Northview Pond Remediation

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Executive Summary

Northview Pond is a stormwater pond located in the Northview Neighborhood that has degraded and has had adverse effects on homeowners. The pond was developed as an alternative to a concrete drainage ditch. It was intended to improve drainage to the Big Blue River and allow sedimentation of suspended particles in runoff. Northview Pond is serving its primary purpose, however, the overgrown vegetation, fish kills, sour smells, and trash accumulation is unpleasant for homeowners and could even decrease property values. Over the past four months, the Natural Resources/Environmental Sciences Capstone Project Team has monitored the pond and conducted research to assess its current condition and provide recommendations to the Northview Homeowners Association (HOA). The team primarily focused on identifying the vegetation present in the pond, analyzing water quality parameters linked to eutrophication and aquatic life health, and delineating the watershed that drains to Northview Pond.

It was determined that the algae present is duckweed (*Lemnoideae*), which is a small vascular plant. Before the analysis was conducted, it was believed that the floating vegetation was cyanobacteria, which is a very harmful algae species to humans and aquatic species alike. The team found that the pond has excessively high input nutrient concentrations, however, concentrations are much lower at sampling locations that are not near pond inlets. This indicates that the existing pond vegetation is likely serving to effectively mitigate nutrient concentrations. Additionally, the pond receives much of its runoff from areas to the west of the Northview Neighborhood. Creative management strategies will need to be employed to significantly improve the quality of the pond and allow it to serve its primary purpose.

Conclusions

Upon completing our tasks, we arrived at the following conclusions:

1. Northview Pond is eutrophic; however, it does not harbor harmful cyanobacteria and the dominant vegetative species is serving to improve the overall quality of the water.

2. Northview Pond is fulfilling its intended function, but will degrade over time if it is not managed properly.

3. A collaborative effort is required between the city and the Northview HOA to find management solutions that improve the aesthetic value of the pond while allowing the pond to serve its intended function.

Recommendations

Drawing upon our conclusions, we recommend the following:

1. Sedimentation should be monitored closely, and the pond should be dredged or excavated once sediment has accumulated excessively.

2. To improve dissolved oxygen concentrations and prevent fish kills, nutrient loading of the pond should be managed.

3. To improve the aesthetic value of the pond, floating duckweed may be removed biologically or through mechanical processes.

Introduction

Northview Pond is a small stormwater pond located in a residential neighborhood in Manhattan, Kansas that needs management balance. It was constructed to serve as flood control, seen as aesthetically more pleasing than a stormwater drainage ditch. Currently, it is also a valued community fishing spot. In the past few years there have been growing concerns about the health of the pond. The Northview Homeowners Association (HOA) has specifically mentioned issues with algal blooms, summer fish kills, litter and trash from heavy rainfall events, as well as excessive muskrat holes. Currently, funding for additional management must be paid for by the HOA. The city does not take ownership of Northview Pond. It is annually stocked by Kansas Fish and Game at no cost, but the state department does not provide management funding.

The HOA has funded various management attempts. Each year they pay for a pond skim and litter clearing. Because the fountain aerator requirements for an impoundment of this size were too expensive, six small solar-powered aerators were installed. In the past two years they have stocked eight sterile grass carp to try to reduce algae and installed three pond cleaners. The pond cleaners are advertised as all-natural, biodegradable pond cleaners that sink to the bottom of a pond and release enzymes to combat pond scum and prevent other issues while promoting pond health. They may be mitigating the algal bloom, however, due to costly price, it would be difficult to install the necessary quantity to eliminate it. Furthermore, high turnover rates experienced by stormwater ponds may flush out any sort of chemicals or biological processes introduced to the pond.

The number one concern from the Northview Homeowners Association is the aesthetics of the pond. Their goal for this project was to understand the causes of what was originally believed to be algal blooms on the pond, and explore methods of reducing algae. However, it was discovered that the algae was misidentified. The floating vegetation is duckweed, a relatively harmless plant that absorbs nutrients and is likely serving to keep the pond water clear. These findings changed the scope of this project. Duckweed is not as harmful as algae, but it is still not visually appealing, indicating the need for mitigation strategies. Below is a picture taken at Northview Pond in October 2017 demonstrating the aesthetic state.

Figure 1: Northview Pond in October 2017

Figure 1 shows the macrophyte bloom that has taken over the pond resulting in poor aesthetics and a displeased HOA.

One of the aims of this project has been to provide the Northview Homeowners Association with solutions that minimize the duckweed growing on the pond while ensuring water quality does not suffer as a result. The overall research objectives for this study were twofold: 1) Provide the HOA with the current physical and biological condition of Northview Pond, 2) Propose beneficial management options to help improve both aesthetic and ecological quality.

Background

To implement the objectives, various mechanisms need to be understood. To assess current conditions influencing aesthetic state, the team researched eutrophication risks, site history, and watershed landscape. These findings sharpened the scope of the project and led to the selection of methodologies and future recommendations.

Eutrophication and Harmful Algal Blooms

Eutrophication is an aging process that ponds, lakes, and sometimes rivers, undergo naturally after thousands of years of nutrient loading and accumulation. However, recently, bodies of water have become eutrophic in a matter of decades primarily due to urban and agricultural runoff, sedimentation, and industrial discharge. With high concentrations of nutrients, algae and other macrophyte species grow abundantly. Over-abundant algae growth leads to oxygen depletion, high turbidity, and can lead to massive fish kills.

A common type of algae present in eutrophic ponds is cyanobacteria, or blue-green algae. When cyanobacteria take over a body of water, the phenomenon is known as a harmful algal bloom (HAB). HABs are extremely toxic for aquatic life as well as for humans and other animals.

They have been linked to many health complications including blue baby syndrome, and lead to foul odors and taste problems. HABs are not only an ecological concern from an environmentalist perspective, but can have serious economic implications when they reduce the fishing output and diminish the aesthetic value of a region.

To prevent the formation of toxic algal blooms, it is imperative that nutrient loading in rivers, ponds, and lakes is controlled. The two most abundant nutrients that lead to eutrophication are nitrogen and phosphorus. If nitrogen and phosphorus concentrations are mitigated, aquatic life can be preserved, which is not only favorable for the overall health of the ecosystem, but also poses economic advantages.

Site Description and History

Natural hydrology is typically abandoned in urban systems. Impervious surfaces like buildings and pavement decrease infiltration. The loss of infiltration capacity is mitigated by using open and closed structures that collect runoff. The resulting increased runoff speeds up the movement or residence time for stormwater. These processes set the stage for nutrient loss, rapid transport, and downstream deposition. This natural hydraulic abandonment was a major concern as the City of Manhattan expanded to the low-lying east where the Northview Neighborhood lies. The figure below shows the part of the expansion that is the area of interest for this study.

Figure 2: Manhattan Expansion Interest Area

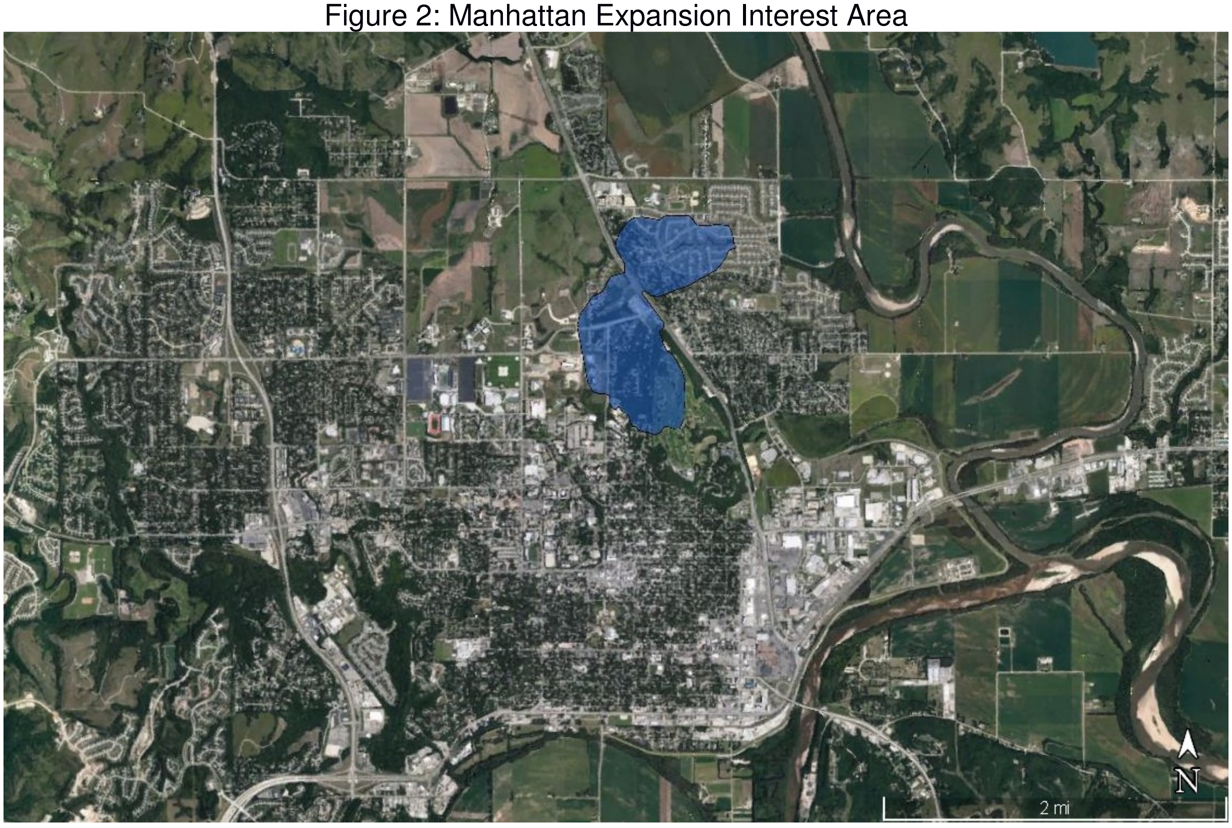

Figure 2 shows the Northview Pond watershed in blue, and its position within the City of Manhattan.

