A Quantitative and Qualitative Assessment of Stormwater Retention Basins: Relationships in Nature and Response to Three Aquatic Weed Control Methods

By

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A QUANTITATIVE AND QUALITATIVE ASSESSMENT OF STORMWATER RETENTION BASINS: RELATIONSHIPS IN NATURE AND RESPONSE TO THREE AQUATIC WEED CONTROL METHODS

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SARAH CATHERINE WAKELIN

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of MASTER OF SCIENCE

Abstract

An intensive water quality study was carried out for 5 months during the summer of 1998 on 58 stormwater retention basins (SRBs) in the City of Winnipeg. The basins' primary function is to serve as land drainage storage reservoirs within the city; however, developers advertise them as pristine 'lakes' to residents in sub-developments. Due to the nature of the ponds, they quickly become choked with vegetation, which disenchants many property owners.

Since a large-scale study had not been completed in the past it was desirable to compose a large database of water quality values with which to make comparisons between the SRBs' overall characteristics. The City of Winnipeg has implemented a series of control measures in order to help alleviate customer dissatisfaction by removing vegetation using the herbicides Karmex-DF and Reglone-A, as well as a mechanical weed harvester. An assessment as to the best method of control was also desired.

In order to gauge the water quality pertaining to these objectives, water quality was assessed on 10 occasions, bi-weekly, from May to September 1998. Of the 70 SRBs in the city, 58 were accessed and water quality parameters were determined. Dissolved oxygen, temperature, transparency, depth, and a visual inspection were completed on site. Samples were collected for analysis of other parameters in the laboratory the following week. These parameters included total suspended solids (TSS), turbidity, chlorophyll-a, fecal coliforms, total Kjeldahl nitrogen (TKN), ammonia, nitrate, total phosphorus (TP), orthophosphate, and pH. The majority of the parameters were determined each sampling period, except TKN and TP, which were determined every second sampling week.

Overall, relationships showed that increases in TSS were a result of increasing chlorophyll-a concentration. Turbidity increases, and decreases in transparency, were a result of algal growth in conjunction with calm periods, where each parameter improved when the weather was calm. Transparency showed the opposite relationship to turbidity; it decreased over summer, for the same reasons given.

TKN increases were the result of the incorporation of nitrogen into proteinaceous material in the algal cells over the summer. Ammonia concentrations showed two maxima, and were attributed to chemoheterotrophic degradation of dead biomass that coincided with periods of calm. This allowed a build-up in the surface layer of the lakes. The peak observed at the end of the summer was thought also to have been a result of a large influx of waterfowl feces due to the Canada geese migration. Nitrate peaks seemed to be a result of anthropogenic inputs of fertilizer; however, a small amount of nitrification may have taken place mid-summer as a result of elevated ammonia concentrations and warm, calm conditions. Based on a lack of inorganic nitrogen observed, it was thought that nitrogen was limiting in these ponds. The observance of blue-green algae further confirmed this.

Orthophosphate made up 30% to 50% of the total phosphorus present and the two followed the same overall trends. A drop in both parameters mid-summer indicated settling of particles with phosphorus attached; higher values during windy periods were thought to have occurred due to sediment re-suspension of sediment phosphorus.

Dissolved oxygen depletions due to chemoheterotrophic degradation of dead biomass occurred in the bottom of the ponds during hot, calm weather; however, a lack of thermal stratification eliminated the dissolved oxygen minima for extended periods. At the end of the summer, differences in oxygen concentrations between layers were minimal, illustrating that temperature and mixing played a greater role than biological factors during these times of the season. Temperature showed no surprises when it increased and then decreased over the summer months, and there was no long-term stratification as the basins were too shallow. pH values were most affected by photosynthesis, when as the lakes became more productive, the pH increased.

Substantial counts of fecal coliform bacteria occurred in the basins in response to the Canada geese migration and were absent for the rest of the summer.

Overall, it was concluded that biological activity and weather conditions had the greatest influence on the various water quality parameters within the SRBs.

Of the three aquatic weed control measures implemented by the City of Winnipeg, it was established by comparing the collected water quality data that Karmex-DF was the optimal control method. It was also suggested that utilization of the herbicide as a long-term aquatic weed control measure proceed with caution and other, more ecologically-sound methods of control be investigated.

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Chapter 1

Introduction

Water is essential for life as we know it. Each person requires at least two litres of drinking water per day. In addition, there are requirements for livestock, irrigation of agriculture crops, power, transportation, industry, recreation, not to mention providing a home to many aquatic wildlife (WRI, 1994; Yassi et al., 1997). The water used for each of these purposes must meet minimum quality guidelines to protect against disease and other negative effects. Increasing populations and drought in many areas have resulted in depletion of available sources of water, leading to the construction of reservoirs or damming of rivers to provide a useable source. The uneven distribution of water around the globe and the forms that it is found in further tighten the noose on available supplies. Only 2.53% of the earth's water is freshwater; of that, 30.1% is in the form of ground water, 69.56% is locked up in permafrost, glaciers, and permanent snow cover, leaving only 0.34% available in surface water (WRI, 1994). The fraction of a percent of surface water available is further limited due to inputs of pollutants, contaminating the water and rendering it unfit for any use. The four major sources of water pollution worldwide include sewage, industrial effluents, agricultural run-off, and storm and urban run-off (WHO/UNEP, 1989-cited in Yassi et al., 1997).

Sources of water pollution are either point or non-point in origin. Point source pollution, such as that entering from an industrial or sewage discharge pipe is a major contributor to pollution, but those sources can be monitored and controlled at the end of the pipe. In the case of non-point source pollution, such as pollutants carried in runoff, the introduction of contaminants is much more widespread making control difficult, and resulting in extensive pollution.

In Canada, freshwater supplies are plentiful for required uses; however, too many Canadians are neglectful of this resource, as they cannot see any impending crises in their lifetimes. Many Canadian lakes are rapidly becoming overproductive and choked with weeds and algae due to non-point sources of nutrient additions. The quantity of water remains the same but its quality is rapidly diminishing. In cities such as Winnipeg, stormwater influx can occur to a great extent in a very short period of time, and when this occurs, a volume enters untreated into natural rivers, as sewage treatment facilities are unable to cope with such a large quantity of water all at once. In order to help alleviate this, Winnipeg began the construction of stormwater retention basins back in the 1960's. Now the city contains over 70 stormwater retention basins (SRBs), which provide storage for stormwater, while allowing for the deposition of sediment, nutrients, and harmful pollutants prior to discharge into Winnipeg's rivers (Wardrop, 1998; Jeung, 1978). Allowing these constituents to run directly into natural receiving waters could result in these waters becoming contaminated and overgrown with weeds, destroying many balanced aquatic ecosystems.

Although the SRBs have provided some relief to the contamination of natural water bodies, they themselves have become overgrown with weeds and are aesthetically unpleasant for residents of the sub-developments that were built around them. Therefore, like natural water bodies, there is the desire to control the water quality within SRBs and try to minimize aesthetic concerns by controlling weed growth.

SRBs have been in place in Winnipeg for many years and data was gathered for the last several; however, collection was affected by budget restrictions and other priorities as designated by the city. This resulted in limited statistical analysis, evaluation, and interpretation of data.

It was desirable to form an inclusive database for the majority of Winnipeg's SRBs. Through a large-scale study of 58 SRBs during the summer of 1998 a comprehensive database was to be made available so that an assessment of the SRBs' behaviour over time could be determined. Unrealistic expectations by residents near the ponds has also led to the desire to find optimal methods of weed control. Numbers provided from a large database would also offer a reference for future aquatic weed control evaluations.

Chapter 2

Literature Review

2.1 Limnological Background

Prior to initiating and interpreting any water quality analysis, a basic understanding of limnology and those water quality parameters to be studied must be carried out. For the purpose of this thesis, only the lake aspects of limnology will be examined, however many of the water quality parameters studied can be applied to a river environment.

2.1.1-Annual Cycle of a Temperate Lake

Lakes undergo various cycles over the course of the year, which is dependent on their geographic location. In a north temperate lake in spring the temperature of the interface between the cover ice and the water is approximately 0°C. The temperature at the bottom of the same lake is about 4°C since water at this temperature is at maximum density and sinks. When the overlying water begins to warm above 0°C, its density increases and it sinks and mixes with the underlying water. This occurs until the entire water column reaches maximum density, at 4°C, at which time any light wind blowing over the surface mixes the entire volume of the lake easily, in a process known as spring turnover (Figure 2.1).

Over the course of summer, density gradients resume due to temperature differentials in the different layers of the lake. If the lake is deep, for example approximately greater than 6m to 10m mean depth, warm overlying waters detain cooler bottom waters and prevent the complete mixing of the lake (Goldsborough, 1997). This process forms a mixing epilimnion at the surface and the more dense, cooler, hypolimnion at the bottom. Between the two layers is the thermocline, or metalimnion, where a maximum density gradient occurs. This entire mechanism is called thermal stratification and is illustrated in Figure 2.2.

During autumn, the upper layer of water begins to cool, reducing the density gradient between the two layers. Eventually, the entire water column reaches a uniform temperature and the volume of the lake experiences fall overturn (Figure 2.1). With a continued decline in air temperature, the surface water cools below 4°C and becomes lighter and lighter until ice forms on the surface.

A temperate lake, such as the one given in the previous example, that mixes in the spring and fall is known as a dimictic lake. In the case of shallower lakes or reservoirs with a mean depth of less than 6m a thermocline may develop during periods of calm weather; however, the depth is such that a moderate-to-strong wind may cause overturn several times during the spring, summer, and fall seasons. This type of lake is referred to as a polymictic one (Reimer, 1984; Wetzel, 1983).

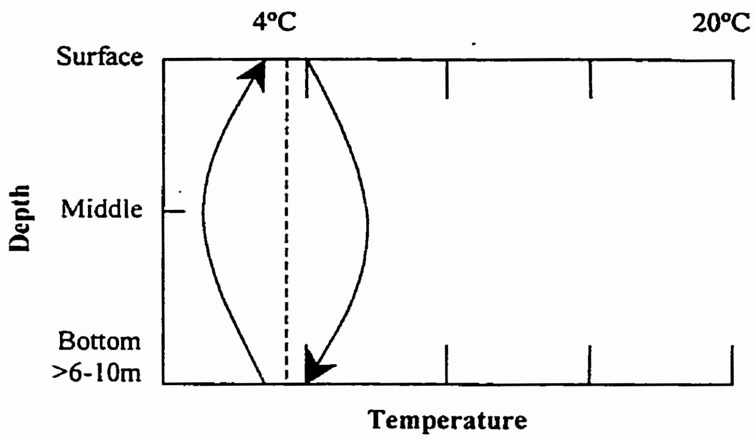

Figure 2.1: Uniform Temperature with Depth Resulting in Overturn
(Adapted from Goldsborough, 1997)

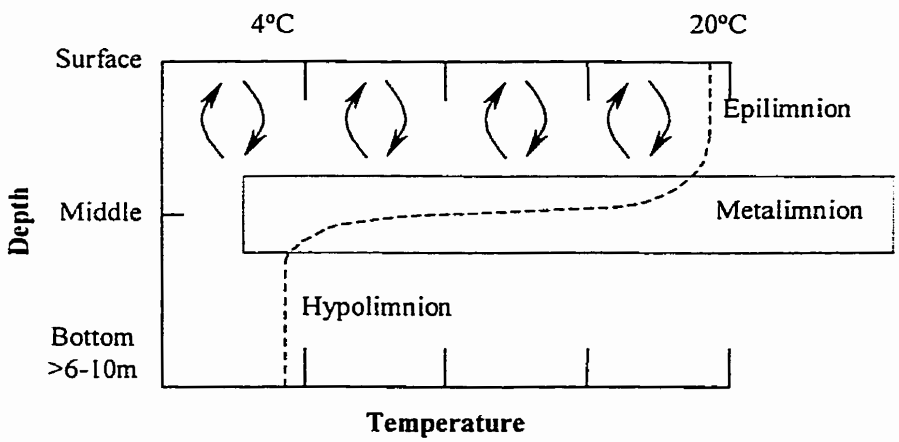

Figure 2.2: Thermal Stratification Resulting in Two Layers
(Adapted from Wetzel, 1983)

In addition to the temperature and mixing regime of any lake, complex interrelationships exist between the biological, physical, and chemical components of the aquatic environment. Should any aspect of the three components change, due to natural or anthropogenic inputs, the entire water body will undergo a significant alteration.

2.1.2-Biological Components of Aquatic Ecosystems

The biological components of a healthy aquatic ecosystem are made up of a variety of organisms from various trophic levels. Because of the subject of this thesis, only the primary producers and coliform bacteria are discussed in detail; however, some of the higher invertebrates and vertebrates are briefly mentioned.

Primary producers are those organisms that manufacture their own food from sunlight and carbon dioxide and are the basis of any food chain. They provide food for consumers that, along with the primary producers, yield substrate for the decomposers to live off of. The primary producers are made up of microphytes and macrophytes.

Microphytes, or algae, are simple organisms that lack the true stems and leaves of higher plants (Allan et al., 1989). They are an ubiquitous group of organisms that are similar to other plants because they all contain chlorophyll-a and produce carbohydrates. Algae can be either microscopic in size or extend for many meters. In the aquatic food chain, algae form the fundamental base (South and Whittick, 1987) and survive year-round in the water, spending the winters near the bottom of the lake. With greater light penetration and heat, microphytes grow very quickly, resulting in the formation of algal mats and scums. The three types of algae usually associated with Canadian waters are the phytoplanktonic, filamentous, and branching algae (Allan et al., 1989).

Phytoplanktonic algae are microscopic, free-floating algae which usually inhabit the upper two meters of the water column. Of greatest importance to their production is temperature, sunlight availability, dissolved nutrients, and the type of water body occupied (Allan et al., 1989; Wetzel, 1983). This group of rapidly growing organisms is responsible for the production of algal blooms in summer, evident by coloured water ranging from green to blue-green to red-brown depending upon the dominant type of algae producing the blooms. These blooms can be toxic in certain instances as various types of algae produce toxins within their cells. This has resulted in the death of livestock drinking from farm dugouts containing them. They also cause aesthetic problems, taste and odour problems for water consumers, and massive fish kills due to oxygen depletion as a result of the decay process of the massive blooms (Allan et al., 1989).

Filamentous algae are colonial algae that are long, stringy, and hair-like. Mats of these algae may float on the surface or small bunches may remain attached to various substrates. During hot weather, filamentous algae are able to trap air bubbles and float to the surface where they are a nuisance to recreationalists and can raise the temperature of the water body due to an increase in the adsorption of radiant energy. This process results in an increase in evapotranspiration (Allan et al., 1989).

Branching algae are often confused with vascular plants, but close examination illustrates their lack of true roots. *Chara sp.* and *Nitella sp.* are the only types found in Canada (Allan et al., 1989).

The macrophytes fall into four groups: emergent, floating unattached, floating attached, and submersed. Emergents' leaves and stems grow above water, but the roots grow beneath a layer of shallow water up to half a meter deep. They are perennials and grow laterally from rhizomes (Riemer, 1984; Allan et al., 1989). This allows them to form the dense stands that sometimes completely surround a water body. Floating attached groups are plants where the leaves float on the surface and are attached by roots to the bottom, whereas floating unattached plants have the majority of the plant's body above the surface of the water and if roots are present they hang free. The latter are able to float with winds and currents and are therefore highly motile. Submerged plants spend their entire life cycle underwater with the exception of certain flowering periods (Riemer, 1984).

Emergent macrophytes, such as cattails, are thought to be the most efficient water-weeds at trapping overland sediment prior to its entrance into a water body. Entrapment of sediments through thick stands of macrophytes causes the settling out of particles such as phosphates, pesticides, and any other substances that may be attached to those particles. Other sediments settle out, burying those that were contaminated, resulting in water that is cleaner running from thick stands of macrophytes. Many macrophytes, including duckweed, bulrushes and cattails, are able to break down organic pollutants, take up heavy metals, and reduce some pathogenic bacteria. Finally, macrophytes are able to take up and hold large quantities of the nutrients nitrogen and phosphorus, removing them from an aquatic system (Kulzer, 1990).

Water quality analysis would not be complete without mentioning the coliform, or more specifically fecal coliform, group of organisms. The relative numbers of fecal coliform bacteria indicate whether or not the water source is safe for various uses. Since this group of bacteria are located in the gut and feces of warm blooded organisms, they are indicative of contamination of a water body by fecal matter, through which many water borne illnesses could arise (Standard Methods, 1980; Jeung, 1978). Sources of fecal coliforms in a water body are numerous. Directly, they can be deposited from sewage discharges and wildlife, and indirectly, they may be released from stormwater, groundwater, and sediments (Weiskel et al., 1996).

2.1.3-Physical Parameters of Aquatic Ecosystems

Directly affecting biological growth of organisms are many physical parameters. The degree of sedimentation into a lake or reservoir depends on the nature of the surrounding watershed, including parameters such as slope and vegetation, size of the watershed, and human activity. Wind and waves ultimately erode shoreline, depending upon the nature of the shoreline, vegetation around the shore, and the amount of wind reaching the water surface. Dead organisms and plants contribute to sedimentation, but especially plants as the low nitrogen to carbon ratio prevents the complete degradation of cellulose. Leaves and litter also affect the degree of sediment accumulation (Riemer, 1984). Should the suspended solids entering the water body increase dramatically, they can have a significant effect on light penetration, resulting in inefficient or minimal photosynthesis. In addition to affecting light, suspended solids may bury plants and animals on the bottom, reduce the volume of a lake basin for storage, and act as a transport medium for many other dangerous compounds (Jeung, 1978). Unless the ponds or lakes are cleaned and maintained by humans, any lake will undergo a natural filling in process which results in their conversion to land (Riemer, 1984).

Suspended solids resulting in sedimentation have a profound effect on light, which is a major component of any ecosystem. In aquatic ecosystems, light penetration determines the depth to which photosynthetic organisms can grow, or the photic zone of a lake (Mitchell, 1974). In this zone, photosynthesis exceeds respiration, producing extra plant mass that serves as food for higher organisms such as zooplankton. Since algae are the basis for any food chain within a lake ecosystem, the importance of light penetration cannot be stressed enough. In addition to suspended solids, many other factors affect the availability of light for photosynthesis. Factors such as latitude, elevation, time of day, season, and cloud cover all effect the amount of light hitting the surface of water. In addition to this, waves and plants can reflect light hitting the surface back into the atmosphere. Light may take many paths once it enters the water, as it may be absorbed by water molecules resulting in heat production, or scattered by the multitude of particles comprising suspended solids (Riemer, 1984; Wetzel, 1983). Transmission of light depends on absorption of it by dissolved particles which produce colour, and turbidity caused by suspended solids in water (Riemer, 1984). The colour of water determines the composition of the light reaching the furthest depths, and the turbidity affects the depth to which light can penetrate. Biogenic, or biologically caused, turbidity absorbs light to a greater extent than abiogenic turbidity, which tends to scatter it back into the water. This phenomenon results from the process of photosynthesis where algae and plants take up and utilize the passing light while abiotic components are inert and reflect it (Talling, 1960 and 1971-cited in Wetzel, 1983).

Overall greatest absorption of light occurs in the upper reaches of the epilimnion as there is more suspended material there, and because the most easily absorbed wavelengths disappear there. Blue and green light tends to penetrate most deeply in clear water and red-orange dominates in stained brown waters (Mitchell, 1974).

Indirectly resulting from light penetration are temperature fluctuations within a lake. Plant and bacterial metabolism are temperature dependent, and are faster at higher temperatures within an optimum temperature range. Temperature indirectly affects mixing of a lake and may be responsible for localized depletions of certain nutrients and gases (Mitchell, 1974), which may hamper plant growth.

2.1.4-Chemical Parameters of Aquatic Ecosystems

Gases are an important chemical parameter in any aquatic ecosystem. The solubility of gases usually increases with increasing temperature, and vice versa. In the case of oxygen, which is required for heterotrophic metabolism, this is not the case, as this gas becomes more soluble in water with a lower water temperature. The major source of oxygen is from the atmosphere and the degree to which it is introduced into a lake is, for the most part, dependent upon mixing of the lake as it diffuses very slowly across the air-water interface (Wetzel, 1983). For reasons mentioned in Section 2.1.1, during summer or winter, large volumes of water within a lake can become cut off from the atmosphere and ultimately from oxygen introduction. This results in dissolved oxygen values ranging from saturation in turbulent, well mixed waters to non-existent in the hypolimnion of some productive, stratified lakes. Even though lake oxygen levels can become supersaturated in the daytime during photosynthesis, the gas may be quickly consumed either during the dark reactions at night or as a result of organic matter decomposition by heterotrophic bacteria. Should oxygen levels become too low, fish kills, foul odours, discolouration, and slime may ensue (Reimer, 1984; Jeung, 1978).

Unlike oxygen, carbon dioxide follows the norm, where its solubility increases with increasing temperature, and the gas diffuses readily through the air water interface (Wetzel, 1983). Carbon dioxide gas is the inorganic carbon source required by aquatic vegetation to produce cellular material and is an important factor in maintaining a certain amount of alkalinity (Mitchell, 1974) which helps to buffer a lake, preventing drastic changes in pH. Carbon dioxide can become limiting in productive lakes containing algal blooms or dense concentrations of weeds (Riemer, 1984).

A lake's pH must be maintained within a reasonable range. Generally, the pH of a majority of lakes ranges from 6 to 9 (Wetzel, 1983). The pH is an important chemical parameter in natural water as it affects the enzyme activities of plant cellular metabolism and the uptake of carbon dioxide and nutrients (Hutchinson, 1957-cited in Mitchell, 1974). During photosynthesis, carbon dioxide is removed from the water and carbonic acid removal results in the pH of the water increasing. Cellular respiration results in the addition of carbon dioxide to the water and the pH is lowered due to an increase in the carbonic acid concentration. Buffering capacity of the water determines the degree to which pH may change over the course of 24 hours. Fluctuations of up to 3 units are not unusual during that time interval in poorly buffered water (Riemer, 1984). Implications of pH values too far beyond the optimal range on aquatic life are detrimental. A pH that is too high may result in ammonia toxicity in many aquatic organisms and if the pH is too low, heavy metals may be released from the sediments (South and Whittick, 1987).

Nutrients are the final important chemical parameters of lakes to be discussed. A large assortment of macronutrients and micronutrients are required for adequate growth and functioning in an aquatic ecosystem; however, the two most prevalent nutrients today in the health of those ecosystems are nitrogen and phosphorus.

Nitrogen is important during the vegetative growth of plants as well as in protein formation (Riemer, 1984). Nitrogen gas from the atmosphere is dissolved in water and converted by nitrogen fixing bacteria, or by filamentous blue-green algae via heterocysts, to provide a usable plant form such as nitrate, or most commonly, ionized ammonia. Heterocyst cells are able to maintain nitrogen fixation, which is an anaerobic process through the control of oxygen production inside. Photosystem II, or the phase of photosynthesis responsible for oxygen liberation, is absent in these cells. This, coupled with respiration, acts to maintain anaerobic conditions within the heterocysts. The nitrogen fixation process reaches a maximum in the presence of blue-green algae, when sources of combined nitrogen are depleted and with excessive concentrations of total phosphorus, and decrease when blue-green algae disappear (South and Whittick, 1987; Lean et al., 1978, Lundgren, 1978, Flett et al., 1980- all cited in Wetzel, 1983).

A large amount of nitrogen enters lakes through land drainage and ground water. When oxygen levels are high the nitrogen is in the form of nitrate, and when they are low, ammonia is the dominant form. These available nitrogen forms are highly soluble, easily leaching out of sediment and soil, and are found in the water column where their concentrations will fluctuate widely (Riemer, 1984). Ammonia is created through degradation of organic matter by bacterial heterotrophs. Nitrification is carried out by *Nitrosomonas* and *Nitrobacter* using organic and inorganic nitrogen compounds so long as the dissolved oxygen remains high enough. Nitrate that is produced is assimilated by plants and algae into ammonia. The rate of assimilation may far exceed nitrate inputs into the lake, resulting in undetectable levels of nitrate. Nitrogen that is in plant and bacterial cells, mainly in the form of proteins, comprises the organic nitrogen. A measurement of Total Kjeldahl Nitrogen (TKN) and ammonia allows one to determine the organic nitrogen by determining the difference between the two (Wetzel, 1983; Standard Methods, 1980). Nitrogen is lost from the water column of a lake through a variety of paths. The outflow of water carries nitrogen with it. Decomposing plant matter may become buried in the sediment and inorganic and organic forms may become attached to sediment particles. Finally, nitrogen gas may leave a lake through denitrification and ammonia volatilization, the latter occurring under high pH conditions (Wetzel, 1983).

Unlike nitrogen, phosphorus is rapidly assimilated by plants, as it is generally the limiting nutrient within an aquatic ecosystem. Its limiting characteristic is a result of the lack of a gaseous reservoir, with the majority of phosphorus coming from weathered rock, and its loading is generally associated with solids loading (Wetzel, 1983; Jeung, 1978). The nutrient's function in plants involves contributions to reproduction and the formation of high-energy bonds such as those found in adenosine triphosphate (ATP). The total phosphorus in any water body is comprised of either dissolved or particulate forms (Reimer, 1984). Orthophosphate, or inorganic soluble phosphorus, is the most widely useable form of phosphorus for aquatic organisms, although there are other dissolved forms present in lakes. These include polyphosphates, which often originate from detergents, organic colloids, and low molecular-weight phosphate esters. Particulate phosphorus includes phosphorus present in aquatic organisms, and phosphorus attached to inorganic complexes such as clays and dead particulate organic matter (Wetzel, 1983).

Equilibrium is maintained between the precipitated phosphorus found in the sediments and in the overlying water. This balance is such that the phosphorus present is sufficient for rapid assimilation by vegetation but a low concentration in the water column is maintained. Oxygen concentration and pH are two factors that regulate the release of phosphorus out of sediment. A decrease in the pH of water would result in an increase in the release of phosphorus. Inorganic precipitates of ferric phosphate remain in the sediment under aerobic conditions; however, should the hypolimnion become anaerobic, soluble ferrous phosphate is released. This, coupled with release from decaying vegetation, leads to a high concentration of phosphorus in the hypolimnion during stratification; if the situation persists until fall overturn, the epilimnion may receive a large influx of phosphorus. The same event may occur in winter, resulting in the maximum phosphorus concentrations often seen after spring and fall overturn (Reimer, 1984).

Nutrients tend to be slowly removed from the epilimnion to the hypolimnion during summer due to the uptake of nutrients by organisms and subsequent death and settling of them later on. Because of this, during the growing season plants' growth is often limited by a depletion of vital nutrients. For this reason, addition of limiting nutrients into a lake will result in the production of massive algal blooms and aquatic plants (Mitchell, 1984).

Ideally, the natural processes occurring in a lake maintain various water quality parameters within reasonable boundaries. Quick plant turnover, due to fast uptake and utilization of limiting nutrients showing high productivity, is termed eutrophication. A lake will naturally proceed from being non-productive, or oligotrophic, to eutrophic. For lakes that are intermediately productive, mesotrophic is the proper term to apply. In addition to its natural progression, eutrophication is a process that can be sped up by humans, due to point and non-point sources of pollution, especially nitrogen and phosphorus, in and around lakes. This accelerated productivity speeds up lake fill-in and is known as cultural eutrophication (Mitchell, 1984; Riemer, 1984)

A eutrophic lake is one that is rich in organic and inorganic nutrients, is turbid with suspended solids or plankton, has gently sloping sides, is relatively shallow in depth, and the primary production and standing crop are very high (Riemer, 1984; Allan et al., 1989). Thick bunches of vascular plants act to speed up the filling in process of a lake or reservoir. The cellulose rich structures are not easily broken down after death and result in accumulation of the sediments. Water flow is impeded when passing through thick plant stands and sediment drops out. The more plants that are present, then the slower the movement of water, and more sediment is dropped. Positive charges on the surfaces of plants results in the aggregation of negatively charged clay particles and the quick deposition of these particles. Filling of a lake results in a continued availability of space for vascular plant growth ultimately resulting in dry land. An increase in aquatic macrophytes stagnates the water column, resulting in higher temperature water than if it were moving. Increased water temperature, coupled with large nutrient inputs, provokes the growth of filamentous and planktonic algae, which often predominate in extremely eutrophic lakes (Riemer, 1984). When a bloom of algae occurs in a lake, the lake's physical and chemical parameters are often unable to sustain it and result in mass die-off and consumption of large amounts of oxygen. This may result in the destruction of higher organisms, such as fish (Barica, 1993).

2.2 Methods of Aquatic Vegetation Control

Because of the nature of humans to use and abuse water and the surrounding watershed, various methods of control have been implemented in order to help maintain water bodies in an acceptable state for all individuals. These include physical, preventative techniques in the surrounding watershed, chemical, biological, and mechanical control agents within the lakes and reservoirs.

Aquatic weed control occurs on a wide scale today and is necessary in the protection of aquatic ecosystems as well as water resources. Thick masses of weeds prevent many activities such as boating, fishing, swimming, water-skiing, and others. Residents value the aesthetics of water encourage weed control since the weeds may reduce property values by choking a pond or producing odours. Large mosquito populations are found in association with stagnant weedy areas as weeds provide a calm environment for the larvae to mature and provide a safe haven from heavy predation (Riemer, 1984). Although the insects are simply a nuisance in much of North America, in many countries mosquitoes are the disease vector for communicable diseases, such as Malaria, which contribute a great deal to mortality in the world each year (Prescott et al., 1990; Yassi et al., 1997). Snails, like mosquitoes, reside in weed stands and contribute to disease in many areas of the world (Riemer, 1984; Prescott et al., 1990). Other problems associated with thick aquatic weeds are losses in the fish hatcheries, navigational problems, irrigation impediment, and other social and economic factors (Reimer, 1984).

2.2.1-Physical Control Methods

Prevention of aquatic weed growth can be incurred by eliminating the introduction of weeds into an area by not planting or transporting seeds into that area (Riemer, 1984). Purple loosestrife was introduced into flower gardens in North America due to its hardiness and beauty; however, it spread into wetland areas, killing off many species of wetland plants that are important to the health of waterways. Because of a lack of natural predators in its non-native habitat, it thrives and threatens the health of aquatic ecosystems. Eradication and control is difficult (Manitoba Environment, 1995).

Management procedures of lakes and reservoirs could include control of the quantity of nutrients entering a water body, minimizing the input of debris such as leaves and litter, which provide excess nutrients, and harvesting of standing crops of plants to eliminate their nutrient additions at times of death. Shape and structure of basins influence the aquatic weed growing process and should be built to minimize this. In the case of pond construction, a deep pond with steep sides and a smaller surface area is desirable as it eliminates much of the area available for growth by submergent or emergent macrophytes. Shelterbelts and vegetative strips planted next to a lake will act to slow the movement of sediment into it, and in the case of the latter, remove a great deal of nutrients prior to entering the water course. Their implementation should be undertaken when planning any watershed management strategy (Riemer, 1984; Allan et al., 1989).

In many instances, the implementation of preventative measures is futile in the prevention of excessive aquatic plant growth due to the strong hold they already have on the aquatic system that they occupy. In such instances stronger measures must be taken.

2.2.2-Chemical Control Methods

Chemical herbicides are probably the most versatile and widespread method for aquatic weed control world wide; however, a herbicide control plan must take into consideration all of the potential uses prior to its implementation. Herbicides are versatile in that they can control very large or very small areas that are or are not easily accessible. In addition, the lethal dose of herbicides to aquatic organisms other than plants requires the application concentration to be a great deal higher than that required to kill the nuisance flora (Riemer, 1984).

Control of macrophytes using a herbicide program should be initiated early in the lifecycle of the weeds or just after the weeds begin to flower. Applications in order to control algae should be completed just as the algae begin to get a foothold. Waiting too late in the season may prove ineffective in destroying aquatic plants as there may be calcium carbonate deposits on the surface of leaves which impede uptake, or the mass of flora may be so great that the application of the herbicide proves not to be environmentally friendly or economically feasible. Application early in the season limits the amount of herbicide required, and reduces the cost and dissolved oxygen consumption resulting from large masses of the algae killed all at once (Allan et al., 1989).

A wide range of herbicides is available for vegetation control; however, guidelines set out by government only allow a select few to be used in water, based on the nature of the medium and its ability to transport herbicides great distances. Three herbicides recognized for use in aquatic systems include Amitrole-T, Karmex-DF, and Reglone-A (Wardrop and Elefsiniotis, 1998).

Amitrole-T, or 1H-1,2,4-triazol-3-amine, is generally used for emergent macrophyte control surrounding a water body. It is slowly absorbed but quickly moves through the plant to inhibit photosynthesis and any regrowth from buds (Allan et al., 1989).

Karmex DF is a diuron (N'-(3,4-dichlorophenyl)-N,N-dimethylurea) based herbicide which will destroy a variety of vegetation, including deep-rooted species

(Wardrop and Elefsiniotis, 1998; Allan et al., 1989). The herbicide is absorbed through the roots of plants and moves up into the plant where it disrupts the Hill reaction in the plant cells (Allan et al., 1989). The Hill reaction describes the photosynthetic conversion of light energy into chemical energy within the chloroplasts of plant cells (South and Whittick, 1987). Water treated with Karmex-DF may not be consumed and irrigation use should not occur prior to one year after application (DuPont Canada Inc, 1996-cited in Wardrop and Elefsiniotis, 1998).

Reglone-A is a diquat based herbicide (Wardrop and Elefsiniotis, 1998). Diquat, 6,7-dihydrodipyrido[1,2-α:2',1'-c] pyrazinediium ion, will control the majority of aquatic weeds. The herbicide is taken up by foliage and forms a free radical which re-oxidizes, forming active free radicals within the plant, such as hydrogen peroxide. The strong oxidant damages cell constituents, impeding important cell functions. The herbicide adsorbs very tightly onto clay and organic particle surfaces where it is ineffective, as it can not be taken into the plant, and is thus inactivated. It therefore should not be used in highly muddy, turbid water. Water containing Reglone-A should not be used for irrigation for five days after application and care should be taken not to let the herbicide come into contact with other non-troublesome vegetation (Riemer, 1984; South and Whittick, 1987; Allan et al., 1989).

Many problems are associated with herbicide use as a means of aquatic weed control. First, herbicides may not become inert for a long period of time and therefore be able to move great distances in an aquatic environment, killing non-offensive vegetation. Massive kills of vegetation provide substrate for growth as they contribute to sedimentation, and may lead to oxygen depletions for other organisms. Massive die-off may also provide advantageous situations for more massive invasions in the future. A loss of plants will have negative effects on higher organisms that require them for food and habitat. Large quantities of herbicide could contaminate all organisms associated with the treated water body. This may result in acute or chronic effects in those life forms (Riemer, 1984). Finally, repeated applications of the same herbicide may result in the development of resistance (Allan et al., 1989).

2.2.3-Mechanical Control Methods

Mechanical weed control methods help to provide predictable results, unlike chemical control where effects on surrounding areas are difficult to surmise. Additionally, mechanical harvesting removes a large standing crop of nutrients and organic matter which would otherwise be released back into the water column should a herbicide have been applied and the plants left to be degraded by bacteria (Mitchell, 1974; Allan et al., 1989).

Mechanical control can be completed by dredging or cutting weeds, where dredging involves removing part of the buried plants from the sediment and cutting involves cropping the plants near their base. Dredging is not used primarily as a weed control operation, but instead to reshape basins by removing sediments. Along with the removal of sediment, overlying vegetation and roots are removed. It has been found in the United Kingdom that dredging often leads to a re-growth of a more diverse population of plants and often the removal of vascular plants results in an invasion of floating filamentous algae (Mitchell, 1974; Allan et al., 1989).

Cutting methods, including the use of hand held scythes, rakes, and forks, are simple but labour intensive and are only feasible in certain parts of the world. Hand cutting is useful in the case of cattails as it provides the proper technique to eliminate the plant. If cut below the surface of the water, a mature cattail will not grow back, since the root systems are dependent on oxygen from the above-water portions. Without oxygen, the roots are unable to produce new shoots and die (Mitchell, 1974; Riemer, 1984).

Because cutting is an ongoing process, mechanical destruction using designed cutters is much more practical in many regions. A problem with cutting is that the dead weeds are often returned to the water where they may re-root themselves or will decompose. This process could result in the utilization of oxygen that may contribute to fish kills, and the release of nutrients, provoking algal blooms or more vascular plant growth. In order to help alleviate this problem, mechanical harvesters are used to remove the standing crop and dispose of it on land (Mitchell, 1974).

One problem with harvesting is that the entire plant is not killed and, depending upon the type of weeds, nutrient content of the water, competition, and climate, the weeds may have to be harvested more than once a season (Riemer, 1984). Any weeds that escape pick-up are a source of new infestations. Also, overwintering structures on the weeds are often more numerous after harvesting as cutting the plants produces a bushier re-growth. This creates a greater density of plants the following growing season (Allan et al., 1989).

2.2.4-Biological Control Methods

A biological control method is advantageous as it provides maintenance at a low cost with very few side effects. Its development for any area is dependent on many factors and must include extensive research prior to implementation (Mitchell, 1974). Introduction of a species of organism before enough research has been completed may result in an increase in problems should that organism become a pest itself. Ideally, a biological control agent should exhibit certain characteristics. It must be able to survive in the natural conditions that it is introduced, it should attack only the undesirable plants, and its use should be economical (Riemer, 1984).

Fish have been a popular choice in the control of aquatic weeds because they can act in two ways. First, they are able to disturb sediments, so much that they actually act to shade out a good portion of aquatic weeds. Second, they consume the weeds. In temperate climates the herbivorous grass carp, *Ctenopharyngodon idella*, has the greatest potential for controlling aquatic weeds. This fish is hardy – it is able to survive temperatures just above the freezing point to temperatures greater than 35°C, which makes its use in extreme climates possible. Low dissolved oxygen concentrations of 0.3mg/L to 0.5 mg/L are survivable by the fish, although they will not feed at less than 2.5 mg/L and therefore, would not be able to cope under continued oxygen deprivation. Finally, grass carp can survive under somewhat saline conditions and at pH values near 11. Besides plants, the fish may survive on small zooplankton and insects, which provide them with food in times when the number of aquatic weeds is limited (Riemer, 1984).

One problem with the grass carp is that it will compete with other fish for food and space; thus, it could stress native populations. Reproduction is feared as a threat to native fish; however, because of the specific conditions that the grass carp require for reproduction, this case seems insubstantial. Grass carp also produce feces with a high amount of undigested material that creates an oxygen demand in lakes. However, because of poor digestion the fish eat more plant life, resulting in greater removal (Riemer, 1984). Other types of living control agents in this category include insects and mites, fish, snails, waterfowl, viruses, and bacteria (Mitchell, 1974). Each of these biological agents, like grass carp, have their advantages and disadvantages.

An interesting method of biological control of algae has also been explored, using barley straw. When barley straw is allowed to rot in water, oxygen liberated through a series of reactions of the lignin from the degrading straw destroy algal cells (Gadawski and Robbie-Draward, 1995). The degree of damage to aquatic macrophytes has not been documented in the literature and because the control involves inhibition and not destruction, the use of the straw is debatable in many instances (Gibson et al., 1990).

2.2.5-Other Control Methods

Many other weed control mechanisms exist; however, their uses have many limitations and hence a selection of them will receive only a brief summary here. First, managers are able to influence water levels in certain reservoirs and ponds due to constructed weirs and other control measures. These water level fluctuations could have negative effects on populations of aquatic weeds (Riemer, 1984). Another method is cold water introduction, which may slow down the proliferation of algae and plants, since both prefer warmer environments. Also, low oxygen levels below 2 mg/L will stimulate blue green algal growth in the middle of summer when water temperatures are warm.

Filamentous algae prefer dissolved oxygen concentration above 5 mg/L. Aerators could help to mix, cool, and introduce oxygen into the water, helping to alleviate some of these problems (Mitchell, 1974; Allan et al., 1989). Shading has been used to control aquatic weed growth using plastic sheeting, fiberglass mesh, and dyes (Riemer, 1984). The extent to which these methods are practical for large scale lakes is questionable. Finally, alum and hydrated lime have been used in the past in the attempt to eliminate internal phosphorus loading in the hypolimnion of reservoirs and are also able to remove algae, sediment, and phosphorus when sprayed over the surface. The duration of control using these chemicals is limited, attributable to the burying of the chemical by sedimentation, phosphorus release from untreated sediment, and external nutrient and sediment inputs (James et al., 1991; Alberta Agriculture, 1996).

Integration of a plan using various control methods may be the best option for a eutrophic lake with multiple use requirements (Mitchell, 1984). For example, mechanical harvesting prior to herbicide application would be beneficial as the large mass of weeds is removed and then low dosages of herbicides are required to finish the job, preventing re-growth and reducing negative water quality effects on other aquatic organisms (Allan et al., 1989). What is important to realise is that no two aquatic habitats are the same and therefore, no overall generalities about aquatic habitats can be made confidently (Riemer, 1984). Knowing this, a thorough investigation of the water quality parameters must be carried out prior to management strategies so that a proper method of control can be chosen which is tailored for that particular lake or reservoir.

2.3 Water Quality Management

Water quality and management are important on the Canadian prairies. Non-point sources of pollution are extensive, resulting in high nutrient loading into lakes. These, coupled with high energy inputs from the sun and the water bodies' shallowness, have resulted in the rapid growth of aquatic vegetation to such levels that fish and wildlife cannot be maintained (Barica, 1993). Construction of man-made reservoirs helps to alleviate demands for water; however, construction is usually such that they are shallow and have large areas for plant growth. Hence, they are subject to the same problems as natural lakes (Wetzel, 1983). The type and amount of various pollutants entering lakes and reservoirs is dependent on the surrounding land use and nature of the watershed. Should the surrounding area be agricultural, pesticides, nutrients, biodegradable material, and sediment will predominate. However, if a lake or reservoir is located in a developed or developing urban area with a lot of construction activity, run-off containing high sediment loads may predominate. Once in a completely developed urban area, run-off, or stormwater, contains a soup of organic chemicals, bacteria, suspended solids, fertilizers, pesticides and heavy metals (Jeung, 1978).

Because of the high surface run-off from urban areas caused by the replacement of vegetation with pavement, sewage treatment facilities are in many cases unable to treat all of the wastewater produced during storm events. This results in a certain quantity of pollutants entering natural lakes and rivers as overflow, which is ecologically unacceptable (Allan et al., 1989). Construction of storm retention basins (SRBs) can alleviate many of these problems by allowing various materials to settle or react, and also provide space for stormwater in areas prone to flooding during rainfall events (Jeung, 1978).

Since the 1960's, Winnipeg, Manitoba has witnessed the construction of 70 SRBs in order to act as land drainage reservoirs within the city. These basins are located, for the most part, in urban sub-developments where they are highly attractive commodities for many property owners. Developers' advertisement of the ponds as genuine freshwater lakes has led to misconceptions by property owners about the SRBs' true function, resulting in numerous complaints to the City of Winnipeg regarding the aesthetic quality of the ponds (Wardrop and Elefsiniotis, 1998).

The greatest concern of property owners in past years has been the propagation of enormous blooms of algae and aquatic weeds in and around the ponds with worsening conditions as the ponds age. Initiations of various control measures were carried out in past years and water quality monitoring was implemented to some extent in order to asses the effects of these methods of control against those influences that were naturally present (Wardrop and Elefsiniotis, 1998). Water quality studies, it is hoped, will provide insight as to which control method is capable of maximizing the water quality of the ponds at an aesthetically acceptable level.

Chapter 3

Research Objectives

Water quality within the stormwater retention basins of Winnipeg has been an important issue in previous years due to the proliferation of aquatic weeds in and around the ponds. Monitoring the water quality was performed in past years; however, an extensive water quality assessment of those ponds has not been undertaken, resulting in a lack of available data with which to asses their overall status.

During the spring and summer of 1998, a large-scale investigation of various water quality parameters was undertaken in order to provide important baseline information for the city to refer to in future years. Monitoring the basins for a five-month period, it was hoped, would provide insight into the overall characteristics within Winnipeg's SRBs.

Because of the state of eutrophication of many of the SRBs, and the numerous complaints the City of Winnipeg has received from property owners, the City of Winnipeg has tried to find a feasible method of maintaining the basins in an acceptable manner. In short, the 1998 SRB study had the following objectives:

1. To produce an all-inclusive database of water quality parameters.
2. To use the data obtained from laboratory analysis to determine the behaviour of the basins over the growing season during the summer of 1998.

3. To asses control method effects regarding a herbicide application program using the herbicides Karmex-DF and Reglone-A, and an aquatic-weed harvesting program, which were implemented by the City of Winnipeg.
4. To compare the use of the three aforementioned control methods and evaluate their effectiveness in destroying aquatic weeds.

In order to meet the stated objectives, an intensive sampling and analysis scheme was carried out from May to September of 1998 on 58 separate SRBs. Water quality parameters collected included: total suspended solids, turbidity, transparency, chlorophyll-a, fecal coliforms, dissolved oxygen, pH, various nitrogen and phosphorus forms, and temperature.

Chapter 4

Materials and Methods

4.1 Sample Collection

Prior to actual sample collection in the SRBs, several steps were carried out in order to ensure the acquisition of the most accurate results, both in the field and laboratory. Three different types of sample bottles were utilized. A 200mL Nalgene bottle collected samples for chlorophyll-a analysis, a 50mL screw-top glass test tube collected the samples for fecal coliform analysis, and a 1 L Nalgene bottle collected water for the rest of the test parameters. After week 5, the 1L sample bottles were pre-rinsed with hot 0.1M hydrochloric acid (HCl) and rinsed five times with de-ionized water in order to help alleviate phosphorus contamination from the dishwasher. Fecal coliform collection vials were sterilized at 121°C for 20 minutes the day before samples were gathered. Three different coolers were filled with the empty sample bottles and packed with frozen ice packs the morning of each sampling day.

Sample collection was carried out every two weeks starting at the beginning of May and finishing at the end of September. A one-month sampling interval occurred between the last two sampling periods, due to time constraints of the individuals involved. The sampling weeks and their corresponding dates are given in Table 4.1.

