Ellie Milano

ENV 300: SIE

Seneca Lake Watershed Project

4/2/2012

Wetlands as Buffer Zone Nutrient Sinks and the Implications for the Seneca Watershed

Introduction

The objective of this report is to provide a detailed discussion of the role in which natural and constructed wetland systems can play in controlling and limiting nutrient flow and water quality in a lake system. It will also identify the current wetlands within the Seneca Lake Watershed, including landfill-associated wetlands, plans for wetland construction in the Seneca Lake State Park, and the potentiality for wetland construction surrounding the lake, drawing specifically on the Catharine Creek Wildlife Management Area as a case study. Additionally, it will provide a brief evaluation of the costs and benefits associated with such a construction project, by examining the potential inputs and outputs for a wetland at Catharine Creek as well as by assessing the processes of constructing a wetland, seen in two other specific projects.

The EPA defines a wetland as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support… a prevalence of vegetation typically adapted for life in saturated soil conditions"[1]. Namely, the most defining characteristic of a wetland is hydric soils, or essentially water-logged soils, alongside characteristic rooted, water-tolerant vegetation. Wetlands can occur as both freshwater (marsh or swamp) and saltwater (salt marsh or forested salt water)[2], where each is generally characterized by distinct habitats and vegetation. In all cases, these areas of hydrophilic vegetation and saturated soils are highly productive, and have the capacity to absorb nitrates, phosphates, suspended solids, and bacteria[3], as well as effectively control physical factors like water temperature and pH, and decrease the effects of high volume flooding or storm events.

Background: Nutrient Loading in Seneca Lake

Over the past couple of decades, Seneca Lake has begun to experience heightened nutrient loading, or increasing levels of phosphorus, leading to the possibility of increased productivity

[1] "Clean Water Act of 1977 Title 40: Protection of Environment; Part 230- Section 404(b) and 501 (a), 33 U.S.C. 1344(b) and 1361(a). Subpart A 230.3 Definitions." epa.gov. US Environmental Protection Agency. Web. 14 February 2012.

[2] Kadlec, Robert H., and Robert L. Knight. *Treatment Wetlands*. Boca Raton, FL: CRC Lewis, 1996. 50-51. Print.

[3] Kadlec and Knight,

and phytoplankton biomass. The phosphorus budget for the lake has been shown to be highly unbalanced; the streams that inlet into Seneca input around 40 million metric tons per year (mtpy) of phosphorus, and septic systems, waste water and the atmosphere input approximately 5 mtpy of phosphorus combined, totaling 45 mtpy entering the lake. Between the small amount of phosphates that get lost in the sediments, and the 8 mtpy exiting the lake via the outlet, approximately 37 mtpy are being added to a lake whose phosphorus levels are already 155 mtpy[4]. Other data indicative of nutrient levels similarly depict increasing trends; chlorophyll levels in the lake have been on a rising trajectory since 1997, as well as decreasing secchi disk depth measurements, and a decline in both zebra and quagga mussel populations, which tend to significantly lower algal biomass[5]. All of these factors indicate that the lake's trophic status has become more mesotrophic over the past couple of decades.

Further, land use in the Seneca Lake Watershed is dominated by agriculture, where 42.2% of land within the watershed is used for agricultural purposes[6]. This indicates that non-point source pollution is a key factor contributing high levels of nutrients to inletting streams, and subsequently the lake. Methods to control non-point source nutrient loading include Best Management Practices or BMPS, which suggest changes in farming practices to control the effect of agriculture on phosphate loading, such as restricting animal access or creating buffer strips between farmland and adjacent streams. In addition, natural and artificially constructed wetlands have been shown to be successful in absorbing nutrients like nitrates and phosphates and acting as riparian-zone buffers[7], which are able to mitigate water flow between agricultural land and streams. Constructed wetlands have also been studied for their use in wastewater treatment; however the applicable focus for the Seneca Lake Watershed is natural or constructed wetlands for non-point source or groundwater filtering-like processes.