In 2005, a drainage study was conducted to investigate the hydrological hurdles involved with the development of Northview Neighborhood, a 72-acre tract in Section 6, Township 10 South, Range 8. An aerial view of Northview Neighborhood can be viewed in Figure 3 below. The drainage study was titled *Northview Drainage Study* and written to compliment a 2001 study for the City of Manhattan and BG Consultants. At the time of the study, this land was managed for agricultural production and served portions of Manhattan as a stormwater drainage route to the Big Blue River. Prior to development, the area was part of the larger Blue Hills Watershed that drained approximately 608 acres or 0.95 square miles. It should be noted that the main motive for evaluating and altering hydrology in Northview, was to decrease the resident time of surface water on its way to the Big Blue River (BG Consultants Inc., 2001).

During examination of a proposed in-line pond, it was determined that only incidental detention storage would be provided after construction. This means the pond was not designed as a reservoir or way of storing excess surface water. Key objectives for the proposal included the conveyance of stormwater from west to east, provide fill material needed to develop the flat site, and discharging water that is relatively free of suspended solids. Allowing solids to drop out of the water column and into the pond would keep the downstream concrete channel clean after discharges (Ruggles & Bohm, 2005). The study concluded that the stormwater sewer system would provide the capacity to handle its designed 100-year rainfall event.

Understanding the expected role of a stormwater pond is paramount when considering management strategies. The pond developed for Northview was built as an aesthetic apparatus to provide function to neighboring residents. At the time of the Northview Drainage Study, residents were complaining of poorly drained backwater areas that would present themselves after average rain events. A majority of the land to be developed was flat with an approximate slope of 0.5% (BG Consultants Inc., 2001). Much like the construction of an overpass, earth was to be removed from one area and used to raise the grade of another. The resulting topography would then yield a low area for water accumulation, and improved drainage from raised areas. The figure below shows an aerial view of the Northview Neighborhood development in August 2005 and July 2008.

Figure 3: Northview Development in August 2005 and July 2008

Figure 3 shows an aerial viewpoint of the Northview Neighborhood development in August 2005 (above) and July 2008 (below) (Google Earth).

Watershed Elements and Nonpoint Source Pollution

The Northview Pond Watershed contains a variety of development types. The lowest reaches are dominated by single family residential lots. Middle reaches are occupied by commercial developments at Tuttle Creek Blvd and Kimball Ave. Larger, single family, residential lots and a portion of the Manhattan country club golf course occupy most of the upper reaches. Each reach contributes sources of nutrients and sediment. The figure below shows the upper, middle, and lower reaches of the Northview Pond Watershed highlighted in red, yellow, and blue, respectively.

Figure 4: Upper, Lower, and Middle Reaches of Northview Pond Watershed

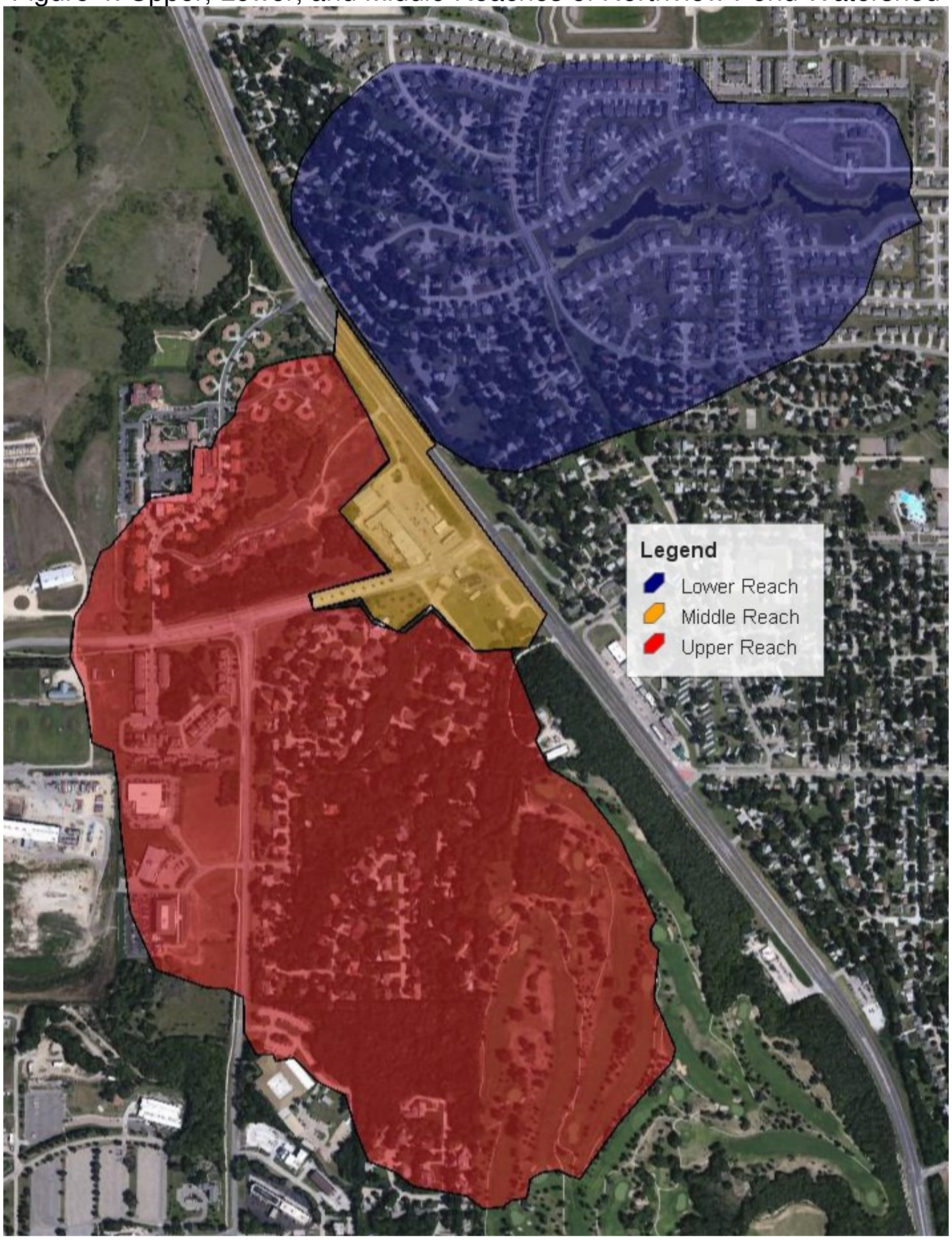

Figure 4 shows the upper, middle, and lower reaches of the Northview Pond Watershed highlighted in red, yellow, and blue, respectively.

Residential landscaping in Manhattan is dominated by irrigated turf grasses that receive applications of granular fertilizer 1 to 2 times per year. Most fertilizer applications will occur early in the growing season or wet months. Furthermore, organic matter from mulched grass clippings and leaf litter increase nutrient availability. When these nutrients become available in areas of high relief, transport downstream becomes much more likely. In the Northview Pond Watershed, the uppermost reaches experience the highest relief. The figure below shows the Northview Neighborhood development in August 2014 with a watershed layer overlaid in blue.

Figure 5: Northview Development in August 2014.

