WATER QUALITY ANALYSIS REPORT – CITY PARK LAKE

PROPERTY NAME: City of Westminster, City Park Lake
SAMPLING DATE: June 21st and 24th, 2019
REPORT DATE: DRAFT July 2, 2019, Revised July 10th, 2019
SUBMITTED TO: City of Westminster
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INTRODUCTION

Following a fish kill observed in City Park Lake on June 20th, SOLitude Lake Management staff biologists completed site inspections to investigate on June 21st. All species and sizes of fish were affected including: Grass carp (White Amur), Common Carp, Catfish, Bluegill, Black Crappie and Largemouth Bass. Prior to the fish kill, the lake had a mild planktonic algae bloom but was considered to be in fair-good condition. During the week, usual park operations were taking place based on scheduled maintenance and the lake was filled. The weather included few cloudy and cooler days followed by a significant rain event in a very short period of time the evening of Wednesday June 19th.

During the site inspections, biologists collected field measurements and water quality samples for laboratory analysis in order to see if the cause of the fish kill could be indicated. On June 21st, field measurements for dissolved oxygen, temperature, and pH were collected around the entire shoreline of the lake from the edge to 6 feet away from shore using a YSI multi-parameter meter. On June 24th, the water samples and measurements were collected near the center of the lake and the same meter was used to read dissolved oxygen, temperature, pH and conductivity.

The results are listed in the sections below, the tables indicate the results and reference water quality standards for each parameter, if applicable. Below are descriptions of each parameter and how they relate to the ecology of the waterbody. These water quality parameters are essential to document the condition of a waterbody and design custom treatment prescriptions to achieve desired management objectives.

WATER QUALITY ANALYSIS

Dissolved Oxygen – Dissolved oxygen (DO) is the amount of oxygen gas dissolved in the water column. Small amounts of oxygen enter the water column by direct diffusion at the air/water interface. However, the primary source of oxygen in a lake or pond is production during photosynthesis by aquatic plants and algae. Lakes and ponds impacted by heavy sediment loads may experience low DO levels since the increased turbidity (cloudiness) caused by suspended clay and soil particles can restrict light penetration and limit photosynthesis. The breakdown of organic matter (i.e., aquatic plants, leaf litter, manure, fish waste) also consumes large amounts of oxygen from the water column. Fish require oxygen for respiration, and become stressed at levels less than 5 mg/L. Colder water is physically able to hold a greater concentration of oxygen then warmer water, and waterbodies may become naturally stressed with low dissolved oxygen levels during the warmer months.

<2 mg/L likely toxicity with sufficient exposure duration; <5 stressful to many aquatic organisms; ≥5 able to support most fish and invertebrates

Chemical Oxygen Demand – Chemical Oxygen Demand (COD) is the measure of all organic and inorganic compounds that can be oxidized in the water. The higher the value the more oxygen is required to break down or oxidize these compounds or pollutants. It is difficult to determine the cause of a COD since many compounds and chemicals have some level of COD.

Biological Oxygen Demand – Biological Oxygen Demand (BOD) is the amount of oxygen required by bacteria to break down or decompose organic compounds in the water. This is not an exact amount but an indication of organic “pollution” and activity of aerobic microbes.

Both COD and BOD are expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of water.

Temperature – Water temperature affects the dissolved oxygen concentration of the water, the rate of photosynthesis by aquatic plants, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, and diseases. All aquatic organisms are dependent on certain temperature ranges for optimal health. If temperatures are outside of this optimal range for a prolonged period of time, the organisms become stressed and can die. Water temperature generally increases with high suspended sediment readings because the particles absorb heat, which reduces dissolved oxygen levels. Since warmer water is able to hold less oxygen than colder water, lakes and ponds may become naturally stressed with low dissolved oxygen levels during the warmer months.

Nutrients – Nutrients are essential for plant growth, but periodic over enrichment can lead to the excess growth of algae and aquatic plants and can alter the composition and species diversity of the aquatic community. Nitrogen and phosphorus are the elements most likely to drive plant growth, although phosphorus is generally the limiting nutrient in freshwater bodies.

Phosphorus – Phosphorus can be found in several forms in freshwater, but the biologically available form for nuisance plant growth is soluble, inorganic orthophosphate, or free reactive phosphorus (FRP). Organic phosphates quickly bind to soil particles and plant roots, and consequently, much of the phosphorus in aquatic systems is bound and moves through the system as sediment particles. This organic form of phosphorus is considered to be biologically unavailable. However, under anoxic (zero oxygen) conditions, bound phosphorus can be released from bottom sediments, and the concentration of biologically available orthophosphate can increase dramatically.

