Update of the Hydrologic and Nutrient Budgets of Honeoye Inlet and Honeoye Lake

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1.0 Introduction

Princeton Hydro, LLC (Princeton Hydro) was contracted by The Nature Conservancy (TNC) and the Honeoye Lake Watershed Task Force (HLWTF) to update the hydrologic and nutrient budgets of Honeoye Lake. With a total surface area of approximately 1,805 acres and a mean depth of only 16 feet, Honeoye Lake is the smallest in surface area and the shallowest of the State's Finger Lakes. The New York State Department of Environmental Conservation (NYSDEC) classifies Honeoye Lake as "AA" and the lake's tributary streams as "C". Honeoye Lake is currently listed on the NYSDEC Priority Waterbody List as impaired due to water supply concerns relating to nutrients (HLWTF, 2007).

Over the past decade, the HLWTF, together with various State, County and local stakeholders, have sought to better manage nutrient (phosphorus and nitrogen) and sediment loading to the lake as part of an effort to control the lake's rate of eutrophication. Although past studies have quantified the lake's hydrologic and nutrient budgets, these data are either incomplete, dated or in need of refinement (Princeton Hydro, 2007). The impact on the lake's trophic state attributable to all of sources of inflow was examined in 2004 and 2007 by Princeton Hydro and in 2009 by Bin Zhu of the Finger Lake Institute (FLI). While Princeton Hydro relied heavily on modeled hydrologic and pollutant loading data, Bin Zhu's data was based on actual sampling of inflow conducted under both baseflow and storm event conditions. As recently summarized by the HLWTF the Princeton Hydro data is valuable for "making long term predictions" while the Bin Zhu data can be used to "apply a correction factor to account for increased nutrient loading during storm events. Additional flow and pollutant sampling data have been collected since 2000 by HLWTF and Honeoye Valley Association (HVA) volunteer monitors. All of these data point to the fact that action is needed to control and reduce pollutant loading to Honeoye Lake from all sources of stormwater inflow. The update of the Honeoye Lake watershed's hydrologic and nutrient loading database developed through this study will greatly aid future decision making particularly with respect to the management of stormwater.

Although this project examines and quantifies the hydrologic and pollutant loading attributes of the entire Honeoye Lake watershed, particular emphasis is given to the Honeoye Inlet subwatershed. The Honeoye Inlet subwatershed is the largest (by area) of the lake's nine (9) major subwatersheds. The three other relatively large subwatersheds are Briggs Gully, Bray Gully, and Affolter Creek; each of which receives drainage from a major stream as opposed to a seasonally-ephemeral stream. Largely as a result of its areal expanse the Honeoye Inlet subwatershed contributes the greatest pollutant load and generates the majority of the inflow to Honeoye Lake (Genesee/Finger Lakes Regional Planning Council, 2007). Additionally, a unique opportunity exists within the Honeoye Inlet subwatershed for the implementation of large-scale stormwater management projects. The Honeoye Inlet Wildlife Management Area is a 2,500 acre tract located almost immediately upgradient of Honeoye Lake. These lands, which were obtained by the State from TNC, are managed by the New York State Department of Environmental Conservation (NYSDEC). Interest has been recently raised by TNC, NYSDEC and the HLWTF project partners in developing a large-scale, multifunctional, stormwater management system within the Honeoye Inlet Wildlife Management Area. In general, most of the lake's watershed is characterized by relatively steep terrain. This is especially true for the subwatersheds that parallel the lake's eastern and western shorelines. Additionally, much of the lands in these eastern and western subwatersheds are forested and privately owned. This combination of steep terrain, private ownership and forested land use precludes the implementation to use of some of the more commonly utilized regional stormwater management techniques such as bioretention basins, created wetlands and retention basins. Conversely, the importance of the Honeoye Inlet subwatershed with respect to the lake's overall pollutant and hydrologic loading, combined with the amount of open land available within the Honeoye Inlet Wildlife Management Area, creates a seemingly unique opportunity for the large-scale management of stormwater loading to the lake.

This report is thus divided into two, separate but related elements. The first element, consisting of Sections 2-5 deals with the update of the hydrologic and pollutant loading database for the entire Honeoye Lake watershed, with particular emphasis given to the Honeoye Inlet subwatershed. The goal of this element of the project is to provide TNC, the HLWTF and all of the other project partners with an updated and refined hydrologic and nutrient loading database. These data will improve the project partners' understanding of the sources and overall effects of baseflow and storm-related pollutant and hydrologic loading on the trophic state and water quality of Honeoye Lake. These data will also enable all the project partners to identify not only those subwatersheds requiring the greatest management, but those subwatersheds where stormwater management is technically feasible. This will also aid in the selection and prioritization of those stormwater management implementation projects having the greatest overall benefit with respect to the long-term management of the lake.

The second element of this report, consisting of Section 6, examines more closely specific stormwater management options for the entire Honeoye Lake watershed. However, particular attention is given to the Honeoye Inlet stream and subwatershed, including multi-functional stormwater management concepts that could be constructed within the Honeoye Inlet Wildlife Management Area. These stormwater concepts are capable of meeting multiple stormwater management goals including a reduction in nutrient and sediment loading, the attenuation of peak flows, reduction in flood volumes, the restoration of previously impacted habitat, the creation of new habitat and further promotion of the recreational use of the Honeoye Inlet Wildlife Management Area.

2.0 The Honeoye Lake Watershed

As per the NYSDEC and the USEPA most of the water quality problems facing our nation's lakes and waterways are largely a function of non-point source pollution (NPS) loading directly linked to watershed development and inadequate stormwater management (NYSDEC, 2010, USEPA, 2010). Recognizing this link between the quality of a lake and the state of its watershed, the North American Lake Management Society developed a catch phrase to emphasize this relationship; "a lake is a reflection of its watershed". This catch phrase is intended to reinforce the concept that the water quality and ecological "health" of a lake is largely dictated by the quality of runoff and inflow entering the lake from the surrounding lands: its watershed. Recognition and understanding of this linkage between a lake and its watershed should facilitate the development and implementation of initiatives aimed at controlling the rate, volume and quality of stormwater inputs. Watershed management and non-point source pollutant control are "active" as opposed to "reactive" approaches to improving a lake's quality. Addressing the causes of lake quality degradation and eutrophication is what, in part, separates lake *management* from lake *maintenance*.

The watersheds of oligotrophic lakes (low productivity waterbodies) typically have been minimally disturbed or developed. Conversely, eutrophic lakes (highly productive waterbodies), are most commonly associated with watersheds that are extensively disturbed, developed or farmed. The conversion of forested land to agricultural, residential, commercial and industrial land brings about an increase in the types and amounts of pollutants transported in stormwater runoff due to increases in erosion and a multitude of anthropogenic factors. As the degree of development increases, the types and amount (load) of pollutants mobilized and transported during each storm event increases. A correlation therefore exists between watershed disturbance and increased pollutant loading. In short, there is a direct proven relationship between the degree of lake eutrophication and the intensity of watershed development. As mentioned above, this interconnectivity between a lake and its watersheds is a central theme to NPS pollution control. Basically, if the amount of pollutant loading can be reduced then the water quality of the lake should improve.

Moreover, as a watershed becomes progressively developed, changes also occur with respect to the watershed's hydrologic and hydraulic properties. The areal expanse of a watershed, along with the prevailing land uses, soil types, topography and geology all affect the quantity of runoff generated during each storm event. The intensity and duration of each storm event, coupled with other variable seasonal and climatic factors, will dictate how much runoff is produced and how quickly that runoff reaches a stream. Thus, there is an interconnection between the natural and anthropomorphic characteristics of a watershed and the volume, rate and velocity of runoff generated by every storm. While stormwater runoff is an obvious mechanism for the transport of non-point source pollutants, runoff in itself can create an additional set of water quality or environmental impacts. Increases in the volume, rate and velocity of runoff causes the scouring and erosion of the receiving stream. This leads to the destabilization of the stream's bed and banks, resulting in physical and biological impacts to the stream ecosystem. The eroded stream bed and bank material eventually settles within the stream itself or within the receiving lake. The accumulated sediment occludes habitat, physically alters flow paths and is often colonized by invasive wetland and aquatic plant species. Similarly, the development, filling, clearing or other alterations of the wetlands, riparian buffers and floodplains associated with a stream reduces the ecological and hydrological services and functions of these areas. The most common consequence of these alterations is increased flooding and the inability to naturally attenuate storm flows and pollutant loads. These impacts are eventually transferred to the receiving lake.

Thus, for Honeoye Lake there is a need to understand both the pollutant loading and the hydrodynamic interrelationships that exist between the lake and its watershed. The Honeoye Lake watershed encompasses a total of 23,349 acres (Figure 2.1), divided into nine (9) subwatersheds (Table 2.1 and Figure 2.2). The four largest subwatersheds are in relative order: Honeoye Inlet, Briggs Gully, Southwest and Southeast. The four subwatersheds that drain to perennial streams are Honeoye Inlet, Briggs Gully, Affolter Gully and Bray Gully. The five remaining subwatersheds either drain to the lake via ephemeral streams or by means of overland runoff. This is an important characteristic, in that essentially 29% of the lake's watershed area only provides inflow to the lake during storm events or during the spring thaw. This further accentuates the need for management of storm-event and seasonal loading to the lake. As noted above, past studies have documented that the majority of the lake's inflow occurs via Honeoye Inlet. The remaining eight (8) subwatersheds individually encompass far less acreage than the Honeoye Inlet subwatershed. Although smaller, by at least an order of magnitude, the drainage areas of these other subwatersheds are however more developed than the drainage area of the main inlet. Also, due to the steeper terrain that characterizes some of these other subwatersheds, the majority of development has occurred close to Honeoye Lake; within a shoreline perimeter area defined by West Lake Road and East Lake Road (Figure 2.1). While much of this development was spurred by a desire to be proximal to the lake, this development pattern is also a function of the more gentle slopes that exist closer to the lake as compared to the slopes throughout much of the headwater areas of these subwatersheds (Figure 2.2). Due to the steeper topography of these subwatersheds and the limited amount of floodplain associated with the streams, these smaller sources of inflow tend to have a "flashier" hydrology than the main inlet. These conditions have been documented in the past through the Bin Zhu/FLI study and storm sampling conducted by the HLWTF volunteers. As noted above, many of the "waterways" associated with these smaller subwatersheds tend to be seasonal sources of inflow or discharge to the lake only after a significant storm event. Thus, although these sources of inflow drain smaller subwatershed areas, their impacts on the lake are potentially significant. This is especially true in the spring and summer when short, intense storm events can quickly channel pulses of sediment and nutrient into the lake via these smaller inlets.

The modeling of both the hydrologic and NPS pollution loading of the Honeoye Lake watershed is a tedious task due to the large size of the watershed. The seasonality of precipitation and the seasonal and climactic factors affecting the amount and rate of runoff also need to be taken into account when developing the hydrologic and NPS pollution loading databases. To properly quantify the watershed's hydrology and NPS pollution loads, therefore, requires the compilation, integration, analysis and interpretation of a large amount of data (Evans 2008).

Geographic Information Systems (GIS) based land use/land cover (LU/LC) analytical tools greatly aid the application of watershed simulation models. GIS effectively increases the computational efficiency and accuracy of the integration of the watershed data that serve as the foundation for the hydrologic, hydraulic and pollutant transport calculations. *MapShed*, a GIS-based watershed modeling tool, simulates runoff, sediment, nitrogen and phosphorus loads from a watershed. *MapShed* also has algorithms for calculating septic loads and allows for the inclusion of point source nutrient loading. The tool essentially duplicates the functionality of a similar software application previously created by The Penn State Institutes of Energy and the Environment called AVGWLF, Arc-View Generalized Watershed Loading Function (Evans et al., 2002). The only significant difference with AVGWLF is that the *MapShed* GIS interface is the freeware GIS software package *MapWindow*. *MapShed* provides a link between the GIS software and an enhanced version of the GWLF watershed model. As with AVGWLF, the watershed simulation tools used in *MapShed* are based on the GWLF model originally developed by Dr. Douglas Haith and colleagues at Cornell University. Princeton Hydro utilized *MapShed* as the primary modeling tool to update the hydrologic and pollutant loads for Honeoye Lake. Sections 3, 4 and 5 of this report present and discuss the results of the *MapShed* modeling effort. The data are subsequently utilized in Section 6 to evaluate stormwater best management practices for the Honeoye Lake watershed, especially the Honeoye Inlet subwatershed.

The following description of the *MapShed* model and GWLF is largely adapted from the User manuals for both. Hydrologic loading is simulated through *MapShed* utilizing the Soil Conservation Service – Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) as inputs. *MapShed* uses daily time steps for weather data and water balance calculations. Monthly calculations are made for nutrient and sediment loads based on the daily water balance accumulated monthly values. In computing the surface (runoff-related) portion of the hydrologic load, the model accounts for area-specific multiple land use scenarios, in concert with natural characteristics of the watershed such as slope, soils and geology. The model does not spatially route the watershed transport of sediments and nutrients, but rather simply aggregates loads from each source area (subwatershed). For the sub-surface (groundwater-related) portion of the hydrologic load, *MapShed* acts as a lumped parameter model using a water balance approach. No distinct areas are considered in the calculation of the sub-surface flow contributions; rather, the computed values are for the entire analyzed subwatershed. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface zone, and infiltration is computed as the difference between precipitation or snowmelt minus surface runoff plus evapotranspiration (Evans 2008).

Erosion and sediment yields are estimated utilizing monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of the KLSCP[1] values for each source area (LU/LC combination). A sediment delivery ratio based on watershed size and a transport capacity average daily runoff value is

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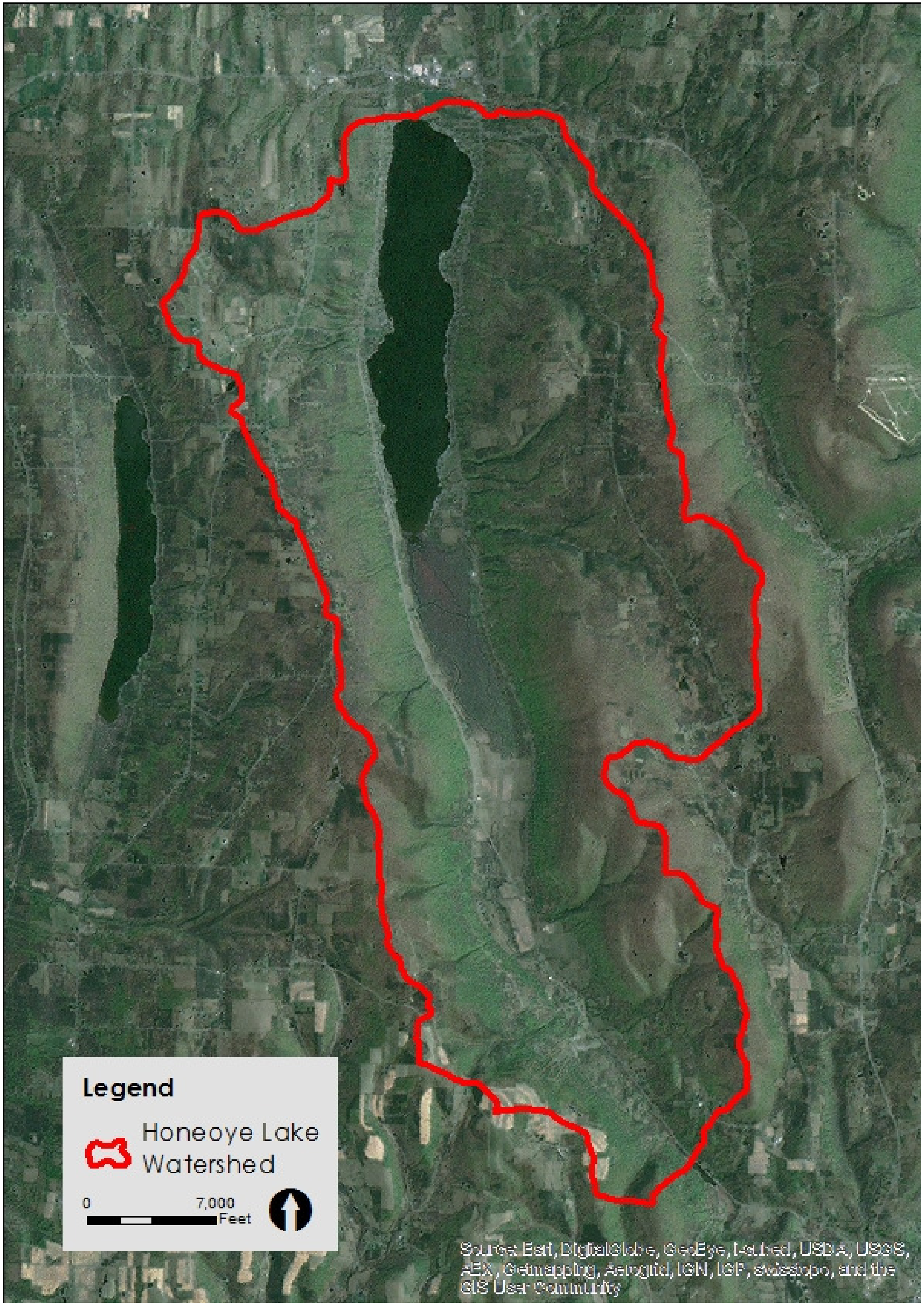
[1] KLSCP are the five parameters used in the USLE (along with watershed area (A) and Rainfall (R), to predict long-term annual soil loss .K- soil erodibility, L and S – topographic conditions, and C and P - crop management factors

then applied to the calculated erosion to determine sediment yield for each source area (subwatershed).

Surface runoff contributed nutrient loads are computed by applying dissolved N and P coefficients to surface runoff values, and a sediment coefficient to the yield portion for each agricultural land use source area. Point sources actively farmed and cultivated lands, and septic systems - are also integrated into the nutrient loading calculations, as the latter two sources are often significant nutrient and fecal coliforms sources for more rural watersheds. Urban nutrient inputs are assumed to be solid-phase and are modeled utilizing an exponential accumulation and wash-off function. Sub-surface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads while the sub-surface sub-model considers a single, lumped parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon LU/LC. Finally, a water balance is performed utilizing supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage and evapotranspiration values (Evans, 2008).

Figure 2.1 **Honeoye Lake Watershed – Aerial Photo Projection**



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 2.2 Honeoye Lake Subwatershed Boundaries – Digital Elevation Model Projection

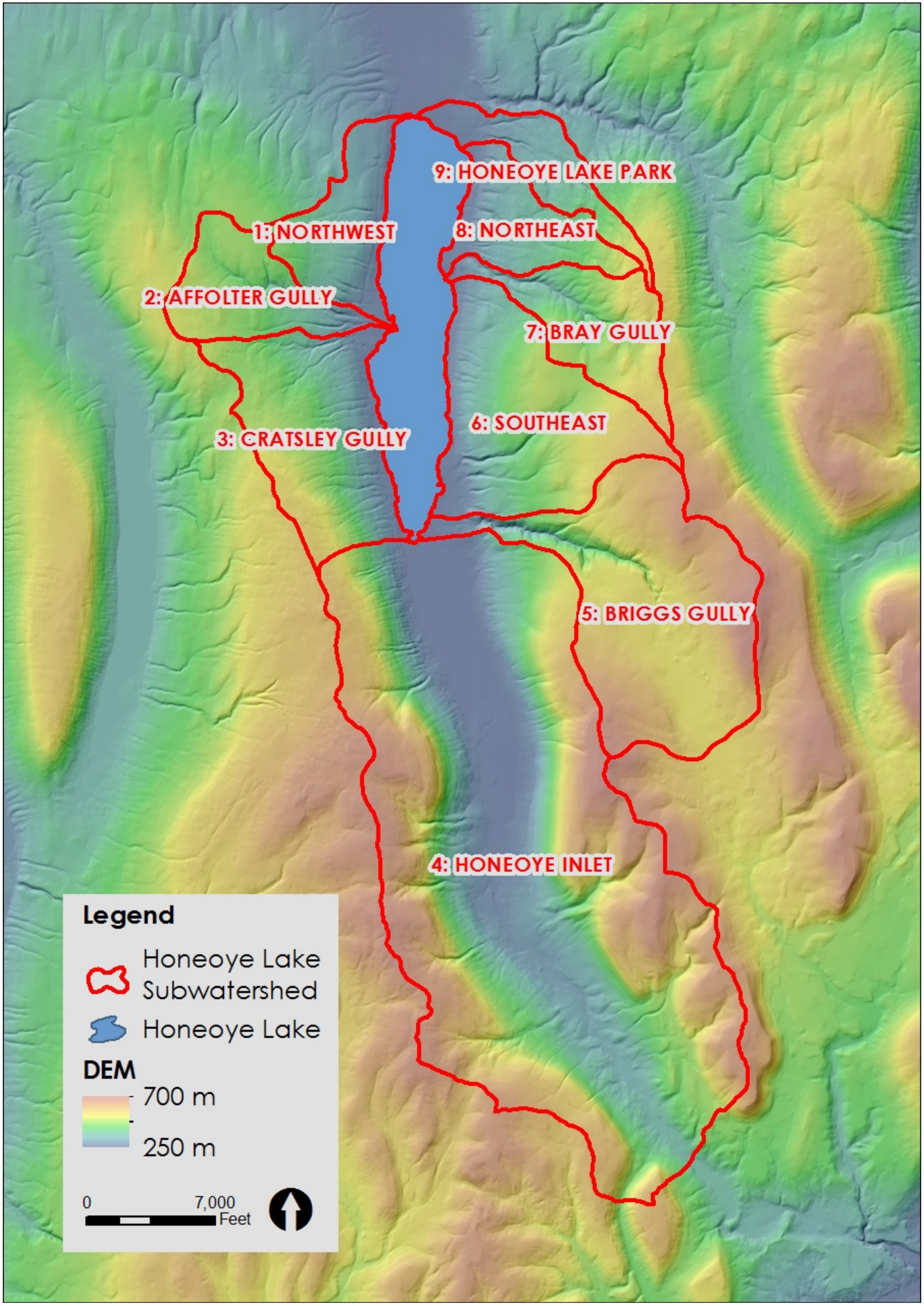


Table 2.1 Watershed and Subwatershed Areas[2]

Subwatershed	**Area**	
	Hectares	**Acres**
1: Northwest	384	948
2: Affolter Gully	403	995
3: Cratsley Gully	781	1,929
4: Honeoye Inlet	4,572	11,293
5: Briggs Gully	1,307	3,228
6: Southeast	926	2,287
7: Bray Gully	439	1,084
8: Northeast	356	879
9: Honeoye Lake Park	285	704
Total Area	**9,453**	**23,349**

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[2] Please note that the sub-watershed numbering and naming used in this report may differ from those used in earlier studies of the lake. For comparative purposes previously used naming/numbering schemes include the following:
1-North Shore
2-Times Union Creek
3-Bray Gully
4-East Shore
5-Briggs Gully
6- Honeoye Inlet
7-Canadice Corners
8-Affolter Gully
9-West Shore

3.0 Methodology and Input Files

MapShed uses a variety of spatial data inputs as well as non-spatial parameters, such as climate data and length of growing season, in order to implement the GWLF model.

