Working draft Long Term Watershed Management plan for Tuxedo Park's Lakes

Introduction

Tuxedo's three lakes are the centerpiece of the Village, they offer beautiful vistas, recreational pleasures and provide drinking water. In many ways they define the community and make it special. These lakes are part of a complex ecosystem that includes the lakes, their flora and fauna, the underlying rocks, surrounding forests and tributary streams. Lake waters contain the essential elements needed for the growth of lake flora. Some of these, called nutrients, are in short supply and limit lake productivity. An oversupply of nutrients can fuel the growth of invasive aquatic plants and produce algal blooms that contain toxins harmful to lake ecology and human health. The ultimate source of nutrients to our lakes are the soils of their watersheds (the lands that drain into the lake). Forest plants use soil nutrients and reduce soil erosion so under undisturbed conditions waters flowing into lakes contain low nutrient and sediment concentrations. Trees with their extensive root systems and leaf canopies are effective barriers to soil erosion. Shrubs and ground cover also hold soil. Finally, dead leaves and needles from the previous fall, form a blanket protecting the soil from erosion by rain and through their decay return nutrients to the soil for future use by trees and shrubs.

Human activities can inadvertently disturb the natural supply of nutrients and sediment to lakes. The removal of trees and shrubs make soils vulnerable to erosion. Most of our lake's watersheds are forested while a small percentage is developed (yellow, Fig. 1). Small modifications to these latter areas can significantly improve our lake's water quality. Most drinking water reservoirs in New York and New Jersey are protected by chain link fences, ours is not. What we do with our properties are individual decisions but these decisions affect our lakes, which are a common resource. This report compares our lakes water quality between 2008 and 2019 and, recommends a series of watershed actions to be developed and implemented over a decade.