The erosion of soil particles from steep slopes, disturbed ground, and streambeds is the primary source of phosphorus in aquatic systems. Surface runoff containing orthophosphates from fertilizers and decaying organic matter will also contribute to biologically available phosphorus enrichment.

> **Total Phosphorus (TP)** is the measure of all phosphorus in a sample as measured by persulfate digestion and includes: inorganic, oxidizable organic and polyphosphates. This includes what is readily available, potential to become available and stable forms.
> *<12 µg/L oligotrophic; 12-24 µg/L mesotrophic; 25-96 µg/L eutrophic; >96 µg/L hypereutrophic*
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> **Free Reactive Phosphorus (FRP)** is the measure of inorganic dissolved reactive phosphorus (PO_4^{-3}, HPO_4^{-2}, etc.). This form is readily available in the water column for algae and nuisance aquatic plant growth.

Nitrogen - Nitrogen can exist in organic and inorganic, particulate and soluble forms. The soluble, inorganic forms (ammonium, nitrite, and nitrate) are the most available for plant growth. Particulate and dissolved organic forms of nitrogen are not immediately available for plant growth, but they can be converted to ammonium by bacteria and fungi and can be oxidized to form nitrites then nitrates. Surface runoff can contain nitrogen in various forms. Inorganic nitrogen from fertilizers and organic nitrogen from animal waste and poorly functioning septic systems are examples.

> **Total Nitrogen –** Total nitrogen is the quantity of all of nitrogen in the water and is calculated by adding the measured forms of organic nitrogen, oxidized nitrogen and ammonia. Nitrogen is an essential nutrient that can enhance growth of algae.
>
> **Nitrites and Nitrates** Nitrites and nitrates are the sum of total oxidized nitrogen, often readily free for algae uptake.
> *<1 mg/L typical freshwater; 1-10 potentially harmful; >10 possible toxicity, above many regulated guidelines*

Ammonia- Ammonia is created as fish excrete waste from food or during large algae die-offs. It can be toxic to fish and interferes with metabolic processes at low levels. In healthy ponds and lakes, ammonia is cycled into other nitrogen forms by bacteria.
0 mg/L ideal, 0.1-0.6mg/L potentially harmful under stressful conditions, ≥0.6 mg/L toxic for more than short periods of time

Nitrogen/Phosphorus Ratio -The ratio of total nitrogen to total phosphorus in a waterbody provides insight into nutrient limitation in the waterbody. Since many species of harmful cyanobacteria (blue-green algae) have the ability to fix nitrogen, they have a competitive advantage over other algae in phosphorus-rich environments when nitrogen is limited and can become dominant over the more beneficial green algae species. Maintaining an N/P ratio greater than 16:1 molar or 7:1 by weight will favor green algae and discourage blue-green algae.

Chlorophyll α - Chlorophyll is the green pigment in plants that allows them to photosynthesize. The measurement of chlorophyll provides an indirect indication of the quantity of photosynthesizing plants found in the water column, such as algae and phytoplankton. More specifically, chlorophyll *a* is a measurement of the portion of the pigment that was still actively respiring and photosynthesizing at the time of sampling and does not include dead biomass.

0-2.6 µg/L oligotrophic; 2.7-20 µg/L mesotrophic; 21-56 µg/L eutrophic; >56 µg/L hypereutrophic

Conductivity – Conductivity is the ability of water to conduct an electrical current. Conductivity increases when more dissolved inorganic solids (positive and negative ions) are present. High sediment loads do not generally increase conductivity readings since sediment particles are generally considered to be suspended rather than dissolved because of their larger size (greater than 2 microns). The geology of the area around the waterbody is the primary factor affecting conductivity, and the readings for a waterbody will generally be within a relatively constant range. Once baseline data for a waterbody has been determined, periodic conductivity readings can be useful to identify potential problems that may need future investigation.

<50 uS/cm relatively low concentration may not provide sufficient dissolved ions for ecosystem health; 50-1500 typical freshwaters; >1500 may be stressful to some freshwater organisms, though not uncommon in many areas

pH – The concentration of acids and bases in the water determines its pH. A low pH (less than 7) is considered acidic, while a high pH (greater than 7) is basic. A pH of 7 is considered neutral. Most aquatic organisms survive best in waters with a pH between 6.8 and 8.2.

