West Brook Conservation Initiative Stormwater Improvement Ponds

A Monitoring Program to Evaluate Current Treatment Effectiveness

2019 Annual Report

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 Board of Supervisors

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Title of the Program: **West Brook Conservation Initiative Stormwater Improvement Ponds. A Monitoring Program to Evaluate Current Treatment Efficiencies**

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Component 1. Background

The West Brook Conservation Initiative Stormwater Improvement Ponds (CI SIP) complex was constructed to capture and treat runoff from Canada Street and the contiguous heavily developed area of ~63.9 acres. Much of the area that drains to the wetland complex includes impervious surfaces, with a major portion including the Canada Street (Route 9) corridor that extends south to the intersection of Route 9N (distance of ~4,500 feet; surface area ~7.8 acres). The wetland treatment complex covers 4.45 acres and includes a series of connected settling ponds that provide contaminant removal by (1) reduction in flow which allows settling of particulates and (2) support vegetation and bacterial communities that are supposed to remove heavy metals and excess nutrients (Pier et al. 2015). The SIP effluent enters West Brook near the outflow to Lake George.

The largest component of storm 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. Runoff from Canada Street and other sub-watershed areas can contain nitrogen and phosphorus through wet and dry deposition, while maintenance of vegetated areas in commercial and residential areas also can contribute nutrient loading from fertilizer application.

The application of winter highway deicing compounds, e.g., NaCl, may contribute to the deterioration of vehicles and highway structures and increase heavy metal concentrations. Road salt also may contain trace amounts of heavy metals such as nickel, cadmium and cyanide (anti-caking compound) which can be released in solution. Precipitation and snowmelt can result in runoff containing high amounts of Na, Cl, and Ca from highway deicing materials. Calcium also can be leached from concrete structures.

Sediment can be problematic in the sub-watershed draining to the wetland. The source of sediment is from the erosion of vegetated surfaces and from sand included with highway road salt to provide abrasion on slippery winter surfaces. In addition to settling out of runoff and adding material to the wetland pond bottom, sediment also carries the plant nutrient, phosphorus, which can be adsorbed to its surface and certain metals.

Component 2. The 2017-2018 Monitoring Program Overview

The Program Cooperators sponsored the 15-month Monitoring Program (MP) which began during the 3rd quarter (August) of 2017 and was completed during the 3rd quarter (September) of 2018. The goal of this MP 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 MP objectives included the implementation of regular base-flow sampling and sampling of selected storm events. The program utilized a very basic means of assessment, the comparison of contaminant concentrations entering and exiting the wetland complex, to determine efficiencies of the treatment chain.

The duration of the MP was determined by the time it took to successfully sample storm events and collect sufficient data to summarize, analyze, and evaluate the wetland nutrient and contaminant removal efficiency. The MP sampling protocol was modified to include specific recommendations in the Final Report for the August 2017 wetland vegetation survey conducted by Bianca Wentzell, which specifically identified Pond #1 and Pond #2 as important components of the wetland sampling protocol based upon their treatment potential along the wetland chain.

Base-flow Sampling

Base-flow samples were collected almost monthly and also just prior to sampling of selected storm events; samples were collected from ***Pond-1***, ***Pond-2*** and the ***Pond-7*** outlet. The ***Gravel Wetland*** outlet was sampled less frequently because this structure only serves as an overflow for ***Pond-7*** above certain water levels but does continue to provide continuous discharge to West Brook when ground water levels provide sub-surface discharge through the complex. The sampling of ***Pond-2*** became problematic during a portion of the MP due to the shallow nature of the pond and the overabundance of vegetation; getting a clean water sample was just not possible on some occasions. A total of 48 base-flow samples were collected during the study.

Storm Event Sampling

A total of 6 storm events were monitored during the program, including 2017 storm events that occurred on October 24th and December 5th, 2017, and 2018 storm events that occurred on January 12th, May 19th, July 17th, and September 18th, 2018. Table 1 below 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.

Table 1.

Event Date	Rainfall Amount	***Inlet***	***Pond 1***	***Pond 2***	***Pond 7***	***GW***	Total Samples
October 24th, 2017	0.69 inches	6			6	1	13
December 5th, 2017	0.84 inches	6			2	1	9
January 12th, 2018	1.07 inches	5			4	2	11
May 19th, 2018	0.50 inches	7	1		2		10
July 17th, 2018	0.14 inches	4	1	1	1		7
September 18th, 2018	0.55 inches	6	2		2		10
Totals	3.79 inches	34	4	1	17	4	60

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 is operated by the 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 in the area during each event.

The duration of each event was determined by the total elapsed time between the increase 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. However, an algorithm was developed using the ***Inlet*** discharge calculations to estimate the amount of water that passed through the chamber and then used back-calculations to determine the inches of water that provided runoff from the sub-catchment.

Seepage Sampling

The original MP work-plan included a task to monitor seepage entering ***Pond-2*** from the higher elevations to the south of the wetland complex, particularly because the chemistry of the pond seemed to be heavily influenced by this ground water influence. Unfortunately, ground water movement through the pond declined during the MP and seepage entering the pond never was sufficient to collect water samples that could be analyzed for chemistry.

Chemistry test pattern

There was a seasonal modification to the MP test pattern of analytes that were sampled in runoff entering the wetland. As mentioned above, some constituents like heavy metals are considered important components of highway runoff and were added to the test pattern during the spring and summer of 2018 coincident with increased corridor transportation as a result of area tourism. JWS contracted with the USGS District Laboratory in Troy, New York and made arrangements for submitting runoff samples for the analysis of copper (Cu), zinc (Zn), iron (Fe), nickel (Ni), cadmium (Cd), lead (Pb), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg) during the remainder of the Program.

Component 3. The 2018 Final Report

A Final Report for the MP was issued in December 2018. The material in this final report presented, summarized and evaluated the variety of data collected during the 13-month program and also provided conclusions and recommendations. The report was organized as follows:

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

Chapter 2 provided 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 provided 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 included a detailed description of the 2017-2018 monitoring program and methodology.

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

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

Chapter 7 provided 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 provided a summary of water movement through the wetland complex during base-flow and storm events.

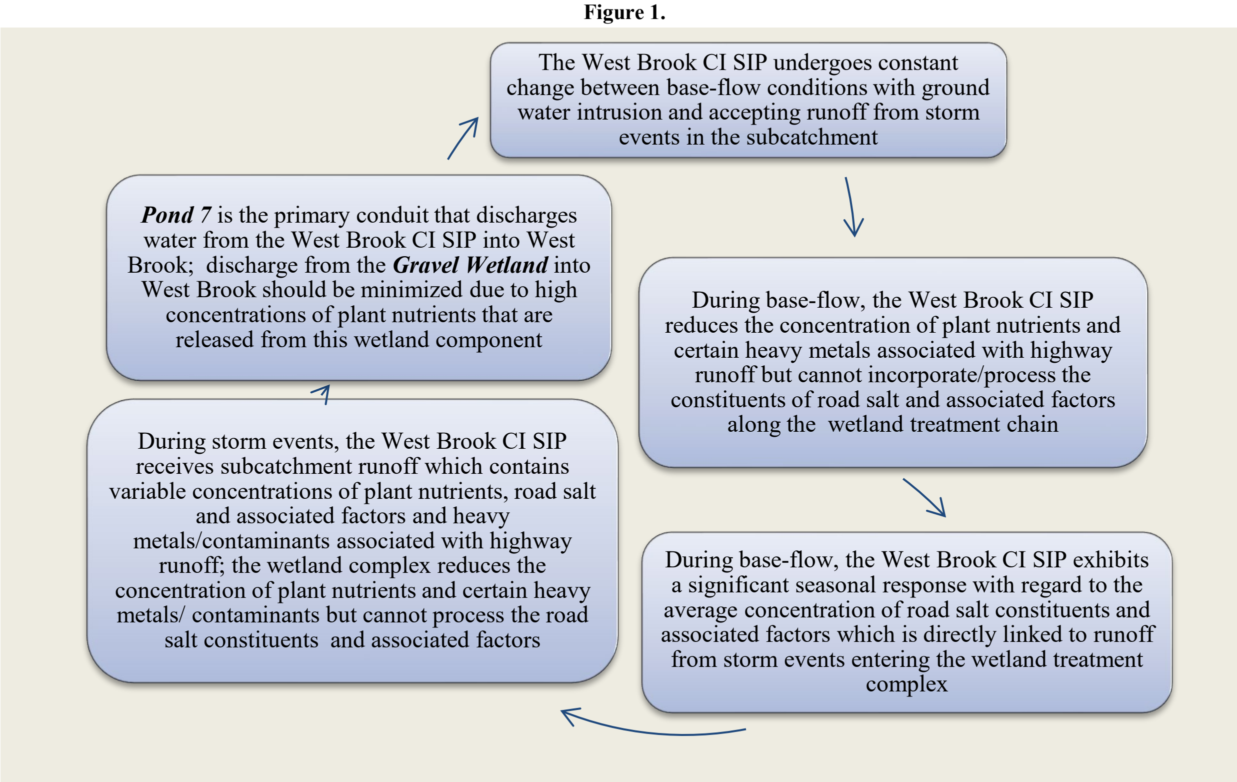
Chapter 9 presented historical background information, a description of the 2017-2018 MP methodology, results and discussion, a brief program summary, conclusions and recommendations.

