LAKE MANAGEMENT AND PROTECTION PLAN

City and County of Denver
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Executive Summary

Why does the City and County of Denver need a Lake Management and Protection Plan? Along with other cities across the country Denver wants to manage and protect their urban lake resources for the benefit of the citizens and the environment. There are many agencies that have a role in this effort and each agency tackles the issues surrounding the urban lakes based upon their specific mission. The purpose of the Lake Management and Protection Plan is to provide these agencies with a document that pulls together information on the history and present condition of the lakes, primary issues that can adversely impact the lakes such as geese and excessive nutrients, and strategies that can be used by the agencies to create more sustainable lake ecosystems.

There are various management practices being utilized by communities/governments across the country to improve lake quality. This Lake Management and Protection Plan emphasizes two management strategies. Design and restore natural, ecologically balanced lake shoreline and shoreland habitat and control impacts at the source (target the cause not the symptom).

Look again at the cover photos of two urban Denver lakes. Based solely on the visual features of these lakes which more closely represents your idea of how an urban lake should look? If you selected the one on the top of the cover you have chosen how most people believe urban lakes should look. It is what people are use to and familiar with in urban areas, bluegrass up to the water's edge. Although the lake in the bottom photo requires a comprehensive restoration effort, there is no bluegrass in the shoreland area which is comprised primarily of trees and native grasses. The photos emphasize another reason why a Lake Management and Protection Plan is needed. It is essential to change the perception of what urban lakes should look like in order to achieve successful restoration and management of the lakes. This requires support from city personnel, management and officials and education of citizens.

None of these strategies are quick solutions. This type of management takes time, determination, patience and funding to accomplish long term sustainable improvement for the lakes.

Section 1
Introduction

1.1 Lake Ecosystem

The following is a brief discussion of lake ecosystems summarized from *Managing Lakes and Reservoirs* (Holdren. et al. 2001).

"The condition of a lake at any one particular time is the result of a complex interaction of many different physical, chemical, and biological factors. Rainfall cycles, watershed characteristics, lake basin shape and depth, the lake water itself, and bottom sediments all contribute to this condition. These physical and chemical factors, in turn support a community of biological organisms that is unique to lakes. In fact, the plants and animals, along with the physical and chemical components of their immediate environment, define the lake ecosystem."

Physical Characteristics

The physical characteristics of a lake (depth, surface area, volume of water in the lake) are normally established when the lake is formed or designed. There are many ways that a lake can be naturally formed, for example glacial lakes. These lakes occurred after the glacial ice retreated and melting ice water filled in depressions in the land surface or valleys that were dammed with rock and debris. The Great Lakes are a good example of glacial lakes.

Chemical Characteristics

The chemical characteristics of a lake are not only dependent upon the physical shape of a lake but also on many other interconnected factors. The geology and soils of the area, climate, vegetative cover, land use within the watershed, size of the watershed and air deposition can play a role. At the least disturbed state the chemical characteristics of natural lakes are primarily dependent upon the geology and climate of the areas where they were formed. Weathering and runoff of the soils settle to form bottom deposits in the lake (sediment). Shallow lakes (mean depth <10 feet) have characteristics that are unique to these systems. For example, two lakes with the same surface area: one that is deep and one that is shallow. More of the shallow lake will be in the photic zone (where light can penetrate) and, therefore, support more plant growth.

Biological Characteristics

The aquatic life system of a lake is often depicted as a simplified food chain. In fact the lake system is a complex, inter-dependent structure of aquatic plant and animal life described as an aquatic food web. Algae and macrophytes are primary producers (they manufacture their own food through photosynthesis) and are the base of the food web in a lake. Algae can be free floating (phytoplankton) or attached (periphyton) where macrophytes are defined as plants with stems that can be rooted in the sediment or free floating. The amount or abundance of these primary producers is dependent on many factors, such as temperature, sunlight and nutrients (nitrogen and phosphorus).

Zooplankton are microscopic and macroscopic animals that either feed on algae, in which case they are herbivores, or feed on other zooplankton. Certain fish species and the young of certain fish species feed upon the zooplankton and are known as planktivores. At the top of the aquatic food chain is the piscivorous fish which feed upon the planktivores. All of these organisms (plant and animal) either through production of waste or when they die provide food for the detritivores and decomposers. As bacteria and fungi decompose organic material deposited in the sediment nutrients are released which are needed by the primary producers.

Although some people may consider any form of algae bad for the lake system and any form of macrophytes as weeds, this is not the case. Primary producers are a vital component of a functional lake system. Only when there is an over abundance, true nuisance or exotic form of the producers, is the system at risk or out of balance.

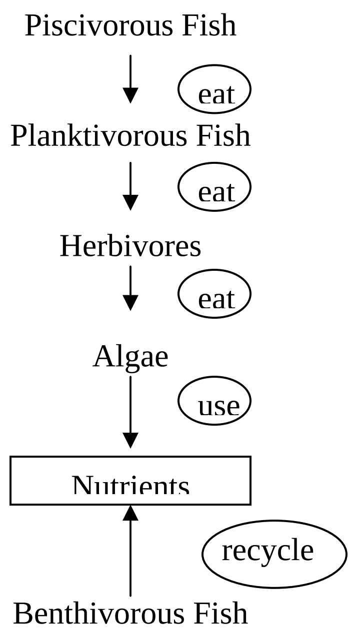

Figure 1: Aquatic Food Chain

Eutrophication (Aging of Lakes)

Natural lakes age through time becoming more and more eutrophic (nutrient rich with excessive plant growth) and eventually age to the point where the lake becomes a swamp or bog that eventually becomes a meadow or forest. The amount of time that it takes a lake to age is dependent upon numerous factors that can be summarized into three categories: amount of nutrient enrichment, climate and shape of the lake basin. There is no definite timeframe for this process to occur. Minnesota's *Water on the Web* (WOW. 2003) web site states that current research indicates that some lakes have not aged since the last glaciation and others appear to have been unproductive for millions of years.

What we do know, however, is that the more anthropogenic (human) pressure there is on lakes the more rapidly they will age. For example, in an undisturbed area the rate of nutrient enrichment is dependent upon the geology, soils and vegetative cover in addition to the weathering that occurs due to the climate. In areas of human disturbance the amount of vegetative cover decreases and the potential for erosion of soils increases in addition to the increase in nutrients from fertilizer application to cultivated lands.

The following figure depicts the range from oligotrophic (low plant productivity with clear water) to eutrophic and hypereutrophic (high plant productivity with cloudy water).

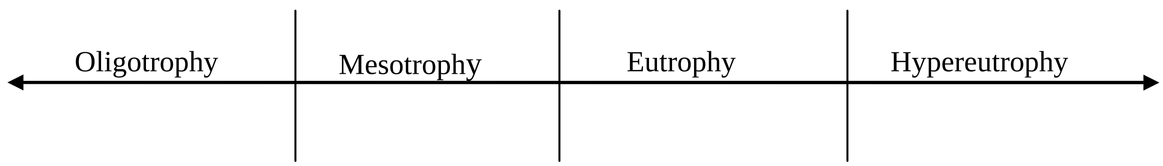

Figure 2: A trophic continuum (U.S. EPA. 2000a)

1.2 Urban Denver Lakes

How do urban Denver lakes compare to natural lake ecosystems? The lakes that are in the parks and open areas are primarily constructed lakes. Many would cite the legend that Sloan Lake was created by a "natural" spring, however, the legend further indicates that the spring or high water table was "hit" by a landowner while drilling a well – human intervention. Urban Denver lakes share a common link with natural lakes, they too will age, but at a greatly accelerated rate, not due to their constructed nature but because of human pressure. Per the evaluation by Denver Environmental Health's Environmental Protection Division, the lakes in Denver are almost all eutrophic to hyper-eutrophic. To maintain the functional nature of urban Denver lakes, human management is required. Numerous lakes have undergone various degrees of dredging in order to remove the enriched bottom sediments to decrease the amount of nutrient rich organic matter and increase the depth of the lakes. These attempts have been met with various degrees of success. Proposals to artificially aerate lakes, re-route or treat storm water have also been proposed. Some structural modifications to the inlets/outlets have been implemented to aide in lake water circulation.

Why develop a Lake Management and Protection Plan (LMPP)?

Denver's *Comprehensive Plan* (2000) is "a guide for Denver in responding to problems, conditions and opportunities for the early part of the 21st Century." One of the primary principals of the plan is environmental stewardship in order to preserve and enhance the natural environment. Strategies to accomplish the objective of "Stewardship of Resources" include:

a) Identify opportunities for City agencies to use native flora in landscape designs.

b) Preserve and restore, wherever possible, natural habitat for wildlife and plants native to the region, such as those at the Rocky Mountain Arsenal National Wildlife Area, Gates Crescent Park, Grant-Frontier, Bear Creek Park, Bear Valley Park, and the Cherry Creek corridor.

c) Introduce natural ecosystem strategies into the maintenance of our public and private lands.

In response to the *Comprehensive Plan* (2000) Denver Parks and Recreation (DPR) developed the *Game Plan* (2003) as their strategic master plan. The *Game Plan* was formally adopted as a supplement to the *Comprehensive Plan* (2000) in April of 2003. The *Game Plan* states that "DPR has the responsibility and perspective to achieve the goal of environmental sustainability outlined in the city's comprehensive plan." The recommendations to achieve the goal for conservation of natural resources are numerous and many play a role in managing and protecting the lakes and will be highlighted in the remaining portions of this plan. This plan directly addresses the lake portion:

> "Establish a comprehensive lake and waterway management program with the city's Water Quality Group" (now known as the Water Quality Committee).

Another document that has been developed by DPR also has facets that interconnect with the LMPP, *The Strategic Water Conservation Plan* (WCP). The WPC (2003) specifically states that it "builds on the environmental objectives and strategies stated in the DPR *Game Plan* and Denver's *Comprehensive Plan* by adding specific goals and tools." The goal of the plan is "to create an environmentally and economically sustainable parks and recreation system through planning, construction, programming, and maintenance practices that result in: on-going water conservation; improved water quality; respect for the Denver park design legacy and integrity.

1.3 What Agencies are Involved and Why

The City and County of Denver has many agencies concerned with maintaining lake functions within the city. Agencies tackle the issues based upon their various, but interrelated, missions. The following are the primary agencies that have direct involvement with aspects of managing the urban Denver lakes. It is clear that they have a common goal to improve water quality. These descriptions were taken from the various department websites. They reflect the established mission/goals/responsibilities that affect the overall goal of this plan to maintain, improve and protect the urban Denver lakes.

The Department of Parks and Recreation's (DPR) mission is to serve citizens by providing quality park and recreation facilities and programs and, thereby, assure that the City continues to be a livable place where all citizens can enjoy a wide range of leisure and recreational opportunities. This includes the responsibility to a) conserve and expand Denver's rich, unique and nationally recognized park and recreation legacy as an oasis on the plains (the foundation of Denver's residential neighborhoods) and a Western tradition of community recreation and outdoor sports; b) to plan with vision, imagination and energy so that today's decisions and actions will assure that the opportunities of future generations are as great as those enjoyed today.

The Planning Division’s mission further states: to plan, design and implement projects in a manner which build upon and enhance the region’s unique natural resources, the traditions of design excellence, and the department’s unique role to create a livable city, both now and in the future. The Natural Areas goals are to change the course of undeveloped, degraded and disturbed lands by nurturing them back into well-balanced, sustainable, healthy ecosystems.

The Department of Environmental Health’s (DEH) mission is to protect Denver’s environment and to safeguard the health and well being of its inhabitants. The Environmental Protection Division (EPD) responsibilities include maintaining and improving water quality. Their goal is that city lakes and streams meet or exceed the State of Colorado Water Quality Control Commission's water quality standards. The Environmental Services Division’s responsibilities include ensuring the city's compliance with environmental laws that protecting public health and environment by providing environmental regulatory compliance and environmental stewardship services for city-owned facilities and activities. The Animal Control Division adds the protection of animals to their mission statement. Their division’s responsibilities include vector control such as mosquitoes.

The Public Works Department, Wastewater Management Division (WMD), Water Quality Section responsibilities include development and implementation of several programs intended to improve the overall quality of stormwater runoff within the City and County of Denver. These programs include measures to: a) reduce pollutants from construction sites and new developments; b) educate the public on water quality; c) prohibit illicit discharges to the storm sewer; and d) assist industrial facilities in implementing stormwater management plans.

Development Engineering Services' mission is to provide a livable community by ensuring public health and safety through orderly development of land in a cost-effective manner that supports the Denver Comprehensive Plan, and coordinates all private use and private construction of public infrastructure in the right-of-way. This includes drainage and sanitary sewer plan review and approval.

Denver Water Department’s (DWD) mission is to provide customers with high quality water and excellent service through responsible and creative stewardship of the assets they manage. As part of their plan, reuse water will be used for industrial purposes and for outdoor irrigation in parks, golf courses and other public spaces. The website further states under City Ditch and Recycled Water Facts that the recycled water will be of a higher quality than the South Platte water.

1.4 Lists of Lakes

For reference, this section identifies all lakes currently under DPR management within the City and County of Denver (mountain park lakes are not listed). The lists include information on location and size of the various lakes as noted under the Parks and Recreation website, except Parkfield Lake. There are four (4) lists presented.

List 1.4.1 – Lakes in Urban City Parks are presented in the same order as the History and Present Use Sections. City Park and Washington Park Lakes are presented first as they were the first two parks, by acquisition or development date, that had lakes as an integral part of the park plan. The remaining lakes are presented by park district, the geographic area can help when discussing the interconnections or history of the development of the park lakes, counterclockwise from northwest to northeast.

List 1.4.2 – For ease of reference, all lakes are listed alphabetically by name. If there is more than one lake within a park, the park is listed alphabetically and then the lakes within the park.

List 1.4.3 – Lakes that are undergoing natural area designations have separate management plans, therefore, are not included in this lake management and protection plan.

List 1.4.4 – Lakes on golf courses or that are golf concessions are not included in this lake management and protection plan.

List 1.4.1
Lakes in Denver Urban City Parks
(By Acquisition then By Park District)

East Montclair District

City Park Lakes
Location: North of 17th Ave. and west of Colorado Blvd. Parking area on the northwest side of the lake between the park and the Denver Zoo.

Ferril Lake – 25 acres; 8 feet maximum depth; perimeter 0.8 miles. There is a sediment basin at 17th Street at the point where the storm sewer/city ditch daylights that is 2 acres in size. The sediment basin discharges to Ferril Lake.
Duck Lake – 6.3 acres; perimeter 0.4 miles

South Denver Park District

Washington Park Lakes
Location: Northeast of the intersection of S. Downing St. and E. Louisiana Ave. The north lake (Smith Lake) has parking areas all around it, while the south lake

Smith Lake – 19 acres; 12 feet maximum depth. *Perimeter:* 0.6 miles.
Grasmere Lake – 19 acres; 10 feet maximum depth. *Perimeter:* 0.8 miles.
Lily Pond – 1 acre; 8 feet maximum depth. *Perimeter:* 0.18 miles.

Northwest District

Berkeley Lake in Berkeley Park
Location: South of I-70 between Sheridan Blvd. And Tennyson St. Main entrance is on 46th Ave. with parking. Also access from Tennyson St.
Size: 40 acres; 12 feet maximum depth; perimeter: 0.9 miles.

Rocky Mountain Lake in Rocky Mountain Lake Park
Location: W. 46th Ave. between Federal Blvd. And Lowell Blvd. Parking areas north of 46th Ave.
Size: 29 acres; 40 feet maximum depth; perimeter: 0.9 miles.

Sloan's Lake (including Cooper Lake) in Sloan's Lake Park
Location: East of Sheridan Blvd. Between W. 25th Ave. and W. 17th Ave. Parking areas all around the lake.
Size: 174 acres; 5 feet deep in the main body of the lake west of the island but upwards of 8 feet deep east of the island; perimeter: 2.6 miles.

Southwest District

Barnum Lake in Barnum Park
Location: West of Federal Blvd. Between 6th Ave. and 3rd Ave., with parking access from Hooker St.
Size: 9 acres; 5 feet maximum depth; perimeter: 0.7 miles.

Bear Creek Ponds in Bear Creek Park
Location: Bear Creek Park is located at S. Raleigh Street and W. Hampden Avenue, 70 acres of natural areas can be accessed from the south boundary of the park which runs along Kenyon Avenue off of Sheridan Boulevard.
Size: There is a series of four (4) ponds along a soft trail across from the Fort Logan Cemetery.

Garfield Lake in Garfield Park
Location: South of W. Mississippi Ave. between S. Federal Blvd. And S. Sheridan Blvd. Access from either S. Lowell Blvd. And Mississippi, or S. Newton St. and W. Arizona Ave. (east from S. Osceola St.).
Size: 10 acres; 4 feet maximum depth; perimeter: 0.5 miles.

Harvey Lake in Harvey Park
Location: Between S. Sheridan Blvd. And S. Federal Blvd., south of W. Evans Ave. and east of S. Tennyson St.
Size: 8.5 acres; 14 feet maximum depth; perimeter 0.4 miles.

Huston Lake in Huston Lake Park
Location: Between W. Ohio Ave. and W. Kentucky Ave. S of the intersection of Ohio and S. Clay St.
Size: 13 acres; 6 feet maximum depth; perimeter*:* 0.6 miles.

Lake of Lakes (A.K.A. Little Lake Henry)
Location: Carr St. and Quincy Ave.
Size: 3.5 acres, perimeter: 0.4 miles.

Overland Pond in Overland Pond Park
Location: North of W. Florida Ave. between S. Santa Fe Dr. and the South Platte River trail. Parking area is north of Florida.
Size: 1.5 acre; 7 feet maximum depth; perimeter: 0.2 miles.

Vanderbilt Pond in Vanderbilt Park
Location: North of W. Tennessee Av. Between S. Santa Fe Dr. and S. Huron St.
Size: 6 acres; 15 feet maximum depth.

Southeast District

Lollipop Lake in Garland Park
Location: Between S. Holly St. and S. Kearney St. north of Cherry Creek Dr. N.
Size: 4 acres; 8 feet maximum depth; perimeter: 0.4 miles.

Northeast District

Parkfield Lake in Developing Park Area
Location: D.I.A. Gateway Chambers N of I-70.
Size: 14 acres, 6 feet mean depth; perimeter: approximately 1 mile. Depth and perimeter information from (Keeton. 2000).

List 1.4.2
Lakes in Denver Urban City Parks
(Alphabetical Listing)

Barnum Lake in Barnum Park – SW District
Location: West of Federal Blvd. Between 6th Ave. and 3rd Ave., with parking access from Hooker St.
Size: 9 acres; 5 feet maximum depth; perimeter: 0.7 miles.

Bear Creek Ponds in Bear Creek Park– SW District
Location: Bear Creek Park is located at S. Raleigh Street and W. Hampden Avenue, 70 acres of natural areas can be accessed from the south boundary of the park which runs along Kenyon Avenue off of Sheridan Boulevard. There is a series of four (4) ponds along a soft trail across from the Fort Logan Cemetery.

Berkeley Lake in Berkeley Park – NW District
Location: South of I-70 between Sheridan Blvd. And Tennyson St. Main entrance is on 46th Ave. with parking. Also access from Tennyson St.
Size: 40 acres; 12 feet maximum depth; perimeter: 0.9 miles.

City Park Lakes– East Montclair District
Location: North of 17th Ave. and west of Colorado Blvd. Parking area on the northwest side of the lake between the park and the Denver Zoo.

Ferril Lake – 25 acres; 8 feet maximum depth; perimeter 0.8 miles. There is a sediment basin at 17th Street at the point where the storm sewer/city ditch daylights that is 2 acres in size. The sediment basin discharges to Ferril Lake.
Duck Lake – 6.3 acres; perimeter 0.4 miles

Garfield Lake in Garfield Park – SW District
Location: South of W. Mississippi Ave. between S. Federal Blvd. And S. Sheridan Blvd. Access from either S. Lowell Blvd. And Mississippi, or S. Newton St. and W. Arizona Ave. (east from S. Osceola St.).
Size: 10 acres; 4 feet maximum depth; perimeter: 0.5 miles.

Harvey Lake in Harvey Park– SW District
Location: Between S. Sheridan Blvd. And S. Federal Blvd., just south of W. Evans Ave. and east of S. Tennyson St.
Size: 8.5 acres; 14 feet maximum depth; perimeter 0.4 miles.

Huston Lake in Huston Lake Park– SW District
Location: East of S. Federal Blvd. About 4 blocks, between W. Ohio Ave. and W. Kentucky Ave. Southeast of the intersection of Ohio and S. Clay St.
Size: 13 acres; 6 feet maximum depth; perimeter*:* 0.6 miles.

Lake of Lakes (A.K.A. Little Lake Henry) – SW District
Location: Carr St. and Quincy Ave.
Size: 3.5 acres, perimeter: 0.4 miles.

Lollipop Lake in Garland Park– SE District
Location: Between S. Holly St. and S. Kearney St. north of Cherry Creek Dr. N.
Size: 4 acres; 8 feet maximum depth; perimeter*:* 0.4 miles.

Overland Pond in Overland Pond Park– SW District
Location: North of W. Florida Ave. between S. Santa Fe Dr. and the South Platte River trail. Parking area is north of Florida.
Size: 1.5 acre; 7 feet maximum depth; perimeter: 0.2 miles.