Table 4.1: Sample Schedule

Sampling Week	Dates of Sample Interval
1	May 4 – May 9
2	May 18 – May 22
3	June 2 – June 4
4	June 15 – June 17
5	June 30 – July 3
6	July 13 – July 17
7	July 27 – July 29
8	August 10 – August 13
9	August 24 – August 27
10	September 21 – September 23

Dates of sampling during the first week of the two-week interval were determined based on the weather conditions. Sampling started at approximately 7 a.m. and finished between 1 and 3 p.m. A four-meter aluminum canoe was paddled into the deepwater portion of each pond and the three different samples were collected by submerging the bottles below the surface to a depth of approximately 20cm. Fecal coliform test tubes were opened at the collection depth with the open end directed into the oncoming, wind-induced current as outlined in Standard Methods (1995). The other two bottles were already open prior to submergence, but the process was done very quickly and surface water entrapment was minimal. Sampling was carried out at one location on each pond as it was believed that composite sampling in this type of experiment (where the medium to be collected is well mixed) would not provide a sample that was more reflective of the basins characteristics. After sample gathering, basin depth was determined by dropping a 2.5cm by 5cm piece of plywood marked with measured graduations to the bottom. In certain instances, the depth of the basin was greater than the length of the measuring stick, in which case the secchi disk was dropped to the bottom and the depth was determined by measuring the rope that was submerged. Transparency, or secchi depth, was determined next. After this, analysis of dissolved oxygen (DO) and temperature were carried out.

Subsequent to sample collection and field analysis measurements, a visual observation was made from the centre of each pond. Basins were qualitatively assessed based on various parameters. Clarity was categorized as being poor, good, or excellent. Any odours were described as best as possible and classified based on the strength. The conditions of the banks were summarized and the presence and approximate quantity of vegetation was determined. The presence of purple loosestrife was recorded and presence of wildlife was also noted. The qualitative SRB data for each sampling week is summarized in APPENDIX D.

Sampling was carried out on 10 different weeks. During week 1 only 55 ponds were analysed. Week 2 resulted in the addition of 2 more ponds to the sampling program and allowed for the sampling of a pond that was previously inaccessible, resulting in the final number of 58 to be analysed for the remainder of the summer. Parameters were decided on and collected according to previous sampling regimes done by the City of Winnipeg. All parameters were determined for every week with the exception of total Kjeldahl nitrogen and total phosphorus, which were determined on week 1, 3, 5, 7, 9, and 10. Nitrate, ammonia, and orthophosphate were not determined on week 2. Omissions were made because of time concerns.

4.2 Sample Storage

After sample collection from the SRBs, samples were separated into their three respective coolers. When the sampling day was finished, samples were taken back to the Environmental Engineering Laboratory to be stored until sample analysis was carried out the following week.

The microbiological and chlorophyll-a sample bottles were immediately stored in a refrigerator at between 0°C and 4°C.

Before storing, the pH of the water in the 1L-sample bottles was taken. Subsequent to this, approximately 25mL of shaken sample was poured into a small sample vial for orthophosphate analysis. This sample was immediately frozen at –10°C until analysis, as outlined in Standard Methods (1995). When the aforementioned measurements and divisions had been made, the sample bottles were acidified using concentrated sulfuric acid to lower the pH to 3.5 in order to prevent ammonia volatilization. The sample bottles were then stored for up to one week prior to analysis in an environmental chamber at between 0°C and 4°C.

4.3 Sample Analysis

4.3.1-pH

pH values for each sample bottle were determined using a Fisher Accumet 50 pH meter with a combination Orion pH/redox probe. Prior to measurement of each day's collected samples, the pH meter was calibrated using 4.0, 7.0 and 10.0 buffers. The probe was submerged just below the surface of the sample water, the meter was allowed to stabilize, and the reading taken. One measurement was taken per sample.

4.3.2-Total Suspended Solids

Crucibles for TSS analysis were prepared using Whatman 934-AH glass microfibre filters and dried at 103°C for at least 5 hours. They were placed in a dessicator and allowed to cool for at least 1 hour prior to obtaining the empty weight. A recorded volume of sample was filtered through each crucible until filtration became slow due to blockage. A maximum volume of 500mL was filtered. Samples were dried as mentioned previously and allowed to cool prior to obtaining the dry weight. Duplicate samples were run the first three sampling weeks. It was determined that the precision was high (>95%) between duplicates and single samples were run after that point. Averages of duplicates were recorded as the final values.

4.3.3-Turbidity

Turbidity was determined using a Hach Portable Turbidity Meter that was pre-calibrated each analysis week using Gelex standards. The turbidity was determined based on the instructions given with that instrument. Duplicate samples were measured and the average was recorded as the final value.

4.3.4-Transparency

Transparency was determined in the SRBs by measuring the depth at which a 20cm diameter secchi disk, when lowered, disappeared from sight under water, and the depth when the same disk re-appeared when raised. The average of the two depths determined the secchi depth and this was the final recorded value. The secchi depth measurement was carried out on the shaded side of the boat where possible; however, at high noon this was not achievable. Measurement in the shade and sun in a pond of exceptional clarity revealed that the secchi depth was altered by only 1 or 2 cm under the different light conditions.

4.3.5-Chlorophyll-a Analysis

Chlorophyll-a analysis was carried out using a method from Manitoba Environment (1989). The refrigerated samples were filtered within 48 hours of sampling. Approximately 100mL of each of the samples were filtered under vacuum pressure through Whatman GF/B glass fibre filters with a 1μm pore size. The amount of sample used depended on the amount of suspended material present that hindered passage through the filters. The filters were placed at the bottom of a 50mL disposable test tube sealed and frozen at –20°C until they could be analysed.

At analysis time, the test tubes were removed from the freezer and to each one, 10mL of 90% (v/v) acid-free methanol was added, ensuring that the filter was wet. The samples were re-covered to prevent evaporation and placed in the dark at room temperature for 24 hours. They were shaken periodically.

After the 24-hour period the filters were removed from the test tubes, and the tubes were covered and centrifuged for 10 minutes at 3000 rpm. A 3mL aliquot of each sample was pipetted into a disposable spectrophotometer cuvette after centrifugation. The sample absorbance was measured at 665nm and 750nm using a spectrophotometer with a 0.5nm to 2nm slit width. The spectrophotometer was zeroed every ten samples using a blank of methanol.

After the initial reading, 0.1mL of 0.01M hydrochloric acid was added to each cuvette, they were mixed, and the cuvettes were re-sealed and placed in the dark for one hour to allow the conversion of chlorophyll-a to its degradation product, pheophytin-a. The samples were re-analysed on the spectrophotometer as previously outlined. One chlorophyll-a measurement was assessed for each sample. Calculations of chlorophyll-a were determined using the equation given in APPENDIX B.

4.3.6-Total Kjeldahl Nitrogen (TKN)

TKN samples were digested following the Semi-Micro Kjeldahl Method 4500-$N_{(org)}$-C, without ammonia removal, as given in Standard Methods (1995). A 50mL sample was digested, and the concentrate was re-diluted and mixed in a 50mL culture tube with a Bakelite cap containing a Teflon liner. The TKN was determined using Standard Methods (1995) 4500-NH_3-H, Automated Phenate Method with an on-line 4M sodium hydroxide neutralization step. Duplicate samples were digested for every sixth sample, and staggered so that each week a different sample would be duplicated. Duplicate samples were averaged. A series of digested urea working standards were made and run at the beginning and end of the sample run. Standard curves were created in the same manner for all automated nutrient analysis methods and an example of a calculation is given in APPENDIX B.

4.3.7-Ammonia

Ammonia was analysed using the automated phenate method 4500-NH_3-H given in Standard Methods (1995). Duplicates of ammonia were only run if unusual results were obtained.

4.3.8-Nitrate

Nitrate concentrations were obtained using the 4500-NO_3-F Automated Cadmium Reduction Method as given in Standard Methods (1995). Duplicate analyses were completed for those samples that had unusually high values. Calibration curves were drawn using a range of potassium nitrate working standards made monthly.

4.3.9-Total Phosphorus and Orthophosphate

Digestion of samples for total phosphorus followed 4500-P-B-5 in Standard Methods (1995), except the digestion acid was made of 300mL concentrated sulfuric acid and 4mL of concentrated nitric acid diluted to 1L.

Total phosphorus and thawed orthophosphate samples were analysed during week 1 and 3 using 4500-P-F Automated Ascorbic Acid Reduction Method, as given in Standard Methods (1995). Poor results led to the re-installation of an automated stannous chloride method developed in the Environmental Engineering Laboratory, which has undergone quality assurance by the head technician and provided excellent results with good precision. The automated stannous chloride method required the following reagents:

1. Ammonia Molybdate Solution – 280mL of concentrated sulfuric acid is added to 400mL de-ionized water. 250g of ammonium molybdate are dissolved in 175mL de-ionized and added to the first solution and diluted to 1L.
2. Stannous Chloride Stock Solution – 5g of stannous chloride is dissolved in 25mL of hydrochloric acid and diluted to 500mL. This solution is stable for only 2 weeks.
3. Stannous Chloride Working Solution – Add 25mL hydrochloric acid, 30mL of stock solution and dilute to 500mL. 0.25mL of Ultrawet wetting agent should be added.

Autoanalysis was determined using a Technicon autoanalyser. The principle of the method follows the reaction between orthophosphate with ammonium molybdate to form heteropoly molybdophosphoric acid, which is reduced to molybdenum blue using a stannous chloride and sulfuric acid medium. The intensity of the molybdenum blue colour is determined colorimetrically at 660nm (Tingley, 1987).

Total phosphorus results were plagued with contamination and losses due to the method of sample digestion, where quantities of algae adhered to the sides of the flasks used. Duplicates were digested and run on every third total phosphorus sample, which helped to illustrate the contamination. Several samples were re-digested, yet contamination still affected certain results. Duplicates were run only on unusual orthophosphate samples. In order to eliminate any poor results, a ratio of orthophosphate to total phosphorus was determined. Values exceeding 1.0 were eliminated so as to maintain reasonable results with which to make plausible estimations of the behaviour of the total phosphorus over time. Only 7% of the total phosphorus results exceeded the ratio and were eliminated.

4.3.10-Dissolved Oxygen and Temperature

Dissolved oxygen (DO) and temperature were determined on the SRBs using 4500-O-G Membrane Electrode Method as outlined in Standard Methods (1995). The probe was pre-calibrated using 4500-O-B Iodometric Methods given in Standard Methods (1995) using de-ionized water as the calibrating agent. This was done each morning before sampling. The probe was contained in a protective housing which vibrated to provide agitation of water, allowing the probe to stabilize more readily.

The probe housing was taped to the depth measuring stick, allowing approximately 5 cm between the bottom of the probe housing and the bottom of the stick in order to eliminate the possibility of submerging the probe in the bottom sediment. The DO and temperature were taken at three depths. Surface values were determined by submerging the probe just below the water surface. Middle values were determined based on the depth of the basin and the probe was lowered to approximately mid-depth. Bottom measurements were determined by lowering the probe down to the sediment, or if a lake was too deep to approximately 2.5 m, which was the length of the stick.

4.3.11-Fecal Coliforms

Fecal coliforms were determined using a modified Standard Methods (1998) procedure given in Section 9222. M-FC media was prepared as per instructions given by the manufacturer. A volume of agar ranging from 5mL to 7mL was dispensed into 12mm petrie dishes and refrigerated until required. Duplicate plates were spread with sample directly and from a one in ten dilution using sterile dilution water as the diluting agent. A 250μL sample of each dilution was spread on the pre-prepared M-FC plates and the plates were incubated. Plates were analysed, appropriate colonies were counted after 24 hours, and colony counts were averaged in order to compose the final number.

Potential experimental errors in this procedure may have been caused by *Escherichia coli*, the predominant fecal coliform organism, which has a very sensitive upper temperature range of 45°C. After this temperature is exceeded, the bacteria rapidly die-off (Standard Methods, 1998; Prescott et al., 1990). Absence of organisms may have taken place for this reason.

4.4 Stormwater Retention Basin Characteristics

4.4.1-Numbering

The two identifying numbers for each SRB were in place prior to this study, issued by the City of Winnipeg. The first number represents the approximate region where the basin is located in the city and the second number is given based on the chronological order of construction of the basins in that area. For example, SRBs 2-2 and 2-4 are located in the Parkdale drainage area of St. James and 2-4 is the more recently constructed basin of the two (Wardrop, 1998). The various SRBs and their locations are given in APPENDIX C.

4.4.2-Structure of SRBs

SRBs' construction is fairly consistent, with an average surface area of 2.8ha +/- 2.3ha that comprises only 5.5% of the drainage area influencing them. Turnover in the basins is approximately 2.8 times per year, making them relatively stagnant for their size. The basins have a slope of approximately 7:1 (horizontal to vertical) with large stones covering the shores and extending into the ponds for 2m. Stone inclusion helps to reduce erosion and, combined with gradual slope, it aids in lowering the probability of accidental drowning of small children. In recently constructed larger ponds, the slope of the basins changes approximately 3m from shore to a ratio of 4:1. The steeper slopes are designed to limit solar irradiance reaching the pond bottom (UMA Engineering Ltd., 1992-cited in Wardrop, 1998).

4.5 Aquatic Weed Control Procedure

4.5.1-Herbicide Application

Herbicide application was undertaken by the city of Winnipeg during the summer of 1998. Karmex-DF was applied to 17% of the 58 analysed SRBs. Application was carried out by dragging a cloth sack filled with the herbicide in a granular form alongside a boat, at a rate of 25kg/ha·m of depth (Dupont Canada Inc., 1996-cited in Wardrop and Elefsiniotis, 1998). Reglone-A was applied to 10% of the SRBs by spraying a mixture of 1:4 parts of Reglone-A to water over the SRB surface. An application of 22L/ha was used as the producers recommended this amount be used in 1.5m of water or less, a range of depth many of the basins fell between (Zeneca Agro, 1995-cited in Wardrop and Elefsiniotis, 1998). Table 4.2 shows the herbicide treated ponds.

Table 4.2: Schedule of Herbicide Treated SRBs

Ponds Treated with Karmex-DF	
SRB Number	Date of Application
2-4	June 4
3-10	June 4
4-9	June 4
5-9	July 17
5-16	June 8
5-18	June 8
6-6	July 17
6-12	July 17
6-13	July 17
6-20	July 22

Ponds Treated with Reglone-A	
SRB Number	Date of Application
4-2	June 8
4-6	June 9
4-10	June 8
5-9	June 9
5-15	June 9
5-21	June 9

4.5.2-Aquatic Weed Harvesting

A diesel-powered harvester was used to cut and remove aquatic macrophytes from the basins. Submerged vegetation was cut to a maximum depth of 1.5m by a 2.15m wide cutting head, moved up a conveyor to a storage area, transferred to a truck, and transported to a landfill. Only large SRBs were harvested as the harvester beached itself any closer then 3m to the shoreline (Wardrop, 1998). The harvested SRBs are given in Table 4.3.

Table 4.3: Schedule of Harvested SRBs

Harvested SRBs			
SRB Number	Date of Harvesting*	SRB Number	Date of Harvesting*
3-2	July 25	5-7	August 11
3-3	July 29	5-8	August 17
3-4	July 31	6-7	July 15
3-5	August 10	6-8	July 3
3-9	August 6	6-9	July 7
4-2	June 15	6-15	July 23
4-4	July 14	6-16	July 24
4-5	June 18	6-17	July 2
5-5	August 12	6-18	July 20
5-6	August 13	6-19	July 13
		6-20	June 24

*Refers to the date when harvesting was finished

4.6 Qualitative Assurance

Various steps were taken in order to optimize the accuracy of results. These assurances are given in the specific sections on sample and methods of analysis and can be found throughout Chapter 4.

4.7 Calculations and Statistics

Nutrient values were determined using a range of standards given in the appropriate methods in Chapter 4. A regression function was determined by applying a trendline to the concentration and the corresponding peak height. This was completed using Microsoft Excel. The generated regression equation was applied to determine the final concentrations. Calculations of the mean and median values and other statistics were also determined using Microsoft Excel. Chlorophyll-a values were established using an equation given in the source of the method illustrated in section 4.3.5. The aforementioned parameters can be found in APPENDIX B.

Chapter 5

Results and Discussion

5.1 Suspended Particulates and Transparency

Chlorophyll-a, signifying phytoplanktonic algae, represents a portion of the suspended particulates and biological activity in the water column. Total suspended solids, turbidity, and transparency all affect the biological regime within a lake. They are responsible as a whole for the maximum depth to which aquatic plants and algae are able to grow (Reimer, 1984). With increasing wind and waves, sediment re-suspension lowers light penetration and favours phytoplankton dominance in a lake (Somlyody, 1982-cited in Hamilton and Mitchell, 1997). In addition, large quantities of suspended sediment decrease zooplankton-grazing efficiency, reducing phytoplankton removal (Arruda et al., 1983-cited in Jeppesen et al., 1997). Water quality effects in the stormwater retention basins in Winnipeg can be assessed only by examining the intricate relationship between these parameters. All of the raw numbers pertaining to these and other water quality parameters obtained in the study can be consulted in APPENDIX A.

5.1.1-Chlorophyll-a

Chlorophyll-a concentrations have been linked to the extent of vegetation within a lake. When macrophytes dominate, concentrations of chlorophyll-a in the water column tend to be low, and when chlorophyll-a values are high, planktonic algae seem to dominate (Moss et al., 1997). This was qualitatively observed within the SRBs in Winnipeg.

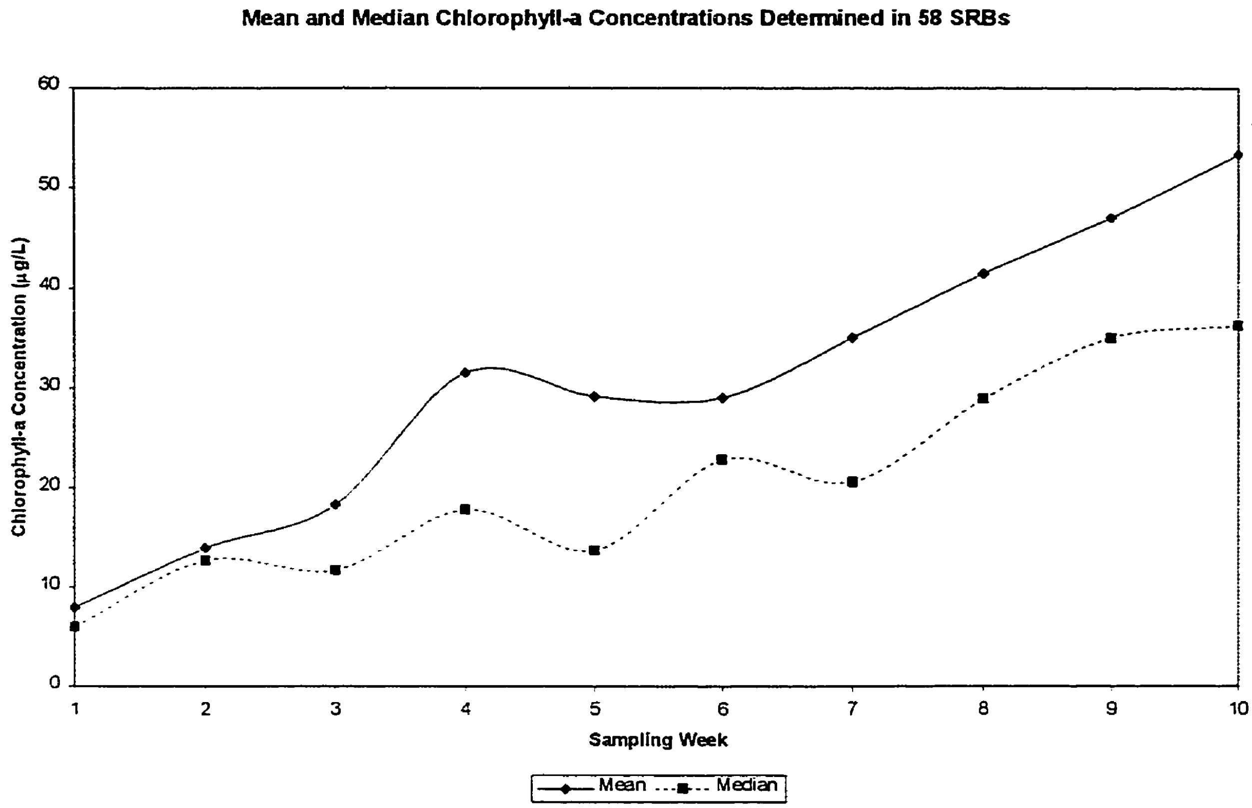

Figure 5.1

Figure 5.1 shows the mean and median values for chlorophyll-a increased over the summer, and from their divergence after week 2's sample one can surmise that the variations in chlorophyll-a concentrations between the SRBs increased as the summer progressed as the quantity of algae fluctuated between different basins. These variations are probably a result of the control practices and age of the basins. Control practices may have affected the type of vegetation present, decreasing the amount of macrophytes and increasing the quantity of phytoplanktonic algae. The older basins would have had a greater quantity of dead organic material at the beginning of the growing season and could have liberated greater nutrients than other younger basins. An overall increase in the chlorophyll-a concentrations would be expected over the growing season as the quantity of phytoplanktonic algae increased, resulting in biomass accumulation within the basins. Algal cells growing in lakes on the prairies have been found to double in numbers every day under exponential growth conditions. This rapid growth is the result of prairie lakes and reservoirs being naturally eutrophic due to the high nutrient loading from agricultural lands, high solar inputs, and shallowness. Because of the natural conditions, very little room is available for anthropogenic inputs without accelerating algal growth (Barica, 1993).

A more illustrative example of the changes in chlorophyll-a concentrations with time may be observed in Figure 5.2.

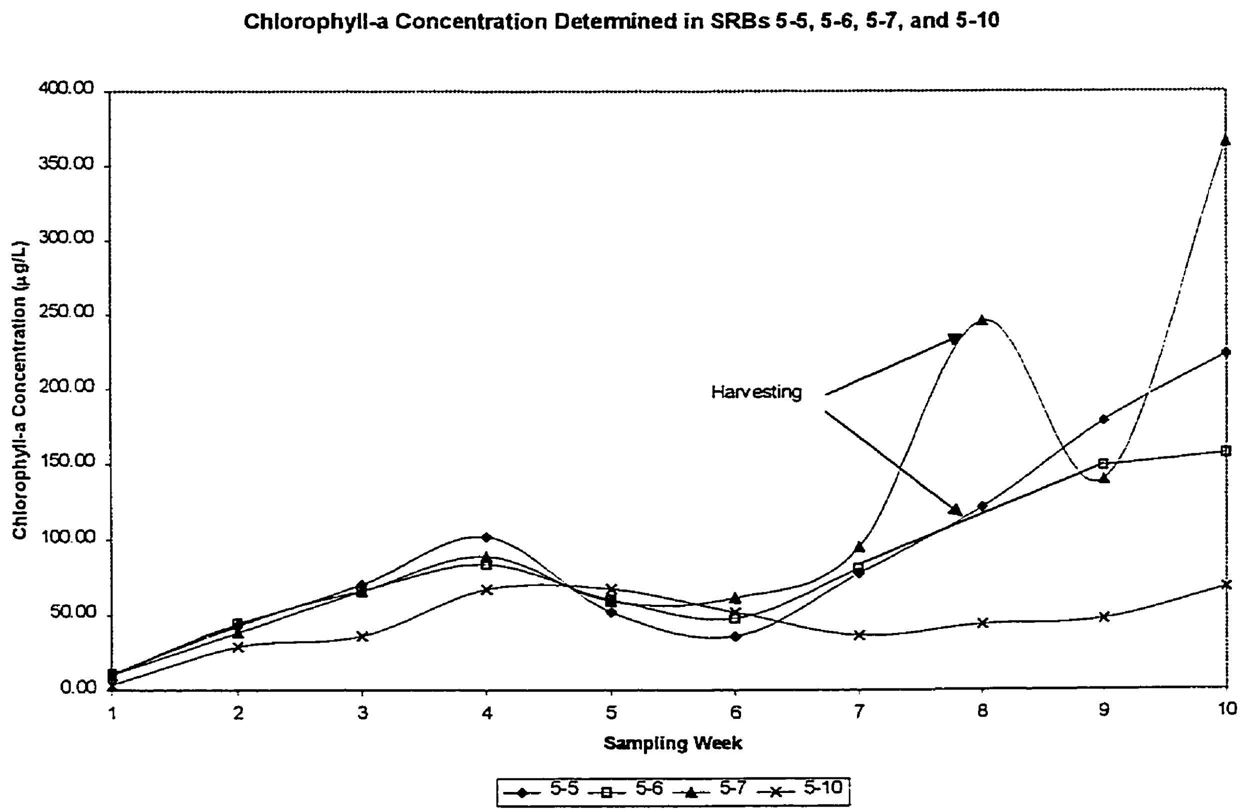

Figure 5.2

SRBs in Southdale were characteristically green during the summer of 1998, and the intensity of the green colour was usually associated with a high concentration of planktonic algae. Figure 5.2 illustrates that the concentration increased over time, but oscillated, as is observed in SRB 5-7. Algae, like other organisms, are dependent on certain parameters, such as light and nutrients, to be maintained at levels required for growth. Smooth curves of chlorophyll-a concentration over time generally illustrate a more sustainable situation as may be observed in pond 5-10 (Barica, 1993). Pond 5-7's oscillations are a sign of instability where the bloom of algae observed during week 8 partially collapsed due to a lack of one or more important factors for growth, such as light or nutrients. An increase in chlorophyll-a between week 9 and 10 illustrated the regeneration of algae due to the sudden availability of the same limiting factor. Concentrations of 20 to 30 μg/L of chlorophyll-a are said to be sustainable in an aquatic ecosystem, whereas concentrations greater than 100 to 150 μg/L result in the probability that at least 50% that the bloom will collapse (Barica, 1993). This is an approximate relationship because the stability of an algal bloom also depends on the nature of the water body. Since the aforementioned probability determination used the results of a natural lake it seems reasonable that the probability of collapse of an algal bloom may be greater in an SRB where conditions are more stressful to the organisms.

5.1.2-Total Suspended Solids

Like chlorophyll-a, the total suspended solids (TSS) increased constantly over the summer. Figure 5.3 shows the overall trend for all 58 ponds and indicates a relatively constant variability between them, in terms of TSS, from week to week. Initially high concentrations during week 1 of around 23 mg/L show an unusual situation that did not follow the trend and was a result of intense weather activity during that week. On the first day of sampling, winds reached periodic yet constant gusts of 80 km/h which would help to explain the high quantity of suspended sediment in the water column during that week (Environment Canada, 1998). A qualitative profile of the wind conditions during each sampling week is located in APPENDIX D.

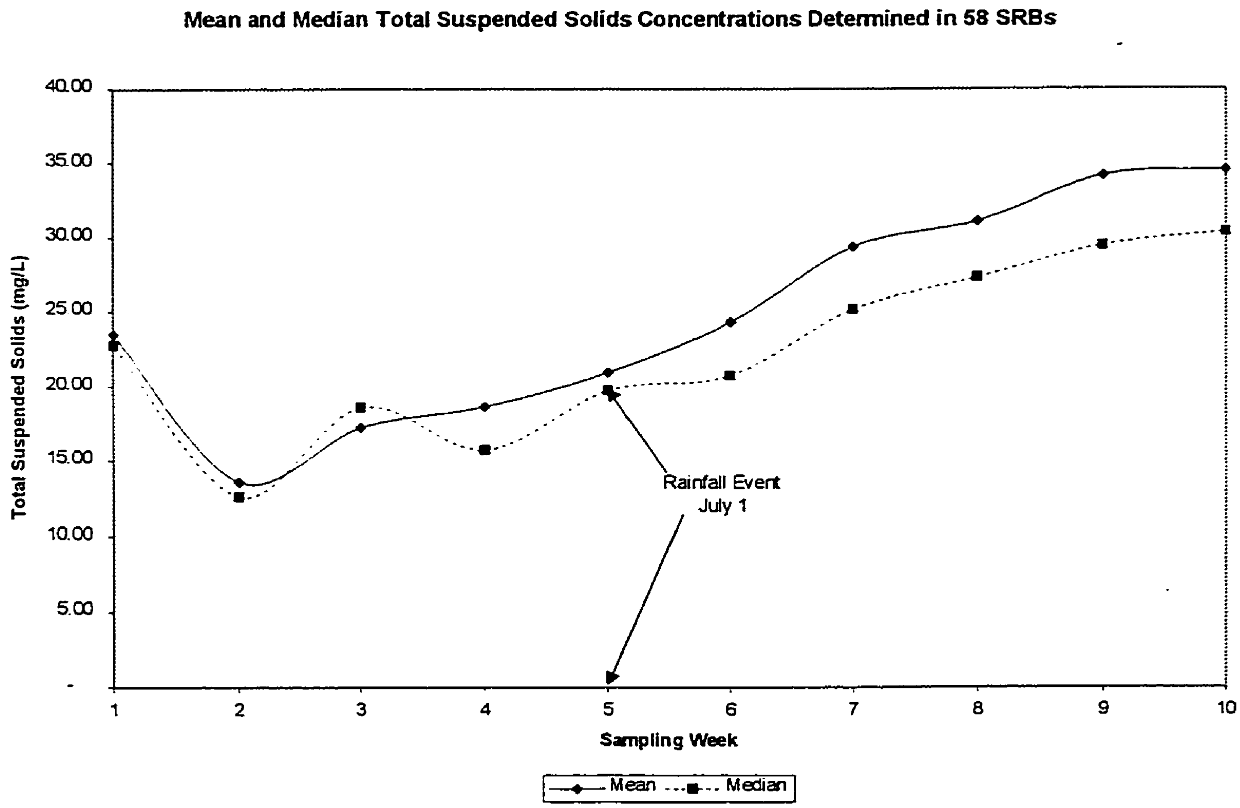

Figure 5.3

The presence of submerged plants was minor during the first week of sampling and therefore, a lack of aquatic macrophytes in the ponds during week 1 was thought to also have contributed to the relative ease of sediment re-suspension. Macrophytes are proficient in reducing currents able to stir up bottom dregs, and hold sediment in place with their roots (Reimer, 1984).

It has been stated that the TSS should increase after storm events because large amounts of sediment are picked up off of paved surfaces and carried in run-off, which is expelled into a water body (Clark and Alkhatib, 1999). From the results in Figure 5.3 it was observed that large influxes of stormwater played a minor role in overall TSS concentrations, as there were no excessive peaks after storm events. The dates of various storm events are located in APPENDIX D. It was surmised that the increase in the sediment within the basins was most effected by biomass accumulation from algal production.

5.1.3-Turbidity

In Figure 5.4, one can observe the change in the mean turbidity values of the 58 SRBs over time.

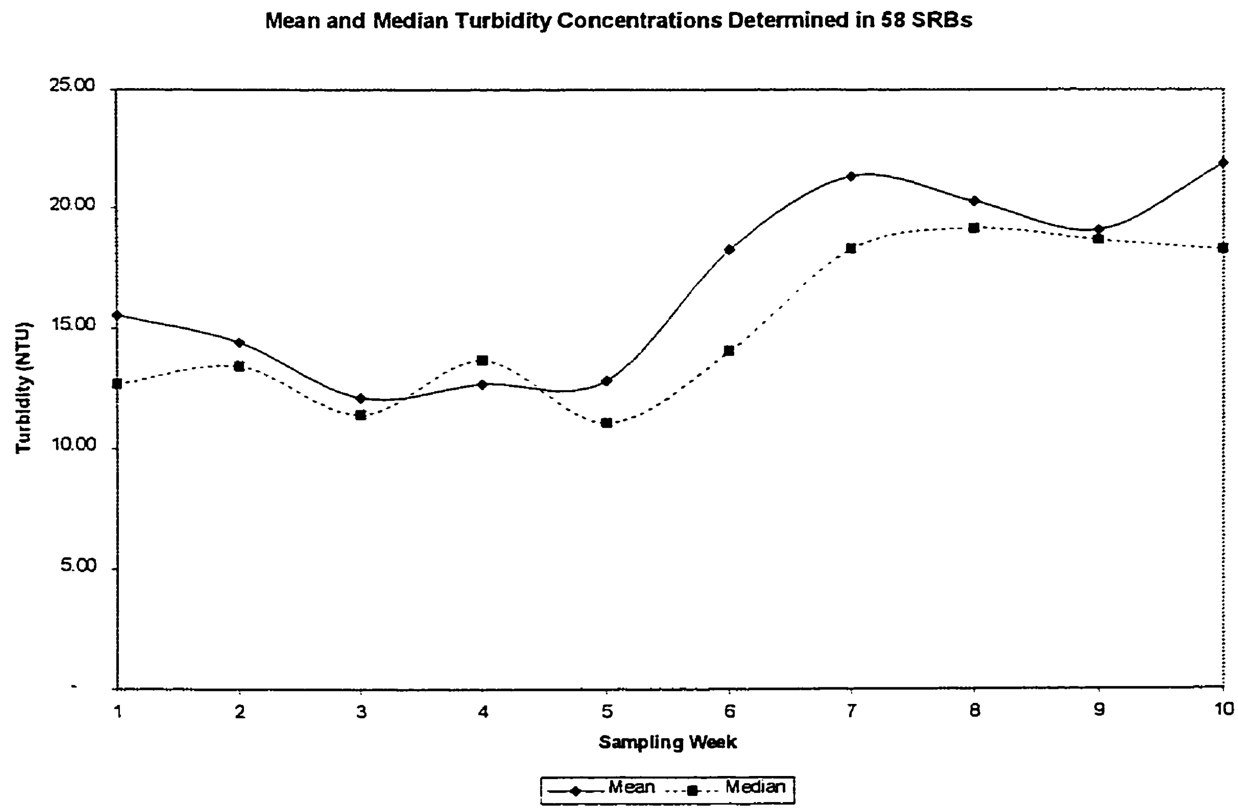

Figure 5.4

The turbidity remained between 11 and 15.5 NTUs until week 5, after which the turbidity increased to between 18 and 21 NTUs and remained there for the duration of the summer. A reason for the observed increase in turbidity between week 5 to the maximum concentration during week 7 by 10 NTUs may have been a result of very dry conditions in July (weeks 5 and 6) where water levels were notably lower. Rainfall data for the sampling period is provided in APPENDIX D. A decrease in water level would have provided improved conditions for sediment re-suspension through wind mixing and concentrated colloid particles already present, resulting in an increase in turbidity.

It was thought that turbidity would closely follow the changes in the TSS over time and in order to eliminate possible redundant explanations, a regression analysis of the effects of TSS on turbidity was performed. It was hoped that there would be a direct correlation between the two parameters; however, it was found that the error variance was non-normally distributed and hence elimination of one of the parameters in the discussion could not be carried out confidently.

5.1.4-Transparency

Transparency showed the opposite relationship of the other three parameters in this group, where it decreased over time, as seen in Figure 5.5. This relationship made sense as the depth to which light could penetrate would be directly related to the particulate material in the water. Transparency's decrease over time is inverse to the pattern of turbidity, whereby the transparency remained fairly constant and then decreased quite rapidly, returning to a fairly constant plateau for the remainder of the experiment. With increasing algal populations suspended in the water column over the summer, this relationship seemed reasonable. As previously mentioned, a period of calm during week 5 may also have resulted in better water clarity, and hence, deeper light penetration at that time.

The main factors thought to contribute to a decrease in transparency values were phytoplankton concentrations, the amount of suspended sediment and weather conditions.

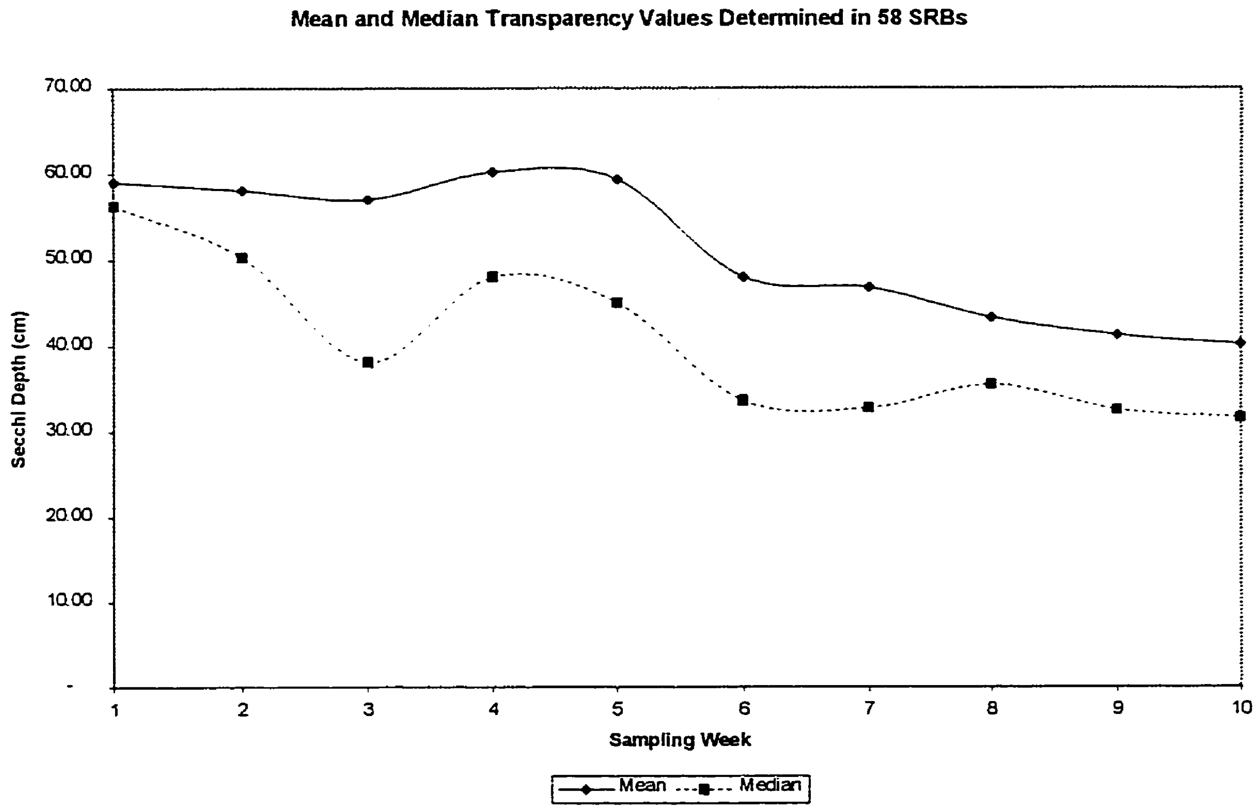

Figure 5.5

Colour played a role in the ponds along Bishop Grandin and Kenaston Blvd., 5-11, 5-12, 5-13, 6-4 and 6-14, as these basins were stained a reddish brown colour. The reasons for the appearance of colour and its sole occurrence in this location are unknown.

5.2 Nutrients

Nutrients are a dynamic component of freshwater ecosystems. Aquatic organisms take up nitrogen and phosphorus, and the degree and speed of release upon death of the consumer organisms is dependent upon environmental conditions and the bacteria present through which they are mineralized (Mitchell, 1974). Respiration rates are faster in shallower lakes, resulting in more rapid turnover of nutrients and quicker production of biomass (Nixdorf and Deneke, 1997). The type of vegetation present is also important as the breakdown and turnover of nutrients present in algae occurs at a faster rate than in aquatic macrophytes as the amount of difficult-to-digest material is sufficiently less (Reimer, 1984).

According to Scheffer et al. (1993), increased nutrient loading is supposed to change a lake from a clear water, macrophyte-dominated state to a more turbid one, consisting for the most part of planktonic algae (cited in Kufel and Kufel, 1997). Since so many of the lakes were extremely turbid, it was thought that nutrient concentrations played a significant role in this project.

5.2.1-Total Kjeldahl Nitrogen

Over the sampling period there was an increase in the TKN in all ponds until week 10, when the values decreased. Figure 5.6 illustrates the overall trend in all of the sampled basins. As would be expected, the amount of TKN increased over the course of the summer due to increases in the quantity of proteinaceous materials that accumulated within algae in the water column (Wetzel, 1983). The proteins within the algal cells make up part of the organic nitrogen, which comprised the major portion of the nitrogen present in the SRBs during the summer of 1998. After week 9's samples the quantity of protein present dropped substantially, as the mean surface water temperature became less optimal for algal survival (APPENDIX A) and the algal cells died off and sunk. The average TKN values increased from approximately 1.5 mg/L to a maximum of 4.0 mg/L to a final sampling concentration of near 3.0 mg/L.

According to Wetzel (1983), in order for a basin to be considered hypereutrophic, the organic nitrogen concentration must exceed 1.2 mg/L, which the majority of the basins did for the sample period.

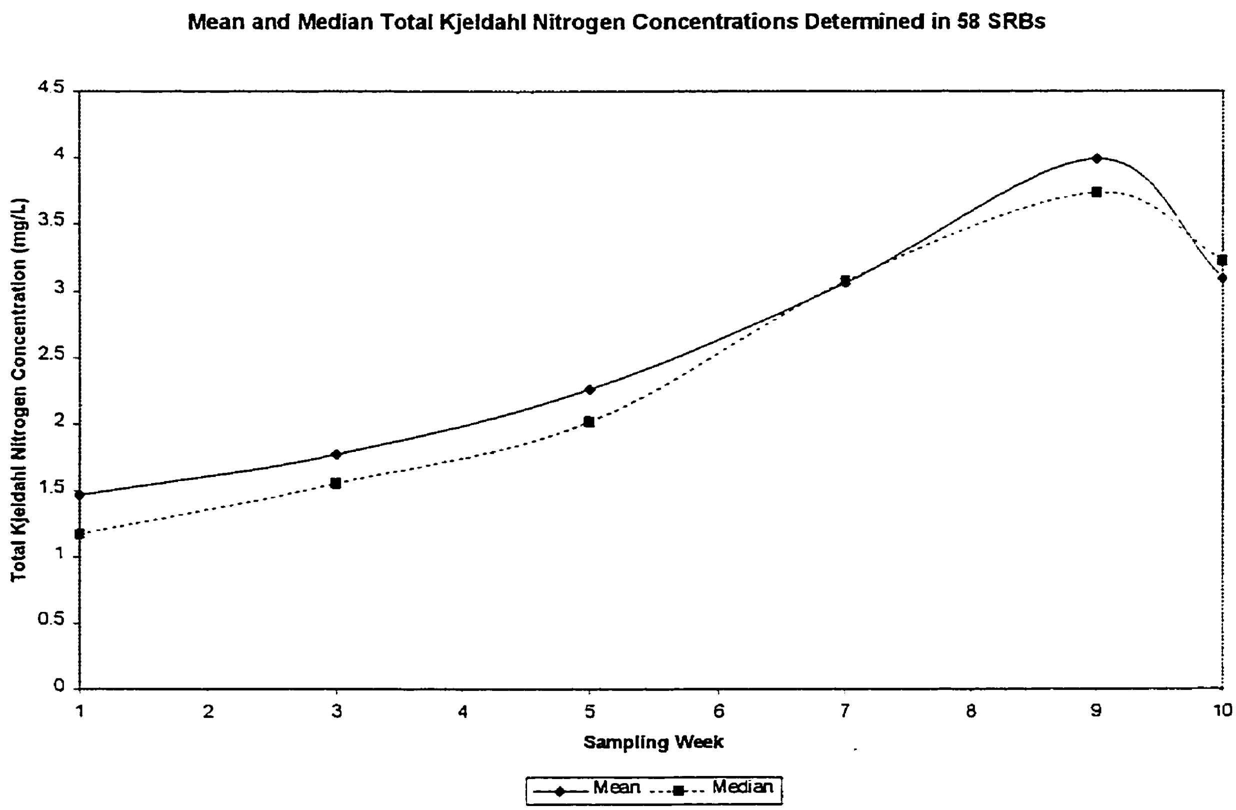

Figure 5.6

Figure 5.7 shows the trend in the TKN concentration on a smaller scale in the ponds of the Bunn's Creek drainage area in North Kildonan and Kilcona Park. Although there were more oscillations in the values over the summer, the overall trends in the basins follow the mean and median values closely.

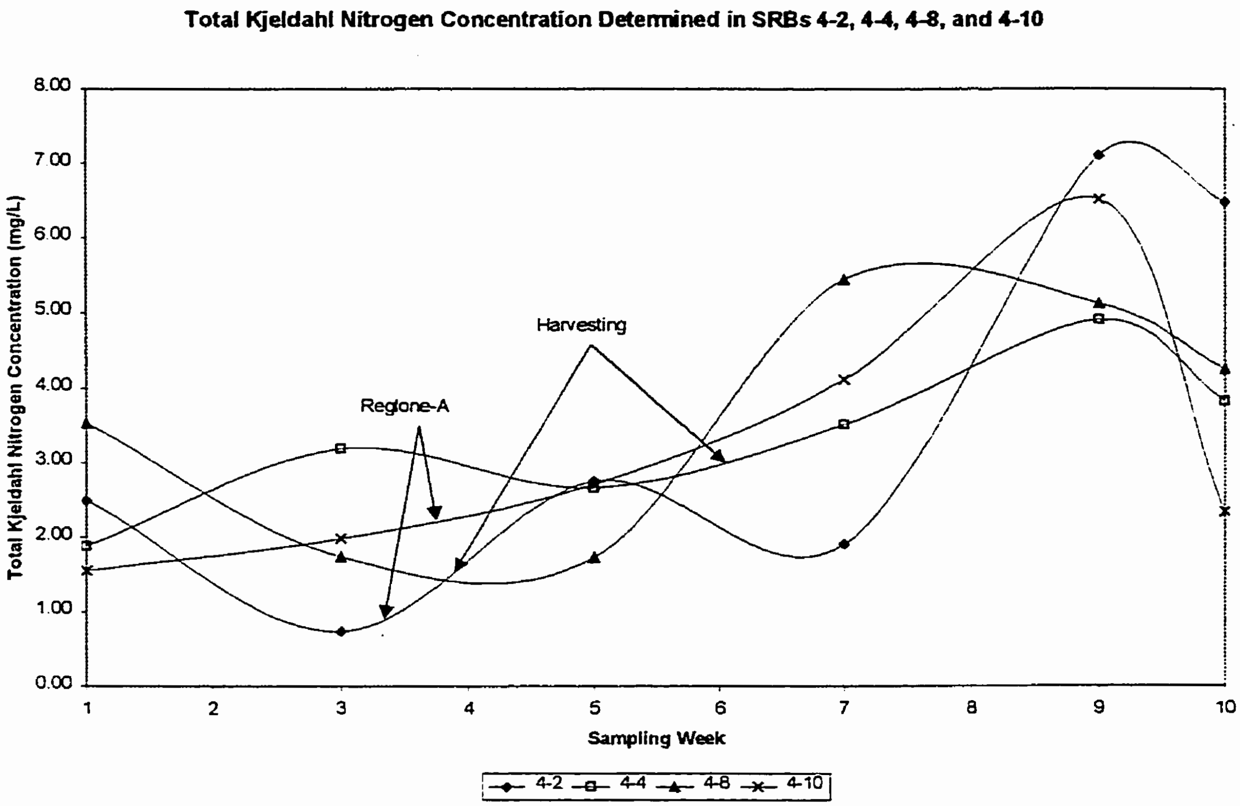

Figure 5.7

5.2.2-Ammonia

An important constituent of TKN is the nutrient ammonia. In this study it was observed that the ammonia concentration made up a very small proportion of the TKN concentration, as can be distinguished from the different scales of Figures 5.6 and 5.8. A uniform overall trend in the ammonia concentration was not observed for all of the SRBs; therefore, predictions as to how the basins performed in terms of this nutrient were hard to surmise. Figure 5.8 illustrates that the variability between sample basins for the monitoring period was quite significant, as the mean and median are not close to coinciding, as would be the case with normally distributed data. This was partly due to the method used to determine the ammonia values. During the phenate method of analysis, certain samples resulted in the production of poorly defined peaks that were artificially high. Since this relationship occurred in a majority of the basins in the northern and northeastern portions of the city it was attributable to potential chemical reactions within the water. This phenomenon was not observed in any of the other regions' basins.