Ecological Services of Wetlands

Nitrates

When uncharacteristically high levels of nitrate/nitrite enter a wetland, it has been shown that the system can functionally reduce nitrogen concentrations by a significant amount[8]. The processes behind this are complex, but most simply involve a conversion process whereby nitrates or nitrites are converted into gaseous nitrogen and released into the atmosphere. Firstly, the nitrates or nitrites that enter the system undergo ammonification, at which point the NH_4 can either be released as NH_3 gas, or it will undergo nitrification, where it combines with oxygen molecules to

---

[4] Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Characterization and Subwatershed Evaluation". Draft.

[5] Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Characterization and Subwatershed Evaluation". Draft.

[6] Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Land Use and Land Cover". Draft.

[7] Kadlec and Knight, 1996.

[8] Kadlec and Knight, 440-442.

produce NO_2^- or NO_3^-. Microbial communities within the sediments then further alter these compounds via a process of denitrification where N_2 or N_2O gases are released into the atmosphere. These microbial communities are a key component of the wetland system, and studies have shown that wetlands can remove anywhere from 40% to 80% of the nitrogen contained within wastewater[9]. A simplified nitrogen cycle is depicted below (also see Table 1).

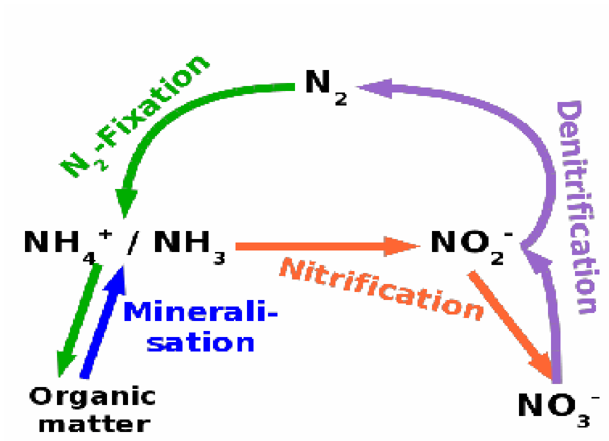

Figure 1: Simplified nitrogen cycle within a wetland. Source : Institute of Biogeochemistry and Pollutant Dynamics. http://www.ibp.ethz.ch/research/environmentalmicrobiology/research/Pioneer_sites

Phosphates

The removal of phosphorus from groundwater in a wetland system is quite effective, especially when considering that wetlands create an ecological pocket of high productivity. In this case, there is a large plant biomass that can uptake soluble phosphorus and store it in tissues to be used for growth[10]. Further, as shown by Figure 2a, there are many pathways of transfer for phosphorus within a wetland, and many different entities that can uptake it. As seen in Figure 2b, plants living and dead and their associated root systems can hold more than 8 g/m^2 of phosphates. Microbiota such as bacteria, fungi, or algae, are also capable of uptaking phosphorus often at a rapid rates for storage in their tissues, and used later for growth and reproduction[11]. Leaf litter or detritus within the system can also be a major sink for soluble phosphorus.

Further, soil absorption or settling of suspended solids can also remove particulate phosphates from slow-moving groundwater[12], Table 1. The complex processes within the wetland do not allow these particulates to re-suspend in the water column, which subsequently allows for the sediments to provide yet another phosphorus sink. Phosphates can be absorbed this way into the

[9] "Constructed Wetlands." *Natural Systems International*. Mindshare Studios, 2012. Web. 8 Apr. 2012. <http://www.natsys-inc.com/resources/about-constructed-wetlands/>.

[10] Kadlec and Knight, 444-445.

[11] Kadlec and Knight, 449.

[12] Kadlec and Knight, 451.

sediments at 60 g/m², as seen in Figure 2b, according to this particular source. Estimates based on phosphate removal however tend to vary.