Parkfield Lake in Developing Park Area – NE District
Location: D.I.A. Gateway Chambers N of I-70.
Size: 14 acres, 6 feet mean depth; perimeter: approximately 1 mile. Depth and perimeter information from the *Biological Aquatic Inventory and Wildlife Habitat Survey* (Keeton. 2000)

Rocky Mountain Lake in Rocky Mountain Lake Park– NW District
Location: W. 46th Ave. between Federal Blvd. And Lowell Blvd. Parking areas north of 46th Ave.
Size: 29 acres; 40 feet maximum depth; perimeter: 0.9 miles.

Sloan's Lake (including Cooper Lake) in Sloan's Lake Park– NW District
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Vanderbilt Pond in Vanderbilt Park– SW District
Location: North of W. Tennessee Av. Between S. Santa Fe Dr. and S. Huron St. Access from W. Mississippi Ave.
Size: 6 acres; 15 feet maximum depth.

Washington Park Lakes – South Denver Park District
Location: Northeast of the intersection of S. Downing St. and E. Louisiana Ave. The north lake (Smith Lake) has parking areas all around it, while the south lake

<u>Smith Lake</u> – 19 acres; 12 feet maximum depth. *Perimeter:* 0.6 miles.
<u>Grasmere Lake</u> – 19 acres; 10 feet maximum depth. *Perimeter:* 0.8 miles.
<u>Lily Pond</u> – 1 acre; 8 feet maximum depth. *Perimeter:* 0.18 miles.

List 1.4.3
Lakes Undergoing Natural Areas Designation

Bluff Lake in Bluff Lake Park – Natural Area
Location: Havana at 32nd Ave.
Size: 9 acres.

Heron Pond in Northside Park – Natural Area
Location: 51st Ave. and Downing St.
Size: 3 acres.

List 1.4.4
Lakes on Denver City Golf Courses or Golf Concession

Kennedy Lake in J.F. Kennedy Golf Course
Location: 10500 E. Hampden Ave.
Size: 5 acres; perimeter: 0.4 miles.

Skeel Reservoir in Wellshire Golf Course
Location: 3333 S. Colorado Blvd.
Size: 13.4 acres, perimeter: 0.6 miles.

Overland Lake in Overland Lake Open Space – Golf Concession
Location: North of W. Florida Ave. between S. Santa Fe Dr. and the South Platte River trail. Parking area is north of Florida.
Size: 11 acres; perimeter 0.7 miles.

Section 2
History

2.1 Overview

The *Game Plan* (2003) developed for the Parks and Recreation Department provides an inclusive description of the legacy of Denver parks tradition from the late 1800s through the creation in 2002 of the Natural Resource Unit. This history section will describe the development of the lake system within the parks. Much of this information was obtained through review of the historical archives of the parks in the City and County of Denver (which can be accessed at the Denver Public Library – Western History and Genealogy Department). These documents were provided to the library by the Parks and Recreation Department.

City Park and Washington Park Lakes are presented first as they were the first two parks, by acquisition or development date, that had lakes as an integral part of the park plan. The remaining lakes are presented by park district. The geographic area helps one to see the interconnections or history of the development of the park lakes, counterclockwise from northwest to northeast.

2.2 Historical Information and Previous Management Plans

East Montclair District

City Park Lakes

Historical Archives

The land that was acquired for City Park was prairie with a drainage used for stock watering. This natural draw ran parallel to City Ditch (manmade conveyance structure acquired by the city after 1875) which made it possible to create the lakes in City Park. Duck Lake was built in 1887 and was intended to provide a natural refuge for birds. Duck Lake has been identified as a black-capped night heron and cormorant rookery.

Specifications for construction of what was termed the "new lake" (Ferril) were dated 1896 and the lake excavation and construction of the "dam" occurred in 1897. An island was also constructed in Ferril Lake and planted with spruce, pines and willows. This island is also a black-capped night heron rookery. An electric fountain was constructed in the center of Ferril Lake and began operation in 1908. The purpose of the fountain was not for lake water quality, but for the citizens visual enjoyment. There was a light system which displayed various colors against the spray of water.

In 1904 the "small" lake (appears to be referring to Duck Lake) was lined with clay and in 1908 the small lake was cleaned out and a bridge constructed between the sediment pond and the large lake.

Prior Management Recommendations/Implementations

In a *City Ditch Study* (Arber, no date) there was a recommendation to remove sediment from Duck Lake. City Ditch is the primary source of water for the lakes in City Park. The recent history of the ditch system is discussed under Washington Park.

The preservation recommendations in the document *Revitalizing the Legacy of City Park* (Mundus, 2001) completed for Parks and Recreation include restoration of a naturalistic character to the Ferril Lake shoreline, adding wetlands and riparian plantings. Also recommended was continuation of the rehabilitation of Duck Lake through the addition of new plantings and habitat improvements, including preserving and enhancing the naturalistic qualities of the sediment pond and its role in water quality and storm water management. It was also recommended that the ornamental and indigenous wetland and riparian vegetation be re-established to improve the visual aesthetic.

Approximately 300 linear feet of Ferril Lake's shoreline has been planted with wetland vegetation. This recent planting has been protected from the resident geese through the use of protective wire fencing. In 2000, portions of Duck Lake's concrete southern shoreline were removed and replaced with native shrubs and wetland plantings. The sediment pond (south of Ferril Lake) shoreline has wetland vegetation on the west side and some on the south, however, the eastern and northern areas adjacent to the park road are eroded. Due to the severity of the erosion, capital improvement funding to repair the shoreline was recommended in 2003 (H. Kuykendall. Memorandum, no date). Work on the sediment pond has not yet begun.

South Denver Park District

Washington Park Lakes

Historical Archives

Prairie land for Washington Park was acquired by the city between 1887 and 1916. Although there is unverified local history that claims Smith Lake began as a "natural" spring that was enlarged for agricultural use, it is also thought to have begun as a buffalo wallow. The notes for the acquisition in 1887 indicate an option on Smith Lake. Clearly signifying there was an existing water body which had been constructed to some extent on the site when the land was bought for development as a park. The south lake (Grasmere) was built in 1906 and deepened in 1909. Lilly Pond (northeast corner) was built in 1913. The framework for the park consisted of the lakes connected by a "great meadow" and the City Ditch system which was built through what would become the parkland in 1867.

One of the original recreational purposes for Smith Lake was swimming. The city added a diving platform and beach along the original shore. In 1955 the lake was closed to swimming by the Managers of the Departments of Health and Hospitals and Improvements and Parks due to water quality concerns.

In the early 1960's odors from Grasmere caused concern and the lake was deepened. The lake was again drained and dredged in the later 1980's due to algae growth and avian botulism concerns.

Prior Management Recommendations/Implementations

In the *City Ditch Study* (Arber) it was recommended that a sediment forebay structure be constructed at Grasmere. Modifications to water flows for Grassmere and forebay addition were noted in several other Arber reports as an example of successful modifications to lower Total Phosphorus in the lake (Arber , 1994).

The *Cultural Landscape Assessment and Preservation Plan* (Mundus, 2003) prepared for Parks and Recreation recommended lakeshore rehabilitation plans be developed for the two lakes and Lilly Pond. This included a plan to improve the lake edge (wall and formal edge) and consider restoring the sandy beaches for Smith Lake. The plan was to improve the edge of Lilly Pond by removing the gabion baskets and create an edge compatible with the natural character of the pond, such as wetland bars and riparian plantings. The plan for Grasmere calls for shoreline materials compatible with the natural character of the lake, such as wetland bars and riparian plantings.

Due to the expansion of Interstate 25, the City Ditch was cut off at the highway south of Washington Park in 2002. In order to continue to have water in the ditch system, Denver Water constructed a dechlorination system at South High School and began discharging dechlorinated potable water into the ditch in the spring of 2002. Denver Water has constructed a reuse plant and conveyance system (which is now on line) and is providing reuse water to the City Ditch (spring of 2004). In order to lower the loss of water out of the lakes in Washington Park, Denver Water has proposed lining the lakes (B. Herwig. interview 2004).

Northwest District

Berkeley Lake in Berkeley Park

Historical Archives

The land that was to become Berkeley Park was acquired in September of 1906 and included 75″ of Rocky Mountain Ditch water. In 1907 development of the lake started with a boat dock, pavilion and bandstand. An article in the Denver Colorado Times dated January 28, 1914 concerning Berkeley Park stated in part:

> "It is planned to make the place essentially a Colorado park, preserving in the main the appearance of a Colorado landscape, with irrigated lawns and grass plots secondary to the general idea of showing the highest type of Colorado landscape in its natural state."
>
> "The appearance of a natural Colorado valley with its verdant vegetation and rich native growths is to be sought in the narrow depression on the south where water flow enters the lake"…."The plan as adopted by the board will make Berkeley the only distinctly Colorado park in the city's system, the others all being treated

> more or less with the Eastern method of ornamentation, including Eastern trees, shrubbery and grasses."

In 1935 the city acquired the 9-hole golf course (Case) to the north of the lake, the right to purchase 80″ of water in the Rocky Mountain Ditch from the Rocky Mountain Water Company, and the right to "wastewater" from Berkeley Lake.

Construction of Interstate 70 in 1965 removed 8.92 acres of land and 6.92 acres of the lake from the park and changed its north shore. The lake was deepened by the State Highway Department to compensate for the reduction in lake volume.

<u>Prior Management Recommendations/Implementations</u>

The *Water Quality Management Plan for Berkeley Lake* (Arber, 1994a) completed for Parks and Recreation recommended aeration using a reconfigured pumping system for parkland irrigation plus forebay and a submerged wetland system on the east side of the lake. The forebay was recommended to be constructed immediately before the wetlands at the lakes inlet. It was to include an energy dissipation structure. These recommendations were not implemented.

Rocky Mountain Lake in Rocky Mountain Lake Park

<u>Historical Archives</u>

The land for Rocky Mountain Park was acquired by various purchases/deeds between 1906 and 1912. The city purchased additional land in 1936. In 1906 a pipeline was laid from Rocky Mountain Lake to Berkeley Lake.

<u>Prior Management Recommendations</u>

There was a *Water Quality Management Plan* completed for Rocky Mountain Lake by Arber and Associates during the same time as the plans for Berkeley, Sloan, Garfield and Overland but could not be located for review. The *Rocky Mountain Lake Existing Condition Report* (Arber, 1993) was available and indicated that the major problems for the lake were aquatic weeds and suspended algae.

During 1998 and 1999 the lake underwent renovations that included deepening the lake in the east and west inlet areas to a depth of approximatley 35' (K. French. interview 2003). Unfortunately as the lake refilled, an algae bloom occurred.

Sloan's Lake (including Cooper Lake) in Sloan's Lake Park

<u>Historical Archives</u>

The land was acquired by deeds in 1906. The lake, according to unverified local legend, was created by a "natural" spring. However, the legend further indicates that the spring or high water table was "hit" by a landowner while drilling a well. A document from 1964 noted that "until some years ago" there were two separate lakes (the eastern lake named Cooper Lake) with Tennyson Street crossing between the lakes. At some point an island was constructed that separated the lakes, but then two channels where dug on the north and south sides making the island smaller, but creating a large body of water for boating. Additional uses of the lake noted in 1964 included fishing and water storage. A noteworthy item was that a community information program from 1974 recorded that the island was a nesting ground for Canadian Wild Geese and other beautiful birds.

Prior Management Recommendations/Implementations

In 1980 and 1981a Clean Lake Study was conducted by DRCOG (Denver Regional Council of Governments) and Denver Health and Hospitals (now Denver Environmental Health) with Federal Clean Lake funds through the Colorado Department of Health. The study described the lake as hypereutrophic and identified management strategies included increasing flows, dredging sediments and diverting storm water around the lake (Arber, 1994b).

The *Water Quality Management Plan for Sloan Lake* (Arber, 1994b) completed for Parks and Recreation noted that sediment removal was attempted in 1990 and 1991 but with limited success due to dewatering problems. Additional water from Rocky Mountain Ditch was diverted in summer 1990. The report noted that since all of the recommendations from the Clean Lakes report were not implemented that water quality had not improved. The 1994 report recommended to once again remove sediment after the Harvey Lake demonstration project was completed and that the storm water be treated. These recommendations were not implemented.

Southwest District

Barnum Lake in Barnum Park

Historical Archives

Specifications for Barnum Reservoir Dam were dated September 4, 1951. The dam area was bounded by Federal Boulevard, West 6th Avenue, Hazel Court and West 5th Avenue. The drainage area contributing to the reservoir was the Weir Gulch drainage which was noted to have mostly good vegetative meadow cover (used to compute maximum runoff). A 1964 document indicated that a 1955 bond issue included a lake. However, the State Highway Department excavated the lake, to the Park Departments plans, to supply the needed fill for 6th Avenue construction. To create a dam the State also constructed the overflow, lake drain and a clay core up to the Federal Boulevard ramp.

Prior Management Recommendations/Implementations

The *Water Quality Management Plan for Barnum Lake* (Arber, 1994c) completed for Parks and Recreation recommended dredging lake sediments, constructing a forebay on the northwest side of the lake to handle a "base flow" of 300cfs, and a reconstructed wetland area adjacent to the forebay to be fed by the forebay. Flows in excess of 300cfs would be diverted through the existing "channel" flow area in the lake bypassing both the forebay and the wetland.

Modifications to Barnum Lake occurred during 1998 and 1999. The lake was deepened and an island constructed with the dredged material. In addition, a forebay was added at the inlet to the lake. The outlet structure in the northeast corner of the lake was modified for bottom release and wetland plantings are being reestablished around the edge (K. French. interview 2003).

Bear Creek Ponds in Bear Creek Park

Historical Archives

The city submitted an application for Surplus Property Disposal of a Portion of Ft. Logan Military Reservation in 1956. In Exhibit A of the application, the city discussed the "Program of Utilization" for the land. Specifically it stated:

> "Need for preservation of the natural resources of the country is recognized, and preservation of the natural terrain and plain material of this region is becoming of greater importance as such resources are being depleted by population growth. The adaptability of this site to such natural preservation is obvious with its water features, drainage and native planting. Such natural characteristics should be preserved."…."It is the only open area in a region where undeveloped land is fast disappearing. Intelligent planning dictates that such open land be acquired to protect it, and the city, from further encroachment."

The land was conveyed to the city by an Instrument of Transfer in December of 1957 and was purchased from the United States Government for park development.

There are four ponds in series on the south side of the park in what is described as the largest undeveloped park area within Denver's city limits, offering a look at nature in a native setting with over 70 acres of natural areas.

Garfield Lake in Garfield Park

Historical Archives

The lake bed and parcels were acquired under an annexation of Virginia Village from Arapahoe County and purchase between 1949 and 1958. The lake was originally known as Garfield Heights Lake or Anderson Lake. In 1955 the city acquired control of all shares of stock, 80″ of water (2 shares of Agricultural Ditch water and 4 shares of Salisbury lateral water) of Garfield Heights Lake from Mutual Ditch and Reservoir Company for water storage rights; surface and flowage rights.

Prior Management Recommendations/Implementations

The *Water Quality Management Plan for Garfield Lake* (Arber, 1994d) completed for Parks and Recreation recommended management alternatives including additional water from the agricultural ditch and sediment removal using the existing hydraulic dredge owned by Parks and Recreation once the Harvey demonstration project was completed. Also recommended were inlet and outlet modifications to bring storm water from the north into the bottom of the lake in center area and the reconfigure outlet to take water off of bottom of lake.

Modifications to Garfield occurred in 1998 and 1999. The lake was dredged and an island was constructed in the lake. The outlet was modified for bottom release. Wetland vegetation was reestablished on the north shore and is in the process of being reestablished on the south shore (K. French. interview 2003).

Harvey Lake in Harvey Park

Historical Archives

Harvey Park land was acquired by annexation in 1954. The Harvey Park Company had rights to 133″ of water from the Agricultural Ditch and in a 1955 agreement with the city the company agreed to furnish water for Park Lake (Harvey), including necessary irrigation of immediate area and construction of an overflow pipe for connection between the two lakes. The two lakes being Harvey Park Lake and Ward Reservoir (known as Riviera Lake).

Historical notes indicate that in 1958 the lake was dredged.

Prior Management Recommendations/Implementations

The *Water Quality Management Plan for Harvey Lake* (Arber 1994e) completed for Parks and Recreation recommended sediment removal using Parks and Recreation's hydraulic dredge and allowing the contractor to demonstrate on-site sediment dewatering equipment. Also recommended were reconfiguring irrigation system to use potable water for the lake (inlet to be on east side) and to reactivate the old pump system on the west side to remove lake water to irrigate park.

Modifications to Harvey Lake occurred in 1995 and 1996 and included draining and dredging the lake. The recommendations for the irrigation system were not implemented.

Huston Lake in Huston Lake Park

Historical Archives

The land for Huston was acquired in 1946 and additional portions in 1951 and 1953. A 1955 bond issue included excavation of the lake bed. Also, notes on a hand drawn map of the lake indicates that there was 80″ of water rights from Salisbury Lateral. Based upon the way that the water is managed this 80″ is the same amount as that noted under Garfield not an additional 80″ or water.

Prior Management Recommendations/Implementations

Renovation of Huston Lake was completed in 2003. The renovation project included draining and dredging sediment that had accumulated over a period of 30 years and removal of encroaching cattails. The lake was refilled and restocked with fish. The street inlets were replaced with a sand filtering system to filter oil and other pollutants from the storm water runoff (www.denvergov.org/Planning_Design_and_Constr. 2003; A. Polonsky, email, 2004).

Lake of Lakes (A.K.A. Little Lake Henry)

Historical Archives

There was no historical record on this lake. However, in August of 2000 the Denver Environmental Health Department received a complaint concerning an extensive algae bloom and fish kill at the lake. During this time there was construction of the condominium complex to the south of the lake.

Overland Pond in Overland Pond Park

Historical Archives

A historical map of the area shows that the site initially was the property of a sand and gravel company and that a concrete company had adjacent property. There are records that indicated that in 1944 and 1950 the city filed quit claim deeds from the sand and gravel company. The lake was created by the sand and gravel operation when the pit filled with water. The one lake was split into two lakes and the larger of the two was leased to a golf concessionaire (Aqua Golf).

Prior Management Recommendations/Implementations

The *Water Quality Management Plan for Overland Ponds* (Arber, 1994f) completed for Parks and Recreation recommended sediment removal and nutrient reduction through an aquatic vegetation system. The recommendations have not been implemented.

Vanderbilt Pond in Vanderbilt Park

Historical Archives

At one time most of the site had been excavated by operation as a gravel pit. In a 1964 document it was noted that "for the last few years" the site had been used as a dump to fill in the "lakes" created by the gravel pit. All of the area except the southeast corner had been filled. The southeast corner was being retained "to provide water for Gates Rubber Company" which had a pump on adjacent property.

Under agreement with the city, the Gates Rubber Company was allowed to discharge process related wastewater to Vanderbilt Lake. Vanderbilt Lake was the discharge point for process-related wastewaters from the Gates Rubber Company including direct contact cooling water, vulcanizer condensate and cooling tower blowdown. The discharge was covered under the Colorado Discharge Permit issued to the company by the Colorado Department of Public Health and Environment. Vanderbilt Lake was noted to be "waters of the state" specifically subject to the limited number of standards applicable to all tributaries to the mainstem of the South Platte River. The discharge point was removed from the permit through an amendment in August of 1992 because the process-related wastewaters were no longer discharged into the lake (EPD/DEH records).

Southeast District

Lollipop Lake in Garland Park

Historical Archives

The city annexed the land from City Park Dairy and the park was dedicated in May of 1963. The indication in the records is that a "small natural lake named Loli-Pop was used for model sail boating.

Prior Management Recommendations/Implementations

In the mid-1990s Lollipop Lake was drained and the bottom lined with bentonite due to interaction between lake water and shallow ground water. Denver Water drilled a 100 foot deep well to supply water to the lake, a pump system that is activated automatically when the flow drops to a certain level provides the lake with well water and the lake water is used to irrigate the parkland.

Northeast District

Parkfield Lake in Current Open Space

This lake was originally designed by a private developer as a storm water retention structure. The area surrounding the lake was a plains open space ecosystem. The "lake" was located at the topographic low spot and was fed by ground water over the years when there was little to no urban development. The bank of the lake is concrete now overgrown with weeds and shoreline vegetation. There are two large concrete culverts flowing into the lake, the largest of the two is located in the southeast, the smaller one is located in the southwest adjacent to the new recreation center surface parking lot. There is an additional smaller storm sewer inlet at the mid point the lake on the southern shore. Each of these inlets has an associated forebay (E. Novak. interview, 2004).

Prior Management Recommendations/Implementations

The *Parkfield Lake Community Park Master Plan* (Norris. no date) noted that it was important for DPR to maintain the lake in a manner that encouraged a healthy fish population. The plan for the west side of the park (adjacent to the west area of lake) is primarily an "active" recreational area with the new Montbello Recreation Center and parking area, small shelters, athletic fields and an amphitheatre. The east side of the park (eastern shoreland area of lake) is recommended to be "reserved as a nature preserve and Denver Parks natural area." The south side of the park (southern shoreland of the lake) is planned as an active and informal recreational area. The plan includes an informal open meadow for recreation area and "irrigated turfgrass" that touches the lake's southern shoreline. The master plan also noted the lake specific recommendations for lake bed aeration and microbial treatment from the *Biological Aquatic Inventory and Wildlife Habitat Survey* (Keeton. 2000) completed for the master plan.