Final Report 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 MP 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 is a concise summary of the West Brook CI SIP and its ability to function regarding improvement of the water quality of storm event runoff from the highly developed subcatchment that drains to the wetland.

Figure 1.



The effectiveness of the West Brook CI SIP to treat stormwater runoff from a highly developed impervious area was evaluated during the 2017-2018 sampling program. The current treatment efficiencies were 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** 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 through ***Pond-7*** into West Brook.

It was not possible to achieve Objective #2 of the proposed 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.

Final Report Conclusions

The following conclusions were developed after careful consideration of the data collected during the 13-month study of the 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 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 continuous 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 reduction of *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 (***Pond-1***) and end (***Pond-7***) of the wetland complex through either uptake or settling or some combination of these factors.

(8) 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.

(9) The ***Gravel Wetland*** is not an appropriate conduit for processing stormwater runoff because it exhibits 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.

Final Report Recommendations

The following recommendations were developed after careful consideration of the water quality data collected during the 13-month study of the West Brook CI SIP wetland complex reported in the final report and were 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. A long-term historic record should be developed to evaluate (1) any land use changes in the subcatchment or (2) the 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-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 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 wetland complex. Any activity that would reduce the amount of road salt application on an annual basis would reduce the loading of road salt constituents and associated parameters that pass through the wetland complex and enter West Brook and then south Lake George. Suggested activities include the application of brine solution prior to anticipated storm events, the use of 'live-edge' plows, and metered application of road salts so that actual applied amounts can be recorded and used for loading calculations in the wetland complex subcatchment.

(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 implementing maintenance in the ***Gravel Wetland*** such as plant harvesting during the winter months to remove biomass and potential plant nutrient material in an effort to evaluate whether this component of the treatment chain can perform more efficiently than documented in the 2017-2018 study reported herein.

The recommendations were not presented in any particular order of importance except for the first recommendation which proposed that a certain level of monitoring be continued into the future.

Component 4. The Proposed Water Quality Monitoring Program for 2019 and Beyond

The Committee accepted and formally approved a continuation of water quality monitoring at the wetland complex for 2019 and beyond based upon a brief proposal prepared by the report author (jws). A copy of this proposal is included in Attachment #1 at the end of this report.

The basic water quality monitoring program for continuation during 2019 and beyond was envisioned as being comprised of base-flow sampling and storm event sampling as follows:

- **Base-flow sampling** monthly (May thru December) with water samples collected from the ***Pond 7*** outlet chamber; the ***Gravel Wetland*** will be sampled 2 times each year at the outlet chamber.
- **Storm event sampling** of one major event each year when the advanced forecast seems reliable; focus will be on a major snow-melt and/or a tropical storm. Water samples during each event will be collected from the ***Inlet chamber*** and the ***Pond-7*** and ***Gravel Wetland*** outlets. Base-flow samples will be collected just prior to the monitored storm event at the ***Pond-7*** and ***Gravel Wetland*** outlets.

Of course, as with any proposed monitoring program, there was a certain amount of flexibility inherent in the design of the work-plan based upon the unpredictable climatic conditions that have been occurring in this region during the past several years, which particularly results in unreliable forecasting of storm events and oftentimes the appearance of sudden and unexpected storm events which are not possible to plan for as far any monitoring. Such was the case during 2019 when monitoring at the wetland complex included only base-flow sampling and, unfortunately, no sampling of 2019 storm events.

The chemistry test pattern for analysis of samples collected from the wetland was the same as used during the 2017-2018 study:

Anions	Nutrients	Other	Cations
Cl, NO3, SO4	**TP, TFP, TN**	**TSS**	**Ca, Mg, Na, K, Pb, Zn, Fe, Cu, Cr, Cd, Ni, Mn**

Samples were processed at the Darrin Fresh Water Institute (DFWI) in Bolton Landing following collection, and the anion and nutrient series submitted at that time for analysis. The cation samples were preserved and stored until the end of the 2019 sampling season and then submitted to the USGS Laboratory in Troy, New York for analysis. The TSS samples usually were collected only during storm events, so no TSS samples were collected and processed during 2019.

2019 Monitoring Program

Five (5) separate sampling excursions were conducted at the wetland complex in 2019 during **base-flow** conditions for a total of 13 samples as summarized in Table 2 below.

Table 2.

Inlet chamber	Pond-7	Gravel Wetland	Comments
April 30th	April 30th	April 30th	Base-flow sample
June 4th	June 4th	June 4th	Base-flow sample
July 2nd	July 2nd	July 2nd	Base-flow sample
	September 24th	September 24th	Base-flow sample
	October 22nd	October 22nd	Base-flow sample

An interesting feature during the first 3 excursions in 2019 was the observation of continuous flow passing through the ***Inlet chamber***, which persisted through the July 2nd sampling but then ceased prior to September 24th. Flow during **base-flow** conditions during the late spring and early summer had not been observed during the 2017-2018 study and may only occur when there is sufficient precipitation to raise the level of ground water in the area which flows toward the wetland from higher elevations.

No storm events were monitored during 2019 either due to the unpredictable nature of certain events forecast to occur or due to the unavailability of personnel to dedicate time to the monitoring effort.

A special sampling excursion was conducted on October 22nd to collect sediment samples from ***Pond-1***, ***Pond-2,*** and ***Pond-7*** for a Target Analyte List of metals (US EPA Method 6010C/7471B) as background information for future dredging and disposal of soils from these ponds to increase water depth. These samples were submitted to Phoenix Environmental Laboratories, Inc. in Manchester, CT for analysis on the day collected.

Component 5. The Results of the 2019 Water Quality Monitoring Program

The chemical characteristics of base-flow were evaluated by comparing the ***Inlet chamber*** 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 section 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, specific conductance and total dissolved solids, and (3) other important highway 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 is comprised of water retained in the system from previous storm events and ground water continuously entering the system from higher elevations to the south.

Nutrients

The chemistry sampling program for the wetland complex has a *test pattern* that includes the plant nutrients **total nitrogen** (**TN**), **nitrate-nitrogen** (**NO3-N**), **total phosphorus** (**TP**), and **total filterable phosphorus** (**TFP**), which is the same as the test pattern followed during the 2017-2018 study. Table 3 presents a summary of *maximum*, *minimum* and *average* concentrations measured for these nutrients during the 13-month sampling period in the ***Inlet chamber*** and the ***Pond-7*** and the ***Gravel Wetland outlets.***

Table 3.

