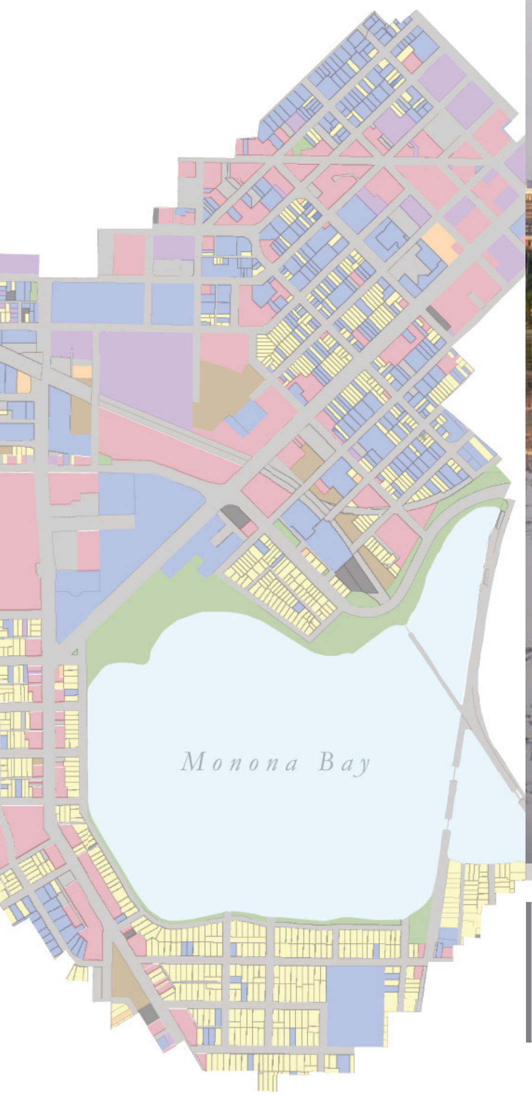
Enhancing an Urban Resource: Watershed Assessment and Management Plan for Monona Bay, Madison, Wisconsin



2007
Water Resources Management Practicum 2006
Nelson Institute for Environmental Studies
University of Wisconsin–Madison

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A note about Web sites

All URLs in this document were current at the time of publication.

The Water Resources Management Practicum is a regular part of the curriculum of the Water Resources Management (WRM) Graduate Program at the University of Wisconsin–Madison. The workshop involves an interdisciplinary team of faculty members and graduate students in the analysis of a contemporary water resources problem.

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ABBREVIATIONS

AMP Adaptive Management Plan

BMAA Beta-N-methylamino-L-alanine

BMPs Best Management Practices

CAPD Community Analysis and Planning Division

CBSQG WDNR Consensus-Based Sediment Quality Guidelines

CDS Continuous Deflective Separation device

CFL Center for Limnology

CLA Clean Lakes Association

CLP Curly Leaf Pondweed

DRO Diesel Range Organics

EPA Environmental Protection Agency

EWM Eurasian water milfoil

FOMB Friends of Monona Bay

FQI Floristic Quality Index

GIS Geographic Information System

LEI Lake Evaluation Index

LID Low Impact Development

MDCDPH Madison Dane County Department of Public Health

MEC Midpoint Effect Concentration

MS4 Municipal Separate Storm Sewer System

NPDES National Pollutant Discharge Elimination System

OM Organic Matter

PAH Polycyclic Aromatic Hydrocarbons

PCB Polychlorinated Biphenyl

PEC Probable Effect Concentration

PSI Pump Systems Inc.

SD Secchi depth

SDI Simpson Diversity Index

SLAMM Source Loading and Management Model

SLOH State Lab of Hygiene

SPAL Wisconsin Soil and Plant Analysis Laboratory

SRP Soluble Reactive Phosphorus

TAPE Technology Assessment Protocol – Ecology (Washington State)

TARP Technology Acceptance and Reciprocity Partnership (8-state partnership)

TEC Threshold Effect Concentration

TSS Total Suspended Solids

USGS United States Geological Survey

UW University of Wisconsin–Madison

UWEX University of Wisconsin Extension

WDNR Wisconsin Department of Natural Resources

WPDES Wisconsin Pollutant Discharge Elimination System

WRM Water Resources Management

CONVERSION FACTORS

Some of the measurements in this report are in the metric system. For those readers who may prefer to use inch–pound (U.S. customary) units, the following table provides conversion factors for International System (SI) of units and abbreviations for terms used in this report.

To convert from	To	Multiply by
millimeter (mm)	inch (in.)	0.03937
centimeter	inch	0.3937
meter (m)	foot (ft)	3.281
kilometer (km)	mile (mi)	0.6214
gram (g)	ounce (oz)	0.03527
kilogram (kg)	pound (lb)	2.205
liter (L)	gallon (gal)	0.26417

PREFACE

The Water Resources Management (WRM) Master's degree program in the Gaylord Nelson Institute of Environmental Studies at the University of Wisconsin–Madison hosts a year-long Practicum (also known as Workshop) as an applied learning opportunity for WRM graduate students. Since the 1960s, workshops have addressed complex water resources management issues in a wide range of settings from Native American Indian Reservations in rural northern Wisconsin to urban watersheds in large cities.

All graduate students in the Water Resources Management program must complete the WRM Practicum in order to earn their Master's degree. The practicum is completed using a hands-on approach in which students gain practical experience tackling real world water resource issues through in-depth study and a professional publication of results. Workshop participants spend the spring planning the project and the summer and fall executing the project.

We, the students of the 2006 WRM Practicum, completed a comprehensive study of Monona Bay and its watershed in Madison, Wisconsin, and made management recommendations based on our findings. The 2006 Practicum was funded by a Lake Planning Grant from the Wisconsin Department of Natural Resources through the Dane County Office of Lakes and Watersheds by the Friends of Monona Bay.

Participants in the 2006 WRM Practicum

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Faculty Advisor for the 2006 WRM Practicum

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EXECUTIVE SUMMARY

Monona Bay and Watershed

Monona Bay is a 187-acre water body located near the downtown of Madison, Wisconsin. It sits on the southwestern edge of the 3,300-acre Lake Monona, one of four glacial lakes (the Yahara Lakes) in the region. The bay is partly separated from Lake Monona by two elevated causeways at its east end, John Nolen Drive, and the Wisconsin and Southern Railroad tracks (built in the 1960s and 1860s, respectively). The causeways create two small triangular-shaped water bodies that are considered part of Monona Bay.

Over the past 150 years, the physical shape and ecological health of the bay have been significantly altered. The originally shallow bay was edged by natural wetlands and had abundant aquatic plants. As Madison began to grow, the bay suffered much abuse. Green scum, dead fish and kitchen garbage plagued the bay during the early years of modern settlement. At the turn of the last century, parts of the bay were dredged to fill land for Brittingham Park and for the development of homes along West and South Shore Drives. During the first half of the twentieth century, treated and untreated sewage were discharged into Lake Monona, and several chemicals were used to control algae. In the 1960s, an exotic invasive aquatic plant, Eurasian water milfoil, first arrived in the Yahara Lakes. It established a significant presence in the bay and persists today.

As the City of Madison and the University of Wisconsin–Madison developed in the Monona Bay watershed, stormwater inputs to the bay from the 1,100-acre highly developed watershed also began to contribute to the bay's problems. Runoff from roads, buildings, and lawns carries sediment, nutrients, toxic metals, trash, and other pollutants into the bay. Although analysis of sediment samples indicated that management practices such as street sweeping appear to have reduced some of the negative impacts of stormwater in recent years, stormwater still significantly affects the health of the bay.

The bay is often choked with floating mats of vegetation and filamentous algae, but public perceptions of the issues complicate management strategies. Monona Bay is frequently used for recreation by boaters, fisherman, and others enjoying the water and the shoreline.

The Friends of Monona Bay (FOMB) funded our watershed assessment and management plan project. We identified and addressed management concerns about the bay and gathered specific information in regard to stormwater issues, water quality, biotic management, and public outreach. Building upon this research, we assessed potential management strategies to address the issues identified and developed a set of recommendations based on the strategies with the most promise to improve conditions.

Stormwater

Sediment accumulation near stormwater outfalls is a frequently repeated concern voiced by the FOMB and nearby residents. In addition to concerns about sediment volume, water-quality impacts from sediment inputs (which carry attached pollutants like heavy metals) are also of concern. Probable major sources of sediment and particles in stormwater include poorly controlled runoff from construction sites, winter street sanding, erosion from non-landscaped areas, atmospheric deposition, and particle buildup in streets from vehicular traffic.

We used the Source Loading and Management Model (SLAMM) to estimate the effects of land use on stormwater volumes and suspended sediment loads in the Monona Bay watershed. The model was used to identify stormwater basins that contribute disproportionately higher loads of sediment per area. As expected, the model showed that the stormwater basins with higher densities, more commercial land, and greater impervious surfaces contributed a disproportionately higher amount of sediment and runoff volume compared to their area. The analysis found that the two basins draining into the north triangle are the most urban and contribute the most suspended solids compared to their area of the watershed. These basins could benefit from targeted stormwater-management practices. Additional research into settling within the triangle and circulation between the lake, triangle, and bay would be helpful. The triangle area may act as a sedimentation pond for the runoff from these two basins. Additional areas that could benefit from the installation of targeted stormwater-quality-treatment systems were the commercial districts along

Park and Regent Streets and around the University, as well as the Erin Street outfall basin, which is dominated by the St. Mary's Hospital Complex.

Development of a City of Madison Stormwater Master Plan could improve the quality of stormwater entering Monona Bay by identifying locations where the most benefit could be achieved for the cost of installing stormwater-treatment devices or using innovative stormwater-management techniques. In addition, providing incentives for the use of innovative stormwater-management techniques could expand their application and improve the quality of Monona Bay.

Key Recommendations

- Create an erosion-control hotline and require posting at construction sites.
- Expand promotion of pollution prevention.
- Expand and enhance litter prevention and clean-up programs.
- Expand and enhance street sweeping.
- Expand stormwater outfall maintenance.
- Develop a City of Madison Stormwater Master Plan.
- Expand stormwater components of Madison Gre²en Commitment.
- Provide incentives for innovative stormwater management.
- Develop a comprehensive environmental sustainability program at University of Wisconsin–Madison.
- Develop a Stormwater Treatment Device Testing Protocol for Wisconsin.

Shoreline

The shoreline survey we conducted indicated that Monona Bay's shoreline is approximately 70 percent riprapped; the remaining 30 percent consists of beaches and natural shoreline, primarily in the southeast corner of the bay. Of the vegetation growing along the bay's shoreline, especially within Brittingham Park, the most abundant plant species are invasive reed canary grass (*Phalaris arundinacea)*, sweet yellow clover (*Melilotus officinalis*), sweet white clover (*Melilotus alba*), and trefoil (*Lotus corniculata*). Several non-native and native shrubs and hardwood trees were also present. These non-native and invasive plants disrupt the functions of native plant communities and provide low-quality habitat for the waterfowl and wildlife that use Monona Bay.

Key Recommendations

- Restore the shoreland area in Brittingham Park to low-profile wet prairie with vegetation native to Wisconsin.
- Incorporate the FOMB, the City of Madison Parks Division, and residents of the bay's watershed into the restoration and management process.
- Employ adaptive management techniques.

Aquatic Plants

We analyzed aquatic plant data collected in the early 1990s and in 2005, conducted our own plant survey in early summer 2006, and assisted the City later that summer with a third survey. The purpose of the surveys was to build a reliable aquatic plant trend dataset for Monona Bay that could be used to monitor the effectiveness of the water circulators.

In all the surveys, the most common species at each vegetated sampling point were (in order of frequency): coontail, Eurasian water milfoil, and curly leaf pondweed. Comparing the early summer 2006 results with those from the 2005 and 2006 late season surveys showed an increase in species richness earlier in the summer. Likewise, the early summer survey results also had higher Floristic Quality Index and Simpson Index ratings than the two late season surveys. These results suggest that sampling in mid-August is too late to capture maximum species diversity in the bay. There also appears to be a slight trend of increasing aquatic plant diversity in Monona Bay since 1990, although the data were not conclusive. Data from Lake Monona and the other Yahara Lakes indicate they are rebounding somewhat from invasion by the two aquatic exotics, Eurasian water milfoil and curly leaf pondweed. Although Eurasian water milfoil made up the largest component of the vegetation in the Madison lakes in the 1960s, it has leveled off over the last decade and the diversity of native species has become greater as water clarity improves. Because the lake's sediments contain large quantities of nutrients, aquatic plants will continue to be abundant, particularly if water clarity continues to improve.

Key Recommendations

- Develop a more intensive harvesting program to address problems with aquatic plants and filamentous algae in Monona Bay.
- Conduct a long-term trial of small-scale, early-spring chemical treatments that target curly leaf pondweed and Eurasian water milfoil to assess the potential for native plants to rebound.
- Control stormwater runoff and reduce external nutrient loading to the bay to minimize algae blooms and nutrient accumulation.
- Continue water-quality monitoring to identify ecosystem changes.
- Encourage volunteers to gather data through the Wisconsin Department of Natural Resources (WDNR) Citizen Lake Monitoring Network to build trends data for the bay over time.
- Continue annual aquatic plant surveys using the WDNR sampling protocol to document changes in the bay's plant community over time.

Water Quality and Sediments

Although few historical data are available about Monona Bay's water quality, it appears typical of other urbanized, shallow, eutrophic water bodies. Consequently, the main water-quality-management challenges facing the bay include eutrophication, elevated levels of fecal bacteria, and the potential for toxic blue-green algae blooms.

We analyzed three previous efforts of water-quality data collection within Monona Bay: 1) the City of Madison's longtime monitoring of public beaches, 2) WDNR Self-Help Citizen Lake Monitoring Network, and 3) the City Engineering Division's SolarBee monitoring plan.

Between 1995 and 2006, the two public beaches on Monona Bay were closed four times due to elevated levels of fecal bacteria found by the Madison Department of Public Health. Beaches were also closed during this time as precautionary measures following excessive rains or other events that may cause an increase in bacteria levels.

Despite the publicity that blue-green algae has received in recent years as a potential threat to recreational usage of Madison lakes, no beach on Monona Bay has been closed due to detected high levels. Data collected by the City of Madison in 2005 and 2006 show that blue-green algae in Monona Bay are seldom present at levels more than 100,000 cells/mL during the active swimming season. However, levels close to 200,000 cells/mL, considered high risk by the World Health Organization, were found once in the bay in October 2005. The 2006 late-season blooms were not as prolific, but still reached counts higher than 100,000 cells/mL.

The June 2006 survey identified filamentous algae at 237 of the 330 sample points, with a frequency of occurrence of 73 percent. This survey is the only one to date that has recorded filamentous algae abundance in Monona Bay.

We analyzed two sets of cores taken by the WDNR in 1988 and 1992, and on June 19, 2006, we collected three sediment cores. Our coring is the deepest of all the efforts and provided the only true background data for Monona Bay available. We found that although historic levels of all pollutants were high deeper in the sediment samples, current levels of PCB and mercury concentrations were not found to be a problem. Copper and lead contamination associated with stormwater runoff continues to be a problem in the Monona Bay watershed. Levels of arsenic, zinc, and PAHs were also found to be high enough to possibly pose a threat to benthic macroinvertebrates, according to the WDNR guidelines.

Key Recommendations

- Continue water-quality monitoring in the bay at the same frequency, at the same sampling sites, and for the same list of chemical and physical parameters as begun in 2005 by the City of Madison.

- Calculate the trophic state index for Secchi depth, chlorophyll-a, and total phosphorus on an annual basis and graph these results in comparison with previous years. Such an index allows for the classification of nutrient enrichment or eutrophication of a lake over time.
- Provide trophic state index data online for public access.

Education and Outreach

To gain a greater understanding of Monona Bay's stakeholders, we conducted a survey covering four main topics: Monona Bay usage, Monona Bay quality, management of Monona Bay, and information about the respondents. The survey aimed to identify the various recreational uses of the bay, perceptions of bay quality by users and residents, and support by users and residents of different management options. The survey also served as an educational tool for recipients.

The survey was distributed in June 2006 to all adjacent-bay residents (defined as those who live on or across the street from Monona Bay), to a sample of each identified user group (anglers, ice anglers, paddlers, rowers, water skiers, and park users), and to a sample of residents in each major neighborhood within the Monona Bay watershed (Regent, Vilas, Capitol, Bay Creek, Greenbush, and Bay View). The survey results indicated that a cross section of recreational users of the bay was reached.

About 73 percent of all respondents described the bay's quality as "degraded" or "poor." About 66 percent felt the quality has decreased since their first exposure to the bay. Respondents also felt that the largest problems in Monona Bay, in order of decreasing importance, were excessive aquatic plants, algal blooms, exotic plants, and trash in and around the bay. Results indicated that cutting of aquatic plants, installing stormwater filters, and removing trash are the management activities that respondents felt would increase their recreational use of the bay and that they would be most willing to support financially.

People were most interested in the following educational opportunities about lake management activities on Monona Bay: paper newsletters, Web sites, fact sheets, and digital newsletters. Respondents were least interested in videos, workshops, and speakers.

Key Recommendations

- Distribute brochures and fact sheets.
- Hold rain garden and NatureMapping workshops.
- Add ecologically focused signs around the bay and watershed.
- Add more trash receptacles; modify existing receptacles to increase use.
- Use waterway markers to slow boat traffic in slow-no-wake zones.
- Continue to expand collaboration between and among friends groups.

CHAPTER 1. INTRODUCTION

In 2005 the Friends of Monona Bay (FOMB) received a Lake Planning Grant from the Wisconsin Department of Natural Resources (WDNR) to develop a comprehensive management plan for Monona Bay. The FOMB used this grant to fund the 2006 Water Resources Management (WRM) Practicum, at the University of Wisconsin–Madison (UW–Madison). As part of this workshop, we assessed many issues affecting the bay and alternative management options for enhancing the bay.

Our main objectives were to identify and address management concerns as well as gather specific information relating to the bay in four broad categories: stormwater issues, water quality, biotic management, and public outreach. We used this research to form management strategies that address the identified issues.

1.1 Monona Bay Setting and History

The City of Madison has more than 200,000 residents and lies amid a chain of four glacially derived lakes. Lakes Mendota, Monona, Waubesa and Kegonsa are known as the Yahara Lakes (fig. 1.1). Much of the central city itself is on a narrow isthmus between Lake Mendota to the northwest and Lake Monona to the southeast.

Monona Bay is on the western edge of Lake Monona (fig. 1.1). The bay is largely isolated from the rest of Lake Monona by John Nolen Drive and railroad tracks at its east end. Part of the bay was once a wetland that has been significantly manipulated over the years. Because it is fed by stormwater from more than 1,100 acres of highly developed land, the problems Monona Bay faces are characteristic of urban lakes. Contaminants and sediment associated with stormwater, accelerated eutrophication, and invasive aquatic plants have significant impacts on this urban bay.

The current condition of Monona Bay has been shaped by its natural history as well as by those who have lived and worked around the bay during modern time. Monona Bay has likely had abundant aquatic plant growth through much of its history because its position sheltered it from the scouring action of strong waves and currents, allowing nutrient-rich sediments to accumulate in the bay and plants to grow in the shallow, light-filled water. However, the bay's historic condition has

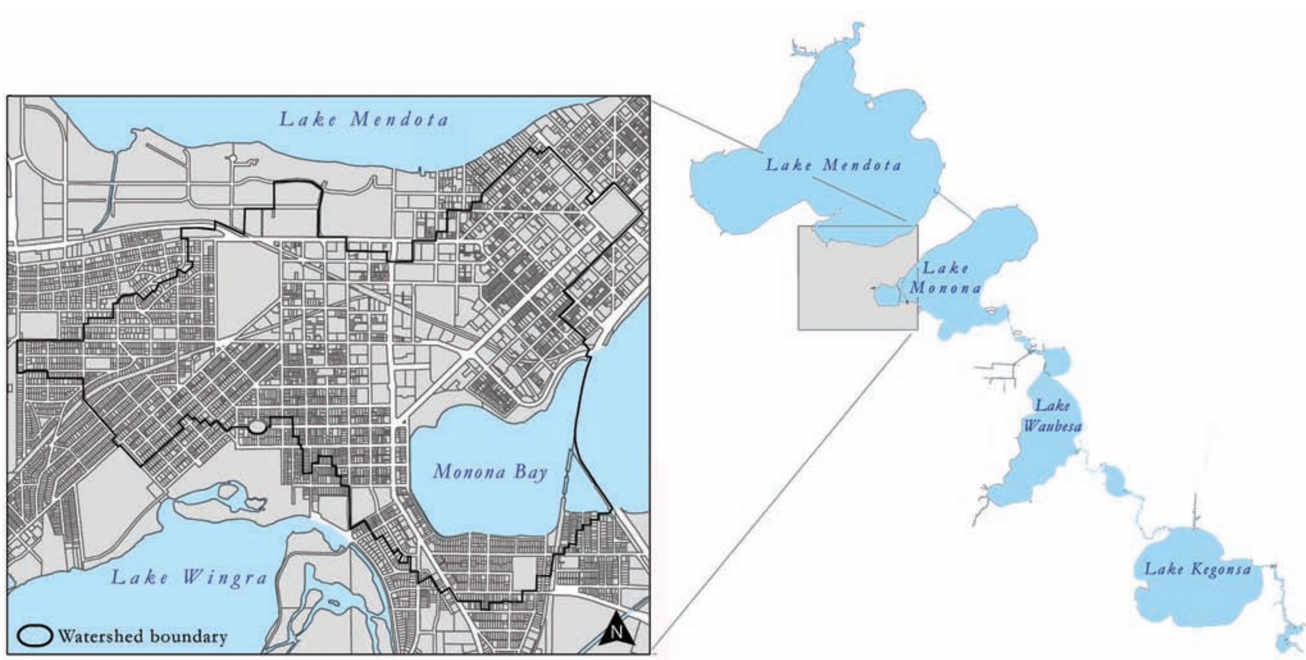


Figure 1.1. The Monona Bay watershed in relation to the Yahara Lakes. Source: City of Madison (2005).

been degraded through the impacts of development in the watershed and the influx of invasive aquatic plant species.

Early Madison developers shaped the bay into its modern form beginning in 1864, with the construction of a railroad trestle along the lakeshore of Lake Monona and across its boundary with Monona Bay (Mollenhoff, 1982). The new railroad boosted Madison's economy, and resulted in an influx of people and wealth for the city. However, typical of the day, Madison's waste-management technologies were underdeveloped. This resulted in the dispersal of the city's treated and untreated sewage into Lakes Monona and Mendota (Mollenhoff, 1982). The deficiencies of the public sewage system continued until 1928, when the present Nine Springs water-treatment plant opened and most of the sewage was more properly treated, but it was not until 1952 that all sewage effluent flowing into Mendota and Monona ceased (Mollenhoff, 1982).

The results of the bay's unnatural inputs were readily apparent. This concerned the city because nearly all Madison's visitors arrived via the new railroad (Mollenhoff, 1982). Visitors to "beautiful Madison" were greeted with green scum, dead fish, and kitchen garbage (Mollenhoff, 1982). To create a better first impression, Thomas E. Brittingham donated $24,500 to construct a park, which bears his name, along the north side of Monona Bay. Creation of this 27-acre park required more land than was available, so Monona Bay was dredged and the lake-bottom sand was used to fill the nearby marshes that would later be dressed with black soil, grass, and trees. This new land formed the present-day Brittingham Park and some of the residential neighborhoods now surrounding the bay, which previously included an extensive beach. Bernies Beach was later formed on the southeastern corner. A boathouse, which still stands today, was constructed along the northern shore and was deemed a local historic landmark in 1977 (Mollenhoff, 1982).

Despite Brittingham's efforts, the bay continued to be plagued with algae; in 1918, copper-sulfate treatments were used to control the problem. These treatments continued through the mid-1900s, when they were replaced with treatments of arsenic compounds (Mollenhoff, 1982).

The 1960s brought two additional changes to Monona Bay. First, construction of the Monona Causeway, which later became John Nolen Drive, began along the bay's shoreline—further segregating the bay from Monona proper. Second, an exotic invasive aquatic plant, Eurasian water milfoil (*Myriophyllum spicatum*), first arrived in the Yahara Lakes (Wisconsin Department of Natural Resources, 2004). Eurasian water milfoil (EWM) established a significant presence in the bay and all the Yahara Lakes, and it persists today.

As the City of Madison and the UW–Madison developed in the Monona Bay watershed, stormwater inputs also began to contribute to the bay's problems. Runoff from roads, buildings, and lawns carries sediment, nutrients, toxic metals, trash and other pollutants into the bay. Although analysis of sediment samples indicates that management practices such as street sweeping appear to have reduced some of the negative impacts of stormwater in recent years, stormwater is still a significant factor affecting the health of the bay.

As with many urban water bodies, there are considerable challenges to enhancing the health of Monona Bay. For much of the summer, the bay can be choked with floating mats of vegetation and filamentous algae. In addition, small parts of the bay are slowly filling in due to sediment from stormwater. Public perceptions of these issues complicate management strategies. However, despite its problems, Monona Bay is still a valued resource in the Madison area. It is frequently used by boaters, fisherman, and others enjoying the water and the shoreline. It provides habitat for turtles, birds, migratory waterfowl, muskrats, raccoons, and other urban wildlife, as well as for fish and other aquatic organisms. The bay has the potential to become an urban gem as management of the bay and its watershed continues to improve. The Monona Bay watershed assessment and management plan provide insight into the current conditions of the bay and options for enhancing it, in hopes of guiding actions that will transform Monona Bay into a jewel that the community enjoys and protects.

CHAPTER 2. WATERSHED FACTORS

2.1 Physical Setting

The City of Madison, home to the state government and the UW–Madison, has rapidly grown both up and out. Much of the upward growth and development is occurring in the highly urbanized Monona Bay watershed, including major parts of the University and downtown.

Monona Bay is a 187-acre water body on the western edge of the neighboring 3,300-acre Lake Monona (Dane County Community Planning and Analysis Division, 2004). Over the past 150 years, the physical shape and ecological health of the bay have been significantly altered. It was once shallower and edged by natural wetlands before being partly dredged to fill land for Brittingham Park and for the development of homes along West and South Shore Drives. The bay was also altered by the construction of two elevated causeways at its east end, which largely isolated it from Lake Monona. The Wisconsin and Southern Railroads and John Nolen Drive causeways also create two triangular-shaped areas that are considered part of Monona Bay. The north triangle is 14 acres and has two openings to the lake and one to the bay. The south triangle is 13 acres and has two openings to the rest of the bay and one to the lake.

Lake Monona and the other lakes in the Yahara chain of lakes were formed during the most recent ice age, more than 10,000 years ago. Receding glaciers left a layer of till across much of southern Wisconsin. This sand and gravel dammed the preglacial Yahara valley and created the chain of lakes. Like other lakes in the eastern part of the United States, the Yahara chain of lakes is situated on and surrounded by geologic materials that are low in phosphorus. Because the major non-anthropogenic source of phosphorus is weathering of rocks, the natural state of the Yahara Lakes is phosphorus limited.

2.2 Hydrology

The City of Madison has a temperate, sub-humid climate that has an average annual temperature of 46° F and an average annual precipitation of 33 in. (fig. 2.1). The following are high temperature and precipitation averages by the season: winter, 29°F and 1.4 in.; spring, 56°F and 2.3 in.; summer, 80°F and 4.1 in.; fall, 58°F and 2.5 in. (Wisconsin State Climatology Office, 2006). Because of a threefold difference in winter and summer precipitation, most runoff enters Monona Bay during the spring melting of snow and heavy summer thunderstorms.

The Monona Bay watershed is not defined by traditional topographical boundaries, but rather by a complex stormsewer network that drains 1,105 acres of urban landscape (fig. 2.2). The bay has no natural stream inputs; the stormsewer system conveys urban stormwater into the bay via 35 outfalls. Of these outfalls, 23 drain immediately adjacent streets and properties; the remaining 12 drain larger, more remote areas of the watershed. The largest of these outfalls drains 605 acres and empties near the Brittingham Park Pavilion. The Monona Bay watershed drains much of downtown Madison, including the State Capitol Building, the State Street downtown pedestrian mall, and 58 acres of the University campus, including the Kohl Center and Camp Randall Stadium athletic facilities.

Monona Bay also exchanges water through several other inflows and outflows. Although the extent and tim-

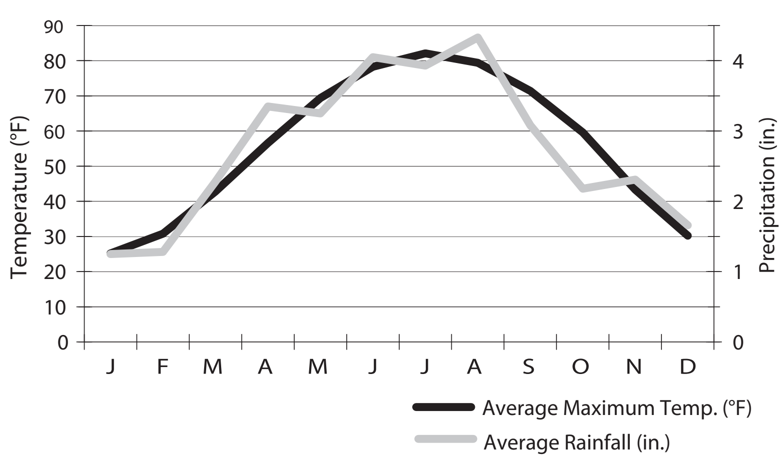


Figure 2.1. Monona Bay average precipitation and temperature. Source: Wisconsin State Climatology Office (2006).

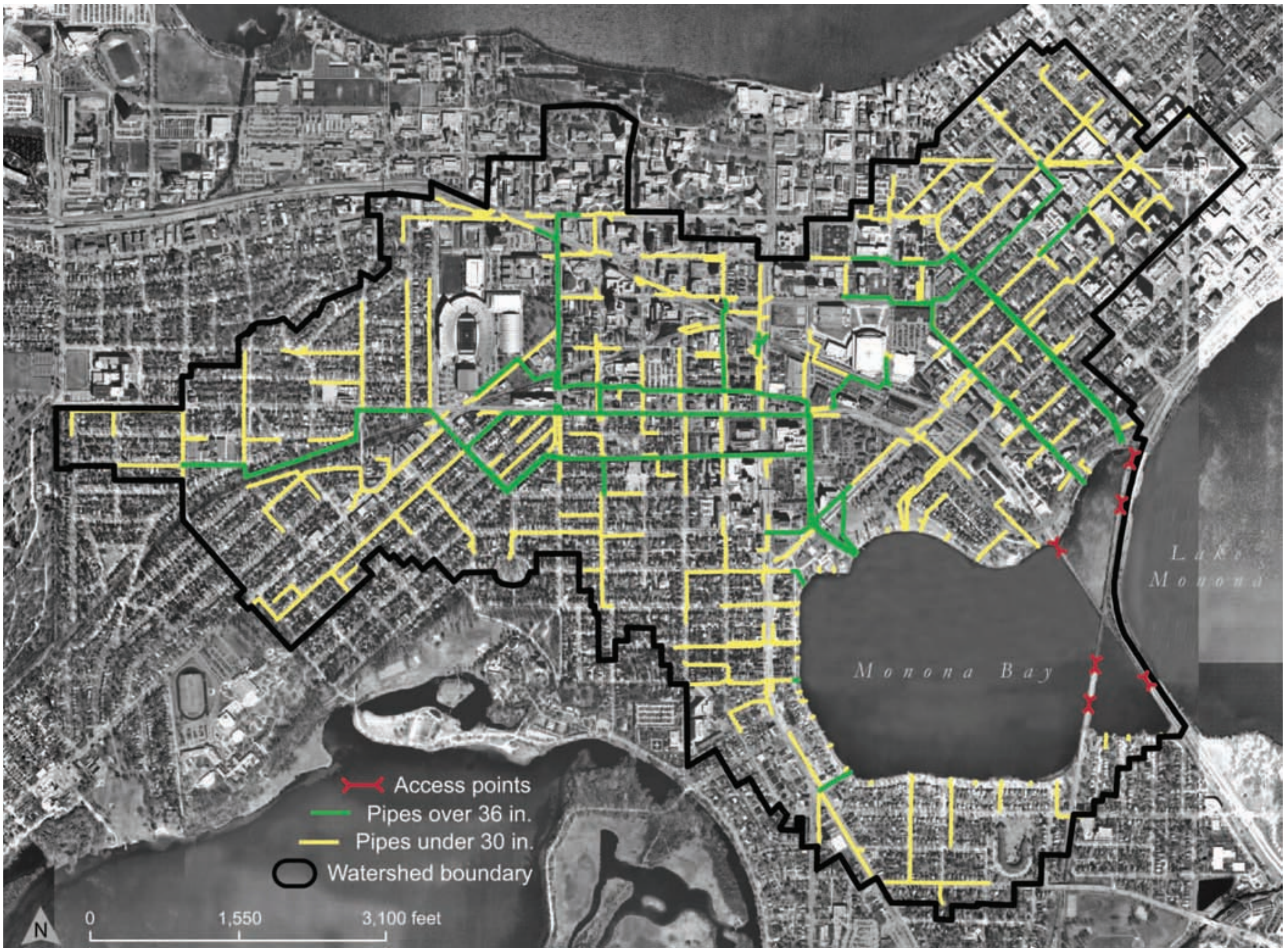


Figure 2.2. Monona Bay stormsewers and watershed. Source: City of Madison Engineering (2006).

Table 2.1. Land-use acreage in the Monona Bay watershed. Source: Dane County Community Analysis and Planning Division (2005).

Land use	Acreage	Percentage of watershed
Utilities	3	0.3
Industrial	13	1
Outdoor recreation	39	4
Commercial	115	10
Institutional/government	153	14
Transportation	371	34
Residential (total)	411	37
• *Single family*	*201*	*18*
• *Two family*	*61*	*6*
• *Multiple family*	*149*	*13*

ing of exchange to and from Lake Monona and Monona Bay have not been established, wind and precipitation play a role in water movement between the lake and bay. The hydraulic gradient of the contributing watershed, the bay, and the Yahara Lakes likely creates a significant outflow from Monona Bay to Lake Monona during rain events. However, wind may also create inflow to Monona Bay from Lake Monona under some conditions.

We attempted to measure flow between Monona Bay and Lake Monona at the railroad causeway bridge openings, but the results were inconclusive. On the calm day during which measurement was attempted in June 2006, there was no significant flow direction or velocity observed between the lake and bay. This was likely due to the weather conditions as well as the effect of the bridge structures, which create turbulence that can disturb readings from the sensitive flow-measurement

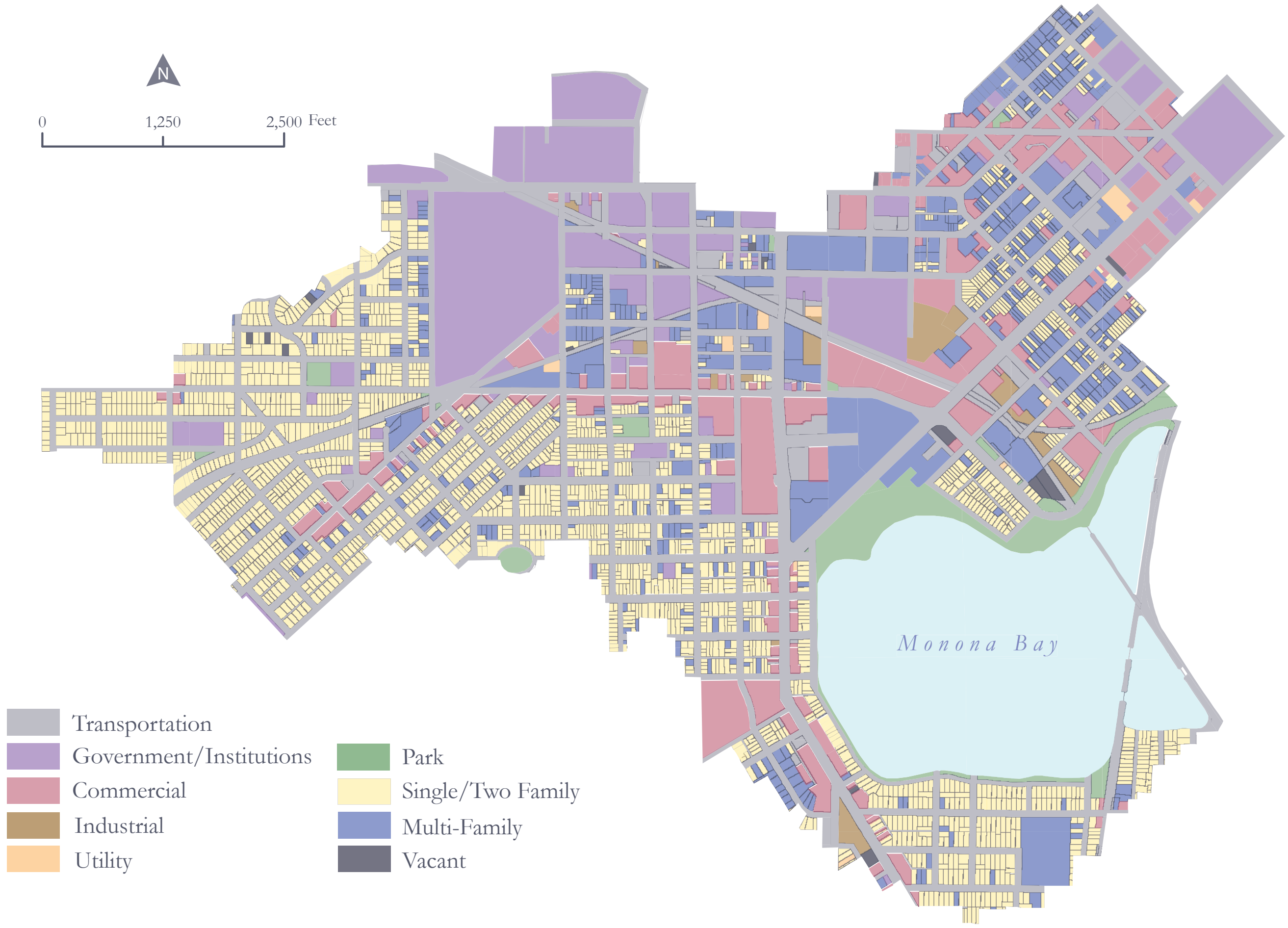


Figure 2.3. Land use in the Monona Bay watershed. Source: City of Madison (2005).

equipment. Professor Chin Wu in the Civil and Environmental Engineering Department at UW–Madison conducts studies of lake circulation using mathematical models and site-specific data. His work may be extended to Lake Monona and Monona Bay in the future, furthering our understanding of the extent, timing, and direction of exchange to and from Lake Monona and Monona Bay.

In addition to surface-water circulation and inputs, there may be exchange between surface water and groundwater in Monona Bay. Historically, the Yahara Lakes were fed by baseflow from groundwater as well as by surface water. However, due to groundwater withdrawals far exceeding the rate of recharge throughout much of region, a 60-ft deep cone of depression that has formed below Lake Monona has reversed baseflow from groundwater to the lake (Lathrop et al., 2005). Water now flows from the lake into the aquifers in many places beneath the city. As a result, it is unlikely that the bay receives any net groundwater inflow, although slight exchange may occur.

2.3 Land Use

Land use in the Monona Bay watershed can be broken down into several traditional categories: transportation, residential, institutional/government, commercial, outdoor recreation, vacant, industrial, and utilities (table 2.1; fig. 2.3). Very little of the watershed is devoted to outdoor recreation, industry, utilities, or vacant land, leaving most to transportation, institutional/government, commercial, and the six residential neighborhoods. The City of Madison is the largest single landholder in the watershed due to its jurisdiction over most of the streets in the transportation category (table 2.2). The UW–Madison owns more than 58 acres. Other principal landowners include the state of Wisconsin, the Community Development Authority (an affordable housing provider), and various hospitals and railroads.

Table 2.2. Major property owners in the Monona Bay watershed. Source: Dane County Community Analysis and Planning Division (2005).

Landowner	Acres
City of Madison	339
University of Wisconsin–Madison	58
State of Wisconsin	23
Community Development Authority	18
Meriter Hospital	12
Wisconsin & Southern Railroad	12
St. Mary's Hospital	10
Union Pacific Railroad	3

Aside from the limited green space around the Capitol Building, University campus, and residential lots, the only significant parkland in the watershed is the 23-acre Brittingham Park, on the north side of Monona Bay.

2.4 Stormwater Quality

2.4.1 Overview of Urban Stormwater Problems

Monona Bay has a highly urbanized watershed and receives no input from natural surface streams; the bay receives rainfall and runoff from throughout the watershed via a stormsewer network. As a result, the bay's hydrologic cycle is significantly impacted by the percentage of impervious land, such as buildings, sidewalks, and roads within the watershed. By preventing rain from infiltrating into the ground, the resulting stormwater runoff instead flows overland into drainage pathways or is channeled into stormsewers.

Stormwater runoff is of concern for several reasons. As runoff is efficiently routed to surface-water bodies or storm drains, it is prevented from infiltrating and recharging the water table. One consequence of lower recharge rates is less water available to flow into streams and rivers during periods of low flow to sustain aquatic life (Burton and Pitt, 2002). In addition, the volume, speed, and timing of runoff can cause erosion and flood events within the watershed. Flooding is generally a problem in areas where rapid development has exceeded stormsewer capacity, near rivers, and in areas where topography makes efficient water removal difficult. Erosion resulting from high runoff volumes and flow velocities can also lead to greater amounts of sediment suspended in the runoff.

Stormwater can also damage receiving water bodies because of the pollutants and sediment it carries (table 2.3). Elevated levels of sediment particles, or total suspended solids (TSS), in stormwater create multiple problems, such as increased turbidity, sedimentation, and nutrient and pollutant loading. Sources of sediment in urban environments include construction sites, eroding landscapes, particulates attributed to vehicular traffic (e.g., tire and brake wear, vehicle exhaust, pavement degradation), sand from rooftops, atmospheric deposition, and sand applications for winter traction. The actual size of sediment carried by stormwater depends on the speed of the water: larger and faster flows can suspend more and larger-grained sediments. During small rain events, coarse particles may move slowly through the sewer system, being periodically deposited and resuspended. A large rain event will scour these larger particles, resulting in a sudden spike of coarse sediment at the sewer outfall.

Although the sediment itself creates problems by filling the receiving water bodies, it also carries with it a range of contaminants—from nutrients to toxic pollutants. As a result, TSS is often used as a surrogate parameter for stormwater quality in general. Stormwater can be "enriched" in nutrients and pollutants because they preferentially bind to fine-grained soil particles than are found in stormwater.

Suspended particles in stormwater cause an increase in turbidity in receiving waters. The turbidity physically shades aquatic plants by decreasing light penetration and stresses aquatic life, such as filter-feeding invertebrates and spawning fish. In addition, because suspended particles can be enriched in plant-limiting nutrients such as phosphorus and nitrogen, the increase in dissolved nutrients can promote algal blooms. Such nutrient loading and the resulting blooms disrupt aquatic plant populations by further decreasing light penetration. As algae eventually die, decomposition of their cells by bacteria consumes dissolved oxygen (DO), which can lead to dangerously low DO levels for fish and other aquatic life (Burton and Pitt, 2002).

Urban stormwater also carries with it myriad contaminants associated with industry, roadways, and development. For example, stormwater sediment is elevated in

Table 2.3. Ranges of common pollutants found in Wisconsin storm sewer monitoring sites from 1989 to 1994 (modified from Bannerman et al., 1996).

Stormwater constituent	Range	Possible sources	Problems
Nitrogen, ammonia, dissolved (mg/L)	<0.01 – 1.3	Fertilizers (lawn and crop), leaves, grass clippings, eroding topsoil, animal waste, treated wastewater effluent	Increases algae growth and eutrophication, decreasing dissolved oxygen levels and adversely affecting aquatic life
Nitrogen, ammonia, organic, total (mg/L)	<0.2 – 34		
Phosphorus (mg/L)	<0.02 – 3.8		
pH	5.63 – 8.11	Metal plating, printing, and graphic industries, cement/concrete production, cleaners, groundwater, air conditioner water	Alters water chemistry, which may kill aquatic organisms[1]
Fecal coliform (colonies/100 mL)	<10 – 370,000	Bacteria from animal and human waste	Risk of infection from pathogens to recreational users
TSS (mg/L)	<2 – 1850	Construction site erosion, winter sanding, windblown soils, tire and brake wear, vehicle exhaust, pavement degradation, atmospheric deposition (Kayhanian 2006)	Reduced water clarity, degraded aquatic habitat, damage to aquatic invertebrates and fish gills, shifts fish community to more sediment-tolerant species. Other pollutants often adhere to sediment particles
Chloride, dissolved (mg/L)	<0.01 – 1000	Winter application of road salt	Alters surface and groundwater chemistry. At high levels (>200 mg/l) may affect survival of aquatic plants and organisms
PCB (mg/L)	<0.1 – 1	Electrical transformers and capacitors. Prior to 1970s, also used in plasticizers, paint additives, adhesives, inks, and lubricants	Can accumulate in sediments and become toxic to aquatic organisms[2]
Lead[2] (mg/L)	<0.04 – 0.09	Automobiles, paints, preservatives, and motor oil[3]	Can be toxic to aquatic organisms and can bioaccumulate[2]
Zinc[2] (mg/L)	0.04 – 0.31		

[1] Harper (2006)

[2] U.S. Environmental Protection Agency (2002)

[3] North Carolina Department of Environment and Natural Resources (2006)

many metals and metalloids (arsenic, cadmium, copper, lead, mercury, and zinc) in particulate and dissolved forms. The presence of toxic organic compounds depends heavily on land use and vehicular activity within the watershed (Burton and Pitt, 2002). Some of the most common types in urban watersheds include pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs).

Trash also contributes to stormwater pollution, creating aesthetic problems in receiving water bodies as well as potentially impacting recreation and ecological functions. Chloride applied as salt for winter deicing is another ubiquitous contaminant that impairs saline-sensitive, freshwater aquatic ecosystems. Unfortunately, alternative deicing agents can also become stormwater contaminants. Stormwater can also carry pathogens, such as fecal bacteria (e.g., *Escherichia coli*) that present a legitimate threat to the safety of humans and pets.

Uncontrolled construction site erosion and runoff is a major contributor to stormwater contamination. According to the WDNR, 30 tons of sediment per acre is eroded from the average, unmanaged construction site into nearby waterways. The lack of vegetation at construction sites and the efficiency of delivery routes of eroded sediment to the stormsewer system and water bodies result in construction sites contributing large amounts of sediment to Wisconsin water bodies. Implementation of proper construction-site erosion control and stormwater-management measures can dramatically improve the quality of stormwater.

As shown in table 2.3, there can be large ranges in amounts of common contaminants in stormwater. This is in part due to various land-use impacts and stormwater-management measures in place in sampled watersheds, and in part due to the difficulty associated with stormwater sampling. Concentrations of pollutants vary spatially and temporally throughout a watershed during a given storm event. For example, stormwater is generally thought to contain the most pollutants during the "first flush" of a rainfall, when accumulated sediments and trash are first picked up by runoff. However, the timing of sampling also reflects the quality of runoff from different areas of the watershed because certain regions will drain more quickly than others.

2.4.2 Stormwater Problems in the Monona Bay Watershed

2.4.2.1 Sources of Contamination

Most stormwater and contaminants within the Monona Bay watershed enter stormsewers from nonpoint-source discharges, such as diffuse runoff from streets, buildings, and lawns. As a result, land-use and management practices within the watershed have a significant impact on stormwater quality. The baseline effects of land use in the Monona Bay watershed on stormwater quality are estimated in the *Source Loading and Management Model Results* section of this chapter.

Currently, the only permitted industrial point source discharging to Monona Bay is the Charter Street Heating and Cooling Plant, owned by the UW–Madison. The plant, on the corner of Dayton and Charter Streets, has a permit from the WDNR to discharge cooling water into the municipal stormsewer system. The permit covers water used to cool the exterior of equipment, but not the process water used in the cooling tower. Process water is kept in a closed system and sent directly to the sanitary sewer system (Larry Benson, Wisconsin Department of Natural Resources, verbal communication, 2006). Under the permit, the plant is required to monitor monthly flow rates, monthly oil and grease discharges, and bimonthly temperature readings. The maximum oil and grease discharge permissible is 10 mg/L; the maximum discharge temperature permissible is 89°F. The plant has had no violations in more than two years (Larry Benson, Wisconsin Department of Natural Resources, verbal communication, 2006), although, because of Monona Bay's average shallow depth, discharging such warm water may further exacerbate temperature-dependent water-quality problems, such as algal growth.

The Charter Street power plant, however, is a potential source of contamination to the bay because of uncovered and poorly constrained open piles of coal. During rain events, water laden with coal sediment can be observed running off the plant site, inevitably reaching the bay via stormsewers (fig. 2.4). Of particular concern is the runoff of PAHs, known carcinogens, which are formed by the incomplete combustion of carbon-containing fuels such as coal. To further research this issue, Midwest Environmental Advocates (MEA), a local nonprofit environmental law firm, has recently taken water-quality samples of runoff from the plant site, though results are not yet available. MEA has also contacted the UW–Madison about potential Clean Water Act violations at the site. The University has agreed to assess possible site changes to minimize contaminated runoff (Brent Denzin, Midwest Environmental Advocates, verbal communication, 2006).

In addition to permitted point sources, over the past few years a number of spills and other accidents have resulted in point discharges of contaminants to Monona Bay. Bancroft Dairy, located at the corner of Fish Hatchery Road and Park Street, was responsible for several ammonia and milk spills before the facility closed in 2004. Two other spills from unknown sources also occurred within the last ten years, both consisting of petroleum products, as documented by the WDNR. In addition, in the summer of 2006, an aquatic plant harvester spilled hydraulic fluid into the bay (Ted Amman, Wisconsin Department of Natural Resources, verbal communication, 2006). In general, any industrial or commercial facility can be a source of stormwater contaminants if a spill occurs near stormsewer drains or if proper spill-response procedures are not followed quickly enough. In addition, employee education regarding proper disposal techniques of industrial byproducts is important. For example, restaurants produce many oil and grease byproducts, which could prove harmful to the bay if dumped down a storm drain. Heating oil from homes is a com-

Figure 2.4. Coal sediment at UW–Madison Charter Street Heating and Cooling Plant can easily be carried away with rainfall.

mon source of residential spills. Another likely source of contaminants in the bay is accidental leaks of oil and gasoline from motor boats used in the bay.

2.4.2.2 Common Pollutants

To better understand contamination of the water and sediment quality of Monona Bay, we used two sources of data: our lake-sediment study and Parr Street stormwater outfall sampling. As part of the sediment study, we analyzed three cores from the following locations for organic and inorganic contaminants: near the main Brittingham Park stormsewer outfall, near the bay's middle, and in the southwest corner of Monona Bay near a smaller, localized sewer outfall. Table 2.4 lists sediment enrichment factors (SEFs) calculated by comparing average surface concentrations of each contaminant with the natural background signal. For example, surface concentrations for the common urban contaminant zinc were 50 to 80 times more elevated than zinc naturally found in the environment for all three cores.

The sediment-sampling results indicated that the quality of water entering Monona Bay has improved over time. The data showed that for almost all contaminants, concentrations are lower in the younger surface sediments and higher in the older, deeper sediments. For example, with the exception of PAHs, all pollutant concentrations in table 2.4 are lower in surface sediments than older, deeper samples. Analysis also revealed particularly pungent concentrations of diesel range organics in sediments now buried by 40 cm of cleaner deposits. This general improvement in sediment quality is probably the result of stricter environmental quality regulations that were introduced beginning in the 1970s, changes in land use in the watershed, and water-quality management practices, such as street sweeping.

The data also suggested that stormsewers draining the largest areas provide the most contaminated stormwater to Monona Bay. For most of the heavy metals and organic contaminants attached to stormwater particles, concentrations of the contaminants are most elevated in the sediments near the main stormsewer outfall at Brittingham Park. (For further discussion of the quality of Monona Bay sediments, refer to the *Sediment Quality* section of chapter 3.)

Table 2.4. Sediment enrichment factors for lake cores taken throughout Monona Bay, comparing average surface concentrations (0–15 cm) to natural background contamination. NA = not available and refers to samples for which surface concentrations were below the instrumental detection limit.

Contaminant	Middle of Monona Bay	Offshore from Brittingham Park	Southwest corner of Monona Bay
Aluminum	11	15	11
Arsenic	9.7	1.0	4.5
Copper	21	20	17.3
Iron	3.5	4.4	3.4
Lead	54	50	55.2
Manganese	0.0	-0.3	-0.2
Mercury	7.5	5.2	6.3
Phosphorus	3.7	3.5	3.5
Zinc	56	80	54
PCBs	NA	2.7	NA
PAHs	104	366	61

Other water samples were collected at the Parr Street stormsewer outfall during two rain events: on July 11, 2006, near the end of a storm, and on July 27, 2006, near the beginning of a major storm. Recorded precipitation amounts were 1.79 in. on July 11 and 1.92 in. on July 27 (Jeff Swiggum, Friends of Monona Bay, verbal communication, 2006). Samples were collected by placing 250 mL bottles at the approximate center of flow out from the outfall into the bay.

The data, analyzed at the Wisconsin State Laboratory of Hygiene, showed that metals in stormwater from the Parr Street outfall contributing area were generally within the typical ranges for urban stormwater (table 2.5) (New York State Department of Environmental Conservation, 2003). However, during the July 27 storm event, copper and zinc concentrations exceeded the typical ranges. Note that the samples taken at the end of the July 11 storm showed that the concentrations of most contaminants were approximately 10 times lower than those of the samples taken at the beginning of the storm on July 27, evidence of the "first flush" effect described earlier.

It is important to note that these data represent several brief "snapshots" of water-quality constituents at the Parr Street stormwater outfall and cannot be used to make any broad statements about stormwater quality in the watershed or the functioning of the stormwater-treatment device that was installed at the Parr Street outfall in August 2006. Comparison of these data with water-quality data obtained after the Parr Street stormwater-treatment device was installed would require a significantly more detailed study involving a large number of samples to account for the high degree of variance in stormwater samples.

2.4.2.3 Nutrient Loading

Stormwater quality affects the health of Monona Bay significantly by contributing incremental increases in dissolved and particulate nutrients. Although Monona Bay has relatively few algal blooms—likely due to thick aquatic plant growth—nutrients entering the bay through eroded soil, lawn fertilizers, and lawn clippings could pose a threat to the future health of the bay if not adequately controlled. Results from the Parr Street stormwater sampling in July 2006 indicated that nitrogen and phosphorus amounts entering the bay during the sampling period were generally within typical ranges for urban stormwater with the exception of total phosphorus during the July 27, 2006 storm, which was very high (table 2.6). The significant local flooding in the Monona Bay watershed during the July 27, 2006 storm may have contributed to the high nutrient loads observed during the sampling on that date.