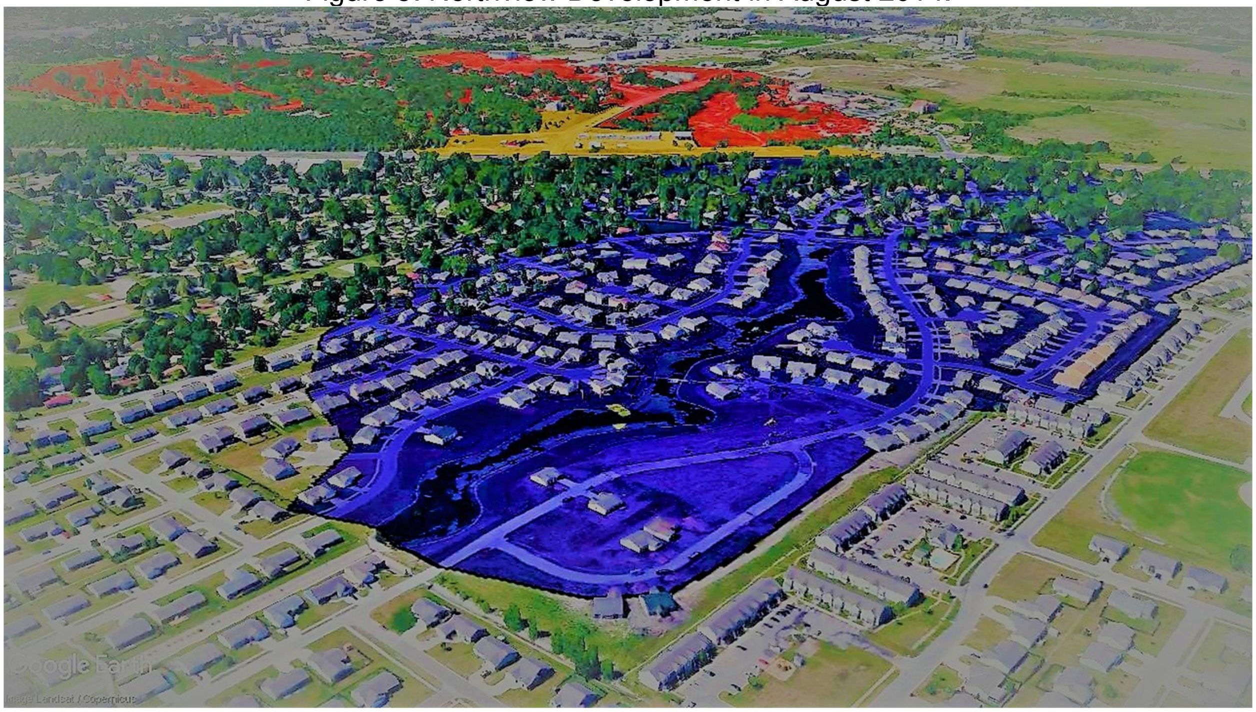

Figure 5 shows the Northview development from a viewpoint northeast of the neighborhood in August 2014 with the watershed reaches overlaid (Google Earth).

The practice of intensively managing non-native landscapes can be seen in the best light on golf courses. In the urban landscape, golf courses are the most intensively managed land use (Shuman, Smith & Bridges, 2000). Due to its dynamic characteristic in the soil, available nitrogen levels tend to decrease over time and, therefore, require regular additions to maintain sufficient, site-specific fertility levels. Phosphorus usually enhances the rate of turf grass establishment from seeds or vegetative plantings. Phosphorus is generally needed during the startup or green-up phase, but subsequent applications may be reduced. Nitrogen is applied to maintain adequate turf growth, density, and color. Application rates across golf courses vary due to climate, site conditions, turf varieties, and expectations of color and density (King & Balogh, 2010).

Methods

To assess the initial condition of the pond, the research team determined that it was imperative to assess four primary factors that affect the aesthetics of Northview Pond. The team determined algae and macrophyte species, analyzed critical water quality parameters, measured cross-sectional depths of the pond, and observed the surrounding geography. With these factors in mind, the team was able to approach management concerns from a more informed position.

Algae and Macrophyte Species Identification

Samples of algae and submerged plant species were collected in early October 2017 and then identified. For algae collection, a plankton tow was used for the water column. Plankton tows are a common limnology tool for collecting concentrated samples of free floating phytoplankton and zooplankton. This sample was taken in the lower pond near the pedestrian bridge.

Additionally, a floating filamentous algae sample was taken, and diluted with pond water in the upper pond near the overflow dam. Algae samples were labeled and taken back to the lab to be analyzed by microscope. Identification was done through various North American Algae dichotomous keys.

Plant samples were collected by removing base of stem and root from sediment substrate. Three different abundant submerged macrophyte species were observed and collected. Samples of plants were stored in water until identification.

Water Quality Analysis

To assess the initial quality of the water, the research team measured the temperature, pH, Chemical Oxygen Demand (COD), 5-day Biochemical Oxygen Demand (BOD_5), nitrogen and phosphorus concentrations at five locations in the pond. Four samples were taken from the lower basin and one from the upper. Sample #1 was taken at an inlet while the rest were not. All samples were drawn from the outer perimeter of the pond at the locations indicated in the figure below.

Figure 6: Aerial View of Northview Pond with Sampling Points

Figure 6 shows an aerial view of the Northview pond with five sampling points marked in order of sampling.

A 6-foot-long pipe fitted with elbow was used to extract the samples, which were then poured into 500 mL plastic bottles. The extraction apparatus is shown in the figure below.

Figure 7: Sampling Apparatus

Figure 7 shows the sampling mechanism used.

The temperature was measured with a thermometer at each sampling point on-site and the five sample bottles were transported to the Environmental Engineering Laboratory in the Civil Engineering Department of Kansas State University. First, pH readings were taken using a standard HACH pH meter. Next, two 300 mL BOD bottles were prepared for each sampling point, one with a dilution factor of 1:300 and the other with a dilution factor of 5:300. The samples were then acidified for the remainder of the analyses. To measure COD, 2 mL of sample from each bottle were directly added to a single HACH™ High Range COD vial. On the following day, each bottle with acidified sample was delivered to the Soils Laboratory in Throckmorton to be tested for Total Nitrogen, Nitrogen as Ammonium, Nitrogen as Nitrate, Total Phosphorus, and Orthophosphate.

Cross-sectional Depth Analysis

To evaluate potential sedimentation and channel geometry of the two ponds, the team conducted two cross-section measurements. Construction documents provided by the City of Manhattan were obtained to show designed depths and contours of both ponds. It is assumed that the ponds were built to the specifications provided. Two sites were selected to perform the analysis based on their location (above and below the concrete weir) and width. A wider span would show geomorphic patterns within the thalweg and in the shallows. Depth measurements were recorded by lowering a weighted rope to the floor of the pond from a single man kayak. Measurements were taken every 10’ in a straight, predetermined path. Another rope was stretched across this path to guide the kayak and prevent drift. Figures 8 and 9 show the cross-section sites that were measured for depth.

Figure 8: Lower Pond Cross Section Site

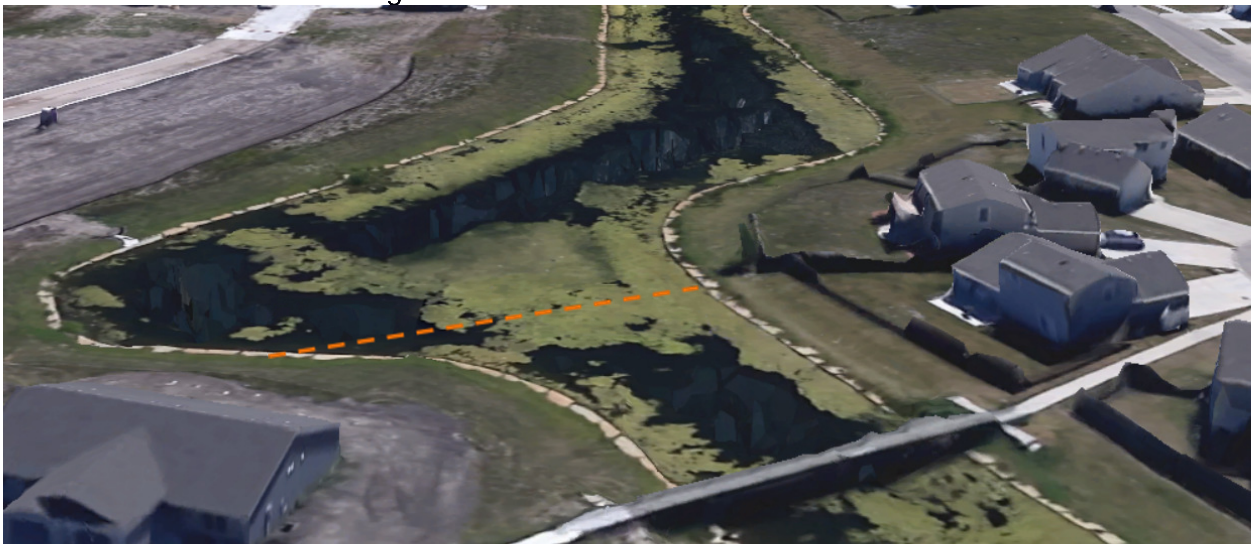

Figure 8 displays an aerial view of the lower pond cross section, which is delineated by the orange dash.