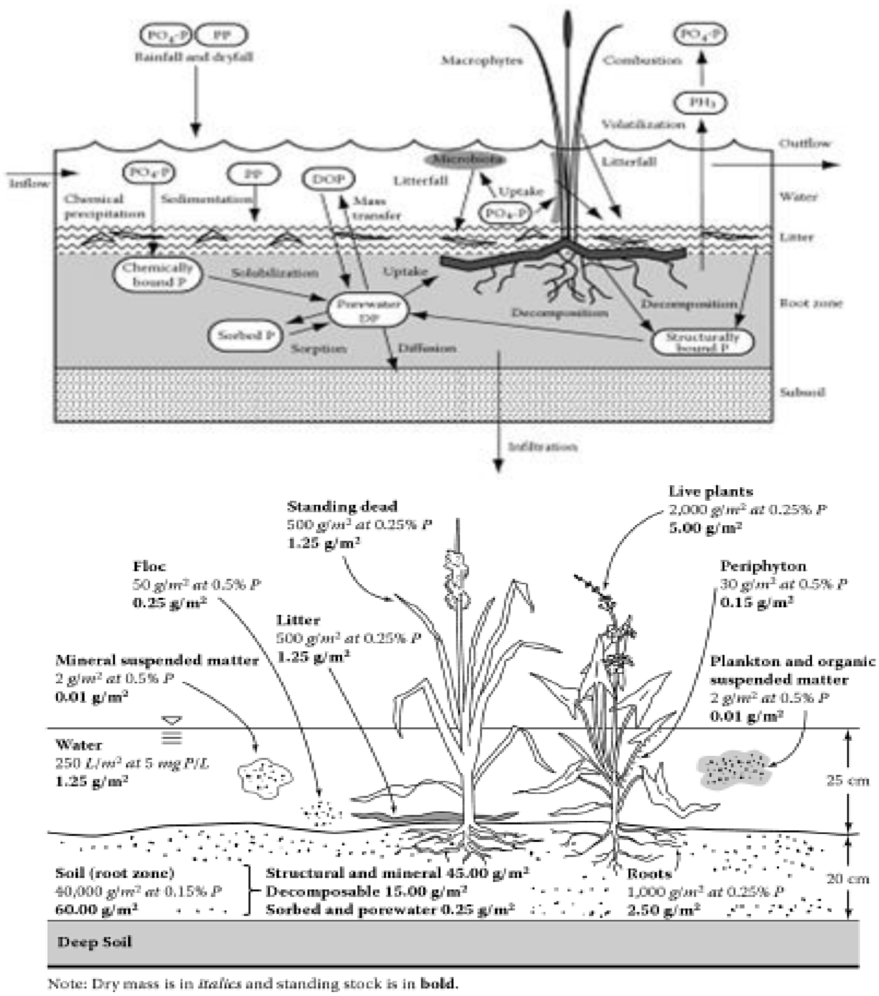

Figure 2: The movement of phosphates (top, 2a) and the storage capacity of various entities (bottom, 2b) within a wetland system. Source: Kadlec and Knight, 350-351.

Sediment Trapping

As previously mentioned, the slowing movement of groundwater through a wetland system allows for total suspended solids (TSS) to settle out and become absorbed into the sediments, such that they cannot be resuspended into the water column. The vegetation and substrata present within the wetland allows for a basic filtration system to occur, whereby slow moving water allows suspended solids and their associated bacteria and particulates (including organic matter, heavy metals, E. coli, and other such pollutants) to be removed from the groundwater[13].

[13] Kadlec and Knight, 315, 323.

These processes can remove up to three quarters of incoming suspended solids, depending on the type and density of vegetation[14].

There is a concern, especially with constructed wetlands that are being used specifically for the treatment of wastewater, that a high volume of TSS being inputted into the system can cause a clogging effect, whereby sediments build up within the bed near the inlet[15]. However, there is uncertainty as to how long it might take a constructed wetland to clog, and there has been investigation into the effectiveness of settling ponds to deflect this particular issue. Further, it seems to be a problem limited to treatment wetlands, rather than riparian buffer zone wetlands, which are more relevant to Seneca Lake.

The processes within a wetland that remove the nutrients and pollutants mentioned here can be seen summarized in Table 1.