To further decrease phosphorus loading into area lakes, the City of Madison and Dane County recently began limiting the sale of phosphorus-containing lawn fertilizers. The ordinance took effect on January 1, 2005, and bans use and retail display of phosphorus from all lawn fertilizers. Exceptions are provided for newly seeded turf or to residents who have a soil test showing that their soils do not have phosphorus necessary for turf growth. However, although the Monona Bay watershed does not contain any agricultural land uses, a large proportion of Lake Mendota's watershed does. As an upstream contributor to Lake Monona, the agricultural practices in the Lake Mendota watershed may affect nutrient loading in Monona Bay, depending on the amount of circulation of water from Lake Monona in Monona Bay. Therefore, although lawn fertilizer is likely a relatively minor source of phosphorus to the bay, it at least can be controlled.

2.4.2.4 Sedimentation

Sediment accumulation near stormwater outfalls is a frequently repeated concern of the Friends of Monona Bay and nearby residents. Stormwater choked with TSS from construction sites, erosion, and sand used on ice in winter has accumulated at the base of sewer outfalls, creating observable mounding. To assess the volume of accumulated sediment, we conducted a detailed assessment of the five major outfalls entering Monona Bay: Parr Street, Emerald Street, west Brittingham Park, the Brittingham Park Pavilion, and the north triangle outfall #2.

To gauge the extent and volume of the accumulated outfall sediments, measurements at depths of 80 to 140 cm were taken at different points around each outfall. At each point, the GPS coordinates, depth, and substrate classification (e.g., rocky, sandy, or mucky) were recorded. Depths were taken at increasing distances away from the outfall until the substrate became consistently mucky or the depth was greater than 95 in. The depth points were then used to produce a contour map for each of the outfalls.

Table 2.5. Trace metal and elemental results from two storm events taken at the Parr Street stormsewer outfall on Monona Bay during July 2006.

Date	Timing during storm	Aluminum (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Calcium (mg/L)	Chromium (µg/L)	Cobalt (µg/L)	Copper (µg/L)
7/11/2006	near end	260.7	ND	ND	4.1	3.701	ND	5
		288.9	ND	ND	4.4	3.885	ND	5
		247.7	ND	ND	4.1	3.667	ND	5
7/27/2006	at beginning	2790	ND	1	33.7	20.61	4	59
		4019	ND	1	38.4	28.38	4	82

Date	Timing during storm	Iron (mg/L)	Lead (mg/L)	Magnesium (mg/L)	Manganese (µg/L)	Nickel (µg/L)	Vanadium (µg/L)	Zinc (mg/L)
7/11/2006	near end	0.4	0.007	1.1	18	1	ND	0.053
		0.5	ND	1.2	19	1	ND	0.059
		0.4	0.003	1.1	18	1	ND	0.056
7/27/2006	at beginning	6.9	0.047	14.2	286	9	10	0.404
		8.9	0.07	17.3	344	12	14	0.516

Table 2.6. Nutrient results from two storm events taken at the Parr Street stormsewer outfall on Monona Bay.

Sample date	Timing during storm	Fraction	pH	Ammonia (mg/L)	Nitrate (mg/L)	Total nitrogen ($NH_3 + NH_4$) (mg/L)	Total phosphorus (mg/L)	Silica (mg/L)
7/11/2006	near end	unfiltered	7	0.067	0.082	0.247	0.036	0.255
7/27/2006	at beginning	unfiltered	—	—	—	3.184	3.093	—
		filtered	—	—	—	1.595	1.799	—

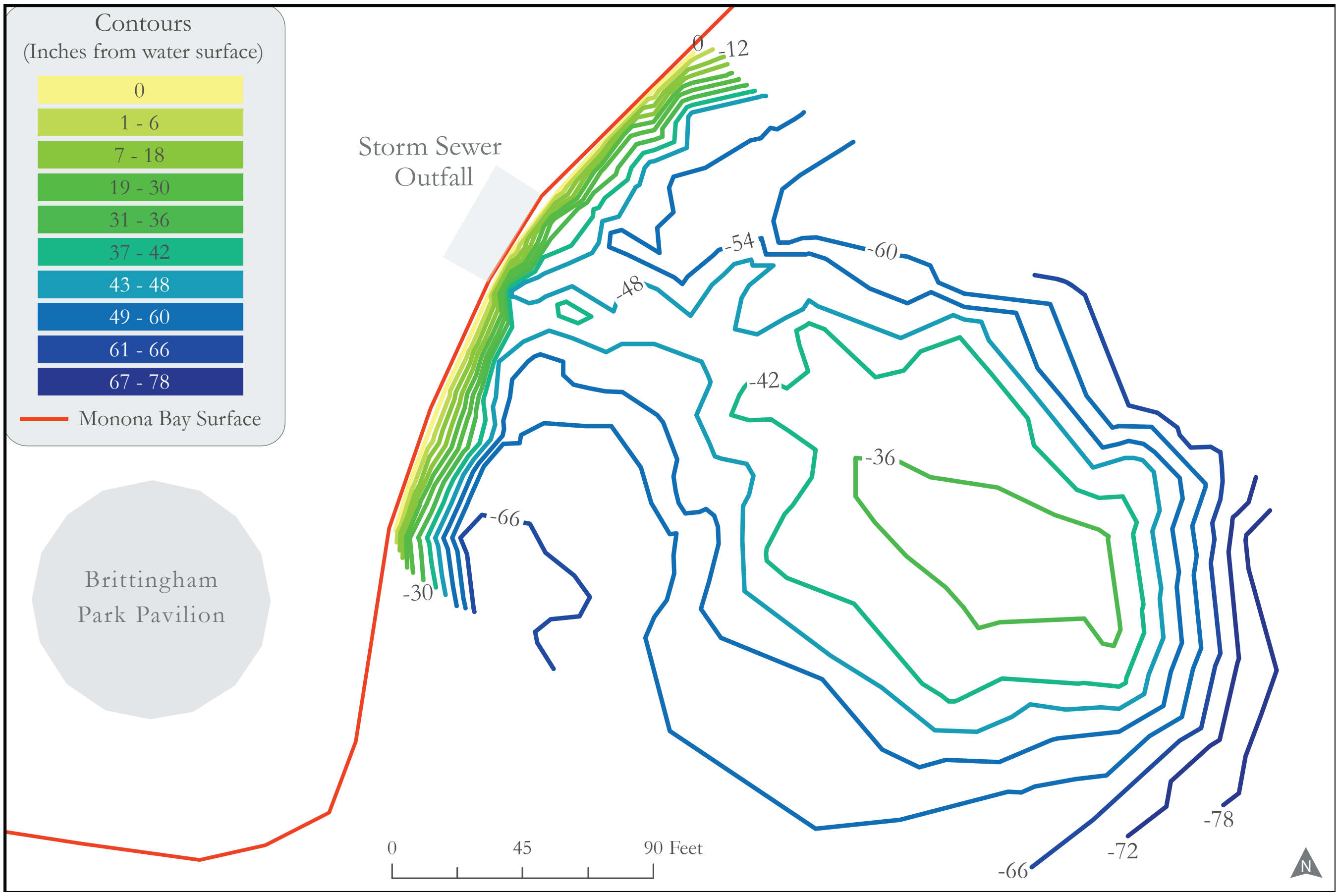
Sediment mounding appears clearly on the contour maps for the outfalls near Parr Street, the Brittingham Park Pavilion, and in the north triangle outfall #2 (figs. 2.5, 2.6, and 2.7). Sediment mounding for Emerald Street and the west Brittingham Park outfalls was not noticeable on the contour maps, probably because they drain smaller basins and the slope and depth in this corner of the bay are generally shallower. In addition, the sediment mound at the north triangle outfall #2 likely under-represents actual stormwater sedimentation because our equipment was not sufficiently long to measure depths of deeper water; thus, some depths were estimated beyond the break in slope.

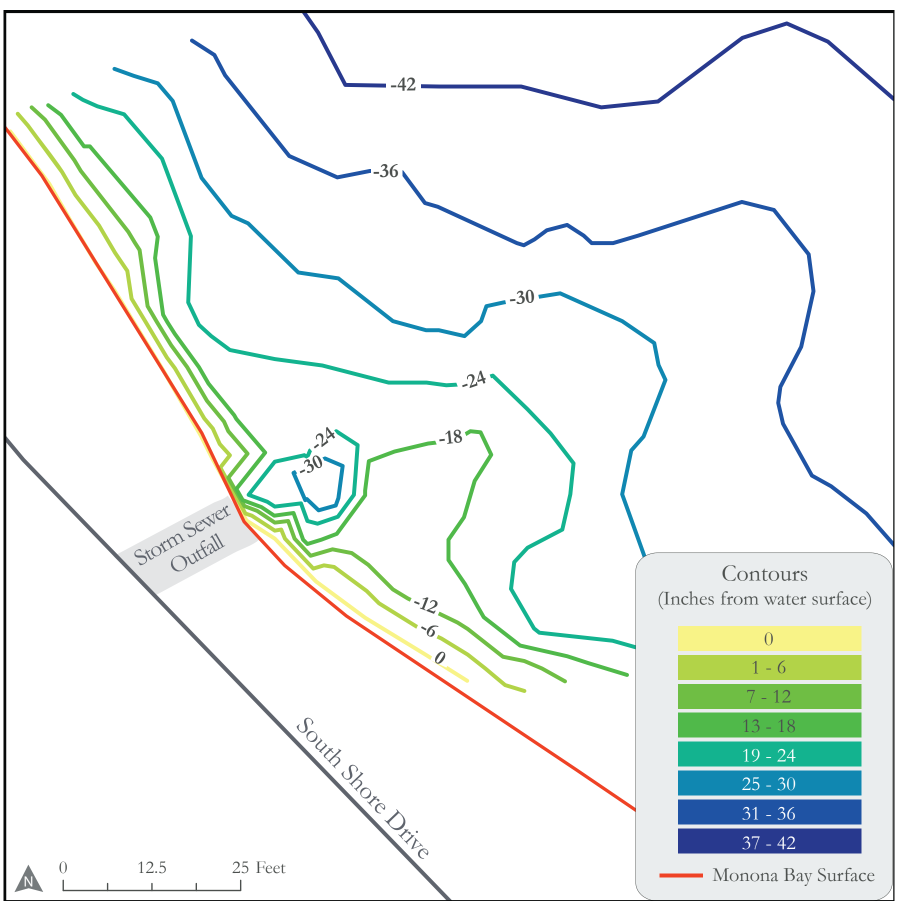
On the basis of the contours, we estimated the volume of deposited sediment by first interpolating average slopes between the 80 to 140 cm collection points for each outfall (table 2.7). A volume was then calculated by subtracting the average interpolated slope from the actual contour map. Note that these estimates are likely low because they do not consider the finer fraction in TSS that is deposited farther out from the outfall. However, the estimated volumes do allow for comparison between sites and show that by far the most sedimentation has occurred at the outfall near the Brittingham Park Pavilion.

The quality of the sediment at each of the outfalls was relatively consistent—coarse particles such as sand and silt, and bits of metal, glass and sinkable litter. Farther from the outfall the sediment became finer, dominated by silt, clay, and a higher percentage of organic material. Samples taken near the Parr Street and west Brittingham Park outfalls also had a strong petroleum smell, likely associated with heavy diesel range organics (DROs).

2.4.2.5 Flooding

Although the Monona Bay watershed is highly urbanized, it has a well developed stormsewer system and subsequently does not have regularly occurring problems





▲ **Figure 2.5.** Sediment contours for area near Monona Bay Brittingham Park Pavilion outfall.

◀ **Figure 2.6.** Sediment contours for area near Monona Bay Parr Street outfall.

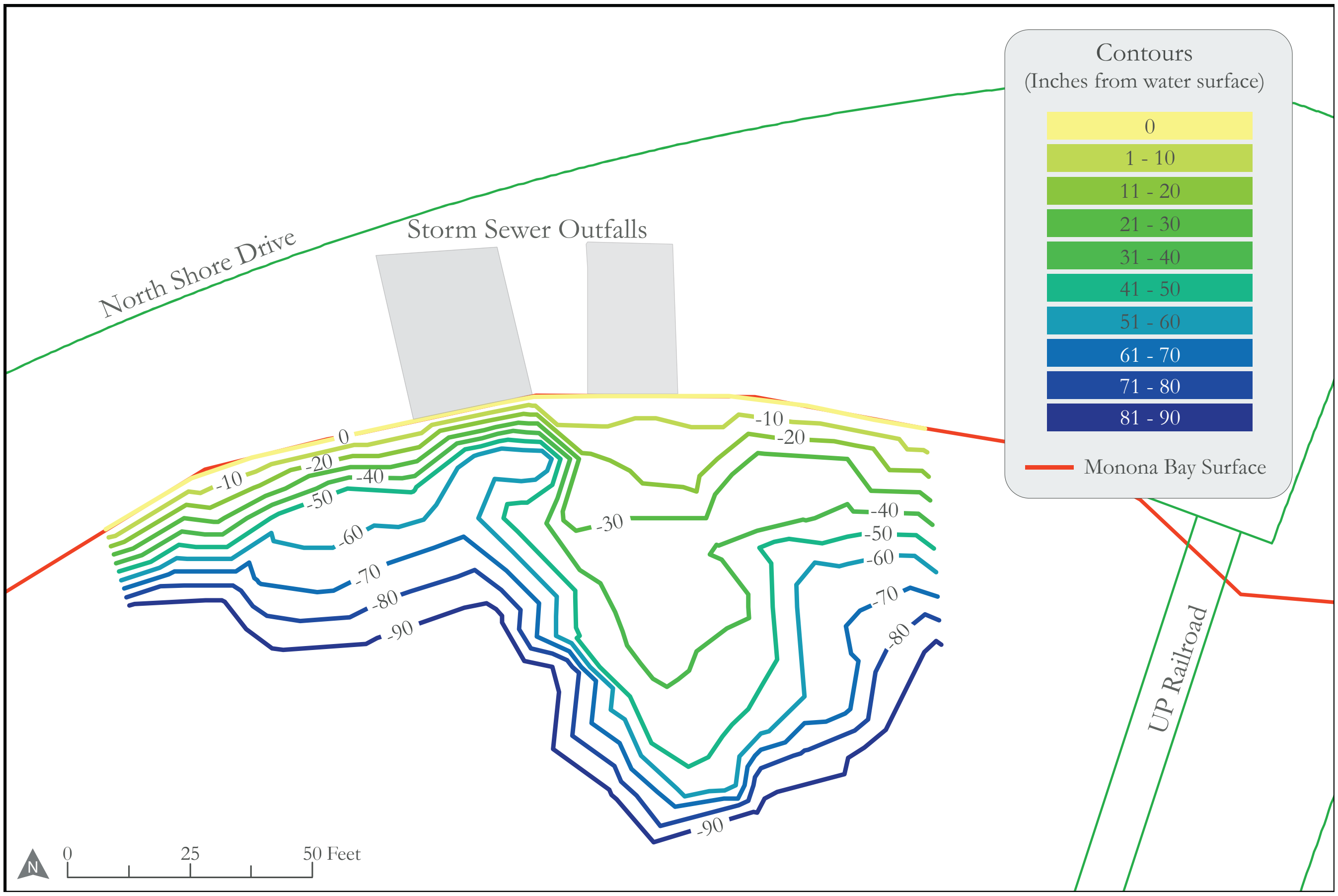


Figure 2.7. Sediment contours for area near Monona Bay north triangle outfall #2.

with flooding. Flooding, however, can occur when the water table of the Yahara Lakes is elevated, allowing lake water to back up into the sewer pipes. When this happens, low-lying areas within the Monona Bay watershed can become filled to overcapacity, leading to localized flooding during heavy storms.

On July 27, 2006, the City and the University experienced extensive flooding in low areas throughout the downtown area due to heavy rainfall. Between 3 and 5 in. of rain fell along the isthmus in just over an hour, flooding areas around Park Street, Regent Street, and Randall Street in particular, along with the basements of many University buildings and apartments.

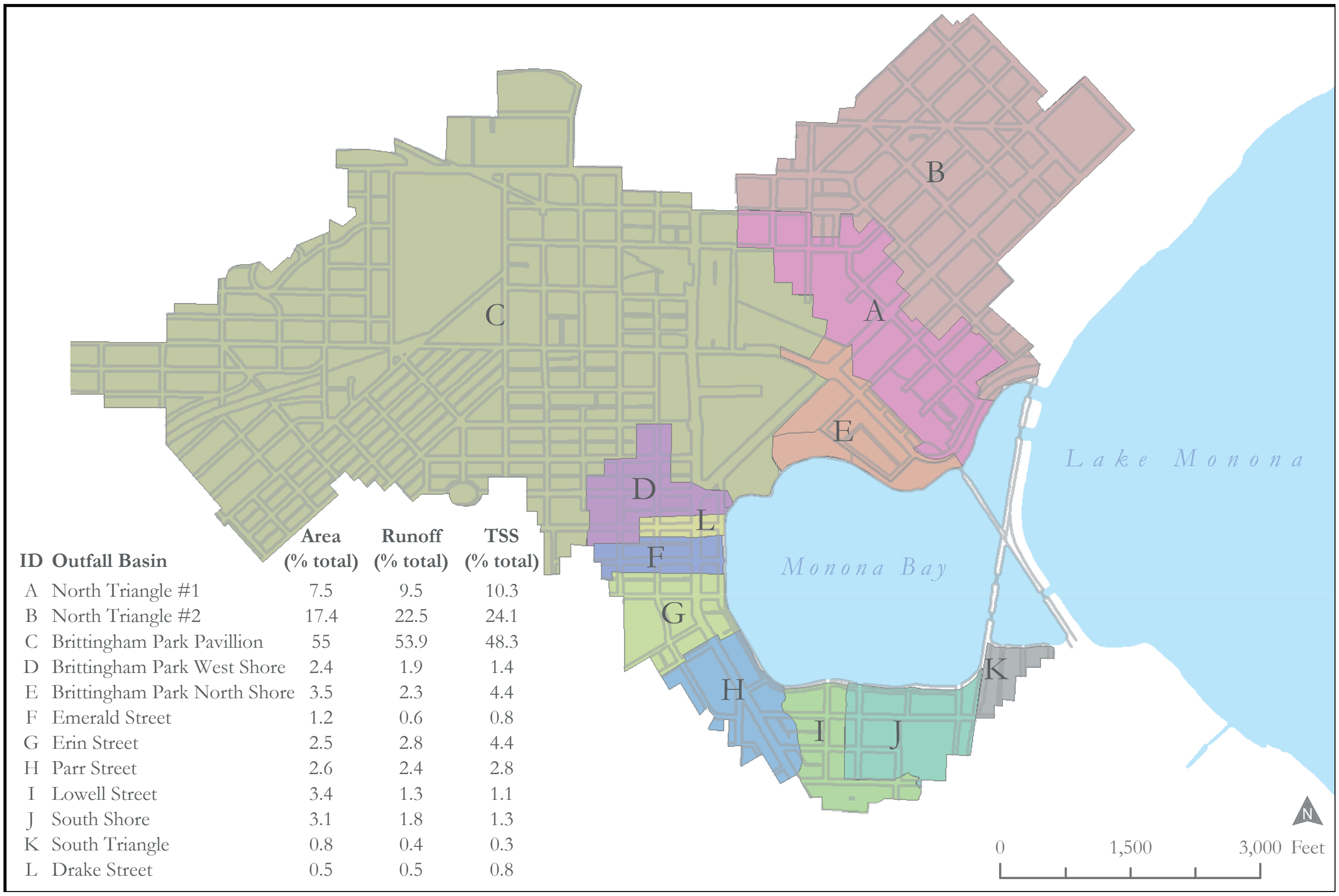
Flooding concerns can spur investment in improvements to the stormwater-management system. Some of these improvements, including increased cleaning of stormwater inlets, construction of stormwater detention systems, and (in innovative locations) reductions in effective impervious surfaces, can not only reduce flooding, but also improve water quality.

Table 2.7. Estimated volume and acreage of the sediment mounds at three outfalls on Monona Bay.

Outfall	Estimated volume of sediment in mound (ft³)	Estimated acreage of sediment mound
Parr Street	2,000	0.1
Brittingham Park Pavilion	47,000	0.9
North triangle outfall #2	13,000	0.2

2.4.2.6 Floatable Litter

Although floatable litter in Monona Bay does not pose a serious ecological or water-quality risk, it does significantly degrade the bay's aesthetic appeal. According to the FOMB, floatable litter has been an increasing problem. Trash left on the streets and sidewalks is carried into the bay during storm events, in many cases becoming entangled in the dense aquatic plant growth. The FOMB conducts monthly cleanups around and in the



ID	Outfall Basin	Area (% total)	Runoff (% total)	TSS (% total)
A	North Triangle #1	7.5	9.5	10.3
B	North Triangle #2	17.4	22.5	24.1
C	Brittingham Park Pavillion	55	53.9	48.3
D	Brittingham Park West Shore	2.4	1.9	1.4
E	Brittingham Park North Shore	3.5	2.3	4.4
F	Emerald Street	1.2	0.6	0.8
G	Erin Street	2.5	2.8	4.4
H	Parr Street	2.6	2.4	2.8
I	Lowell Street	3.4	1.3	1.1
J	South Shore	3.1	1.8	1.3
K	South Triangle	0.8	0.4	0.3
L	Drake Street	0.5	0.5	0.8

Figure 2.8. The SLAMM analysis results for Monona Bay outfall basins.

bay, collecting 11 bags of trash on average (Nina Emerson, Friends of Monona Bay, verbal communication, 2006). In 2004, the City of Madison installed a fence across the Parr Street stormsewer outlet to trap floatable litter, allowing the FOMB to document the quantity of trash coming into the bay from this smaller stormsewer. (These data were not available at the time of writing.)

According to the FOMB, much of the trash entering the bay seems to come from the University during sporting and tailgating events at Camp Randall Stadium and the Kohl Center. The University does not own the streets around these stadiums, so they are not technically responsible for street sweeping after games. However, according to officials, the University performs extensive trash collection in and around the stadiums during game events to prevent littering. If the University requests the City to perform street sweeping after an event, the City is willing to do so, but will bill the University for the cost of the sweeping (George Dreckman, City of Madison Recycling Coordinator, verbal communication, 2006). (See *Stormwater Controls* section of chapter 5 for further discussion of litter management in the Monona Bay watershed.)

2.4.3 Source Loading and Management Model Results

We used the Source Loading and Management Model (SLAMM) to determine the effects of land use on stormwater volumes and suspended sediment loads in the Monona Bay watershed and to identify stormwater basins that contribute disproportionately higher loads of TSS per area. The model is calibrated with local data regarding average pollutant loading and runoff from different land uses. For example, in the model, freeways have been shown to contribute some of the highest quantities of TSS, followed by industrial and commercial areas with extensive parking and high turnover rates, such as shopping malls. Commercial areas with limited parking, institutional sites (e.g., hospitals), and high density residential areas are in the third highest category of TSS-generating areas. The lowest TSS-generating areas include low and medium density residential areas and parks. The model can also incorporate a variety of stormwater best management practices, such as street sweeping and porous pavement, to compare management options.

The model was completed under a "no management" scenario, meaning that results do not reflect the effects of ongoing street sweeping, stormwater-treatment devices, rain gardens, or other stormwater-management activities. Instead, the results provide baseline information about where stormwater-management activities will most efficiently benefit runoff quantity and quality. For modeling purposes, the Monona Bay watershed was divided into 12 basins based on the stormsewer system, with nine draining to single outfalls. The Brittingham Park North Shore basin, the South Shore basin, and the south triangle basin are groupings of a few smaller outfall basins. Figure 2.8 shows the watershed divisions and the SLAMM results regarding runoff and TSS. Table 2.8 lists the basin percentage areas of the watershed, and contributing percentages of runoff volume and TSS. (For a detailed description of inputs and assumptions, see appendix 1.)

As expected, stormwater basins with higher densities, more commercial land, and impervious surfaces contribute a disproportionately higher amount of TSS and runoff volume compared to their area.

Table 2.8. Results of the SLAMM analysis.

Outfall basin	Monona Bay watershed (%)	Runoff (%)	TSS (%)
Brittingham Park Pavilion	55.0	54.0	48.3
North triangle outfall #2	17.4	2.5	9.5
North triangle outfall #1	7.5	9.5	10.3
South triangle	7.5	9.5	10.3
Brittingham Park North Shore	3.5	2.3	4.4
Lowell Street	3.4	1.3	1.1
South Shore	3.14	1.8	1.3
Parr Street	2.6	2.4	2.8
Erin Street	2.5	2.8	4.5
Brittingham Park cul-de-sac	2.4	2.0	1.4
Emerald Street	1.2	0.6	0.8
Drake Street	0.5	0.5	0.8

- The Erin Street outfall basin is 2.52 percent of the watershed area, but contributes 4.45 percent of the suspended solids. This outfall basin is dominated by the St. Mary's Hospital complex, a large impervious area and nonpoint pollutant source. This basin could benefit from the installation of targeted stormwater-quality treatment systems at the hospital and other high-use parking areas.
- The Brittingham Park Pavilion outfall basin drains the largest area of the watershed, 55 percent, but contributes only 48 percent of the suspended solids. Most of the basin contains single family homes. If the basin were broken down into smaller basins for analysis, then areas for improvement could be found in the commercial districts along Park and Regent Streets and around the University.
- The two basins draining into the north triangle are the most urban and contribute the most suspended solids compared to their area of the watershed. Targeted stormwater-management practices would provide the most benefits for these basins. Additional research into sedimentation within the north triangle and circulation between the lake, triangle, and bay might be helpful. The north triangle may act like a sedimentation pond for the runoff from these two basins.
- Although Drake Street, South Shore, south triangle, and Emerald Street have comparatively low contributions of runoff and pollutants, inexpensive retrofits or best management practices could reduce those contributions further.

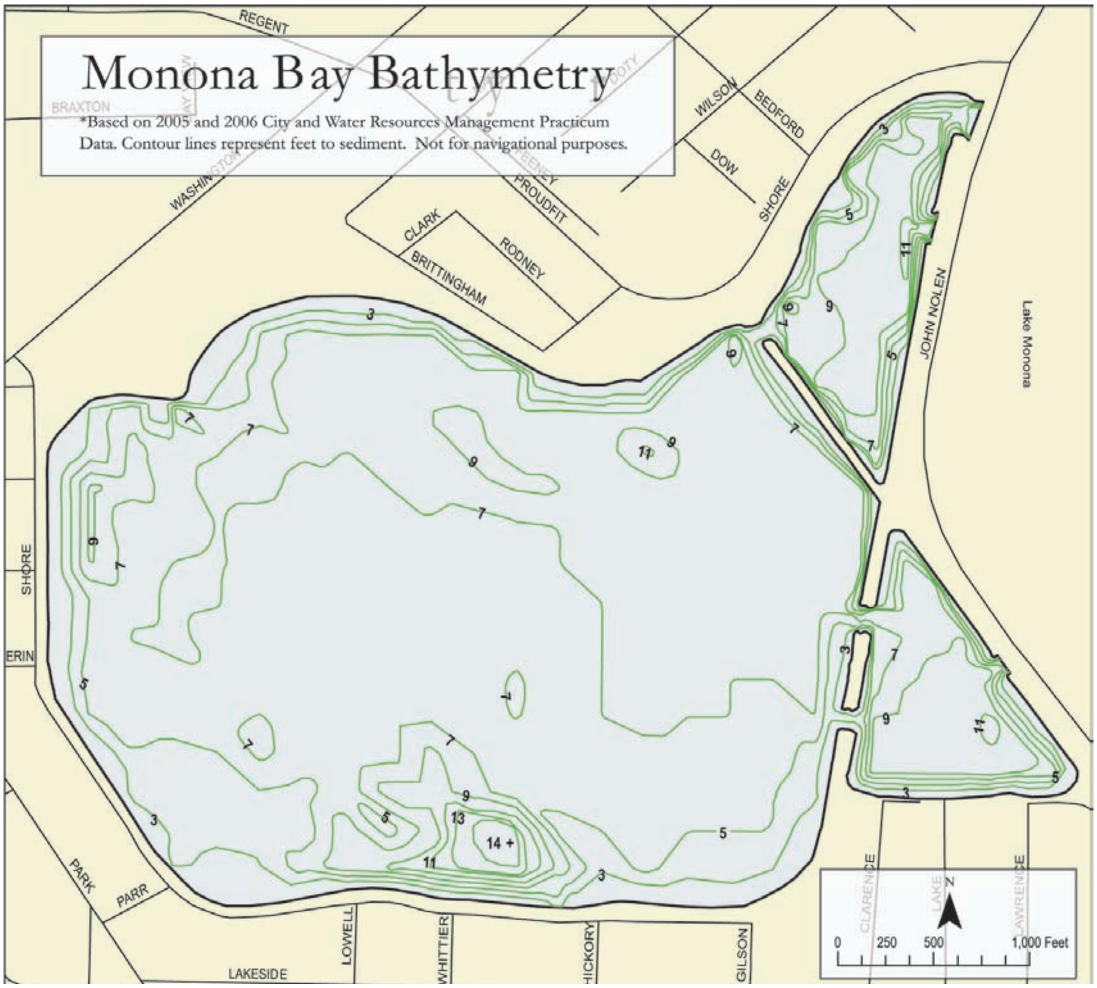


Figure 3.1. Monona Bay bathymetric map.

CHAPTER 3. MONONA BAY ECOLOGY

3.1 Shallow Lake Ecology

Shallow lakes are generally characterized by an average depth of 10 ft or less (Cooke et al., 2001), and Monona Bay's ecology is typical of a nutrient-rich (eutrophic), shallow water system. Lake bays typically have abundant aquatic plant growth because these areas are sheltered from the scouring action of strong waves and currents, allowing nutrient-rich sediments to accumulate. The most important factors affecting the abundance and distribution of plants within lakes are light availability, nutrients, sediment characteristics, wind, and wave energy (Nichols, 2001). Shallow, nutrient-rich lakes generally exist in one of two stable states: either turbid and dominated by algae, or clear and dominated by rooted aquatic plants (Cooke et al., 2001). Because Monona Bay is partly isolated from Lake Monona by the railroad trestle and John Nolan Drive, an overview on the dynamics and alternate states of shallow lakes will be helpful in determining the best combination of management strategies for Monona Bay.

3.1.1 Eutrophication

Eutrophication is a natural process in shallow lakes and refers to the increase in nutrient loading over time as a lake ages. The nutrients can be inorganic or organic and can be dissolved or particulate matter, such as silt, plant debris, manure, or fertilizers. Water quality in Monona Bay, however, is the result of human-induced eutrophication: the influx of excessive nutrients associated with urban and agricultural runoff (Cooke et al., 2005). For example, areas of Monona Bay are becoming shallower as a result of the accumulation of eroded soil carried by stormwater. Because silt can be enriched in adsorbed nutrients and organic matter, incoming stormwater can stimulate algae growth, which can be detrimental to the ecological health and recreational potential of the bay.

Historical sources of nutrient loading into Monona Bay include treated sewage and runoff associated with stormwater. The City of Madison discharged municipal sewage effluent into Lake Monona from the mid-1880s until the mid-twentieth century; the influx of nutrients into Lake Monona created dense algal blooms in Lake Monona as early as the late 1800s (Mollenhoff, 1982). In addition, soil erosion caused by agricultural activity and urban development has deposited a blanket of nutrient-enriched silt and sand on the bottom of Monona Bay, further feeding aquatic plant growth. At present, the City is making efforts to decrease nutrient loading to Monona Bay through a variety of stormwater-control measures.

3.1.2 Lake Morphometry

Although physically connected to Lake Monona, Monona Bay functions differently than its deeper neighbor because of its shallowness (fig. 3.1). Lake Monona is thermally stratified in the summer, but most of Monona Bay remains relatively well mixed. Thermal stratification occurs when solar energy sufficiently warms surface water, creating a density difference large enough to resist mixing by wind or wave turbulence (Kalff, 2001). In temperate, eutrophic lakes, this results in a warm, oxygenated, well mixed surface layer (epilimnion) separated from a cool, stagnant and sometimes anoxic bottom layer (hypolimnion). However, oxygen profiles taken throughout the 2006 summer showed that Monona Bay was generally well mixed and only became anoxic in the 6 in. or so above the sediment interface.

In addition, the bay's depth allows rich aquatic vegetation to grow throughout the entire bay, unlike in Lake Monona, which supports such plants only along its margins. As a result, aquatic plants play a more important role in understanding the functioning of the bay than in deeper water bodies (Scheffer, 2001). Because shallow lakes have a higher surface area to volume ratio, sediment–water interactions play a more important role than in deeper lakes. For example, warmer sediment temperatures in summer can lead to higher mineralization rates of nutrients as the summer progresses (Scheffer, 2001).

3.1.3 Roles of Algae and Aquatic Plants

It should be recognized that some level of algae and aquatic plants is integral to healthy lakes. Algae are primary producers, playing the vital role of cycling nutrients throughout the lake ecosystem and providing the food base for most lake organisms, including fish and benthic invertebrates. Likewise, according to Cooke et al. (2005), aquatic plant communities are the foundation of lake ecosystems, providing

- oxygen for aquatic life,
- habitat and food for waterfowl, fish, amphibians, invertebrates, and insects,
- protection of the shoreline from erosive waves, and
- stabilization of bottom sediments from resuspension.

However, excessive algal and aquatic plant growth and its effects on water quality are the most common problems addressed in the management of shallow, eutrophic lakes (Cooke et al., 2005). Excessive algal blooms hinder lake recreation, are unsightly, and deplete lake oxygen levels during decomposition. Even worse, certain strains of blue-green algae can be toxic to people and animals if ingested; thus, algae-dominated lakes require close surveillance to ensure public safety. Aquatic plants, especially invasive exotic species, can also grow out of control in nutrient-rich lakes. Excessive aquatic plant growth similarly hinders lake recreation, is unsightly, crowds out native plants, and can negatively alter lake food webs.

Nevertheless, although frustrating to lake users, dense plant growth is to be expected in shallow, eutrophic lakes with nutrient-rich sediments. In such environments, aquatic plant abundance is primarily determined by light availability. A common misconception is that internal and external nutrient loading causes weed growth; in actuality, such conditions promote algal blooms that actually limit plant growth. In managing the plant growth of Monona Bay, it is important to accept that the desire to have a "weed-free" lake is, in the words of Cooke et al. (2005) "both naïve and unreasonable." Because most sediment within Monona Bay falls within the photic zone, we should expect that the bay will continue to support dense growth of aquatic plants in the future. Management goals, as a result, should focus on switching the bay's plant diversity away from canopy-forming invasives and toward deeper-growing native species.

3.1.4 Nutrient Cycling

Although aquatic plant growth in Monona Bay is primarily limited by light, the algal growth in the bay is limited by water-column nutrients. The cycling of nutrients in lakes is complex and dependent upon a variety of physical, chemical, and biological factors. In aquatic systems, phosphorus (P) and nitrogen (N) are the most limiting nutrients for algal growth; generally, the addition of these nutrients to a lake will increase the rate and amount of algae production (Bachmann, 2001). Although algal growth in Monona Bay is probably phosphorus limited, as it is in Lake Monona, nutrients behave differently within the bay because of its shallowness. For example, in deeper lakes, there is a continual loss of nutrients from the epilimnion to the hypolimnion as algae and particulate matter die and sink to the bottom of the lake. In contrast, the constant mixing of shallow lakes, such as Monona Bay, ensures a relatively rapid return of nutrients from most settled material into the water column.

3.1.4.1 Phosphorus

Phosphorus has probably received more attention than any other nutrient in limnology because it is the most common growth-limiting factor in lakes, in many instances found in the shortest supply compared to algal demand. Sources of phosphorus entering Monona Bay include runoff from the watershed and groundwater exchange. Due to the highly urbanized nature of the bay's watershed, most terrestrial phosphorus is likely attached to silt-sized soil particles or as organic phosphorus in the form of leaves, grass clippings, or other organic matter (Burton and Pitt, 2002).

Once phosphorus enters Monona Bay, it can follow several metabolic and chemical pathways. In lakes dense with aquatic plant growth, much of the particulate phosphorus, sorbed to oxides and soil particles, precipitates out of the water column. Below the oxygenated surface layer, deeper sediments may become oxygen-depleted (anoxic), releasing the bound phosphorus at a rate much faster than oxygenated sediments (Horne and Goldman, 1994). At this point, most phosphorus is released back to the surface water because of turbulence or turnover events. In addition, phosphorus can be recycled, a process by which phytoplankton reuse the phosphorus excreted by fish, zooplankton, and bacterial activity (Horne and Goldman, 1994). In Monona Bay, phosphorus is likely removed from the system through limited mixing with Lake Monona, by the physical removal of fish or macrophytes, sedimentation, and groundwater exchange.

Most of the phosphorus in Monona Bay is trapped in the organic and unavailable form as plant and animal detritus. For organic phosphorus to be used by plants and algae, it must be converted to a simpler, dissolved, inorganic form. Rooted macrophytes take up most of their phosphorus from the sediment; algae tend to absorb phosphorus from the water column. Note that macrophytes and phytoplankton do not generally compete for the same nutrients, although they can act as sources or pools of nutrients for each other.

For example, although aquatic plants take up most of their nutrients from the sediment, they release much of that phosphorus into the water column when they die. A square meter of EWM can remove up to 3 grams of phosphorus from the sediment per year. When the plants die, however, 93 percent of the phosphorus is released into the water (Carpenter and Adams, 1978). Because phytoplankton growth is correlated with water phosphorus concentrations, milfoil decay may subsequently promote algal blooms, possibly such as the fall blue-green algae blooms recorded in Monona Bay during 2005 and 2006.

Because phosphorus can be adsorbed or bound to other sediment particles, or held in the dissolved form in interstial sediment pore water, any activity that causes physical turbulence of the bottom sediments can change the amount of phosphorus in the water column. Such activity includes wind and wave energy as well as bioturbation, sediment disturbance caused by benthic invertebrates and bottom-dwelling fish, such as the common carp (*Cyprinus carpio)*. The stirring up of such sediments can result in the release of phosphorus into the water column—an increase in dissolved phosphorus—or the scouring of dissolved phosphorus as it adsorbs to suspended sediment—a decrease in dissolved phosphorus.

3.1.4.2 Nitrogen

Unlike phosphorus, nitrogen is highly mobile and has a significant atmospheric component. The primary nitrogen sources for Monona Bay include runoff from the watershed and biological fixation of atmospheric nitrogen by blue-green algae. Biological nitrogen fixation is the process by which blue-green algae (cyanobacteria) transform nitrogen gas into ammonia (Horne and Goldman, 1994). Because blue-green algae manufacture their own nitrogen, they are not nitrogen limited, giving them an advantage over other types of phytoplankton in the water column.

Whether nitrogen is made available through biological fixation or by other processes such as fixation from lightning, it must be converted to ammonium (NH_4^+) or nitrate (NO_3^-) for uptake by plants and algae. Most nitrogen in eutrophic lakes is in the form of organic nitrogen in the sediments (Cooke et al., 2005). As a result, bacteria play an important role in decomposing this organic matter and releasing more biologically available forms of nitrogen (and phosphorus).

3.1.5 Stable-State Equilibrium Theory

Shallow, nutrient-rich lakes usually exist in one of two stable states: a vegetation-dominated, clear state or an algal-dominated, turbid state (Cooke et al., 2001). These alternative equilibria can exist over a range of nutrient levels in most shallow lakes, making it difficult to predict when a switch between states may occur. Cooke et al. (2001, p. 46) noted, however, shallow lakes free of plants and algae are "uncommon, unexpected, and essentially unattainable in most areas of North America without regular chemical treatment." As previously explained, an abundant and rich aquatic plant community should be expected for shallow water bodies. The focus of many lake-management strategies is how to convert an algal state back to the more natural aquatic plant dominant state (Cooke et al., 2001). Consequently, when considering a management plan for Monona Bay, it is important to recognize that the current plant-dominated state of the bay has the potential to convert to a considerably worse state, dominated by blue-green algae blooms.

3.1.5.1 Feedback Mechanisms

A variety of feedback mechanisms promote either vegetation or algae steady states. Shallow lakes generally have more aquatic plant growth than deeper lakes because of the area of bottom sediment in the photic zone. Light availability is directly linked to water clarity (Cooke et al., 2005). Water clarity is controlled by algae, suspended sediment, and water color—all of which can limit light penetration, in turn reducing aquatic plant growth. Shallow lakes with deep layers of soft sediments can easily become turbid if waves from motorboat traffic and wind stir up the sediments. Excessive dissolved nutrients in the water column can promote algal blooms, physically shading plants and decreasing their growth; therefore, in turbid conditions, even shallow lakes will have few submersed aquatic plants.

In contrast, shallow lakes with abundant aquatic vegetation typically have lower amounts of algae and better water clarity than they would if the aquatic plants were not present. The improvement in water quality results from the following:

- Aquatic plants physically trap sediment and lessen the erosive activity of waves, preventing sediment resuspension, and reduce water currents that would keep planktonic (free-floating) algae in suspension.
- Some species (such as coontail) take up nutrients in the water column that otherwise would have been used by algae.
- Dense plant growth provides cover for zooplankton that graze on algae, thereby keeping the water clean.

Due to these factors, removal of significant amounts of aquatic plants from shallow lake systems can result in an increase in the abundance of algae, even with no change in nutrient loading (Bachmann, 2001). This removal could happen by mechanical harvesting, killing plants with herbicides, or by altering the morphometry by deepening the area below the photic zone.

Certain fish play a significant role in maintaining turbid, algae-rich water in shallow lakes, preventing the conversion back to clearer, aquatic plant dominated lakes (Cooke et al., 2001). Large populations of carp, bullheads, and similar species of bottom-feeding fish that can tolerate very shallow water will increase suspended sediment and nutrients as the fish stir up lakebeds and uproot aquatic plants when they feed. Because shallow lakes generally have limited stratification, resuspended sediment and nutrients mix throughout the water column, increasing turbidity and further promoting algal growth. Such internal nutrient cycling from the sediments can keep water-column nutrients sufficiently high to prevent an algal-dominated lake from converting back to a clear-water aquatic-plant lake, even after a significant reduction in external nutrient loads. Fortunately, Monona Bay is still dominated by aquatic vegetation rather than algal blooms.

In addition, zooplankton of the genus *Daphnia* play a role in reducing algae through grazing. However, *Daphnia* populations are controlled by zooplankton-eating fish called planktivores, such as juvenile bluegill, stunted bluegill, European carp, crappie, sunfish, perch, and a number of other juvenile fish species (Cooke et al., 2001). Because of these food-web interactions, lake managers can use a technique called biomanipulation to shift fish species composition from planktivorous to predatory fish, promoting an increase in algae-grazing *Daphnia* (Cooke et al., 2001). Because predatory fish prefer rooted aquatic plants for habitat, maintaining an aquatic plant community in Monona Bay is important in keeping the bay relatively free of future algal blooms.

3.2 Shoreline Composition

Monona Bay's shoreline is a mixture of private, landscaped lots, city parks, beaches, and undeveloped scrubland.

To minimize erosion from wave action and flooding, the City of Madison has strongly armored most of the bay's shoreline with large boulders, or riprap, ranging in size from 1 to 3 ft. Our shoreline survey indicated that Monona Bay's shoreline is approximately 70 percent riprap, with the remaining 30 percent beaches and natural shoreline and found primarily in the southeast corner of the bay. Because of costly flood damage in 1993, 1996, and 2000, the City would like to eventually raise the riprap to 1 ft above flood elevation for better protection.

The two public beaches maintained by the City of Madison are Brittingham and Bernies, located on the north and southeast edges of the bay, respectively. Immediately east of Bernies Beach is 150 ft of heavily wooded natural area, void of riprap and extending 60 ft back from the shore. Most private residences grow only lawn grass.

Of the vegetation growing along the bay's shoreline, especially within Brittingham Park, the most abundant plant species are reed canary grass (*Phalaris arundinacea)*, sweet yellow clover (*Melilotus officinalis*), sweet white clover (*Melilotus alba*), and trefoil (*Lotus corniculata*). Other species present included several non-native and native shrubs and hardwood trees. The shorelines of the two triangles are primarily undeveloped, not maintained, and plagued by similar invasive plants.

In accordance with recommendations from the WDNR, the Parks Division mows the vegetation along the bay's shoreline two times per season allowing it to grow tall in order to discourage ducks and geese from congregating at the shoreline. Waterfowl feces can wash into the bay and may lead to *E. coli* outbreaks. The tall grass along the shoreline encourages deep-rooted plants to establish, thus protecting the shoreline. The vegetation, however, is dominated by non-native plant species, particularly reed canary grass. This buffer area is up to 50 ft wide and extends from John Nolen Drive to the Brittingham Park pier.

Near-shore aquatic plants are extensive in Monona Bay and are similar to those found in deeper water, with the dominant species being EWM (exotic invasive), curly leaf pondweed (CLP, exotic invasive), coontail (native), sago pondweed (native) and duckweed (native). The near-shore aquatic substrate is a mixture of soft mud, sand, gravel, and rubble. Stormwater outfalls typically have sandier substrates, which appear to deter EWM growth and promote the native sago pondweed.

3.3 Water-Quality Data

Although few historical data are available on water quality in Monona Bay, it is typical of other highly urbanized, shallow, eutrophic water bodies. The bay receives stormwater runoff from its urban watershed as well as overland flow from the surrounding residential and commercial properties. Consequently, the main water-quality management challenges facing the bay include eutrophication, elevated levels of fecal bacteria, and the potential for toxic blue-green algae blooms.

3.3.1 Previous Data Collection Efforts

The water-quality data summarized here represent three efforts of collection within Monona Bay: 1) the City of Madison's longtime monitoring of public beaches, 2) WDNR Self-Help Citizen Lake Monitoring Network, and 3) the City Engineering Division's SolarBee monitoring plan (see the *SolarBees* section of chapter 5 for more information about SolarBees program).

Since the 1950s, the City of Madison has monitored the water quality around Monona Bay's two public beaches, Brittingham and Bernies, for elevated levels of bacteria (City of Madison, 2006a). In the 1970s or 1980s, this program was expanded to include monitoring for potentially toxic blue-green algae blooms (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006).

The next monitoring effort started in 2003 when volunteers for the Friends of Monona Bay began participating in the WDNR Self-Help Citizen Monitoring Network by taking regular Secchi depth readings, as well as visually noting the water color, clarity, and level. In May 2005 their monitoring program was expanded to included monthly dissolved oxygen levels, chlorophyll-a, and total phosphorus concentrations. These data are available for review by the public at the WDNR Self-Help Web site (Wisconsin Department of Natural Resources, 2006a).

Finally, the most rigorous water quality data collection was initiated in conjunction with the installation of six water circulation devices called SolarBees on May 26, 2005. To monitor the SolarBees effectiveness in reducing blue-green algae and aquatic plant growth, the City of Madison's Engineering Division worked with the WDNR to develop a biweekly sampling plan for June through October. Water samples were analyzed at the Wisconsin State Laboratory of Hygiene for orthophosphorus, total phosphorus (TP), ammonia (NH_4), nitrate (NO_3), total Kjeldahl-N (TKN), chlorophyll-a, and silica. Surface samples were collected for these parameters at five sites in Monona Bay proper, one site in the north

Table 3.1. Average concentrations of water-quality parameters in Monona Bay for 2005 and 2006, compared to neighboring Lake Monona 2005 data and other eutrophic lakes.

	Monona Bay (2005)		Monona Bay (2006)		Lake Monona (2005)	Typical eutrophic lakes
Parameter	**Range**	**Average**	**Range**	**Average**	**Average**[b]	
Total phosphorus (µg/L)	34 - 260	86	32 - 148	68	89	> 25[c]
Chlorophyll-a (µg/L)	1.5 - 87	21	4.2 - 52	18	11.9	> 11.0[c]
Nitrogen-Kjeldahl (mg/L)	0.62 - 1.9	1.1	0.60 - 4.8	1.1	-	-
Secchi depth (m)	0.5 - 2.4	1.1	0.5 - 4.3	1.4	2.5	< 5.0[c]
Silica (mg/L)	0.1 - 4.3	1.8	0.1 - 3.9	1.8	0.66	-
pH	8.2 - 9.7	9.0	8.0 - 9.8	9.0	8.2	-

[a] City of Madison Engineering Division (range from June-October 2005 and June-October 2006)

[b] North Temperate Lakes Long-Term Ecological Research Program. Center for Limnology, University of Wisconsin, Madison, Wisconsin, USA. Available online at <http://lter.limnology.wisc.edu>.

[c] Lille and Mason (1983)

triangle and one site in the south triangle. In addition, in-situ readings for water temperature and dissolved oxygen were taken at three locations at 1-ft depth intervals. These locations included one site in Monona Bay, one site in the north triangle and one site in the south triangle. From May through October, weekly water samples from the north and south triangles, Brittingham Beach, Bernies Beach, and the middle of Monona Bay were tested for the presence of sixteen species of blue-green algae (see the *Algae and Fecal Bacteria* section of this chapter). The same sampling plan was repeated in 2006.

3.3.2 Essential Nutrients and Physical Parameters

Data for the parameters outlined below are found in tables 3.1, 3.2, and 3.3. Table 3.1 gives the range and average concentration for each parameter for 2005 and 2006 in the bay as well as for Lake Monona. Table 3.2 presents data from 2006, showing how parameter concentrations vary within Monona Bay from May through October. Table 3.3 shows that 2006 data vary across the seven different sampling sites in the bay.

3.3.2.1 Phosphorus

Knowing the phosphorus concentrations in Monona Bay is important because phosphorus is the primary nutrient limiting algal growth and, therefore, the nutrient most closely linked to eutrophication (Schindler, 1977). A water body is considered eutrophic when the total phosphorus water concentration exceeds 0.025 mg/L (Lillie et al., 1983); the concentrations in Monona Bay as found by the City in 2005 and 2006 never dropped below this mark (fig. 3.2). These concentrations of phosphorus may be considered low when the local runoff of an urban watershed is taken into account. The resiliency of the bay may be attributed to its morphology, which allows the more efficient control of nutrients through trophic interactions in the food web (O'Sullivan and Reynolds, 2005). In additional, aquatic plants physically trap nutrient-rich sediments and help prevent their resuspension.

Phosphorus occurs in lakes and streams in several forms. Orthophosphate is the inorganic form of phosphate (PO_4), which is a major component of soluble reactive phosphorus (Dodson, 2004). Soluble reactive phosphorus is directly taken up by algae and aquatic plants; its concentrations tell us how much phosphorus is available for growth. Total phosphorus measures all phosphorus forms in water, including any phosphorus released from the particulate (sediment) bound state (Dodson, 2004). The concentrations of soluble reactive phosphorus and total phosphorus found in the bay between June and October of 2005 and 2006 showed levels consistent with eutrophic lakes. (See appendix 2 for detailed water-sampling results.

3.3.2.2 Nitrogen

Nitrogen is an especially important factor for aquatic plant growth because it is in many cases the limiting nutrient. However, even in oligotrophic (nutrient poor)

Table 3.2. Variation of water-quality parameters over time: Averages for the five Monona Bay sampling sites monitored by the City of Madison in 2006. (Data collected by Genesis Bichanich, City of Madison, 2006.)

Parameter	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
Total phosphorus (µg/L)	54	74	45	45	44	107	110	88	72
Chlorophyll-a (µg/L)	15.4	12.4	6.2	8.3	10.7	48.4	25.0	17.0	16.6
Nitrogen-Kjeldahl (mg/L)	0.85	0.90	0.77	1.52	0.69	1.55	1.60	1.33	1.12
Secchi Depth (m)	1.7	1.6	1.9	2.1	2.6	0.6	0.6	0.6	0.7
Silica (mg/L)	0.2	1.7	0.9	0.7	1.5	2.7	3.3	3.4	2.5
pH	9.4	9.5	9.7	9.1	9.0	9.2	8.8	8.6	8.4

Table 3.3. Variation of water-quality parameters among sites, June through October 2006.

Parameter	10 (North triangle)	11 (South triangle)	12 (Monona Bay)	13 (Monona Bay)	14 (Monona Bay)	15 (Monona Bay)	16 (Monona Bay)
Total phosphorus (µg/L)	57	62	77	71	63	71	72
Chlorophyll-a (µg/L)	17.2	17.9	17.6	17.9	15.7	20.1	17.6
Nitrogen-Kjeldahl (mg/L)	0.91	1.01	1.07	1.47	1.04	1.13	1.04
Secchi depth (m)	1.6	1.5	1.3	1.4	1.8	1.2	1.3
Silica (mg/L)	1.2	1.7	2.0	1.9	1.7	1.7	2.0
pH	8.6	8.7	9.0	8.9	9.2	9.1	9.2

lakes, nutrients sufficient for plant growth can be in the sediments. In practice, nutrient limitation for aquatic plants is rare, and there are few substantiated reports (Cooke et al., 2005). Although nutrients in the sediments are important for aquatic plant growth, the external loading of nutrients into the water column is important for algae. If nitrogen is in low supply in the water column, blue-green algae are able to fix, or acquire, nitrogen from the atmosphere.

Nitrogen occurs in several different forms in aquatic systems, and the City tested for three inorganic forms in 2005 and 2006: nitrate-nitrogen, nitrate-ammonia, and total Kjeldahl-nitrogen (the combination of total organic nitrogen and ammonia). Nitrate and ammonia can be taken up directly by plants or other organisms. Depending on the land-use characteristics of the watershed, total nitrogen (including all organic and inorganic forms) is typically between 0.4 and 2.7 ppb in lakes (Wetzel, 2001).

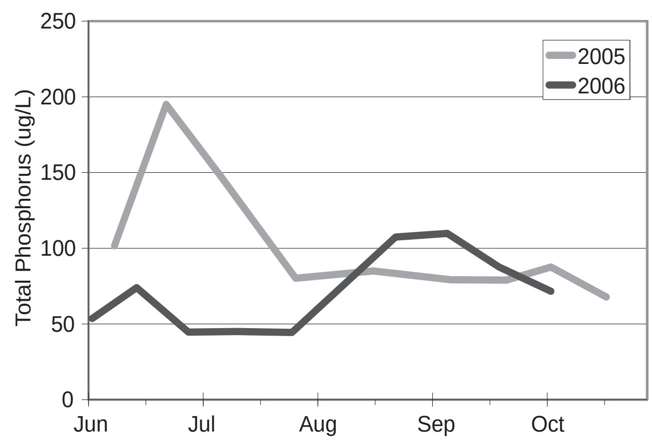


Figure 3.2. Average total phosphorus concentrations in Monona Bay for 2005 and 2006. (Data collected by Genesis Bichanich, City of Madison, 2006.)