	TN (mg/L)	NO3-N (mg/L)	TP (µg/L)	TFP (µg/L)
Inlet chamber				
Inlet *minimum*	0.44	0.31	41.1	39.3
Inlet *maximum*	0.55	0.42	114.2	80.8
Inlet *average*	0.51	0.35	74.0	60.0
# of samples	3	3	3	3
Pond- 7 outlet				
Pond-7 *minimum*	0.18	0.005	11.8	2.6
Pond-7 *maximum*	0.31	0.03	20.2	5.3
P-7 *average*	0.25	0.02	16.7	4.2
# of samples	5	5	5	5
Gravel Wetland outlet				
Gravel Wetland *minimum*	0.34	0.005	180.0	3.0
Gravel Wetland *maximum*	1.27	0.005	280.4	12.6
Gravel Wetland *average*	0.97	0.005	196.2	5.6
# of samples	5	5	5	5
0.00 = value reported is one-half the lower limit of detection				

Nitrogen. Some characteristics of the base-flow nitrogen dynamics in the West Brook CI SIP wetland complex during 2019 that are apparent from the data summarized in Table 3 are as follows:

- The *average* **NO_3-N** concentration of base-flow entering the ***Inlet chamber*** from late April to early July was high (0.35 mg·L^{-1}) while the *average* concentrations measured in the ***Pond-7*** and ***Gravel Wetland*** outlets from late April to late October either were low (0.02 mg·L^{-1}) or below detection (0.005 mg·L^{-1}), respectively.
- About two-thirds of the average **TN** entering the ***Inlet chamber*** from late April through early July was in the form of available **NO_3-N**, while the remainder was in the form of **organic nitrogen** (**ON**).
- Essentially all of the **TN** exiting the wetland complex from late April through late October was in the form of **ON**, whether from the ***Pond-7*** (0.25 mg·L^{-1}) or ***Gravel Wetland*** (0.97 mg·L^{-1}) outlets.
- The *average* **TN** concentration in the ***Pond-7*** outlet (0.25 mg·L^{-1}) was one-half the *average* concentration measured in the ***Inlet chamber*** (0.51 mg·L^{-1}), while the *average* concentration in the ***Gravel Wetland*** outlet (0.97 mg·L^{-1}) was twice as high as the Inlet chamber *average* concentration.

Wetland complex samples collected during the 2017-2018 study were submitted for analysis of **ammonium-nitrogen** on several occasions with concentration results that were below the detection level (<0.01 mgL^{-1}). Thus, if we consider that **ammonium** and **nitrite** are minor forms of nitrogen in the wetland system, then the major component of **total nitrogen** being measured during 2019 would be **organic nitrogen**.

Phosphorus. Some characteristics of the base-flow phosphorus dynamics in the West Brook CI SIP wetland complex during 2019 that are apparent from the data summarized in Table 3 are as follows:

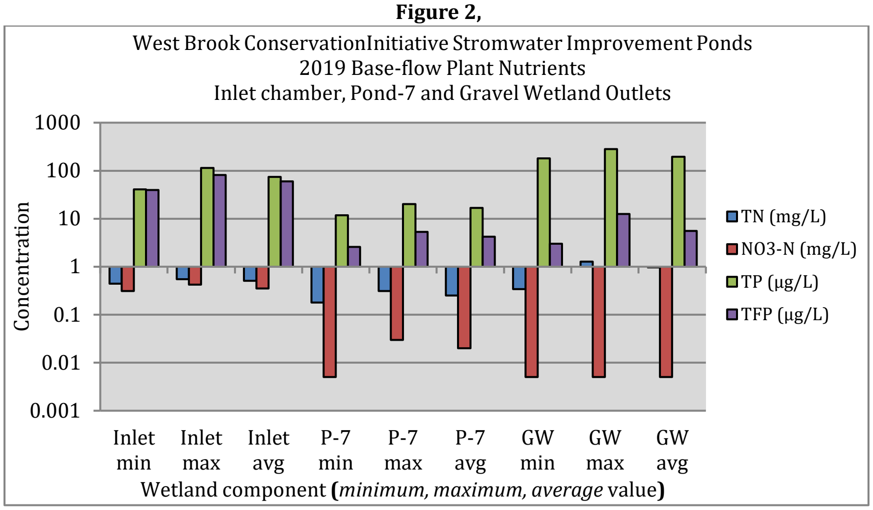
- The *average* **TFP** concentration of base-flow entering the ***Inlet chamber*** from late April through early July (3 sampling dates) was high (60 µg·L^{-1}) and comprised about 85 percent of the *average* **TP** concentration (74 µg·L^{-1}) during the five sampling dates.
- About 15 percent of the average TP concentration entering the ***Inlet chamber*** from late April through early July included **organic phosphorus** (**OP**).
- There was an *average* reduction in **TFP** concentration of 93 percent between the ***Inlet chamber*** and the ***Pond-7 outlet***, while there also was a 77 percent reduction in the *average* **TP** concentration between the ***Inlet chamber*** and the ***Pond-7 outlet***.
- The ***Gravel Wetland*** did not perform phosphorus removal as efficiently as ***Pond-7***; the *average* **TFP** concentration was reduced 91 percent, from 60 µg·L^{-1} entering ***Inlet chamber*** to 5.6 µg·L^{-1}.

- There was ~2.6-fold increase in *average* **TP** between the ***Inlet chamber*** (60 µg·L^{-1}) and the ***Gravel Wetland outlet*** (196.2 µg·L^{-1}); however, almost all of this TP (97 percent) was comprised of OP which accumulated beneath the mat of emergent plants growing in this area.

The significant increase in *average* **TP** in the ***Gravel Wetland*** is to be expected because this component of the wetland complex serves exclusively as the recipient of over-flow from high water levels in the main system and vegetation in this area constantly grows, dies and decomposes during successive growing seasons.

The data summarized in Table 3 above also are presented in Figure 2 to provide a better visual comparison of the nutrient data collected from the wetland complex.

Figure 2,



Please note that the ***y-axis*** in the above figure is in logarithm scale so that the full range of nutrient concentrations can be more accurately represented and compared both within and among components of the wetland system (***Inlet chamber***, ***Pond-7 outlet***, *and* ***Gravel Wetland outlet***).

Road Salt Constituents and Associated Parameters

The New York State Department of Transportation (NYSDOT) maintains the section of Route 9 that traverses the wetland subcatchment and applies ClearLane™ Enhanced Deicer (Cargill, Lansing, NY) as the winter deicing product.

The numerous paved areas, parking lots and secondary access roads that are adjacent to, and drain to, the Route 9 corridor are maintained during the winter by local government (Village and Town of Lake George) and local contractors with application of deicing materials.

The Village of Lake George uses ClearLane™ for winter deicing whereas the Town of Lake George and local contractors likely use Bulk Ice Control Salt (Cargill, Lansing, NY) for parking lots and roadways. Table 4 summarizes the components included in Bulk Ice Control road salt and ClearLane™ Enhanced Deicer.

Table 4.

Bulk Ice Control		ClearLane™ Enhanced Deicer	
component	**% of composition**	**component**	**% of composition**
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%

The use of winter deicing materials in the subcatchment that drains to the wetland complex requires a specific focus on road salt products that are applied for winter deicing maintenance. This section, therefore, presents and discusses the base-flow wetland characteristics of **road salt** (**Na**, **Cl**) and related parameters including **calcium (Ca)**, **magnesium (Mg)**, **specific conductance (spC)**, and **total dissolved solids (TDS)**.

Table 5 summarizes the 2019 base-flow characteristics of these analytes measured in the ***Inlet chamber***, ***Pond-7*** and ***Gravel Wetland*** outlets.

Table 5.