Listed below are the required and optional data files that were used to model the Honeoye Lake watershed, including the sources for these data:

Required -

- Watershed boundary – Princeton Hydro delineated using the 30m USGS digital elevation model
- Digital elevation model – USGS (30m resolution)
- Land Use and Land Cover – Ontario County GIS
- Streams – USGS NHD High Resolution Dataset
- Soils – NEIWPCC (New England Interstate Water Pollution Control Commission/ Penn State
- Weather – NEIWPCC / Penn State (Modeling Period: 1990 – 2004)

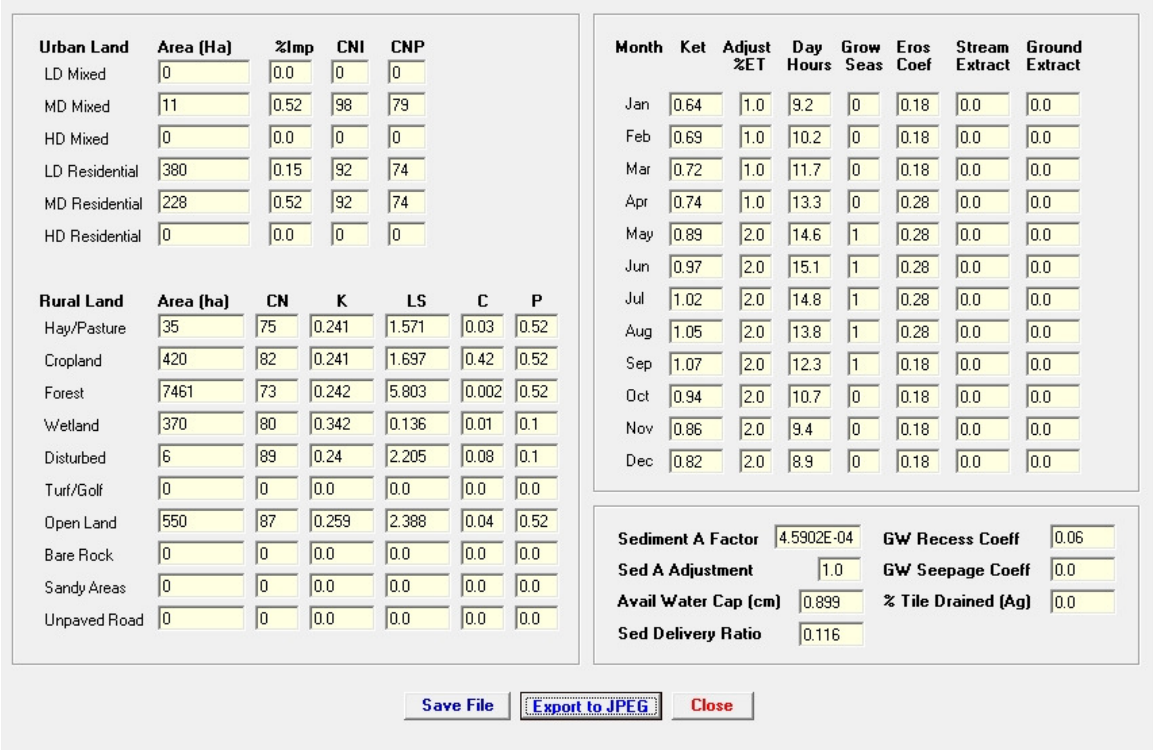
Optional -

- Soil phosphorus – NEIWPCC / Penn State
- Groundwater nitrogen – NEIWPCC / Penn State
- Septic – Ontario County GIS

The aforementioned data files served as the input parameters used to create the transport, nutrient and delivery files. Modeling was conducted for each of the nine (9) subwatersheds, the entire Honeoye Lake watershed (aggregate), and for the Honeoye Inlet Wildlife Management Area sub-section of Subwatershed 4, or the ‘project area‘, located immediately south of Honeoye Lake. Hydrologic and pollutant loading data are presented in both monthly and annualized scales over a 15-year modeling period (1990 – 2004). In addition, Princeton Hydro modeled the storm-specific hydrologic and pollutant loads associated with the 1-year, 2-year, 5-year, 10-year and 100-year frequency of occurrence storm events.

The remainder of this section details the input data applied to the model. For the sake of brevity only the input data for the aggregate watershed are presented. However, similar input files were created for each of the lake’s nine subwatersheds. The “Adjust %ET” parameter was iteratively adjusted during the hydrology calibrations of the model. This will be discussed in further detail in Section 4 of the report. As illustrated in Figure 3.1, a host of land cover, land use, precipitation and hydrologic factors are taken into account by *MapShed*. Therefore, although the model is simplistic, it is capable of generating very detailed data for each of the lake’s subwatersheds.

Figure 3.1: Transport Input File



Urban Land	Area (Ha)	%Imp	CNI	CNP
LD Mixed	0	0.0	0	0
MD Mixed	11	0.52	98	79
HD Mixed	0	0.0	0	0
LD Residential	380	0.15	92	74
MD Residential	228	0.52	92	74
HD Residential	0	0.0	0	0

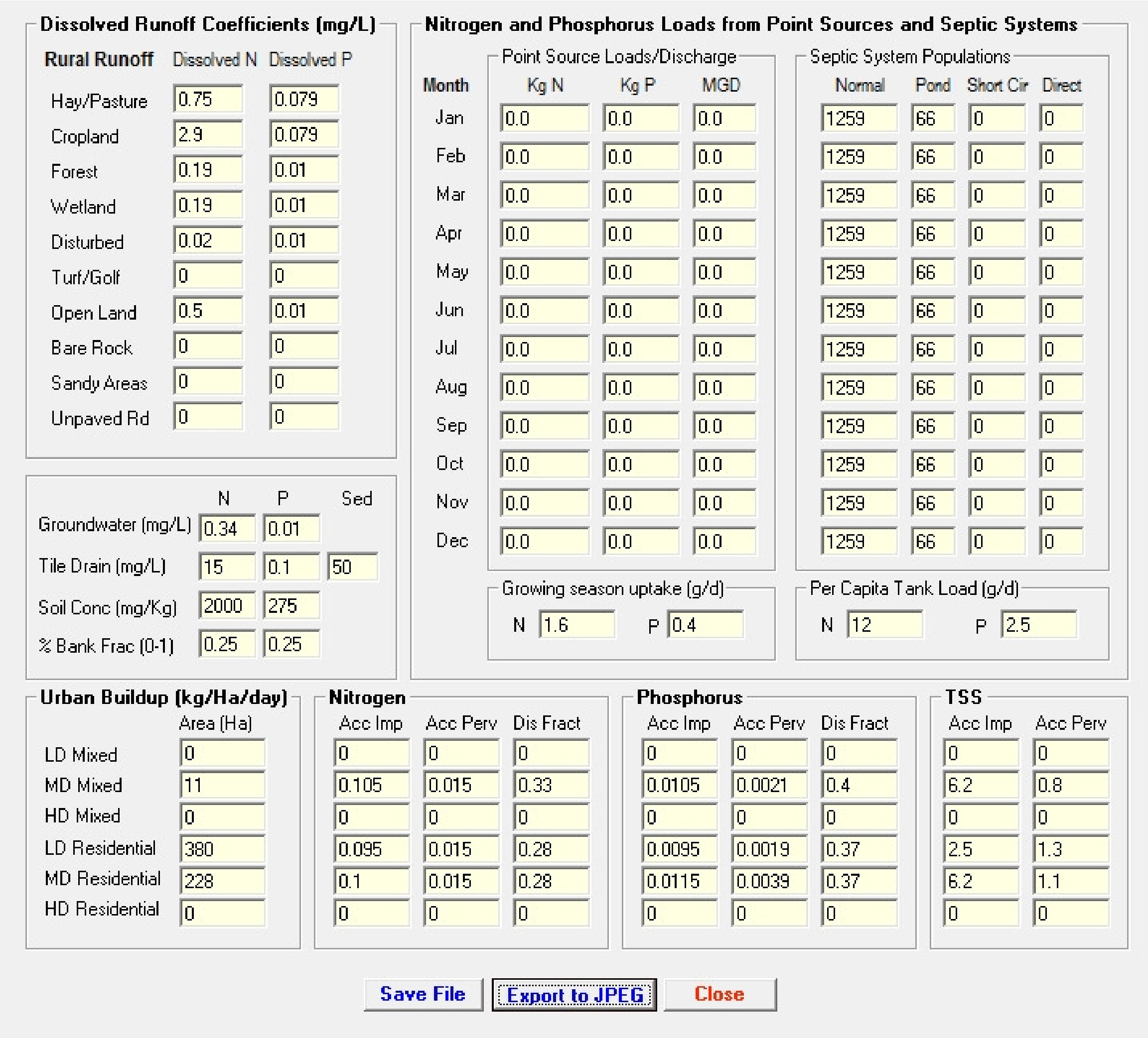
Rural Land	Area (ha)	CN	K	LS	C	P
Hay/Pasture	35	75	0.241	1.571	0.03	0.52
Cropland	420	82	0.241	1.697	0.42	0.52
Forest	7461	73	0.242	5.803	0.002	0.52
Wetland	370	80	0.342	0.136	0.01	0.1
Disturbed	6	89	0.24	2.205	0.08	0.1
Turf/Golf	0	0	0.0	0.0	0.0	0.0
Open Land	550	87	0.259	2.388	0.04	0.52
Bare Rock	0	0	0.0	0.0	0.0	0.0
Sandy Areas	0	0	0.0	0.0	0.0	0.0
Unpaved Road	0	0	0.0	0.0	0.0	0.0

Month	Ket	Adjust %ET	Day Hours	Grow Seas	Eros Coef	Stream Extract	Ground Extract
Jan	0.64	1.0	9.2	0	0.18	0.0	0.0
Feb	0.69	1.0	10.2	0	0.18	0.0	0.0
Mar	0.72	1.0	11.7	0	0.18	0.0	0.0
Apr	0.74	1.0	13.3	0	0.28	0.0	0.0
May	0.89	2.0	14.6	1	0.28	0.0	0.0
Jun	0.97	2.0	15.1	1	0.28	0.0	0.0
Jul	1.02	2.0	14.8	1	0.28	0.0	0.0
Aug	1.05	2.0	13.8	1	0.28	0.0	0.0
Sep	1.07	2.0	12.3	1	0.18	0.0	0.0
Oct	0.94	2.0	10.7	0	0.18	0.0	0.0
Nov	0.86	2.0	9.4	0	0.18	0.0	0.0
Dec	0.82	2.0	8.9	0	0.18	0.0	0.0

Sediment A Factor	4.5902E-04	GW Recess Coeff	0.06
Sed A Adjustment	1.0	GW Seepage Coeff	0.0
Avail Water Cap (cm)	0.899	% Tile Drained (Ag)	0.0
Sed Delivery Ratio	0.116		

As illustrated above, for this project the Total Suspended Solids (TSS) loss rate was changed from a default value of zero to 0.25. This factor was changed in order to account for sedimentation processes throughout the watershed. In addition, Percent Drainage was adjusted on a subwatershed basis depending on the percent of wetlands in each subwatershed (figure 3.3). This adjustment accounts for the flow attenuation function of wetlands. Although, by their nature they do not function as recharge areas, they can decrease the total amount and volume of runoff by storing and detaining storm flows.

Figure 3.2: Nutrient Input File



Dissolved Runoff Coefficients (mg/L)

Rural Runoff	Dissolved N	Dissolved P
Hay/Pasture	0.75	0.079
Cropland	2.9	0.079
Forest	0.19	0.01
Wetland	0.19	0.01
Disturbed	0.02	0.01
Turf/Golf	0	0
Open Land	0.5	0.01
Bare Rock	0	0
Sandy Areas	0	0
Unpaved Rd	0	0

	N	P	Sed
Groundwater (mg/L)	0.34	0.01	
Tile Drain (mg/L)	15	0.1	50
Soil Conc (mg/Kg)	2000	275	
% Bank Frac (0-1)	0.25	0.25	

Nitrogen and Phosphorus Loads from Point Sources and Septic Systems

	Point Source Loads/Discharge			Septic System Populations			
Month	Kg N	Kg P	MGD	Normal	Pond	Short Cir	Direct
Jan	0.0	0.0	0.0	1259	66	0	0
Feb	0.0	0.0	0.0	1259	66	0	0
Mar	0.0	0.0	0.0	1259	66	0	0
Apr	0.0	0.0	0.0	1259	66	0	0
May	0.0	0.0	0.0	1259	66	0	0
Jun	0.0	0.0	0.0	1259	66	0	0
Jul	0.0	0.0	0.0	1259	66	0	0
Aug	0.0	0.0	0.0	1259	66	0	0
Sep	0.0	0.0	0.0	1259	66	0	0
Oct	0.0	0.0	0.0	1259	66	0	0
Nov	0.0	0.0	0.0	1259	66	0	0
Dec	0.0	0.0	0.0	1259	66	0	0

Growing season uptake (g/d): N 1.6 P 0.4

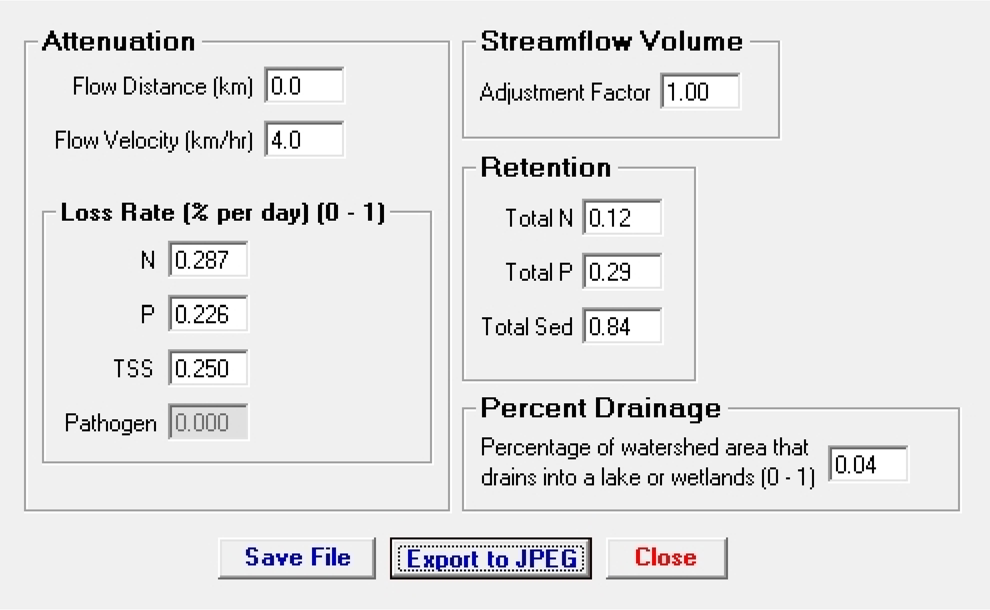
Per Capita Tank Load (g/d): N 12 P 2.5

Urban Buildup (kg/Ha/day)		Nitrogen			Phosphorus			TSS	
	Area (Ha)	Acc Imp	Acc Perv	Dis Fract	Acc Imp	Acc Perv	Dis Fract	Acc Imp	Acc Perv
LD Mixed	0	0	0	0	0	0	0	0	0
MD Mixed	11	0.105	0.015	0.33	0.0105	0.0021	0.4	6.2	0.8
HD Mixed	0	0	0	0	0	0	0	0	0
LD Residential	380	0.095	0.015	0.28	0.0095	0.0019	0.37	2.5	1.3
MD Residential	228	0.1	0.015	0.28	0.0115	0.0039	0.37	6.2	1.1
HD Residential	0	0	0	0	0	0	0	0	0

As illustrated in Figure 3.2, the model accounted for nutrient and sediment loading originating from a variety of sources. The County GIS data served as the basis for segregating and grouping various categories of land use, thus enabling us to compute pollutant loads for rural, suburban, and agricultural lands. As shown above, developed lands were divided into mixed use and residential categories and then ranked as low, medium or highly developed. The more developed the greater the amount of impervious cover. The model also accounted for the loading attributable to the remaining septic systems occurring within the Honeoye Lake watershed. As previously noted, the model also accounted for nutrients in both a particulate (solid) and dissolved state. Soil phosphorus concentrations (Soil Concentration (mg/kg)) were variable amongst subwatersheds and ranged from 250 – 300 mg/kg dependent on the soil P GIS grid. Septic system populations were assumed to exhibit 5% failure rates, represented in Figure

3.2 as "Pond". Also as illustrated in Figure 3.2, the model accounted for vegetation related nutrient uptake that occurs during the "growing season", defined as May through September. It would be expected that vegetation during this time of year will assimilate some of the available nutrients, thus decreasing the amount of loading to the lake. It should also be noted that there are no identified point sources within the Honeoye Lake watershed.

Figure 3.3: Delivery Input File



Attenuation
Flow Distance (km) 0.0
Flow Velocity (km/hr) 4.0

Loss Rate (% per day) (0 - 1)
N 0.287
P 0.226
TSS 0.250
Pathogen 0.000

Streamflow Volume
Adjustment Factor 1.00

Retention
Total N 0.12
Total P 0.29
Total Sed 0.84

Percent Drainage
Percentage of watershed area that drains into a lake or wetlands (0 - 1) 0.04

4.0 Hydrology Calibration

The aforementioned transport input data was iteratively manipulated in order to adjust resulting stream flow to a best fit with several regional USGS gages. Four (4) regional USGS gages, which represented similar land cover characteristics with the Honeoye watershed and were within relative close proximity to Honeoye Lake, were chosen for this calibration. The streams and respective USGS gaging stations utilized for this calibration are as follows:

- Honeoye Creek at Honeoye Falls – USGS 04229500
- Ninemile Creek near Marietta, NY – USGS 04240180
- Canaseraga Creek above Dansville, NY – USGS 04224775
- Keuka Lake Outlet at Dresden, NY – USGS 04232482

The data obtained from each of the four gaging stations is presented in Figure 4.1. As depicted, the majority of the flow, regardless of the monitored stream, occurs in the spring months (months 3 and 4, March and April). The resulting calibration of the hydrologic data is depicted in Figure 4.2, which presents the initial model run, the mean flows of the four reference gages, and the "best fit" iteration (Hydrocal9).