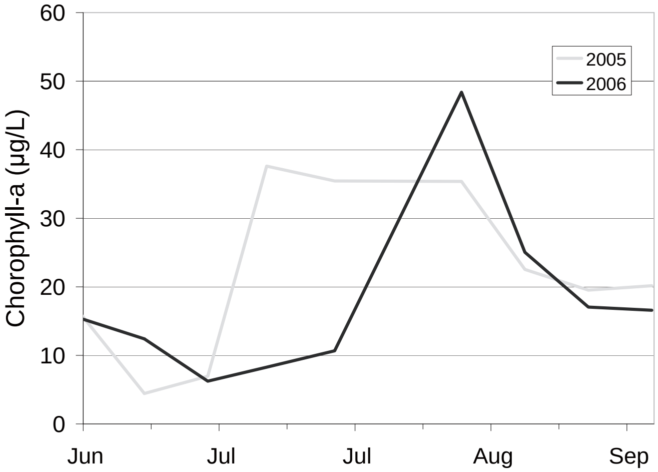


Figure 3.3. Average chlorophyll-a concentrations in Monona Bay for 2005 and 2006. (Data collected by Genesis Bichanich, City of Madison, 2006.)

3.3.2.3 Chlorophyll-a

In addition to nitrogen and phosphorus, chlorophyll-a is an important component in the productivity of aquatic systems because it is used in photosynthesis by algae. Measuring chlorophyll-a in Monona Bay provides an estimate of the planktonic algae present in the bay, and thus is a proxy for overall biological productivity.

Chlorophyll-a concentrations in Monona Bay ranged from 5.8 to 32.9 µg/L over the 2005 summer months and 4.18 to 51.5 µg/L in 2006 (fig. 3.3). These ranges vary throughout the course of the year because algal densities can change rapidly under a variety of biological and climactic factors, but generally reach a peak in August (see appendix 2). Chlorophyll-a is directly related to other trophic state indicators—parameters measured in a lake that indicate whether it is an oligotrophic, mesotrophic, or eutrophic lake. For example, if phosphorus levels increase, it is expected that water clarity will decrease and chlorophyll-a concentrations will increase.

3.3.2.4 Silica

Silica can be an important limiting nutrient for algae called diatoms. The average silica concentration for aquatic systems is usually 13 mg/L. Concentrations less than 5 mg/L indicate stressful conditions for diatom growth (Dodson, 2004). During the 2005 and 2006 summers, the dissolved silica levels never exceeded 4.3 mg/L (table 3.1), indicating that diatoms are at a competitive disadvantage in Monona Bay. By observation, it was found that diatoms were present in the bay in the months of June and July as epiphytes, or organisms that grow on other plants. Even so, silica is usually a product of the lakebed geomorphology; given the bay's history as a dredged wetland, low concentrations in such a system are not unusual.

3.3.2.5 pH

Because the pH of Monona Bay averaged 9.0 in 2005 (table 3.1), it is considered alkaline. Most natural waters range from 6.5 and 8.5; a higher pH can indicate high levels of photosynthesis in the water column because carbon dioxide is being removed (Dodson, 2004). In the case of Monona Bay, the elevated pH is likely due to the extensive aquatic plant growth that blankets the bay for much of the growing season. Generally, the major concern with pH is its relationship with the solubility and biological availability of heavy metals and nutrients (Michaud, 1991). Although heavy metal contamination is a concern in Monona Bay, the high pH will resist the transformation of many of these metals to soluble, more hazardous forms. Conversely, a pH of 8.5 or higher can cause significant amounts of phosphorus to be released from bottom sediments (Robertson et al., 1998).

3.3.2.6 Temperature and Dissolved Oxygen

The temperature and dissolved oxygen readings taken by the City and by us indicate that an isothermic (constant temperature throughout) water column typically occurred in the bay during the summers of 2005 and 2006 (see appendix 2). This is typical of shallow, well mixed water bodies like Monona Bay. Stratification, in which a warm, well oxygenated epilimnion forms over a cooler, oxygen-depleted hypolimnion, does not typically occur in the bay. Instead, a small layer just above the sediments, where most of the oxygen is being used by decomposition, tends to become anoxic (fig. 3.4). The north and south triangles and the deepest part of the bay (a hole 13–14 ft deep) have larger anoxic zones because they are deeper, but they do not stratify.

3.3.2.7 Secchi Depth

Secchi depth is a useful for comparing changes in water clarity. A Secchi disk, a black and white disk, is lowered through the water column; until it can no longer be seen. At this transition point the depth is recorded. Secchi depth was the first consistently measured parameter in Monona Bay by FOMB volunteers starting in 2003 (Wisconsin Department of Natural Resources, 2006a); Secchi depths were also taken by the City in 2005 and 2006. The monthly recorded Secchi depth data show the dynamic changes that the bay undergoes on a yearly basis; these changes can most likely be attributed to the periodic high concentrations of nutrients in spring (from runoff) and the fall (plant decomposition).

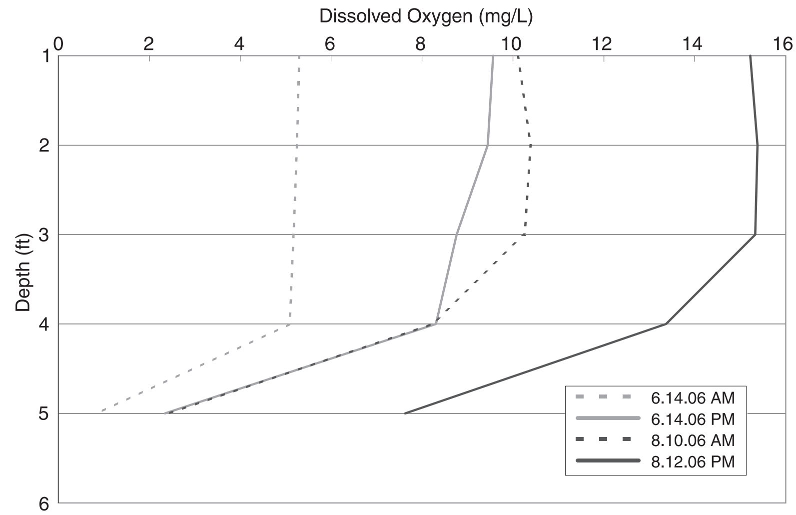


Figure 3.4. Dissolved oxygen profiles collected in mid-June and mid-August in Monona Bay.

3.3.3 Measures of Eutrophication: Trophic State Index

Indices are useful for classifying the water quality of a lake over time. Ideally, a water-quality index is easily measured and can be used as a tool for comparison among lakes. The most common index used to classify nutrient enrichment is the trophic state index (TSI) developed by Carlson (1977). The trophic state index uses three variables—total phosphorus, chlorophyll-a, and Secchi depth—as a way to estimate algal biomass. The values for these parameters are logarithmically transformed to normalize the data and allow for comparison among lakes on a scale of 0 to 100. Although there is a tendency to average these parameters to achieve one central value, it is recommended to look at the three trophic state indicators independently.

Although aquatic plants are an important part of primary production in a lake, they are not accounted for in the TSI parameters. To accommodate for this variable, the lake-evaluation index was created. This index considers the TSI variables *plus* aquatic plants (Porcella et al., 1980). We considered recommending the lake-evaluation index as a preferred index; however, this calculation it is not commonly used and is unfamiliar to many lake managers.

On the TSI scale from 0 to 100, a lake with TSI values less than 40 is characterized as oligotrophic. In these systems nutrients are typically in limited supply and algal populations low. Mesotrophic lakes are classified as having TSI values between 40 and 50. In these systems nutrients are generally in moderate supply, and there is an increased risk of algal blooms. Lakes with TSIs greater than 50 are considered eutrophic. These are nutrient-rich systems that in many cases have water-quality problems associated with seasonal algal blooms and poor water clarity. Lakes are considered hypereutrophic if their TSIs are greater than 60. Extensive algal blooms throughout the summer are typical of these systems (Robertson et al., 2005).

All three of the TSI parameters calculated for 2005 and 2006 indicate that Monona Bay is in a eutrophic–hypereutrophic state (table 3.4; fig. 3.5) Given the characteristics associated with eutrophic–hypereutrophic water bodies, we would expect Monona Bay to have more frequent and extensive algal blooms and poor water quality throughout the summer.

The TSI of total phosphorus is greater than that of Secchi depth and chlorophyll-a in 2005 and 2006. This indicates some factor other than phosphorus is limiting algal biomass. The role of aquatic plants may be an important variable that helps explain the relatively low to moderate algal counts in the bay throughout much of the summer. Comparing the averaged TSI variables for the two years indicates a slight water-quality improvement in 2006. Many factors can cause the water quality to vary from year to year. A few of these factors could include the positive effects of watershed-management activities and variability due to climatic influences (e.g., periods of drought or heavy rainfall).

Information explaining how to calculate the trophic state index can be found at the Web site: <http://dipin.kent.edu/tsi.htm#Calculating%20the%20TSI>.

Table 3.4. Transformed TSI variables for chlorophyll-a (CHL), total phosphorus (TP), and Secchi depth (SD). Averages were taken for 2005 and 2006. See appendix 2 for variable transformation. Sources: Genesis Bichanich, City of Madison (2006); Carlson (1977).

Date	TSI (CHL)	TSI (TP)	TSI (SD)
6/8/05	57.8	70.6	—
6/22/05	45.2	80.6	—
7/6/05	49.6	—	—
7/27/05	66.2	67.3	53.4
8/17/05	65.6	69.0	63.4
9/7/05	65.6	67.3	63.4
9/22/05	61.2	67.3	65.6
10/4/05	59.7	69.0	68.1
10/19/05	60.1	65.4	61.0
6/8/06	57.4	61.6	52.0
6/22/06	55.3	66.3	53.1
7/6/06	48.6	58.9	50.5
7/27/06	51.3	59.0	49.0
8/17/06	53.8	58.8	46.4
9/7/06	68.7	71.6	67.1
9/22/06	62.2	71.9	67.7
10/4/06	58.4	68.6	66.9
10/19/06	58.1	65.7	65.8

3.4 Sediment Quality

Clues to understanding the historic and current environmental state of Monona Bay lie in its sediments. The bay has an average depth of 5 ft and continually receives stormwater sediment from erosion throughout its urbanized watershed. This sediment influx changes the shape of the bay, its morphometry, and is commonly enriched in essential plant-limiting nutrients, such as phosphorus and nitrogen. The incoming sediment and stormwater also carry a number of contaminants that, once deposited in the bay, serve as measures of historical contamination over time. Deposited pollutants and nutrients can undergo a series of changes, making them more or less available to plants, animals, and invertebrates. As a result, it is important to understand the source and composition of what lies at the bottom of Monona Bay.

3.4.1 Coring Methods

We looked at three sets of coring data. The WDNR took cores in 1988 in an effort to characterize mercury, PCBs, and other contaminants in Lake Monona and its tributaries. A piston core sampler was used to collect two cores in Monona Bay, one on the west side and another on the north side of the bay, each capturing the upper 30 cm of sediment. The WDNR collected a second set

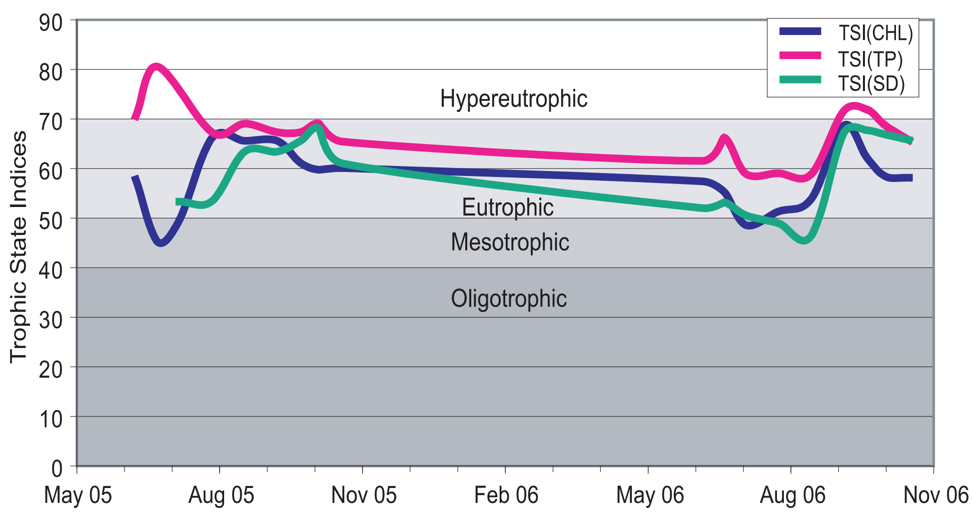


Figure 3.5. Trophic state index values based on surface sampling conducted by the City of Madison. These log-transformed values were based upon a 0 to 100 scale. See appendix 2 for variable transformation. Source: Genesis Bichanich, City of Madison.

of sediment data from a set of three piston cores collected on October 23, 1992 in Monona Bay, although the exact locations are unknown. Samples were analyzed for a series of heavy metals, mercury, and PCBs.

We collected three cores on June 19, 2006, with the assistance of Paul Garrison of the WDNR (fig. 3.6). The first coring site was in the middle of the bay (core A). The second core was taken near the main stormwater sewer outlet at Brittingham Park to capture sedimentation and contamination resulting from stormwater input (core B). The third core was taken in the southwest corner of the bay near a smaller stormwater outlet (core C). All three cores were vertically extruded in the field and sectioned into 2 cm intervals for further analysis. The piston corer was composed of a rubber piston that was attached to a clear, acrylic barrel that was manually pushed into the lake sediment using aluminum pipe extensions. Our sediment data are the deepest of all previous efforts; we sampled to 75 cm.

3.4.2 Sedimentation Sources and Rates

In 1905, the Madison Parks and Pleasure Commission dredged the edges of Monona Bay; how much sediment was actually removed is unknown. To date the core sampled near the Brittingham Park outfall, we used recorded contamination peaks of pollutants (fig. 3.7). For example, records indicate that copper and arsenic use as aquatic herbicides peaked in the 1940s and mid-1960s, respectively. Similarly, the lead peak probably coincides with the late-1970s, when lead was phased out as an additive in paint and gasoline.

By using the historic peaks shown in figure 3.7, we see that since the 1980s, approximately 1.1 cm per year has been deposited offshore the Brittingham Park outfall. Because this core was sampled approximately 50 m from shore, the area immediately adjacent to the outfall has likely received higher rates of deposition. The outfall survey that we conducted (described in *Stormwater Quality* section of chapter 2) confirmed this trend and indicated that the outfalls at the Brittingham Park Pavilion, Parr Street, and the north triangle have received significant deposition due to stormwater.

3.4.3 Bulk Composition of Sediments

The cores we extracted during the summer of 2006 showed three major types of sediment in Monona Bay. All three cores were capped by 20 to 60 cm of dark brown, organic-rich, silty sediment. This darker deposit was abruptly underlain by either glacially deposited sand (core C) or by calcium carbonate-rich material containing small shells; this is typical of pre-European settlement lakebed deposits and is referred to as "marl" (cores A and B) (fig. 3.8).

Given the uncertainty surrounding the exact locations of dredging in Monona Bay, it is difficult to determine

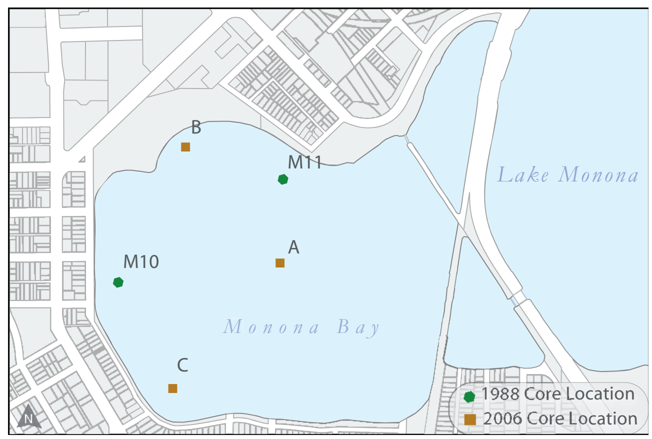


Figure 3.6. Locations of sediment cores taken by the WDNR (1988) and the 2006 WRM Practicum.

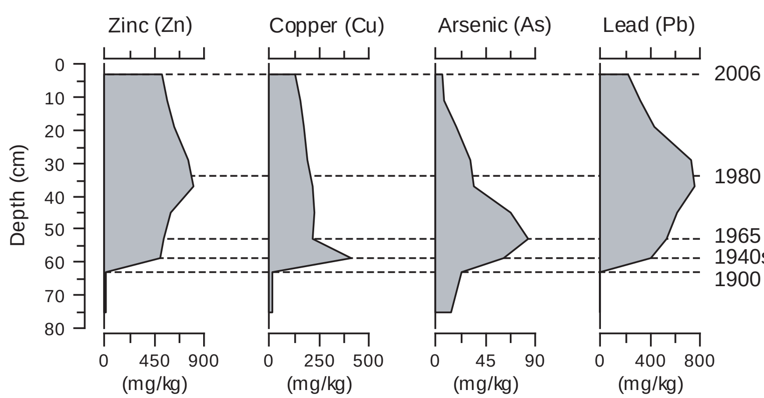


Figure 3.7. Profiles of common contaminants in core B, taken offshore from Brittingham Park. Dates are approximations.

Figure 3.8. A. Sample core taken from Monona Bay showing the transition from pre-settlement marl to post-settlement muck. **B.** Organic, silty, "contaminated" muck. **C.** Relatively contaminant-free, calcium carbonate-rich marl.

exactly what year the abrupt boundaries between the organic-rich silt and marl/sand represents. In the case of core C, this boundary is likely the lake-bed surface created when the edges of Monona Bay were dredged for sand to fill in land for Brittingham Park and the surrounding homes. However, for cores A and B, where organic-rich silt changes to marl, it is difficult to say whether this transition was created because of the original dredging in 1905 or when Madison was originally settled in the mid-1800s. Regardless, the transition from marl to organic-rich silt was created as a result of the upland erosion of soil as the Monona Bay watershed was developed at the turn of the century.

3.4.4 Sediment Nutrients

Figure 3.9 shows selected profiles of several nutrients and elements for core B, taken offshore from the Brittingham Park stormwater outfall. Just above the transition from carbonate-rich marl to organic-rich sediment, sediment phosphorus increases markedly and calcium clearly decreases. Sediment phosphorus increased because the element preferentially attaches to the fine-grained soil particles that are more likely to erode (Brady and Weil, 2002). As a result, as erosion of the Monona Bay watershed increased at the turn of the century, it carried with it this plant-limiting nutrient. Likewise, the decrease in calcium was probably caused by the element becoming "diluted" by the incoming sediment rather than an actual decrease in the amount of calcium precipitate.

We can determine the possible sources of phosphorus to the bay—whether it was bound to organic matter or attached to soil particles—using several methods. For example, aluminum and titanium are good indicators of soil erosion because they can be found in clay-sized soil particles. Thus, by plotting the ratio of titanium to phosphorus (titanium:P), we see that after the initial increase, the profile remains relatively constant, indicating that the main source of phosphorus to Monona Bay was soil erosion (fig. 3.9).

In addition, zinc is generally a good indicator of urbanization because it can be associated with corrosion of vehicles, tires, and roofs (Bannerman et al., 1996). By looking at the ratio of zinc to phosphorus (zinc:P) (fig. 3.9) we see that since initial development, urban runoff has been a significant contributor of soil phosphorus to Monona Bay. The profile peaks at around 20 cm depth (around 1990, assuming linear deposition), indicating a decrease in the amount of stormwater pollution entering the bay since that time. This may be the result of increased street sweeping and other stormwater controls.

3.4.5 Sediment Contamination

Monona Bay has a highly urbanized watershed; as a result, it has received a variety of organic and inorganic contaminants. According to Marshall's (1989) report on sediment contaminants in Lake Monona, nonpoint source runoff, wastewater discharge, and inorganic aquatic herbicides were the principal sources of contamination. Because some of the most polluted sites in Lake Monona were in Monona Bay, the report specifically recommended additional testing. To address this recommendation, we considered three types of contamination: mercury, trace metals (e.g., copper and arsenic), and or-

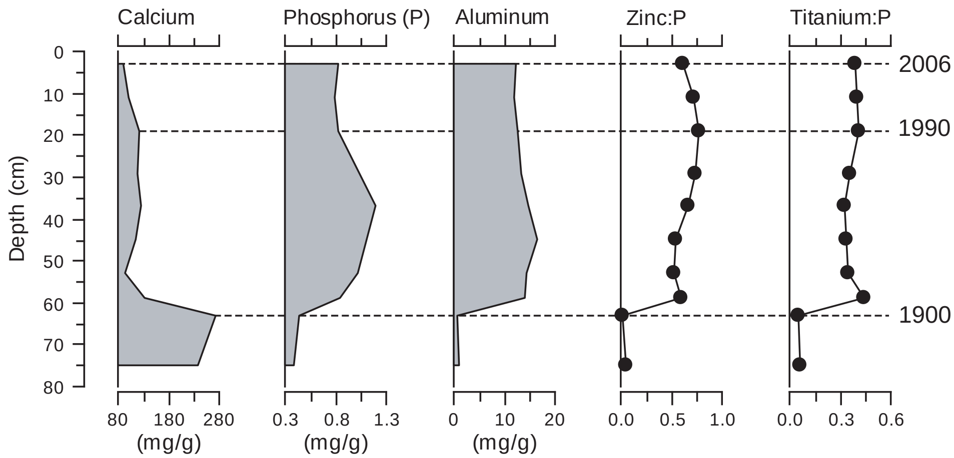


Figure 3.9. Profiles of ratios of selected elements and phosphorus for core B, offshore from the Brittingham Park stormwater outfall. The titanium:phosphorus ratio (Ti:P) is an indication of soil erosion; the zinc-phosphorus (Zn:P) ratio is an indication of urban runoff to Monona Bay. Dates are approximate.

ganics (e.g., DROs, PCBs, and PAHs). (Please refer to appendix 3 for our complete sediment data.)

To assess the ecological risk associated with the different types of sediment contamination, we compared values in Monona Bay to the consensus-based sediment quality guidelines (CBSQG) developed by the WDNR (2003a). These guidelines address effects to benthic macroinvertebrate species only, meaning they do not consider possible biomagnification and/or bioaccumulation in fish or humans. For each contaminant, these guidelines specify a probable effect concentration (PEC) above which toxicity to benthic-dwelling organisms has a likelihood of greater than 50 percent. Such effects may include reduced survival rate, growth, or reproduction. They also specify a tolerable effect concentration (TEC), below which toxicity to benthic organisms is minimal. The midpoint effect concentration (MEC) falls between the TEC and PEC.

3.4.5.1 Mercury

Mercury contamination in Monona Bay has been a public concern since the first WDNR results labeled the bay as a "hot spot" in Lake Monona back in 1988. Mercury is extremely toxic and can bioaccumulate. In its methylated form, mercury interferes with the nervous system of the human body and can result in death or coma (Huber, 1997). Mercury also is highly persistent and tends to accumulate in fish tissue and then biomagnify within the food chain into animals that eat fish, such as loons, otters, and humans.

According to Marshall (1988), peak total mercury levels in sediment from Lake Monona (1.9 mg/kg) roughly coincided with peak sewage discharge into the Yahara Lakes. In a subsequent report, Marshall (1989) noted that surface mercury concentrations in Lake Monona have decreased since full sewage diversion was completed in the early 1950s; in 1989 the highest level found in Monona Bay was 1.1 mg/kg. We found even lower average surface mercury levels (0.5 mg/kg) (fig. 3.10).

Sites considered by the WDNR for dredging due to contamination have significantly higher mercury levels. For example, recent WDNR dredging sites around the state have excavated sediment with mercury concentrations ranging from 3 to 20 mg/kg (Jim Amrhein, Wisconsin Department of Natural Resources, verbal communication, 2006). Thus, although Monona Bay has had historically elevated mercury levels when compared to Lake Monona, surface concentrations show a decreasing trend and are well below "problem" areas within Wisconsin.

3.4.5.2 Trace Metals

Table 3.5 lists average concentrations of common trace metals and contaminants found in the Monona Bay surface sediment (i.e., the upper 20 cm). Because many of these compounds are persistent, they offer a glimpse into the history of Monona Bay, including the effects of initial development, aquatic plant management, and urbanization. For comparison, the table also lists the WDNR consensus-based sediment-quality guidelines,

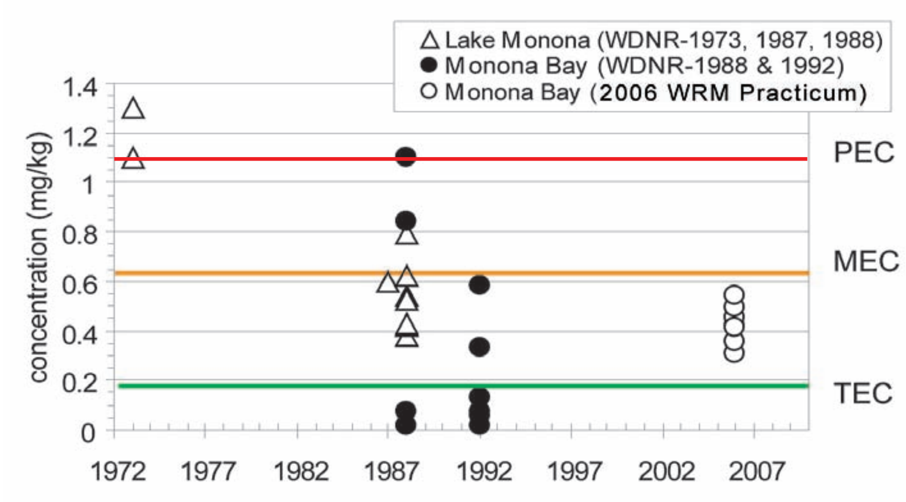


Figure 3.10. Mercury concentrations in sediment sampled in the upper 20 cm of Monona Bay. Open circles represent our data. Solid circles are data collected by the WDNR in 1988 and 1992. For comparison, results from a 1987 WDNR study in Lake Monona are included. TEC = threshold effect concentration; MEC = midpoint effect concentration; PEC = probable effect concentration.

addressing probable toxicity to benthic organisms. The trace metal analyses were conducted by the Wisconsin Soil and Plant Analysis Laboratory using ICP-OES procedures following digestion of the sediment with concentrated nitric acid on a hotplate. Figures 3.7 and 3.11 show profiles of zinc, copper, arsenic, and lead. Again, note that core B was taken offshore from the Brittingham Park outfall and core A from the middle of the bay.

Copper. Copper contamination in Monona Bay primarily resulted from the use of copper sulfate ($CuSO_4$) as an algaecide in early to mid-1900s. Records indicate that between 1922 and 1978, significant amounts of copper sulfate, approximately 1.5 million pounds, were applied to Lake Monona, and it is assumed that some of that was applied in the bay (Marshall, 1989). Copper herbicide application likely peaked in the mid-1940s (WDNR, 2001). Our data showed that average surface concentrations (146 mg/kg) coincided with the CBSQG PEC of 150 mg/kg. However, surface copper concentrations appear to have slightly decreased over time (fig. 3.12). In addition, our core results show that historic copper peaks (535 and 416 mg/kg) were significantly higher that current concentrations. In all three cores, these copper peaks are below the upper 20 cm, considered the "active" zone for benthic invertebrates. Regardless of the location of the most elevated concentrations, however, surface levels indicate that copper contamination associated with stormwater runoff continues to be a problem in the Monona Bay watershed. Potential current sources include metal corrosion, brake-pad wear, industrial paint, and electroplating waste (Burton and Pitt, 2002).

Arsenic. Sodium arsenite ($NaAsO_2$) was commonly used to kill rooted aquatic plants. Arsenic compounds were the primary chemicals applied in early years of aquatic plant management, but their use was discontinued after 1964 because of concerns about the cumulative toxic effect in the environment (Lathrop et al., 1992). Records indicate that between 1947 and 1964 36,000 pounds of sodium arsenite were applied in Monona Bay.

Figure 3.13 compares the surface concentrations of arsenic in Monona Bay over the past 20 years to historic values in Lake Monona. Like copper, surface levels are still elevated and sometimes surpass the CBSQG PEC. Likewise, there is considerably more historic contamination buried beneath the benthic zone, with peak values of 84 (core B) and 110 mg/kg (core C). Interestingly, the lowest surface values were found in the core taken near Brittingham Park, and the most elevated levels were from the middle of the bay—the reverse of most stormwater-related pollutants. This is probably because the core near the stormwater outfall receives sand, silt, and other suspended solids that effectively dilute the arsenic signal through burial. In contrast, the core from the middle of the bay receives significantly less sediment deposition, and arsenic deposited in the 1960s continues to re-

Table 3.5. Trace metal concentrations in Monona Bay surface sediment from three cores taken by the 2006 WRM Practicum. Averages and ranges are based on number of surface samples (n) taken from the upper 20 cm. TEC = tolerable effect concentration; MEC = midpoint effect concentration, and PEC = probable effect concentration.

	mg/kg dry wt			mg/kg dry wt		
Metal	**Average surface levels**	**Surface range**	**n**	**TEC**	**MEC**	**PEC**
Aluminum	10334	8605 - 12739	9	—	—	—
Arsenic	26	16589	9	9.8	21.4	33
Copper	146	117 - 178	9	32	91	150
Iron	13591	11959 - 17356	9	20000	30000	40000
Lead	286	224 - 430	9	36	83	130
Manganese	450	381 - 497	9	460	780	1100
Mercury	0.426	0.305 - 0.545	7	0.18	0.64	1.1
Phosphorus	810	718 - 870	9	—	—	—
Zinc	440	352 - 638	9	120	290	460

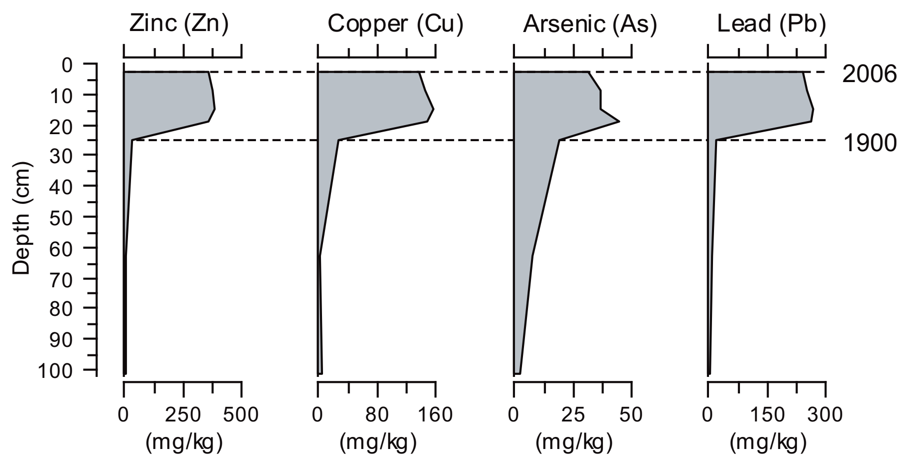


Figure 3.11. Profiles of common contaminants in core A, taken in the middle of Monona Bay. Note that there has been significantly less deposition here than shown in the core taken offshore from the stormwater outfall at Brittingham Park (compare to fig. 3.6).

main close to the surface, periodically churned by invertebrates living in the sediment. Levels of arsenic in the middle of Monona Bay are high enough to pose a threat to benthic macroinvertebrates, according to the WDNR guidelines.

Lead. Most lead contamination in Monona Bay is associated with stormwater runoff rather than intentional in-bay herbicide application. Principal sources within the watershed included peeling or chipped leaded paint, contaminated soils, vehicle wear, batteries, and residual leaded gasoline. Since the 1980s, many common applications of lead, including its use in residential house paint and as an additive in gasoline, have been phased out by the federal government.

As a result, the historical lead peak in the core taken near the Brittingham Park outfall (fig. 3.7) likely dates to the early 1980s, with levels peaking at 760 mg/kg. The lead concentrations for all 16 samples taken from the contaminated silt layer—rather than the clean marl deposit—in Monona Bay were above the WDNR PEC of 130 mg/kg. These results suggest that lead contamination from stormwater runoff is a continuing problem, and the health and integrity of the benthic invertebrate community within the bay are almost surely compromised.

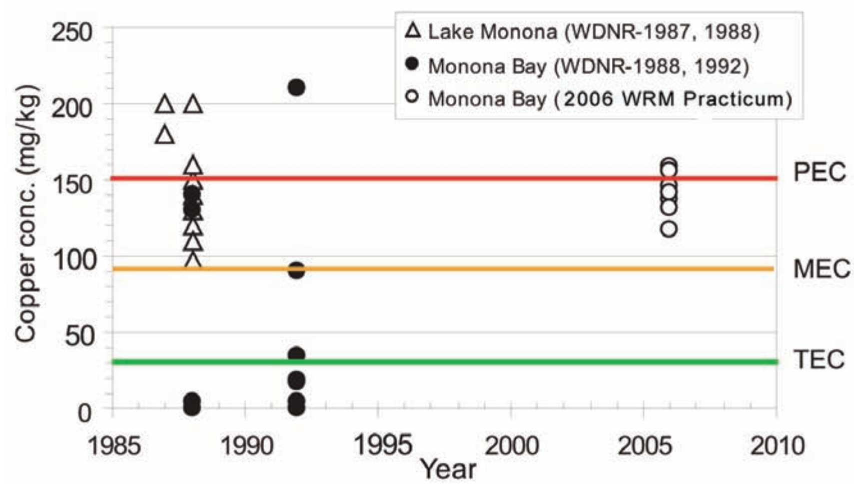


Figure 3.12. Copper concentrations in sediment sampled in the upper 20 cm of Monona Bay. Open circles represent our data. Solid circles are data collected by the WDNR in 1988 and 1992. For comparison, results from a 1987 WDNR study in Lake Monona are included. TEC = threshold effect concentration; MEC = midpoint effect concentration; PEC = probable effect concentration.

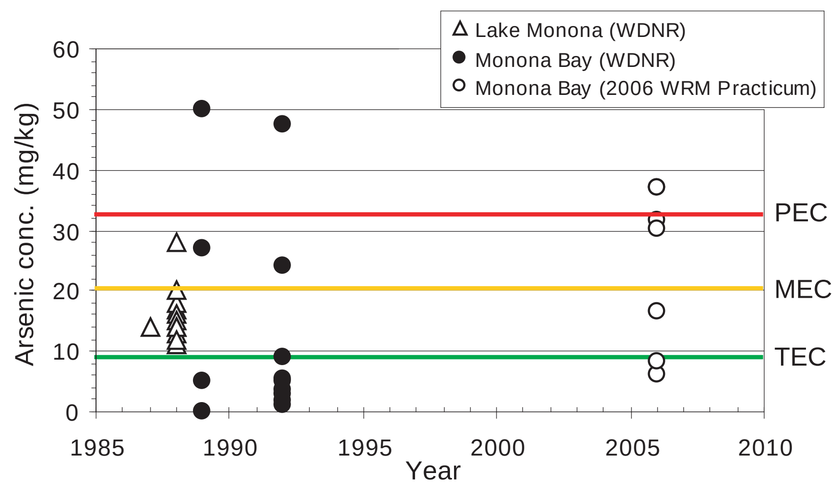


Figure 3.13. Arsenic concentrations in sediment sampled in the upper 20 cm of Monona Bay. Open circles represent our data. Solid circles are data collected by the WDNR in 1988 and 1992. For comparison, results from a 1987 WDNR study in Lake Monona are included. TEC = threshold effect concentration; MEC = midpoint effect concentration; PEC = probable effect concentration.

Zinc. Zinc is a ubiquitous urban stormwater contaminant; prominent sources include tire wear, galvanized steel, metal corrosion, road salt, and rubber (Burton and Pitt, 2002). Our sampling indicated that surface concentrations average around the WDNR PEC of 460 mg/kg (table 3.5). Unlike the previous contaminants, zinc had a more constant source historically, and we do not see the clear peaks associated with the arsenic, copper, or lead. However, zinc deposition does appear highest around the late 1970s, according to figure 3.7 in the core taken near the Brittingham Park outfall. Levels may have decreased since then because of increased street-sweeping efforts by the City of Madison.

3.4.5.3 Organic Contamination

Polycyclic aromatic hydrocarbons. Polycyclic aromatic hydrocarbons are considered the most commonly detected toxic organic compound found in urban runoff (Burton and Pitt, 2002). The PAHs are formed by the incomplete combustion of carbon-containing compounds, such as vegetation, wood, coal, diesel, and tar. They also represent the largest class of known carcinogens. In urban environments, possible sources include coal tar, crude oil, creosote, roofing tar, driveway sealants, and some pesticides. Historic sources into Monona Bay may include wastewater containing waste from the former Madison Gas and Electric coal gas plant on Blount Street. Support pilings for the two railway causeways crossing the bay may have been treated with coal tar creosote to prevent decay (David Liebl, written communication, University of Wisconsin–Madison, 2006). Current sources into the bay include possible coal dust runoff from the UW–Madison Charter Street Heating and Cooling Plant as well as from coal tar in some asphalt sealants used on driveways and parking lots throughout the watershed.

The PAH data that we collected is the first analysis of bay sediments for this suite of contaminants. Of the three cores analyzed, total PAH concentrations in surface sediment exceeded the WDNR PEC of 22,800 µg/kg only in core B, sampled near the Brittingham Park outfall. Core B sediments also exceed the *individual* PEC levels for the following compounds: acenapthene, benzo(a)anthracene, benzo(a)pyrene, dibenz(a,h)anthracene, fluoranthene, chrysene, phenanthrene, and pyrene. The first five compounds are "reasonably anticipated to be human carcinogens based on sufficient evidence of carcinogenicity in experimental animals," as determined by the U.S. Department of Health and Human Services (2005).

Poly-chlorinated biphenyls. Testing for PCBs in Lake Monona became a priority in the late 1980s after the WDNR determined that two carp contained elevated PCB concentrations of 1.1 and 1.7 ppm (Marshall, 1989). These values did not exceed the health standard of 2.0 ppm, but were high enough to cause alarm. As a result, two locations in Monona Bay were chosen that year for PCB analysis by the WDNR. These data indicated that the most and least contaminated sites on Lake Monona were in Monona Bay, on the north and west sides, respectively (fig. 3.14). Our cores indicated that although PCB contamination was widespread—it was found at all three cores—contamination was most elevated deeper in the sediments, indicating that PCB loading to the bay has decreased over the past fifty years. Surface concentrations in all three cores were below the detection limit, further supporting that PCB contamination has decreased over time. Prior to its being phased out of most commercial uses since the 1970s, PCBs were used heavily in capacitors, transformers, paints, pesticides, sealants, plastics, and flame retardants. Use continues in closed system applications, such as for capacitors and transformers. Historical industrial sources to Monona Bay are unknown.

3.5 Aquatic Plants

Major ecological disturbances and physical alterations have strongly impacted the aquatic plant community of Monona Bay. Dredging and shoreline filling along the north, west, and south edges of the bay have eliminated its natural, marshy shoreline, replacing it with a sharp, riprapped shoreline. The railroad trestle, completed in 1854, and John Nolen Drive, built in the 1960s, restrict water exchange between the bay and Lake Monona. Extreme nutrient loading occurred for approximately 70 years as the City dumped raw sewage and partially treated effluent into Lake Monona. Invasions of exotic species have further stressed this system. Today, large amounts of stormwater regularly transport nutrients, sediment, and other pollutants into the bay, impacting the quality of aquatic plant habitat and diversity.

3.5.1 Historic Aquatic Plant Growth and Management

3.5.1.1 Historic Diversity and Abundance

The Monona Bay aquatic plant community is typical of a nutrient-enriched, shallow water system. Aquatic plant growth has always been abundant in Lake Monona, particularly in the bay (Winkelman and Lathrop, 1992). An account from 1920 described Lake Monona as having a "practically continuous belt" of aquatic plants to a depth of about 3 m, covering "considerably more than 20 percent of the lake area" (Lathrop et al., 1992, p. 51). According to the same report, in 1914 the bay was described as "filled with a large amount of vegetation," prior to being partially dredged in 1907. A 1962 Dane County report listed the "Brittingham Bay area" as an area with aquatic vegetation problems (Andrews, 1986, p. 37).

Aside from plant abundance, early survey records also indicated that the Yahara Lakes historically had a rela-

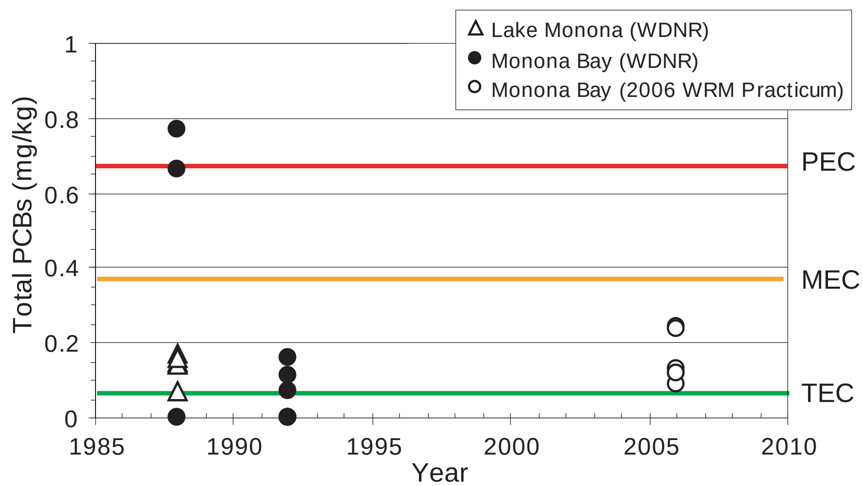


Figure 3.14. Total poly-chlorinated biphenyl (PCB) concentrations in sediments sampled in the upper 20 cm of Monona Bay. Open circles represent our data. Solid circles are data collected by the WDNR in 1988 and 1992. For comparison, results from a 1987 WDNR study in Lake Monona are included. TEC = threshold effect concentration; MEC = midpoint effect concentration; PEC = probable effect concentration.

tively diverse plant community. Aquatic plant data specific to Monona Bay is sparse, although some records about aquatic plants in Lake Monona are available. Algae decreased water clarity at times historically, but native aquatic plant abundance and species diversity were still relatively high until the 1960s. Lake Monona was dominated by sago pondweed (*Stuckenia pectinata L.);* other abundant species included coontail (*Ceratophyllum demersum)*, elodea (*Elodea canadensis*), Richardson pondweed (*Potamogeton richardsonii*), wild celery (*Vallisneria americana*), and other pondweeds (*Potamogeton spp.*) (Winkelman and Lathrop, 1992). All major groups of submersed aquatic plants were represented in Lake Monona during the late 1940s through early 1950s (Lathrop et al., 1992). Table 3.6 provides a summary of historic aquatic plant growth trends in Lake Monona.

3.5.1.2 Arrival and Spread of Exotic Species

Exotic species are introduced to a new area intentionally or inadvertently from distant lands. Many exotic species are not invasive, but may become so if their new habitat lacks the natural checks and balances that controlled them in their homelands. Without their co-evolved natural competitors and predators, some exotic species will grow wildly when they are brought to new areas. Disturbed ecosystems are especially susceptible to the spread of exotic species if there is an ecological niche to fill. Exotic species can dominate when the delicate balance of an ecosystem is disrupted by environment alteration (e.g., nutrient loading, sedimentation, dredging) or by restricting or eliminating natural processes, such as water-level fluctuations. See appendix 4 for pictures and identifying features of the aquatic plants found in Monona Bay.

Eurasian water milfoil. Arrival of the exotic invasive Eurasian water milfoil (*Myriophyllum spicatum*) in the 1960s to the Madison lakes was a drastic disturbance to Monona Bay's aquatic plant community. After becoming heavily infested by the mid-1960s, the Yahara Lakes continued to be dominated by dense EWM growth through the mid-1970s; EWM has since largely replaced the native Northern water milfoil (*Myriophyllum sibiricum*) in the Madison area lakes. The explosive growth of EWM, its efficiency at colonizing from fragments, and its tendency to form surface canopies make it a formidable invasive species that has never been eradicated permanently from any lake, and probably never will be.

Eurasian water milfoil quickly dominated the native plant community in Monona Bay through various competitive advantages. First, the plant readily colonizes disturbed habitats, such as areas where native plant communities are removed or stressed through shoreline development or motorboat activity (Engel, 1993). Indiscriminate use of broad-spectrum herbicides aids EWM colonization by removing native competitors. Both of these conditions apply to Monona Bay, given its history of dredging, widespread herbicide application, and continuing input of sediment-laden stormwater.

Although EWM can reproduce by seeds, it more effectively spreads vegetatively through fragment dispersal, such as when broken by motorboat propellers. Fragments of EWM can stay alive for days to weeks if kept moist, resulting in colony establishment at boat landings as fragments are inadvertently introduced and boat activity further uproots intact native plants (Engel, 1993). Early mechanical control efforts that involved cutting without immediately collecting the aquatic plant cuttings probably increased EWM spread (Lathrop et al., 1992).

Another advantage that EWM has is its tendency to form thick surface mats, effectively shading out native aquatic plants. By concentrating growth at or near the water's surface, EWM is less affected by poor water clarity compared to deeper growing native species. Eurasian water milfoil grows from early spring through fall, even overwintering as green shoots. Because most native aquatic plants begin actively growing in late spring, the plant gains another edge over natives. It also has less habitat and food value for aquatic life than the native plants it displaces.

Curly leaf pondweed. Curly leaf pondweed (*Potamogeton crispus L.*) is another aggressively growing exotic species that became prevalent in the Yahara Lakes the 1940s. Like EWM, CLP has competitive advantages that can allow it to dominate aquatic plant communities. Because it begins growing early in the season, CLP reaches the water's surface before other species, in many cases before natives even break their spring dormancy. It also dies earlier than other species, with its entire growth cycle ending by the beginning of July (Madsen and Crowell, 2002). The resulting midsummer dieback can lead to an atypical release of nutrients into the water column during the height of the growing season, resulting in nuisance algal growth (Madsen and Crowell, 2002). Similar to EWM, the main nuisance caused by CLP is the formation of dense surface mats, which can shade out native species. However, CLP has not dominated

Table 3.6. Summary of Lake Monona's aquatic plant history and average depth of plant growth.

Year	Maximum depth of plant growth	Comments
1920s	less than 3 m	Massive algal blooms caused by Madison's sewage effluent restrict maximum depth of aquatic plant growth. Aquatic plants cover greater than 20 percent of Lake Monona area in a continuous belt along lake edge.
1925 to 1940s	3–5.5 m	Increased water clarity due to extensive copper-sulfate treatments to address algae blooms (Hauxwell, 2006).
1950s	less than 1.8 m	Copper-sulfate treatments are discontinued. Light penetration decreased due to algal blooms, yet aquatic plants along the edges "grew luxuriantly" (Lathrop, 1989). Aquatic plant species diversity was also high, with sago pondweed dominating, and other pondweeds, wild celery, and coontail present (Lathrop et al., 1992).
1960s	1.8 m	Situation similar to 1950s, except that sago pondweed was less abundant and EWM was more abundant, invading all Yahara lakes (Lathrop et al., 1992).
1970s	NA	The maximum depth of plant growth was not available, but median summer Secchi disk depths for Monona were approximately 5 ft. Reports note that plant growth density declined during a period in the late 1970s due to dense summer algae blooms and generally poor water clarity (Wisconsin Department of Natural Resources, 2001).
1980s	3 m	Aquatic plant growth resurgent with improved water clarity.
1990s	4.5 m	Median water clarity levels were higher in 1992 than 1991. More aquatic plant species were found in 1992 than in previous years in Lake Monona, suggesting a trend toward greater diversity of native species as weedy species level off and water clarity improves (Winkelman and Lathrop, 1992).

Monona Bay's aquatic plant community to the extent of EWM. Repeated harvesting before CLP sets its overwintering buds (turions) can reduce its reproductive ability over time (Cooke et al., 2005).

3.5.1.3 A native that can be a nuisance: Coontail

Although it is a native plant, coontail (*Ceratophyllum demersum*) can grow to nuisance levels and has exceeded EWM densities in Lake Monona (Winkelman and Lathrop, 1992). It is a rootless aquatic plant and one of the few submersed species that draws most of its nutrients from the water column rather than the sediments. This has led to creative application of the plant in pond management: permeable containers of coontail are used to reduce water phosphorus levels, thereby reducing algae concentrations (Borman et al., 1997). Although coontail growth is heavy in Monona Bay, it does not form the branching surface mats like EWM or CLP. It is these dense surface mats of vegetation that interfere most with the bay's recreational use.

3.5.1.4 Historic Management

In an effort to control dense aquatic plant growth, early on the City of Madison relied heavily on broad-spectrum herbicides and mechanical controls. Herbicides were used as early as 1926 to control aquatic plants, particularly in Lake Monona (Lathrop et al., 1992). Arsenic compounds were widely used until 1964, when they were banned due to the toxic effect of arsenic in the environment (Lathrop et al., 1992). From the 1960s until the early 1980s, organic-based herbicides such as 2,4-D, diquat, and a variety of endothall products were used for large-scale plant control (Lathrop et al., 1992).

In addition to chemicals, since the 1920s the City has used weed cutters to control aquatic plants (Lathrop et al., 1992). In early methods, the plants were cut, but not collected until the cut material floated to shore—an inefficient method used only in isolated areas. In the 1950s, as public concern regarding widespread use of chemicals grew, the City of Madison increased weed cutting with more efficient machines (Lathrop et al., 1992). But it was not until 1965 that the City purchased a weed harvester that cut aquatic plants and simultaneously gathered the clippings. Cutting with older equipment continued through 1969.

In 1970 the City of Madison turned over the aquatic plant harvesting program to the Dane County Public Works Department (Lathrop et al., 1992). The County proceeded to expand the program and today harvesting is the main tool used to manage the region's aquatic plants. Although Dane County does not at present use chemical herbicides, waterfront landowners can apply to WDNR for permits to apply herbicides in small, high-use areas around private piers (ch. NR 107, Wisconsin Administrative Code).

3.5.2 Aquatic Plant Surveys, 1990–1993

Table 3.7 summarizes the aquatic plant species present in Monona Bay. In three surveys (1990, 1991, and 1993; Lathrop, 1993), EWM and CLP were found; coontail was not found in 1991, but it was in 1990 and 1993. Two additional native plants, elodea and leafy pondweed, were found in 1993. Winkelman and Lathrop (1992) found the plants EWM, CLP, coontail, sago pondweed, elodea, and water stargrass in Monona Bay.

3.5.3 Aquatic Plant Surveys, 2005 and 2006

In 2005, in compliance with a WDNR-issued permit to place water circulators in Monona Bay, the City of Madison's Engineering Department conducted a comprehensive aquatic plant survey of Monona Bay. The following year, we repeated a similar plant survey in early summer and assisted the City later in the summer with a third survey to build a reliable aquatic plant trend dataset that could be used to possibly monitor the effectiveness of the water circulators in Monona Bay. The data can also be used to compare Monona Bay's plant population to that of other area lakes, providing a reference to differentiate annual variability from actual composition changes. Good baseline data and consistent survey methodology in future years will be key to more accurately assessing the health of Monona Bay's aquatic plant community over time.

3.5.3.1 Sampling Protocol

The plant survey conducted by the City in 2005 followed the WDNR's aquatic plant sampling protocol (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2005; fig. 3.15). Approximately half of the sample points were surveyed on

Table 3.7. Summary of aquatic plant species in Monona Bay. Sources: Lathrop (1993); City of Madison (2006); this study.

Common Name	Scientific Name	1990 [1]	1991 [1]	1992 [2]	1993 [1]	2005 [3]	June 2006 [3]	Aug. 2006 [3]
Coontail	*Ceratophyllum demersum*	X		X		X	X	X
Muskgrass	*Chara* spp.					X		
Elodea, common waterweed	*Elodea Canadensis*			X	X	X	X	
Water stargrass	*Heteranthera dubia* (*Zosterella dubia)*			X		X	X	
Eurasian water milfoil	*Myriophyllum spicatum*	X	X	X	X	X	X	X
Curly leaf pondweed	*Potamogeton crispus*	X	X	X		X	X	
Leafy pondweed	*Potamogeton foliosus*				X	X	X	X
Small pondweed	*Potamogeton pusillus*						X	
Stiff water crowfoot	*Ranunculus aquatilis*						X	
Sago pondweed	*Stuckenia pectinata* L. (*Potamogeton pectinatus)*			X		X	X	X
Wild celery	*Vallisneria americana*							X

[1] The 1990, 1991, and 1993 data are from one transect line surveyed in Monona, just east of the gauging station at Brittingham Park. Aquatic plant species were recorded along the transect line beginning at 0.5 m(1.6 ft) deep and continuing every 0.5 m of depth down to 3.0 m. Survey dates were June 26, 1990, June 27, 1991, and June 28, 1993.

[2] The 1992 data are from a set of inter-transects that were conducted as part of an aquatic plant survey for Lake Monona. The inter-transect lines in Monona Bay were determined by dividing the area between two of Lake Monona's established transect lines (12 and 13) into five shoreline regions. This inter-transect survey was conducted during the second and third weeks of August (Winkelman and Lathrop, 1992).

[3] The 2005 and 2006 data used the point-intercept method. It is a significantly more extensive aquatic plant survey of Monona Bay. The point-intercept approach uses sampling locations distributed evenly in a 332-point grid over the entire surface of Monona Bay and the two adjacent triangles. Grid resolution and number of sample points were based upon the shape of the lake and size of the littoral zone.

July 29, 2005, and the remainder on August 30, 2005 (Genesis Bichanich, City of Madison, written communication, 2006). At each sample site a rake was thrown, dragged across the bay's bottom toward the boat, and pulled up, carrying with it a representation of the plant density and diversity of that point (see appendix 5). Data were then collected on water depth, sediment type (e.g., sand, muck, or rock), aquatic plant species present, and density (rated on a three-point scale: 1 = low, 3 = high) of the two aquatic invasives, EWM and CLP. All other species observed were recorded as "present" (Genesis Bichanich, City of Madison, written communication, 2006; University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2005).

