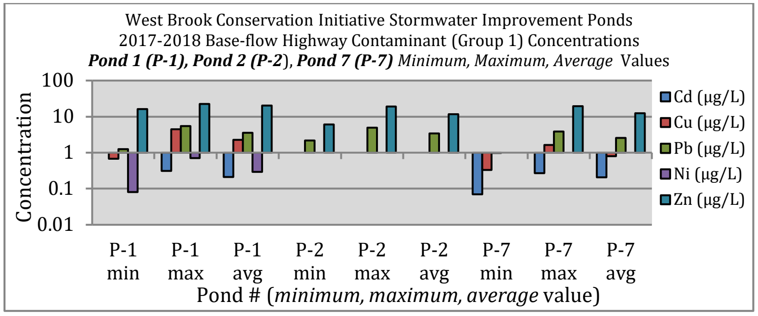
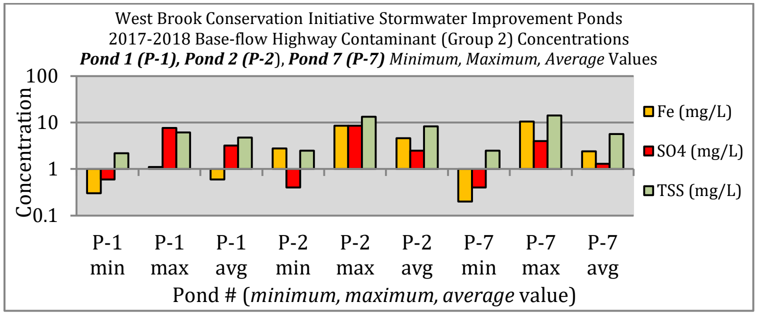


Figure 5-14



Please note that the units for analytes presented in Figure 5-13 are in µg/L^{-1} while the units for the Figure 5-14 analytes are in mg/L^{-1}.

5.2.3 Seasonal Characteristics of Base-flow Chemistry

A more thorough examination of the base-flow chemistry data collected during the 13-month period of the sampling program revealed that certain *test pattern* analytes exhibited cycles of concentration related to seasons of the year. These analytes included **sodium**, **chloride**, **specific conductance** and **total dissolved solids**, the same parameters that are associated with highway maintenance and the application of road salt for winter deicing practices.

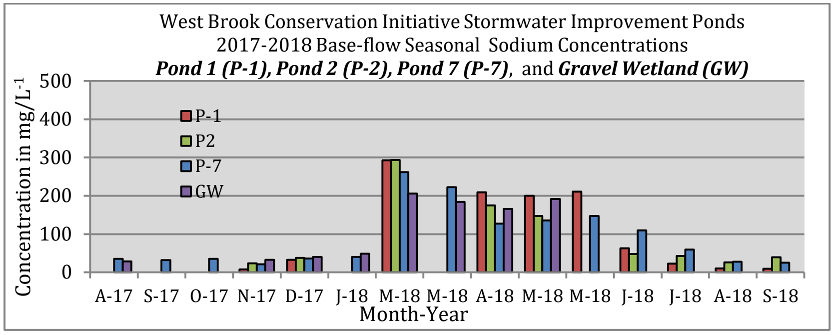
There was not enough **magnesium** data collected during the sampling program to evaluate any season pattern of concentration. A seasonal pattern of concentration was not evident for other parameters in the program *test pattern* such as **total filterable phosphorus**, **total phosphorus**, **nitrate-nitrogen, total nitrogen**, and **calcium**.

Road Salt Constituents and Associated Parameters.

A seasonal effect on the concentration of road salt constituents and related parameters was apparent in all of the wetland components sampled during 2017-2018 including ***Pond 1***, ***Pond 2***, ***Pond 7***, and the ***Gravel Wetland***.

Sodium. Figure 5-15 summarizes the seasonal concentration base-flow data measured for **sodium,** the major cation constituent included in road salt.

Figure 5-15



The first indication of elevated **sodium** levels in the wetland complex occurred in the March 1st 2018 base-flow samples collected in the 3 ponds and the ***Gravel Wetland***. Prior to that date, all of the concentrations measured along the treatment chain were less than 50 mg **Na**·L^{-1} although there were very slight increases of **sodium** detectable during December and early January (Figure 5-15 above).

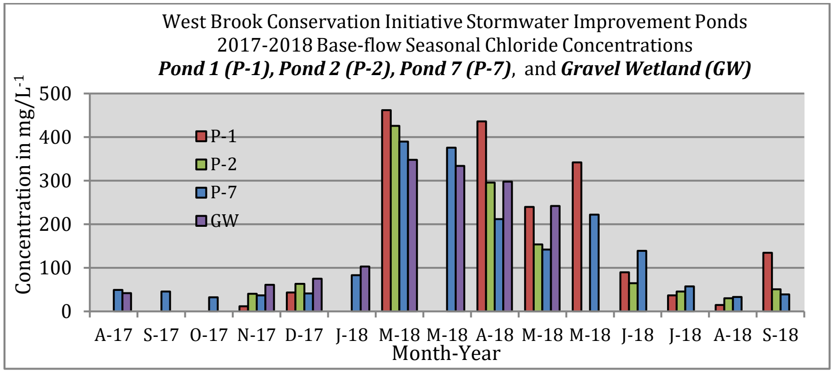
On March 1st 2018, the range of **sodium** concentrations in the wetland components was 206-294 mg **Na**·L^{-1}. The base-flow samples in January 2018 were collected occurred just prior to the warming trend that included rainfall and snowmelt, and there was very little indication of increased **sodium** concentration in the ponds at that time.

A delayed pattern of increased **sodium** concentration in the wetland complex would be expected if below freezing temperatures persisted through the end of 2017 and no melting of the snowpack occurred because any melting would have introduced elevated concentrations of **sodium** into the treatment chain.

The **sodium** data presented in Figure 5-13 also show the gradual decrease in concentration throughout all of the ponds and ***Gravel Wetland*** in the treatment complex as the seasons of 2018 progress from late winter through early spring and summer. These data represent a 'flushing' of the wetland complex subcatchment of the analytes related to winter application of road salt for deicing maintenance following a cessation of application after winter ends.

Chloride. Basically the same seasonal pattern of elevated concentrations was evident with **chloride** in the wetland complex as shown in Figure 5-16.

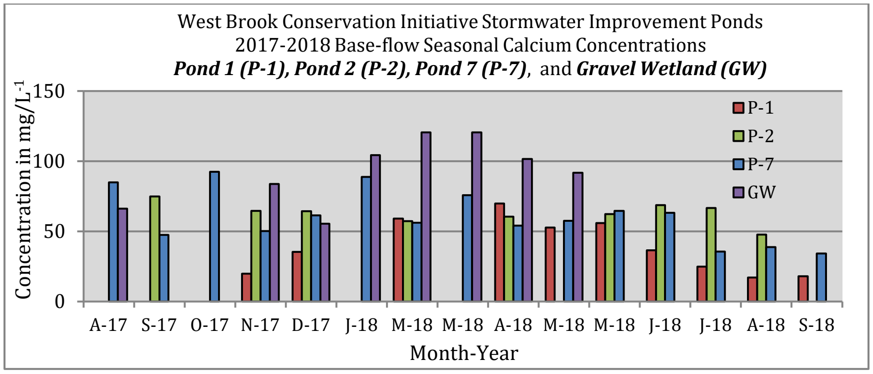
Figure 5-16



Here, however, there was a noticeable rise in **chloride** concentration from November through early January before the 4-fold increase in concentration in the wetland components was documented. This pattern provides evidence of some minimal runoff during late 2017 that added to the base-flow **chloride** concentration measured in the 3 wetland ponds and the ***Gravel Wetland***.

Calcium. The seasonal pattern of this analyte in the program sampling *test pattern* exhibited mixed results when concentration data from various ponds of the wetland complex were examined carefully. As shown in Figure 5-17, **calcium** concentrations in ***Pond 1*** increased during late fall-early winter 2017, continued to increase during winter 2018, and then declined through spring and into September 2018. In contrast, ***Pond 2*** concentrations remained fairly stable, ranging from 47.8–68.8 mg **Ca**·L^{-1} through the entire period. Furthermore, ***Pond** 7* revealed a different response than ***Ponds 1*** and ***2***, exhibiting a decrease in ***calcium*** concentration throughout the entire period, averaging ~75 mg Ca·L^{-1} during the first three months of the sampling program and ~ 36 mg **Ca**·L^{-1} during the final three months of the program.

Figure 5-17

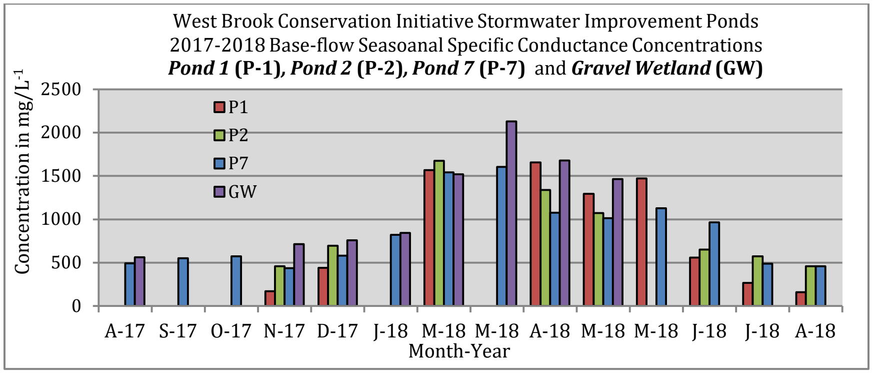


A likely explanation for the **calcium** patterns described above is that the concentration of this analyte is not affected much by plant metabolism in the wetland complex, but rather passes through the system, accumulating in ***Pond 7*** during the late winter and spring and then flushing out of the wetland as the growing season and storm events occur.

Specific conductance. The gradual rise in concentration of constituents that are associated with road salt at the end of 2017 was most noticeable in the graphs that present the **specific conductance** and **total dissolved solids** data.

As shown in Figure 5-18, the base-flow concentration of this constituent started increasing during November 2017 and continued through early January 2018; by early March 2018, there had been at least a 2-fold increase in **specific conductance** concentration in all of the wetland ponds and the ***Gravel Wetland***.

Figure 5-18



Total dissolved solids (TDS). The same pattern of seasonal concentration was apparent when the **total dissolved solids** data were presented graphically (Figure 5-19).

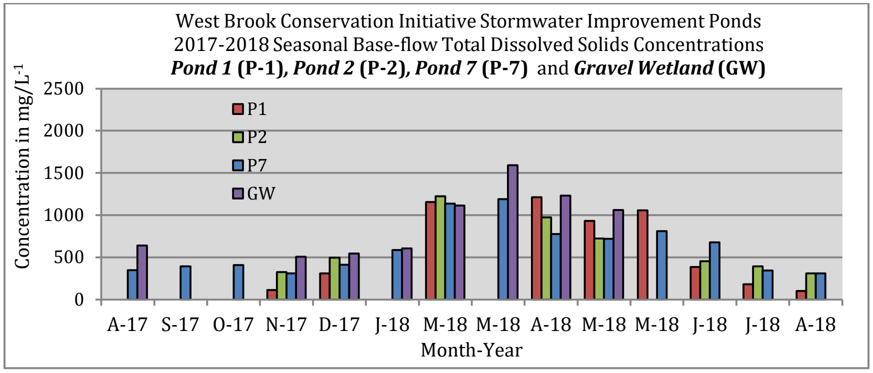
Both of these parameters (**specific conductance** and **total dissolved solids**) include the anion, **chloride**, and major cations such as **calcium**, **sodium**, **sulfate**, **potassium** and **magnesium**, as well as lesser amounts of other ions (see Chapter 3 for a more detailed explanation of **specific conductance** and **total dissolved solids**).

The seasonal graphs shown above for **specific conductance** and **total dissolved solids** provide further confirmation that some storm event runoff occurred during late 2017 that added cations (such as **sodium**) and **chloride** to the base-flow concentrations in ***Pond 1***, ***Pond 2***, ***Pond** 7* and the ***Gravel Wetland***.

5.2 Discussion and Summary

Base-flow chemistry conditions constitute the major portion of residence time for water in the wetland complex, either during extended periods of dry (non-storm event) weather or following events when some of the volume in the treatment chain has been displaced by runoff entering the chain, where it remains until replaced by the movement of ground water discharge through the area or runoff from a subsequent event. When runoff occurs, the volume of water at the head of the treatment chain becomes diluted and, depending upon the amount of runoff, water level in the head of the complex rises and initiates flow (movement of water) along the complex from one pond to the next, moving toward the outlet. This situation explains why base-flow chemistry conditions are so important in terms of understanding how water in the wetland complex is treated as it moves along the treatment chain toward West Brook.

Figure 5-19



This chapter presented the fundamental characteristics of base-flow chemistry including *minimum*, *maximum*, and *average* concentrations for the suite of chemistry analytes that comprised the *test pattern* for the 2017-2018 wetland sampling program.

The *minimum* and *maximum* concentrations of an analyte merely describe the range of values measured for that parameter during the sampling program, and the range of values most likely are affected by the time of base-flow sampling when compared with the time since antecedent runoff entered the wetland complex.

The *average* concentrations describe the mean value of the analyte for all of the samples collected during the 13-month program. If we rely solely upon *average* concentrations of analytes at the beginning (***Pond 1***, ***Pond 2***) and end (***Pond 7***, ***Gravel Wetland***) of the wetland complex to evaluate treatment, then the following statements can be made concerning base-flow chemistry of the plant nutrients:

- *Average* concentrations of **nitrate-nitrogen** declined between ***Pond 1*** (0.11 mg **N**·L^{-1}) and ***Pond 7*** (0.02 mg **N**·L^{-1}) indicating that uptake of this available nutrient was occurring along the treatment complex,
- *Average* concentrations of **total nitrogen** essentially were the same in ***Pond 1*** (0.41 mg **N**·L^{-1}), ***Pond 2*** (0.43 mg **N**·L^{-1}), and ***Pond 7*** (0.44 mg **N**·L^{-1}), suggesting that the uptake of **nitrate-nitrogen** in the treatment chain resulted in the production of **organic nitrogen**, the major component of **total nitrogen**, which explains the similar *average* concentrations measured in ***Pond 1*** (0.41 mg **N**·L^{-1}) and ***Pond 7*** (0.44 mg **N**·L^{-1}),
- *Average* concentrations of **total filterable phosphorus** were unchanged between the beginning of the wetland chain (***Pond 1*** = 5.4 µg **P**·L^{-1}) and the ***Pond 7*** outlet to West Brook (5.6 µg **P**·L^{-1}), which indicates that there was no uptake of this available plant nutrient,
- *Average* concentrations of **total phosphorus** were unchanged along the wetland complex, with concentrations of 22.5 µg **P**·L^{-1} measured in ***Pond 1*** and 22.7 µg **P**·L^{-1} measured in ***Pond 7***,
- The ratio of **total filterable phosphorus** concentration to **total phosphorus** concentration was the same between beginning and end of the treatment chain, indicating that **particulate phosphorus** contained in plankton and seston comprised most of the **total phosphorus** measured in the wetland during base-flow,

- The ***Gravel Wetland*** discharged a low *average* concentration of **total nitrogen** (1.48 mg $\mathbf{N}\cdot L^{-1}$) and a high **average** concentration of **total phosphorus** (106 µg $\mathbf{P}\cdot L^{-1}$), which contained an average of about 25 percent **total filterable phosphorus**.

It is not possible to provide any overall evaluation of wetland treatment efficiency with regard to plant nutrients until we consider the impact of runoff from individual storm events which will be the focus of description and review in subsequent report chapters.

The base-flow chemistry of **road salt** (**Na**, **Cl**) and related parameters including **calcium**, **magnesium**, **specific conductance** and **total dissolved solids** can be summarized as follows:

- *Average* concentrations of **sodium**, **chloride**, **specific conductance** and **total dissolved solids** are extremely elevated in base-flow throughout the wetland chain, indicating that there is no treatment of **sodium** and **chloride**, although there may be a certain amount of dilution along the chain from ground water entering the system from higher elevations that are not affected by winter deicing practices,
- *Average* concentrations of base-flow **calcium** measured in the wetland were considerably higher than *average* concentrations measured in Lake George tributaries and storm-sewers during a year 2000 study (Sutherland et al. 2001) indicating that ground water was not the primary source of this analyte and that dissolution of concrete-based structures in the sub-catchment were at play here.
- *Average* concentrations of **magnesium** measured in the wetland ponds was higher than the average concentrations measured during previous studies (Sutherland et al. 1983, Eichler and Boylen, 2012) indicating that the source of **magnesium** was from ground water supplemented by storm runoff inputs from the portion of the subcatchment that received winter deicing compounds.
- Road salt constituents (**Na**, **Cl**) and related parameters all exhibit seasonal patterns of concentration in the wetland ponds monitored during the 13-month sampling program, with the highest concentrations occurring during mid-winter and concentrations decreasing thereafter from dilution via storm events and ground water movement flushing these analytes out of the subcatchment.

With regard to the base-flow chemistry of the heavy metals and other highway constituents evaluated during the present study, the wetland complex does not have the ability to appreciably reduce the concentration of these contaminants, regardless of whether they are dissolved in the water column or adsorbed to the surface of fine-grained particles.

5.3 Literature Cited.

Eichler, L.W. and C.W. Boylen. 2012. *West Brook Stormwater Runoff Study*. DFWI Technical Report 2012-3. Prepared for The FUND for Lake George. 28 pp. (including appendices).

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program***.** New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + appendices.

Sutherland, J.W., J.A. Bloomfield, R.T. Bombard and T.A. West. 2001. *Final Report. Ambient Levels of Calcium and Chloride in the Streams and Stormsewers That Flow into Lake George (Warren County), New York.* New York State Department of Environmental Conservation, Division of Water, Albany, New York. 25 pp. + Appendices.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

Final Report

Chapter 6

Water Quality Results – Examination of an Individual Storm Event

This page intentionally left blank

6.0 Introduction

This chapter summarizes the physical and chemical data collected during one of the storm events that was monitored for discharge and chemistry during 2017-2018 at the West Brook Conservation Initiative Stormwater Improvement Ponds wetland complex. The objective in this chapter is to familiarize the reader with the dynamics of storm event runoff and associated monitoring while presenting a rather detailed look at the discharge and chemistry data collected during this event. A subsequent chapter will present, summarize and discuss the discharge and chemistry data collected for all of the six (6) events monitored during the sampling program.

As mentioned earlier, there is no base-flow discharge through the ***Inlet*** chamber during non-event (dry) periods, in contrast to storm events, when all runoff from the sub-catchment is directed through the ***Inlet*** chamber. All chemistry samples were collected from the outlet of this device that directs discharge towards ***Pond 1*** along an open channel with rip-rap and vegetation to slow the movement or water and encourage the settling of suspended material and associated contaminants. A continuous water level recorder was installed in the chamber at the beginning of the sampling program to document water passing through the chamber during runoff events; these data and manual gaging of water exiting the chamber outlet provided the information that was necessary to construct a rating curve that described discharge during each event and the total runoff entering the wetland system.

6.1 Results for October 24th 2017 Storm Event

A detailed summary of the October 24th 2017 storm event follows, including individual concentration and discharge plots for the major groups of analytes analyzed for the program *test pattern*, which consisted of **plant nutrients**, **road salt and related analytes**, and **total suspended sediment** (**TSS**). The following amount of detail is presented only for the October 24th event; subsequent events are summarized more succinctly in a later chapter with *minimum*, *maximum* and *average* values, as presented in Chapter 5 on base-flow chemistry.

Figure 6-1 is a photograph of the outlet of the ***Inlet*** chamber where manual gaging and the collection of samples for chemistry and field measurements occurred.

Figure 6-1

The outlet chamber consisted of a defined structure and solid stone bottom which provided good conditions for the manual collection of grab samples for chemistry and field measurements and manual gaging of event discharge.

6.1.1 *Inlet* Chamber

Precipitation associated with the October 24th 2017 storm event began at 0824 hours and ended at 1540 hours, depositing a total of 0.80 inches (20.32 mm) of precipitation during the 7–hour and 14-minute period. Antecedent precipitation occurred 8 days, 11 hours and 17 minutes prior to this event and totaled 0.06 inches of rainfall. Six (6) chemistry samples were collected from the ***Inlet*** chamber during the event, and manual gaging of discharge from the ***Inlet*** chamber was conducted six (6) times.

The October 24th storm event hydrograph documented by the Telog recorder located in the ***Inlet*** chamber is presented in Figure 6-2 along with the time-line of event precipitation (in mm) from the Cedar Lane Atmospheric Deposition Station..