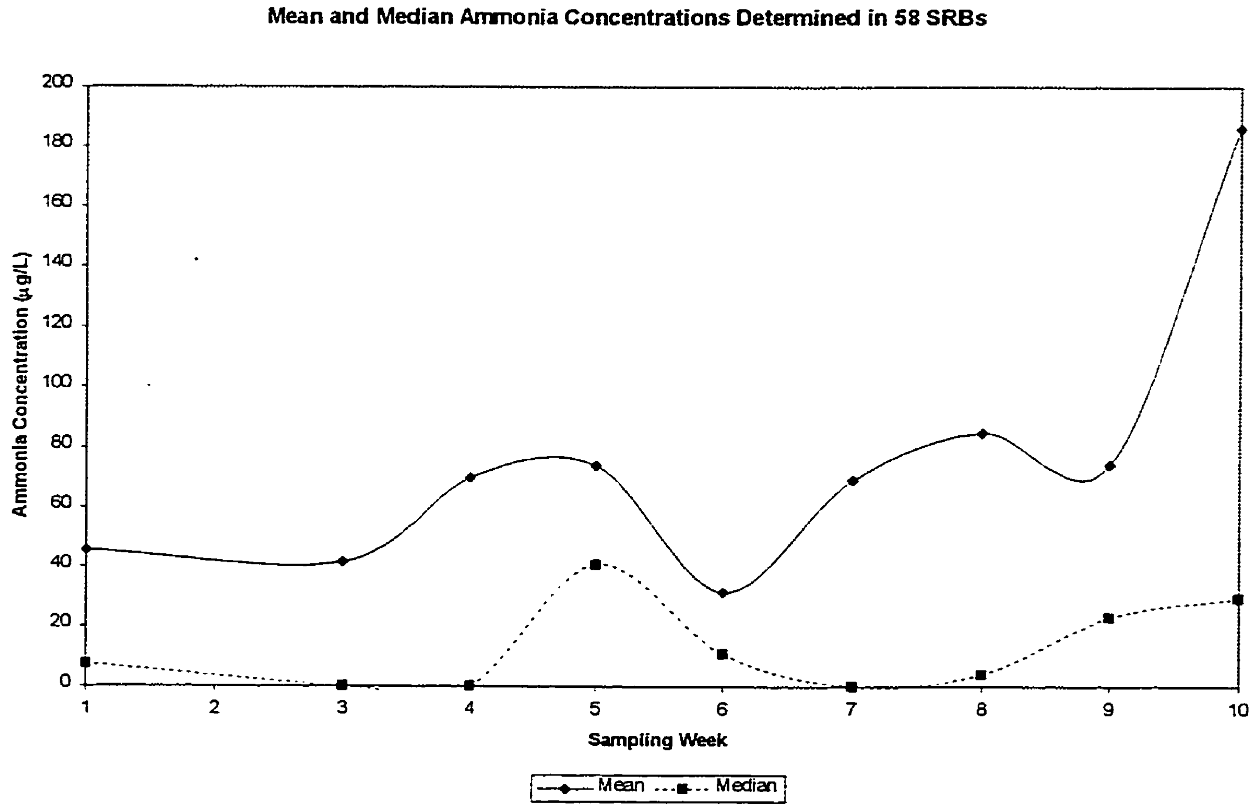

Figure 5.8

Observations made on Figure 5.8 illustrate two trends that were characteristic of many of the basins in terms of ammonia. A peak in the concentration during week 5, extending between June 30 and July 3, resulted in the maximum concentration in ammonia observed during the best part of the summer. The mean and median ammonia concentrations were approximately 75 µg/L and 40 µg/L, respectively. It was thought that this ammonia maximum was a result of the degradation of biomass by chemoheterotrophic bacteria (Wetzel, 1983), coupled with a week of very calm, hot, weather. Ammonia production from the degradation of proteins within the plant biomass was liberated, and coincided with a meteorological, high-pressure system. This calm allowed the build-up of ammonia in the surface water of the lakes due to a lack of mixing and absence of dilution throughout the entire water column. High mean temperatures during mid-summer (APPENDIX A) would have aided in the quick metabolic functioning of the decomposers that may have resulted in the large influx of ammonia into the water column.

Results such as those observed in Figure 5.10 (from nitrate analysis) illustrated that the nitrate concentration was very high during weeks 3 and 4. Therefore, another plausible reason for the high concentration of ammonia during week 5 may have been the assimilation of some of the excess nitrate into ammonia. This process dominates over nitrification in the lit portion of any lake (Wetzel, 1983).

Increases in the ammonia concentration at the end of the summer between weeks 8 and 10, as seen in Figure 5.8, may have occurred for two reasons. First, after week 9, when a decrease in the TKN concentration within the basins representing algal destruction occurred, one would expect to see the liberation of ammonia as a decay product. Second, elevated ammonia concentrations may have also resulted in part from the large influx of waterfowl feces during that period of time. In a study completed by Pettigrew et al. (1997), addition of waterfowl feces was found to increase the concentration of ammonia by up to 30 times the baseline concentrations in Delta Marsh. Since migrating geese and ducks inhabited many of the basins, with numbers ranging in the hundreds, this was thought to be a plausible explanation. A calm, sunny period during the last two weeks of sampling were thought to have amplified the large values of ammonia, for reasons outlined previously.

The aforementioned ammonia trends are illustrated further by observing the ammonia concentrations over the summer of 1998 in the SRBs of south St.Vital in Figure 5.9.

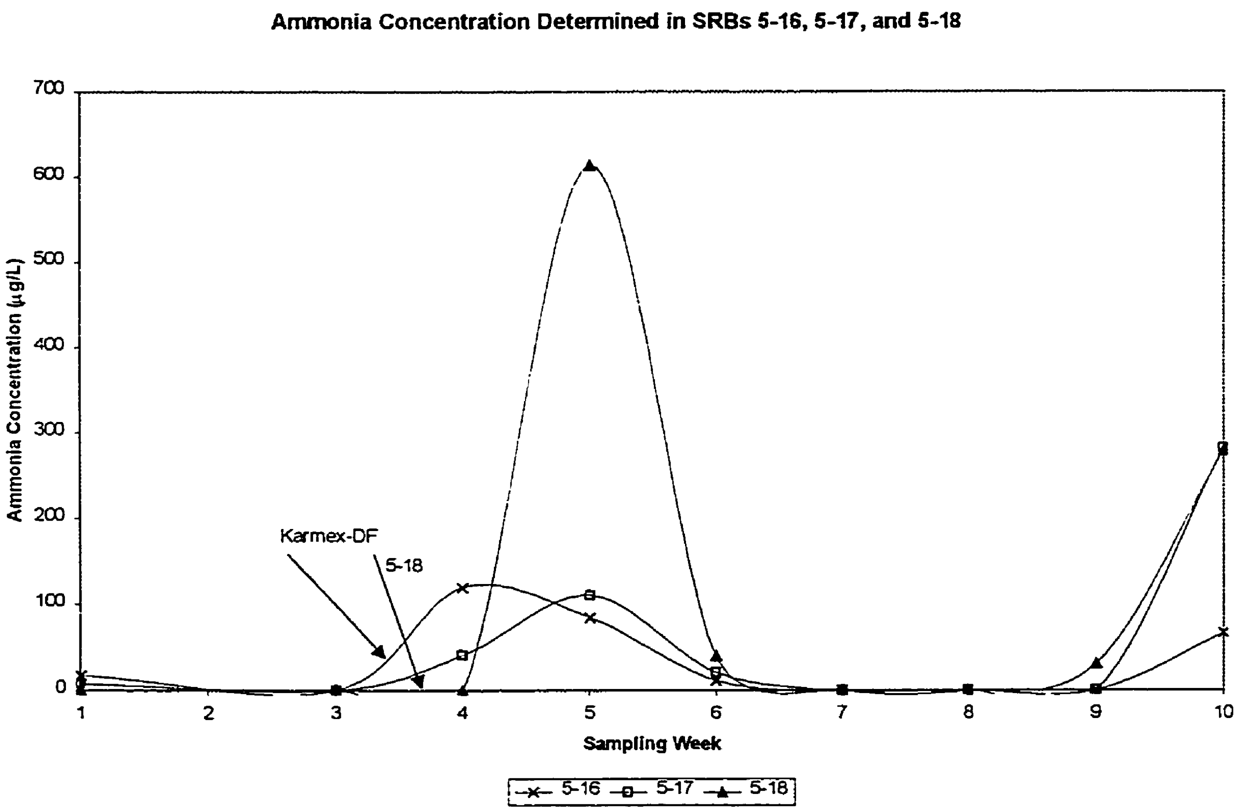

Figure 5.9

The graph shows variations in the ammonia concentrations within different basins within close proximity to each other. These variations are attributable to natural differentiation between the basins.

5.2.3-Nitrate

In addition to the ammonia concentrations, it was observed that nitrate did not follow any specific trends with respect to the growing season.

Overall, the nitrate concentrations observed in the ponds were low. APPENDIX A illustrates that sporadic peaks occurred in several ponds and then, in most cases, disappeared the following sampling week; of all of the analysed samples, 84% of the measurements did not show detectable nitrate concentrations.

An assessment of the average and median nitrate concentrations led one to discern that the variations between the basins skewed the average such that it was deceptively large at the beginning of the summer. Some of the high values observed are shown in Figure 5.10.

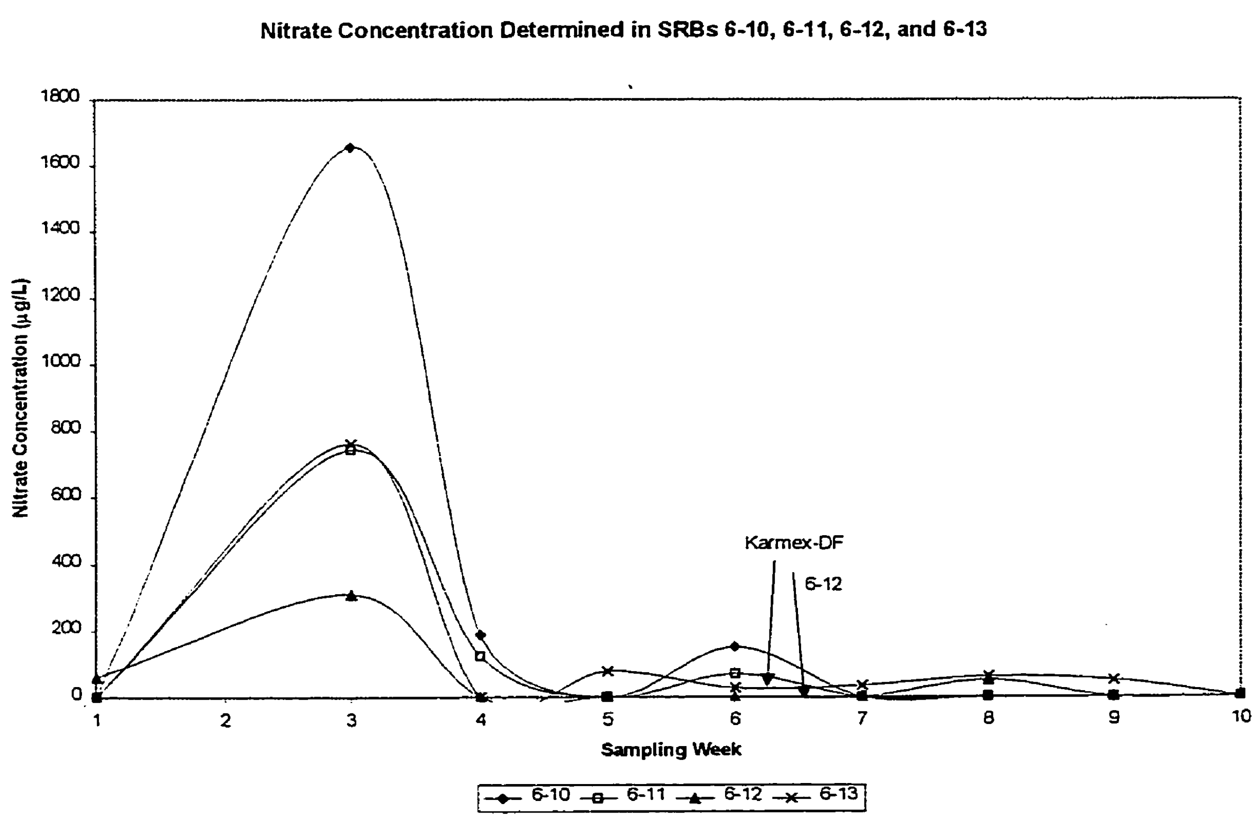

Figure 5.10

Basins in St. Norbert and Waverly Heights illustrate that the nitrate concentration was excessive during week three and the situation was not duplicated for the rest of the summer. Concentrations exceeding 300 μg/L were observed in only 6 basins over the sample period. In basins 5-23, 6-10, 6-11, 6-12, and 6-13, this peak was exhibited between week 2 and 3. The best explanation for this relationship was that nitrates were introduced into the water column through the use of inorganic fertilizers. Since 5-23 is located in the country, input from crop fertilization was probably the origin of elevated levels of nitrate. Since SRBs 6-10 through 6-13 are in residential neighbourhoods it is safe to assume a large influx of nitrate was probably a consequence of lawn fertilizer application. Since week 3 samples were taken just after the May long week-end when many people start their gardening and there was at least one rainfall event (APPENDIX D) between then and the sampling dates, this explanation seemed reasonable.

Peaks of nitrate were observed sporadically around the city during many other weeks but those crests disappeared after two weeks, when the next sampling period took place. Quick assimilation of nitrate into ammonia by aquatic plants is probably the reason for its absence after two weeks time (Wetzel, 1983).

In the water column and at the sediment, autotrophic and heterotrophic organisms rapidly assimilate ammonia, which often results in too low an ammonia concentration to observe significant nitrification (D'Angelo and Reddy, 1993; Wetzel, 1983). However, the calm hot weather of weeks 5 and 6, which aided in the production of elevated concentrations of ammonia, was thought to have promoted nitrification during the month of July. This would explain a slight elevation in the concentration of nitrate during weeks 5 and 6, as seen in Figure 5.10.

Figure 5.11 illustrates that SRB 2-2 contained large quantities of nitrate over the entire summer, with an initial peak on week 4 reaching to a concentration greater then 1000 μg/L. This value decreased over time, but the nitrate concentration in the pond never diminished to values lower than 400 μg/L for the rest of the summer. This pond was the only one to exhibit this behaviour. Perhaps there was an uncommonly large influx of inorganic fertilizer into this pond; however, because this one and 2-4 were the smallest sample basins, the nitrate present in SRB 2-2 was unable to be assimilated by the weeds present.

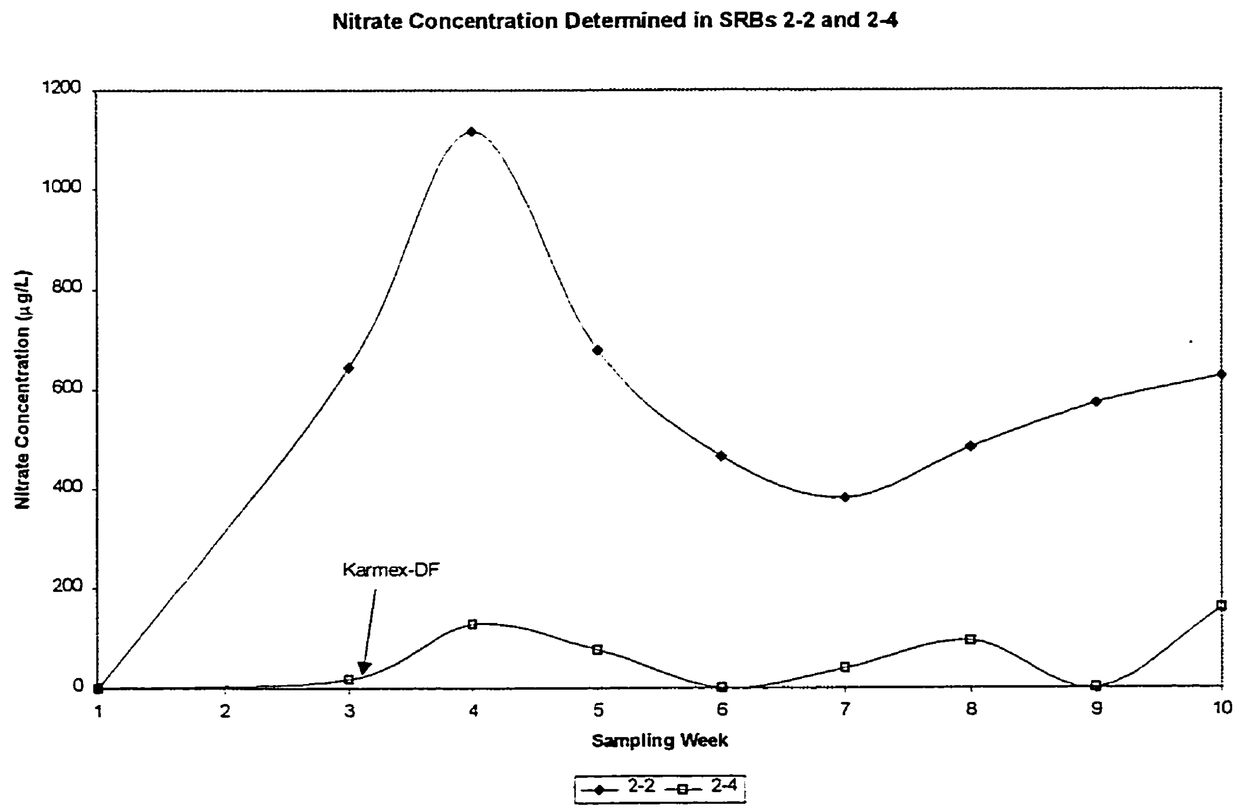

Figure 5.11

Wetzel (1983) stated that the inorganic nitrogen concentration for hypereutrophic productivity in a lake should be greater than 100 μg/L. When the nitrate and ammonia concentrations were added together (not shown), their values fell short of that deemed in the literature by approximately ten fold. Microscopic examinations were carried out on random samples taken from several surface scums and subsequent algal identifications were made. In the samples observed, blue-green algae containing heterocysts frequently made up the largest numbers of the algae identified. The presence of heterocysts is indicative of the absence of utilizable inorganic nitrogen (South and Whittick, 1987). From this identification and the observation of remnants of a blue-green algal bloom in pond 4-7, it was deduced that there was a shortage in the inorganic nitrogen supply for the aquatic organisms present. The competitive advantage of blue-green algae, and their ability to fix their own nitrogen from dissolved nitrogen gas in the water using heterocysts, supplemented inorganic nitrogen and allowed them to grow (Wetzel, 1983).

Cyanobacteria did not occur exclusively in the basins for various reasons. Fluctuations of nutrient concentration in shallow lakes are very common because of the frequent mixing, diurnal temperature changes, and re-suspension of nutrients. This is thought to be why there is a competitive advantage for green algae in shallow hypereutrophic basins over cyanobacteria (Sommer, 1985-cited in Jeppesen et al., 1997). Light limitations were probably the greatest reason why cyanobacteria were unable to dominate all of the basins. Intense irradiance is required by cyanobacteria to fix nitrogen as it is a metabolic process requiring extensive energy inputs and TSS concentrations were not conducive to this principle (Phlips et al., 1997).

Generally, north temperate lakes are limited by phosphorus and hence, the degree of suspended organic matter production is dependent on it. With limited phosphorus, less inorganic nitrogen is incorporated into biomass and remains in solution where it subject to other microbial transformations, such as denitrification (van der Molen et al., 1998).

Since in this situation no surplus of inorganic nitrogen was observed except for in SRB 2-2, it was thought that denitrification played a minor role in the overall nitrogen cycling in the surface water of the SRBs (Hellstrom, 1996).

5.2.4-Total Phosphorus and Orthophosphate

Soluble phosphorus and total phosphorus follow the same general trends where they fluctuate widely in the epilimnion due to dynamic changes in the phytoplankton populations (Wetzel, 1983). During a multitude of studies, it was observed that the majority of the total phosphorus in natural temperate lakes was comprised of organic phosphorus, with less than 5% of it being soluble inorganic phosphorus, or orthophosphate. This is partially a result of the rapid and luxury uptake of phosphorus by algae and bacteria within the surface waters of lakes (Einsele, 1941-cited in Wetzel, 1983;Wetzel, 1983). In this study, between 30% and 50% of the total phosphorus was made up of inorganic phosphorus, and the reaction of total phosphorus over time was dependent on the orthophosphate concentration. For this reason it seemed redundant to compare the two types of phosphorus separately. The mean and median values for total phosphorus shown in Figure 5.12 exclude the erroneous points discussed in section 4.3.9.

Figure 5.12 illustrates the behaviour of total phosphorus and orthophosphate over the five-month sampling period. The basins were hypereutrophic in terms of total phosphorus as the mean concentration was greater then 100 μg/L, as is the requirement for hypereutrophy given in Wetzel (1983). Certain basins' total phosphorus concentrations oscillated such that they were at times only eutrophic (Wetzel, 1983), but the majority of basins were hypereutrophic. This indicates the SRBs were not limited in terms of phosphorus. A somewhat high concentration of phosphorus was observed during week 1, and since so many contamination problems arose during the experiment, as was discussed in section 4.3.9, it was thought that the initial values were a reflection of the contaminated glassware used during the first week. The only scientific explanation for the initial high results were that the first week was extremely windy, hence launching a great deal of bound phosphorus out of the sediment (Wetzel, 1983). This is reasonable as the sum of phosphorus in the sediments would have been elevated due to the degradation of plant material form the previous year's detritus.

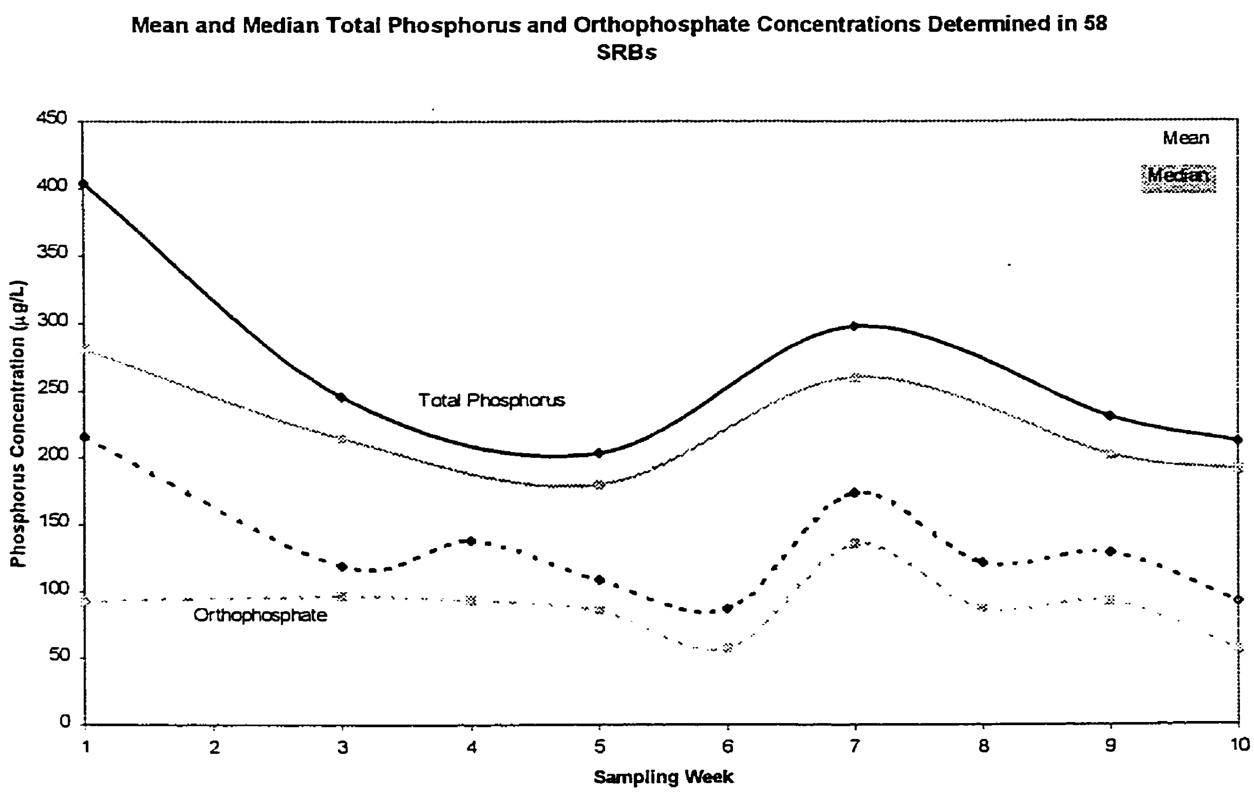

Figure 5.12

Both orthophosphate and total phosphorus decreased from the first week to week six and five respectively. Since total phosphorus was not sampled on week 6, whether or not there was a further decrease in the concentration during that time is unknown. Weeks 5 and 6 fell within the month of July and samples were taken during periods of calm weather. During this time, orthophosphate concentrations fell from between 85µg/L and 110 µg/L to between 60 µg/L and 85 µg/L. Total phosphorus and orthophosphate may have exhibited lows during the calm period due to the settling of algae, or removal of orthophosphate that was attached to settling particles (Borden et al., 1998; Hamilton and Mitchell, 1997). Phosphorus settling was probably responsible for the minimum concentrations in this study. The drop in concentration of both forms of phosphorus may also have been attributable to a rainfall event on July 1 (APPENDIX D), where 22 mm of rain fell in a short time. This may have diluted the already low phosphorus concentration during those weeks (Environment Canada, 1998). Maximum phosphorus values were attained during week 7 sampling. Week 7's increase in total phosphorus and orthophosphate coincided with a an incidence of lower water levels in the basins and may have been a result of the minute amount of precipitation and warm temperatures between the rainfall event at the beginning of July and week 7. This could have acted to concentrate the phosphorus present (Hamilton and Mitchell, 1997). In addition, mixing of the basins between week 6 and 7 could have liberated orthophosphate from the sediment back into surface water for use. The low concentration during week 10 probably resulted from the settling of phosphorus due to calm weather conditions.

5.3 Environmental Parameters

5.3.1-Dissolved Oxygen

Figures 5.13 and 5.14 depict the change in dissolved oxygen (DO) concentrations with depth for the mean and median oxygen values, respectively.

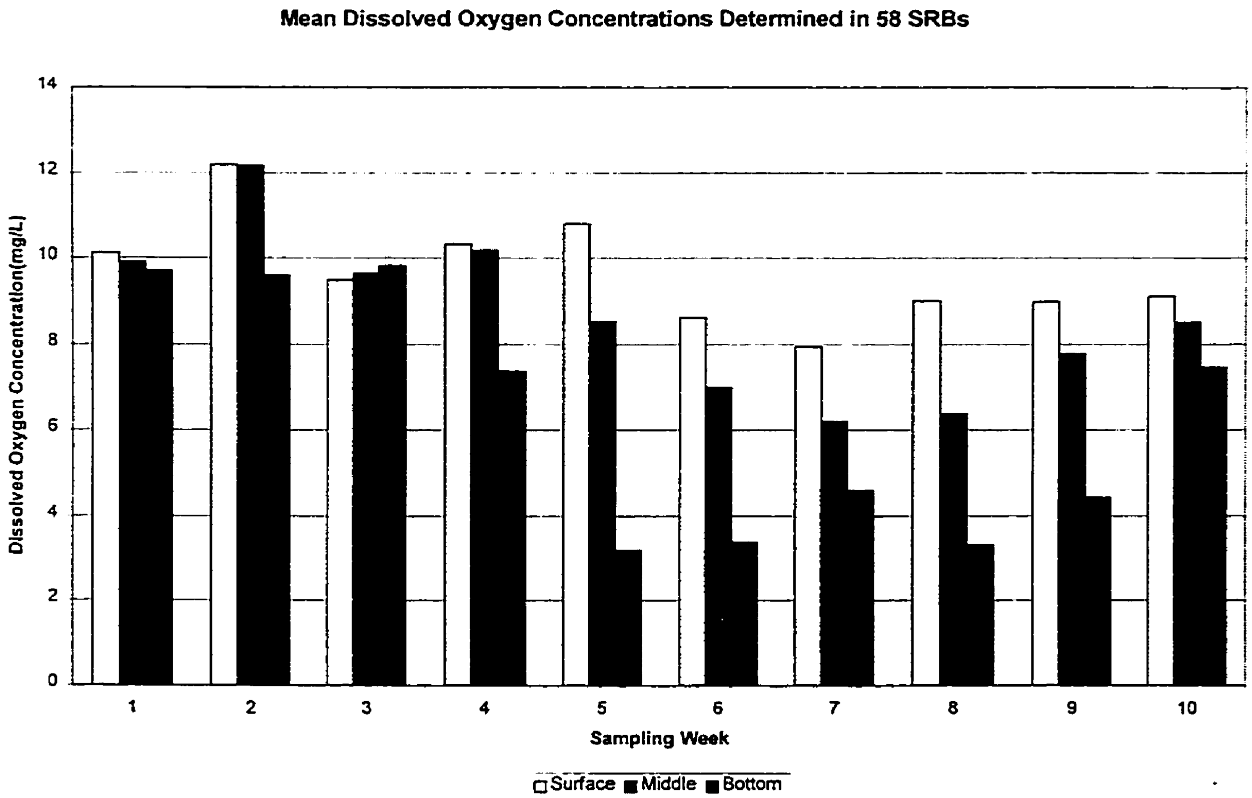

Figure 5.13

During week 1, the DO in the lakes was constant from top to bottom, illustrating that the lakes were completely mixed. Since there was little biological activity occurring during week 1, it was felt that temperature and mixing were the major factors contributing to DO concentrations during that week. Through week 2, higher DO in the upper and middle layers of the lake was indicative of the biological activity in the ponds, where an increase in sunlight and temperature of the water activated algae which produced oxygen as a by-product of photosynthesis. Elevated oxygen levels were not maintained as the mean surface temperature dropped from 18.7°C during week 2 to 13.1°C through week 3 (APPENDIX A), which probably slowed algal metabolisms or resulted in the death of many algal cells (Wetzel, 1983; Environment Canada 1998). This may have cause the consumption of the oxygen surplus observed in week 2. After week 3, one witnessed a decline in the mean DO from top to bottom of the 58 ponds.

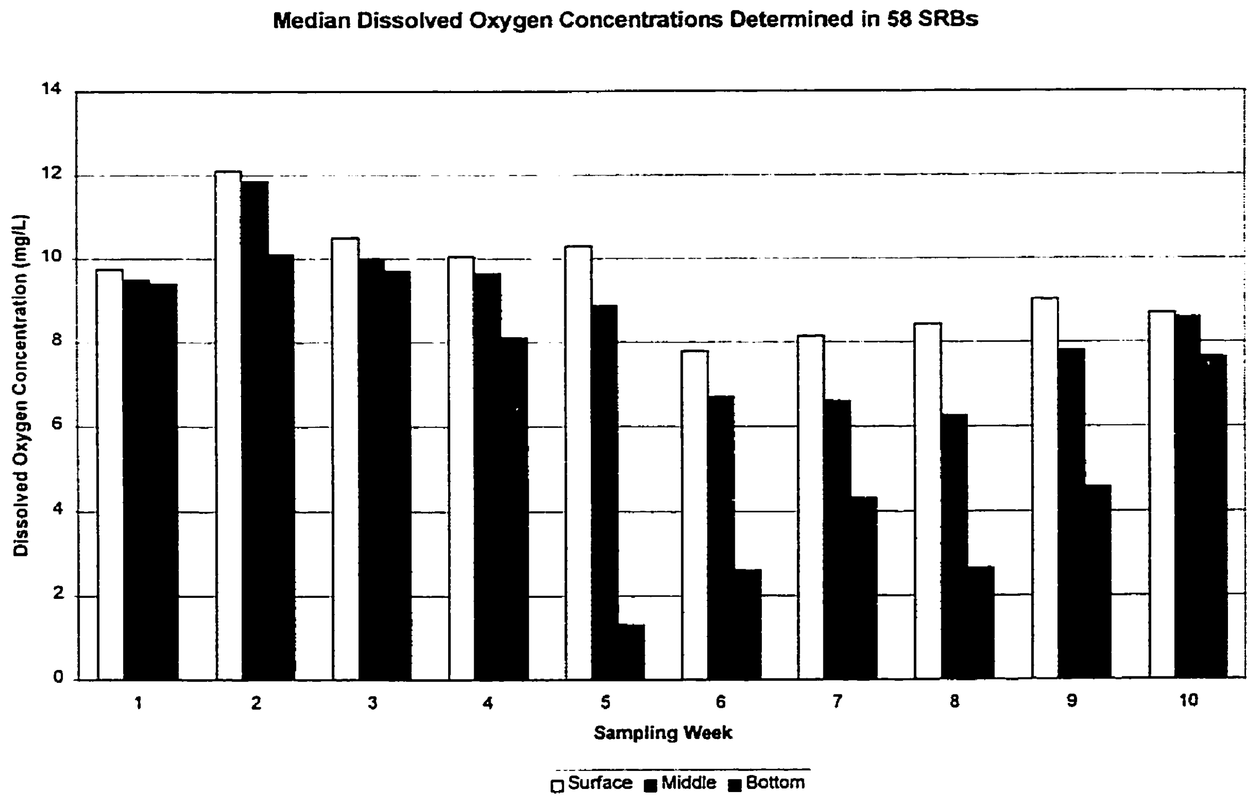

Figure 5.14

Differences in the DO from top to bottom in the SRBs illustrated the chemoheterotrophic depletion of oxygen within the bottom layer of the lake due to breakdown of dead vegetation. This situation never persisted for very long as the lakes were mixing constantly; however, there must have been a great deal of dying biomass to keep the DO at the bottom at such a low level. Shallow lakes have been found to rarely display long periods of anoxia when exposed to the air (Dickman, 1992). A very low DO concentration at the bottom of many lakes during week 5 was probably induced by the calm sunny period during that time. Calmness prevented mixing and DO reduction occurred in the bottom.

After week 5, the difference in DO from top to bottom began to decrease, as a result of increased mixing in the basins; however, there was enough biological activity occurring to maintain a substantial variation until week 10. It was estimated that during week 10 there was very little biological growth taking place as the mean bottom temperature, illustrated in APPENDIX A, dropped from 23.5°C during week 9 to 14.9°C through week 10. This slowed the metabolism of bacteria at the bottom and reduced oxygen consumption. Mixing in the basins also maintained the DO at constant concentrations from the top to the bottom of the water column during week 10.

Extremely high concentrations of DO at the surface (supersaturated conditions) were observed in a few lakes. Oxygen concentrations have been found to be elevated in response to high chlorophyll-a concentrations (Branco and Senna, 1996), and those lakes that exhibited supersaturated conditions were often the lakes that were the most green. DO concentrations in excess of 20 mg/L were observed only 3 times on those weeks where the weather was calm or there was a light breeze. This further illustrates the effect a lack of mixing had on the SRBs' oxygen profiles.

5.3.2-Temperature

Temperature values over the course of the experiment were as expected for a north temperate climate, whereby the temperature increased over time and later decreased as autumn approached. It was evident from recorded data that stratification did not occur to any appreciable extent in any of the ponds, and the greatest temperature change of 3.5°C occurred in the middle of the summer during week 5, where extremely calm conditions arose. It has been found that during warm sunny periods almost all lakes will stratify slightly (Cochlan et al., 1991-cited in Nixdorf and Deneke, 1997). Stratification in the SRBs occurred at such a high temperature, between 25°C and 20°C, that any density gradients would have been minimal, as the density of water would not change substantially between those temperatures. Convection currents, involving the process where water cooled at night and sank, would also have contributed to fairly constant circulation (Wetzel, 1983). Mixing would have also been promoted by regular winds that blew during and between sampling weeks. This would have prevented any long-term stratification in the ponds. A large surface area to volume ratio for most of the lakes and their shallowness (all being less than 3 meters deep) were also major factors contributing to their constant mixing and lack of stratification (Wetzel, 1983). Temperature and depth data are given in tables in APPENDIX A.

5.3.3-pH

Overall, the pH in Winnipeg's SRBs is slightly alkaline, illustrating the presence of carbonates produced from the solubilization of limestone and calcareous deposits typical of temperate glaciated regions (Wetzel, 1983). Since rainwater is naturally acidic and the pH did not appear to change substantially, the buffering capacity of these basins was thought to be relatively high.

The pH of the SRBs showed a similar relationship to that of the temperature, where the pH increased to a peak during the middle of the summer, and then decreased.

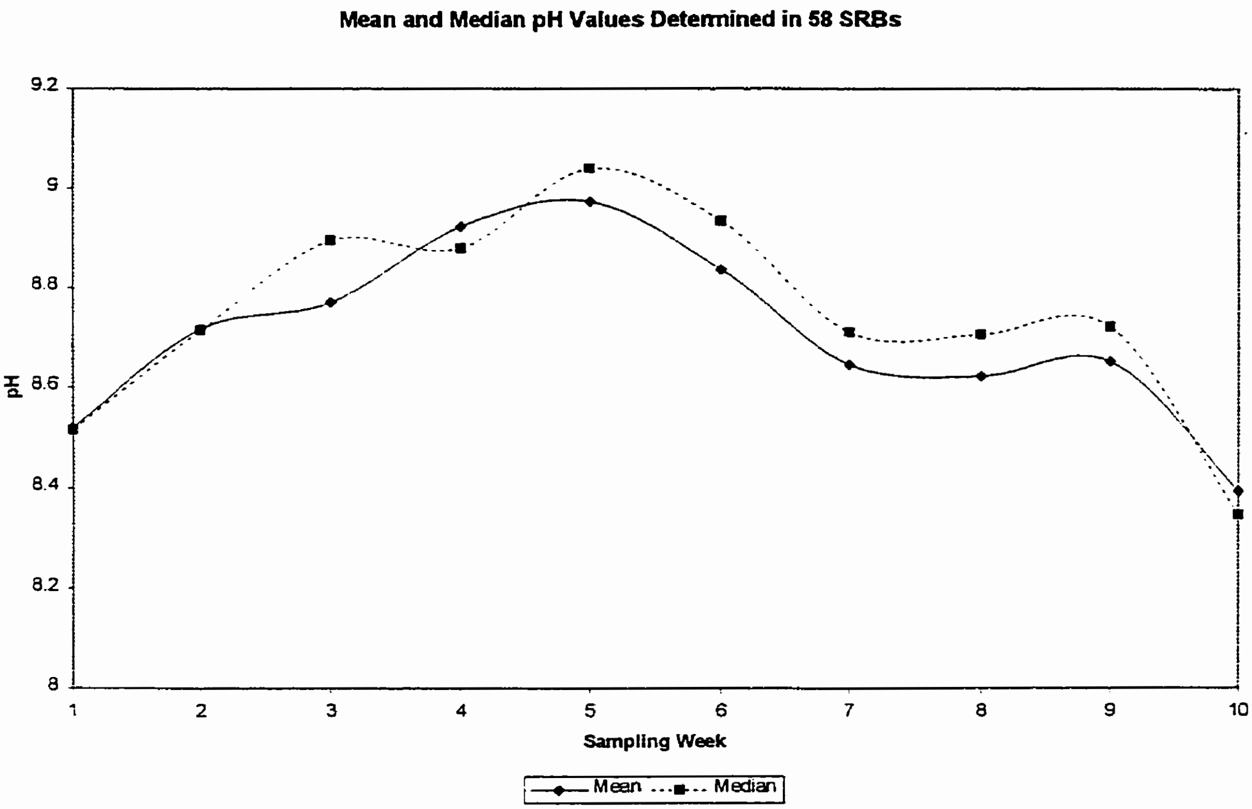

Figure 5.15

Figure 5.15's mean and median values show that this change in pH was not considerable, varying by about 0.7 pH units. The pH relationship with temperature in a lake containing some bicarbonate and carbonate alkalinity generally results in a slightly elevated pH at higher temperatures as the solubility of carbon dioxide gas in water is reduced (Wetzel, 1983).

Figure 5.15 shows that a maximum pH value was reached during week five, where the pH rose to approximately 9 units. The rise and fall in pH over the summer was also attributable to biological activity within the SRBs. Elevations in pH were in response to accelerated photosynthesis due to greater solar irradiance and higher temperatures. This process increased carbon dioxide absorption, altered bicarbonate equilibrium, and produced hydroxyl ions that drove up the pH (Branco and Senna, 1996). Since the heterotrophic degradation of decaying material results in the opposite relationship, whereby the pH is lowered, larger fluctuations in the pH of the basins may have been observed should the pH have been taken at the bottom of the SRBs or at night (Wetzel, 1983).

It was thought that the rate of photosynthesis by phytoplanktonic algae played the largest role on pH fluctuations in the SRBs. This may be observed by examining two different scenarios. Figure 5.16 illustrates the pH in basins containing minimal quantities of algae for the experimental period, whereas Figure 5.17 shows the same parameter in basins containing excessive amounts.

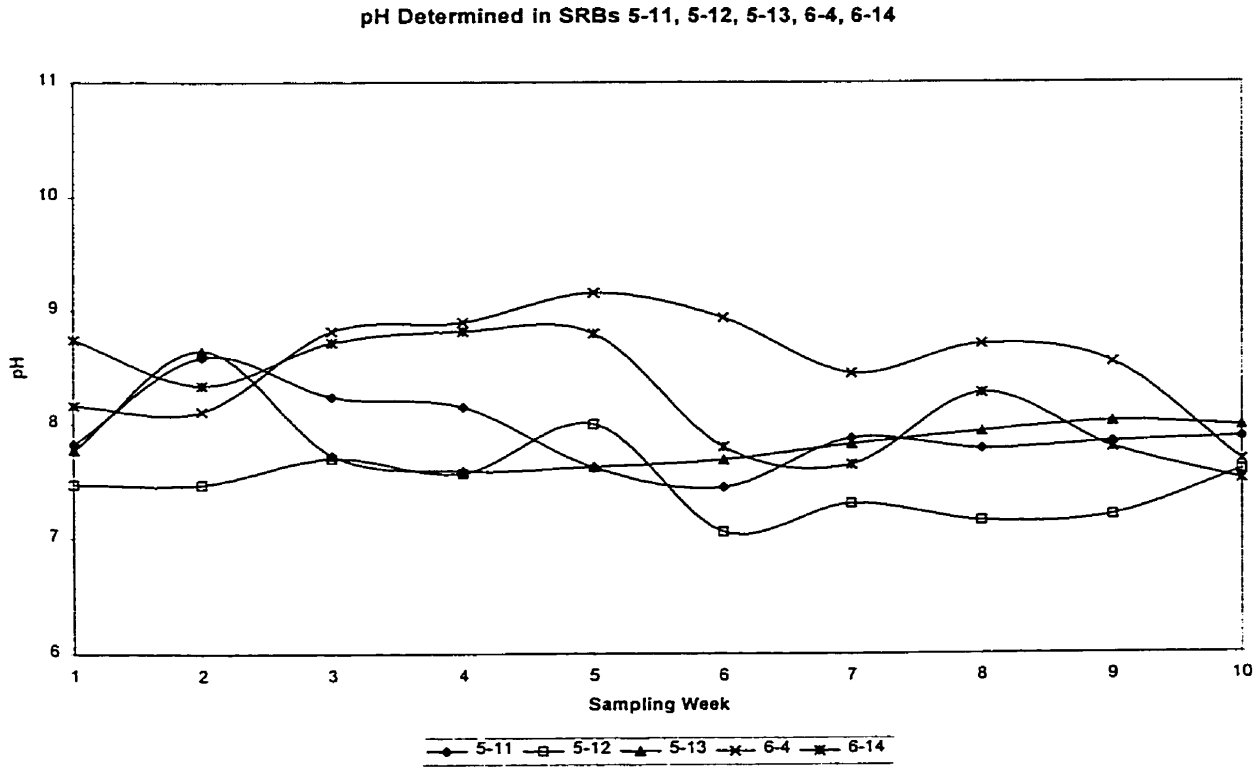

Figure 5.16

Since the ponds illustrated by Figure 5.16 contained very little algae during the summer, the pH remained constant and at values less than 9. The basins shown in Figure 5.17 show the relationship where greater activity by the algae caused the pH to fluctuate more widely rising to approximately 10.5 during the middle of the summer when productivity was at its maximum.