Our plant surveys were similar and followed the most current sampling protocol recommended by the WDNR (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2006). The 2006 protocol recorded the same parameters listed above, but contained a few key differences. New items recorded in the 2006 survey were:

- filamentous algae on the density scale from 1 to 3.
- density ratings for every aquatic plant species observed on a scale from 1 to 3.

To document early summer plant growth, namely for CLP, we conducted our first 2006 survey during the last week of June. Along with the City of Madison Engineering Department, we also replicated the survey on August 17–18 and 20–21, 2006 to provide a more direct comparison with the 2005 late season survey. See tables 3.7, 3.8, and 3.9 for a summary of the aquatic plant survey results from 2005 and 2006. Individual species statistics for the three surveys are in appendix 6.

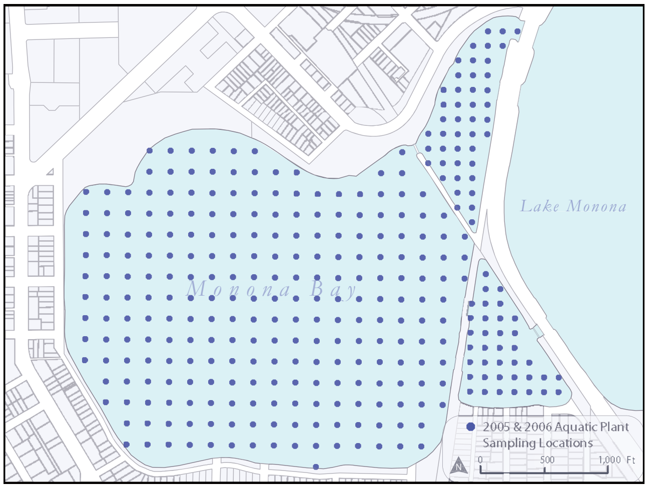


Figure 3.15. Sampling grid for aquatic plant survey, conducted by City of Madison Engineering Division in 2005 and 2006 WRM Practicum.

3.5.3.2 Biomass Weights

Different aquatic plant species vary tremendously in the amount of biomass they produce. Our June 2006 survey recorded biomass weights of each species found at 24 random points (appendix 5). This was done to better describe what the rake fullness ratings mean by providing a more tangible number—weight in grams. Previous research indicated that EWM is approximately 90 percent water by weight and 75 percent air by volume (Cooke et al., 2005). Our 2006 data yielded similar results. On average, the aquatic plant biomass field weights were 92 percent water (includes EWM, CLP, and coontail). Filamentous algae biomass field weights were on average 95 percent water. See table 3.10 for a comparison of average wet wrung and dry weights of field samples from the June 2006 aquatic plant survey.

3.5.3.3 Diversity Indices

Overall, native plant diversity in Monona Bay is poor. As a measure of the aquatic plant diversity of Monona Bay, two indices were calculated: the Simpson Diversity Index (SDI) and the Floristic Quality Index (FQI). The SDI estimates aquatic plant community heterogeneity on the basis of the relative frequency of different plant species (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2006). The closer the SDI for a given lake is to 1, the more diverse the plant community. The SDIs for Monona Bay for August 2005 and 2006 were 0.51 and 0.50, respectively. However, the June 2006 data indicated an SDI of 0.65, attributed to an additional four native species present.

The FQI, a standardized tool, is useful for comparing the biotic quality of lakes and for tracking changes of one lake's aquatic plant community over time. This system uses a coefficient of conservatism (C value) to rank each native plant species on a scale of 1 to 10. Plants that have higher C values are more likely to be found in pristine, natural ecosystems and are generally intolerant to disturbances. Conversely, a species valued at 1 is widespread and likely to be found in highly degraded or disturbed ecosystems. Note that C values are not assigned to the exotic species, such as EWM and CLP; the FQI only considers the diversity of the native plant population (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2005).

The mean C value for the July–August 2005 survey was 4.7, on the basis of six native species. The mean C value for the August 2006 survey was 4.5, based on four native species. The highest mean C value of 5.0 was found in June 2006, further indication that species diversity is higher earlier in the growing season. The FQI value is generated by multiplying the average C value by the square root of the number of native species found in the bay. The FQIs calculated for Monona Bay were 11.4 for August 2005, 13.2 for June 2006, and 9.0 for August 2006. The FQI varies around Wisconsin, ranging from 3.0 to 44, with a median of 22.2 (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2005). To put Monona Bay's FQI rankings into a regional context, the median FQI for southeast Wisconsin is 20.9, with a median of 14 plant species (Big Muskego Lake/Bass Bay Protection and Rehabilitation District, 2004).

3.5.4 Aquatic Plant Key Findings

3.5.4.1 Limitations of the Surveys

When comparing Monona Bay aquatic plant data, several factors should be taken into consideration. Because of differences between 2005 and 2006 sampling protocols, density ratings were not collected for plants other than CLP and EWM in 2005. Similarly, data for fila-

Table 3.8. Frequency of occurrence of aquatic plants for the 2005 and 2006 surveys of Monona bay. Note that filamentous algae was not recorded in 2005. Sources: City of Madison and 2006 WRM Practicum.

Frequency of occurrence within vegetated areas (in %)	Eurasian water milfoil *Myriophyllum spicatum*	Curly leaf pondweed *Potamogeton crispus*	Coontail *Ceratophyllum demersum*	Chara *Chara spp.*	Elodea *Elodea Canadensis*	Leafy pondweed *Potamogeton foliosus*	Water star-grass *Heteranthera dubia*	Sago pondweed *Stuckenia pectinata L.*	Wild Celery *Vallisneria americana*	Small pondweed *Potamogeton pusillus*	Stiff water crowfoot *Ranunculus aquatilis*	Filamentous algae
July/August 2005	59.1	2.6	99.0	0.3	0.3	0.3	1.3	1.7	—	—	—	—
June 2006	81.5	35.4	96.6	—	0.6	2.2	0.9	1.9	—	0.3	1.9	73.5
August 2006	73.9	—	96.7	—	—	1.0	—	—	0.3	—	—	28.1

Table 3.9. Summary statistics for total aquatic vegetation, excluding filamentous algae, for the 2005 and 2006 plant surveys. The July 29, 2005 (points 166–337) and August 30, 2005 (points 1–165) surveys were conducted by City of Madison Engineering Department and the WDNR. The June 23–24, 2006 and 29–30, 2006 survey was conducted by the 2006 WRM Practicum. The August 17–18 and 20–21, 2006 survey was conducted by City of Madison Engineering Department and 2006 WRM Practicum. During each survey, not all points could be sampled due to obstacles, anglers or other recreational users.

Survey date	July/August 2005	June 2006	August 2006
Total number of points sampled	324	330	331
% number of sites with vegetation	93.5%	98.4%	92.4%
Maximum depth of plants (feet)	11.5	12.0	12.5
Average number of all species per site (vegetated sites only)	1.65	2.21	1.72
Average number of native species per site (vegetated sites only)	1.04	1.08	1.01
Species richness	8	9	4
Simpson diversity index	0.51	0.65	0.50
Floristic quality index	11.4	13.2	9.0

mentous algae were not collected in 2005. In addition, completion of the late season survey in 2005 was actually conducted over an entire month. This is significant because a number of aquatic plant species, such as the pondweeds, begin to die back by mid-August, suggesting that the 2005 diversity results may be slightly biased. The transect surveys of the 1990s took considerably fewer sample points than the 2005 and 2006 surveys, so they are therefore not comparable to these more intensive surveys.

3.5.4.2 Most Common Species

To determine the most common plants present in Monona Bay for the 2005 and 2006 surveys, the frequency of occurrence was calculated for each species by taking the number of times a species was observed divided by the total number of vegetated sampling points, expressing the result as a percentage. In all three surveys the most common species at each vegetated sampling point was the native coontail. It was present at 99 percent of the vegetated sample points in 2005 and 97 percent of the points for both 2006 surveys. The next most

Table 3.10. Aquatic plant biomass weights from the June 2006 aquatic plant survey.

Species	Ave. rake density rating	Range of wet wrung field weights (grams)	Ave. wet wrung weight (grams)	Ave. dry weight (grams)	Ave. percent water (%)
Filamentous algae	1	< 10 - 150	42.5	2.0	95.3
Coontail	2	< 10 - 4,450.0	1,049.6	20.9	98.0
Eurasian water milfoil	2	< 10 - 760.0	222.3	16.7	92.5
Curly leaf pondweed	1	< 10 – 200.0	51.0	6.6	87.1

common species for all three surveys was EWM, present 59 percent of the time in 2005, 82 percent in June 2006, and 74 percent in August 2006. The third most common species, CLP, was actually absent from the August 2006 survey because it had already seasonally died back, indicating the importance of sampling time. It was present at 3 percent of vegetated sample points in 2005, and in 35 percent in June 2006 (table 3.8).

3.5.4.3 Seasonal and Overall Diversity

By comparing the June 2006 results with those from the 2005 and 2006 late season surveys, we see a definite increase in species richness earlier in the summer. Four more native species were found in June 2006 than in August 2006. The June survey results also had higher FQI and SDI ratings than the two late season surveys. These results suggest that mid-August is too late to capture maximum species diversity in the bay. For example, native narrow-leaved pondweeds tend to die back by mid-August (University of Wisconsin–Extension and Wisconsin Department of Natural Resources, 2006). The invasive CLP also dies back by this time, as evidenced by its complete absence from the August 2006 survey. Even in the June survey, although CLP was still actively growing, its turions were abundant, a sign the plants were nearing the end of their growth cycle. In addition, overall plant biomass was greater earlier in the season than later on, as shown by the higher average rake densities. The increase in plant diversity and biomass earlier in the summer is likely a function of better water clarity as well as the growth cycle preferences of different species.

There also appears to be a slight trend of increasing aquatic plant diversity in Monona Bay since 1990, although the data are not conclusive. Yet data from Lake Monona and the other Yahara Lakes indicate they are rebounding somewhat from invasion by the two aquatic exotics, EWM and CLP. Although EWM made up the largest component vegetation in the Madison lakes in the 1960s, it has leveled off lake-wide over the last decade (Hauxwell, 2006). Regular aquatic plant harvesting focused on removing surface mats may be stressing the invasives enough to balance EWM among other species. A general trend toward greater diversity of native species becomes apparent as water clarity improves. Because the lake sediments contain large quantities of nutrients, aquatic plants will continue to be abundant, particularly if water clarity continues to improve (Wisconsin Department of Natural Resources, 2001). It is very important to continue regular aquatic plant surveys to build a reliable dataset of trends for Monona Bay over time. Good data will also help assess whether aquatic plant management tools are working.

3.5.4.4 Maximum Plant Depth

The bay's maximum depth is 14.5 ft, with an average depth of 7.4 ft. The maximum depth of plants for the three point-intercept surveys was 11.5 ft in 2005, 12 ft in June 2006, and 12.5 ft in August 2006. The frequency of occurrence of aquatic plants at sites shallower than these depths ranged from 94 to 100 percent. The implications of these depths are discussed further in the *Aquatic Plant Management Alternatives* section of chapter 6.

3.6 Algae and Fecal Bacteria

Like aquatic plants, algae and bacteria are essential parts of the ecosystem of Monona Bay and receive the most attention when they cause problems that conflict with recreation, public health, or aesthetics. Understanding the characteristics of these organisms is therefore critical for management.

3.6.1 Fecal Bacteria

Since the 1950s, the Madison Department of Public Health has monitored water quality at Monona Bay's two public beaches, Brittingham and Bernies, for fecal bacteria contamination (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). Current sources of contamination include waterfowl feces, heavy rains, stagnant water and, on occasion, broken sewer mains (City of Madison, 2006b).

Between 1995 and 2006, the two public beaches on Monona Bay were closed four times due to elevated levels of fecal bacteria found by the Madison Department of Public Health (table 3.11). Beaches were also closed during this time as precautionary measures following excessive rains or other events that can cause an increase in bacteria levels. In addition to beach closures, the City keeps track of any complaints officially filed and specific health-related incidents that have been reported for the bay, two of which occurred in recent years. In 2002, two children contracted a gastrointestinal illness after swimming in the bay. Another child contracted an unidentified skin rash after being at Bernies Beach in 2003 (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). A more detailed discussion of beach closings follows in the *Water Quality* section of chapter 5.

Table 3.11. Beach closings on Monona Bay from 1996 to 2006. (Modified from Kirsti Sorsa, City of Madison, written communication, 2006.)

Year	Month/Day	Beach	Cause
1998	June 19	Bernies, Brittingham	Flooding*
1998	July 9	Bernies, Brittingham	Diquat dibromide (herbicide) treatment*
2000	June 2	Bernies, Brittingham	Heavy rain*
2000	August 8	Bernies	Elevated bacteria levels
2004	August 25	Bernies	Elevated bacteria levels
2005	August 16	Bernies	Elevated bacteria levels
2006	July 26	Brittingham	Elevated bacteria levels

*Beaches were closed as a precaution, not due to actual detected fecal bacteria.

3.6.2 Nontoxic Filamentous and Planktonic Algae

Algae have several different growth forms, but can be placed into two general categories: planktonic and filamentous. Planktonic are free-floating, and either motile or suspended in the water column by mixing. Filamentous algae are non-motile and usually anchored to a substrate (Stevenson et al., 1996; Wehr and Sheath, 2003). Throughout the course of a year, the planktonic algal community of Monona Bay is likely to follow a seasonal succession similar to stratified lakes (Dodson, 2005; Vanni and Temte, 1990). During the winter, when ice cover limits light penetration, very few species of planktonic algae are present. As the snow and ice melt, light penetration into the water column increases, creating a bloom of algae. This continues until spring mixing incorporates nutrients from the sediments into the water column. In addition, the abundance of diatoms, unicellular algae encased in silicate shells, reaches its annual peak at this time. Late spring is usually marked by a clear-water phase caused by the intense grazing of algae by zooplankton. In the summer algal blooms return mostly in the form of blue-green algae. Finally, before the water freezes over in the autumn, diatom blooms are once again prevalent.

3.6.2.1 Filamentous Algae in Monona Bay

Despite the presence of both types of algae in Monona Bay, filamentous algae deserve more attention because of their tendency to create extensive visible growths. While conducting the June aquatic plant survey, we identified species such as *Rhizoclonium* and *Oedogonium* (Chlorophyta, green algae) attached to EWM near the bay's surface. These filamentous species and others create the massive surface mats that have become associated with the bay's poor appearance during the summer months. Filamentous algae are likewise extremely abundant in the bay. Our June 2006 survey identified filamentous algae at 237 of the 330 sample points, with a frequency of occurrence of 73 percent. Note that this survey is the only one to date that has recorded filamentous algae abundance in Monona Bay.

3.6.2.2 Associated Problems

The problems related to filamentous and planktonic algae relate to aesthetics and ecosystem health. Filamentous blooms can deter boaters by clogging intake pipes, aquatic filters, and boat motors (Wehr and Sheath, 2003; Stevenson et al., 1996). Thick blooms also discourage swimmers from using the bay. As filamentous algae die back or break off from the substrate, the mats tend to collect at the surface or along the shoreline. In this event, nearby residents can be subjected to strong, unpleasant odors associated with these decaying materials. Although no known health effects are associated with this natural process of decay, the smell can be a public nuisance. Planktonic algae can also cause a reduction in water clarity. Algae blooms of some species can result in a thin film on the water surface and can cause discoloration of water, turning it brown, green, or even red (Wehr and Sheath, 2003). This is an aesthetic problem for Monona Bay users.

A reduction in water quality is also a concern from an ecological point of view because it may signal a decline in ecosystem health and may adversely affect other organisms. For example, extensive algae growth can prevent sunlight from reaching native aquatic plants, thus reducing aquatic plant health and abundance. Excessive algal blooms can also lead to "fish kills" (Boyd et al., 1975), in which massive amounts of algae begin to die and decompose, and oxygen is depleted to a level at which most fish cannot survive.

3.6.3 Blue-Green Algae

Blue-green algae are also important to consider when examining the biotic quality of Monona Bay. Blue-green algae are found in most surface waters in planktonic and filamentous forms. These algae are important primary producers and are especially abundant in the summer when nutrient concentrations are highest (Vanni and Temte, 1990). Blue-green algae can also thrive in nitrogen-depleted environments because several species are able to fix atmospheric nitrogen (Andrews, 1986; Stevenson et al., 1996). Blooms occur when blue-green algae are able to outcompete other algal species. For example, various species (e.g., *Lyngbya* spp., *Anabaena* spp.) can regulate their buoyancy in response to light by controlling the carbon dioxide levels within their cells (Wehr and Sheath, 2003). As light levels decrease, these species can increase their buoyancy and rise to a depth more optimal for photosynthesis. The result is a self-perpetuating cycle in which blue-green algae continue to shade other algae species by continually rising to the surface (Andrews, 1986).

3.6.3.1 Toxins

Blue-green algae have the potential to cause problems in Monona Bay in the same ways that other algae do. Some blue-green algae will form a film or mat on the surface during blooms. The changes in water quality caused by blue-green algae can harm other organisms.

The major problem associated with blue-green algae, however, is the group's ability to produce toxins. The different blue-green algae are known to produce more than 70 toxins, which can be categorized into three groups: lipopolysaccharides, hepatotoxins, and neurotoxins (Graham and Wilcox, 2000). Lipopolysaccharides are endotoxins that are produced by such species as *Anabaena* spp. and *Microcystis* spp., and cause fever and inflammation in people. Hepatotoxins cause liver bleeding and eventual breakdown. Microcystin is a well studied hepatotoxin that persists in freshwater for weeks before it is degraded. Neurotoxins, as the name implies, block neuromuscular activity and eventually depress breathing (Graham and Wilcox, 2000). *Anabaena* and *Planktothrix* (both common to Monona Bay) are examples of genera that may produce neurotoxins. A recent study by Cox et al. (2005) found that a specific neurotoxin, β-N-methylamino-L-alanine (BMAA), may be produced by all known groups of blue-green algae. It is dangerous because it can bioaccumulates, becoming bound by proteins in the human body. Then the toxin is slowly released over years following exposure (Cox et al., 2005). We must treat every kind of blue-green algae as having the potential of being toxic.

The presence of small amounts of blue-green algae in a natural water body is generally not indicative of a health risk, but its overabundance raises concerns. The World Health Organization (WHO) has provided guidelines to judge the risk of illness due to blue-green algae toxins (Chorus and Bartram, 1999). The WHO stated that if blue-green algae are present at less than 20,000 cells/mL, adverse health effects are unlikely. At 20,000 to

100,000 cells/mL the health risks are moderate; at more than 100,000 cells/mL there is a high risk of long-term health effects from blue-green toxins (Chorus and Bartram, 1999). Because the WHO standards were set before the previously mentioned BMAA study, they should be regarded as provisional until another set of standards (WHO or otherwise) takes into account more recent information.

3.6.3.2 Concentrations in Monona Bay

Despite the press that blue-green algae has received in recent years, no beach on Monona Bay has been closed due to detected high levels (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). Data collected by the City of Madison in 2005 and 2006 show that blue-green algae in Monona Bay were seldom present at levels more than 100,000 cells/mL during the active swimming season (fig. 3.16). However, levels close to 200,000 cells/mL—considered high risk by the WHO—were found once in the bay in October 2005. The 2006 late-season blooms were not as prolific, but still reached counts higher than 100,000 cells/mL. These blooms may be spurred by the annual release of nutrients into the water column due to the death and decay of the bay's abundant aquatic plant community.

Of particular interest to the City when sampling for blue-green algae are species of concern or species known to produce dangerous levels of toxins. Some species of concern in Monona Bay include *Anabaena* spp., *Aphanizomenon* spp., *Microcystis* spp., *Planktothrix* spp. Some of these blue-green algae species are present in the bay at high levels, such as *Aphanizomenon* spp. in mid-summer and *Planktothrix* spp. in the autumn. Although these numbers are high, they do not occur during the swimming season when humans are most susceptible to toxin exposure. As a result, when *Planktothrix* spp. counts spiked in fall of 2005, the City of Madison posted a warning sign rather than closing any beaches (Genesis Bichanich, City of Madison, verbal communication, 2006). Regardless of the peaks that may occur in September or October in Monona Bay, the concentrations throughout the sampling season of 2005 do not warrant any immediate concern for human health. Concentrations at the beaches and in the bay remain under 100,000 cells/mL when people are the most active in the bay (fig. 3.16). Because the bay is a popular spot for runners and walkers, however, is important for anyone with a dog to know that it is probably not safe for the animal to drink large amounts of water from the bay in the fall. This is a precautionary measure to avoid animal deaths due to cyanobacteria toxins, which has happened previously in Madison.

3.7 Fishery

Monona Bay is a popular fishing spot that draws thousands of anglers annually from southern Wisconsin and northern Illinois (Flaherty et al., 2003). Game fish, panfish, and carp live in the bay's waters where bluegills and crappies tend to be the most popular fish for anglers. The bay's fish, however, can pose a health risk to humans because they may have a wide range of mercury and PCB concentrations in their muscle and fatty tissues. The WDNR issues fish consumption advisories, which give the public guidelines on which fish species to avoid, safe consumption quantities, and appropriate preparation.

3.7.1 Fish Species and Health

3.7.1.1 Panfish and Game Fish

The most common fish in Monona Bay are panfish such as bluegills *(Lepomis macrochiris)* and black crappies *(Pomoxis nigromaculatus).* Panfish generally prefer the bay's shallow, warm water and dense aquatic vegetation for spawning and habitat. Yellow perch (*Perca flavescens*), although not technically a panfish, are also common and depend on weed beds for spawning. All three species subsist on zooplankton, insects, crustaceans, and very small fish, and as the most prevalent species in Monona Bay, are caught more often than game fish by anglers (Flaherty et al., 2003).

Monona Bay does host a variety of game fish, including walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), and largemouth bass (*Micropterus salmoides*). In general, game fish hunt smaller fish and prefer more open water than provided by the densely vegetated Monona Bay.

The health of the bay's fishery is demonstrated by sam-

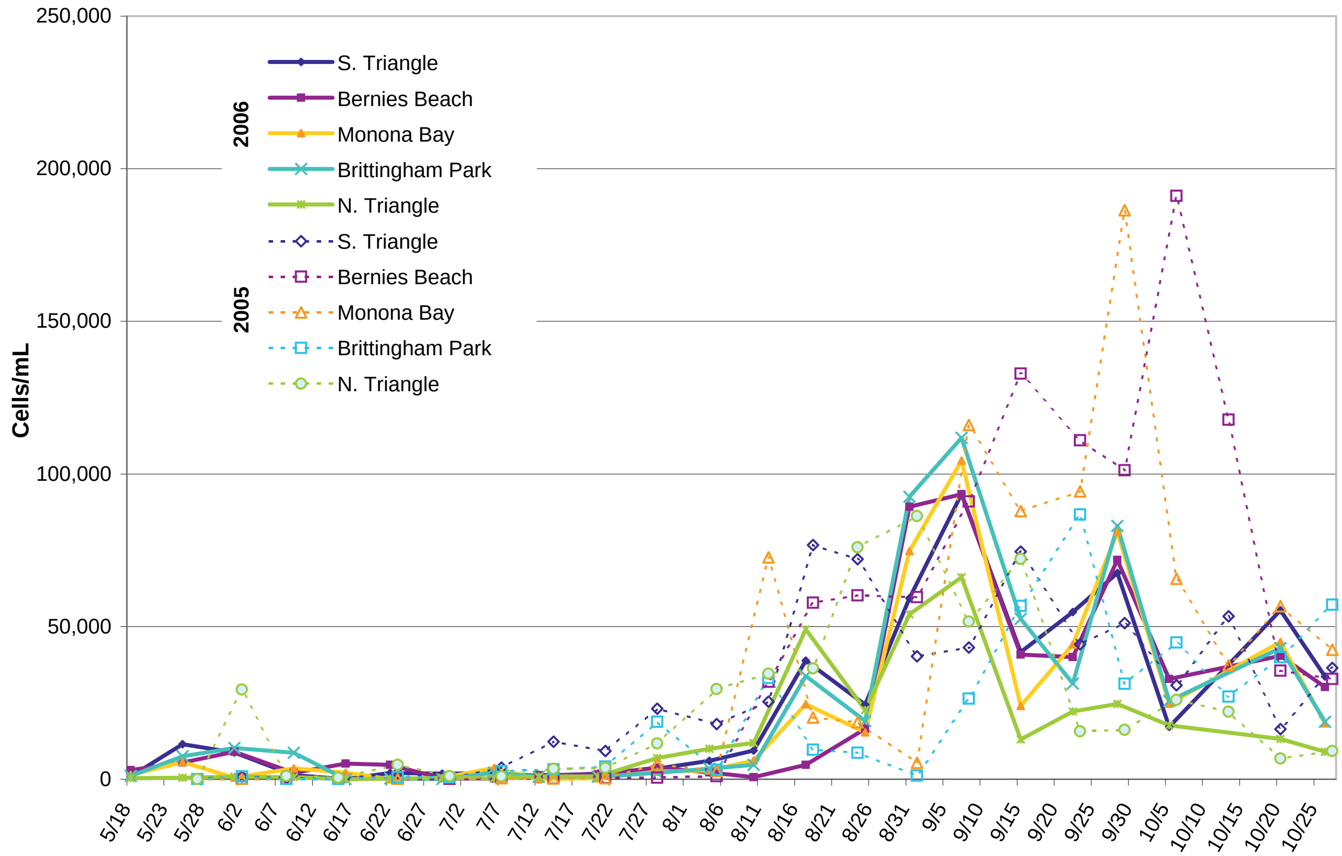


Figure 3.16. Total blue-green algae counts (cells/mL) in five locations of Monona Bay in 2005. (Data collected by Geneis Bichanich, City of Madison Engineering Division.)

pling rates taken by the WDNR in 2005 (Kurt Welke, Wisconsin Department of Natural Resources, written communication, 2006) (table 3.12). During standard samplings of Madison area lakes using electroshocking techniques, Monona Bay had a much higher catch rate than all the other lakes. Although many factors control these rates, the fact that the catch rate in the bay was considerably greater than in the rest of area lakes provides an example of the vitality of the bay's fishery. The bay is not, however, immune to the problems associated with the other area lakes.

3.7.1.2 Carp

The exotic, common carp (*Cyprinus carpio*) are bottom-feeding, opportunistic omnivores that prefer soft, vegetative sediments and are generally unaffected by low dissolved oxygen, turbidity, poor water quality, or drastic temperature swings (Lathrop et al., 1992). Research shows that carp decrease aquatic vegetation by physically uprooting plants and by resuspending sediments, thereby shading vegetation (Lathrop et al., 1992). Such turbidity decreases the habitat quality for sight-feeding fish that must track prey. Carp also out-compete other species by consuming their eggs as well as reducing invertebrate densities.

Monona Bay's shallow and thick aquatic plant stands are ideal spawning ground and habitat for the common carp. However, the bay does not typically appear to have problems related to carp and resuspended sediments. The fish are indeed present in the bay, but researchers are unsure why the fish have not become problematic as in other, shallow area lakes, such as Lake Wingra. One possibility is that the dense aquatic vegetation dissipates wind and wave energy that would otherwise keep the resuspended sediment in the water column.

3.7.2 Effects of Aquatic Plants and Harvesting on Fish Habitat

High aquatic plant densities can stunt pan and game fish in two ways (Olson et al., 1998). First, dense aquatic plants reduce feeding rates and foraging efficiency of game fish by increasing refuge options for pan fish (Olson et al., 1998). Second, dense aquatic vegetation lowers predator-induced mortality rates of pan fish, which leads to greater population densities and thus competition between pan fish (Olson et al., 1998). Therefore, optimal game and pan fish sizes are maximized at intermediate aquatic plant densities (Olson et al., 1998).

Monona Bay's fishery may be enhanced by cutting harvest channels that reduce aquatic plant densities. Cutting channels in aquatic plant beds "increases the amount of vegetation-open water edge," which is thought to be a vital area for fish to forage, hunt, and find refuge (Olson et al., 1998). Olson et al. (1998) demonstrated that removing 20 percent of a lake's aquatic vegetation by cutting channels in aquatic plant beds from the shoreline out to the edge of the littoral zone increased bluegill size 8 to 10 mm. However, after two years, the channels were overgrown with aquatic plants, so it is necessary to perform regular harvesting to maintain open channels (Olson et al., 1998).

Table 3.12. Wisconsin Department of Natural Resources sampling rates of fish caught per hour among area lakes.

Water body	Catch rate
Monona Bay	278.0 per hour
Lake Monona	66.3 per hour
Lake Mendota	21.6 per hour
Lake Kegonsa	90.6 per hour
Lake Waubesa	100.8 per hour

3.7.3 Fish Consumption and Human Toxicity

Because Monona Bay sediments are known to be contaminated by mercury, PCBs, and other pollutants, there is particular concern regarding the safety of eating fish from the bay. Sediment-dwelling organisms, such as insects, accumulate a contaminant by consuming small amounts from the sediment. As they are eaten by panfish, which are then consumed by higher trophic fish such as walleye, the contaminant becomes further concentrated in a process referred to as biomagnification. Some contaminants, such as mercury, are slowly secreted by the organism; fat-soluble pollutants such as PCBs continue to accumulate over an organism's lifetime.

3.7.3.1 Mercury and PCB Levels

Certain bacteria play a key role in transforming inorganic mercury to methylmercury through a process called methylation. This transformation is significant because methylmercury is more toxic than inorganic mercury and because it takes considerably longer to eventually excrete methylmercury compared to the inorganic form (U.S. Geological Survey, 1997). Once methylated, these bacteria can then be either consumed by higher-trophic organisms directly, or they can release the methylmercury back into the water where it adsorbs onto plankton, which are eventually consumed by higher-trophic animals, eventually working up through fish to humans.

Although fish specifically harvested from Monona Bay have not been tested by the WDNR for mercury, there is an accumulating database for neighboring Lake Monona. Average total mercury concentrations for Lake Monona fish species are listed in table 3.13 and indicate that for the most common species found in Monona Bay—bluegills and black crappie—mercury in fish tissue ranged from 0.07 to 0.11 ppm. Walleye tissue levels, however, were threefold greater and averaged 0.35 ppm—further indication of biomagnification.

The U.S. Environmental Protection Agency (2006) noted that although nearly all fish contain traces of mercury, the risks from mercury exposure depends on the amount of fish eaten, the mercury concentrations in the fish, and the age and gender of the consumer. As a result, the WDNR recommends not exceeding 0.7 µg mercury per kilogram weight per week (i.e., 0.05 mg for the average 150-lb male). Because mercury is a neurotoxin, it is also important to further limit exposure to children and women of child-bearing age. Table 3.14 outlines WDNR guidelines for fish consumption for these groups, differentiating between panfish, which generally are lower in mercury, and game fish, which generally are more contaminated. Muskellunge should never be consumed; they have extremely high mercury levels.

Specifically for Monona Bay, Flaherty et al. (2003) concluded that adult males fishing in the bay could safely consume 23 bluegill sunfish per week, but less than 1 walleye. Of the 138 male ice anglers interviewed, the authors found that those eating exclusively panfish were not at risk of exceeding threshold levels of mercury consumption. However, eating a mixed-fish diet consisting of panfish and game fish greatly increased the anglers'

Table 3.13. Concentrations of total mercury and PCBs in common Lake Monona fish.

Fish species	Mean mercury concentrations (mg/kg)[1]	Mean PCB concentrations (mg/kg)[2]
Walleye	0.349	0.16
White bass	0.345	0.14
Muskellunge	0.28	no data
Largemouth bass	0.256	no data
Northern pike	0.25	<0.2
Carp	0.155	<0.2
Rock bass	0.137	0.48
Yellow perch	0.135	<0.2
Black crappie[3]	0.112	<0.2
Freshwater drum	0.11	<0.2
Blue gill[3]	0.07	<0.2

[1] From Flaherty et al. (2003)
[2] Wisconsin Department of Natural Resources, unpublished data, 2005 (Kurt Welke, Wisconsin Department of Natural Resources, written communication, 2006)
[3] Most commonly consumed fish from Monona Bay

risk. The implications of this study are discussed further in the *Public Awareness and Education of Fish Consumption Advisories* section of chapter 6.

The second most common fish-tissue contaminants are PCBs, which were once used extensively in industry. Although their use has been banned in the United States since 1977, they continue to persist in lake sediments and accumulate in fish. The amount of PCBs in any given fish depends on the species, age, size, fat content, and diet (Wisconsin Department of Natural Resources, 2006b). Unlike methylmercury, PCBs accumulate in fat tissue and are not slowly excreted over time. However, this also means that a large part of the PCBs in a fish can be removed through proper trimming, skinning, and cooking to reduce fatty tissue. Again, no data specifically for PCB concentrations in fish from Monona Bay exist, but we can use information from Lake Monona (Ted Bier, University of Wisconsin–Madison Center for Limnology, verbal communication, 2006).

Table 3.14. Wisconsin Department of Natural Resources 2006 safe eating guidelines for most Wisconsin inland waters.

Childbearing age women, nursing mothers, children younger than 15 years may consume:	Women beyond childbearing age and men may consume:
1 meal per week: bluegill, crappie, yellow perch or bullhead (panfish)	Unlimited: bluegill, crappie, yellow perch or bullhead (panfish)
1 meal per month: walleye, northern pike, bass, catfish, carp or any other species (game fish)	1 meal per week: walleye, northern pike, bass, catfish, carp or any other species (game fish)

CHAPTER 4. STAKEHOLDERS

4.1 Principal Land Holders and Recreational Users

Land within the Monona Bay watershed is currently occupied by a combination of residential, commercial, industrial, and governmental entities. However, the watershed is predominantly zoned for residential use. Renters and homeowners live in eight Madison neighborhoods: Bay Creek, Bayview, Capitol, Dudgeon-Monroe, Greenbush, Regent, South Campus, and Vilas (fig. 4.1), and most have active neighborhood associations serving as important outreach and education outlets. Approximately 110 homes are located directly across the street from the bay on the north, west, and south shores. Many homes on the south and west shores have private docks on the bay.

State and local government-owned buildings also make up part of the watershed; approximately one-fifth of the UW–Madison campus and the entire State Capitol Building lie within the watershed. Commercial businesses on Park, Regent, Monroe, and State Streets are within the watershed as well.

Monona Bay is host to a variety of recreational activities, including

- fishing: both open water and ice;
- motorized uses: boating, waterskiing, jet skiing;
- non-motorized uses: kayaking, canoeing, rowing;
- swimming at Bernies Beach;

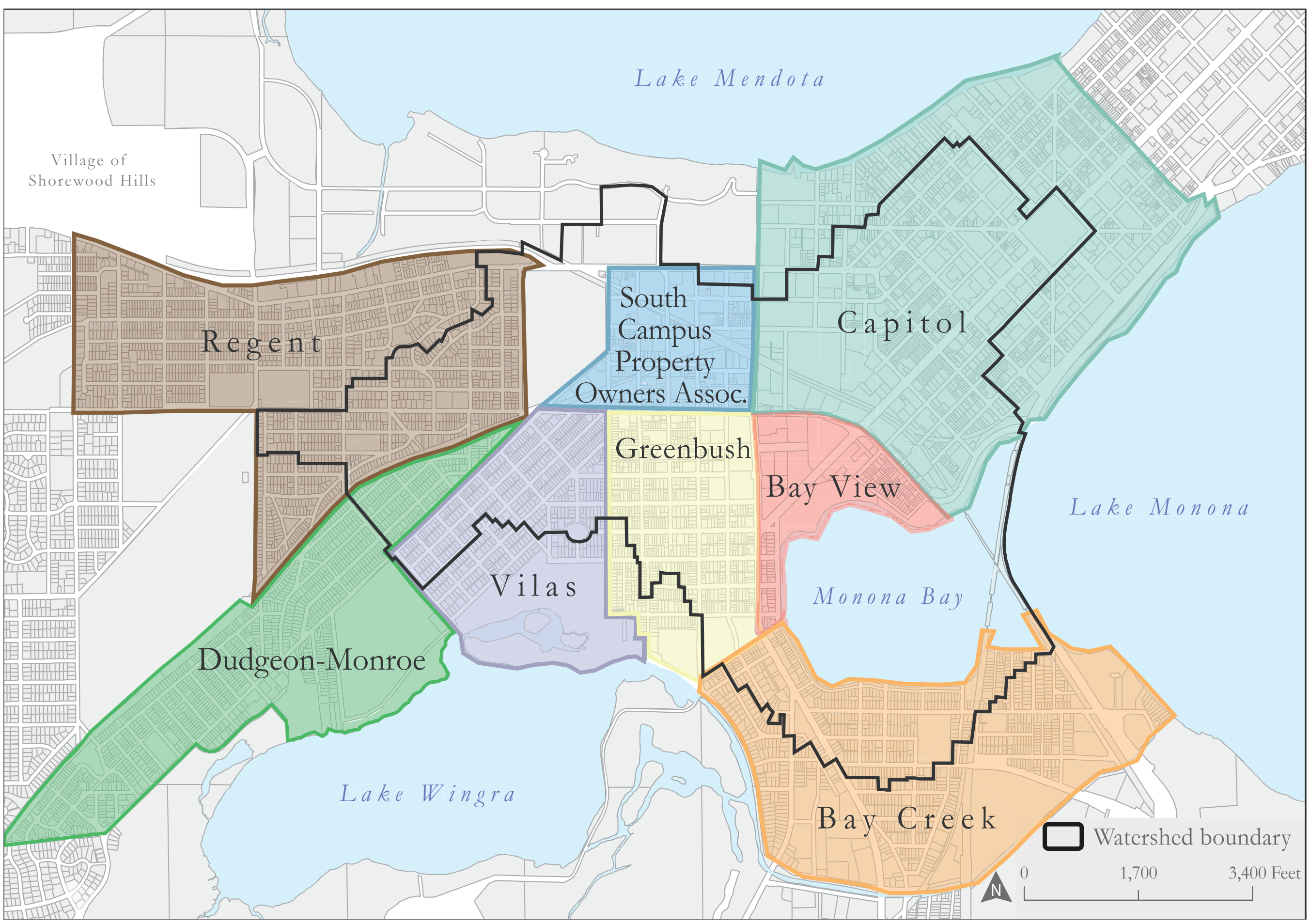


Figure 4.1. Major neighborhoods within the Monona Bay watershed.

- Brittingham Park use; and
- walking, running, and biking around the bay.

4.2 Stakeholder Survey

4.2.1 Purpose and Methodology

To gain a greater understanding of Monona Bay's stakeholders, we conducted a survey. The survey aimed to identify the various recreational uses of the bay, perceptions of bay quality by users and residents, support by users and residents of different management options, and information about the respondents (see appendix 7 for complete survey information).

The survey also served as an educational tool for recipients. Those who completed the survey learned which neighborhoods were within the watershed, something they may have not previously known. Respondents were also exposed to ideas about how bay quality could be improved, ranging from modifications homeowners could make to reduce runoff from their property to larger-scale management projects, such as aquatic plant harvesting, dredging, and chemical treatments. In addition, survey respondents were given an opportunity to disclose personal information if they were interested in getting involved in Monona Bay improvement activities.

We distributed the survey in June 2006 to all residents who lived adjacent to the bay (on or across the street from Monona Bay), to a sample set of each identified user group (anglers, ice anglers, paddlers, rowers, water skiers, and park users), and a sample set of residents in each major neighborhood located within the Monona Bay watershed—Regent, Vilas, Capitol, Bay Creek, Greenbush, and Bay View. Note that there are two other neighborhoods within the watershed; however, the six surveyed make up a larger proportion of the watershed and included more homeowners than renters.

Surveys and a brief cover letter were distributed by hand to the adjacent-bay residents, anglers, paddlers, water skiers, park users and watershed neighborhood residents. The ice anglers and rowers received surveys by mail. Addresses were collected from willing ice anglers while they were fishing during the winter of 2006 in anticipation of conducting the survey. A total of 511 surveys were distributed, the largest proportions of which went to the Bay Creek neighborhood and adjacent-bay residents (19% and 22%, respectively) under the assumption that those living closest to the bay were more invested in it. As a result, it is possible that the survey results may be biased toward this targeted group. An approximately equal proportion (4–6%) of surveys was distributed to the remaining targeted participants. Of the 511 distributed surveys, a total of 209 were returned, yielding a response rate of 41 percent. However, 21 of the returned surveys arrived too late for analysis, resulting in a sample size of 188 (a 37% response rate). All participants were willing adults, and their responses remain confidential.

Analysis of the results depended upon the question style. If the respondents were asked to rate something numerically or categorically, the data was compiled quantitatively. Percentages were calculated and then analyzed in terms of general trends. Written responses were read through and commonly repeated responses were considered significant and relevant for our work. It should be noted that some respondents did not answer all survey questions; therefore, the percentages for some questions do not sum exactly to 100. (See appendix 7 for further information.)

4.2.2 Survey Results

4.2.2.1 User Groups

The survey results indicated that we reached a cross section of recreational users of the bay. About 25 percent of the respondents said that they used the bay for fishing, 9 percent for ice fishing, 29 percent for motor boating, 32 percent for rowing, 26 percent for swimming, 15 percent for waterskiing, and 80 percent for scenic enjoyment. However, only one person reported sailing on the bay and fewer than five reported jet skiing.

When asked if there were any additional user groups that respondents felt inhibited their enjoyment or use of Monona Bay, 12 percent responded Brittingham Park users. Some commented that some of the people who spend time at the Brittingham Park Pavilion were a problem due to drinking, drug use, noise, fighting and littering. Others responded that they felt Brittingham Park was unsafe.

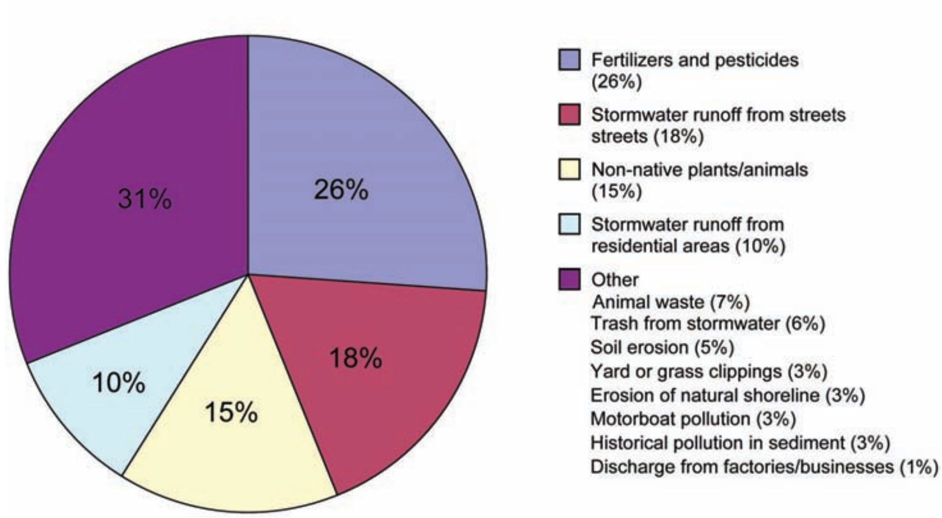


Figure 4.2. Factors survey respondents specified as contributing most to water-quality problems in Monona Bay.

4.2.2.2 Water-Quality Perceptions

Approximately 73 percent of all respondents described the bay's quality as "degraded" or "poor." About 66 percent felt the quality has decreased since their first exposure to the bay. Respondents also felt that the largest problems in Monona Bay, in order of decreasing importance, were excessive aquatic plants, algal blooms, exotic plants, and trash in and around the bay. Excessive aquatic plants were reported as a major problem by 70 percent of the respondents. In addition, respondents felt the factors that contributed most to water-quality problems were fertilizers and pesticides, stormwater runoff from streets, non-native species of plants and animals, and stormwater runoff from residential areas (fig. 4.2).

4.2.2.3 Support of Management Activities

Cutting aquatic plants, installing stormwater filters, and removing trash were the management activities respondents would be most willing to support financially. These are also the top management activities that respondents said would increase their recreational use of the bay.

Respondents would like to see restrictions on jet skiing (51%), motor boating (34%), water skiing/tubing (30%), ice fishing (12%), and fishing (7%). People indicated in writing that jet skiing, motor boating and waterskiing/tubing were too noisy, too dangerous, created pollution, and that large wakes were destructive to the bay's ecosystem and shoreline. The respondents also felt that those who engage in the above water-sports in many cases disregard the state's slow-no-wake laws. Several people suggested that stricter slow-no-wake rules be implemented, including making slow-no-wake hours over the entire bay. Respondents wanted to restrict ice fishing and fishing because of trash and dead fish left along the shores of the bay by these users.

The compiled results also revealed that respondents were most comfortable with the "natural biological control" management strategy and least comfortable with "chemical treatments." It should be recognized that each of these management strategies was described *briefly* in the survey, and it is possible that more in-depth explanations would have yielded different results. Specific word use may play a role in the social and emotional responses to these management activities. For example, "natural" may come across as a more benign and safe method, but "chemical" may appear to be a more dangerous method.

4.2.3 Key Findings

The survey results highlight key areas that can guide effective education and outreach efforts. (Approaches to addressing these issues are discussed in further detail in the *Outreach Alter*natives section of chapter 6.) Specifically, the results conveyed the following:

- problematic issues that could be addressed through community efforts (e.g., trash problems);
- user conflicts;

- areas where more education is needed;
- a sense of what watershed residents are willing to personally take action on; and
- how respondents prefer to receive educational information.

The results indicated that trash accumulation is viewed as a major problem and inhibits people's enjoyment of the bay. The results also showed that trash removal is an activity that people are willing to financially support. Unlike excessive aquatic plant growth, the trash problem is one that can be tackled by hands-on work of the community. This implies that education and outreach can play a role in cutting down the amount of trash.

There is clearly a conflict between motorboaters and those who do not want motorboats on the bay. Many people suggested banning motorboats on the bay. This is a difficult issue that must be dealt with on each lake. Changes to ordinances could be made to clear up some of these conflicts. Some respondents felt that some who use motorized vehicles in the bay do not obey slow-no-wake rules. The community can take steps to curb that behavior.

Further education is needed about the different strategies for managing excessive plant growth in the bay. On the basis of written responses, it is clear that people would like a long-term solution to the problem. Responses indicate that some people think that plant harvesting is supposed to have long-term effects. However, harvesting is a short-term fix to make the bay more attractive and navigable. Although respondents expressed a strong interest in reducing the plant problem, they were less comfortable with the techniques that could potentially have long-term effects on plant populations in the bay, such as some chemical treatment techniques and dredging. It is important to clear up misconceptions among residents about what each management strategy aims to do.

Respondents living in the watershed expressed a strong willingness to take personal action to help increase the bay's quality. Many (41%) reported that they were willing to make modifications to their homes to decrease runoff, such as modifying roof gutters and/or downspouts and installing rain gardens. Approximately half of watershed residents were also willing to use compostable leaf bags as well as adopt a stormwater outlet and/or inlet. Eighty-nine percent of respondents living adjacent to the bay said that they were willing to restore their shorelines to natural vegetation as long as others living adjacent to the bay were willing to do the same. A good outreach program will turn these claims into action by effectively educating the community on how to go about doing them.

People were most interested in the following educational opportunities about lake management activities on Monona Bay: paper newsletters (46%), Web sites (46%), fact sheets (45%), and digital newsletters (38%). Respondents were least interested in videos (10%), workshops (21%), and speakers (22%). Surprisingly, 31% of those living adjacent to the bay reported that they had not heard of the Friends of Monona Bay. The same was true for 41 percent of all respondents.

CHAPTER 5. CURRENT MANAGEMENT ACTIVITIES

5.1 Regulatory Context

The management of the Monona Bay watershed is affected by regulations and programs at the federal, state, and local levels (table 5.1). We found that there are relatively low requirements for stormwater quality and quantity control in redevelopment projects and a lack of requirements for retrofitting existing development with stormwater controls, both of which are important considerations in managing water quality in the already developed Monona Bay watershed.

5.1.1 Federal Regulations

5.1.1.1 Stormwater

The Federal Water Pollution Control Act Amendments of 1972, commonly known as the Clean Water Act, forms the basis for many of the regulations guiding water-quality and stormwater management in the Monona Bay watershed. One of the primary objectives of the Clean Water Act is to regulate and prevent pollutants from reaching waterways to ensure the nation's waters can be safely used for swimming, fishing, and other uses. Although the Act gives the U.S. Environmental Protection Agency (U.S. EPA) authority to implement legislation, the U.S. EPA has delegated much of its authority to the states, provided that states enact legislation that meets federal standards. Wisconsin was granted this authority in 1974 and tasked the WDNR with implementation and enforcement of rules within the state.

Under the Clean Water Act amendments of 1987, the U.S. EPA developed the National Pollutant Discharge Elimination System (NPDES) to regulate and improve the quantity and quality of stormwater and other discharges, such as treated wastewater, industrial process water, and runoff from construction sites. As a part of the NPDES program, stormwater discharges by many municipal separate stormsewer systems (MS4s) require permits.

After passage of Wisconsin's NPDES implementing rules, NR 216, the WDNR had the authority to regulate urban nonpoint source pollution through Wisconsin Pollutant Discharge Elimination System (WPDES) permits. During Phase I of the NPDES program, which

Table 5.1. Key regulators of the management of Monona Bay at the federal, state, and local levels.

Federal
- U.S. Environmental Protection Agency
  - Water quality regulations
    - Clean Water Act
  - Stormwater regulations
    - National Pollutant Discharge Elimination System (NPDES) permitting program

State
- Wisconsin Department of Natural Resources
  - Stormwater regulations
    - NR 216 and Wisconsin Pollutant Discharge Elimination System (WPDES), NR 151
  - Invasive species regulations
    - Aquatic plant removal from boats, Wis. Stat. 30.715
    - Statewide Invasive Species Control Program, Wis. Stat. 23.22
  - Aquatic plant removal regulations
    - Chemical control permitting (NR 107) and Manual control permitting (NR 109)
  - Shoreline and pier regulations
    - NR 326
  - Dredging regulations
    - NR 326, Statute 30.20
  - Boating regulations
    - Chapter 30 and NR 5
  - Fishing regulations
    - Chapter 29, NR 20, 21-25
- Department of Commerce
  - Stormwater regulations
    - COMM 20/21 Residential Dwelling Sites (with no land disturbance)
    - COMM 60 Commercial Development

Local
- Dane County
  - Aquatic plant management
  - Invasive species
  - Boating regulations (including slow-no-wake)
    - Chapter 72, Dane County Ordinances
  - Stormwater management and erosion control
    - Chapter 14, Dane County Ordinances
- City of Madison
  - Stormwater management
    - Madison Ordinances, Chapter 37 authorizes City of Madison Stormwater Utility
  - Public health
- University of Wisconsin–Madison
  - Stormwater management

began in 1990, only large urban areas with populations greater than 100,000 people and construction sites 5 acres or larger were required to obtain permits to discharge stormwater. In Wisconsin, the Phase I municipal permitting requirements applied to the Cities of Milwaukee and Madison and the UW–Madison. Phase II of the federal stormwater program began in 1999. Under Phase II rules, many smaller communities with MS4s and construction sites larger than 1 acre must obtain permits to discharge stormwater.

To improve efficiency in meeting WPDES permitting requirements, the City of Madison has joined with Dane County, the UW–Madison, and 16 other surrounding communities included in the Phase II rules to renew its WPDES MS4 Phase I permit. The co-permittees are known as the Madison Area Municipal Stormwater Partnership (MAMSWaP).

Under the WPDES permits, communities must address six stormwater-management measures. These include:

- public education and outreach,
- public involvement and participation,
- illicit discharge detection and elimination,
- construction-site stormwater-runoff control,
- post-construction stormwater management, and
- pollution prevention for municipal operations.

The joint WPDES permit for the City of Madison, Dane County, UW–Madison, and the other MAMSWaP communities is Permit WI-S058416-2; information about the permit can be found at the Web site, <http://danewaters.com/management/mamswap.aspx>.

5.1.2 State Regulations

5.1.2.1 Stormwater

At the state level, NR 216 addresses the issuance of municipal WPDES permits and fees. However, NR 216 did not set specific water-quality targets for stormwater management. To address this need, in 2004 the state passed NR 151 as a part of a suite of Wisconsin's Polluted Runoff Management Rules; NR 151 addresses the runoff management performance standards for rural and urban areas. Briefly, these standards in urban areas include the following:

- New construction sites larger than 20,000 ft^2 require an 80-percent reduction in TSS in runoff.
- Redevelopment sites require a 40-percent reduction in TSS.
- Infiltration of runoff is required with most new construction, but the infiltration requirements vary according to land use. Redevelopment sites, infill development sites less than 5 acres, and roads in commercial and institutional land uses are exempt from infiltration requirements.
- Municipalities with WPDES permits must, by March 2008, reduce their TSS discharge to state waters by 20 percent. By 2013 this reduction increases to 40 percent.

The TSS reduction standards set by NR 151 are an average throughout an entire municipality. As a result, areas with newer development subject to stormwater control requirements may offset older areas developed prior to stormwater-quality-control requirements. This is an important point because NR 151 has relatively low requirements for control of stormwater quality and quantity in redevelopment projects (compared to new development standards) and no requirements for retrofitting existing development with stormwater controls. Thus, managing water quality in the already fully developed Monona Bay watershed will likely be more dependent on non-structural stormwater controls, such as street sweeping and public education efforts, along with voluntary improvements to stormwater management during redevelopment projects.

In the area of construction-site erosion control and stormwater management, NR 216 creates an administrative split between two state agencies, the Wisconsin Department of Commerce and the WDNR: Commerce regulates the stormwater runoff from construction sites for public buildings and places of employment and the WDNR regulates other construction sites. Many of the development and redevelopment projects in the Monona Bay watershed are public buildings or places of employment, putting construction-site stormwater management for these sites under the jurisdiction of Commerce.

Under NR 216 (and Department of Commerce's COMM 20, 21, and 60 rules), specific requirements must be met before a WPDES stormwater permit can be issued for a construction site. Developers must file a Notice of Intent to discharge that states that the following have been developed: an erosion-control plan, a stormwater-management plan, and a long-term maintenance agreement. Unfortunately, for Commerce-regulated projects, these plans and agreements do not have to be submitted with the Notice of Intent and do not have to be reviewed prior to receiving a WPDES permit (Midwest Environmental Advocates, 2005). This creates the potential for erosion-control and stormwater-management requirements at Commerce-regulated construction sites to be less rigorously implemented and for violations to be less vigilantly enforced and corrected.

Wisconsin's agreement with the U.S. EPA to run the NPDES program in the state requires Commerce and the WDNR to run equivalent stormwater-control programs. The U.S. EPA Region V has been asked by stakeholders to evaluate whether the two programs are equivalent and, in particular, whether Commerce's program is adequately protecting water quality (Brent Denzin, Midwest Environmental Advocates, written communication, 2006).