Section 3
Present Conditions, Plans and Uses

3.1 Photos and Descriptions

The following photos depict current conditions as noted during field visits conducted from November 2003 through March 2004. The information on future plans is per the Parks and Recreation Planning Division and/or Public Works Department and they are lake specific. Overarching plans (the *Game Plan* and the *Water Conservation Plan*) and how they relate to the lakes are discussed in Section 5. The lakes are listed in the same order as Section 2 -History.

Table 1 that follows the photo documentation represents the uses that are either in place or intended through practice or representation to the public (e.g. The lake web page under the Parks and Recreation web site includes information about fishing from the Colorado Division of Wildlife's book *Fishing Close to Home*, a Colorado Outdoors Special Edition by Phil Goebel. Almost all the lakes are listed as having fish. This indicates to the public that fishing is an acceptable recreational activity at these lakes).

East Montclair District

City Park Lakes

Ferril

Photo 1 (11/20/2003): Southeast area of the lake looking northwest. The island that was created in the lake is in upper left of area of the photo. Dense tree cover on the lake can be noted. Bluegrass is adjacent to the lake with a hard surface trail at various distances from the lake.

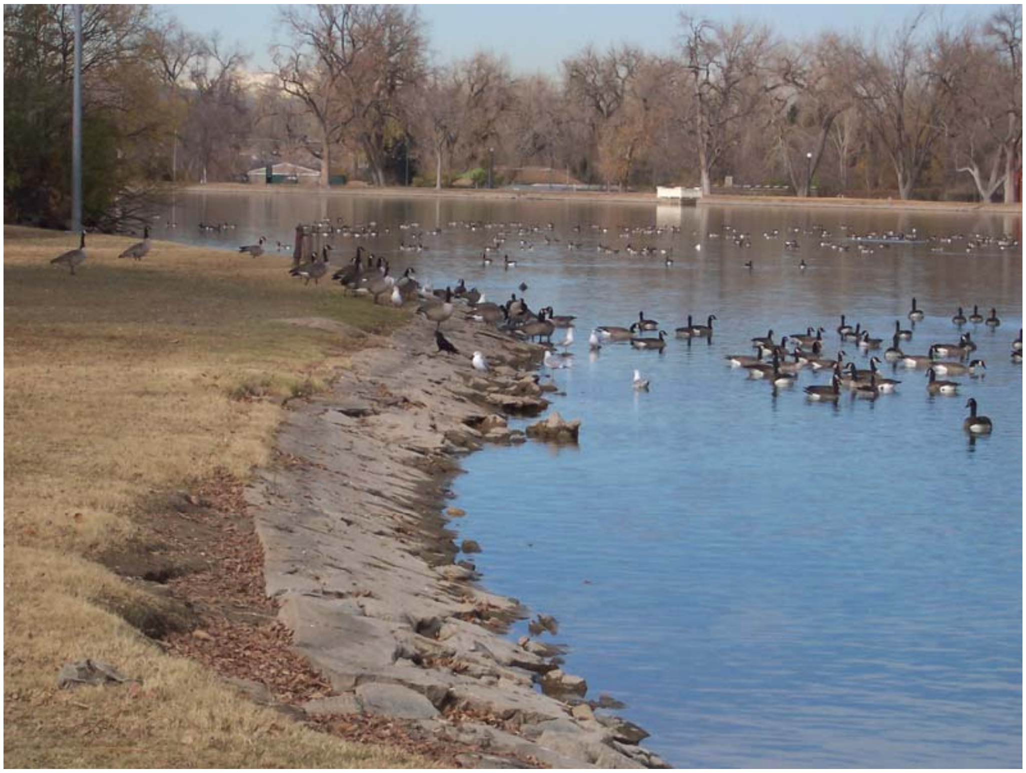


Photo 2 (11/20/2003): Close-up of the southeast “rock” shoreline area adjacent to an expanse of bluegrass. Geese are prevalent in this area.

Photo 3 (11/20/2003): South-central shoreline with bluegrass shoreland in background, trees on island to the right, pavilion between in far background.

Photo 4 (11/20/2003): Close-up of wetland plantings area along southwest shoreline/littoral zone with fencing to protect the plantings from the geese.

<u>Duck</u>

Across an internal park road from Ferril Lake is Duck Lake.

Photo 5 (11/20/2003): Southern area of lake with the island in center. The shoreline is primarily concrete with bushes adjacent to the zoo fence line to the north.

Additional Ponds/Water Structures

What is referred to as Little Lake or the sediment pond is to the south of Ferril Lake. This structure is the first in the park to receive the flow from the City Ditch system (contained in underground pipe after leaving Washington Park some urban storm water also enters this piped system). As noted in the historical section this pond has an established wetland vegetation area on the east and some vegetation to the south. The water level was very low at the time of the field visit in March 2004. The pond is surrounded by bluegrass except to the north where there is an interior park road that is used for park recreation (walking, riding, etc.) and maintenance vehicles but is closed to other vehicular traffic. The location known as Lilly Pond in City Park was completely dry during March 2004 field visit.

Plans

The Public Works Department and their consultants McLaughlin Water Engineers, are in the process of completing a basin project for the Montclair storm sewer basin system which includes City Park. One of the options for expanding the capacity of the storm sewer system is to use Ferril Lake as a storm water detention structure. This option would require that the lake be deepened in order to contain a 5 year storm event (Denver Montclair Basin Project Progress Meeting. March 23, 2004).

South Denver Park District

Washington Park Lakes

Grasmere

DWD was working on lake at time of field visit and the water level had been substantially drawn down.

Photo 6 (11/20/2003): Northern area of the lake, primarily concrete and stone walls. There is vegetation emerging between the stones on the western shore. A hard surface trail is immediately adjacent to the lake on the western edge with bluegrass adjacent to the trail.

Photo 7 (11/20/2003): Just south of Photo 6. Hard surface trail on the left and draw down of lake apparent.

Photo 8 (11/20/2003): Southern area of the lake. The ponded water is in the "forebay" area immediately north of the south inlet. Wetland vegetation is apparent at the inlet and along the shoreline.

Smith

Photo 9 (11/20/2003): Shoreline almost exclusively rock riprap with chicken wire over rock in locations. Bluegrass and trails surround lake.

Photo 10 (11/20/2003): Eastern shoreline/shoreland with bluegrass adjacent to the lake. There is a parking area adjacent to the western area of the lake.

Lilly

Completely dry during November 2003 field visits.

Plans

As noted in Section 2, Washington Park is part of the current plans by DWD to supply reuse water to certain areas around the city. Reuse water is on-line as of spring 2004 supplying water to the City Ditch which in turn feeds the lakes. There are discussions underway concerning lining the lakes to prevent seepage to the groundwater. Under DPR the stone wall that is the edge of the lake is being repaired and there are plans to have a manual gate valve on the west side of the lake to overflow, when needed, directly to the storm sewer system (B. Herwig. Interview 2004).

Northwest District

Berkeley Lake in Berkeley Park

Photo 11 (12/06/2003): Southeastern area of the lake looking west. The lake has an extensive amount of wetland vegetation along this shoreline/littoral zone. Bluegrass is adjacent to wetland vegetation and there is a hard surface trail around the lake.

Photo 12 (12/06/2003): Additional photo of southern shoreline/shoreland area. Wetland vegetation, bluegrass, hard surfaced trail and a further expanse of bluegrass.

Photo 13 (12/06/2003): Western area of lake; northern area in background. Grass strip between trail and lake becomes narrower, mainly soil along northern shore, with the Interstate 70 on ramp and highway north of trail on the northern side of the lake.

Plans
The plan that is currently being worked on that would impact Berkeley Lake pertains to the *Rocky Mountain Ditch Outfall Systems Planning Study* (HDR. 2003). Public Works, Wastewater Management Division and the Urban Drainage and Flood Control District contracted for the study to evaluate the drainage problems in the northwest area of the city associated with the Rocky Mountain Ditch and storm sewer system. The study notes that the Rocky Mountain Ditch conveys irrigation flows (and some storm water) to Berkeley Lake and Rocky Mountain Lake but that the ditch owners currently shut down the ditch if runoff is expected to prevent potential overflows. This in turn causes interruption of irrigation flow to the lakes.

The selected plan for improvement recommends elimination storm runoff inflows into Rocky Mountain Ditch and notes that with the elimination of the inflows the ditch may operate more consistently providing more reliable delivery of water to Berkeley and Rocky Mountain Lakes. The plan also includes an alternative to discharge storm sewer lines into Berkeley Lake instead of the proposed installation of a new storm sewer extending to Clear Creek. (Currently most storm water flows are conveyed past the lakes and discharge to Clear Creek. Flows from large events that exceed the capacity of the current storm sewer system and sheet flow from the surrounding area do discharge into the lakes.) If storm sewer flow is directed to Berkeley Lake the plan includes the installation of an outlet debris basin and energy dissipater and a water quality pond to mitigate potential adverse impacts to the lake. The plan also talks about a design that would allow the parks manager the ability to either allow the base flows to enter the lake or bypass the lake. Currently the manager has no control over the water delivered to the lake either through storm events or the Rocky Mountain Ditch (R. Caldwell, interview, 2004).

Rocky Mountain Lake in Rocky Mountain Lake Park

Photo 14 (12/06/2003): South-central area of the lake looking northwest. There is no established trail adjacent to the lake along southern shore but there is a "social trail" that is apparent due to wear on the bluegrass. The shoreline/littoral vegetation is sporadic.

Photo 15 (12/06/2003): Long view of southern area of lake looking north. Sporadic nature of shoreline/littoral vegetation can be seen. Bluegrass is adjacent to the lake and in some areas extends to the bank of the lake. There are playing fields are in this area of the park and a hard surface trail is to the south of the fields.

Photo 16 (12/06/2003): Eastern area of the lake looking north. The hard surface trail swings closer to the lake edge in this area. The shoreland is bluegrass up to the edge of the lake with little shoreline/littoral vegetation. Extensive goose droppings can be seen on the trail.

<u>Plan</u>

As noted under Berkeley Lake the implementation of part of the selected plan in the *Rocky Mountain Ditch Outfall Systems Planning Study* (HDR. 2003) could provide Rocky Mountain Lake with more consistent delivery of Rocky Mountain Ditch water.

Sloan's Lake (including Cooper Lake) in Sloan's Lake Park

Photo 17 (12/03/2003): Southwest area of lake looking northwest. The shoreland is primarily trees and bluegrass.

Photo 18 (12/03/2003): Expanded view of south-central area of lake with larger expanse of bluegrass adjacent to lake.

Photo 19 (12/03/2003): Southeastern area of lake with bluegrass and adjacent hard surface trail.

Southwest District

Barnum Lake in Barnum Park

Photo 20 (11/21/2003): Southern area of lake looking northeast. The shoreland of the lake has large expanses of bluegrass with sporadic areas of shoreline/littoral vegetation.

Photo 21 (11/21/2003): Expanded view of lake from inlet area of Weir Gulch looking north. Concrete outlet structure in middle background of picture.

<u>Plan</u>

Continue to reestablish the wetland vegetation along the shoreline of the lake (K. French. interview. 2003).

Bear Creek Ponds in Bear Creek Park

Photo 22 (2/22/2004): 1st pond at beginning of trailhead off of parking area. Natural vegetation in areas adjacent to ponds with a soft surface trail.

Photo 23 (2/22/2004): 2nd pond in the series of 4 showing shoreline vegetative area.

Garfield Lake in Garfield Park

Photo 24 (11/21/2003): Western area of lake looking south. There is a large expanse of bluegrass adjacent to lake, very little shoreline/littoral vegetation along the southern shoreline/littoral zone.

Photo 25 (11/21/2003): Expanded view of the lake from eastern shoreland looking west. The island in the lake can be noted in upper right of photo with shoreline/littoral vegetation of the northern shore.

<u>Plan</u>

Continue to re-establish the wetland plantings on the southern shoreline of the lake (K. French. interview. 2003).

Harvey Lake in Harvey Park

Photo 26 (11/25/2003): Southern area of lake looking north. The snow is covering the bluegrass area.

Photo 27 (11/25/2003): Western are of lake looking south showing the expanse of shoreline/littoral vegetation. Bluegrass is adjacent to the shoreline vegetation with a hard surface trail and additional bluegrass.

Photo 28(11/25/2003): North-central area of lake, island can be noted in middle portion of photo in background area.

Huston Lake in Huston Lake Park

Photo 29 (11/21/2003): Eastern area of lake. The foreground of the photo is the southern shoreline. There is sporadic shoreline/littoral vegetation around lake with expanses of bluegrass and a hard surface trail adjacent.

Photo 30 (11/21/2003): South-central area of lake by horseshoe pit. There are large expanses of bluegrass around the lake and geese were present in the lake and on shore.

Photo 31 (11/21/2003): Additional photo of southern shoreline and shoreland area, noting sparse shoreline/littoral vegetation.

Lake of Lakes (A.K.A. Little Lake Henry)

Photo 32 (11/25/2003): Lake shoreline/littoral zone is almost completely comprised of vegetation including some large cattail stands. There is only a very small strip of bluegrass between the lake and a hard surfaced trail. The lake is immediately adjacent to houses (west), condominium complex (south/east) and roadways (north/east).

Photo 33 (11/25/2003): Southwest inlet area for lake, extensive shoreline/littoral vegetation apparent.

Overland Pond in Overland Pond Park

Photo 34 (12/01/2003): Eastern area of lake. The shoreline is primarily large stones with natural grasses and trees adjacent. A hard surface trail is between the lake and the South Platte River to the west.

Photo 35 (12/01/2003): Southern area of lake. A pier can be noted in left portion of the photo. The stone shoreline can be seen along the northern bank area. In the foreground is a natural grass expanse adjacent to a soft trail area.

Vanderbilt Pond in Vanderbilt Park

Photo 36 (11/21/2003): Eastern shore area of lake looking southwest. The shoreland area surrounding the lake is comprised of dense foliage; trees, shrubs, grasses with an egress area in the location where the photo was taken. Traditional bluegrass is adjacent to the denser foliage shoreline to the east and north.

<u>Plans</u>

The Parks Planning Division is in the process of contracting with a consultant for a scope of work that involves evaluating and enhancing the vegetation surrounding the lake (R. Murayama. interview 2004).

Southeast District

Lollipop Lake in Garland Park

Photo 37 (11/20/2003): Eastern area of lake. Wetland vegetation can be noted in the left portion of the photo at the eastern "low" area of the lake. The remaining part of the lake has no shoreline vegetation and bluegrass extends to the lake edge. Hard surface trails surround the lake.

Northeast District

Parkfield Lake in Current Open Space

Photo 38 (1/15/2004): Southwest corner of lake. There are two distinct branches of the lake to the right and left of the land area in the middle of the photo. Note in the foreground what appears to be a bluegrass area being established (adjacent to the parking area for the Montbello Recreation Center).

Photo 39 (1/15/2004): Southeast inlet area located on the “right” branch of the lake. Forebay structure can been noted in the channeled area before the lake widens. The inlet for this area is a large concrete culvert. The banks of the lake are concrete blocks that have almost been obscured by vegetation. In the background the building that can be seen is the Montbello Recreation Center.

Photo 40 (1/15/2004): “Left” Branch of the lake with rock riprap in the lake. The immediate area adjacent to the lake is almost totally surrounded by undeveloped open space and the associated vegetation including weeds (note the exception to this in the area of the recreation center). The surrounding land is in the process of being developed.

Plan

The Montbello Recreation Center and associated parking area have been constructed on the eastern side of the lake. There has been relatively little additional done on the remaining portions of the *Parkfield Lake Community Park Master Plan*.

3.2 Summary of Current Conditions

In most cases there is a large expanse of bluegrass adjacent to the shoreline of the lakes. Current exceptions are; Vanderbilt where the bluegrass is separated from the lake by dense shoreland foliage and sand, Overland Pond and Bear Creek Ponds that have no bluegrass on the surrounding shoreland area and Parkfield Lake, however, a bluegrass area is being established on the western shoreland area and as noted in the historical section the master plan (Norris. no date) calls for turfgrass on the southern shoreline. Lake of Lakes has very little bluegrass near the lake although the adjacent condominium complex and houses are landscaped with bluegrass.

Shoreline/littoral vegetation ranged from continuous thick vegetation at Lake of Lakes to almost nothing except the small wetland area at Lollipop.

Bear Creek Ponds, Lake of Lakes, Overland Pond, and Parkfield Lake had no evidence of geese (see Section 4 on Geese for further discussion of this issue).

Barnum and Parkfield had evidence of substantial amounts of trash in the lake area. This included tires floating in Parkfield Lake.

3.3 Uses

TABLE 3.1: Current or Potential Uses of the Urban Denver Lakes

District	Lake or Pond	Uses							
		Irrigation	Fishing		Boating	Water Skiing	Wildlife Watching Potential	Urban Amenity for Citizens	SW Detention Structure
			CDOW Stocked	Fish Present					
East Montclair	Ferrril -City Park	Yes	Yes		Yes		Yes	Yes	
	Duck - City Park						Yes	Potential	
South Denver	Grassmere -Wash Park	Indirectly - Release to Smith.	Yes				Yes		
	Smith - Wash Park	Yes	Yes		Yes		Yes	Yes	
	Lilly - Wash Park		Yes				Yes		
Northwest	Berkeley	Due to Be Reactivated (2004)	Yes				Yes	Yes	
	Rocky Mountain		Yes				Yes	Yes	
	Sloan (including Cooper)	Yes	Yes		Yes	Yes	Yes	Yes	
Southwest	Barnum			Yes			Yes	Potential	Yes
	Bear Creek						Yes	Yes	
	Garfield			Yes			Yes	Yes	
	Harvey Park			Yes			Yes	Yes	
	Huston			Yes			Yes	Yes	
	Lake of Lakes (Little Lake Henry)			Yes					
	Overland	Indirectly (gravity drains to Aqua Golf which is used to irrigate golf course)		Yes			Yes	Yes	
	Vanderbilt			Yes but minimal			Yes	Potential	
Southeast	Lollipop	Yes		Yes			Yes	Yes	
Northeast	Parkfield in Open Space			Yes			Yes	Yes	Yes

Section 4
Primary Issues

4.1 Flow

The most fundamental water balance of a lake can be summarized as: water input = water output +/- the amount of water stored in the lake. However, the individual components that can make up the various portions of the equation can be very complex. The inputs for the urban Denver lakes can include: surface water flow from streams/gulches, ditch water, groundwater, well water, direct precipitation, sheet flow runoff from surrounding land, storm water conveyed through the municipal storm sewer system, and reuse water. The outputs are evaporation, loss to ground water, overflow or other release, and irrigation use. When the inputs exceed the outputs the lake levels rise (to the point of overflow or release) but when the outputs exceed the inputs, like during the drought, the lake levels decrease. The balance between hydraulic inputs and outputs influences the nutrient supply to the lake, the lake's water residence time (the average time required to completely renew a lake's water volume), and, consequently, the lake's productivity and water quality (Holdren., et al. 2001). If the hydraulic residence time of a lake is extremely short, algal cells can be washed out faster than they can grow and accumulate. The longer the residence time, the more time algae and other macrophytes have to assimilate nutrients, grow and accumulate. It is, therefore the combined effect of nutrient input (or loading) and the residence time that influences the production of algae.

Barnum is the only one urban Denver lake under the direct influence of a surface water body. Weir Gulch flows directly into the lake and from historical records, Barnum Lake was created by construction of a dam across the gulch. Due to the direct "on-line" nature of the lake, Barnum tends to have the most continuous source of input water. Unfortunately, the lake also serves as a primary sediment basin for the upper watershed. Although the recent modifications to the lake included a forebay area, the settling of the sediments over the years has caused the lake to become very shallow which in turn creates a separate set of ecological conditions.

The other lake that is influenced by a surface water body is Overland Pond. However this is not a direct inflow but rather a pumped source of water out of the South Platte River. The pump station is located approximately 1 mile below the outfall from the Littleton/Englewood Wastewater Treatment Plant which plays a role in the quality of this water source to the pond.

As noted in the historical section, there are other lakes (Berkeley, Rocky Mountain, Sloan, Garfield and Huston) that have a certain amount of water right allocations associated with their on-going management. However, the actual amount of water available is subject to the ditch provider, drought and peak flow conditions as well as seniority of the water rights. Harvey Lake is subject to the agreement with Ward Reservoir which can also be affected by drought. The reuse water for City Ditch is likely to be a steady state source of input water for Washington Park and City Park lakes.

The actual hydraulic residence time for the individual lakes can not be determined since there is little or no flow measurement capability on both inputs and overflow/outlets.

Aside from the source and amount of input flow that can be counted upon for the various lakes, there are two other aspects to the management of the Denver lakes that can play a vital role in the health of the lakes. From the perspective of quantity of water, these are location of inlets (input) and outlets (overflow), and irrigation use of the lake water. These two aspects play a role in mixing and short-circuiting of the water within the lakes. Mixing of the lake water has been discussed in several previous proposed lake management plans (Arber, 1994). In some instances these plans have been put into practice, at least partially, (e.g. Garfield Lake has a bottom release point as does Barnum Lake). Short-circuiting is a potential issue that can create zones of stagnant water within an otherwise functional system, if care is not taken in the designs of the inlets and outlets.