Wastewater constituent	Removal mechanisms
Suspended Solids	Sedimentation/filtration
BOD	Microbial degradation (aerobic and anaerobic)
	Sedimentation (accumulation of organic matter/sludge on the sediment surface)
Nitrogen	Ammonification followed by microbial nitrification and denitrification
	Plant uptake
	Ammonia volatilization
Phosphorus	Soil sorption (adsorption-precipitation reactions with aluminum, iron, calcium, and clay minerals in the soil)
	Plant uptake
	(Phosphine production)
Pathogens	Sedimentation/filtration
	Natural die-off
	UV radiation
	Excretion of antibiotics from roots of macrophytes

Table 1: A summary of the key services rendered by wetlands; the removal processes of nitrogen phosphorus, suspended solids, and the removal of pathogens via various process occurring within the wetland system. Source: Moshiri, Gerald A. *Constructed Wetlands for Water Quality Improvement*. Boca Raton: Lewis, 1993. Print.

Flood Control

The extent to which a wetland is able to store standing water or groundwater is a function of not only the system's hydrology, but also the landscape features, and the inflows and outflows[16]. However, this storage capacity at any degree makes wetlands a good control on not only stream flow, but also high volume event flow from storms. Event flow or storm water can often cause a high influx of particulate matter and the bacteria and pollutants associated with these suspended particulates. As such, in the case where a wetland provides a barrier before stream inlets, high nutrient loading effects from storm water run-off can be significantly reduced. High volumes of water during storms are essentially retained in the wetland system, or at least significantly

[14] Kadlec and Knight, 331.
[15] Kadlec and Knight, 335.
[16] Kadlec and Knight, 81.

slowed by the natural wetland processes, thereby allowing filtration and settling to remove pollutants and nutrients.

Wildlife Habitat

Another key ecological service that wetlands provide is a diverse habitat for many species across the biological kingdoms, because a given wetland typically consists of multiple distinct habitat types. For instance, a typical wetland could include emergent, wet prairie, wet mesic prairie, mesic forest, forested wetlands, and upland savannah ecosystems, providing habitat for plant species such as shagbark hickory, white oak, red maple, swamp white oak, and many other similar wetland-dwelling plants[17]. The differing ecosystems contained within a wetland provides habitat for countless communities, providing a rich source of biodiversity. Further, the species used in the construction of different wetlands can be vastly different, based not only upon the geographical location of the wetland, but also whether there is a particular service that it is being constructed to perform[18].

Seneca Watershed Wetlands

According to the United States Fish and Wildlife Services Inventory (Table 2), wetlands cover 53,813.5 acres within the Seneca Lake Watershed. However, this inventory counts standing bodies of water including ponds and the lake as wetlands, thus these water bodies account for around 43,000 of those 53,000 acres. Taking into account actual land cover values which ignore the lake and account for only woody and emergent wetlands, approximately 4.2% of total land within the watershed is covered by wetlands[19]. The wetland cover shown by the green shaded areas in Figure 3 highlights this fact. As seen in this figure, most of the wetland cover in the watershed is small and disconnected. This being the case with most watersheds, scientists have found it difficult to quantify the effects of wetlands on the overall water quality of the watershed[20]. Larger bodies of wetlands, especially those constructed, for instance, by large corporations such as landfill owners as part of a restoration project, are much simpler in scope to understand and quantify the effects, and have a greater effect on the overall water quality within the watershed.

Within the Seneca Lake Watershed, the most notable wetlands include the Seneca Meadows Wildlife Preserve on the eastern side of the lake, and the Ontario County Waste Management-owned wetland on the western side of the lake. In addition, the NYS Parks has created an initiative to restore Seneca Lake State Park back into a wetland, and the DEC has identified

---

[17] "Seneca Meadows, Inc." *Seneca Meadows, Inc.* 2012. Web. 7 Apr. 2012. <http://www.senecameadows.com/>.

[18] Kadlec and Knight, 49-55.

[19] Hobart and William Smith Colleges (2012). “Seneca Lake Watershed Management Plan: Land Use and Land Cover”. Draft.

[20] Whigham, D. F., C. Chitterling, et al. (1988). "Impacts of Freshwater Wetlands on Water Quality: A Landscape Perspective." Environmental Management **12**(5): 663-671.

Catharine Creek at the southern end of the lake as an additional site for a potential wetland restoration project.