Figure 9: Upper Pond Cross Section Site

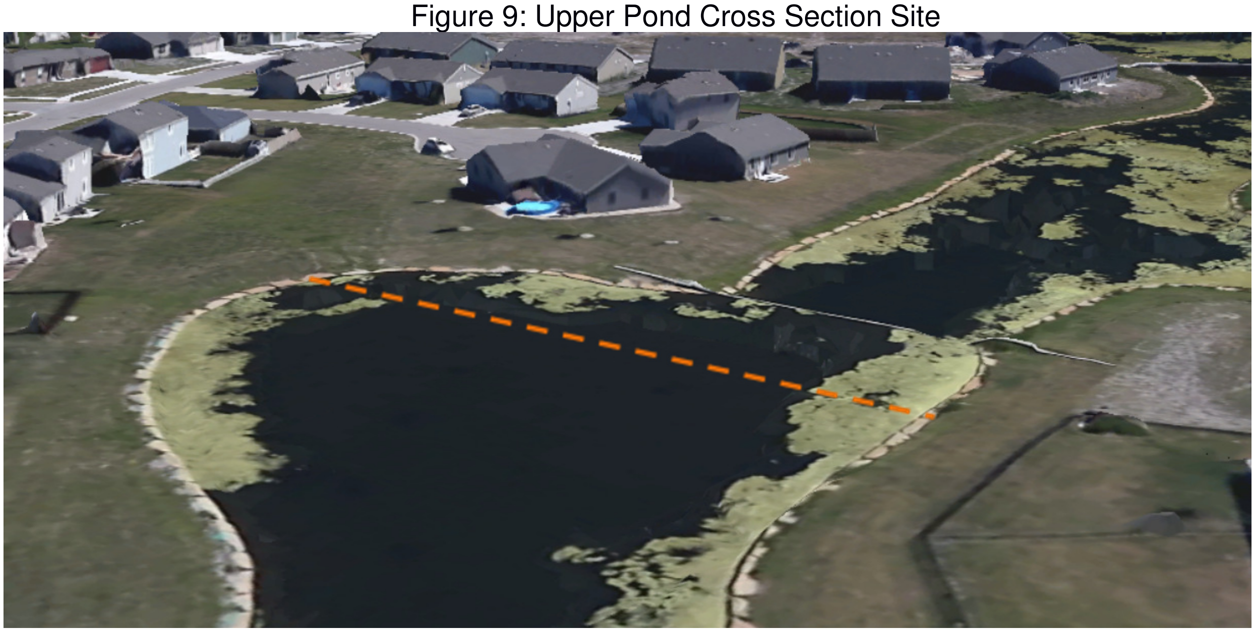

Figure 9 displays the upper pond cross section site.

Both existing and planned depths were drawn into SketchUp. This software allowed the team to analyze changes in bank slope and depth by comparing the two cross sectional drawings. An example of the software is shown below.

Figure 10: Precision Cross Section Rendering

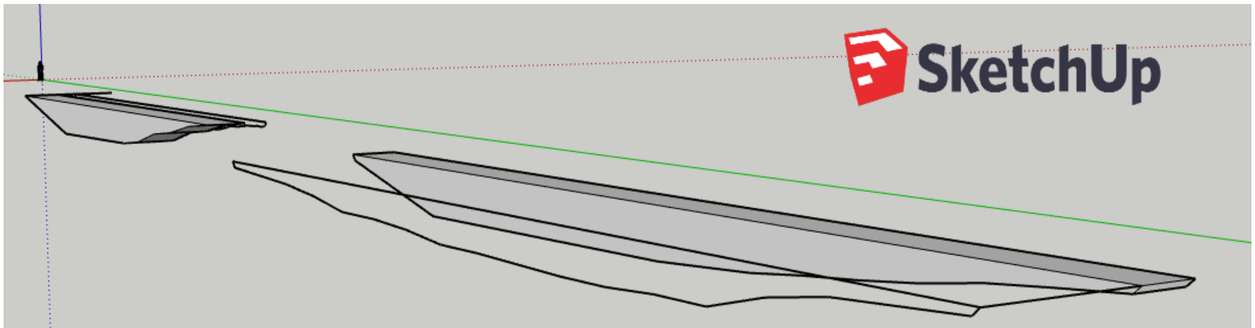

Figure 10 shows the Northview Pond cross sectional rendering process.

Geographic Mapping

Two DEM raster files were combined to display topography within the Northview Pond Watershed. The elevation data was obtained from the United States Geological Survey (USGS) and has a resolution of 1 meter. Arcgis symbology preferences were altered to display higher elevations in red, and lower elevations in green. Values were stretched across this color range to show slope. Additionally, the hillshade effect was turned on under the symbology tab to enhance the rougher terrain in the upper reaches and highlight raised roadways. Autocad files supplied by the City of Manhattan were uploaded, geo-referenced, and given their own symbologies.

Due to the large amount of alterations within the watershed, further investigation was needed to delineate. This was done by evaluating contours in the raster file, and exploring areas of the watershed on foot to ensure that the stormwater structures were properly placed on the map and receiving upstream surface flow.

Results

Most results were expected, but a few deviated significantly. These deviations dramatically shift the perception of the pond from an ecological standpoint and affect the recommendations for the Northview Homeowners Association.

Algae and Macrophyte Species Identification

Algae present were surprisingly diverse in two water samples taken. A comprehensive list, along with general characteristics of algae genera are outlined in Table 1. The most surprising discovery was that the abundant floating "algae" was duckweed (*Lemnoideae*). Duckweed is the smallest known flowering vascular plant. Also, the pond was not found to have an excessive amount of cyanobacteria in either its water column or filamentous floating masses. A high diversity of green algae species was found.

Table 1: Genera Identified in Northview Pond

Genus Found	Morphological Characteristics	Algae Group Classification

Phacus	Flagellated	Green algae
Euastrum	Amoeboid	Green algae (desmid)
Cosmarium	Amoeboid	Green algae (desmid)
Closterium	Amoeboid	Green algae (desmid)
Ceratium	Flagellated	Dinoflagellate
Rhizoclonium	Filamentous	Green algae
Anabaena	Filamentous	Cyanobacteria
Oocystis	Colonial/Spherical	Green algae
Spirogyra	Filamentous	Green algae
Ankistrodesmus	Sessile	Diatom
Melosira	Filamentous	Green algae
Microspora	Filamentous	Green algae
Sphaerocystis	Colonial/Spherical	Green algae
Gloeocystis	Colonial/Spherical	Green algae
Paramecium with Chlorella	ciliated protozoa with spherical algae	Eukaryote with ingested green algae
Actinocyclus	Sessile	Diatom

Filamentous algae were more abundant in the surface water sample than the zooplankton tow sample. This is because filamentous algae are primarily associated with submerged macrophytes and/or becomes caught around floating duckweed. Since filamentous species are immobile, this is an adaptation to prolong sinking rates. From the open water plankton tow water sample, flagellated motile species were most abundant. Only one cyanobacterial species was identified (Anabaena). Desmids (an amoeboid green algae) was the most abundant type of algae present in the water column. Some spherical, colonial genera were also found. (Oocystis, Gloeocystis, Sphaerocystis). Overall algae composition was diverse and indicated a relatively healthy ecosystem. Filamentous algae were not overly abundant, and cyanobacterial blooms were not found. For more extensive algal community understanding, species samples should be taken in height of spring and summer seasons as well.

The plant identification found three major submerged macrophytes. These plants all seemed to be voluntarily established without human introduction. Illustrations of these are shown in Figure 11 below. The most abundant plants in Northview Pond were *Ceratophyllum demersum* (Figure 11A), *Najas guadalupensis* (Figure 11B), and *Potamogeton nodosus* (Figure 11C). All are native. *Ceratophyllum* (coontail) is a hornwort, and submersed perennial herb. It is rootless and free-floating. Coontail leaves are toothed, fan-shaped and arranged in whorls on the stem. *Najas* (common water nymph, southern naiad) is an annual, fully submerged rooted plant with extensive branching and thin leaves. Very fine teeth can be found on its leaves, which are usually a dark green color. American pondweed (*Potamogeton*) has floating and submerged leaves. Its floating leaves are oval shaped with parallel vein pattern and long petioles. Its submerged leaves are less abundant, almost transparent and blade shaped.

Figure 11: Three Major Submerged Aquatic Plants of Northview Pond

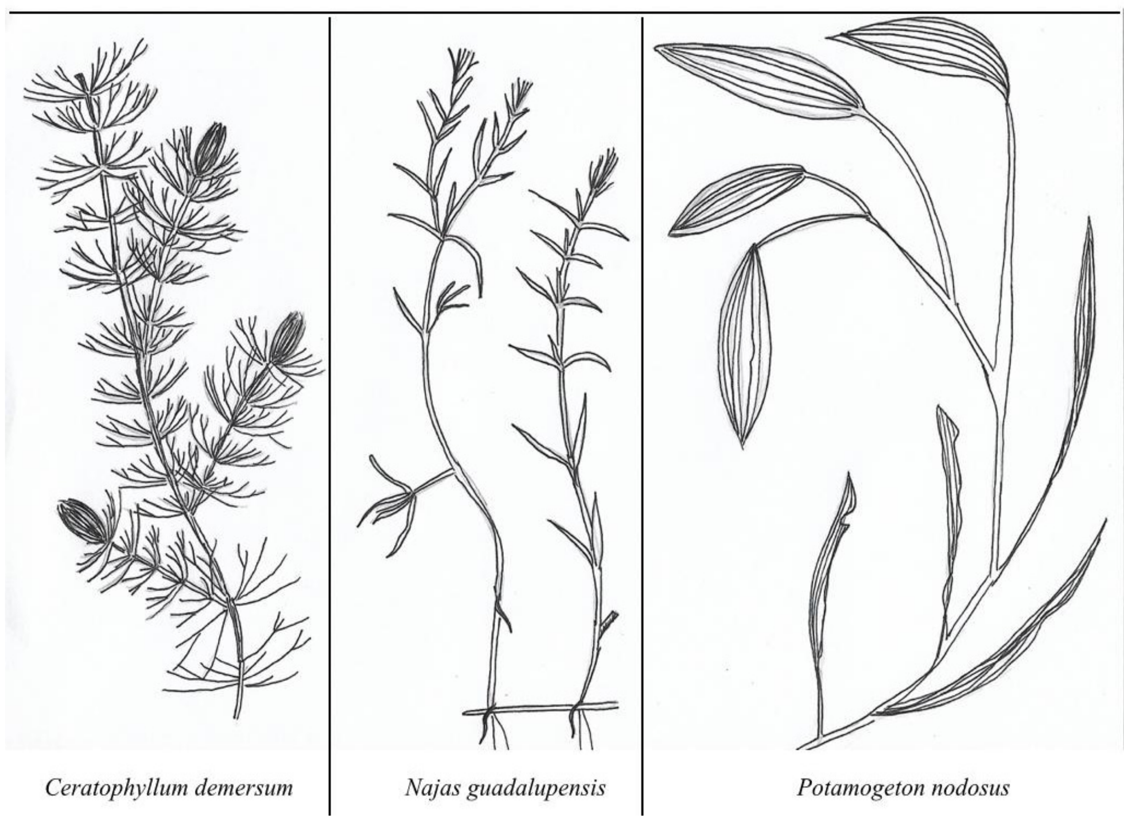

Figure 11: A) Plant profile of Certophyllum demersum, common name; Coontail. B) Plant profile of Najas gudalupensis, common name: Common Water Nymph (Southern Niad). C) Plant profile of Potamogeton nodosus, common name: American Pondweed.