See Appendix A which schematically presents current information on the flow patterns for each lake.

4.2 Geese

Over the years the increasing number of geese in most of the urban Denver parks has caused many people to consider them a nuisance species instead of a wild, beautiful bird as noted in the 1974 Sloan Lake community information program. There are issues related to the lakes that are associated with geese, but first there should be an understanding of how resident or non-migratory geese evolved since they are an on-going issue for park managers.

The following is a summary of information from a Colorado Extension Service news release in May of 2001 entitled *Mid-60s captive breeding program means Canada geese are here to stay.* The entire article can be accessed on their website at www.ext.colostate.edu/news/010521.html. Human's changed the migratory instincts of the Canadian geese through two incidents. One was the use of wounded or captured geese as "decoy flocks" for hunting in the late 1800's and early 1900's. When the captured geese reproduced, the wings of offspring were clipped so they would remain captive. Eventually the offspring learned not to fly "south" from the behavior of the parent geese and clipping the wings became unnecessary. In the 1930's, hunting with live decoys became illegal and most people with decoy flocks released them into the wild or gave them away. Combined with the learned non-migratory behavior these geese had been cared for by humans which made them comfortable in the surroundings and living year round in one location became the norm.

The second incident happened as a result of hunting pressure on wild geese. It was generally thought that the giant Canada goose had been hunted out of existence until an Illinois biologist, Harold Hanson documented that there were survivors. After the 1965 publication of his book, "The Giant Canada Goose," programs were established to propagate the birds and to disperse them throughout North America. Most wildlife agencies across the nation were involved in captive breeding programs and the restoration effort became one of the great success stories for wildlife management. The population of geese began to increase over the years and thousands where relocated to marshes, ponds, and lakes but, as with the descendants of the decoy flocks, the migratory instinct became nonexistent. The lack of migratory instinct in combination with the urbanization of the landscape means non-migratory or "resident" geese are here to stay.

So resident geese are here to stay. Why is that a problem, particularly for urban lake areas? It should be noted that resident geese are wildlife and overall the emphasis in park planning is to create wildlife habitat. However, the current shoreline and shoreland areas, of most of the urban Denver lakes, are not natural and although very favorable for geese to live and propagate, the areas do not favor natural predators of the geese. The lake ecosystems are out of balance. The large number of geese that have thrived under the conditions present at the lakes can create the following problems:

1) se droppings contain nitrogen and phosphorus and can add unwanted nutrient loading to the lakes which may add to an imbalance of nutrients available to aquatic plants.
2) Fecal contamination of the lakes can also occur from the goose droppings which can contribute to exceedances of the state recreational water quality standard.
3) Additional nutrient and fecal loadings to the lakes can occur from washing off surrounding hard surface trails if the water is allowed to run into the lakes. This is also considered a non-point source of pollution but if there is a direct discharge to the lakes this would be a point source discharge subject to permitting.
4) Aesthetics, goose droppings can be unsightly and raise public concern over contact issues.

Information on habitats which are specifically welcoming for the geese can be found on numerous websites. For instance, the Colorado Division of Wildlife web site states: "In urban areas, traditional landscaping for lawns and parks, with expansive areas of bluegrass lawn and numerous ponds and lakes, creates ideal conditions for resting, molting, brood rearing and foraging. Canada geese will feed on newly sprouted lawns and established grass in urban areas." The USDA Forest Service website states: "Nesting sites that offer good visibility of the surrounding area, protection from predators, and are fairly close to the water (within 1 to 94 meters) are usually adequate enough to support a viable population of geese."

The resource book *Techniques for Mitigating Human/Goose Conflicts in Urban & Suburban Environments – Habitat Modification & Canada Geese* (Keller. et al, no date) specifically discusses the "Do's" and "Don'ts" of habitat areas related to geese. The following photos highlight issues at specific Denver lakes and these are discussed in relation to the Do's and Don'ts in the resource book. Not every lake is depicted in these photos but it should be kept in mind that all of the lakes except, Overland Pond, Bear Creek Ponds, Lake of Lakes and Parkfield had geese related issues.

Photo 1: Barnum Lake at the eastern shore looking west. Bluegrass covered with goose droppings up to shoreline of lake. Currently the shoreline/littoral zone of lake has very little vegetation.

Photo 2: Garfield Lake western shoreland/shoreline. Same conditions as Barnum Lake. Bluegrass covered in goose droppings up to sparsely vegetated shoreline/littoral zone in this area.

Both of these lakes epitomize one of the primary don’ts in the resource book. Don’t “Scalp your lawn!” Why”? Because parks that have the typical features of a pond or waterbody with an open expanse of turf grass mowed extremely short right up to the water's edge with little to no tree or shrub layer will have little to no wildlife species other than generalists and provide little to no vegetation cover for predators. These sites are prime areas for geese.

Photo 3: Berkeley Lake Southern Shoreline - although this lake has extensive shoreline/littoral vegetation there is an expanse of bluegrass adjacent to the lake and a break in the vegetation that allows unimpeded egress to the water for the geese.

Photo 4: Berkeley Lake close-up of goose egress area. Note large amount of goose droppings on trail.

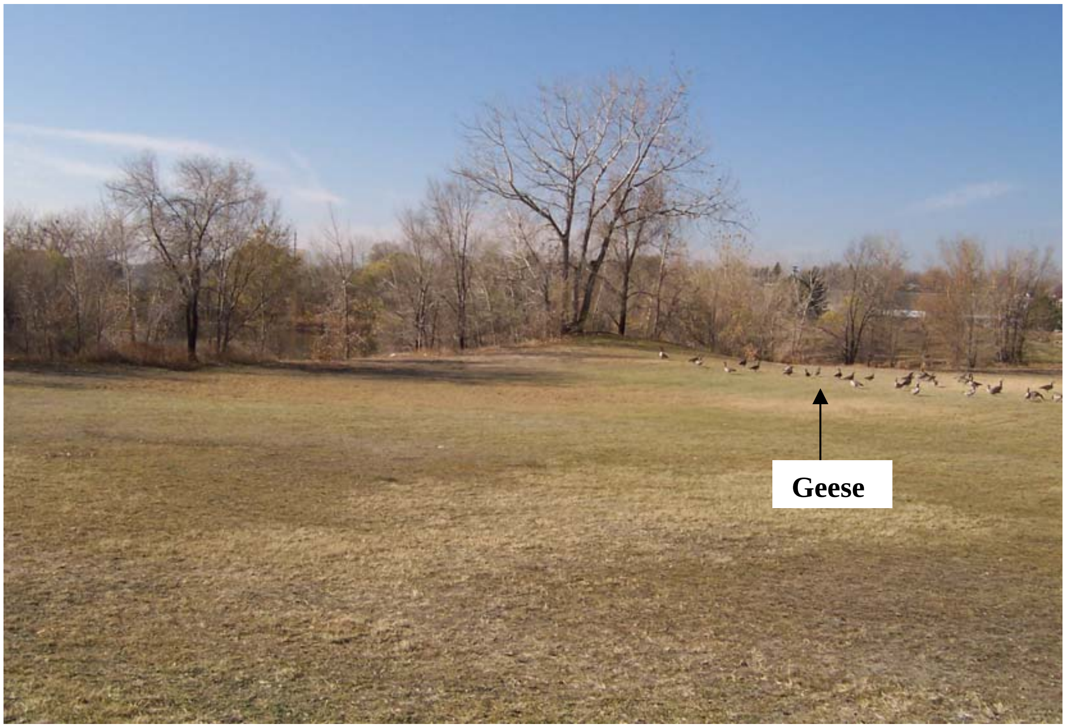


Photo 5: Parkland adjacent to Vanderbilt Lake. Large expanse of bluegrass with geese present.

Photo 6: Egress area from bluegrass parkland in photo 5 down to Vanderbilt Lake. Geese can be seen in the lake.

Berkeley and Vanderbilt Lakes have examples of both "Do's & Don'ts". Do "vegetate a shoreline to make the site less attractive to geese." Canada geese avoid areas where plants obstruct their view of the surrounding area. The resource book includes the shoreland in their discussion of shoreline and also states that "a dense strip of naturally occurring trees and shrubs (20-30 feet wide) should be left along the shoreline. An unmowed shoreline buffer of native grasses and wild flowers that grow 20-30 inches tall in a strip 20-30 feet wide along a shoreline can also discourage geese." The mowed area of the bluegrass up to the edge of the vegetation at Berkeley is a Don't as is the mowed bluegrass adjacent to the dense vegetation at Vanderbilt. Another Don't is "Don't allow access to geese through breaks in your barrier plantings!" Both lakes have this problem.

There are numerous other examples of the "Do's & Don'ts" at the various urban Denver lakes that have not been included here. Habitat modification will be specifically discussed in the next Section on "What Can Be Done" since habitat modifications address many of the lake issues. However, although habitat modifications will make the lake areas less attractive, the geese will still congregate on the other expanses of bluegrass. There are additional resources that address human/goose conflicts and most promote multiple means of controlling geese. In addition to habitat modifications for the lakes, an effective means of reducing the overall population of resident geese to an acceptable level (no program should eliminate the geese) is oiling or addling the eggs (requires a permit issued by Colorado Division of Wildlife). This strategy has been implemented at Sloan Lake (K. French. interview. 2003) but the resources emphasize the need to implement the strategy on a geographically wide basis.

4.3 Habitat

4.3.1 Shoreline and Littoral Zone

The shoreline of a lake is defined as the area where the lake and the land meet (WOW. 2003). The littoral zone is defined as the shallow zone along the shore of a lake; that portion of a water body extending from the shoreline lakeward to the greatest depth occupied by rooted plants. Plants growing here support a rich biological community (Holdren., et al. 2001).

Algae have been a problem in the shoreline/littoral zone of many of the urban Denver lakes that the managers have had to contend with over the years. Algae can interfere with the natural lake processes and can be aesthetically unpleasant. Excessive or nuisance algae are indicative of other problems within the lake, usually excessive nutrients and/or decreased flow. However, algae in the appropriate proportions play an important role in the lake ecosystem. They convert inorganic material to organic matter through photosynthesis; oxygenate the water, also through photosynthesis; and serve as the essential base of the food chain (U.S. EPA. 1991).

Urban Denver lakes vary considerably in the amount of shoreline vegetation or littoral rooted aquatic plants. Some lakes have very sparse or confined areas of vegetation (Lollipop) while other lakes have a very dense shoreline/littoral vegetative area

(Berkeley). Aquatic plants also are an important part of a healthy lake ecosystem. Through photosynthesis, aquatic plants convert inorganic material to organic matter and oxygenate the water. They provide food and cover for aquatic insects, crustaceans, snails, and fish. Aquatic plants are also a food source for many animals. Waterfowl, muskrats, and other species use aquatic plants for homes and nests. In addition, aquatic plants are effective in breaking the force of waves and therefore reduce shoreline erosion. Emergent aquatic plants serve to trap sediments, silt, and organic matter flowing off the watershed. Nutrients are also captured and utilized by aquatic plants, thus preventing them from reaching algae in the open portion of a lake (U.S. EPA. 1991).

Again, the issue for lake managers is excessive or exotic (Eurasian watermilfoil) aquatic plants. The cause of increased rooted aquatic plant growth can also be associated with excessive nutrients and shallow growing areas where light can penetrate down to the sediments. Fragmentation is also a means of reproduction for some aquatic plants and can contribute to a spread of aquatic vegetation (U.S. EPA. 1991; Holdren., et al. 2001).

It is important to evaluate each lake to determine the types and amounts of algae and aquatic plants that are present.

4.3.2 Shoreland

Shoreland is defined as the land that extends 1000 feet from the ordinary high water level. (WOW. 2003). Most of urban Denver lakes have very poor to non-existent shoreland habitat that assist in filtering pollutants. Kentucky bluegrass surrounds most of the lakes. Although this was considered a normal and accepted landscape for urban parks in the past, more and more municipalities are establishing rehabilitation or restoration plans designed to create a healthy, diverse native shoreland area. These areas are sometimes referred to a “buffer” zones because they are meant to protect the lake from human activities that could create imbalances within the ecosystem. Various literature and/or plans have recommended that these zones be any where from 25' to over 100' depending upon the watershed impacts and available area. The designs that have been established take into account visual aesthetics, water quality benefits and the citizen use.

4.3.4 Wetlands and West Nile

The spread of West Nile virus in the United States caused many people to associate the carrier mosquito with wetlands. The fear of wetlands creating extensive breeding areas for the mosquitoes has caused some people not only to insist that no further construction or restoration of wetlands be allowed but also, in some instances, they have actually called for the draining of wetlands. This reaction is dangerous to a well balanced ecosystem. If care is taken to ensure that wetlands are designed and sustained in a healthy state they can be an essential part of a well balanced lake ecosystem. EPA’s brochure on Wetlands and West Nile Virus (U.S. EPA. 2003) notes:

"Healthy wetlands are not uncontrolled breeding grounds for mosquitoes. These unique ecosystems sustain numerous species of fish, insects, amphibians and birds that feed on mosquitoes. Moreover, the mosquito species that are primarily responsible for West Nile transmission do not prefer to reproduce in healthy wetlands. They tend to breed readily in abandoned tires, birdbaths, roof gutters and other artificial containers that lack wetland predators."

4.4 Water Quality

4.4.1 State Classifications and Standards

The water quality of a lake is a primary driver in determining the overall health of the system. Water quality is a measure of the way the system is functioning and whether other critical issues for lakes (e.g. flow, geese, habitat) are balanced and managed to maximize the functional capabilities of the lake. The urban lakes in Denver are "waters of the state" and are therefore subject to state water quality regulations. Through a regulatory process the lakes have been designated as being used for certain purposes (e.g. recreation, aquatic life, agriculture). In regulatory terms the lakes have been assigned "use classifications" and those uses are protected under the state's Water Quality Control Act and per regulation. The regulations include numeric standards that must be met in order to protect the designated uses. The following table lists the numeric standards applicable to the lakes in Denver's urban parks (WQCC Regulation #38).

TABLE 4.4.1: Colorado Water Quality Control Commission Adopted Standards

Numeric Standards		
Physical and Biological	Inorganic mg/l	Metals mg/l
D.O.=5.0 mg/l	NH3(ac)=TVS [1]	As(ch)=100(Trec)
pH=6.5-9.0	NH3(ch)=0.06	Cd(ac/ch)=TVS
F.Coli=200/100ml	Cl2(ac)=0.019	CrIII(ac/ch)=TVS
E. Coli=126/100ml	Cl2(ch)=0.011	CrVI(ac/ch)=TVS
	CN=0.005	Cu(ac/ch)=TVS
	S=0.002	Fe(ch)=1000(Trec)
	B=0.75	Pb(ac/ch)=TVS
	NO2=0.5	Mn(ac/ch)=TVS
		Hg(ch)=0.01(Tot)
		Ni(ac/ch)=TVS
		Se(ac/ch)=TVS
		Ag(ac/ch)=TVS
		Zn(ac/ch)=TVS

[1]TVS indicates that, for a particular parameter, a "table value standard" has been adopted. This designation refers to numerical criteria set forth in the Basic Standards and Methodologies for Surface Water. Most of the Table Value Standards for metals are derived through mathematical equations that take into account the hardness of the water in determining the level of metals that will not cause harm to the aquatic biota. As the hardness concentration in the water body increases (not to exceed a maximum concentration of 400mg/l) the allowable amount of the metal will increase.

There are additional numeric and narrative standards that apply to lakes in Denver urban parks, however, due to the complexity of the regulations, they are not shown in this table, but can be found in the Water Quality Control Commission Regulations #38 and #31. (See the section on Denver Environmental Health's Monitoring Program or contact Denver Environmental Health for more information on applicable standards and the quality of the Denver urban lakes.)

4.4.2 Nutrient Criteria

EPA's 1996 National Water Quality Inventory report identified excessive nutrients as the leading cause of impairment in lakes. Currently the state's standards do not include specific criteria for total nitrogen and total phosphorus however there is EPA national guidance for nutrients and the state has submitted a plan to EPA that describes their proposal for developing criteria for Colorado.

The concept of nutrient criteria is based on the idea that nutrients produce changes in streams, lakes and reservoirs that are considered to be detrimental to the function or use of the water body. This idea of nutrient control can be traced back to 1929 when Einar Naumann, a limnologist, explained the relationship between nutrients and lakes (nutrient paradigm). His concept can be summarized in the following four statements:

- The primary factors that determine algal biomass (the amount of plant organic material) are the plant nutrients phosphorus and nitrogen.
- The geology (and land use) within the lake's watershed determines the amount of nutrients that enter the lake and, therefore, plant biomass.
- Changes in the plant biomass affect the entire lake's biology.
- There is a natural ontogeny to lakes. The amount of plant biomass and, therefore, the entire biology of the lake increases as the lake ages.

Today, this nutrient paradigm states that the factor that is in shortest supply relative to the needs of the plants limits the growth of those plants. This concept insists that very few factors (usually only one factor, often a plant nutrient such as nitrogen or phosphorus) will actually limit plant growth. However, the factor that limits plant biomass can change seasonally or over longer periods of time, can vary depending on the land use, or vary regionally. (U.S. EPA. 2000a)

EPA's approach to developing nutrient criteria is based upon establishing appropriate reference (unimpacted) conditions for each physical lake class within each particular ecoregion or subecoregion. These reference conditions are then used as a standard for comparison and assist in establishing appropriate nutrient criteria. EPA does include the use of all data for a particular class of lakes if there are an insufficient number of natural reference lakes available. In these cases a lower percentile of the data would be used to establish the "reference" value. Normally the 25^{th} percentile is used, but if most of the lakes are impacted to some extent EPA has noted that the 5^{th} percentile may be more appropriate to establish a reference value (U.S. EPA. 2000a).

For Ecoregion IV (*Great Plains Grass and Shrublands*), subecoregion 26 (*Southwestern Tablelands*) which includes Denver, EPA established reference values using the 25th percentile of the available data. The total nitrogen calculated value (nitrite+nitrate+total kjeldhal nitrogen) is 0.39 mg/l and the total phosphorus value is 0.02 mg/l (U.S. EPA. 2001).

4.4.3 Basin or Watershed Influence

The structure of the watershed that contributes to the flow that discharges into lakes plays a significant role in the health of the system (as noted under the nutrient paradigm). In urbanized areas the "watershed" is comprised of the overland flow runoff from the surrounding land and the storm sewer "basin" that has been designed to carry storm water flow away from developed areas and which discharge to lakes (or other surface water bodies). The more urbanized the area draining into the lake the less pervious the land (less infiltration capability) due to roads, pavement and buildings. The less pervious an area the more runoff that can eventually end up in the lake. The runoff will carry all of the various pollutants associated with the land use in the basin or watershed (residential, industrial, commercial).

In order to control the amount of pollutants present in the runoff water the EPA and subsequently the State of Colorado enacted regulations to control the levels of pollutants through issuance of storm water permits. The City and County of Denver was one of the first municipalities in Colorado to be covered under a storm water permit for the municipal storm sewer system. Much of the permit relies on Best Management Practices (BMPs) and public education to improve storm water quality. The urban lakes in Denver are the point of discharge for numerous storm sewers (see Appendix A), therefore, the control of pollutants within these watersheds can have a direct impact on the quality and function of the lakes.

The Urban Drainage and Flood Control District has developed both structural and non structural BMPs for use by storm water permitted municipalities. The structural BMPs include habitat designs such as grass buffers, grass swales and constructed wetlands. (UDFCD. 1999)

An additional issue associated with the storm sewer system is discharges not associated with storm events. These discharges are either legally covered under the state discharge permit system, are illicit discharges that are not allowed or are the result of poor management practices that need to be corrected. These types of discharges can occur on an intermittent basis or seasonally but are a part of the base flow that can impact the lakes. The surrounding land can also be a source of non-storm water impact.

4.4.4 Denver Environmental Health Monitoring Program

The Environmental Protection Division of the Denver Department of Environmental Health (EPD/DDEH) has been conducting sampling of the lakes in Denver to various degrees for more than 20 years (see Clean Lake sampling under the history of Sloan Lake in Section 2). Currently there are only three lakes that are not included in the sampling program: Parkfield Lake, Bear Creek Ponds and Lake of Lakes. It should be noted that Bear Creek Ponds and Lake of Lakes were sampled on a request basis by DEH. Parkfield Lake was sampled for the Parkfield Lake Community Park Master Plan (Norris. no date) by Keeton Industries, Inc. and the report on the lake (Keeton. 2000) indicated that the lake would be classified as eutrophic.

The sampling program has changed over the years to include almost all of the urban Denver lakes in a summer sampling. The parameters and means of sampling have also advanced over the years to include sediment sampling, dissolved oxygen and temperature profiles (measurements are taken at set distances, usually each foot, from the surface to the bottom), chlorophyll-a, metals, nutrients and bacteriological indicators. In addition to the routine list of parameters that are measured/sampled, there have been special sampling events based upon identified areas of concern. EPD/DDEH has compiled the results of the sampling efforts for 2003 in a report (Denver DEH 2003 Lake Report).