Figure 6-2

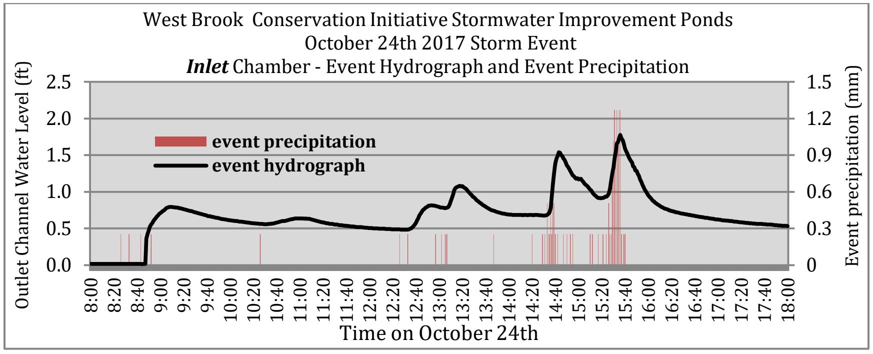
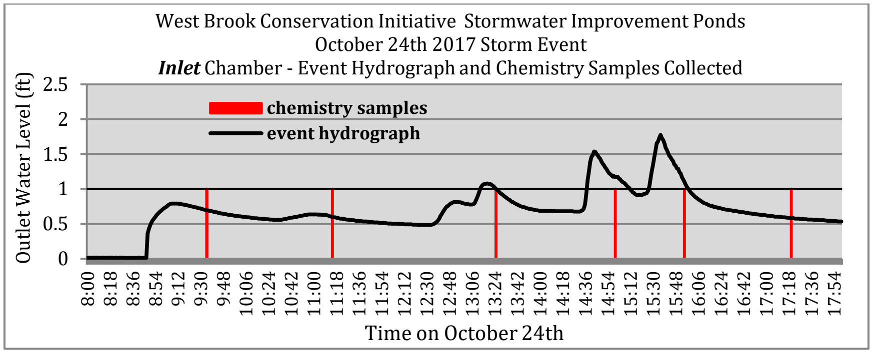


Figure 6-2 clearly shows the responsiveness of the event hydrograph to the increments of precipitation during the event, i.e., every peak along the hydrograph was in response to previous increments of rainfall and the precipitation intensity determined the slope of the rising phases of the hydrograph during the event.

Figure 6-3 is the event hydrograph, the time-line of chemistry sample collection and gaging of the ***Inlet*** outlet culvert for discharge.

Figure 6-3



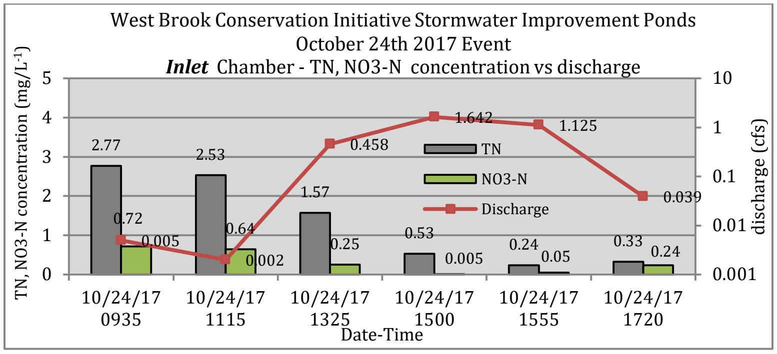
Six (6) chemistry samples were collected during this event along with manual gaging of the chamber outlet so that a storm event rating curve could be established and discharge determined from the curve.

A detailed summary of the October 24th 2017 storm event follows, including individual concentration and discharge plots for the major groups of analytes analyzed for the program *test pattern* including **plant nutrients**, **road salt**, and **total suspended sediment** (**TSS**). The following amount of detail is presented only for the October 24th event; subsequent events are summarized more succinctly in this chapter with *minimum*, *maximum* and *average* values, as presented in the chapter on base-flow chemistry; however, individual concentration and discharge graphs for each storm event that was monitored are presented in an attachment to this report.

Plant nutrients. The concentration and event hydrographs for **total nitrogen**, **nitrate-nitrogen**, **total phosphorus** and **total filterable phosphorus** and are presented and discussed in this section.

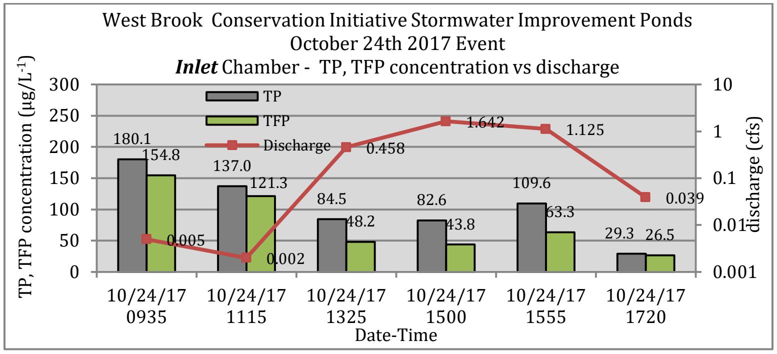
Figure 6-4 is a summary of the **total nitrogen** and **nitrate-nitrogen** concentrations of the samples collected during the storm event and the corresponding discharge (in cfs). The secondary ***y***-axis on the right side of Figure 6-3 and subsequent figures presented in this section uses a logarithm scale so that full range of discharge values can be plotted in the figure with the nutrient concentrations.

Figure 6-4



Discharge at the beginning of the runoff event was very low (0.005 and 0.002 cfs), so the first two samples collected represent the ‘first flush’ from the subcatchment when the highest concentration of **total nitrogen** and **nitrate-nitrogen** occurred. The same pattern occurred with **total phosphorus** and **total filterable phosphorus** as shown in Figure 6-5 below.

Figure 6-5



This pattern of high concentrations during first flush usually is exhibited during runoff events because material that has accumulated on impervious surfaces since the previous storm event is the first to wash off as precipitation falls and travels toward the wetland complex.

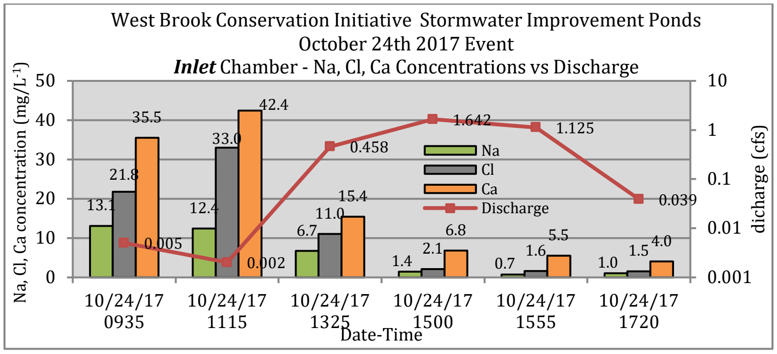
Thereafter, discharge during the storm event gradually increases to the maximum measured (1.642 cfs) and then subsides to 0.039 cfs near the end of the runoff event. There is no distinct pattern between discharge velocity and concentration of plant nutrients washed from the subcatchment into the wetland chain during this event.

Road salt constituents and associated parameters. Road salt used for winter deicing maintenance in the wetland subcatchment is applied by the NYSDOT, the Town of Lake George and private contractors that maintain local businesses and residences. The products used are Bulk Ice Control road salt or ClearLane™ Enhanced Deicer, which both are primarily **Na^+** and **Cl^-** (98.0 percent in Bulk Ice Control and 95.9 percent in ClearLane™ Enhanced Deicer) plus lesser amounts of some additional compounds.

Table 3-1 on page 25 shows the constituents contained in Bulk Ice Control and ClearLane™ Enhanced Deicer. There is a minor amount of **calcium** and **magnesium** (0.4%) in Bulk Ice Control deicer, and a minor amount of **magnesium chloride** (26-29 of 4.1%) in ClearLane ™ Enhance Deicer. Winter deicing materials would contribute some of the calcium measured in the wetland, while the primary source of this cation in runoff would be dissolution of the large surface area of concrete-based structures along the Route 9 corridor. Magnesium was not measured during the early part of the sampling program but was added during the spring of 2018 along with other important highway contaminants.

As shown in Figure 6-6, the pattern of concentration for **sodium**, **chloride** and **calcium** in storm runoff for the October 24th event was similar to the pattern exhibited for plant nutrients.

Figure 6-6

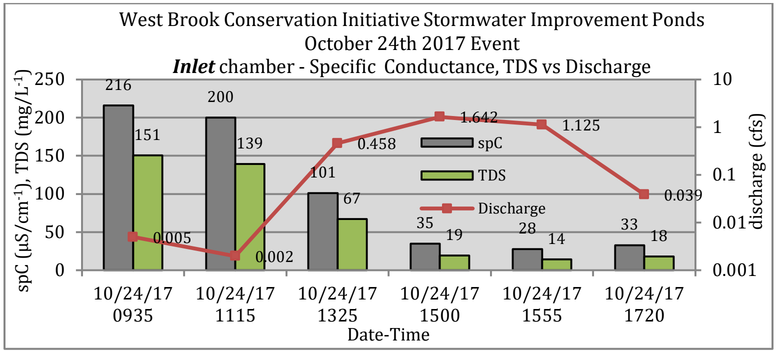


The highest concentrations occurred during the 'first flush' with concentrations decreasing as storm event discharge through the outlet increased. The low **sodium** and **chloride** values documented during this runoff event compared with concentrations measured during winter suggest that most of the residual material from the previous winter deicing materials applied to surfaces had been captured in runoff and previously removed from the subcatchment.

Although the concentrations of **specific conductance** and **total dissolved solids** are affected by a variety of ions, **chloride**, **sodium** and **calcium** are primary constituents and would have a major impact in the West Brook wetland subcatchment due to the prominent highway corridor (in excess of 8 acres) where winter deicing occurs and the significant amount of concrete-based structures along the corridor that are susceptible to dissolution of **calcium**.

Thus, we see the same event runoff patterns of concentration for **specific conductance** and **total dissolved solids** (Figure 6-7) as demonstrated above for other analytes included in the wetland sampling program test pattern.

Figure 6-7



In fact, if we take all of the West Brook wetland complex storm event runoff concentrations for **specific conductance** and **total dissolved solids** and produce a scatterplot of these values, there is a distinct linear relationship between the two variables with a robust R^2, which = 0.9986 (essentially 1.0). Although the scatterplot is not shown here, the equation that describes the relationship is as follows:

$$\mathbf{y = 0.7717x - 35.021}$$

where, y = total dissolved solids concentration in mg/L^{-1}, and x = specific conductance in $\mu S/cm^{-1}$.

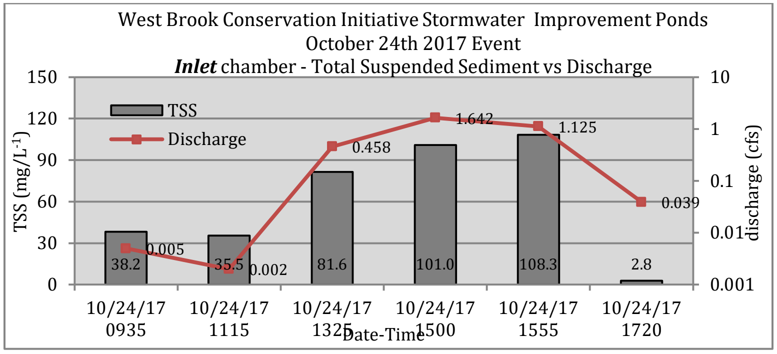
Values for total dissolved solids can be calculated using the above equation if there is a corresponding value for the concentration of specific conductance.

Total suspended sediment (TSS). This analyte is important because sediment washed from impervious surfaces often transports the plant nutrient **phosphorus** adsorbed to its surface. It also is likely that many of the **heavy**

metals associated highway surfaces are carried in the runoff associated with any particulate matter (sediment) that has collected during periods without any storm events.

Figure 6-8 presents the concentration of **TSS** samples collected during the storm event versus discharge leaving the ***Inlet*** chamber and flowing toward ***Pond 1***.

Figure 6-8



In general, we see a direct relationship between the concentration of TSS (in mg/L^{-1}) in the runoff and the discharge that was measured at the outlet of the ***Inlet*** chamber. TSS concentration is low during the '*first flush*' because the discharge values are very low and not able to effectively move the larger sediment particles in the sheet flow.

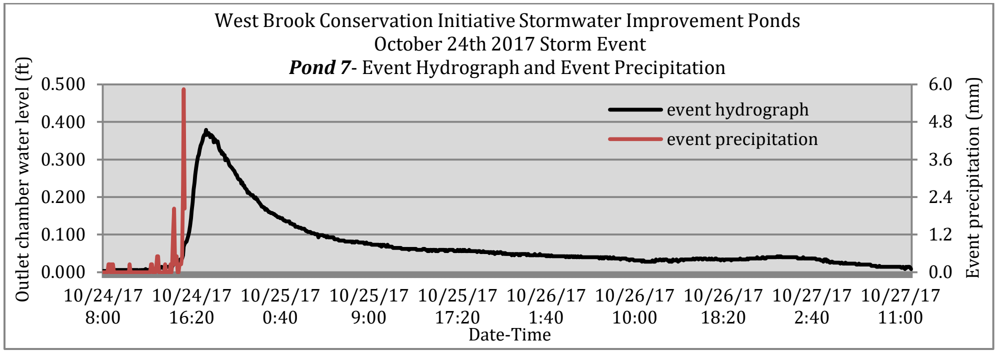
Heavy metals associated with highway runoff are not presented here because the detailed analysis of these contaminants was not added to the sampling program *test pattern* until the spring of 2018 following the end of the winter snowpack and increased traffic along the Route 9 corridor.

6.1.2 *Pond 7* Outlet Chamber

Six (6) samples for chemistry were collected from the ***Pond 7*** outlet during the event; individual post-event samples for chemistry were collected from the ***Pond 7*** outlet on October 25th and October 27th.

The October 24th storm event was well under way before the ***Pond 7*** outlet chamber showed any detectable change in water level as a result of water flowing through the wetland. Figure 6-9 presents the storm event hydrograph recorded at the ***Pond 7*** outlet chamber along with the pattern of precipitation (in mm) that occurred during the event.

Figure 6-9

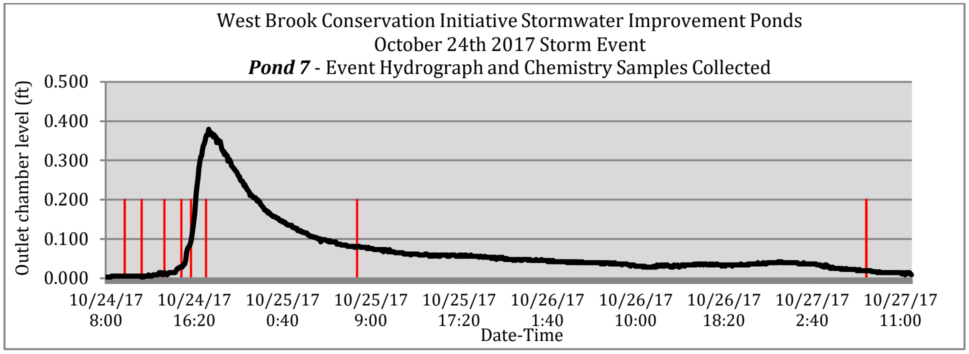


Based upon the water level data collected at this site, it appears that the first significant rise in pond level occurred at about 1300 hours, a total of 4 hours and 36 minutes after the start of the event.

A total of 8 samples were collected for chemical analysis at the ***Pond 7*** outlet and manual gaging of the outlet channel also was conducted. Figure 6-10 presents the October 24th storm event hydrograph recorded at the ***Pond 7*** outlet chamber along with the time-line for chemistry sample collection and channel gaging that occurred when the samples were collected.

Based upon the information presented in Figure 6-10, the first 2 samples collected during the event from the ***Pond 7*** outlet were not yet impacted by flow through the wetland complex from the storm event. Samples #3 through 6 were collected during the rising phase of the hydrograph for the event, while sample #7 was collected the morning following the event (25th) and sample #8 was collected on October 27th, approximately three (3) days following the storm event.

Figure 6-10



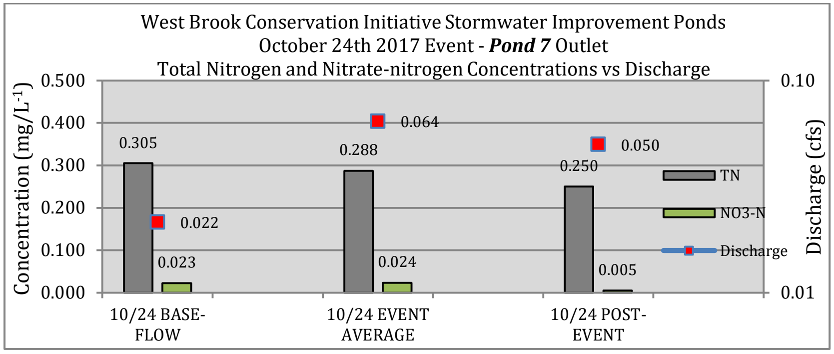
The data for samples collected from the ***Pond 7*** outlet were summarized as follows: (1) samples #1 and #2 were considered base-flow samples and *average* concentrations were calculated for the analytes for these 2 samples, (2) samples #3 through #6 were considered 'event' samples and affected by flow through the pond during the storm event; average concentrations were calculated for the analytes from these 4 samples, and (3) samples #7 and #8 were considered 'post-event' samples are were considered separate from the previous samples and representing chemistry in the pond following the event.

The following figures present individual concentration and discharge plots for the ***Pond 7*** outlet groups of analytes included in the program *test pattern*, i.e., **plant nutrients**, **road salt**, and **total suspended sediment (TSS)**. This is the same format presented earlier in this chapter for the ***Inlet*** chamber during the event.

Plant nutrients. The concentration and event hydrographs for **nitrate-nitrogen**, **total nitrogen**, **total filterable phosphorus**, and **total phosphorus** at the ***Pond 7*** outlet are presented and discussed in this section.

Figure 6-11 provides a summary of the **nitrate-nitrogen** and **total nitrogen** concentrations of the ***Pond 7*** samples collected before, during and following the storm event and the corresponding discharge (■ in cfs). The secondary ***y***-axis on the right side of Figure 6-11 and subsequent figures presented in this section uses a logarithm scale so that full range of discharge values can be plotted in the figure with the nutrient concentrations.

Figure 6-11

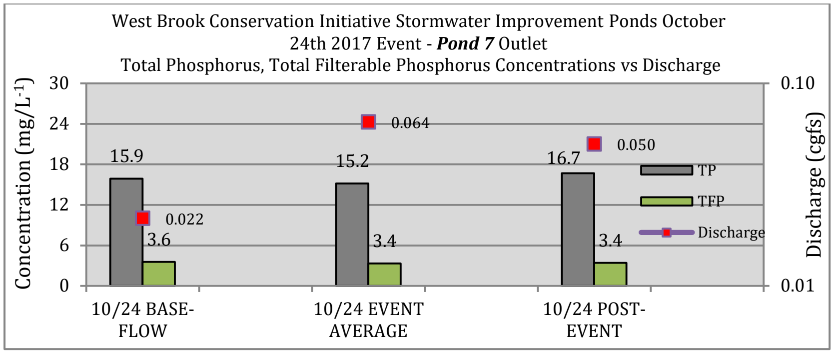


An initial observation from the above figure is that there is no relationship exhibited between discharge and the concentration of **total nitrogen** and **nitrate-nitrogen** in the ***Pond 7*** data, nor should we expect to see a direct relationship. Low volume storm events such as the October 24th 2017 event do not add enough runoff volume to the wetland treatment system to realize any concentration versus discharge effect.

Both **total nitrogen** and **nitrate-nitrogen** exhibit a progressive decrease in concentrations from base-flow through samples collected post-event (October 25th and 27th). In fact, it appears that the concentration of **total nitrogen** in the pond prior to the event was diluted by runoff volume entering the pond during the event, while **nitrate-nitrogen** exhibited the same concentrations prior to and during the event. Following the event however, the **nitrate-nitrogen** level was reduced to below detectable levels (0.005 mg $N \cdot L^{-1}$) which indicates uptake and metabolism in the water column of the pond during the period following the event.

The **total phosphorus** and **total filterable phosphorus** data for ***Pond 7*** prior to, during and following the October 24th 2017 storm event are shown in Figure 6-12.