Water Quality Analysis

Temperature, pH, Chemical Oxygen Demand (COD), 5-day Biochemical Oxygen Demand (BOD_5), Total Nitrogen, Total Phosphorus, Ammonia Nitrogen, Nitrate Nitrogen, and Orthophosphate were measured at the five sample points indicated previously. Each metric was selected to determine how suitable the pond is for aquatic life and monitor the nutrient concentrations present.

Excessively high or low temperatures could be a cause of fish kills and high temperatures are linked to algal blooms (Swistock, 2017). pH measures the acidity of water and is one of the most universal water quality parameters. It can portray the general quality of a water sample and can be used for a wide variety of purposes. Most fish can only survive in water with a pH between 6 and 8. In addition to water temperature and pH, the concentration of dissolved oxygen in the pond is critical for aquatic life. The maximum amount of dissolved oxygen in a pond is determined by its temperature (the higher the temperature, the less dissolved oxygen). In general, fish need above 6 mg/L of oxygen to survive and low oxygen levels are the most common cause of fish kills in ponds (Swistock, 2017). Biological decay of organic matter reduces dissolved oxygen concentrations and can be measured via BOD and COD analyses. COD measures the amount of oxygen that is consumed by organic and inorganic chemicals. BOD measures the amount of oxygen that is just consumed by the organic matter native to the sample. The temperature, pH, COD, and BOD5 results are displayed in Table 2 below.

Table 2: Temperature, pH, COD, and BOD_5 of Each Sample

Sample	Temperature (℃)	pH	COD (mg/L)	BOD_5 (mg/L)
1	23.5	8.81	94.7	-72.6
2	24.0	10.09	106	28.2
3	22.5	8.88	45.2	27
4	24.0	9.43	19.3	17.1
5	No Data	10.08	27.9	-7.2
Average	23.5	9.46	58.6	-1.5

The temperatures observed at each sampling point are relatively consistent and close to the ambient temperature during sampling. However, pH, COD, and BOD_5 values vary greatly between samples. It is presumed that these differences are partially caused by variation between sampling points. Some samples were drawn closer to inlet points than others and sample four was drawn from the upper pond while the rest were not. It is possible that a portion of variation is due to human error during laboratory analysis

The pH is basic for each sample and is likely caused by high alkalinity and the presence of algae. Alkalinity indicates the presence of hydroxide, carbonates, and bicarbonates, which are a direct result of the surrounding soil and mineral composition. The pond is lined with clay, but it is likely that exposed limestone on the edges of the pond is contributing to the high pH values. It is possible that the pH is lower at points farther away from the edges of the pond. Moreover, algae consume carbon dioxide while they photosynthesize resulting in pH values as high as 10 during the day (Northeast Georgia Regional Development Center, 2011). For most fish, the recommended pH range is between 6 and 9 and some fish species die at pH above 10 (Fondriest Environmental, Inc., 2013). According to the data gathered at the selected sampling points, the Northview Pond barely meets the maximum requirement to keep fish alive. If the pH raises much higher than 10 throughout the pond, some fish will not be able to survive .

The COD values vary much more significantly than pH. This is likely caused by variation of mixing between sampling points. Some may have been more aerated depending on their proximity to the surface and the geography of the pond at that point. It is interesting to note that the lowest COD value of 19.3 mg/L was observed in the upper pond. The expected COD value for mild untreated wastewater is approximately 250 mg/L (Kiepper, B., 2010), which is well above the average COD values and more than double the highest COD value. However, the normal COD for a natural pond is 10 mg/L and a pond with a COD above 60 mg/L requires treatment (Allen Murray Corp.). The average COD of the Northview Pond is just below 60 mg/L, which would be extremely high for a natural pond. However, considering it is a stormwater pond that receives runoff with COD values near 73 mg/L, which is typical for residential stormwater (Pritts, Strassler, & Strellec, 1999), this value is not extreme. The average COD in the Northview Pond is high compared to a natural pond, but is expected considering residential stormwater is the dominant input source.

The BOD_5 measurements gathered in this study vary greatly and have been deemed unreliable. It is likely that the cause of such large errors was the sample dilutions of 1/300 and 5/300. There was not nearly enough sample to consume the oxygen in the BOD bottles, which resulted in inaccurate readings. For the 5-day BOD test, the dissolved oxygen concentration should decrease by at least 2 mg/L after 5 days and should be no smaller than 1 mg/L for the results to be reliable. To get reasonable BOD_5 values, it is recommended that the test is repeated with larger sample concentrations of 50/300 or even 100/300.

In addition to temperature, pH, COD, and BOD_5, nutrient concentrations were also observed for each of the five samples. Nitrogen and phosphorus are the primary nutrients that contribute to the growth of algal blooms. Nitrogen can exist in many forms, both organic and inorganic. In ponds, nitrogen is typically in the form of ammonia or nitrate (Swistock, 2017). Different forms of nitrogen can be calculated from the following equations:

$$\text{Total Nitrogen} = \text{TKN} + (\text{Nitrate} + \text{Nitrite})$$
$$\text{Total Organic Nitrogen} = \text{TKN} - \text{Total Ammonia}$$
$$\text{Total Inorganic Nitrogen} = (\text{Nitrate} + \text{Nitrite}) + \text{Total Ammonia}$$
$$\text{TKN} = \text{Total Organic Nitrogen} + \text{Total Ammonia}$$

Like nitrogen, phosphorus contributes extensively to algal blooms. It is typically present in the form of phosphates, which can be classified as orthophosphates (reactive phosphates), condensed phosphates (pyro, meta, and polyphosphates) and organic phosphates.
The total amount of phosphorus (Total P) and the reactive phosphate (Ortho-P) were analyzed. Orthophosphate is of particular interest because it is a main component of agricultural and residential fertilizers. It is speculated that much of the excess nitrogen and phosphorus in Northview Pond can be attributed to fertilizer which is carried by the runoff that drains into the pond. Detecting high levels of orthophosphate would build the case for this hypothesis.The results are displayed in the table below.

Table 3: Total N, Total P, NH4-N, NO3-N, Ortho P, and TKN of Each Sample

Sample	Total N (ppm)	Total P (ppm)	NH4-N (ppm)	NO3-N (ppm)	Ortho P (ppb)	TKN
1	1.64	0.95	0.18	0.04	924	Undetectable
2	1.42	0.24	<0.01	0.02	118	Undetectable
3	1.77	0.29	<0.01	0.01	104	Undetectable
4	0.57	0.06	<0.01	0.01	22	Undetectable
5	0.92	0.05	<0.01	0.14	5	Undetectable
Average	1.26	0.32	Cannot determine	0.04	235	Undetectable

A measurable difference in nutrient concentrations can be observed between sample one and every other sample. Recall that sample one was taken at a pond inlet. The difference between nutrient concentrations at the inlet and other points in the pond is most notable for ammonia Nitrogen and orthophosphate. It can be reasonably assumed that the pond is receiving runoff with high nutrient concentrations from lawn fertilizer or other nutrient-dense material.

The total phosphorus concentration found at the inlet sample is notably large compared to the the typical value of 0.343 ppm observed for residential stormwater (Pritts, Strassler, & Strellec, 1999). At 0.95 ppm, this measured value is nearly three times greater than what is typical for a residential landscape. It is possible that the nearby golf course is contributing to the high total phosphorus concentration. Although the inlet concentration is high, the average concentration at the other four sampling points is just 0.16 ppm which is likely due to dilution in the pond and algal activity. Any detectable concentration of Total P indicates pollution from fertilizers, manure, or other nutrient-rich wastes (Swistock, 2017). Mitigating these inputs, would greatly reduce the presence of total phosphorus in the pond and would likely decrease of the abundance of algae.

Ammonia nitrogen is the pollutant that is particularly toxic for aquatic life (Pritts, Strassler, & Strellec, 1999). Although the pond is receiving ammonia nitrogen, it is completely undetectable at every sampling point that is not an inlet. It is likely that the vegetation present in the pond is contributing to the consumption of the input ammonia nitrogen and making the Northview Pond more habitable for fish species. Fortunately, ammonia nitrogen is not a concern in Northview Pond.