	Na (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	spC (µS/cm @ 25°C)	TDS (mg/L)
Inlet chamber						
Inlet *minimum*	86.6	119	32.2	4.96	730	489
Inlet *maximum*	103	312	38.0	5.94	682	738
Inlet *average*	95.6	190	36.0	5.60	717	517
# of samples	3	3	3	3	3	3
Pond- 7 outlet						
Pond-7 *minimum*	32.3	44.1	33.6	5.40	457	328
Pond-7 *maximum*	58.8	88.8	54.6	10.7	554	393
P-7 *average*	44.9	59.9	45.1	7.76	509	362
# of samples	5	5	5	5	5	5
Gravel Wetland outlet						
Gravel Wetland *minimum*	46.0	66.0	70.2	10.7	723	524
Gravel Wetland *maximum*	61.5	98.2	95.9	12.9	912	665
Gravel Wetland *average*	53.2	78.2	82.5	11.7	796	577
# of samples	5	5	5	5	5	5

As summarized in Table 5, the base-flow dynamics of road salt and related parameters observed in the West Brook CI SIP during 2019 include the following:

- The ***Inlet chamber*** exhibited high *minimum*, *maximum* and *average* concentrations of **Na**, **Cl**, **specific conductance** and **TDS** throughout the spring and early summer, although concentrations decreased from high to low values for all parameters as samples were collected during April, June and July.
- A comparison of the *average* concentrations of **Na** and **Cl** measured at the ***Inlet chamber*** and the ***Pond-7 outlet*** indicates that some depletion of these parameters occurred, likely due to dilution from surface water entering the wetland complex during and after storm events and the influence of ground water continuously flowing through the system. Alternatively, there could be stratification occurring in ***Pond-7***, with more dense, colder water near the bottom enriched with **Na** and **Cl.**
- The *minimum*, *maximum* and *average* concentrations of **Mg** were high in the ***Inlet chamber*** and the ***Pond-7*** and ***Gravel Wetland outlets*** as a result of winter road maintenance in the subcatchment which is discussed below.
- The ***Gravel Wetland*** exhibited the highest *average* concentration for all parameters summarized in Table 4 which, again, is to be expected because this component of the system normally is not active in processing flow-through and storm water and merely acts as a repository for materials carried in the ground water from higher elevations.
- The *average* concentrations of Ca measured in the ***Pond-7 outlet*** and ***Gravel Wetland*** during 2019 are similar to the *average* values of this contaminant reported for these wetland components in the 2018 Final Report.

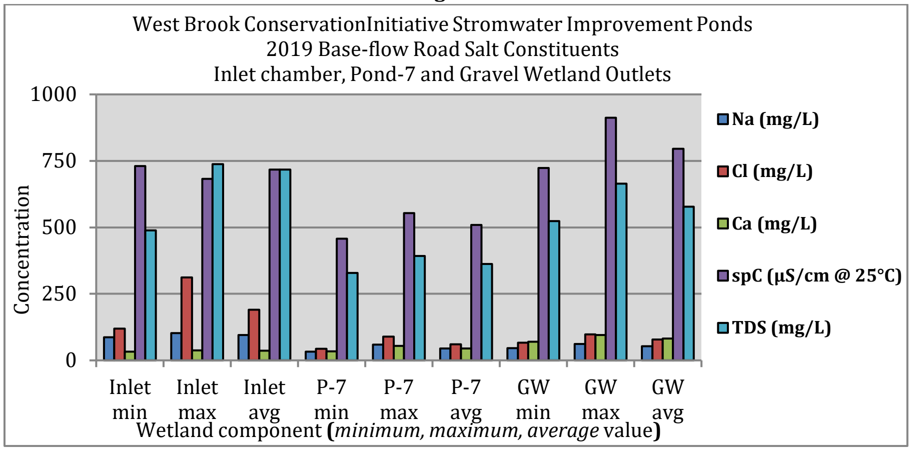
The source of **magnesium** entering the wetland complex is primarily the Bulk Ice Control and ClearLane™ Enhanced Deicer used for winter safety maintenance on impervious surfaces in the subcatchment. As summarized in Table 4 above, both deicing agents contain significant amounts of **magnesium.**

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. As a reminder, however, the entire surface of Route 9 (Canada Street) is maintained during winter with ClearLane™ Enhanced Deicer which does not have a **Ca** component in its makeup. The areas adjacent to Route 9 that also drain the wetland complex are the areas that are treated during winter with Bulk Ice Control.

Road salt loading of soils adjacent to all 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).

The data summarized in Table 5 above also are presented in Figure 3 below to provide a better visual comparison of the nutrient data collected from the wetland complex.

Figure 3.



In summary, any apparent reduction in concentration of these road salt associated analytes between the Inlet chamber and outflow to West Brook is less likely due to uptake and more likey due to dilution from ground water moving through the wetland complex from higher elevations to the south.

Other Important Highway Contaminants

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 may contribute to the deterioration of vehicles and highway structures and increase heavy metal concentrations. In addition, road salts may contain trace amounts of heavy metals such as nickel, cadmium and cyanide (anti-caking compound) which can be released in solution.

A full list of highway runoff constituents and their primary sources as summarized by Smith and Lord (1990) is presented in Table 5.

Table 5.

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

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

The movement and deterioration of automobiles, trucks and other vehicles and their parts on road surfaces, parking lots, driveways and other surfaces produce sizeable amounts of environmental contaminants that accumulate on these impervious surfaces and are carried by runoff during rain and snow events into local bodies of water. Prior to the construction of the West Brook CI SIP 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 stormwater runoff from Canada Street and adjacent areas on the water quality of West Brook has been well-documented (Sutherland et al. 1983; Eichler and Boylen 2012), and provided the basis for considering construction of a man-made wetland to treat runoff and improve the water quality entering West Brook.

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

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 likely reflect these analytes in the dissolved state. However, extremely fine and suspended clay particles could have adsorbed metals which would reflect particulate forms. 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 6 summarizes the heavy metal and associated highway contaminant data collected for the ***Inlet chamber*** and the ***Pond-7*** and ***Gravel Wetland*** outlets during base-flow conditions in 2019.

Table 6.

	Cd (µg/L)	Cu (µg/L)	Fe (mg/L)	Pb (µg/L)	Ni (µg/L)	SO_4 (mg/L)	Zn (µg/L)
Inlet chamber							
Inlet *minimum*	nd	0.51	0.03	nd	nd	4.15	10.8
Inlet *maximum*	nd	2.36	0.06	1.88	nd	4.72	14.5
Inlet *average*	nd	1.62	0.04	1.88	nd	4.41	12.5
# of samples	3	5	3	3	3	3	3
Pond- 7 outlet							
Pond-7 *minimum*	nd	0.14	0.45	nd	nd	0.67	8.41
Pond-7 *maximum*	nd	0.61	2.23	nd	nd	2.47	27.1
P-7 *average*	nd	0.43	0.93	nd	nd	1.29	16.6
# of samples	5	5	5	5	5	5	5
Gravel Wetland							
Gravel Wetland *minimum*	nd	nd	16.4	0.04	nd	0.15	8.63
Gravel Wetland *maximum*	nd	nd	20.7	1.34	nd	1.48	19.7
Gravel Wetland *average*	nd	nd	18.1	0.62	nd	0.70	13.6
# of samples	5	5	5	5	5	5	5

Please note in the Table 6 that concentrations for **cadmium** (**Cd**), **copper** (**Cu**), **lead** (**Pb**), **nickel** (**Ni**) and **zinc** (**Zn**) are reported in $\mu g \cdot L^{-1}$, while concentrations for **iron** (**Fe**), **magnesium** (**Mg**) and **sulfate** (**SO_4**) are reported in mg·L^{-1}. In addition, **sulfate** is not a cation; rather, it is an anion that is included here because it is considered an important highway runoff constituent. Total suspended sediment (TSS) was not measured in any of the base-flow samples collected during 2019.