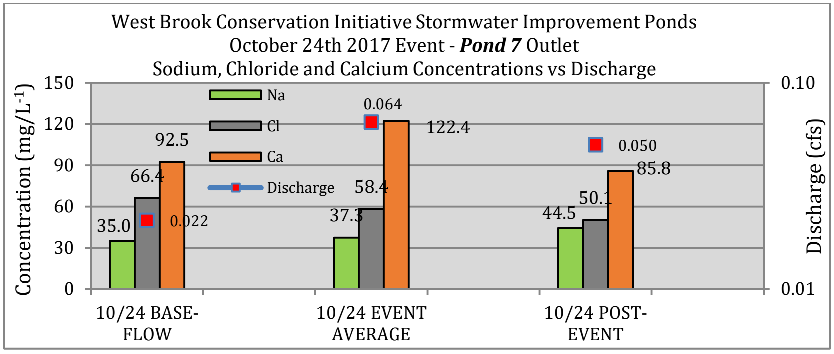
Figure 6-12



The concentration of **total phosphorus** is virtually unchanged when comparing the samples collected prior to (base-flow) and during the storm event (event average), and there is a slight increase in concentration during the post-event period. On the other hand, **total filterable phosphorus** is essentially the same during all three periods. The **total filterable phosphorus** concentrations are very low; therefore, it is not surprising that there is no uptake of this analyte from the ***Pond 7*** water column, especially this late during the growing season. If we assume that the difference between the **total** and **total filterable phosphorus** concentration is **organic phosphorus** in the water column, then most of the **total phosphorus** is contained in living and dead organic material and other detritus (seston) suspended in the water column. The assumption is not totally correct but close enough to reality for the purposes of the current discussion.

Road salt constituents and associated parameters. The concentrations of **sodium**, **chloride** and **calcium** in ***Pond 7*** prior to, during and following the October 24th 2017 storm event are presented in Figure 6-13.

Figure 6-13

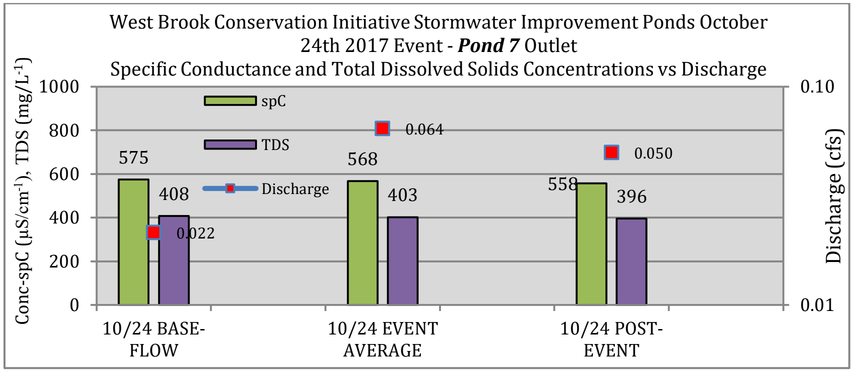


Sodium exhibits a slight increase in concentration when comparing base-flow to post-event (35.0→44.5 mg $Na \cdot L^{-1}$, respectively) while the **chloride** concentration decreases from 66.4 to 50.1 mg $Cl \cdot L^{-1}$ during the 3-day period. There is nothing noteworthy about these **sodium** and **chloride** concentrations in ***Pond 7***. The ponds in the wetland chain are being purged of the residual **sodium** and **chloride** remaining in the subcatchment from the previous winter (2016-2017) road and highway deicing period.

On the other hand, the **calcium** concentrations exhibited in Figure 6-13 are noteworthy because both **calcium** and **magnesium** are such a small proportion of the total composition of Bulk Ice Control (0.4%); the only other source of these high **calcium** concentrations is the dissolution of the sizeable amount of concrete structures within the subcatchment draining to the wetland.

The **specific conductance** and **total dissolved solids** concentrations in ***Pond 7*** prior to, during and following the October 24th 2017 storm event are presented in Figure 6-14.

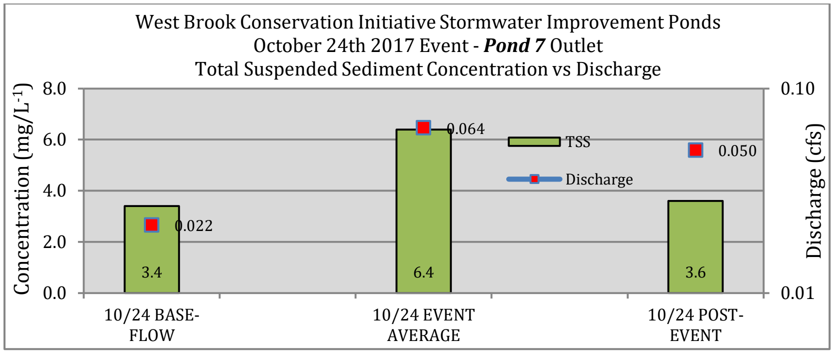
Figure 6-14



Both analytes exhibited a slight decrease in concentration from base-flow to post-event samples, which is what would be expected during late fall each year because the subcatchment draining to the wetland still is flushing the components of road salt application from the previous winter.

Total suspended sediment (TSS). Figure 6-15 presents the **TSS** data summarized for the base-flow, event *average*, and post-event samples collected for the October 24th 2017 storm event.

Figure 6-15



This analyte in ***Pond 7*** is not the same as **TSS** entering the wetland ***Inlet*** chamber during a storm event. By the time the volume of water from a particular storm event reaches the end of the treatment chain, much of the particulate material introduced by the event has settled out and **TSS** probably is more related to other suspended material in the water column such as phytoplankton (algae) and non-living organic matter (seston).

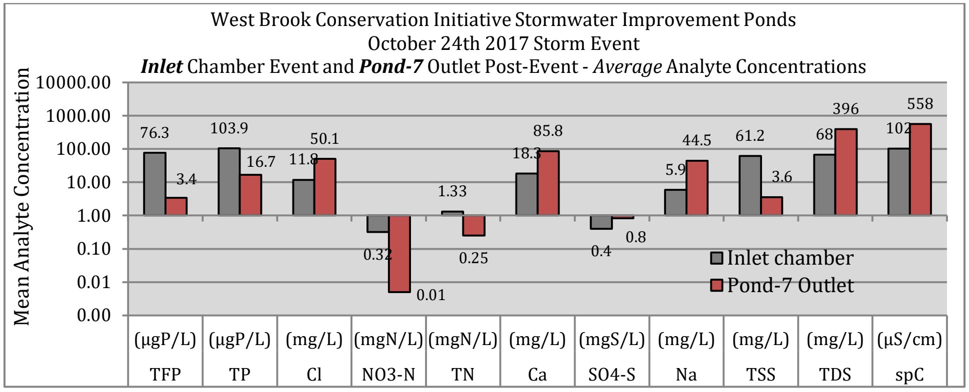
6.1.3 Evaluation of Nutrient and Contaminant Removal Efficiency - October 24th 2017 Event

The West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) was constructed on its present site to capture and treat stormwater runoff primarily from Canada Street (Route 9) and the contiguous developed area which totals about 63.9 acres of surface area. Most of the developed area that drains to the West Brook SIP is comprised of impervious surfaces, with a major portion being the Canada Street (Route 9) corridor that extends south to the intersection of Route 9N, a distance of about 4,500 feet. The wetland treatment complex has a surface area of 4.45 acres and includes a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulate material and (2) support vegetation and bacterial communities that remove heavy metals, salts and excessive nutrients (Pier et al 2013). The effluent from the SIP enters West Brook, which flows into south Lake George.

This section will briefly examine contaminant removal efficiency for the storm event that occurred on October 24th 2017 by comparing the average concentration of analytes entering the wetland complex through the ***Inlet*** chamber with the average concentration of those same analytes exiting the ***Pond 7*** outlet and discharging into West Brook.

Figure 6-16 presents the average concentration for analytes measured in the runoff entering the ***Inlet*** chamber during the storm event and the average analyte values measured in samples collected from the ***Pond 7*** outlet following the event on October 25th and on October 27th.

Figure 6-16



The following discussion is related to the major groups of analytes analyzed for the program *test pattern* including **plant nutrients**, **road salt**, and **total suspended sediment** (**TSS**).

Plant nutrients. The mean **TP** concentration (103.9 µg P·L^{-1}) entering the ***Inlet*** chamber is high and the concentration in the individual samples was directly related to discharge (cfs) passing through the ***Inlet*** chamber. The high **TP** concentration could be the result of several factors including fertilizer applied in the subcatchment, animal feces on impervious surfaces or soil disturbed by erosion which then releases phosphorus bound to the soil particles. It also is significant that the average **filterable phosphorus** concentration was 73 percent of the average **TP** concentration, which is available for uptake by algae and plants in the wetland complex..

At the other end of the wetland treatment complex, the **total phosphorus** (**TP**) was reduced by 84 percent to 16.7 µg P·L^{-1}, while the **total filterable phosphorus** (**TFP**) was reduced by 96 percent to 3.4 µg P·L^{-1}.

The average **TN** concentration (1.33 mg N·L^{-1}) entering the ***Inlet*** chamber (Figure 6-16) is not particularly high and most of that concentration consists of **organic nitrogen** since only about 24 percent of the **TN** concentration is comprised of **nitrate-nitrogen** which is available for uptake by plant material. The average concentrations at the ***Pond 7*** outlet are markedly lower, with **TN** reduced by 63 percent to 0.25 mg N·L^{-1} and **nitrate-nitrogen** reduced by 97 percent to 0.01 mg N·L^{-1}.

Road salt constituents and associated parameters. The *average* concentrations of **sodium** (**Na**) and **chloride** (**Cl**) entering the ***Inlet*** chamber are low, 5.9 and 11.8 mg·L^{-1}, respectively, while the *average* concentration of both analytes in ***Pond 7*** are elevated at 44.5 mg·L^{-1} for **sodium** and 50.1 mg·L^{-1} for **chloride**. This situation indicates that the volume of water that resides in the wetland complex still is being flushed of the road salt components that entered the wetland during the 2017 growing season from deicing application the previous winter.

The same phenomenon is true for the ***Inlet*** and ***Pond 7*** outlet *average* concentrations of **specific conductance** and **total dissolved solids** (Figure 6-16), i.e., residual concentrations from road salt application during the winter of 2016-2017 still are being flushed/diluted out of the wetland complex.

The average concentration of **calcium** at the ***Inlet*** and ***Pond 7*** outlet, 18.3 and 85.8 mg $Ca \cdot L^{-1}$, respectively, follows the same pattern described above for other road salt related analytes. However, while some of the **calcium** entering the wetland is from highway deicing products, the much higher average concentration of **calcium** relative to **Na** and **Cl** indicates that the major source of this cation is dissolution of concrete structures associated with the transportation corridor along Route 9.

Total suspended sediment. **TSS** resulting from storm event discharge in a 'normal' watershed that drains to a stream typically can include significant quantities of granular sand and fine soil or clay particles that have entered the stream channel either from areas where erosion of the channel bank has occurred or where sediment has been carried into the stream from adjacent developed or undeveloped areas via conveyances such as gutters, swales and drop basins.

The **TSS** resulting from storm events in the West Brook CI SIP wetland subcatchment will not have these same characteristics due to the different, 'man-made' conveyance channel and the adjoining area that drains to the wetland, compared with a normal stream channel and watershed where erosion can occur along the streambanks. Runoff from the 63.9 acres of developed area that comprise the West Brook CI SIP wetland sub-watershed is conveyed by the Canada Street corridor with its surface and sub-surface drainage that extends ~0.85 miles south of the wetland area and averages ~85 feet in width. This 'channel' of the drainage system is almost totally impervious and has a surface area of 8.8 acres with numerous adjacent areas along its length that also are impervious and drain directly to the 'channel'. While there is some overland flow from the areas farther removed from the main corridor, most of the runoff is generated by the corridor and contiguous impervious areas.

Much of the particulate matter that remains on the **TSS** filters processed following an event result from vehicle and transportation corridor breakdown products as defined in Table 3-2 (page 26). As such, these materials appear on the **TSS** filters as very fine particulates and have a dark, organic color. In spite of these potential differences in the **TSS** characteristics from the wetland subcatchment, the treatment chain was able to process 94 percent of the **TSS** concentration entering the wetland during the October 24th storm event (61.2 mg $TSS \cdot L^{-1}$), with only 3.6 mg $TSS \cdot L^{-1}$ exiting the ***Pond 7*** outlet into West Brook.

The following pages present photographs (Figure 6-17) of a sequence of TSS filters processed from the October 24th storm event at the West Brook SIP. In each case, filters are shown for the ***Inlet*** chamber sample and the corresponding ***Pond-7*** outlet chamber sample. The different appearance of these filters is immediately obvious and indicates the effective processing of TSS in event stormwater that enters the wetland complex.

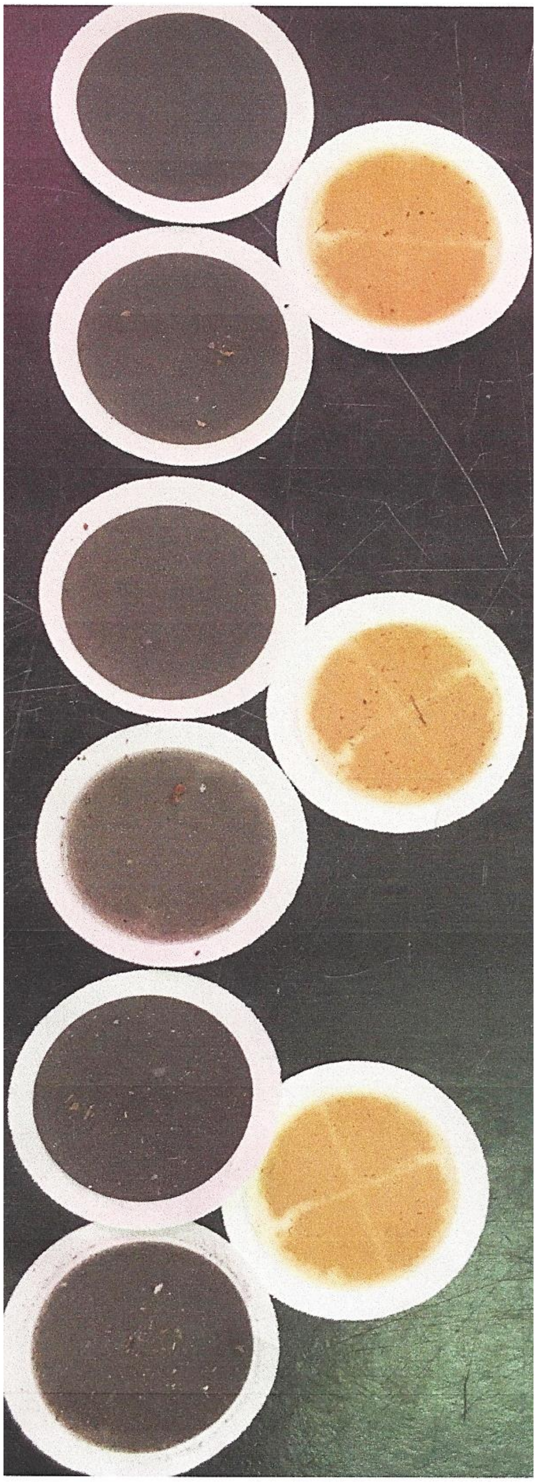
6.2 Summary

A detailed examination of the October 24th 2017 storm event identified the concentrations of (1) plant nutrients and (2) road salt constituents and associated parameters entering the ***Inlet*** chamber from the wetland subcatchment and exiting the wetland complex via the ***Pond 7*** outlet following the event.

A comparison of ***Inlet*** concentrations with the ***Pond 7*** outlet concentrations following the storm event revealed that the wetland complex was functioning well at processing nutrients in the water column via uptake for algae and plant metabolism.

The same phenomenon was not observed, however, for road salt constituents (Na, Cl) and associated parameters including calcium, magnesium, specific conductance and total dissolved solids. For each analyte, the concentration exiting the wetland complex from ***Pond 7*** was elevated when compared with the concentrations entering the wetland via the ***Inlet*** chamber. These data can be interpreted as follows: excessive amounts of road deicing materials applied to impervious surfaces in the wetland subcatchment each winter require an extended period of time to be flushed from the subcatchment, particularly from the soils adjacent to areas where road salts are applied. This flushing process takes a good portion of the ice-free season from May through October each year because of the large amounts of road salts applied. By the time that the October 24th 2017 storm event occurred, the remnants of road salt applied during the winter of 2016-2017 still were being removed from the subcatchment. However, concentrations of these analytes in the wetland complex still were elevated from previous storm events carrying these analytes into the complex from early spring through the time of the October 24th storm event.

Figure 6-17.

<table>
<tr><td colspan="3">OCTOBER 24TH STORM EVENT</td></tr>
<tr><td colspan="3">SEQUENCE OF TOTAL SUSPENDED SEDIMENT FILTERS</td></tr>
<tr><td>INLET CHAMBER</td><td rowspan="4"></td><td>POND-7 OUTLET</td></tr>
<tr><td>SAMPLE #1 (2 FILTERS)
0935 HOURS
TOTAL VOLUME 555 mL
DISCHARGE – 0.005 cfs
38.2 mg TSS/L</td><td>SAMPLE #1
0945 HOURS
TOTAL VOLUME 560 mL
DISCHARGE – 0.020 cfs
3.4 mg TSS/L</td></tr>
<tr><td>SAMPLE #2 (2 FILTERS)
1115 HOURS
TOTAL VOLUME 575 mL
DISCHARGE – 0.002 cfs
35.5 mg TSS/L</td><td>SAMPLE #2
1120 HOURS
TOTAL VOLUME 505 mL
DISCHARGE – 0.023 cfs
3.4 mg TSS/L</td></tr>
<tr><td>SAMPLE #3 (2 FILTERS)
1325 HOURS
TOTAL VOLUME 510 mL
DISCHARGE – 0.458 cfs
81.6 mg TSS/L</td><td>SAMPLE #3
1330 HOURS
TOTAL VOLUME 520 mL
DISCHARGE – 0.020 cfs
2.9 mg TSS/L</td></tr>
</table>

<table>
<tr><td colspan="3">OCTOBER 24TH STORM EVENT</td></tr>
<tr><td colspan="3">SEQUENCE OF TOTAL SUSPENDED SEDIMENT FILTERS</td></tr>
<tr><th>INLET CHAMBER</th><th></th><th>POND-7 OUTLET</th></tr>
<tr><td>SAMPLE #4
1500 HOURS
TOTAL VOLUME 500 mL
DISCHARGE – 1.642 cfs
101.0 mg TSS/L</td><td rowspan="11"></td><td>SAMPLE #4
1505 HOURS
TOTAL VOLUME 520 mL
DISCHARGE – 0.048 cfs
5.0 mg TSS/L</td></tr>
<tr><td>SAMPLE #5
1555 HOURS
TOTAL VOLUME 460 mL
DISCHARGE – 1.125 cfs
108.3 mg TSS/L</td><td>SAMPLE #5
1600 HOURS
TOTAL VOLUME 470 mL
DISCHARGE – 0.098 cfs
8.1 mg TSS/L</td></tr>
<tr><td>SAMPLE #6
1720 HOURS
TOTAL VOLUME 500 Ml
DISCHARGE – 0.039 cfs
2.8 mg TSS/L</td><td>SAMPLE #6
1725 HOURS
TOTAL VOLUME 500 mL
DISCHARGE – 0.091 cfs
9.6 mg TSS/L</td></tr>
<tr><td></td><td rowspan="8">SAMPLE #7
COLLECTED 10/25/17
0740 HOURS
TOTAL VOLUME 505 mL
DISCHARGE – 0.072 cfs
4.4 mg TSS/L</td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

6.3 Literature Cited

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

Final Report

Chapter 7

Water Quality Results

Evaluation of Monitored Storm Events and Effectiveness of the Wetland Treatment Complex

This page intentionally left blank

7.0 Introduction

This chapter summarizes the physical and chemical data collected during the storm events that were monitored for discharge and chemistry during 2017-2018 at the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) wetland complex.

The objective here is to summarize the storm event data collected from the Inlet chamber at the head of the wetland complex and determine the effectiveness of the treatment chain to process stormwater runoff before it is released into West Brook and south Lake George.

7.1 Background

A total of six (6) runoff events were monitored for discharge and chemistry during the 2017-2018 sampling program including storms that occurred on October 24th and December 5th 2017, and on January 12th, May 19th, July 17th, and September 18th 2018. Table 7-1 summarizes important information for each runoff event including the amount of precipitation, duration of the runoff event, and the number of chemistry samples collected from the different components (ponds) of the wetland system prior to (base-flow), during and after the runoff event.

Table 7-1

					Number of Storm Events Samples Collected					
Event Date	Event #	Antecedent Precipitation Amount	Hours Since Antecedent Precipitation	Rainfall Amount	***Inlet***	***Pond 1***	***Pond 2***	***Pond 7***	***GW***	Total Samples
October 24th, 2017	SE-1	0.06 inches	202.4	0.80 inches	6			8	1	15
December 5th, 2017	SE-2	0.05 inches	108.2	0.84 inches	6	1	1	3	2	13
January 12th, 2018	SE-3	0.03 inches	60.03	2.14 inches	5			5	3	13
May 19th, 2018	SE-4	0.03 inches	67.4	0.44 inches	7	2		3		12
July 17th, 2018	SE-5	0.03 inches	38.33	0.19 inches	4	1	1	1		7
September18th, 2018	SE-6	2.06 inches	185.62	0.69 inches	6	3	1	3		13
Totals				3.24 inches	34	7	3	23	6	73

The monitored storm events were assigned individual numbers 1 through 6 in the above table for easier identification and comparison with other storm events when presented in figures throughout this chapter.