The report summarizes various water quality aspects of the lakes and each lake must be evaluated for potential issues of concern that may only relate to that individual system. For example, Berkeley Lake is currently listed on the state's 303(d) list for exceeding the arsenic fish ingestion standard. A 303(d) listing means that an applicable standard is not being met and the state must prioritize the impaired waters (rivers, streams, lakes, and reservoirs) based upon the severity of impact, determine the cause(s) of the water quality problem and allocate the responsibility for controlling the sources contributing to the exceedance. Although the state has overall responsibility for implementation, in practice, most or all efforts towards finding the cause of the exceedance normally rests with the party or parties responsible for the discharges to and/or management of the listed waters. In the case of Berkeley Lake, the responsibility for the lake primarily rests with the city.

There are water quality issues for the lakes that are fairly ubiquitous and these are discussed in the following portion of the plan.

Trophic State Index

As noted in the introduction, most of the lakes that have been sampled, at some point and have been determined to be either eutrophic or hypereutrophic according to Carlson's (1977) trophic state index (TSI). Increasing TSI values indicate increasing eutophication. Where an individual lake falls in the range of trophic states associated with the TSI is based upon calculations derived by measurement of chlorophyll-a, secchi depth and total phosphorus (see Appendix B). Although these three variables are indicative of related issues, they measure different components of eutrophication. EPA has stated in several of the documents for developing nutrient criteria (U.S. EPA. 2000; 2001) that there are both causal and response variables. Plant nutrients, phosphorus and nitrogen, are the primary factors that affect lake productivity. They are casual. The physical response to increased nutrients is an increase in algal (phytoplankton) biomass which can be indirectly measured by chlorophyll-a. The increase in the mass of algae in a lake can be reflected in a decrease in water clarity which is measured by the secchi depth (how far down in the lake can the secchi "disk" can be seen).

Based upon chlorophyll-a, Garfield, Harvey, Huston, Rocky Mountain and Lollipop lakes have recently had TSI values that would place them within the mesotrophic state (chlorophyll-a sampling commenced in 2001, therefore, long term trends are not yet available). Improvement in TSI values can be associated with lake draining and sediment removal projects due to a decrease in lake productivity (algal biomass). Unfortunately, the noted improvements to urban Denver lakes have generally not been sustained for more than one of the sampled years and may be more indicative of other factors. For example, Lollipop Lake chlorophyll-a TSI value decreased from 2001 to 2002 (indicating less productivity) but increased again in 2003. The chlophyll-a TSI values and the increase in water clarity in 2002 (decreased secchi TSI value) tends to be indicative of some form of lake algae treatment or removal rather than the result of dredging that occurred in the mid-1990s. Harvey Lake and Rocky Mountain Lake also have not had a sustained improvement in lake productivity and the TSI values may be more indicative of lake algae treatment.

Garfield Lake, although technically hovering between mesotrophic and eutrophic, appears to be sustaining more of a trend towards less productivity. Although this may also be due in part to algae treatment, the more sustained decrease in productivity could also be associated with flow management practices implemented by the Park and Recreation personnel in the Southwest District. Input flow of water can be increased from the Salisbury Lateral to the lake if algae or odor problems are noted during the summer (Hernandez J., telephone communication, 2004).

Huston Lake's dredging project was just completed in 2003, therefore, a trend in productivity can not be determined at this time.

Sediment Copper

Although chemical treatment to control algae in lakes is a management technique that is used by DPR (and elsewhere throughout the United States), there are detrimental affects associated with such treatment. For example, some disadvantages noted in the resource book *Managing Lakes and Reservoirs* (Holdren., et al. 2001) are:

- toxicity to aquatic fauna as a function of concentration, formulation, temperature, pH, and ambient water chemistry;
- less effective at colder temperatures or at high inorganic solids levels;
- ionic form is persistent and accumulates in the sediment or moves downstream of the lake;
- certain green and blue-green nuisance species of algae are resistant to copper;
- lysing of cells releases cellular contents (including nutrients and toxins) into the water column.

The 25th percentile of the copper sediment data collected by EPD/DDEH between 1996 and 2001 is 50 ug/g (eliminating an outlier value for Huston in 2000). Using this value as a reference for comparison to evaluate potential copper accumulation in lake sediments shows that Berkeley, Harvey, Huston, Garfield, Rocky Mountain, and Vanderbilt concentrations tend to be almost twice to over four times higher. The accumulation in

Vanderbilt is probably indicative of the industrial land use in the surrounding area and may relate to the historical discharge. The concentrations in the other lakes could, in part, be a result of algae treatment.

Nutrients
Total nitrogen (calculated) and total phosphorus for all of the urban Denver lakes are in excess of the reference values established by EPA for Nutrient Ecoregion IV (2001). The reference values once again are 0.39 mg/l and 0.02 mg/l respectively.

Before summarizing the nutrient data for the urban Denver lakes it needs to be noted that over the years there has been fluctuation in the laboratory detection levels for some of the nutrients monitored by EPD/DEH. Because there was a period when the detection level for nitrate, TKN and total phosphorus were relatively high, the "typical" practice of using half the value or zero (which is the acceptable practice for EPA dependent upon the data) would be inappropriate and that data was not used.

The lowest calculated total nitrogen value for the urban Denver lakes was 0.72 mg/l for Ferril Lake in City Park in June of 1998. The highest value in recent years (1998 through 2003) for the sampled lakes was 7.81 mg/l for Overland Pond in July of 2002. The lowest concentration for total phosphorus was 0.04 mg/l for Huston Lake in June of 2003; the highest concentration was 1.41 mg/l for Overland in July of 2002. These values show the urban Denver lakes to be 2 to 20 times the EPA reference for total nitrogen and 2 to 70 times the reference for total phosphorus. Although the state's criteria will probably be a refinement of EPA's based upon conditions specific to Colorado, the concentrations in the urban Denver lakes are indicative of nutrient impairment.

4.5 Connections Among Issues

As is apparent in the previous portions of this section, all of the primary issues affecting the urban Denver lakes are interrelated.

1. flows are not kept at a rate where the residence time of the input water is kept at an optimum level then lake areas can become stagnant and the nutrient concentrations in the lakes can also increase.

2. shoreline/littoral and shoreland habitats for most of the lakes are a prime attractant for geese who in turn add to the nutrient loadings in the lakes either directly or as a result of runoff or wash off. The bluegrass habitat of the shorelands also adds to the nutrient loadings of the lakes due to the application of fertilizer on the parklands and since there is little to no buffer zone to help in filtering and uptake of any excess nutrients that may run off os the land.

3. The watershed of the urban lands that drain to the lakes contributes to the nutrient loadings due to increased impervious areas and the ubiquitous use of fertilizers and compost for lawn and garden care; whether households, commercial or

industrial properties. However, if source control (for nutrients and other pollutants) and reduction of unnecessary application of lawn care products was successful then this source of input flow could benefit the urban lakes.

4. Items 1, 2 and 3 all affect the water quality of the lakes. Quality of the source input water directly affects the lakes along with sheet flow runoff from the adjacent park land and storm water runoff and/or discharges from the watershed. The other source that affects water quality in the lakes is internal loadings. The decay of plants and animals in the lake adds to the nutrient loadings which settle in the sediments if not flushed from the system by flows. The pollutants present in the input water as well as pollutant sources as a result of management practices (e.g. algae treatment) can also settle to the bottom of the lakes in the sediments. These nutrients and other pollutants can be re-suspended or solubilized into the water column of the lake under the proper conditions.

Section 5
What Can Be Done to Manage/Protect the Lakes?

5.1 Overview

Denver is among other cities across the country that wants to manage and protect their urban lake resources for the benefit of the citizens and the environment. There are common themes that arise from the latest information on management practices, key among them are restoration to a more natural, ecologically balanced habitat and controlling impacts at the source. The primary focus of this section is to identify strategies that are aimed at reducing the cause of impacts to the lakes so that the lakes can become biologically balanced and the need to treat symptoms of impact, such as excessive algae, can be reduced or eliminated. These recommendations should be considered basic elements of lake management and protection. Some concepts are already being put into practice and are included for reference with potential areas for expanded implementation. Some of the concepts can be implemented almost immediately, while some are dependent upon funding. This is not a quick solution. It takes time, determination and patience to accomplish long term sustainable improvement for the lakes. It should be emphasized that if a strong commitment to a long term process is not made then there is not much hope of success. The personnel that will be tasked with implementing the various aspects of this plan will need support from management, city officials and the citizens.

5.2 Habitat Improvement and Restoration – Design with One Voice

There are various planning groups within the city and many of them overlap when it comes to designing improvement projects that either directly or indirectly affect the lakes. It is doubtful that any new lakes will be constructed within the urban parks. However, as noted under "present plans" in Section 3, the existing lakes are being evaluated for expanded uses primarily related to storm water retention and irrigation usage for parkland. Many of these past, current and future plans are intended to extend the life of the lakes and add to their aesthetic value for the citizen's of Denver. Specific design concepts required by all planning and design personnel in Denver with regards to the lakes should be institutionalized. Just as road infrastructure requires ASTM specifications for road base and concrete must be adhered to, the planners and designers must institute base requirements on plans involving lakes. In this sense the city must speak with one voice stating that plans for lakes will be designed to improve the water quality as well as conserve, restore or improve the habitat to more natural conditions.

5.2.1 Integrate Natural Characteristics

Many of the historical and recent management plans for the lakes have included dredging which, for shallow urban lakes, can be an on-going maintenance cost. The dredging projects have had various degrees of success. In some cases the fine, slurry-like nature of the sediment made dredging impossible, Sloan Lake dredging had to be abandoned due to issues encountered with dewatering of the sediment. It is also becoming more costly to remove and dispose of the sediment and, therefore, the material is being reused on-site, again with varying degrees of success (K. French, interview, 2003).

Improved shoreline/littoral and shoreland vegetation has also been recommended in various management/preservation plans and must be considered a required design component for the lakes. Natural vegetation assists lakes in the following ways:

- Natural buffer strips and wetlands act as filtering mechanisms to reduce the amount of sediment and nutrients that enter the lakes, create wildlife habitat and help restore the lakes' biological integrity.

- Structure and function are closely linked in river corridors, lakes, wetlands, estuaries and other aquatic resources. Reestablishing the appropriate natural structure can bring back beneficial functions. (U.S. EPA 2000b)

- Habitat modification through natural landscaping techniques offers both an ecological and humane means of reducing human/goose conflicts in urban and suburban environments (Keller., et al.)

This does not mean that the vegetation does not have to be managed once established the systems have to be maintained in a healthy state which requires:

- monitoring the vegetation,
- removing vegetation that has died before decomposition occurs,
- replacing vegetation as necessary, and
- sediment removal in the littoral and transitional zones as determined necessary based upon the individual site conditions

How can lake and lake shoreland habitat rehabilitation or improvements be incorporated into design plans?

Currently the WCP establishes four typologies (Traditional Park, High Plains Prairie, Northern Stream and Southern Stream) to be used to classify parks and open space. Each typology is composed of a combination of one or more habitat types. Types of parks are defined and the "composition" of the parks established by the typology. For example;

> Large urban parks serve the entire community of Denver and the metropolitan area. The park character will be composed of the Traditional Park typology.

Whether parkland is of a "traditional" or a "natural open space" typology, the lakes and their shoreland area have to be thought of and managed as unique ecosystems. To achieve this goal, lake and lake shoreland need to be added to the WCP as a separate typology. Shoreland to be defined as a minimum of 30' to 35' or the maximum distance that can be improved before a major unalterable impediment is encountered. The type of vegetation that can be used for the shoreline/littoral and shoreland areas would be designated by the Natural Areas Unit and incorporated in to the WCP.

In addition the *Game Plan* already states that the planning process should:

- Address the entire system (not just the site), considering elements and conditions such as urban waterways, stormwater, tree canopy, natural areas, and parklands.

- Work closely with other agencies, developing all potential public lands as green infrastructure, including stormwater control and quality, and wildlife habitat.

- Require DPR Natural Resource review of plans for new parks and drainage system.
- Require DPR Natural Resource review of plans for private developments

DPR Natural Areas review of plans involving lake or lake shoreland should be incorporated into this portion of the *Game Plan*.

Integrating natural characteristics into lake ecosystems designs will address components of both the *Game Plan* and the WPC.

Game Plan:

- Incorporate sustainable planting designs that conserve water, create wildlife habitat, and are low-maintenance.

- Increase naturalized areas and reduce bluegrass in parks and golf courses, where compatible with recreation activities.

- Protect, restore, or create wetlands in new developments and when naturalizing parkland and golf courses. Develop zoning and plan review processes for natural areas.

WCP:

Design guidelines for retrofitting appropriate areas of existing parks into more water wise and diverse landscapes. This includes an overall inventory of appropriate parks, areas, treatments, and funding opportunities.

The in-house DPR expertise on natural ecosystems in the Natural Areas Unit should be more effectively utilized and expanded to assist in achieving the existing recommendations contained in the plans. In addition, building on the current expertise will reduce the need for the city to hire consultants and assist in ensuring consistent, coordinated implementation of appropriate natural characteristics in park plans, to include lake and lake shoreland, throughout the city.

5.2.2 Coordination Among the Agencies

Although there are design teams that meet to discuss conceptual and design plans for various projects within the city there is a strong need for better, more efficient coordination for projects involving lakes. The challenge is that the member agencies that participate on the design teams are those that are invited. The agencies invited to be present tend to be those that have a clear responsibility in the design process or are known to have an interest. In the case of the lakes the connection with the agencies and divisions within those agencies listed in section 2 is not necessarily apparent. The input from all of these agencies on planning and design can be made easier and more effective if plans are presented at the earliest possible time to the Water Quality Committee (previously known as the Water Quality Group) for any project that may affect (again either directly or indirectly) the lakes. Input would be provided at the beginning of the planning process and agencies with responsibility for some aspect of lake management that would be impacted by the design would become a member of the project team.

It should be noted that the comprehensive plan specifically includes the statement that; "An intra-agency water quality group has been formed to review City projects that may have potential adverse impacts on Denver's lakes and streams."

The *Game Plan* recommends establishing working teams and partnerships with other agencies, such as CPD, PublicWorks, the Water Quality Group, the Department of Environmental Health, Denver Water, Wastewater, and Vector Control.

Because the Water Quality Group was initially formed at the request of Mayor Webb's South Platte Commission, and not through a formal executive order, in practice all City projects have not been reviewed by the committee and a stronger working relationship with DPR, besides the Natural Areas Unit, has not occurred. If the recommendations in this LMPP do not serve to create an informal workable agreement between the agencies then an Executive Order should be established requiring that city projects are reviewed by the Committee.

5.3 Management Practices

5.3.1 Realistic Strategies for Park Superintendents and Field Personnel

Management strategies that can be implemented by park personnel to assist in improving the lakes that will not require capital improvement/equipment or substantial funding are:

1. Establish a nutrient budget for the park. The bluegrass areas of the parks only require a certain amount of nutrients to grow at a healthy level. The sources of nitrogen and phosphorus have to be established in order to minimize the possibility of excess amounts (more than the grass uptake rate) running off the turf area into the lakes. The following sources of nutrients need to be established:

a) Soil - Soil testing is recommended by Colorado State University Extension Service to determine the plant available nutrient content of the existing system. This testing by itself may indicate that no additional fertilizer (nutrient) is needed at the time.

b) Non-potable Irrigation Water Source – Testing of the irrigation water source if it is the lake would be necessary to determine the concentration of nutrients in the water. This source needs to be added to the overall nutrient budget for growth. DEH would be able to provide information on nutrient concentrations in the lakes that could be used in conjunction with irrigation rates to estimate the amount from this source. Denver Water may also be involved in this determination for reuse water.

c) Fertilizer – Depending upon the results from the other sources the type of fertilizer used may need to be modified, for example to a phosphorus free fertilizer.

Creating a nutrient budget should occur each year as soil or irrigation water contributions could, and hopefully would, change. A determination has to be made regarding what agencies will assist DPR in this task.

2. Work with the Water Quality Committee to establish a formal Integrated Pest Management Plan (IPM) to reduce or eliminate the use of pesticides. It is critical for the park personnel to be involved in evaluating what types and amounts of pesticides (including herbicides and algaecides) are used and why (e.g. citizen complaints, disease). Alternative practices to pesticide use that can be implemented without major costs can be established throughout the DPR park system.
3. Establish a no-mow zone adjacent to the lakes to assist in keeping the grass clippings from decaying in the lake and adding to the internal nutrient loadings. As noted in *Habitat Modification & Canada Geese* (Keller., et al.) "Do let the green grass grow!" Renaturalizing a site by letting the grass grown in certain low human use areas will reduce the attractiveness of your site to geese. The resource book notes that in one case study, renaturalization reduced the numbers of geese at the site by over 70%.

Management strategies that can be used by the park personnel to assist in improving the lakes that require funding are:

1. Cleaning equipment for the hard surfaced trails that vacuum up the residual water and waste for disposal into the sanitary sewer system (Wastewater Management would have to approve that disposal method).
2. Increase staff or equipment to fully implement the IPM. Decreased use of chemicals means increased need for people power and some alternatives methods that reduce the use of pesticides require equipment. For example

there is relatively new application technology that was developed for use along roadways, but now has commercial application. There are various different brands such as, Burch Wet Blade®, Weed Bug and Brown Brush Monitor. The technology is meant to reduce the amount of chemicals and labor costs associated with herbicide application as well as be safer for the applicator. One web site noted the cost of a system to be $25,000, however, the cost may be lower as more are produced.

5.3.2 Control at the Source(s) in the Watershed

As noted in Section 4, the City and County of Denver is subject to a Municipal Storm Water Permit that requires implementation of Best Management Practices for commercial and residential properties in Denver. The Wastewater Management Division in Public Works is the responsible agency for implementation of the permit requirements. This effort commenced in the mid-1990's as a cooperative effort with other municipalities and the Urban Drainage and Flood Control District. The following are some areas where the other city agencies can assist in the effort to reduce impacts at the source in the watershed:

1. Educate and Enforce with One Voice. Coordinate and cooperate among the various agencies that have field personnel. Each city agency should be using the same information to inform commercial and residential owners when they encounter practices that impact the quality of water in the storm sewer system and will therefore impact surface waters including the lakes.
2. Let Parkland Management Set an Example. Set the management of the park "turf" and natural areas as example of environmentally sound, safe and practical practices that can be implemented by the surrounding community.
3. Emphasize the need for the surrounding communities to take ownership of the lakes through their own personal practices (see education portion).

5.3.3 Other Potential Management Strategies that Require Coordination and Support

There are management techniques that can be used to bring the lakes into a biological balance. Some of these, as previously noted, have been implemented or are being implemented.

1. Continue to look for means of creating a sustained flow for all of the lakes.
2. Continue to design/modify the input and overflow/output to maximize the circulation of the lake water and avoid short circuiting.
3. Evaluate the feasibility of harvesting aquatic plants (macrophytes) or dense mats of algae. **Note:** Harvesting is labor intensive and extreme care has to be taken with aquatic plant harvesting so that all of the plant material is removed from the lake (fragments can actually spread the plant). This is especially critical if there is any Eurasian watermilfoil present in the lake (see next bullet).

4. Hire summer biology intern(s) that work with the Natural Areas Unit, Park Superintendents and Environmental Health to identify and map the algae and macrophyte species and densities present in the lakes.
5. Evaluate, in conjunction with the Colorado Division of Wildlife, whether biomanipulaiton would be viable in any of the lakes.

5.3 Education – Teach the Children So They May Inspire and Inform the Adults

Many city programs emphasize education; storm water, water conservation, natural areas, environmental stewardship, to name a few. All of the various strategies in this plan hinge on education, from educating the city officials on the need for natural buffers around lakes, to educating field personnel on implementation strategies to educating the public not to feed the waterfowl and to pick up after their dogs. So there is nothing new about educational efforts and many programs have facets that include children but there needs to be a coordinated, concerted effort by the city agencies to establish a Water Stewardship Program that targets grade schools and middle schools and is designed to educate the children about their own environmental "back yard" and what they can do that will make a difference. This program can start with the lakes. Since there is a grade school or middle school in the watershed neighborhood of every lake this is a prime opportunity. However, schools are stretched as much as government if not more so, therefore in order to have the program work an "educator" needs to be hired by the city. The following are some ideas on how the schools could assist in the educational effort:

1. The schools can "adopt-their-lake" and through the science and biology classes the children can track the progress of the lake through restoration or improvement projects. This can include photo documentation of the progress and field notes on plant and animal species present at the lake and how they change as the lake changes. The results can be used in science projects or in a special parent day.
2. The schools art classes can design signs to educate the rest of the public on why the lake shoreline/littoral zone and shoreland are changing.
3. The children can help design programs that they thought cause adults to care more about their impacts on the lakes.
4. Coordinate a city-wide day where school children can be at the park lakes to promote good management practices, e.g. not feeding the geese and ducks, picking up after dogs.