More information about these programs and rules can be found at the following Web sites:

- WDNR WPDES program, NR 216, and NR 151 <http://dnr.wi.gov/org/water/wm/nps/stormwater.htm>
- WDNR Construction Erosion Control program <http://dnr.wi.gov/org/water/wm/nps/stormwater/const.htm>
- Department of Commerce Construction Erosion Control program <http://commerce.wi.gov/sb/SB-SoilErosionControlProgram.html>

The WDNR also has jurisdiction over spills into Monona Bay, although other departments (Public Works, Engineering, Parks, and the Fire Department) have assisted with first response. Anyone who causes a hazardous substance to spill into a water body is required to report it to the WDNR and to take measures to clean it up. But if the source is not known, the WDNR performs spill response. If a spill is discovered, citizens should call the WDNR 24-hour hotline number (1-800-943-0003). The WDNR also has a Web site that has spill-response fact sheets: <http://dnr.wi.gov/org/aw/rr/spills/index.htm>.

5.1.2.2 Other

Wisconsin has several boating statutes and regulations relevant to Monona Bay. Boats are required to operate at a "slow-no-wake" speed within 200 ft of shore, or 100 ft of a pier, dock, or other boat. Boats towing water skiers must remain at least 100 ft from other boats or public landings. A number of fishing regulations also apply to Monona Bay. Anglers should be aware of licensing requirements, as well as bag limits, minimum and maximum catch lengths, and recommended consumption limits before fishing in the bay.

Wisconsin has several statutes and regulations that address invasive species control, aquatic plant removal, shoreline and pier management, and dredging. To reduce the spread of invasive aquatic species, Wisconsin Statute 30.715 requires boaters to remove aquatic plants and zebra mussels from boats before entering a water body. Owners of public boat-access sites must post a notice with this requirement, and game wardens and other law enforcement officers are authorized to require boaters to comply with the rule and fine boaters $50 to $100 for noncompliance. However, this rule may be ineffective without extensive public education due to limitations in enforcement staff availability.

To further combat invasive species, Wisconsin Statute 23.22 established a Statewide Invasive Species Control Program. As a part of this program, the WDNR developed a comprehensive management plan to prevent further introductions and control existing populations of aquatic invasive species in 2003. In addition, the WDNR is providing education and encouraging research concerning invasive species and offers cost-sharing grants for up to 50 percent of the costs of projects to control invasive species, such as education and inspection activities at boat landings. WDNR offers $1.5 million for cost-sharing grants annually.

The WDNR permits and manages aquatic plant removal according to NR 107 (for chemical control) and NR

109 (for manual control). Shoreline and pier regulations are addressed under NR 326; dredging regulations are addressed under NR 326 and Wisconsin Statute 30.20.

More information about these programs and rules can be found at the following Web sites:

- WDNR Invasive Species program, Wisconsin Statutes 30.715 and 23.22 <http://dnr.wi.gov/invasives/laws.htm>
- •WDNR Aquatic Plant Management program, NR 107 and 109 <http://www.dnr.state.wi.us/org/water/fhp/lakes/aquaplan.htm>
- WDNR Shoreline and Pier regulations, Wisconsin Statute 30.20; and NR 326 <http://dnr.wi.gov/org/water/fhp/waterway/piers.shtml>

5.1.3 County Regulations

5.1.3.1 Stormwater

Dane County is a co-permitee on the Madison Area Municipal Stormwater Partnership joint WPDES permit. In 2002 Dane County adopted an erosion-control and stormwater-management ordinance in Chapter 14 of the Code of Ordinances. The County's stormwater-control requirements meet or exceed the minimum standards in NR 151. The County administers those requirements through its Land and Water Resources Department. If cities and villages adopt their own requirements that are at least as strict as the County's, such as in Madison, the municipality can administer the rules instead of the County. To improve lake-water quality by reducing phosphorus runoff, in 2004 Dane County adopted an ordinance in Chapter 80 of the Code of Ordinances that prohibits the use of phosphorus-containing lawn fertilizers (unless a soil test shows that phosphorus is necessary).

In late 2004, the County released its updated water-quality plan, which includes the following recommendations:

- Implement the state NR 151, NR 216 and Federal Phase II NPDES stormwater regulations along with the existing Chapter 14 County Erosion Control and Stormwater Management Ordinance.
- Vigorously enforce and expand comprehensive erosion-control and stormwater-management requirements beyond the minimum standards of the Dane County Ordinance.
- Revise building ordinances to require roof drainage to grassed areas, where feasible, for new development.
- On the basis of the results of the pilot street-sweeping program in the isthmus area, pursue expanded street sweeping in other priority areas.

More information about these rules can be found at the following Web sites:

- Dane County erosion control and stormwater management ordinance <http://www.co.dane.wi.us/pdfdocs/ordinances/ord014.pdf>
- Dane County phosphorus control ordinance <http://danewaters.com/management/phosphorus.aspx>

5.1.3.2 Other

Dane County, along with the WDNR, assumes several lake-management responsibilities, including management of aquatic vegetation and boating activities in county lakes. Dane County has primary responsibility for the aquatic weed-harvesting program in Monona Bay, obtaining permits from the WDNR under NR 109. The County established an Aquatic Plant Management Committee in 2006 to evaluate aquatic plant-management options. The County is also actively involved in managing and reducing invasive species in the Yahara Lakes, such as zebra mussels, through education and outreach.

In addition, in Chapter 72 of the County Code of Ordinances (Regulation of Boating on Yahara Lakes), the County established a 200 ft slow-no-wake zone around shorelines of the Yahara Lakes, which exceeds the state boating rules.

The Dane County Lakes and Watershed Commission, an advisory body for the Dane County Board, has assumed a coordinating role among the many state and local agencies addressing water-quality and water-resources management in Dane County. Its responsibilities include conducting or coordinating studies of local surface water and groundwater, maintaining liaisons with other public agencies involved in protecting or managing water resources, and developing public information programs.

More information about these rules and programs can be found at the following Web sites:

- Dane County Aquatic Plant Management Program <http://danewaters.com/management/AquaticPlantManagement.aspx>
- Dane County Invasive Species Program <http://danewaters.com/management/invasives.aspx>
- Dane County Slow-No-Wake Ordinance <http://danewaters.com/private/SlowNoWake.aspx>
- Dane County Lakes and Watershed Commission <http://www.danewaters.com/about/default.aspx>

5.1.4 City Regulations

5.1.4.1 Stormwater

The City of Madison implements a number of stormwater-management programs to comply with its WPDES MS4 permit. In addition, in Chapter 37 of the City of Madison's Code of Ordinances, the city agrees to meet the NR 151 20-percent TSS reduction standard by 2007 (one year early) and the 40-percent goal by 2011 (two years early) if other area communities also agree to do the same.

Chapter 37 also outlines the rules that govern the operation of the city's Stormwater Utility.

The Stormwater Utility, which was developed in 2001, funds stormwater-management activities in Madison, including maintenance and repair of stormsewer pipes and implementation of water-quality controls, such as street sweeping. The Stormwater Utility is funded from a water bill line item that is based on property size and the amount of impervious surface on the property. The cost to the average homeowner is $16.75 every six months. Large commercial land owners pay significantly higher rates due to the large amount of impervious surface on their properties.

More information about these rules and programs can be found at the following Web site:

- City of Madison Stormwater Program <http://www.ci.madison.wi.us/engineering/stormwater/permit.htm>

5.1.4.2 Other

Private shoreline with many private docks border much of Monona Bay. These docks are located on private land that the City leases from property owners in a 999 year lease. The City also maintains this thin strip of land between the street and the bay, installing riprap when needed to address erosion and managing the shoreline vegetation. The City manages Brittingham Park and Bernies Beach, including mowing vegetation and managing recreational areas and structures. The City is also responsible for leaf collection in the fall and applying road salt and other deicing agents during the winter.

The City rules related to litter give jurisdiction for dealing with problems to two departments depending on the location of the litter (George Dreckman, City of Madison Recycling Coordinator, verbal communication, 2006). Litter in the streets is under the responsibility of the Madison Police Department to address. Litter elsewhere, up to the curb of the streets, is the responsibility of the Building Inspection Unit. The Building Inspection Unit can act on complaints about litter by giving a property owner 48 hours to clean up the litter before being cited.

The Madison Department of Public Health performs water-quality sampling of area lakes, streams, stormwater outfalls, and point and nonpoint source runoff to surface water and groundwater. The Department of Public Health has a beach monitoring program to assess the safety of beaches with respect to blue-green algae and fecal coliform concentrations. Beaches are closed by the Department of Public Health if public safety is potentially at risk due to water quality.

More information about these rules and programs can be found at the following Web site:

- City of Madison Department of Public Health Beach Monitoring <http://www.cityofmadison.com/beaches/>

5.1.5 University Regulations

5.1.5.1 Stormwater

The 2003 WRM Practicum evaluated stormwater management at UW–Madison; chapter 3 of the report describes in detail the University's stormwater practices (Water Resources Management Practicum, 2004). The report is available at http://www.nelson.wisc.edu/wrm/workshops/2003/.

In October 2003, the Campus Planning Committee passed a resolution requiring that runoff from new development and redevelopment projects be less than or equal to the runoff that would have occurred under "native conditions." This was partially in response to the 2003 WRM Practicum findings that 42 percent of the land surface of the UW–Madison campus is highly impervious and that almost one-third of the annual warm weather rainfall that falls on campus runs off directly into Lake Mendota and Monona Bay, depositing 90 tons of suspended solids each year (WRM Practicum, 2004; Garcia et al., 2005). The resolution is funded through construction costs related to building projects (Campus Planning Committee, 2004).

The work done by the 2003 WRM Practicum also led to the creation of a document called University of Wisconsin–Stormwater Runoff Management (Garcia et al., 2005), which is used as a guide when considering future development and redevelopment projects on campus.

5.2 Stormwater Controls

The City of Madison implements a number of stormwater-control practices throughout the Monona Bay watershed, affecting water and sediment quality within Monona Bay. The City of Madison created "Clean Lakes and Beaches: A Water Quality Plan" (City of Madison, 2006c). The report describes the City's current management activities that are intended to improve water quality as well as potential future practices the City is considering implementing. Table 5.2 summarizes the current water-quality controls (or best management practices) that are being implemented in the Monona Bay watershed.

Decreasing TSS in stormwater is an important method of improving receiving water health by reducing stormwater concentrations of pollutants and nutrients adhered to solids, reducing turbidity, and reducing sedimentation. Cleaning sediment off streets, filtering stormwater in treatment devices, and controlling runoff from construction sites are some of the most common and effective ways of reducing TSS in developed watersheds like Monona Bay.

Multi-purpose water-quality improvement projects include a variety of City activities intended to enhance water-quality and water-quantity control, to study and improve stormwater control practices, and to educate and involve the public. These activities include many collaborative projects being implemented by all the communities in the Madison Area Municipal Stormwater Partnership.

Rain gardens and other innovative practices that encourage infiltration and improve water quality hold great promise for enhancing the Monona Bay watershed if implemented more widely. Rain gardens are currently the only type of stormwater control implemented in the watershed primarily intended to decrease stormwater volume and increase stormwater infiltration. Green roofs may be incorporated into some private and university developments in the near future. These controls can be implemented at scales ranging from single residential homes to large institutional and commercial sites, during new construction and as retrofits to mature existing development.

The City is also implementing or evaluating several programs intended to decrease contaminants in stormwater through source control, which includes reducing the use of the contaminants or providing removal of the contaminants before they can be intercepted by stormwater.

5.2.1 Current Estimates of Stormwater Treatment

The City is required to meet NR 151 standards for a 20-

Table 5.2. Summary of City of Madison water-quality controls in Monona Bay watershed. Source: City of Madison (2006c).

Purpose	Control measure	Applies To	Description and notes
Decrease total suspended solids (TSS)	Basic mechanical sweeper	62 percent of Monona Bay watershed (see fig. 5.1)	• 10-percent efficiency using mechanical sweeper *monthly* • 20-percent efficiency using mechanical sweeper *weekly* or *monthly with polymers*
	High-efficiency, vacuum sweeper with parking restrictions	38 percent of Monona Bay watershed (see fig. 5.1)	• 30–80 percent efficiency depending on season and load • Polymers could increase efficiency
	Stormwater treatment devices	Francis Street and Parr Street	"CDS" stormwater-treatment devices intended to remove trash and larger sediment particles from stormwater entering Monona Bay • Off-line devices treat only a small percentage of annual runoff volumes from contributing areas • Efficiency for removal of TSS and trash is estimated at ≥80 percent for treated runoff
	Additional WPDES Stormwater Permit Initiatives	Citywide	• Construction erosion controls • Study of street-sweeping effectiveness
Multi-purpose water-quality improvements	Additional WPDES Stormwater Permit Initiatives	Citywide	• Requirements for post-construction stormwater quantity and quality control • Examination of Stormceptor treatment device • Study of phosphorus sources in residential areas • Study of rain gardens • Information and education position funded to educate public about stormwater runoff • My Fair Lakes public education campaign
Decrease stormwater volume	Rain gardens	Citywide	Rain garden for Brittingham Park east parking lot installed 2006. City of 1,000 Rain Gardens Project: City and WDNR will fund two-thirds of rain garden construction cost in residential areas when funding becomes available.
Decrease contaminants in stormwater (source control)	Phosphorus ban	Citywide	Not permissible to apply phosphorus-containing fertilizer to an established residential lawn as of January 2005
	Road salt evaluation	Citywide	Evaluating options for City reduction in road salt application. Also developing materials for public education on proper use of salt and environmental impacts of salt usage.
	Integrated pest management / pesticide use reduction	City-managed landscape areas	City Departments to: • evaluate and give preference to non-pesticide management practices and use alternative pest control methods. • minimize pesticide use through integrated pest management and use pesticides as a last resort.
	Urban waterfowl management	City-managed land	Parks Division implementing management and public education program to reduce waterfowl populations in sensitive areas to reduce impacts of waterfowl fecal matter.

percent reduction in TSS in stormwater runoff by 2008 and a 40-percent reduction by 2013. Removal of TSS is a common surrogate parameter used to estimate removal of a variety of stormwater pollutants because many pollutants adhere to sediment particles in runoff.

The City currently meets the 2008 TSS removal requirement primarily through street sweeping and, in outlying areas of the city developed after 1980, detention basins; the City estimates its current TSS reduction to be 29 percent. This is a citywide average and does not reflect pollutant reduction in specific drainage subbasins within Madison. Some receiving waters benefit more through the City's stormwater program than others:

- Although 27 percent of the City area is treated with detention basins to an estimated 60- to 80-percent TSS removal rate, none of these detention basins is in the Monona Bay watershed (City of Madison, 2006c). It is unlikely that any surface-detention basins will be constructed in the watershed in the future because of space limitations.
- Although subsurface detention and treatment systems could be installed in the Monona Bay watershed at locations with large surface parking lots, the City is focusing on street sweeping as a more cost-effective control measure at this time. In the 63 percent of the City where street sweeping is the primary water-quality control practice (including the entire Monona Bay watershed), it is estimated that TSS is reduced by 10 to 30 percent at a minimum (City of Madison, 2006c).

5.2.2 Street Sweeping

Street sweeping is used to remove sediment (and pollutants adhered to sediment) from streets prior to the sediment becoming suspended in stormwater and discharged to a receiving body. Depending on the equipment used, frequency of sweeping, and ability of equipment to reach the curb (affected by parking restrictions), the efficiency of street sweeping ranges from 10 to 80 percent as measured by mass removal of sediment from the street (City of Madison, 2006c). The City has placed the most emphasis on street sweeping in ultra-urbanized areas, such as the Monona Bay watershed, which have no other treatment prior to discharge (City of Madison, 2006c). The City spent $1.6 million on street sweeping in 2004, at a cost of approximately $2,000/street mile/year.

The City began street sweeping in the mid-1950s, although records were not available to determine when sweeping specifically in the Monona Bay watershed began (Genesis Bichanich, City of Madison, written communication, 2006). Over time, the equipment available to sweep streets has become increasingly advanced and the City has increased its sweeping program frequency to improve water quality and stormsewer maintenance. The City sweeps the entire city area, with the exception of certain parts of the UW–Madison campus. The City sweeps the campus area streets south of University Avenue; UW–Madison is responsible for sweeping streets north of University Avenue on the campus.

The type of sweeping practice used currently depends on the location within the City. In much of downtown (most of Aldermanic Districts 2, 6, and 13), an enhanced street-sweeping program includes parking restrictions during spring, summer, and fall for four-hour periods, once a week. This allows street sweepers to reach the curb, increasing their efficiency. In other areas, a basic sweeping program includes monthly sweeping without parking restrictions. As illustrated in figure 5.1, in the Monona Bay watershed, 38 percent of the watershed is within District 13, which is part of the enhanced street-sweeping program, and 62 percent of the watershed is within Districts 4, 5, 8, and 10, which are part of the basic street-sweeping program.

In the central city (downtown areas in District 4), the City restricts parking for a single day in May for enhanced street sweeping. The City has previously considered expanding the enhanced street-sweeping program in the downtown area (including the rest of District 2 and all of District 4), but there was a lack of Aldermanic support for pursuing the expansion due to concerns over increased parking restrictions in student neighborhoods (George Dreckman, City of Madison Recycling Coordinator, verbal communication, 2006). However, it is likely that the City plans to pursue expanding the enhanced street-sweeping program in the downtown area in the future.

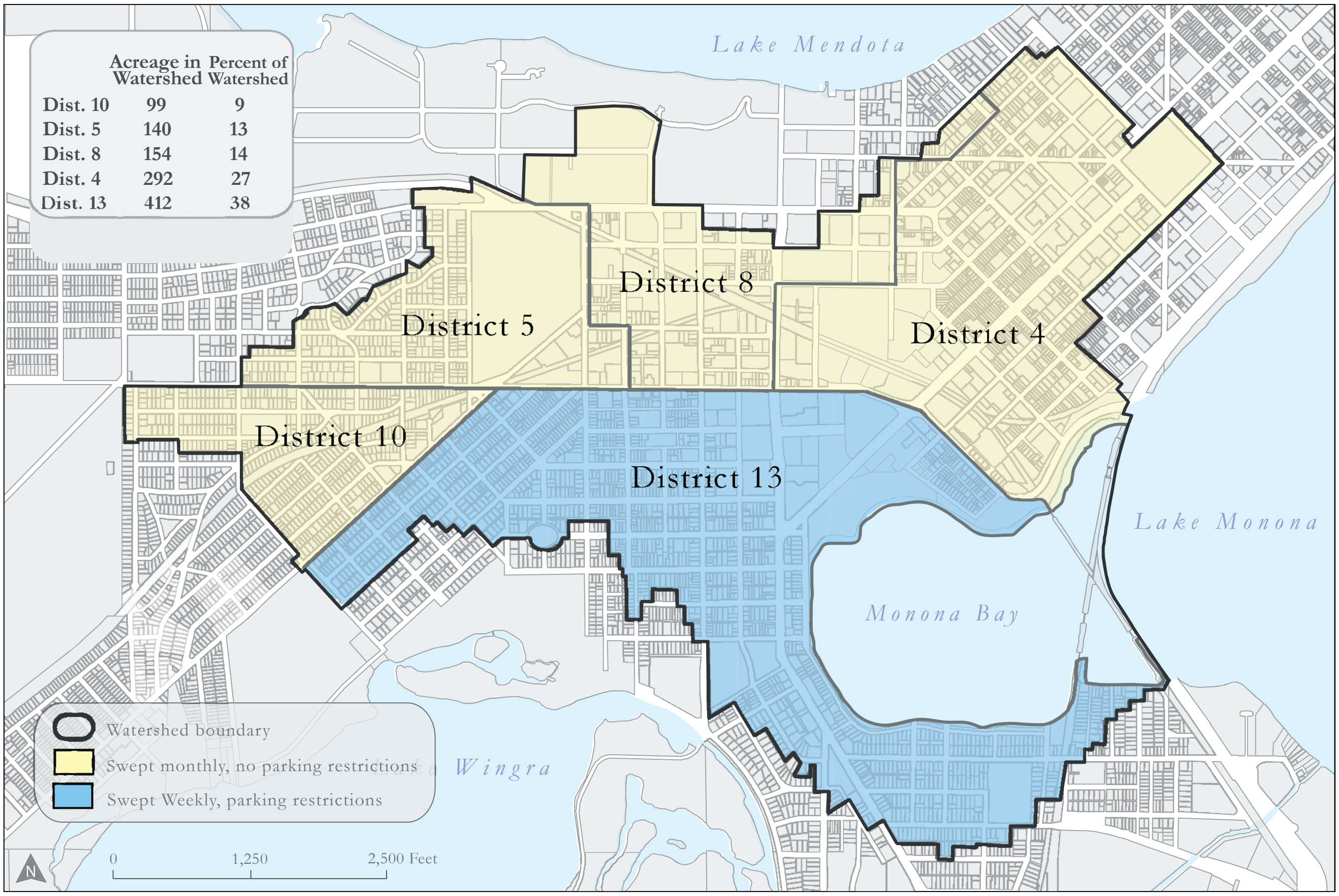


Figure 5.1. Street-sweeping policies by aldermanic district in the Monona Bay watershed in 2006. Source: City of Madison (2005).

5.2.2.1 Street-Sweeping Efficiencies

Key factors that affect the efficiency of street sweeping include the location of the solids load on the street, the ability of street sweepers to reach the solids, and the size of the particles. During the summer, approximately 80 percent of the solids load is found within approximately 3 ft of the curb, where sweepers are designed to operate (City of Madison, 2006c). However, the City of Madison has found that in the spring (when street dirt loads are the heaviest), solids seem to be more evenly distributed across the entire street width. Because of this varying load distribution, the efficiency of street sweepers varies throughout the season. Weekly sweeping with a high-efficiency sweeper can range from 30-percent efficiency during the spring to 80 percent during the summer, as measured by mass removal from the street surface (City of Madison, 2006c).

The City estimates the following citywide annual average TSS removal efficiencies for various street-sweeping practices:

- 10-percent reduction from monthly street sweeping with a standard mechanical sweeper,
- 20-percent reduction from weekly sweeping with a standard sweeper, and
- 30-percent reduction from weekly sweeping with a high-efficiency, vacuum sweeper.

5.2.2.2 Street-Sweeping Study

The City has been conducting a street-sweeping study with the U.S. Geological Survey since 2001 to determine how street-sweeping efficiencies and overall stormwater quality could be improved as a result of street sweeping. The options the City is evaluating include those listed in table 5.3.

Although these changes would likely help the City meet its requirement for 40-percent reduction in TSS by 2013, the desired improvement to water quality from these practices may be challenging to achieve. The NR 151 standard requires the City to evaluate TSS removal

Table 5.3. Estimated costs of improved street-sweeping practices.

Street-sweeping option	Estimated cost (City of Madison, 2005)
Increasing the areas of the City swept with a high efficiency vacuum sweeper (from the current mechanical sweeper).	Estimated cost for each sweeper purchased is $150,000.
Increasing the frequency of sweeping (to weekly sweeping from the current monthly sweeping in many areas).	Estimated operating cost of $7,400/street mile/year, or approx. $6.1 million/year in increased operating cost.
Adding polymers to street sediments immediately prior to sweeping to coagulate smaller particles and increase sweeper efficiency.	Estimated cost of $137/street mile/year, or approximately $80,000/year.
Increasing the areas of the City where parking restrictions allow street sweepers to reach the curb (where the majority of sediment sits).	Cost estimate not available.

by what can be measured in the discharge pipe, not by what is removed from the street. This can result in difficulty in directly relating the effect of street-sweeping practices to in-pipe water quality.

Furthermore, studies have shown that as street-sweeping efficiencies approach 30 percent (as measured by removal of street debris on a mass-loading basis), the quality of runoff water (measured in the pipe) can actually decrease (City of Madison, 2006c). This is typically attributed to the design of sweepers, which function to remove primarily larger, sand-size particles. This allows the smaller silt- and clay-size particles to be mobilized during an event, and washed into the stormsewer. Nutrients and heavy metals are generally attached in higher proportions to small-size particles rather than larger sand particles (City of Madison, 2006c). The City is seeking ways to address this issue so that the TSS-reduction standards can be met while the intent of improving water quality can also be achieved.

Due to the problems associated with sweeper ability to pick up smaller particle sizes, the City is planning to test the efficiency of adding polymers to street sweepers after the completion of the current street-sweeping study. Adding polymers to street-sweeping washwater causes the smaller-sized particles to bind together, allowing the sweeper to pick up more particles. It is expected that polymers will increase the efficiency of mechanical sweepers from about 10 percent to at least 20 percent with monthly sweeping, and may also improve the water quality of runoff in areas where high efficiency sweepers are used.

To meet the 40-percent TSS reduction requirement in NR 151, the City estimates that at least 56 percent of the areas not treated with detention basins will need to be included in a weekly sweeping program with a high-efficiency sweeper (City of Madison, 2006c). However, the results of the future polymer studies could result in modifications to this estimate.

5.2.3 Trash and Leaf Management

The City Streets and Recycling Division is responsible for trash (refuse) and leaf collection in the Monona Bay watershed. Refuse collection occurs weekly and is currently performed manually. The City will be converting to an automated refuse collection system in 2007, in which a driver uses an arm on a truck to lift and dump the refuse bins into the truck. This conversion will require a conversion of public as well as private trash cans to bins that are compatible with the truck arm function. The City Streets and Recycling Division is generally responsible for maintaining and collecting refuse from public trash cans, although the Parks Division has responsibility for public trash cans in the Mall Concourse area along State Street and in City parks.

The City rarely adds additional public trash cans due to budget restrictions on adding more long-term maintenance needs. If businesses or community groups request the addition of public trash cans, the City may be willing to provide them, but will generally ask the requesting group to take responsibility for emptying the cans (George Dreckman, City of Madison Recycling Coordinator, verbal communication, 2006). The average cost of a public trash can is approximately $350 for the can itself, but the long-term maintenance costs for the City are significantly higher.

The City is actively pursuing ideas to reduce the overall waste volume in Madison, including ideas that could impact Monona Bay. For instance, the City is encouraging the University and businesses to use reusable cups for selling beverages at events. The hope is that reusable cups will cut down on the number of disposable cups that end up as litter, and that when reusable cups are thrown away they will be heavy enough to stay in the trash rather than being picked up by the wind and blown into the streets.

The City also collects yard waste and leaves. Fall leaf collection begins in October and generally runs through November, or as long as weather permits. Residents typically pile their leaves loose on the street edge, although some residents cover the piles or bag the leaves to prevent the leaves from blowing. The City also operates free yard-waste drop off sites and provides free brush collection monthly from April through October. All material collected is chipped and recycled as mulch or compost.

5.2.4 Erosion Control and Stormwater Management at Construction Sites

Erosion from construction sites can contribute dramatically to poor stormwater quality. Responsibility for regulating construction sites is split between the WDNR and the Department of Commerce, but the WDNR has more rigorous requirements for erosion control and stormwater management at residential construction sites than Commerce has for commercial and state-owned construction sites.

The WDNR requires the following information to be submitted with a Notice of Intent to build:

- percentage of impervious cover before and after construction,
- plans for infiltration,
- list of specific erosion-control practices used during and after construction,
- verification that stormwater management plans and erosion control plans have been completed, and
- verification that information is true.

Commerce does not require any of those items to be submitted with a Notice of Intent. Furthermore, Commerce has no process in place to address deficient Notice of Intents, requires no application fee, does not assess the quantity of stormwater coming from a site, and does not require erosion-control or stormwater-management plans to be on-site. Commerce's rules leave it without the power to require individual (rather than general) permits, to revoke WPDES coverage, or issue a Notice of Non-Compliance or a Notice of Violation. The only enforcement ability Commerce has is under the Uniform Dwelling Code, under which it can issue a stop order or a $100 fine. There is no evidence that Commerce has brought enforcement action against any developer not meeting stormwater standards to the Department of Justice (Brent Denzin, Midwest Environmental Advocates, written communication, July 2006).

Many ways of addressing erosion from construction sites are available. Minimally, the following practices should be implemented:

- a silt fence around the perimeter of the site,
- protection around storm drains (such as a temporary filter insert),
- use of straw or other material to cover bare ground, and
- a method that cleans the tires of vehicles entering and exiting the site.

Although ultimate WPDES stormwater-permit coverage for commercial sites is granted through the WDNR, Commerce is responsible for enforcement of erosion control at many of the re-development projects in the Monona Bay watershed. Given the number of construction sites and the limited amount of resources available for enforcement, citizen monitoring becomes very important. To report a suspected stormwater violation at a commercial building site, call the Department of Commerce at 608/266-1018.

A useful Web site for more information is: <http://www.midwestadvocates.org/advocacy/Sustaining%20Communities/toolkit.htm**>.**

5.2.5 Stormwater-Outfall Maintenance

According to City of Madison, dredging at the outfalls in Monona Bay was fairly common 20 to 30 years ago (Genesis Bichanich, City of Madison, written communication, 2006). However, the WDNR lacks any records of past dredging projects in the bay other than a 2001 Metropolitan Sewer District project that replaced 17 stormsewer outfalls. (Records not in the WDNR database may be in storage.) As part of the Sewer District project, 6 cubic yards or less of sediment was removed. Because of the small volume, sediment samples were not required (Cami Peterson, Wisconsin Department of Natural Resources, written communication, 2006).

Historic maps and records from the City indicate a dredging plan was proposed in 1970 for the south triangle and southwest corner of Monona Bay. The dredging project in the south triangle was approved by the City in 1970, but it is unclear if the southwest corner of Monona Bay was dredged at this time as well. The City of Madison Engineering Department collected water-depth data before and after dredging in the south triangle. These data shows water depth was only 3 ft in several locations in the south triangle. After dredging, water depth ranged from 7 to 12 ft.

Because sediment is transported in stormwater and deposited at outfalls, localized dredging for stormwater outfall maintenance may be necessary in the near future. However, for dredging to be considered in Monona Bay, it is likely that sediment infilling would need to be such that it impeded boat access (Genesis Bichanich, City of Madison, written communication, 2006).

5.2.6 University of Wisconsin–Madison Water-Quality Practices

The UW–Madison has been actively addressing stormwater-quality issues for more than 10 years. At present, innovative stormwater-management practices are being implemented in all new campus development projects. However, as with the rest of the Monona Bay watershed, much of the campus was developed before there was a significant emphasis on stormwater quality in site design. Although retrofitting projects are being considered to improve stormwater quality and enhance infiltration throughout the campus, these projects are usually expensive and difficult to implement. As a result, improvements to stormwater quality are a part of a gradual process of redeveloping and enhancing the entire campus over time.

The 2003 WRM Practicum assessment of current stormwater management practices on the UW–Madison campus was part of a larger project funded by the WDNR under the Wisconsin Nonpoint Source Water Pollution Abatement Program. It was intended in part to help the University move beyond simply complying with current regulations to implementing more innovative stormwater-management practices (Water Resources Management Practicum, 2004).

Many of the general recommendations of the 2003 Practicum focused on reducing construction impacts, avoiding soil compaction, and promoting infiltration. Design of buildings, parking lots, and pedestrian walkways to facilitate these goals as well as minimize salt use and ease snow removal was also a major recommendation. Finally, the Practicum recommended a no-net-loss of greenspace (Water Resources Management Practicum, 2004).

Although the specific recommendations from the WRM Practicum are being studied by the University, none have been implemented yet. For the most part, University staff note that the recommendations have not moved forward because they were made by a student group and were not part of a professional engineering study. To meet state requirements, a professional study would have to be conducted for each recommendation before moving forward. The University is evaluating whether the recommendations are viable enough options to warrant moving ahead with more expensive professional studies. Although the University has a number of faculty whose research and academic work supports innovative stormwater-management practices, the University lacks a staff member in the role of Stormwater Coordinator, who could advocate for better stormwater treatment on campus (Gary Brown, University of Wisconsin–Madison, Facilities Planning and Management, verbal communication, 2006).

Some innovative stormwater best management practices are being incorporated into new development on campus. For example, at the University Square development currently in progress, a green roof is being installed. However, no infiltration practices are being included in the area around the building. The paving outside is traditional and the property will be hooked into the municipal stormsewers. Infiltration was deemed impractical because there was not enough room in such an urban environment to use swales or other infiltration practices.

Currently, the University manages stormwater quality through a street-sweeping and leaf-collection program. The University uses an Elgin Pelican and sweeps on average once per week if the weather is favorable. In spring, the University sweeps two to three times per week and more if there is construction. Sweeping generally begins in March and continues through November until the leaves have fallen. If the weather is warm enough, sweeping continues when possible through the winter. In the fall, the University also participates in leaf-collection activities, using a Giant Vac or Bobcat to pile and remove the leaves before they can clog the street sweeper. Three drop-in filters with pull-out baskets have been installed near the Walnut Street greenhouses on campus. They have to be cleaned by hand, but were installed in the summer of 2005 and have only had to be cleaned once.

In addition to regular trash pickup around campus, the University also has developed a trash-collection routine for the sports season in an effort to ensure that the campus is not a source of floatables and other trash in the surrounding lakes. At the beginning of the football season, the University scatters 20 to 25 large red dumpsters in every parking lot around Randall Stadium, and several more dumpsters around the stadium itself. They empty the dumpsters in the parking lots the day before games, at half-time on Saturday, and again on Monday. They empty the dumpsters around the stadium itself and pick up garbage within the stadium on Saturday after every game. The University also has recycling dumpsters around the stadium. This routine continues throughout the football season (Peter Lowrey, Facilities Planning and Management, verbal communication, 2006). There are recycling dumpsters at the Kohl Center, but garbage pickup is handled by a private company.

5.3 Shoreline Maintenance

5.3.1 Public and Private Owners

The Parks Division (Parks) of the City of Madison maintains the shoreline landscape of Monona Bay, including Bernies Beach, the land between South and West Shore Drives and the shoreline, up to and including Brittingham Park, over to Brittingham boathouse and ultimately to John Nolen Drive (James Morgan, City of Madison Parks Division, verbal communication, 2006). Specifically, Parks mows the vegetation, maintains the riprap, annually removes woody plants, and pulls noxious weeds that have been deemed a nuisance. According to Superintendent Morgan, private homeowners have riparian rights to the shoreline adjoining their property and the privileges associated with those rights (i.e., the right to place a pier for water access along their frontage). However, the City has a 999-year lease to tend and maintain the riparian areas. Homeowners have the discretionary right to revoke their individual leases, effectively assuming maintenance responsibilities.

Monona Bay's shoreline has two distinct problems: large populations of nuisance Canada geese and infestations of non-native plants, such as reed canary grass. Per WDNR suggestion, in the spring of 2006, the Parks adopted a no-mow policy along the shoreline; this resulted in a strip of tall vegetation (i.e., shoreland buffer) ranging from 0 to 50 ft wide (James Morgan, City of Madison Parks Division, verbal communication, 2006). The WDNR and Parks hope the buffer will deter waterfowl from gathering, increase surface stormwater infiltration and stop silt from entering the bay.

Homeowners along the bay can elect to mow their lawn down to their waterfront; in fact, most private lots consist of turf grass and some ornamental landscaping. Only Brittingham Park has shoreland buffers of varying width. The no-mow policy is in its infancy, and it is premature to gauge its impact, although it saves the City revenue because a smaller area is mowed.

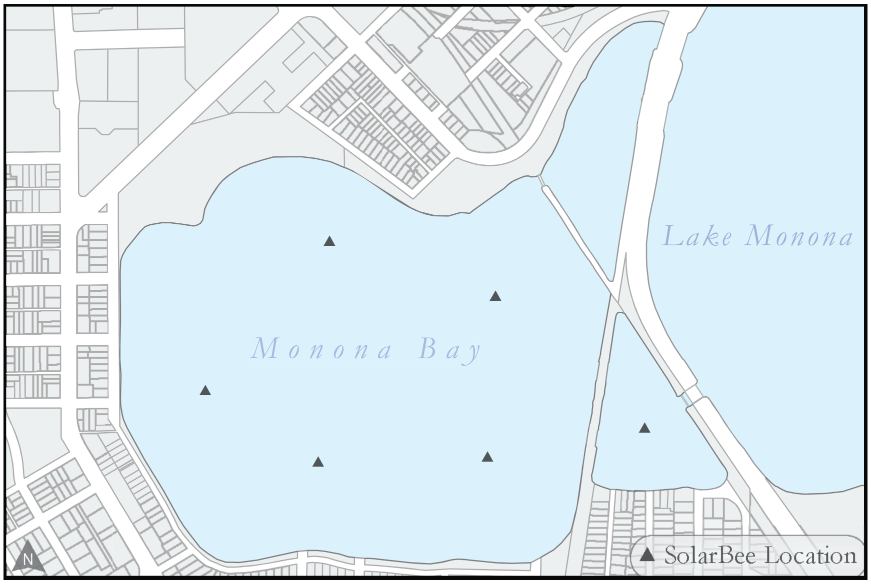


Figure 5.2. Monona Bay SolarBee placement, May 2006. Source: City of Madison Engineering Division (2006).

5.3.2 Riprap

Parks works in conjunction with the WDNR to maintain the ecological and physical integrity of the bay's shoreline. The WDNR issued a permit to Parks in 2001 to armor the bay's shoreline within its jurisdiction using riprap. The riprap was placed to stabilize the shoreline and protect it from wave erosion following a 2001 storm that caused significant shoreline erosion (James Morgan, City of Madison Parks Division, verbal communication, 2006). Parks repairs any dislodged riprap and replaces it when needed.

5.4 Water Quality

High blue-green algae and fecal bacteria concentrations can adversely affect the health of Madison's lake users (see the *Algae and Fecal Bacteria* section of chapter 3). Therefore, these concentrations are monitored in Madison area lakes; management actions, such as beach closures, are taken to reduce risks to human health.

5.4.1 Fecal Bacteria

Bacteria levels have been monitored at Madison beaches since the 1950s. The Madison Department of Public Health monitors the two beaches on Monona Bay, Brittingham and Bernies, on a weekly basis from June to October for levels of fecal coliform, enterococci, and *E. coli*. These bacteria indicate fecal contamination and suggest the possible presence of human pathogens (City of Madison, 2006b). The City will close a beach when tested levels of *E. coli* exceed 1,000 MPN (most probable number) per 100 mL; this criterion is based on historic data from local beaches (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). Beaches may also be closed as a precaution or whenever conditions such as heavy rains warrant concern (Holtan, 2005).

5.4.2 Blue-Green Algae

The Madison Department of Public Health began monitoring beaches for blue-green algae blooms some time in the 1970s or 1980s and, in 2002, began to keep track of the species present (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). Today, the method of monitoring for blue-green algae by the Madison Department of Public Health is still mostly qualitative. During the swimming season, beaches are surveyed regularly and sampling can be triggered by a report of a bloom from a field worker, lifeguard, or concerned citizen. Water samples are examined for the presence and abundance of blue-green algae species of concern (Kirsti Sorsa, Madison Department of Public Health, written communication, 2006). If a species of concern, or a species known to produce dangerous levels of toxins, is found in high numbers, then a beach will be closed.

5.4.2.1 SolarBees

Due to water quality concerns voiced by Monona Bay residents, the City of Madison installed six solar powered water circulators, known as SolarBees, in the summer of 2005. The City of Madison approached the makers of SolarBees, Pump Systems, Inc. (PSI), after meeting with residents concerned about blue-green algae and trash in the Bay in early 2005 (Genesis Bichanich, City of Madison, written communication, 2006).

SolarBees are solar-powered stationary devices that are anchored into the lake sediment. The SolarBees used in Monona Bay were designed to pump 10,000 gallons of water per minute. Excess energy generated during the day was stored in an onboard battery to allow for continuous operation 24 hours per day (SolarBee, 2005). The SolarBees circulate water from an intake hose positioned approximately 1 ft above the lake sediment. Each device is designed to radially spread water up to 800 ft and prevent blue-green algae blooms in a 50-acre circle (C.F. Knud-Hansen, SolarBee, written communication, 2005).

The management purpose of the devices in Monona Bay was to control blue-green algae and aquatic plant growth. The company states the primary goal of the devices in Monona Bay was to prevent blue-green algae blooms (C.F. Knud-Hansen, SolarBees PSI, written communication, 2006); however, aquatic plant control is of equal importance to the bay residents and the topic of much discussion prior to their installation (Lisie Kitchell, FOMB, written communication, 2006). In the spring of 2005 the WDNR required monitoring for blue-green algae because there was concern decreased aquatic plant densities would result in greater algal counts (Cami Peterson, Wisconsin Department of Natural Resources, written communication, 2006).

Because the company was interested in testing the effectiveness of SolarBees in weedy areas, the SolarBees were placed in Monona Bay for a one-year trial during the summer of 2005 (fig. 5.2). The company indicated there was preliminary data that showed they may be able to control invasive plants such as Eurasian water milfoil. In addition, the Army Corps of Engineers was planning to do an independent study on the effect of SolarBees on invasive weeds in the summer of 2006; however, this study was suspended.

Although the company did not charge a rental fee for 2005, a one-time installation, delivery, startup, and retrieval cost of $13,350 was paid by the City (Genesis Bichanich, City of Madison, written communication, 2006). The six SolarBees were placed in Monona Bay again in the spring of 2006; that year the City spent $78,120 to rent them for 12 months. The purchase price is $37,075 per SolarBee, or $222,450 for all six, although 60 percent of the rental fee can be applied to the purchase price.

With the installment of the SolarBees in May 2005, the City of Madison began surveys of blue-green algae species in Monona Bay to track and monitor the effectiveness of the SolarBees in the bay. Weekly sampling occurred during the summers of 2005 and 2006 at five sites: the north and south triangles, the two beaches and one in Monona Bay proper. Blue-green algae species present in the samples were identified and counted (Genesis Bichanich, City of Madison, verbal communication, 2006). The data collected by the City currently provide the most comprehensive picture of the status of blue-green algae in the bay. Because the first extensive water sampling in Monona Bay began in 2005 (see Water-Quality Data section of chapter 3), no data are available to compare water quality with and without the SolarBees.

The use of SolarBees generated much criticism. Many of these concerns relate to the lack of evidence that blue-green algae blooms are a problem in Monona Bay during the swimming season, the lack of published studies on the effectiveness of SolarBees in controlling blue-green algae and aquatic plant densities, the lack of successful empirical evidence from water bodies similar to Monona Bay, and realistic limitations to company theories regarding water circulation and nitrogen limitation. These concerns are explained in more detail below.

Defining the Problem. As identified in the Monona Bay Stakeholder Survey, the major problem in Monona Bay is excessive aquatic plant growth. Although plant growth in shallow lakes is natural, residents identify aquatic plants as problematic because they impede recreational use, such as boating, and create a visual eyesore. Algae was identified as a secondary management problem in Monona Bay. One important limitation of the survey is that blue-green algae and filamentous algae were not differentiated in the survey questions.
Analysis of the last 10 years of beach closing data indicates the two beaches on Monona Bay have never been closed because of blue-green algal blooms (City of Madison [Beach water sampling], 2006) (See section 3.6). This warrants the question as to whether blue-green algae blooms are or will be a threat to human health in the bay during the summer months given its clear-water aquatic plant dominated state.

Measuring Effectiveness. To date, the operating mechanisms, which purportedly control blue-green algal blooms and reduce aquatic plant densities, have not been substantiated by research resulting in published peer-reviewed articles.

Because no comprehensive water quality, aquatic plant or limnological study was conducted on the bay prior to the SolarBee installation, it was difficult to track trends over the past two seasons in regards to aquatic plant growth and blue-green algae blooms. Although qualitative observation is relevant (e.g. the presence or absence of algal scums), in order for a scientific evaluation to have validity, quantitative data are necessary to track long-term trends.

SolarBee Applications. SolarBees are being used on numerous water bodies around the United States. These include freshwater, saltwater, potable water and wastewater installations. Freshwater applications include reservoirs, cooling ponds and natural systems. These systems differ from Monona Bay in terms of lake depth, management objectives and/or density of aquatic plants (SolarBee, 2006). Lakes are dynamic systems and the success of SolarBees in one application may not result in a similar success in another application.

Nitrogen Limitation. The company cites case studies where invasive submerged aquatic plants, such as Eurasian water milfoil, were eliminated or reduced by sediment oxygenation in the littoral zone (Joel Bleth, SolarBee PSI, verbal communication, 2006). The company's argument for the control of aquatic plants relies upon the oxygenation of the lake sediments and the transformation of nitrogen from ammonia-N to nitrate. According to the company this creates a nitrogen limiting situation for Eurasian water milfoil in the littoral sediments. Although many aquatic plants are nitrogen limited, it is highly unlikely that rooted Eurasian water milfoil is experiencing this nutrient limitation in Monona Bay.

However, if nitrogen is limiting, three of the many questions the company's explanation raises are: 1) the role of aquatic plants in interrupting the circulating flows of the SolarBees; 2) if there are enough SolarBees and if they are placed strategically to facilitate needed levels of circulation; and 3) how this circulation differs from natural wave action and circulation induced by the wind.

The SolarBees will not return in 2007. According to the City, two years of water-quality data did not justify their continued use and there was a lack of public support (Genesis Bichanich, City of Madison, written communication, 2006). We support the City's decision to remove the SolarBees from Monona Bay. Other proven management tools can be employed or intensified to achieve the water quality and aesthetic objectives based upon the best available science. The use of SolarBees in Monona Bay diverted valuable human resources and budget from more proven effective management tools.

5.5 Aquatic Plants

Large scale chemical control of plants in the Monona Bay has not been used for many years. According to the Dane County Lakes and Watershed Commission (2006b), the County's current aquatic plant management program includes harvesting, shoreline cleanup, nutrient reduction, and education. The County chose harvesting as the main tool because it

- efficiently manages plants in large areas,
- removes some nutrients from the lakes,
- reduces the amount of chemical herbicides used, and
- does not affect areas beyond those harvested (Dane County Lakes and Watershed Commission, 2006b).

The WDNR requires Dane County to submit aquatic plant harvesting plans for approval under NR 109 of the Wisconsin Administrative Code. The Dane County Parks Division of the Department of Land and Water Resources is responsible for the County's aquatic plant-harvesting program. Dane County currently owns a total of eight harvesters; an additional harvester is proposed in the 2007 budget (Sue Jones, Dane County Lakes and Watershed Commission, written communication, 2006). The County hires seasonal limited-term employees to perform the harvesting. The supervised crews harvest aquatic plants from mid-May until mid-August, depending on when the budget runs out. Harvesting is done on a rotating basis among various lakes in Dane County. Crews are trained to focus on areas that have dense, exotic plants and to avoid areas with native aquatic plants. Dane County policy is to cut and harvest Eurasian water milfoil and other invasive plant species to help provide for reasonable use of the lakes for boating, fishing, and swimming while preserving the health and balance of lake ecosystems (Darren Marsh, Dane County Parks Division, written communication, 2006).

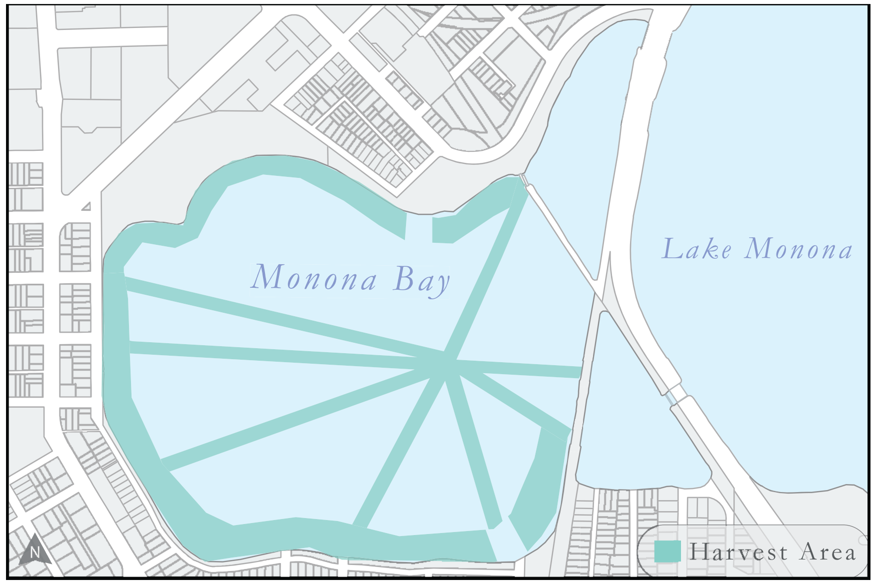


Figure 5.3. Monona Bay aquatic plant example harvesting area, 2006. Source: Dane County Office of Lakes and Watersheds (2006).

Figure 5.3 shows the approximate harvesting routes within Monona Bay in 2004 and 2005. The harvest pattern provides boat access for waterfront-property owners, recreational boaters, and fishermen as well as habitat for fish. The harvested channels in the bay are about 30 ft wide and from 4 to 5 ft deep. When possible, cutting along the shoreline is done in a zigzag pattern to leave vegetation for fish habitat. Park officials found that cutting as close to the shore as possible prevented trash accumulation at the water's surface, and as a result the Parks Division received fewer complaints about trash from users. In 2006, harvester routes have been much the same with the exception that during July, large sections of the bay were experimentally harvested at a 2-ft depth following a protocol permitted by WDNR (Darren Marsh, Dane County Parks Division, written communication, 2006) to provide better nuisance relief from surface mats of aquatic plants and filamentous algae. As harvesters become full, plants are brought to shore, loaded onto trucks, weighed and hauled to remote composting sites.

Harvesting plans have varied over the years, and, although the weights of harvested plants have been kept for entire lakes, the harvested quantities within different parts of the same lake have not usually been recorded. However, data from 2006 indicate that between May and the end of July 522 tons (473,550 kg) of plant material were harvested from Monona Bay (Darren Marsh, Dane County Parks Division, written communication, 2006).

Funding for the harvesting activities comes from the Dane County Office of Lakes and Watersheds and Dane County Parks Division, with the majority of money for personnel costs coming from the Department of Solid Waste. Although costs associated with Monona Bay are difficult to determine, the total budget for this year's program was 100,000 (plus maintenance costs, which are part of the Dane County Park's Department's operating equipment expenses), but included a proposal for an extra $284,000 for two additional harvesters, which would be expected to last 30 to 40 years (Dane County Office of Lakes and Watersheds, 2005). The 2007 budget included a proposal for an additional harvester (Sue Jones, Dane County Office of Lakes and Watersheds, written communication, 2006). The personnel costs for the harvesting activities in the bay from June to the end of July totaled approximately $3,514, including 282 hours for a limited term employee at $12.46/hour (Darren Marsh, Dane County Parks Division, written communication, 2006).

Many waterfront property owners on Monona Bay continue private plant and algal control. Methods used include raking, pulling by hand, netting, and chemical application. The WDNR records indicate that they have permitted chemical application at an average of 11 piers and waterfront properties of the bay each year since 1998. In this time period mainly Diquat and Cutrine Plus (a copper-based algaecide) have been used. However, the following chemicals have also reportedly been used in Lake Monona, possibly in the bay: copper sulfate and other chelated copper products, Aquathol K,

Table 5.4. Number of properties in Monona Bay and the triangles receiving chemical treatment. Source: Wisconsin Department of Natural Resources, South-Central Headquarters (1998–2006).

Year	Areas permitted	Areas receiving early season treatment	Areas receiving late season treatment
2006	11	8	7
2005	—	8	—
2004	13	8	2
2003	9	5	2
2002	13	10	7
2001	10	—	—
2000	—	—	—
2000	14	—	—
1999	11	—	—
1998	11	—	—

weedR-64, and Navigate. In 2006 permits were granted for the treatment of 11 of the 90 parcels (approximately 50-ft frontage sections) adjoining Monona Bay, with early season treatments at eight sites and a second late-season treatment at seven sites. These treatments totaled approximately 0.8 acre (less than 1% of the bay). Table 5.4 shows the number of areas where chemical application was permitted.

Property owners usually pay a local company, Clean Lakes Associates, for treatment. The company then applies for one permit that includes property owners from around Lake Monona. Previously, a WDNR representative would supervise application and determine which areas were acceptable to treat, but because of staff constraints, this oversight will be discontinued. The following criteria are used to determine acceptable locations:

- The weather is fair and water is calm/non-turbid.
- Water levels are sufficiently low so that no terrestrial vegetation is in contact with lake water, even downwind with storm-driven waves.
- Treatment signs must identify areas that are treated with chemicals, visible from water and land, and include lake-property number/address sign.
- Riparian treatment is only allowed within 100 ft of shore for no more than 50 ft per property.
- Standard rake test shows significant plant/algal growth.
- Application is limited to high use areas near piers (Susan Graham, Wisconsin Department of Natural Resources, verbal communication, 2006).

5.6 Outreach and Education

Several groups at the state, county, city, and citizen level currently work to educate the public about Monona Bay and what can be done to ensure the bay is as clean and safe as possible.

The WDNR supports and organizes a program called Citizen Lake Monitoring. It encourages citizen involvement in water-quality monitoring and simultaneously serves as an educational tool. The program aims to collect high quality data, to educate and empower volunteers, and to share this data and knowledge. The WDNR and University of Wisconsin–Extension staff have taught more than 1,000 volunteers to measure lake water clarity, chemistry, temperature and dissolved oxygen since the program's inception. State and other agencies often use the data gathered by the citizen volunteers.

Through this program, volunteers from the Friends of Monona Bay (FOMB) have measured water clarity in the bay two times per month during summer months since 2003. The FOMB is a small, active nonprofit organization working to improve the health and enjoyment of Monona Bay through monitoring, education, stewardship and advocacy. The FOMB, along with the Bay Creek Neighborhood Association, organizes hands-on activities, such as bay cleanups on Earth Day. They also host panel discussions, give informative presentations to neighborhood groups, sponsor informal education tables at community events, and hand out educational material door-to-door. The FOMB approximate annual budget is $1,200 for these activities.

The Madison Area Municipal Stormwater Partnership used grant money obtained from the WDNR for the "My Fair Lakes" media campaign. The campaign raises awareness of stormwater impacts in the greater Madison area. A Web site, <www.myfairlakes.com>, provides information about ways that residents can help keep lakes clean. The slogan for the campaign, "In Dane, only the rain goes down the drain," was used in television and radio advertisements. In a separate campaign including Friends of Lake Wingra, Friends of Starkweather Creek, the Madison Area Municipal Stormwater Partnership, the City of Madison and Dane County "Love your lakes, don't leaf them," asks that citizens help reduce nutrient loading to the lakes by keeping yard waste from entering the lakes. Signs for both campaigns have been distributed to residents of the Monona Bay watershed for display in their yards.