The amount of rainfall for each storm event was determined from monthly precipitation files received from the Cedar Lane Atmospheric Deposition Station adjacent to the Lake George Battlefield Park, which currently is operated by the ongoing Jefferson Project. This station originally was established by the report author and his colleagues during the 1980-1982 Lake George Urban Runoff Study (Sutherland et al. 1983). Precipitation data from another station operated at the Village of Lake George Wastewater Treatment Plant were used as a reference to confirm the total amount of rainfall that occurred during each event.

The duration of each event was determined by the total elapsed time between the rise of the water level in the ***Inlet*** chamber until the return of the water to that same level following the event.

The January 11th 2018 storm event included both precipitation and melting of the snowpack that had accumulated in the sub-catchment, so the total amount of water associated with that event was unknown although an algorithm was developed using the ***Inlet*** discharge calculations to determine the amount of water that passed through the chamber and then use back-calculations to determine the inches of water that provided runoff from the sub-catchment.

7.2 Results and Discussion

Initially, analyte chemistry data collected from the ***Inlet*** chamber have been summarized for each storm event similar to the technique that was used in Chapter 5 where base-flow chemistry was presented and described. By calculating and presenting the simple statistics of *minimum*, *maximum* and *average* values, the individual storm events can be compared with one another to determine if there is any seasonal pattern of concentration associated with the various analytes measured during the sampling program.

The next step was to compare the *average* value of analytes for individual storm events entering the ***Inlet*** chamber with the values of analytes measured in ***Pond 7*** at the end of the event (or post-event) to evaluate the efficacy of the wetland complex to provide treatment for the stormwater runoff. Each storm event will be evaluated using this process to determine whether there are seasonal differences in the efficiency of runoff treatment.

7.2.1 *Inlet* Chamber

The following material summarizes the *minimum*, *maximum* and *average* values of chemistry results in groups of related analytes that comprised the sampling Program *test pattern* including (1) plant nutrients, (2) road salt constituents (Na, Cl) and associated parameters (calcium, magnesium, specific conductance and total dissolved solids), and (3) other important highway runoff contaminants.

Plant nutrients. Table 7-2 presents a summary of *maximum*, *minimum* and *average* concentrations measured for **total nitrogen** (**TN**), **nitrate-nitrogen** (**NO_3-N**), **total phosphorus** (**TP**), and **total filterable phosphorus** (**TFP**) during the 13-month period of the sampling program.

Table 7-2

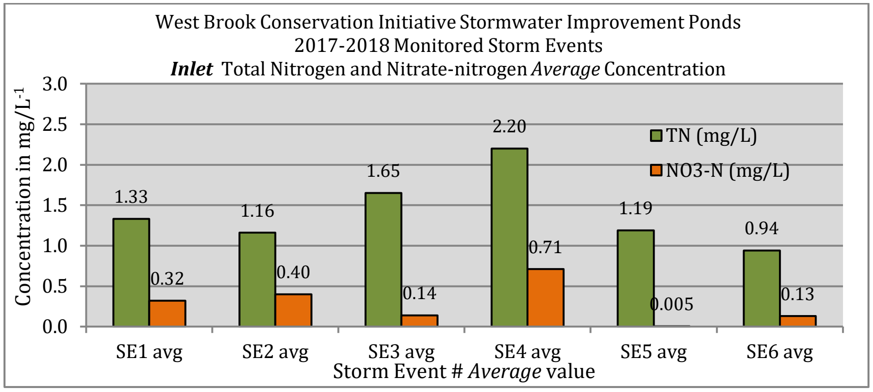
	TN (mg/L)	NO3-N (mg/L)	TP (µg/L)	TFP (µg/L)
October 24th 2017 (SE-1)				
SE-1 minimum	0.24	0.005	29.3	26.5
SE-1 maximum	2.77	0.72	180.1	154.8
SE-1 average	1.33	0.32	103.9	76.3
n (= sample size)	6	6	6	6
December 5th 2017 (SE-2)				
SE-2 minimum	0.36	0.11	51.8	16.2
SE-2 maximum	2.1	0.77	271.9	57.9
SE-2 average	1.16	0.40	128.2	36.3
n (= sample size)	5	5	5	5
January 12th 2018 (SE-3)				
SE-3 minimum	0.96	0.08	81.0	24.2
SE-3 maximum	2.59	0.18	346.4	64.1
SE-3 average	1.65	0.14	150.7	42.8
n (= sample size)	5	5	5	5
May 19th 2018 (SE-4)				
SE-4 minimum	0.43	0.005	34.2	30.8
SE-4 maximum	3.67	1.08	303.9	177.3
SE-4 average	2.20	0.71	188.9	108.0
n (= sample size)	7	7	7	7
July 18th 2018 (SE-5)				
SE-5 minimum	0.63	0.005	48.2	22.9
SE-5 maximum	2.18	0.005	150.2	41.9
SE-5 average	1.19	0.005	93.2	30.0
n (= sample size)	4	4	4	4
September 18th 2018 (SE-6)				
SE-6 minimum	0.26	0.05	25.4	13.3
SE-6 maximum	2.13	0.27	138.4	82.9
SE-6 average	0.94	0.13	72.7	48.7
n (= sample size)	6	6	6	6

###.# = value reported is one-half the lower detection limit

The first step toward evaluating the ***Inlet*** chamber nutrient data for the monitored storm events was to compare the *average* values for the plant nutrient concentrations graphically to see the range of *average* values and whether there was any seasonal influence on concentration.

Figure 7-1 presents the *average* **total nitrogen** and **nitrate-nitrogen** data summarized in Table 7-2 for the 6 storm events sampled during the 2017-2018 Program.

Figure 7-1

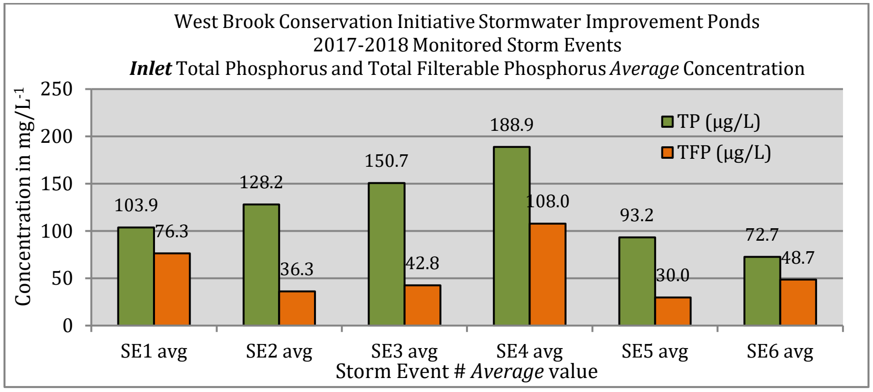


The *average* **total nitrogen** concentrations ranged from 0.94–2.20 mg $\mathbf{N}\cdot L^{-1}$, with the lowest *average* concentration measured during the September 18th 2018 storm event and the highest *average* concentration measured during the May 19th 2018 storm event. From the data presented here, it appears that the highest *average* concentrations of total nitrogen occurred during winter and early spring, which is when contaminants accumulate on impervious surfaces and in the winter snowpack and may require several storm events with sufficient runoff to wash this material from the subcatchment into the wetland. An additional observation here is that the *average* **total nitrogen** concentrations entering the wetland complex are not very high.

The *average* **nitrate-nitrogen** concentrations ranged from 0.005–0.71 mg $\mathbf{N}\cdot L^{-1}$, with the lowest *average* concentration occurring during the July 17th event and the highest *average* concentration occurring during the May 19th 2018 storm event. As mentioned above for **total nitrogen**, these *average* **nitrate nitrogen** concentrations are not elevated and the highest *average* value (0.71 mg $\mathbf{N}\cdot L^{-1}$) occurring during late spring makes sense because accumulated contaminants still are being ‘flushed’ from the wetland subcatchment.

Figure 7-2 presents the *average* **total phosphorus** and **total filterable phosphorus** data summarized in Table 7-2 for the 6 storm events.

Figure 7-2



In contrast to **nitrogen** described above, most of the *average* **total phosphorus** (**TP**) and **total filterable phosphorus** (**TFP**) concentrations were elevated. As shown in Figure 7-2, the *average* **TP** concentrations increased from 103.9 µg **P**·L^{-1} during the October 24th 2017 storm event to 188.9 µg **P**·L^{-1} through the May 19th 2018 storm event; thereafter the **TP** concentrations decreased. A possible explanation for this pattern is the accumulation of **TP** in the snow-pack from December through the end of May when eventually the high concentrations decrease after being captured in runoff and transported to the wetland complex.

TFP did not exhibit any concentration pattern throughout the wetland sampling period; the range of this analyte was 30.0-108.0 µg **P**·L^{-1}, with the highest concentration measured during the May 19th 2018 storm event. In general **TFP** comprised 30-72 percent of the **total phosphorus** concentration.

Road salt constituents and associated parameters. Table 7-3 summarizes the *minimum*, *maximum* and *average* concentrations of analytes related to road salt application in the wetland subcatchment including **sodium** (**Na**), **chloride** (**Cl**), **calcium** (**Ca**), **magnesium** (**Mg**), **specific conductance** (**spC**), and **total dissolved solids** (**TDS**).

Table 7-3

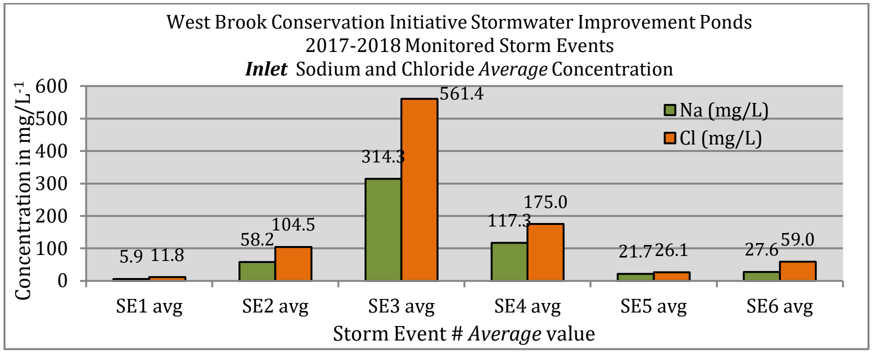
	Na (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	spC (µS/cm)	TDS (mg/L)
October 24th 2017 (SE-1)						
SE-1 minimum	0.7	1.5	4.0		28	14
SE-1 maximum	13.1	33	42.4		216	151
SE-1 average	5.9	11.8	18.3		102	68
n (= sample size)	6	6	6		6	6
December 5th 2017 (SE-2)						
SE-2 minimum	6.4	9.2	6.5		67	45
SE-2 maximum	140.5	246	19.6		900	649
SE-2 average	58.2	104.5	11.6		411	292
n (= sample size)	5	5	5		5	5
January 12th 2018 (SE-3)						
SE-3 minimum	133.1	242	17.3		880	638
SE-3 maximum	509.6	885	64		3097	2420
SE-3 average	314.3	561.4	31.3		1997	1511
n (= sample size)	5	5	5		5	5
May 19th 2018 (SE-4)						
SE-4 minimum	13.2	18.9	10.9	7.0	114	74
SE-4 maximum	157.7	224	56.1	10.2	1062	759
SE-4 average	117.3	175	41.8	3.2	828	589
n (= sample size)	7	7	7	7	7	7
July 18th 2018 (SE-5)						
SE-5 minimum	8.5	9.8	10.9	2.7	97	61
SE-5 maximum	45.3	53	28.2	8.7	430	288
SE-5 average	21.7	26.1	16.7	6.0	208	136
n (= sample size)	4	4	4	4	4	4
September 18th 2018 (SE-6)						
SE-6 minimum	4.3	5.1	6.1	1.5	63	40
SE-6 maximum	63.8	198	20.1	7.0	420	280
SE-6 average	27.6	59	11.5	5.5	212	138
n (= sample size)	6	6	6	6	6	6

As with the ***Inlet*** chamber nutrient concentration data presented above, the *average* concentrations of these road salt-related analytes first were evaluated to determine whether there was any seasonal effect from runoff entering the wetland treatment chain.

We expect that there should be a seasonal effect on concentration because road salt only is applied during the winter months when deicing maintenance is required and runoff during these periods and into spring and early summer should exhibit higher concentrations of these analytes than during periods later in the year when storm event runoff has 'flushed' most of the remnants of these analytes from the subcatchment prior to the start of another series of winter deicing applications.

Figure 7-3 presents the *average* concentrations of **sodium** (**Na**) and **chloride** (**Cl**) for each of the 6 storm events that were monitored during the wetland sampling program.

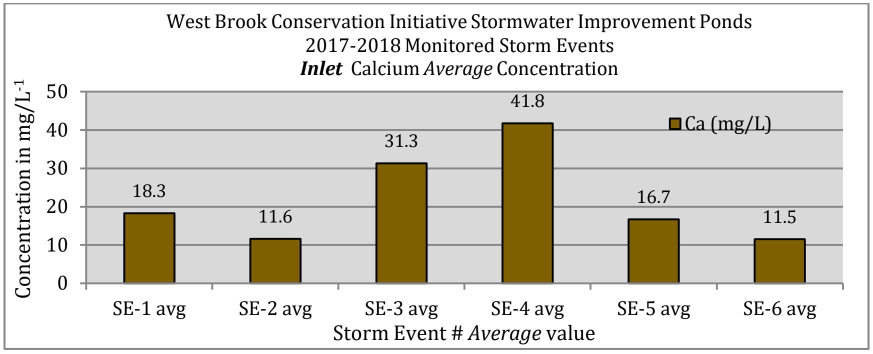
Figure 7-3



As expected, there was a pronounced seasonal effect on the *average* concentrations of **Na** and **Cl** entering the ***Inlet*** chamber during the sampling program, with the October 24th 2017 storm event (SE1) producing the lowest *average* concentrations of **sodium** (5.9 mg **Na**·L^{-1}) and **chloride** (11.8 mg **Cl**·L^{-1}), and the January 12th 2018 storm event (SE3) producing the highest *average* concentrations of **sodium** (314.3 mg **Na**·L^{-1}) and **chloride** (561.4 mg **Cl**·L^{-1}).

The same seasonal influence on *average* concentration was apparent with the ***Inlet*** chamber **calcium** (**Ca**) data which are presented in Figure 7-4.

Figure 7-4

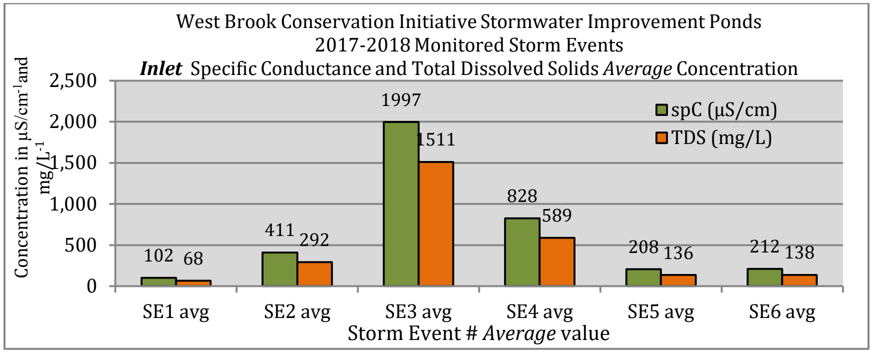


In the case of this analyte, the lowest *average* **Ca** concentrations occurred during the December 5th 2017 storm event (SE2) (11.6 mg **Ca**·L^{-1}) and the September 18th 2018 storm event (SE6) (11.5 mg **Ca**·L^{-1}), while the highest *average* **Ca** concentration occurred during the May 19th storm event (SE4). While some of the **Ca** contained in runoff from the subcatchment is from road salt application during winter maintenance, the other source of this analyte is the dissolution of concrete structures along the Route 9 (Canada Street) transportation corridor.

As might be expected from the data presented above, the same seasonal influence on *average* concentrations measured at the ***Inlet*** chamber was exhibited by **specific conductance** and **total dissolved solids** whose concentrations are heavily influenced by the anion **chloride** and the cations **sodium** and **calcium**. The January 12th 2018 storm event provided the highest *average* concentrations of these two parameters; 1,997 µS·cm^{-1} for **specific conductance** and 1,511 mg·L^{-1}for **total dissolved solids**. These elevated concentrations are orders of magnitude greater than the lowest *average* values of these parameters measured during the October 24th 2017 storm event, 102 µS·cm^{-1} for **specific conductance** and 68 mg·L^{-1}for **total dissolved solids**. All of these data support the premise that the winter application of highway deicing materials takes numerous storm events and many months to be ‘flushed’ from the subcatchment before the annual application cycle starts once again.

These *average* **specific conductance** and **total dissolved solids** concentration data for the 6 storm events that were monitored at the ***Inlet*** chamber are presented in Figure 7-5.

Figure 7-5



Other important highway runoff contaminants. Our concern in this section is focused on heavy (trace) metals and other cations that are produced by the wear of vehicles and the breakdown of highway surface and parking lots. More specifically, the data for heavy metals such as **cadmium**, **copper**, **lead**, **nickel** and **zinc** will be presented and discussed here, along with other important cations related to highway runoff including **iron** and **sulfate**.

Unfortunately, the full complement of important highway constituents were not sampled during the entire 13-month period of the wetland complex sampling program. Samples for these constituents were collected and preserved beginning in May 2018 and continuing through September 2018 when the sampling program was completed; these samples were submitted to the USGS Laboratory for analysis at that time.

In spite of the abbreviated sampling effort for this group of constituents, there are sufficient base-flow data to evaluate the dynamics of these analytes as they enter the wetland complex via previous storm events and base-flow from higher elevations and describe their fate prior to entering West Brook at the other end of the treatment process.

Table 7-4 summarizes the *minimum*, *maximum*, and *average* concentrations of the highway runoff contaminants measured during the May 19th, July 18th and September 18th 2018 storm events that were monitored as part of the sampling program.

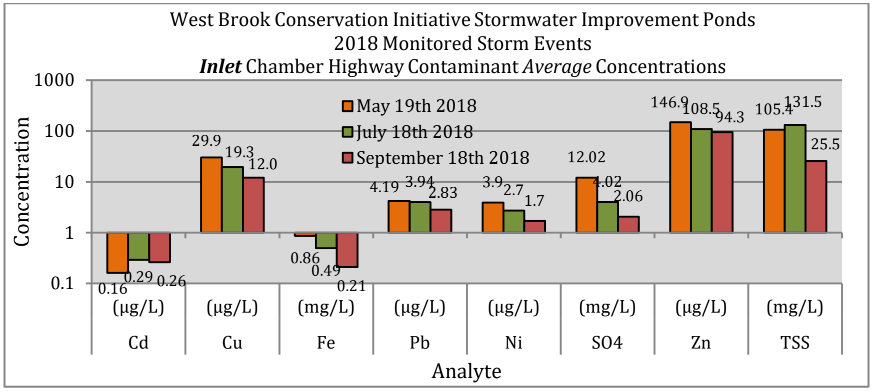
Table 7-4

	Cd	Cu	Fe	Pb	Ni	SO_4	Zn	TSS
	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)
May 19th 2018 (SE4)								
SE4 minimum	0.07	2.2	0.06	1.32	0.9	2.06	28.5	6.5
SE4 maximum	0.30	54.8	1.35	5.98	8.2	19.70	231.6	229.6
SE4 average	0.16	29.9	0.86	4.19	3.9	12.02	146.9	105.4
n (= sample size)	7	7	7	7	7	7	7	7
July 18th 2018 (SE5)								
SE5 minimum	0.26	9.0	0.22	2.84	0.9	1.70	57.7	28.9
SE5 maximum	0.32	30.2	0.62	4.68	4.8	8.49	138.1	194.6
SE5 average	0.29	19.3	0.49	3.94	2.7	4.02	108.5	131.5
n (= sample size)	4	4	4	4	4	4	4	4
September 18th 2018 (SE6)								
SE6 minimum	0.19	3.6	0.06	0.62	0.5	0.70	32.3	3.7
SE6 maximum	0.33	25.2	0.53	4.55	4.0	4.24	210.4	76.1
SE6 average	0.26	12.0	0.21	2.83	1.7	2.06	94.3	25.5
n (= sample size)	6	6	6	6	6	6	6	6

The constituents summarized in the table above include **cadmium** (**Cd**), **copper** (**Cu**), **iron** (**Fe**), **lead** (**Pb**), **nickel** (**Ni**), **sulfate** (**SO_4**), and **zinc** (**Zn**). Please note in the table that the notations for the constituent concentrations are either $\mu g \cdot L^{-1}$ or $mg \cdot L^{-1}$. **Total suspended sediments** (**TSS**) have been included in this group of analytes because some heavy metals may be adsorbed to the surface of fine particles suspended in the storm event runoff which means that this form of contaminant must be considered.