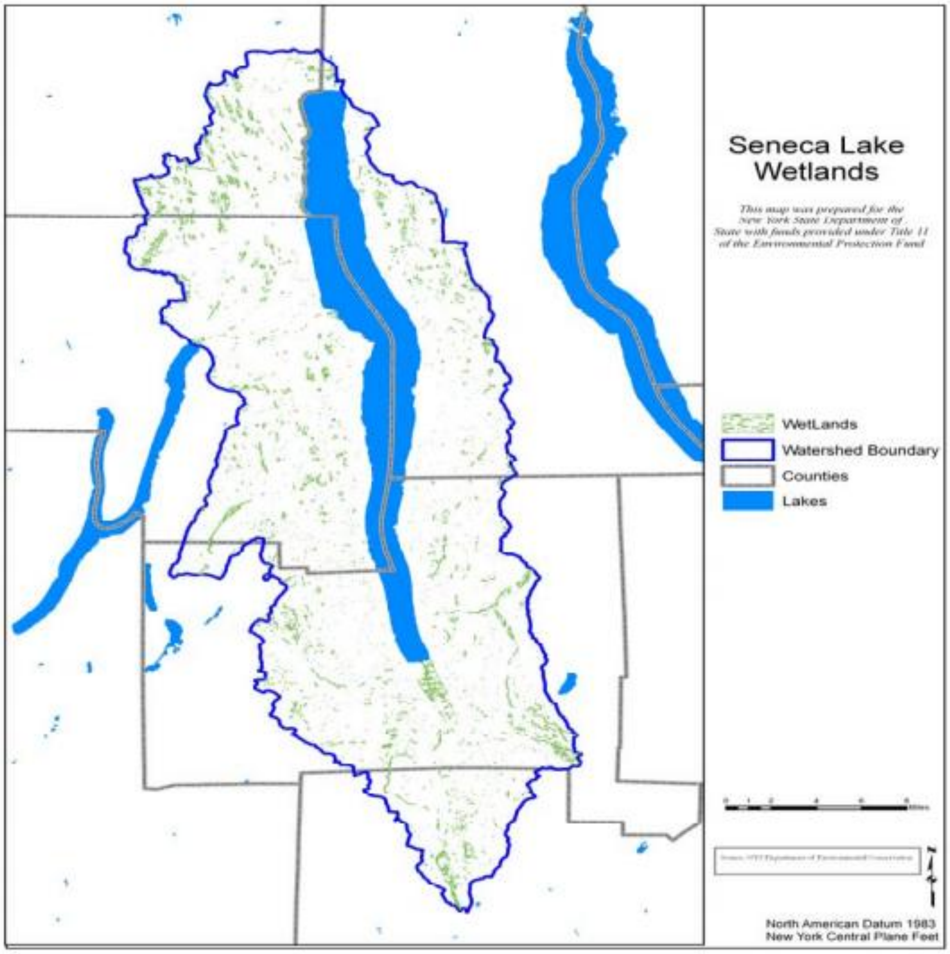

Figure 3: A depiction of the wetlands (shaded green areas) within the Seneca Lake Watershed. Typical Inventories of wetlands include standing water, thus the actual wetland representation here may be misconstrued. Source: Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Land Use and Land Cover". Draft.

Table 4.5 US Fish and Wildlife Service National Wetlands Inventory for the Seneca Lake WS

County	Total Acreage	*Freshwater Emergent Wetland*	*Freshwater Forested/Shrub Wetland*	*Freshwater Pond*	*Lake*	*Other*	*Riverine*
Chemung County	804.5	458.5	212.1	133.9			
Ontario County	2,042.9	298.0	1,690.5	48.6	5.7	0.2	
Schuyler County	10,234.6	1,174.2	1,900.4	317.7	6,746.2	4.1	92.0
Seneca County	22,504.2	102.8	1,127.8	60.3	21,213.4		
Yates County	18,227.2	435.0	2,078.3	178.4	15,504.3	0.6	30.8
Watershed	**53,813.5**	**2,468.5**	**7,009.0**	**738.9**	**43,469.5**	**4.8**	**122.8**

Table 2: The total acreage of wetlands within Seneca Lake Watershed, and the acreage for each different type of wetland. Note that the lake, ponds, and rivers account for a significant portion of the total acreage. Source: Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Land Use and Land Cover". Draft.