Yahara Lakes Week is a celebration and campaign to raise awareness for the Yahara Lakes that includes the "Take a Stake in the Lakes" shoreline cleanup. The Dane County Lakes and Watershed Commission organizes the annual event with support from many partners. Activities at the event include shoreline cleanups and "Dump No Waste" stenciling and marking on storm drains to decrease lake pollution.

CHAPTER 6. MANAGEMENT ALTERNATIVES ANALYSIS

The issues affecting Monona Bay include problems with stormwater inputs and water quality, shoreline maintenance, aquatic plants, and filamentous algae. In addition, developing effective education and outreach plans is critical to the success of any management strategy. The consequences of different management actions taken to address these issues could be complex and far-reaching, possibly affecting more aspects of Monona Bay than intended. Thus, prior to evaluating specific management alternatives, it is valuable to understand what the current and possible future "big-picture" scenarios are for Monona Bay.

With the existing and possible future conditions of the bay in perspective, the next step in developing a watershed plan for Monona Bay is to assess individual management alternatives. Advantages, disadvantages, costs, and applicability given current conditions should be examined for each management alternative before selecting the recommended alternatives that will compose the overall management plan.

6.1 Current and Future Scenarios

The current conditions in Monona Bay fit the classification of a vegetation-dominated, clear water, stable-state shallow lake. The high concentrations of nutrients in the soil are creating a very productive eutrophic lake that has thick mats of aquatic plants, and the conditions in the bay are consistent enough that the state of the bay is relatively constant from year to year. Although the excessive aquatic plants in the bay can detract from its recreational usage, this vegetation does help keep the water in the bay clear. (The ecologic functions related to the bay's current state are discussed in detail in the *Overview of Shallow Lake Ecology* section of chapter 3.)

Shallow, nutrient-rich lakes will exist either in the vegetation-dominated clear state that Monona Bay is currently in, or in a turbid state dominated by algae. It is highly unlikely that a healthy bay could exist in another state, particularly one in which the bay had neither abundant aquatic plants nor algae. Thus, the factors that contribute to the development of these potential scenarios for the bay are important to consider when evaluating the possible effects of different management alternatives that could switch the bay from one stable state to another.

6.1.1 Potential Management Impacts

According to our survey results, excessive aquatic plant growth is one of the primary concerns of the users of Monona Bay; thus, several of the management alternatives we consider here address this issue. Increasing harvesting is one option to reduce undesired plant growth. Dredging the bottom of the bay could also reduce plant growth by making the bottom deep enough that plants at the bottom cannot obtain enough sunlight. A well timed herbicide application with a complementary harvesting regime may increase the abundance of native plants in the bay and reduce the quantity of invasive EWM.

Of these three primary aquatic plant management alternatives, harvesting or a combination of targeted herbicide application and harvesting would be unlikely to cause damaging shifts in the bay's condition to a turbid, algal-dominant state. Large-scale dredging of the bay, however, has the potential to result in the worst-case scenario of turning the clear-water vegetation-dominant state into "pea soup," or a turbid algae-dominant state. This is especially undesirable because emissions from certain types of toxic blue-green algae have previously been documented in Lake Monona. The possibility of additional toxic algae production to the Lake Monona system in Monona Bay would create a state that is much worse that the current conditions.

Although other potential disadvantages are associated with some of the additional management alternatives analyzed in this chapter, none of these is expected to cause a transition in the bay from its current clear-water vegetation-dominant state to a turbid, algal state. Activities intended to improve stormwater quality and shoreline conditions are generally expected to enhance the recreational and ecological conditions in the bay within the physical limits of the bay's morphology and watershed influences.

6.2 Stormwater Management Alternatives

The regulatory environment does not emphasize improvements to existing stormwater infrastructure in developed watersheds such as Monona Bay's. Thus, for stormwater quality in the watershed to significantly improve, the City of Madison and private entities, such as homeowners, business owners, and institutional entities, such as churches, must adopt new stormwater-management approaches that capitalize on opportunities for enhancing water quality in the watershed.

One of the most important places to start improving the quality of runoff is with pollution-prevention activities and removal of sediments and trash from impervious surfaces before being picked up by runoff. Ensuring that runoff from construction sites is adequately treated and stored on-site and that erosion is not occurring is another important management tool for improving stormwater quality.

Stormwater-treatment devices can also be used to address specific problems with stormwater pollution, but due to the installation and maintenance costs associated with these devices; it is most beneficial to install them in targeted locations as a part of a long-term planned improvement program. Innovative stormwater-management practices, such as rain gardens, can be effective at increasing stormwater infiltration, but some practices can be expensive to retrofit into existing development. Including innovative stormwater practices in redevelopment projects is beneficial to stormwater quality and lake baseflow.

Policy tools can help create a better institutional/municipal environment for improving stormwater quality through innovative practices. The most promising of these tools includes providing incentives to developers and building owners to add innovative stormwater-management systems to their buildings and creating a long-term stormwater-management plan for the City of Madison that targets opportunities for water-quality enhancements through redevelopment projects in developed watersheds. Regulatory agencies can also improve watershed conditions by rigorously evaluating existing and new stormwater-treatment technologies to provide better data about their performance, offering decision makers better information to use when allocating scarce resources.

6.2.1 Water-Quality Activities

The City of Madison and the university improve stormwater quality by performing street sweeping and trash collection, and the WNDR and Department of Commerce regulate construction site runoff and erosion. These programs could be complemented and improved upon by the following activities:

- creating an erosion-control hotline and require posting of the number at construction sites,
- expanding promotion of pollution prevention,
- expanding and enhancing litter prevention and cleanup programs,
- expanding and enhancing street sweeping, and
- expanding stormwater outfall maintenance.

6.2.1.1 Create an Erosion-Control Hotline

Uncontrolled erosion and runoff from construction sites add significantly to the TSS load of stormwater. The disturbed ground and heavy machinery usage at construction sites make them highly susceptible to erosion problems. In developed watersheds like Monona Bay's, sediment-laden runoff from construction-site erosion quickly enters the stormsewer system on the surrounding streets, and the sediment ends up in the receiving water body.

Although erosion-control plans and BMPs are required at most construction sites, inspection and enforcement of these plans and BMPs to ensure they are being implemented can be lacking. As a result, sediment-laden stormwater can be observed running off sites into the stormsewer system if silt fences and straw bales are improperly installed or fail.

One barrier to effective enforcement of construction-site erosion-control plans is lack of funding for inspectors to visit all sites on a regular basis. This barrier can be cost-effectively addressed by establishing an erosion-control hotline number for citizens to call when they observe erosion at a site and requiring all construction projects to post the number and an explanation of it in visible locations throughout their sites. To reduce costs, the erosion-control hotline number could be unstaffed, with a simple answering machine system asking call-

Figure 6.1. Sediment tracked onto street from equipment at a construction site in the Monona Bay watershed.

ers to provide the location and type of problem. Once a call is received, the site can then by visited by an inspector and the problem can be addressed. The current telephone number available for reporting suspected stormwater violations at a commercial building site is through the Department of Commerce: 608/266.1018.

Applicability to Monona Bay

Although much of the bay watershed is already developed, there is considerable redevelopment occurring on the university campus and around the downtown area. We conducted a visual survey, and it was clear that erosion and poor housekeeping practices at construction sites in the Monona Bay watershed are contributing sediment to the stormwater that enters the bay. Trucks and equipment can track sediment from construction sites into the streets, and filter fabric placed in stormsewer grates as a precautionary measure can overflow with sediment if not properly maintained (figs. 6.1 and 6.2).

An erosion-control hotline could be established by the City of Madison or as a cooperative effort by all of the Madison Area Municipal Stormwater Partnership WPDES MS4 co-permittees, in conjunction with the Wisconsin Department of Commerce and the WDNR, who share responsibility for enforcement of erosion-control plans at construction sites. The FOMB and other friends groups in Dane County could advocate for the creation of a hotline as a cost-effective way of addressing the problems associated with construction-site erosion.

Figure 6.2. Sediment clogging a storm drain adjacent to a construction site in the Monona Bay watershed.

6.2.1.2 Expand Promotion of Pollution Prevention

Keeping pollutants from entering stormwater is a key step to improving water quality. The following pollution-prevention activities will reduce nutrient loading and toxins entering the bay and can be performed by individual homeowners and businesses as well as institutional landowners.

- Dispose of household chemicals, litter, and motor oils properly. Do not dump anything or wash anything into a storm drain that you would not want to swim in.
- Dispose of lawn clippings and leaves through the City leaf and yard-waste curbside collection program or in compost bins.
- Do not overuse fertilizers and pesticides or spread them on impervious surfaces; they should be avoided whenever possible.
- Clear debris from around nearby storm drains and put it in the trash or take it to yard-waste pickup sites.

- Prevent erosion on your property. Cover bare areas with vegetation, mulch, or other erosion control.
- Report any spills or dumping into the stormsewers or bay to the City of Madison.
- If you own a business that has a parking area, keep it swept and free of trash and sediment.

Although many of these pollution-prevention activities may seem like common sense, promoting such activities among homeowners, business owners, and other landowners can help improve stormwater quality.

Applicability to Monona Bay

Expanding promotion of pollution-prevention activities in the Monona Bay watershed would have a positive impact on water quality. It is important to help homeowners, business owners, and other landowners understand how their actions can directly affect Monona Bay and give them tools for taking actions that have a positive impact. The FOMB could create or use existing fact sheets on pollution prevention for stormwater to distribute to bay residents and businesses, or the City could perform a similar role by including such materials in sewer bills. Resources are available on household hazardous waste-disposal options at the City of Madison and Dane County "Clean Sweep" program Web site: <http://www.danecountycleansweep.com/pdf/2006/RecycTransFactSheet.pdf>.

Dane County Office of Lakes and Watersheds has several fact sheets and brochures available on topics such as "You're the solution to water pollution." For more information, see their Web site: <http://www.danewaters.com/private/tips.aspx>.

6.2.1.3 Expand and Enhance Litter Prevention and Cleanup Programs

Trash and litter that reach water bodies reduce their recreational appeal and aesthetic value and can also cause ecological harm. The City of Madison and the university collect trash throughout the Monona Bay watershed and provide trash baskets to reduce litter on many of the downtown streets. However, a problem remains with trash being carried into Monona Bay by stormwater; this is probably due to littering.

The large volume of student housing in the watershed along with university event centers, such as the Camp Randall football stadium and the Kohl Center, creates unique conditions for litter accumulation during parties and events. Common types of litter found in Monona Bay include beverage containers, such as plastic bottles and cups used at parties. Business areas with fast food restaurants and convenience stores are also likely areas where litter can accumulate, such as along Park and Regent Streets in the Monona Bay watershed.

To effectively address litter problems, there is a need for education of the problem, provision of more waste-management tools (such as trash receptacles), establishment of clear rules prohibiting littering, and enforcement of rules. Many resources are available to guide efforts to expand and enhance litter prevention and cleanup programs. Keep America Beautiful has excellent resources available on litter prevention strategies, which can be found on the Web site: <http://www.kab.org/aboutus.asp?id=34&rid=55>. The Washington State Department of Ecology initiated an anti-litter campaign in 2001 that showed positive results. Information on the campaign can be found on the Web site: <http://www.ecy.wa.gov/programs/swfa/litter/campaign.html>.

Applicability to Monona Bay

Expanding and enhancing litter prevention and cleanup programs would improve the quality of Monona Bay and its aesthetic and recreational value. The FOMB, the City of Madison, and the university can work together to improve litter prevention and cleanup in the Monona Bay watershed.

6.2.1.4 Expand and Enhance Street Sweeping

Street sweeping is one of the key tools relied upon by municipalities to improve stormwater quality in urbanized areas in which there are few stormwater-quality treatment systems. A variety of strategies can be used to improve the effectiveness of street sweeping, including restricting parking so sweepers can reach the curb, sweeping more frequently, using high efficiency vacuum sweepers, and using polymers to coagulate smaller particles on the street and increase the sweeper efficiency in picking them up. In addition, street sweeping can be performed in the winter to remove sand and salt buildup on the roads as well as during the spring, summer, and fall.

The City of Madison is evaluating how street sweeping can be improved to provide greater pollutant and sediment removal. The results of this study will guide future efforts to improve street sweeping, but because cost will be a factor in the timing and level of implementation of improvements, it is important that the FOMB and other stakeholders advocate for options that will improve water quality in Monona Bay.

Applicability to Monona Bay

Sixty-two percent of the Monona Bay watershed is in the basic street-sweeping area in which sweeping is only performed on a monthly basis without parking restrictions. Expanding the enhanced street sweeping program (which includes weekly sweeping with parking restrictions so sweepers can reach the curb) to include all the Monona Bay area would improve bay water quality. Once signs are installed, the cost to expand the enhanced street-sweeping program is related to the operating costs of increased frequency of sweeping and the cost of purchasing additional sweepers. Each high efficiency sweeper costs about $150,000, and the estimated additional operating cost of increasing street sweeping from monthly to weekly sweeping is approximately $7,400/street mile (City of Madison, 2006c).

The City has previously considered expanding the enhanced street-sweeping program in the downtown area, but there was lack of alderman support for pursuing the expansion (Mike Daily, City of Madison, verbal communication, 2006). However, there are a number of benefits to expanding the enhanced sweeping area in addition to the water-quality benefits. Weekly parking restrictions can also provide better access for garbage and recycling haulers to reach bins on the curb if such services are coordinated on the same day as street sweeping. Furthermore, if parking restrictions are included year-round, they provide an opportunity for plows to reach the curb once a week.

Due to these advantages, the City is planning to increase areas of the city in the enhanced street-sweeping program as the stormwater budget allows (George Dreckman, City of Madison, verbal communication, 2005). The City is planning to add the rest of District 2 and all of District 4 to the enhanced street-sweeping program, possibly as soon as 2008 (Mike Daily, City of Madison, verbal communication, 2006). The FOMB and other stakeholders could voice support to their aldermen for expanding the enhanced street sweeping program to the entire Monona Bay watershed to encourage implementation as soon as possible.

The City is studying whether adding polymers during street sweeping will more effectively remove small particles. If the results of this study are positive, then the FOMB could also advocate for including polymer addition in the Monona Bay watershed street sweeping.

An area that has not been explored extensively by the City is increasing the street-sweeping program to include winter sweeping (when possible) to remove the salt and sand from streets. The FOMB could express their support for winter street sweeping to the City engineering staff and their aldermen.

Greater coordination of street sweeping efforts by the City and the university could be pursued. At present, the City only performs special (beyond scheduled) street sweeping around university event centers if requested to by the university. Implementing a street-sweeping schedule that emphasizes addressing litter in the streets after major events could improve the quality of Monona Bay.

6.2.1.5 Expand Stormwater Outfall Maintenance

Stormwater that contains suspended sediment can create depositional “deltas” at stormwater outfalls; the relatively fast-moving stormwater reaches the slower-moving receiving water body, and sediment is deposited in the calmer water. Sediment mounds are noticeable at several of the major outfalls in Monona Bay. We estimated that more than 47,000 cubic feet of sediment has accumulated at the large Brittingham Park Pavilion outfall.

The City of Madison performs stormwater-system maintenance, including cleaning and maintaining stormsewer pipes and outfalls. The stormwater-maintenance program could be expanded to include outfall maintenance. The City is addressing sediment buildup at outfalls in Lake Wingra through a proposed plan to remove sediment from a small area around the Lake Wingra boathouse in conjunction with a shoreline erosion-control project (Schuetz, 2006). The estimated cost for the Lake Wingra sediment removal and erosion-control project is approximately $203,000 (Schuetz, 2006).

Applicability to Monona Bay

Some FOMB members have noted that the sediment buildup at Monona Bay stormwater outfalls is resulting in shoaling of boats and other recreational impediments. However, the sediment is not yet mounding above the water surface as it is in Lake Wingra at several locations, where islands have formed. Thus, the sediment mounding in Monona Bay may not have yet reached a level that the City will deem necessary to address with sediment removal. However, if the City expands its stormwater-outfall maintenance program to address the mounding of sediment at outfalls in Monona Bay, a plan could be established to remove the sediment where needed when funding is available and permitting is approved.

Although the cost to remove sediment around the stormwater outfalls in Monona Bay has not been estimated by the City, we estimated the cost on the basis of general volume-related dredging cost estimates provided by dredging companies. To dredge the Brittingham Pavilion outfall sediment plume, it would cost roughly $3,600,000 for sediment removal, dewatering, and disposal. This estimate does not include project study and design or fixed contractor equipment fees.

To determine this estimate, we used our sediment plume data, a rough removal depth of 60 inches, and cost per cubic yard figures as per the current bidding rate for local dredging projects (Charles Nahn, Nahn & Associates, L.L.C., written communication, 2006). This calculation estimates the removal of 216,000 cubic feet or 72,000 cubic yards of sediment, to be disposed in a landfill. The Wisconsin DNR has indicated that sediment down to the marl layer would need to be removed because of contamination (Jim Arhmein, Wisconsin Department of Natural Resources, written communication, 2006). The exact depth of sediment to the uncontaminated marl layer is unknown at this location. However, for the purpose of this estimate we assumed a removal depth of 60 inches. We made this assumption oon the basis of our data collected from sediment core B.

We made a similar calculation for the Parr Street outfall. This is a smaller area than the Brittingham outfall; however, the sedimentation is greater at this location, resulting in shallower water. Using our sediment plume depth data collected and the assumptions used above for sediment depth and cost per cubic yard, an estimated 18,750 cubic feet or 6,250 cubic yards of sediment would need to be removed at a cost of $312,500. This estimate incorporates sediment removal, dewatering, and disposal, but does not include project study and design or fixed contractor equipment fees.

6.2.2 Stormwater-Treatment Devices

A fully developed urban watershed excludes opportunities for typical large-scale stormwater-management practices, such as detention ponds and infiltration basins. An alternative option in the Monona Bay watershed is to retrofit the existing infrastructure with stormwater-treatment devices. These devices are installed in-line with the stormsewer system, use little land space or are buried underground, and mechanically remove pollutants from stormwater. Some examples are catchbasin/catchbasin inserts, continuous deflective separation devices, filtration devices, combination devices, and trash-removal devices.

These devices can be designed to capture a wide range of pollutants from trash to sediment to oils and greases. The percentage of removed pollutants is highly dependent on many factors, including cleaning frequency, flow variability, and pollutant concentrations. When choosing a device, the user must consider the targeted pollutants, desired removal rates, expected flows, capital costs, and the maintenance commitment. After the initial capital cost and installation, all treatment devices will require long-term maintenance by the City of Madison or by a private landowner who chooses to take on the maintenance requirements. Due to the initial and long-term expense of stormwater-treatment devices and the targeted applications of the devices, they are best installed as a part of a long-term stormwater-planning process that has evaluated the best options for placing devices to achieve maximum return on the investment.

Hundreds of stormwater-treatment devices are on the market. Most have been patented and are available only from approved suppliers. The U.S. EPA created the Environmental Technologies Verification (ETV) program to certify products that have undergone rigorous peer-reviewed technology performance. A few specific products are mentioned in this section as examples, but not as endorsements. A full list of the ETV products can be found on the U.S. EPA Web site: <http://www.epa.gov/etv/verifications/verification-index.html>.

6.2.2.1 Catchbasin and Storm Inlet Inserts

The term catchbasin refers to a stormwater inlet with a sump area—a storage space for stormwater to settle out sediments prior to being discharged to the stormsewer system. The sump area usually extends 1.5 to 3.0 ft below the bottom of the outlet; the area captures an appreciable amount of coarse sediment and debris, but must be periodically cleaned to remain effective (Hird and Sansalone, 2003). Many of the stormwater inlets in the Monona Bay watershed were constructed before sump areas were regularly installed. The City does not have records of which inlets have sump areas in the older urban areas of Madison, but in 2007 the Sewer Maintenance Department will begin a survey of stormwater inlets. All stormwater inlets and catchbasins are cleaned with a city-owned vacuum truck twice a year, usually in the spring and fall (Kathleen Cryan, City of Madison, verbal communication, 2006).

Stormwater inlets and catchbasins can be enhanced with commercially available retrofits or inserts (fig. 6.3). Most of these products make use of screens, filter fabric, or filtration media that are fashioned into treatment devices that can be installed within an existing catchbasin or storm inlet to capture sediments, trash, and other solid pollutants. Inserts can be cleaned or replaced without the use of a vacuum truck. A well designed product will not increase flooding risks even when clogged. Installation of a hood over the catchbasin outlet is another simple retrofit option. The hood will prevent floatable material from entering the storm drain system. Catchbasin sumps and inserts are not effective at removing soluble or fine particles, but they can be effective at removing trash and larger particles.

One of the major advantages of catchbasin and inlet inserts is that they make it possible to retrofit existing drainage systems for stormwater-quality treatment without tearing out the existing system components or otherwise requiring major construction investments. In addition, removal efficiencies for litter are usually high if cleanouts are frequent (Nicklow, 2001). Although the product costs and installation are relatively inexpensive for most inserts, the primary cost associated with them involves long-term cleaning and maintenance and the large number that may be needed to treat a drainage area. Although the inserts are removable or easily accessible and the trapped volumes are relatively small, most require removal and cleaning by hand (England, 1999). The inserts made from fabric can be damaged by vacuum trucks.

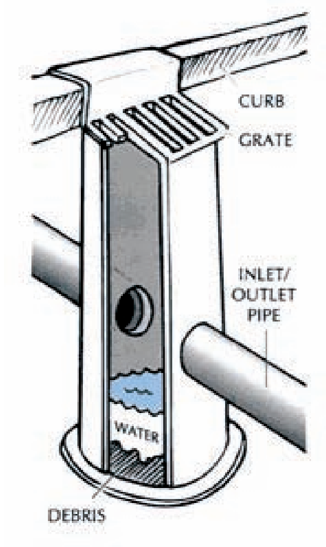


Figure 6.3. Illustration of a typical storm inlet and catchbasin (from http://www.ci.farmington.mi.us/basincare.htm).

Applicability to Monona Bay

Catchbasin and inlet inserts have the potential to improve water quality in Monona Bay, but issues that need to be addressed for successful application of these devices include cleaning processes and maintenance costs. The City prefers cleaning all stormwater inlets and catchbasins with vacuum trucks and no longer has any staff cleaning these structures by hand. Thus, it would be important to use inserts that can withstand vacuum cleaning. Basket-type devices could serve this function, but these devices tend to primarily remove trash and vegetation from stormwater rather than sediment, which is generally able to pass through the mesh of the basket. Baskets with filtration media inside are able to trap sediment, but these media need to be periodically cleaned out by hand.

Clean outs can be required after every rain event or as infrequently as annually, depending on the size of the

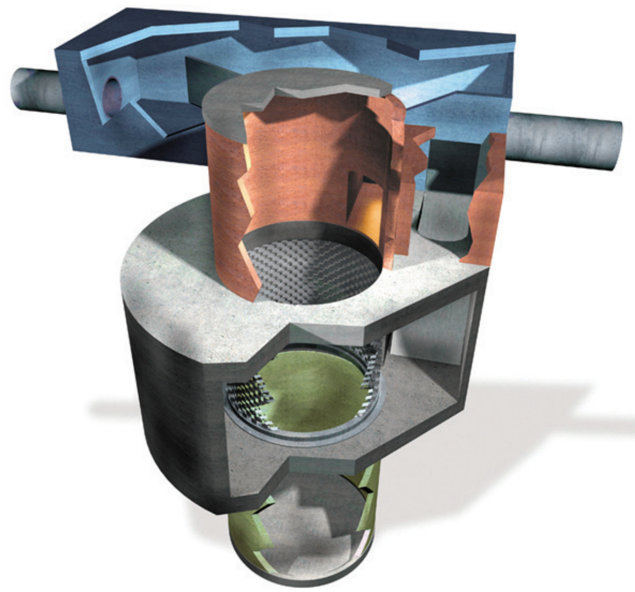


Figure 6.4. Illustration of offline CDS stormwater-treatment device similar to the device installed at the Parr Street outfall (from http://www.cdstech.com/stormwater/offlineunit.htm).

insert and pollutant load (Lau et al., 2001). The City would need to determine a clean-out schedule based on rainfall patterns, catchment area, land use, and cost effectiveness. If sumps and inserts are not cleaned frequently enough, then pollutants could become resuspended or water could become trapped in the sump or inlet, creating a mosquito breeding area (Lau et al., 2001).

Catchbasins usually only service a catchment area of a few acres. The Monona Bay watershed typically has a few catchbasins per city block. Many inserts would need to be installed to cover such a large area (Nicklow, 2001). Product costs and installation range from $50 for simple fabric filters to $500 for more complex inserts (Lau et al., 2001).

As of August 2006, the average cost for vacuuming each stormwater inlet/catchbasin in the City of Madison is $30.39. At current funding levels, the City sewer maintenance department would not be able to increase cleaning frequencies of catchbasins and stormwater inlets beyond twice a year (Kathleen Cryan, City of Madison, verbal communication, 2006). Stormwater inlets without sumps in areas that have problematic trash and large sediment-particle loading would benefit the most from the installation of large basket inserts that will work effectively throughout the year with two vacuum cleanings.

6.2.2.2 Continuous Deflective Separation Devices

Continuous deflective separation (CDS) devices use a filter screen to remove litter and particles larger than the screen openings (fig. 6.4). The device consists of circular inner and outer chambers separated by a screen. Stormwater enters the inner chamber tangentially, follows a vortex-like flow path, and then exits through the outer chamber. The swirling action clears the screen and directs litter and sediment to the center of the inner chamber. Sediment and litter then settle into a sump area below the screen and outer chamber (Armitage, 2001).

The City of Madison has begun making use of CDS devices. As of summer of 2006, of the five CDS devices in Madison, two are in the Monona Bay watershed. One was installed in 2003 on Francis Street between University Avenue and Johnson Street, and the other was installed on the Parr Street outfall in August 2006 (fig. 6.5). The Parr Street CDS device is an offline model from CDS Technologies, Inc. Due to site constraints, the Parr Street CDS device is sized to only capture flows from small rain events and the first flush of larger events; high flows bypass the unit and discharge directly into the bay (John Reimer, City of Madison, verbal communication, 2006).

A CDS device can treat part of the runoff from a large catchment area, which is an advantage over inlet inserts. The Parr Street unit has a catchment area of 32 acres (John Reimer, City of Madison, verbal communication, 2006). The Francis Street unit has a catchment area of about 4 acres (Kathleen Cryan, City of Madison, verbal communication, 2006). The CDS devices are excellent at removing litter and large particles. CDS Technologies, Inc., claims 100-percent removal of floatables, neutrally boyant material, and oil and grease in treated stormwater as well as 80-percent removal of TSS in treated stormwater. The overall efficiency of removal is dependent on the volume of stormwater captured and treated by the device and the volume that is bypassed. The Parr Street device, which will bypass high flows, will have a reduced overall efficiency than the maximum efficiency possible for the devices.

Figure 6.5. Parr Street CDS device during installation.

The device is comparatively low maintenance for the runoff volumes treated. The City vacuums the sumps twice a year. For the few years the City of Madison has been using CDS devices, there have not been any problems with maintenance (Kathleen Cryan, City of Madison, verbal communication, 2006). A disadvantage of the CDS devices is that the product and installation costs are high. In addition, the devices do not remove soluble pollutants or small particles, and bypass flows from large storm events will carry sediment and litter directly to the bay.

Applicability to Monona Bay

Widespread use of CDS or similar devices could likely significantly reduce litter and coarse sediment from entering the bay, but not fine particles. More could be learned about the cost effectiveness of CDS devices and their applicability to Monona Bay if the Parr Street device is monitored. Although the City does not plan to monitor the stormwater quality from the Parr Street CDS device, the City generally weighs all debris from stormwater device and intlet cleaning (John Reimer, City of Madison, verbal communication, 2006). In addition, the FOMB collected litter volumes from the outfall in 2005, and we took stormwater samples from the outfall after two events in July 2006. Although these data are not sufficient to fully establish pre-installed conditions for comparison, if monitoring of effluents or captured materials is continued after the device is installed under low flow conditions (when the device is treating stormwater) and high flow conditions (when stormwater is bypassing the device), this information can be used to determine whether the device is appropriate for other outfalls around the bay. The outfall near Brittingham Park and West Shore Drive is roughly the same size with the same land uses as the Parr Street outfall basin and could be another location for a CDS or similar device.

The Parr Street CDS unit will cost approximately $25,000 for the product and installation. The City paid for 50 percent of the Parr Street CDS unit using stormwater-utility funds and 50 percent of the project cost was paid for by a Dane County Urban Water Quality. The CDS devices can range in cost from $5,000 to more than $50,000. The projected maintenance cost for the Parr Street unit is $600/year (two cleanings a year).

6.2.2.3 Trash-Removal Devices

Other devices designed primarily to remove trash are known as gross solids removal devices. The California Department of Transportation (Caltrans) began designing its own trash removal devices in 2001 after a total maximum daily load for trash was issued for the Los Angeles River that required Caltrans to significantly reduce trash entering the river from its properties.

The Caltrans gross solids removal devices use louvered screens to trap debris inside a vault. Due to the large number of devices Caltrans needed to install (more than 2,600), the devices are designed to be cost effective to construct and maintain and relatively easy to retrofit into the existing stormwater system. The devices are intended to trap debris for up to one year between cleanings. Two of the designs, the linear radial device and the inclined-screen devices, captured 100 percent of the gross solids in a pilot study performed in 2002 (Sobelman et al., 2005).

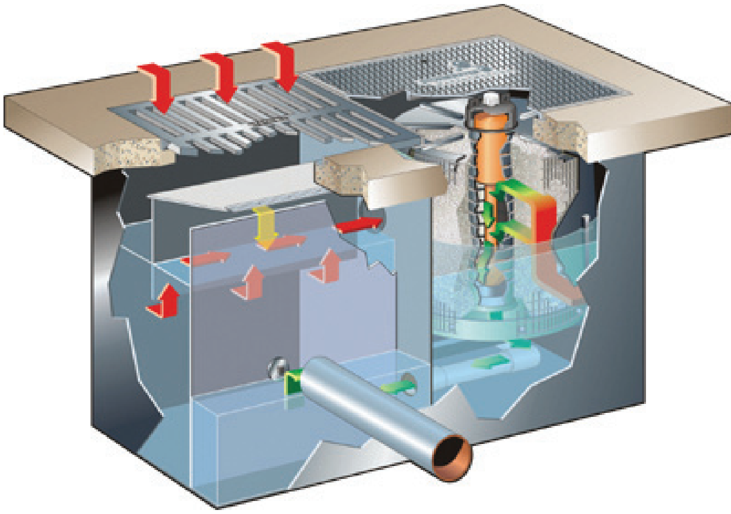


Figure 6.6. Illustration of a media filtration stormwater-treatment device with a pre-treatment settling chamber (from Contech Stormwater Solutions, http://www.contech-cpi.com/stormwater/products/filtration/stormfilter/15).

A primary difference between the Caltrans gross solids removal devices and other stormwater-treatment devices is that they are not proprietary devices that are purchased pre-manufactured and ready to install. Caltrans has a set of standard details for the devices that are used to construct the devices out of readily available construction materials. Caltrans is willing to share the standard details of the devices and guidelines on how to develop them with other cities and states. More information on the Caltrans gross solids removal devices is available at the Web site <http://www.pubs.asce.org/ceonline/ceonline05/1005feat.html>.

Applicability to Monona Bay

The Caltrans gross solids removal devices could be an effective stormwater-treatment retrofit in the Monona Bay watershed targeted at specifically reducing trash. Gross solids removal devices could be installed by the City or by the university at locations that are found to generate high trash volumes, such as near event centers and high traffic streets with convenience stores and fast food restaurants.

Although these trash-removal devices would require more time by the City or university to size, design, and install than proprietary devices would, the devices could still be cost effective because they are not purchased from a for-profit company. The actual costs to the City or university would need to be determined through a pilot study and compared to the cost of using proprietary devices. Caltrans performed a pilot study of eight sites with drainage areas ranging from 0.9 to 6.2 acres. The devices were sized to capture 100 percent of trash from a one-year rain event, which in the California study area would deliver 0.6 inches of rain in an hour, and to be large enough to hold a full year of the trash load so that only annual maintenance would be required. Construction times ranged from 20 to 37 working days for the sites, and construction costs ranged from $48,000 to $156,000 per site (Sobelman et al., 2005). Construction costs could be lowered by increasing the planned maintenance frequency, which would decrease the storage size needed for the devices, or by changing the storm criteria.

6.2.2.4 Media Filtration Devices

A media filtration device is a type of stormwater-treatment device that uses filtering media (such as sand, compost, peat, activated carbon, zeolite, wood-product waste, or a mixture of these) to filter pollutants out of stormwater (fig. 6.6). A higher level of stormwater treatment can be reached with media filtration devices than with devices that rely on deflection or coarse screens because the media can remove fine sediments and dissolved pollutants. As a result, media filtration devices are typically used to treat runoff from small sites that have high concentrations of pollutants in the runoff or where a high effluent quality is desired.

The choice of filtering media used depends on the pollutant removal target and filter run time before replacement. Clark and Pitt (1999) found that filters were limited by clogging in the top few inches before a reduction in pollutant-removal capability was observed. Reducing suspended solids with pretreatment will slow clogging and extend the life of the filter material. In general, an activated carbon-sand filter mix had the best absorption for a wide range of stormwater pollutants.

Many private and public organizations test stormwater-treatment products that use filtration media. One such product, the Multi-Chambered Treatment Train (MCTT), is a product that was installed and monitored in Milwaukee and Minoqua public work yards. In the MCTT, stormwater is presettled and aerated before filtering through a mixture of sand and peat. In both cases, the catchment areas were small and mostly paved lots. Removal rates for suspended solids, zinc, phosphorous, and many organic toxicants were between 65 and 100 percent.

The U.S. Forest Service Forest Products Laboratory on the UW–Madison campus has been testing wood-product filtering media as well as different filter-device designs. The focus of their work has been on the removal of metal ions. High removal rates for metals in mine runoff were found when using alkali-treated bark in a series of cartridges within a tank. The lab is currently studying a filter tank at an urban site in the City of Middleton (Roger Rowell, verbal communication, University of Wisconsin–Madison, 2006).

The primary advantage of media filters is that a well designed filter will have high removal rates for many pollutants or a few targeted pollutants. They are ideal for treating runoff from critical source areas (heavily used parking lots, industrial sites, gas stations). Most product designs will accept many filtering-media types. The filtering-media type can be adapted and optimized over time.

A disadvantage to media filters is that filtration rates are typically slow; thus, they usually require a large storage capacity to hold stormwater prior to filtering. As a result, filters should generally be used to treat small catchment areas with high pollutant concentration or the first flush of stormwater.

Maintenance is also a major concern for stormwater filters. They must be monitored for clogging, particularly if the stormwater is not pretreated. In some cases, only the clogged outer layer of the media needs to be replaced. The removal capacity of the filtering media declines over time and must be replaced, clogged or not. Some product designs can significantly prolong the life of a filter media. The filter cartridges in the Stormwater Management StormFilter System from Contech Stormwater Solutions increase longevity with uniform pollutant loading and a system of filter scrubbing with forced air.

Applicability to Monona Bay

Filter devices could be best used in critical source areas, like gas stations or heavily used parking lots, with pretreatment (such as oil/water separators and inlet basket inserts) provided prior to usage. The City or the FOMB could partner with the UW–Madison or the Forest Products Laboratory to install a pilot filter device.

Most filtration products are expensive to buy, install, and maintain. Costs can vary widely, but tend to be high in comparison to other treatment options. The MCTT device in Milwaukee cost $74,000 to buy and install; the Forest Products Laboratory device in Middleton costs only a few thousand dollars. Long-term maintenance costs are high as well. Used filter material must be disposed of and replaced or processed for reuse. However, the targeted improvements in water quality that can result from placing media filtration devices at high pollutant loading sites can make them cost-effective if the devices are placed as a part of a long-term stormwater planning process.

6.2.3 Low Impact Development

Low impact development (LID) is a term used to describe techniques that are intended to make urban areas function more like the natural environment by capturing stormwater on-site and allowing it to infiltrate, evaporate, feed vegetation, or be stored for later use. Although LID is most commonly used to refer to practices installed with new development, we use the term to refer to all innovative stormwater-management techniques that meet the LID goals, including those that could be implemented in the existing urban infrastructure or in new development.

The LID techniques offer greater environmental benefits, are more aesthetically pleasing, and can be less expensive than traditional methods of stormwater management (American Rivers, 2004). The primary underlying principle behind LID is preservation of the natural hydrologic regime to the greatest extent possible under developed conditions, including the quantity and quality of water that runs off and infiltrates a site. This is generally accomplished by

- conserving or mimicking natural features and processes that retain and filter water,
- reducing impervious surfaces,
- focusing on managing runoff as close as possible to its source, and
- treating stormwater as a resource on-site rather than a problem to be mitigated later.

Techniques in LID include site components such as green roofs, porous pavement, rain gardens, rain barrels, vegetated swales, infiltration basins, and swales. Each of these techniques has primary functions as well as secondary benefits, ranging from increasing infiltration, increasing evapotranspiration of runoff, reducing the need for external water sources on-site, and improving runoff quality. Some LID techniques are more appropriate than others, depending on unique site and watershed conditions.

To select the appropriate practices, it is important to begin by considering the primary problems associated with stormwater in an area and the function of various LID practices. For instance, in the Yahara Lakes watershed, loss of infiltration to groundwater and pumping of groundwater are resulting in less groundwater discharge to lakes. Although pumped groundwater is treated and eventually returned as wastewater effluent to surface water, it is returned downstream of the Yahara Lakes or into another watershed. The Yahara Lakes have lost about 60 cfs of flow as a result of this diversion of wastewater (K.W. Potter, UW–Madison, written communication, 2006). Because flooding has not been identified as a key issue in the Monona Bay watershed, LID techniques that primarily serve to store rainfall for evapotranspiration in order to reduce runoff volumes (such as green roofs) may be less appropriate for meeting the most important needs of the watershed. Instead, LID techniques that encourage infiltration in the urban landscape (such as rain gardens and porous pavement) will most effectively meet the needs of the watershed.

Another important issue in the Monona Bay watershed is the quality of stormwater runoff, particularly the concentration of suspended sediments and nutrients in stormwater. Relatively clean runoff from building roofs can actually dilute the concentrations of stormwater pollutants in lower-quality runoff from surfaces such as parking lots and roads. Thus, although infiltration of clean runoff is the most desirable option, using clean runoff to dilute lower-quality runoff may also be worth considering if infiltration is not feasible. Another option is to use LID practices that are intended to reduce pollutant loads in stormwater, such as parking-lot swales. However, these types of practices can be difficult to install in highly urbanized areas that have space limitations.

The Monona Bay watershed is entirely urban. As a result, a high percentage of the watershed is covered with impervious surfaces. In many cases, water-quality problems become noticeable when 5 to 10 percent of a watershed is covered in impervious surfaces, and when impervious surface totals exceed 25 percent, severe water-quality problems can result (Brabec et al., 2002). Low impact development practices can reduce the "effective" impervious surface percentage in a watershed by changing the way that water runs off impervious surfaces. Using LID to reduce the effective impervious surfaces in the Monona Bay watershed to a level that will result in stormwater having less of an impact on the bay would greatly benefit the bay.

6.2.3.1 Porous Pavement

More than 30 percent of the Monona Bay watershed is devoted to transportation land uses, such as streets. These impervious surfaces can have a negative effect on the health of Monona Bay due to the stormwater pollutants commonly found on roads and the direct connection of streets and parking areas to stormsewers. Porous pavement is an LID technique that can address the problems associated with such surfaces, reducing the effective impervious area while still maintaining the functionality provided by asphalt and concrete (fig. 6.7).

Porous pavement decreases runoff volume and peak flow, and aids in groundwater recharge (U.S. Environmental Protection Agency, 1999). Porous pavement, whether asphalt or concrete, uses a reduced quantity of fine materials and a special binder that allows water to infiltrate. Another form of porous pavement is paving

Figure 6.7. Porous pavement (left) and permeable pavement (right). (from http://www.psat.wa.gov/Publications/LID_studies/permeable_pavement.htm).

blocks that have gaps between blocks filled with soil or vegetation. These paving blocks are not suitable for high traffic areas, however, and require more maintenance than standard pavement. In general, porous pavement does not filter pollutants to a high degree, although certain designs (i.e., paving blocks) can trap sediments if vacuumed periodically.

Porous pavement is especially well suited for use in parking lots, driveways, road shoulders, and paths. It has been found that snow melts faster from porous pavements because of the improved drainage and air space in and below the asphalt (American Rivers, 2004). It is necessary to minimize the amount of sand used on porous pavement in the winter because the sand can clog the pavement pores. Because of this susceptibility to clogging, additional maintenance of porous pavement is required, including vacuuming of pavement two to four times annually (U.S. Environmental Protection Agency, 1999), although some studies have shown that functionality is still retained even with little maintenance. Although some concerns have been raised about durability in cold conditions, the Ford Motor Company plant in Dearborn, Michigan, has successfully used porous asphalt and has not seen any issues associated with longevity (Adams, 2003).

There are some uncertainties about the water-quality impacts of using porous pavement in high traffic areas where pollutant loads may be high. To ensure the quality of the infiltrated water, pollutants must be adequately trapped on the surface of the pavement and removed using sweeping or vacuuming, and pollution-prevention tools must be in place to prevent spills and other pollutant sources.

Applicability to Monona Bay

Although high traffic streets may not yet be well suited for porous pavement, numerous parking lots, driveways, sidewalks, and patios could be converted to porous pavement over time in the Monona Bay watershed. As a part of a long-term stormwater master planning process, the City could identify locations in which porous pavement would be well suited. The FOMB and other stakeholders could work with institutional landowners, such as churches and schools, as well as other landowners, such as business owners and homeowners, to encourage the installation of porous pavement in appropriate locations. Pilot studies could also be performed in the watershed at locations on the university campus or in Brittingham Park.

Porous pavement generally is designed to infiltrate rainstorms of up to 1.5 in. It generally costs $2 to $3 per square foot. Traditional asphalt by contrast costs $0.50 to $1.00 per square foot. Maintenance costs for porous pavement are estimated at $200 per acre (U.S. Environmental Protection Agency, 1999).

6.2.3.2 Green Roofs

Green roofs (fig. 6.8) can range from small gardens in planters to roofs completely covered by soil and various types of plants. Green roofs, also known as ecoroofs and vegetated roofs, have been used in Europe for years,

Figure 6.8. Green roof on Chicago City Hall (from Chicago Department of Environment, 2007).

add insulation to buildings and reduce the heat-island effect common to urban areas, prolong roof life by reducing wear, and create wildlife habitat and pleasant aesthetic features in urban landscapes.

Although green roofs can significantly extend the lifespan of commercial roofs, they may also require greater maintenance than traditional roofs. It can also be expensive to fix leaks, although modular designs and other strategies are being developed to address this issue.

It can be very expensive to retrofit to existing buildings with green roofs, depending on the structural capacity of the building and existing roof. Adding a green roof to a building is generally equivalent to adding another story to the building height (depending on the soil depth and type of plants used), and thus it requires careful engineering analysis to ensure adequate structural building support.

Green roofs are becoming more widely used. In Germany roughly 12 percent of buildings with flat roofs have roof gardens (Michigan State University, 2006). In Wisconsin, the UW–Stevens Point library and UW–Milwaukee Water Institute have installed green roofs. The University Square development near the UW–Madison campus in the Monona Bay watershed will include an intensive green roof with a pedestrian mall, patio, and benches for people to use (Slater, 2006). In addition, Epic Systems in Verona, the ABC Supply headquarters in Beloit, and the Milwaukee Housing Authority have or are planning vegetated roofs of more than 10,000 ft^2. In other Midwest locations, Downtown Chicago is making extensive use of green roofs, including on City Hall. The world's largest green roof (10.4

but are just now catching on in the United States. These roofs, most often seen on larger buildings with flat roofs, include vegetation and soil and are classified as "intensive" or "extensive." Extensive roofs use a very thin layer of soil material (2–6 in.) and are therefore lighter, less expensive, less versatile, and require less maintenance. Intensive roofs use a much thicker soil layer and can support a greater variety of plant species and can serve as parks for people as well. Intensive roofs must be carefully designed to support the weight of the soil, plants, and whatever else is included and are therefore much more expensive. Green roofs are best suited for buildings with flat roofs, although roofs with slight pitches can be vegetated as well.

Because roofs make up a large percentage of the impervious area footprint in urban areas, vegetating these roofs to make use of the rain that falls on them reduces much of the urban stormwater runoff. Green roofs store rainfall in the soil on the roof and allow it to evapotranspirate through the vegetation. One inch of rain over 1,000 ft2 of roof creates 600 gallons of runoff. Depending on climate and design, green roofs can retain 60 to 100 percent of stormwater and evapotranspirate it on-site or release it to the stormwater system more slowly over time (Michigan State University, 2006). In addition to reducing stormwater runoff volume and storing stormwater runoff to reduce peak flows, green roofs can

Figure 6.9. Rain garden. (Courtesy of K.W. Potter).

acres) is located in Dearborn, Michigan, on Ford Motor Company's automotive plant that opened in 2004 (Greenroof Project Database, 2006).

Applicability to Monona Bay

In Chicago and Milwaukee, green roofs are preferred because they reduce runoff volumes, thereby reducing flooding, combined sewer overflows, and strain on the stormwater and wastewater systems. However, in Madison, where infiltration and discharge of clean water to lakes is needed and runoff volumes are less of a concern, green roofs may not be the most appropriate LID technique because they use up relatively clean stormwater through evapotranspiration. Despite this, because green roofs can also be used as aesthetic and recreational features and wildlife habitat and can improve building energy efficiency, they will likely be considered in future green building plans in the area. One way of improving their overall ecological value in the Madison area would be to use more extensive designs (with thinner soil layers and smaller plants) that will temporarily store stormwater and treat it prior to discharging it to the stormwater system or to an accompanying infiltration system on the ground.

Green roofs require a greater initial investment than traditional roofs. Depending upon the size and type of roof they can vary from $5 to $12 per square foot plus an additional $10 to 20 per square foot for roofs that need waterproofing (Natural Resources Defense Council, 1999). However, over the lifetime of the roof, the savings, including longer life, greater insulation, and reduced need for expensive off-site stormwater treatment can more than make up for the increased initial cost if the roof meets the needs of the watershed. For Ford's Dearborn plant, the roof cost $3.6 million to install, but is expected to save up to $35 million over the long term by eliminating the need for stormwater treatment and providing other ecosystem services (American Rivers, 2004).

6.2.3.3 Rain Gardens

Rain gardens (fig. 6.9) are small infiltration areas that make use of native vegetation. They are simple to design, easily installed, and relatively inexpensive. Rain gardens are especially well suited for individual residential yards or small businesses, but they can be designed to capture larger areas of runoff from parking lots and schools. Far more water can infiltrate through the soil in a rain garden than in traditional lawns, which are typically compacted in such a way as to significantly reduce infiltration (Dane County Office of Lakes and Watersheds, 2006a). The deep roots of native plants in rain gardens and the mixture of highly permeable substrate and soil encourage a large amount of infiltration as well as a small amount of evapotranspiration.

A rain garden was installed in 2005 to capture water coming from one of the parking lots in Brittingham Park near Monona Bay. There are more than 100 other rain gardens throughout the City of Madison, and the City is currently working on mapping the locations of these features (Genesis Bichanich, City of Madison, written communication, 2006).

Once established, rain gardens require no more work than traditional landscaping and may actually require less maintenance than a highly manicured lawn that is mowed and fertilized frequently. In addition to facilitating infiltration and reducing runoff, rain gardens also provide wildlife habitat and add beauty to the landscape. Rain gardens can be relatively inexpensive to install, particularly if the native soils are appropriate for infiltration. If native soils have high clay content or otherwise restrict infiltration, it is necessary to amend the soils with more permeable substrate, such as a combination of compost and larger particle sediment, such as loam and possibly also sand or pea gravel. Rain gardens must be built correctly or they can lead to standing water or erosion.

Applicability to Monona Bay

Large and small rain gardens could be used in the Monona Bay watershed to improve water quality and baseflow to the bay. From large new dormitories or research facilities down to individual residential homes, rain gardens are a simple way to reduce runoff and beautify the city. The FOMB could implement a campaign to encourage homeowners and businesses to install rain gardens on their properties, providing resources such as hosting a native plant sale, promoting the Better Gutters and Gardens tour, and hosting and publicizing a rain garden workshop. These activities could be implemented in conjunction with the Dane County/Madison Area Municipal Stormwater Partnership rain garden grant program (more information available at <www.danewaters.com/business/PlantDane.aspx>).

Traditional landscaping varies a great deal in maintenance, expense, and quality. Rain gardens are no different. If small rain gardens are installed by individuals using plants that they already own, they can be very inexpensive. If professional designers and builders are brought in and plants are bought and planted in a large garden, costs can quickly escalate.

Rain gardens are a tool that can be easily incorporated by landowners interested in improving their impact on water resources. The WDNR has compiled a variety of resources with guidance for designing and building rain gardens, available at <http://www.dnr.state.wi.us/org/water/wm/nps/rg/links.htm#howto>. Dane County also has excellent resources on rain gardens at <http://www.danewaters.com/private/raingarden.aspx>.

6.2.3.4 Rain Barrels

Rain barrels (fig. 6.10) collect runoff from roofs when gutters are funneled into the barrel. The stored water can then be used to water gardens or lawns, reducing groundwater use. Rain barrels are inexpensive, especially if subsidized through a municipal program. Using rain barrels can lower water bills by providing water for the lawn and garden, and they are small enough that they can fit in just about any yard. If improperly installed they can attract insects, but most rain barrels are equipped with tight-fitting mosquito-proof lids.

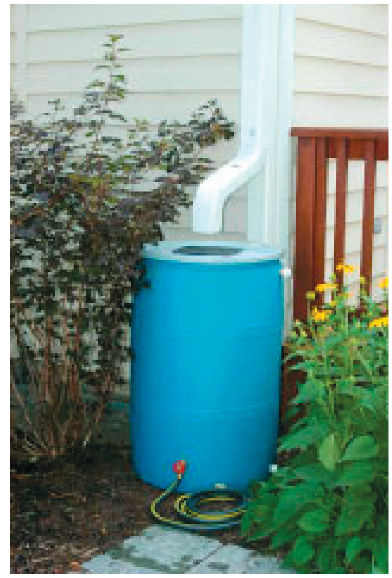


Figure 6.10. Rain barrel (from WRD Environmental, 2007).

Applicability to Monona Bay

Rain barrels are a simple tool that homeowners throughout the watershed can use to capture rainfall and make use of it in their own yard for vegetable gardens or other outdoor use, reducing the need for pumped groundwater. As with rain gardens, the FOMB could implement a campaign to encourage homeowners and businesses to install rain barrels on their properties and work with Sustain Dane, the City, or Dane County to obtain rain barrels at reduced cost.

The retail cost of rain barrels ranges from $40 to more than $200, depending upon size and features. Many communities, such as Milwaukee, offer rain barrels to residents at significantly reduced cost. Other communities have programs through which limited numbers of rain barrels are given away. Do-it-yourself designs offer homeowners a less expensive option. Sustain Dane provides a reduced-cost rain barrel program in Madison, offering rain barrels for $75 for self installation and $99 if installed by Sustain Dane. More information can be found at <www.sustaindane.org/main/rainbarrel_right.htm>.

Because rain barrels generally range in size from 20 to 80 gallons, and a 1-in. rainfall on a 1,000 ft^2 roof creates more than 600 gallons of runoff, effectively reducing the runoff from a house requires using multiple rain barrels. However, even when a single rain barrel is used it reduces an equivalent demand on groundwater pumping and promotes infiltration of the captured water, which is beneficial to area lakes.

Figure 6.11. Tanner Springs Park in Portland, Oregon, features wetlands, art glass, a bubbling spring, and native plants in a setting designed by the renowned landscape architecture firms of Atelier Dreiseitl and GreenWorks. (Photograph by J. Belknap Williamson.)

6.2.3.5 Comprehensive LID Case Studies

In some highly urbanized areas, developers and city planners have been successful in combining many aspects of LID to use stormwater holistically as an aesthetic and ecological resource. The following case studies provide examples of creative uses of stormwater in highly populated areas.

In the United States, many cities are implementing innovative LID techniques throughout residential and commercial areas. Numerous public and private projects in Portland, Oregon, have invested in LID techniques: a rain garden at the Convention Center, a stormwater-fed waterfall, a water garden at a school, parking-lot swales, unique landscape designs at apartment buildings, and several ecoroofs. The City of Portland is actively publicizing these projects, and has developed a tour map of some of the projects on the eastern side of the city. The tour map and descriptions of 19 of the projects, including costs, benefits, and photographs, are provided at <http://www.portlandonline.com/bes/index.cfm?c=36848&>.

Portland is seeking ways of incorporating water into public spaces as much as possible to reinforce its importance to residents and encourage them to care about the impact they have on water resources. The City created a traveling exhibit titled “Landscapes for Rain: The Art of Stormwater” that showcases stormwater as a resource and illustrates opportunities to integrate it with art, landscape, and architecture in ways that bring nature back to the city (fig. 6.11). A brochure with photographs and descriptions of the projects featured in the exhibit is available at <http://www.portlandonline.com/shared/cfm/image.cfm?id=104413>.

Also in the Portland area, the Leadership in Energy and Environmental Design (LEED) gold-certified American Honda Northwest Regional Facility in Gresham, Oregon, highlights many of the LID techniques that can be used for a commercial or industrial green building. The project includes a rainwater-harvesting system used for site irrigation and to flush the toilets in the buildings and a large stormwater pond that enhances the aesthetics of the buildings while providing wildlife habitat. More information on this site is available at <http://www.trane.com/commercial/library/AmericanHonda.pdf>.

In Seattle, Washington, Seattle Public Utilities has funded several innovative residential street redesign projects and large-scale LID projects to mimic natural drainage. The projects, started in 1999, provide excellent examples of how stormwater can be infiltrated and used as a resource in dense urban areas. The Street Edge Alternatives project narrowed an existing residential street to reduce the impervious surface and created vegetated swales to store and infiltrate runoff from the street. This innovative project reduced the total volume of runoff from the street by 98 percent for a two-year storm event.

Another natural drainage project funded by Seattle Public Utilities is the Seattle Public Housing High Point development, one of the largest urban applications of nat-

ural drainage systems in the country. The project uses swales, pervious paving, downspout disconnects, rain gardens, tree preservation, and bioretention to manage the runoff from 129 acres of mixed-income housing. Public art and open spaces are also creatively integrated into the stormwater facilities, creating a development that fully uses stormwater as an aesthetic and ecological resource. More information on Seattle Public Utilities natural drainage projects, including photographs, can be found at the Web site:
<http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Natural_Drainage_Overview/index.asp>.