The *average* concentrations for the heavy metal and other highway contaminant data summarized in Table 7-4 are presented in Figure 7-6.

Figure 7-6



An initial observation regarding the data presented in Figure 7-6 is that almost every analyte exhibited a decreasing *average* concentration from the May 19th storm event through the September 18th storm event. The significance of this decreasing trend exhibited by all of the heavy metal and other highway contaminant data is not certain. However, it could mean that a series of many storm events are required during the ice-free season to wash these heavy (trace) metals and other contaminants from the subcatchment up until the time when winter takes hold in the area and most of these contaminants are concentrated in the ice and snowpack once again. Then the cycle begins again with the spring snowmelt and subsequent storm events with associated runoff which wash these contaminants from the subcatchment into the wetland.

7.2.2 Evaluation of *Inlet* Chamber Data and *Pond 7* Outlet Data

The functional basis for constructing the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) wetland complex was to capture and treat stormwater runoff from the highly developed subcatchment that drains to this structure. And while the subcatchment is a mixture of both commercial and residential development, the high commercial designation in conjunction with the significant transportation corridor are the primary contributors of runoff which previously entered West Brook without any provision for treatment to remove contaminants which then flowed directly into the south end of Lake George.

Pond 7 serves as the primary outlet for discharge from the wetland treatment chain; the ***Gravel Wetland*** only functions as a conduit for stormwater runoff when a certain water level is exceeded at the ***Pond 6*** weir, which then directs flow to both of these wetland components.

The most basic technique to evaluate the actual functioning of the wetland complex is to dissect individual storm events and compare the *average* concentration of analytes entering the ***Inlet*** chamber with the *average* concentration of these same analytes at the ***Pond 7*** outlet prior to entering West Brook.

The following 6 graphs (Figures 7-7 through Figure 7-13) provide these visual comparisons for the reader for each of the 6 monitored storm events during 2017-2018. Please note that the ***y***-axis scale on all of these graphs is in logarithm format so that the wide range of analyte concentrations can be displayed with realistic representation on the same figure.

.

Figure 7-7

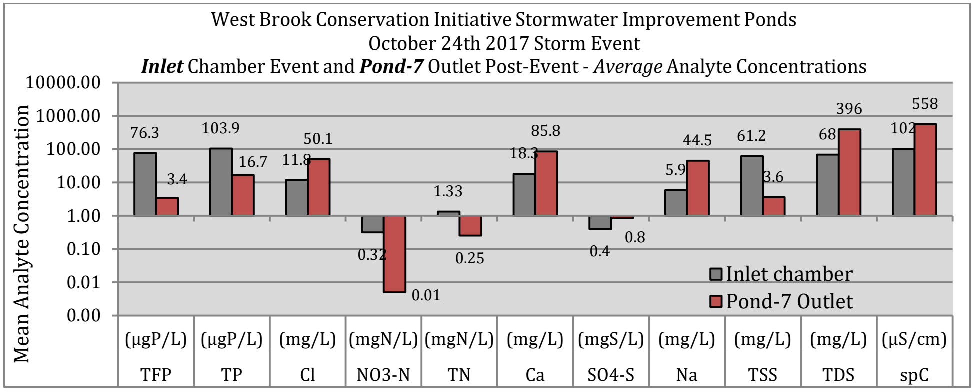


Figure 7-8

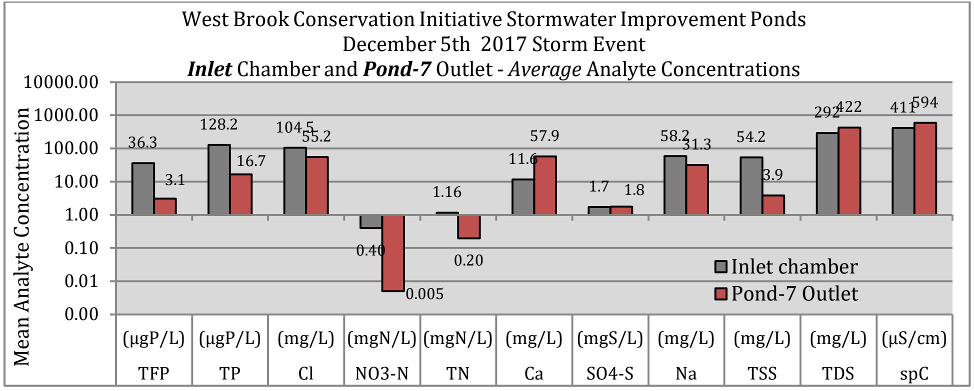


Figure 7-9

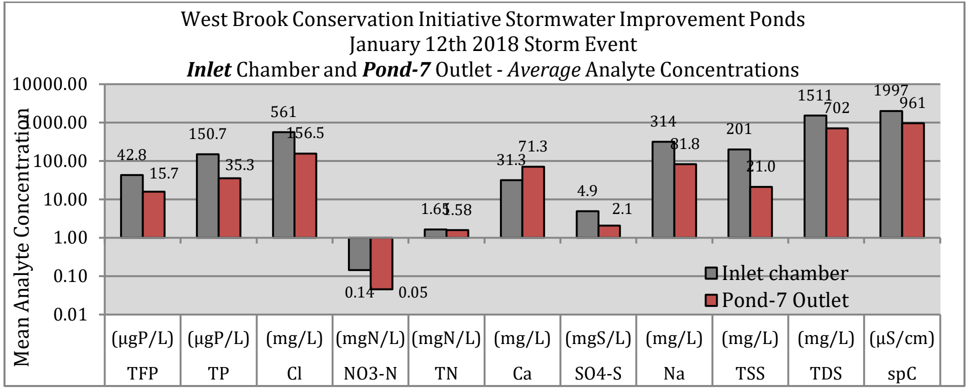


Figure 7-10

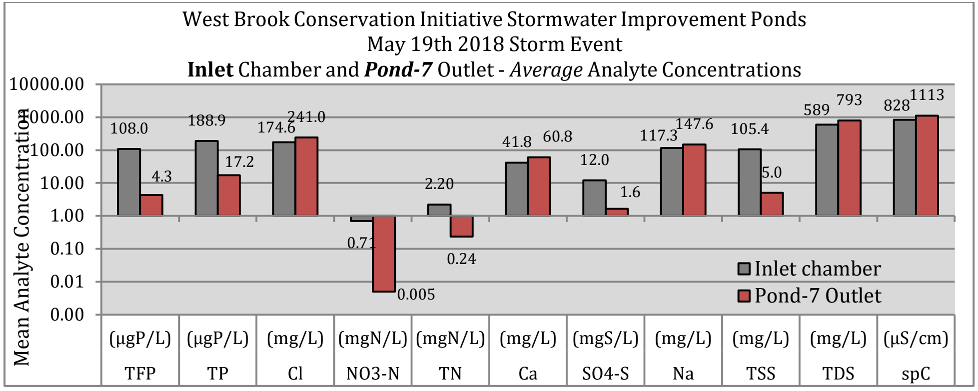


Figure 7-11

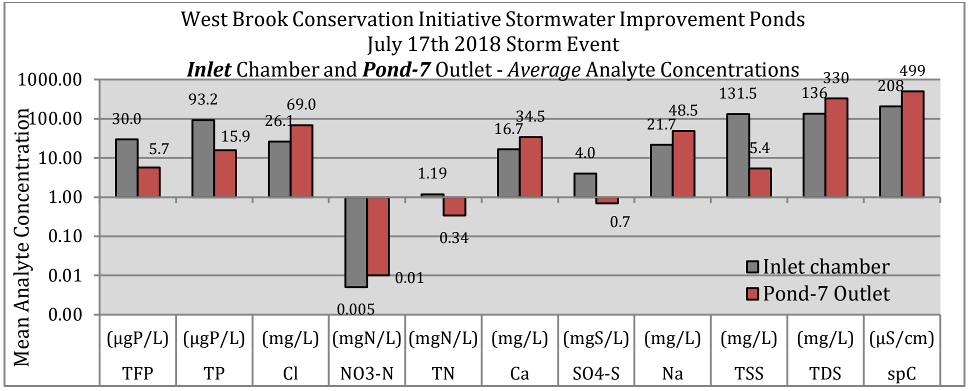
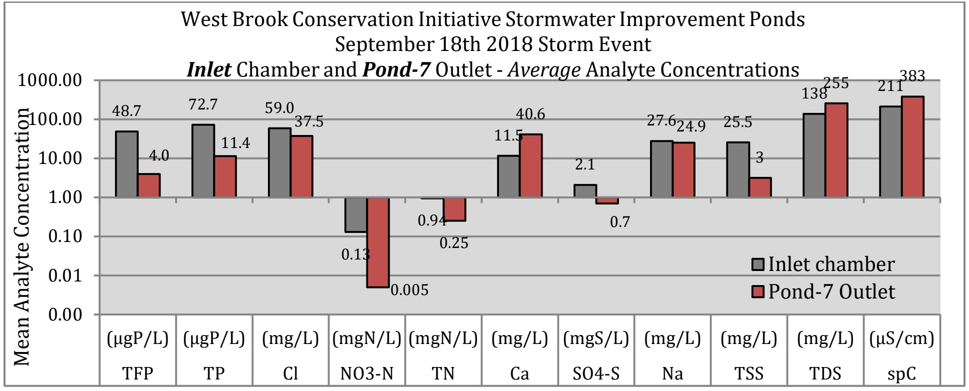


Figure 7-12



While the above graphs allow us to visually see the difference between ***Inlet*** chamber and ***Pond*** *7* outlet chamber concentrations for each storm event, they don't quantify the difference for each analyte and whether or not there was an increase or decrease in concentration. The next step, therefore, was to provide a table of summary data for each major analyte and an assessment of percent increase or decrease in concentration when comparing the ***Inlet*** chamber with the ***Pond*** *7* outlet.

Plant nutrients. Table 7-5 summarizes the plant nutrient data (**total nitrogen** (**TN**), **nitrate-nitrogen** (**NO_3-N**), **total phosphorus** (**TP**), and **total filterable phosphorus** (**TFP**)) for each monitored storm event including (1) the ***Inlet*** chamber *average* concentration of each analyte, (2) the ***Pond*** *7* outlet *average* concentration of each analyte, (3) the amount of concentration increase or decrease for each analyte, and (4) the percent of decrease or increase of each analyte concentration relative to the *average* concentration measured at the ***Inlet*** chamber. TSS also is included in this summary table because of its potential phosphorus adsorption capability.

The first significant observation from viewing the data summarized in Table 7-5 is that each nutrient exhibited a decrease in concentration between the ***Inlet*** chamber and the ***Pond*** *7* outlet for each storm event monitored. The only exception occurred with respect to **nitrate-nitrogen** during the July 17th 2018 storm event when the ***Inlet*** chamber and ***Pond*** *7* outlet both exhibited concentrations of 0.005 mg **N**$\cdot$L^{-1}, or one-half the lowest detection limit.

The percent reduction of **total nitrogen** between the ***Inlet*** chamber and ***Pond*** *7* outlet ranged from 4-89 percent, although the 4 percent value occurred during the January 12th 2018 storm event; all of the other reductions were 71 percent or greater. The summary data for the reduction of **nitrate-nitrogen** in the treatment complex (Table 7-5) were even more impressive. The event on July 17th with ***Inlet*** chamber and ***Pond*** *7* outlet *average* concentrations of 0.005 mg **N**$\cdot$L^{-1} was already mentioned. For the other 5 storm events, the reduction of **nitrate-nitrogen** ranged from 64-99 percent. The 64 percent reduction occurred during the January 12th storm event when cold weather would have limited any significant metabolism in the wetland and complete uptake of this available plant nutrient.

The reduction of **total phosphorus** between ***Inlet*** and ***Pond 7*** outlet ranged from 77-91 percent, with the lowest decrease occurring during the January 12th 2018 storm event when the water column in the wetland ponds would be cold (near 0°F) and most dense, which would hinder the settling of **organic phosphorus,** the principal component of the **total phosphorus** concentration. The reduction of **total filterable phosphorus** ranged from 63-96 percent, with the lowest reduction (63 percent) occurring during the January 12th 2018 storm event when low temperatures would have minimized uptake and reduction of the concentration of this plant nutrient in the water column.

TSS reduction between the ***Inlet*** chamber and the ***Pond 7*** outlet ranged from 87-96 percent for the series of 6 storm events that were monitored during 2017-2018; the lowest percent reduction occurred during the September 18th storm event (87 percent) which also had the lowest range of individual **TSS** concentrations (3.7-76.1 mg **TSS**·L^{-1}) when compared with the other monitored storm events.

Table 7-5

	TN	NO3-N	TP	TFP	TSS
	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)
October 24th 2017					
Inlet chamber average concentration	1.33	0.32	103.9	76.3	61.2
Pond 7 outlet average concentration	0.27	0.02	16.5	3.5	6.2
concentration decrease (↓), increase (↑)	↓1.06	↓0.30	↓87.4	↓72.8	↓55.0
percent increase (↑), decrease (↓)	↓80	↓94	↓84	↓95	↓90
December 5th 2017					
Inlet chamber average concentration	1.16	0.40	128.2	36.3	54.2
Pond 7 outlet average concentration	0.20	0.005	16.7	3.1	3.9
concentration decrease (↓), increase (↑)	↓0.96	↓0.39	↓111.5	↓33.2	↓50.3
percent increase (↑), decrease (↓)	↓83	↓98	↓87	↓91	↓93
January 12th 2018					
Inlet chamber average concentration	1.65	0.14	150.7	42.8	201.1
Pond 7 outlet average concentration	1.58	0.05	35.3	15.7	21.0
concentration decrease (↓), increase (↑)	↓0.07	↓0.09	↓115.4	↓27.1	↓180.1
percent increase (↑), decrease (↓)	↓4	↓64	↓77	↓63	↓90
May 19th 2018					
Inlet chamber average concentration	2.20	0.71	188.9	108.0	105.4
Pond 7 outlet average concentration	0.24	0.005	17.2	4.3	5.0
concentration decrease (↓), increase (↑)	↓1.96	↓0.70	↓171.7	↓103.7	↓100.4
percent increase (↑), decrease (↓)	↓89	↓99	↓ 91	↓ 96	↓95
July 17th 2018					
Inlet chamber average concentration	1.19	0.005	93.2	30.0	131.5
Pond 7 outlet average concentration	0.34	0.005	15.9	5.7	5.4
concentration decrease (↓), increase (↑)	↓0.85	0.0	↓77.3	↓24.3	↓126.1
percent increase (↑), decrease (↓)	↓71	0.0	↓83	↓81	↓96
September 18th 2018					
Inlet chamber average concentration	0.94	0.13	72.7	48.7	25.5
Pond 7 outlet average concentration	0.25	0.005	11.4	4.0	3.2
concentration decrease (↓), increase (↑)	↓0.69	↓0.12	↓61.3	↓44.7	↓22.3
percent increase (↑), decrease (↓)	↓73	↓92	↓84	↓92	↓87

Road salt constituents and associated parameters. Table 7-6 provides a summary of **sodium** (**Na**), **chloride** (**Cl**), **calcium** (**Ca**), **magnesium** (**Mg**), **specific conductance** (**spC**) and **total dissolved solids** (**TDS**) for each monitored storm event including (1) the ***Inlet*** chamber *average* concentration of each analyte, (2) the ***Pond 7*** outlet *average* concentration of each analyte, (3) the amount of concentration increase or decrease for each analyte, and (4) the percent decrease or increase of each analyte concentration relative to the *average* concentration measured at the ***Inlet*** chamber.

Sodium (**Na**) and **chloride** (**Cl**) exhibited a mixed response among the 6 monitored storm events, which appeared to be related to the time of the year and the flow pattern through the wetland treatment chain (Table 7-6). During the October 24th 2017 event, the *average* concentrations of **Na** and **Cl** entering the ***Inlet*** chamber were low (5.9 and 11.8

mg·L^{-1}), while the ***Pond** 7 average* concentrations were considerably elevated (40.6 and 47.9 mg·L^{-1}) because **sodium** and **chloride** still were being flushed from the remnant volume of high concentration water in the wetland complex from winter deicing during the previous (2016-2017) winter.

Thereafter, there was a reversal of trend for the following two (2) winter storms on December 5th 2017 and January 12th 2018 when *average* concentrations entering the ***Inlet*** chamber were considerably elevated as a result of recent road salt application along the State Route 9 (Canada Street) corridor (Table 7-6). Then another reversal of trend during the May 19th and July 17th 2018 storm events when *average* concentrations of **Na** and **Cl** were decreasing in the subcatchment and the volume of water in the wetland still contained high concentrations of both analytes from the winter 2017-2108 road deicing applications.

Table 7-6

	Na	Cl	Ca	Mg	spC	TDS
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µS/cm @ 25°C)	(mg/L)
October 24th 2017						
Inlet chamber average concentration	5.9	11.8	18.3	ns	102	68
Pond 7 outlet average concentration	40.6	47.9	85.8	ns	560	397
concentration decrease (↓), increase (↑)	↑34.7	↑36.1	↑67.5	ns	↑458	↑329
percent increase (↑), decrease (↓)	↑690	↑410	↑470	ns	↑550	↑580
December 5th 2017						
Inlet chamber average concentration	58.2	104.5	11.6	ns	411	292
Pond 7 outlet average concentration	31.3	55.2	57.9	ns	594	422
concentration decrease (↓), increase (↑)	↓26.9	↓49.3	↑46.3	ns	↑183	↑130
percent increase (↑), decrease (↓)	↓46	↓47	↑500	ns	↑140	↑140
January 12th 2018						
Inlet chamber average concentration	314	561	31.3	ns	1997	1511
Pond 7 Outlet average concentration	81.8	157	71.3	ns	961	702
concentration decrease (↓), increase (↑)	↓232.2	↓404	↑40.0	ns	↓1036	↓809
percent increase (↑), decrease (↓)	↓74	↓72	↑230	ns	↓52	↓54
May 19th 2018						
Inlet chamber average concentration	117.3	175	41.8	7.0	828	589
Pond 7 Outlet average concentration	147.6	241	60.8	10.2	1113	793
concentration decrease (↓), increase (↑)	↑30.3	↑66	↑19.0	↑3.2	↑285	↑204
percent increase (↑), decrease (↓)	↑130	↑140	↑150	↑150	↑130	↑140
July 17th 2018						
Inlet chamber average concentration	21.7	26	16.7	2.7	208	136
Pond 7 Outlet average concentration	48.5	69	34.5	8.7	499	330
concentration decrease (↓), increase (↑)	↑26.8	↑43	↑17.8	↑6.0	↑291	↑194
percent increase (↑), decrease (↓)	↑220	↑270	↑210	↑320	↑240	↑240
September 18th 2018						
Inlet chamber average concentration	27.6	59	11.5	1.5	212	138
Pond 7 Outlet average concentration	24.9	38	40.6	7.0	383	255
concentration decrease (↓), increase (↑)	↓2.7	↓21	↑29.1	↑5.5	↑171	↑117
percent increase (↑), decrease (↓)	↓10	↓36	↑350	↑470	↑180	↑190

Calcium (**Ca**) exhibited an increase in *average* concentration between the ***Inlet*** chamber and the ***Pond** 7* outlet for all 6 storm events that were monitored; the range of **Ca** concentration increase was 150 percent to as much as 500 percent. Given the results presented in Table 7-6, it is difficult to determine whether there is any uptake of **Ca** from the water column within the treatment chain. The primary sources of **calcium** include road salt and dissolution of concrete structures within the subcatchment, so there appears to be a steady supply of this analyte year-round.

Magnesium (**Mg**) data were available for the last 3 storm events that were monitored. In each case, the *average* concentration of this analyte increased between the ***Inlet*** chamber and the ***Pond** 7* outlet. Since the primary source of this analyte is road salt application, it is likely that the year-round dynamics of concentration are similar to the trends exhibited by **calcium**.

Specific conductance and **total dissolved solids** responded in a similar manner and both exhibited the same pattern of trends demonstrated by **sodium** and **chloride**, which is to be expected since **sodium** and **chloride** are principal cations that determine the absolute concentrations of **specific conductance** and **TDS**, along with other cations like **calcium** and **magnesium**.

Other important highway runoff contaminants. There were water samples collected and processed for heavy (trace) metal and associated highway contaminants during the 2018 ice-free season and the final three (3) storm events monitored in the wetland complex including May 19th, July 18th and September 18th 2018. The analytical data for these contaminants are summarized in Table 7-7 using the same format presented above for **plant nutrients** and **road salt constituents and associated parameters**.