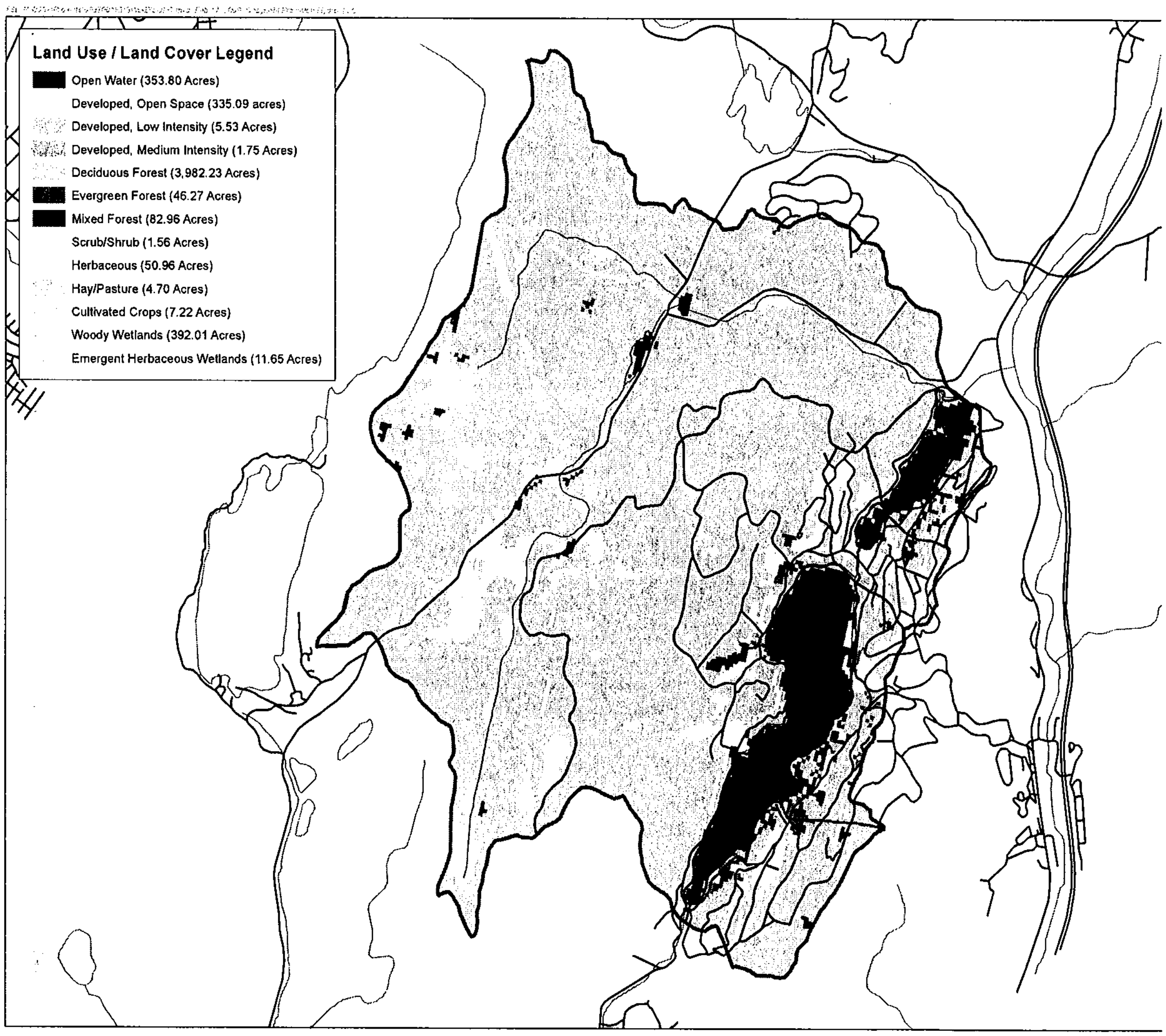

Figure 1 Tuxedo Lakes watershed and sub watersheds with types of vegetation.

Recent History

In 2008 the Village Environmental Committee, under the leadership of Susan Goodfellow, made three recommendations. 1) The Village Board of Trustees (BOT) develop a Lakes Management Plan. Princeton Hydro LLC was engaged and produced a 176 page Plan in 2009. 2) The Village join the Citizens Statewide Lake Assessment Program (CSLAP). Through this program, resident volunteers annually (except for 2013 and 2020) have generated water quality measurements on all three lakes. 3) That Kevin Sumner, of Orange County Soil and Water, review the Village's storm water management system and recommend improvements, his report is Appendix I.

In the fall of 2011, Eurasian Water Milfoil (EWM), an invasive aquatic plant, was discovered in the northern portion of Tuxedo Lake. The Village Board of Trustees (BOT) quickly organized the mapping of its distribution and initiated a program for divers to uproot the EWM plants. In spite of these efforts, EWM has spread around Tuxedo Lake, into Little Wee Wah Pond and Wee Wah Lake. Because Little Wee Wah Pond and Wee Wah Lake are shallow, EWM can spread throughout most, if not all, the waters of both lakes, while in the deeper Tuxedo Lake, the infestation is restricted to water depths of less than 14 feet, around the lake's margins. Several years ago, another invasive plant, Brittle Naiad, was discovered in Tuxedo Lake

To cope with EWM, the BOT hired the services of Solitude Lake Management in 2016 and subsequently engaged North East Aquatic Research (NEAR) in 2019 to be the Village's Lake Manager. Solitude and NEAR have produced maps of the distribution of EWM in our lakes, attempted to control and reduce its spread by pulling and the use of herbicides and NEAR has made extensive water quality measurements in all three lakes throughout the summer and Fall. Reports of this work (NEAR 2019) together with the Princeton Hydro report of 2009 (PH 2009) and the Orange County Soil and Water report (OCSW 2008) are used extensively in this document. Readers interested in more detail than is contained here, should refer to them.

Facts about our lakes

Tuxedo Lake is a natural glacial lake with a dam that raises the lake level, while Little Wee Wah Pond and Wee Wah Lake are impounded artificial lakes. They form a string of connected lakes, so their watersheds are additive, with Tuxedo Lake having the smallest and Wee Wah Lake the largest (Table I). Tuxedo Lake, because of its larger volume and smaller watershed, has the longest residence or flushing time (the time an empty lake takes to refill). A lakes residence time is important for a number of reasons, including that it determines the time dissolved pollutants are retained in it. The residence times in Table I are annual averages, but they vary through the year.

	Tuxedo Lake	Little Wee Wah Pond	Wee Wah Lake
Area of watershed	1775 acres	2230 acres	5,280 acres
Area of water body	292 acres	12 acres	54 acres
Depth (mean)	8 meters	2.5 meters	2.5 meters
Depth (max)	19 meters	4.5 meters	5 meters
Residence time	625 days	8.9 days	16.4 days

Table I Features of Tuxedo Park's lakes and water sheds (PH2009).