<6 notably acidic   6 – 9 standard for typical freshwaters   >9 notably basic

0 1 2 3 4 5 6 7 8 10 11 12 13 14

9

Alkalinity – The alkalinity of a waterbody is a measure of the acid-neutralizing or "buffering" capacity of the water. Waterbodies with higher alkalinity are resistant to broad swings in pH, which can be stressful for aquatic organisms. Waters with lower levels are more susceptible to pH shifts. Alkalinity is influenced by bicarbonates, and is reported as the concentration of calcium carbonate ($CaCO_3$) in the water.

≤50 mg/L as $CaCO_3$ low buffered; 51-100 moderately buffered; 101-200 buffered; >200 high buffered

Hardness – Hardness is a measurement of calcium and magnesium ions in the waterbody and can be important for aquatic organisms that obtain their calcium directly from the water.

0-60 mg/L as $CaCO_3$ soft; 61-120 moderately hard; 121-180 hard; >181 very hard

Turbidity – Turbidity is a measurement of water clarity. Suspended particulates in the water such as algae and plankton, detritus, and soil particles are the primary constituents influencing turbidity. High turbidity can have both detrimental and positive effects on aquatic ecosystems depending on the suspended particles. Algae and plankton in moderation serve as a great source of food for aquatic life while suspended soil particles and detritus materials can clog fish gills and impair respiration, smother spawning areas, negatively affect egg and larval development, and reduce growth rates in fish. Since high turbidity does attenuate light, photosynthesis and the related production of dissolved oxygen may be dangerously reduced. Suspended particles also play a role in transporting phosphates and other compounds, including toxic substances.

Suspended solids usually settle out of standing water over time. However, clay particles can remain in suspension because of the negative electrical charges associated with them. Therefore, persistent turbidity is generally due to the presence of clay particles in the water column.

<4 NTU is clear to the naked eye; <10 NTU drinking water standard and typical trout waters; 10-50 NTU moderate; >50 NTU potential impact to aquatic life

RESULTS

The field measurements on June 21st found dissolved oxygen (DO) concentrations ranging from 1.25 to 5.97 mg/L around the shoreline. The highest levels were on the south and west side of the lake and the lowest were to the north and northeast. DO levels below 5mg/L can be stressful and below 2mg/L is likely lethal to fish. The pH ranged from 9.07 to 9.2.

On June 24^{th,} the dissolved oxygen was above 7 mg/L near the surface and decreased after 1 meter to below 3mg/L at 2 meters below the surface. The pH values were 8.91 near the bottom to 9.24. There was also a difference of 1.5 degrees F between 1 and 2 meters indicating some thermal stratification.

The laboratory water quality analysis showed hyper-eutrophic conditions which is indictive of low transparency of the water, high chlorophyll-a (algae) and very high levels of phosphorus. In addition, the conductivity and hardness were much higher than typical freshwater ponds or lakes indicating high dissolved solids in the water. The laboratory pH was slightly lower than the field measurements but still above the ideal range. The laboratory DO was higher than the field measurements but field readings are always more accurate due to changes than can take place in transport. Table 1. shows the results of the laboratory water quality analysis and Table 2. shows the dissolved oxygen and temperature profile collected on 6/24/19.