Table 7-7

	Cd	Cu	Fe	Pb	Ni	SO_4	Zn	TSS
	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)
May 19th 2018 (SE4)								
Inlet chamber average concentration	0.16	29.9	0.86	4.2	3.9	12.0	146.9	105.4
Pond 7 outlet average concentration	0.17	0.20	0.49	2.3	nd	1.6	14.8	4.0
concentration decrease (↓), increase (↑)	↑0.01	↓29.7	↓0.37	↓1.9	↓3.9	↓10.4	↓132.1	↓101.4
percent increase (↑), decrease (↓)	↑6	↓99	↓43	↓55	↓100	↓87	↓90	↓96
July 18th 2018 (SE5)								
Inlet chamber average concentration	0.29	19.3	0.49	3.9	2.7	4.0	108.5	131.5
Pond 7 outlet average concentration	0.10	0.07	0.21	2.2	nd	0.7	8.4	5.4
concentration decrease (↓), increase (↑)	↓0.19	↓19.2	↓0.28	↓1.7	↓2.7	↓3.3	↓100.1	↓126.1
percent increase (↑), decrease (↓)	↓34	↓99	↓43	↓56	↓100	↓83	↓92	↓96
September 18th 2018 (SE6)								
Inlet chamber average concentration	0.26	12	0.21	2.8	1.7	2.1	94.3	25.5
Pond 7 outlet average concentration	0.14	2	0.25	nd	nd	0.7	1.1	3.2
concentration decrease (↓), increase (↑)	↓0.12	↓10	↑0.04	↓2.8	↓1.7	↓1.4	↓93.2	↓22.3
percent increase (↑), decrease (↓)	↓54	↓83	↑19	↓100	↓100	↓67	↓99	↓87

The data presented in Table 7-7 are for the cations **cadmium** (**Cd**), **copper** (**Cu**), **lead** (**Pb**), **nickel** (**Ni**) and **zinc** (**Zn**), as well as other important analytes, including **iron** (**Fe**), **sulfate** (**SO_4**) and **total suspended sediments** (**TSS**). Please note in Table 7-7 that the analyte concentration units are listed either in $\mu g \cdot L^{-1}$ or $mg \cdot L^{-1}$ depending upon the analyte summarized.

In almost all cases, there was a significant decrease of contaminant concentration within the wetland complex when comparing the ***Inlet*** and ***Pond 7*** outlet concentrations. The *average* percent removal for the analytes listed in Table 7-7 among the three storm events monitored was as follows: **nickel** (**Ni**), 100 percent; **zinc** (**Zn**), 94 percent; **copper** (**Cu**), 94 percent; ; **sulfate** (**SO_4**), 79 percent; **lead** (**Pb**), 70 percent; **iron** (**Fe**), 35 percent; and **cadmium** (**Cd**), 27 percent.

Total suspended sediment (**TSS**) was considered to be one of the target contaminants when designing the wetland complex to capture and treat runoff from the highly developed Route 9 and adjacent subcatchment with considerable impervious surface. From Table 7-7 above, we see that an *average* of 93 percent of the particulates was removed from the May, July and September 2018 storm events. When evaluating all 6 storm events that were monitored, an *average* of 92 percent of **TSS** concentration was removed by the wetland processing (Table 7-5)

7.3 Summary

The runoff entering the West Brook CI SIP wetland from storm events depositing precipitation in the subcatchment carries low concentrations of **total nitrogen** and **nitrate-nitrogen** and moderate-to-high concentrations of **total phosphorus** and **total filterable phosphorus**. All of these plants nutrients are effectively removed from the water column as follows: **total nitrogen**, 67 percent removal; **nitrate-nitrogen** 89 percent removal; **total phosphorus**, 84 percent removal; and **total filterable phosphorus**, 92 percent removal. **Total suspended sediment** (TSS), which is known to have phosphorus adsorbed to its surface, had a removal efficiency of 92 percent when comparing the ***Inlet*** chamber concentration and ***Pond*** *7* outlet concentration.

The efficiency of plant nutrient removal in the wetland complex was lowest for the January 12th 2018 storm event for all of the nitrogen and phosphorus fractions described above, probably because the low temperatures in the wetland water column resulted in low rates of algae and plant metabolism and corresponding low rates of **nitrate-nitrogen** and **total filterable phosphorus** uptake. Most of the **total nitrogen** and **total phosphorus** is comprised of organic material contained in the floating plants (algae) and animals (zooplankton) in the water column plus dead and decaying organic matter.

There was absolutely no removal demonstrated for **road salt constituents and associated parameters** due to the extremely high application rates of deicing materials to the subcatchment during the winter months. This deicing material is flushed from the subcatchment during the ice-free season of the year and requires considerable amounts of precipitation and a large number of successive storm events to reach low concentrations of **sodium**, **chloride**, **calcium**, **magnesium**, **specific conductance** and **total dissolved solids** in the wetland water column before the next cycle of road salt loading to the subcatchment occurs.

Other important highway runoff contaminants exhibit low-to-moderate concentrations in stormwater runoff entering the wetland complex and are, for the most part, effectively removed from the water column before exiting the complex and entering West Brook. Exceptions to efficient removal include **iron** (**Fe**) which appears to be a primary constituent in the ground water entering ***Pond 2*** and perhaps other ponds in the wetland, and this intrusion has effects on iron concentration removal efficiency further down the treatment chain.

7.4 Literature Cited

United States Environmental Protection Agency. (1983). *Results of the Nationwide Urban Runoff Program*. Washington, DC: USEPA, Water Planning Division.

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

Final Report

Chapter 8

Water Movement through the Wetland Complex during Base-flow and Storm Events

This page intentionally left blank.

8.0 Introduction

This chapter summarizes the base-flow and storm event water movement (discharge, flow) that occurred through the West Brook Conservation Initiative Stormwater Improvement Ponds during the 2017-2018 sampling program. These two types of discharge, base-flow and storm event, are being presented and handled separately in this chapter of the report even though they are virtually impossible to split into individual components of the total water that passes through the wetland complex at any given time.

Understanding the hydrology of the wetland treatment chain is not a trivial matter. Base-flow occurs during non-storm event (dry) periods; however, it also is affected by antecedent precipitation which (1) contributes runoff to the wetland and has an effect through (2) the influence of the precipitation on local ground water within the area of the subcatchment that drains to the wetland. For the purposes of this report, base-flow in the wetland complex refers to water levels at least 72 hours following antecedent precipitation and just prior to the start of an event within the wetland subcatchment.

8.1 Results and Discussion

The base-flow and storm event discharge data reported here officially began on August 22nd 2017 when the ***Inlet***, ***Pond 7*** and ***Gravel Wetland*** chambers were instrumented with Telog Inc. WLS-31 water level data-loggers that continuously recorded water level (in feet). The ***Inlet*** recorder was programmed to store levels at 1-minute intervals while the ***Pond 7*** and ***Gravel Wetland*** recorders were programmed to store data at 5-minute intervals. The ***Inlet*** chamber was gaged during storm events when samples for water chemistry were collected, while the ***Pond 7*** and ***Gravel Wetland*** outlet channels were gaged on various occasions during the project to determine discharge in either cfs (cubic feet per second) or mgd (millions of gallons per day).

8.1.1 Base-flow Discharge

An aerial view of the West Brook Conservation Initiative Stormwater Improvement Ponds taken from Google™ Earth is shown in Figure 8-1.

Figure 8-1

The figure above traces the sequence of the wetland runoff treatment process from ***Pond 1*** through the series of succeeding ponds, with water finally discharging either to ***Pond 7*** or to the ***Gravel Wetland***, depending upon the level of water in the area of the ***Pond 6*** weir.

If there is no stormwater runoff passing sequentially through ponds in the system, then the flow is controlled by ground water moving from the south and southwest areas through the wetland complex, north toward West Brook. Because the wetland complex almost always provides discharge to West Brook, it is important to characterize this **base-flow** discharge quantitatively so that the impact of base-flow chemistry can be determined and compared with the chemical characteristics of stormwater runoff discharged from the wetland following different events.

Water Level in the *Inlet* Chamber.

During dry, non-storm event periods, the ***Inlet*** chamber never exhibited any discharge to the outlet channel that conveys runoff to ***Pond 1*** in the wetland complex. Figure 8-2 shows the channel exiting the ***Inlet*** chamber during a non-storm event (dry) period.

Figure 8-2

This dry feature of the ***Inlet*** chamber during non-event periods confirms the fact that the subsurface drainage system that was constructed in the wetland subcatchment along Route 9 (Canada Street) to convey runoff to the wetland is a closed system that does not allow any infiltration of ground water in the immediate area.

Discharge from the *Pond 7* Outlet.

Water flows from the wetland complex into West Brook via two (2) outlet structures that convey discharge from the ***Pond 7*** and the ***Gravel Wetland*** outlet chambers under Warren County Route 69, and terminate in culverts adjacent to the stream channel.

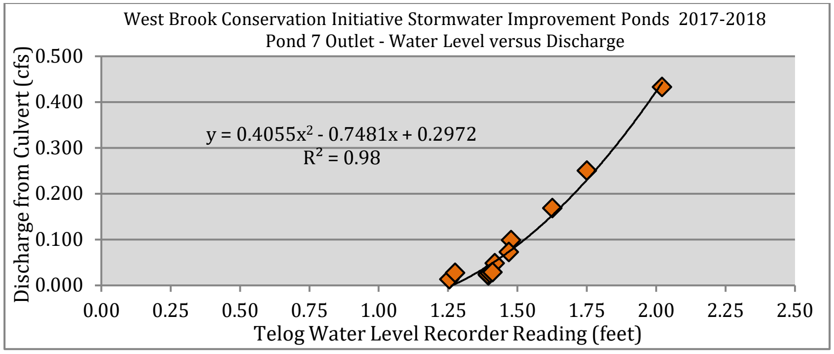
Efforts were made during the sampling Program to determine the amount of water continuously moving through the wetland complex as a result of ground water movement from higher elevations to the south. The ***Pond 7*** outlet culvert is shown in Figure 8-2.

Figure 8-3

The outlet channel was gaged 15 times during 2017; data collected during the manual gaging process were used to calculate discharge (in cfs and mgd) and these data were paired with the Telog recorder level data collected from the ***Pond 7*** outlet chamber for the same times that the gagings were performed to establish a rating curve that would define the discharge of water through this wetland component.

However, the outlet channel was poorly configured for manual gaging and 4 of the 15 channel gaging values were considered suspicious due to either very low discharge during the times that the gagings were performed or discharge values that disagreed with previous values calculated under similar circumstances. The remaining 11 channel gagings were used to derive an equation that related discharge with Telog water level (in feet). A plot of Telog water level (in feet) versus discharge (in cfs) leaving the ***Pond 7*** culvert is presented in Figure 8-4.

Figure 8-4



The relationship that links the ***Pond 7*** water level and discharge is a polynomial equation as follows:

$$y = 0.4055x^2 - 0.7481x + 0.2972$$

where, y = Telog recorder level (in feet), and x = ***Pond 7*** outlet channel discharge (in cfs).

The relationship described by the equation is robust ($R^2 = 0.98$). The equation was used in the ***Pond 7*** Telog data file to convert level readings (in feet) to mgd (million gallons per day) and these data were used to summarize daily discharge (in mgd) through the ***Pond 7*** outlet chamber during the 13-month period of the study.

There were several periods during the 13-month sampling program when either the ***Pond 7*** outlet channel and/or the ***Gravel Wetland*** outlet channel were observed to be dry (no discharge). The corresponding Telog water levels in each chamber at those times were noted and were used to distinguish periods of no water discharge versus periods of positive water discharge.

Discharge from the *Gravel Wetland* Outlet.

This device provides the second means for water to discharge from the wetland complex during base-flow conditions and during storm event periods when the water level in ***Pond 6*** rises above the level setting of the weir. Figure 8-5 shows the ***Gravel Wetland*** outlet culvert; note the abundance of oxidized iron precipitate in the channel.

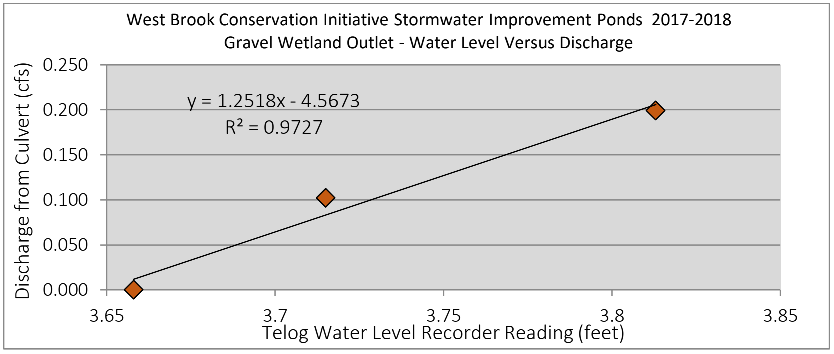
Figure 8-5

This outlet channel was extremely difficult to gage manually because the channel constantly was choked with vegetation and oxidized iron precipitate (Figure 8-5), literally making accurate manual gaging very difficult to achieve and usually permanently staining any objects that came in contact with the oxidized material.

The ***Gravel Wetland*** outlet channel was gaged 8 times during 2017; data collected during the manual gaging process were used to calculate discharge (in cfs and mgd) and these data were paired with the Telog recorder level data collected from the ***Gravel Wetland*** outlet chamber for the same times that the gagings were performed to establish a rating curve that would define the discharge of water through this wetland component.

Three (3) of 8 channel gaging values representing low, mid and high level discharge through the outlet channel were used to generate the equation that described the relationship between the Telog water level in the outlet chamber and the discharge exiting the outlet channel into West Brook. The plot of this relationship is presented in Figure 8-6.

Figure 8-6



The relationship that links the two parameters (level and discharge) is linear, and described by the following equation

$$\boldsymbol{y = 0.9882x - 3.569}$$

where, $\boldsymbol{y}$ = Telog recorder level (in feet), and $\boldsymbol{x}$ = ***Gravel Wetland*** outlet channel discharge (in cfs).

The relationship described by the equation is very robust, with R^2 = 1.0; in other words there is total agreement between the two variables. The equation was used in the **Gravel Wetland** Telog data file to convert level readings (in feet) to mgd (million gallons per day) and these data were used to summarize daily discharge (in mgd) through the Pond 7 outlet chamber during the 13-month period of the study (see Table 8-# at the end of this chapter).

8.1.2 Storm Event Discharge

The runoff from storm events enters the wetland complex via the ***Inlet*** chamber at the head of the treatment chain (see Figure 8-1), although there likely is a limited amount of sheet flow along the edges of the various ponds when the intensity of rainfall is high. The volume of water that enters the wetland system is a function of the amount of the precipitation event and/or the extent of snow-melt during winter warming periods or late spring. The volume of water entering ***Pond 1*** will mix with water in the pond to a certain extent and also will displace an equivalent volume of water to ***Pond 2***, with a repeated effect down the treatment chain.

It is not the purpose of this chapter to evaluate the volume of water that passed through the wetland complex as a result of all the storm events that occurred during 2017-2018. Instead, this chapter will evaluate only those events that were monitored for discharge and water chemistry during the 13-month Program sampling effort.

A total of 6 runoff events were monitored for discharge and chemistry during the 2017-2018 sampling program including storms that occurred on October 24th and December 5th 2017, and on January 12th, May 19th, July 17th, and September 18th 2018. Table 8-1 summarizes important information for each runoff event including the amount of precipitation, duration of the runoff event, the number of times the Inlet chamber was manually gaged for discharge during the storm event and various comments concerning the storm events.

The amount of rainfall for each storm event was determined from monthly precipitation files received from the Cedar Lane Atmospheric Deposition Station adjacent to the Lake George Battlefield Park, which currently is operated by the ongoing Jefferson Project. This station originally was established by the report author and his colleagues during the 1980-1982 Lake George Urban Runoff Study (Sutherland et al. 1983) and subsequently relinquished to the Darrin Fresh Water Institute when JWS retired in 2005.The Cedar Lane station is located about

3,000 feet northeast of the wetland. Precipitation data from another station operated at the Village of Lake George Wastewater Treatment Plant were used as a reference to confirm the total amount of rainfall that occurred during each event; this rain gage is located about 1,750 feet southwest of the wetland complex..

Table 8-1

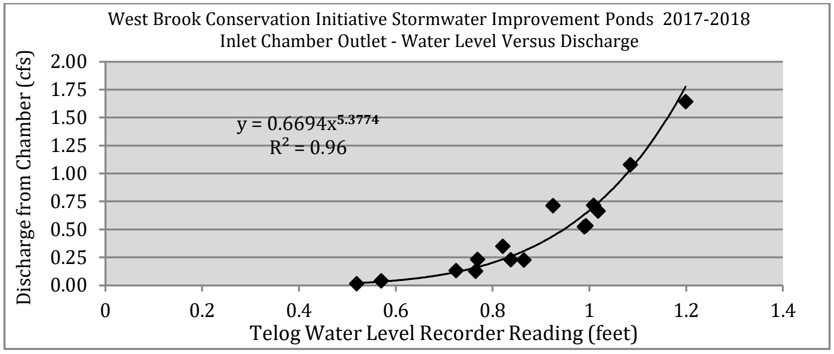
Event Date	Rainfall Amount	Rainfall Duration	# Manual Gagings	Comments
October 24th, 2017	0.80 inches	7 hours 14 minutes	6	rain, T-storm
December 5th, 2017	0.84 inches	13 hours 24 minutes	6	rain, T-storm
January 12th, 2018	2.14 inches	25 hours 39 minutes	0	rain + snowmelt
May 19th, 2018	0.44 inches	4 hours 58 minutes	5	rainfall
July 17th, 2018[1]	0.19 inches	3 hours 55 minutes	0	rain, short duration, less than predicted
September18th, 2018	0.69 inches	6 hours 31 minutes	2	rainfall, remnants of TS Florence
Totals	3.24 inches		19	
[1] Telog recorder data for this event were lost due to data not being downloaded before overwriting of file occurred				

The January 12th 2018 storm event included both precipitation falling as rain and melting of the snowpack that had accumulated in the sub-catchment, so the total amount of water associated with that event was unknown.

The outlet of the ***Inlet*** chamber was gaged 19 times during 2017-2018; data collected during the manual gaging process were used to calculate discharge (in cfs and mgd) and these data were paired with the Telog recorder level data collected from the ***Inlet*** chamber for the same times that the gagings were performed to establish a rating curve that would define the discharge of water through this wetland component. In some cases, the Telog recorder data had to be corrected by deducting the amount of sediment in the bottom of the ***Inlet*** chamber and these using the corrected level value to calculate discharge.

Four (4) of the 19 manual channel gagings were considered suspicious and were discarded from the set of values used to generate an equation that described the relationship between Telog recorder level and discharge from the ***Inlet*** chamber. The plot of the resulting relationship is presented in Figure 8-7.

Figure 8-7



The relationship that links the two parameters (level and discharge) is exponential, and is described by the following equation

$$\boldsymbol{y = 0.6694x^{5.3774}}$$

where, y = Telog recorder level (in feet), and x = ***Inlet*** chamber outlet channel discharge (in cfs).

The relationship described by the equation is robust, with $R^2 = 0.96$. The equation was used in the ***Inlet*** chamber Telog data file to convert level readings (in feet) to mgd (million gallons per day) and these data were used to summarize the monitored storm event discharge (in mgd) through the ***Inlet*** chamber.

The Telog water level data were lost for the July 17th storm event due to the fact that the recorder was not downloaded within a sufficient period of time following the event and the event data for that particular storm were overwritten by the recorder.

8.1.3 Summary of Wetland Discharge

The tables presented below summarize wetland discharge during the current study including the following: (1) precipitation that occurred and discharge through the ***Inlet*** chamber during the 6 storm events that were monitored in

2017 and 2018 (Table 8-2), (2) *average* daily discharge (in gallons) through the ***Pond 7*** outlet chamber during the period from August 22nd 2017 through September 30th 2018 (Table 8-3), and (3) *average* daily discharge (in gallons) through the ***Gravel Wetland*** outlet chamber during the same period (Table 8-4).

Table 8-2

	PRECIPITATION				
DATE	START TIME	STOP TIME	TOTAL DURATION	TOTAL AMOUNT (INCHES)	EVENT SAMPLED (INCHES)
October 24th	0826 hours	1540 hours	7 hours 14 minutes	0.80	0.80
December 5th-6th	1106 hours	0030 hours (13th)	13 hours 24 minutes	0.84	0.35
January 12th-13th	0222 hours	0401 hours (13th)	25 hours 39 minutes	2.14	0.50
May 19th	1142 hours	1640 hours	4 hours 58 minutes	0.44	0.44
July 17th	0508 hours	0903 hours	3 hours 55 minutes	0.19	0.19
September 18th	0144 hours	0813 hours	6 hours 31 minutes	0.69	0.69

	STORM EVENT				
DATE	START TIME	STOP TIME	TOTAL DURATION	TOTAL VOLUME (GALLONS)	VOLUME SAMPLED (GALLONS)
October 24th	0848 hours	0030 hours (25th)	16 hours 22 minutes	229,714	223,643
December 5th-6th	1215 hours	1155 hours (6th)	23 hours 40 minutes	264,125	94,730
January 12th-13th	0222 hours	0445 hours (13th)	26 hours 23 minutes	383,840	231,634
May 19th	1238 hours	1933 hours	6 hours 55 minutes	92,826	71,909
July 17th	storm data lost due to over-writing of data in recorder; didn't download soon enough				
September 18th	0147 hours	0830 hours	6 hours 43 minutes	171,362	171,150

The duration of each event was determined by the total elapsed time between the rise of the water level in the ***Inlet*** chamber until the return of the water to a steady level following the event.