A little limnology

Phosphorous is an essential nutrient for photosynthesizing organisms. It is in short supply in northern lakes, so its concentration controls photosynthetic production in a lake's illuminated surface water. In summer, the warmed surface water becomes less dense than cooler deeper water, creating a stable stratification. The wind mixes the warmed surface water bringing it repeatedly in contact with the air, thereby maintaining its dissolved oxygen concentration within a mixed surface layer with uniform temperature. Organic matter, formed by phytoplankton (photosynthetic free floating cells) in the illuminated part of the surface layer, is composed of a number of elements including phosphorous. As it sinks, this organic matter is consumed by zooplankton (small aquatic animals) and microorganisms. Below the warmed mixed layer, consumption of sinking organic matter reduces oxygen and returns phosphorous to the adjacent water. Any unconsumed organic matter that reaches the bottom is buried in the sediments. Here its phosphorous combines with other elements; the resulting compounds are stable if oxygen is plentiful but if the bottom water is anoxic (dissolved oxygen, DO <1mg/liter) phosphorous is released to the deep water. Fall cooling increases surface layer density and a lake's stratification is broken.

Under ideal conditions, and this occurs in some deep lakes with undisturbed watersheds, the organic matter produced by photosynthesis in the surface mixed later is largely consumed there by zooplankton and microorganisms, so little sinks to deeper water. In this situation, phosphorous is mostly recycled in the surface waters and the deep-water is neither severely depleted in oxygen nor enriched in phosphorous. If photosynthetic production exceeds consumption in the surface layer, often caused by increased phosphorous inputs to surface waters, then organic matter will sink below the mixed layer and reach deep-water, where its decomposition reduces dissolved oxygen and increases phosphorous concentrations.

Changes of lakes water quality between 2008 and 2019

For the sake of brevity only two measures of lake water quality are used here. Secchi Disk depth (the depth at which a Secchi Disk disappears as it is lowered through the water) measures water clarity that is impaired by algal cells and sediment and total phosphorous, measured in micrograms/Liter of water, (One microgram is .000001 grams).

The surface water quality of the three lakes, as measured by clarity and total phosphorous, is little changed between 2008 and 2019 (Table II). Green algae and diatoms dominated a Tuxedo Lake spring phytoplankton bloom in 2008, however, by 2019 Cyanobacteria became dominant. The latter dominated the phytoplankton in the smaller lakes in both years.

Modeling of 2008 nutrient budgets, estimates half of Tuxedo Lake's phosphorous input came from its sediments, the rest from the watershed, while most of the phosphorous to the other lakes came from their watersheds, with only 4.2% for Little Wee Way pond and 7.2% for Wee Wah Lake coming from their sediments (PH 2009). The highest watershed phosphorous contribution, as measured in mg/acre, came from the eastern side of the lakes.

In 2008 and 2019 an anoxic layer developed below 4 meters in the smaller lakes. By Fall of 2008 anoxia developed below 12 meters in Tuxedo lake but has thickened since. By October 2020, the top of Tuxedo Lake's anoxic layer reached between 8 and 9 meters depth at NEAR station 1 and between 9 and 10 meters at NEAR station 2 (Fig. 2), substantially less than the 12m depth measured in 2008. The water intake pipe, (depth 7 to 7.7 meters), close to NEAR station 2, is now less than two meters above the Fall anoxic layer. Trout, to thrive, need temperatures below 20 degrees C and DO > 5mg/L; in July of 2008 this zone of appropriate trout habitat was 6 meters thick but by late August it had shrunk to 2 meters (PH 2009). In September of 2019, the window of trout habitability had shrunk to 1.5

meters at NEAR Station 1 and 1.3 meters at NEAR station 2 (NEAR 2019) (Fig. 2).