Constructed Wetlands

Constructed wetlands can occur as restoration projects implemented by a Park Service or governmental department, as reclamation projects created by landfills, or to provide a certain treatment technology/service for a wastewater facility. The latter technologies have been widely studied for the implications of controlling and filtering wastewater by simulating natural processes. However in the Seneca Lake Watershed, most wetlands occur as a result of the former two initiatives. By law, landfills must create 3 acres of habitat for every 1 acre that they destroy[21]. The two landfills located within close proximity of the Seneca Lake Watershed are the Ontario County Landfill and the Seneca Meadows Landfill, both of which have created wildlife wetland preserves within the watershed. In this way, constructed or restored artificial wetlands play a critical role in the ecology of the watershed as a whole. Natural wetlands were often destroyed in this area for the construction of canals, or the expansion of industrial parks, and in cases such as Catharine Creek, are now at a point where they may be restored to their historic wetland condition[22].

Seneca Meadows Wildlife Preserve

In 2007 Seneca Meadows hired a company called Applied Ecological Services to begin work converting 350 acres of farmland into a wetland preserve, containing six or more unique types of wetland habitat. The scope of the project aims to eventually create a preserve that is approximately 1200 acres, and the estimated value of work done on the project thus far is around $800,000[23]. The processes involved in this particular restoration included planning and preparation, where workers had to survey the land to determine the structure of the preserve, and acquire adequate seeds for the species they wished to plant. Next, AES workers spent years rebuilding the land by creating pockets of habitats, some forested, or emergent wetlands, mesic prairies, or a standing pond, etc. The workers then had to seed the entire preserve, reseed the next season, and so on, until they were at a point where the natural system could take over. Currently, the team is assessing what kind of maintenance will be needed in the future, and what kind of steps should be taken toward their goal of expansion of the preserve.

Figure 4: Left, an aerial image of the various habitats within the Seneca Meadows Wilidlife Preserve. Right, an image of the preserve showing standing water and characteristic wetland vegetation.

---

21 "Seneca Meadows, Inc." *Seneca Meadows, Inc.* 2012. Web. 7 Apr. 2012. <http://www.senecameadows.com/>.

22 “Catharine Creek Fish and Wildlife Management Area.” dec.ny.gov. NYS Department of Environmental Conservation, 2012. Web. 13 February 2012. <http://www.dec.ny.gov/outdoor/24429.html>.

23 "Applied Ecological Services, Inc. (AES)." *Applied Ecological Services (AES), Inc.*Computer Knowhow, 2012. Web. 7 Apr. 2012. <http://www.appliedeco.com/>.

Seneca Lake State Park

Within the past couple of years, New York State Parks Services has identified Seneca Lake State Park as an area that ought to be restored to its historic condition, implying that the area will eventually be converted into a large wetland, with multiple ponds and ecosystems to attract various biota and enforce certain ecological processes. The scope of the project is currently in its infancy, much unlike the project undertaken by Seneca Meadows. NYS Parks Services is currently in the planning stages of their restoration project. The team is working to collect data regarding soil types to assess whether the soils are saturated enough to support a wetland, biological indices to assess what species are present and what species will not to be brought in, statistical analyses regarding the potential success of the project, and mapping out the location of each type of habitat.

Case Study: Catharine Creek

The New York State Department of Ecological Conservation has recently identified Catharine Creek Wildlife Management Area as a potential area to be restored to its historic wetland condition as well. This project, as opposed to the two others described in this report, has not yet been undertaken or committed to by any party. The Wildlife Area is a 1,000 acre piece of land located just south of Seneca Lake, nestled directly next to a major inlet to the lake, as seen in Figure 5. Interestingly, the DEC has described the area as a place that has over the years begun a natural process of returning to a wetland state[24]. The current question is whether government ought to intervene and further the process, creating an additional piece of wetland that could have positive effects on Seneca's water quality and nutrient loading from the south end. Estimates regarding the cost of restoring a wetland range from $3,500 to $85,000[25]. For the 1,000 acre preserve at Catharine Creek, these estimates would place construction values somewhere between $3.5 Million and $85 Million, not including projected costs of future maintenance. Costs would be estimated to run on the lower side of this scale, considering that the current state of the preserve is not as far from the desired state as, perhaps, a cropland would be. Based on a survey done nation-wide comparing Willingness-to-Pay analyses with survey data, farmers' perceptions of wetland construction is that the costs will be very high, but might be worth it in the case that a restored wetland can adequately perform the ecological functions of a natural wetland[26].