A nitrate nitrogen concentration of above 3 ppm indicates the presence of fertilizer, manure, or other nutrient-rich wastes (Swistock, 2017). Surprisingly, the nitrate nitrogen concentration in Northview Pond is nearly 100 times smaller than this value. The largest value of 0.14 ppm was found at sampling point 5 and is nearly ten times greater than the average of the other sampling points, which is 0.02 ppm. The cause of this significant increase is unknown. It is possible that a nearby point source is causing this spike in concentration.

A typical value for orthophosphate, or soluble phosphorus, is 143 ppb for stormwater residential areas (Pritts, Strassler, & Strellec, 1999). Excluding the inlet point, the average concentration of orthophosphate in Northview Pond is approximately 62.3 ppb. Similar to the ammonia nitrogen, it is likely that the algae present in the pond is contributing to the lower levels of orthophosphate. However, this nutrient is more dominant than ammonia nitrogen and with values as high of 118 ppb, it should be monitored closely.

Cross-Sectional Analysis

Cross-section measurements show that the pond is performing as a sediment forebay. Aggradation was observed at both sites, but more significantly on the upstream side of the concrete weir. Narrower parts of the pond seemed to have maintained depth to a greater degree. It appears that the pond has developed a shelf or shallow area within 8’ of the limestone liner. This shelf provides a well-lit growing medium for aquatic plants. Much of the sedimentation on the north side of both ponds appears to have been caused by improper soil stabilization practices during development. The figure below shows a rendering of the cross section measured in the upper pond.

Figure 12: Upper Pond Cross Section

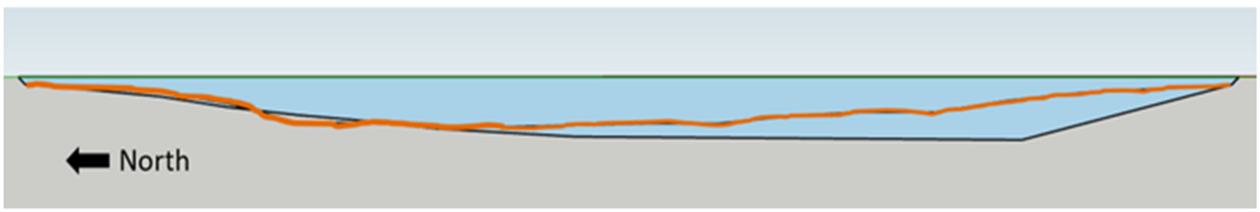

Figure 12 shows a cross sectional rendering of the designed channel in blue and current channel floor in orange. Channel banks were designed with a 4:1 slope and a max depth of 8 ft.

Northview Pond likely suffers from poor erosion control, which could be a major contributing factor to the observed sedimentation delineated above. An erosion sock has either washed in from the bank, or been discarded in the pond and is shown in Figure 13. Erosion socks are typically made from mesh cloth and filled with wood mulch. They are placed on a slope to trap sediment while allowing water to pass through. The section shown in the Figure 13 below is 8 to 10 inches in diameter and would measure over 80’ in length.

Figure 13: Poor Erosion Control

Figure 13 shows an erosion sock that sits at the bottom of Northview Pond.

Geographic Mapping

The watershed studied in this report is significantly influenced by stormwater channelization. Two major roadways move through the middle reaches and are elevated relative to the adjacent terrain. This is important to note when investigating the extent of the catchment because the sole use of a digital elevation model (DEM) is not sufficient. Stormwater is routed under these elevated surfaces that would otherwise trap or re-route the flow. Figure 14 is the combination of a 1 meter resolution, DEM paired with geo-referenced data points and lines. With a geographic information system (GIS), this spatial data can be analyzed and visualized. The point data (white circles) represent the termination of a buried stormwater pipe. Line data (black lines) show a buried channel. A hillshade effect was used to sharpen topographic features. All point and line data was provided by the City of Manhattan's Stormwater office and represent structures that carry water to the Prairie Lakes pond.

Figure 14: GIS Mapping of Prairie Lakes Watershed Elements

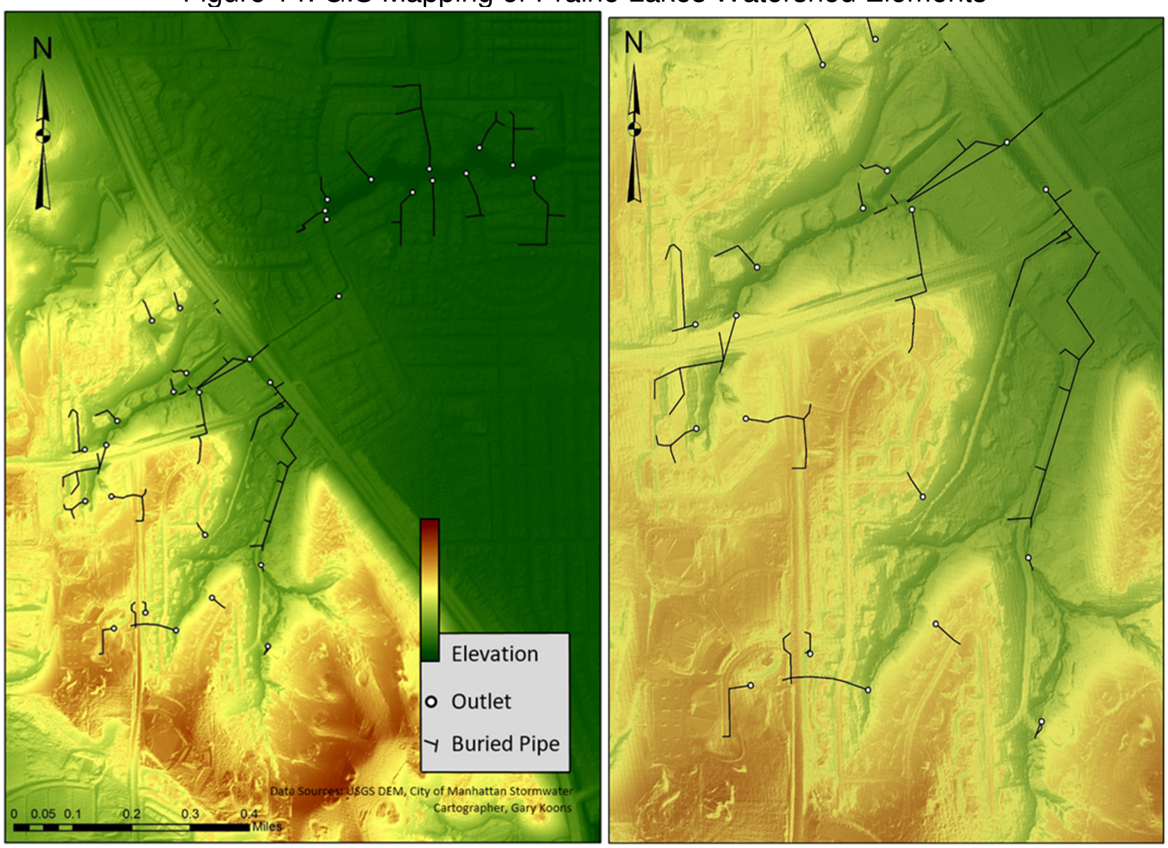

Figure 14 shows elevation and stormwater structures on the left, and a closer view of the upper and middle reaches to the right.

Google Earth software proved to be a very useful, low-tech tool for analyzing the watershed. This mapping application is limited when compared to GIS, but is easily accessible from smartphones and PCs. During the ground-truthing phase, parts of the delineation and the existence of features like stormwater structures and terrain features could be adjusted or confirmed.

Discussion

As stated previously, a few findings deviated from expectations and greatly shifted the focus of this study. It was most unexpected that the nutrient concentrations, particularly nitrogen, would be so minimal and that the vegetation present was duckweed. The pond's aesthetics still suffer, however, it is likely that the duckweed is maintaining a relatively high water quality and may prevent more harmful algal species from being introduced. A greater understanding of the implications of algal and macrophyte presence and determinants of aesthetic value is needed before appropriate management goals can be established.

The composition of submerged macrophytes and algae species reveal several characteristics of Northview Pond's ecological function. First, there must be substantial incoming nutrient supply (i.e, nitrogen and phosphorus) in the system to support a dominant macrophyte community. Secondly, due to the pond's shallow depth, light is not limiting and therefore enables extensive plant life. Macrophytes contribute substantially to nutrient uptake and water clarity in small lakes. This is through their ability to absorb excess nutrients from the water column (Monaghan et al. 2016; Peretyatko, Symoens, & Triest, 2007), oxygenate water and sediment, regenerate nutrients from sediments, and slow water flux through littoral zones (Bronmark and Weisner, 1992). Depending on density and expansion, both duckweed and submerged plants have been found to filter nutrients especially in stormwater runoff (Hu, Hansen, & Monaghan, 2017; Platt, 1993.) by trapping excessive nitrogen and detoxifying chemicals (Helfrich et al. 2009). Submerged vegetation also reduces suspension of sediment and stores nutrients (Gu et al. 2016).