Figure 4.1: Hydrology Calibration – Regional USGS Gages

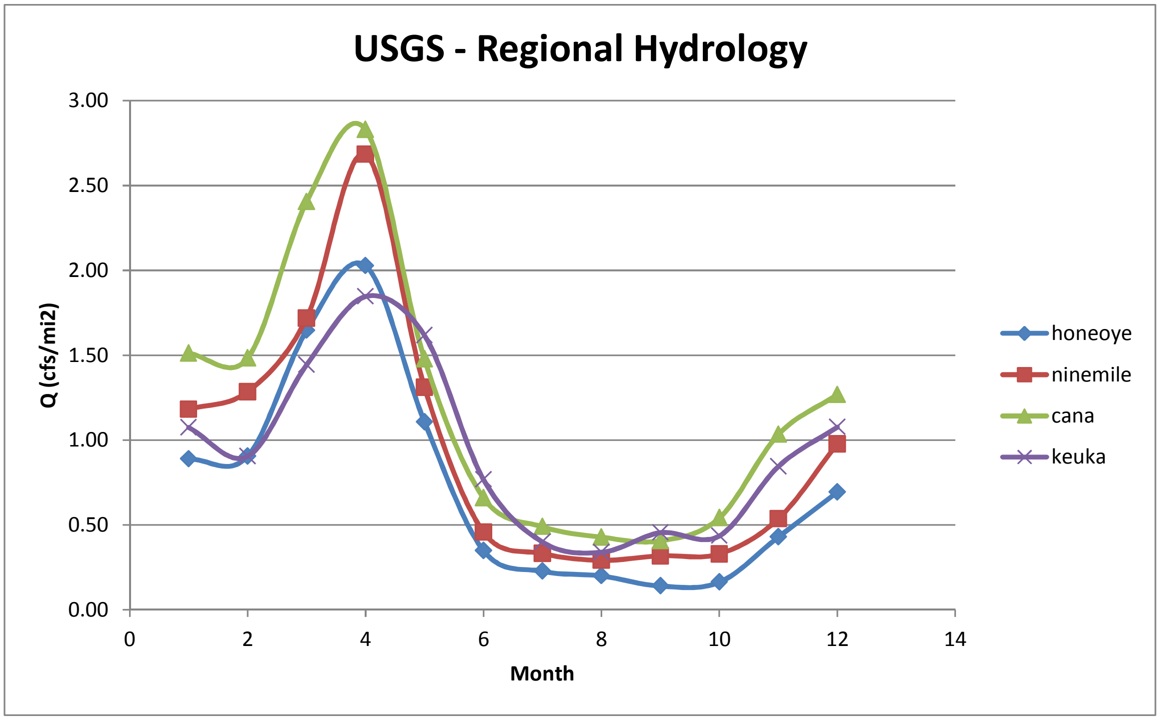
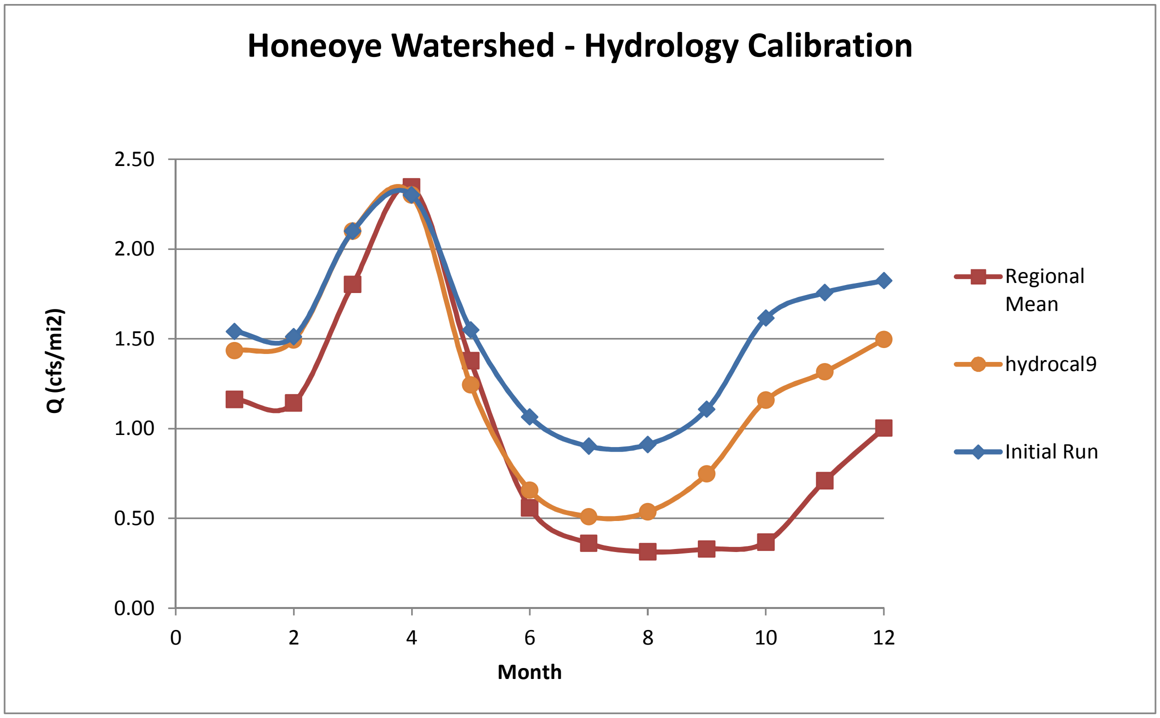


Figure 4.2: Hydrology Calibration



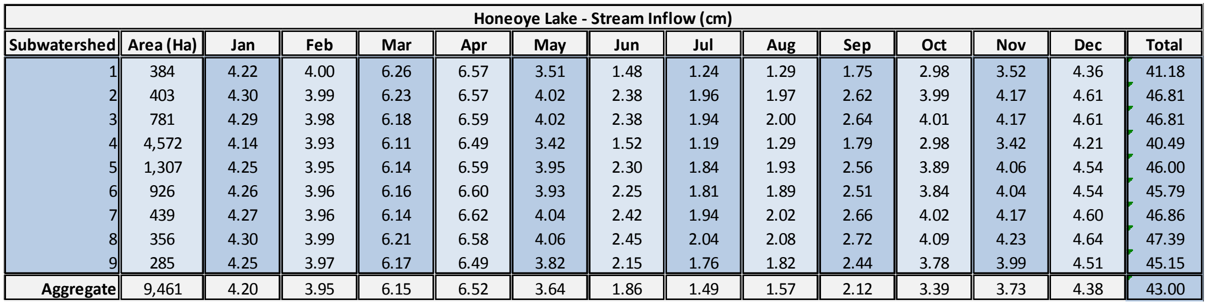
As previously mentioned, the lake's hydrologic data was iteratively manipulated through adjusting the "Adjust %ET" field. Specifically, a factor of 2 was applied from May through December, thus increasing the percent ET. The resulting adjusted discharge (Hydrocal 9 data) matches up rather well from the months of January through June. The modeled adjusted discharge from July through December was, however, higher than the regional gages. The difference in adjusted modeled data versus the regional data may likely be explained by the relatively unique topography of the Honeoye watershed. The prevailing slopes of the Honeoye Lake watershed, particularly the topography characteristic of the southwest and southeast subwatersheds, are steeper than the slopes characterizing the watersheds of the reference gages. The steeper topography of the Honeoye Lake watershed likely leads to both greater volumes of discharge and more rapid flows than would be characteristic of watersheds with lesser relief. As per the data presented in Figure 4.2, this effect is more pronounced during the growing season. When vegetative cover is both denser and photosynthesis is at or near peak rates, evapotranspiration and subsurface recession will also be at or near peak rates. In watersheds characterized by lesser relief (flatter topography) the rate of flow through this cover will be further reduced and the amount of runoff further decreased. Thus, although the relative rate and volume of runoff should always be greater for steeper sloped as compared to gentler sloped lands, the rate and volume of runoff will be further reduced in flatter terrain areas during the growing season when the density and photosynthetic activity of the vegetation peaks.

5.0 Results

5.1 Hydrology

Monthly stream flow for each subwatershed and the watershed as an aggregate is presented in Table 5.1.

Table 5.1: Hydrology



Honeoye Lake - Stream Inflow (cm)

Subwatershed	Area (Ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	384	4.22	4.00	6.26	6.57	3.51	1.48	1.24	1.29	1.75	2.98	3.52	4.36	41.18
2	403	4.30	3.99	6.23	6.57	4.02	2.38	1.96	1.97	2.62	3.99	4.17	4.61	46.81
3	781	4.29	3.98	6.18	6.59	4.02	2.38	1.94	2.00	2.64	4.01	4.17	4.61	46.81
4	4,572	4.14	3.93	6.11	6.49	3.42	1.52	1.19	1.29	1.79	2.98	3.42	4.21	40.49
5	1,307	4.25	3.95	6.14	6.59	3.95	2.30	1.84	1.93	2.56	3.89	4.06	4.54	46.00
6	926	4.26	3.96	6.16	6.60	3.93	2.25	1.81	1.89	2.51	3.84	4.04	4.54	45.79
7	439	4.27	3.96	6.14	6.62	4.04	2.42	1.94	2.02	2.66	4.02	4.17	4.60	46.86
8	356	4.30	3.99	6.21	6.58	4.06	2.45	2.04	2.08	2.72	4.09	4.23	4.64	47.39
9	285	4.25	3.97	6.17	6.49	3.82	2.15	1.76	1.82	2.44	3.78	3.99	4.51	45.15
Aggregate	9,461	4.20	3.95	6.15	6.52	3.64	1.86	1.49	1.57	2.12	3.39	3.73	4.38	43.00

As per these data, the greatest amount of inflow occurs in the spring (May and April) and the least occurs in the summer (June – August). Additionally, although not the largest subwatershed in total area, Subwatersheds 2, 3, 7 and 8 are the top four contributing sources of inflow to the lake, on a per unit area basis.

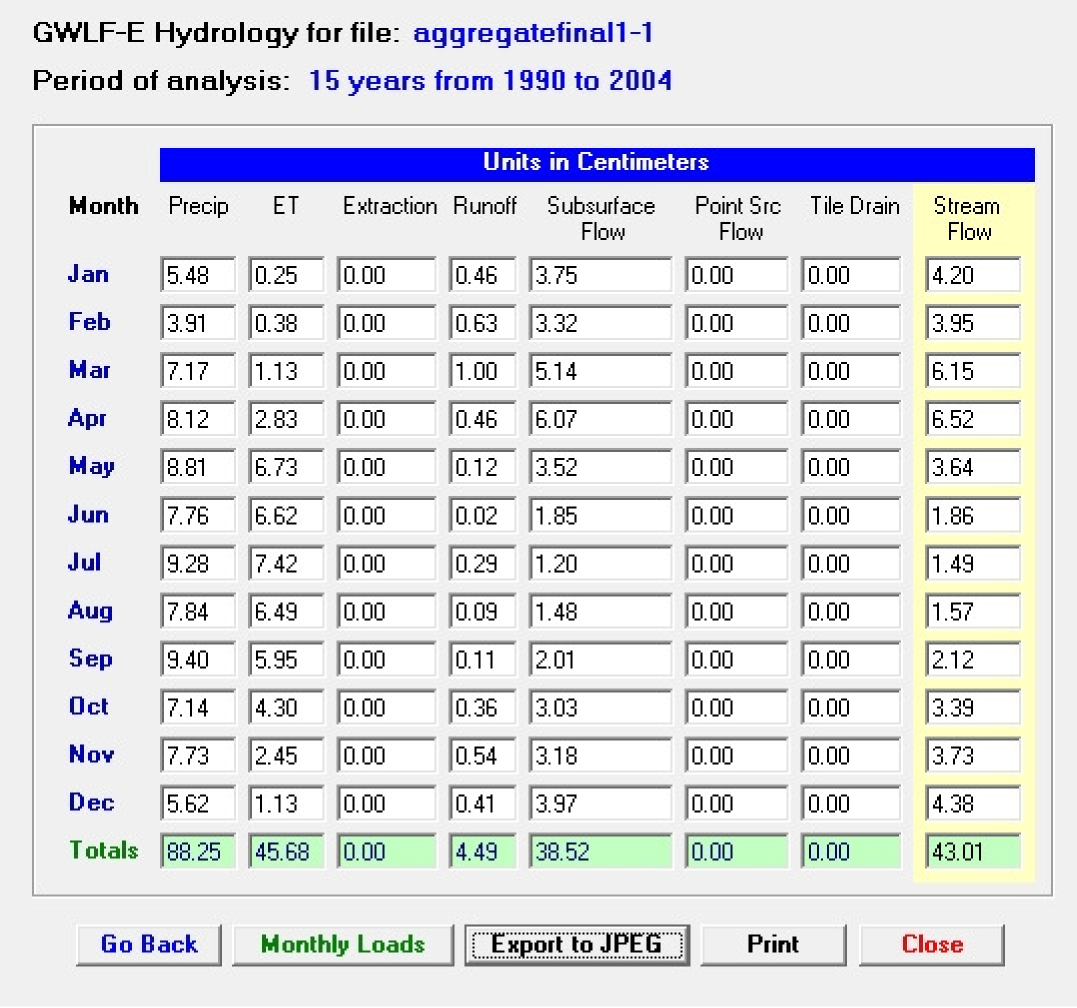
Hydrologic characteristics for the watershed, when modeled as an aggregate, are provided in Table 5.2 and Figures 5.1 and 5.2.

As an aggregate, 43.00 cm of water flows into the lake via the watershed on an annual basis. Volumetrically, this equates to 4.07 x 10^7 m^3 of water entering the lake on an annual basis. This value is less than Princeton Hydro's original estimate of 4.7 x 10^7 m^3, which was calculated as part of the *Honeoye Lake Nutrient and Hydrologic Budget* (Princeton Hydro, 2007).

Honeoye Lake has an estimated volume of 3.4 x 10^7 m^3 which translates to a retention period of 0.85 years (310 days). This is generally in line with past studies of the lake, and slightly higher than Princeton Hydro's previously reported retention period of 0.75 years (275 days) Princeton Hydro, 2007). These data are in keeping with previously published computed estimates of the lake's flushing rate (Schaffner and Oglesby, 1978). Regardless, although Honeoye Lake may be the fastest flushing of all the Finger Lakes, its annualized lake hydrologic retention time of 0.75 - 0.85 years is slow. Thus, there is ample opportunity both for the settling of the sediments transported into the lake via runoff and the assimilation of dissolved nutrients by the lake's primary producers (aquatic plants, algae and phytoplankton). Slower hydrologic retention times facilitate the eutrophication process.

For management purposes it is critically important to parse out hydrology components into those associated with groundwater (baseflow) and those associated with surface flows (storm flows). Figure 5.1 provides a breakdown of stream flow into the lake showing the groundwater and surface water components.

Table 5.2: Aggregate Hydrology



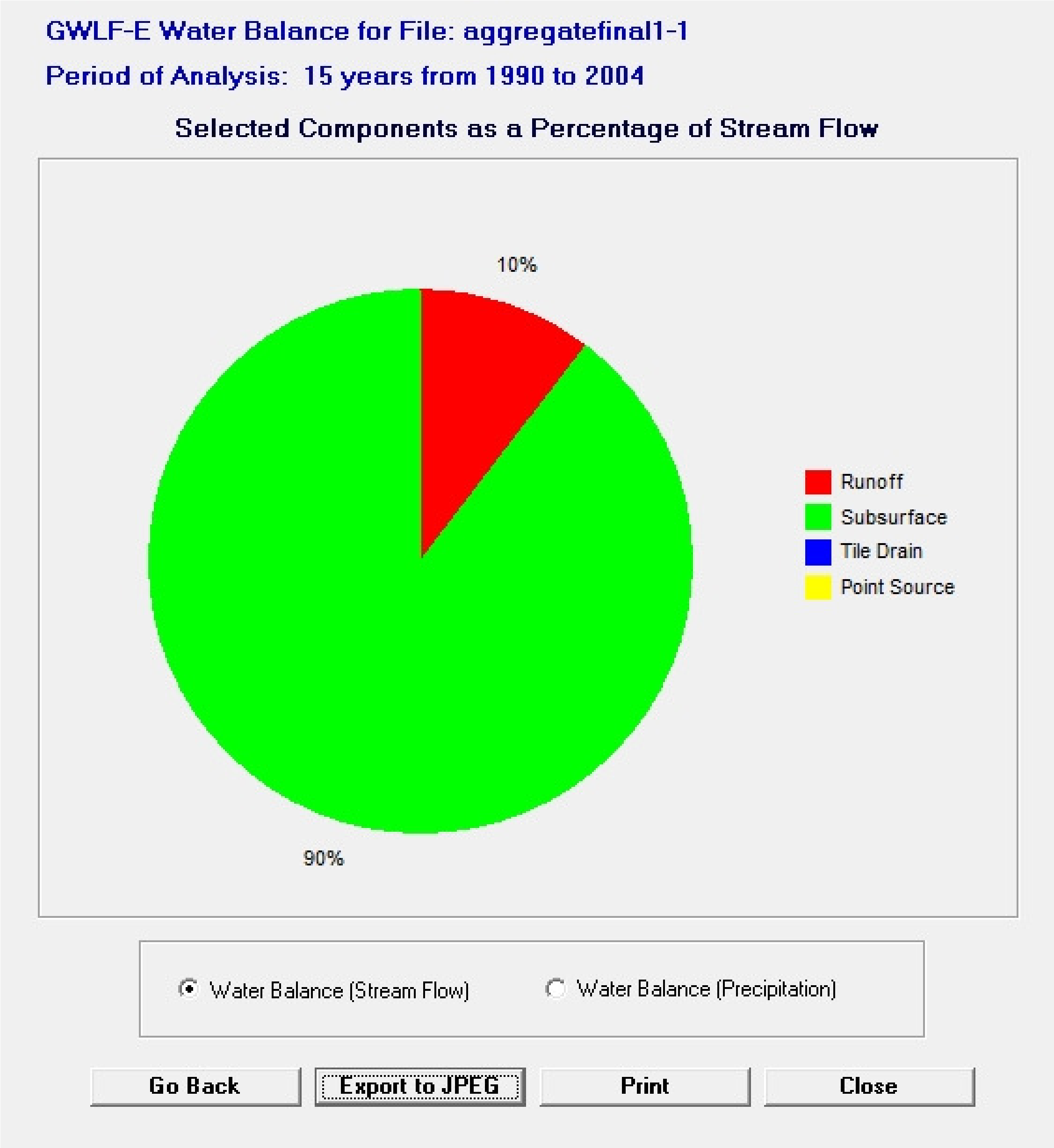
GWLF-E Hydrology for file: aggregatefinal1-1

Period of analysis: 15 years from 1990 to 2004

Units in Centimeters

Month	Precip	ET	Extraction	Runoff	Subsurface Flow	Point Src Flow	Tile Drain	Stream Flow
Jan	5.48	0.25	0.00	0.46	3.75	0.00	0.00	4.20
Feb	3.91	0.38	0.00	0.63	3.32	0.00	0.00	3.95
Mar	7.17	1.13	0.00	1.00	5.14	0.00	0.00	6.15
Apr	8.12	2.83	0.00	0.46	6.07	0.00	0.00	6.52
May	8.81	6.73	0.00	0.12	3.52	0.00	0.00	3.64
Jun	7.76	6.62	0.00	0.02	1.85	0.00	0.00	1.86
Jul	9.28	7.42	0.00	0.29	1.20	0.00	0.00	1.49
Aug	7.84	6.49	0.00	0.09	1.48	0.00	0.00	1.57
Sep	9.40	5.95	0.00	0.11	2.01	0.00	0.00	2.12
Oct	7.14	4.30	0.00	0.36	3.03	0.00	0.00	3.39
Nov	7.73	2.45	0.00	0.54	3.18	0.00	0.00	3.73
Dec	5.62	1.13	0.00	0.41	3.97	0.00	0.00	4.38
Totals	88.25	45.68	0.00	4.49	38.52	0.00	0.00	43.01

Figure 5.1: Aggregate Hydrology Stream Flow Components



GWLF-E Water Balance for File: aggregatefinal1-1

Period of Analysis: 15 years from 1990 to 2004

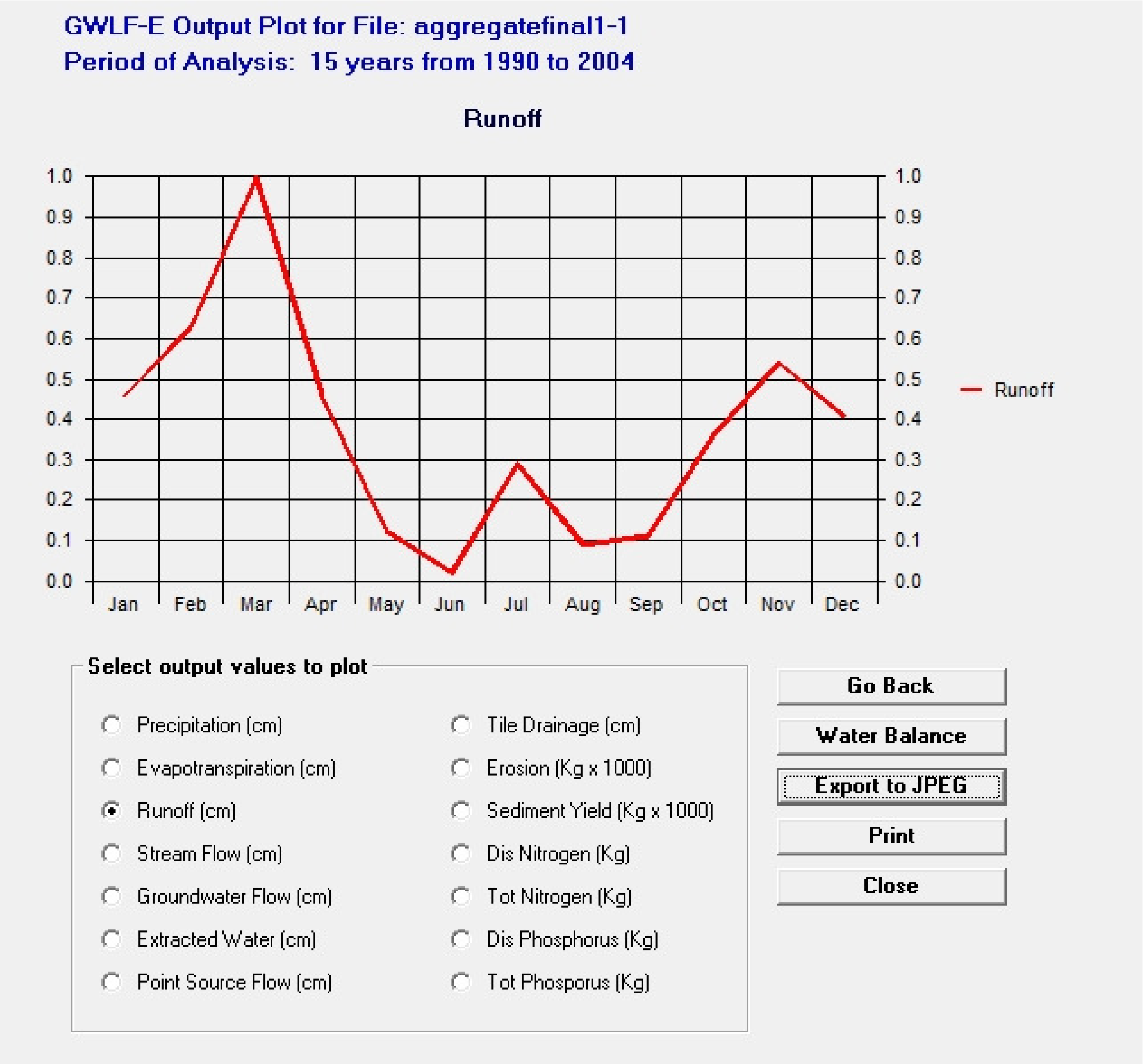
Selected Components as a Percentage of Stream Flow

● Water Balance (Stream Flow)
○ Water Balance (Precipitation)

As evidenced above, 90% of the hydrologic inflow into Honeoye Lake is estimated to be derived from base flow (sub-surface sources). The remaining 10% is estimated to occur via surface runoff during storm events.