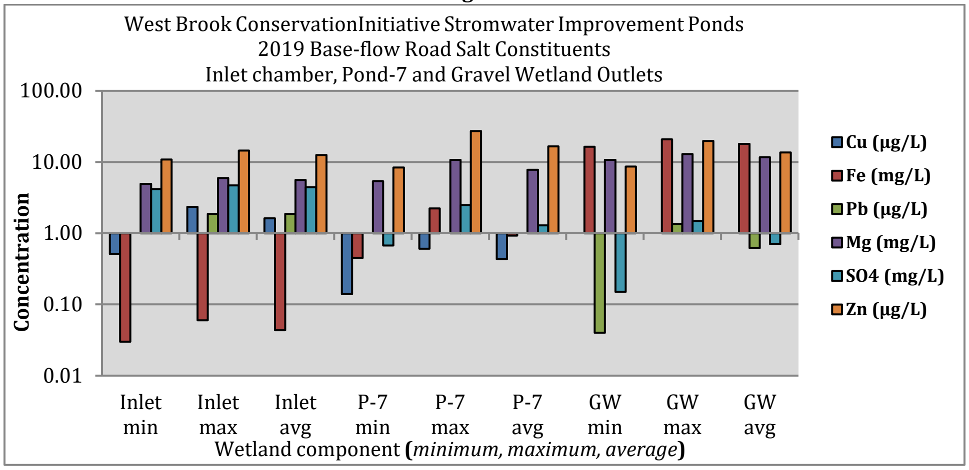
As summarized in Table 6, the base-flow dynamics of important highway runoff contaminants observed in the West Brook CI SIP during the 2019 sampling program include the following:

- **Cadmium** (**Cd**) was not detectable in any of the samples collected. This is in contrast to the 2018 Final Report when **cadmium** was reported in the ***Inlet chamber*** and the ***Pond-7 outlet***. **Cadmium** is a breakdown product of tire wear,
- **Copper** (**Cu**) was present in samples collected from the ***Inlet chamber***, exhibited a wide range of *minimum* (0.51 μg·L^{-1}) and *maximum* (2.36 μg·L^{-1}) concentrations, and had an *average* concentration of 1.62 μg·L^{-1}. The *average* concentration in the ***Pond-7*** **outlet** was reduced by ~75 percent to 0.43 μg·L^{-1}, and there was no **copper** detected in samples collected from the ***Gravel Wetland outlet***. **Copper** is a breakdown product of automotive metal plating, bearing and bushing wear, brake linings and moving engine parts,
- **Iron** (**Fe**) was detected in all samples collected from the 3 sites and is a significant component of ground water chemistry in the area, described in the 2018 Final Report, with ***Pond-2*** exhibiting the highest concentrations which likely resulted in the 2019 increase in *average* concentration between the ***Inlet chamber*** (0.04 mg·L^{-1}) and the ***Pond-7 outlet*** (0.93 mg·L^{-1}). In addition to high concentrations in the local ground water, **iron** is a breakdown product of vehicle body rust, steel highway structures, and moving engine parts,
- **Lead** (**Pb**) was detected in only one of three samples collected at the ***Inlet chamber***, was not detected in any samples collected at the ***Pond-7 outlet***, and was present in all samples collected from the ***Gravel Wetland outlet***. The absence of lead in ***Pond-7*** is in contrast to the previous 2017-2018 results where this contaminant had rather high *minimum* (0.98 μg·L^{-1}), *maximum* (3.88 μg·L^{-1}) and *average* (2.59 μg·L^{-1}) concentrations.
- **Nickel** (**Ni**) was not detected in any of the samples collected during 2019. 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 high *average* **sulfate** concentration measured at the ***Inlet chamber*** (4.41 mg·L^{-1}) likely was the result of Bulk Ice Control (see Table 4) applied during winter deicing in the subcatchment and also degradation of roadway material and fuel combustion. The *average* concentration measured in the ***Pond-7 outlet*** (1.29 mg·L^{-1}) was reduced by 70 percent, while the *average* concentration measured in the ***Gravel Wetland outlet*** was a 78 percent reduction.
- The *average* levels of **zinc** (**Zn**) ranged from 8.63-27.1 μg·L^{-1} in all components of the wetland system and the difference in the *average* values among the ***Inlet chamber*** (12.5 μg·L^{-1}) and the ***Pond-7*** (16.6 μg·L^{-1}) and ***Gravel Wetland*** (13.6 μg·L^{-1}) outlets was not significant due to variability of the individual sample readings. These 2019 concentrations were similar to the values reported in the 2018 Final Report.

The data summarized in Table 6 above also are presented in Figure 4 to provide a better visual comparison of the nutrient data collected from the wetland complex. Two heavy metals, **cadmium** (**Cd**) and **nickel** (**Ni**) were not detected in any 2019 **base-flow** samples collected from the wetland complex and are not shown in the above figure. **Lead** (**Pb**) only occurred in one sample collected from the ***Inlet chamber*** and was present in the Gravel Wetland where it likely is accumulating with the dead and organic layer beneath the actively growing wetland vegetation.

The other contaminants from highway runoff entering the wetland including **copper** (**Cu**), **iron** (**Fe**), **magnesium** (**Mg**), **sulfate** (**SO_4**) and **zinc** (**Zn**) do not appear to be a water quality problem in terms of concentration, and either are reduced by settling of particulate matter or by ground water entering the chain of ponds from the higher elevation to the south.

Figure 4.



Please note that the ***y-axis*** in the above figure is in logarithm scale so that the full range of concentrations can be more accurately represented and compared both within and among components of the wetland system (***Inlet chamber***, ***Pond-7 outlet***, *and* ***Gravel Wetland outlet***). Also, the concentrations of some analytes are expressed in mg·L^{-1} while other analytes are expressed in µg·L^{-1}.

Target Analyte List of Sediment Metals Data Collected from Pond-1, Pond-2 and Pond-7

A special sampling excursion was conducted on October 22nd to collect sediment samples from ***Pond-1***, ***Pond-2,*** and ***Pond-7*** for a Target Analyte List of metals (US EPA Method 6010C/7471B) as background information for future dredging and disposal of soils from these ponds to increase water depth.

Personnel met at the wetland complex on the morning of October 22nd. After putting on chest waders, individuals walked out from the shoreline of each pond, waited several minutes for disturbed material to settle, then pushed a short section of 2-inch Plexiglas tubing into the bottom sediment and capped the open end to trap material contained in the tube.

The material trapped in the Plexiglas tubing then was transferred to sample containers, one for each pond, provided by Phoenix Environmental Laboratories, Inc. in Manchester, CT. A blind quality assurance sample was collected from ***Pond-1*** and submitted to the laboratory for analysis. The collected samples then were delivered to the Village of Lake George Wastewater Treatment Plant where they were picked up by courier service and delivered to the laboratory in CT on the same day accompanied by a chain of custody form.

Table 7 provides a summary of abbreviations for the various metals that were analyzed in the sediment samples collected from the wetland chain.

Table 7.

Ag - silver	**Co – cobalt**	**Na – sodium**
Al – aluminum	**Cr – chromium**	**Ni - nickel**
An - Antimony	**Cu – copper**	**Pb - lead**
As – arsenic	**Fe – iron**	**Se - selenium**
Ba – barium	**Hg – mercury**	**Tl - thallium**
Be – beryllium	**K – potassium**	**V - vanadium**
Ca – calcium	**Mg – magnesium**	**Zn - zinc**
Cd – cadmium	**Mn – manganese**	**% Solid – percent solids**

The analytical results from the sediment samples were received from Phoenix Laboratories on October 24th. These results are summarized in the following 3 graphs for ***Pond-1*** (Figure 5), ***Pond-2*** (Figure 6) and ***Pond-7*** (Figure 7). The results presented in the ***Pond-1*** figure (Figure 5) are the *average* value for the two sediment samples (regular + quality assurance) that were collected.

Figure 5.