Table 1: Water Quality City Park Lake, 6/24/19

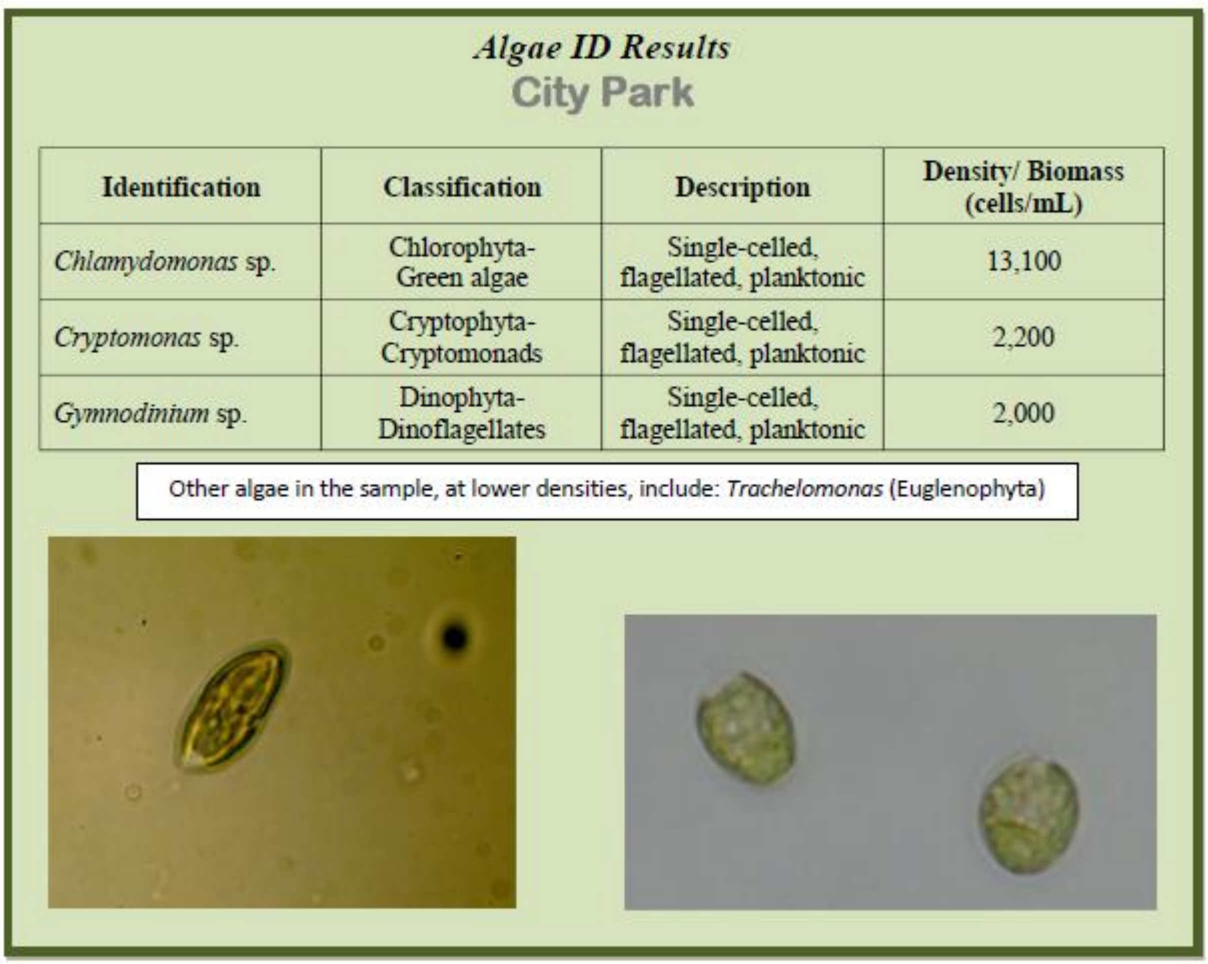
Date	**6/24/19**	**Optimal**	**Description**
Parameter		n/a	
Total Phosphorus (µg/L)	743.8	<25	Very High amount: Hypereutrophic
Free Reactive Phosphorus (µg/L)	362	<25	Very High
Conductivity (us/cm)	1,544	>50	Higher than typical fresh water
pH	8.5	6.8-8.2	High
Alkalinity (mg/L)	171	>20	High buffered
Hardness (mg/L as $CaCO_3$)	303.2	>30	Very hard
Turbidity (NTU)	4.7	<10	Low
Dissolved Oxygen (mg/L)	7.8*	>5.0	Acceptable for fish, *see field measurements
Nitrates (mg/L)	<0.02	<5.0	Low
Nitrites (mg/L)	<0.02	<0.25	Low
Total Nitrogen (mg/L)	2.3	<1.0	Moderate
Chlorophyll *a* (µg/L)	190.5	<20	High
Total Kjeldahl Nitrogen (mg/L)	2.1	<5	Acceptable
Total Nitrate & Nitrite (mg/L)	<0.02	<5	Low
Ammonia (mg/L)	0.56	<0.1	High
Biological Oxygen Demand (BOD)	ND	-	Normal
Chemical Oxygen Demand (COD)	76	<40	Elevated

Table 2: Temperature and dissolved oxygen profile. June 24th, 2019.

Water Depth (meters)	Water Depth (Feet)	Temperature (C)	Temperature (F)	Dissolved Oxygen (mg/l)
0.25	0.8	21.4	70.5	7.64
0.5	1.6	21.0	69.7	8.75
1.0	3.3	19.5	67.1	5.66
2.0	6.6	18.6	65.6	2.71
3.0	9.8	18.5	65.3	2.59
3.7	12.1	18.4	65.1	2.11

At the time the sample was collected, City Park Lake was dominated by Chlorophyta or flagellate green algae species. However, since changes in algal dynamics can play a role in low dissolved oxygen related fish kills, it is possible that prior to the fish kill, other species may have been present. Figure 1. Illustrates the species found and some pictures of the samples.