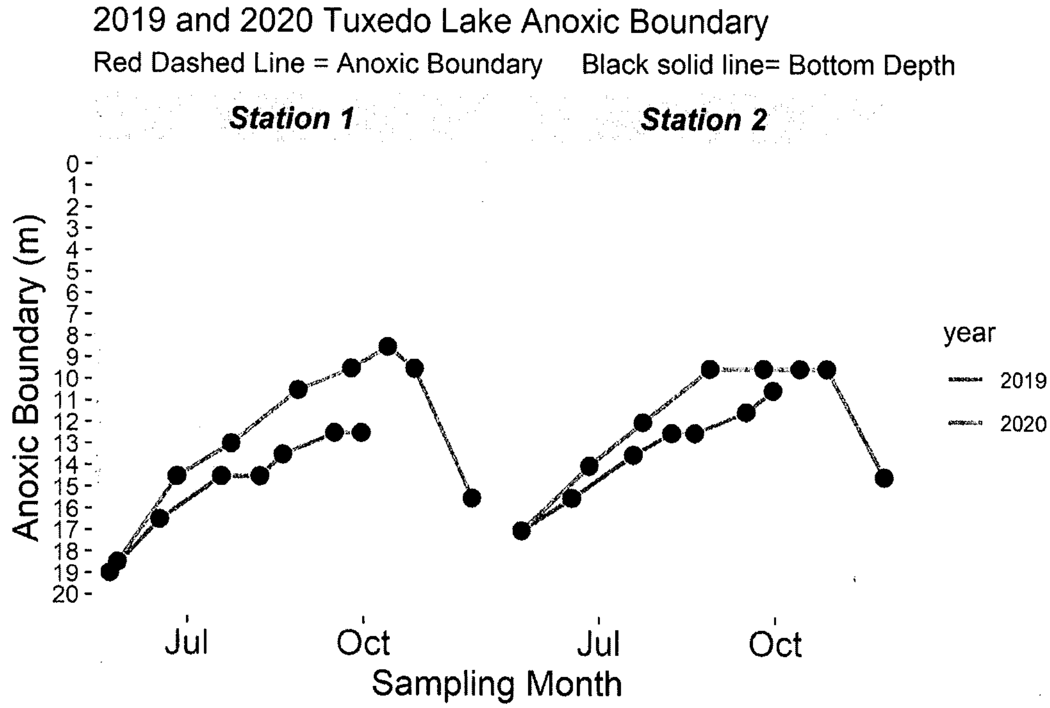

Figure 2. Depth to upper boundary of Tuxedo Lake's anoxic layer (NEAR 2020).

Because there is a phosphorous gradient in Tuxedo Lake's seasonally developing anoxic layer, care must be taken when comparing total phosphorous measurements that samples were taken at similar depths and times of year. A 15 meter sample, taken 10/1/2008 at a station with maximum depth of 17meters (PH 2009), is compared with a 15 meter sample taken 9/30/2019 at a station with the same maximum depth (NEAR 2019). The total phosphorous concentration of the 2019 sample is more than 10 times that of the 2008 sample (Table II). Phosphorous concentrations of deep and outlet samples from the other two lakes are also much higher in 2019 than 2008 (Table II).

These data indicate a deterioration in water quality between 2008 and 2019 in all three lakes, as expressed by greater total phosphorous values in their deeper waters (Table II), probably caused by excess phosphorous input over that recycled in surface waters or flushed from the lakes. The thickening anoxic zone in Tuxedo Lake exposes increasing areas of lake bottom to oxygen depleted water, enhancing the release of phosphorous from sediments. Its rising upper limit threatens the water intake pipe, for anoxic water will have unpleasant taste and odor, and reduces the window of trout habitability. The shallowing phosphorous rich water increases the risk that summer wind events will bring this water into the surface layer causing harmful algal blooms. These trends are slow so there is time to react.

Tuxedo Lake	Summer- Fall season	Water Clarity Secchi disk depth in meters	Average Total Phosphorous (micro grams/lite)
Surface	2008	3.5 - 4.65	6.5
	2019	3.0 – 4.5	8.1 (Sta. 1), 13.5(Sta. 2)
Bottom (15m)	2008 (Oct. 1)		38.0
Bottom (15m)	2019 (Sept. 30)		403.0
Outlet	2008		8.0
	2019		37
Little Wee Wah Pond			
Surface	2008	1.2 - 2.5	25
	2019	2 – 3	17.5
Bottom	2008		51
	2019		182
Outlet	2008		16
	2019		100.8
Wee Wah Lake			
Surface	2008	1.4 – 3.2	25
	2019	2 – 3	19.3
Bottom	2008		42
	2019		114..3
Outlet	2008		23
	2019		43.8

Table II Water quality measurements 2008 (PH 2009) vs. 2019 (NEAR 2020)

Village expenditures on lake management

Much work has been done on our lakes since 2008 at considerable cost (Table III). Most has focused on the lakes, assessing water quality and managing EWM, with little on watersheds. Yet the watershed is important to the long term health of our system of lakes.