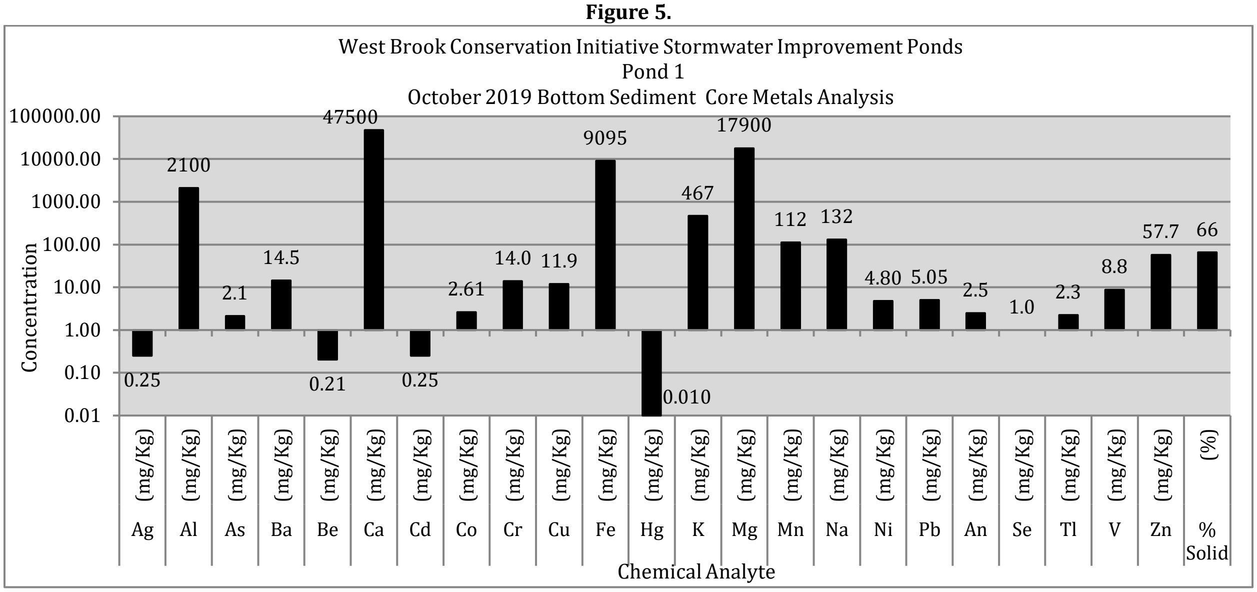


Figure 6.

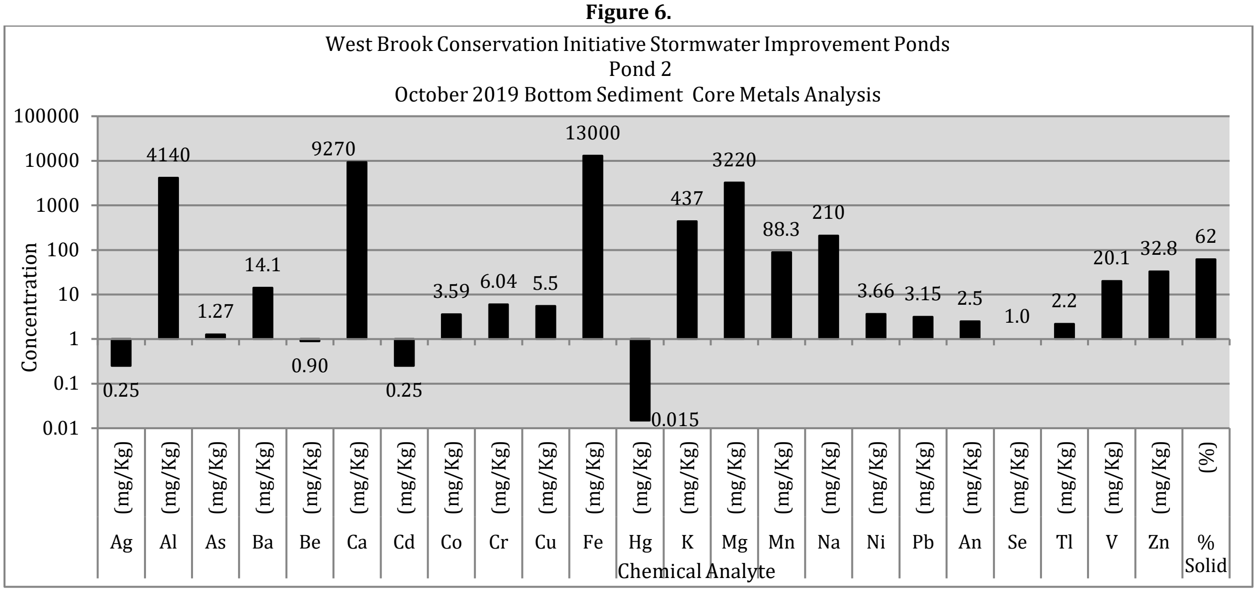
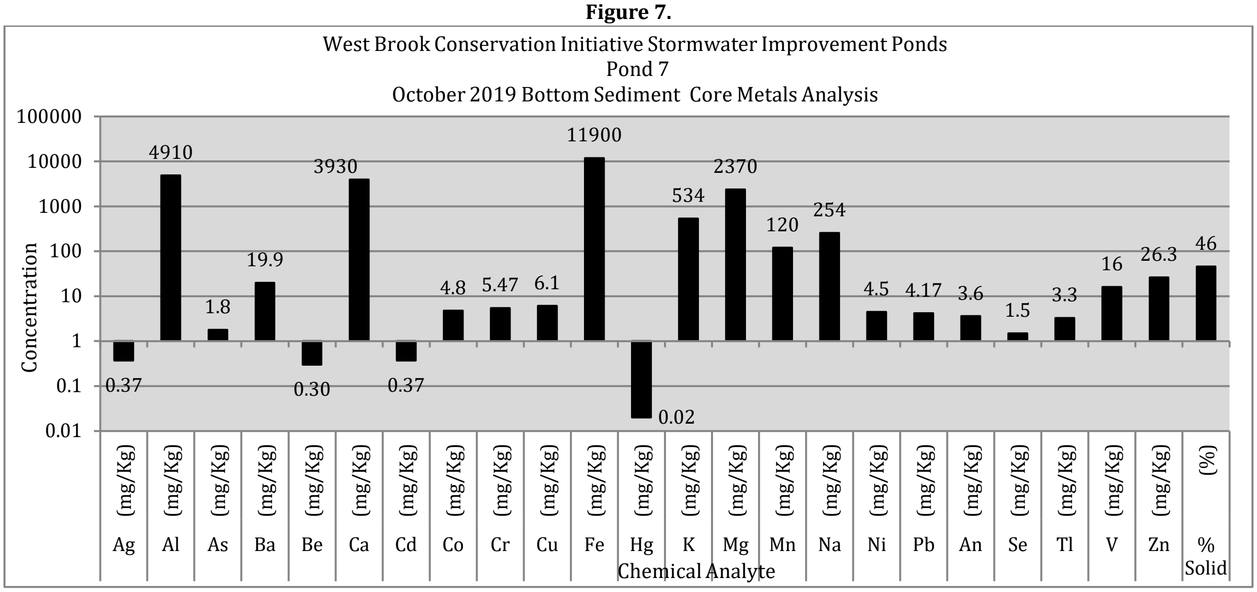


Figure 7.



The results for the TAL metals analyses are discussed below in three (3) groups according to their levels of concentration measured in the sediment samples.

Group 1. Seven (7) of the 23 metals analyzed in the TAL test pattern were below the limit of detection (Table 8). These metals are segregated and summarized here because it was not possible to distinguish these '**non-detect**' data on the above figures that present a visual comparison of the analytical results.

Table 8.