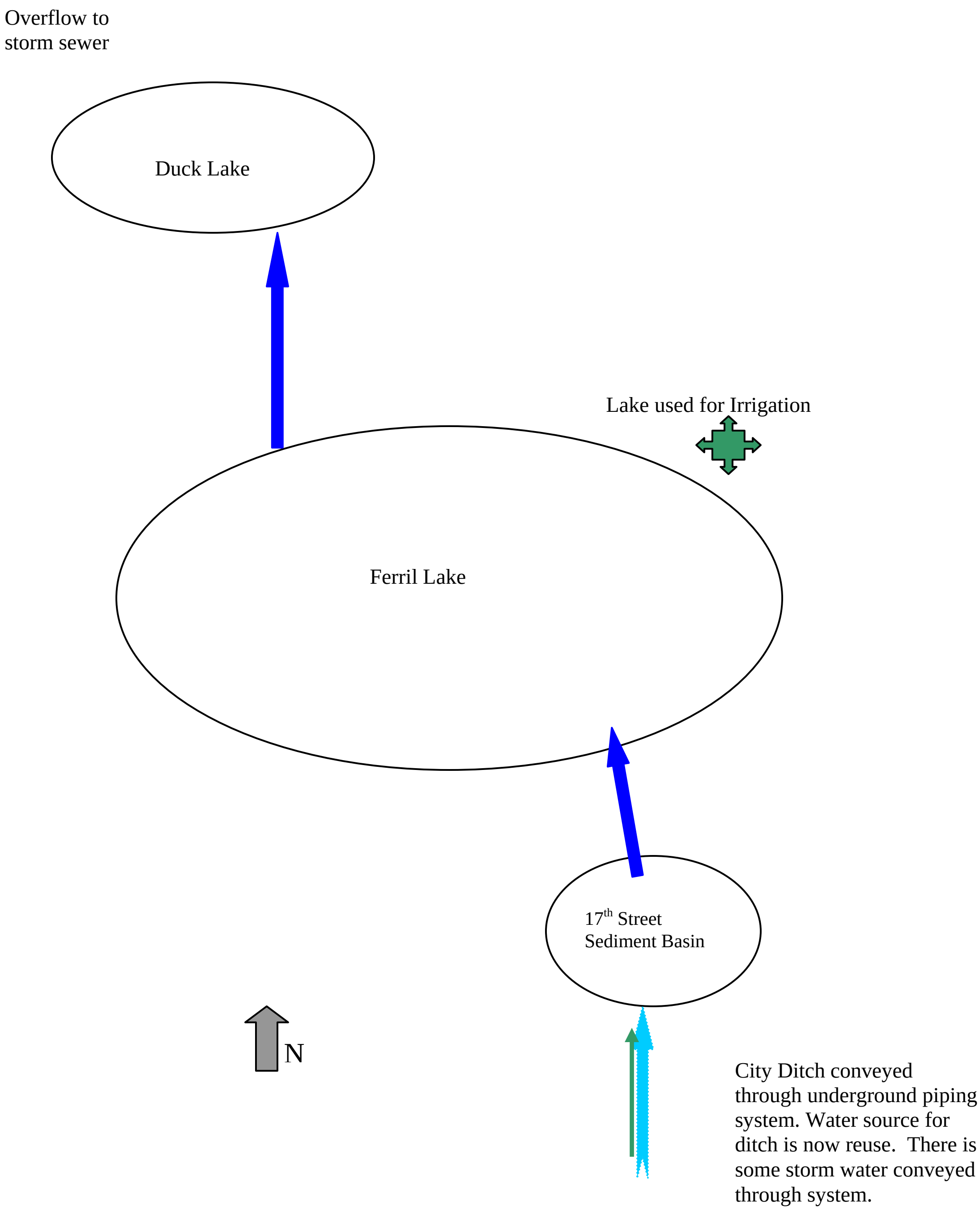
APPENDIX A
Lake Flow Patterns

The following basic schematics depict what is currently known about the lake flow patterns. Resources for this information include the 1994 Arber and Associate reports on Berkeley, Garfield, Harvey, Rocky Mountain, Sloan and Overland Lakes; the *Parkfield Lake Community Park Master Plan*; discussion with Denver Water Department; discussion with DPR, Planning Unit; discussion with DPR, Park Maintenance Unit; information from Denver Public Works Department; and field observations. It should be noted that the storm sewer outfalls to the lakes have to date not been required to be identified by the Wastewater Management Division, Water Quality Section under the storm water permit. There may be further refinement or identification of storm sewer outfalls once the mapping is required either through permitting, when storm sewer basins undergo master plan design or when rehabilitation plans are implemented.

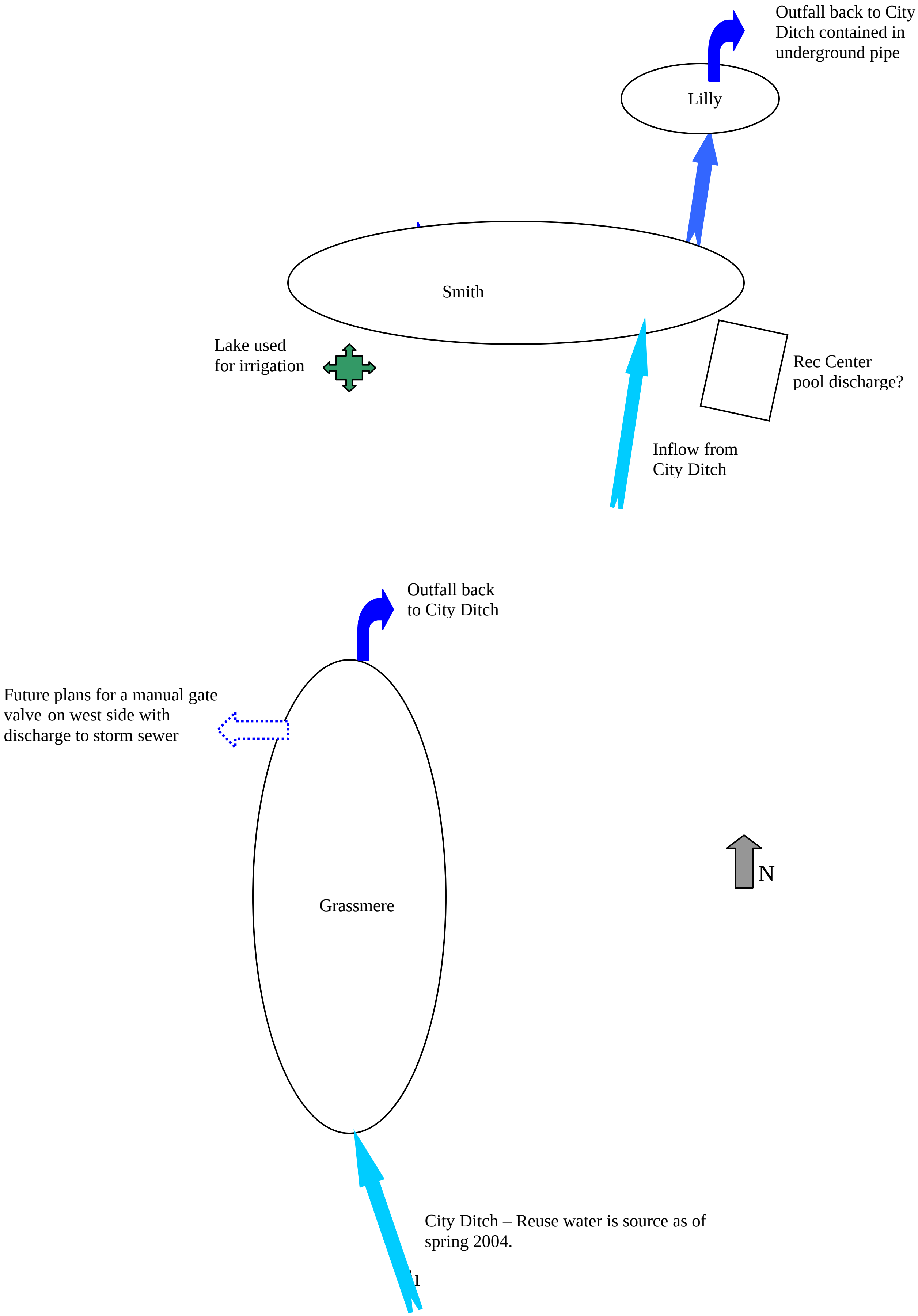
At least some of the swimming pools and roof drains from the recreation centers adjacent to lakes appear to drain into the lakes. Under the *Water Conservation Plan* (2003) the end of season pool water is to be used for irrigation of parkland.

Throughout the schematics storm water is depicted by a green arrow and/or the designation SW. Flow between lakes is depicted by a blue arrow. Other designations are noted on the schematics.