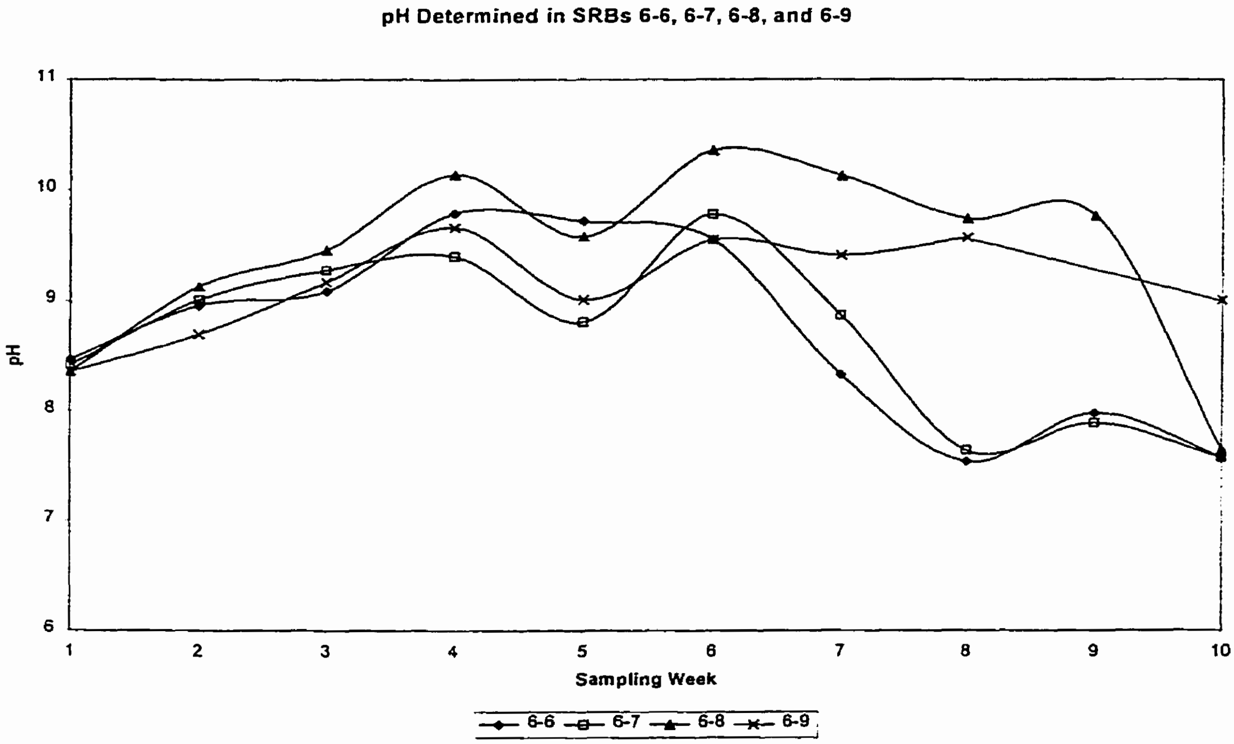

Figure 5.17

5.4 Fecal Coliforms

Because fecal coliforms (FC) are a group of organisms that may only grow in the intestines of warm-blooded animals, they are very useful in determining the sanitary quality of any water body by indicating the presence of fecal pollution. Die-out rate is dependent on the temperature of the water, the effects of sunlight, and the populations of other bacteria present (Prescott et al., 1990; Figueras et al., 1994).

During the summer of 1998, prior to the eighth sampling week, fecal coliforms were only present in sufficient numbers to be detected seven times in all of the ponds that were tested. On weeks eight and ten, large counts of the organisms were obtained in certain areas of the sampling region. This data is given in Table 5.1. During week 8, 12 ponds were observed to have FC, and many were clustered in the southeast and south of Winnipeg.

Table 5.1: Presence of Fecal Coliform (MPN/100mL) bacteria during the last 3 sampling weeks

SRB Number	Sampling Week			SRB Number	Sampling Week		
	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)		8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
2-2			200	5-11			200
3-2			4600	5-15			200
3-3			3000	5-19	200	200	
3-4			2000	6-4	1600		
3-5			200	6-8			200
3-9			2400	6-10	800		
3-10			1000	6-11	400		
4-4			400	6-12	1800		
4-7	400		800	6-13	800		200
4-9			200	6-14	400		600
5-5	200			6-16	400		
5-7	1600			6-17			400
5-9	1200	200		6-20			200

Basins in St. Norbert, Waverly Heights, along Bishop Grandin and Kenaston, and in Southdale contained between 200 and 1800 MPN/100ml. Following week 8's large numbers, sampling week 9 illustrated no growth for essentially all of the basins. Week 10's samples illustrated the largest growth of FC for the entire summer, where 17 ponds exhibited growth of 200 to 4600 MPN/100ml. Very few ponds exhibited growth during both week 8 and 10 and the majority of the FC were found in ponds in the north and northeast regions of the city on week 10.

The main reason for the large number of bacteria during the final weeks of sampling could be waterfowl contamination during their migration in late summer and early fall. Qualitative data for weeks 8 to 10 illustrate that the populations of geese and ducks occupying the ponds was quite large, with quantities estimated to be in the hundreds during these weeks. Weiskel et al. (1996) determined deposition by waterfowl contributed to approximately 67 % of the total FC present in bays along the coast of Massachusetts. The quantity of the bacteria deposited is also compounded by the fact that 98% of the FC originating from these birds are deposited during migration over a short period during the year. Although the waterfowl only occupy the SRBs as a stopover prior to proceeding further south, this could have constituted a significant input of FC organisms as the utilization of the ponds for migrating waterfowl continues for three or four months. Canada geese, or *Branta canadensis*, may excrete FC of 10^7 per goose per day, and ducks can produce 10^9 per cap. per day (Hussong et al., 1979; Koppelman and Tanenbaum, 1982-cited in Weiskel et al., 1996).

In addition to waterfowl origins, FC in the SRBs may have originated from other sources. Stormwater contains FC originating from the bowels of wild and domestic animals and collects on land surfaces in dry weather conditions only to be expelled into SRBs after storm events. Sediment may contain a number of viable FC organisms, and if the sediment were disturbed, those organisms may have been re-suspended into the water column (Weiskel et al., 1996). Mixing in the basins was a constant process, as was illustrated by the lack of thermal stratification during the sampling period, probably as a result of the basins' shallowness and windy conditions in the city. Since there were low FC densities during the entire period up to week 8, it was safe to conclude that the sediments played a small role, if at all, in their contributions to the FC concentrations. Several storm events occurred during the summer, some of which took place the day before sampling was carried out, such as June 14 and July 1 (APPENDIX D), where 11mm and 22 mm of rain fell, respectively (Environment Canada, 1998). The absence of FC immediately after these storm events indicates that heavy rainfall did not play a significant role in this study's FC results.

The sporadic sampling of fecal coliform bacteria every two weeks limited the hypotheses one could make about the nature of the SRBs in terms of FC over the summer. This variability is evident by the absence of FC during week 9 and a lack of consistently high values for a particular area for more than one week. The lack of FC counts for week 9 could be attributable to a number of biological, physical, and chemical factors, or some analytical error as outlined in section 4.3.11.

Varying water quality effects on *Escherichia coli*, the predominant fecal coliform organism (Standard Methods, 1998), were studied by Faust et al. (1975). They determined that there was an inversely proportional relationship between the temperature and survival time of *E. coli*, where it took 12 hours to kill off half of the population at 28°C and over 35 hours to kill the same number at 5°C. APPENDIX A indicates that on week 9 of the 1998 SRB study, the average surface water temperature was identical to week 8, reaching 24.9°C. However, the average surface water temperature on week 10 was 16.0°C. Since the average temperature during week 10 was significantly lower than the previous weeks, it is prudent to assume that in addition to waterfowl contributions, temperature played a role in the inflated numbers of FC enumerated on week 10.

Average turbidity for all three sampling weeks 8 to 10 was comparable, illustrating that an increase in fecal coliforms was not accompanied by an increase in suspended material. Higher turbidity values indicate the presence of solids which may act to protect FC from predation by higher organisms, as well as shield them from ultra violet radiation entering the water (Faust et al., 1975; Wetzel et al., 1983).

Weather conditions were fairly consistent for the last three weeks of sampling with sunny conditions, calm to light winds, and few clouds. This eliminates any variations in the solar radiation penetrating the water. Increased wave action or cloud cover would act to decrease the amount of ultraviolet light penetrating the water column. Seasonal variations in the angle of incidence of the sun may have had a slight effect on the number of fecal coliforms found during sampling week 10. Sampling week 10 was offset until September 21 to 23, one month after week 9. This time lapse could have resulted in a larger population of fecal coliforms present during week 10 due to the nature of the sunlight hitting the water surface. Light made up of smaller wavelengths would be scattered more by particulates in the atmosphere due to the lower angle of incidence of the sun during September than the previous month, thus changing the type of light hitting the water. When this occurs, less light of the harmful nature, in terms of bacteria, reached the water's surface. This may have resulted in the larger fecal coliform numbers during week 10 (Wetzel, 1983).

Fecal coliforms were high in certain areas of the city as opposed to being evenly distributed because the geese appeared to flock together. Ponds had either very high numbers of geese or very few. Probably different concentrations were observed in different SRB groupings for ecological reasons such as protection and available food supplies, but a deeper investigation into the flocking patterns of migrating waterfowl is beyond the scope of this investigation.

When the presence of fecal coliforms was observed, often there were colonies observed in addition to the fecal coliform group. These colonies were often present in numbers that far exceeded the counts for fecal coliforms and were present on occasion when fecal coliforms were absent. Generally, non-fecal colonies will not grow on the selective M-FC medium due to the temperature of incubation and the nature of the ingredients (Standard Methods, 1998). Figueras et al. (1994) determined that this media was poor in enumerating bacteria in seawater, with false negatives up to 5.1%. This indicates that the number of fecal coliforms in those basins with high positives may actually have been higher.

5.5 Effect of Weed Control on Water Quality

5.5.1-Karmex-DF

Karmex-DF was one aquatic herbicide to be used on Winnipeg's SRBs and was applied to 17% of the basins. Figures 5.18, 5.19 and 5.20 show the relationships between the SRBs treated with Karmex-DF and control basins by comparing the TSS, turbidity, and transparency, respectively.

TSS and turbidity concentrations were fairly similar between the Karmex-DF treated and control basins. Transparency values were also similar and indicate the inverse relationship. Exceptions are noted on weeks 2, 5, 6, and 9 where the values in the Karmex treated SRBs were somewhat higher in the cases of TSS and turbidity, and lower in the case of transparency, than in the control ponds. Since Karmex application was not carried out until after week 3's sampling, a discrepancy between the control and treatment basins was thought to be a result of the nature of the lakes. The majority of the treated SRBs were in residential areas, surrounded by houses and paved surfaces, which probably resulted in a higher sediment load then in those industrial or park areas, where there was a greater amount of treed and grass areas. Accumulated sediment on the roadways was washed into the basins during the extensive rainfall that fell between week 1 and 2 (Jeung, 1978, Environment Canada, 1998).

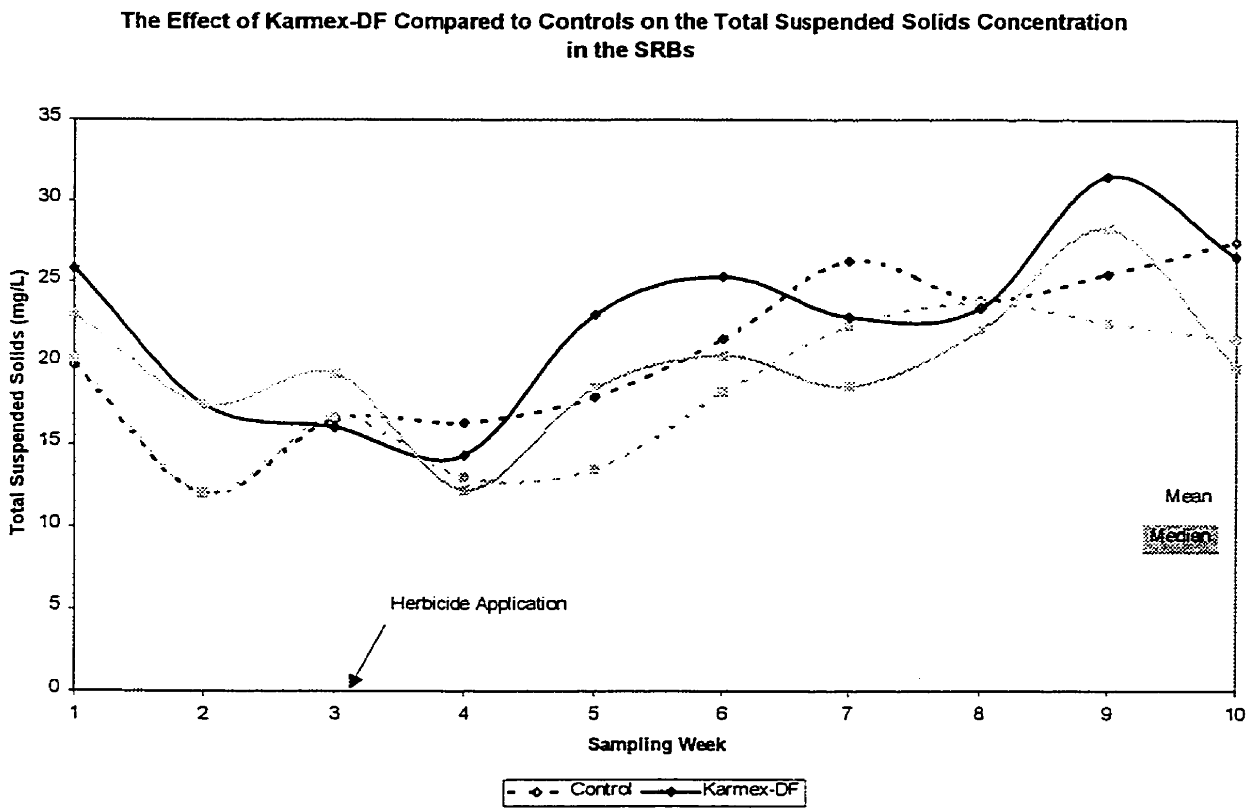

Figure 5.18

The Effect of Karmex-DF Compared to Controls on the Turbidity Values in the SRBs

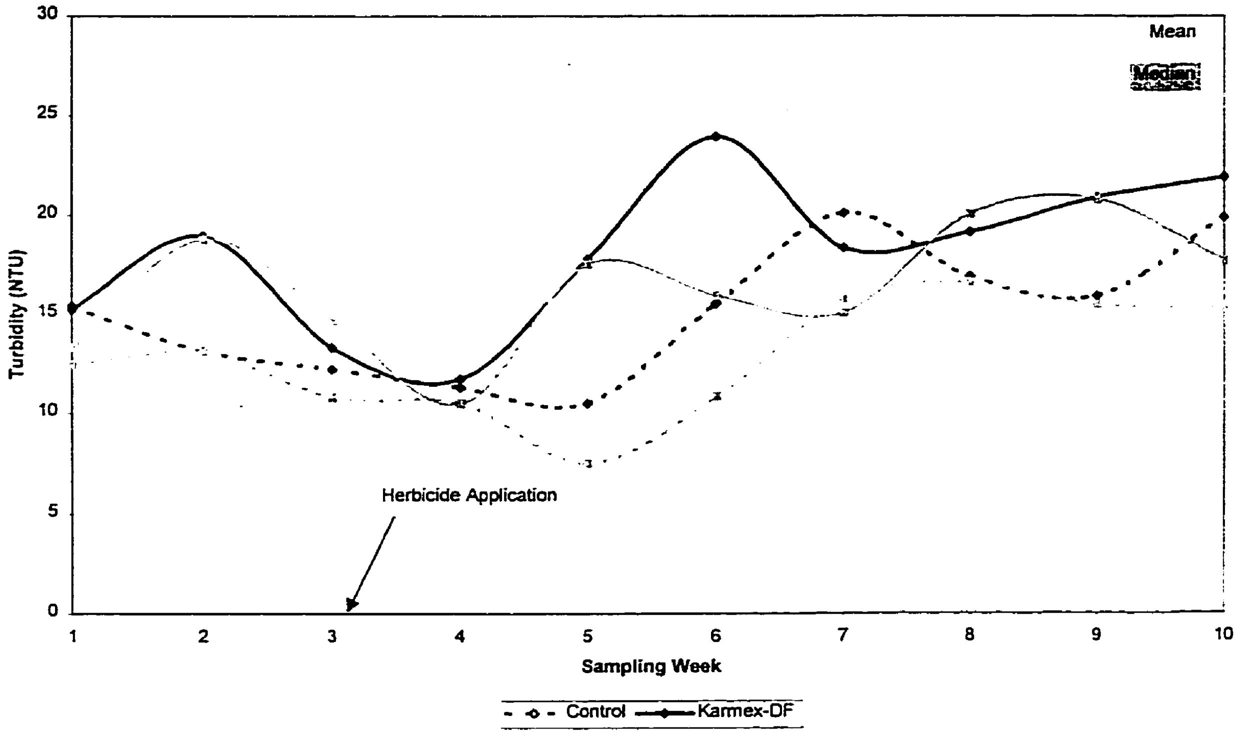

Figure 5.19

The Effect of Karmex-DF Compared to Controls on the Transparency in the SRBs

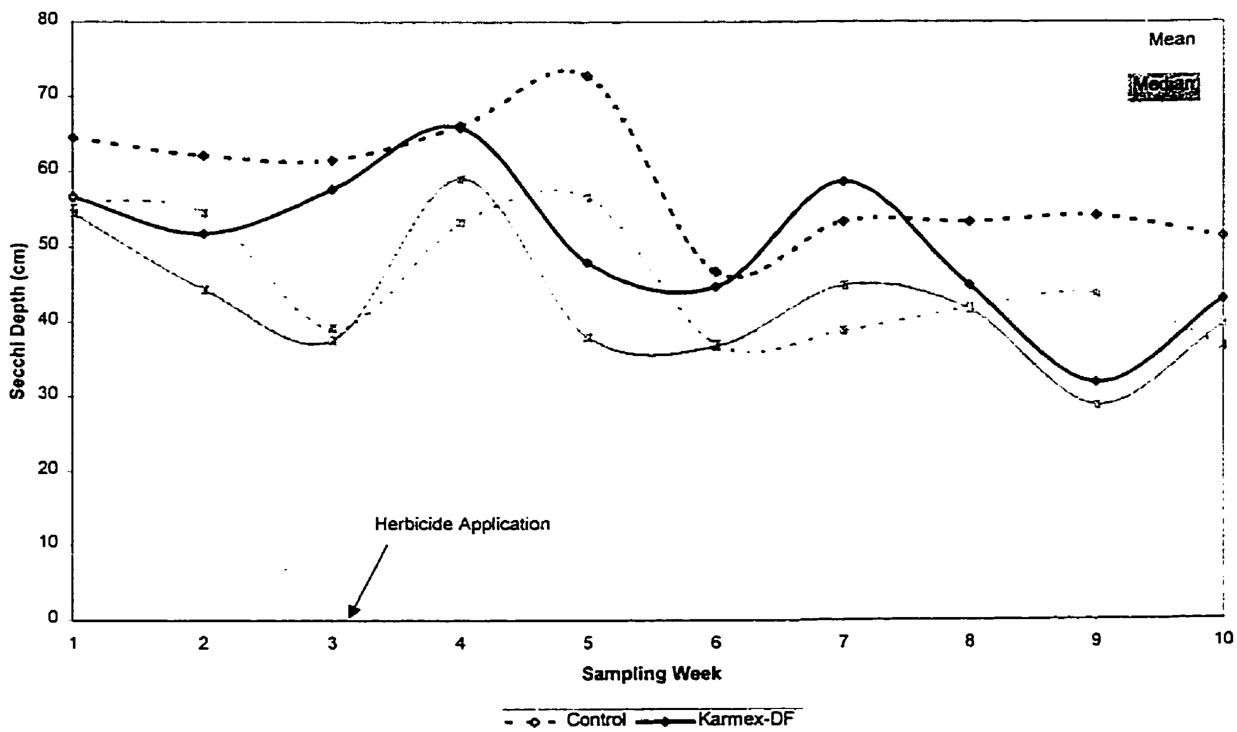

Figure 5.20

Increases in suspended matter during weeks 5, 6, and 9 occurred approximately one month after the herbicide was applied. The first application was completed on 60% of the treatment basins during or just after week 3's sampling period and just prior to week 7; 40% of the basins were treated in a separate application. The peaks were thought to illustrate the incorporation of nutrients provided by the decaying macrophytes within the basins into algal cells that contributed to the sediment within the basins.

Analysis of chlorophyll-a concentration for the Karmex-DF treated basins was conducted in order to prove this reasoning. As can be observed in Figure 5.21, the chlorophyll concentration did increase dramatically during week 9. Since this relationship was not observed during weeks 5 and 6 it was thought that the increase in sediment and decrease in transparency during those weeks was brought about by the intense rainfall that fell on July 1 (week 5).

Since the chlorophyll-a contained in the macrophytes was not determined, Karmex-DF's effect on the submerged plant life in the basins could only be estimated. From visual observations, it was determined that the treated basins showed little evidence of any plants two weeks after treatment. From Figure 5.21 it is obvious that the chlorophyll-a concentrations in the treated basins were lower than those in the control basins for weeks 3 to 7. This illustrates that the Karmex-DF applied provided a significant residual to suppress algal growth for the above-mentioned period. One might have expected the effect of the herbicide on chlorophyll-a concentrations would have been more profound. Since algae and aquatic macrophytes compete for light, nutrients, and other resources, destruction of one group would greatly affect the other. In the control ponds, both the algae and macrophytes existed and balanced one another.

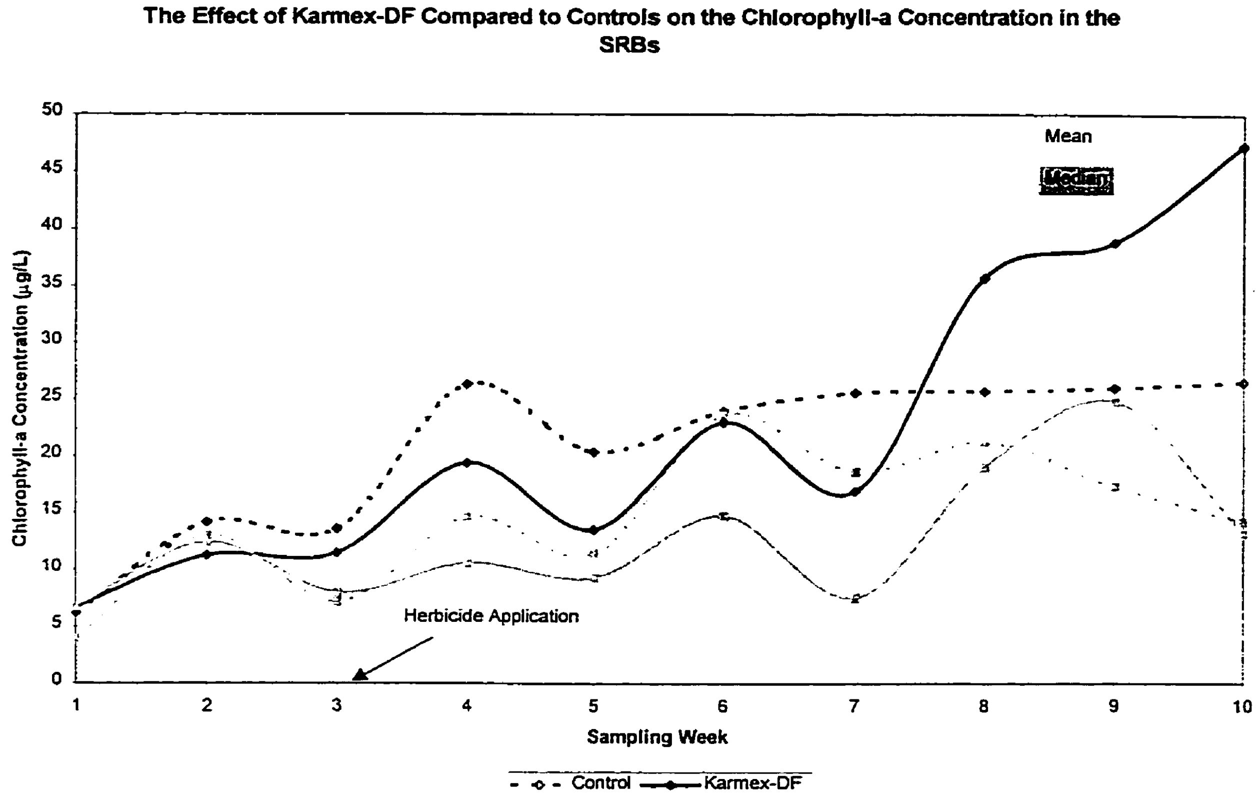

Figure 5.21

In the treated ponds, both groups were eliminated, and because algae are faster growing than macrophytes and resource availability was great, algal growth would occur unabated unless there was sufficient residual to keep their numbers low. This residual was sufficient between weeks 3 and 7 but after this, as seen in Figure 5.21, increased growth was observed due to dissipation of the Karmex-DF.

Nitrogen concentrations in the treated basins followed the expected trends based on the quantity of plants present. Ammonia oscillated as would be natural from the decay of macrophytes and other organisms after massive destruction using the herbicide. Large discrepancies between the mean and median values, as observed in Figure 5.22 between weeks 6 and 9, illustrate the extremely high concentrations in certain ponds where there were massive algal blooms and macrophytes prior to treatment. Upon destruction, high concentrations of ammonia in those ponds acted to skew the mean.

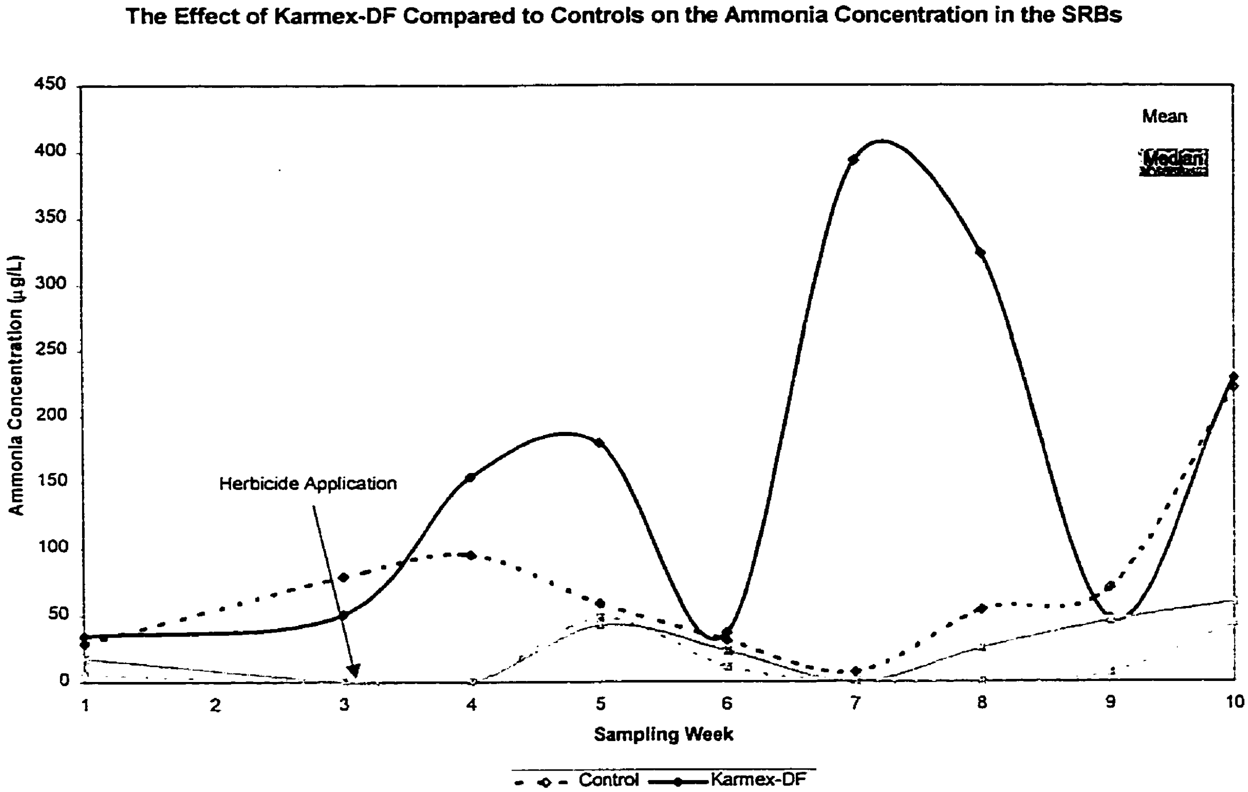

Figure 5.22

In Figure 5.23 one can see the behaviour of nitrate over the sample period. Median nitrate concentrations were observed to increase in the treated SRBs during week 5, but not in the control ones. With a lack of macrophytes to take up large quantities of ammonia, some of it was probably nitrified into nitrate, since temperature conditions at that time in the season would have favoured the process.

The Effect of Karmex-DF Compared to Controls on the Nitrate Concentration in the SRBs

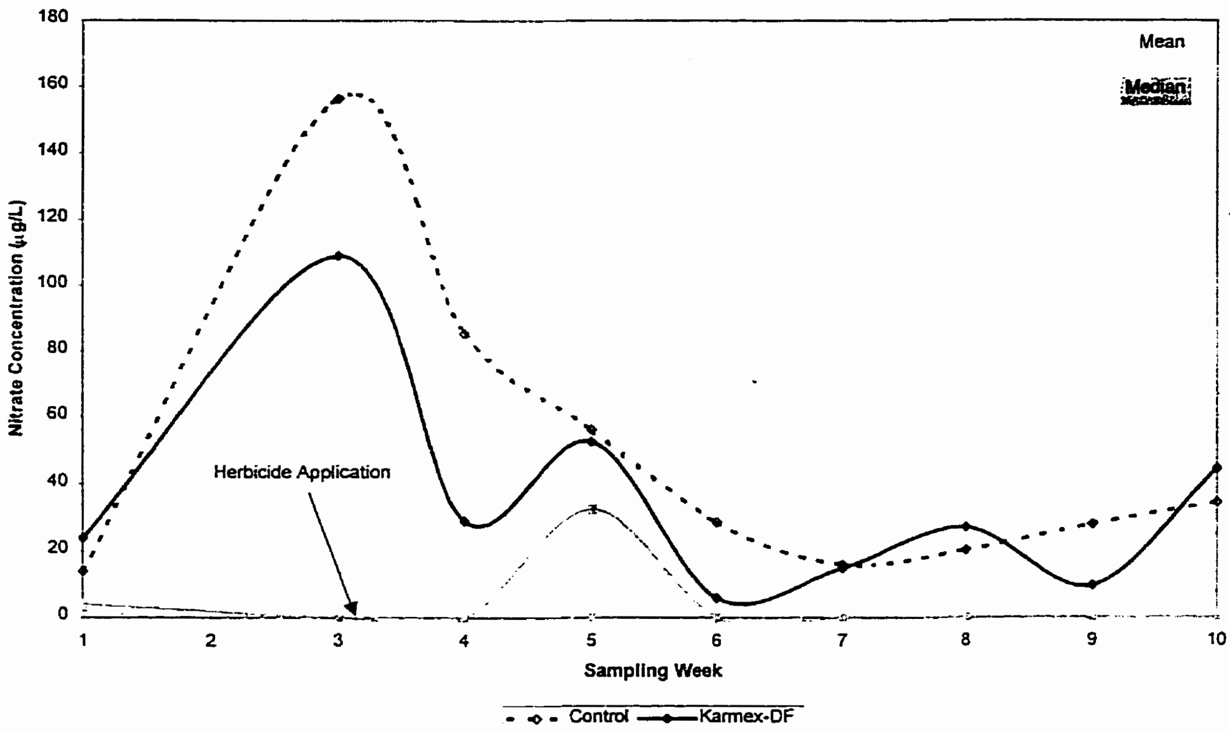

Figure 5.23

Total phosphorus and orthophosphate were closely associated in all of the basins, and generally the changes in orthophosphate concentrations regulated the oscillations in phosphorus levels. Figure 5.24 shows that Karmex-DF resulted in the mass destruction of much vegetation and a subsequent lack of uptake of orthophosphate until after week 7 when vegetation re-growth began gradually to remove it from the water.

The lack of plants' uptake of orthophosphate is evident in the gradual increase in the concentration of the nutrient between weeks 3 and 7, as seen in Figure 5.24, when the control orthophosphate concentrations were decreasing during the same time interval. Total phosphorus concentrations in the treatment basins paralleled those in the controls.

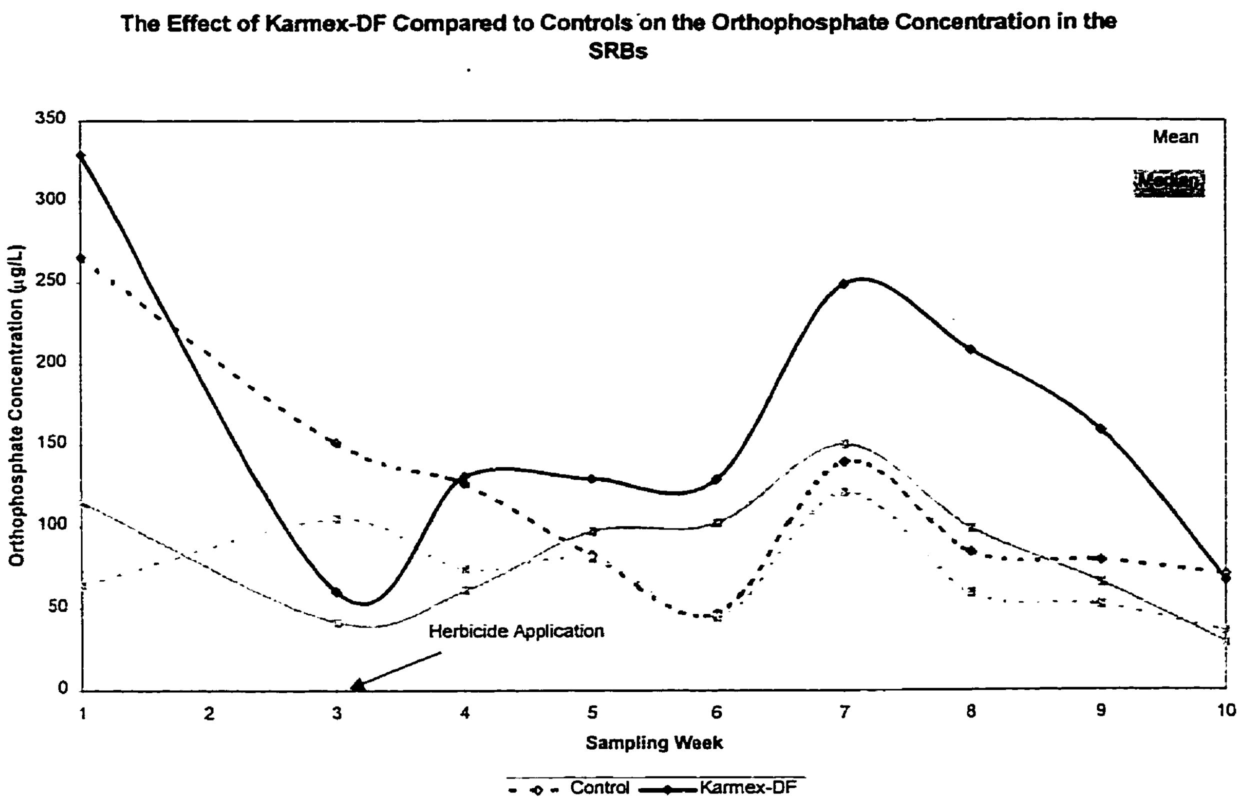

Figure 5.24

Another key factor in assessing the effectiveness of the various treatment methods was to conclude whether or not there were any oxygen depletions in the bottoms of the basins. Oxygen depletions could have an increased effect on phosphorus releases from the sediment and the extent to which the destroyed organic material at the bottom breaks down. This could speed up the process of the basins filling in (Wetzel, 1983; Reimer, 1984). Top and middle values for the DO were not analysed as the average and median values at these depths did not approach anoxic conditions. Figure 5.25 shows that treatment basins followed the control ones very closely through the entire study. This illustrates that although biological activity played a large role in the SRBs the oxygen levels in the ponds were controlled to a greater extent by weather phenomena.

The Effect of Karmex-DF Compared to Controls on the Dissolved Oxygen Concentration at the Bottom of the SRBs

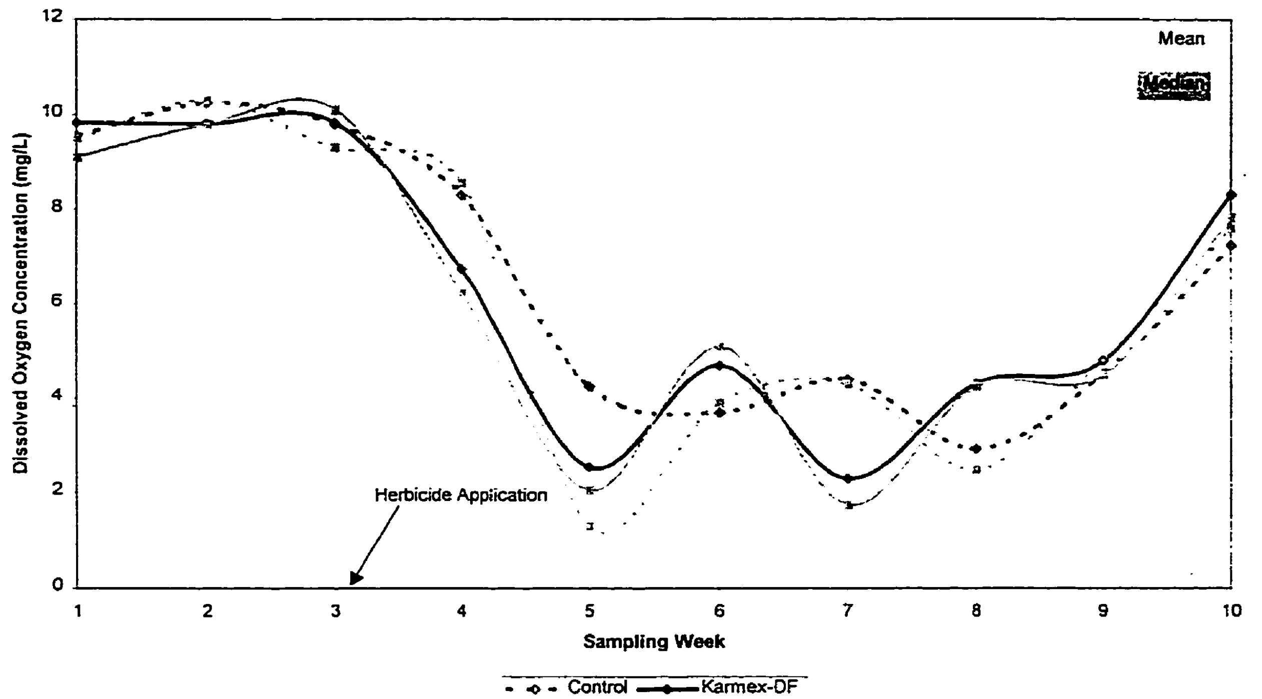

Figure 5.25

Overall, after examination of the mean and median values for the various water quality parameters in the SRB study, it was determined that Karmex-DF was the most effective aquatic weed control agent of the three types used.

5.5.2-Reglone-A

Reglone-A was the second herbicide utilized to restrict the weed and algal growth within Winnipeg's SRBs. Again, since the quantity of aquatic macrophytes was not determined, it was difficult to assess the herbicide's performance in terms of macrophyte destruction. Mean chlorophyll-a levels in treated basins exceeded concentrations in control SRBs.

The effects of application of Reglone-A on the suspended material were mirrored by the change in chlorophyll-a concentration over time, as seen in Figure 5.26. Overall, one can say that the increase in the TSS, turbidity, and transparency was a result of algal growth over the summer. An increase in the suspended material present in the ponds identified that the herbicide was successful in killing a portion of the aquatic vegetation. This was concluded based on the fact that, with a lower population of macrophytes in the treated basins, algae assimilated more of the excess nutrients, and hence the suspended material increased. However, the fact that algae in the treatment ponds were able to grow in excess of the algae in the control ponds after week 3, suggested that the herbicide, present initially, rapidly disappeared.

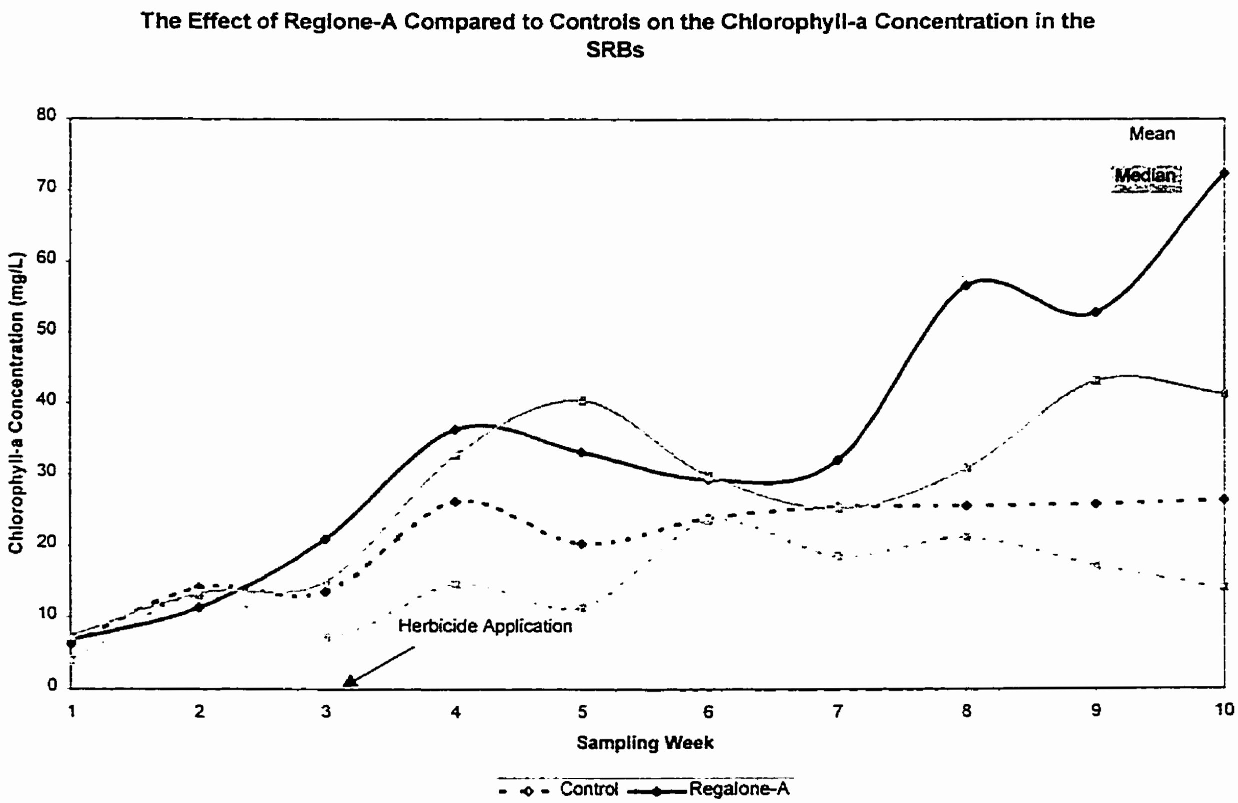

Figure 5.26

Ammonia concentrations followed the patterns of Karmex-DF, where there were larger quantities after herbicide application; however, Figure 5.27 shows that the amount was slightly lower during week 5. A high concentration of ammonia would indicate decay of a mass of vegetation.

Reglone-A had a slight effect on the submerged macrophytes. Nitrate concentrations were not different from the control basins, illustrating that the nitrate present was being quickly assimilated into ammonia for algal uptake. As expected, TKN values followed a pattern indicating greater algal biomass.

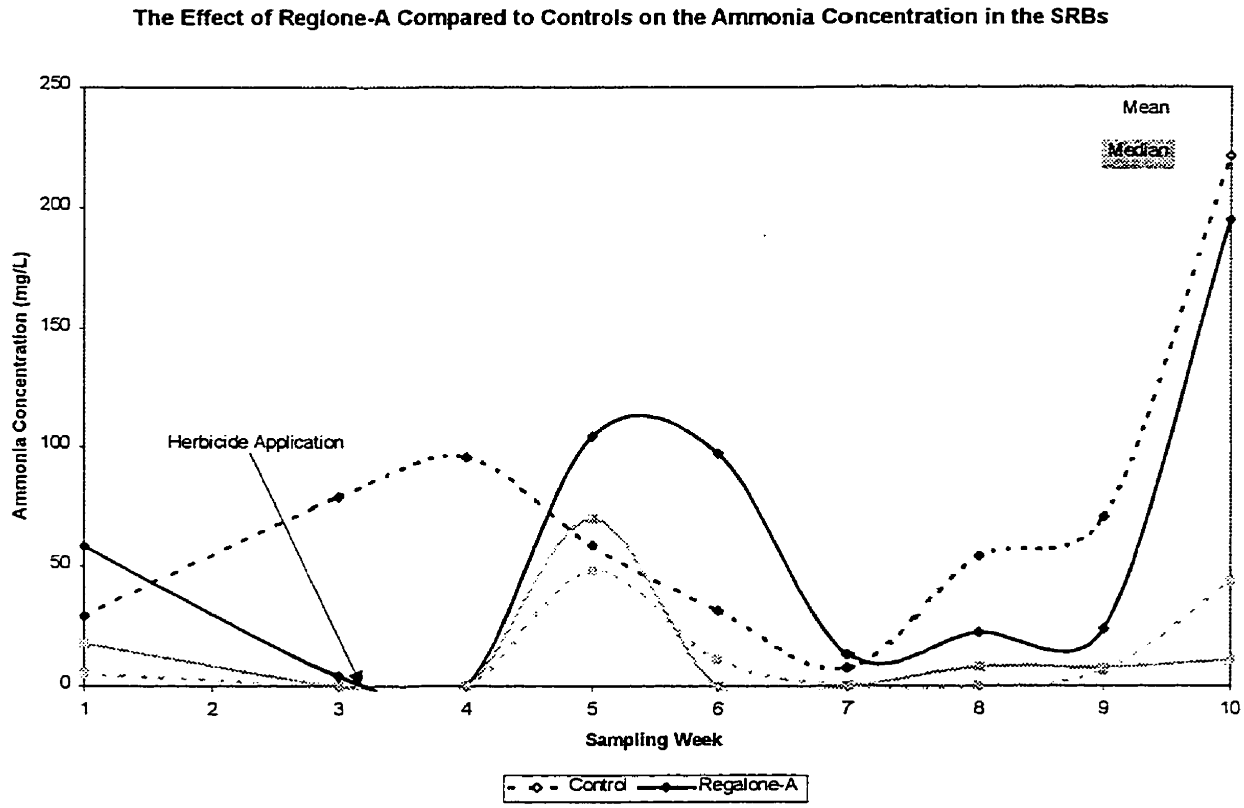

Figure 5.27

Orthophosphate concentrations followed the concentrations within the control basins closely. Total phosphorus concentrations shown in Figure 5.28 illustrate that there was a greater quantity of phosphorus in the form of algal cells than in the control basins, where more of the organic phosphorus was retained in the aquatic plants. This further illustrates that there was some aquatic macrophyte destruction.