Year	Cost in dollars	Year	Cost in dollars
2009	19263.00	2015	37,666.00
2010	900.00	2016	52,234.77
2011	3,270.00	2017	67,600,68
	49,551.00	2018	32,157.79
2013	50,976.00	2019	65,098.27
2014	59,860.88	2020	212,630.74

Table III Dollars spent by Village of Tuxedo Park on Lake Management since 2008.

Tuxedo Lake's longer residence time, with half its phosphorous input coming from sediments, means it will probably respond more slowly to watershed changes than the smaller lakes, with shorter residence times and phosphorous input mainly from their watersheds. The deteriorating conditions in Tuxedo lake's deep-water argues that modifications to its watershed should take priority over those to the smaller lakes.

The balance of this document focuses on Watershed modifications. Its organization follows the Nine Element Watershed Management Plan developed by the Environmental Protection Agency (EPA) and adopted by the New York State Department of Environmental Conservation (DEC). It should be considered a work in progress. An outline format is chosen to facilitate emending.

Nine Element Watershed Management Plan for Tuxedo Park

I. Identify and quantify sources of pollution in the watershed

Little is known about the sources and quantity of watershed pollutants to our lakes. The first step is to identify potential sources, then devise methods to quantify pollutant concentrations from each source. Modifications of the Village's storm water systems may be the quickest and possibly the cheapest way to reduce pollutants to our lakes.

A. **Storm water drainage system**
   The Villages storm water system of catch basins and pipes should be mapped, the outflow from pipes near the lakes sampled and pollutants measured e.g., sediments, Phosphorous, Nitrogen, Sodium Chloride.
B. **Landscaping**
   Cleared land and lawns can contribute sediments and chemical pollutants to our lakes. To reduce this landscaping guidelines for lands adjacent to our lakes and their tributary streams need to be developed.
C. **Geese**
   A goose can consume up to four pounds of vegetation a day, creating three pounds of fecal matter. Large concentrations of geese feeding on lawns marginal to our lakes can contribute to nutrient loading of the lakes. Goose droppings also contain the fecal bacteria *E. Coli* which in large amounts can cause nausea, vomiting and diarrhea. (PH 2009). Identify areas geese gather and develop ways to discourage their return.
D. **Phosphate bearing lawn fertilizers and septic systems**
   Although the Village passed a resolution banning the use of phosphorous containing lawn fertilizers in ________ (Appendix II) and they are banned in New York State but can be acquired out of state, so they remain a potential source of pollutants. Septic systems near the southern end of Tuxedo Lake are another potential source of pollutants.
E. **Roads adjacent to lakes.**

31

Salting of roads in winter can contribute sodium chloride to our lakes harming their ecology, especially from roads such as West Lake road, that runs close to Tuxedo Lake. In-lake chloride should be measured

F. **In-Lake sources**

1. **Lake sediments**

   Tuxedo Park's lakes bottom water become anoxic (<1mg/L of dissolved oxygen DO) in Summer and Fall allowing the release of a suite of dissolved nutrients into the overlying water. Phosphorus is released from its bond with Iron and ammonia via microbial decomposition of organic matter. This phosphorous is in a form that is readily available for algae and aquatic plant growth.

2. **Eurasian watermilfoil (EWM)**

   EWM and the masses of filamentous algae that cloak it, likely introduce organic matter to lake sediments in the Fall. The reduction of this infestation, in all three lakes, is important to the health of the lakes.

G. **Potential introduction of invasive species (biological pollutants)**

1. **The Tuxedo Club and Village Boat Club launch sites.**

   Both boat launch sites are continuing zones of vulnerability for the introduction of new invasive plants.

2. **Four Corners Pond via Warwick Brook**

   Two invasive species exist in Four Corners Pond, west of Wee Wah lake (Fig. 1), that are not in any of Tuxedo Park's lakes, namely Water Chestnut and Curly Leaf Pondweed. Warwick Brook, a major tributary of Wee Wah Lake, drains Four Corners pond and could carry invasive plant fragments or seeds to Wee Wah Lake.

II. Identify water quality target or goal and pollution reductions needed to achieve the goal

These goals are tentative and should be carefully considered by the Lake manager and members of the BOT. The amount of reduction to achieve goals is uncertain. A. J. can you help with this?