In terms of management, our focus is generally placed on the “runoff” component of stream discharge as this is the component of inflow which transports much of the sediment and nutrient load into the receiving waterbody. As such, Figure 5.2 summarizes monthly runoff patterns.

Figure 5.2: Aggregate Hydrology Stream Flow Components



GWLF-E Output Plot for File: aggregatefinal1-1
Period of Analysis: 15 years from 1990 to 2004

Select output values to plot

- ○ Precipitation (cm)
- ○ Evapotranspiration (cm)
- ● Runoff (cm)
- ○ Stream Flow (cm)
- ○ Groundwater Flow (cm)
- ○ Extracted Water (cm)
- ○ Point Source Flow (cm)
- ○ Tile Drainage (cm)
- ○ Erosion (Kg x 1000)
- ○ Sediment Yield (Kg x 1000)
- ○ Dis Nitrogen (Kg)
- ○ Tot Nitrogen (Kg)
- ○ Dis Phosphorus (Kg)
- ○ Tot Phosporus (Kg)

As per the model, peak flows occur in March, coinciding with the spring thaw when the ground is largely frozen and there is little vegetation growing. In April through June, "leaf out" and increased plant evapotranspiration decreases overland runoff. A slight increase in the surface runoff is predicted for July due to rainfall amounts and intensity patterns, but runoff declines from August through September largely due to plant evapotranspiration. A slight increase occurs from October through November due to "leaf fall", but dips again from December through February, with the winter months producing the least amount of runoff.

5.2 Pollutant Loading

Table 5.3 presents pollutant loading to Honeoye Lake on a subwatershed and aggregate basis. The Erosion Load is the total projected amount of soil/sediment mobilized from each subwatershed annually. The Sediment Load is the amount of the Erosion Load that is actually transported and conveyed into the receiving waterway. As such the Sediment Load is of greater concern in our analyses.

The dissolved N and P loads are part of the total N and P loads. Again the TN and TP loads are of greatest importance in our analyses, even though the dissolved load is readily assimilated and "biologically active".

Table 5.3: Honeoye Lake – Pollutant Loading

Honeoye Lake - Pollutant Loading							
Subwatershed	Area (Ha)	Erosion kgx1000/yr	Sediment kgx1000/yr	Dis. N kg/yr	TN kg/yr	Dis. P kg/yr	TP kg/yr
1	384	1369	310	748	1382	26	118
2	403	1057	223	961	1393	29	92
3	781	1170	310	1668	2217	53	131
4	4572	6966	1248	7138	9339	212	535
5	1307	202	52	2302	2397	68	80
6	926	241	85	1545	1710	49	68
7	439	70	27	844	888	25	31
8	356	250	71	693	854	23	42
9	285	165	59	546	663	18	33
Sum	9453	11490	2386	16445	20844	502	1130
Aggregate	9461	11173	2877	16391	20196	500	1005

On an aggregate basis, 2,877,000 kg/yr of sediment, 20,196 kg/yr of total nitrogen and 1,005 kg/yr of total phosphorus are transported to Honeoye Lake. The difference between the aggregate modeled loads and the summation of the subwatershed modeled loads is due to computational differences associated with internal raster conversions. It is important to normalize the previously mentioned subwatershed loads in order to determine which subwatersheds are contributing a disproportionate load per unit area, see Table 5.4.

Table 5.4: Honeoye Lake - Normalized Pollutant Loads

Honeoye Lake - Normalized Pollutant Loads (kg/ha)						
Subwatershed	Erosion	Sediment	Dis. N	TN	Dis. P	TP
1	3564	808	1.95	3.60	0.07	0.31
2	2624	553	2.39	3.46	0.07	0.23
3	1498	396	2.14	2.84	0.07	0.17
4	1524	273	1.56	2.04	0.05	0.12
5	154	40	1.76	1.83	0.05	0.06
6	260	92	1.67	1.85	0.05	0.07
7	158	62	1.92	2.02	0.06	0.07
8	703	201	1.95	2.40	0.06	0.12
9	581	208	1.92	2.33	0.06	0.12

Subwatershed 1 (Northwest) ranks as the highest contributor of sediment, total nitrogen and total phosphorus **on a per unit area scale**. The second highest contributor of sediments and total nutrients to the lake **on a per unit area** basis is Subwatershed 2 (Affolter Gully).

An important component of management lies in parsing out ‘manageable’ versus ‘unmanageable’ pollutant loads. For the sake of this project, ‘unmanageable’ refers to loads originating from forests or wetlands and loads derived from groundwater. ‘Manageable’ loads are assigned to those originating from all other land use types and from stream bank erosion and septic systems. Table 5.5 provides a breakdown of these loads.

Table 5.5: Honeoye Lake – Manageable and Unmanageable Pollutant Loads

Honeoye Lake - Manageable and Unmanageable Pollutant Loads

Subwatershed	Sediment				TN				TP			
	M (kg/yr)	% M (%)	UM (kg/yr)	% UM (%)	M (kg/yr)	% M (%)	UM (kg/yr)	% UM (%)	M (kg/yr)	% M (%)	UM (kg/yr)	% UM (%)
1	304	98	7	2	897	65	485	35	101	86	16	14
2	218	98	4	2	804	58	590	42	74	80	19	20
3	283	92	26	8	1007	45	1210	55	89	67	43	33
4	1023	82	225	18	2989	32	6350	68	288	54	247	46
5	23	44	29	56	392	16	2005	84	14	17	66	83
6	59	70	26	30	298	17	1412	83	20	30	48	70
7	17	61	11	39	198	22	690	78	8	25	23	75
8	66	92	6	8	316	37	538	63	24	59	17	41
9	57	96	2	4	258	39	405	61	21	62	13	38

Manageable pollutant loads are highest, on a percent basis, in Subwatershed 1, which is also the subwatershed that is the greatest per unit area basis pollutant contributor to the lake. As such, best management practices could prove to be very effective in reducing the pollutant loading of Subwatershed 1 to the lake. Conversely, while the ratio of the manageable versus unmanageable pollutant load for Subwatershed 4 is lower, the total amount of loading to the lake that could be reduced by implementing stormwater management measures in this subwatershed are significant. Additionally, unique opportunities exist within the boundaries of the Honeoye Inlet Wildlife Management Area for the implementation of stormwater Best Management Practices (BMP) having both flood and pollutant load mitigation capabilities.

5.3 Storm Specific Loading

Storm specific loading represents the hydrologic and pollutant loading that occurs under discrete storm frequencies. Princeton Hydro analyzed the effects of the 1-year, 2-year, 5-year, 10-year and 100-year 24-hour storm events as a component of the selection of appropriate best management practices. These events are defined as the probability of a storm of a given magnitude occurring within time frame, or “return frequency”. Thus a 1-year storm statistically has a 100% probability of occurring at least once in a given year, a 2-year storm a 50% probability, a 5-year storm a 20% probability, a 10-year storm a 10% probability and a 100-year storm a 1% probability. It must be emphasized that these are probabilities and thus it is “possible”, although unlikely, to have two or three 100-year events within a single year. The rainfall amounts associated with each of these events reflects and intensity or rate; that is the amount of rainfall occurring over a 24-hour period. Using the USDOC (1963) rainfall isopleths and guidance provided in the New York Stormwater Management Manual (NYSDEC, 2010), the 1-year event equates to 2.0” over 24 hours, the 2-year to 2.2”, the 5-year to 3.2”, the 10-year to 4.0” and the 100-year to 4.8”.

In order to conduct the storm specific analyses Princeton Hydro first determined the precipitation amounts which correlated with the aforementioned storm frequencies. The *MapShed* weather input files were then modified to allow for the input of the above storm event values. We also modified the input files to enable us to compute the spring, summer, fall and winter loads generated by each targeted storm. The model was run and the results culled and analyzed. The subwatershed specific results of this analysis are presented in Tables 5.6 through 5.15. Table 5.16 presents the storm specific loading data computed for only that portion of Subwatershed 4 contained within the boundaries of the Honeoye Inlet Watershed Management Area. It should be noted that the spring, summer, fall and winter loads are not additive. The loads listed under each storm for each season reflect seasonal differences affected by productivity, ambient soil conditions, and potential for pollutant mobilization and transport. Additionally, the loading generated by the 2, 5, 10 and 100-year events inherently include the loads generated by the 1-year event. Finally, storms up to and including the 1-year event cumulatively account for 90% of all the rainfall occurring over a given year. Thus, even the majority of rain events occurring annually are relatively small, collectively they account for the majority of the total annual rainfall and the total runoff generated from a watershed.

Some relevant findings are as follows:

- Spring and summer storms, regardless of the magnitude of the event, generate the greatest percentage of pollutant load

- The highest pollutant concentrations are associated with spring and fall events

- The 1-year (water quality) event is responsible for a large percentage (as much as 70%) of the storm-specific loads generated by the larger, less frequent events. This is because regardless of the overall magnitude of a storm, the majority of the pollutant loading occurs during the first flush of the event. As such, from the perspective of pollutant load reduction, BMPs sized to manage the 1-year event should have the greatest cost-effectiveness. Additionally, the larger events have less of a probability of occurring during any one year. Thus, designing stormwater quality improvement BMPs for the 1-year event typically generates the greatest cost-benefit.

- Comparing the 1, 2, 5 and 10-year events, the worst flooding and scour impacts appear to be caused by the 5-year storm as based on the comparative flow rates of the modeled events. The 5-year event has a 20% probability of occurring during any one year.

Table 5.6: Honeoye Lake – Aggregate Stormwater Specific Loads

Aggregate Watershed - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	673,514	28,188	43.51	245.15	0.40	13.66	0.02
	Spring	1,844,748	276,729	160.65	813.81	0.54	65.66	0.04
	Summer	411,317	174,782	373.55	326.80	0.85	30.84	0.08
	Fall	929,845	614,840	715.66	1,054.67	1.40	116.22	0.15
2-yr	Winter	802,187	33,381	43.42	286.67	0.40	15.88	0.02
	Spring	2,288,420	349,671	164.15	1,003.10	0.52	81.77	0.04
	Summer	606,093	256,394	397.05	464.36	0.82	44.78	0.08
	Fall	1,216,701	794,771	755.05	1,367.34	1.39	151.76	0.15
5-yr	Winter	1,197,484	49,614	43.27	417.46	0.39	22.99	0.02
	Spring	3,458,892	539,273	165.75	1,536.02	0.50	127.07	0.04
	Summer	1,088,318	460,033	405.02	852.63	0.81	84.53	0.08
	Fall	1,938,405	1,245,997	782.61	2,221.35	1.41	248.72	0.16
10-yr	Winter	1,365,771	56,991	45.48	473.19	0.39	25.93	0.02
	Spring	4,317,569	651,442	157.46	1,923.28	0.49	158.17	0.04
	Summer	1,722,880	646,954	378.32	1,252.82	0.77	124.03	0.08
	Fall	2,668,972	1,668,756	743.15	3,024.43	1.35	340.11	0.15

Table 5.7: Honeoye Lake – Subwatershed 1 Stormwater Specific Loads

Subwatershed 1 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	29,638	2,187	48.92	24.97	0.59	1.75	0.03
	Spring	83,809	45,386	574.42	108.64	1.61	11.60	0.17
	Summer	18,773	30,000	1376.37	50.52	2.90	5.92	0.32
	Fall	42,299	115,380	2881.00	180.84	5.39	24.03	0.70
2-yr	Winter	35,061	2,686	49.70	29.04	0.56	1.99	0.03
	Spring	102,738	58,065	604.69	134.98	1.58	14.47	0.17
	Summer	26,775	43,772	1505.93	70.93	2.86	8.39	0.33
	Fall	54,344	147,891	3047.54	232.46	5.36	30.91	0.71
5-yr	Winter	51,709	4,388	53.53	42.07	0.55	2.80	0.03
	Spring	151,652	92,806	654.31	210.32	1.59	22.84	0.17
	Summer	44,965	80,209	1680.65	130.46	3.00	15.73	0.36
	Fall	83,194	230,568	3342.01	374.18	5.65	49.91	0.75
10-yr	Winter	58,929	5,282	52.80	47.46	0.53	3.11	0.03
	Spring	187,903	113,652	636.83	263.26	1.56	28.43	0.17
	Summer	71,110	115,609	1638.11	192.73	2.93	23.32	0.35
	Fall	113,581	314,526	3318.52	513.59	5.58	68.67	0.75
100-yr	Winter	86,034	8,730	54.94	69.29	0.52	4.48	0.03
	Spring	286,556	179,181	643.30	423.66	1.57	46.15	0.17
	Summer	133,136	208,683	1592.28	368.86	2.95	45.15	0.36
	Fall	188,816	525,981	3220.93	896.86	5.58	120.66	0.75

Table 5.8: Honeoye Lake – Subwatershed 2 Stormwater Specific Loads

Subwatershed 2 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	30,944	1,092	22.94	23.55	0.53	0.97	0.02
	Spring	86,695	34,178	419.19	91.80	1.25	7.73	0.11
	Summer	86,695	34,178	419.19	91.80	1.25	7.73	0.11
	Fall	47,234	96,072	2194.37	149.74	3.66	18.44	0.45
2-yr	Winter	36,682	1,445	24.63	28.32	0.53	1.17	0.02
	Spring	106,706	43,697	434.81	115.85	1.25	9.85	0.11
	Summer	34,181	40,153	1127.66	66.31	2.03	7.02	0.21
	Fall	60,839	124,266	2308.15	196.30	3.78	24.24	0.47
5-yr	Winter	54,267	2,621	28.60	43.44	0.53	1.85	0.02
	Spring	158,768	68,740	454.51	184.13	1.28	16.01	0.11
	Summer	57,923	70,724	1179.37	122.07	2.16	13.23	0.23
	Fall	94,453	192,436	2387.76	321.21	4.01	39.85	0.50
10-yr	Winter	61,939	3,294	28.71	50.37	0.53	2.18	0.02
	Spring	196,843	83,717	439.55	233.91	1.28	20.30	0.11
	Summer	87,430	97,971	1127.22	177.15	2.13	19.19	0.23
	Fall	127,633	256,336	2309.88	436.65	3.95	54.46	0.50
100-yr	Winter	90,600	5,761	30.86	76.86	0.53	3.47	0.02
	Spring	301,225	131,184	442.26	383.19	1.33	33.79	0.12
	Summer	159,741	171,253	1082.00	336.42	2.19	36.74	0.24
	Fall	211,599	416,199	2178.00	754.08	3.96	94.48	0.50

Table 5.9: Honeoye Lake – Subwatershed 3 Stormwater Specific Loads

Subwatershed 3 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	56,122	2,364	34.54	29.58	0.48	1.79	0.02
	Spring	153,836	41,756	291.87	111.00	0.90	10.53	0.09
	Summer	33,791	26,838	671.23	47.26	1.49	5.07	0.15
	Fall	77,981	101,150	1371.27	162.36	2.58	20.43	0.32
2-yr	Winter	66,745	2,874	34.79	34.60	0.47	2.06	0.02
	Spring	190,489	53,259	302.90	137.63	0.87	13.10	0.08
	Summer	49,209	39,696	741.79	67.31	1.47	7.34	0.15
	Fall	101,263	130,512	1470.77	210.21	2.59	26.46	0.32
5-yr	Winter	99,393	4,560	36.03	50.51	0.46	2.98	0.02
	Spring	286,939	83,636	313.32	212.80	0.85	20.69	0.08
	Summer	86,431	72,465	795.12	124.77	1.50	14.12	0.17
	Fall	159,193	205,420	1586.13	342.14	2.70	43.64	0.35
10-yr	Winter	114,005	5,409	35.54	57.48	0.45	3.36	0.02
	Spring	357,946	101,350	298.21	266.30	0.82	25.79	0.08
	Summer	138,069	102,943	752.00	183.94	1.43	20.90	0.16
	Fall	218,964	277,400	1529.21	468.08	2.62	60.08	0.34
100-yr	Winter	168,205	8,614	35.85	84.63	0.44	4.92	0.02
	Spring	554,447	156,905	290.51	426.60	0.82	41.47	0.08
	Summer	264,726	182,453	698.59	350.76	1.40	40.08	0.16
	Fall	370,994	455,318	1408.84	810.16	2.53	104.22	0.33

Table 5.10: Honeoye Lake – Subwatershed 4 Stormwater Specific Loads

Subwatershed 4 - Daily Loads

Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	320,097	7,613	21.53	93.30	0.36	4.45	0.01
	Spring	872,692	177,794	221.26	400.38	0.57	38.06	0.05
	Summer	184,211	124,601	575.65	171.94	0.95	19.95	0.10
	Fall	430,235	451,132	1151.06	660.21	1.85	85.68	0.24
2-yr	Winter	382,025	9,693	22.33	111.03	0.36	5.41	0.01
	Spring	1,085,815	227,092	227.63	504.15	0.55	48.77	0.05
	Summer	278,486	183,843	611.25	256.65	0.97	30.32	0.11
	Fall	568,483	585,781	1217.73	872.82	1.90	113.78	0.25
5-yr	Winter	572,176	16,514	23.92	167.45	0.36	8.61	0.01
	Spring	1,650,071	354,617	230.14	801.32	0.55	79.75	0.05
	Summer	516,336	330,057	610.74	499.33	0.99	60.34	0.12
	Fall	919,310	922,212	1239.38	1,456.80	1.97	191.43	0.26
10-yr	Winter	658,216	20,220	23.91	195.45	0.36	10.27	0.01
	Spring	2,063,192	428,239	217.33	1,012.77	0.53	100.56	0.05
	Summer	822,720	461,232	563.71	739.77	0.95	88.90	0.11
	Fall	1,272,205	1,231,224	1159.05	2,000.97	1.89	263.29	0.25
100-yr	Winter	975,494	33,625	24.49	299.40	0.36	16.52	0.01
	Spring	3,213,053	660,998	210.14	1,660.30	0.54	166.47	0.05
	Summer	1,594,344	807,256	511.13	1,437.48	0.94	172.38	0.11
	Fall	2,181,842	1,992,864	1032.43	3,478.65	1.81	457.41	0.24