Like Karmex-DF, Reglone-A treatment basins closely followed the control basins in terms of oxygen concentrations, and it appeared the concentration of oxygen in the bottom was independent of herbicide application.

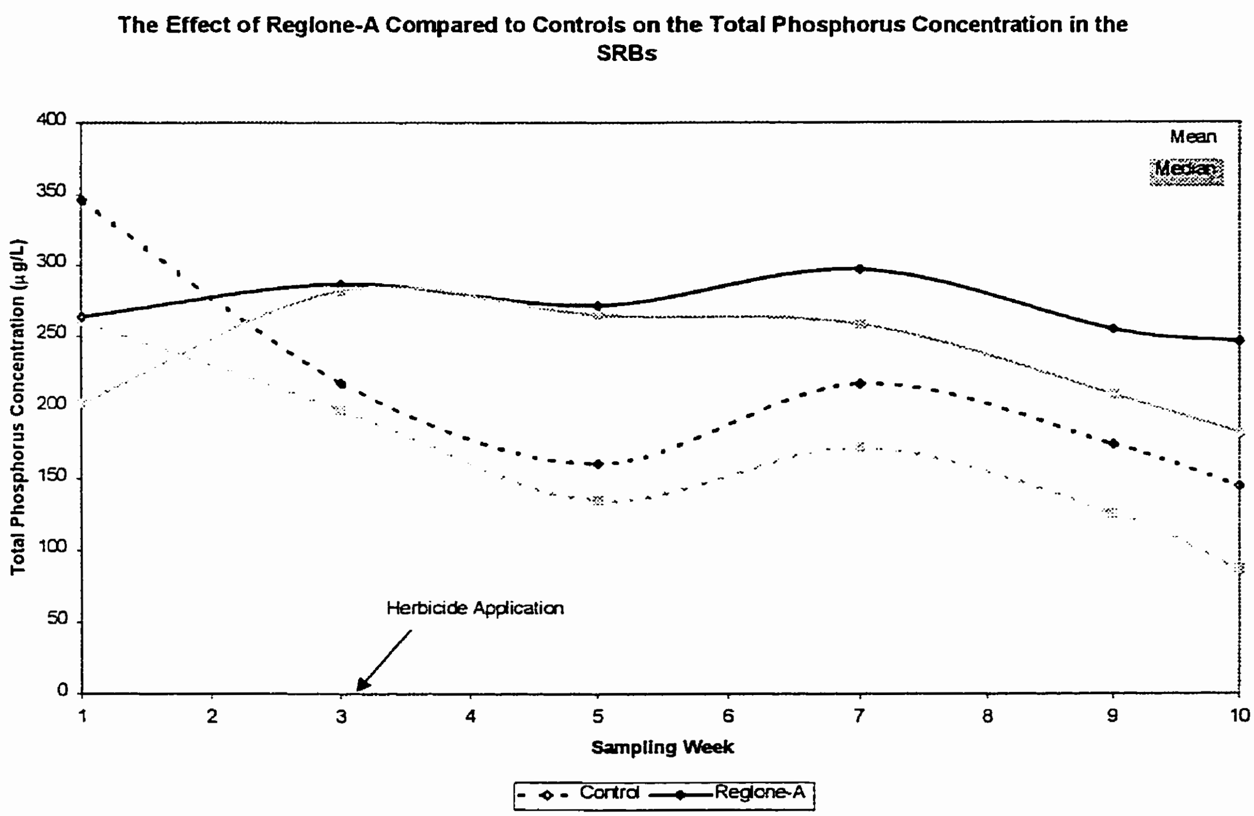

Figure 5.28

Overall, the performance of this herbicide was not as good as Karmex-DF. One reason for the poor control by this herbicide may have been the large concentrations of suspended material within the basins. Since Reglone-A binds very tightly onto clay and organic particles, SRBs containing high amounts of either of these would render the herbicide inactive because of the inability of the plants to take it up. After binding to particles, the herbicide settled and was buried (Riemer, 1984; Allan et al., 1989). This is probably a reason for the herbicide's inability to provide a residual sufficient to suppress algal growth, and the overall performance was poor.

5.5.3-Weed Harvesting

Shifts to a turbid water state have been attributed to the mechanical disturbance of macrophytes. Removal will most likely cause the rapid proliferation of algae, due to the lack of uptake of nutrients present in sediments and in the water column itself. Rapid assimilation by algae will prevent the re-establishment of macro, leading to a more turbid water state (Reimer, 1984).

With higher macrophytes, one attains a higher transparency and lower turbidity due to the stabilization of sediment, calming of water, and habitat provisions for zooplankton. Nutrient concentrations in surrounding water decrease because of their confinement in biomass. Chlorophyll decreases from grazing pressures and lower nutrient concentrations (Blindow et al., 1993; Wetzel, 1983; Reimer, 1984).

Because of the nature of harvesting, which only removes submerged macrophytes, the effectiveness of the process was limited in comparison to herbicide application. While sampling was carried out at the ponds, qualitative observations were made. After aquatic weed harvesting, many patches of weeds remained throughout the ponds and near the shores. In certain ponds, 6-19 in particular, aquatic weeds appeared to be growing back bushier than prior to harvesting. Floating dead weeds were observed, often in thick bunches, around the shoreline. Also, many of the ramps leading into the water were mutilated. The harvester had no effect on algae, and it is evident from the results that the process increased the quantity of planktonic algae. Qualitative data is available for consultation in APPENDIX D.

The TSS, turbidity, and transparency within the harvested basins gradually worsened over time. Harvesting took place over the entire summer, with one or two basins done every week, and it appeared that as the number of harvested basins increased, the parameters began to diverge away from the control ponds and deteriorate. This departure is clearly illustrated in Figure 5.29, depicting the chlorophyll-a concentration.

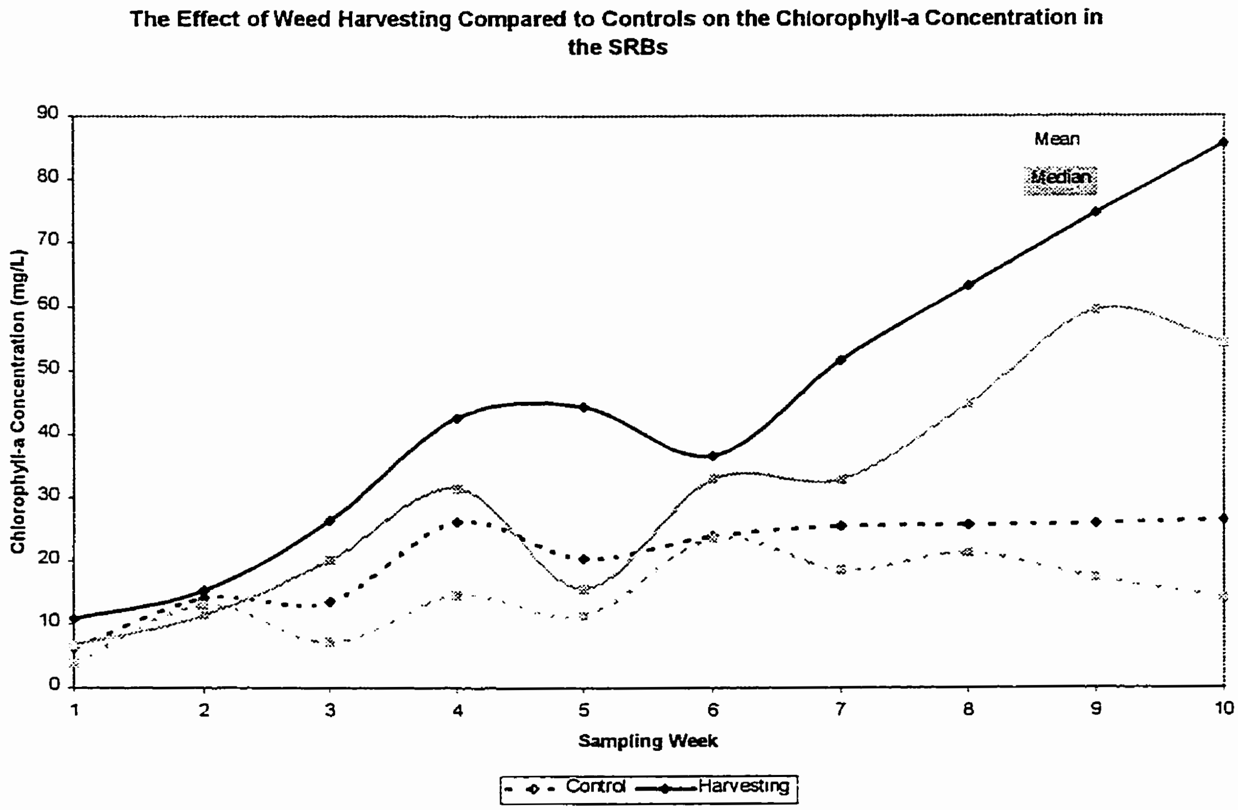

Figure 5.29

Chlorophyll-a, enumerating planktonic algae, rose in concentration as the number of basins harvested increased. The excess algae that were produced contributed to the increase in TSS, turbidity, and poorer transparency.

The date of harvesting, whether early or late in the summer, played an insignificant role in the aforementioned parameter values. Table A-1 (APPENDIX A) illustrates this, showing chlorophyll-a concentrations for ponds 4-2 and 4-5, which were harvested during the same week early in the summer. 4-2's chlorophyll-a concentration decreased after harvesting and 4-5's increased. The same relationship was observed for ponds 5-5 and 5-7 that were harvested during the last week of the control method's utilization. In this case, the chlorophyll-a concentration in 5-7 decreased, while the concentration in 5-5 increased. The variations in these results responded to the prevalent type of vegetation in the basins. As a result, individual basins sometimes behaved oppositely in terms of chlorophyll-a after harvesting; however, the mean level for all SRBs increased as the number of harvested basins increased.

Increases in TKN followed chlorophyll-a concentrations, and there was very little observable nitrate in the basins. Figure 5.30 shows that the amount of ammonia present increased to levels higher then those observed within the control basins.

Technically, ammonia concentrations should not have changed, as the nitrogen present in the macrophytes was removed through removal of the biomass. The observed increase was probably due to the accumulation of organic material that escaped collection and removal and sank to the bottom.

Total phosphorus concentrations were reflective of the mass of algae accumulating in the surface water where, as harvesting progressed, total phosphorus increased. Dissolved oxygen concentrations over the summer illustrated that the harvested basins did not differ from the control basins significantly, just as the other two treatment types.

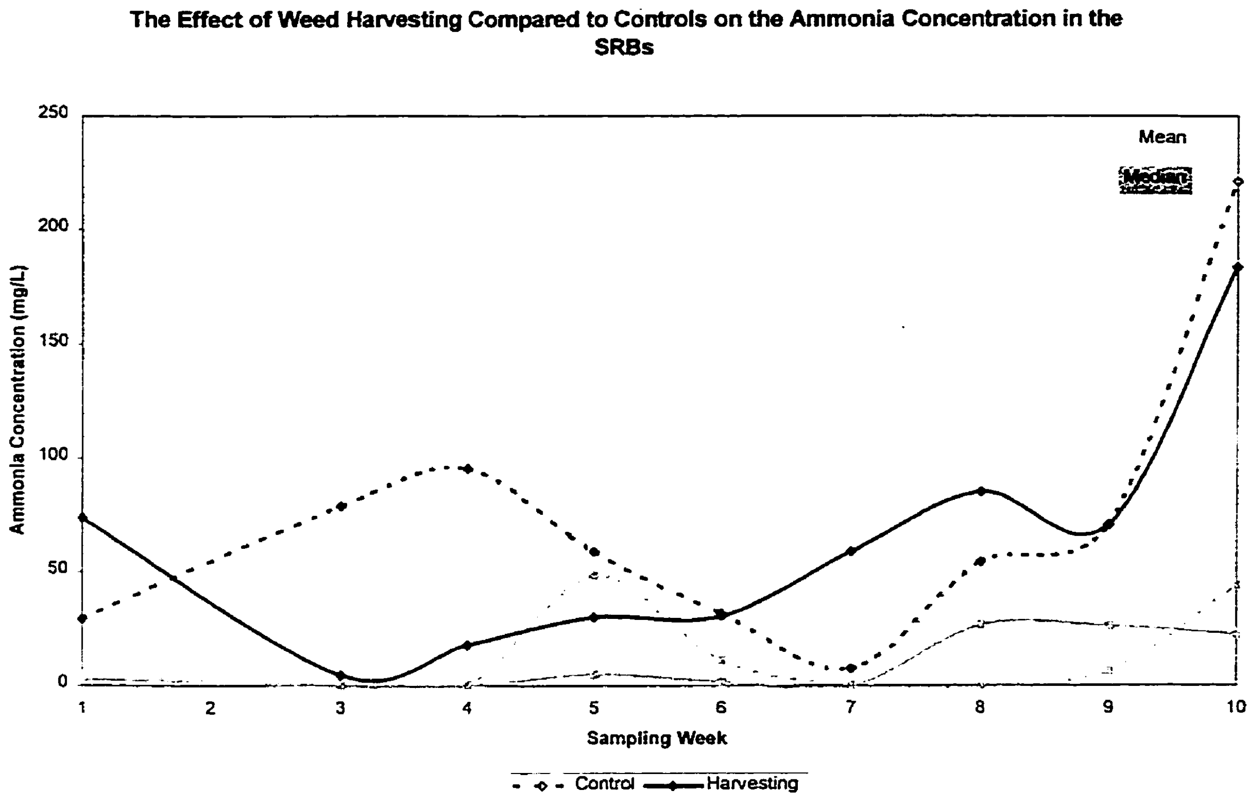

Figure 5.30

5.5.4-A Comparison of Karmex-DF, Reglone-A, and Harvesting

Since the control methods used in this study were employed to reduce the quantity of vegetation within the ponds, it was desirable to observe the best overall treatment in terms of chlorophyll-a suppression. Figure 5.31 shows the three treatments' mean chlorophyll-a concentrations over the study period as compared to the control basins.

Due to the nature of harvesting, its removal of algae is minimal; however, one can see from the graph that by removing aquatic macrophytes the conditions for algal growth are optimal, as there are large provisions of nutrients, light, and other resources. Herbicides must contribute a sufficient residual in order to suppress algal growth; otherwise, algae will thrive under conditions where there is no competition from macrophytes. Figure 5.31 shows the natural ability of the control ponds to maintain chlorophyll-a concentrations in a steady state after week 7, where the chlorophyll-a concentration remained constant with no further increases. This shows a feedback mechanism in nature, where planktonic algae in the SRBs attained an upper limit. This limit is affected by certain growth factors, such as light and nutrients, where the limiting factor determined the maximum amount of vegetation that could be present in the pond at one time. When the biomass that the available growth factor could sustain was exceeded, the excess died off.

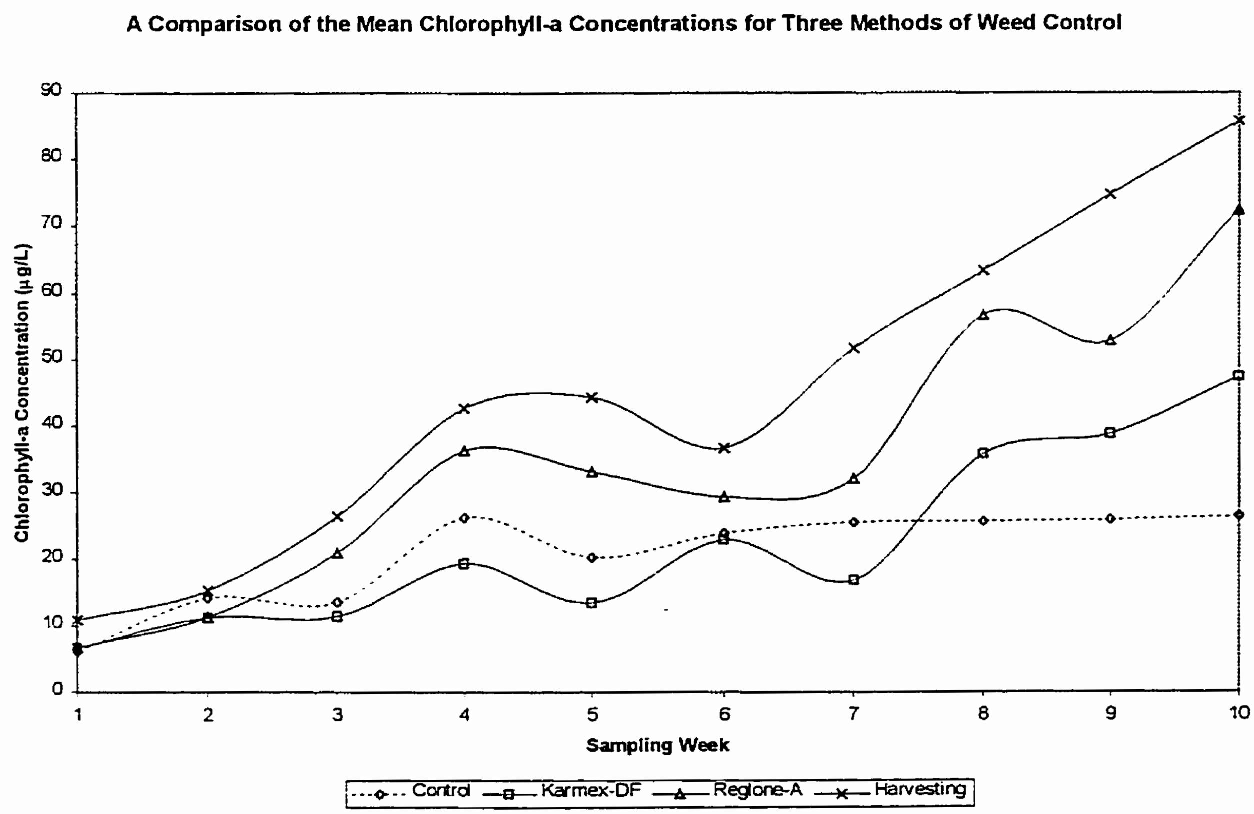

Figure 5.31

It is obvious from Figure 5.31 that Karmex-DF was the superior control agent; however, one observes that the control ponds' mean chlorophyll-a concentrations were lower than all others after week 8. This shows a situation in nature that was not achieved with any control agent. In a hypereutrophic lake there are two states. The first one occurs when weeds dominate and the water is very clear. The second is a lake with few weeds, or with the weeds removed, where the lake is turbid with algae. A choice must be made as to which one is less desirable as one will prevail over time.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

Based on the quantity of data obtained from the 58 SRBs analysed during the summer of 1998, several characteristics could be observed. Visually there was very little vegetation in the SRBs analysed; however, as summer progressed, the basins developed masses of vegetation either in the form of algae or submerged macrophytes resulting in basins of hypereutrophic productivity.

An overall increase in chlorophyll-a concentrations, representing planktonic algae, over the summer months resulted in an increase in TSS and turbidity and decreasing transparency values in the basins. Periods of calm weather tended to result in an improvement of these parameters.

TKN results illustrated that the majority of nitrogen observed was of the organic variety, which was the reason why TKN closely followed fluctuations in the chlorophyll-a concentrations. Increases in ammonia seemed to correspond with the degradation of dead vegetation coupled with atmospheric high-pressure systems. Based on the results from nitrate analysis, it appeared that nutrient loading from anthropogenic sources in the form of artificial fertilizers was adding to inorganic nitrogen concentrations; however, nitrification was observed in select ponds where ammonia concentrations were exceedingly high.

Orthophosphate made up between 30% and 50% of the total phosphorus, and fluctuations of the total phosphorus were in response to fluctuations in orthophosphate due to dry weather and calm. High concentrations of phosphorus for the summer of 1998 led one to asses that nitrogen was the limiting nutrient in the city's SRBs. Observances of nitrogen fixing blue green algae helped to further prove this.

Although low concentrations of oxygen were observed at the bottom of many basins, the situation did not persist through the entire summer. This was a result of the shallowness and lack of thermal stratification that occurred in the basins. In terms of bacteria, fecal coliform contamination was almost solely influenced by Canada geese migration during the last three sampling weeks. Overall, the nutrient and oxygen concentrations observed were controlled by biological and meteorological conditions.

Of the three control methods employed, it appeared that the herbicide Karmex-DF was most proficient in controlling aquatic vegetation growth through the majority of the summer. The herbicide Reglone-A was negatively affected by a high concentration of suspended material in the basins and was unable to produce a sufficient residual for continued algal control. Aquatic weed harvesting removed only the aquatic macrophytes, thereby providing an optimal situation for algal proliferation. After sufficient time passed, though, none of the control methods surpassed the ability of control ponds at suppressing algal growth due to the natural feedback mechanisms present in the non-manipulated SRBs. From this it was deduced that one of two conditions prevail in the 58 SRBs over time – a macrophyte dominated clear water state, or a state of extremely high turbidity resulting form phytoplanktonic algae growth.

6.2 Future Recommendations

A variety of steps could be taken in the future to proceed towards optimising Winnipeg's SRBs for all types of uses both functional and aesthetic.

1. It is suggested that mechanical weed harvesting be phased out over the next several years due to aggravation of algal growth, and production of bushier weeds.
2. Aquatic weed and algae control using Karmex-DF should be employed in the immediate future in order to appease public concern; however, investigations into other weed control mechanisms such as biological control should be undertaken. No amount of herbicide entering the environment is safe and problems may arise with weeds developing tolerance to one type of herbicide. Future studies of the effect of sterilized grass carp and barley straw are two explorative opportunities.
3. Quantification of chlorophyll-a contained in aquatic macrophytes will provide more insight into overall vegetation relationships within the basins, and the measurement should be included in future studies.
4. Increase vegetation such as trees and shrubs around the basins in the park areas. Trees will act to shade the basins, which would reduce light entering the lakes, and negatively effect vegetative growth.
5. Public education is key to the success of aquatic weed control. Pamphlet distribution to people living in suburban areas about proper fertilizer application and the effects of fertilizers on vegetation in the SRBs could reduce anthropogenic inputs. Informing them of the nature of water proceeding from pristine to eutrophic over time could help to alleviate public misconceptions and may help them to appreciate the basins as a living entity.

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APPENDIX A

List of Raw Data Tables

Table A-1: Chlorophyll-a Concentration in 58 SRBs										
Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Chlorophyll-a Concentration (µg/L)									
2-2	3.83	11.35	5.45	8.88	14.26	2.33	9.16	2.46	9.12	0.00
2-4	0.00	1.34	0.00	3.42	3.04	14.31	2.42	2.39	15.72	0.00
3-1	0.00	9.88	2.14	15.96	43.30	49.58	46.91	43.19	17.99	56.64
3-2	2.30	8.49	4.62	19.66	9.77	6.21	33.36	41.79	91.86	46.28
3-3	0.00	2.36	0.00	0.30	10.42	0.50	10.73	28.83	65.98	89.28
3-4	0.71	8.16	5.14	1.77	11.22	0.00	13.28	46.56	105.37	43.46
3-5	13.37	6.98	22.13	11.03	9.62	5.91	18.50	31.03	32.78	23.06
3-6	0.00	19.96	0.04	15.48	0.00	0.00	1.40	0.00	0.00	1.77
3-9	7.38	13.51	1.15	0.77	4.67	18.50	19.03	39.94	50.00	65.80
3-10	6.94	18.07	9.34	7.95	23.96	11.54	9.51	19.90	11.19	9.64
4-2	4.07	10.73	14.59	38.64	12.86	3.45	20.04	14.50	24.29	54.39
4-4	23.66	15.05	3.62	61.97	25.06	45.31	58.59	18.96	68.73	75.96
4-5	9.18	19.60	11.01	7.01	13.27	39.44	22.29	21.64	13.13	31.72
4-6	8.69	19.18	15.59	26.97	18.65	30.08	10.67	25.41	33.49	42.86
4-7		16.08	3.44	65.31	11.09	35.96	26.30	52.00	1.61	0.00
4-8	33.76	22.19	5.65	9.61	6.68	40.34	28.89	10.39	5.86	26.19
4-9	6.86	22.20	22.91	30.31	6.24	16.55	8.17	5.48	15.45	9.81
4-10		16.03	12.21	27.08	44.41	16.96	39.57	36.07	61.99	39.96
5-1	15.60	20.49	50.77	110.69	69.01	53.91	90.78	49.44	112.11	102.80
5-2	10.76	20.88	18.35	62.54	8.00	28.03	24.26	38.40	35.25	21.52
5-3	2.35	8.13	22.35	15.19	11.44	12.10	21.08	41.14	56.80	62.39
5-4E	12.52	10.60	14.61	7.03	11.11	24.10	21.62	18.13	26.45	15.85
5-4W	10.96	13.11	43.61	33.12	19.63	25.05	8.84	17.16	22.82	5.05
5-5	10.52	42.91	70.45	101.93	52.03	35.77	77.84	121.41	178.97	223.49
5-6	10.96	44.35	66.43	83.85	60.52	47.91	81.05		149.14	157.45
5-7	10.44	38.36	65.83	88.91	59.24	61.67	95.09	245.67	139.95	365.90
5-8	11.51	8.49	54.59	81.55	47.25	72.01	126.84	54.23	112.32	162.83
5-9	12.30	2.56	44.52	69.24	42.18	53.24	10.52	158.38	113.41	235.27
5-10	3.48	28.79	35.98	67.26	67.62	51.83	36.45	43.93	47.53	68.55

Table A-1 cont'd.: Chlorophyll-a Concentration in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Chlorophyll-a Concentration (μg/L)**									
5-11	8.04	12.96	6.14	9.07	11.36	14.09	4.09	7.61	10.38	5.17
5-12	6.30	0.92	4.49	5.28	25.64	8.57	5.60	7.38	7.60	15.50
5-13	1.90		1.29	4.78	5.22	6.45	0.62	7.43	8.40	6.30
5-15	1.32	16.64	25.24	43.70	40.91	29.73	81.52	79.95	31.10	32.41
5-16	6.58	12.51	9.06	11.30	17.42	15.20	6.90	18.27	10.02	2.84
5-17	4.45		11.36	12.13	11.81	23.15	7.74	19.13	13.94	7.06
5-18	10.74	1.78	7.54	15.40	5.38	21.80	19.08	16.34	14.03	16.35
5-19	0.00	1.40	19.57	41.14	47.89	36.26	79.17	64.11	50.58	9.84
5-20	9.49	27.72	26.47	62.54	52.46	61.79	72.03	56.68	46.42	42.07
5-21	7.40	3.04	13.71	12.59	40.11	42.77	30.65	26.03	53.01	29.25
5-22		6.67	13.78	7.95	5.54	11.91	16.11	30.44	16.56	23.87
5-23		12.50	2.67	1.97	10.58	4.67	0.00	0.00	0.00	2.64
6-4	0.00	7.61	2.64	4.02	0.05	2.76	4.67	1.35	10.80	84.88
6-6	3.55	9.33	8.55	36.20	13.06	81.11	108.11	50.49	70.14	38.09
6-7	3.08	5.08	20.22	27.52	33.60	22.51	122.26	72.76	57.91	35.44
6-8	5.87	13.47	26.92	63.89	438.63	166.76	138.81	202.39	121.27	53.08
6-9	7.49	8.75	73.15	104.23	49.84	83.74	119.11	62.73	128.52	121.89
6-10	2.29	20.10	8.16	20.65	22.17	27.09	61.49	25.47	38.93	
6-11	3.97	22.29	5.93	14.12	15.08	42.14	32.63	43.09	38.49	
6-12	2.98	12.35	5.33	7.74	8.89	2.53	0.43	28.34	59.80	93.13
6-13	11.02	16.99	6.74	9.97	5.35	3.43	2.14	8.97	45.01	58.24
6-14	0.00	17.22	17.30	28.30	8.74	7.27	7.04	15.14	34.56	12.79
6-15	0.00	21.45	35.55	74.86	15.70	41.17	27.23	53.23	54.03	51.30
6-16	88.02	19.04	28.51	31.63	26.55	57.92	49.33	80.19	56.77	74.96
6-17	0.00	11.49	18.75	21.31	14.59	11.36	12.16	19.69	18.80	36.83
6-18		2.67	31.50	67.34	24.88	33.05	33.00	43.30	59.62	58.32
6-19	2.76	5.63	1.57	6.46	2.69	7.41	6.51	18.27	6.01	17.31
6-20	6.18	15.40	0.79	2.63	9.73	9.95	1.58	49.03	33.85	9.98
6-22	4.97	0.39	4.17	7.18	10.36	5.63	6.66	23.41	10.42	12.05

Table A-2: Total Suspended Solids Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Total Suspended Solids (mg/L)									
2-2	3.50	6.50	3.00	6.75	11.67	8.00	12.00	8.50	10.00	4.50
2-4	4.25	3.25	5.00	0.33	7.50	8.00	11.00	4.50	18.50	7.00
3-1	9.75	11.25	6.75	9.00	21.50	19.50	25.00	27.33	13.96	66.67
3-2	36.00	12.00	6.25	6.00	13.67	3.00	18.54	26.00	50.00	96.77
3-3	29.50	2.50	4.00	4.00	8.00	3.25	18.79	17.00	44.00	43.00
3-4	20.50	5.17	8.25	7.25	13.75	3.00	12.50	28.86	41.00	31.00
3-5	23.50	15.00	20.00	6.00	16.00	4.00	14.04	17.57	23.33	17.20
3-6	7.00	12.50	8.75	7.00	4.25	3.83	3.80	4.83	6.50	7.50
3-9	19.00	6.00	2.25	5.83	5.00	8.50	19.00	42.50	30.00	30.00
3-10	22.50	17.00	14.00	3.50	27.50	19.00	19.00	24.50	21.79	16.25
4-2	23.00	8.75	12.25	18.00	14.50	11.50	25.50	20.50	25.50	48.00
4-4	24.25	9.75	31.96	24.50	25.00	30.50	50.00	54.00	57.00	69.00
4-5	20.00	11.25	9.25	7.83	12.75	26.00	28.10	29.00	27.83	20.75
4-6	21.00	14.75	13.00	11.00	16.00	16.00	13.00	19.50	18.67	21.53
4-7		16.50	25.25	12.50	8.33	24.59	14.50	30.32	17.00	10.00
4-8	41.00	12.00	8.00	8.50	5.00	17.00	18.79	10.50	18.00	18.12
4-9	25.50	18.00	24.50	20.50	22.00	51.50	29.50	20.00	31.50	20.27
4-10	60.00	18.50	38.25	38.00	27.50	34.50	54.00	27.67	46.00	30.79
5-1	32.00	13.75	28.00	34.67	38.00	52.00	75.00	54.00	69.00	40.72
5-2	19.00	12.75	19.00	34.00	41.00	35.00	21.00	23.18	29.00	31.00
5-3	21.50	6.50	11.00	9.25	8.50	11.00	18.83	28.38	36.00	75.00
5-4E	25.50	9.50	17.75	17.50	19.50	17.00	23.56	22.50	16.00	18.00
5-4W	31.00	9.00	22.00	23.67	21.00	12.50	24.00	30.32	24.50	16.50
5-5	9.00	17.25	27.75	49.50	37.50	27.70	32.00	63.00	50.00	63.00
5-6	35.50	20.00	29.25	41.67	31.75	38.00	43.50	53.00	55.00	47.00
5-7	31.50	19.25	21.75	43.00	41.00	46.00	47.00	74.00	51.00	66.00
5-8	9.00	20.75	20.75	28.50	44.25	42.00	45.00	27.33	39.00	44.00
5-9	15.00	15.75	20.50	45.00	60.00	58.00	18.27	46.50	44.50	50.00
5-10	25.50	25.00	27.75	37.75	37.50	28.50	32.47	27.33	33.33	43.50

Table A-2 cont'd.: Total Suspended Solids Concentration in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Total Suspended Solids (mg/L)**									
5-11	8.00	6.50	9.75	9.50	8.70	12.50	9.00	9.33	10.17	6.50
5-12	3.50	3.75	5.75	2.50	13.00	5.00	9.00	8.00	9.00	21.50
5-13	14.00	8.25	5.00	5.00	7.75	4.00	5.25	9.00	6.00	10.00
5-15	23.00	18.00	30.00	39.25	30.50	69.50	86.00	59.00	65.00	43.00
5-16	60.00	28.75	21.00	19.00	26.50	22.00	43.00	20.00	27.00	19.00
5-17	31.50	20.50	22.50	24.00	25.00	56.50	43.17	24.33	26.50	26.00
5-18	56.00	18.75	22.75	15.50	39.50	41.50	43.50	20.00	46.00	23.50
5-19	38.50	16.00	23.50	25.50	27.50	25.67	44.30	31.08	59.00	72.00
5-20	22.00	21.75	20.75	43.50	37.00	61.00	80.00	40.67	58.00	47.00
5-21	27.00	10.50	10.75	14.50	23.08	30.00	41.50	54.00	80.16	61.00
5-22		12.00	33.00	17.50	14.00	21.50	28.00	26.85	24.50	21.50
5-23		14.75	39.00	7.00	1.83	20.00	35.50	18.00	15.50	34.00
6-4	4.00	4.75	3.00	6.50	3.00	8.50	3.00	7.50	20.50	11.00
6-6	9.50	8.75	6.75	16.00	15.00	28.00	38.00	27.33	28.29	18.42
6-7	21.00	8.50	8.00	20.00	20.00	34.50	44.00	32.89	29.50	16.78
6-8	29.00	13.50	21.75	27.00	27.00	78.00	86.00	146.75	93.00	74.64
6-9	18.50	12.25	24.75	35.00	32.00	43.50	55.50	55.00	59.50	71.00
6-10	24.00	14.50	15.00	13.50	26.00	28.50	43.00	55.00	32.26	24.84
6-11	34.50	15.25	16.00	16.50	30.00	28.50	45.27	41.50	39.00	25.17
6-12	23.50	11.75	18.25	9.00	10.00	2.00	6.75	31.78		52.00
6-13	11.00	33.00	24.25	9.00	10.50	8.75	11.50	15.23	38.00	40.00
6-14	8.00	10.75	17.50	13.50	10.50	8.50	12.50	22.88	27.33	17.92
6-15	14.00	20.00	24.00	38.33	14.00	21.50	25.42	41.00	50.50	49.00
6-16	54.50	24.50	22.75	19.50	50.00	36.00	32.50	35.06	42.00	34.50
6-17	13.50	11.75	22.25	18.50	21.50	9.00	18.00	26.00	22.52	36.00
6-18	30.00	17.25	24.25	35.50	26.50	18.50	26.00	39.00	44.00	48.00
6-19	27.50	8.25	10.75	8.00	3.25	7.00	9.50	10.00	7.50	15.33
6-20	31.00	20.00	3.75	6.00	11.50	14.50	7.98	24.17	28.00	19.25
6-22	17.50	4.75	9.00	7.50	10.00	7.25	4.50	12.00	10.50	11.00

Table A-3: Turbidity Values in 58 SRBs

Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Turbidity (NTU)									
2-2	9.30	3.50	1.80	3.00	2.98	5.65	4.40	2.15	3.05	1.13
2-4	3.05	3.20	1.45	1.70	2.80	5.13	4.35	3.95	5.60	2.10
3-1	13.55	15.05	3.60	3.23	8.13	11.80	10.80	14.80	4.95	30.30
3-2	24.55	15.80	5.05	4.23	9.25	3.90	13.80	20.30	27.80	38.80
3-3	12.05	1.95	2.75	2.30	4.45	2.90	16.55	17.30	22.30	22.30
3-4	7.80	3.65	5.30	5.13	5.08	4.95	16.30	15.05		14.80
3-5	11.80	12.80	8.50	4.00	9.03	3.65	7.18	11.30	16.80	7.35
3-6	5.55	1.80	2.40	3.03	3.30	13.30	3.70	3.20	4.90	2.70
3-9	7.30	5.25	2.00	3.25	3.15	6.50	15.80	28.05	16.80	15.55
3-10	10.30	13.30	7.00	4.30	22.55	18.05	16.30	19.05	14.80	16.80
4-2	10.80	5.25	7.60	14.05	7.13	16.05	24.55	19.30	19.30	28.80
4-4	22.30	5.80	20.30	16.05	8.00	23.80	22.05	29.05	30.80	45.80
4-5	9.30	7.30	6.05	4.75	5.25	17.05	17.80	15.80	22.30	11.05
4-6	11.05	8.10	8.05	11.03	16.80	14.30	9.75	14.30	6.58	8.00
4-7		20.55	22.80	9.30	4.10	21.05	13.80	15.80	8.45	6.40
4-8	18.80	4.85	6.75	5.60	3.95	8.40	9.05	17.30	7.35	11.55
4-9	14.30	20.55	20.80	23.55	24.30	52.30	27.55	16.55	30.30	18.05
4-10	26.55	15.80	31.30	33.80	17.30	29.30	40.30	22.05	23.55	14.80
5-1	12.05	13.55	13.05	14.30	19.30	24.05	43.55	22.80	32.30	33.80
5-2	10.55	12.30	9.80	14.30	20.05	13.80	7.80	14.80	12.80	14.30
5-3	9.55	6.35	5.30	3.73	3.00	4.60	12.80	20.30	15.55	42.30
5-4E	9.55	9.85	15.05	11.70	11.05	9.18	17.30	15.30	9.30	18.30
5-4W	14.30	11.55	17.30	18.30	11.10	7.90	18.80	16.30	15.30	13.55
5-5	11.30	21.80	15.80	22.80	14.05	18.30	22.80	32.55	24.30	28.55
5-6	13.30	23.80	16.55	24.80	11.55	24.05	23.80	23.30	28.30	19.05
5-7	13.80	23.55	14.55	21.30	19.55	32.55	34.05	48.05	22.55	30.80
5-8	13.80	24.80	12.30	22.30	27.05	28.05	30.30	16.55	24.80	25.05
5-9	13.30	16.80	11.05	20.30	33.30	37.55	13.80	31.55	26.80	41.30
5-10	11.80	30.80	17.30	19.55	19.80	19.80	26.80	16.80	27.30	31.30

Table A-3 cont'd.: Turbidity Values in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Turbidity (NTU)**									
5-11	15.30	15.30	7.03	5.30	2.48	9.65	15.93	6.90	5.70	6.35
5-12	7.05	2.20	3.90	4.35	6.90	4.60	6.35	5.28	19.30	7.05
5-13	5.80	5.05	2.00	2.80	4.20	3.63	3.40	6.50	5.00	6.15
5-15	23.05	17.55	19.30	23.05	17.05	59.30	68.30	36.30	40.80	38.80
5-16	27.80	30.05	18.30	16.30	23.55	39.30	36.80	23.05	22.55	16.80
5-17	17.80	22.55	20.80	21.30	22.30	45.30	36.05	23.05	19.05	26.30
5-18	26.30	21.05	18.55	19.80	36.30	42.55	39.30	21.05	36.30	22.80
5-19	36.80	18.80	14.55	16.30	14.80	21.30	29.80	26.05	41.30	67.30
5-20	23.30	27.05	11.80	29.55	20.30	48.80	62.80	29.55	39.05	43.30
5-21	11.30	7.30	5.75	9.65	15.30	21.30	22.55	25.80	31.30	39.55
5-22		17.55	26.30	20.80	11.80	4.00	26.05	21.55	17.80	15.05
5-23		12.55	40.55	4.95	3.28	24.55	38.30	19.05	18.30	35.05
6-4	9.05	4.80	2.15	4.80	1.95	3.68	2.30	5.40	6.20	8.65
6-6	13.30	5.70	4.35	13.30	5.35	13.30	25.55	21.55	13.80	10.55
6-7	9.80	7.80	4.48	8.10	7.65	22.30	24.80	19.05	8.20	6.90
6-8	13.55	12.55	10.20	14.80	29.80	35.55	50.05	62.80	33.30	36.30
6-9	11.30	12.30	13.30	20.55	21.55	19.55	32.30	30.30	31.30	43.05
6-10	22.80	16.05	16.30	15.30	22.30	27.55	36.05	39.80	16.05	16.30
6-11	36.55	18.30	18.80	19.05	25.55	25.30	36.05	31.80	25.55	15.55
6-12	13.30	17.05	21.30	7.05	7.15	5.65	3.15	24.30		43.05
6-13	19.55	37.80	27.05	7.65	12.55	11.80	12.80	13.05	20.80	30.30
6-14	12.80	16.55	8.65	14.80	6.13	9.90	15.55	19.80	21.55	18.30
6-15	11.05	25.55	12.30	15.80	4.45	12.80	18.80	24.55	16.30	20.80
6-16	62.80	31.55	16.05	20.30	26.30	25.05	19.80	25.80	15.05	18.55
6-17	15.30	12.05	17.05	14.80	19.55	8.70	15.05	21.05	15.30	27.05
6-18	12.05	21.30	12.80	24.80	13.05	7.80	21.30	17.30	19.05	19.80
6-19	12.55	7.55	9.30	6.15	2.55	10.30	5.83	5.85	4.18	13.80
6-20	11.05	23.80	3.33	3.30	9.95	13.80	3.80	17.30	17.05	17.30
6-22	9.80	8.05	5.05	5.70	3.13	4.70	5.10	10.80	4.90	5.55

Table A-4: Transparency Values in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Secchi Depth (cm)**									
2-2	124	68	140	137.5	145	85.5	100.25	140	106	130
2-4	95	118	108	103	105	56.25	74	116	55.75	105
3-1	43.25	50	98	84.5	52	30.5	32	43	57.25	19.5
3-2	35.5	46.5	101.5	63.25	43.25	141.25	32	34.75	21.75	15.5
3-3	107	178	176	169.5	107.5	164	65.75	56.75	30	22
3-4	66	113.5	78	79	78.75	134.75	74.5	29.25	39	37.25
3-5	71	50.5	51.75	92	70.75	100	61.75	56	52.5	71.5
3-6	97	110	120	120	111	39	120	120	112	115
3-9	69	85.5	138.5	155.5	140	82.75	49.5	32	29	32.25
3-10	59.5	59.5	63	110	35.5	46.75	48.5	40.75	46.75	50.25
4-2	58	74.5	56.5	37.75	65	63	48	47.75	46	22.25
4-4	38.25	46.5	23	31.5	38	27.25	21.75	27	24.75	15.25
4-5	51	57	66.5	79.5	75.75	34.75	33	39.75	49.75	42.75
4-6	55.25	36.5	55.5	51.5	51.5	51.5	61.5	51.5	53.5	40
4-7		47.25	21.75	58	126.5	53	70.75	65.25	93	106.5
4-8	48.25	59	72	77.75	121.5	32.5	50	57.5	74.25	45.5
4-9	49.25	40.5	37	29	29.25	20	28.25	35.75	28.25	43
4-10	23.5	32.75	23.75	23.75	26.5	19	18.5	25.25	27	26.5
5-1	60	57	24.5	25.25	25.5	22.5	15	22.5	19	18
5-2	64.25	45.5	38.75	21	21	24.25	67.5	33	35.25	37.25
5-3	52.25	83.25	75.5	68.5	91.5	73.5	57	38	32.5	19.25
5-4E	70	63.75	28.75	34	36.5	43.5	36.5	55.75	44	42.25
5-4W	44.5	52.5	23	29.5	53.75	48.25	32.5	35.25	35.5	53.25
5-5		37.5	25	18.75	20.5	19.25	18.5	20.5	18.75	13.5
5-6	47.5	39.5	27.25	18.25	26	18	18.5	20	16.25	14
5-7	36.5	29.75	28.5	18.75	22.75	16	18.5	16.5	18.25	16.25
5-8	70	37.25	31.75	24.75	20	18	15.75	32	20.75	19.5
5-9	53	47	38.25	18	16.5	14.75	41.25	23.5	24	27
5-10	43	32.5	25.25	25.5	25.75	24	20.25	34.5	27.25	26