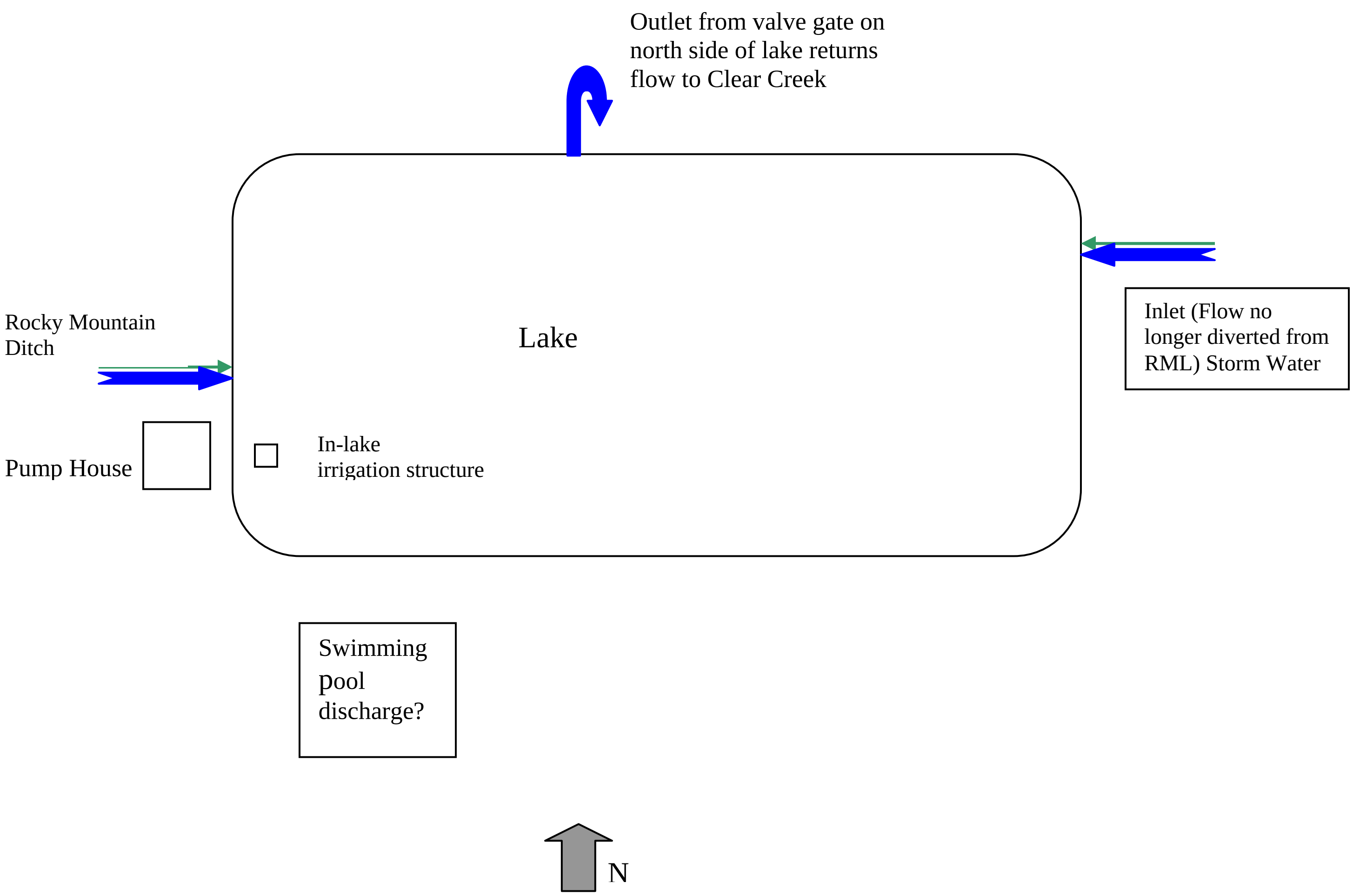
City Park Flow Pattern



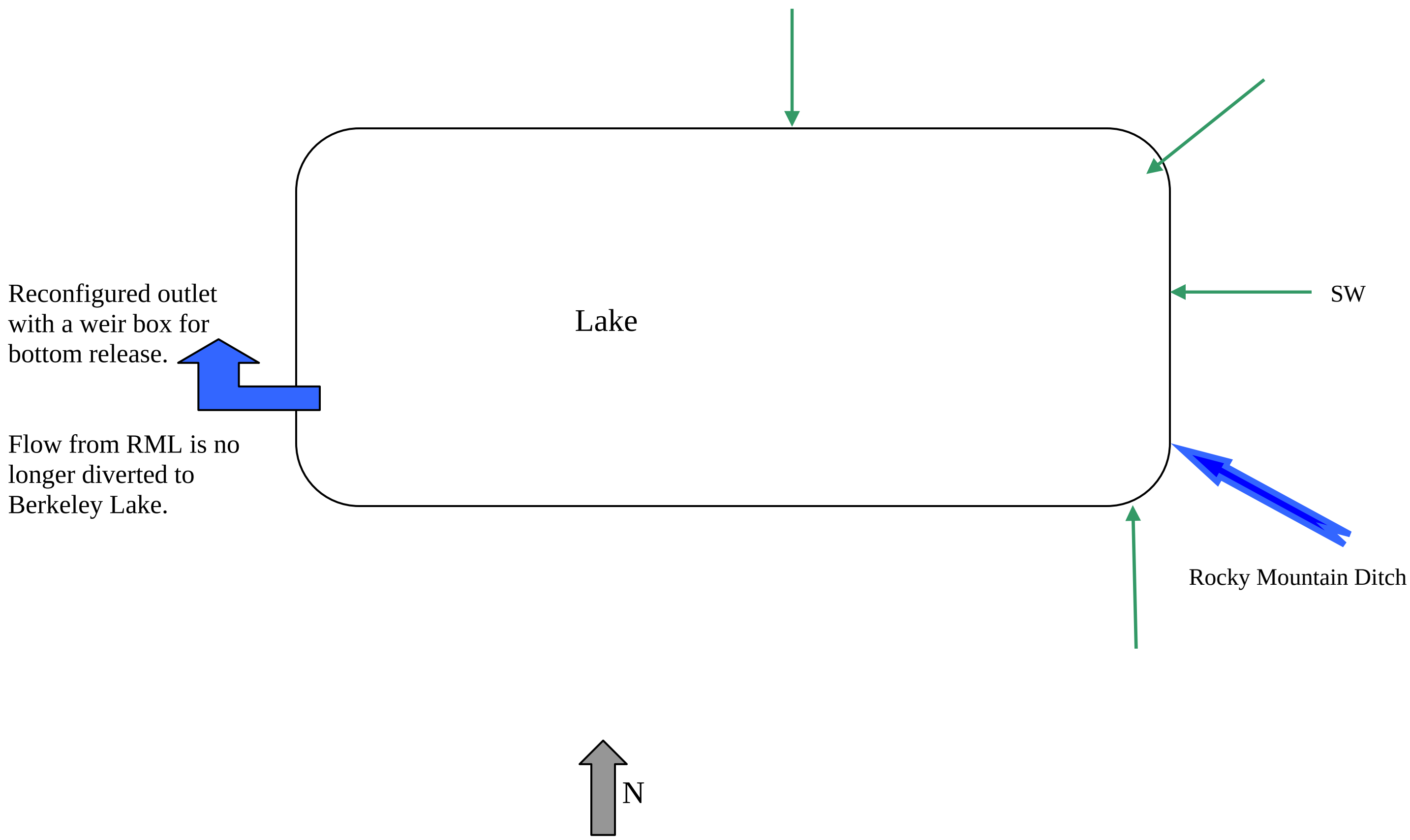
Washington Park Flow Pattern



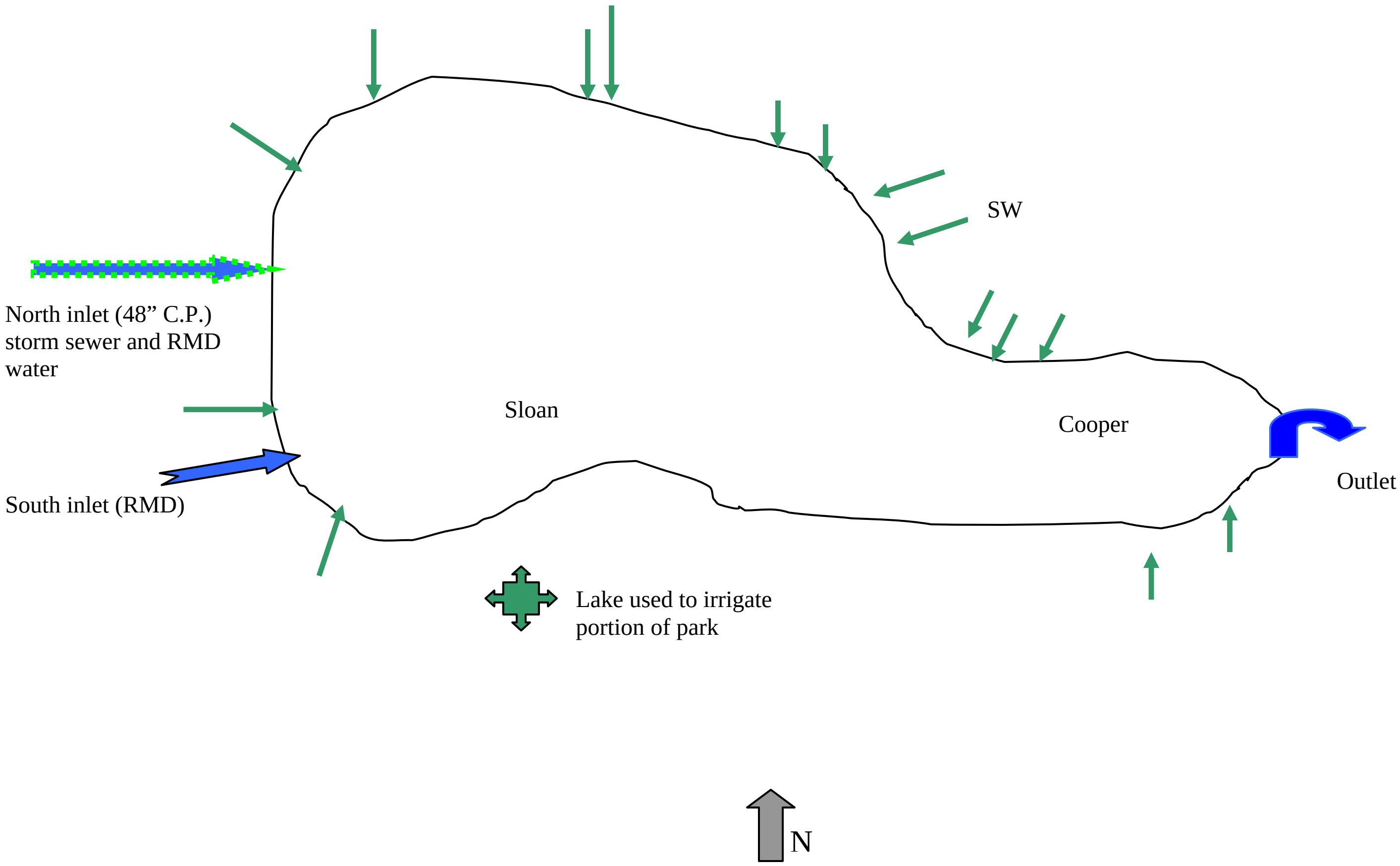
Berkeley Flow Pattern



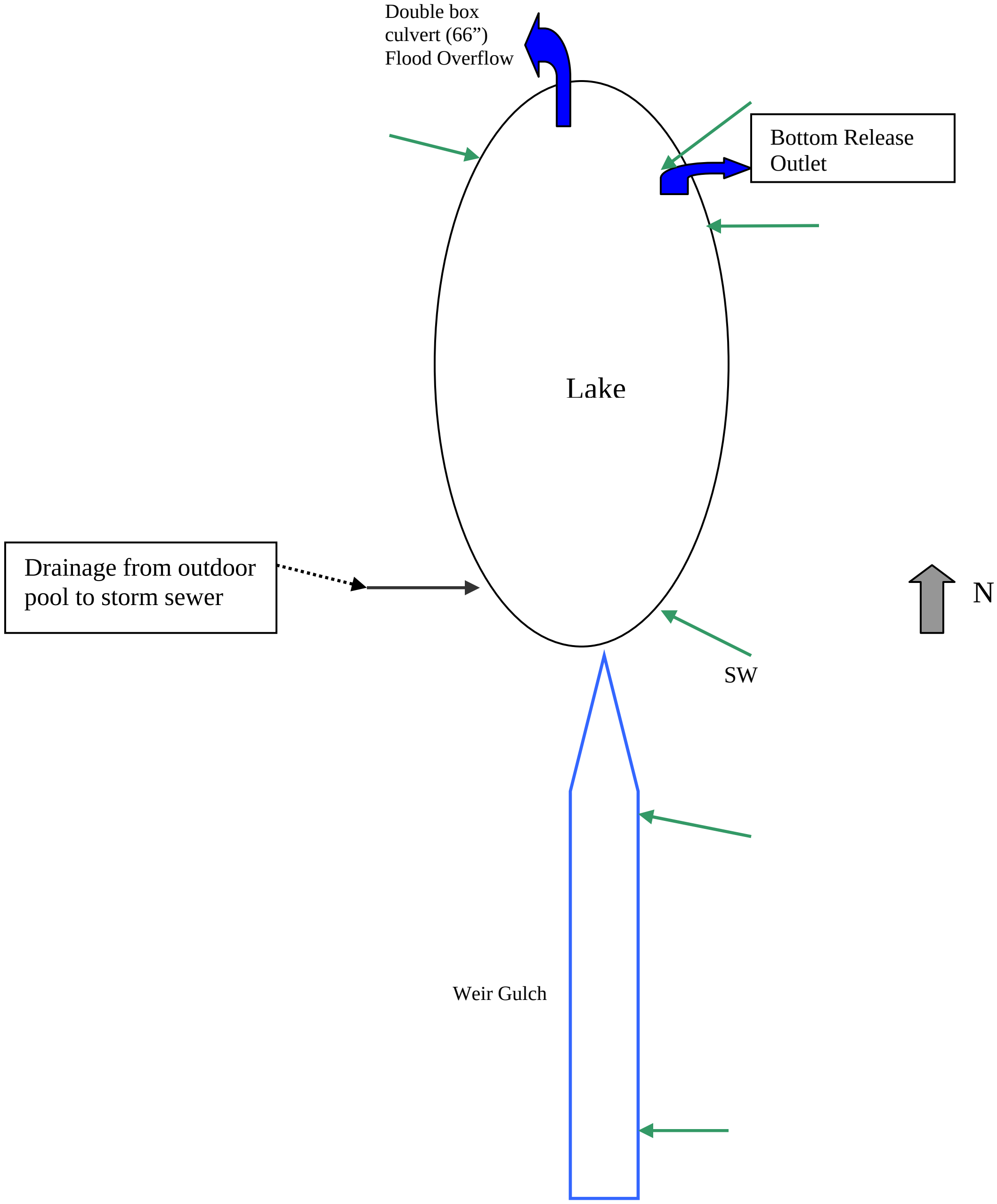
Rocky Mountain Flow Pattern



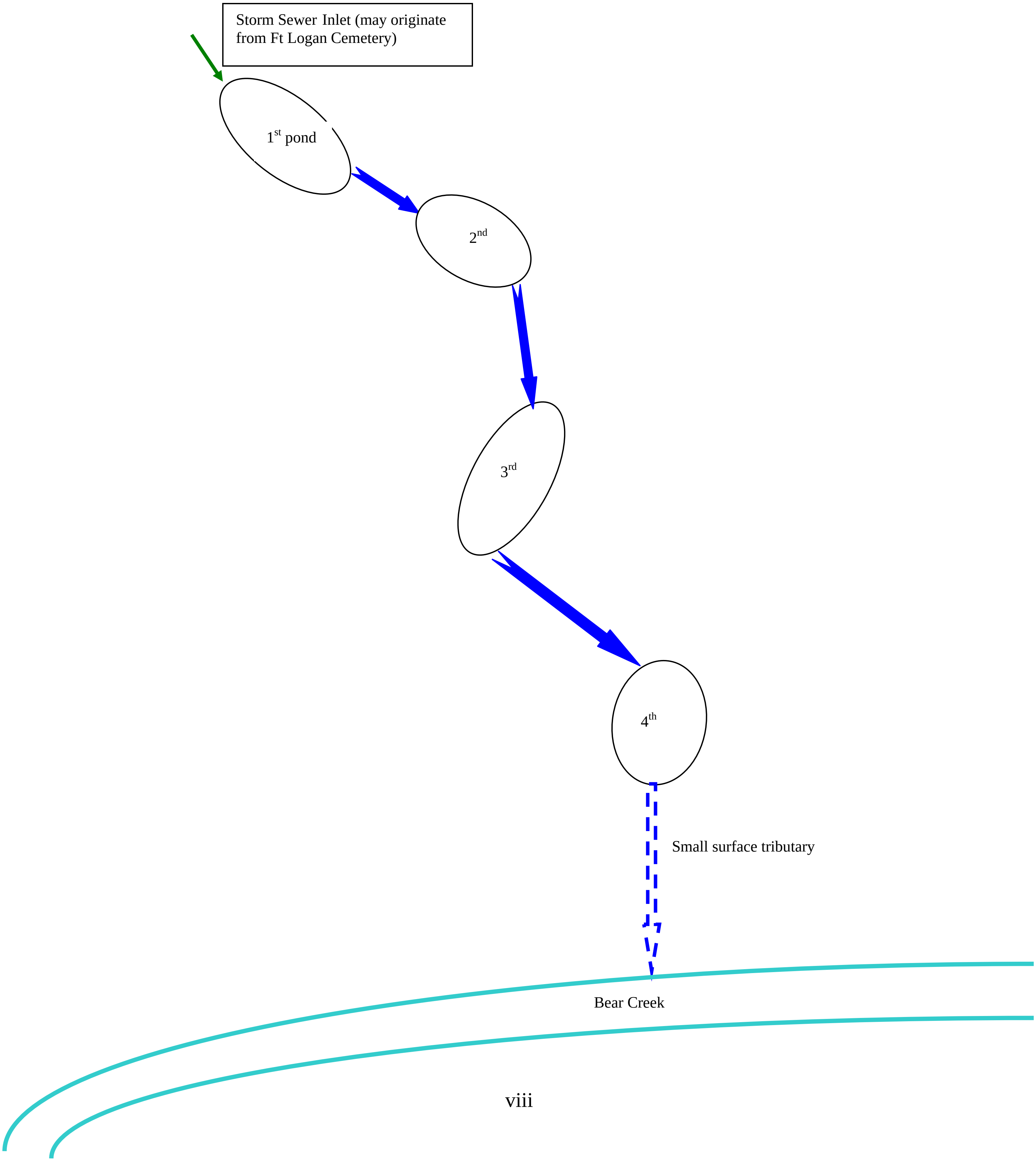
Sloan Flow Pattern



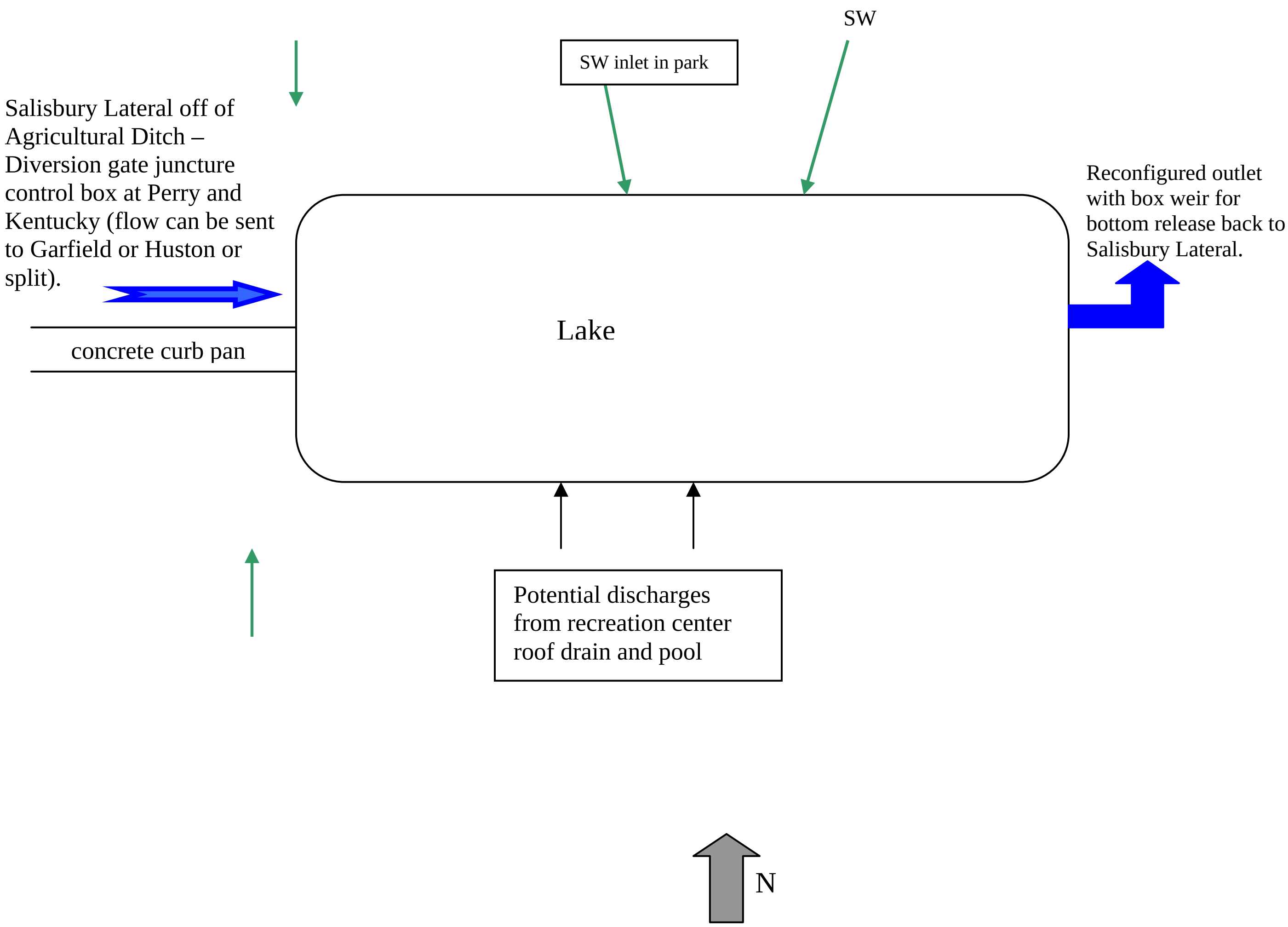
Barnum Flow Pattern



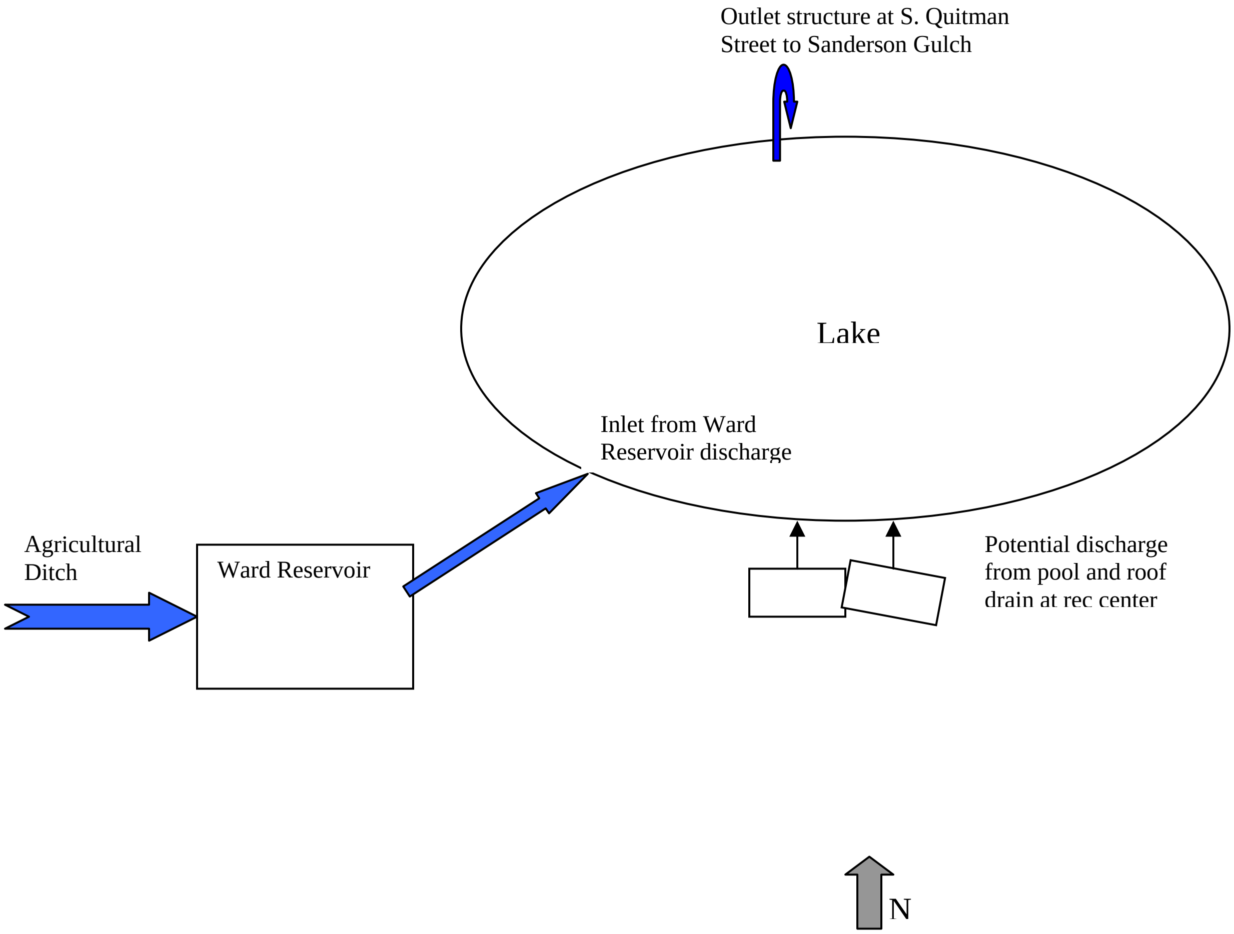
Bear Creek Ponds Flow Pattern



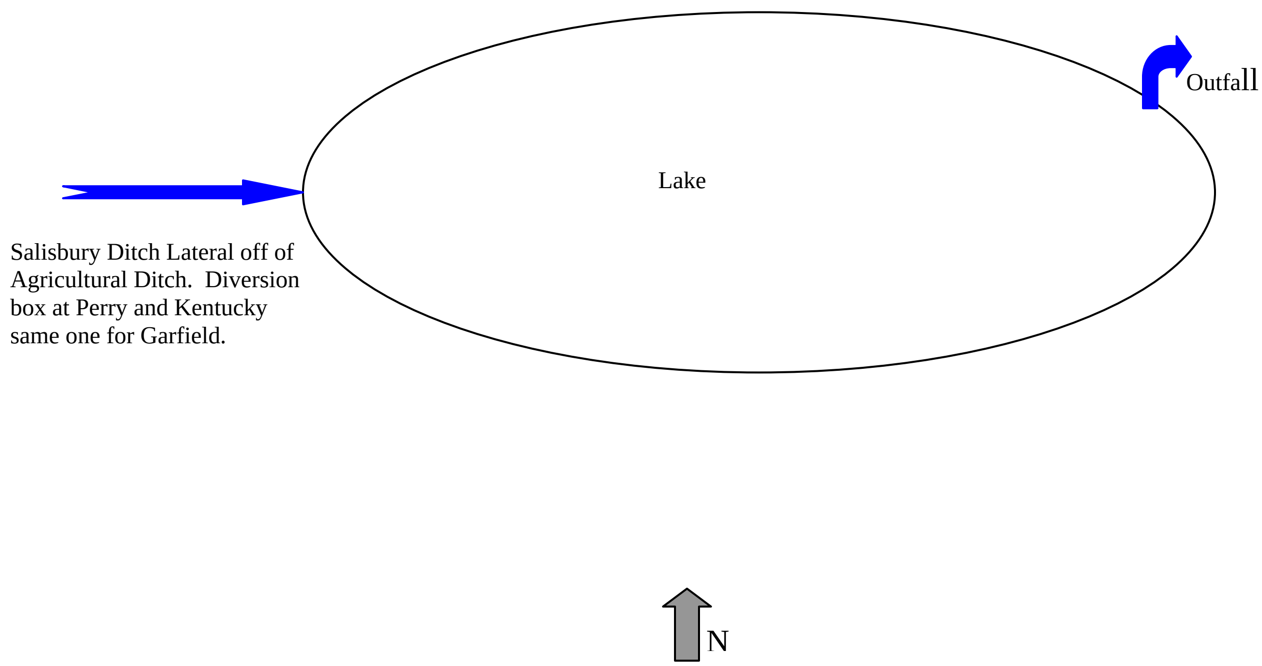
Garfield Flow Pattern



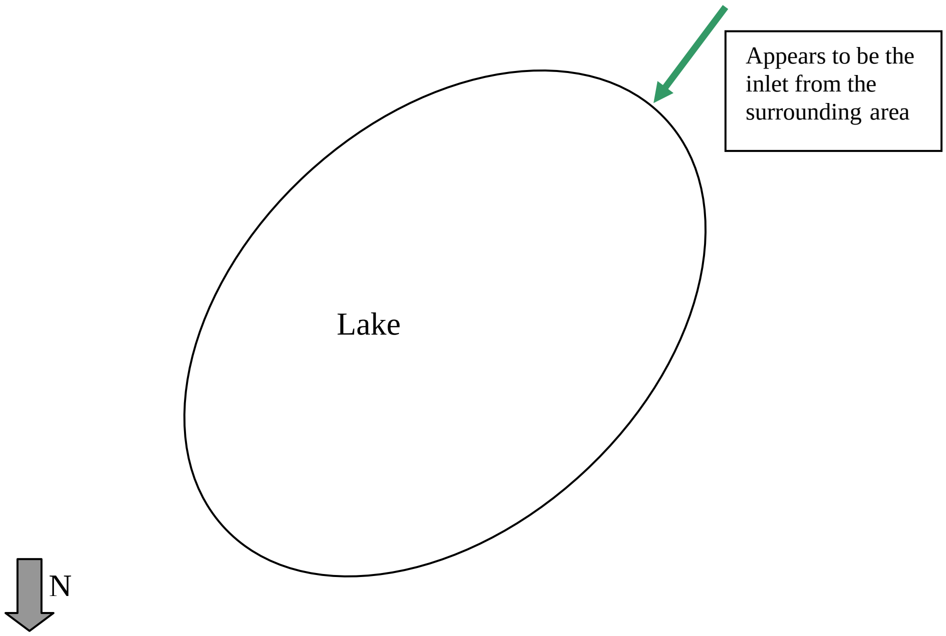
Harvey Flow Pattern



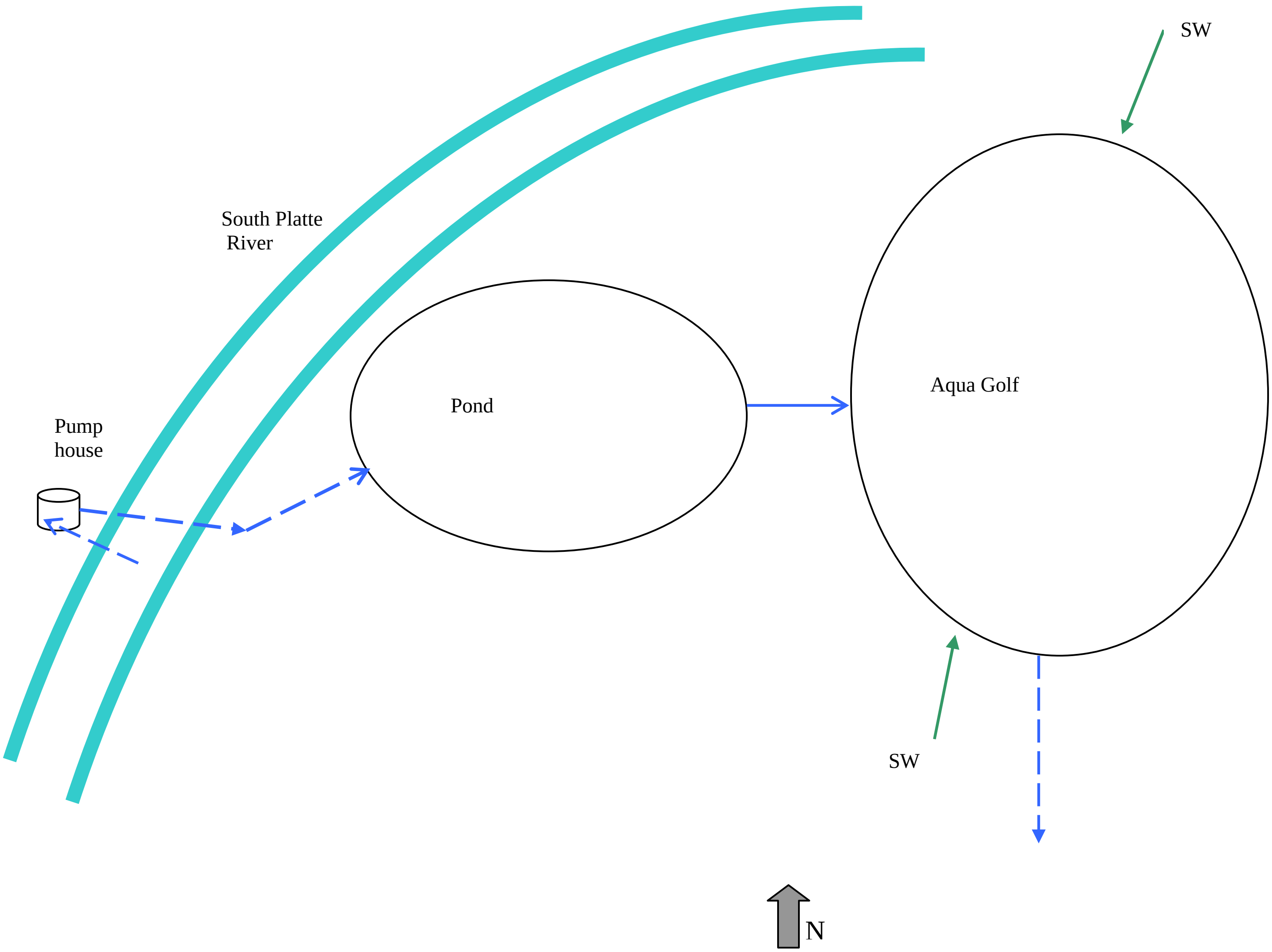
Huston Flow Pattern



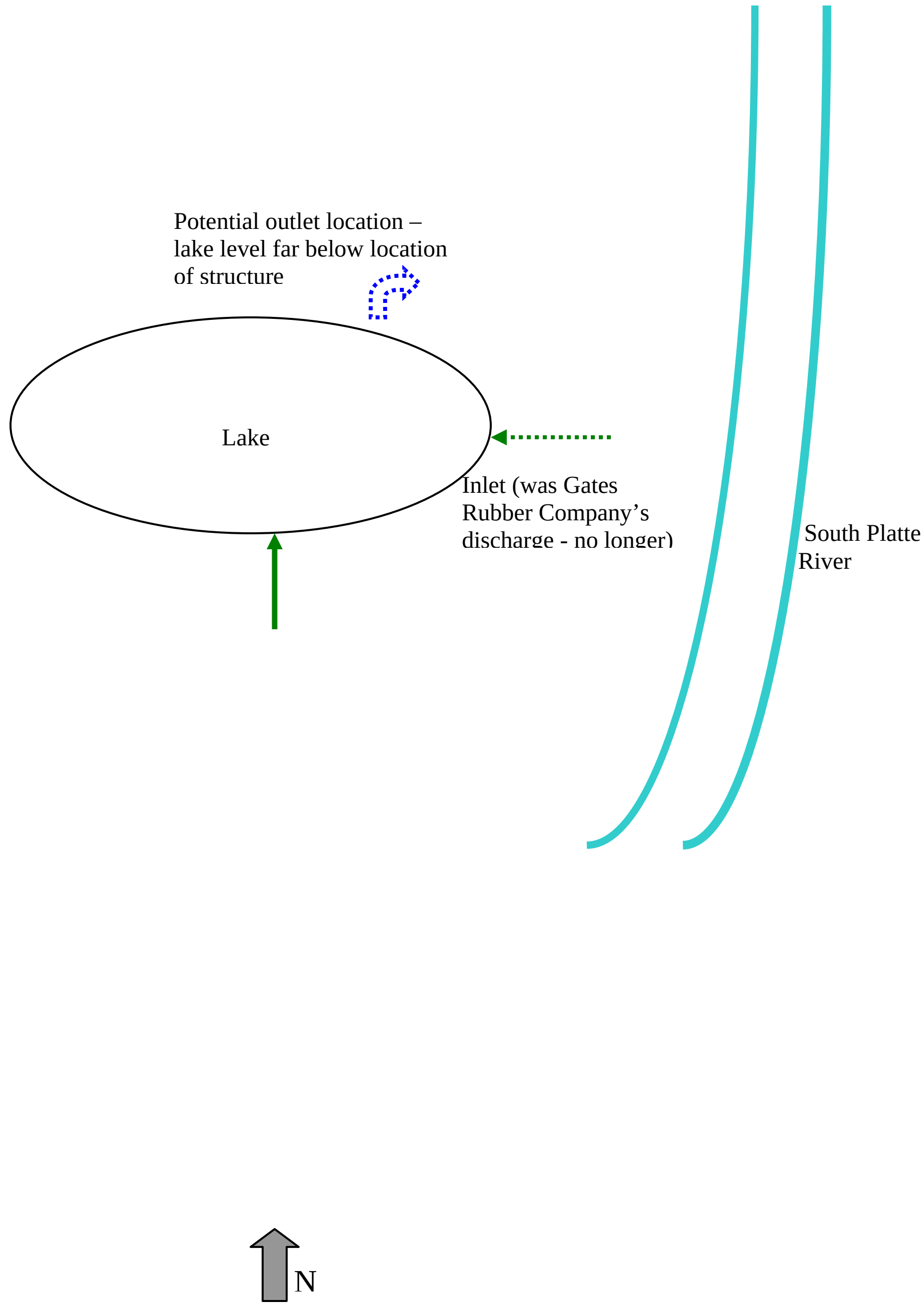
Lake of Lakes Flow Pattern
(A.K.A. Little Lake Henry)



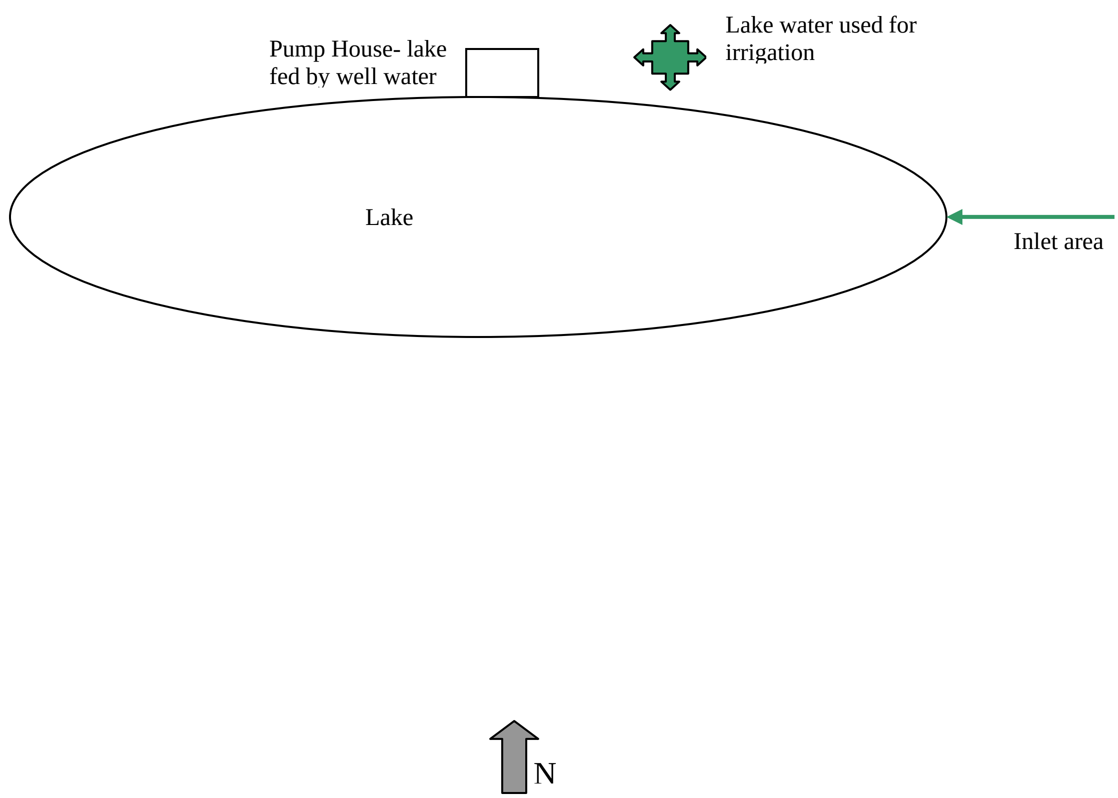
Overland Ponds Flow Pattern



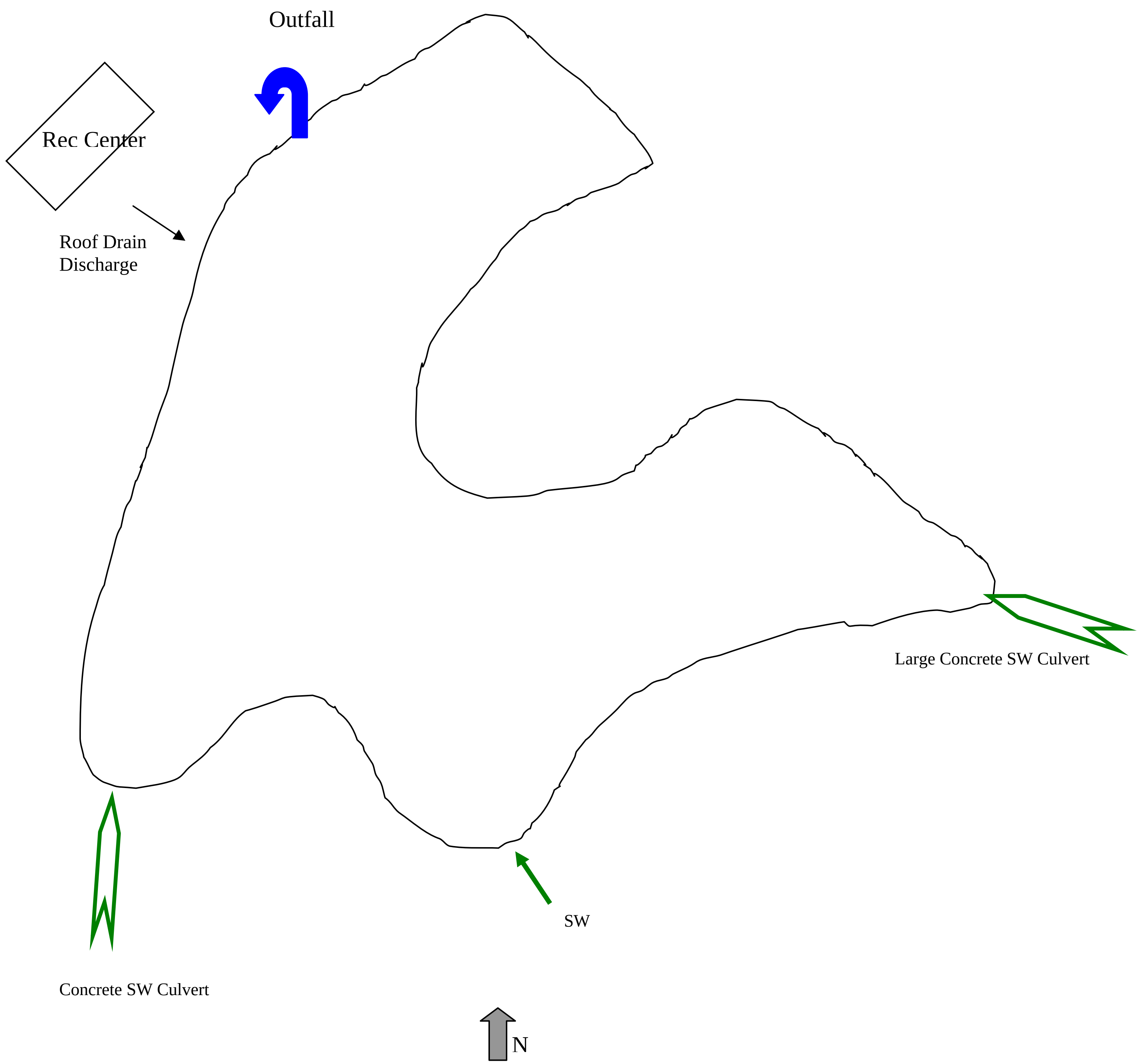
Vanderbilt Flow Pattern



Lollipop (Garland Park) Flow Pattern



Parkfield Lake Flow Patterns



Appendix B
TSI Calculated Values for Urban Denver Lakes

Calculations:	
chlorophyll-a	**= 9.81*(LN(chlora))+30.6**
secchi	**= 60-(14.41* ln(SD*m*))**
total-P	**= 14.42*ln(total-P*ug/L*)+4.15**
secchi: X*in* * 0.0254 = *m*	

TSI classifications	
status	**value**
oligo	**<40**
meso	**41-50**
eutro	**51-70**
hypereutro	**>70**

			TSI values	
lake	**date**	**secchi**	**tot-P**	**Chl-a**
Barnum	1/19/00			
Barnum	6/19/00	70	77	
Barnum	6/20/01	69	78	75
Barnum	6/18/02	69	80	74
Barnum	6/11/03	67	73	70
Berkeley	7/9/98	69	74	
Berkeley	7/7/99	64	75	
Berkeley	6/28/00	74	76	
Berkeley	6/25/01	68	81	63
Berkeley	4/23/02	85	89	74
Berkeley	6/20/02	72	81	66
Berkeley	10/15/02	75	84	67
Berkeley	6/19/03	72	80	65
Ferril	6/23/98	62	64	
Ferril	6/16/99	65	71	
Ferril	6/21/00	61	71	
Ferril	6/27/01	61	71	53
Ferril	7/30/01	64	71	60
Ferril	4/29/02	59	71	51
Ferril	6/25/02	50	76	47
Ferril	10/22/02	68	72	70
Ferril	5/20/03	62		59
Ferril	7/8/03	67	71	64
Ferril	10/8/03	61		72
Duck	6/23/98	69	81	
Duck	6/16/99	72	75	
Duck	6/21/00	73	98	
Duck	6/27/01	65	81	68
Duck	7/30/01	68	80	71
Duck	4/29/02	61	107	46
Duck	6/25/02	61	87	65
Duck	7/8/03	55	106	60
Garfield	8/12/98	55	64	
Garfield	7/14/99	57	71	
Garfield	7/12/00	63	71	
Garfield	7/19/01	55	71	56
Garfield	4/18/02	56	71	46
Garfield	7/1/02	63	63	53

			TSI values	
lake	date	secchi	tot-P	Chl-a
Garfield	6/25/03	64	64	44
Grasmere	6/30/98	63	63	
Grasmere	6/23/99	62	71	
Grasmere	7/10/00	65	71	
Grasmere	7/16/01	64	71	61
Grasmere	6/26/02	68	72	60
Grasmere	7/1/03	77	93	72
Harvey	7/8/98	69	78	
Harvey	6/30/99	53	71	
Harvey	7/6/00	61	69	
Harvey	6/21/01	53	71	45
Harvey	7/1/02	62	68	51
Harvey	7/10/03	70	95	64
Huston	6/24/98	74	79	
Huston	6/28/99	76	75	
Huston	7/6/00	71	67	
Huston	6/21/01	72	76	64
Huston	6/25/03	60	63	35
Lollipop	7/6/98	62	65	
Lollipop	6/30/99	70	73	
Lollipop	6/19/00	69	73	
Lollipop	6/20/01	70	71	61
Lollipop	6/18/02	51	71	46
Lollipop	6/11/03	71	66	67
Overland	7/1/98	70	92	
Overland	7/12/99	72	83	
Overland	7/19/00	68	84	
Overland	7/18/01	71	94	74
Overland	7/9/02	73	108	
Overland	6/17/03	77	100	80
Rocky Mntn	8/19/98	49	76	
Rocky Mntn	7/7/99	49	76	
Rocky Mntn	6/28/00	44	77	
Rocky Mntn	8/3/00	45	73	
Rocky Mntn	6/25/01	64	71	64
Rocky Mntn	6/20/02	42	70	47
Rocky Mntn	6/19/03	46	70	57
Sloan	4/30/98		71	
Sloan	5/18/98			
Sloan	6/1/98		77	
Sloan	6/22/98		75	
Sloan	6/29/98		86	
Sloan	7/14/98	87	82	
Sloan	7/27/98		71	
Sloan	8/11/98		74	

			TSI values	
lake	**date**	**secchi**	**tot-P**	**Chl-a**
Sloan	5/11/99		79	
Sloan	5/24/99		76	
Sloan	6/7/99		77	
Sloan	6/22/99	78	80	
Sloan	5/9/00		73	
Sloan	7/17/01		81	
Sloan	7/10/02		78	
Sloan	6/12/03		77	
Smith	4/30/02	60	71	58
Smith	6/26/02	60	74	62
Smith	10/22/02	62	57	63
Smith	5/20/03	66		58
Smith	7/1/03	61	75	59
Smith	10/8/03	63		66
Vanderbilt	6/24/98	46	81	
Vanderbilt	6/28/99	69	71	
Vanderbilt	7/12/00	68	76	
Vanderbilt	7/19/01	66	71	69
Vanderbilt	5/30/02	71	83	
Vanderbilt	7/11/02	71	78	73
Vanderbilt	6/23/03	62	65	79
Little Henry	6/28/01		71	

Appendix C
Glossary

The following definitions are from one of two resources; *Managing Lakes and Reservoirs* (Holdren, C., et al. 2001) or Water on the Web - Monitoring Minnesota Lakes on the Internet and Training Water Science Technicians for the Future (WOW, 2003).

Algae:
Small aquatic plants that occur as single cells, colonies, or filaments. They contain chlorophyll but lack special water-carrying tissues. Through the process of photosynthesis, algae produce most of the food and oxygen in water environments.

Benthic:
Refers to life or things found on the bottom of a lake. Examples: benthic animals, benthic sediment.

Benthos:
Macroscopic (seen without aid of a microscope) organisms living in and on the bottom sediments of lakes and streams. Originally, the term meant the lake bottom, but it is now applied almost uniformly to the animals associated with the substrate.