The reason Northview Pond's water clarity is high is most likely due to the abundant amounts of *Ceratophyllum* and *Najas* on the benthic floor. Submerged plants in addition to nutrient absorption can suppress phytoplankton growth by increasing competition for nutrients (Gao et al. 2017). It is common for shallow stormwater ponds with high nutrient influxes, like Northview, to fluctuate between a clear water state with well-established submerged macrophyte community, or a nutrient concentrated turbid-water state with extensive phytoplankton. Numerous studies have found that submerged macrophytes, regardless of composition are crucial for maintaining a clear-water states (De Backer, Onsem, & Triest, 2010; Petyatko et al., 2007). The dense macrophyte community in Northview is even more interesting when considering small fishing ponds predominantly have poorer water clarity than non-fishing ponds. Decreased macrophyte coverage is more common in ponds with larger populations of planktivores. By eating zooplankton grazers and excreting additional nutrients into the water, planktivores indirectly harm macrophyte growth by liberating phytoplankton and epiphyton from grazing restrictions (DeBacker et al. 2010). Extensive growth of phytoplankton can light limit macrophytes by shading mechanisms, depleted oxygen, and reduced water transparency. Eutrophication, a primary water quality issue for many lakes, occurs when a submerged macrophyte dominated community transitions to a phytoplankton dominated state. (Gao et al. 2017, Han & Cui 2016, Peretyatko et al. 2007). Therefore, macrophytes can be indicators for lakes under eutrophication pressure (Han & Cui, 2016). To prevent submerged macrophyte depletion, it's critical to understand their relationship to phytoplankton growth. Peretyatko et al. (2007) discussed how phytoplankton community structure differed between submerged macrophyte ponds and floating or non-vegetation ponds. Non-vegetated ponds were dominated by chlorophytes and bloom-forming cyanobacteria. However, when submerged macrophytes were present, phytoplanktonic composition moved away from filamentous species (those associated with algae blooms), towards flagellated species (those that control their position in water column such as: cryptophytes or diatoms). From the algae found in Northview, flagellated species were more dominant than filamentous species (i.e, Anabaena, Oscillatoria, Microspora). Several blue-green algae species were present in minimal amounts. Indicating that algal blooms are being at least partially abated by macrophyte nutrient uptake.

The benefits of macrophyte ability to abate algal blooms and promote water clarity is clear. However, on the other hand, high densities of submerged and/or floating plants can cause ecological concerns. *Ceratophyllum*, *Najas* and *Potamogeton* are considered “weedy” in many landscape management respects. They are associated with recent soil erosion and fertilizer runoff events (Helfrich et al. 2009). Erosion has been prevalent in the past years due to construction on lots bordering the pond. Fertilizer and grass clippings are common causes of nutrient inputs, from adjacent backyard lawns. The abundant biomass of aquatic plants under these conditions can be detrimental in the summertime. At night, during peak growing season, extensive oxygen depletion can cause fish kills. Duckweed’s invasive character can exacerbate further ecological concern. If its growth becomes too thick, benthic plant growth could be hindered by light limitation. Management practices may be necessary in order to prevent these harmful positive feedback loops.

In addition to ecological concern, it is important to consider how duckweed (and other aquatic plant establishments) influence the aesthetic state of the pond. The homeowners bordering Northview Pond interact with it frequently, designating them as major advocates for management strategies. Therefore, it is imperative to understand their expectations and perceptions of Northview Pond’s function. However, once these public attitudes are integrated into aquatic plant management strategies, priorities can become dichotomous. As Monaghan et al (2016) describes, “The visual appeal of manicured landscapes with few ecological qualities have even been perceived as demonstrating environmental stewardship while naturalistic landscapes with valuable ecological functions have been perceived as undesirable” (pg 844). The importance of macrophytes in a pond ecosystem may diverge from the open water preferences of pond-side homeowners, seeing as the HOA have clearly expressed their discontentment with the duckweed abundance. Hopefully, if the importance of macrophytes in preventing algae blooms can be successfully explained to homeowners, attitudes towards plant presence may improve. Understanding the ecological impact of macrophytes on all levels of the trophic system is necessary to both promote aesthetic quality *and* ecological function of Northview Pond.

Recommendations

Multiple options exist to control the nutrients and, thus, vegetation that inhabit Northview Pond. To comprehensively manage the pond, it is suggested that multiple techniques are employed. Options include nutrient prevention, nutrient management within the pond, and biological and mechanical duckweed removal. Because nutrient concentrations and vegetation are so intimately linked, it is likely that addressing one aspect will affect the other. For example, if nutrients are completely removed from runoff before it discharges into the pond, the amount of duckweed floating on the surface will likely decrease dramatically and will reduce the need for duckweed removal practices. In addition, sediment build-up in Northview Pond is inevitable and should be monitored closely and removed when necessary.

Nutrient Loading Prevention

Lawn applications and runoff are very crucial to the success of the pond. Runoff from surrounding lawns contribute to excess nutrients in urban ponds. A comparison of seven different watersheds showed that only 22 percent of phosphorus and 80 percent of nitrogen's total inputs were retained on lawns (Hobbie, S). Inputs include but are not limited to fertilizer, pet waste, leaf litter, and lawn trimmings. Stormwater drain exports leading causes are fertilizer and pet waste. Fertilizer applied to lawns carry nitrogen and phosphorus into the pond. Soil samples should be collected to determine the appropriate amounts of nutrients needed to prevent excess nutrients present in runoff.

Another practice is to properly dispose of all leaf litter and lawn trimmings. Phosphorus and nitrogen runoff levels increase by around 50% in residential areas because yard waste is not disposed of properly. Another method of preventing runoff is maintaining longer grass in a 10 foot buffer zone around the pond. Longer grass has healthy root growth and better uptake of nutrients and can significantly reduce the concentration of nutrients introduced to the pond.

Nutrient Loading Management

The design and implementation of green infrastructure is a relatively new practice, and scientists still don't understand its full limitations, however, it has the potential to solve a variety of issues associated with stormwater management. Planting more trees along streams or introducing new grasses to banks can assist stream systems with increasing solid and nutrient loading. Algae and harmful bacteria need sunlight to grow. Reducing access to sunlight through green infrastructure could allow streams to function with higher nutrient loads without fear of algae or bacteria blooms (Jeznach, Hagemann, Park & Tobiason, 2017).

To manage nutrients within the pond, biological systems such as a biological filter can be implemented. A biological filter is a regeneration zone that allows the water more time to be filtered through plants and media before it continues through the watershed. A typical biological filter has a retaining wall that is at least 2 ft. high and has uniform, porous holes along the top of the wall for clear water to flow through. The filter is filled with at least 18 inches of media in order to sequester nutrients and ground plant roots. A mixture of silt, clay and limestone is typically recommended for the media because it is sturdy and good at capturing nutrients. Wetland treatment plants should then be planted at a rate of one every square foot of the filter area. A combination of wetland plants is recommended for maximum filtration. The purpose of a biological filter is to force incoming water to go through an initial step of filtration before it reaches a larger body of water.

Figure 15 shown below gives a general idea of what a biological filter system looks like. Instead of a pumping system to move water through the regeneration area, the incoming streams of water that feed into Northview Pond will serve as the mechanical system that moves water through the pond. Once water reaches a certain height, it will spill out of the filter through the holes along the top of the retaining wall – they should be at least 2" in diameter to prevent clogs – after being retained and filtered for a period of time (Lui, Engel, Flanagan, Gitau, McMillan & Chaubey, 2017).

Figure 15: Regeneration Zone

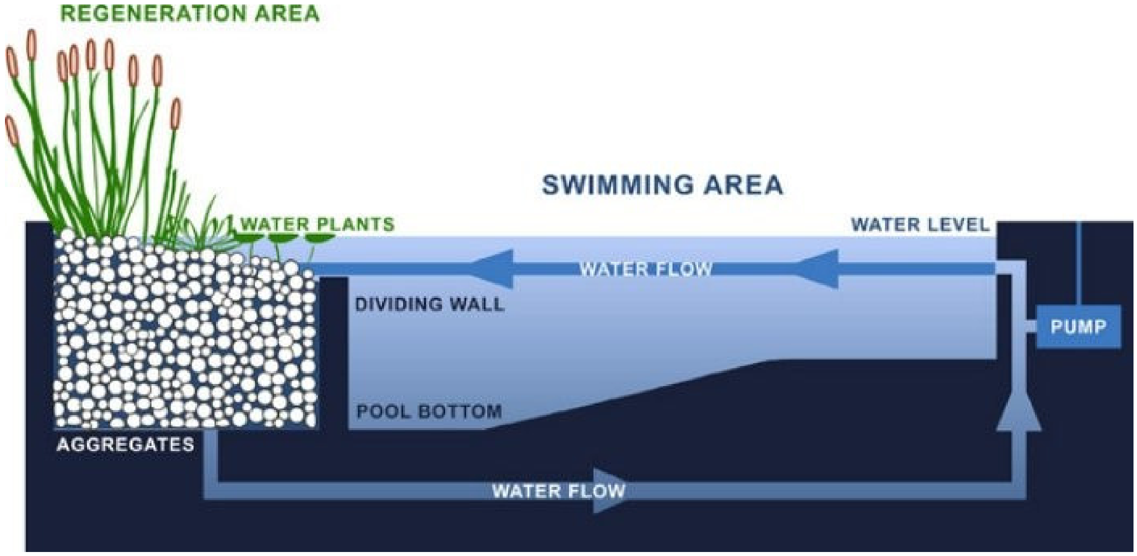

Figure 15 depicts a typical biological filtration system (Keiren, 2017).