Ag (**silver**) Ponds 1,2 and 7	**Cd** (**cadmium**) Ponds 1,2 and 7	**Tl** (**thallium**) Ponds 1, 2 and 7
An (**antimony**) Ponds 1,2 and 7	**Hg** (**mercury**) Ponds 1,2 and 7	
Be (**beryllium**) Ponds 1 and 7	**Se** (**selenium**) Ponds 1, 2 and 7	

Of the '**non-detect**' metals summarized in Table 8 above, **cadmium** (**Cd**) was discussed in the previous section (**Other Important Highway Contaminants)** and also was 'non-detect' in the water samples collected from the ***Inlet chamber***, ***Pond-7*** and the ***Gravel Wetland outlets***.

Group 2. Five (5) of the remaining 16 metals analyzed in the sediment samples exhibited '**detectable**' concentrations <10 mg·Kg^{-1}, including **arsenic** (**As**), **cobalt** (**Co**), **nickel** (**Ni**), **lead** (**Pb**), and **vanadium** (**V**). In general, the concentrations of these metals either remained about the same among the 3 ponds (**arsenic**, **nickel**, **lead**) or increased along the chain from ***Pond-1*** to ***Pond-2*** to ***Pond-7*** (**cobalt**, **vanadium**). **Nickel** and **lead** were discussed in the previous section dealing with highway runoff contaminants; **nickel** was not detected in any of the water samples collected during 2019, while **lead** was detected in one sample collected from the ***Inlet chamber*** but was not detected in the samples collected from ***Pond-7.***

The other three contaminants also can be traced back to transportation corridor breakdown products. **Arsenic** is used in alloys of **lead** (car batteries) and the trioxide compound of **arsenic** is used in the production of pesticides, treated wood products, herbicides and insecticides. **Cobalt** is primarily used in lithium-ion batteries, and in the manufacture of magnetic, wear-resistant and high-strength alloys. **Vanadium-**steel alloys are used to make such things as axles, crankshafts and gears for cars, and springs.

Group 3. All of the remaining 11 TAL metals exhibited concentrations in excess of 10 mg·Kg^{-1} in ***Pond-1***. Only **aluminum** (**Al**), **barium** (**Ba**), **chromium** (**Cr**) and **potassium** (**K**) were not discussed in the previous section on contaminants in highway runoff; however, these metals should be added to the list of highway runoff constituents summarized in Table 5. **Manganese** (**Mn**) was not discussed in the previous section and already is listed in Table 5.

The **aluminum** concentration measured in ***Pond-1*** (2100 mg·Kg^{-1}) increased in ***Pond -2*** (4140 mg·Kg^{-1}) and ***Pond-7*** (4910 mg·Kg^{-1}), suggesting some form of fine particulate matter that does not completely settle out along the wetland chain. **Aluminum** is used extensively in automobile manufacture due to its light weight which increases fuel mileage efficiency.

Barium showed little change between ***Pond-1*** (14.5 mg·Kg^{-1}) and ***Pond-2*** (14.1 mg·Kg^{-1}) and then a slight increase in ***Pond-7*** (19.9 mg·Kg^{-1}). **Barium** is used extensively in the manufacture of alloys for nickel and barium parts are found in ignition equipment for automobiles.

Chromium decreased in concentration from ***Pond-1*** (14.0 mg·Kg^{-1}) to ***Pond-2*** (6.04 mg·Kg^{-1}) to ***Pond-7*** (5.47 mg·Kg^{-1}) suggesting some reduction due to settling out of particulate matter along the treatment chain. **Chromium** is used extensively for plating auto parts.

In general, **potassium** exhibited consistently moderate concentrations among ***Pond-1*** (467 mg·Kg^{-1}), ***Pond-2*** (437 mg·Kg^{-1}) and ***Pond-7*** (534 mg·Kg^{-1}); the major source of **potassium** is as a trace contaminant in the products used as deicing compounds during winter road maintenance.

Manganese exhibited essentially the same concentration in the progression from ***Pond-1*** (122 mg·Kg^{-1}) to ***Pond-2*** (88.3 mg·Kg^{-1}) to ***Pond-7*** (120 mg·Kg^{-1}) suggesting a form of particulate matter in suspension with some reduction through settling along the treatment chain as well as some material remaining in suspension until the end of the treatment process. **Manganese** is a break-down product of moving engine parts.

The six (6) remaining metals including **calcium** (**Ca**), **copper** (**Cu**), **iron** (**Fe**), **magnesium** (**Mg**), **sodium** (**Na**) and **zinc** (**Zn**) were presented previously when highway runoff contaminants were discussed. **Calcium**,

magnesium, and **sodium** are constituents of winter deicing products used in the subcatchment that drains to the wetland.

Calcium concentrations were extremely elevated in the sediments from ***Pond-1*** (47,500 mg·Kg^{-1}), ***Pond-2*** (9270 mg·Kg^{-1}) and ***Pond-7*** (3930 mg·Kg^{-1}) suggesting a particulate component that decreased through a settling process along the treatment chain. In addition to highway deicing products, the elevated levels of **calcium** also were the result of concrete structure dissolution occurring along the highway corridor. **Magnesium** exhibited the same pattern of decreased concentration from ***Pond-1*** (17,900 mg·Kg^{-1}) to ***Pond-2*** (3220 mg·Kg^{-1}) and ***Pond-7*** (2370 mg·Kg^{-1}). **Sodium** concentrations exhibited a slight increase from ***Pond-1*** (132 mg·Kg^{-1}) to ***Pond-2*** (210 mg·Kg^{-1}) and then ***Pond-7*** (254 mg·Kg^{-1}). The large difference in concentration between **sodium** and **calcium-magnesium** measured in the sediments confirms the conservative nature of **sodium** dissolved in water and the fact that some association of **calcium** and magnesium with particulates has occurred in order to achieve such high concentrations in the sediment.

Copper concentrations were reduced between ***Pond-1*** (11.9 mg·Kg^{-1}) and ***Pond-2*** (5.5 mg·Kg^{-1}) and ***Pond-7***. (6.1 mg·Kg^{-1}); sources of copper are metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides.

Iron concentrations also were elevated among ***Pond-1*** (9095 mg·Kg^{-1}), ***Pond-2*** (13,000 mg·Kg^{-1}) and ***Pond-7*** (11,900 mg·Kg^{-1}). While some **iron** is the result of runoff from highway contaminants, most of the *iron* in the wetland sediments likely is from the elevated concentrations in the ground water constantly moving through the system from higher elevations.

Magnesium also was extremely elevated in Pond-1, Pond-2 and Pond-7 primarily because it is a constituent of road salt products used in the sub-watershed.

This concludes the section of the current annual report where 2019 **base-flow** data are presented and discussed.

Component 6. 2019 Monitoring Program Discussion and Conclusions

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.

This annual report 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 2019 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 2019 program. If we rely solely upon *average* concentrations of analytes at the beginning (***Inlet chamber***) 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** decreased between the ***Inlet chamber*** (0.35 mg·L^{-1}) and ***Pond 7*** (0.02 mg·L^{-1}) indicating that uptake of this available nutrient was occurring along the treatment complex; **nitrate-nitrogen** was not detected in the ***Gravel Wetland***,
- *Average* concentrations of **total nitrogen** were reduced between the ***Inlet chamber*** (0.51 mg·L^{-1}) and the ***Pond 7*** (0.25 mg·L^{-1}), indicating that some settling of material occurred along the treatment

chain; the *average* concentration of **total nitrogen** in the ***Gravel Wetland*** was high (0.97 mg·L^{-1}) and likely due to the accumulation of **organic nitrogen** beneath this extensive area of vegetative growth,

- *Average* concentrations of **total filterable phosphorus** were greatly reduced between the beginning of the Inlet chamber (60.0 µg·L^{-1}) and the ***Pond 7*** (4.2 µg·L^{-1}) and Gravel Wetland (5.6 µg·L^{-1}) outlets, indicating substantial uptake of this available plant nutrient along the treatment chain,
- *Average* concentrations of **total phosphorus** were unchanged along the wetland complex, with concentrations of 22.5 µg·L^{-1} measured in ***Pond 1*** and 22.7 µg·L^{-1} measured in ***Pond 7***,

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** were elevated in **base-flow** entering the ***Inlet chamber*** and reduced in the ***Pond-7*** and ***Gravel Wetland*** outlets indicating 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 was a factor 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.