Detritus:
Organic Material composed of dead plants or animals, or parts thereof (e.g., leaves, grass clippings) that settle to the bottom of a lake. Bacteria and fugi slowly decompose detritus, thus recycling it back into the lake's ecosystem.

Epilimnion:
Uppermost, warmest, well mixed layer of a lake during summertime thermal stratisfication. The epilimnion extends from the surface to the thermocline.

Euphotic zone:
Layer of water where sunlight is sufficient for photosynthesis to occur.

Eutrophication:
The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake or reservoir that cause a water body to age. If the process is accelerated by human influences, it is termed cultural eutophication.

Flushing Rate:
The rate at which water enters and leaves a lake relative to lake volume, usually expressed as time needed to replace the lake volume with inflowing water.

Hypolimnion:
The bottom, and most dense layer of a stratified lake. It is typically the coldest layer in the summer and warmest in the winter. It is isolated from wind mixing and typically too dark for much plant photosynthesis to occur.

Hypolimnetic Oxygen Depletion:
A condition where the dissolved oxygen in the bottom layer (hypolimnion) of a water body is gradually consumed through respiration and decomposition faster than it can be replaced over the course of the summer. A similar phenomenon may occur in the winter under ice cover. The rate at which O_2 is depeleted is a measure of the productivity of the system.

Limnetic zone:
Open water zone.

Littoral:
The shallow zone along the shore of a lake: that portion of a water body extending from the shoreline lakeward to the greatest depth occupied by rooted plants. Plants growing here support a rich biological community.

Metalimnion:
The middle or transitional zone between the well mixed epilimnion and the colder hypolimnion layers in a stratified lake. This layer contains the thermocline but is loosely defined depending on the shape of the temperature profile.

Lake Management:
The practice of keeping lake quality in a state such that attainable uses can be achieved.

Lake Protection:
The actof preventing degradation or deterioration of attainable uses.

Lake Restoration:
The act of bringing a leake back to its attainable uses.

Macroinvertebrates:
Aquatic insects, worms, clams, snails, and other animals visible without the aid of a microscope, that may be associated with or live on substrates such as sediments and macrophytes. They supply a major portion of fish diets and consume detritus and algae.

Macrophytes:
Plants large enough to be seen without magnification. Some forms, such as duckweed and coontail (Ceratophyllum), are free-floating forms without roots in the sediment.

Phytoplankton:
Microscopic algae and microbes that float freely in open water of lakes and oceans. In some lakes, they provide the primary base of the food chain for all animals. They also produce oxygen by a process called photosynthesis.

Plankton:
Small, mostly microscopic plants and animals that are too small to outswim most currents, so the movement of water tends to move them from place to place. Plankton consists of phytoplankton (plankton plants) and zooplankton (platonic animals).

Plantivores:
Fish and invertebrates that collectively prey on zooplankton.

Shoreline:
The zone where lake and land meet.

Shorelands:
Are defined as the lands that extend 1000 ft from the ordinary high water level.

Trophic State:
Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Watershed:
A drainage area or basin in which all land and water areas drain or flow towards a central collector such as a stream, river, or lake at a lower elevation.

Zooplankton:
Microscopic animals that float freely in lake water, graze on detritus particles, bacteria, and algae, and may be consumed by fish.

Appendix D
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Additional Web Sites

City and County of Denver
www.denvergov.org/DEH
www.denvergov.org/Parks_Recreation
www.denvergov.org/PublicWorks
www.water.denver.co.gov

To Obtain a Copy of the EPA Brochure *Wetlands and West Nile Virus*

http://www.epa.gov/epahome/pubsearch.html
Publication Number - EPA-843-F-03-012
Hard Copy Order

Or

www.valleywater.org/media/pdf/WestNile_epa.pdf
Santa Clara Valley Water District, Santa Clara County, CA
Downloadable Version

To access a downloadable copy of *Techniques for Mitigating Human/Goose Conflicts in Urban & Suburban Environments – Habitat Modification & Canada Geese*

www.animalalliance.ca

Additional Information on Geese

www.geesepeace.org/integratedsolutions.html