Another method of mitigating incoming nutrients is splitting incoming streams. By splitting inlets far upstream it reduces the amount of water coming from different parts of the watershed and usually gives the water more time to flow through the inlets before reaching the bigger body of water. Splitting inlets coupled with increasing the plant life along these inlets will improve the quality of the water before it even reaches Northview Pond.

If splitting inlets proves to be difficult, another effective stormwater control measure is reducing erosion of stream and river banks. Enlarging stream channels or lining banks with concrete or plastic allow for peak flow to occur through rivers and streams without detrimental erosion. Basins have also proven to be helpful when placed upstream of rivers. The basins can retain water for longer periods of time so that rivers don’t see drastic fluxes in water volume during droughts or rain events (Hopkins, Loperfido, Craig, Noe & Hogan, 2017).

When the water is in Northview Pond, it is much harder to trap nutrients. Nutrients may collect along certain areas where the water does not flow through as much and may cause algae blooms that can spread rapidly to other areas of the pond. Pumps can be installed at the bottom of areas of high nutrient concentration, or mobile pumps can be purchased that can be inserted manually into areas of nutrient collection to pump out these nutrients periodically. Installing a permanent pump could be expensive, but it would be easier than having to manually remove nutrients at regular times during the year. Nutrients are typically used for farming and could be sold to local farmers to earn back some money for this equipment.

Biological Duckweed Removal

Fish are very beneficial to ponds by keeping a balance; they help reduce nutrient runoff, eat insects, and even control dead or unwanted plants. However, stormwater ponds are not to be maintained in the same manner as the average fishing pond. Not all fish are able to thrive in the same environment. The best combination of fish for a stormwater pond are bream (bluegill and sunfish) or panfish (bass, grass carp,tilapia). The panfish will control insects as well as be suitable prey for bass. The bream species of fish should be stocked as 500 fish per acre to maintain an equal balance. Bass should only be stocked at 50 fish per acre or a 10:1 ratio to the bream fish. Bass have a very broad diet, which will help filter nutrients and keep the balance of bream fish. Lastly, grass carp should be stocked at 20 fish per acre with heavy vegetation problems. Grass carp will feed on the vegetation, will prevent the dead vegetation from decaying, and also help filter excess nutrients in the pond. Blue and Nile tilapia are very beneficial to stormwater ponds, however, need to be stocked annually at 200-400 fish per acre because they have a hard time surviving in cold weather (Clemson 2017). Tilapia will control weeds, feed bass, and help control surface vegetation (duckweed/watermeal) and submerged plants. Catfish and crappie are commonly stocked in stormwater ponds, but will compete with the bass and deplete the prey fish. They are top predators and will cause an unbalanced ecosystem. Fish harvesting is necessary to prevent overpopulation (Clemson, 2017).

Mechanical Duckweed Removal

Mechanical removal of floating duckweed could be another possible management tool for Northview. It would help improve aesthetic value, while simultaneously avoiding the risk of possible eutrophication or loss of water clarity. If this route is considered, efforts should be concentrated during summer season, when duckweed production is highest. This is also when the risk of oxygen depletion and shading out rooted aquatic plants is greatest. (Limbi, 2009). Removing duckweed then would also reduce dead organic matter accumulating at the sediment surface. Additionally, mechanical removal avoids expensive chemical and herbicidal treatments. It also ensures unharmed submerged plant growth. One of these common manual practices is the use of a pond skimmer to clean surface water. Figure 15 depicts a common duckweed tool used for smaller impoundments; the *Parachute Skimmer*.

Figure 16: Parachute Skimmer

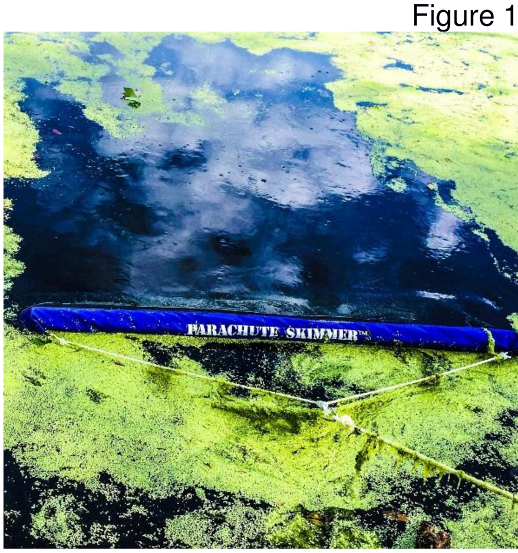

Figure 16: The Parachute Skimmer™ is meant to skim the surface of a water body or pool (*The Parachute Skimmer*, 2015)

Manually dragging the skimmer's five-foot-wide head across the pond's surface gathers and catches floating algae, dead leaves, and duckweed into its net. Various sizes are available depending on pond size. This would be a relatively cheap investment, with retail prices at maximum of $150 (Solitude Lake Management, 2010). However, it does require repetitive manual labor since during summer seasons duckweed can proliferate again within a few weeks, if nutrient sources are still available (Lembi, 2009). Net hole size would also be important to consider, since some duckweed is very small, and may risk slipping with the net. There are numerous ways to construct collection nets or floating filtration systems to skim pond surfaces with simple materials as well.

Another less labor-intensive option would be to invest in a surface skimmer pump. These are usually two-part systems. The first part is a floating collection unit, which draws in floating surface debris (e.g, duckweed, dead leaves). Then a pump system sucks in this water through a house to the land unit. This then filters out the debris, replacing water back into the pond. Mechanical units like this can be moved to different areas of the pond edge, and able to clear a couple acres of surface water in a few hours ("Proskim, surface skimmer" 2017). Though a more expensive initial investment, this mechanism could reliably keep duckweed density at a more manageable level. Additionally, it would disturb the water surface. Duckweed prefers nutrient rich, stagnant waters, so pumping may add an aeration benefit as well (Limbi, 2009).

Sedimentation Control

Northview Pond was developed primarily to keeping downstream areas clean. While it is technically doing its job, the pond itself still suffers from water quality issues and has accumulated large amounts of sediment. The size of the watershed coupled with the high relief area in the upper reach is largely contributing to the sedimentation in Northview Pond. Particles accumulate in runoff and are not able to drop out of the water column until it reaches the pond. Ultimately, the long-term solution to sedimentation is to dredge Northview Pond. This process can be quite complicated and expensive, so in order to prolong the necessity of dredging, it is critical that the rate of sedimentation is reduced. This means more comprehensive erosion control and potentially re-routing areas that largely contribute to sedimentation. It is recommended that cross-sectional depths are monitored to determine the rate of sedimentation and plan for necessary dredging.

Conclusion

The quality of Northview Pond determined by algae and macrophyte identification and water quality analysis was much better than was expected at the beginning of the study. Nutrient levels are higher than typical values for a natural pond, but do not exceed concentrations commonly observed in stormwater ponds. The floating vegetation on the surface of the pond is not cyanobacteria, but rather duckweed, a small flowering vascular plant. Although perceived as an eyesore, it is likely that the duckweed is absorbing a significant amount of nutrients that would otherwise deem the pond entirely uninhabitable for fish. It is likely that the pond is receiving large amounts of sediment from the middle and upper reaches of the Northview Watershed. Since the impoundment was implemented in 2008, sedimentation has accumulated notably. Sediment will continue to accumulate as the pond serves its chief function. Unless management practices are successfully employed, the pond will continue to degrade until it is no longer an asset to the Northview Neighborhood or the City of Manhattan as a whole.

To improve the understanding of Northview Pond, ongoing analysis would greatly benefit the residents. The reproduction of this analysis on a seasonal or annual basis would allow homeowners to engage in adaptive management by deploying a management strategy, evaluating and recording its effectiveness, then adjusting.

Additional research of the macroinvertebrate community of Northview Pond is suggested. The diversity and density of these phytoplankton grazers play a role in determining overall health and function of the pond. If macroinvertebrate (i.e, copepods, daphnia, snails, rotifers) populations are low, this could mean the fish population is too high, or there are not enough piscivores to balance out planktivorous fish species. This also could explain the higher level of algae in the pond during summer time, since macroinvertebrates are major grazers of phytoplankton. Further biological community surveys like these may be needed to understand Northview Pond's function at an ecosystem level.

In addition, sedimentation must be managed closely. This can be done via periodic cross-sectional depth measurements that will help indicate the rate of sedimentation and establish a dredging or excavation period for the pond. Because of the intended purpose of the pond as a sedimentation zone for runoff, dredging is inevitable and should be included in the long-term management plan.

Northview Pond must be closely managed in order to keep this problem from getting worse. Each area that surrounds the pond is responsible for contributing sediment, nutrients, and other damaging substances to the pond. Retention pond design factors such as depth and macrophyte presence can improve the function of the impoundment, however, they cannot accommodate for excessive concentrations of nutrients or sediment loading. To truly improve the health and consequently, the appearance of Northview Pond, each area in the watershed must also work to decrease harmful outputs that may be present in runoff. If both angles are addressed, Northview Pond has the potential to be maintained for many years. It will continue to not only improve the quality of influent entering the Big Blue River, but serve as an asset to the Northview Neighborhood that residents can enjoy for years to come.

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