8.2 Literature Cited

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program***.** New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + appendices.

Table 8-3

	2017					2018								
DATE	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1		34077	47438	44930	0	0	0	4190	14007	46358	82085	81159	135945	135945
2		30263	41129	70948	0	0	0	5826	12483	50028	112261	91475	135624	135624
3		89391	37815	54204	0	0	0	0	15636	55003	82902	98213	138867	138867
4		45748	38471	42000	0	0	0	0	42597	63062	98763	98592	228576	228576
5		34509	43474	42975	2215	0	0	0	19057	70298	63279	89987	174451	174451
6		45191	43190	62108	10486	0	0	0	16952	63301	55207	148655	157583	157583
7		53345	41441	32810	0	0	0	1846	15856	60265	53623	106128	163971	163971
8		34295	70094	24411	0	0	0	1526	10894	55323	53547	89725	174067	174067
9		28983	94894	18625	0	0	0	0	8338	59657	53907	81908	185852	185852
10		30561	58686	16143	0	0	0	0	10672	61733	55034	74095	171746	171746
11		28739	49796	5304	0	0	0	0	10662	56922	54717	71925	164131	164131
12		33867	46966	3798	0	21962	0	0	14879	50032	52691	71711	162171	162171
13		41531	38131	5103	0	19999	0	0	30484	44238	57957	73448	167078	167078
14		49862	37987	4511	0	0	0	0	15736	48843	92252	74259	228280	228280
15		59478	38592	4908	0	0	0	0	15421	53628	67634	90051	194926	194926
16		64296	40393	11807	0	0	0	0	61739	52769	66443	95395	184978	174978
17		67297	31626	5927	0	0	0	0	36833	66752	69733	107894	201495	201495
18		69720	27304	4605	0	0	0	0	23913	59576	76013	105664	229217	229217
19		72124	26078	31660	0	0	0	0	20605	71657	71392	85350	182246	172246
20		72833	26416	2768	0	0	16562	0	17454	64328	60528	74473	174008	174008
21		71562	24768	215	0	0	32726	0	20517	51226	54456	74418	170888	170888
22	88012	67209	24802	299	0	0	7741	0	24620	68777	50772	76037	180280	180280
23	85252	60108	24913	0	0	28216	0	0	29794	62253	54702	170800	166417	166417
24	57628	61242	54859	1016	0	0	0	0	35766	53932	85069	132384	153180	153180
25	50959	64294	46420	0	0	0	21209	0	76446	57962	93043	131214	150887	150887
26	45417	67986	35496	0	0	0	6707	0	80793	62267	69996	189027	149643	149643
27	47271	72542	31089	0	0	0	4149	0	56818	63116	89156	131658	151322	151322
28	45681	71965	26303	0	0	0	5759	7777	60368	58640	141019	129354	155772	155772
29	43096	59359	69162	0	0	0		8923	85826	61654	80518	136352	164239	164239
30	40599	58830	87490	0	0	0		32364	54468	63206	74552	134446	223554	223554
31	39068		29729		0	0		17672		65909		134399	171115	171115
average daily discharge (mgd)	54,298	54,707	43,063	16,369	410	2,264	3,388	2,585	31,321	58,797	72,442	104,845	173,952	179,084
total monthly discharge (mgd)	542,983	1,641,207	1,334,952	491,075	12,701	70,177	94,853	80,124	939,634	1,822,715	2,173,251	3,250,196	5,392,509	5,372,509

Table 8-4

	2017					2018								
DATE	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**
1		1324	0	24560	58797	57237	63034	73060	51020	102505	9648	28259	0	0
2		4334	0	81542	58789	55954	60349	67215	46205	113054	0	9062	0	0
3		120665	0	51226	58844	57759	54528	66059	47258	130921	13481	11438	0	0
4		65069	0	37564	57601	61925	59620	66210	96209	114986	46387	0	3059	0
5		35418	0	52366	95005	59074	60365	62361	46807	47876	31728	0	0	0
6		39901	0	98324	153751	58005	59248	62677	43631	144788	24600	42768	0	0
7		59375	0	57538	98205	58258	62440	62218	46807	126129	22390	4223	0	0
8		32195	37081	53309	92709	63929	61783	61173	36757	131309	26707	0	0	0
9		27110	64618	55368	91473	65061	60880	59541	36986	111795	26350	0	0	0
10		24148	8064	49365	93295	63477	63850	56421	36083	88068	21986	0	0	0
11		23158	0	45611	90523	67073	63818	55148	34943	50236	0	0	0	0
12		21424	0	49008	100121	187641	57466	53148	43987	117299	0	0	0	0
13		18549	0	52715	102941	158259	58139	55263	49879	110377	0	0	0	0
14		18431	0	54710	91172	79174	61862	56676	34333	115683	41762	0	0	0
15		13631	0	56864	75285	72838	63058	55090	34975	71460	0	0	0	0
16		10337	0	72799	67097	71080	63622	51817	150379	53411	4658	0	0	0
17		8175	1982	58353	61957	71136	58718	51297	86191	78548	9972	0	0	0
18		6425	0	55811	65497	69219	56627	39182	48795	14233	8911	0	0	0
19		6242	0	129052	69362	67010	58496	43454	45215	88678	2061	0	0	0
20		5173	0	76743	68538	65853	86848	45603	32226	57387	13972	0	0	0
21		0	0	65948	64824	63675	100977	45983	30619	25772	0	0	0	0
22		0	0	63564	63818	64364	73052	51966	28686	64071	0	0	0	0
23		0	0	65045	74660	167984	67944	48669	29051	26184	11263	2473	0	0
24		0	47654	66970	73242	85232	72830	52239	36590	15651	25843	0	0	0
25		0	32979	67857	75666	69069	87775	50222	151092	41603	6393	0	0	0
26		0	7153	62804	68039	65378	77558	49371	216595	0	0	0	0	0
27		0	3748	60088	63644	65546	72884	49727	167074	0	48897	0	0	0
28		0	5561	57775	60183	68182	74074	59453	208461	21963	115153	0	0	0
29		0	71302	58330	61244	67255		57867	159352	5601	31625	0	0	0
30		0	120546	60286	62028	65354		81072	104509	0	31617	0	0	0
31			24323		57942	62020		52710		5110		0	0	0
average daily discharge (mgd)	0	18036	13710	61383	76653	75936	66494	56222	72691	66926	19180	3168	99	0
total monthly discharge (mgd)	0	541084	425011	1841495	2376252	2354021	1861845	1742892	2180715	2074698	575404	98223	3059	0

West Brook Conservation Initiative Stormwater Improvement Ponds Wetland Complex - The Results of a Monitoring Program to Evaluate Current Treatment Efficiencies

----

2018 Final Report

Chapter 9

Background, 2017-2018 Monitoring Program and Methodology, Results and Discussion, Summary, Conclusions and Recommendations

This page intentionally left blank

9.0 Background

Stormwater runoff from West Brook entering south Lake George has been characterized by previous scientific investigations including Fuhs (1972), Sutherland et al. (1983), Hyatt et al. (1995), and Eichler and Boylen (2012). The focus on runoff from this watershed is warranted by the high density of developed area in close proximity to the lake and the impact of emerging ground water in the form of seepage streams that result from effluent applied to infiltration beds at the Village of Lake George Wastewater Treatment Plant (Aulenbach et al. 1975, Sutherland and Navitsky 2015).

The Canada Street (Route 9N) corridor south of West Brook has been recognized as a major contributor of contaminants including sand, road salt and forms of phosphorus to south Lake George for several decades (Sutherland et al. 1983, Eichler and Boylen, 2012). The corridor traverses a distance of 4,500 feet within the West Brook sub-catchment and the average width of the corridor (roadway + sidewalks) is 85 feet (2 lanes in both directions plus a turning lane in the middle), which translates to a total of 8.78 acres of impervious highway surface that drains directly to the wetland complex.

The West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) were constructed during 2011-2013 to capture and treat stormwater runoff from Canada Street and its contiguous developed areas totaling about 60 acres. The West Brook CI SIP has a surface area of 4.45 acre and consists of a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulate material and (2) support vegetation and bacterial communities that remove heavy metals, salts and excessive nutrients (Pier et al 2013). The effluent from the SIP enters West Brook and then flows into south Lake George.

During September 2012, naturally established plants growing in the SIP were removed, the original pond shapes were restored and 85 plant species were artificially introduced based upon a planting design prepared by Chazen Companies (2010) to mimic natural wetland vegetation gradients. Several modifications including mowing, skimming and weir lowering were made during the fall of 2013. The inlet to the West Brook SIP received flow beginning in October 2013.

The Darrin Fresh Water Institute (DFWI) initiated base-flow sampling of the West Brook SIP on 20 August 2013 and continued to collect base-flow samples on about a monthly basis through July 2014; 12 sets of base-flow samples were collected. Interim Reports issued by DFWI for the sampling program mention the collection of water chemistry samples for a single storm event that occurred on 27 and 28 November 2013.

With only one storm event sampled from the West Brook SIP during 2013-2014, it is not possible to evaluate the efficacy of this wetland system to treat stormwater runoff. Additional event monitoring is required before a thorough evaluation can be completed with definitive statements concerning treatment efficiency and possible recommendations associated with fine-tuning of the wetland ponds.

The Program Team (Sutherland and Navitsky) developed a work-plan to conduct an updated analysis and evaluation of the stormwater runoff in the West Brook CI SIP to determine whether the expected treatment of runoff is achieved by the construction design of the facility. The Program objectives include (1) implementation of sufficient base-flow and storm event monitoring to realize the goal of West Brook CI SIP evaluation, specifically with regard to storm event treatment, and (2) determine the amount and quality of ground water seepage that emerges from the southern slope adjacent to Pond #2 which appears to originate from higher elevations to the south along Canada Street. The summary and analysis of data collected during this study will determine the need and nature of any alternative strategies that could be recommended if fine tuning of the wetland is required.

9.1 2017-2018 Monitoring Program Summary

During early 2017, a small Working Committee comprised of the Lake George Land Conservancy, the Lake George Association and the Fund for Lake George held a series of meetings to discuss and develop a work-plan to study the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP). The intent of the study was to determine the extent to which the wetland complex was treating stormwater runoff from the sub-catchment before releasing the water to West Brook which discharges directly into south Lake George. The co-authors of this Final Report, also known as the Program Team (Sutherland and Navitsky), developed the monitoring work-plan and budget describing the strategy that would be used to evaluate the wetland complex and reviewed said document with the Working Committee before finalizing the monitoring program.

Data collected from the West Brook CI SIP prior to 2017 by the Darrin Fresh Water Institute were insufficient to allow a critical evaluation of this system with regard to its treatment efficiency. Base-flow samples were collected monthly from August 2013 through July 2014, while only a single storm event had been monitored during that period (November 27th-28th 2013).

The goal of the sampling program described in this Final Report was to conduct an updated analysis and evaluation of the stormwater runoff in the West Brook CI SIP to determine whether the expected treatment of runoff was being achieved by the construction design of the facility.

The program objectives included the following:

- Implementation of sufficient base-flow and storm event monitoring to realize the goal of West Brook CI SIP wetland complex evaluation, specifically with regard to storm event treatment of runoff from the subcatchmnet which was the basis for developing and constructing this stormwater treatment system.

With regard to the above objective, one of the report co-authors (CN) recalls that an original goal of the design and construction of the wetland was 50 percent removal of **phosphorus** and 90 percent removal of **TSS**.

Early during the Program while the work-plan was being developed, it was realized that ground water flow was moving through the wetland complex during non-event periods and was responsible for discharge from the ***Pond 7*** and ***Gravel Wetland*** outlets. Thus, a subsequent program objective was included to determine the nature of this contribution to the wetland complex.

- Determine the amount and quality of ground water seepage that emerges from the southern slope adjacent to Pond #2 which is believed to originate from higher elevations along south Canada Street and the Village of Lake George Waste Water Treatment Plant.

The summary and analysis of data collected during this study would determine the need and nature of any alternative strategies that could be recommended if fine tuning of the wetland was required.

The Program Team originally designed and implemented a 12-15 month program that included field sampling of base-flow and storm event conditions at locations within the wetland complex to examine the chemical characteristics of water passing through the series of ponds before exiting the wetland and flowing into West Brook.

Base-flow sampling. This type of sampling is exactly what the term implies, i.e., water sample collection during non-storm event periods to determine the chemical composition of the water in the wetland complex which is comprised of residual water from previous storm events and ground water entering the complex from higher elevations to the south and southwest.

Early in the Program, field excursions to sample base-flow included monthly sampling of the ***Pond 7*** outlet channel and less frequent sampling of the **Gravel Wetland** outlet because this component only received storm event discharge from the wetland complex during periods of high flow when the water elevation was exceeded at the weir located in ***Pond 6***. Later, base-flow sampling was expanded to include ***Pond 1*** and ***Pond 2*** at the head of the wetland complex based upon recommendations made by Bianca Wentzell in a summary report of a vegetation survey that was conducted in the wetland complex during August 2017.

Base-flow sampling at the wetland complex usually occurred when at least 72 hours had passed since any antecedent precipitation although this was not always the case.

Storm event sampling. A total of six (6) storm events were sampled during the Program in order to gather sufficient data to evaluate the processing of runoff through the wetland complex. Although close attention was paid to weather forecasting to help select appropriate storm events for monitoring, it was evident, particularly during the summer of 2018, that major events were very localized in nature, making storm event prediction less reliable than several decades ago during the Lake George Urban Runoff Study, even with the use of local weather radar for the south end of Lake George.

The wetland complex monitoring program was initiated on June 21st 2017 and concluded on September 19th 2018. There were a total of 27 separate field sampling excursions and a total of 108 samples collected for water chemistry and field measurements during the 13-month monitoring program.

Base-flow samples were transported immediately to the Darrin Fresh Water Institute (DFWI) laboratory in Bolton Landing for processing following collection. Storm event samples either were brought to the laboratory for processing immediately following the event or were kept on ice overnight and processed within 15-18 hours following collection.

All samples were processed in the laboratory by taking sub-samples determined by the specific analytes that comprised the base-flow and storm-water runoff *test pattern*. The primary test pattern for base-flow and event samples in this Program during the first 8 months included the following analytes:

- total phosphorus (TP),
- total filterable phosphorus (TFP),
- total nitrogen (TN),
- anions (nitrate-nitrogen (NO_3-N), sulfate (SO_4), and chloride (Cl)),
- cations (calcium (Ca), sodium (Na) and iron (Fe).)

During the last 5 months of the Program, the cation test pattern was expanded to include the metals listed above plus magnesium (Mg), copper (Cu), zinc (Zn), nickel (Ni), cadmium (CD) , and lead (PB). All of these cations are important constituents of highway runoff and adding these analytes to the test pattern occurred when seasonal traffic on the Canada Street corridor increased following the winter and spring of 2018. The expanded cation test pattern samples collected during the last 5 months of the Program were preserved and held in a refrigerator until delivery to the USGS Laboratory in Troy, NY for analysis during September 2018 when the sampling program was completed..

Total suspended sediment (TSS) was run on most samples immediately following collection and processing in the DFWI laboratory by the report co-author (JWS).

In order to obtain meaningful and accurate information concerning the amount of water processed by the wetland treatment system over a period of time, it was necessary to install water level recorders along the treatment chain to continuously collect water level data in different components of the wetland complex.

In addition to collecting continuous water level records at the ***Inlet*** chamber and the ***Pond 7*** and ***Gravel Wetland*** outlet chambers, it was necessary to manually gage different components of the system (Inlet chamber, Pond 7 and Gravel Wetland outlet chambers) to develop rating curves that would allow the conversion of water levels to discharge (either *cubic feet per second* or *million gallons per day*).

9.2 Results and Discussion

The West Brook CI SIP has been operable since October 2013 and accepting stormwater runoff from a sizeable subcatchment with considerable impervious area for several years without the benefit of a thorough evaluation of treatment efficiency to ascertain whether the system is functioning properly and/or to offer possible recommendations to achieve fine-tuning of the wetland ponds. As a result of these circumstances, the principal objective of the study detailed in this Final Report was to sample base-flow and storm event chemistry in the wetland complex to evaluate the treatment efficiency of the system to process runoff from the highly developed subcatchment which drains to this man-made remediation structure.

An aerial view of the West Brook CI SIP taken from Google™ Earth is shown in Figure 9-1. The view is looking from south to north and shows the different components of the wetland complex including ***Pond 1***, ***Pond 2*** and the ***Pond 7*** and ***Gravel Wetland*** outlets which were sampled for base-flow chemistry during the Program. The ***Inlet*** chamber at the head of the wetland complex receives flow from the highly developed subcatchment that includes the Route 9 (Canada Street) corridor and was the location where storm events samples were collected during the 2017-2018 sampling program.

Figure 9-1

Figure 9-1 traces the sequence of the wetland treatment process for storm event discharge entering the system from the ***Inlet*** chamber to ***Pond 1*** and then through the series of succeeding ponds, with water finally discharging either to ***Pond 7*** or to the ***Gravel Wetland***, depending upon the level of water in the area of the ***Pond 6*** weir. During dry (base-flow) conditions, however, water movement through the system is entirely dependent upon ground water flow which moves from higher elevation to the south (bottom of Figure 9-1) toward West Brook (top of Figure 9-1).

9.2.1 Base-flow

Base-flow chemistry conditions constitute the major portion of residence time for water in the wetland complex, either during extended periods of dry (non-storm event) weather or following events when some of the volume in the treatment chain has been displaced by runoff entering the chain, where it remains until replaced by the movement of ground water discharge through the area or runoff from a subsequent event. When runoff occurs, the volume of water at the head of the treatment chain becomes diluted and, depending upon the amount of runoff, water level in the head of the complex rises and initiates flow (movement of water) along the complex from one pond to the next toward the outlet. This situation explains why base-flow chemistry conditions are so important in terms of understanding how water in the wetland complex is treated as it moves along the treatment chain.

Plant nutrients. The *average* base-flow **nitrate-nitrogen** concentration decreased between ***Pond 1*** (0.14 mg $N \cdot L^{-1}$) and ***Pond*** *7* (0.02 mg $N \cdot L^{-1}$) during the study, indicating that uptake of this available plant nutrient was occurring along the treatment chain. In addition, the data suggest that **total nitrogen** increased in *average* concentration along the treatment chain, likely from the uptake of **nitrate-nitrogen** which produced **organic nitrogen** that eventually is discharged from ***Pond 7*** to West Brook.

The *average* concentration of **total filterable phosphorus** was unchanged between ***Pond 1*** (5.7 µg $P \cdot L^{-1}$) and the ***Pond 7*** outlet (5.8 µg $P \cdot L^{-1}$) to West Brook, indicating that there was no base-flow uptake of this moderate level of nutrient available for plant metabolism. *Average* concentrations of **total phosphorus** were unchanged along the wetland complex, with concentrations of 23.4 µg $P \cdot L^{-1}$ measured in ***Pond 1*** and 23.9 µg $P \cdot L^{-1}$ measured in ***Pond 7***.

The ratio of **total filterable phosphorus** concentration to **total phosphorus** concentration was the same when comparing the beginning and end of the treatment chain, indicating that **particulate phosphorus** contained in plankton and seston (dead and decaying organic material) comprised most of the **total phosphorus** measured in the wetland during base-flow.

Base-flow discharge from the ***Gravel Wetland*** showed a high *average* concentration of **total nitrogen** (14.9 mg $N \cdot L^{-1}$), which primarily is **organic nitrogen** contained in live or dead organisms, and a high *average* concentration of **total phosphorus** (106 µg $P \cdot L^{-1}$), which contained an *average* of 25 percent **total filterable phosphorus**.

Road salt constituents and associated parameters. The base-flow chemistry of **road salt** (**Na**, **Cl**) and associated parameters including **calcium**, **magnesium**, **specific conductance** and **total dissolved solids** exhibited a mixed response when comparing concentrations at the beginning and end of the treatment chain. *Average* concentrations of **sodium**, **chloride**, **specific conductance** and **total dissolved solids** were elevated in base-flow throughout the wetland chain, indicating that there is no treatment of **sodium** and **chloride**, although dilution may occur along the flow path from either ground water entering the system from higher elevations not affected by winter deicing practices or storm runoff during late summer and early fall following the cessation of highway deicing practices.