Table A-4 cont'd.: Transparency Values in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Secchi Depth (cm)**									
5-11	92	70.5	68.5	109	99	68.5	84.25	84.5	98	90
5-12	117.5	128	114	99.25	58	88.25	92	86.25	78	77.75
5-13	90.5	77.75	162	148.75	130.25	117	123	85	94	88.25
5-15	41.5	38.5	25.75	22.25	22	14.25	10.75	19.25	16.25	20
5-16	38.5	35.25	31.5	43.5	28.75	25.25	18.75	42.5	29.5	45.5
5-17	47.5	43.5	27.25	37.5	34.5	20.75	22.25	39.25	37	36
5-18	36.25	33.5	34.5	38.25	26.5	25.25	22.75	45.5	19	36.5
5-19	33	38.5	30.5	25	26.75	24	16.75	27.75	16	16
5-20	39.5	36.25	28.75	20	17	15.25	12	26	18.75	20.25
5-21	57	54	62.5	50.25	28	25.25	25	25	19.75	20.25
5-22		52.25	24.25	36.5	55	35.25	30.25	40.75	34.75	32.5
5-23		56.5	21.75	141	156	32.75	26	47.75	45.25	25.5
6-4	113	75.25	132.5	67	154	84	71.5	61.75	73.25	71.25
6-6	69	67	91.5	53	40.5	26.75	23	25	33.25	48.25
6-7	62	61.75	54	37.25	37.5	22.75	17.25	24	27.5	41.5
6-8	47	46.5	30	36	19.25	12.75	11.25	8.5	12.25	14.25
6-9	61.75	51.5	31.25	22.25	20	17.5	17	18.75	16.5	18.75
6-10	42	43.5	40.75	47.5	35.5	20.75	22.25	26.75	32.5	31.5
6-11	26	43	39.5	46	33	28	23	19.25	26.25	31.75
6-12	52.5	49.5	35.25	72.5	65.5	69.75	130	28.25	22	18.75
6-13	56	26	32.5	65.25	53.25	73.75	54.75	47.75	26	20
6-14	77.5	51	38	48.5	64	44.75	41	25	43.5	24.5
6-15	59.5	46.5	28.5	23	63.75	34.25	32.5	23.25	23.25	20.75
6-16	22.5	28.5	28.5	45.25	19	24	25	19	25	24.75
6-17	56.25	54.5	28	49.5	46.75	58.25	50.25	42.5	37	29.25
6-18	63	43	26	25.5	37.25	33	33	25.5	21.75	22.5
6-19	62.25	71	56.75	73.5	135.5	82	83.5	86	122.5	62.75
6-20	58	41.75	105	126.25	79	88.5	145	43.75	34.75	36.5
6-22	71.5	106	81.5	78	74.5	66	115.5	64.25	66.5	77

Table A-5: Total Kjeldahl Nitrogen Concentration in 58 SRBs						
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**5** (Jun 30-Jul 3)	**7** (July 27-29)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**TKN (mg/L)**					
2-2	0.66	0.95	1.91	1.32	6.88	0.52
2-4	2.22	1.22	2.00	0.98	5.85	0.30
3-1	0.84	1.24	1.64	6.21	5.56	4.21
3-2	1.64	2.35	1.11	4.64	7.91	4.79
3-3	1.63	1.42	1.73	5.87	5.56	3.75
3-4	8.20	1.82	1.91	2.72	8.27	3.30
3-5	2.26	2.11	2.08	1.60	7.47	3.99
3-6	0.88	0.95	1.20	1.20	1.29	1.25
3-9	0.94	2.44	1.55	3.06	8.27	4.55
3-10	1.13	1.90	1.97	3.51	5.70	2.84
4-2	2.49	0.74	2.75	1.91	7.10	6.47
4-4	1.88	3.18	2.66	3.51	4.89	3.81
4-5	1.34	1.44	1.64	3.12	3.06	1.96
4-6	0.92	1.19	1.46	1.66	2.40	2.01
4-7		1.53	1.62	4.57	6.73	3.15
4-8	3.53	1.73	1.73	5.44	5.11	4.23
4-9	0.38	1.57	4.22	1.14	2.40	0.95
4-10	1.55	1.98	2.71	4.11	6.51	2.33
5-1	1.38	3.14	3.51	5.24	4.97	6.06
5-2	2.48	2.35	3.71	3.29	2.62	2.42
5-3	0.78	1.55	1.91	2.37	3.06	5.51
5-4E	1.42	1.40	2.26	1.96	1.59	1.34
5-4W	2.05	2.15	2.44	1.76	1.81	1.18
5-5	1.07	2.69	3.42	3.91	4.23	5.61
5-6	2.10	2.83	2.82	3.60	4.75	4.29
5-7	3.64	2.31	3.60	3.81	4.53	4.95
5-8	1.74	2.19	2.80	4.01	3.64	4.01
5-9	0.94	5.01	3.60	6.93	4.16	5.54
5-10	1.05	2.19	2.80	2.42	2.47	2.94

Table A-5 cont'd.: Total Kjeldahl Nitrogen Concentration in 58 SRBs						
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**5** (Jun 30-Jul 3)	**7** (July 27-29)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**TKN (mg/L)**					
5-11	0.59	1.44	1.35	1.04	1.59	0.66
5-12	0.42	0.82	2.04	4.11	5.11	1.12
5-13	0.48	2.65	1.11	0.73	4.53	1.62
5-15	0.84	2.15	2.04	3.19	2.19	2.42
5-16	0.47	0.99	1.11	1.20	1.87	1.14
5-17	1.03	2.48	1.46	1.25	1.22	1.42
5-18	1.14	0.90	2.44	3.17	3.74	2.41
5-19	0.58	1.48	2.71	2.83	2.37	2.59
5-20	1.07	2.89	2.62	3.40	2.48	2.40
5-21	1.51	0.99	2.44	3.09	3.74	2.30
5-22		0.82	1.42	2.53	1.00	0.98
5-23		0.82	1.02	0.89	2.44	3.50
6-4	1.12	0.61	2.00	1.25	3.38	3.40
6-6	2.75	1.48	1.86	4.16	3.74	2.65
6-7	0.57	1.28	1.60	4.52	5.11	2.78
6-8	1.06	2.89	6.02	6.37	4.53	3.52
6-9	0.78	2.81	3.37	5.37	5.03	5.20
6-10	1.21	1.48	1.73	3.17	2.59	3.31
6-11	0.99	1.69	2.26	2.44	3.20	3.71
6-12	1.09	1.36	2.00	4.35		3.48
6-13	1.39	0.74	1.57	2.61	3.95	5.21
6-14	0.71	1.61	2.17	2.27	4.24	4.05
6-15	1.39	2.50	1.68	3.29	4.10	4.54
6-16	2.02	1.73	4.13	2.95	2.62	2.95
6-17	1.70	1.24	2.08	1.71	1.87	2.31
6-18	1.49	2.19	3.02	3.96	4.10	3.93
6-19	1.28	1.15	2.04	2.58	3.16	3.38
6-20	1.74	1.19	1.82	2.39	3.45	3.78
6-22	1.42	0.90	1.55	1.04	1.40	0.49

Table A-6: Ammonia Concentration in 58 SRBs									
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Ammonia Concentration (μg/L)**								
2-2	17.64	0.00	0.00	0.00	0.00	0.00	248.52	0.00	0.00
2-4	47.17	0.00	0.00	42.75	0.00	0.00	25.29	0.00	0.00
3-1	0.00	0.00	616.33	42.23	146.32	0.00	0.00	0.00	244.43
3-2	0.00	0.00	0.00	60.09	0.00	0.00	0.00	284.28	300.20
3-3	312.94	0.00	0.00	4.92	0.00	0.00	197.01	27.12	0.00
3-4	17.64	0.00	0.00	4.86	0.00	0.00	0.00	311.88	346.42
3-5	0.00	0.00	0.00	93.45	0.00	0.00	0.00	0.00	0.00
3-6	61.27	0.00	0.00	4.75	0.00	0.00	0.00	26.00	51.91
3-9	2.88	0.00	0.00	39.35	0.00	0.00	0.00	42.74	23.36
3-10	0.00	0.00	1146.59	141.70	23.48	0.00	0.00	75.90	590.57
4-2	224.35	21.11	0.00	38.48	396.73	0.00	8.12	0.00	606.16
4-4	0.00	0.00	0.00	71.56	33.88	0.00	0.00	24.64	22.08
4-5	0.00	0.00	0.00	37.64	12.58	0.00	0.00	0.00	0.00
4-6	17.64	0.00	0.00	70.03	0.00	0.00	8.12	0.00	0.00
4-7		1090.37	1135.31	231.49	0.00	0.00	506.09	798.29	1008.94
4-8	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00	1016.11
4-9	17.64	0.00	119.92	734.93	178.27	0.00	0.00	69.39	0.00
4-10	34.37	0.00	0.00	67.14	0.00	0.00	0.00	7.62	0.00
5-1	7.46	0.00	0.00	159.81	12.24	0.00	0.00	489.18	0.00
5-2	7.46	0.00	0.00	65.79	0.00	151.02	0.00	37.19	0.00
5-3	34.37	0.00	0.00	34.63	42.67	0.00	0.00	0.00	213.89
5-4E	135.76	0.00	176.33	34.29	0.00	0.00	0.00	36.33	0.00
5-4W	76.70	0.00	0.00	4.05	52.37	0.00	0.00	21.55	0.00
5-5	0.00	0.00	0.00	92.84	0.00	0.00	0.00	7.10	0.00
5-6	61.94	0.00	7.10	3.98	0.00	0.00	0.00	0.00	0.00
5-7	194.82	0.00	0.00	91.07	0.00	0.00	25.29	6.94	43.30
5-8	0.00	0.00	0.00	90.22	11.80	151.02	626.29	171.72	914.87
5-9	7.46	0.00	0.00	146.38	11.75	3963.50	729.32	631.92	188.56
5-10	0.00	0.00	0.00	74.43	0.00	0.00	0.00	6.72	186.35

Table A-6 cont'd.: Ammonia Concentration in 58 SRBs									
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Ammonia Concentration (µg/L)**								
5-11	194.82	5.93	0.00	59.75	0.00	0.00	0.00	0.00	0.00
5-12	76.70	0.00	0.00	59.21	11.60	0.00	0.00	0.00	0.00
5-13	0.00	0.00	0.00	141.11	0.00	0.00	0.00	6.51	95.94
5-15	7.46	0.00	0.00	112.62	88.71	0.00	0.00	45.13	358.19
5-16	17.64	0.00	119.92	84.63	11.45	0.00	0.00	0.00	66.40
5-17	7.46	0.00	40.94	110.64	20.96	0.00	0.00	0.00	282.57
5-18	0.00	0.00	0.00	613.58	39.93	0.00	0.00	31.27	279.52
5-19	0.00	0.00	0.00	69.30	0.00	0.00	0.00	6.19	1192.37
5-20	0.00	0.00	0.00	172.98	20.70	0.00	0.00	6.13	777.26
5-21	7.46	0.00	0.00	234.15	0.00	64.94	95.94	66.17	10.86
5-22		0.00	0.00	54.28	11.16	0.00	54.24	0.00	0.00
5-23		344.58	323.00	91.64	11.11	0.00	26.45	100.35	98.78
6-4	0.00	0.00	0.00	0.00	66.80	0.00	109.83	64.33	35.46
6-6	0.00	0.00	0.00	0.00	1.77	151.02	248.82	17.38	59.79
6-7	0.00	31.40	0.00	0.00	0.00	0.00	165.43	0.00	364.69
6-8	106.23	0.00	0.00	0.00	38.45	0.00	137.63	142.24	0.00
6-9	76.70	0.00	0.00	0.00	65.71	0.00	95.94	28.19	0.00
6-10	0.00	222.23	0.00	0.00	211.03	0.00	82.04	0.00	0.00
6-11	17.64	234.12	0.00	0.00	28.92	0.00	137.63	0.00	0.00
6-12	194.82	182.65	0.00	0.00	28.80	1036.50	637.96	93.35	55.90
6-13	0.00	232.40	0.00	0.00	46.67	1270.17	1888.80	92.54	9.66
6-14	0.00	0.00	0.00	0.00	118.11	28.04	109.83	70.16	100.18
6-15	0.00	0.00	345.56	0.00	28.46	0.00	137.63	294.30	0.00
6-16	34.37	0.00	0.00	0.00	10.58	0.00	68.14	5.31	0.00
6-17	0.00	0.00	18.38	0.00	10.54	0.00	82.04	15.78	108.53
6-18	0.00	0.00	0.00	0.00	28.12	0.00	109.83	26.09	118.50
6-19	490.12	0.00	0.00	0.00	0.00	0.00	26.45	46.57	9.15
6-20	32.41	42.23	0.00	0.00	1.67	1085.69	109.83	46.19	996.93
6-22	0.00	0.00	0.00	0.00	1.66	0.00	26.45	25.46	8.99

Table A-7: Nitrate Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Nitrate Concentration (µg/L)								
2-2	0.00	644.33	1115.43	678.40	465.86	381.46	484.01	572.01	626.49
2-4	1.12	18.03	127.69	76.80	0.00	39.39	94.84	0.00	160.41
3-1	0.00	18.03	67.33	0.00	0.00	0.00	0.00	0.00	0.00
3-2	177.48	0.00	0.00	68.84	0.00	0.00	0.00	0.00	130.82
3-3	151.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-4	7.00	0.00	0.00	0.00	0.00	0.00	0.00	44.39	0.00
3-5	0.00	0.00	78.30	180.39	0.00	0.00	0.00	0.00	0.00
3-6	7.00	0.00	0.00	60.87	0.00	0.00	0.00	0.00	0.00
3-9	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-10	0.00	0.00	78.30	64.85	0.00	0.00	0.00	0.00	0.00
4-2	12.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-5	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-6	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-7		126.34	0.00	252.10	0.00	0.00	0.00	0.00	197.40
4-8	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-9	7.00	0.00	0.00	152.50	0.00	0.00	0.00	0.00	0.00
4-10	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.53	0.00
5-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-4E	18.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-4W	12.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-5	0.00	22.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-6	36.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-7	71.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-8	0.00	0.00	0.00	0.00	0.00	30.39	0.00	56.66	0.00
5-9	0.00	0.00	0.00	0.00	0.00	0.00	65.29	44.39	0.00
5-10	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-7 cont'd.: Nitrate Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Nitrate Concentration (µg/L)								
5-11	48.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-12	18.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-16	59.91	0.00	83.79	0.00	0.00	0.00	0.00	0.00	0.00
5-17	71.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-18	77.54	0.00	0.00	156.49	32.03	0.00	0.00	0.00	116.02
5-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-20	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-21	24.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-22		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-23		564.28	555.71	272.02	0.00	0.00	0.00	0.00	0.00
6-4	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-6	0.00	0.00	0.00	0.00	0.00	39.39	0.00	0.00	0.00
6-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-10	0.00	1656.76	188.05	0.00	151.21	0.00	0.00	0.00	0.00
6-11	0.00	743.22	122.20	0.00	70.17	0.00	0.00	0.00	0.00
6-12	59.91	309.99	0.00	0.00	0.00	0.00	50.51	0.00	0.00
6-13	0.00	762.05	0.00	76.80	27.26	34.89	60.36	50.53	0.00
6-14	0.00	0.00	0.00	88.76	0.00	0.00	0.00	44.39	0.00
6-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-17	1.12	0.00	0.00	80.79	0.00	0.00	0.00	0.00	0.00
6-18	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-19	95.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-20	33.45	0.00	0.00	0.00	0.00	34.89	0.00	0.00	167.81
6-22	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A-8: Total Phosphorus Concentration in 58 SRBs						
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**5** (Jun 30-Jul 3)	**7** (July 27-29)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Total Phosphorus (μg/L)**					
2-2	197.34	66.86	100.82	99.13	63.41	0.00
2-4	1502.36	49.95	89.51	70.21	77.27	8.01
3-1	455.26	106.31	151.71	225.64	115.41	297.05
3-2	213.52	372.56	146.06	243.71	313.01	441.57
3-3	294.19	1423.01	185.64	352.14	278.35	254.54
3-4	311.84	204.62	117.79	222.02	250.61	263.04
3-5	159.74	198.04	134.75	124.43	202.08	97.27
3-6	1100.90	448.30	202.61	135.27	105.01	33.51
3-9	294.19	237.55	276.12	388.29	285.28	280.05
3-10	562.66	227.67	264.81	214.79	167.41	59.02
4-2	179.91	356.10	259.15	265.40	209.01	365.06
4-4	280.75	474.64	219.57	48.53	323.41	314.05
4-5	132.85	244.14	117.79	185.88	132.74	67.52
4-6	159.74	428.54	270.46	142.50	174.34	178.03
4-7		263.90	134.75	254.55	493.28	365.06
4-8	267.30	138.76	134.75	128.05	77.27	207.79
4-9	159.74	201.33	106.48	12.38	143.14	59.02
4-10	225.97	257.31	134.75	250.94	202.08	161.03
5-1	280.75	382.44	434.44	460.58	403.15	484.07
5-2	540.83	349.51	448.58	316.00	382.35	263.04
5-3	54.22	224.38	117.79	287.08	271.41	331.05
5-4E	213.52	105.84	134.75	156.96	118.88	59.02
5-4W	1170.55	198.04	179.99	99.13	118.88	84.52
5-5	589.51	286.67	293.08	344.92	354.61	471.32
5-6	321.08	331.75	199.78	323.23	378.88	331.05
5-7	321.08	264.12	327.01	648.53	507.15	671.10
5-8	616.36	286.67	293.08	388.29	340.75	365.06
5-9	508.96	286.67	377.90	605.16	410.08	407.56
5-10	253.86	199.31	276.12	554.56	181.28	297.05

Table A-8 cont'd.: Total Phosphorus Concentration in 58 SRBs						
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**5** (Jun 30-Jul 3)	**7** (July 27-29)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Total Phosphorus (μg/L)**					
5-11	562.66	224.38	55.59	164.19	77.27	16.51
5-12	186.63	132.18	134.75	99.13	91.14	76.02
5-13	455.26	316.58	66.90	99.13	77.27	42.02
5-15	132.85	277.07	394.86	214.79	278.35	186.53
5-16	267.30	224.38	112.13	70.21	122.34	50.52
5-17	200.08	198.04	208.26	117.20	132.74	59.02
5-18	186.63	138.76	123.44	48.53	105.01	63.27
5-19	105.96	336.34	196.95	355.76	209.01	161.03
5-20	294.17	138.76	196.95	434.08	202.08	195.04
5-21	374.86	112.42	191.30	303.05		178.03
5-22		257.31	21.66	113.77	115.41	76.02
5-23		481.23	49.93	55.54	35.67	25.01
6-4	79.07	132.18	106.48	179.29	188.21	88.77
6-6	1153.33	100.67	123.44	477.76	361.55	220.54
6-7	1609.75	151.40	281.77	404.96	319.95	195.04
6-8	401.57	331.75	522.09	550.56	250.61	288.55
6-9	186.63	297.94	270.46	703.43	465.55	518.08
6-10	401.57	128.85	163.02	368.56	202.08	110.02
6-11	428.42	145.76	134.75	237.53	160.48	84.52
6-12	374.72	190.85	338.32	768.95		552.08
6-13	468.69	202.12	293.08	717.99	659.69	331.05
6-14	105.96	86.08	157.37	186.57	313.01	101.52
6-15	321.02	125.59	117.79	215.69	222.88	212.04
6-16	1905.09	145.76	383.55	354.00	264.48	263.04
6-17	186.63	161.82	236.53	317.61	233.28	161.03
6-18	159.74	306.70	267.63	361.28	229.81	195.04
6-19	105.96	92.66	72.55	186.57	77.27	59.02
6-20	253.86	112.42	134.75	201.13	153.54	127.03
6-22	79.07	142.06	44.28	70.09	45.57	25.01

Table A-9: Orthophosphate Concentration in 58 SRBs									
Sampling Week	**1** (May 4-9)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Orthophosphate Concentration (μg/L)**								
2-2	64.22	41.47	34.99	58.10	57.20	105.87	0.00	10.59	0.00
2-4	1914.43	0.00	60.84	13.74	18.84	17.20	0.00	10.59	0.00
3-1	140.98	9.85	151.30	47.01	57.20	135.42	92.87	37.97	359.87
3-2	93.02	152.13	9.14	58.10	108.34	105.87	92.87	298.13	373.97
3-3	180.35	120.51	138.38	91.37	121.13	253.65	126.95	92.74	106.04
3-4	93.02	0.00	9.14	58.10	31.63	120.64	81.51	147.51	63.73
3-5	64.22	57.28	9.14	91.37	18.84	76.31	47.42	65.36	35.53
3-6	972.28	879.38	164.22	135.73	159.48	31.98	1.98	24.28	0.00
3-9	179.42	73.09	241.76	246.63	172.27	253.65	240.57	106.44	91.93
3-10	46.71	57.28	151.30	102.46	82.77	164.98	36.06	37.97	7.32
4-2	150.62	183.75	190.07	146.82	172.27	150.20	70.15	24.28	148.34
4-4	46.71	167.94	164.22	80.28	95.56	342.32	104.23	229.67	176.55
4-5	0.00	136.32	86.68	58.10	18.84	120.64	24.70	339.20	35.53
4-6	19.98	88.90	60.84	102.46	95.56	76.31	104.23	51.67	49.63
4-7		104.70	34.99	47.01	57.20	224.09	535.96	325.51	204.75
4-8	64.22	25.66	138.38	146.82	44.41	105.87	47.42	51.67	63.73
4-9	19.98	25.66	34.99	47.01	57.20	46.75	138.31	10.59	0.00
4-10	64.22	136.32	47.91	58.10	57.20	135.42	47.42	133.82	35.53
5-1	150.62	57.28	202.99	146.82	133.91	164.98	92.87	325.51	247.06
5-2	100.17	183.75	112.53	157.91	44.41	150.20	138.31	243.36	106.04
5-3	64.22	120.51	9.14	35.92	18.84	120.64	92.87	92.74	162.44
5-4E	64.22	25.66	34.99	80.28	31.63	371.87	126.95	51.67	21.42
5-4W	0.00	183.75	190.07	80.28	6.06	105.87	161.04	65.36	35.53
5-5	100.17	73.09	164.22	69.19	57.20	120.64	138.31	215.97	232.95
5-6	121.82	231.18	202.99	80.28	121.13	179.76	195.12	215.97	190.65
5-7	93.02	199.56	293.46	113.55	133.91	283.20	251.93	284.43	232.95
5-8	972.28	152.13	177.15	113.55	108.34	164.98	70.15	133.82	134.24
5-9	46.71	25.66	215.92	191.18	261.77	519.65	126.95	147.51	176.55
5-10	93.02	57.28	99.61	124.64	108.34	430.98	58.79	106.44	91.93

Table A-9 cont'd.: Orthophosphate Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Orthophosphate Concentration (μg/L)								
5-11	19.98	167.94	47.91	47.01	6.06	268.43	1.98	0.00	0.00
5-12	46.71	120.51	99.61	80.28	6.06	17.20	149.68	10.59	7.32
5-13	19.98	104.70	60.84	35.92	6.06	46.75	1.98	10.59	7.32
5-15	19.98	136.32	99.61	102.46	133.91	105.87	115.59	92.74	35.53
5-16	121.82	88.90	47.91	58.10	108.34	17.20	0.00	10.59	0.00
5-17	121.82	104.70	86.68	135.73	82.77	17.20	104.23	37.97	7.32
5-18	121.82	57.28	9.14	91.37	108.34	31.98	1.98	10.59	0.00
5-19	136.22	326.04	99.61	69.19	31.63	120.64	70.15	92.74	91.93
5-20	2773.44	41.47	60.84	80.28	57.20	179.76	58.79	79.05	49.63
5-21	121.82	9.85	177.15	102.46	44.41	120.64	81.51	161.20	49.63
5-22		326.04	0.00	58.10	0.00	2.42	24.70	37.97	21.42
5-23		9.85	396.84	13.74	6.06	0.00	0.00	0.00	0.00
6-4	64.22	405.09	34.99	91.37	18.84	150.20	58.79	51.67	21.42
6-6	688.18	9.85	60.84	69.19	95.56	194.54	149.68	147.51	49.63
6-7	46.71	25.66	34.99	91.37	133.91	135.42	104.23	120.13	134.24
6-8	100.17	120.51	86.68	412.98	364.05	194.54	342.82	435.05	218.85
6-9	93.02	167.94	86.68	379.71	236.20	445.76	251.93	229.67	289.36
6-10		120.51	887.92	69.19	57.20	179.76	36.06	37.97	63.73
6-11	307.24	88.90	34.99	113.55	57.20	283.20	47.42	51.67	21.42
6-12	179.42	215.37	267.61	290.99	248.98	726.54	854.08	749.97	261.16
6-13	46.71	120.51	422.69	313.17	236.20	637.88	706.38	366.59	120.14
6-14	64.22	25.66	34.99	80.28	57.20	76.31	81.51	106.44	35.53
6-15	46.71	88.90	422.69	69.19	95.56	224.09	161.04	161.20	120.14
6-16	168.69	73.09	241.76	202.27	133.91	164.98	92.87	202.28	120.14
6-17	19.98	73.09	125.45	180.09	44.41	179.76	104.23	65.36	21.42
6-18	93.02	199.56	34.99	102.46	82.77	224.09	81.51	202.28	106.04
6-19	150.62	9.85	551.92	35.92	57.20	46.75	24.70	0.00	21.42
6-20	107.42	0.00	34.99	113.55	69.98	135.42	70.15	92.74	49.63
6-22		104.70	9.14	47.01	18.84	61.53	36.06	37.97	63.73

Table A-10: Surface Dissolved Oxygen Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Dissolved Oxygen (mg/L)									
2-2	2.7	17.2	3.6	7.6	10	8.3		5.2	8.6	8.5
2-4	14	18.8	5.5	3.2	3.8	6.3		6.2	8.95	8.6
3-1	10.6	11.6	5.4	9.9	10.8	7.1		6.6	8.2	8.7
3-2	10	7.7	12.4	9.3	8.3	6.7		4.6	10.2	8.9
3-3	6.8	7.8	12.8	10.2	10.3	6.6		7	10.9	7.7
3-4	12	12	12.4	8.7	9.3	6.7		10.3	8	7.4
3-5	13.4	15.4	12.2	8	7.3	7.1		9.4	8.7	8.05
3-6	13.6	10.5	14.2	10.6	12.2	1.2		6.7	5.6	7.1
3-9	11.4	11	13.8	7	9.8	5.2		7.5	9.6	7.3
3-10	12.2	12.6	10.6	5.9	8.4	5.8		8.1	5.4	5.9
4-2	13.2	9.6	12.2	10.2	9.6	6.8		8.9	8.6	9.3
4-4	15	12.4	11.6	10.2	11.8	8.7		8	10.8	8.4
4-5	14.4	14	11.6	10.5	10.6	5.4		13.2	12	9.4
4-6	12.4	13.2	10.3	7.6	10.2	6.6		12.2	10.6	9.3
4-7		9.3	6.4	5.6	8.9	11		13.3	7.8	4.9
4-8	14	14	8.2	9.2	9.3	8.6		8	7.35	6.1
4-9	11	12.6	9.6	8.2	6.2	4.6		10.2	8.8	8.55
4-10	12.2	12.2	9.1	8.5	10.6	9.5		11.8	12.2	9.3
5-1	12.2	10.7	12	7.8	10.6	8.5		3.9	9.6	8.7
5-2	11.2	12.4	10.6	12.3	14.5	3.2		10.4	9.7	9.6
5-3	12.2	10.2	10.4	12.8	6.9	4		5.6	9.2	8.8
5-4E	10.4	10.2	9.9	9.9	9.2	5.7		11.4	11.5	10.4
5-4W	10.7	10.5	11.4	10.1	11.4	7.7		12	13.1	9.6
5-5		13.8	3.5	15.2	16	6.4		19.2	12.6	14.8
5-6	9.25	14.3	4	16.2	16.8	10.8		16.8	12.6	11.2
5-7	9.7	13.8	3.3	15.2	19.2	14		20	9.4	17.4
5-8	7.5	13	2.9	10.6	16.5	14.6		11.7	9.8	12.7
5-9	10.1	15.8	6.6	9	20	12.2		18.2	5	15.2
5-10	9.5	9.4	3.4	13	18.6	9.3		14.3	9.9	13.8

Table A-10 cont'd.: Surface Dissolved Oxygen Concentration in 58 SRBs										
Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Dissolved Oxygen (mg/L)									
5-11	9.2	12.2	11.1	9.1	6.4	5.2		11.2	8.8	7.8
5-12	9	7.8	9.5	9.1	8.9	7.1		11.8	3.6	7.2
5-13	10.2	15.5	9.8	7.6	6.4	7.5		9.5	9.6	10.9
5-15	8.25	13.8	11.4	11.4	12.4	8.4		10.6	9.7	9.8
5-16	9.3	13.4	11.3	7.75	8.1	7.9		11	8.8	10.3
5-17	8.4	14.5	10	7.6	7	6.7		11.2	8.4	8.7
5-18	9.8	10.1	10.8	8.6	6.9	7		10.4	7.9	9.2
5-19	8.3	11.4	10.6	10.3	12	5.65		8.25	7.2	6.9
5-20	9.4	13	11.2	11.4	15.6	8		11.2	7.55	8.8
5-21	10.4	11.6	11	10.7	14.8	8.4		12.4	8.45	8.7
5-22		11	10.8	8.9	10.6	6.8		10.6	9.7	10.3
5-23		16.5	8.9	11.8	10.3	7.6		8.1	7	8.6
6-4	11	10.9	14.6	10	15.4	14.8	17	6.2	6.25	5.5
6-6	8.25	11.7	9.8	14.6	12.5	12.8	10.3	2.7	6.3	7.9
6-7	8.9	12	11	12.9	8.8	17.9	8.2	2.05	5.2	7.25
6-8	10.1	12.8	6.8	16	12.8	20	14	6.6	11.6	5.4
6-9	9.6	9.5	6.6	11.7	6	12.4	9.75	8.6	9.25	8.2
6-10	9	10	5	9.3	12.2	9.6	6.8	7.5	7.4	12.4
6-11	8.75	13.4	5.2	8.2	10.4	13.4	7.2	7	9.2	10.5
6-12	9	10.4	5.2	9.7	7.2	7.4	0.4	0.8	5.7	10.2
6-13	8.2	10.6	5.1	9	6.6	5.6	2.35	1.8	7	13.8
6-14	8.8	9.6	13.2	12.4	9.2	2.8	4.2	3.2	7.3	4.2
6-15		15.4	16.2	15.9	11.2	13.2	7.8	5.5	14.8	8.9
6-16	7.35	9.9	4.3	9.9	12.2	8.1	8.15	7.1	7.3	11.3
6-17	7.8	14	11.4	12	9.75	11.5	8.1	7.2	9.6	7.7
6-18	9.2	14.6	12.6	14.8	10.3	11.8	8.3	4.45	11.4	11.6
6-19	8.8	11.6	10.2	12.4	14	9.4	10.8	10.2	11.6	7.2
6-20	9.2	13.2	15.4	11.8	9.2	11.6	1.9	8.1	10.2	4.7
6-22	10.2	10.7	11.4	11.3	12.4	12.4	9.9	6.2	9.1	8.3

Table A-11: Mid-Depth Dissolved Oxygen Concentration in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Dissolved Oxygen (mg/L)**									
2-2	2.7	16.8	10.8	9.5	10.2	8.1		5.4	9.1	10.8
2-4	14.2	17.8	8.4	3.2	3.8	6.2		6.05	9.35	10.2
3-1	11.2	9	5.5	8.2	10.5	6.7		5.6	7.8	7.6
3-2	9.8	8.2	13.6	9.7	7.7	6.5		4.5	8.35	7.5
3-3	6.9	10	13.3	11.2	10.2	6.4		6.5	10.5	7.4
3-4	12.2	13	13	10.8	8.2	6.1		7.4	7.4	7.6
3-5	13.4	16.4	12.6	9.2	7.3	0.9		5.85	8.6	9.4
3-6	13.6	13.4	14.2	11.2	10.2	1.1		5.75	5.4	7.6
3-9	12	11.6	14.3	8.8	9.5	4.2		6.55	9.1	7.4
3-10	12.5	15	11	8.2	8.1	5.75		7.9	5.55	6
4-2	11.2	10.6	12.6	11.2	9.6	6.8		9.2	8.7	9.2
4-4	10.2	12.4	12.4	10.1	7.2	5.4		8	7.25	6.3
4-5	14.2	14.8	12.4	9.6	10.4	5.25		13	10.9	9.3
4-6	13.4	13	11	9.6	9.8	5.7		10.3	8.2	8.6
4-7		9.1	7.2	7.2	8.9	11.1		3.5	5.45	4.9
4-8	13.8	10.2	8.4	9.5	7.3	1.4		6.5	6.1	4.8
4-9	10.4	12.4	10	9.3	5.6	4.5		10.9	8.3	8.6
4-10	12.5	13	9.3	9.2	10.3	8.7		10.6	11.6	8.6
5-1	10.4	10.9	10.6	7.6	8.1	8.1		1.55	8.5	8.1
5-2	11	13	10.6	13.2	13.6	2.9		9.15	8.5	9.2
5-3	12.6	10.2	11.4	12.2	7.2	3.8		4.7	6.35	8
5-4E	10.4	10.8	9.4	10.4	9.05	6.7		12.2	10.6	9.9
5-4W	10.4	11.5	10	8.1	11.4	3.85		12.2	10.4	9.6
5-5	9.4	13.8	4.4	12.4	10.6	2.7		5.1	7.9	6.75
5-6	9	14	4.7	8.5	5	10.2		5.35	7.7	8.8
5-7	9.4	13.6	3.8	14.2	2.2	3.5		4.7	5.7	9.4
5-8	7.6	12.8	2.6	7.7	3.4	10.4		3.7	8.2	10.4
5-9	10.1	16.6	6.9	9.1	9.2	11.7		6.5	4.8	12.8
5-10	9.6	9.9	3.6	13	8.7	9		4.95	7.3	13.8

Table A-11 cont'd.: Mid-Depth Dissolved Oxygen Concentration in 58 SRBs

Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Dissolved Oxygen (mg/L)									
5-11	9.2	11.8	10.2	9.8	6.2	4.6		7.7	8.8	7.9
5-12	9	6.8	9.5	9	8.15	5		2.8	2.35	7.2
5-13	9.6	14.7	10	7.6	6.25	7.4		6.4	7.7	9.9
5-15	8.4	14.5	10	12	11.2	6.1		5.35	8.7	9.2
5-16	9.2	11	10.2	7.8	7.8	7.9		9.1	8.5	10.4
5-17	8.5	14.7	9.25	8.1	6.6	6.6		10.2	7.8	8.8
5-18	9.5	9.8	8.7	9.7	6.4	7.4		8.4	7.1	8.7
5-19	8.3	11	8.9	8.7	9.5	5.5		3.8	7.4	5.7
5-20	8.8	13.8	9.9	11.2	12.8	7.7		6.15	7.3	8.8
5-21	10.2	12	9.9	11	11.2	7.5		2.4	7.2	8.2
5-22		10.8	8.7	9.9	10	6.6		8.1	9.2	10.3
5-23		16.2	8.6	3.3	10.4	7.1		6.2	5.1	8.6
6-4	10.2	10.1	15.2	9.3	11.4	5.9	3.8	4.3	4.6	5.55
6-6	8.15	11.2	11	14.7	3.1	7.4	8.85	2.4	3.8	6.8
6-7	8.7	12	10.8	14	7.4	13.2	7.55	2.35	3.6	7.2
6-8	10	13.2	7.7	16.8	5.3	7.5	12.4	6.5	10.5	4.9
6-9	9.2	9.4	6.9	11.6	4.9	11.8	8.7	7.9	7.3	8.1
6-10	9	11	4.6	8.8	11.8	8.6	5.1	6.9	6.2	10.4
6-11	8.9	10.2	5.7	8.3	8.2	10.6	5	5.9	7.55	10.4
6-12	8.3	10.4	5.4	8.3	5.7	5.1	0.5	1	4.5	10.2
6-13	8.5	10.2	5.2	8.15	5.8	5.3	2.3	1.7	5.7	12.8
6-14	8.5	9	13	12.6	8.85	2.6	4.1	3.6	6.8	4.2
6-15		15.4	15.6	15.4	11.1	12.8	5.2	5	14.2	9.4
6-16	7.2	10.2	4.4	9	11.5	7.2	6.7	7.05	5.7	11.2
6-17	7.8	14.3	11.3	12.6	9.15	11.4	6.6	6.6	8.8	7.7
6-18	9.2	11.9	12.4	14.4	5.1	11	7.7	5	10.8	11.2
6-19	9	11.8	10.6	12.2	13.2	9.4	10.2	9.9	11.4	7.2
6-20	8.8	13.4	15	12.2	9.2	12	1.9	7.7	9.9	5.3
6-22	10.4	10.8	11.8	11.9	12.8	11.7	8.85	6.3	9	8.1

Table A-12: Bottom Dissolved Oxygen Concentration in 58 SRBs										
Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Dissolved Oxygen (mg/L)									
2-2	4	17.8	10.8	10.1	12	6.2		5.8	10.1	12.9
2-4	14	18.8	11.1	4.9	3.9	5.7		6.3	9.8	11.8
3-1	10.2	3	7.7	8.3	9.9	4.5		4.6	7.6	7.7
3-2	10	7.9	14.4	11.6	3.3	2.3		0.7	0.95	8
3-3	6.8	7	12.6	13.4	10.4	0.8		1.8	8.4	8.6
3-4	12.2	12.8	13.7	11.4	3.2	1.8		1.1	5.95	9.1
3-5	14	11	13.6	10.4	1.3	4.2		1.8	5.8	10.2
3-6	13.4	17	15.5	17	11.4	0.45		6	5.35	9.4
3-9	12.2	12.6	14.8	11.8	5.3	0.9		6.2	5.1	8.5
3-10	13	5.6	11.8	10.8	3.9	5.6		6.8	5.95	7.2
4-2	11	10.4	13.2	11.2	0.9	0.7		6.5	8.5	8.7
4-4		5.5	13.1	7.8	0.4	2		0.5	4.4	6
4-5	12.5	12.4	13.3	9	8.5	4.1		4	8.8	8.7
4-6	11.7	7.2	12.4	11.6	4.4	5.4		3.5	0.9	7.3
4-7		9.3	7.2	9.6	11.8	10.4		3.5	5.8	5.5
4-8		7.8	9.2	10.4	2.3	0.6		0.5	1.4	3.5
4-9	8.6	9.8	10.4	8.6	1.7	4.2		5.2	5.5	7.3
4-10	12.3	10.2	10	8.1	3.1	8.7		6.1	7.6	7.3
5-1	10.4	11.6	11	1.9	0.6	7.1		0.55	8.2	7.6
5-2	11.3	12.8	10.8	12.6	0.5	0.6		2.45	5.4	6.3
5-3	12.2	10.8	12.4	8.8	1.5	0.9		0.6	1.25	6
5-4E	11	12.5	9.4	10.2	0.9	5.5		2.8	4	7.7
5-4W	10.4	12.2	9.6	8.1	10.8	3.3		1.7	3.2	5.2
5-5		6.6	3.1	1.6	0.5	0.5		0.5	1.2	5.2
5-6	8.9	1.4	4.3	1.2	0.5	9.9		0.3	0.7	8.2
5-7	9	1.8	3.8	1.2	0.6	0		0.5	0.7	3.3
5-8	7.6	1.2	2.9	1.5	0.4	0.5		0.4	7.9	2.4
5-9	10.1	4	6.7	1.7	0.4	0.4		4.5	3.4	8.9
5-10	9.5	9.9	3.6	1.3	0.4	0		0.5	0.7	8.3

Table A-12 cont'd.: Bottom Dissolved Oxygen Concentration in 58 SRBs										
Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Dissolved Oxygen (mg/L)									
5-11	9.1	3.8	8.45	12.3	0.9	0.3		1.6	5.6	7.6
5-12	7.6	3.1	9.2	4.7	0.65	0.3		0.5	0.4	5.6
5-13	11	6.8	10.8	6.3	1.3	2.9		1.5	5.2	8
5-15	8.8	10.6	9.2	11.6	1.25	5.85		2.2	6.3	8.75
5-16	9.6	13.4	9.8	7.55	2.4	7.15		4	4.4	7.7
5-17	8.3	13.8	9.2	6.1	2.8	6.15		2.5	6.6	7.3
5-18	9.5	9.8	8.7	10.9	6.3	7.5		2.2	4.2	8
5-19	8.2	10.4	8.8	5.7	0.7	5.35		2	6.5	5.05
5-20	8.7	12.8	9.4	12.2	1.3	6.9		2.8	4.4	6.6
5-21	10.3	13.6	9.5	9.2	0.7	3.4		0.4	0.7	7.3
5-22		5.4	8.3	10	0.4	6.25		0.4	9.2	9.7
5-23		15.8	9.1	3.7	10.4	6.9		6.35	5.2	8.7
6-4	9.8	5	17.4	3.2	1.3	0.3	3.1	1.1	0.5	4.1
6-6	8.4	11.6	11.2	1.3	0.7	0.3	5.3	3.1	0.6	5.5
6-7	8.8	11.4	11.2	2.8	0.7	2.3	2.6	0.7	1.8	7.1
6-8	9.9	2.8	6.8	0.6	0.5	0.2	11	5.85	5.9	3.9
6-9	6.9	10	5.9	0.5	4.5	0.2	7.7	6.6	0.45	7.4
6-10	9.2	10.2	5.5	4.65	0.5	6.6	4.3	7.3	1.6	9.9
6-11	9.3	9.4	6.4	7.35	1.3	6.45	4.7	4.7	3.8	9.3
6-12	8.3	6.2	4.7	3.2	0.7	0.7	0.4	1.1	3.5	9.7
6-13	8.1	4.6	4.9	3.85	1.7	4.6	2	2.3	4.6	11.3
6-14	8	8.2	12.5	11.4	8.2	0.2	4	3.9	4.5	4.2
6-15		17.2	12.2	9.8	0.7	0.4	4.3	1.4	1.6	9.4
6-16	6.8	7	4.3	1.2	0.8	0.35	4	7.2	3.8	10.3
6-17	7.8	8.5	8.2	2.8	1.6	4.7	3.2	5.9	5.3	7.7
6-18	9	12	11.7	4	0.6	0.2	6.1	4	3	5.2
6-19	8.9	11.4	11.2	7.2	3.2	1.2	7.8	10.4	5.1	7.4
6-20	8.7	14.2	19	14.6	3.7	10.8	1.5	7.6	6	5.9
6-22	10.3	16.4	12.8	13.2	10.2	0.4	5.9	6.5	1.9	7.8

Table A-13: Water Temperature at the Surface in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Temperature (°C)**									
2-2	15	21	11.5	16.5	19.5	24	21.5	22	20	11
2-4	16	18.5	11.5	16.5	20	24	21	22	19	10.5
3-1	11	17	12.5	17.5	21	24	22	23	21	12.5
3-2	12	18	13.5	17	21	24.5	22.5	23	22	13.5
3-3	12	18	13.5	18	23	25	22.5	24	22	13.5
3-4	13	19	13	18	23.5	25	22.5	24.5	23	14
3-5	13	20	12.5	19	22		22.5	27	21.5	16.5
3-6	13.5	20	12.5	20	23	35	23	24.5	22	15.5
3-9	12	18.5	13	18	23	24	23	25	22	13.5
3-10	13	18.5	12.5	19.5	23	25	22	25	23	14
4-2	14	19	13.5	20	22		23	27	21.5	16.5
4-4	17	21	13.5	20	23		23	27	21	16
4-5	15	21	11.5	20	24.5		24	29	23	20.5
4-6	15.5	21	11.5	20	23		24	28	23	19
4-7		16	10.5	20	23.5		23.5	28	23	18
4-8	16	19.5	13.5	21	24.5		23	26.5	22	17.5
4-9	16.5	21	13	20.5	24		23	26	22	17.5
4-10	14.5	22	12.5	20	23		23	26	22.5	15
5-1	13	18	11.5	18	24		21.5	23.5	23.5	15
5-2	13.5	17.5	11	19	24		21	25	23	13
5-3	15	17.5	11	19.5	23.5		21	23	23	13.5
5-4E	11.5	18.5	11.5	20	24.5		24	27	23	14.5
5-4W	13	19.5	11	20.5	26.5		25.5	28	26	14.5
5-5	13	20	15		27.5		23	26	30	21
5-6	13	19	15.5		27		23	27	31.5	19
5-7	13	19	15		28		23.5	26	31	20.5
5-8	16	18.5	15		24.5		23	26	29.5	19
5-9	16	18.5	14.5		27.5		23	26	30	18.5
5-10	11	18	14		30		23.5	26	31	19

Table A-13 cont'd.: Water Temperature at the Surface in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Temperature (°C)**									
5-11	13	18.5	14		24		24.5	25.5	28	18
5-12	16.5	18.5	14.5		23		24	29	25	17
5-13	16.5	18.5	15		27.5		24	29	25.5	19.5
5-15	13	21	12		26		21.5	26	29	18
5-16	10.5	19.5	12.5	19	23.5		23.5		26.5	18
5-17	12	20	13		23		23		27	20.5
5-18	12	20	12.5		23		22.5		26	17
5-19	14	18	12.5		25		22	27	29	15
5-20	13	20	12		26		22	26	24	14.5
5-21	13	18	12.5		25		21.5	24	23	14.5
5-22		18	13		25		23.5	26	29	18
5-23		17	12	18.5	23.5		22	23	21.5	13
6-4	15.5	19	14.5		28		24	22	25	14
6-6	15	18	13	22	26	28	23	22.5	29	16
6-7	14	18	13	21.5	24	28	23.5	22.5	26	16
6-8	19	18	14	20	25	29.5	23	22	24.5	16.5
6-9	17	18	14.5	20	24	27	23.5	22.5	26	16.5
6-10	12.5	17	13.5	19	25	25	22	23	24	19.5
6-11	12.5	16.5	13	19	25	25	21.5	23	24	19.5
6-12	10	16.5	13	19	23.5	24	23	22	25.5	18.5
6-13	12	17	13	19	24	25	23.5	22	20	16
6-14	13.5	18	13.5	23.5	27	27	22.5	24.5	27	15
6-15	17.5	19.5	15	25	25	27	23	23	28.5	14
6-16	13	17	14	19.5	25.5	25	23.5	23	24.5	16
6-17	14	18	14	22	30	26.5	24	23	28	13
6-18	12	19.5	14	23.5	25	26	23	22	25	14
6-19	12	20	14	24.5	26.5	27	24	25	27	13.5
6-20	13.5	17	14	22	29	27.5	25	24.5	26	13
6-22	11	19	13.5	24	25.5	27	22	24	25.5	13