Figure 1. Algae ID June 24, 2019



Algae ID Results

City Park

Identification	Classification	Description	Density/ Biomass (cells/mL)
Chlamydomonas sp.	Chlorophyta- Green algae	Single-celled, flagellated, planktonic	13,100
Cryptomonas sp.	Cryptophyta- Cryptomonads	Single-celled, flagellated, planktonic	2,200
Gymnodinium sp.	Dinophyta- Dinoflagellates	Single-celled, flagellated, planktonic	2,000

Other algae in the sample, at lower densities, include: *Trachelomonas* (Euglenophyta)

CONCLUSIONS

The water sample and field measurements collected indicate that likely the fish kill was due to low oxygen concentrations in the water, but the cause is not known. The water sample was very high in nutrients, specifically phosphorus, which is likely due to the contributions from the water source, watershed as well as internal loading from within the lake. These high nutrient levels drive the excessive phytoplankton or algae growth in the lake. As these organisms grow and photosynthesize, they increase oxygen concentrations in the water during the day and remove it at night during respiration. Sometimes, if there are few cloudy days, these populations can crash causing significant drop in the oxygen concentrations as they die due to lack of sunlight.

On 6/24/19, the dissolved oxygen levels of the water had increased to safe levels for fish at or near the surface but were still lower than ideal below 2 meters. There was also a noticeable temperature difference between 1 and 2 meters, this indicates thermal stratification. These values indicate the possibility either biological activity due to high nutrients or an external pollutant was still utilizing oxygen in the water at depth.

The biological oxygen demand, BOD, was below detection limits and the chemical oxygen demand, COD, has not been provided by the lab yet. Comparing these values may provide additional information.

The pH was above 8.5 in the laboratory sample and above 9.0 in the field measurements both of which are slightly higher than ideal for a freshwater ecosystem. Fish are likely to experience stress when the pH is above 9.0, but these levels can be present in the heat of the day during high levels of photosynthesis from phytoplankton populations.

The ammonia was also higher than ideal in the laboratory sample. This could be from the water prior to the fish kill but low oxygen does also interfere with the conversion by nitrifying bacteria. It could also be due the fact that dead fish had been decomposing in the water for the last 3-4 days at the time of sample collecting which would elevate the concentration in the sample.

The conductivity of the water is high for a freshwater lake indicating high amounts of dissolved solids in the water, such as salts and minerals. These elevated values could be due to the surrounding landscape, soil composition and/or water source. Re-use water commonly has higher levels of salts and other compounds in the water than other water sources.

The current aeration system is not sufficient to overcome significant oxygen demand due environmental conditions or an external input. An enhanced aeration system would increase the oxygen concentrations in the water and oxidize nutrients in the water and help sequester them in the sediments in addition to reducing the risk of contaminants entering the lake causing an oxygen demand.

Although the phytoplankton species identified at the time of sampling were green algae species, it would be beneficial to complete additional analysis if the populations throughout the year to determine how the dynamics change. Based on appearance, it seems that the lake does experience cyanobacteria or blue-green algae blooms throughout the season. Since these species can fix nitrogen from the atmosphere, they are not limited in phosphorus loaded water. The concern is that these species can be toxic to humans, pets and wildlife. Additional monitoring would be beneficial so the public could be notified if there is any risk present.

The reduction of rough fish that root around on the bottom stirring up the nutrient rich sediments may improve the water clarity and suspended nutrients in the water. When re-stocking occurs, it would be beneficial to stock predatory fish such as Largemouth Bass to help control juvenile Common Carp populations.

Nutrient remediation in the forms of beneficial bacteria, bio-char or other nutrient binding products would be very helpful to cycle or remove some of the excess phosphorus in the water. A buffered edge of native grasses or shoreline plants around the perimeter lake may also be beneficial to reduce runoff containing nutrients, sediments and other potential contaminants into the lake. In addition, park operations should take environmental conditions and weather patterns into consideration. Low phosphate, slow release fertilizers should be used, and applications scheduled when no significant precipitation in the forecast.

The exact cause of the fish kill could not be determined from the results of the water quality analysis. Based on the site conditions, and results found it appears that one or possibly many factors contributed to the event. The poor water quality, filling of the pond, weather, undersized aeration system, and park operations could all have played a role in the conditions that lowered the dissolved oxygen concentrations in the water.

Continued management for algae will help maintain the current conditions but without additional measures, the appearance and overall health of the resource will not improve due to the poor quality of the source water. We look forward to working with the City of Westminster to help determine the best options for long term management to improve the health of the lake and reducing the potential for future fish kills.