A. **Eliminate Cyanobacteria blooms (HAB) in all three lakes.**
B. **Stabilize deep- water Total phosphorous concentrations in all three lakes.**
C. **Stabilize or shrink the anoxic layer in Tuxedo Lake.**
D. **Reduce seasonal input of total phosphorous, from streams and storm water pipes, to all three lakes, beginning with Tuxedo Lake.**
E. **Reduce EWM infestation to a financially sustainable level in all three lakes.**

III. Identify the best management practices (BMP) that will help achieve reductions needed to meet the water quality goal/target.

A. **Storm water system**
   1. Reduce storm water flow to lakes.
      Divert storm water to: the forest, rain gardens, rain barrels or cisterns etc. Rain gardens are an effective method to absorb pollutants, both sediments and chemicals, before they reach the lakes.
   2. Map storm water intake and outflow pipes.
      Establish GPS location of storm water intake and outflow pipes.
   3. Sample effluent from storm water pipes.
   4. Analyze samples from 3 for elements recommended by Lake Manager.
   5. Determine connections between catch basins and outlet pipes.
   6. Retrofit catch basins of those parts of the system identified in 4 or design methods to reduce flow to these catch basins or both.
   7. Using maps generated in (2) determine areas drained by pipes with high pollutant loads (3).
   8. Develop ways to reduce pollutants from areas identified in 7.

B. **Landscaping**
   Engage a landscape architect to establish guidelines for lakeshore property landscaping, defining the spatial patterns, minimum width and height of vegetated borders at lakes edge etc. These characteristics should be

directly linked to and dictated by the slope of the land and the native plant composition of each vegetative border. Similar guidelines should be established for the banks of stream tributaries to the lakes.

C. **Geese**

Geese need at least 50 feet of runway to take off, are wary of areas that conceal predators and seek unobstructed views of escape routes to the safety of open water. Landscaping that limits their take-off space, provides cover for predators and obstructs their view of nearby water, such as vegetative lake borders 2 to 3 feet high, can be effective deterrents. Dogs and noise makers can temporarily scare geese from lawns. Addling or oiling their eggs to prevent hatching requires a permit and often requires interactions with mother goose.

D. **Lawn fertilizer and septic systems**

Although phosphate bearing lawn fertilizers are banned in Tuxedo Park and in New York State they may be acquired out of state. Landscapers should be notified each spring that their right to do business in Tuxedo Park is threatened if they apply such fertilizers in the Village. Septic systems should be routinely pumped.

E. **Road Salt**

Between 400 and 700 tons of salt is spread on Village roads each winter but its effect on our lakes is unknown. It may reach our lakes through the storm water drainage system or through ground water infiltration, reaching the lakes via underwater springs. If the latter, it may accumulate over the summer in Tuxedo Lake's anoxic bottom layer. Fall chloride measurements in this layer could detect such contamination. The short residence times of the smaller lakes likely flushes salt from them within weeks.

F. **In Lake Sources**

1. **Lake sediments**

Phosphorous released from lake sediments can be reduced by coating the sediments with Alum (aluminum sulfate), or some other material to reduce phosphorous release. There are some drawbacks such as toxicity (PH 2009).

2. **Biomanipulation**

(34)

The introduction of species that prey on zooplankton feeders could increase zooplankton grazing on algae. This should be considered after watershed measures to reduce phosphorous input have been explored. Grass carp could be considered to check EWM. Success stories, demonstrating invasive plant control by grass carp would be helpful.

G. Introduction of Invasive species

1. **Introduction from Tuxedo Lake Boat launch locations**

   Both the Tuxedo Club Boat house and the Village Boat Club have rules to safe guard Tuxedo Lake. These rules should be reviewed and strictly enforced.

2. **Four Corners Pond**

   The water chestnuts can be removed from this pond by volunteers. The Village should work with Sterling Forest State Park or Palisades State Park to control and possibly eliminate Curly Leafed Pond Weed from this pond. The beaver ponds downstream from Four Corners Pond should be checked for these invasive species.

IV. Describe the financial and technical assistance needed to implement the BMP's identified in III.

A. Storm water system

Funds for the following will be needed.

1. Personnel to locate and record GPS readings of storm water catch basins and outflow pipes near lakes.
2. Personnel to sample effluent from storm water outflow pipes near lakes.
3. Laboratory analyses of samples collected in (2) for elements selected by Lake Manager.