In Malmo, Sweden, landscape architect Christer Goransson has created projects that bring the aestheticism of stormwater and our role in the water cycle into prominence (Goransson, 1999). Many of his works create areas of topographic relief in which patterns will appear after a rainstorm, and then disappear after the rain has gone. One project incorporated this concept into a schoolyard, creating a shallow concrete basin with sinuous lines and rounded stepping stones that would fill in with clean rainwater and create an interesting area for children to play in. Another project routed roof runoff from private homes into a central square containing a swirled pattern of cobblestones in relief that, when filled with rain, would evoke water draining from a tub. These examples highlight ways to provide stormwater detention in densely populated areas in a manner that is useful and engaging to the public.

The Potsdamer Platz, in Berlin, Germany, is an excellent example of using stormwater as an ecological and aesthetic resource. The buildings around the square are designed to harvest rainwater through rooftop systems. Some of the buildings, such asthat of Daimler–Chrysler, also have green roofs. The rainwater from the roofs is collected and stored in underground cisterns and filtered for use in irrigation and toilet flushing, saving millions of gallons of drinking water each year. After being stored in cisterns, the water that is not used for other purposes is routed to a waterscape that is the central attraction of the square (More information and photos of the square can be found on the design firm's Web site: <www.dreiseitl.de/en/index.html>). Angular shallow pools and bridges create a gathering place for people while also acting as detention and biofiltering (Dreiseitl, 1999; Ermengem, 2006; International Green Roof Congress, 2004; Spirn, 2005).

These case studies of LID projects around the world illustrate some of the possible changes that could be made in the Monona Bay watershed to enhance the connectivity of residents with the health of the watershed and improve water quality in the bay.

Many other resources on innovative options for stormwater management can be accessed for additional information. The Low Impact Design Center in Beltsville, Maryland, offers design examples for a full suite of innovative stormwater management alternatives. More information is available at their Web site: <http://www.lowimpactdevelopment.org/home.htm>.

6.2.4 Policy Tools

A variety of public policy tools that could assist in improving the quality of Monona Bay are available to the local government. The City of Madison has jurisdiction over stormwater management and development standards in the Monona Bay watershed, and Dane County has jurisdiction over management of the bay itself. These entities are pursuing a wide range of activities to manage and improve the bay, but additional policy tools are available that could improve the bay. These policy tools include

- developing a City of Madison Stormwater Master Plan,
- expanding stormwater components of Madison GRE^{2}EN commitment,
- providing incentives for innovative stormwater management,
- developing a comprehensive environmental sustainability program at UW–Madison, and
- developing a stormwater-treatment device testing protocol for Wisconsin

6.2.4.1 Develop a City of Madison Stormwater Master Plan

Developing a stormwater master plan and long-term stormwater-utility budget could help promote a systematic upgrade to the Madison stormwater infrastructure that would include additional water-quality improvements in developed watersheds. Nearly all the stormwater utility fees collected by the City of Madison are used for the maintenance and operation of the existing stormwater-drainage system or debt service to support large-scale capital projects, such as regional detention ponds (Greg Fries and Mike Daily, City of Madison, verbal communication, 2006).

The stormwater-utility budget provides only a small amount of funds annually for capital projects to improve water quality in the developed areas of the city, such as retrofitting stormwater inlets or outfalls with treatment devices. Currently, the City prioritizes how to use the stormwater-utility budget on an annual basis, making use of opportunities for improvements (such as planned street reconstructions) and pursuing projects with a high degree of public support (such as the Parr Street outfall treatment device).

However, as neighborhood groups and conservation groups are becoming increasingly aware of the problems caused by stormwater, requests to the City for stormwater improvements are rising. As requests for limited funds increase, there is a risk of pitting residents in some parts of the city against residents of other parts of the city in a competition for addressing water-resource issues. A comprehensive planning process that evaluates the opportunities and relative costs and benefits of specific projects in all city watersheds would help assure residents that stormwater-utility funds will be used equitably throughout the city over a long-term planning horizon.

The City of Madison Stormwater Utility was created in 2000. In 2006, the utility budget was approximately $6.5 million. The utility is funded by charges to landowners in the City based on the impervious and pervious areas within parcels. The charge per parcel in 2006 was composed of three components: 1) a customer charge of $3.20 per six months; 2) an impervious area charge of $.00709 per square foot per six months; and 3) A pervious area charge of $0.000495 per square foot per six months. For a residential lot with 2,500 ft^2 of impervious surface and 4,000 ft^2 of pervious surface, the annual cost is about $46. For a large commercial establishment (such as a shopping mall or large office park) with 1,000,000 ft^2 of impervious area and 10,000 ft^2 of pervious area, the annual cost is about $14,200.

The stormwater-utility fee has been increasing at an average annual rate of 10 to 12 percent since the utility began operation (Mike Daily, City of Madison, verbal communication, 2006). Large commercial property owners, who generally pay the highest amounts in fees, are expected to begin pressuring the City to slow the rate of increase of the fee. However, according to a survey of municipal stormwater rates published by the Wisconsin Chapter of the American Public Works Association in 2004, the City of Madison's rates for residential customers are well within the typical range for Wisconsin municipalities. In fact, Madison's rate for average residential landowners is lower than many municipalities such as Fitchburg, Monona, Sun Prairie, Appleton, Green Bay, and Milwaukee. Thus, it will be important for the City to consider utility-budget planning as it impacts the majority of fee payers (residential landowners) as well as those fee payers who pay the highest fees (large commercial landowners).

To better guide the Stormwater Utility budget process and provide defensibility of the budget increases against potential detractors, the City of Madison could undertake a stormwater master planning process to evaluate the best opportunities for improvements to water quality through stormwater system retrofits and upgrades.

Applicability to Monona Bay

Developing a stormwater master plan and a long-term stormwater-utility budget could have a positive impact on Monona Bay, particularly if the plan made it a priority to increase stormwater retrofits for water-quality improvement in highly developed watersheds like Monona Bay. Opportunities for implementing LID techniques and installing stormwater-treatment devices where they will have the most benefit could be identified by the plan, and increased stormwater-utility funds could become available to implement recommended improvements to the Monona Bay watershed.

The cost to the City to hire a consultant to assist in the development of a long-term utility budget and stormwater master plan could be in the range of $150,000 to $300,000 or more. The UW–Madison has spent in the range of $50,000 to $100,000 to develop a comprehensive plan for managing stormwater around the UW–Madison's Arboretum. The process used by the Arboretum to evaluate current problems and opportunities for improvement, which involved local experts from UW–Madison as well as neighborhood residents and other stakeholders, could serve as a model for a citywide stormwater-planning process.

6.2.4.2 Expand Stormwater Components of Madison's GRE²EN Commitment

Mayor Dave Cieslewicz has established a vision to make Madison a "green capital city." At this time, the primary focus of Madison's GRE²EN Commitment (Sustainable City) program is on energy; GRE²EN stands for Green building, Resource & Energy Efficiency, and ENvironment. This initiative provides an excellent opportunity to enhance the overall environmental sustainability of all aspects of City-owned property and City-funded projects. Expanding the scope of the GRE²EN Commitment to specifically address water-quality improvements as well as energy improvements would bring together two important environmental concerns for Madison residents.

This policy option would use existing resources being devoted to the GRE²EN program implementation to ensure that innovative stormwater-management projects are implemented and publicized wherever feasible. However, it could require greater financial investment in GRE²EN program initiatives and would expand the program scope beyond the primary energy focus.

Applicability to Monona Bay

Elements of the GRE²EN program include retrofitting existing City-owned buildings to be more energy efficient and requiring LEED certification for future City-funded projects, including tax incremental financing for commercial projects. Although LID practices might be included in GRE²EN program initiatives, a stronger inclusion of stormwater-quality and water-conservation objectives in the program goals would help ensure Madison's lakes are enhanced through the program.

Specific approaches to including water resources objectives in the GRE²EN program that could improve the Monona Bay watershed include the following:

- Capitalizing on opportunities to use runoff as an aesthetic and economic resource in parks, landscaped areas, and public gathering places through art installations, fountains, underground cisterns to hold and use runoff, etc.
- Hosting design competitions for prominent publicly funded buildings to include innovative runoff-management strategies.
- Requiring all capital projects and developments funded with contributions from City taxpayers to not only meet LEED criteria, but also to meet higher standards of runoff water quality and infiltration using specific performance criteria.
- Hosting workshops and provide resources to foster a culture of creativity regarding water management among developers.
- Promoting and publicizing new developments that use LID principles to improve runoff.

The full report on the GRE²EN program recommendations is available at <http://www.cityofmadison.com/mayor/pdfs/GreenCapitalReport_1.pdf>.

The costs associated with expanding the focus of the GRE²EN program to include water-quality objectives are unknown, but because this tool involves using resources being devoted to an existing program, the costs per benefit received are expected to be reasonable.

6.2.4.3 Incentives for Innovative Stormwater Management

Implementation of innovative or LID stormwater-management practices, such as pervious pavement parking areas, can require greater up-front investment by developers for some part of site infrastructure or structures. The investment may come in the form of increased time and cost to design and permit the project, or in increased construction costs. Residential and commercial building owners may also be interested in retrofitting existing structures and sites with innovative practices, but may be deterred by the required investment costs. With little regulatory pressure to implement innovative stormwater-management practices in developed watersheds, incentives are needed to increase the implementation of these practices. Providing developers and building owners with incentives to implement innovative stormwater practices is likely to increase the application of such practices.

Although the costs that accrue to the developer or building owner may be offset somewhat by related benefits, the public and the jurisdiction responsible for maintaining stormwater systems and water quality are typically the primary beneficiaries of innovative stormwater-management projects. Thus, there is a strong public interest basis for providing financial incentives for these projects. Incentives could include cash grants, tax breaks, fee waivers, city publicity of private LID projects, and flexibility in permitting requirements or meeting development standards.

An example of an incentive program for innovative stormwater management is the City of Chicago, Illinois, green roof grant program, which provides $5,000 to residential and small commercial building owners to offset costs for planning and installation of green roofs. A five-year maintenance agreement by the building owner is required. Twenty grants were awarded initially (City of Chicago, 2005). Another incentive program provides regulatory incentives rather than financial incentives: the City of Lacey, Washington, Zero Effective Impervious Area Ordinance (City of Lacey, 2006). To allow for demonstration projects that protect water resources through innovative urban design techniques (such as LID), but deviate from current engineering designs and standards, the City of Lacey allows flexibility for developers in meeting certain design standards.

Applicability to Monona Bay

Incentive programs promoting innovative stormwater management could have a positive effect on Monona Bay, particularly if they are targeted toward retrofitting existing buildings and sites in priority areas (such as the bay watershed) with techniques that increase infiltration and improve water quality. Although the initial impact of such a program may be small, improved practices implemented in the watershed consistently over time could have a substantial impact in the future if widely adopted or if adopted by significant contributors of stormwater, such as owners of large commercial buildings and parking lots.

There appears to be ample opportunity for the City of Madison, Dane County, and the WDNR to provide incentives to developers and building owners to implement innovative stormwater practices, but funding sources and strategies remain barriers in some cases.

Dane County recently announced a new funding program to improve the quality of Madison-area lakes. The Land and Water Legacy Fund will be supported by $1.5 million in bonding and is expected to be included in the 2007 County budget. Currently planned uses of the fund include providing money to local governments to retrofit stormsewer outfalls to trap trash and piloting the use of pervious surfaces and green roofs at county facilities. Although it has not been proposed to use the fund for incentives to promote innovative stormwater management, such a proposal is in keeping with the intent of the fund and could be implemented in the future if advocated by the public.

Dane County has operated a rain garden and native plant incentive program for the Madison Area Stormwater Partnership since 2004. The program was made possible by grants of plants and seeds from the Graham-Martin Foundation. As of 2006, the program has supported the installation of 200 acres of native plants.

The City of Madison attempted to begin an incentive program for innovative stormwater practices through its 1,000 Rain Gardens initiative. The intent of the initiative was for the City and WDNR to fund two-thirds of rain garden construction costs in residential areas starting in spring of 2006. However, the City did not receive the necessary grants to move forward with the private rain garden cost-sharing program (City of Madison, 2006c). Without grant funding, the City would likely need to incorporate incentive programs into its stormwater-utility budget, raising stormwater-utility fees.

The City of Madison's GRE^{2}EN Commitment (Sustainable City) program includes a recommendation to provide incentives for green building, energy efficiency, and renewable energy practices. Incentives include ideas such as reducing stormwater utility fees for sites that collect rainwater in on-site systems and prioritizing green projects by relaxing some of the permitting requirements, lowering fees, or giving temporal priority to green projects. Cash grants would likely further increase the interest in green building projects, and grants targeted at specific projects that will improve water quality, such as rain gardens and parking lot swales, would be particularly valuable to efforts to enhance the conditions of Madison's lakes.

Depending on the scope of the program, the costs to the City for an incentive program could range from a fairly small percentage of the annual stormwater-utility budget (for a program offering $25,000–$50,000 per year in payments) to a larger percentage. The City could seek grants or use stormwater fees to pay for the incentive program. If grants or other outside funding sources are not available to assist municipalities in funding incentive programs, the additional cost would likely be funded all or in part through stormwater-utility budgets, bonding, or municipal natural resource-related budgets. Costs to the City could potentially be offset by reduced stormwater system maintenance costs in the future due to lower TSS loads, one benefit of implementing innovative stormwater-management techniques.

6.2.4.4 Expand We Conserve Program into a Comprehensive Environmental Sustainability Program

The UW–Madison has implemented a campaign to reduce campus energy consumption per square foot of building area by 20 percent by year 2010. The campaign, called We Conserve, seeks to invest in energy-efficient systems on campus as well as educate and involve all campus community members in reducing consumption. The Web site for the We Conserve program is <http://www.conserve.wisc.edu/goals_strategies.htm>. The campaign is an admirable beginning to reducing the environmental impact of the UW–Madison campus. However, it lacks recognition of the aspects beyond energy use that affect the environment.

This initiative provides an excellent opportunity to enhance the overall environmental sustainability of university operations and property. Just as with the expansion of the focus of the City's GRE^{2}EN program, expanding the scope of the We Conserve campaign to develop a comprehensive environmental sustainability program at UW–Madison would bring together work on important environmental concerns.

For example, Duke University established a comprehensive environmental policy in 2005. The policy commits the university to leadership in three areas: environmental research and education, environmentally responsible operations, and environmental stewardship in the community. The policy brings together efforts for reducing the impact of Duke's operations on the environment under one umbrella. The various campus "greening initiatives" Duke is pursuing, which include addressing energy usage and water management, are described at the Web site <http://www.duke.edu/web/ESC/campus.html>.

Applicability to Monona Bay

It would make sense for the university to develop a comprehensive environmental sustainability program to focus not only on energy usage, but on the full range of environmental impacts of operating the campus. Because the university is a large contributor of stormwater to Monona Bay, targeted improvements to the university's impact on water resources under the guidance of a comprehensive environmental sustainability program could greatly benefit Monona Bay.

The university is already devoting resources to lessening its impact on the environment in a number of areas, including energy, waste, and stormwater. Bringing these initiatives together under a comprehensive environmental sustainability program could result in administrative cost savings to the university. Developing a comprehensive environmental sustainability program at UW–Madison could use existing resources being devoted to We Conserve program implementation to address the full range of environmental impacts from the university, including water-resources impacts. However, such a program could require greater financial investment in We Conserve program initiatives and expands the scope beyond the primary energy focus.

Purchasing energy and managing waste cost the university a great deal more currently than managing water resources, giving the university significantly greater motivation to address energy and waste issues over water issues. Over time it is likely that a comprehensive environmental sustainability program for the university would benefit water resources along with the other natural resources the campus impacts. Developing a comprehensive environmental sustainability program at UW–Madison would help elevate the visibility of the school on environmental issues and complement its existing environmental academic programs, such as the Nelson Institute for Environmental Studies.

6.2.4.5 Develop a Stormwater Treatment Device Testing Protocol for Wisconsin

One major issue with incorporating stormwater-treatment devices into development requirements is that it can be difficult to determine whether they are effective at removing the desired amount of TSS and other pollutants. Recent installations of commercial treatment devices in the Madison area have proven frustrating because they are not living up to their claims (Lisie Kitchell, Wisconsin Department of Natural Resources, verbal communication, 2006). Vendors of stormwater-treatment devices may use their own methods to test their products or test them in environments that are not similar to the environments in which they are being installed. Although the U.S. EPA has a technology-verification program, the Environmental Technology Verification Program, it is a general program, not specifically focused on stormwater treatment, and it is not climatically or regionally specific (U.S. Environmental Protection Agency, 2006).

To remedy the lack of uniform testing methods, some states have created testing protocols for evaluating the amount of pollution removed by a stormwater-treatment device. In 2002 the state of Washington developed the Technology Assessment Protocol–Ecology (TAPE) protocol. This protocol was intended to test commercially available technologies and public domain practices, such as wet ponds and sand filters. Vendors who submit their technology for testing must include information and claims about pollutant reduction, potential applications and uses of the technology, how to size the device, and which pollutants should be used to evaluate it. The technology is then evaluated according to the TAPE protocol and given one of several designations, the broadest being the General Use Level Designation (Washington State Department of Ecology, 2002).

Another protocol, the Technology Acceptance and Reciprocity Partnership (TARP), was formed by eight states: California, Illinois, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and Virginia. It is designed to ease the burden of testing on individual states by allowing "participating states to consider the data, approvals, and permits from another state as if they had been produced in their respective states" (Pennsylvania Department of Environmental Protection, 2006). Massachusetts created a data clearinghouse of information about technologies that had been tested to enable easier data sharing among states. The TARP protocol uses a tiered system of guidance to clarify the standards that must be met by each technology. Some tiers of guidance inform vendors about appropriate data-collection methods and technology approval criteria; other tiers of guidance instruct regulators on permitting and approving technology (Pennsylvania Department of Environmental Protection, 2006).

The advantages of such programs include that they provide a standardized system for evaluating technology and allow access to data from previously completed tests. In addition, they improve the accuracy of quantification of water-quality benefits received from specific technology. This is particularly important in watersheds in which total maximum daily loads are developed for specific pollutants and municipalities are required to quantify the treatment levels they provide for the regulated pollutants. Although the Madison area does not have any total maximum daily loads established yet, they could be developed in the future through the regulatory process.

Implementing treatment-device testing protocols can delay the use of new technology in building projects, and costs associated with technology verification could fall to the City or state if a funding mechanism tied to development permits is not established.

Applicability to Monona Bay

Participation in or development of a technology-verification program such as TAPE or TARP at the state or county level could have positive benefits for Monona Bay. Because stormwater inputs to the bay come through the stormsewer system, one of the major stormwater-improvement options will be the installation of stormwater-treatment devices. Having standards for acceptable devices could save the City time and money that would otherwise be wasted installing devices that might not live up to their performance claims.

The cost of a technology verification program would depend on the scope of the program and the availability of existing staff to manage the program. It is possible that a half-time or full-time employee could be needed to manage the program at the local or state level. Some costs associated with implementation of the program could be borne by vendors of proprietary devices seeking to have their devices approved for use or by stormwater-user fees charged to developers.

6.3 Shoreland Management Alternatives

The shoreline of Monona Bay has been significantly modified from its natural state. The ecological quality and function of the existing vegetation is poor, reducing the habitat and forage opportunities around the bay for desirable birds and wildlife and creating conditions that favor less desirable species. A large proportion of the banks of the bay have been hardened with riprap, which reduces erosion, but also creates a poor shoreland environment for amphibians and other desirable species.

Options for enhancing the ecological function of Monona Bay's shoreland environment include passive and active restoration. Shoreland restoration is intended to return native plant species to degraded shoreland environments that are dominated by invasive plant species or are denuded. Restoration in an urban environment such as Monona Bay is typically not intended to return land to a predevelopment condition, but rather to increase the ecological function of an area within the constraints of other uses and altered conditions. Restoration of shorelands can be performed in an area or strip along the shore to create what is called a buffer. Restored buffers are planted with native plant species and provide ecological services vital to a shoreland habitat, including wildlife habitat, deterrence to waterfowl nesting in undesirable locations, water-quality protection through surface-water infiltration and through trapping nutrients and silt in surface-water runoff, aesthetic beauty, and erosion control.

Each restoration option has distinct positive and negative attributes and costs that need to be considered when selecting the best approach for the Monona Bay shoreland area. Shoreland restoration should be designed to meet the multiple needs of the bay users and the constraints of mixed land use. Because of the infrastructure surrounding the bay (e.g., sidewalks and bike paths), in some places the buffers will be narrower than the 50-ft target the Parks Division has set as its width for buffers (James Morgan, City of Madison Parks Division, verbal communication, 2006).

In Wisconsin, shoreland restoration has become a popular and effective approach to improve water quality and control non-native plant species of the state's inland lakes (Friends of Lake Wingra, 2003). Many organizations, companies, and academic institutions have completed or are currently implementing restoration plans in Wisconsin (including Dane County and the WDNR) and have made their experiences and resources available in printed form or electronically via the Internet.

Successful implementation of a Monona Bay shoreland-restoration project could employ adaptive management, a combination of research, management, evaluation, and adjustment (Friends of Lake Wingra, 2003). The project could incorporate the City of Madison Parks Division, individual citizens, the University of Wisconsin, and the Friends of Monona Bay. As with the Lake Wingra Management and Protection Project, "this shoreline buffer project is intended to promote an active watershed community by engaging neighbors, park users, students, and park managers in collaborative planning, planting, and maintaining" of Brittingham Park's shoreline habitat (Friends of Lake Wingra, 2003). Furthermore, restoration in the park could serve as an educational example for individual homeowners interested in conducting shoreland restoration on their property.

In developing a shoreland-restoration plan, it is important to consider the goals of the restoration and possible effects on desirable and undesirable species as well as recreational usage of the area. One important element to consider is the height of the restored vegetation. Buffers of tall vegetation would likely discourage Canada geese *(Branta canadensis maxima)* from gathering along the bay's shoreline. Canada geese prefer areas with clear, open views and access to water through short vegetation or no vegetation. If tall shoreline vegetation were added to create a continuous buffer along the entire bay shoreline, it could reduce the quantity of geese using the bay for a nesting location. Goose excrement is a potential source of *E. coli* in many lakes and can contribute to water-quality problems that affect recreational usage of water bodies (City of Madison Parks Division, 2006). However, it is important to note that goose population problems may not be significantly changed if only part of a shoreline is restored to include a taller vegetative buffer because geese may move and congregate in any additional open or low-vegetation buffer areas left around the bay.

Canada geese have become adapted to urban habitats, where they tend to remain year-round (Friends of Lake Wingra, 2003). Once established, migrating populations of geese often join established urban populations, compounding the problem (Friends of Lake Wingra, 2003). In 2002, the Madison City Council convened an Ad Hoc Committee on Integrated Waterfowl Management to address the Canada geese problem afflicting its lakes and parks (Friends of Lake Wingra, 2003). The committee recommended the following measures to controlling geese populations (Ad Hoc Committee on Integrated Waterfowl Management, 2002):

- development and implementation of a scientific protocol for the documentation of bird counts, feces quantity, locations, numbers of nesting pairs, and survival rates of hatchlings;
- facilitation by the Parks Division of discussions on strategies for urban waterfowl management with adjoining communities;
- development and distribution of an informational brochure;
- trial use of herding dogs at the Yahara Hills Golf Course;
- consideration of reproductive control techniques, such as oiling or addling eggs; and
- consideration of modifications to shoreline habitats.

6.3.1 Passive Restoration

Also called "naturalizing," passive restoration is one approach to creating a shoreland buffer and restoring the bay's shoreland habitat. Invasive and undesirable plants are continuously removed and a no-mow approach is employed. Desirable, existing vegetation is allowed to grow in an area along the shore; competition from aggressive invasive vegetation is reduced. Seeds from native plants can lie dormant in the soil for years, and by not disturbing the ground, these seeds may eventually germinate and grow (University of Wisconsin–Extension, 2006).

Passive restoration is relatively inexpensive and simple to implement. Labor to implement the strategy is the primary cost of passive restoration. Volunteer labor can help reduce the costs associated with this method. However, passive restoration may not achieve the desired results because of site issues. The seed bank or rhizomes of abundant, hearty invasive plant species (such as reed canary grass) may not be removed through hand weeding. In addition, native plant species may not return to the restoration area if there is a lack of available seed bank for those species.

Applicability to Monona Bay

Few material costs would be associated with a passive restoration plan because the existing native vegetation along the Monona Bay's shoreline would simply be given the opportunity to grow unimpeded by invasive vegetation. Significant additional labor would be needed to remove undesirable vegetation and to perform regular maintenance of the restoration. Costs could be kept lower by enlisting bay area citizens to perform these tasks voluntarily (through an expansion of current volunteer activities to remove invasive vegetation), but without this the City would need to assign staff to perform the tasks.

Passive restoration is not expected to enhance the shoreland of Monona Bay significantly. On the basis of shoreland survey results, the shoreland has little existing seed bank of native vegetation. It is dominated by invasive species, particularly the aggressive reed canary grass, which is difficult to remove by hand. As a result, passive restoration alone is not likely to successful address the need for more native plants and fewer invasive plants along the bay's shoreland.

6.3.2 Active Restoration

Active restoration is the most aggressive approach to creating a native vegetated buffer on Monona Bay's shoreline. This approach is implemented when the shoreland is infested with aggressive, non-native plant species, have few to no native species, or is void of vegetation and seed bank of native species. The approach of active restoration is to 1) kill the undesirable and non-native plant species, and 2) actively plant native species that are appropriate to the desired shoreline ecology. Typically, a period of three to five years of annual removal of undesirable and non-native species will be needed to successfully establish a viable native plant community (Green Lake Association, n.d.).

Monona Bay's shoreland could be restored to a low-profile (plants only as tall as 4 ft) wet prairie and planted with vegetation native to southern Wisconsin, such as sedges, prairie grasses, shrubs, and flowers. Such a restoration plan would allow recreational users of the shoreland to enjoy the bay visually while providing improved habitat for desirable wildlife and birds, and potentially also reducing the undesirable goose population. The shoreland could be restored to a continuous buffer if all public and private shoreline landowners participated in the restoration, or it could be restored in smaller sections by willing landowners.

Vegetation could also be planted amidst the riprap on the banks of Monona Bay to improve the ecological function of the shoreline area. This technique involves creating spaces or joints in existing riprap where either a living willow, cottonwood post, or other water-tolerant shrub or tree is inserted. This not only provides a vegetative covering to the riprap but also "combines biological and technical shore protection techniques that allow excellent waterside erosion protection with natural scenic beauty similar to biological shore protection" (Wisconsin Department of Natural Resources, 2006e). The vegetative covering acts as a natural ecosystem; furthermore, dead woody materials can replace the woody cover typically removed during the installation of riprap. However, dense stands of willows or cottonwoods would grow and likely block views of the bay from shore as well as make access to the water difficult.

Depending on the extent and type of restoration, a buffer enhanced through active restoration can protect water quality by filtering nutrients from surface-water runoff, improve habitat for desirable wildlife, bird, and amphibian species, deter undesirable waterfowl from using the shoreline, enhance aesthetics by establishing a natural appearance of the bay, and enhance public and private cooperation in the management of the bay.

However, active restoration can be labor and time intensive, likely requiring more than three years to establish and consistent management over time. Many invasive species are extremely difficult to remove or reduce significantly enough to allow native vegetation to outcompete the invasives and establish a healthy native population. Once established, an actively restored buffer with taller vegetation could serve as a place to discard trash or shield unwanted activity in the shoreline area. However, at a height of 4 feet or less, this concern would likely not be an issue.

Applicability to Monona Bay

Monona Bay is an excellent area for a shoreline-restoration project. Many residents living in the bay's watershed desire ecological restoration, and many shoreline residents are interested in restoring their property on the shoreline if other landowners also restore theirs. Brittingham Park, on the bay's northern shore, is an ideal location to conduct a restoration project. The City of Madison Parks Division is in agreement with shoreland restoration east of the park's pier and is willing to participate with local residents (Si Widstrand, City of Madison Parks Division, verbal communication, 2006). The FOMB is motivated and willing to participate with the City and recruit interested individuals.

Active restoration of Monona Bay's shoreland would require purchasing herbicide and prairie seed. No special tools are necessary beyond what the City of Madison and citizen volunteers have in their machine shops and garages. Labor costs could be kept low with volunteers treating the proposed restoration site with herbicide, removing the dead vegetation, and seeding the proposed restoration site.

6.3.2.1 Restoring the Shoreland of Brittingham Park

Brittingham Park's shoreland could be restored to a low-profile wet prairie, composed of native short prairie grasses, sedges, rushes, and wildflowers. The resulting shoreline buffer would likely deter nuisance Canada geese from gathering in the park, reduce the abundance of reed canary grass and other invasive plant species, provide improved habitat for wildlife, and add aesthetic beauty to the park's shoreland environment.

The FOMB and individual citizens could participate with the Parks Division of the City of Madison to conduct the initial phase of shoreland restoration on the north side of Brittingham Park. The restoration project could serve as an opportunity for the City and private citizens to build cooperative relationships and as an educational tool for homeowners interested in shoreland restoration on their property. The Parks Division could hold public meetings to discuss the planning, design, and implementation of the restoration project. The FOMB could use their role in the bay's watershed to motivate and organize interested citizens and serve as liaison between homeowners and the city.

Monona Bay's shoreland-restoration plan would consist of three phases: 1) pre-planting, 2) planting, and 3) maintenance (University of Wisconsin–Extension, 2006). It is crucial that throughout the life of the project, the FOMB maintain communication between the city and homeowners. Citizen participation will be key to the success of the project. A number of steps would likely be included in the restoration planning and implementation process.

Shoreland Regulation. County and town shoreland-zoning ordinances can be more restrictive than state ordinances for the management of land in shoreland areas. Current ordinance guidelines and permits pertinent to shoreline alteration can be obtained at Dane County's Zoning Office and are an important starting point.

Site Evaluation. Soil, slope, moisture, light conditions, access points, and shoreline traffic patterns must be evaluation, and native and non-native plant species identified. Consideration should be given to where to plant native vegetation, to which areas have been or could be eroded, and to the locations of structures (e.g., house, pier) and trees, shrubs, and other native vegetation. It is also important to consider lake access and views.

Developing a Site Plan. To provide boaters, anglers, and pedestrians access to the water, pathways through the vegetation could be installed. Native Wisconsin prairie vegetation should be planted that is tall enough to deter geese from gathering, yet short enough top allow for unobstructed views of the bay.

Site Preparation. Eliminating undesirable and non-native plants must be done before planting. Killing this vegetation is done by covering the area with black plastic (smothering) or by applying herbicide (Green Lake Association, n.d.). For greatest elimination, herbicide can be applied and the area then covered with black plastic. Smothering is most effective when the sheeting is left in place four to six weeks during early to mid summer (UW-Extension, 2006). Reed canary grass dominates the bay's shoreland. Roundup Herbicide is effective at killing individual plants. However, reed canary grass rhizomes are difficult to kill and may require physical removal. For more information, Dane County has a list of approved herbicides.

Selecting Appropriate Plants. The water table is high and water ponds along the north side of the bay after significant rain. A seed mixture for low, moist areas like the bay's shoreland in Brittingham Park could result in a prairie habitat that is not only hardy, but also aesthetically pleasing. It is important to select vegetation native to Wisconsin. Several nurseries in Wisconsin cultivate and sell native prairie vegetation, in particular, Prairie Nursery, Inc., of Westfield, Wisconsin, sells a variety of native prairie vegetation and seed mixtures, the bulk of which are long-living perennials. In particular, their "Moist Meadow Mix," which contains short prairie grasses, sedges, rushes, and wildflowers, would be ideal for restoring the bay's shoreland in Brittingham Park to a low-profile moist prairie.

Planting Guidelines. Planting guidelines will need to be developed to implement the restoration plan. After removal of the existing non-native vegetation, the area should be raked to expose bare soil. Dead roots should be left in place to reduce the risk of erosion. If the soil is thin, adding topsoil and working it in will give seeds a good start. Desired native plant species can then be introduced to the site by either direct spreading of seeds to the soil or by planting plant plugs (pre-started plants) at specific spacings. Generally, seeding is less effective than planting plugs in restoring shoreland areas because it takes time for seeds to germinate and grow, and seeds of nearby weeds may blow into the seeded area (University of Wisconsin–Extension, 2006). However, seeding can be superior to planting plugs because the seeded sites often (but not always) yield higher plant species richness and more desirable volunteer species (Weiher et al., 2003). After seeding or planting the plugs, bare soil areas should be covered with mulch (e.g., leaves, marsh hay, or straw) to discourage weeds and alien grasses while the seeds take hold.

Local nurseries and landscaping companies can provide planting times for the desired plants and the climate zone. Typically, the best time to plant is spring, after the ground thaws and nighttime temperatures are above freezing. Autumn plantings should be completed well before the first frost. High daytime temperatures that stress young plants can hamper successful planting in summer unless extra precautions are taken with mulch, temporary shade, and watering (University of Wisconsin–Extension, 2006).

Maintenance and Monitoring. *Season One*—Watering recent plantings is necessary, with the amount depending upon local weather conditions. Plantings generally require 1 in. of water per week. Removing invasive or non-native plant material will likely be necessary every two to three weeks, but should diminish as native plants establish themselves. Native plant species should not be fertilized because fertilization encourages non-native plants that may be in the soil. Native plants have evolved in native soils and are able to find the nutrients they require.

Season Two—Watering should be done mostly during prolonged dry periods, and mainly only for those plants that are have not established with as much vigor as the others. During the spring, vegetation should be cut to 2 in.; the cuttings should be used as mulch. Undesirable plants should be removed every three to four weeks. Dry vegetation should be left standing to trap blowing leaves from the bay. This vegetation can also serve as food for wildlife during the winter.

Season Three and Beyond—During spring, dried vegetation can be cut and removed, if desired. Undesirable plant species should be removed and mulch added, if needed. The site should be surveyed once a month to identify invading species. No watering should be necessary after the second season of growth. Dried vegetation should be left standing in the fall.

Individual homeowners with shoreline property should be encouraged to visit the restoration site, attend planning meetings, and even participate in the restoration activities. The lessons learned from the project, the methodology, and the planting specifications can be scaled down to the individual lot. Interested homeowners could then conduct small shoreland restorations on their property.

6.4 Aquatic Plant Management Alternatives

All aquatic plant-management techniques have positive and negative attributes, and none are without potentially harmful environmental consequences. Competing uses of our lakes create different perceptions of the problems and the solutions in a lake community. For example, is the highest concern to maintain a healthy fishery or promote recreational boating? Eliminating a "weed problem" in a lake can improve boating conditions, but harm the lake's fishery. Lake managers stress that a holistic view of an individual lake's ecology is necessary when evaluating aquatic plant-management strategies. Effective strategies should take into consideration a lake's ecology, the desired level of control, future uses, and environmental and economic constraints.

Aquatic plant management techniques can be generally classified into the following four groups:

- Physical controls—use of water-level drawdowns or dredging.
- Biological controls—use of living organisms to control nuisance plants.
- Chemical controls and aquatic restoration—use of herbicides to kill nuisance plants in conjunction with an active aquatic restoration plan to repopulate native plants.
- Mechanical controls—including harvesting and manual removal.

Additional information on each of these techniques can be found in *Management Options for Aquatic Plants*, a WDNR publication available at: <http://danewaters.com/pdf/2006/management_options_aq_plants.pdf>.

Any aquatic plant-management tool requires consistent monitoring to understand how the aquatic plant community is changing over time and to determine whether the tool is working. Researchers assessing long-term impacts of the commonly used aquatic plant-control techniques in southeast Wisconsin lakes—mechanical harvesting, chemical treatments, a combination of the two, and no management—found that in seven of nine lakes, native aquatic plant species increased or remained the same regardless of the management tools used (Cooke et al., 2005). In eight out nine lakes studied, EWM remained the same or declined regardless of the tools used (Cooke et al., 2005).

6.4.1 Large-Scale Dredging

Dredging is the removal of sediment from a water body. Sediment removal has four main objectives: aquatic plant control, deepening for navigational purposes, nutrient control, and toxic substances removal (Cooke et al., 2005). For Monona Bay, sediment removal to control aquatic plants would be the main management goal of a large-scale dredging project. Deepening for navigational purposes and recreational usage would be the management goal for targeted, small-scale dredging where stormwater has caused sedimentation at outfalls. Although obstructed navigation due to sediment infilling near stormwater outfalls has not reached action levels as defined by the City of Madison and the WDNR, targeted dredging near the outfalls may be necessary in the future. Dredging near outfalls would benefit landowners and recreational users by preventing shoaling.

Issues that result from the removal of sediment include the disturbance caused by digging in water, sediment transport and disposal, and the amount of land space needed for the removal of water from the sediment, known as dewatering. The WDNR has rules and regulations to mitigate any potentially negative ecological repercussions.

6.4.1.1 Dredging Techniques

Dredges that are commonly used in lakes are divided into mechanical and hydraulic types.

Mechanical Dredging. If a small-scale shoreline dredging project were undertaken on the bay, a mechanical dredge would most likely be used. They are often used for near-shore dredging around docks and in areas of soft to stiff mud (Cooke et al., 2005). Mechanical dredges feature a clamshell bucket and a crane-like arm.

Mechanical dredges are advantageous in some situations because they can be easily transported and can work in confined areas. However, dredging mechanically is time-consuming, the clamshell bucket creates rough, uneven contours when scraping the bottom sediment, and, because this style of dredge grabs sediment and pulls it through the water column, turbid water can result.

Hydraulic Dredging. If large-scale dredging in Monona Bay were to occur, a special purpose hydraulic dredge would probably be used. An example of such a dredge is the Mud Cat. This machine uses a horizontal auger to dislodge sediment. The loosened sediment is then sucked up by a shielded dredge head and transported through a pipeline to shore.

In addition to its ability to remove flocculant sediment, the Mud Cat generates low turbidity and features high-precision depth control. Sediment plumes due to dredging with the Mud Cat are shown to be limited to a 20-ft area surrounding the dredge, and its slurry contains 30 to 40 percent solids versus the 10 to 20 percent common to hydraulic dredges (Nawrocki, 1974). The Mud Cat was successfully used on small lake-restoration projects in New York state and Europe (Cooke et al., 2005). Despite a reduction in turbidity compared to other dredging techniques, there is still concern over contaminants, such as PCBs, that are associated with particles less that 74 µm in diameter (Murakami and Takeishi, 1977). The removal of contaminated sediment from Lake Järnsjön in Sweden was monitored closely for TSS. Although the amount of TSS during the operation was relatively low, the disturbance of sediment resulted in a six-fold increase in PCB levels at a downstream monitoring site (Cooke et al., 2005).

6.4.1.2 Sediment Dewatering and Disposal

Dredging projects are complicated and costly in part because of sediment dewatering and disposal. Sediment removal is especially difficult in urban areas such as Madison that lack open space for dewatering and disposal of sediments. Dewatering is a necessary step due to the large amount of water present in lake sediment. Depending upon the type of dredge used, dredge slurries can range from 60 to 90 percent water. To settle out solids from the water, retention ponds are constructed close to the site. The process is slow, and the discharge water returned to the water body is subject to stringent turbidity standards. To accelerate this process, technologies are employed to induce coagulation, but many have environmental side effects (Cooke et al., 2005).

Because arsenicals were historically used in the bay, dredge material exceeding 3,000 cubic yards must go to a landfill or be disposed of under the authority of a low hazard exemption. For an area less than 3,000 cubic yards, disposal in a landfill is not necessary as long as the material is not hazardous, and performance standards (such as no detrimental effect on groundwater) can be met (Gene Mitchell, Wisconsin Department of Natural Resources, verbal communication, 2006). Uncontaminated sediments can be land-spread on upland agricultural fields or used as fill.

6.4.1.3 Environmental Concerns

Despite the advancements made in dredging technologies, environmental concerns persist. Because dredging is highly disruptive, habitat destruction and nutrient and contaminant resuspension are two primary concerns.

Habitat Destruction. Despite the nuisance conditions that excessive macropyhte growth can cause, rooted aquatic plants are natural and provide essential habitat for fish and other aquatic life (Cooke et al., 2005). If dredging is considered for Monona Bay, a careful sediment-removal plan must be developed to preserve fish habitat.

Removing sediment from a water body will be destructive to aquatic organisms. Of concern to fish managers is the destruction of fish spawning and nursery areas and the habitat of benthic organisms that feed fish. Although studies indicate that benthic fauna recover fairly quickly in most lakes (1–3 years, depending upon dredging intensity) (Carline and Brynildson, 1977; Cooke et al., 2005), recreational opportunities such as fishing will be affected. If a dredging plan is approved for the bay, areas of high value for fish and wildlife would need to be identified and protected from dredging.

Nutrient and Contaminant Resuspension. Phosphorus suspension is a concern because of its high concentration in sediment interstitial water (Cooke et al., 2005). The disturbance of sediment caused by dredging, coupled with wind action, can cause undesirable algal blooms (Cooke et al., 2005). Case studies indicate nutrient enrichment due to dredging to be a short-term problem. However, because lakes are dynamic systems, the response to sediment resuspension is unique to every lake. Dredging techniques, such as silt curtains and special hydraulic dredge heads, can be employed to reduce sediment disturbance.

Sediment contamination is of concern because dredging operations can cause environmental impacts during or after sediment removal. In the case of Monona Bay, two primary pathways exist by which contaminated sediments could be resuspended into the water column. One pathway is the release of toxic substances from the sediment by disturbing historic deposition. In Monona Bay, peak levels of contaminants are in effect “capped” by lesser contaminated sediment. The second potential pathway is the discharge of contaminants via hydraulic dredge carriage water. After sediment dewatering, the water would most likely be released back into Monona Bay. Despite strict turbidity standards, this water may have elevated levels of contaminants.

6.4.1.4 Regulations and Permitting

Several Wisconsin statutes and administrative codes oversee dredging procedures. Chapter 30 of the Wisconsin Statutes requires a written permit for dredging on or near a waterway. Chapter NR 345, Wisconsin Administrative Code, *Dredging in Navigable Waterways,* establishes reasonable procedures and limitations for dredging in water bodies; Chapter NR 347, *Sediment Sampling and Analysis, Monitoring* Protocol and Disposal Criteria for Dredging Projects, outlines the various rules and steps involved in a Wisconsin dredging project. A dredg-

Table 6.1. Sediment sampling parameters for urban lakes, as required by Chapter NR 347, Wisconsin Administrative Code. Bold indicates parameters tested for by the 2006 WRM Practicum. (Adapted from *Guidance for Applying the Sediment Sampling and Analysis Requirements* of Chapter NR 347, Wisconsin Administrative Code.)

Inorganics (metals)	Inorganics (nutrients)	Organics	Physical tests
Arsenic	Oil and grease	Chlordane	**Particle size**
Cadmium	**Total phosphorus**	DDT	**Moisture content**
Chromium (total)	Nitrate + nitrite	DDD and DDE	
Copper	Ammonia-nitrogen	**PCBs (total)**	
Lead	Total Kjeldahl nitrogen	**Total organic carbon**	
Mercury		**PAHs**	
Nickel			
Selenium			
Zinc			

ing application can be obtained from the Dane County water management specialist at the WDNR.

The WDNR has outlined a multi-step dredging review process. The applicant submits a preliminary application to the WDNR. The water management specialist at the WDNR reviews the application and solicits comments and recommendations from fisheries, wildlife, wastewater, water-resources, and waste-management staff. The WDNR determines sampling requirements; for urban water bodies; the list is comprehensive and includes sampling for metals, nutrients, and organics (table 6.1). On the basis of advice from the WDNR, the applicant submits a sampling and analysis plan. Following approval of the sampling plan, samples are collected and results submitted. This information is used to characterize the quality of the sediments at the proposed dredging site. If the sediment is characterized as contaminated, the WDNR uses the data to examine the following:

- hot spots of sediment contamination,
- the potential for and spatial extent of harm to benthic organisms,
- the need for sediment remediation, and
- the need for further monitoring programs to assess the extent of contamination and the effects on benthic organisms.

The WDNR then determines the permits and approvals necessary to continue the process. Once the applicant submits all the necessary applications, the WDNR will issue a decision. If the volume of sediment is greater than 3,000 cubic yards and it is determined to be contaminated, additional environmental analysis and remediation may be necessary, according to NR 347. Dredging more than 3,000 cubic yards of material also requires an environmental assessment under NR 150: *Environmental Analysis and Review Procedures for Department Actions.* A detailed sediment-removal plan must be proposed and sediment-loading sources must be controlled before dredging is likely to be permitted (Charles Nahn, Nahn & Associates, written communication, 2006). The details of the WDNR dredging review process are available online at <http://www.dnr.wi.gov/org/water/wm/sms/NR347_Guidance_Final.pdf>.

Contaminated Sediment. According to Chapter NR 347, contaminants at high concentrations can pose risks to aquatic or terrestrial organisms through bioaccumulation or toxicity. Due to these concerns the WDNR has developed Consensus-Based Sediment Quality Guidelines, based upon the work of MacDonald et al. (2000). The purpose of these guidelines is for the protection of benthic-dwelling species that reside either in the sediment or sediment pore water. Organisms may be exposed to such risk during dredging operations, disposal, or beneficial reuse. The guidelines do not consider food-chain bioaccumulation and transfer of contaminants such as PCBs or methyl mercury on humans or wildlife If bioaccumulative compounds are involved, other tools may be used to assess risk.

The evaluation of sediment-contaminant concentration is taken on a case by case basis, and there is no specific formula for determining regulatory action (Gene Mitch-

Table 6.2. Tested parameters of potential concern in dredged sediment. Peak concentrations of contaminants found in core B are shown in relation to the threshold effect concentration (TEC) and probable effect concentration (PEC) as specified by the WDNR Consensus-Based Sediment Quality Guidelines. (TEC and PEC values from Wisconsin Department of Natural Resources, 2006d.)

	Sediment mg/kg dry wt		
Contaminant	**Peak concentration in core B**	**TEC**	**PEC**
PCBs (total)	0.83	0.06	6.76
Arsenic	84	9.8	33
Copper	416	32	150
Iron	22,464	20,000	40,000
Lead	735	36	130
Manganese	567	460	1100
Mercury	0.65	0.18	1.1
Zinc	802	120	460

ell, Wisconsin Department of Natural Resources, verbal communication, 2006). However, when sediment is considered to exceed the TEC criteria, as outlined in the guidelines, additional information will be needed. (Table 6.2 shows the concentrations of contaminants exceeding TEC criteria in the core we took near a stormwater-sewer outlet at Brittingham Park.) The applicant must demonstrate the dredge water, sediment carriage, and/or interstitial water, can be treated to comply with effluent standards.

Dewatering Sediment. An additional permit is necessary to address discharge carriage and/or interstitial water generated by dredging operations. The regulations for this discharge water are covered under the general Wisconsin Pollutant Discharge Elimination System (WPDES) permit. The general permit primarily addresses uncontaminated sediment or moderately contaminated sediments that are unlikely to have an environmental impact. The Consensus-Based Sediment Quality Guidelines are used qualitatively to evaluate the degree of risk from the dredge sediment and the likelihood the dredge water will be contaminated.

Applicability to Monona Bay

Advancements in dredging technologies have made this management technique a more desirable and less environmentally destructive practice for lake-sediment removal, depending upon sediment-contamination levels. Despite the advances, there are three potentially prohibitive points regarding large-scale dredging in Monona Bay: the unknown ecosystem response, environmental degradation, and cost.

Large-scale dredging is an unlikely management alternative for Monona Bay, at least in the near future. It is important to acknowledge that dredging is not a preventative measure, but a tool of last resort. Dredging is a long-term management tool that is rarely preformed solely for aquatic plant management (Madsen, 2000). However, it is frequently used as a comprehensive remediation technique for lakes that have been filled in with sediments, have excessive nutrients, need deepening for specific purposes such as navigation, or require removal of toxic substances because they pose harm to ecosystem health.

Unknown Ecosystem Response. The ecosystem response to dredging is unknown. Dredging can create more depth gradients, and more diverse habitats, which may then yield a more diverse aquatic plant community (Madsen, 2000). However, given the aggressive nature of EWM, the WDNR is skeptical that a large-scale dredging project in Monona Bay would achieve increased diversity or its stated objective of aquatic plant control (Jim Amrhein, Wisconsin Department of Natural Resources, written communication, 2006).

Because lakes are able to switch from one stable state to another, the aquatic plant dominated state that now exists in Monona Bay could switch to an algal dominated state, resulting in additional management problems and be worse than its current condition.

Environmental Degradation. The main environmental concerns in Monona Bay include the destruction of habitat and the resuspension of sediment nutrients and contaminants.

If the objective for dredging in Monona Bay is aquatic plant control, fishing opportunities may be limited by the reduction in plant densities in the bay. Monona Bay is a popular fishery because of its abundance of pan fish. Vegetation plays a key role in the structuring of fish communities in eutrophic shallow lakes (Lammens, 1989). A vegetated lake will have different fish assemblages than an unvegetated lake because of the effects of aquatic plants on food availability and predation risk. Many invertebrates are found among submerged aquatic plants; they provide a rich food source for some fish. Dense vegetation provides important refuge from predators for smaller fish (Scheffer, 1998).

Elevated levels of several contaminants were found in sediment cores collected by the WDNR and WRM 2006 Practicum. Because many of these contaminants fall between the midpoint effect concentration and probable effect concentration, detailed environmental analysis would be necessary to determine the effect of dredging on the ecological health of Monona Bay. The higher levels of contaminants that are located deeper in Monona Bay's sediments would be exposed during dredging. Dredging will stir up sediments, resuspend contaminants into the water column, and present a risk to organisms.

Costs. The cost of dredging in Monona Bay is dependent upon several factors. Of primary consideration are the contamination of sediments and the likelihood of land-spreading dredge material. If local land-spreading is permitted by the WDNR, the costs for disposal and transport are significantly less ($10 to $30 per cubic yard of sediment). However, this is unlikely for Monona Bay, given its historical contamination. If the sediment is classified as contaminated and needs to be transported to a landfill, the cost is roughly $50 per cubic yard. (These costs are dependent upon volume and are per unit estimates based upon current bidding prices in the Madison area [Charles Nahn, Nahn & Associates, written communication, 2006].) Finding a suitable site for land-spreading in the Madison area is also a limiting factor.

The depth and volume of sediment removal are also important. If dredging to prevent plant growth is the primary goal, dredging beyond the photic zone is desirable because light is the major limiting factor in rooted autotrophic plant growth (Hutchinson, 1975). There have been few studies on the necessary dredging depths to prevent the regrowth of aquatic plants. The appropriate depth is determined on the basis of field observations of the maximum depth of aquatic plants. Our field data indicated the maximum depth of plant growth to be 12 ft; this depth is variable depending upon substrate, light availability, and season. A dredging-depth calculation must also consider sediment infilling over several decades from the watershed.

Because of the varying degrees of contamination within the bay, the WDNR has indicated that it would require dredging to a minimum depth of the shell/marl layer (Jim Amrhein, Wisconsin Department of Natural Resources, written communication, 2006). This is to prevent buried layers of contamination from being exposed.

Additional costs to consider include the planning and design of the proposed dredging project and the cost for the assembly and disassembly of equipment on-site. The study and design phase is typically 15 percent of the total dredging cost. The dredging contractor usually charges a fixed amount for equipment assembly/disassembly. This can range from $30,000 to $50,000 and is not dependent upon the volume of sediment removed (Charles Nahn, Nahn & Associates, written communication, 2006).

Because of the high cost of dredging, its environmental impacts, and the problem of disposal, dredging should not be performed for aquatic plant management alone. Dredging is best used as a multipurpose lake-remediation technique under different conditions than in Monona Bay.

6.4.2 Biological Controls

Biological controls used to control abundant aquatic plant growth include the introduction of species-specific pathogens, allelopathy (growth of plants that release chemical compounds that inhibit other plants from growing), and stocking of insects that eat specific plants. Of these options, the most promising biological control method for Monona Bay is use of the milfoil weevil (*Eubrychiopsis lecontei*), a sesame-seed-sized weevil native to Minnesota and Wisconsin. The milfoil weevil evolved with our native northern water milfoil *(Myriophyllum sibiricum),* but shows a preference to eating EWM as well and has been shown to control EWM when adequate weevil densities are reached and sustained (Newman, 2006).

The main factors limiting milfoil weevil populations include the presence of adequate habitat and predation levels by fish. Milfoil weevils require natural shoreline vegetation, such as a mixture of trees, shrubs, and groundcovers, in which to overwinter by burrowing into dry leaf litter or similar insulating groundcover. Lake researchers have found that weevil densities are higher in areas that have less disturbed shoreline and that highly developed shorelines may limit weevils overwinter habitat (Newman, 2004). Weevil populations are also impacted by predation by fish, particularly sunfish, such as bluegill, pumpkinseed, and green sunfish. Sunfish densities greater than 25 to 30 per trap net are likely to severely limit weevil population and their ability to control EWM (Newman, 2004).

For milfoil weevils to adequately control EWM, they must be present in high enough densities. Weevil densities of 0.25 per stem can stress EWM, but weevil densities greater than 1 per stem are usually needed to be an effective control agent (Newman, 2004). In many lakes, however, weevils either do not reach adequate densities, or their densities do not persist long enough to sustain control. Although weevils can be stocked, this practice is not recommended in lakes with high sunfish densities (Newman, 2004).

Weevils for stocking can be purchased for about $1.25 to $1.50 per insect from the environmental services firm EnviroScience, Inc. (Scholl, 2006). The necessary number of stocked weevils is highly site specific, but most projects require stocking at least 6,000 to 10,000 weevils. Specific numbers of weevils to stock depends on the current population, shoreline habitat, fishery, lake size, density and location of EWM beds, and other lake-specific factors. Stocking programs are intended to augment existing weevil populations or provide founder colonies in lakes that have no existing weevil populations. At lakes with weevil-stocking projects, the average number of stocked weevils ranged from approximately 13,000 to 65,000 weevils per year for the project period. Stocking programs typically lasted from two to five years, according to the case studies of EnviroScience, Inc. (2006).

Applicability to Monona Bay

In July 2005, researchers conducted a survey of milfoil weevil densities in Monona Bay, Lake Wingra, and Fish Lake in Dane County. The study found that the lowest average weevil densities were observed in Monona Bay at 0.01 weevil per stem; the highest densities were found in Lake Wingra at 0.24 weevil per stem (Anderson and Lathrop). Several differences between Lake Wingra and Monona Bay may explain this difference in density.