A recent study involving wetland removal of nutrients in the Florida Everglades placed estimates on phosphorus removal capacity per acre to between 57 and 372 kg/acre. This would place estimate phosphorus removal for a wetland as large as Catharine Creek between 57,000 and 372,000 total kg, or 57 to 372 metric tons. Though this range is quite large, removing 57 metric

[24] "Catharine Creek Fish and Wildlife Management Area." dec.ny.gov. NYS Department of Environmental Conservation, 2012. Web. 13 February 2012. <http://www.dec.ny.gov/outdoor/24429.html>.

[25] White, Ken. "Wetland Restoration/ Constructed Wetlands." *Brookhaven National Laboratory*. The University of Chicago. Web. 8 Apr. 2012. <http://www.bnl.gov/erd/peconic/factsheet/wetlands.pdf>.

[26] Gelso, B. R., J. A. Fox, et al. (2008). "Farmers' Perceived Costs of Wetlands: Effects on Wetland Size, Hydration and Dispersion." American Journal of Agricultural Economics **90**(1): 172-185.

tons of phosphorus would significantly improve the current phosphorus budget for the lake. It should be noted that this study is not wholly comparable with the system in question at Catharine Creek, however, should these estimates prove accurate, this would be a major phosphorus sink for Seneca Lake, and would have an outstanding capacity to quell a portion of the nutrient loading that is currently occurring in the watershed.

The next step to determine the effectiveness of converting this wildlife area into a wetland might be to assess potential funding sources, and attempt to acquire both financial and public support for the idea. This would increase the current wetland land cover in the watershed considerably, and could potentially mitigate a significant amount of nutrient loading in the lake, and so should become a serious consideration for improving water quality.

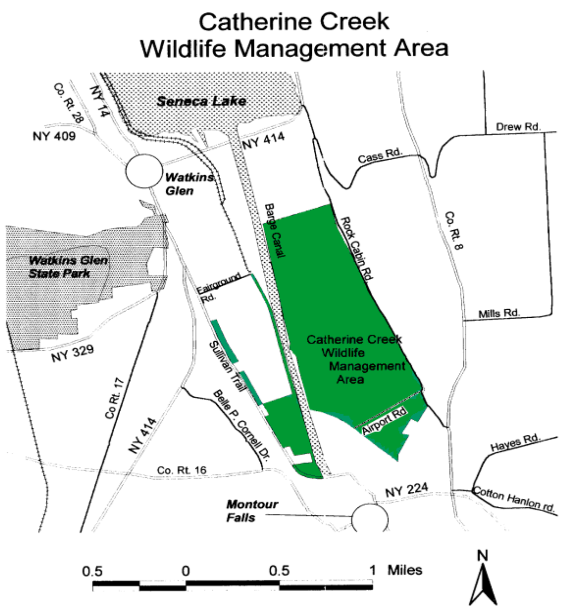

Figure 5: A sketch of the Catharine Creek Wildlife Management area, showing its proximity to canals and major inlets to Seneca Lake. Source: DEC <http://www.dec.ny.gov/outdoor/24429.html>.

Conclusions

The major conclusions that can be drawn from the above information are as follows:

Wetlands possess the capacity to absorb and retain particulate matter, nutrients, and suspended solids, enhancing local water quality. Not only do they provide pockets of high productivity to absorb nutrients, but slowed groundwater allows purification and filtration of TSS from groundwater. These areas can effectively mitigate the interplay between agricultural land and stream inlets via these processes. However, the breakdown of wetlands can release these pockets of nutrients back into the lake. This may have implications for future management and the long-term costs of constructing artificial wetlands to ensure that they do not clog and break down.