Table A-14: Water Temperature at Mid-Depth in 58 SRBs

Sampling Week	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	**Temperature (°C)**								
2-2	6.50	3.00	6.75	11.67	8.00	12.00	8.50	10.00	4.50
2-4	3.25	5.00	0.33	7.50	8.00	11.00	4.50	18.50	7.00
3-1	11.25	6.75	9.00	21.50	19.50	25.00	27.33	13.96	66.67
3-2	12.00	6.25	6.00	13.67	3.00	18.54	26.00	50.00	96.77
3-3	2.50	4.00	4.00	8.00	3.25	18.79	17.00	44.00	43.00
3-4	5.17	8.25	7.25	13.75	3.00	12.50	28.86	41.00	31.00
3-5	15.00	20.00	6.00	16.00	4.00	14.04	17.57	23.33	17.20
3-6	12.50	8.75	7.00	4.25	3.83	3.80	4.83	6.50	7.50
3-9	6.00	2.25	5.83	5.00	8.50	19.00	42.50	30.00	30.00
3-10	17.00	14.00	3.50	27.50	19.00	19.00	24.50	21.79	16.25
4-2	8.75	12.25	18.00	14.50	11.50	25.50	20.50	25.50	48.00
4-4	9.75	31.96	24.50	25.00	30.50	50.00	54.00	57.00	69.00
4-5	11.25	9.25	7.83	12.75	26.00	28.10	29.00	27.83	20.75
4-6	14.75	13.00	11.00	16.00	16.00	13.00	19.50	18.67	21.53
4-7	16.50	25.25	12.50	8.33	24.59	14.50	30.32	17.00	10.00
4-8	12.00	8.00	8.50	5.00	17.00	18.79	10.50	18.00	18.12
4-9	18.00	24.50	20.50	22.00	51.50	29.50	20.00	31.50	20.27
4-10	18.50	38.25	38.00	27.50	34.50	54.00	27.67	46.00	30.79
5-1	13.75	28.00	34.67	38.00	52.00	75.00	54.00	69.00	40.72
5-2	12.75	19.00	34.00	41.00	35.00	21.00	23.18	29.00	31.00
5-3	6.50	11.00	9.25	8.50	11.00	18.83	28.38	36.00	75.00
5-4E	9.50	17.75	17.50	19.50	17.00	23.56	22.50	16.00	18.00
5-4W	9.00	22.00	23.67	21.00	12.50	24.00	30.32	24.50	16.50
5-5	17.25	27.75	49.50	37.50	27.70	32.00	63.00	50.00	63.00
5-6	20.00	29.25	41.67	31.75	38.00	43.50	53.00	55.00	47.00
5-7	19.25	21.75	43.00	41.00	46.00	47.00	74.00	51.00	66.00
5-8	20.75	20.75	28.50	44.25	42.00	45.00	27.33	39.00	44.00
5-9	15.75	20.50	45.00	60.00	58.00	18.27	46.50	44.50	50.00
5-10	25.00	27.75	37.75	37.50	28.50	32.47	27.33	33.33	43.50

Table A-14 cont'd.: Water Temperature at Mid-Depth in 58 SRBs									
Sampling Week	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Temperature (°C)**								
5-11	6.50	9.75	9.50	8.70	12.50	9.00	9.33	10.17	6.50
5-12	3.75	5.75	2.50	13.00	5.00	9.00	8.00	9.00	21.50
5-13	8.25	5.00	5.00	7.75	4.00	5.25	9.00	6.00	10.00
5-15	18.00	30.00	39.25	30.50	69.50	86.00	59.00	65.00	43.00
5-16	28.75	21.00	19.00	26.50	22.00	43.00	20.00	27.00	19.00
5-17	20.50	22.50	24.00	25.00	56.50	43.17	24.33	26.50	26.00
5-18	18.75	22.75	15.50	39.50	41.50	43.50	20.00	46.00	23.50
5-19	16.00	23.50	25.50	27.50	25.67	44.30	31.08	59.00	72.00
5-20	21.75	20.75	43.50	37.00	61.00	80.00	40.67	58.00	47.00
5-21	10.50	10.75	14.50	23.08	30.00	41.50	54.00	80.16	61.00
5-22	12.00	33.00	17.50	14.00	21.50	28.00	26.85	24.50	21.50
5-23	14.75	39.00	7.00	1.83	20.00	35.50	18.00	15.50	34.00
6-4	4.75	3.00	6.50	3.00	8.50	3.00	7.50	20.50	11.00
6-6	8.75	6.75	16.00	15.00	28.00	38.00	27.33	28.29	18.42
6-7	8.50	8.00	20.00	20.00	34.50	44.00	32.89	29.50	16.78
6-8	13.50	21.75	27.00	27.00	78.00	86.00	146.75	93.00	74.64
6-9	12.25	24.75	35.00	32.00	43.50	55.50	55.00	59.50	71.00
6-10	14.50	15.00	13.50	26.00	28.50	43.00	55.00	32.26	24.84
6-11	15.25	16.00	16.50	30.00	28.50	45.27	41.50	39.00	25.17
6-12	11.75	18.25	9.00	10.00	2.00	6.75	31.78		52.00
6-13	33.00	24.25	9.00	10.50	8.75	11.50	15.23	38.00	40.00
6-14	10.75	17.50	13.50	10.50	8.50	12.50	22.88	27.33	17.92
6-15	20.00	24.00	38.33	14.00	21.50	25.42	41.00	50.50	49.00
6-16	24.50	22.75	19.50	50.00	36.00	32.50	35.06	42.00	34.50
6-17	11.75	22.25	18.50	21.50	9.00	18.00	26.00	22.52	36.00
6-18	17.25	24.25	35.50	26.50	18.50	26.00	39.00	44.00	48.00
6-19	8.25	10.75	8.00	3.25	7.00	9.50	10.00	7.50	15.33
6-20	20.00	3.75	6.00	11.50	14.50	7.98	24.17	28.00	19.25
6-22	4.75	9.00	7.50	10.00	7.25	4.50	12.00	10.50	11.00

Table A-15: Water Temperature at the Bottom in 58 SRBs									
Sampling Week	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Temperature (°C)								
2-2	18	11.5	16.5	19.5	24		21	19.5	11
2-4	18	11.5	16.5	19	24		21	19	10
3-1		12	17	20	24		23	20.5	12
3-2		13	17	19.5	22.5		21	20	12
3-3		13	17.5	21.5	21.5		23	21.5	12.5
3-4		13	17.5	22	24		23.5	22	13.5
3-5		12.5	18	18			24.5	20.5	16
3-6		12	21.5	21.5	31.5		23.5	21.5	15
3-9		12.5	17.5	22.5	22		23.5	20	13
3-10		12	19	22	25		24.5	22	13
4-2		13.5	19	17			26	21	16
4-4		13	14.5	18			22	20	14
4-5		11.5	19.5	21.5			25	21	17
4-6		11.5	19.5	20.5			24	20.5	17
4-7		10	20	21			24.5	23.5	16.5
4-8		13.5	16	19			22	20	15
4-9		12.5	18.5	20.5			24	20.5	13
4-10		12.5	18.5	21.5			23	20.5	13
5-1		11.5	18	19.5			23.5	23	13
5-2		11	17.5	23			24	22.5	13
5-3		11	14	22			21.5	22.5	12
5-4E	18	11	15.5	20			24	21	13.5
5-4W	19	10.5	18.5	23			23	22.5	14
5-5	18	14.5		18.5			22	27.5	18
5-6	16.5	15.5		19			23	27	18
5-7		145		20.5	23		23	28	17
5-8	16	14.5		20			23	28.5	17
5-9		14		18.5			24	27.5	17
5-10		14		21			23	29	17

Table A-15 cont'd.: Water Temperature at the Bottom in 58 SRBs									
Sampling Week	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Temperature (°C)								
5-11	16.5	35		20.5			24	26	16
5-12	17	14		19	27		25	23	15.5
5-13	15.5	14		23			27	23	16.5
5-15	17.5	11.5		23			25	27	17
5-16	18.5	12	19	23				25	16.5
5-17	17.5	12.5		23				24.5	17.5
5-18	18	12		22.5				25	16
5-19	17	12		21			24	25	14
5-20	18.5	12		22			25	24	14
5-21		12		21.5			20	22.5	13.5
5-22	16.5	12.5		20.5			22.5	27	16
5-23	17	12	18	23			22.5	22	13
6-4	17	13		20.5		23.5	19	22	14
6-6	16	12	18.5	18.5	20.5	22.5	22	27	15.5
6-7	16	13	17.5	19.5	25.5	22	22	25.5	15.5
6-8	16.5	14	15	22.5	23.5	22	22	24	15.5
6-9	17.5	14.5	17	23	21.5	23	22	25	16
6-10	15	13	18.5	20.5	24	21.5	23	23	19
6-11	16	13	18	22.5	24	21	22	21	19
6-12	15.5	12.5	17	22	19.5	23	22	23	18
6-13	16	13	17	22	22.5	22	22	24	16
6-14	17.5	13	23	24	25	22	24.5	27	15
6-15	17.5	13	23	20.5	24	22	22	26	14
6-16	16.5	14	18	21	22.5	23	23	24	16
6-17	17	13	21	27	25	23	22.5	24.5	12.5
6-18	18	14	21	19.5	22	22	22	24.5	13
6-19	16	13.5	22.5	20.5	25	23	25	25.5	13
6-20	15.5	14	21	28	25.5	25	24	24.5	13
6-22	17.5	13	22	19	21	22	24	24	12.5

Table A-16: Average Water Temperature at Three Depths in 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
Depth	**Temperature (°C)**									
Surface	13.7	18.7	13.1	20.2	24.6	26.2	22.9	24.9	24.9	16.0
Middle		18.1	15.2	19.6	23.3	25.3	23	23.7	24.1	15.3
Bottom		17	15.4	18.4	21.1	23.7	22.5	23.1	23.5	14.9

Table A-17: pH Values for 58 SRBs

Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	pH									
2-2	8.27	8.35	8	7.8	8.11	8.01	7.9	7.74	7.91	7.84
2-4	9.2	8.51	7.92	7.42	7.51	7.78	7.8	7.58	7.93	7.88
3-1	8.83	8.7	8.59	8.61	9.09	9.26	8.92	8.75	8.75	9.43
3-2	8.57	8.06	9.04	9.09	9.2	8.82	9.06	8.6	9.04	9.21
3-3	8.67	8.11	8.99	9.16	9.63	9.31	8.81	8.69	8.86	8.8
3-4	8.7	8.59	9.08	9.25	9.49	8.87	8.6	8.68	8.37	8.29
3-5	8.45	8.75	8.82	8.8	8.5	8.44	8.61	8.52	8.46	8.34
3-6	9.45	9.52	9.85	9.28	9.25	8.12	8.55	8.2	8.2	8.11
3-9	8.12	8.43	9.29	9.41	9.56	9.44	9.23	8.94	8.85	8.27
3-10	8.79	9.01	8.89	7.61	8.59	8.47	8.14	8.43	8.11	7.84
4-2	8.51	7.65	8.53	8.49	8.22	8.16	8.34	8.42	8.4	8.21
4-4	9.1	8.9	9.23	9.09	9.32	9.16	9.15	9.12	9.22	8.68
4-5	9.01	9.1	9.33	9.52	9.14	8.83	9.27	9.12	9.57	9.48
4-6	8.99	8.99	9.1	8.81	8.85	9.06	9.34	9.32	9.56	9.17
4-7		8.22	7.92	8.02	8.17	9.02	9.37	8.75	8.73	7.8
4-8	8.69	8.77	8.61	8.77	9	9.21	9.12	9.04	8.75	7.88
4-9	8.48	8.56	8.68	8.24	7.81	7.84	8.4	8.28	8.4	8.28
4-10	8.45	8.56	8.26	8.16	8.72	8.75	8.79	8.89	9.04	8.45
5-1	8.37	8.53	9.33	9.1	9.15	9.38	9.75	9	9.07	8.52
5-2	8.36	8.84	9.39	9.8	10.1	9.15	8.63	9.1	9.33	9.28
5-3	8.26	8.61	9.19	9.75	9.78	8.97	8.5	8.7	9.02	9.19
5-4E	8.39	8.68	8.83	8.86	8.93	8.7	9.22	9	9.06	8.47
5-4W	8.52	8.81	9.21	9.51	9.66	9.11	9.44	9.33	9.16	8.84
5-5	8.77	9.17	9.06	10.14	9.72	9.11	8.9	9.44	9.29	9.02
5-6	8.87	9.2	9.02	10.17	9.75	9.55	9.19	9.46	9.46	8.72
5-7	8.77	9.2	9.18	9.88	9.71	9.48	9.06	9.25	8.92	8.93
5-8	8.57	9	8.9	9.51	9.82	9.83	8.74	8.65	8.64	8.44
5-9	9.08	9.43	9.3	9.87	9.64	9.31	7.21	8.88	8.35	8.55
5-10	8.52	8.79	8.94	9.54	9.73	9.01	8.66	8.76	8.74	8.62

Table A-17 cont'd.: pH Values for 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**pH**									
5-11	7.82	8.59	8.24	8.15	7.62	7.45	7.88	7.79	7.85	7.89
5-12	7.47	7.47	7.7	7.57	8	7.06	7.31	7.16	7.21	7.6
5-13	7.77	8.65	7.73	7.59	7.63	7.69	7.83	7.94	8.03	7.99
5-15	8.32	8.96	8.72	8.85	9.02	8.62	8.51	8.78	8.72	8.35
5-16	8.01	8.78	8.27	8.01	8.63	7.94	8.26	8.22	8.28	8.26
5-17	8.33	9.03	8.63	8.06	8.39	8.22	8.02	8.28	8.04	8
5-18	8.22	8.42	8.53	8.34	8.17	8.24	8.23	8.12	7.96	8.08
5-19	8.36	8.6	8.7	8.82	8.92	8.58	8.78	8.52	8.62	7.82
5-20	8.3	8.43	8.98	8.86	9.18	8.84	8.72	8.77	8.72	8.17
5-21	8.99	9.06	9.13	8.92	9.06	8.93	9.24	9.62	9.37	8.64
5-22		8.88	8.46	8.54	8.68	8.32	8.47	8.66	8.54	8.53
5-23		9.29	8.4	8.23	8.54	8.75	8.29	8.03	8.21	8.23
6-4	8.16	8.11	8.82	8.9	9.16	8.94	8.45	8.71	8.55	7.69
6-6	8.47	8.96	9.09	9.79	9.72	9.55	8.33	7.54	7.98	7.58
6-7	8.42	9.01	9.28	9.4	8.81	9.78	8.87	7.64	7.89	7.57
6-8	8.36	9.13	9.46	10.14	9.58	10.36	10.13	9.74	9.76	7.65
6-9	8.36	8.7	9.17	9.66	9.01	9.55	9.41	9.57		9
6-10	8.53	8.17	7.72	8.22	8.71	8.38	8.57	8.13	8.33	8.36
6-11	8.69	8.51	7.63	8.21	8.54	8.67	8.7	8.18	8.55	8.38
6-12	7.7	8.05	7.37	8.28	7.75	8.58	7.14	7.62	8.06	7.96
6-13	8.54	8.19	7.37	8.46	8.08	8.46	7.35	7.46	8.39	8.49
6-14	8.74	8.34	8.72	8.82	8.8	7.8	7.65	8.28	7.8	7.52
6-15	8.99	9.5	9.62	10	9.67	9.32	9.02	9.06	9.37	9.33
6-16	8.54	8.71	8.58	8.8	9.5	9.24	9.26	9.06	9.04	8.66
6-17	8.77	9.05	8.93	8.9	8.61	9.49	8.87	8.72	8.72	8.3
6-18	9.1	9.27	9.44	9.68	9.48	9.38	9.17	8.94	9.19	9.34
6-19	8.17	8.67	8.55	8.91	9.63	9.16	9.35	9.47	9.28	8.95
6-20	8.65	9.31	9.93	10.09	9.41	9.08	7.63	8.2	8.44	7.6
6-22	8.39	8.72	9.02	9.71	10.03	10	9.35	9.23	9.01	8.31

Table A-18: Depth Values for 58 SRBs										
Sampling Week	1 (May 4-9)	2 (May 18-22)	3 (June 2-4)	4 (June 15-17)	5 (Jun 30-Jul 3)	6 (July 13-15)	7 (July 27-29)	8 (Aug 10-14)	9 (Aug 24-26)	10 (Sep 21-23)
SRB #	Depth (cm)									
2-2	135	137	140	137.5	145	125		140	142	130
2-4	95	100	108	103	105	120		116	117	105
3-1	172.5	160	158	155	163	155		152.5	160	162
3-2	117	167	168	210	195.5	185		200	205	207
3-3	160	178	176	192	223	190		190	190	203
3-4	142	154.5	163	154	140	170		150	145	135
3-5	196.5	160	190	182	207	185		215	182	212
3-6	97	110	120	120	111	130		120	112	115
3-9	126	163	138.5	155.5	140	160		135	155	171
3-10	157	159	102	158	160.5	170		160	155	150
4-2	134	190	210	245	235	215		150	145	142
4-4		205	235	225	235	215		211	215	235
4-5	146.5	175	155	162	175	175		170	165	164
4-6	160	158	170	168	164.5	160		165	167	163
4-7		117	105	128	126.5	155		135	93	160
4-8		205	205	225	220	301		215	215	235
4-9	159	200	155	147	160	155		155	155	155
4-10	134	131	122	134	130	140		140	140	137
5-1	170	205	194	200	190	185		181	192	175
5-2	162.5	166	200	162	160	205		162.5	152	141
5-3	158.5	160	201	229	190	225		215	212	155
5-4E	163	160	169	166	170	170		168	165	150
5-4W	130	118	127	130	124	135		134	135	115
5-5		189	181	213	204	210		206	197	187
5-6	150	205	199	211	215	214		210	208	205
5-7	175	193.5	211	220	230	210		205	198	190
5-8	200	212	210.5	213	208.5	220		205	208	200
5-9	165	149	152	151	153.5	145		145	137	125
5-10	150	124	153	167	9.73	175		155	154	140

Table A-18 cont'd.: Depth Values for 58 SRBs										
Sampling Week	**1** (May 4-9)	**2** (May 18-22)	**3** (June 2-4)	**4** (June 15-17)	**5** (Jun 30-Jul 3)	**6** (July 13-15)	**7** (July 27-29)	**8** (Aug 10-14)	**9** (Aug 24-26)	**10** (Sep 21-23)
SRB #	**Depth (cm)**									
5-11	150	188	207	216	200	200		185	182	171
5-12	180	179	192	205	205	210		195	187	167
5-13	154	162	162	175	177	180		170	148	143
5-15	130	138.5	123	114	140	115		120	123	107
5-16	171	170	175	167	156	170		175	167	175
5-17	164	154.5	158	159	160	160		160	155	160
5-18	165	154.5	160	173	180	180		192	170	182
5-19	200	200	225	235	235	230		230	215	228
5-20	155	151	138.5	136	149	145		157	141	130
5-21	171	157	181	165	233	180		235	202	192
5-22		220	225	225	235	215		235	227	225
5-23		215	225	225	235	225		225	230	225
6-4	160	140	132.5	8.4	160	130	145	140	130	115
6-6	162	176	179	169	190	175	180	162.5	155	162
6-7	140	131	113	152	150	145	138	125	140	131
6-8	113	148	128	131	160	145	135	135	133	129
6-9	151	167.5	160	161	180	175	165	170	165	162
6-10	165	149	160	157	160	160	145	145	156	160
6-11	165	147	128	146	160	160	155	132	155	138
6-12	116	109.5	130	137.5	140	130	130	120	124	110
6-13	115	102	136	121.5	130	125	117	110	110	80
6-14	155	161.5	148	142.5	150	150	135	122	123	115
6-15		113	163	140	140	120	125	115	118	148
6-16	175	169.5	185	185	198	170	170	165	165	160
6-17	140	150.5	134	142.5	135	140	150	140	145	130
6-18	160	165	180	172	180	175	180	177	173	173
6-19	160	171	180	183	185	175	185	192	175	177
6-20	145	136.5	152	153.5	140	145	145	145	148	141
6-22	160	173	120	163.5	170	175	205	160	173	170

APPENDIX B

List of Calculations and Statistics

$$Chlorophyll-a(\mu g/L)=\frac{F\times(Ab-Aa)\times K\times E\times D}{V\times l}$$

Where:

Ab	=	absorbance of pigment solution at 665nm minus absorbance at 750nm <u>before</u> acidification.
Aa	=	absorbance of pigment solution at 665nm minus absorbance at 750nm <u>after</u> acidification.
Y	=	Maximum acid factor (solvent-specified) calculated from the ratio of Ab to Aa of a solution containing no pheopigments (Y=1.58 for 90% methanol)
F	=	Factor relating the change in absorbance at 665nm to chlorophyll-a concentration calculated using maximum acid factor {F=Y/(Y-1)}
SAC	=	Specific absorption coefficient of chlorophyll-a in the chosen solvent which relates the absorbance of the solution at 665nm to concentration (L/g/cm) (SAC=77.90 for methanol)
K	=	Factor based on the specific absorption coefficient of chlorophyll-a in the chosen solvent {K=1000 x (1/SAC)}
D	=	Dilution correction
E	=	Volume of solvent used in extraction in mL
l	=	Path length of the cuvette
V	=	Volume of original water sample filtered in L
174.8	=	Combines factors F, K, and E

Figure B-1: Equation for Determining Chlorophyll-a
(Manitoba Environment, 1989)

Nitrate Concentration (mg/L)	Peak Height
0	0
0.05	4
0.05	5
0.1	9
0.1	10
0.2	19
0.2	22
0.5	49
0.5	54.5
0.7	71
0.7	79
1	100.5
1	111
1.2	121.5
1.2	134.5
1.5	153
1.5	170.5
2	200

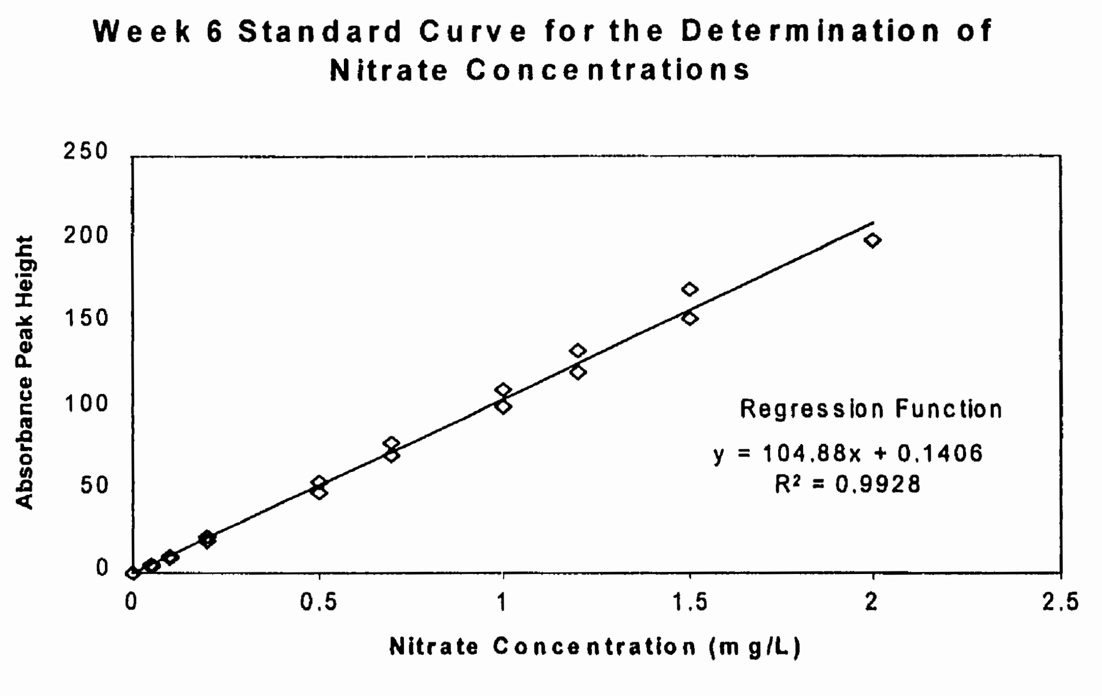

Figure B-2: Standard Curve Generation and Evaluation

Table B-1: Chlorophyll-a Statistics for Harvested SRBs Generated by Microsoft Excel

Sampling Week	1	2	3	4	5	6	7	8	9	10
	May 4-9	*May 18-22*	*June 2-4*	*June 15-17*	*Jun 30-Jul 3*	*July 13-15*	*July 27-29*	*Aug 10-14*	*Aug 24-26*	*Sep 21-23*
	1	2	3	4	5	6	7	8	9	10
Mean	10.87458	15.33246	26.50031	42.72681	44.38799	36.69302	51.74503	63.30726	74.72898	85.65404
Standard Error	4.261045	2.686233	5.506749	7.999913	20.12154	8.462574	9.859718	13.63777	10.68688	18.2576
Median	6.776694	11.4931	20.22339	31.63394	15.70287	33.05468	33.00224	44.92943	59.61554	54.38851
Standard Deviation	19.05597	12.30987	25.23509	36.66021	92.20846	38.78039	45.1829	60.98996	48.97342	83.66682
Sample Variance	363.1301	151.5328	636.8099	1343.971	8502.4	1503.918	2041.495	3719.775	2398.396	7000.137
Range	88.01666	41.98113	73.1538	103.938	435.9438	166.7592	137.2282	231.1701	172.9602	355.918
Minimum	0	2.364656	0	0.296189	2.689978	0	1.584853	14.50257	6.01312	9.982051
Maximum	88.01666	44.34579	73.1538	104.2342	438.6338	166.7592	138.8131	245.6727	178.9734	365.9001
Sum	217.4916	321.9816	556.5066	897.263	932.1478	770.5534	1086.646	1266.145	1569.309	1798.735
Count	20	21	21	21	21	21	21	20	21	21
Confidence Level(95.0%)	8.918472	5.603382	11.48687	16.68752	41.97277	17.65261	20.567	28.54419	22.29242	38.08466

APPENDIX C

List of Figures Mapping Winnipeg's Stormwater Retention Basins

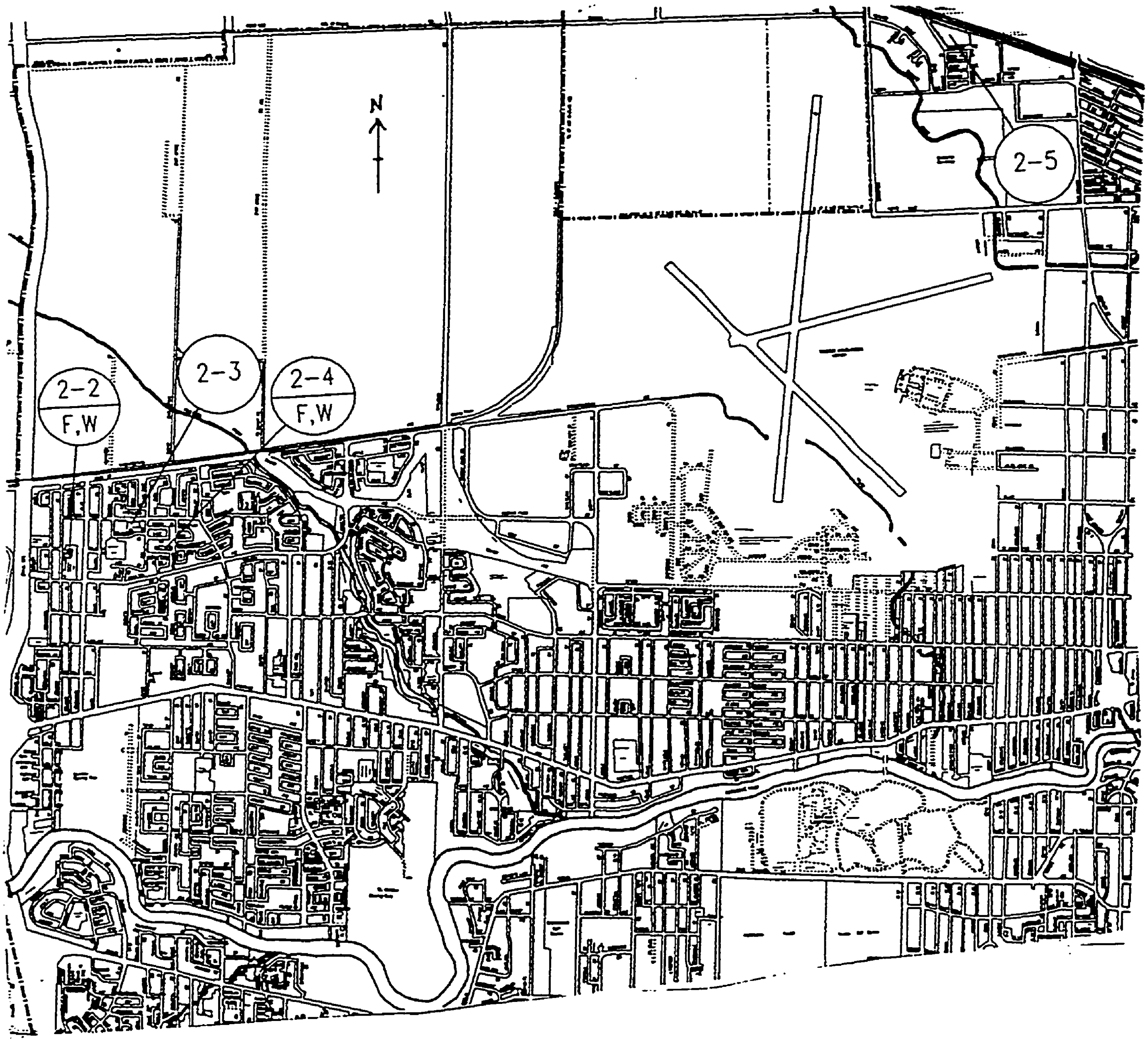

Figure C-1: Location of Region 2 SRBs
(City of Winnipeg, 1998)

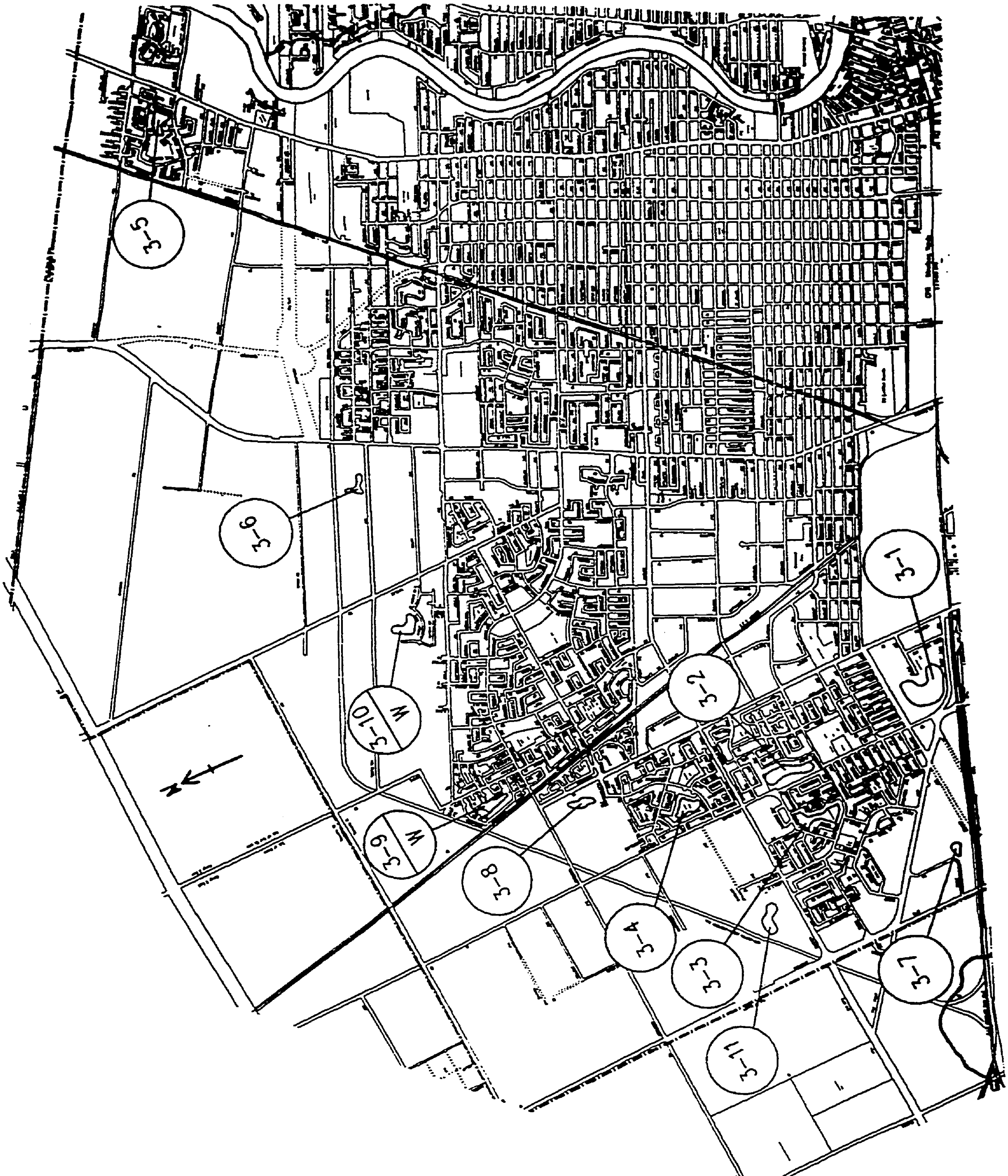

Figure C-2: Location of Region 3 SRBs
(City of Winnipeg, 1998)

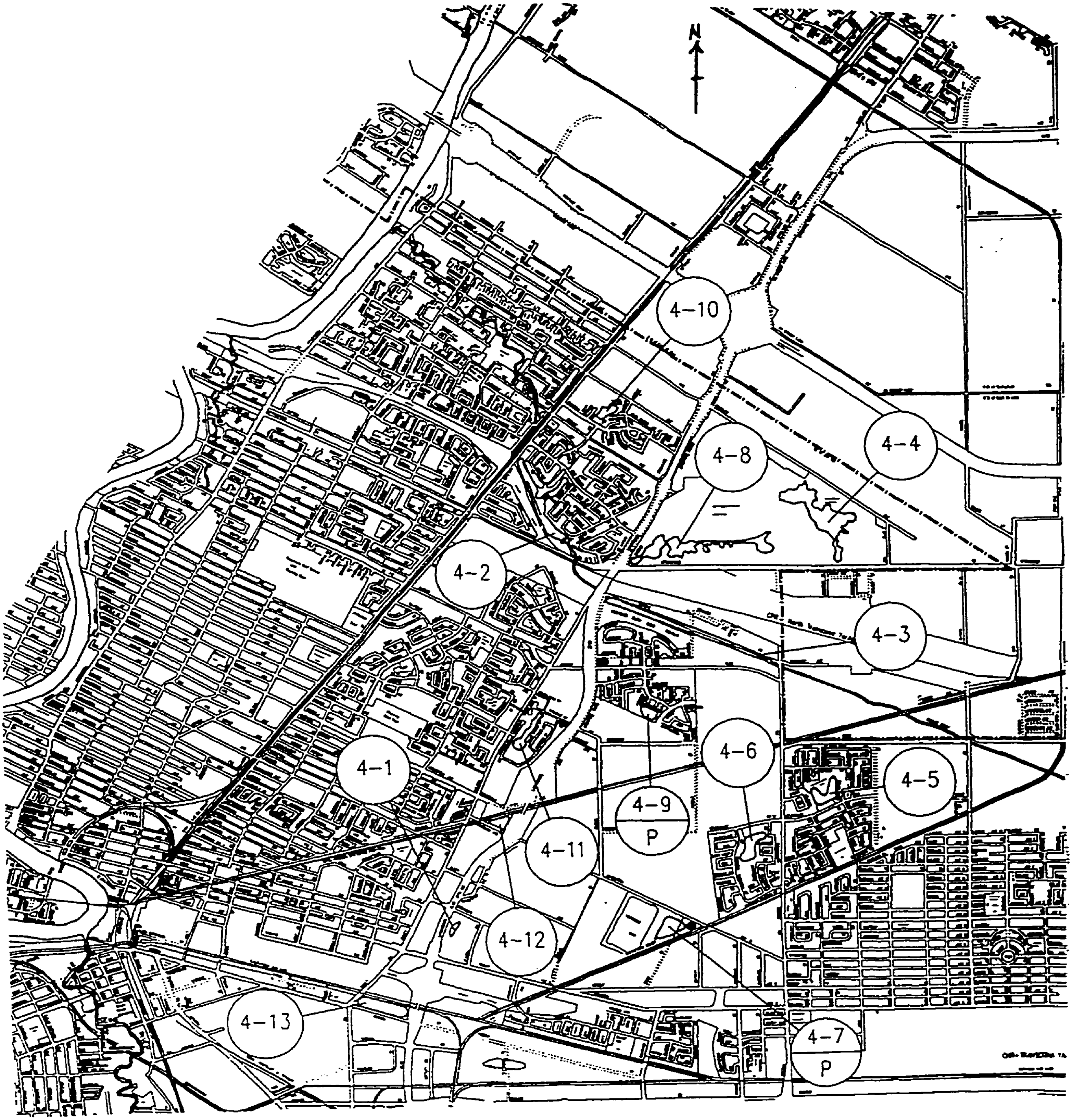

Figure C-3: Location of Region 4 SRBs
(City of Winnipeg, 1998)

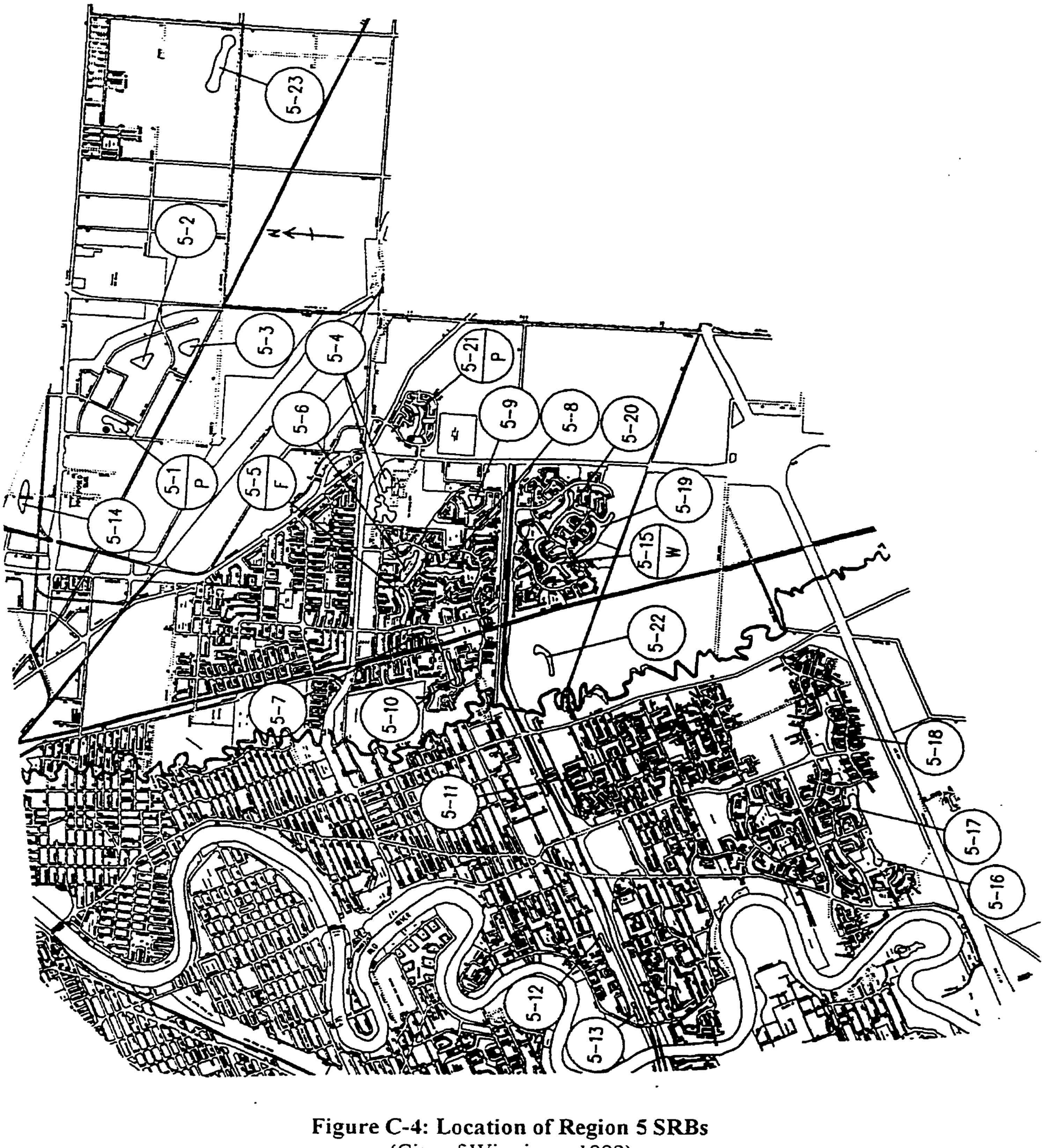

Figure C-4: Location of Region 5 SRBs
(City of Winnipeg, 1998)

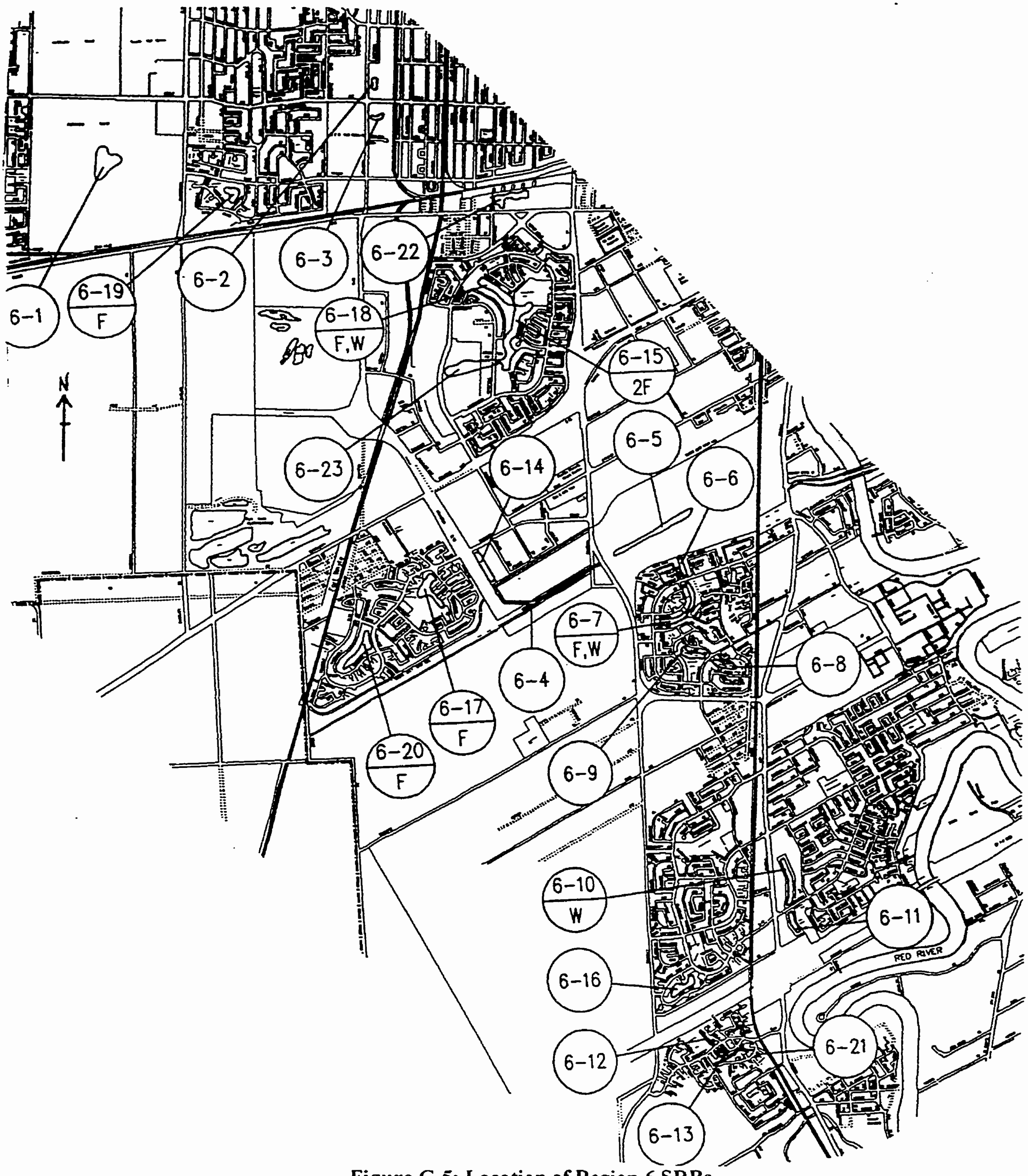

Figure C-5: Location of Region 6 SRBs
(City of Winnipeg, 1998)

APPENDIX D

Qualitative SRB Data

Qualitative SRB Data Continued

Qualitative SRB Data Continued

Table D-1: Qualitative Data for SRB 2-2

Date	Weather Conditions	Visual Inspection
May 5	16°C, sunny, moderate wind	Excellent-banks in good condition; no odour or garbage
May 22	21°C, sunny, calm	Odour, slight weed and algal growth, garbage.
June 2	8.5°C, cloudy	As above also many weeds and algae
June 15	Partly cloudy, light wind	As previous week, many invertebrates associated with the algae
June 30	Sunny, calm	As above
July 13	Sunny, calm	Much algae around the shore, smells of fish, poor water clarity, weedy
July 27	Sunny, calm	As above only less weeds then previous
August 10	Sunny, calm	Slight odour, few weeds and algae, better clarity
August 24	Sunny, calm	As above only stronger odour, some scum, many snails
September 21	Partly cloudy, calm	Excellent clarity, lots of filamentous algae and thick weeds

Table D-2: Qualitative Data for SRB 2-4

Date	Weather Conditions	Visual Inspection
May 5	16°C, sunny, windy	Excellent clarity, some algae growing on the bottom
May 22	20°C, sunny, calm	Extensive floating, filamentous, algae
June 2	8.5°C, cloudy, moderate wind	As above, also weeds and odourous
June 15	Cloudy, calm	Much less algae and weeds (still some of the latter), smells like chemicals
June 30	Sunny, calm	No living algae or weeds, excellent clarity, no smell
July 13	Sunny, calm	Poorer clarity, some filamentous algae near shore
July 27	Sunny, calm	Poor clarity, lots of filamentous algae
August 10	Sunny, calm	As above, clarity better
August 24	Sunny calm	As above, poor clarity, abundant snails, small dead fish
September 21	Sunny, calm	Odour of soil, better clarity, thick floating algae