The is no base-flow **calcium** uptake during transport through the treatment complex; rather, the **calcium** concentration increases, and the primary sources of this cation entering the wetland complex are either ground water or runoff from previous storm events that contain remnants of Bulk Ice Control road salt applied in the subcatchment the transportation corridor along with dissolution of concrete-based structures in the sub-catchment.

The cation **magnesium** also increases during base-flow through the wetland complex, most likely from the use of ClearLane™ applied along the Route 9 (Canada Street) corridor and Bulk Ice Control road salt applied on other impervious surfaces in the subcatchment.

Road salt constituents (**Na**, **Cl**) and related parameters all exhibited seasonal patterns of base-flow concentration in the wetland ponds monitored during the 13-month sampling program, with the highest concentrations occurring during mid-winter and concentrations decreasing thereafter from dilution due to storm events and ground water movement flushing these analytes out of the subcatchment.

Other important highway runoff contaminants. The base-flow chemistry of heavy (trace) metals and other important highway runoff contaminants exhibited mixed results when comparing *average* concentrations measured in ***Pond 1*** and ***Pond 7***. **Nickel** exhibited a low *average* concentration in ***Pond 1***, but was not detectable in ***Pond 7***, suggesting that this cation settled out of the water column along the treatment chain. **Copper** was substantially reduced in *average* base-flow concentrations between ***Pond 1*** and ***Pond 7***. **Cadmium** and **lead** were present in low and moderate *average* concentrations, respectively, in ***Pond 1*** and ***Pond 7***, and both cations appear to pass through the complex during base-flow without an appreciable reduction in *average* concentration. The *average* **sulfate** concentration is unchanged by the wetland treatment process. **Zinc** exhibited the highest *average* base-flow concentrations throughout the wetland complex; there was no uptake or settling out of this cation.

9.2.3 Storm Events

Base-flow chemistry in the wetland complex is a dynamic condition because the pond contents constantly are being altered by the intrusion of ground water entering the system from higher elevations to the south. The rate of ground water movement is variable and affected by storm events which will increase the rate of ground water flow or extended dry periods which will slow the rate of ground water flow. Six (6) storm events were monitored as part of the 2017-2018 West Brook CI SIP sampling program to determine the water quality characteristics of runoff entering the wetland complex and the extent to which the wetland treatment process could modify the water quality entering the system.

Plant nutrients. The wetland complex receives a modest amount of 'plant' nutrient material from the subcatchment in the form of **total phosphorus** and **total filterable phosphorus**, with lesser amounts of **total nitrogen** and

nitrate-nitrogen. The **total filterable** (dissolved) **phosphorus** and **nitrate-nitrogen** are the forms of **phosphorus** and **nitrogen**, respectively, which are available for uptake by algae and plants as stormwater runoff moves through the wetland treatment chain.

The reduction of **total filterable phosphorus** (**TFP**) when comparing average concentrations entering the ***Inlet*** chamber and exiting ***Pond*** *7* ranged from 63-96 percent, with the 63 percent reduction occurring during mid-winter (January 2018) storm event when temperatures in the treatment chain were at a minimum and rates of metabolism but algae and plants would be low. The reduction of **TFP** through the treatment chain for the remaining 5 events ranged from 81-96 percent and the 4 highest efficiencies achieved were 91, 92, 95 and 96 percent.

The reduction of **nitrate-nitrogen** when comparing the beginning and end of the treatment chain process ranged from 64-99 percent, with the 64 percent value also occurring during the January 12th 2018 storm event, as documented and mentioned for **TFP** above. The remaining reductions of **nitrate-nitrogen** by the treatment chain were 92, 94, 98 and 99 percent, with one storm (July 17th 2018) exhibiting the same lower detection limit (0.005 mg $N{\cdot}L^{-1}$) for nitrate at both the ***Inlet*** and ***Pond*** *7* outlet.

Road salt constituents and associated parameters. There was no removal efficiency evident for road salt constituents (**Na**, **Cl**) and related parameters (**Ca**, **Mg**, **specific conductance**, **total dissolved solids**) from storm event runoff. In general, there was no capacity for wetland processing to lower these concentrations during any time of the year or, if there was, it was not apparent from the data collected during this 13-month study. The pattern of road salt and related parameters in the West Brook CI SIP subcatchment includes application (loading) of road salt to impervious areas from October-November through March-April each year, with elevated concentrations of these parameters entering the wetland complex during successive runoff events or accumulating in the road-side ice and snowpack until melting and runoff occur. Once high concentrations of these parameters enter the wetland and accumulate within the treatment chain, the only way that flushing of these materials occurs is through the mechanism of dilution from intrusion of ground water or from storm events that occur during the ice-free season (May through October).

The Canada Street corridor that drains to the West Brook CI SIP includes about 4,500 feet of highway with 2 travel lanes in each direction (north and south) plus a left-turn lane in the middle. With an estimated *average* of 13 tons of deicing compound applied per lane-mile within the Lake George drainage basin, the total application each winter to the Route 9 corridor within the wetland subcatchment converts to 55 tons of compound. The NYSDOT uses ClearLane™ Enhanced Deicer exclusively for winter highway maintenance, which includes **sodium chloride** (95.9%), **magnesium chloride** (26-29 of 4.1%), and **sodium** gluconate (0.25-0.35 of 4.1%), so we should expect elevated amounts of all of these constituents in runoff from the subcatchment. With 55 tons of material applied to the highway corridor on an annual basis, it is inconceivable that all of this material would be 'flushed' from the subcatchment during a single annual cycle or alternating dry periods and storm events.

Some of the road salt material that scatters off of the road surface and onto the shoulder containing vegetated areas will leach into the soils, displacing cations ('+' charged ions) from exchange sites in soils; these desorbed cations follow a simple ion-exchange model , with lower sodium and higher calcium, magnesium and potassium fluxes in surface runoff and in ground water (Sutherland et al. 2018) which, if up-gradient of the wetland complex will move toward West Brook carrying these constituents in the ground water flow.

Other important highway runoff contaminants. A substantial number of important highway runoff constituents (heavy metals, trace metals) were sampled during the 2017-2018 program including cadmium, copper, iron, lead, nickel, sulfate, zinc, and total suspended sediments during three (3) of the six (6) storm events that were monitored. In general, the results show that there was sufficient removal of these analytes from the wetland complex either through the settling of material along the wetland chain or dilution among different components of the wetland system from runoff due to non-monitored events or base-flow ground water moving through the complex.

The *average* removal of these metals from the wetland treatment chain when comparing the ***Inlet*** chamber and ***Pond 7*** outlet were as follows: nickel (100 percent), copper (94 percent), zinc (94 percent), total suspended sediments (93 percent), sulfate (79 percent), lead (70 percent), iron (35 percent) and cadmium (31 percent).

There is no evidence in the literature that deicing salts contribute to the increase in heavy (trace) metals concentrations. Instead, the concentrations appear to be influenced by the more intense wear of highway pavement during the winter by studded tires in combination with the chemical effects of deicing salts used for maintenance (Karlsson et al. 2003).

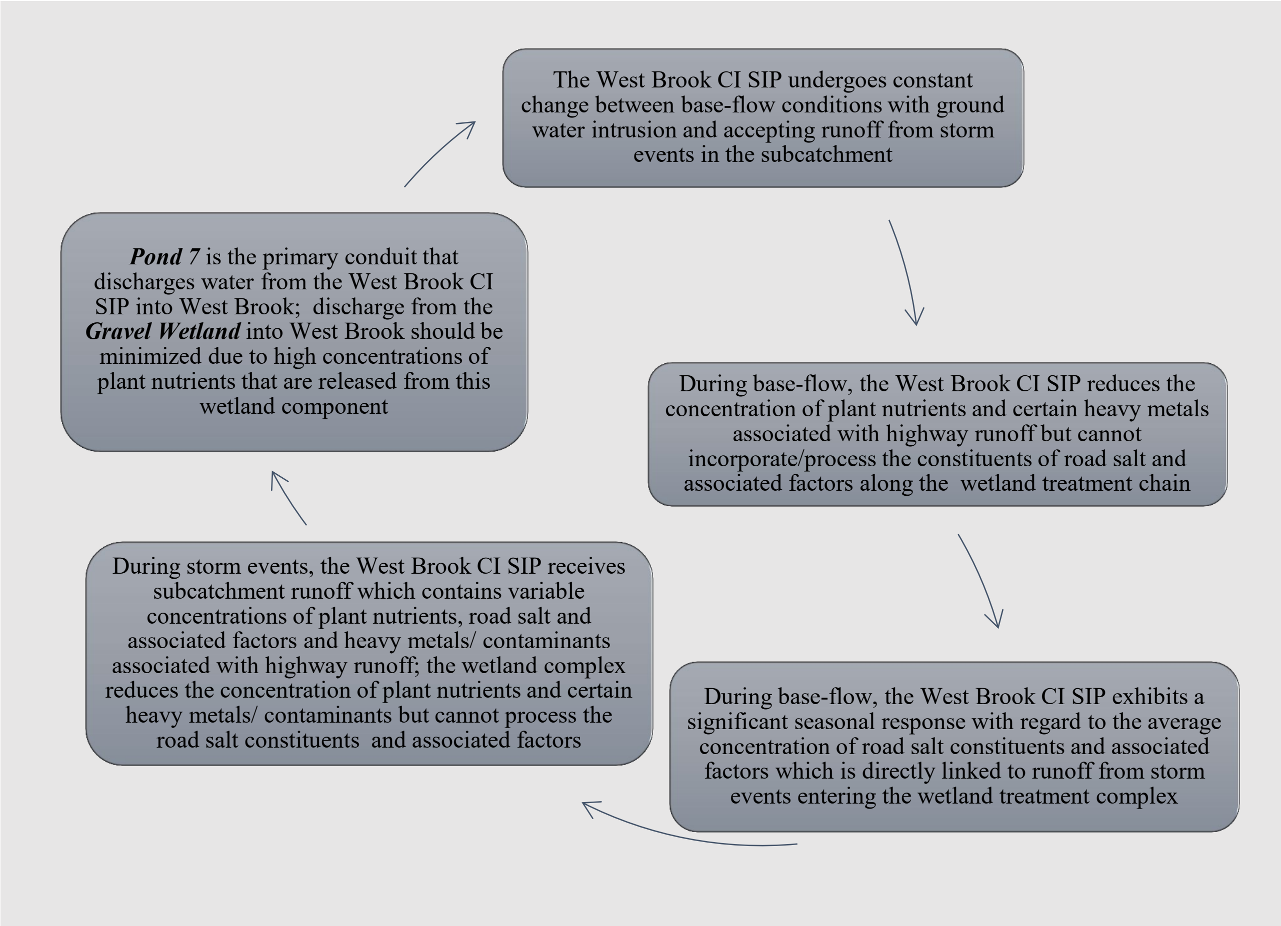
It was not possible to determine the water quality of ground water entering Pond 2 from higher elevations due to reduced levels of ground water intrusion during the study period and the inability to collect sufficient volume of samples that could be submitted for chemistry analysis.

9.3 Summary

The West Brook CI SIP is a dynamic feature of the south Lake George landscape that functions during base-flow conditions as well as during storm events. Early during the 2017-2018 sampling program it was realized that ground water is flowing from higher elevations to the south of the wetland complex through the wetland and into West Brook via the outlets for ***Pond 7*** and the ***Gravel Wetland***.

The conceptual diagram presented in Figure 9-2 is a concise summary of the West Brook CI SIP and its ability to function toward improvement of the water quality of storm event runoff from the highly developed subcatchment.

Figure 9-2



The effectiveness of the West Brook CI SIP to treat stormwater runoff from a highly developed impervious area was determined during the 2017-2018 sampling program presented in this final report. The current treatment efficiencies are best described as very satisfactory for the available plant nutrients **nitrate-nitrogen** and **total filterable phosphorus**. The overall average removal efficiency for **nitrate-nitrogen** in the wetland complex was 89 percent, while the average removal efficiency for **total filterable phosphorus** in the wetland complex was 86 percent.

The ability of the wetland treatment chain to process important **highway runoff heavy (trace) metals** and **total suspended sediments** was more variable with **nickel** (**Ni**) completely (100 percent) removed from the water column, while the wetland complex was less able to process **iron** (**Fe**) and **cadmium** (**Cd**) with *average* removal efficiencies of 35 percent and 31 percent, respectively.

On the other hand, **road salt** (**Na**, **Cl**) and related parameters including **calcium** (**Ca**), **magnesium** (**Mg**), **specific conductance** (**spC**) and **Total Dissolved Solids** (**TDS**) passed through the wetland chain without any uptake or processing before exiting ***Pond*** *7* into West Brook.

It was not possible to achieve Objective #2 of the current study which was to characterize the water quality of the ground water entering Pond 2 due to low levels of intrusion during the 13-month period and the inability to collect sufficient volume of samples for chemistry analysis.

9.4 Conclusions

The following conclusions have been developed after careful consideration of the data collected during the recently completed 13-month study of the West Brook Conservation Initiative Stormwater Improvement Ponds (West Brook CI SIP) wetland:

(1) The West Brook CI SIP wetland was constructed during 2011-2013 to capture and treat stormwater runoff from Canada Street and its contiguous developed area totaling about 63.9 acres.

(2) The West Brook CI SIP wetland has a surface area of 4.45 acres and is a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulate material and (2) support vegetation and bacterial communities that remove heavy metals, salts and excessive nutrients (Pier et al 2015); the effluent enters West Brook and then flows into south Lake George.

(3) The West Brook CI SIP wetland is a dynamic feature of the south Lake George landscape that functions during base-flow conditions as well as during storm events. Early during the 2017-2018 sampling program, it was realized that there is significant ground water intrusion into the wetland system from higher elevations to the south, which moves through the wetland and into West Brook via the outlets for ***Pond 7*** and the ***Gravel Wetland***.

(4) During base-flow conditions, the West Brook CI SIP wetland reduces the *average* concentration of **plant nutrients** and certain **other important highway runoff contaminants** through the processes of uptake and settling out of the water column, respectively, although dilution from ground water intrusion also could be a factor in the reduced *average* concentrations.

(5) During base-flow conditions, there is no definitive evidence that the West Brook CI SIP wetland is able to incorporate and/or process the **road salt (Na, Cl) constituents and associated parameters** including **calcium**, **magnesium**, **specific conductance** and **Total Dissolved Solids**.

(6) Storm event runoff from the West Brook CI SIP wetland subcatchment introduces moderate-to-high *average* concentrations of **plant nutrients** and **road salt constituents and associated parameters** and low-to-moderate *average* concentrations of **important highway runoff contaminants.**

(7) The West Brook CI SIP wetland reduces the *average* concentration of **plant nutrients** and certain **other important highway runoff contaminants** between the beginning of the wetland complex (***Pond 1***) and the end of the treatment chain (***Pond 7***) through either uptake or settling or some combination of these factors.

(8) The full extent of concentration reduction of **plant nutrients** and **other important highway contaminants** is detailed in this Final Report; however, with regard to the original goal of the design and construction of the wetland complex achieving 50 percent removal of **phosphorus** and 90 percent removal of **TSS**, the system has proven to perform above expectations, with an average removal of phosphorus of ~85 percent and an average removal of TSS of 92 percent, as described in this Final Report.

(9) Storm event runoff from the West Brook CI SIP wetland subcatchment introduces low-to-high *average* concentrations of **road salt constituents and associated parameters** which exhibit a significant seasonal cycle of *average* concentration; there was no definitive evidence during the current study that the wetland system is able to process these parameters except perhaps through dilution from ground water intrusion.

(10) The ***Gravel Wetland*** is not an appropriate conduit for processing stormwater runoff because it provides fluctuating levels of *average* concentrations of **plant nutrients** and high *average* concentrations of **road salt constituents and associated parameters**, suggesting that this wetland component alternates between functioning as a 'sink' and a 'source' of analytes which discharge into West Brook.

9.5 Recommendations

The following recommendations have been developed after careful consideration of the water quality data collected during the current 13-month study of the West Brook CI SIP wetland complex reported in this final report and are presented for consideration by the West Brook CI Easement Committee (Committee).

(1) The Committee should consider continuing some level of water quality monitoring at the wetland complex to maintain an awareness of the facility and develop a long-term historic record that can be used to evaluate either any land use changes in the subcatchment or implementation of any recommendations presented in this report or developed in the future. A modest water quality monitoring program could include monthly base-flow samples collected from ***Pond 1***, ***Pond 2***, ***Pond 7*** and the ***Gravel Wetland,*** which would be submitted to the DFWI laboratory for analysis using the same test pattern presented herein, including the heavy metals and other contaminants submitted to the USGS Laboratory in Troy New York. Some very limited storm event sampling could occur, such as a sustained spring snow-melt using the automated samplers to collect water for chemical analysis. In addition, the recording and downloading of water level data to document the hydrology of the facility should be continued.

(2) The Committee should enter into discussions with the New York State Department of Transportation and encourage this agency to implement 'smart' technology road salt application along the entire State Route 9 corridor in the Lake George drainage basin but particularly the segment that discharges to the West Brook CI SIP. Any activity that would reduce the amount of road salt application on an annual basis would likewise reduce the amount of road salt constituents and associated parameters that pass through the wetland complex and enter West Brook and then south Lake George. It is suggested to implement Best Management Practices with 'smart' technology actions including the application of brine solution prior to anticipated storm events, the use of 'live-edge' plows, and installing meters and GPS systems in trucks that maintain the corridor so that actual applied amounts can be determined and recorded.

(3) The Committee should investigate the possibility of having the portion of State Route 9 (Canada Street) within the wetland subcatchment cleaned with a sweeper each spring and on a regular basis during the ice-free period of the year to remove sediment and other important highway contaminants from the road surface and minimize the concentrations of these heavy (trace) metals that enter the wetland complex.

(4) The Committee should consider temporarily adjusting the level of the weir in ***Pond 6*** to reduce the amount of water entering the ***Gravel Wetland*** during periods of heavy precipitation and high discharge (flow) through the wetland because this component of the treatment chain currently appears to be a significant source of high concentrations of plant nutrients and road salt constituents and associated parameters to West Brook which should be reduced to the extent possible. Once the amount of water flowing into the

Gravel Wetland has been reduced, maintenance, in the form of plant harvesting, should be conducted during the winter months to determine whether this strategy has any effect on the performance efficiency of this wetland component as compared with the results documented in the 2017-2018 study reported herein.

(5) The Committee should agree to continue some regular schedule of meetings each year (bi-monthly, quarterly) to keep all participants informed of any activities and/or changes that have occurred at the site and to also keep all participants active in the long-term management of this important functional component of the south Lake George landscape.

These recommendations are not presented in any particular order of importance except for the first recommendation which proposes that a certain level of monitoring be continued beyond the period of the study that just concluded.

9.6 Literature Cited

Aulenbach, D.B., N.L. Clesceri, T.J. Tofflemire, S. Beyer and L. Hajas. 1975. *Water Renovation Using Deep Natural Sand Beds*. Jour. AWWA 67(9): 510-515.

Chazen Companies. 2010. *West Brook Conservation Initiative South Parcel Stormwater Improvements. Landscape Plan Plant Tables*. Chazen Job 90730.04.

Eichler, L.W. and C.W. Boylen. 2012. *West Brook Stormwater Runoff Study*. DFWI Technical Report 2012-3. Prepared for The FUND for Lake George. 28 pp. (including appendices).

Fuhs, G.W. 1972. *The Chemistry of Streams Tributary to Lake George, New York*. New York State Department of Health, Albany, New York. Environmental Health Report No. 1. 52 pp. + appendix.

Hyatt, R.M., J. W. Sutherland and J.A. Bloomfield. 1995. *Final Report: A Study of the Feasibility of Reducing the Impacts of Stormwater Runoff in Developed Areas of the Lake George Park*. New York State Parks Management and Research Institute, Saratoga Springs, New York. Lake Services Section, Division of Water, New York State Department of Environmental Conservation, Albany, New York. 115 pp. + appendices.

Pier, B.M., B.R. Dresser, J.J. Lee, C.W. Boylen, and S.A. Nierzwicki-Bauer. 2015. Ecological analysis before and after planting in a constructed wetland in the Adirondacks. Wetlands35: 611-624. DOI 10.1007/s13157-015-0652-4

Sutherland, J.W. and C. Navitsky. 2015. Final Report. *Village of Lake George Wastewater Treatment Plant – A Monitoring Program to Document Current Treatment Efficiencies.* Prepared for The Village of Lake George. 129 pp. + appendices.

Sutherland, J. W., J. A. Bloomfield and J. M. Swart. 1983. *Final Report: Lake George Urban Runoff Study, U. S. Environmental Protection Agency Nationwide Urban Runoff Program***.** New York State Department of Environmental Conservation, Division of Water, Bureau of Water Research. Albany, New York. 84 pp. + Appendices.

Sutherland, J.W., S.A. Norton, J.W. Short, and C. Navitsky. 2018. Modeling salinization and recovery of road salt-impacted lakes in temperate regions based on long-term monitoring of Lake George, New York (USA) and its drainage basin. Sci. Total Environ. 637-638, 282-294.