The cumulative effects of wetland land cover within watersheds remains difficult to study, and the viability of small wetlands remains difficult to assess. In this watershed, it seems unlikely that efforts will be made to construct wetlands for the sole purpose of controlling point-source waste water pollution. As such, most wetland construction will be restorative or compensatory by landfill companies. This may have serious implications for the extent to which wetlands are constructed in the area, especially considering the project expansion of the Seneca Meadows Landfill, and NYS Parks Service restoration initiative, and the projected plans for the Catharine Creek Wildlife Management Area. The two critical issues drawn from this are 1) whether these wetlands will provide tangible, adequate changes in water quality for the lake, and 2) whether additional wetlands should be constructed around farmlands to provide buffer zones for agricultural land, especially where large inlets exist.

Finally, wetlands within a watershed are important ecological entities that provide key services to the associated streams and water bodies. As such, the investigation of wetlands and the consideration to construct additional, larger patches of wetland appears to be a healthy choice for the water quality of the lake, provided that both financial backing and public opinion would support it.

Sources

"Applied Ecological Services, Inc. (AES)." *Applied Ecological Services (AES), Inc.*Computer Knowhow, 2012. Web. 7 Apr. 2012. <http://www.appliedeco.com/>.

"Catharine Creek Fish and Wildlife Management Area." dec.ny.gov. NYS Department of Environmental Conservation, 2012. Web. 13 February 2012. <http://www.dec.ny.gov/outdoor/24429.html>.

"Clean Water Act of 1977 Title 40: Protection of Environment; Part 230- Section 404(b) and 501 (a), 33 U.S.C. 1344(b) and 1361(a). Subpart A 230.3 Definitions." epa.gov. US Environmental Protection Agency. Web. 2012. <http://www.epa.gov/owow/wetlands/pdf/40cfrPart230.pdf >.

"Constructed Wetlands." *Natural Systems International*. Mindshare Studios, 2012. Web. 8 Apr. 2012. <http://www.natsys-inc.com/resources/about-constructed-wetlands/>

Gelso, B. R., J. A. Fox, et al. (2008). "Farmers' Perceived Costs of Wetlands: Effects on Wetland Size, Hydration and Dispersion." American Journal of Agricultural Economics **90**(1): 172-185.

Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Characterization and Subwatershed Evaluation". Draft.

Hobart and William Smith Colleges (2012). "Seneca Lake Watershed Management Plan: Land Use and Land Cover". Draft.

Johnston, C. A., N. E. Detenbeck, et al. (1990). "The Cumulative Effect of Wetlands on Stream Water Quality and Quantity. A Landscape Approach." Biogeochemistry **10**(2): 105-141.

Kadlec, Robert H., and Robert L. Knight. *Treatment Wetlands*. Boca Raton, FL: CRC Lewis, 1996. Print.

Whigham, D. F., C. Chitterling, et al. (1988). "Impacts of Freshwater Wetlands on Water Quality: A Landscape Perspective." Environmental Management **12**(5): 663-671.

Moshiri, Gerald A. *Constructed Wetlands for Water Quality Improvement*. Boca Raton: Lewis, 1993. Print.

Osborne, L. L. and D. A. Kovacic (1993). "Riparian vegetated buffer strips in water-quality restoration and stream management." Freshwater Biology **29**(2): 243-258.

Sano, Daisuke, Alan Hodges, and Robert Degner. "Economic Analysis of Water Treatments for Phosphorus Removal in Florida." *EDIS*. The University of Florida, 2012. Web. 8 Apr. 2012. <http://edis.ifas.ufl.edu/fe576>.

"Seneca Meadows, Inc." *Seneca Meadows, Inc.* 2012. Web. 7 Apr. 2012. <http://www.senecameadows.com/>.

White, Ken. "Wetland Restoration/ Constructed Wetlands." *Brookhaven National Laboratory*. The University of Chicago. Web. 8 Apr. 2012. <http://www.bnl.gov/erd/peconic/factsheet/wetlands.pdf>.