4. The Village needs the help of Orange County Soil and Water to map catch basins and outlet pipes on topographic maps this may be done at no cost to Village.
5. Engineering help inspecting and making inventories of existing catch basins, inflow pipes without catch basins and providing advice on suitable retrofits for catch basins.
6. Technical advice on ways to determine connections between catch basins and outflow pipes.
7. Engineering help in developing measures to reduce nutrient load from areas drained by catch basins.

B. Landscaping

The Village needs the advice of one or more Landscape Architects in order to; develop landscaping guidelines, aid the Architectural Review Board with landscaping plan approvals and advise Village residents about appropriate landscaping.

C. Financial incentives to property owners

Financial incentives, such as tax rebates or discounts on water bills may be effective in persuading property owners, especially those along lake shores, to implement behavioral changes to minimize their contribution of pollution to the lakes. A tiered system of incentives could be considered.

V. Describe the stakeholder outreach, explain how their input was incorporated, and include the role of stakeholders in implementing the plan.

A. Dissemination of this plan to the community when completed and approved by the Village BOT.
B. Development of guidelines for landscaping with community input.
C. Presentation by landscape architect/s.
D. Written landscaping guidelines for dissemination to the community.
E. Presentation by lake manager to community.
F. Publication of lake managers annual report to the BOT.

(36)

G. Annual report by the BOT on the state of our lakes.
H. Articles in tpfyi about lake matters
I. Signs at Village Boat Club and Tuxedo Boat Club about lake protection.

VI. Estimate a schedule to implement the BMPs identified in the plan.

Emphasis should be placed on Tuxedo Lake's storm water system of catch basins and pipes and its pollutant input, during the early years of this decade and continue lake water quality measurements as recommended by Lake Manager.

A. 2021

1. Inventory storm water catchment basins feeding water to Tuxedo Lake
2. Locate storm water outlet pipes near Tuxedo Lake
3. Sample outflow from located storm water pipes near lakes.
4. Sample tributary streams
5. Engage landscape architect
6. Enforce ban of phosphate containing lawn fertilizer.
7. Review rules controlling the launching of boats.
8. Measure chloride in Tuxedo Lakes Fall anoxic layer of all lakes

B. 2022

1. Map catch basins and storm water outflow pipes.
2. Sample streams and outflow from located storm water pipes near lakes.
3. Develop landscaping guidelines including geese deterants..
4. Determine types of catch basins to be used for retrofitting,
5. Chloride measurements of Tuxedo Lake Fall anoxic layer.

C. 2023

1. Determine connections between storm water catch basins and outlet pipes.
2. Continue to sample storm water outflow pipes and streams.
3. Budget retrofitting specific catch basins leading to Tuxedo Lake.
4. Continue to measure chloride in Tuxedo Lake's Fall anoxic layer.

D. 2024

1. Retrofit selected catch basins near Tuxedo Lake or develop other ways to mitigate pollutant input to the lake.
2. Consider Alum treatment of Tuxedo Lake sediments.

(37)

3. Consider biomanipulation in Tuxedo Lake.

E. 2025 – 2030

BMP's in these years will depend on the results of actions taken in prior years.

VII. Describe the milestones and estimated timeframes for BMP implementation.

I am perplexed by this section I don't see how it materially differs from VI.

VIII. Identify the criteria that will be used to assess water quality improvement as the plan is implemented.

A. At current lake sampling stations in all three lakes the following will help monitor changes in water quality.

1. increased water clarity
2. deep water reduction of total phosphorous and increased dissolved oxygen
3. Elimination of HABs
4. possibly others? What do you think A. J. ?

B. Reduced phosphorous concentrations in storm water pipe effluent.

IX. Describe the monitoring plan to collect water quality data that will be used to measure improvements using the criteria described in VIII.

A. The annual water quality monitoring plan currently in place by CSLAP and NEAR (NEAR 2020) is probably adequate. These include multiple seasonal measurements of surface water clarity together with total phosphorous and dissolved oxygen concentrations at multiple depths in all lakes.

B. Continued pollutant measurement from storm water drains and streams.

Acknowledgements

Appendix I OCSW study

Appendix II Ban of Phosphorous containing lawn fertilizer

(38)

Appendix III. Tree Cutting Rules

Appendix IV Rules regarding Tuxedo Lakes