Table 5.11: Honeoye Lake – Subwatershed 5 Stormwater Specific Loads

Subwatershed 5 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	90,190	427	3.86	17.70	0.33	0.87	0.01
	Spring	243,626	7,083	31.55	46.21	0.23	2.82	0.01
	Summer	52,656	4,618	74.38	13.67	0.28	1.00	0.02
	Fall	122,415	16,954	149.11	41.61	0.42	3.56	0.03
2-yr	Winter	107,627	516	3.89	20.46	0.33	1.02	0.01
	Spring	303,427	8,980	32.26	55.79	0.22	3.49	0.01
	Summer	78,241	6,823	80.57	18.92	0.26	1.44	0.02
	Fall	160,661	21,938	159.30	53.02	0.40	4.62	0.03
5-yr	Winter	161,254	807	4.00	29.26	0.32	1.50	0.01
	Spring	462,408	13,855	32.22	83.69	0.20	5.37	0.01
	Summer	142,749	12,274	82.02	34.03	0.25	2.71	0.02
	Fall	258,140	34,463	165.17	84.92	0.39	7.53	0.04
10-yr	Winter	185,665	948	3.93	33.57	0.32	1.76	0.01
	Spring	578,909	16,643	30.22	104.78	0.19	6.88	0.01
	Summer	228,300	17,205	75.85	51.42	0.24	4.15	0.02
	Fall	356,913	45,980	154.95	115.56	0.38	10.51	0.03
100-yr	Winter	275,618	1,475	3.91	49.48	0.32	2.62	0.01
	Spring	904,368	25,406	28.78	167.73	0.19	11.04	0.01
	Summer	443,456	30,074	68.54	100.98	0.24	8.07	0.02
	Fall	612,350	74,232	137.70	200.40	0.36	18.13	0.03

Table 5.12: Honeoye Lake – Subwatershed 6 Stormwater Specific Loads

Subwatershed 6 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	64,575	1,107	13.43	17.72	0.36	1.22	0.02
	Spring	175,328	10,425	64.47	49.80	0.36	4.01	0.03
	Summer	36,244	6,059	141.00	17.28	0.53	1.55	0.05
	Fall	87,105	21,829	269.30	49.94	0.78	4.92	0.07
2-yr	Winter	76,963	1,265	12.83	20.10	0.35	1.39	0.01
	Spring	217,876	13,012	65.24	59.10	0.33	4.84	0.03
	Summer	53,837	8,899	151.82	23.17	0.47	2.13	0.04
	Fall	113,930	28,046	285.26	62.24	0.71	6.26	0.07
5-yr	Winter	115,072	1,772	12.20	27.68	0.33	1.87	0.01
	Spring	330,599	19,716	64.54	85.32	0.30	6.90	0.02
	Summer	97,351	16,047	156.50	39.78	0.42	3.70	0.04
	Fall	181,615	44,037	301.23	96.52	0.66	9.71	0.07
10-yr	Winter	132,335	1,967	11.65	30.82	0.33	2.03	0.01
	Spring	413,496	23,631	60.49	104.23	0.28	8.34	0.02
	Summer	157,389	22,760	145.85	58.15	0.40	5.38	0.04
	Fall	251,326	59,318	286.51	129.25	0.62	13.05	0.06
100-yr	Winter	196,101	2,770	11.12	43.29	0.33	2.77	0.01
	Spring	644,289	35,515	56.74	159.81	0.26	12.63	0.02
	Summer	306,688	39,727	131.29	108.23	0.37	10.01	0.03
	Fall	430,298	96,254	256.74	218.20	0.58	22.14	0.06

Table 5.13: Honeoye Lake – Subwatershed 7 Stormwater Specific Loads

Subwatershed 7 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	29,965	288	8.46	6.64	0.36	0.36	0.01
	Spring	80,532	3,050	41.09	17.54	0.27	1.17	0.02
	Summer	16,267	1,783	90.49	5.28	0.36	0.40	0.03
	Fall	39,828	6,551	175.11	15.80	0.52	1.40	0.04
2-yr	Winter	35,772	337	8.33	7.64	0.35	0.42	0.01
	Spring	100,410	3,840	41.82	21.08	0.25	1.42	0.02
	Summer	24,418	2,644	98.81	7.22	0.32	0.57	0.02
	Fall	52,321	8,460	188.28	20.00	0.48	1.78	0.04
5-yr	Winter	53,643	492	8.20	10.67	0.34	0.63	0.01
	Spring	153,351	5,858	41.30	30.84	0.23	2.24	0.02
	Summer	44,900	4,781	101.14	12.64	0.29	1.11	0.03
	Fall	84,149	13,329	198.38	31.35	0.46	3.04	0.04
10-yr	Winter	61,812	558	8.00	12.14	0.34	0.70	0.01
	Spring	192,215	7,018	38.58	38.30	0.22	2.74	0.02
	Summer	72,969	6,759	93.37	19.01	0.28	1.64	0.02
	Fall	116,794	17,861	186.31	42.55	0.43	4.10	0.04
100-yr	Winter	91,887	813	7.80	17.54	0.34	1.00	0.01
	Spring	300,940	10,615	36.26	60.19	0.21	4.25	0.01
	Summer	143,396	11,848	83.64	36.73	0.27	3.11	0.02
	Fall	201,195	28,935	164.94	73.01	0.41	6.95	0.04

Table 5.14: Honeoye Lake – Subwatershed 8 Stormwater Specific Loads

Subwatershed 8 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	26,257	871	22.16	14.02	0.47	1.01	0.02
	Spring	72,725	9,956	146.70	42.74	0.74	3.67	0.06
	Summer	16,244	5,987	314.62	17.18	1.19	1.57	0.10
	Fall	37,132	22,220	629.95	48.84	1.76	5.04	0.18
2-yr	Winter	31,151	1,000	21.20	16.01	0.45	1.12	0.02
	Spring	89,677	12,503	150.76	51.31	0.70	4.33	0.06
	Summer	23,281	8,744	345.47	23.08	1.10	2.09	0.10
	Fall	47,835	28,450	669.19	61.18	1.66	6.26	0.17
5-yr	Winter	46,197	1,430	20.51	22.26	0.43	1.46	0.02
	Spring	133,993	19,381	155.94	74.82	0.65	6.10	0.05
	Summer	39,797	15,980	379.43	39.56	1.04	3.56	0.09
	Fall	74,084	44,655	734.09	94.83	1.61	9.53	0.16
10-yr	Winter	52,853	1,603	19.41	24.64	0.41	1.55	0.02
	Spring	166,736	23,468	148.94	91.70	0.61	7.30	0.05
	Summer	63,505	22,953	364.86	57.28	0.98	5.12	0.09
	Fall	101,545	60,814	721.88	127.29	1.54	12.75	0.16
100-yr	Winter	77,667	2,329	18.66	34.49	0.40	2.06	0.02
	Spring	256,802	35,989	144.44	140.73	0.59	11.05	0.05
	Summer	120,723	40,807	343.49	105.31	0.93	9.50	0.08
	Fall	170,660	100,624	680.64	215.56	1.47	21.84	0.15

Table 5.15: Honeoye Lake – Subwatershed 9 Stormwater Specific Loads

Subwatershed 9 - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	20,755	743	28.13	10.89	0.47	0.74	0.02
	Spring	57,302	7,022	131.17	32.21	0.72	2.74	0.06
	Summer	12,086	3,982	279.71	12.56	1.21	1.17	0.11
	Fall	28,742	14,789	540.91	34.90	1.70	3.84	0.18
2-yr	Winter	24,643	851	27.24	12.42	0.45	0.83	0.02
	Spring	70,747	8,779	134.12	38.51	0.67	3.29	0.06
	Summer	17,509	5,805	303.72	16.72	1.09	1.58	0.10
	Fall	37,138	18,875	571.63	43.43	1.57	4.83	0.17
5-yr	Winter	36,601	1,199	26.33	17.40	0.43	1.11	0.02
	Spring	105,951	13,410	136.62	56.26	0.62	4.76	0.05
	Summer	30,200	10,501	327.72	28.57	1.00	2.74	0.09
	Fall	57,705	29,280	621.33	67.24	1.49	7.50	0.17
10-yr	Winter	41,913	1,339	25.40	19.31	0.42	1.21	0.02
	Spring	131,995	16,230	130.34	69.06	0.59	5.80	0.05
	Summer	48,737	15,155	314.07	41.37	0.93	4.01	0.09
	Fall	79,355	39,952	611.03	90.09	1.41	10.19	0.16
100-yr	Winter	61,693	1,914	24.58	27.10	0.40	1.59	0.02
	Spring	203,733	24,869	126.05	105.92	0.56	8.66	0.05
	Summer	93,467	27,077	294.64	76.05	0.87	7.31	0.08
	Fall	133,867	66,442	576.91	152.26	1.33	17.09	0.15

Table 5.16: Honeoye Lake – Project Area Stormwater Specific Loads

Project Area - Daily Loads								
Storm Event	Season	Flow	TSS		TN		TP	
		(m3)	(kg)	(mg/L)	(kg)	(mg/L)	(kg/)	(mg/L)
1-yr	Winter	213,899	5,484	22.28	72.17	0.38	3.33	0.01
	Spring	580,943	139,306	260.55	306.14	0.65	28.91	0.06
	Summer	125,280	96,930	655.50	133.11	1.09	15.10	0.12
	Fall	290,436	354,343	1322.69	501.11	2.06	65.07	0.26
2-yr	Winter	255,162	7,041	23.26	86.09	0.38	4.06	0.01
	Spring	722,820	178,226	268.76	386.02	0.64	37.04	0.06
	Summer	187,281	143,311	707.20	197.50	1.11	22.93	0.12
	Fall	381,982	460,239	1413.26	661.58	2.13	86.30	0.28
5-yr	Winter	381,927	12,186	25.26	130.35	0.37	6.44	0.01
	Spring	1,098,819	278,908	272.35	614.33	0.63	60.50	0.06
	Summer	342,954	258,025	717.89	381.77	1.15	45.55	0.13
	Fall	614,390	725,604	1459.88	1,103.04	2.24	144.97	0.30
10-yr	Winter	439,350	15,025	25.26	152.06	0.37	7.69	0.01
	Spring	1,374,230	336,833	257.06	777.13	0.62	76.32	0.06
	Summer	546,771	361,104	664.61	565.38	1.10	67.22	0.13
	Fall	848,950	969,620	1370.85	1,515.10	2.16	199.61	0.29
100-yr	Winter	651,141	25,290	26.00	233.02	0.38	12.37	0.01
	Spring	2,141,425	520,192	248.35	1,274.03	0.62	126.32	0.06
	Summer	1,058,271	632,749	603.99	1,096.16	1.08	130.36	0.13
	Fall	1,453,752	1,570,659	1224.38	2,633.56	2.06	346.94	0.27

6.0 Stormwater Management Options for the Honeoye Lake Watershed

As stated in the introduction, the genesis of the project was the collective interest of the HLWTF, TNC and NYSDEC to reduce the pollutant loading and control flood flows associated with the Honeoye Inlet subwatershed. Additionally, with regards to the entire Honeoye Lake watershed, the HLWTF with their project partners and Honeoye Lake stakeholders have become increasingly cognizant of the stormwater induced impacts affecting the lake and the lake's tributaries. Over the past fifteen years increasing attention has been given to investigating the relationship between Honeoye Lake and its watershed. While stream sampling data (Makerowicz, et. al., 2002; Starke, 2002 and 2003) verify that seasonal and storm-event loading is affecting the lake's overall productivity, the variability in flow rates and the intermittent nature of some of the lake's sources of inflow has compounded how best to deal with this loading. Additionally, as summarized in the Honeoye Lake Watershed Management Plan (Genesee/Finger lake Regional Planning Council, 2007), there are major erosion problems affecting the lake and its tributaries. The Plan's key recommendations included implementation of a detailed inventory of eroded/eroding streams and waterways, development of a program to minimize sediment loading to the lake, and the adoption of municipal land use regulations to minimize erosion. These recommendations are termed "source control" measures as they are directed to preventing pollutant loading and mitigating erosional impacts that negatively affect all of the lake's tributaries. Steps have been taken to follow-through on these recommendations. For example, Ontario County recently initiated mitigative measures to address and correct road-side swale erosion problems by rock armoring sections of the swales and installing catch basins along portions of West Lake Road.

The results of the *MapShed* data presented in Sections 3, 4 and 5 confirm the role of storm-event loading and support the need for the implementation of better stormwater management for the entire Honeoye Lake watershed. The balance of this report pertains mostly to the presentation and discussion of the stormwater management recommendations for the Honeoye Inlet Wildlife Management Area (the focus area of this study). Princeton Hydro also evaluated stormwater management opportunities for each of the lake's nine (9) primary subwatersheds. As based on those data, this section of the report provides generalized recommendations for the four subwatersheds generating the greatest aggregate annual loads. Basic recommendations are also provided regarding the correction of other major sediment, erosional or nutrient loading problems affecting all of the lake's tributaries. It must be emphasized, though, that even for the Honeoye Inlet Wildlife Management Area the scope of this project limits us to the presentation of stormwater management concepts as opposed to actual designs. Further work will be needed to shape the concepts discussed herein into actual stormwater management and erosion control BMPs that are ready for permitting, construction or implementation.

6.1 Honeoye Inlet Wildlife Management Area

As noted in the introduction of this report, a key objective of this study was to assist the HLWTF and TNC in the evaluation of stormwater management options for the Honeoye Inlet subwatershed. As such, in accordance with the scope of work, particular attention was given to the review and analysis of potential stormwater management BMPs that could be effectively implemented and used to manage both the hydrologic and pollutant loads computed for the Honeoye Inlet subwatershed (Subwatershed 4). The stormwater concepts discussed in this section of the report are based on the data presented in Sections 3, 4 and 5, data and observations compiled during our site visits, and information provided by the project partners.

In 2002, the State of New York acquired from TNC three parcels of land, collectively encompassing approximately 2,500 acres. The aggregate land mass is located immediately south of Honeoye Lake and the Finger Lake Community College's Muller Field Station, within the Honeoye Lake Inlet subwatershed. These lands, which subsequently became the Honeoye Inlet Wildlife Management Area, are managed by the New York State Department of Environmental Conservation (NYSDEC). The Honeoye Inlet Wildlife Management Area is open to the public for both passive and active recreational use.

Two of the three parcels of land that make up the Honeoye Inlet Wildlife Management Area were originally part of the Wild Rose Ranch. These lands were extensively farmed throughout the mid-1900s. To facilitate the farming of these lands, that portion of the Honeoye Inlet stream running through the Wild Rose Ranch was channelized. Additionally, a number of drainage ditches were cut perpendicular to the stream to help dewater the wetlands and riparian lands associated with the stream. Since being acquired by TNC and NYSDEC, the farmland has undergone successional change and the majority of the lands within the Honeoye Inlet Wildlife Management Area are presently best defined as successional fields.

As documented in Section 5 of this report, Subwatershed 4, which largely drains to the lake through the Honeoye Inlet Wildlife Management Area, is responsible for the majority of the lake's total inflow and pollutant loading. Recently, TNC in concert with HLWTF, NYSDEC, Ontario County Soil and Water Conservation District (OCSWCD), and the Finger Lake Institute (FLI), began examining how best to manage the Honeoye Inlet's pollutant load as part of ongoing Honeoye Lake water quality and trophic state management and restoration efforts. The general consensus has been to construct within the Honeoye Inlet Wildlife Management Area some form of on-line bioretention stormwater treatment system. For example, OCSWCD (2012) recommended the construction of a large (100 acre) regional stormwater management system capable of controlling the stream's storm flows and decreasing its pollutant load. A general consensus is that the stormwater management system must be sustainable, have minimal structural elements, and not decrease the Management Area's ecological and recreational attributes. The BMPs presented herein were deigned in keeping with these multiple objectives.

As part of Princeton Hydro's investigation of BMPs suitable for implementation within the Honeoye Inlet Wildlife Management Area, we determined it would be beneficial to analyze the area's soil properties. It was determined that a better understanding of soil composition, along with the site's soil characteristics, such as depth to groundwater, depth to bedrock and evidence of mottling (depth of seasonal high water table), was needed to enable us to better assess BMP options. In August 2013, with the assistance of the NYSDEC, HLWTF and OCSWCD, Princeton Hydro witnessed seven (7) test pits that were excavated within the project area (Appendix A, Figure A-1). The test pit logs are provided as an appendix to this report. As based on soil samples collected from each test pit, the soils at each location were classified with respect to soil texture class, moisture, consistency, structure, color, and organic content. In general, the uppermost 1-2 feet of soil was characterized as formerly cultivated, organic topsoil. Below this organic upper horizon was typically a thick layer of clayey silt or silty clay, often with evidence of groundwater influence (mottling). Some test pits revealed layers of sand or sand and gravel, often with perched groundwater flowing through. At the bottom of the majority of the test pits we observed saturated silt and clay layers, relics of the former lakebed or original wetlands. Overall the data compiled via these soil test pits revealed the following:

- Soil conditions throughout the tested areas (as reflected in the soil log data) were relatively consistent.
- The upper soil layers (1-2 feet) for the most part could be characterized as a dark brown friable clay loam.
- From 2 feet to 4 feet the soils could be characterized as gray clayey silt with reddish mottles and some traces of organics.
- From 4 feet to the bottom of the test pit (typically 7 feet) the soils were mostly light brown coarse sand with some small gravel and silt.
- Groundwater, mottling or seepage was typically observed at fairly shallow depths (3-4 feet) from the surface. This shallow depth to groundwater will dictate the types of BMPs that could effectively be used to manage the stormwater loading associated with Honeoye Inlet (the main stream feeding the lake).

In terms of stormwater management BMP options, these data basically establish that bioretention, created wetland and/or wet meadow type BMPs should function well within this setting. Conversely infiltration and recharge based BMPs will not perform as well.

While the collective desire of the project partners is to implement some type of stormwater management system within the project area, there is also the need to ensure that the recommended stormwater management BMPs would not substantially disturb the wildlife management area or detract from its recreational use. An additional design goal was to use the stormwater management BMPs to improve or expand existing wildlife habitat (aquatic and terrestrial) and restore previously impacted habitat. As such, the stormwater management system designed for the Honeoye Inlet Wildlife Management Area should meet the following project objectives:

- Reduce pollutant loading
- Control and reduce storm flows and flood volumes
- Result in minimal disturbance of the area
- Complement, mitigate or restore existing wildlife habitat
- Accomplish all of the above and enhance the recreational use of the area.

Given the areal expanse of the Wildlife Management Area, it is possible to construct a regional basin capable of managing storms up to and including the 100-year event. However, the hydrologic data shows that in order to do so it would be necessary to significantly regrade, and alter the site. As per the NYSDEC Stormwater Management Manual (2010) the surface area of a stormwater wetland must equal between 1% and 1.5% of the contributing drainage area. This translates to a basin between 112 and 170 acres in size. Additionally, the basin must be able to accommodate at least 25% of the water quality volume (WQv) in deep water zones greater than four feet in depth. To direct flow into the basin an inlet weir or diversion would need to be constructed along the edge of the stream and the basin would need an outlet control structure to ensure that the captured stormwater is detained for the proper amount of time and is released back into the stream at a rate that does not cause downstream flooding or erosion. Finally any berms used to contain the diverted stormwater would need to be engineered to safely pass without failing the 100-year storm. A large regional basin approach is therefore inconsistent with the project's objectives of minimizing impacts to the site's recreational use, maximizing the creation of new wildlife habitat, and complimenting existing wildlife habitat. The cost estimate for a created wetland basin large enough to manage the 1-year (water quality) storm event is between $700,000 and $1,800,000 (2014 dollars) calculated as per Brown and Schueler (1997) and Weiss, et al. (2005). Factoring into this the additional costs of site survey, permitting, bid specifications, contactor selection, contractor oversight and other related costs escalates the price of such a project into the $1,000,000 to $2,200,000 range.

After careful consideration of all of the data and project objectives, it was determined that a better approach involves focusing on reconnecting Honeoye Inlet with its floodplain. As detailed below, this approach minimizes the overall disturbance of the site, while still enabling us to meet the project's pollutant load reduction and habitat creation/improvement objectives and satisfy most of the flood flow control objectives. The recommended approach is also cost-effective, ecologically sustainable, and requires minimal future maintenance.

As illustrated in Figure 6.1, there are four main elements to Princeton Hydro's recommended approach:

- **Floodplain Reconnection** - Effectively raise the existing stream bed thereby causing the stream during periods of high flows to "spill out" in to the adjacent lands. In contrast, in other locations lower the stream bank elevation and create a neighboring 'basin' to capture storm flows that have "spilled out'. Both techniques work in unison to replicate the flood storage functionality of a floodplain.
- **Ditch Plugging** - Fill some of the ditches that run perpendicular to Honeoye Inlet. Again, this will force flood flows out into the adjacent land. The fill used to plug these ditches would be obtained by creating minor depressions along-side the ditches and material excavated to create the basin. These depressions could become vernal pools if flooded long enough during the spring.
- **Lengthen Stream** - Recreate meander and sinuosity in the stream at its more northern end. Use rock grade controls to manage flows, reduce velocity and protect the recreated channel from erosional impacts during periods of higher flows.