Table D-3: Qualitative Data for SRB 3-1

Date	Weather Conditions	Visual Inspection
May 8	15°C, sunny, light wind	Patches of cattails, some shore erosion
May 18	21°C, sunny, light wind	As above, water level noticeably higher
June 2	8°C, cloudy, strong winds	As above, good water quality, odour of algae
June 15	Partly cloudy, moderate winds	As above, also pelagic algae (needle shaped)
June 30	Sunny, calm	As above, weedy, many more of the previous periods' algae
July 13	Sunny, light wind	As above also poor water clarity, garbage, Cormorants
July 27	Sunny, light wind	Water level lower, cattails, algae, weeds, poor clarity
August 10	Sunny, calm	As above, not as green, odourous
August 24	Sunny, calm	Excellent water clarity, thick weeds toward the shore, not green at all
September 21	Partly cloudy, calm	Thick weeds, green water (poor clarity) algae, geese, cattails

Table D-4: Qualitative Data for SRB 3-2

Date	Weather Conditions	Visual Inspection
May 8	16°C, sunny, moderate winds	Strong odour, many cattails on the residential side, poor clarity, garbage
May 18	13°C, sunny calm	As above also noticeable submerged weeds, one dead fish
June 3	12°C, partly cloudy, moderate winds	Same as above
June 15	Mainly cloudy, moderate winds	Same as above
June 30	Sunny calm	Same as above
July 13	Sunny, light wind	As above but water clarity better
July 27	Sunny, moderate winds	Harvesting in progress, poor clarity, pelagic algae otherwise as above
August 10	Sunny, calm	No weeds, thick filamentous algae at shore, poor water clarity, strong odour, cattails as before
August 24	Sunny, calm	As above also extremely green (algae)
September 21	Sunny, calm	As above, geese feathers on the surface

Table D-5: Qualitative Data for SRB 3-3		
Date	**Weather Conditions**	**Visual Inspection**
May 8	16°C, sunny, moderate winds	Good clarity, odour, garbage, cattails
May 18	20.5°C, sunny, calm	Same as above
June 3	11°C, cloudy, moderate winds	As above also some weeds visible
June 15	Partly cloudy, moderate winds	As above also some algae
June 30	Sunny, calm	Same as before only poorer water clarity then previous
July 13	Sunny, moderate winds	Same as before only water clarity good
July 27	Sunny, windy	Pelagic algae, poor clarity, cattails, thick weeds
August 10	Sunny, calm	Green scum, floating filamentous algae, poor clarity, geese and ducks
August 24	Sunny, calm	Extremely green (different algae then last time), large number of geese, as above
September 21	Sunny, calm	Same as last time

Table D-6: Qualitative Data for SRB 3-4		
Date	**Weather Conditions**	**Visual Inspection**
May 8	Sunny, moderate winds	Odour, patches of rushes, garbage on the hill and at shore
May 18	22°C, sunny, light winds	As above also algae at the shore and dead fish
June 3	11°C, cloudy, moderate winds	Weedy, foam at the shore, dead fish, garbage
June 15	Partly cloudy, windy	Extensive weeds, lots of garbage
June 30	Sunny, calm	Same as last time but many geese present
July 13	Sunny, moderate winds	Excellent water clarity, garbage, patches of weeds
July 27	Sunny, calm	Same as last time only poor clarity and lots of geese
August 10	Sunny, calm	Green scum, odour (fishy), poor clarity, algae, weed patches
August 24	Sunny, moderate winds	Same as last time
September 21	Sunny, calm	Hundreds of geese, poor clarity, green water

Table D-7: Qualitative Data for SRB 3-5

Date	Weather Conditions	Visual Inspection
May 8	20°C, sunny, windy	Patches of cattails, some algae
May 18	Sunny, light winds	Same as before, also odourous and many weeds
June 3	10°C, partly cloudy, windy	Same as before
June 15	Partly cloudy, moderate winds	Thick weeds near shore, good clarity, same as before
June 30	Sunny, light wind	Same as before
July 13	Sunny, moderate winds	Same as before only lots of algae now
July 27	Sunny, mild winds	Same as before, cattails have been destroyed but there is new growth
August 10	Sunny, light winds	Lots of dead weeds and algae, poorer clarity, cattails, scum, ducks
August 24	Sunny, moderate winds	Same as last time
September 21	Sunny, calm	Same as last time but now the water is green with algae and there are many geese

Table D-8: Qualitative Data for SRB 3-6

Date	Weather Conditions	Visual Inspection
May 8	22°C, sunny, moderate winds	Floating patches of algae on the surface and in the water column, excellent water clarity, extensive cattails
May 18	23.5°C, sunny, calm	Same as last time only more algae
June 3	10°C, partly cloudy, moderate winds	Same as last time
June 15	Partly cloudy, moderate winds	Same as last time only malodourous and water clarity poorer
June 30	Sunny, light winds	Same as before only water clarity has greatly improved
July 13	Sunny, moderate winds	Water is brown and murky (poor clarity), submerged weeds and algae are dead and brown, foamy
July 27	Sunny, moderate winds	Dead weeds and algae, excellent water clarity, foam gone
August 10	Sunny, calm	Same as last time
August 24	Sunny, calm	Same as last time but water clarity not as good
September 21	Sunny, calm	Thick weedy patches, excellent clarity, snails, geese

Table D-9: Qualitative Data for SRB 3-9

Date	Weather Conditions	Visual Inspection
May 8	19.5°C, sunny, calm	Good, some garbage
May 18	24°C, sunny, light winds	Same as last time, algae growing at the bottom
June 3	12°C, cloudy, moderate winds	Same as last time, very good water clarity
June 15	Partly cloudy, windy	Very good clarity, extensive weeds, tadpole or minnow eggs
June 30	Sunny, calm	Same as last time, eggs hatched-lots of tadpoles or minnows
July 13	Sunny, windy	Same as last time only poorer water clarity and odourous
July 27	Sunny calm	Same as last time, water level is lower, many leeches
August 10	Sunny, calm	Fewer weeds, green scum at one end, poor clarity, damaged boat launch
August 24	Sunny, moderate winds	Poor water clarity, no weeds/algae, no longer green
September 21	Sunny, calm	Same as last time, hundreds of geese

Table D-10: Qualitative Data for SRB 3-10

Date	Weather Conditions	Visual Inspection
May 8	20°C, sunny, windy	Looks good, some garbage
May 18	22°C, sunny, gusting winds	Same as last time
June 3	11°C, partly cloudy, moderate winds	Same as last time
June 15	Partly cloudy, moderate winds	Same as last time, good water clarity
June 30	Cloudy, light winds	Poor water clarity, otherwise excellent
July 13	Sunny, moderate winds	Same as last time
July 27	Sunny, light wind	Same as last time, slight odour
August 10	Sunny, calm	No odour, many geese, same as before
August 24	Sunny, moderate winds	Odour, no geese, same as before
September 21	Sunny, calm	Same as last time only many geese

Table D-11: Qualitative Data for SRB 4-2

Date	Weather Conditions	Visual Inspection
May 8	21.5°C, sunny, moderate winds	Excellent, some garbage, no algae
May 18	Sunny, moderate winds	Many weeds, water slightly red/brown coloured, good clarity
June 3	10°C, cloudy, strong winds	Same as last time
June 15	Partly cloudy, strong winds	Same as last time
June 30	Sunny, light winds	Same as before only much fewer weeds, some algae growth at the shore
July 13	Sunny, moderate winds	Few weeds, poor water clarity, algae, purple loosestrife on residential side
July 27	Sunny, moderate winds	No weeds or algae, thick loosestrife on one property, poor clarity
August 10	Sunny, calm	Same as last time, cattails
August 24	Partly cloudy, moderate winds	Same as last time, ducks and cormorants present
September 21	Sunny, calm	No purple loosestrife, scum at the shore, poor clarity (green with pelagic algae), cattails

Table D-12: Qualitative Data for SRB 4-4

Date	Weather Conditions	Visual Inspection
May 8	20°C, sunny, strong winds	Garbage, bank erosion
May 18	Sunny, light winds	Same as last time, water level higher
June 3	12°C, partly cloudy, moderate winds	Same as last time, weeds, poor water clarity
June 15	Mostly sunny, moderate winds	Same as last time
June 30	Sunny, moderate winds	Garbage, weeds near the shore, algae, rotten egg odour, a lot of goose feces
July 13	Sunny, moderate winds	Same as last time
July 27	Sunny, moderate winds	Same as last time, water has a green tinge to it
August 10	Sunny, calm	Many dead floating weeds, poor clarity
August 24	Sunny, moderate winds	Water level is down, green, weedy, cattail growth, many geese and ducks
September 21	Sunny, calm	Same as last time

Table D-13: Qualitative Data for SRB 4-5

Date	Weather Conditions	Visual Inspection
May 9	Sunny/haze, calm	Fishy odour, patches of cattails
May 18	Sunny, mild/moderate winds	Same as last time
June 3	Partly cloudy, moderate winds	Same as last time, some new weeds
June 15	Partly cloudy, moderate winds	Harvesting in progress, patchy weeds remain, same as last time
June 30	Sunny, moderate winds	Many weeds remain, floating weeds at one end, many leeches
July 15	Overcast, moderate winds	Same as last time, purple loosestrife (few), poorer water clarity
July 27	Sunny, moderate winds	Same as last time, water is greener, some geese
August 10	Sunny, calm	Same as last time, some scum
August 24	Sunny, moderate winds	Same as last time, no scum or geese
September 21	Sunny, calm	Same as last time many geese present

Table D-14: Qualitative Data for SRB 4-6

Date	Weather Conditions	Visual Inspection
May 9	17°C, sunny, calm	Excellent condition
May 18	Sunny, moderate wind	Poorer water clarity, some floating debris, water level noticeably higher
June 3	12.5°C, partly cloudy, moderate wind	Water level lower, many weeds, garbage
June 15	Partly cloudy, moderate wind	Same as last time
June 30	Sunny, calm	Same as last time, poor clarity, leeches
July 15	Cloudy, moderate winds	Weeds, moderate clarity, no algae
July 27	Sunny, moderate winds	Same as last time
August 10	Sunny, calm	Same as last time, greenish hue
August 24	Partly cloudy, moderate winds	Same as last time
September 21	Sunny, calm	Same as last time, many geese

Table D-15: Qualitative Data for SRB 4-7		
Date	**Weather Conditions**	**Visual Inspection**
May 20	Sunny, light winds	Poor water clarity, lots of garbage surrounding, strong odour
June 3	11.5°C, partly cloudy, moderate winds	Same as last time
June 15	Sunny, moderate winds	Same as last time, no weeds and algae yet
June 30	Sunny, light winds	Needle shaped pelagic algae, excellent water clarity, garbage
July 14		Many of the algae present now, lots of snails, water clarity poor again, brown scum at periphery
July 27	Sunny, moderate winds	Algae, odour, many insects at shore, weedy, improved water clarity, lower water level
August 10	Sunny, light wind	Same as last time with white foam near the shore, no odour
August 24	Sunny, moderate winds	Low water level, extremely fishy smell, peacock blue foam around shore
September 21	Sunny, calm	Water level higher, water is greenish colour, a few geese, fair clarity

Table D-16: Qualitative Data for SRB 4-8		
Date	**Weather Conditions**	**Visual Inspection**
May 8	20°C, sunny, light wind	Patches of rushes, eroding shores, garbage, leeches
May 18	Sunny, light winds	Same as last time, water level higher
June 3	12°C, partly cloudy, moderate winds	Same as before, also weedy, smells of sulfur, good clarity
June 15	Mainly sunny, calm	Same as last time
June 30	Sunny, calm	Same as last time, no smell, thick weeds
July 13	Sunny, moderate wind	Same as last time
July 27	Sunny, calm	Fewer weeds around shore, odour, poorer clarity
August 10	Sunny, light winds	Same as last time, floating dead weeds
August 24	Sunny, moderate winds	Same as last time, floating weeds gone, water level has gone down
September 21	Sunny, calm	Same as last time, greener colour

Table D-17: Qualitative Data for SRB 4-9

Date	Weather Conditions	Visual Inspection
May 9	17.5°C, sunny, calm	Good, cattails on the non-residential side
May 18	Sunny, light wind	Same as last time, water level has gone up
June 3	12.5°C, partly cloudy, moderate winds	Same as last time, garbage
June 15	Partly cloudy, moderate winds	Same as last time, more weeds, poor clarity
June 30	Sunny, light winds	Same as last time, no weeds
July 15	Cloudy, moderate winds	Same as last time, water level has gone down, new cattails
July 27	Sunny, moderate winds	Same as last time, filamentous algae growing on the rocks around shore
August 10	Sunny, calm	Same as last time, geese
August 24	Sunny, moderate winds	Poor clarity, cattails, few weeds and algae, water level down
September 21	Sunny, calm	Same as last time, green yellow colour

Table D-18: Qualitative Data for SRB 4-10

Date	Weather Conditions	Visual Inspection
May 8	21.5°C, sunny, light wind	Patches of cattails surrounding, poor clarity (dirty looking), slime and algae on rocks.
May 18	Sunny, gusty winds	Same as last time, filamentous algae on the shore
June 3	11°C, cloudy, moderate winds	Same as last time
June 15	Partly cloudy, light wind	Same as last time
June 30	Sunny, calm	Same as last time, looks very green, few weeds near the shore
July 13	Sunny, moderate winds	Same as last time
July 27	Sunny, light winds	Same as last time
August 10	Partly cloudy, calm	Same as last time, geese
August 24	Sunny, moderate winds	Same as last time, no geese
September 21	Sunny, calm	Same as last time

Table D-19: Qualitative Data for SRB 5-1		
Date	**Weather Conditions**	**Visual Inspection**
May 9	18°C, hazy, calm	Good, some garbage
May 20	Sunny, moderate winds	Very muddy banks
June 3	10°C, partly cloudy, moderate winds	Water level down, much greener then last time, odour of algae
June 16	Cloudy, drizzle	Water extremely green, poor clarity
July 2	Partly cloudy, calm	Same as last time, no weeds, dead fish, many geese
July 15	Cloudy, moderate winds	Same as last time also lots of leeches
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, calm	Same as last time, water not as green
August 25	Cloudy, calm	Same as last time
September 22	Sunny, calm	Same as last time, no geese

Table D-20: Qualitative Data for SRB 5-2		
Date	**Weather Conditions**	**Visual Inspection**
May 9	16.5°C, hazy, calm	Patches of cattails, garbage, some shore erosion
May 20	Sunny, moderate winds	Same as last time
June 3	10°C, partly cloudy, moderate winds	More weeds and algae than last time, poor clarity
June 16	Cloudy, light winds	Same as last time, very thick weeds
July 2	Sunny, calm	Same as last time, many geese
July 15	Cloudy, moderate winds	Same as last time, odourous
July 28	Sunny, moderate winds	Thick weeds
August 13	Hazy, dead calm	Thick algae at shore, some weeds, water is green, odourous, many leeches
August 25	Cloudy, calm	Same as last time
September 22	Sunny, calm	Same as last time, clarity slightly better

Table D-21: Qualitative Data for SRB 5-3

Date	Weather Conditions	Visual Inspection
May 9	16°C, hazy, calm	Some algae around the shore (filamentous)
May 20	Sunny, light winds	Thick algae at shore, weeds, good clarity
June 3	11°C, sunny, moderate winds	More weeds and algae
June 16	Cloudy, calm	Same as before, thicker weeds, poor clarity
July 2	Partly cloudy, calm	Same as last time
July 15	Cloudy, light winds, cool	Very few weeds, lots of floating dead weeds, poorer clarity
July 28	Sunny, moderate winds	Weeds are gone, few patches of cattails around the shore
August 13	Hazy, calm	Same as last time, poor clarity
August 25	Cloudy, calm	Green algae at shoreline, very green, no rushes, poor clarity, cormorants
September 22	Sunny, calm	Same as last time, odourous

Table D-22: Qualitative Data for SRB 5-4E

Date	Weather Conditions	Visual Inspection
May 7	16°C, sunny, moderate winds	Eroding banks, poor clarity
May 20	Sunny, moderate winds	Same as last time, weeds near shore
June 4	9°C, sunny, light winds	Same as last time
June 15	Partly cloudy, light winds	Same as last time
June 30	Sunny, light winds	Same as last time
July 15	Partly cloudy, moderate winds	Same as last time
July 27	Sunny, moderate winds	Same as last time
August 12	Sunny, calm	Lots of weeds, poor clarity, water level lower than last time
August 24	Partly cloudy, moderate winds	Same as last time
September 22	Sunny, calm	Many floating weeds, geese, and cattails, clarity improved

Table D-23: Qualitative Data for SRB 5-4W		
Date	**Weather Conditions**	**Visual Inspection**
May 7	16°C, sunny, moderate winds	Eroding banks, patches of cattails
May 20	Sunny, calm	Poor clarity, thick weeds throughout, cattails
June 4	11°C, sunny, light winds	Same as last time
June 15	Partly cloudy, mild winds	Same as last time, water being pumped into from a sewer?
June 30	Sunny, light winds	Same as last time, better clarity then 5-4E
July 15	Partly cloudy, moderate winds	Same as last time
July 27	Sunny, moderate winds	Water level down, many cattails, poorer clarity
August 12	Sunny, calm	Same as last time
August 24	Partly cloudy, moderate winds	Same as last time, water level higher
September 22	Sunny, calm	Floating algae, green colour, many weeds and algae, clarity better

Table D-24: Qualitative Data for SRB 5-5		
Date	**Weather Conditions**	**Visual Inspection**
May 5	17°C, sunny, moderate winds	No weeds, poor clarity, erosion, garbage
May 20	Sunny, calm	Same as last time, odour (fishy), dead fish
June 2	11.5°C, cloudy, moderate winds	Lots of garbage, poor water clarity, algae
June 16	Rain, light wind	Same as last timed, weedy and dirty
July 2	Partly cloudy, light winds	Same as last time, water brown, scum
July 13	Sunny, moderate winds	Malodourous, green colour, algae, poor clarity, no visible weeds
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, calm	Same as last time
August 25	Sunny, calm	Extremely green, cattails, poor clarity, purple loosestrife, many geese
September 22	Sunny, light winds	Same as last time, many geese

Table D-25: Qualitative Data for SRB 5-6

Date	Weather Conditions	Visual Inspection
May 7	17°C, sunny, light winds	Poor clarity, many ducks, erosion, garbage
May 20	Sunny, calm	Same as last time, lots of algae at shores, pollen and seeds on the surface
June 2	11°C, cloudy, moderate winds	Poor clarity, garbage, algae
June 16	Drizzle, light wind	Same as last time, weedy
July 2	Mostly sunny, light winds	Same as last time, scum purple loosestrife
July 13	Sunny, moderate winds	Poor clarity, few weeds, green colour
July 28	Sunny, moderate winds	Same as last time, loosestrife
August 13	Hazy calm	Same as last time, green scum at shore
August 25	Sunny, light winds	Extremely green, some weeds near the shore, loosestrife gone, lots of geese and ducks
September 22	Sunny, light winds	Terrible clarity, green scum, many geese, otherwise same as last time

Table D-26: Qualitative Data for SRB 5-7

Date	Weather Conditions	Visual Inspection
May 7	Sunny/hazy, moderate winds	Garbage, fish, erosion
May 20	Sunny, calm	Weeds, poor water clarity
June 2	Cloudy, moderate winds	Same as last time, odour
June 16	Rain, light winds	Same as last time
July 2	Cloudy, light winds	Same as last time
July 13	Sunny, light winds	No weeds, green, poor clarity
July 28	Sunny, moderate winds	Same as last time, water level lower, many ducks
August 13	Hazy, calm	Same as last time, no cattails
August 25	Sunny, moderate winds	Same as last time, many geese and ducks
September 22	Sunny, light breeze	Same as last time, odour, many geese

Table D-27: Qualitative Data for SRB 5-8		
Date	**Weather Conditions**	**Visual Inspection**
May 5	Sunny, moderate winds	Muskrat, fish, good clarity
May 20	Sunny calm	Same as last time, pollen and seeds on surface
July 2	11°C, cloudy, moderate winds	Poor water clarity
June 16	Drizzle, light winds	Cattails, poor clarity, lots of weeds and algae, odour (decay)
July 2	Sunny, light winds	Same as last time, no odour
July 13	Sunny, windy	Same as last time
July 28	Sunny, moderate winds	Extremely green water, poor clarity, no weeds, cattails
August 13	Hazy, calm	Same as last time, some loosestrife
August 25	Sunny, moderate winds	Same as last time, many geese
September 22	Sunny, light winds	Same as last time, no geese, green scum

Table D-28: Qualitative Data for SRB 5-9		
Date	**Weather Conditions**	**Visual Inspection**
May 5	15.5°C, sunny, moderate winds	Good condition
May 20	Sunny, calm	Thick weeds near shore, poor water clarity
June 2	11°C, cloudy, moderate winds	Extremely thick weeds, same as last time
June 16	Cloudy, light winds	Very poor water clarity (green), thick weeds
July 2	Partly cloudy, light winds	Poor clarity, dead weeds floating near shore, garbage, some algae
July 13	Sunny, moderate winds	No weeds, water is green, poor clarity
July 28	Sunny, light winds	Same as last time, water level lower, not green
August 13	Hazy, calm	Poor clarity, water is black and turbid
August 25	Sunny, light winds	Dark brown and murky, no algae or weeds, geese
September 22	Sunny, light winds	Same as last time

Table D-29: Qualitative Data for SRB 5-10		
Date	**Weather Conditions**	**Visual Inspection**
May 7	16°C, sunny, moderate winds	Thick cattails around the shore, some garbage, erosion on residential side
May 20	Sunny, light winds	Cattails, poor clarity
June 2	10°C, cloudy, moderate winds	Same as last time
June 16	Rain, light wind	Same as last time, weedy
July 2	Cloudy, calm	Same as last time
July 13	Sunny, moderate winds	Same as last time, green water (algae), loosestrife
July 28	Sunny, moderate winds	Cattails, floating algae (filamentous), poor clarity
August 13	Hazy, calm	Same as last time, clarity better then the other ponds in Southdale
August 25	Sunny, light winds	Same as last time
September 22	Sunny, light winds	Green water, poor clarity, cattails

Table D-30: Qualitative Data for SRB 5-11		
Date	**Weather Conditions**	**Visual Inspection**
May 7	16°C, sunny, light winds	Thick cattails around, lots of garbage
May 22	17.5°C, sunny, calm	Fewer cattails and garbage
June 4	11.5°C, mostly sunny, calm	Same as last time; also weeds and ducks
July 3	Sunny, moderate winds	Much garbage, thick weeds of variety, cattails, excellent water clarity, water has different colour
July 15	Partly cloudy, moderate winds	Excellent water clarity, very few weeds, same as last time
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, light winds	Same as last time, new weeds
August 28	Sunny, moderate winds	Same as last time, clarity poorer, loosestrife
September 22	Sunny, light wind	Same as last time, clarity poor, many fish

Table D-31: Qualitative Data for SRB 5-12		
Date	**Weather Conditions**	**Visual Inspection**
May 5	16°C, hazy, moderate winds	Garbage, thick cattails and weeds, good clarity
May 22	18.5°C, sunny/haze, calm	Same as last time; also pelagic algae, odour
June 4	12°C, partly cloudy, light winds	Many weeds, floating algae, excellent clarity, cattails, odour
June 16	Drizzle, light winds	Same as last time, ducks
July 3	Sunny, moderate winds	Same as June 4, water clarity not as good as 5-11
July 15	Partly cloudy, calm	Lots of filamentous algae by shore, weeds, odour, cattails, good clarity, water is brown colour
July 28	Sunny, light winds	Lots of weeds and algae, no more pelagic algae, fewer cattails, very good clarity, coloured water
August 13	Hazy, light winds	Same as last time; new cattails?
August 25	Partly cloudy, light wind	Same as last time
September 22	Sunny, light winds	Lots of cattails, less floating algae, satisfact. Clarity, dark colour, dead cattails, odour

Table D-32: Qualitative Data for SRB 5-13		
Date	**Weather Conditions**	**Visual Inspection**
May 5	14°C, hazy, light winds	Garbage, good clarity, thick cattails, filamentous algae near shore, odour
May 22	18.5°C, sunny, calm	Same as last time also pelagic algae
June 4	12°C, partly cloudy, calm	Same as last time
June 16	Drizzle, light winds	Same as last time, less pelagic algae
July 3	Sunny, moderate winds	Same as last time
July 15	Cloudy, light winds	Excellent clarity, not as much algae as 5-12, cattails, weeds
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, light winds	Lots of weeds, algae cattails, good clarity, floating algae, odour, dead duck
August 25	Cloudy, calm	Same as last time
September 22	Sunny, light winds	Same as last time, water very dark

Table D-33: Qualitative Data for SRB 5-15

Date	Weather Conditions	Visual Inspection
May 5	14°C, sunny, moderate winds	Excellent, much aquatic life
May 20	Sunny, calm	Algae at shore, few weeds, cattails
June 4	11°C, cloudy light winds	Lots of algae at shore, weeds, poor clarity, odour
June 16	Cloudy, calm	Same as last time
July 2	Partly cloudy, calm	Same as last time, geese feces
July 15	Cloudy, moderate winds	Poor clarity, cattails, green coloured water, purple loosestrife, lily pads, odour
July 28	Sunny, moderate winds	Same as last time, water level down
August 25	Sunny, calm	Green scum at shore, poor clarity, rushes, many geese
September 22	Sunny, light winds	Same as last time

Table D-34: Qualitative Data for SRB 5-16

Date	Weather Conditions	Visual Inspection
May 7	16°C, cloudy, light wind	Few rushes, poor water quality
May 21	20°C, sunny, light winds	A few weeds, poor clarity, garbage
June 4	12.5°C, partly cloudy, light winds	Same as last time
June 17	Cloudy, calm	Same as last time
July 3	Sunny, moderate winds	No weeds, poor clarity
July 15	Partly cloudy, moderate winds	Same as last time, odour
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, calm	Green water, poor clarity, malodourous, many gulls
August 25	Sunny, moderate winds	Poor clarity, no weeds or algae
September 22	Sunny, light winds	Same as last time, lots of geese

Table D-35: Qualitative Data for SRB 5-17		
Date	**Weather Conditions**	**Visual Inspection**
May 7	16°C, hazy, light winds	Excellent
May 21	22°C, sunny, calm	Poor water clarity, odour
June 4	11.i°C, mainly cloudy, light winds	Same as last time
June 16	Cloudy,	Same as last time
July 3	Sunny, moderate winds	Same as last time
July 15	Partly cloudy, moderate winds	Same as last time, loosestrife in residential gardens surrounding
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, light winds	Green water, poor clarity, same as last time
August 25	Sunny, moderate winds	Same as last time, many gulls and geese
September 22	Sunny, light winds	Same as last time, many geese

Table D-36: Qualitative Data for SRB 5-18		
Date	**Weather Conditions**	**Visual Inspection**
May 7	16.5°C, hazy, moderate winds	Poor clarity
May 21	21.5°C, sunny, light winds	Poor quality, many snails
June 4	13°C, partly cloudy, light winds	Garbage, patches of cattails, poor clarity, dead fish
June 16	Cloudy, calm	Same as last time, odour
July 3	Sunny, moderate winds	No weeds, few cattails, poor clarity
July 15	Cloudy, moderate winds	Same as last time
July 28	Sunny, moderate winds	Same as last time, many geese
August 13	Hazy, calm	Rushes are dead, water is green, poor clarity, many geese
August 25	Sunny, moderate winds	Poor clarity, odour, dead cattails
September 22	Sunny, light winds	Many geese, green water, poor clarity

Table D-37: Qualitative Data for SRB 5-19

Date	Weather Conditions	Visual Inspection
May 5	14°C, sunny, moderate winds	Excellent, no weeds or odour
May 20	Sunny, light winds	Same as last time, floating pollen and weeds
June 4	12.5°C, partly cloudy, light winds	Poor water quality, algae at the shore
June 16	Cloudy, calm	Same as last time, odour
July 2	Sunny, calm	Much dead algae at shore, weeds, poor clarity
July 15	Cloudy, moderate winds	Same as last time, water is green
July 28	Sunny, moderate winds	Poor clarity
August 13	Hazy, calm	Same as last time, green water, scum
August 25	Sunny, calm	Same as last time, geese
September 22	Sunny, light wind	Poor clarity, brown and silty water, many geese

Table D-38: Qualitative Data for SRB 5-20

Date	Weather Conditions	Visual Inspection
May 5	16°C, sunny, moderate winds	Excellent
May 20	Sunny, light winds	Same as last time, floating pollen and weeds
June 4	12°C, partly cloudy, light winds	Poor water clarity
June 16	Cloudy	Same as last time
July 2	Sunny, calm	Poor clarity, weeds, dead fish
July 15	Cloudy, moderate winds	Poor clarity, water is green, few weeds
July 28	Sunny, moderate winds	Poor clarity, no weeds, some algae
August 13	Hazy, calm	Same as last time
August 25	Sunny, calm	Same as last time, green water, geese
September 22	Sunny, light winds	Poor clarity, many geese

Table D-39: Qualitative Data for SRB 5-21

Date	Weather Conditions	Visual Inspection
May 7	16.5°C, sunny, moderate winds	Poor clarity, garbage, patches of cattails, odour
May 20	Sunny, moderate winds	Same as last time
June 4	12°C, sunny, calm	Same as last time
June 16	Cloudy	Same as last time, some weeds
July 2	Partly cloudy, calm	Same as last time, water is green
July 15	Cloudy, light winds	Same as last time
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, calm	Poor clarity, floating weeds (dead)?, green water
August 25	Sunny, calm	Poor clarity, cattails
September 22	Sunny, light winds	Same as last time, scum

Table D-40: Qualitative Data for SRB 5-22

Date	Weather Conditions	Visual Inspection
May 22	15°C, sunny, calm	Algae at the shore, poor water clarity
June 4	11°C, partly cloudy, light winds	Same as last time
June 16	Cloudy, light winds	Same as last time, weeds
July 2	Partly cloudy, light winds	Same as last time
July 15	Cloudy, moderate winds	Same as last time, odour (fishy)
July 28	Sunny, moderate wind	Same as last time
August 13	Hazy, light winds	Green water, poor clarity, cattails growing, algae at shore
August 25	Sunny, moderate winds	Same as last time, geese
September 22	Hazy, calm	Same as last time, no cattails, green, many geese

Table D-41: Qualitative Data for SRB 5-23

Date	Weather Conditions	Visual Inspection
May 22	16.5°C, sunny, calm	Excellent, muddy banks
June 4	11°C, sunny, calm	No weeds or algae, poor clarity, lots of dirt
June 16	Cloudy, calm	Excellent water clarity
July 2	Sunny, calm	Same as last time
July 15	Cloudy, moderate winds	Poor clarity, water skiing
July 28	Sunny, moderate winds	Same as last time
August 13	Hazy, calm	No skiing, many feathers, poor clarity
August 25	Partly cloudy, calm	No skiing, poor clarity
September 22	Sunny, calm	Same as last time, many feathers

Table D-42: Qualitative Data for SRB 6-4

Date	Weather Conditions	Visual Inspection
May 5	16°C, hazy, moderate winds	Thick cattails and algae, excellent clarity, duckweed
May 22	18°C, sunny, calm	Same as last time weeds
June 4	14°C, cloudy, calm	Same as last time, much wildlife
June 17	Cloudy, calm	Thick weeds, algae at shore, cattails, excellent clarity, duckweed
July 3	Sunny, calm	Same as last time
July 15	Partly cloudy, moderate winds	Same as last time, water is a brown colour
July 29	Sunny, moderate winds	Same as last time, loosestrife, geese
August 14	Sunny, moderate winds	Same as July 15, more duckweed, water clarity not as good
August 26	Sunny, light winds	Same as last time
September 23	Overcast, calm	Same as last time

Table D-43: Qualitative Data for SRB 6-6

Date	Weather Conditions	Visual Inspection
May 4	16°C, sunny, moderate winds	Cattails, filamentous algae on shore rocks, excellent
May 21	18°C, sunny, calm	Same as last time, some weeds
June 2	8°C, moderate winds, cloudy	Same as last time
June 17	Cloudy, calm	Extremely thick weeds, cattails surround pond
July 3	Partly cloudy, moderate winds	Same as last time
July 14	Sunny, light winds	Floating dead weeds and garbage, poor clarity
July 29	Sunny, light winds	Most weeds gone, many cattails
August 14	Sunny, moderate winds	Same as last time, loosestrife
August 26	Sunny, calm	Poor clarity, water is green, most cattails look dead
September 23	Overcast, calm	Satisfactory clarity, dead cattails, odour

Table D-44: Qualitative Data for SRB 6-7

Date	Weather Conditions	Visual Inspection
May 4	16.5°C, cloudy, strong winds	Patches of cattails, lots of algae and garbage, dead fish
May 21	19°C, sunny, calm	Same as last time, large weed patches
June 2	8.5°C, cloudy, moderate winds	More weeds and algae than previous time
June 17	Cloudy, calm	Thick weeds throughout, garbage
July 3	Partly cloudy, moderate winds	Same as last time
July 14	Sunny, moderate winds	Lots of dead floating weeds, garbage, algae, poor water clarity
July 29	Sunny, light winds	Water is green, weeds gone, cattails, odour, poor clarity
August 14	Sunny, moderate winds	Same as last time, loosestrife
August 26	Sunny, calm	Green water, poor clarity, dead cattails, green scum
September 23	Overcast, calm	Same as last time, many geese, odour

Table D-45: Qualitative Data for SRB 6-8

Date	Weather Conditions	Visual Inspection
May 9	20°C, sunny, light winds	Many weeds, algae, scum
May 21	17°C, sunny, light winds	Same as last time
June 2	8.5°C, cloudy, moderate winds	Same as last time, less scum, poor quality
June 17	Hazy, light winds	Thick weeds, garbage, scum
July 3	Partly cloudy, moderate winds	Floating dead weeds, green water resulting in poor clarity (algae)
July 14	Sunny, light winds	New cattail growth, a few weeds, poor clarity (green), much algae
July 29	Partly cloudy, calm	Same as last time
August 14	Sunny, moderate winds	Extremely green very poor clarity, ducks
August 26	Sunny, light winds	Same as last time, black scum on one side
September 23	Overcast, calm	Weeds and geese, poor clarity, yellow/brown colour

Table D-46: Qualitative Data for SRB 6-9

Date	Weather Conditions	Visual Inspection
May 9	21°C, sunny, light winds	Algae on rocks, garbage, better than 6-8
May 21	16°C, sunny, light winds	Cattails, same as last time
June 2	8.5°C, cloudy, moderate winds	Same as last time, water is green
June 17	Sun/haze, calm	Some garbage, lots of algae, thick algae near the shore
July 3	Sunny, moderate winds	Harvesting in progress, many dead floating weeds, poor water clarity
July14	Sunny, moderate winds	Poor clarity. Purple loosestrife is thick in front of one property, no weeds but lots of algae
July 29	Sunny, calm	Better clarity than 6-8, water green, no weeds loosestrife gone
August 14	Sunny, moderate winds	Same as last time, new loosestrife growing, thick algae near shore
August 26	Sunny, calm	Same as last time
September 23	Overcast	Same as last time, many geese

Table D-47: Qualitative Data for SRB 6-10

Date	Weather Conditions	Visual Inspection
May 5	12°C, sunny, light wind	Scum, poor clarity, garbage
May 21	14°C, sunny, calm	Same as last time, goldfish (big)
June 2	8°C, cloudy, moderate winds, cold	Poor clarity, garbage
June 17	Cloudy, calm	Same as last time, odour, algae near shore
July 3	Sunny, moderate winds	Same as last time
July 14	Sunny, moderate winds	Same as last time
July 29	Partly cloudy, calm	Same as last time, geese
August 14	Sunny, moderate winds	Same as last time, no geese
August 26	Sunny, calm	Same as last time
September 23	Cloudy, moderate winds	Many geese, dark green, scum and garbage at shore, poor clarity

Table D-48: Qualitative Data for SRB 6-11

Date	Weather Conditions	Visual Inspection
May 5	11°C, sunny, calm	Poor clarity, garbage
May 21	13.5°C, sunny, calm	Same as last time, yellow scum at shore
June 2	8°C, cloudy, moderate winds, cold	Poor clarity, garbage
June 17	Hazy, calm	Same as last time, odour (fishy), algae near the shore
July 3	Sunny, light winds	Same as last time
July 14	Sunny, moderate winds	No weeds, greenish colour, poor clarity, garbage
July 29	Cloudy, calm	Odour, no weeds, algae near the shore, poor clarity
August 14	Sunny, light winds	Same as last time
August 26	Sunny, calm	Same a last time
September 23	Partly cloudy, moderate winds	Poor clarity, a few geese, garbage

Table D-49: Qualitative Data for SRB 6-12

Date	Weather Conditions	Visual Inspection
May 7	17°C, hazy, calm	Patches of cattails, poor clarity, garbage, duckweed
May 21	15°C, sunny, calm	Many weeds, lots of floating algae, garbage, cattails, erosion
June 2	9°C, cloudy, moderate winds	Same as last time, water level lower
June 17	Cloudy, calm	Same as last time, odour
July 3	Sunny, light winds	Lots of weeds and filamentous algae, loosestrife, green scum, duckweed
July 14	Sunny, strong winds	Extensive weeds and algae, good clarity, loosestrife
July 29	Mostly cloudy, calm	Many weeds, cattails, loosestrife, foam at one end, good water clarity
August 14	Sunny, moderate winds	Poor clarity (worse than 6-13), no weeds, loosestrife, ducks
August 26	Sunny, calm	Same as last time, water is green; dead duck floating, dead cattails
September 23	Overcast, calm	Poor clarity, yellow/brown, dead cattails

Table D-50: Qualitative Data for SRB 6-13

Date	Weather Conditions	Visual Inspection
May 5	15°C, sunny, moderate winds	Filamentous algae near shore, so-so clarity
May 21	15.5°C, sunny, calm	Many weeds, lots of floating algae, scum banks better than 6-12
June 2	6°C, cloudy, moderate winds	Many weeds, odour
June 17	Cloudy, calm	Same as last time
July 3	Sunny, light winds	Lots of weeds and floating algae, garbage, duckweed
July 14	Sunny, moderate winds	Water clarity poor, fewer weeds then in 6-12, lots of algae
July 29	Mainly cloudy, calm	Good clarity, no weeds, loosestrife, odour
August 14	Sunny, moderate winds	Poor clarity, odour, loosestrife, ducks
August 26	Sunny, calm	Same as last time, dead cattails, green water
September 23	Overcast, calm	Poor clarity, brown colour, dead cattails, many geese

Table D-51: Qualitative Data for SRB 6-14

Date	Weather Conditions	Visual Inspection
May 4	16°C, partly cloudy, strong winds	Patches of cattails, garbage, odour, good clarity
May 21	20°C, sunny, calm	Same as last time, erosion, weeds
June 4	13°C, cloudy, calm	Same as last time, algae at shore
June 17	Cloudy, light winds	Same as last time
July 3	Sunny, moderate winds	Same as last time, floating things look like mould
July 14	Sunny, light winds	Good clarity, reddish/brown water, few weeds, floating organisms gone
July 29	Cloudy, windy	Same as last time
August 14	Partly cloudy, moderate winds	Same as last time, poor clarity
August 26	Sunny, calm	Same as last time
September 23	Sunny, light winds	Same a last time, many geese and cattails, cormorants

Table D-52: Qualitative Data for SRB 6-15

Date	Weather Conditions	Visual Inspection
May 9	20.5°C, sunny, calm	Many weeds
May 21	20°C, sunny, light winds	Poor quality, foam at shore, cattails many patches of thick weeds
June 4	15°C, partly cloudy, calm	Same as last time, poor clarity
June 17	Hazy, light winds	Same as last time, odour
July 3	Sunny, moderate winds	Same as previous weeks
July 14	Sunny, moderate winds	Same as last time, loosestrife
July 29	Sunny, light winds	Fewer weeds (many dead floating ones), water is green, cattails, ducks and geese, loosestrife
August 14	Sunny, windy	Same as last time
August 26	Sunny, light winds	Same as last time
September 23	Sunny, light winds	Green, poor clarity, many cattails, many geese

Table D-53: Qualitative Data for SRB 6-16

Date	Weather Conditions	Visual Inspection
May 5	14°C, sunny, moderate winds	Poor clarity, filamentous algae on shore rocks
May 21	17°C, sunny, calm	Same as last time
June 2	9°C, cloudy, moderate winds	Same as last time
June 17	Cloudy, calm	Abundance of green filamentous algae floating near the shore, odour of fish.
July 3	Sunny, moderate winds	Purple loosestrife, poor water clarity, water is green (algae)
July 14	Sunny, moderate winds	Same as last time, cattails and no weeds
July 29	Cloudy, calm	Same as last time
August 14	Sunny, moderate wind	Same as last time, many geese and ducks
August 26	Sunny, calm	Same as last time, no waterfowl
September 23	Overcast, light winds	Very green, poor clarity, patches of cattails, many geese

Table D-54: Qualitative Data for SRB 6-17

Date	Weather Conditions	Visual Inspection
May 4	14.5°C, cloudy, moderate winds	Patches of cattails, odour
May 21	20.5°C, sunny, calm	Algae, poor clarity, same as last time
June 4	13°C, cloudy	Very strong fishy smell, weeds, algae
June 17	Cloudy, light winds	Weedy, algae, garbage, patches of cattails
July 3	Sunny, calm	Many floating dead weeds, cattails, odour (fishy)
July 14	Sunny, light winds	No weeds, algae around shores otherwise same as last time
July 29	Cloudy, moderate winds	Same as last time
August 14	Cloudy, moderate winds	Same as last time, new cattails
August 26	Sunny, calm	Many cattails, many geese and ducks
September 23	Sunny, light winds	Poor clarity, cattails, brownish colour, weeds on the banks, scum

Table D-55: Qualitative Data for SRB 6-18		
Date	**Weather Conditions**	**Visual Inspection**
May 8	13°C, sunny, light winds	Patches of cattails, algae near shore
May 21	21°C, sunny, light winds	Thick algae around the shore, weeds, foam, patches of cattails
June 4	15°C, partly cloudy, light winds	Same as last time, odour, poor clarity
June 17	Hazy, light winds	Same as last time
July 3	Sunny, moderate winds	Thick weeds near the shore, same as last time
July 14	Sunny, moderate winds	Loosestrife, better clarity, patches of weeds gone, floating weeds and algae
July 29	Sunny, moderate winds	Poor clarity, floating weeds cattails
August 14	Sunny, moderate winds	Same as last time, water is green
August 26	Sunny, moderate winds	Same as last time
September 23	Sunny, light winds	Same as last time

Table D-56: Qualitative Data for SRB 6-19		
Date	**Weather Conditions**	**Visual Inspection**
May 8	13°C, sunny, calm	Garbage, slime on rocks, algae
May 21	20.5°C, sunny, calm	Same as last time
June 3	11°C, partly cloudy, moderate winds	Same as last time, few weeds
June 17	Hazy, calm	Same as last time, weeds throughout
July 3	Sunny, moderate winds	Same as last time, many fish, yellow scum
July 14	Sunny, moderate winds	Loosestrife, dead floating weeds, few remain, water clarity poorer
July 29	Sunny, moderate winds	Patches of cattails, no weeds fishy odour
August 14	Sunny, moderate winds	Many weeds growing up, algae at shore, good clarity, loosestrife
August 29	Sunny, light winds	Same as last time, many geese
September 23	Sunny, light breeze	Cattails, green/yellow colour, moderate clarity

Table D-57: Qualitative Data for SRB 6-20		
Date	**Weather Conditions**	**Visual Inspection**
May 4	14°C, cloudy, strong winds	So-so water clarity
May 21	20°C, sunny, calm	Poor clarity, few weeds
June 4	12°C, cloudy, light winds	Thick filamentous algae at the shores, weedy
June 17	Cloudy, calm	Same as last time, good clarity
July 3	Sunny, light winds	Same as last time
July 14	Sunny, light winds	Some weeds left, water clarity not as good
July 29	Cloudy, moderate winds	Good clarity, odour of fish, many weeds, no algae, snails
August 14	Sunny, moderate winds	Poorer clarity, no weeds or algae, geese feces
August 26	Cloudy, calm	Same as last time, many geese
September 23	Sunny, light breeze	Same as last time, odour, no geese

Table D-58: Qualitative Data for SRB 6-22		
Date	**Weather Conditions**	**Visual Inspection**
May 8	12.5°C, sunny, light wind	Garbage
May 21	25°C, sunny, moderate winds	Algae around the shore, good water clarity
June 3	12.5°C, partly cloudy, moderate winds	Same as last time, weeds
June 17	Hazy, calm	Same as last time, thicker weeds
July 3	Sunny, moderate winds	Same as last time, dead seagull
July 14	Sunny, moderate winds	Extensive weeds, algae with many floating weeds, good clarity
July 29	Partly cloudy, moderate winds	Same as last time
August 14	Sunny, moderate winds	Fewer weeds, water clarity poorer, some algae near shore
August 26	Sunny, moderate winds	Same as last time
September 23	Sunny, light breeze	A few weeds, greenish, good clarity

Table D-59: Qualitative Wind Assessment for the Ten Week Sampling Period

Sampling Week	1	2	3	4	5	6	7	8	9	10
Calm (C) or Windy (W)	W	C	W	W	C	C	W	W	C	C

Table D-60: Rainfall Data for the Ten Week Sampling Period (Environment Canada, 1998)

Sampling Week	1	2	3	4	5	6	7	8	9	10
Rainfall Accumulation Since previous Sampling Week (mm)	0	84.9	16.6	26.7	31.3	26.5	11.2	13.5	11.2	79.5

Table D-61: Rainfall Events During the 10 Week Sampling Period

Date	Quantity of Rain Received (cm)
May 6	25.2
May 13	11.0
May 16	25.6
May 28	8.0
June 10	10.5
June 14	11.0
July 1	22.0
August 26	15.0
August 27	55.0