With regard to the **base-flow** chemistry of the heavy metals and other highway constituents evaluated during the 2019 study, **iron**, **magnesium**, **sulfate** and **zinc** appear to be the most problematic in terms of high concentrations entering and exiting the wetland complex to West Brook. Except for **sulfate**, 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.

Component 6. 2019 Monitoring Program Recommendations

The following recommendations are presented after a thorough review of the water quality results from the 2019 monitoring program:

- Continue during 2020 with the **base-flow** monitoring effort similar to the sampling that was conducted during 2019 with special emphasis on the ***Inlet chamber***, if it has flow moving through it; otherwise, sample ***Pond-1*** and the ***Pond-7*** and ***Gravel Wetland outlets***.
- Initiate regular download of level data-loggers installed in the ***Inlet chamber*** and the ***Pond-7*** and ***Gravel Wetland outlets***.
- Sample at least one storm event when reliable forecasting data are available; collect **base-flow** samples prior to the event and least several samples from the ***Inlet chamber*** and the ***Pond-7 outlet***.

As explained in a later section of this report, the budget available for continuation of the wetland complex monitoring effort places severe restrictions on the number of samples than can be collected during any 12-month period.

<u>Planned Progress in the Future</u>:

Base-flow and **storm event** sampling will continue during 2020 as described in the section above.

<u>Identification of Problems</u>:

The DFWI Laboratory in Bolton Landing is shut down during the current pandemic.

<u>Proposed Solutions</u>:

It will be necessary to send chemistry samples to Phoenix Environmental Laboratories for analysis until the DFWI Laboratory re-opens.

Analysis of Incurred Cost:

The total budget for the 2019 and beyond water quality sampling program was estimated at $3,000.00 each year and is broken down by budget category below.

A proposed budget, by category, for the West Brook CI SIP continuation sampling program.

Category	Amount
Laboratory analytical services	$1,650.00
Personal services	$1,350.00
Program Total Amount	$3,000.00

A detailed breakdown of the Program budget costs during 2019 including chemistry and personnel services charges is provided below.

Actual expenditures, by category, for the West Brook CI SIP 2019 continuation sampling program.

Category	Amount
Laboratory analytical services	$1,365.00
Personal services	$1,350.00
Program Total Amount	$2,715.00

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Attachment #1

West Brook Conservation Initiative Stormwater Improvement Ponds

Proposed and Accepted Water Quality Monitoring Program - 2019 and Beyond

A comprehensive water quality monitoring program was implemented during a 13-month period in 2017-2018 to evaluate the wetland complex treatment efficiencies, with the Final Report for this study released in December 2018.

The first recommendation in the Final Report was that the West Brook Conservation Initiative Easement Committee (Committee) consider the continuation of some level of water quality monitoring at the wetland complex to (1) maintain a local awareness of the facility and (2) develop a long-term historic record that can be used to evaluate either any land use changes in the subcatchment or the implementation of any recommendations presented in the Final Report or developed in the future.

At a subsequent meeting, the Committee approved the continuance of a water quality monitoring program at the wetland complex. The purpose of this document is to provide a brief summary of the water quality monitoring program and to receive approval from the Committee for implementation of this program.

Program overview.

Water quality monitoring during 2019 and future years at the wetland complex will consist of the following:

- **Base-flow sampling** monthly (May thru December) with water samples collected from the ***Pond 7*** outlet chamber; the ***Gravel Wetland*** will be sampled 2 times each year at the outlet chamber.
- **Storm event sampling** of one major event each year when the advanced forecast prediction seems reliable; focus will be on events such as a major snow-melt and/or a hurricane/tropical storms. Water samples during each event will be collected from the ***Inlet*** chamber and the ***Pond 7*** and ***Gravel Wetland*** outlets. Base-flow samples will be collected just prior to the monitored storm event at the ***Pond 7*** and ***Gravel Wetland*** outlets.

The Telog Inc. continuous water level recorders currently installed at the Inlet chamber and the ***Pond 7*** and ***Gravel Wetland*** outlet chambers will be downloaded on a monthly basis and data interpreted so that a record of discharge through the wetland complex will be maintained.

Water chemistry test pattern.

The test pattern for analysis of **base-flow** and **storm event** raw water samples will include the suite of parameters shown below.

Anions	Other	Cations
Cl, NO3, SO4	**TFP, TSS**	**Ca, Mg, Na, K, Pb, Zn, Fe, Cu, Cr, Cd, Ni, Mn**

Samples will be processed at the Darrin Fresh Water Institute (DFWI) in Bolton Landing following collection. The *anion*, *phosphorus* and *nitrogen* series will be submitted at that time to the DFWI Laboratory for analysis. The *cation* samples will be preserved and stored at 4°C until the end of each sampling season and then will be submitted to the USGS Laboratory in Troy, New York for analysis. The TSS samples will be processed and analyzed at DFWI by JWS following collection.

Field data.

Data collected on-site during **base-flow** and **storm event** sampling will include water temperature, dissolved oxygen (concentration, percent saturation), specific conductance, total dissolved solids, and pH.

Gaging of discharge.

The gaging of discharge from the ***Pond 7*** and ***Gravel Wetland*** outlet chambers will be attempted during visits to collect **base-flow** and **storm event** samples. It may be possible to determine more accurate discharge readings by removing the iron grate covering each outlet chamber and collecting discharge in a marked bucket and measuring the time to fill the bucket to pre-measured levels.

Reporting.

An annual report of program progress will be prepared and submitted to the Committee and will include updates on sampling accomplishments, data summaries and noteworthy observations from an analysis of the chemistry and discharge data.

Annual Estimated Costs.

The following budget (see below) reflects a minimal sampling effort at the wetland complex while still providing sufficient water quality data on an annual basis to advance the solid foundation provided by the 2017-2018 investigation of wetland efficiency. The time required under *Personal services* is far under-estimated in order to remain within the annual budget allocated for continued monitoring; JWS is willing to consider the extra time spent on the water quality effort as *donated* to keep the collection of data an active process.

Category	Sub-Total	Total
1 – Laboratory Analytical Services		
• **Base-flow** sampling (monthly, May thru December) (1 site) (***Pond 7***)		
Lab Analysis – Chemistry (1 site/month x 8 months = 8 samples; @ $75.00/sample)	$600.00	
• **Base-flow** sampling (2 times/year) (1 site) (***Gravel Wetland***)		
Lab Analysis – Chemistry (1 site – 2x/year = 2 samples; @ $75.00/sample)	$150.00	
• **Storm event** sampling - Pre-storm **base-flow** - (2 sites))(***Pond 7*** and ***Gravel Wetland*** outlets)		
Lab Analysis – Chemistry (2 sites x 1 sample each = 2 samples; @ $75.00/sample)	$150.00	
• **Storm event** sampling – (1 storm, 2 sites)(***Inlet*** chamber and ***Pond 7*** outlet)		
Lab Analysis – Chemistry (2 sites x 4 samples = 8 samples; @ $75.000/sample)	$600.00	
• **Storm event** sampling (1 storm, 1 site) (***Gravel Wetland*** outlet)		
Lab Analysis – Chemistry (1 site x 2 samples = 2 samples; @ $75.00/sample)	$150.00	$1,650.00
2 – Equipment and Supplies		
materials will be used from other projects to save costs	$0.00	$0.00
3 - Personal services		
Field excursions for sampling, sample processing, data-download		
(15 hours @ $50.00/hour)	$750.00	
Data summary, analysis, and report writing		
(12 hours @ $50.00/hour)	$600.00	$1,350.00
4– Review Meeting and Presentation of Report and Final Implementation Plan	$0.00	
Total Cost		$3,000.00