- **Backwater Wetland** - Construct a small wetland basin at the north end of the stream to provide additional pollutant removal.

As illustrated in Figure 6.1, the primary element of this plan is the reconnection of the stream to the floodplain. This is accomplished using two different approaches. The first approach involves lowering the stream bank elevation in given locations thus allowing the stream to "jump" its banks during periods of storm flows and flood the adjacent (but presently disconnected) floodplain. In these targeted areas the adjacent floodplain would also be slightly excavated thereby creating a more pronounced depression capable of detaining and storing flood water, essentially acting as a bioretention basin. To prevent the detained flood water from easily returning to the stream, the excavated soils would be used to construct a shallow berm along the backwater edge of the depression. The elevation of the berm is less than the targeted flood elevation of the stream, but greater than the stream's baseflow elevation. Not only does this help detain the trapped flood waters, but this feature facilitates the creation of wetlands within the excavated floodplain depression. The berms would be planted with wet meadow vegetation; vegetation capable of withstanding periodic flooding as well as extended periods of exposure. The depressions would be planted with wetland obligate and facultative species. It is expected that due to the shallow depth to groundwater (seasonal high water table) and the frequency of flooding, the created floodplain depressions will remain inundated or saturated for prolonged periods of time. The trapped flood water will eventually be "lost" via photosynthetic evapotranspiration or via infiltration into the underlying soils. Due to the site's soil properties, the infiltrated flood water will move horizontally recharge and maintain the stream's baseflow, similar to what occurs in a natural floodplain environment.

The second approach to reconnecting the stream to the floodplain involves raising the streambed's elevation in given locations using rock grade controls. Raising the streambed's elevation enables the stream during periods of high flows to jump the banks more frequently and flood the neighboring floodplain. The proposed grade change is accomplished by importing and securely placing and packing large rocks and boulders in the bottom of the stream. Our plan calls for modifying only two sections of Honeoye Inlet in this manner. Each modified area would affect approximately 100 to 150 linear feet of the stream bed. When completed, the rock grade controls will resemble a natural cobble/boulder riffle similar in appearance to sections of Affolter and Bray Gullies. The grade control also facilitates raising the streambed by slowing flows and promoting bedload accumulation. To maintain longitudinal ecological connectivity, the rock grade controls will be designed to ensure the continued baseflow passage and mobility of fish and other aquatic organisms.

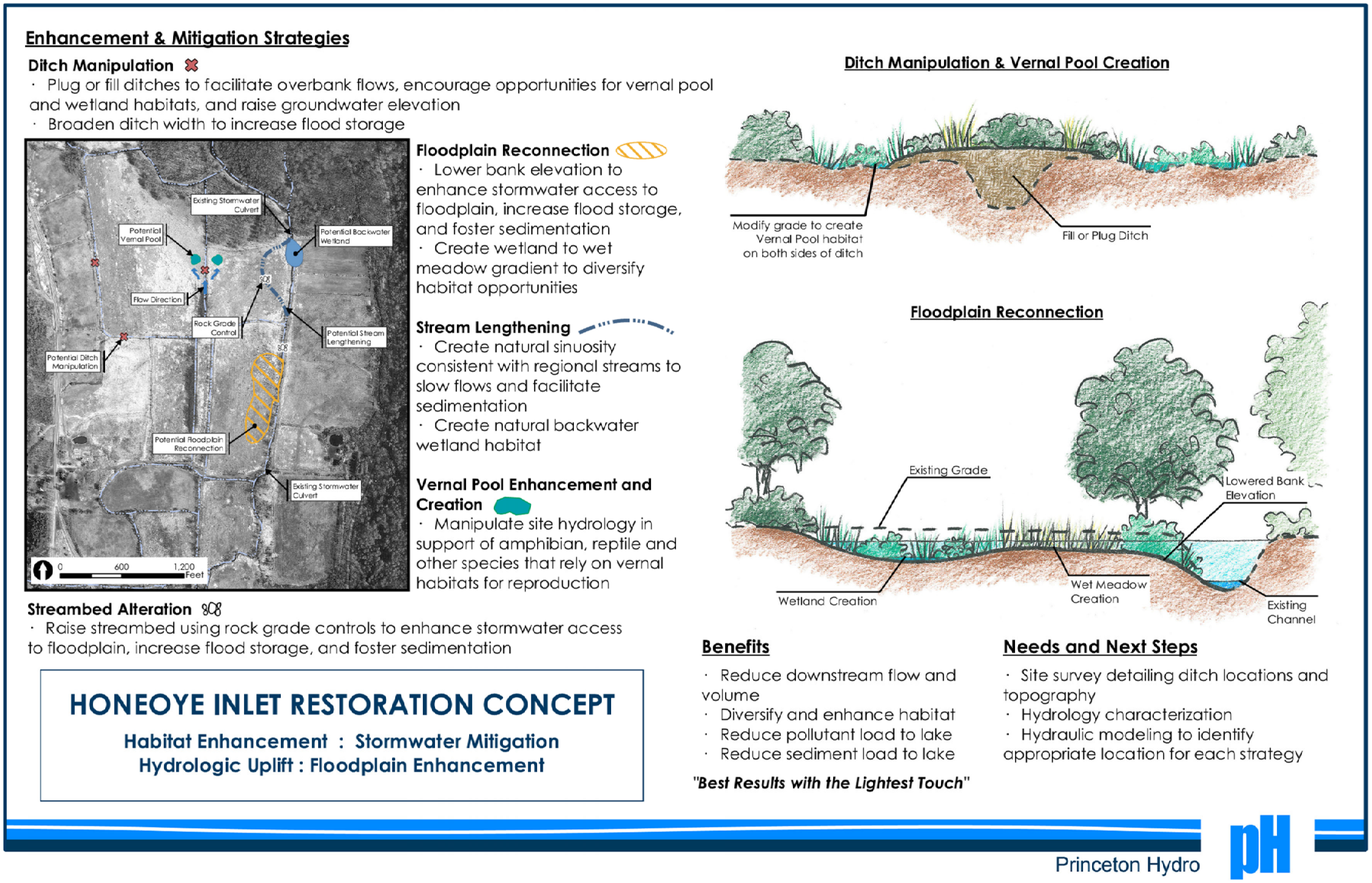
It is important to use these two stream channel modifications in tandem. Honeoye Inlet is presently significantly incised and no one single approach will facilitate floodplain reconnection while minimizing overall site disturbance. We have utilized both techniques in concert to meet similar watershed management goals. Our project experience shows that this floodplain reconnection approach is less costly, results in less overall disturbance and is more stable as compared to raising the streambed using soils excavated from the adjacent land or creating a new, shallower stream channel. With this approach all four of the project's primary objectives are met: flood attenuation, pollutant removal, habitat creation and increased passive recreational opportunities. Additionally, as compared to the creation of a large regional stormwater basin or a major realignment of the stream, there is far less disturbance of the Honeoye Inlet Wildlife Management Area, and the resulting stormwater management system blends in better with the overall existing aesthetics and habitat properties of the site.

It should be noted that consideration was given to the creation of an entirely new channel and associated floodplain. The existing stream is channelized, linear and, as noted above, incised. Thus the concept of creating a new, shallower and broader stream channel with greater sinuosity is therefore a well-founded idea. However, this approach is cost prohibitive and creates a significantly larger disturbance footprint than the proposed alterations of the existing channel. It would still be necessary to import a large amount of rock to help stabilize the new channel, especially at each new bend. Consequently, Princeton Hydro determined that the approach recommended herein, that is intended to gently guide and “persuade” the stream into a new natural, stable state meets the project’s overall goal and objectives in a less invasive and less costly manner.

The modification of the stream channel and adjacent floodplain areas will require close coordination with the NYSDEC with respect to permits and approvals. Specifically a “Protection of Waters Permit” is required for disturbing, either temporary or permanently, the bed or banks of a stream, including those such as Honeoye Inlet with a “C” classification. The OCSWCD can assist with the NYSDEC Notice of Intent and provide guidance, based on their local experience and expertise, to ensure that these changes are implemented in a manner that minimizes or prevents construction related soil erosion and soil compaction impacts.

It should be noted that a similar approach has been proposed for the Owasco Flats Wetland Restoration and Riparian Buffers Initiative (Cayuga County). That project also calls for the reconnection of a channelized stream located in a historically farmed area with an adjacent recreated floodplain and wetland areas (NYS Environmental Facilities Corporation).

Figure 6.1 Stormwater Management Concepts for the Honeoye Inlet Wildlife Management Area



Enhancement & Mitigation Strategies

Ditch Manipulation ✖
- Plug or fill ditches to facilitate overbank flows, encourage opportunities for vernal pool and wetland habitats, and raise groundwater elevation
- Broaden ditch width to increase flood storage

Floodplain Reconnection ▨
- Lower bank elevation to enhance stormwater access to floodplain, increase flood storage, and foster sedimentation
- Create wetland to wet meadow gradient to diversify habitat opportunities

Stream Lengthening
- Create natural sinuosity consistent with regional streams to slow flows and facilitate sedimentation
- Create natural backwater wetland habitat

Vernal Pool Enhancement and Creation ●
- Manipulate site hydrology in support of amphibian, reptile and other species that rely on vernal habitats for reproduction

Streambed Alteration ∞
- Raise streambed using rock grade controls to enhance stormwater access to floodplain, increase flood storage, and foster sedimentation

HONEOYE INLET RESTORATION CONCEPT

Habitat Enhancement : Stormwater Mitigation
Hydrologic Uplift : Floodplain Enhancement

Ditch Manipulation & Vernal Pool Creation

Floodplain Reconnection

Benefits
- Reduce downstream flow and volume
- Diversify and enhance habitat
- Reduce pollutant load to lake
- Reduce sediment load to lake

"Best Results with the Lightest Touch"

Needs and Next Steps
- Site survey detailing ditch locations and topography
- Hydrology characterization
- Hydraulic modeling to identify appropriate location for each strategy

Princeton Hydro

The second element of this stormwater management plan involves the selective plugging of a few of the ditches and channels running perpendicular to Honeoye Inlet. Some of these ditches convey runoff from both County Road 36 (West Lake Road) and East Lake Road to Honeoye Inlet. Our plan focuses on plugging two or three ditches on western side of the site. Again, we have successfully used this approach to manage stormwater runoff, especially in headwater areas. While, once again, the concept is grounded in the reconnection of the stream and its floodplain, as compared to the management of flows in Honeoye Inlet, the ditches convey far less volume and the flows also tend to be more storm-event driven and seasonal in nature. The overall approach is relatively simplistic. Basically, depressions would be excavated in an area adjacent to a ditch and the soil used to fill the ditch. During storm events the runoff flowing through the ditch will encounter the earthen "plug" and be forced into the created adjacent depressions as well as the microtopography already present at the site. Because the majority of the flows conveyed by these ditches occur during the spring-thaw, it is very possible that the created depressions could become vernal pools providing habitat for amphibians, reptiles and other species that rely on vernal habitats. Planting of these areas with appropriate species would enhance their vernal habitat properties (Kenney and Burne, 2000). Similar to the reconnected stream/floodplain effort, the ditch plugging creates habitat while controlling flows and reducing pollutant loading to the lake.

The third element of the project entails the lengthening of the northern end of the Honeoye Inlet stream channel within the proposed project area. The objective would be to restore some of the natural sinuosity of the stream and eliminate in part the channelized nature that characterizes the stream as it passes through the Honeoye Inlet Wildlife Management Area. This would be accomplished by the actual re-grading of the stream channel. Excavated soil would be used in part in the recreation of the stream and possibly to conduct some of the aforementioned ditch plugging. Rock grade controls would be used to help further manage storm flows and velocities thereby protecting the recreated stream channel from subsequent erosion and down-cutting. The amount of recreated sinuosity would be in keeping with that observed in the headwater areas of the inlet and the other streams that drain to Honeoye Lake. The design would be backed by hydrologic and hydraulic data and be conducted in a manner consistent with standard stream restoration practices (Shields, et al., 2003).

The fourth and final element of the proposed concept involves the creation of a relatively small (3-5 acres) created wetland basin. The basin would be constructed at the far northern end of the Honeoye Inlet, just before it becomes the braided, forested wetland that is within the proposed project area. The primary function of this basin would be pollutant removal and secondarily, flow attenuation. Rather than be on-line, the created wetland would be an off-line, backwater area strategically located to receive flows from the downstream culvert crossing. It would be flooded during storm events, but remain flooded by its direct connection to the stream and by excavating it to the depth of the seasonal highwater table. The created wetland basin augments the habitat value of the adjacent forested wetland area, while in-part controlling flows and reducing pollutant loading to the lake.

Again all of the project elements listed above will likely require a "Protection Of Waters Permit" due to the disturbance of the bed or banks of Honeoye Inlet and the smaller contributing tributary ditches. Additionally the disturbance of any existing wetlands will likely trigger the need for Army Corps of Engineers and NYSDEC wetland permits.

6.2 Stormwater Management Options for Other Subwatersheds

While the focus of this study was to examine stormwater management options that could be implemented within the Honeoye Inlet Wildlife Management Area, an assessment was conducted of how to address runoff and stormwater loading impacts associated with the lake's other subwatersheds. Past studies of the lake conducted by Princeton Hydro (2007) and Bin Zhu (2012) quantified the pollutant load generated by each of the lake's nine subwatersheds. Sampling conducted by the HLWTF volunteers measured the concentration of nutrients and sediments transported into the lake during storm events (Starke 2003, 2004). Also, a 2012 detailed assessment of the streams and inflows to the lake completed by the Ontario County Soil and Water Conservation District (OCSWCD) located and inventoried erosion and scour impacts in each of the tributaries that drain to the lake. Each of these studies made it clear that watershed management is needed in some capacity, whether to stem pollutant loading to the lake or ameliorate chronic and acute erosion problems.

In Section 5, the top five subwatersheds contributing the greatest and most manageable pollutant loads were identified. The normalized pollutant loading data (Table 5.4) were used to determine which subwatersheds are contributing a disproportionate load per unit area. The top three ranking subwatersheds are: Northwest (1), Affolter Gully (2) and Cratsely Gully (3), all of which are located along the lake's western shore. The fifth largest contributor is the Northeast subwatershed (8). While the Honeoye Inlet subwatershed (4) has the highest total load, these other four subwatersheds have greater per-unit-area loads. This is a function of the more residential nature of these four subwatersheds as compared to the lake's remaining subwatersheds. Combining the loading data presented in Table 5.3 (actual) and Table 5.4 (normalized), the lake's subwatersheds with the greatest stormwater management net return on the investment are Subwatershed 1 (Northwest), 2 (Affolter Gully), 3 (Cratsley Gully), and 7 (Bray Gully). In keeping with the project's scope of work, a list of BMPs are provided herein each having the ability to effectively manage the estimated pollutant loads generated by each of the top contributing subwatersheds. As will be discussed below, the majority of these BMPs should also prove effective in managing the loading generated from the lake-side developed portions of the other subwatersheds.

Princeton Hydro also evaluated the possibility of constructing basins or installing manufactured treatment devices (MTDs) along the major roadways servicing the Honeoye Lake watershed. We know from our survey of the watershed that the existing stormwater infrastructure is designed basically to move runoff as quickly as possible from the watershed into the lake. Consisting mostly of road side swales and a few scattered catch basins, the stormwater collection systems running along Route 37, West Lake Road (Route 36) and East Lake Road offer little opportunity for any major retrofits. Although it would be ideal to manage the road runoff from the surrounding watershed using large structural BMPs such as extended detention basins or retention ponds, the construction of such BMPs is not feasible due to the lack of available public land and constraints caused by the topography of the watershed, shallow depth to bedrock and the aforementioned design of the existing stormwater collection system (or lack thereof). Basically, the right-of-ways are too narrow, the flows too great and the depth to bedrock too shallow to facilitate the construction of regional basins or even the installation of any sizable MTD. The east/west cross-roads that connect to these major thoroughfares (e.g., Cratsley Hill Road, Jersey Hill Road and Wesley Road) are also too steep and have minimally developed piped stormwater networks and little publicly owned lands that would facilitate the construction of basins or the installation of MTDs. Steps have been taken by Ontario County to mitigate bed and bank erosion in some of the streams before they drain to Honeoye Lake. For example, the Affolter Gully stream channel was recently armored with rip-rap and a few catch basins and drainage pipes installed to better manage roadside runoff. Such projects should be continued. As documented in Table 5.3, these smaller subwatersheds (especially Subwatersheds 1, 2, 3 and 8) are individually and collectively important sources of erosional and sediment loading to the lake. Our findings are in keeping with the OCSWCD (2012) conclusions, the sampling results of the HLWTF, and as reported by Zhu (2009). The significance of the erosional and sediment loading impacts attributable to these subwatersheds are even more evident upon review of the normalized loading data (Table 5.4). While we support the stream stabilization efforts of the County, we suggest that larger rock be used and channel armoring be conducted in accordance with stream restoration protocols as opposed to swale maintenance practices.

Therefore, based on the generated data, our inspection of the watershed and our review of past studies, the cost-benefit ratio of any large-scale retrofits of the Honeoye Lake stormwater collection system is too high to make such projects feasible. Also for the reasons stated above, it is unlikely that much could be done to modify the existing stormwater collection system to significantly reduce nutrient loading to the lake. Additionally, referring to Figure 5.1, only 10% of the stream flow is a function of stormwater runoff, and as per Table 5.3, these smaller subwatersheds account on an individual basis for no more than 10% of the lake’s annual phosphorus load (whereas 47% of the annual external phosphorus load is contributed via the Honeoye Lake Inlet, Subwatershed 4). Thus, instead of relying on larger regional BMPs, emphasis will have to be given to smaller, site-specific, Community Based Initiatives.

6.3 Community Based Initiatives

The following recommendations are considered Community Based Initiatives. Most are homeowner directed stormwater management measures that can be implemented throughout the entire Honeoye Lake watershed. While **Fertilizer and Pesticide Management** and **The Preservation or Restoration of Lake-side and Stream-side Riparian Buffers** would be most successful if supported by local ordinances, these measures can be pushed along through active public education and outreach. Small foot-print BMPs such as **Vegetated Swales, Rain Gardens**, **Alternative Landscaping** and similar techniques are intended to intercept and treat runoff on a lot-specific basis. Admittedly, it is difficult to accurately quantify the pollutant reductions or the amount of flood control that could be achieved through each of these measures. However, if done on a community-wide scale they will reduce nutrients and sediments reaching the lake.

Fertilizer and Pesticide Management - Integrated pest management (IPM) is a common sense, but technically well-structured approach to the use of fertilizers and pesticides. Although more commonly associated with large intensive use areas such as golf courses, public parks, and ball fields, it can be implemented at the homeowner level. Central to the success of IPM is the use of environmentally friendly methods to maintain pests below defined damage levels. Unfortunately, a considerable amount of over application of pesticides and fertilizers occurs during the routine care of residential lawns. Homeowners often operate under the assumption that if "a little is good, more is better". This leads to the over-application of products and an increased potential for off-site transport of pesticides and fertilizers. By applying only the quantity of fertilizer necessary for optimum plant growth, the amount that potentially can be mobilized and transported to surface and groundwater resources is minimized. Not only is this good for the lake, but will save the homeowner money. Thus, homeowners and lawn care services should be educated regarding proper lawn maintenance.

Even more important for Honeoye Lake is the use of non-phosphorus fertilizers or slow-release nitrogen fertilizers as these products actually decrease nutrient loading to the lake. Fertilizer applications must also be timed properly to account for plant needs and to anticipate rainfall events. For example, nutrients are most needed in the spring and fall, not throughout the summer. Also, rain induced fertilizer losses are greatest immediately following an application because the material has neither become adsorbed by the soil nor taken up by the plants. Fertilizer uptake and retention is promoted by proper soil pH. A detailed survey of homeowners in Virginia commissioned as part of the Chesapeake Bay Initiatives, found that less than 20% tested their soils to determine whether fertilization was actually necessary. Although soil pH can have a significant bearing on the ability of soils to retain nutrients, such testing is not commonly conducted by homeowners. The application of lime can improve phosphorus uptake and retention. Other non-chemical lawn care treatments such as de-thatching and aeration are also rarely conducted. Urban soils, even those associated with lawns, can become compacted and function almost no differently in respect to the generation of runoff than impervious surfaces. Aerating lawns helps promote better infiltration and the generation of less runoff.

An additional means by which to decrease fertilizer and pesticide use and the subsequent transport of these pollutants to Honeoye Lake is through the creation of shoreline aquascaped buffers. Where appropriate, the use of native plants or plants that have lower irrigation needs than typical suburban lawns needs to be promoted. These can be relatively narrow (10') and should be planted with wet-tolerant, native plants. Depending on the amount of light exposure this can include such plants as bulrush, spike rush and button bush (within the water), blue flag iris, cone flower, black-eye Susan, red-osier dogwood, and a variety of other attractive, easily to maintain species that do well in "soggy" soils. Guidance pertaining to the creation of aquascaped shorelines is readily available through North American Lake Management Society (NALMS), Connecticut Department of Environmental Protection (CTDEP) and the University of Connecticut.

Preservation or Restoration of Lake-side and Stream-side Riparian Buffers - Over 84% of the Honeoye Lake watershed is forested and/or consists of some type of land cover identified as either water or wetland. With the exception of the lands directly adjacent to the lake, overall development pressure over the past 2-3 decades has been fairly low. Given that forested lands generate the lowest surface runoff pollutant loads and wetlands can actually assimilate nutrients and other pollutants, measures that limit watershed disturbance and loss of additional forested lands need to be supported by the community.

The majority of development in the watershed is focused along the shoreline. With increasing shoreline development came the destruction of the critical buffer zone which exists between the open water of the lake proper and upland habitats. This buffer zone provides vital functions in terms of habitat for aquatic and terrestrial organisms and nutrient attenuation through vegetative uptake. Furthermore, this area is dually stressed as the now denuded habitat is burdened with increased nutrient pollution associated with lakeshore housing through pet wastes, fertilizers and erosion. As such, restoration of lakeshore buffers will serve to not only increase habitat for amphibians, birds, invertebrates, etc., but also serve to assimilate pollutants from non-point sources. Steps can be taken to re-vegetate these critical zone utilizing native, low growing plants that provide ecosystem function while still maintaining site lines for the lakeshore residents.

In addition to the preservation of lakeside buffers it is critical to maintain the integrity of buffers surrounding the streams and gullies which feed Honeoye Lake. This is particularly crucial in this watershed given the steep relief which allows for accelerated erosion and subsequent transport of sediments and pollutants to the lake.

Use of Alternative Landscaping - Utilizing alternative landscaping is a preventative pollutant load management technique that when properly implemented can reduce the need for the repeated fertilization of lawns, decrease the rate or frequency of pesticide applications and decrease irrigation requirements. Especially for the homes bordering the lake, homeowners should be encouraged to allow nature to take its course along the water’s edge. Focus should be placed on maintaining natural ground covers in lieu of manicured lawns, and supplementing areas having sub-optimal ground cover with selected plantings. By utilizing a combination of design, plants and mulches, homeowners and landscapers can create a landscape that decreases maintenance, is aesthetically pleasing and is environmentally suited to the area.

Rain Gardens, Vegetated Swales and On-Site Stormwater Management - By now the general public is fairly aware of what are rain gardens and their benefits. In general, rain gardens are relatively small vegetated depressions that function as mini-biofilters or bioretention basins. They are used most often to treat roof top runoff that would otherwise simply sheet flow across a lawn or down a sidewalk. They can also be used to treat the runoff from driveways, patios or any other hardscape. Rain gardens are more than a simple planted landscaped feature. Their proper construction entails the use of sand mix subsoil that has the ability to infiltrate the collected runoff. The plant material is also selected for its tolerance for periodically wet conditions, but perhaps extended period of dry conditions. When properly planted and constructed, a rain garden can control the peak flow of runoff, reduce the volume of runoff and reduce pollutant loading, while at the same time serving as a low-maintenance, attractive amenity. A lot of the same grasses, flowering plants and shrubs used to create an aquascaped shoreline such as cone flower, black-eye Susan, red-osier dogwood, switch grass, winterberry holly and New England aster can be used in a rain garden. The ultimate plant selection is a function of the amount of runoff being captured, the infiltration rate of the soils, the amount of shade and the owners own preferences.

Chapter 5 of the NYSDEC Stormwater Management Manual (NYSDEC, 2010) provides design criteria for rain gardens. Other excellent links to documents for home owners interested in creating a rain garden are available through the NYSDEC (**www.dec.ny.gov/public/44330.html**), the University of Connecticut (**http://nemo.uconn.edu/publications/rain_garden_broch.pdf**) and via the Rutgers University__web site: njaes.rutgers.edu/environment/raingarden-manual.asp**.** A community based rain garden initiative conducted by the Town of Coventry, CT is summarized in a layperson friendly, downloadable document with multiple illustrations: http://www.thamesriverbasinpartnership.org/acrobat_files/Coventry%20Rain%20Garden%20Demonstration%20Project.pdf. Ontario County also provides guidance regarding erosion control for single family dwelling construction, an often overlooked source of sediment: **http://ontswcd.com/Miscellaneous/SOIL%20EROSION%20CONTROL%20FOR%20SINGLE%20FAMILY.pdf**

Vegetated swales are shallow depressions that can be used to convey and treat stormwater runoff. Depending on the depth to groundwater such swales may also aid in the infiltration of the captured runoff. Vegetated swales perform best when used on minimally sloped (<3%) land or when constructed perpendicular to a slope. The amount of pollutant removal attained with these features is a function of slope, swale length and the roughness and composition of the vegetation.

6.4 Curtis Road Subdivision

Concern has been raised, based on recent HLWTF and OCSWCD sampling data that the townhouse subdivision located along Curtis Road in the Affolter Gully subwatershed (Subwatershed 2) is generating a substantial NPS pollutant load. There is an opportunity in this section of Subwatershed 2, because of the prevailing terrain and the availability of County land, to potentially construct a bioretention basin that could treat the runoff from this development. However before the construction of a basin is even contemplated it is highly advisable that a monitoring program be implemented to determine whether the source of the measured elevated pathogen and nutrient concentrations is due to the development’s communal septic field or is due to stormwater runoff from the site. Appropriate data could be obtained by sampling a few shallow, groundwater monitoring wells. These wells would be installed up-gradient and down-gradient of the development’s communal septic system. The routine (quarterly) sampling of those wells should yield enough data to determine whether the septic field is functioning properly and whether it is a major source of pollutant loading. Similarly, stormwater samples could be collected from the roadside ditch running parallel along Curtis Road, sampling upgradient and down gradient of the subdivision. The combination of the well and stormwater data could then be used to assess whether there is any major water quality benefit of constructing a bioretention basin to manage the site’s stormwater runoff.

On a relative scale, the cumulative amount of impervious cover associated with this subdivision is relatively minimal, even when the entire contributing catchment area is taken into consideration. As based on a GIS delineation of the land area encompassing the development and adjacent contributing lands, the total landmass encompassing the development's drainage area (houses, driveways, lawns, septic field and adjacent woodlands) totals 61.3 acres, of which only 3.6 acres is impervious and 20 acres is mapped as lawn. Using this areal value in applying the *MapShed* pollutant loading coefficients to this 61.3 acre drainage area, the development's storm related phosphorus load is only in the range of 10-20 kg/yr, or approximately only 2-4% of the subwatershed's total annual phosphorus load.

If it was determined that the development's runoff should be treated and managed, this would be best accomplished using on-site, small foot-print bioretention stormwater management techniques similar to those recommended for the nearshore areas adjacent to the lake and for Subwatersheds 8 and 9. An additional on-site option includes allowing the lawn to grow into a meadow, mowing only twice a year. However, as noted above, because of the availability of County owned lands, stormwater management could also be accomplished off-site using the combination of a roadside vegetated swale and a bioretention basin. Chapter 5 of the NYSDEC Stormwater Management Manual (NYSDEC, 2010) provides design criteria for vegetated swales and bioretention basins.

The off-site management of the development's stormwater runoff could be accomplished as followed. At the base of the driveways leading into the development a vegetated swale would be constructed along the western edge of Curtis Road, within the roadway's right-of-way. As the runoff exits the site it would be collected in the swale and then conveyed down gradient towards the north. Approximately 500' north of the development, on the eastern side of Curtis Road, there is a parcel of County owned land. Although this lot is partially wooded it could be cleared and regraded and a bioretention basin constructed within this area. The sizing of the bioretention basin will be predicated on the runoff volumes and runoff rates conveyed from the development and the runoff from the sections of Curtis Road intercepted by the swale. The basin would need to be sized to manage the water quality event generated from the entire 60+ acre subwatershed. It will also need to be capable of safely controlling and passing the 100-year storm.

Based on the size of the development's delineated drainage area, we expect the basin to be at least one (1) acre in size. Depending on the hydrologic and physical properties of the native soils and the soil's organic content, it may be necessary to import a suitable bioretention soil mix. The soil mix needs to have enough porosity (dictated by sand content) to facilitate the infiltration of the captured runoff, but enough organic content to enable the establishment of proper vegetative cover. Depending on the depth to bedrock or seasonal high water table it may also be necessary to design the basin with an underdrain to prevent the prolonged ponding of water. The basin's outlet structure will need to ensure the proper detention of the runoff generated by storms up to and including the 100-year event. Outfall scour protection will need to be provided at the point of the basin's discharge into the stream to ensure that as the detained runoff is routed back into the stream it does not cause or exacerbate downstream erosion problems.

7.0 Cost Projections for the Recommended Honeoye Inlet Wildlife Management Area Stormwater Management Measures

Within this section of the report cost estimates are provided for each of the stormwater management measures recommended for implementation within the Honeoye Inlet Wildlife Management Area. The cost estimates that follow reflect the complete cost to finalize project designs, prepare construction plans and specifications, prepare NYSDEC application materials, implement the proposed stormwater management/ habitat creation measure and provide contractor oversight. The PRedICT module of *MapShed* includes a cost estimating tool that was examined and evaluated as part of this project. Given the assumptions needed to run the module, it was determined that PRedICT would not yield representative cost estimates. Therefore, the cost estimates are based on Princeton Hydro's past experience in conducting restoration and stormwater management projects of this nature and the prices provided herein reflect regional construction cost estimates. Finally, it must be emphasized because the cost-estimates are based on concepts and not detailed construction plans and specifications, while realistic they cannot be assumed to be definitive or final.

Also, please note that with respect to the site's topography, although the available LiDAR data was suitable for the purposes of concept development, it is no substitute for detailed site survey data. TNC should assume the need to develop detailed site survey data in advance of finalizing project designs and making any site improvements. Given the areal expanse of the Honeoye Inlet Wildlife Management Area and the need for survey data capable of identifying the site's micro-topography (1-foot contour intervals), $80,000 - $100,000 should be allocated for the preparation of a detailed site survey.

Floodplain Reconnection and Stream Grade Changes – The total cost of this element of the project is estimated to be in the range of $880,000. This is the largest and most significant project proposed for the Honeoye Inlet Wildlife Management Area. This project meets the habitat creation, stormwater management, and pollutant load reduction goals, while minimizing the amount of total site disturbance. Referring to Figure 6.1, the proposed Floodplain Reconnection and Stream Grade Changes require both "shaving down" portions of the existing stream bank and, in two locations, raising the base elevation of the existing stream bed. This will essentially cause the stream during periods of high flows to "spill out" into the adjacent lands. This is the best and most effective way of managing the runoff generated from Honeoye Inlet subwatershed and decreasing its pollutant load to the lake. Reconnecting the stream and the adjacent lands through using this combination of stream bank shaving and stream bed grade controls essentially mitigates the existing down cutting and channelization of the stream while restoring the functionality of the stream's floodplain. Compared to excavating and re-grading a new stream channel, this approach also greatly minimizes the amount of site disturbance that would be needed to achieve the same effect. Again we need to stress that the elevation of the southern culvert in the project area largely dictates the elevation of the stream bed, which in turn dictates the elevational changes that are needed to reconnect the stream and the floodplain.

As discussed above, to construct the two proposed grade controls and achieve the desired increase in stream bed elevation some amount of rock will need to be imported. The creation of the two grade controls (material and labor) represents less than 20% of the total project cost ($163,000). The majority of the cost is associated with the labor associated with the regrading of the new “floodplain” ($590,000). We have factored into the cost of the floodplain’s reconstruction the importation of some organic material (rotted leaf litter) that may be needed to promote the quick reestablishment of plant cover within the re-graded floodplain corridor. The up-front costs associated with final design, plan and specification preparation and construction oversight was calculated to be in the range of $175,000.

Again referring to Figure 6.1, the restored floodplain corridor will run the length of the stream channel (east and west banks) for a total length in the range of 1,000 feet (essentially from the southern culvert to the primary grade control). Site regrading of the stream corridor will be dictated by existing topography. As noted above, this will necessitate detailed site survey data. Our concept assumes that the re-grading of the lands adjacent to the stream will be limited to a width of approximately 100 feet on either side of the stream channel. We have assumed a “cut” approximately two feet in depth. The cut material can be used as part of the ditch plugging effort or used otherwise on site as part of the new floodplain’s creation. The two in-stream grade controls, created with the imported rock, are each 100 feet in length. The amount of rock that will be needed is totally dependent on the width of the stream and its depth at each location where the grade controls are created. For our purposes we have assumed that each grade control structure will require 2,000 yds^3 to create; this is a very conservative (high) material estimate.

Ditch Plugging – The ditch plugging element of the project involves filling some of the ditches that run perpendicular to Honeoye Inlet. Referring to Figure 6.1 we identified three (3) possible locations within the ditch network on the western side of the site where ditch plugging could be conducted. The total cost to conduct the plugging of theses ditches totals $7,500. The cost associated with the ditch plugging again was conservatively estimated, but does cover all construction, material and upfront engineering and permitting costs.

As noted in the Section 6, for the Honeoye Inlet Wildlife Management Area this is the easiest and most cost effective means of both managing stormwater runoff and creating new habitat. As with the reconnection of the stream’s floodplain, the goal of the ditch plugging is to force flood flows out into the adjacent land. The fill used to plug these ditches would be obtained by creating minor depressions along-side the ditches. These depressions could become vernal pools if flooded long enough during the spring. Alternatively, the fill material as noted above could be obtained from the above floodplain recreation project. Overall, we have estimated that each “plug” will require the use of approximately 600 – 700 yds^3 of onsite material. With the exception of some minor regrading of the adjacent areas and perhaps some reseeding the majority of the cost is associated with creating the channel plugs.

Lengthen Stream and Recreate Sinuosity – Another element of the overall plan involves recreating some stream sinuosity in order to mitigate past channelization impacts. Referring again to Figure 6.1, the proposed plan calls for introducing a meander at the northern end of the stream. The total cost for this element of the project is $170,000, which is inclusive of all of the final engineering design costs, preparation of construction specifications and permit application materials, as well as construction labor and material costs and construction oversight.

The majority of the cost associated with this element of the project (approximately $155,000) pertains to the actual excavation of the new segment of stream channel. We have assumed that all excavated materials will be retained on site and used to re-fill the existing channelized segment of the stream channel. The plan does not require filling the abandoned channelized section of the stream to the same elevation as the surrounding lands. Thus we are not calling for the importation of any soil material for this purpose. If necessary, some of the soil excavated during the recreation of the floodplain could also be used to refill the abandoned channel segment.

However, there will be the need to import stone that will be used to basically block the southern end of the abandoned channel. The imported rock will be used to create the grade controls needed to divert flows into the new channel and to reduce stream velocities to further protect the recreated channel from erosional impacts during periods of higher flows. We have not factored into our restoration plan the use of any large trees; however their presence will be important in bank armoring. The majority of the stabilization of the new stream channel will be accomplished using bioengineering techniques (dictated in part by the projected flow rates and velocities) that rely more on seeding, plugs and perhaps some live stakes to vegetate the newly created stream banks. The revegetation of the filled, abandoned channel will be by means of seed and any volunteer plants that colonize the area upon project completion. We feel that there is an ample seed bank in the soils that will be moved from the other areas of the site to facilitate the rapid stabilization of the filled channel. However, the OCSWCD may impose different revegetation and stabilization standards.

Finally, with respect to the cost of this project, we have not factored into the design or cost the creation of fish, aquatic fauna or avifauna habitat. We recognize that this is another opportunity for the NYSDEC or TNC to increase the area’s habitat diversity or create habitat for specific species. Doing so would add some additional cost to this project’s total.

Backwater Wetland Basin – The final element of the project involves the construction of a small wetland basin at the far northern end of the stream. The purpose of this basin is to provide an opportunity for additional pollutant removal. This is not a “flow through” basin. Rather, it is a backwater design that functions as a stormwater polishing system only during periods of higher flows during which stream flow would back up into the basin. The basin’s construction is rather simple involving limited regrading that would be conducted in concert with the stream meander project discussed above. The basin’s construction does not involve the construction of an inflow or outflow control structure or the installation of any grade controls. Inflow and outflow from the basin will be dictated by stream elevation and flow. The basin itself was projected to encompass between 1 -2 acres in total area. The cost to construct this basin is projected to total $60,000, inclusive of all of the final engineering design costs, preparation of construction specifications and permit application materials, as well as construction labor and material costs and construction oversight. The cost assumes that once constructed the basin will be colonized by plants from the adjacent wetland areas. That is, no supplemental planting is being proposed as part of the basin's creation. Additionally, as is the case with the new stream meander we have not factored into the design or cost the creation of fish, aquatic fauna or avifauna habitat.

Curtis Road Bioretention Swale and Basin - The costs to construct these stormwater management features should be relatively low assuming that the work will be conducted by County personnel. The swale itself is largely in place and simply needs to be expanded and replanted. We expect the need to place stone at the point where runoff enters the swale from the two driveways. This will control any storm scour. There may be the need to install an underdrain along the base of the swale to promote the evacuation of the swale between storm events. The expanded swale will need to be lined with jute matting or similar material to prevent its erosion during the growing-in phase. A wet-tolerant seed mix should be used to vegetate the swale. *The swale should be mowed no more than once annually and to a height of no less than 8".* The projected cost to implement this element, including the installation of the underdrain, is $8,000.

The swale will need to connect to a catch basin and pipe system that will collect the runoff from the swale and convey it under Curtis Road to the bioretention basin. The dimensions of the bioretention basin will be predicated on the computed flows generated from the contributing watershed area. The basin itself, while designed to treat the runoff generated by the 1-year event, will need to be able to manage all storms up to and including the 100-year event and be able to safely pass flows exceeding the 100-year event. Although the creation of this basin will largely involve the clearing of the existing vegetation and then the excavation of the native soils, there will be significant costs associated with the construction of the basin's inlet and its outlet control structure. Based on the properties of the existing soils there may be the need to import soils having better permeability and biotreatment properties than provided by the native soils (refer to the 2010 NYSDEC BMP Manual for a specification). The importation of such a soil mix could significantly add to the overall cost. Also depending on the depth to seasonal highwater or any restrictive horizons it may be necessary to include an underdrain in the basin's design. Finally, erosion control will need to be provided at the discharge point of the basin into the stream to prevent downstream scour and erosion. While there are many unknowns associated with this basin, based on our past experience, it should be possible to construct this basin (including the crossing under Curtis Road) for approximately $150,000.

8.0 Load Reduction Projections Associated with the Recommended Honeoye Inlet Wildlife Management Area Stormwater Management Measures

The two overarching goals set by TNC and HLWTF for this project are: decrease pollutant loading (primarily phosphorus and sediment) to Honeoye Lake, and increase the habitat quality and diversity of the Honeoye Inlet Wildlife Management Area. Decreasing phosphorus and sediment loading specifically addresses the objectives of the HLWTF and the NYSDEC to control Honeoye Lake's rate of eutrophication and the associated negative consequences of eutrophication, in particular algae blooms. TNC and NYSDEC also recognize that focusing on the Honeoye Inlet Wildlife Management Area provides a unique opportunity to both manage the runoff and loading generated from the lake's largest subwatershed while reshaping and restoring the ecological attributes of this site. Through this project the HLWTF, using the updated and expanded watershed's nutrient loading database, are also able to identify other subwatersheds having the greatest pollutant loading impact on the lake.

As per Table 5.5, in addition to subwatershed 4 (which includes the Honeoye Inlet Wildlife Management Area) the four subwatersheds with the greatest manageable pollutant loads were 1 (Northwest), 2 (Affolter Gully), 3 (Cratsley Gully) and 8 (Northeast). For the Honeoye Inlet watershed and these four subwatersheds, recommendations were developed regarding how best to effectively manage or mitigate the sources of the computed pollutant loads. In our scope of work we proposed to place emphasis on the use of bioretention type BMPs given their high propensity for the removal of nutrients and sediments, the two major types of pollutants affecting the lake's rate of eutrophication and overall water quality. However, due to topographical, ownership and existing land use and land development restrictions, the construction of regional bioretention basins was found to be neither practical nor possible. Rather, with the exception of a basin proposed in the headwater section of the Affolter subwatershed, the best approaches for decreasing the sediment and nutrient loads of Northeast (1), Affolter (2), Cratsley (3) and Northwest (8) subwatersheds involves stream stabilization, the use of lot-specific rain gardens, vegetated swales, the maintenance or restoration of stream buffers and the implementation of source control measures such as reduced fertilizer use. Details of these recommendations are provided in Section 6 of this report.

The load reductions achievable through the implementation of these types of measures are not easily computed as there are too many site specific variables that affect the performance of these techniques. As such, our load reduction analyses are limited to the assessment of the performance measures proposed for the Honeoye Inlet Wildlife Management Area. We attempted to compute these reductions using the *MapShed* PRedICT (Pollution Reduction Impact Comparison Tool) module. Upon our completion of this project we found that it was not feasible to use PRedICT, or even STEPL, to analyze the pollutant removal achievable through the proposed Honeoye Inlet Wildlife Management Area load reduction measures. This was largely due to two main reasons:

1. The module is designed primarily to be used in an agricultural watershed where non-structural, agricultural BMPs are being utilized to reduce pollutant loading, and
2. None of the BMPs proposed for use in the Honeoye Lake watersheds meet the model's use "scenarios".

With respect to the latter, when dealing with "urban BMPS" PRedICT only allows for the analysis of the load reductions achieved through the use of detention basins, bioretention areas and created wetlands (referred to in the manual as urban BMPs). Table 9 of the PRedICT User's Manual (Evans, et al., 2008) identifies the percent load reductions for each of the urban BMPs as follows:

Table 8.1 PRedICT Load Reduction Coefficients for Urban BMPs

	Sediment	**Phosphorus**	**Nitrogen**
Detention Basin	93%	51%	40%
Constructed Wetland	88%	51%	53%
Bioretention Area	10%	61%	46%

There are no assigned load reduction coefficients for the ditch plugging, floodplain reconnection or even the back water wetland basin. Additionally, none of the BMPs proposed for the Honeoye Inlet Wildlife Management Area are on-line systems. That is, none of them have defined inlet/outlet structures and they are not designed to detain captured runoff for a specified amount of time. However, while it is not possible to directly utilize the model to compute load reductions, it is possible to apply the removal efficiencies manually, with some assumptions, to arrive at the load reductions likely achievable through the implementation of the ditch plugging and floodplain reconnection elements. In essence, the ditch plugging and floodplain reconnection creates a wetland-type habitat; consequently, the following removal efficiencies are based on constructed wetland systems.

First, the ditch plugging and floodplain reconnection elements will treat most, but not all of the runoff generated from Subwatershed 4. There is a portion of the far northern end of the subwatershed and portions of the eastern side of the subwatershed that do not drain directly into Honeoye Inlet or sheet flow across that lands that will be affected by the ditch plugging. This is largely inconsequential as most of these "untreated/unmanaged" lands are minimally developed and drain to forested wetland before reaching Honeoye Lake.

Second, as detailed in Section 5.3, 1-year (water quality) events are responsible for over 70% of the lake's total pollutant loading. As such, from the perspective of pollutant load reduction, BMPs sized to manage the 1-year event should have the greatest effectiveness. For comparative purposes Table 8.2 presents the Honeoye Inlet, **1-year (water quality) event** and the **total annual loads** projected by *MapShed* to be transported into the lake.

Table 8.2 – Honeoye Inlet (Subwatershed 4) Loading		
Pollutant	**Mean 1-year Storm Computed Load**	**Total Annual Computed Load**
TSS	190,285 kg	1,248,000 kg/Yr
TP	37 kg	535 kg/Yr
TN	331 kg	9,339 kg/Yr

For the **entire Honeoye Lake watershed** the aggregate annual loading is 2,877,000 kg/yr TSS, 1,005 kg/yr TP, and 20,196 kg/yr TN. As such, the Subwatershed 4 annual loads account for approximately 50% of Honeoye Lake's total annual TSS, TP and TN loads.

Applying the PRedICT TSS, TN and TP load reduction efficiencies ascribed to constructed wetland systems, the treatment of the captured runoff by the stormwater management measures proposed for the Honeoye Inlet Wildlife Management Area decreases the respective post-treatment Subwatershed 4, **1-year storm event loads** and **total annual loads** to:

Table 8.3 – Honeoye Inlet (Subwatershed 4) Post-Treatment Loading as per PRedICT		
Pollutant	**1-year Storm Post-Treatment Load**	**Total Annual Post-Treatment Load**
TSS	41,863 kg	274,560 kg/Yr
TP	18 kg	292 kg/Yr
TN	156 kg	4,390 kg/Yr

These values represent the total loading to Honeoye Lake originating from Subwatershed 4 caused by **1-year storm events after treatment by means of the cumulative proposed BMPs**. Likewise, applying the same constructed wetland coefficients to the **total annual** Subwatershed 4 loads results in the decreased loading illustrated in Table 8.3.

However, we feel that the load reductions computed using the PRedICT module values are conservative. A review of the literature shows that most other sources ascribe higher TSS, TN and TP removal values for bioretention systems than does the PRedICT module. For example, the NYSDEC Stormwater Management Manual (2010) ranks bioretention BMPs as having good (highest ranking) nutrient, sediment and pathogen removal capabilities. Likewise the Connecticut and Pennsylvania BMP manuals (CTDEP, 2004 and PADEP, 2006) as well as the USEPA (2002) recognize bioretention systems as providing some of the highest nutrient and sediment removal efficiencies of all the classes of BMPs. The New Jersey Department of Environmental Protection (2010) assigns removal efficiencies to bioretention systems of 80% TSS, 60% TP and 50% TN. Simpson and Weammert (2009) reviewed the performance of bioretention BMPs utilized in the Chesapeake Bay area and assigned removal efficiencies as high as 90% for TSS, 85% for TN and 80% for TP. As such, applying removal efficiencies of **85%, 70% and 60%,** respectively for TSS, TP and TN provides alternative pollutant reduction estimates that are comparable to those generated using the PRedICT module. Using these alternative, standardized removal coefficients predicts the proposed Wildlife Management Area stormwater management system will reduce the Subwatershed 4 **1-year storm post-treatment loads** and **total annual post-treatment loads** to:

Table 8.4 – Subwatershed 4 Post-Treatment Loading as per Standardized Removal Coefficients		
Pollutant	**1-year Storm Post-Treatment Load**	**Total Annual Post-Treatment Load**
TSS	28,543kg	187,200 kg/Yr
TP	11 kg	161 kg/Yr
TN	132 kg	3,736 kg/Yr

These projected pollutant removals are in the same range as predicted by the Cayuga County Department of Planning and Economic Development for the previously noted Owasco Flats Wetland Restoration and Riparian Buffers Initiative (CCDPEC, 2011).

Therefore, whether using the PRedICT constructed wetland reduction coefficients or the reduction coefficients developed by others for bioretention and constructed wetland systems, a fairly high load reduction will be achieved through the implementation of the recommended stormwater management measures. However, we expect the cumulative pollutant removal capabilities of the Honeoye Inlet Wildlife Management Area's stormwater management system to be even greater. Our studies of similar systems constructed at Pennswood Village, Newtown, PA, Deal Lake, NJ and along Walnut Brook, Flemington, NJ, shows that very little of the flow diverted into similar floodplain storage systems actually migrates back into the stream system as surface flow. Rather, the captured flow either infiltrates through the soils into the surficial groundwater aquifer or is lost via evaporation and transpiration. Consequently, such systems effectively remove most, if not all, of the TSS, TN and TP load from the captured and detained flows.

In summary, the stormwater management system proposed for the Honeoye Inlet Wildlife Management Area provides a unique opportunity to effectively manage a large percentage of the annual TSS, TP and TN loading to Honeoye Lake. At the same time the stormwater management measures provide an additional benefit by actually restoring and expanding the habitat properties of the Honeoye Inlet Wildlife Management Area.

Overall, the projected costs to implement the full suite of measures proposed for the Honeoye Inlet Wildlife Management Area total between $1,100,000 and $1,400,000. Not all of this work has to be conducted simultaneously, but to reduce total site disturbance and ensure the integrated functionality of the stormwater management system it would be desirable to implement these measures as part of one large construction project. Additionally, as reflected in the lower end of the cost range, conducting all of the improvements as part of a single large project avoids multiple bidding and permit preparation costs, decreases the cost associated with contractors mobilizing and demobilizing multiple times, and decreases the amount of construction oversight time.

For the balance of the Honeoye Lake watershed, management of the watershed's stormwater loads is complicated by a number of factors. First, the majority of the lands are privately owned. Additionally, there is little available land for the construction of regional basins and the structures needed to properly manage the streams' flood flows.

Second, much of the sediment loading is a function of the watershed's steep topography and is more the result of stream bed and bank erosion than sediment inputs attributable to land development activities. This means that more meaningful reductions in TSS loading can be achieved through stream restoration as opposed to stormwater quality management.

Third, the overall watershed is for the most part sparsely developed. While the exceptions to this are the Northeast (8) and Honeoye Lake Park (9) subwatersheds, much of the total loads generated throughout the Honeoye Lake watershed originate from forested lands. Such loading is considered "background" loading and is usually characterized as an unmanageable element of the total load.

Fourth, generally the loading associated with the more heavily developed nearshore areas and subwatersheds is best managed using "small footprint", homeowner BMPs such as rain barrels, rain gardens, vegetated swales and stream-side and lake-side buffers.

Finally, watershed-based stormwater management must be a part of the overall strategy used to decrease pollutant loading to Honeoye Lake. However, given the relative magnitude of the watershed loads, the fact that much of the loading is background loading, and the limitations posed in the implementation of standard, regional stormwater BMPs throughout the majority of the watershed, the management of the lake's internal phosphorus load must remain a primary element in the comprehensive efforts being taken to control the lake's rate of eutrophication.

9.0 References

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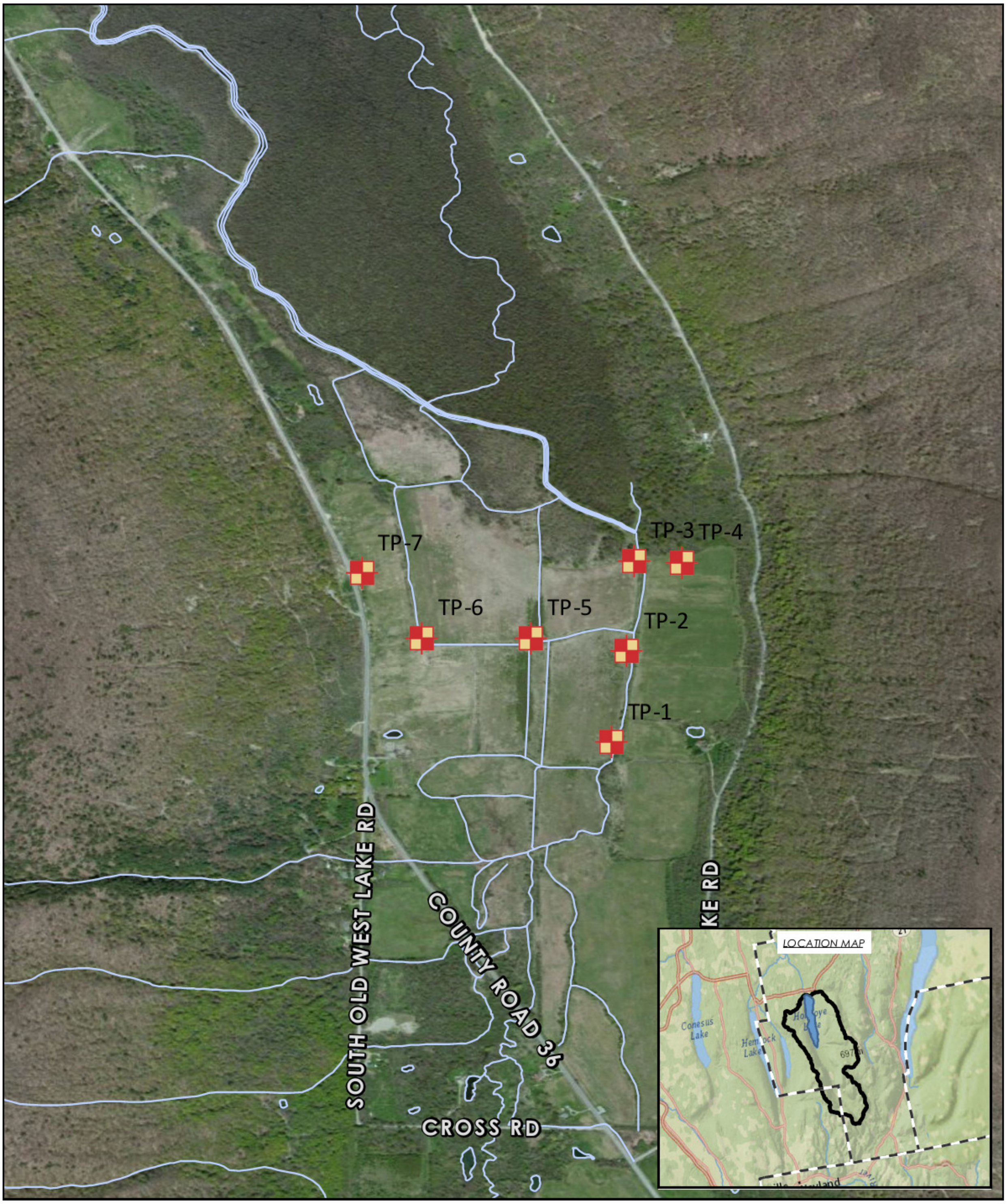
Appendix A

Soil Test Log Data



TEST PIT LOCATIONS

HONEOYE LAKE
TOWN OF RICHMOND
ONTARIO COUNTY, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:

1. USGS topographic digital raster graphic obtained from Terrain Navigator Pro, Brewster, NY quadrangle.

0 1,000 2,000 Feet

Map Projection: GCS North American 1983

pH no.: 1034.003	Boring ID:	Sheet: 1 of 7

SOIL BORING LOG

PROJECT: Honeoye Lake
LOCATION: Test Pit 1
ELEVATION:
DRILLER:
METHOD: Excavator
LOGGED BY: KCD
▼ DEPTH:
DATE: 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	**SOIL DESCRIPTION** Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	**COMMENTS** Well Details, Field Test, Instrument Reading, Notes/Observations
gs	0-1ft					
0.5						
1					Dark brown friable clay loam	Organic layer with roots (formerly plowed)
1.5						
2						
2.5	1-5.8ft					
3						
3.5						
4						
4.5						
5						
5.5					Friable grey silty clay with reddish brown mottles	Moist
6						
6.5	5.8-7.3ft					
7					Gray sandy clay with reddish brown mottles and some shale fragments with 2-3-inch cobbles	GW seeping in at 5.8ft
7.5						
8						
8.5						
9						
9.5						
10						
10.5						
11						
11.5						
12						
12.5						
13						
13.5						
14						
14.5						
15						

pH no.: 1034.003 | Boring ID: | Sheet: **2 of 7**

SOIL BORING LOG

PROJECT:	Honeoye Lake	**LOCATION:**	Test Pit 2
ELEVATION:		**DRILLER:**	
METHOD:	Excavator	**LOGGED BY:**	KCD
▼ DEPTH:		**DATE:**	8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	**SOIL DESCRIPTION** Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	**COMMENTS** Well Details, Field Test, Instrument Reading, Notes/Observations
gs 0.5 1 1.5	0-1.3ft				Dark brown friable clay loam	Organic layer with roots, formerly plowed, moist
2 2.5	1.3-2.5				Gray friable silty clay with reddish brown mottling and roots	
3 3.5 4 4.5 5	2.5-5ft				Gray silty clay with roots and rounded gravel and cobbles <2-inches	Laminated layers with good root structure
5.5 6	5-6ft				Light brown silty sandy gravel <2inches	Wet
6.5 7	6-7ft				Light brown clayey silt with distinct layers (alternating silt and clay)	Saturated
7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15						

pH no.: **1034.003** | Boring ID: | Sheet: **3 of 7**

SOIL BORING LOG

PROJECT: Honeoye Lake | **LOCATION:** Test Pit 3

ELEVATION: | **DRILLER:**

METHOD: Excavator | **LOGGED BY:** KCD

▼ DEPTH: | **DATE:** 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	SOIL DESCRIPTION Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	COMMENTS Well Details, Field Test, Instrument Reading, Notes/Observations
gs						
0.5	0-1.83 ft					
1						
1.5					Dark brown friable clay loam with some cobbles (edge of field)	Organic layer with roots (formerly plowed)
2	1.83-2.5 ft				Dark brown friable organic silty loam with wood fragments	
2.5						(former forest organic layer)
3						
3.5						
4	2.6-7 ft					
4.5						
5						
5.5						
6						
6.5						
7					Gray clayey silt with light brown to reddish mottles and some traces of organics	GW seeping in at 7 ft
7.5						
8						
8.5						
9						
9.5						
10						
10.5						
11						
11.5						
12						
12.5						
13						
13.5						
14						
14.5						
15						

Princeton Hydro

pH no.: 1034.003 | **Boring ID:** | **Sheet:** 4 of 7

SOIL BORING LOG

PROJECT: Honeoye Lake | **LOCATION:** Test Pit 4

ELEVATION: | **DRILLER:**

METHOD: Excavator | **LOGGED BY:** KCD

▼ DEPTH: | **DATE:** 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	SOIL DESCRIPTION Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	COMMENTS Well Details, Field Test, Instrument Reading, Notes/Observations
gs 0.5 1	0-1 ft				Dark brown friable clay loam with some organics and angular pieces of shale gravel	Organic layer with roots (formerly plowed)
1.5 2	1-2 ft				Gray clayey silt with light brown to reddish mottles and some traces of organics	
2.5 3 3.5	2-3.5 ft				Light brown course sand with some small gravel and silt	Perched water table in sand layer
4 4.5	3.5-4.5 ft				Light brownish gray clayey silt with some reddish brown iron deposits	Laminated layers alternating silt and clay
5 5.5 6 6.5 7 7.5 8	4.5-8 ft				Dark gray clay	Obvious depositional layers with some marine fossils
8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15						

pH no.: **1034.003** Boring ID: Sheet: **5 of 7**

SOIL BORING LOG

PROJECT: Honeoye Lake **LOCATION:** Test Pit 5

ELEVATION: **DRILLER:**

METHOD: Excavator **LOGGED BY:** KCD

▼ DEPTH: **DATE:** 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	**SOIL DESCRIPTION** Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	**COMMENTS** Well Details, Field Test, Instrument Reading, Notes/Observations
gs						
0.5	0-1.5 ft					
1						
1.5					Dark brown friable clay loam with roots	Organic layer with roots (formerly plowed)
2	1.5-2.5 ft					
2.5					Gray clayey silt with extensive reddish mottles and some traces of organics	
3	2.5-3 ft				Gray clay with reddish mottles	
3.5						
4						
4.5	3-6 ft					
5						
5.5						
6					Gray clay transitions into saturated gray silt with few reddish mottles	Saturated
6.5						
7						
7.5						
8						
8.5						
9						
9.5						
10						
10.5						
11						
11.5						
12						
12.5						
13						
13.5						
14						
14.5						
15						

pH no.: 1034.003
Boring ID:
Sheet: 6 of 7

SOIL BORING LOG

PROJECT: Honeoye Lake
LOCATION: Test Pit 6
ELEVATION:
DRILLER:
METHOD: Excavator
LOGGED BY: KCD
▼ DEPTH:
DATE: 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	SOIL DESCRIPTION Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	COMMENTS Well Details, Field Test, Instrument Reading, Notes/Observations
gs						
0.5	0-2 ft					
1						
1.5						
2					Dark brown friable clay loam with roots	Organic layer with roots (formerly plowed)
2.5						
3	2-4 ft					
3.5						
4					Gray clayey silt with reddish mottles and some traces of organics	
4.5						
5	4-5.5 ft				Brown silty sand with some gravel and pieces of wood	
5.5						Groundwater
6						
6.5	5.5-8 ft					
7						
7.5						
8					Gray sandy clay with some fine gravel	Saturated
8.5	8-9 ft					
9					Light brown course sand with gravel and fines	Saturated
9.5						
10						
10.5						
11						
11.5						
12						
12.5						
13						
13.5						
14						
14.5						
15						

pH no.: 1034.003 | **Boring ID:** | **Sheet:** 7 of 7

SOIL BORING LOG

PROJECT: Honeoye Lake
LOCATION: Test Pit 7
ELEVATION:
DRILLER:
METHOD: Excavator
LOGGED BY: KCD
▼ DEPTH:
DATE: 8/22/2013

Depth Below Ground Surface (bgs) in ft	Interval (ft)	Recovery (ft)	Sample ID	Graphic	SOIL DESCRIPTION Soil Name, USCS Group, Color, Moisture, Consistency, Structure, Mineralogy, Fossils	COMMENTS Well Details, Field Test, Instrument Reading, Notes/Observations
gs						
0.5	0-1 ft					
1					Dark brown friable clay loam with roots	Organic layer with roots (formerly plowed)
1.5	1-1.5 ft				Dark gray brown clay loam with 3-4 inch cobbles	
2						
2.5	1.5-3.5 ft					
3						
3.5					Gray silty clay with reddish mottles and some traces of organics	
4						
4.5						
5						
5.5	3.5-7.5 ft					
6						
6.5						
7						
7.5					Bluish gray sandy clay with angular fragments of shale	Saturated at depth
8						
8.5						
9						
9.5						
10						
10.5						
11						
11.5						
12						
12.5						
13						
13.5						
14						
14.5						
15						