Lake Wingra has extensive native shoreline as part of the UW–Madison's Arboretum. Monona Bay, on the other hand, is almost exclusively riprapped and devoid of natural shoreline vegetation for overwintering.

In addition to lack of habitat, Monona Bay's low weevil densities may be associated with the bay's frequent mechanical harvesting of aquatic plants (Anderson and Lathrop, 2006). Adult and larvae weevils are generally found in the upper meter of milfoil plants. The weevils are also weak swimmers and tend to remain on a plant even after it has been disturbed (Newman, 2006). Harvesters can readily pick up the adult and juvenile weevils as they remove the surface mats of vegetation. As a result, frequent aquatic plant harvesting may essentially negate any potential control by milfoil weevils by effectively removing them periodically throughout the summer.

Monona Bay has a healthy sunfish population that is fished heavily year round by anglers. The robustness of this fishery may also preclude the growth of dense milfoil weevil populations.

As a result, a number of confounding factors interfere with the viability of using milfoil weevils as a biological control in Monona Bay. Because these factors are not well understood, and they can differ from lake to lake, current biological control methods tend to yield unpredictable and sometimes unsatisfying results. For weevils to be effective, significant parts of the bay's shoreline would require naturalization to provide adequate overwintering habitat. Mechanical harvesting would also likely need to cease for weevils to reach sufficient densities. Last, the healthy sunfish population may simply negate any efforts at stocking or promoting the native weevil population.

6.4.3 Chemical Controls

Another major management alternative for aquatic plant growth is the use of chemical herbicides. Although aquatic application of chemicals carries potential risks, if applied as a part of a targeted program to reduce invasive nuisance plant populations and enhance native aquatic plant populations, chemical controls can be a useful tool. However, herbicides alone are not likely to permanently eliminate nuisance plant growth in Monona Bay. A more appropriate goal for using aquatic herbicides is to shift the dominance of aquatic plants from canopy-forming invasives, such as EWM and CLP, to more acceptable native plants such as native pondweeds and wild celery.

Herbicides are generally classified as either contact—acting immediately on the tissues contacted, or systemic—taken up throughout the plant system. In general, contact herbicides affect only tissue that is touched, are faster acting than systemic, but do not have long-lasting effects; in contrast, systemic herbicides are slower acting, but can kill the entire plant (Madsen, 2000). Herbicides can be further classified as selective—targeting only certain types of plants, or broad-spectrum—killing a wide range of plant types. A number of herbicides approved for aquatic use offer varying degrees of selectivity to target either monocotyledons (monocots, such as pondweeds) or dicotyledons (dicots, such as water milfoils, coontails, water lilies, or bladderworts). Adjusting the dosage and timing of herbicide applications also improves the selectivity of the chemicals because certain species show more sensitivity to certain chemicals at different concentrations (Madsen, 2000). Most aquatic herbicides can be applied to the growing plants in either liquid or granular form.

At present, seven types of herbicides are approved by the U.S. EPA for aquatic use: 2,4-D, endothall, diquat, fluridone, glyphosate, triclopyr, and a variety of copper compounds. The three most appropriate for Monona Bay include 2,4-D, triclopyr, and endothall because they offer the most selectivity and the least harm to non-target organisms (table 6.3). The herbicide 2,4-D is a systemic that targets dicots, such as EWM and coontail, but not pondweeds. Triclopyr is one of the newer registered aquatic herbicides that could be used instead of 2,4-D. Triclopyr has a similar activity spectrum to 2,4-D, is effective for spot treatment of EWM because many native plant species are unaffected by the chemical, and has lower toxicity (Petty et al., 1998). Triclopyr has lower toxicity to aquatic animals. Endothall, in contrast, is a broad-spectrum, contact herbicide that is effective at controlling CLP and EWM. However, because it is broad spectrum, it also can kill many native pondweeds. To avoid killing these native plants, it should be applied in early spring when water temperatures are approximately 12° to 15°C and most later-emerging native species are not yet active. Such applications in early spring have been shown to reduce CLP turion density by 86 percent (Sprecher et al., 2002) and may reduce CLP reestablishment if applied several years in a row (Skogerboe et al., 2003).

6.4.3.1 Broad-Scale Chemical Control

Modern use of aquatic herbicides is not like the indiscriminate use of the past. Herbicide use increasingly strives to selectively control aquatic invasives and restore balanced native aquatic plant communities. Prolonged, widespread use of chemicals is not recommended by responsible lake managers. Instead, herbicide use should be considered a short-term method of controlling heavy plant growth in targeted or confined areas, or for the initial control of pioneering invasive plants (Thornton, 2003). Although the primary advantage of broad-scale treatment would be speedy and easy eradication of much of the aquatic plant biomass, the disadvantages are numerous. First, widespread application across the entire bay may lead to nuisance algae blooms due to the increase in available nutrients. When aquatic plants die under natural conditions, 33 to 50 percent of the biomass typically breaks down within three weeks (Cooke et al., 2005). However, after herbicide treatment, this biomass can decompose much more quickly, rapidly releasing nutrients into the water column, promoting algal blooms and even leading to eventual fish kills because of the subsequent oxygen depletion as the algae eventually decompose (Thornton, 2003).

By killing plants, herbicide use also eliminates important habitat cover, food sources, and spawning areas for fish and aquatic life. A number of chemicals, even when applied properly, are also harmful to fish and other aquatic life. For example, many herbicides also kill desirable species, such as water lilies, along with the targeted "weeds" because both species are dicots. If improperly

Table 6.3. Characteristics of the aquatic herbicides 2,4-D, Triclopyr, and Endothall. Sources: Wisconsin Department of Natural Resources (2006); Poovey et al. (2006); Cooke et al. (2005); Skogerboe et al. (2003); Petty et al. (1998).

Herbicide	Characteristics	Pros	Cons
2,4-D 2,4-Dichlorophenoxy acetic acid Example trade names: Weedar, Navigate	• Systemic	• Selective to dicots • Widely used to target EWM • Can be used in combination with endothall for early spring control of CLP and EWM	• Toxic to fish
Triclopyr 3,5,6 -trichloro-2-pyridinyloxyacetic acid Example trade names: Renovate, Garlon 3A, Garlon 4	• Systemic • Newer registered aquatic herbicide that offers control similar to 2,4-D	• Selective to dicots • Controls EWM and other broad-leaved species such as purple loosestrife • Can be used in combination with endothall for early spring control of CLP and EWM • Low order of toxicity to fish and wildlife	• May impact some native plants at higher doses • May be toxic to sensitive invertebrates at higher concentrations
Endothall 7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid Example trade names: Aquathol, Aquathol K, Hydrothol 191	• Contact herbicide • Aquathol K active ingredient: inorganic dipotassium salt • Hydrothol 191 active ingredient: Monoamine (N, N-dimethylalkylamine) endothall salt	• Low dose, early spring treatments can be selective • Aquathol K has low toxicity to aquatic vertebrates	• Broad-spectrum • Hydrothol 191 is 200-400 times more toxic to fish than Aquathol K • Hydrothol products should not be used in waters where fish are an important resource because of extreme toxicity

applied, aquatic herbicides can cause unintended lethal and sublethal consequences on human and aquatic life.

Applicability to Monona Bay

Because of the possibility of converting Monona Bay into an algal-dominated state, we do not recommend any large-scale aquatic herbicide applications. With the resulting poor water quality, native plants would likely not repopulate the bay, and instead, the invasives that are so pervasive throughout the Yahara Lakes would likely eventually recolonize the bay (Hauxwell, 2006; Newman, 2004).

6.4.3.2 Small-Scale Chemical Control

In contrast to broad-scale treatments, an effective option may be the use of small-scale herbicide applications conducted on a trial basis to target nuisance species, such as EWM, CLP, and coontail, that minimize the threat of converting the bay into an algal dominated state. Such treatments would follow the research of the U.S. Army Corps of Engineers to apply a low dose combination of herbicides to trial areas just after the spring thaw (J.G. Skogerboe, U.S. Army Corps of Engineers, verbal communication, 2006). The U.S. Army Corps of Engineers recommends a low dose combination of 2,4-D or triclopyr and endothall to be used on a trial basis in 20- to 30-acre blocks at a time for approximately 3 to 4 consecutive years. This approach targets specific invasives and gives native species time and space to reestablish and propagate. After such applications, invasives typically do not return for 2 to 4 years (Poovey et al., 2006), although this may be prolonged if a robust native community establishes, thereby lessening the density of reinvasion (J.G. Skogerboe, U.S. Army Corps of Engineers, verbal communication, 2006).

The application timing is important because EWM and CLP are the first plants to begin growing in the spring. Selective herbicides applied shortly after ice-out will kill these plants with little damage to later-growing native plants (J.G. Skogerboe, U.S. Army Corps of Engineers, verbal communication, 2006). The early spring timing is also before active fish spawning. Because of overall less plant foliage, early applications release fewer nutrients into the water column, minimizing the potential for algal blooms. Knocking back invasives in early spring gives native plants the time and room to reestablish. The trial plots would require close monitoring to record the species composition that reestablishes.

The goal of such treatments would be to establish a more diverse community of native plants over time, rather than to simply eradicate all plants instantly. The invasives in Monona Bay and throughout the Yahara Lakes are long-established, large-scale infestations, and complete eradication is not a realistic goal. However, it might be possible to decrease the dominance of the invasive species by diversifying the aquatic plant community, creating a more balanced mix of native and invasive species. The main drawback with this method is that a diverse native plant community will not reestablish if native seed or propagule bank in the lake is inadequate or regeneration is poor due to algae blooms, poor water quality, or other problems (Cooke et al., 2005).

Applicability to Monona Bay

Although small-scale chemical control in Monona Bay is a more realistic management option than broad-scale treatment, it is not without its own complications. Users and residents should decide whether the goal is to simply limit plant biomass or to shift the aquatic plant community to a more desirable mix of species. Because the success of chemical control is based heavily on the plant community that reemerges, treatment can have unpredictable results. Even if a more diverse plant community emerges, given the bay's setting and physical characteristics, it will still likely be dominated by aquatic plant growth. In addition, similar to broad-scale treatments, small-scale herbicide application can also be harmful to desirable natives and a variety of aquatic life. Even if used properly, few data are available about the sublethal effects of herbicides on fish, aquatic organisms, and even people.

Our survey results indicated low public support for chemical control. An important element of public education and outreach will be helping Monona Bay users understand the bay's natural limitations and potential and the overall unpredictability of chemical results.

6.4.3.3 Small-Scale Chemical Control with Plant Restoration

According to Cooke et al. (2005), the plant community that results after herbicide treatment may not be the anticipated one. The possibilities are 1) the original targeted invasive may return due to surviving rootstock, creating another monoculture; 2) plants resistant to the herbicide may dominate, such as *Chara* spp., a submersed macro-alga that looks like a plant, or other pioneering species; or 3) a diverse aquatic plant community containing a mix of invasives, resistant species, and others may emerge (Cooke et al., 2005). Because research has shown that the abundance of invasives can be inversely correlated with cumulative native plant cover, the establishment of a robust native community may lessen future re-establishment by invasives (Madsen, 1999).

Lake managers have learned that protecting native aquatic plant communities from disturbances is key to preventing the spread of invasives. Table 6.4 summarizes the factors that increase or decrease aquatic plant restoration success. In general, restoration efforts can be impeded by poor water quality, herbivorous wildlife, uprooting by bottom-feeding fish, motorboat and wave activity, and poor sediment conditions (Cooke et al., 2005).

If natural revegetation occurs, the extra cost and time-consuming effort of planting will not be needed. However, if no or few native aquatic plants return to areas treated with herbicides, then an experiment to actively propagate appropriate natives is an option. The "founder colony" approach to aquatic plant restoration establishes small plant colonies in a few locations and aims to promote the conditions that will allow them to spread over time (Cooke et al., 2005). It does not require a large initial investment in plant material. Species survival and expansion potential would also be tested throughout the project. Because of adaptive management, site-specific complications can be evaluated and corrected where practical before spending effort and money on a possible failure (Cooke et al., 2005).

According to Cooke et al. (2005), plant establishment with the founder colony approach should have three phases:

1. Mature plants with well developed shoots and

Table 6.4. Decision items for assessing aquatic plant restoration potential and suggested remedies (modified from Cooke et al., 2005, p. 296).

Factors for assessing aquatic plant restoration potential	Decreases success	Increases success	Remedies*
Water clarity	Turbid water	Clear water during most of growing season	1, 2, 3, 9, 10
Population of herbivores (e.g., waterfowl, muskrats, carp)	High	Low	2, 3, 4
Wave energy	High	Low	3, 7
Sediment characteristics			
Density (mushy, flocculent vs. firm substrate)	Low density	Moderate–high density	5
Organic matter content	High OM	Moderate-Low OM	5
Toxicity	Toxic	Non-toxic	5, 6
Aquatic plant populations			
Residual plants	Few or none	Abundant	8
Sediment seed/propagule bank	Few or none	Abundant	8
Native plant population in the vicinity	Few or none	Abundant	8
Non-desirable species (e.g., algae, EWM, CLP)	Abundant	Few or none	8, 9, 10

* Types of remedies:
1) Nutrient limitation.
2) Fish population manipulation (e.g., removal of bottom-feeding fish, such as carp). Managed by WDNR fisheries staff.
3) Physical barriers (e.g., wave barriers, breakwaters, curtains).
4) Herbivore population control (e.g., netting, fencing, fish exclosures).
5) Sand blanket/pea gravel, or shallow dredging. Requires permits from WDNR. Dredging would also require detailed analysis of the sediments.
6) Aeration.
7) Slow-no-wake or no-motor boating regulations.
8) Plant appropriate native aquatic plants. Consult with WDNR staff first. May require permits from WDNR.
9) Selective plant/algae control (e.g., algaecides, aquatic herbicides).
10) Do nothing.

leaves are planted in small protected enclosures. Plants are preferred over seeds or root stock because they have a greater chance of growing and can be planted over a longer time frame during the growing season. In general, only native plants common to the area should be used. The young plants must be protected until they become established and begin spreading with measures such as carp exclosures, motor boat exclosures, wave barriers, netting, and fencing to protect against waves, waterfowl, muskrats, bottom-feeding fish, and other creatures that eat or uproot the new plants.

2. If phase 1 is successful, more species are planted during the second growing season to increase diversity. These plants require continued protection from waterfowl and other herbivores, bottom-feeding fish, motorboat traffic, and waves. Survival of the newly added species is evaluated during next growing season.
3. If phase 2 is successful, the established species from the founder colonies should expand into adjacent areas by their natural reproductive means in the following growing seasons. The founder colonies serve as seed and propagule sources for natural colonization throughout the lake (Cooke et al., 2005). However, if active restoration attempts fail and there is minimal natural regeneration of desirable native species after four years, this approach should be abandoned.

While conducting founder-colony aquatic plant restoration in conjunction with targeted chemical treatments, several questions should be periodically revisited. Do the chemical treatments have negative effects on the fish and native aquatic plant communities? Which native plant species, if any, return post-treatment? Can these returning natives successively bar reinvasion by invasive species? Does the resultant plant community grow to nuisance levels and require constant harvesting?

The following are several useful resources about aquatic plant restoration and aquatic plant management:

- *Aquatic Plant Management in Wisconsin (2006):* This guide, developed by the Wisconsin Lakes Partnership, helps lake communities understand and protect healthy aquatic plant communities and develop holistic aquatic plant management plans. It is available online at <http://www.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp>.
- *Update to the Propagation and Establishment of Aquatic Plants Handbook (2005):* A technical report from the U.S. Army Engineer Research and Development Center, available online (ERDC/EL TR-05-4) at <http://el.erdc.usace.army.mil/publications.cfm?Topic=TechReport&Code=apcrp>.
- *Wisconsin Native Plant Sources and Restoration Consultants (2004):* a WDNR and UW–Extension fact sheet providing names of nurseries that sell native plants and seeds and information about restoration and native ecosystems, available online (DNR PUB WT-802 or UWEX publication GWQ041) at <http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/restoration.htm>.
- *Native Plant Nurseries and Restoration Consultants in Wisconsin (2001):* a WDNR Bureau of Endangered Resources list of plant nurseries, available online at <http://www.dnr.state.wi.us/org/land/er/invasive/info/nurseries.htm>.

Applicability to Monona Bay

Of the three chemical management alternatives proposed for Monona Bay, small-scale chemical application coupled with aquatic plant restoration likely has the highest chance of success. Given the low frequency of native plants recorded during the 2005 and 2006 aquatic plant surveys, chemical treatment in Monona Bay is not likely to naturally result in a diverse native community. Like all aquatic restoration efforts, the success of a bay-wide reestablishment of native plants is unpredictable. Despite the known benefits of establishing native communities, there are few documented successful large-scale aquatic plant restorations. As a result, although this is a practical approach to aquatic plant restoration for Monona Bay, it would require significant expenditures and monitoring efforts by local lake managers, the WDNR, and other partners over several years.

6.4.4 Aquatic Plant Harvesting

In lakes that have large areas of established invasive plant growth, perhaps the most useful management technique is mechanical control through harvesting (Thornton, 2003). Aquatic plants can be mechanically harvested with specialized equipment consisting of a cutting apparatus that cuts up to 5 ft below the water surface and a conveyor system that picks up the cut plants and hauls them to shore to be used as mulch or compost. Harvesting is most effective in water depths greater than 2 ft.

The primary advantage of harvesting is that it cuts and removes surface mats of aquatic plants instantly, without the lag time and eventual decay associated with biological or chemical controls. By immediately collecting the cut plants, harvesting removes plant matter before it decays and "re-fertilizes" the lake by releasing nutrients back into the water column. A typical harvest of submerged aquatic plants from nutrient-rich lakes in southeastern Wisconsin can yield between 140 and 1,100 lbs of biomass, 4 and 34 lbs of nitrogen, and 0.4 and 3.4 lbs of phosphorus per acre per year (Thornton, 2003).

This nutrient removal can also have an impact on a lake's natural internal nutrient cycling. For example, aquatic plant decay accounted for approximately half the internal phosphorus load in Lake Wingra (Cooke et al., 2005). Ecosystem modeling results predicted that a harvest of 50 percent of the aquatic plants in Lake Wingra could reduce phosphorus availability by about 30 percent or more, depending on the season (Thornton, 2003). Yet harvesting alone will not change a lake from being eutrophic (Madsen, 2000).

Harvesting can also stress the regrowth of invasive species like EWM. Some studies have indicated that regrowth of EWM decreases as harvesting frequency increases (Thornton, 2003). Other studies have shown that two to three harvests of the same plot per year are necessary to provide adequate annual control and reduce regrowth (Madsen, 2000). Harvesting also removes filamentous algae along with the cut plants.

Harvesting can improve a lake's fishery by providing "cruising lanes" for predator fish (Thornton, 2003). When aquatic plant beds are too dense, predator fish are challenged to find smaller fish to eat. By harvesting cruising lanes, more "edge" habitat is created, reducing stunted panfish populations in areas where excessive cover has negatively influenced predator–prey relationships. With increased predation on young panfish, predators and the remaining panfish may show increased growth (Thornton, 2003).

However, because harvesting is nonselective, it can remove beneficial natives, insects, and semi-aquatic vertebrates (e.g., turtles and frogs), and small fish (Madsen, 2000). Repeated harvesting of aquatic plants continually sets back natural plant succession, changing a diverse native plant community to one more opportunistic and tolerant of disturbance—"weeds" (Nichols, 1998). It is not known whether native plant communities respond preferentially to harvesting in the long-term (Madsen, 2000; Cooke et al., 2005). Likewise, fish, especially young-of-the-year bluegills and largemouth bass as well as fish-food organisms, are frequently caught in the harvester. As much as 5 percent of the juvenile fish population can be removed by harvesting; Thornton (2003) found that approximately four pounds of fish were removed per ton of plants harvested.

Especially in shallow nutrient-rich lakes, it is important that harvesting operations do not remove too many aquatic plants; this can cause shallow lakes to switch from a clear-water, plant-dominant state to a turbid, algae-dominant state (Cooke et al., 2005). Once this switch has occurred, it is difficult to return to the desirable state (Cooke et al., 2005).

Application to Monona Bay

Harvesting is the current aquatic plant management tool used in Monona Bay because it balances reasonable recreational access to open water, habitat for fish and other aquatic life, and maintenance of a clear-water, plant-dominant state. However, a more intensive harvesting program might better address problems with aquatic plants and filamentous algae in Monona Bay.

The timing of harvesting could be improved to stress the aquatic invasives, EWM and CLP, while still minimizing the impacts on native aquatic plants and fish spawning. Three or more harvests throughout the growing season across greater areas of the bay would be most effective at reducing plant growth during subsequent years. Because the invasive CLP tends to "top out" in May or early June, the first expansive harvest would be most effective in early May. Although this is before the Dane County harvesting program typically begins, it would allow four harvesters to be simultaneously dedicated to the bay. This approach would require increased county staffing assigned to do the work prior to the hiring of summer seasonal workers. Another optimum time to harvest the bay would be in late September and early October when EWM begins to die off. Such timing would ideally minimize the spike in dissolved phosphorus released as EWM decays, causing dangerous, late-season blue-green algal blooms. A harvester could also be dedicated to the bay throughout the summer to more quickly respond to nuisance conditions in high-use areas.

The harvesting program would benefit from varying the depth of harvesting. We recommend two to three expansive, but shallow cuts, ranging from 2 to 3 ft deep, in high-use areas of the bay to reduce the filamentous algae problems associated with surface mats of aquatic vegetation. Although the algae will still grow on the deeper plants, surface algal mats should be reduced. It is unlikely this approach will address algal or plant surface mat problems close to shore or along the beaches. However, residents and Parks Division employees could effectively address this unsightly problem through the use of a long modified fishing net, somewhat similar to those pulled behind fishing boats. To maximize navigation and habitat for predator fish, we also recommend continuing to harvest the deeper "pinwheel" of lanes to allow for boat traffic.

The actual harvesters themselves could be improved to better pick up filamentous algae, plant fragments, and near-shore debris. Harvesters could also be equipped with GPS units to better track and record harvesting information. This data could be used to better understand the long-term effects of harvesting and to avoid specific fish spawning grounds or other sensitive habitat.

6.5 Water-Quality Monitoring Alternatives

6.5.1 Continued Water-Quality Monitoring

Water-quality data can provide lake managers with valuable information regarding the health of a water body. Various chemical and physical parameters can indicate biological productivity or whether a system is well mixed or thermally stratified. For example, total phosphorus, chlorophyll-a, and Secchi depth values can be used to calculate the TSI, which can help track the nutrient enrichment of a lake and how it compares to other water bodies. The three parameters are strongly correlated because as phosphorus and chlorophyll-a concentrations increase, algal biomass is expected to increase and Secchi depth is expected to decrease. An increase in nutrients from stormwater may indicate a rise in construction within the watershed and the inadequate control of runoff from these sites. A seasonal spike in phosphorus can indicate a storm event or the die off of aquatic plants such as CLP. (See the *Measures of Eutrophication: Trophic State Index* section of chapter 3 for a more detailed analysis of water-quality parameters.)

Applicability to Monona Bay

Because Monona Bay is situated in a highly urbanized environment, the collection of chemical and physical parameters is critical to understanding how this shallow lake is influenced by its surrounding watershed. Long-term data collection can allow lake managers to track water-quality trends and the success of various management practices over time.

Additionally, the morphometry of Monona Bay lends itself to strong sediment–water interactions. The dense aquatic vegetation helps prevent the resuspension of nutrient-rich sediment, and therefore increases water clarity and decreases the frequency of algal blooms. For this reason, Monona Bay is classified as being in a clear-water, plant-dominated state. However, this state can switch to a much less desirable turbid and algal dominated condition if the bay is not managed carefully. The continued monitoring for nitrogen, phosphorus, chlorophyll-a, Secchi depth, and blue-green algae can aid in the analysis of the bay's stable-state condition and the resiliency of this ecosystem in response to various management practices.

Given the importance of water-quality data and the number of people that use and live on the bay, it would be beneficial for the City to continue monitoring at the same frequency, at the same sampling sites, and for the same list of chemical and physical parameters as begun in 2005. This also includes weekly monitoring for blue-green algae at five sites within the bay. These data can assist the City, County, or WDNR when making management decisions within the Monona Bay watershed. The City could also annually calculate the trophic state index for Monona Bay and track the variables that make up this index over time. This valuable information would be an excellent public outreach tool, particularly if it were available online. The City of Madison Engineering Division's Web site on the Madison lakes and water-quality issues is an appropriate venue for this data.

However, if resources are limited, a continued sampling program that assesses fewer parameters can still provide valuable information. At a minimum, the TSI parameters should be collected to allow the City to monitor water clarity, algal growth, and the degree of eutrophication. Continued monitoring for pH, dissolved oxygen, and temperature would also be valuable. These parameters should be monitored at the same frequency within Monona Bay proper; data collection in the triangles may be omitted due to the unique setting of these areas, which are unlike the rest of the bay. The City Health Department will continue to collect data on blue-green algae at the bay's beaches; however, the data will provide less information regarding the species and counts present than is desirable to obtain a complete understanding of water quality and conditions in the bay over time. Thus, additional blue-green algae data collection in the bay would be also helpful, but could be performed less frequently as a complement to the beach data collected.

6.6 Outreach and Education Alternatives

Environmental education and outreach can be implemented by organizations ranging from small conservation groups to large municipalities and organizations. Volunteers can implement many education and outreach activities at relatively low cost.

6.6.1 Educational Opportunities

Education and outreach can bring people closer to the bay and give them a better understanding of the environmental issues pertinent to it. Appreciation and awareness can lead to more advocacy and stewardship and in the process a healthier Monona Bay.

6.6.1.1 Brochures and Fact Sheet

Brochures and fact sheets are a quick way to put concise information in people's hands. A clear and simple presentation of the information makes materials easy to use and understand. About 45 percent Monona Bay stakeholders surveyed expressed an interest in fact sheets; residents also expressed an interest in brochures (23%). We designed a fact sheet about stormwater issues for homeowners for the FOMB to use as an education tool (appendix 8). The fact sheet provides information about how residents can address the issue by using local businesses and agencies in the Madison area. It is tailored specifically for the bay, but many brochures about lakes already exist. Many of these can be found at the local UW–Extension office; some can be printed from their Web site, <http://clean-water.uwex.edu/pubs/>.

Applicability to Monona Bay

The fact sheet that we designed has the advantage of being focused on issues that are important in the bay, and it is ready to use. In general, the people who responded to the survey expressed a preference for hard copy rather than electronic as a way to receive more information. However, the printing and distribution costs are a drawback to paper brochures or fact sheets.

6.6.1.2 Mass Media Campaigns

Mass media campaigns that use radio and television are good ways to reach large audiences. The Madison Area Municipal Stormwater Partnership (MAMSWaP) funded the My Fair Lakes media campaign that ran from the spring 2005 to spring 2006. Although the media campaign is over, the Web site (myfairlakes.com) that was developed as part of the campaign continues to be maintained by MAMSWaP and the Dane County Office of Lakes and Watersheds.

Applicability to Monona Bay

Although they reach significant audiences, this scale of outreach may be more than what is necessary for Monona Bay's small watershed. Media campaigns can be expensive, and a media campaign has recently been run in the Madison area. However, if FOMB could form a partnership with local media outlets for some *pro bono* publicity, a media campaign could be a useful tool.

6.6.1.3 Workshops and Demonstration Sites

Survey results showed that respondents were interested in demonstration sites (33%) and workshops (21%). Rain garden demonstrations and NatureMapping workshops are available in the Madison area. NatureMapping is a volunteer driven wildlife program. NatureMapping involves recording and reporting the plants and animals you see in your backyard, schoolyard, or while enjoying a walk around Monona Bay. All information is kept in an online database and can be viewed through a geographic information system and used by the public, municipalities, and natural resource managers in making management decisions. These workshops are inexpensive and an easy way to educate those interested in stormwater, native plants, and local wildlife.

Applicability to Monona Bay

Several rain gardens in the bay area could be toured; for example, Peter Taglia, who can be reached at 608/255.0987, is willing to host tours of the rain garden and porous paver infiltration practices on his property. A rain garden in Brittingham Park boasts an interpretive sign.

Wisconsin NatureMapping can be found online at <http://www.wisnatmap.org> and is a partnership of the Environmental Inventory and Monitoring Section of the WDNR and Beaver Creek Reserve, a nature center in northern Wisconsin. A free, one-hour workshop about NatureMapping could enable residents to monitor and inventory the wildlife around Monona Bay. For more information about NatureMapping, or to schedule a workshop, contact Rick Koziel, (telephone, 715/877.2212; email, csc@beavercreekreserve.org).

6.6.1.4 Environmental Monitoring

The Citizen Lake Monitoring Network is an excellent way for volunteers to learn the basics of lake ecology and gain a sense of stewardship for their water body. Volunteers dedicate many more hours to their lake than resource professionals would be able to, considering that Wisconsin has some 15,000 lakes. Citizen lake monitors become the local experts on their lakes. For more information see the WDNR Web site, <http://www.dnr.state.wi.us/org/water/fhp/lakes/selfhelp/>, or email Laura Herman (Laura.Herman@uwsp.edu).

Applicability to Monona Bay

Monona Bay already has two volunteers that regularly monitor Secchi depth and dissolved oxygen. This monitoring is an excellent way to gather long-term trends data about the bay. A disadvantage to this type of work is that the information that volunteers gather is sometimes regarded as lesser quality than data gathered by agency professionals.

6.6.1.5 Signage

Interpretive signs are an effective way to convey on-site information to the general public. Signs could help people understand more about the bay's history, ecology, and watershed. These signs would not only serve to educate the public, but could also boost appreciation for the positive qualities of the bay. Two signs could be developed: one could focus on the biota of the bay, including a simplified explanation of shallow lake ecology and invasive species; the other, on the natural history of the bay, the watershed, and stormwater. Signs could also be added around the watershed to identify the Monona Bay watershed and help citizens understand how their actions in the drainage area affect the bay.

Applicability to Monona Bay

The City participates in cost-sharing and would likely cover half of the costs for the signs; however, the City prefers having commitments from groups to take on long-term maintenance of the signs. A single 36 x 24 in. outdoor sign from Badger State Industries in Madison costs about $115. Post-mount frames can be purchased for around $240.

We recommend that the FOMB take on the long-term maintenance responsibilities of at least two interpretive signs near the bay. These responsibilities include checking the signs periodically to make sure that they are clean and in good shape. We also recommend that the City of Madison (possibly in conjunction with Dane County) add watershed-identification signs in the Monona Bay watershed.

Signs reach people of all ages who enjoy and spend time around Monona Bay. They require a one-time cost with minimal maintenance involved and can last for years. However, signs in public areas are vulnerable to vandalism.

6.6.1.6 Public Awareness and Education of Fish Consumption Advisories

There are concerns regarding the contamination of fish in Monona Bay with PCBs and mercury. The WDNR and the UW–Extension maintain Web sites that contain not only current fish consumption advisories, but also resources for detailed information regarding toxicity due to contaminants found in fish. Unfortunately, a significant number of bay anglers that, due to language barriers or lack of access to the Internet, are not benefiting from the information contained in these advisories.

Applicability to Monona Bay

Maria Powell of the Madison Environmental Justice Organization stated that "African-American, Latino, Hmong and poor subsistence anglers could be particularly at risk, because they often depend on fish as a free food source and many consider fishing an important social and cultural activity" (Weier, 2006). Public education and outreach regarding mercury and PCB toxicity from fish should be targeted at those most at risk. Stronger and more directed efforts should be made toward these demographic groups to alleviate the lack of awareness, lack of understanding of fish consumption advisories, and lack of trust in governmental regulatory organizations (Flaherty et al., 2003).

6.6.1.7 Internet-Based Outreach

Web sites are an effective way for lake groups to centralize information on the lake and the activities of the group. Email lists, digital newsletters, and online forums are other ways that the internet can be used to increase the effectiveness of a lake group. Constant Contact (http://www.constantcontact.org) is a Web-based company that aids organizations in the management and distribution of electronic mail. The pricing is based on the number of email addresses used and monthly fees can be as low as $15 for a mailing list of up to 500.

Applicability to Monona Bay

The FOMB currently has an Internet discussion list and a Web site, <http://www.mononabay.org>. Both are well maintained and an example that other such organizations could use as a model. However, adding a digital-based newsletter may be an effective and inexpensive way to educate the membership base.

6.6.1.8 Community-Based Social Marketing

Community-based social marketing (CBSM) is an innovative approach to education and outreach aimed at changing the behaviors of people to increase the quality of the environment. The strategy uses tools to aid in behavioral changes, including getting people to commit to making a change, using prompts to remind people of their commitment, introducing incentives and more. Doug McKenzie-Mohr is an environmental psychologist and an expert in CBSM. His company's comprehensive set of resources is online at <http://www.cbsm.com>.

Applicability to Monona Bay

A guide is available on the CBSM Web site that can be used a resource to enhance the success of their efforts of those trying to encourage behavioral change. It provides articles, downloadable reports, graphics, and case studies on fostering sustainable behavior. This could be a valuable tool for all stakeholders to encourage sustainable behavior in regards to the quality of Monona Bay.

6.6.2 Recreational Use Conflict Resolution

Monona Bay is a valued resource for a variety of recreational uses. Some of these activities include fishing, swimming, motorboating, rowing, paddling, and waterskiing among others. The bay is in an urban landscape and is heavily used. This use is associated with unsightly trash in and around the bay. Unfortunately, along with the range of activities that the bay attracts come conflicts between different recreational users and others. Brittingham Park, which is adjacent to the bay, is also a concern for area residents because of the displaced people that loiter there and some of the illicit activities associated with their presence. Although these conflicts are a common occurrence in public access water bodies, a few actions can help minimize conflict and promote safe enjoyment of Monona Bay.

6.6.2.1 Trash Receptacle Modification

One of the major problems identified by survey respondents was trash accumulation in and around the bay. Although some of this trash comes into the bay with stormwater, it is also left behind by people who use the bay. Providing more trash cans around the bay itself could help curb littering. Another option would be to add design and signage on trash receptacles to remind people of the importance of keeping the bay and park clean and safe. One study done in a shopping mall showed that trash receptacles designed like an animal with an antilitter prompt on them collected 60 percent more trash than unpainted receptacles (Geller et al., 1979).

Applicability to Monona Bay

The FOMB could work with the City and possibly host an event in which the community designs and paints the trash receptacles at Brittingham Park and around the bay to raise awareness of the trash problems. A partnership could be formed with businesses in the Monona Bay Watershed to sponsor this event and defray the costs of the trash receptacles. This activity is a simple but effective way to deal with trash in the bay area.

6.6.2.2 Cleanup Days

Community cleanup days are a great way to collect the accumulated trash and build community support for the bay. The FOMB host cleanup days around the bay on the second Saturday of each month. In addition, they coordinate with the Dane County Lakes and Watershed Commission's "Take a Stake in the Lakes" shoreline cleanup in June. The FOMB could expand the effectiveness of these days by developing partnerships with some of the six neighborhoods in the Monona Bay watershed.

Applicability to Monona Bay

Cleanup days provide an opportunity for camaraderie among those concerned about the bay. They provide a chance to get outside and take part in an activity that has a visible effect on the state of the bay. The FOMB could also extend invitations to those who use the bay area, especially those users who may be contributing to the trash, to lend a hand on cleanup days.

6.6.2.3 Waterway Markers

Our survey results indicated that more than 30 percent of all respondents have a problem with the use of motorboats on the bay and expressed a desire to further regulate boating for reasons such as "the bay is too small for motor boating" and "motor boaters and jet skiers do not follow the no-wake rules." The slow-no-wake rule applies to watercraft, and says that no one shall operate at a speed exceeding slow-no-wake within 200 ft of the shoreline. *Slow-no-wake means a boat moves as slowly as possible, while still maintaining steerage control.*

Applicability to Monona Bay

Increasing the amount of waterway markers in Monona Bay could be helpful to create a safer environment for recreational users. Once a boat speed limit or controlled area has been lawfully established, regulatory signs or buoys may be posted by the local government pursuant to a permit issued by the WDNR. Placement of regulatory buoys must be approved by the local WDNR conservation warden and by the local unit of government.

To put slow-no-wake buoys in Monona Bay, the City will need to a pass a local ordinance authorizing the placement of the buoys, and specifically describe the location of all buoys. Then the City must complete the Waterway Marker Application (Form 8700-58) and submit it to the appropriate conservation warden. Although some find that waterway markers to be an eyesore, citizens could work with regulatory agencies to ensure that only the minimum amount of markers necessary for effectiveness are placed around the bay. The markers could be placed 200 ft from the shoreline in areas where people often violate the rule.

Citizens living around the bay who would like to see buoys placed should contact the 13th District Alderperson. The email address is district13@cityofmadison.com and the telephone number for the Common Council office is 608/266.4071.

6.6.2.4 Tools for Addressing Recreational Use Conflicts

Recreational uses on lakes can be a source of conflict among stakeholders. Regulating and restricting certain uses can be complicated and requires work within the community. Decisions must be made to protect the lake's ecological resources, provide public safety, and to minimize conflicts between users. The North American Lake Management Society has published the book *How's the Water: Planning for Recreational Use on Wisconsin Lakes and Rivers*. It provides guidance on the design of local boating ordinances and recreational use plans. It can be purchased online at <http://www.nalms.org/bkstore/p1-02.htm>. The Wisconsin Association of Lakes has several fact sheets on local ordinance and waterway-marker guidelines posted online at <http://www.wisconsinlakes.org>.

Applicability to Monona Bay

How's the Water provides guidance and advice for dealing with the challenges of use conflicts. One of the authors, Robert Korth, has directed the Wisconsin Lake Partnership at UW–Stevens Point since 1990, so the information is applicable to Wisconsin lakes. The North American Lake Management Society views it as an excellent tool to aid elected officials, citizens, and property owners in working together about lake issues and developing a strong lake community, and it would be helpful to those working with Monona Bay.

6.6.3 Expanding Participation and Membership for the Friends of Monona Bay

The FOMB is a well organized, effective group. The group has subcommittees that address specific areas of interest among the group, and many activities, but effectiveness could be increased if the group had greater visibility.

6.6.3.1 Door-to-Door Distribution

Our survey results revealed 35 percent of the people living on Monona Bay had never heard of the FOMB. The percentage was similar for those living in the nearby Bay Creek neighborhood. On the basis of this information, the FOMB could work to expand its membership and reach out to those who care about the condition of the bay, but have not yet been active in the group. To do this, handing out printed information about the FOMB, including events that the group organizes and participates in, its goals, and how to join and participate, could be effective. Our survey results indicated that people are most interested in receiving information in paper format. Going door to door to distribute surveys was also well received; contacting people face-to-face about the FOMB would also be beneficial. Not only might these processes expand the membership base, but they may also diversify the group to incorporate a larger pool of concerns and ideas. The FOMB members could distribute educational information about the bay and how to get involved, but also receive feedback from these key stakeholders and build community.

Although digital and Web-based materials are informative and effective, some people do not use these media. The FOMB could create a regular paper newsletter to distribute to members and possibly nonmembers who live near the bay, but the costs associated with printing and distributing newsletters could be prohibitive. However, many of the neighborhoods that are located fully or partially within the Monona Bay watershed already distribute newsletters. The FOMB could approach and provide these neighborhood groups with newsletter articles to include in existing publications. The UW–Extension Lakes Program provides many such articles to lake organizations free as long as Extension is acknowledged. These articles can be downloaded from <http://www.uwsp.edu/cnr/uwexlakes/editorscorner/articles/>.

Applicability to Monona Bay

Although door to door distribution of newsletters may be effective in getting the word out, it is time consuming and potentially very costly. Further, the fact that the survey was handed out door-to-door and in paper format may have biased the sample toward people who prefer this format. It might be wise to establish relationships and partnerships with the neighborhood associations that already distribute newsletters and submit timely articles through them to the watershed.

6.6.3.2 Subcommittees

As expected, our survey revealed a variety of ways that people use and appreciate Monona Bay. A good way to involve a greater number of people who use the bay and influence its quality is to provide additional opportunities for targeted involvement related to certain issues that may be of interest to different user groups. The FOMB could form subcommittees on issues of interest to increase membership and membership participation. The subcommittees would be well defined and advertised in all forms of communication the FOMB has with members and nonmembers. Subcommittees could take turns leading or contributing to monthly meetings. Having focused and clearly defined meeting agendas would likely draw in more participants. Possible ideas for subcommittee topics include trash management, membership recruitment, shoreline restoration, stormwater, and water quality. The Wisconsin Association of Lakes is a nonprofit group based in Madison and is a great resource for lake groups. This group offers online tools and advice for the organization of lake groups and can be accessed online at <http://www.wisconsinlakes.org>.

Applicability to Monona Bay

Although subcommittees are an established way to address smaller and more specific needs and interests within the whole, at the moment the FOMB may be too small to further divide. Some members only help on cleanup days; others prefer to help with the Web site. Forming additional subcommittees is a valuable strategy, but it might not be applicable until more people attend the monthly meetings or become interested in actively participating in FOMB.

6.6.3.3 Collaboration

The FOMB could increase collaboration with other "friends" groups. Not only could the groups expand their opportunities to share success stories and pass on useful tactics and information, but they could also consolidate efforts to improve effectiveness. For example, the Friends of Lake Wingra and the Friends of the Arboretum work toward similar goals. The Friends of Lake Wingra are active in shoreline restoration, rain garden, and fall leaf cleanup programs. They can be contacted through info@lakewingra.org or by telephone at 608/663.2838. The Friends of the Arboretum can be contacted through friends@uwarboretum.org or by telephone at 608/263.7760.

Many Dane County "friends" groups have already formed an informal network that has been meeting approximately quarterly. These groups could work with the FOMB to organize and provide restoration workshops and rain garden demonstrations sites as well as become a more effective lobbying unit, encouraging the City to increase incentives for low-impact development for homeowners. For more information contact Rhea Stangel-Maier, the Adult Conservation Team Manager, at 608/224.3601 or stangel-maier@co.dane.wi.us.

Applicability to Monona Bay

Expanding collaborating with other "friends" groups would be a good way to form partnerships in the area and continue to make the FOMB more widely known. The fact that many groups in the area are already doing this makes it an easy action to follow. Unfortunately, although the goal of the network of Dane County "friends" groups was to meet on a quarterly basis, sometimes meetings are less frequent. It is, however, worth the effort to form partnerships.

CHAPTER 7. RECOMMENDATIONS

Monona Bay has the potential to become an important urban resource, valued for its recreational, aesthetic, and ecological contributions to the City of Madison. To improve the conditions in Monona Bay, a number of issues need to be addressed, including problems with stormwater inputs and water quality, shoreline maintenance, aquatic plants, and filamentous algae, as well as developing effective education and outreach plans. We analyzed in detail a variety of alternative tools and management strategies that could be employed to address the issues affecting Monona Bay in chapter 6. Here, we highlight the alternatives with the most promise to improve bay conditions. A summary of the recommendations including the purpose of each recommendation and possible implementing partners is provided in table 7.1.

Many stakeholders in the Monona Bay watershed are already actively involved in enhancing the watershed and improving conditions in the bay, including the City of Madison, the UW–Madison, Dane County, and the FOMB. The recommendations in this report are intended to complement the existing work being done in the watershed while also providing new ideas and insight into possible solutions to issues in the bay. In making specific recommendations, we considered funding availability and other factors that can limit implementation. However, in an effort to increase the dialogue about innovative options to explore in the future, we included some ideas that could be a part of longer-term plans, even if current barriers to implementation have been identified.

7.1 Stormwater-Management Recommendations

We recommend the following activities, tools, and management strategies to address stormwater problems affecting the bay, including reduced infiltration of runoff resulting in diminished groundwater baseflow to the bay, accumulation of toxic substances in the bay's sediments, nutrient loading, sedimentation, and trash inputs to the bay. These issues affect the recreational usage of the bay as well as its ecological conditions, impacting the health of the bay's fish and other aquatic organisms, wildlife, aquatic plant growth, swimming and boating, and the bay's aesthetic qualities.

7.1.1 Water-Quality Activities

The City of Madison and the UW–Madison improve stormwater quality by performing street sweeping and trash collection, and the WNDR and Department of Commerce regulate construction site runoff and erosion. These programs could be complemented and improved upon by the following recommended activities:

- Create an erosion-control hotline and require posting at construction sites.
- Expand promotion of pollution prevention.
- Expand and enhance litter prevention and clean-up programs.
- Expand and enhance street sweeping.
- Expand stormwater outfall maintenance.

7.1.2 Stormwater Treatment Devices and Low-Impact Development Techniques

We evaluated a variety of stormwater-treatment devices (including catchbasins/catchbasin inserts. continuous deflective separation devices, filtration devices, combination devices, and trash-removal devices) and low-impact development techniques (including porous pavement, green roofs, rain gardens, rain barrels, and comprehensive LID case studies).

These devices and techniques hold a great deal of promise for improving conditions in Monona Bay by removing trash, sediment, and other pollutants from stormwater before it enters the bay and by increasing stormwater infiltration. Many opportunities exist for the implementation of these tools in the watershed, including in the parking lots of businesses and institutions, such as churches, on private residential properties, and throughout the public stormwater system.

7.1.3 Policy Tools

Due to the expense associated with purchasing, installing, and maintaining stormwater-treatment devices and with implementing LID techniques, these devices and techniques are most cost effective when used as a part of a long-term strategy for improving stormwater qual-

Table 7.1. Recommendations for Monona Bay watershed assessment and management plan.

Possible implementors

- Partner in implementing tool/strategy (light shading)
- Partner in advocating for tool/strategy (dark shading)

Recommendation	Purpose	City of Madison	Dane County	University of Wisconsin-Madison	Friends of Monona Bay	Department of Natural Resources	Department of Commerce	Homeowners and business owners
Stormwater focus								
Create an erosion-control hotline and require posting at construction sites	Reduce unenforced construction erosion violations to reduce sediment and pollutants entering bay	Implementing	Implementing	Implementing	Advocating	Implementing	Implementing	Advocating
Expand and enhance litter-prevention and cleanup programs	Reduce litter entering bay	Implementing	Implementing	Implementing	Advocating			Advocating
Expand promotion of pollution prevention	Reduce pollutants entering bay	Implementing	Implementing	Implementing	Implementing			Advocating
Expand and enhance street sweeping	Reduce sediment and pollutants entering bay	Implementing		Implementing	Advocating			Advocating
Expand stormwater-outfall maintenance	Improve recreational access in bay	Implementing			Advocating			Advocating
Develop a City of Madison Stormwater Master Plan	Evaluate locations and plan funding for implementing stormwater-treatment devices and LID techniques	Implementing			Advocating			Advocating
Expand stormwater components of City of Madison's Gre²en Commitment	Increase implementation of LID techniques in watershed	Implementing			Advocating			Advocating
Provide incentives for innovative stormwater management	Increase implementation of LID techniques in watershed	Implementing	Implementing		Advocating	Implementing		Advocating
Develop a comprehensive environmental sustainability program at UW-Madison	Expand university activities for improving water quality			Implementing	Advocating	Advocating		Advocating
Develop a Stormwater Treatment Device Testing Protocol for Wisconsin	Improve knowledge of effectiveness of stormwater-treatment devices				Advocating	Implementing		Advocating
Shoreline focus								
Shoreland restoration in Brittingham Park and on private land of willing owners	Restore shoreland area to low-profile, wet prairie, with native prairie vegetation	Implementing		Implementing	Implementing			

Table 7.1. *Continued.*

Recommendation	Purpose	City of Madison	Dane County	University of Wisconsin-Madison	Friends of Monona Bay	Department of Natural Resources	Department of Commerce	Homeowners and business owners
Aquatic plant focus								
Option 1. Improved harvesting program	More effectively use existing equipment and resources to manage biomass, stress invasive plant regrowth, and provide nuisance relief from surface mats of plants and filamentous algae							
Option 2. Small-scale chemical treatment and restoration	Research effectiveness of treatments to reduce undesirable aquatic plants and provide opportunity for native plants to establish							
Water-quality focus								
Continue monitoring the bay's water quality for the same parameters tested in 2005 and 2006 or for a selected subset of parameters if funding is limited	Understand how bay is influenced by its surrounding watershed; track long-term trends and the effectiveness of various management practices over time							
Outreach and education focus								
Continue monitoring the bay with the Citizen Lake Monitoring Network Program	Ascertain stewardship and a sense of ownership over the bay and establish long-term monitoring trends							
Continue monthly cleanup days	Form community among stakeholders while cleaning the bay							
Continue use of Internet as an education tool	Serve as a data tool for the public and those seeking more information							
Distribute brochures and fact sheets as educational tools	Place hard copy information in the hands of those who need it							
Plan and implement NatureMapping workshops and rain garden demonstration sites	Increase groundwater infiltration, establish data about bay wildlife and educate participants							
Form a partnership with the City and post ecologically focused informational signs around the Bay	Serve as a permanent marker to raise appreciation for the bay among users and watershed residents							
Gain sponsorships from local businesses and decorate and distribute trash receptacles	Decrease trash around the bay and form partnerships with businesses in the area							
Strategically place waterway markers in the bay	Slow motorists and reduce noise pollution on the Bay							
Continue to expand collaboration with Friends groups in the area	Form advocacy partnerships on similar issues and learn from others experiences							

ity and infiltration in a watershed. Therefore, at this time we recommend several policy tools related to implementing these devices and techniques over a longer planning horizon instead of specific locations for immediate implementation.

7.1.3.1 Develop a City of Madison Stormwater Master Plan

- Develop a ten-year Capital Improvement Program and budget that includes targeted improvements to water quality in the Monona Bay watershed (and other City watersheds), including structural options, such as stormwater-treatment device retrofits, and non-structural options, such as increased street sweeping frequencies.
- Revise SLAMM models or use alternative models to include more detail for modeling retrofitting scenarios (i.e., evaluating relative benefits of installing stormwater-treatment devices and LID techniques at various locations).

7.1.3.2 Stormwater Components of City of Madison's Gre²en Commitment Program

- Expand stormwater components of Gre²en Commitment (Sustainable City).
- Capitalize on opportunities to use stormwater runoff as an aesthetic and economic resource in parks, landscaped areas, and public gathering places through art installations, fountains, underground cisterns to hold and use runoff, and other LID practices.
- Host green design competitions on prominent publicly funded buildings to include innovative runoff-management and graywater-reuse strategies.
- Require all capital projects and developments funded with contributions from City taxpayers to meet higher standards of runoff water quality and infiltration (specific performance criteria).
- Host workshops and provide resources to foster a culture of creativity regarding water management among developers.
- Promote and publicize new developments that use LID principles to improve runoff.

7.1.3.3 Brittingham Park Redesign

Due to its location near downtown and the main entrance routes to Madison—used by visitors to Monona Terrace, the Alliant Energy Center, and the university—Brittingham Park has the potential to become an open-space showpiece for the City. Not only could the park be enhanced to better reflect the legacy of important landscape architects in Madison, such as John Nolen, it also has the potential to incorporate artful stormwater-treatment features into its design. Following in the path of "greener" urban open spaces described in the LID case studies that celebrate and improve water resources, we recommend the following enhancements for a redesigned Brittingham Park:

- water sculpture or fountain features using treated stormwater,
- multi-process stormwater-treatment facility built under pavilion parking lot, possibly leading to wetland treatment west of parking lot,
- wetland treatment for stormwater at triangles on central east side and far east side,
- addition of signs to describe stormwater practices in park, including existing rain garden next to east parking lot, and
- shoreland restoration to native plant buffer.

7.1.3.4 Incentives for Innovative Stormwater Management

- Increase or revise the stormwater-utility budget to include funding for incentives and grant programs to promote innovative or high standards of water management, such as green roofs and on-site infiltration.
- Primarily target the incentives and grants at the heaviest contributors of runoff, such as larger commercial and institutional buildings and neighborhoods located in the watersheds that have the potential to impact the bay the most.
- Secondarily target redevelopment projects, which have the lowest stormwater-quality-treatment requirements and no infiltration requirements.

7.1.3.5 Expand UW-Madison's We Conserve Program into a Comprehensive Environmental Sustainability Program

Expand the We Conserve program at UW–Madison into a comprehensive environmental sustainability program similar to the comprehensive Environmental Policy at Duke University, committing the university to leadership in three areas:

- environmental research and education,
- environmentally responsible operations, and
- environmental stewardship in the community.

The policy would bring together all efforts for reducing the impact of UW–Madison's operations on the environment.

7.1.3.6 Develop a Stormwater-Treatment Device Testing Protocol for Wisconsin

- Develop a statewide technology verification program, targeting commercially available technologies and public domain practices.
- Create a data-sharing network to make data available across the state.
- Begin requiring developments to use only verified stormwater treatment technologies to meet pollutant removal standards.

7.2 Shoreland-Restoration Recommendations

Monona Bay is better suited to an active restoration approach than a passive restoration approach because of the significant populations of invasive plants and lack of native plants along the shore. Although restoration of the entire bay shoreline into a continuous buffer of native plants with naturalized, gently sloped banks would provide the most ecologic benefit for the area, this may not be feasible due to the urban nature of the bay and the resulting physical constraints along the shore (e.g., piers, roads, train tracks, and riprap to control erosion).

However, there are areas within Brittingham Park and along privately owned shoreland that would be excellent places to begin an active restoration program. We recommend restoration of Brittingham Park's shoreland environment to a low-profile, wet prairie buffer, with plants up to 4 ft in height. The restored buffer would be composed of native vegetation, such as short prairie grasses, sedges, rushes, and wildflowers. Similar to the shoreland restoration conducted by Friends of Lake Wingra, this restoration project will ideally "promote an active watershed community by engaging neighbors, park users, students, and park managers in collaborative planning, planting, and maintaining of the shoreline habitat restoration site" (Friends of Lake Wingra, 2003). The restoration project would serve as a model for individual shoreline property owners who are interested in restoring their shoreland to native prairie.

We do not recommend vegetated riprap banks for inclusion in the shoreland restoration. The dense stands of willows or cottonwoods that would grow from a vegetated riprap effort are not suitable for the bay's location because they would likely block views of the bay from shore as well as make access to the water difficult.

7.3 Aquatic Plant Management Recommendations

We recommend balancing the needs of recreational users with the quality of fish and wildlife habitat and the overall ecological health of the bay. The bay's current stable, clear water, plant-dominated state should be maintained; excessive aquatic plant removal that would switch the bay to a turbid water, algae-dominant state should be avoided. Although the dense aquatic plant community can be a nuisance to recreational activity, it helps to maintain water clarity and provides important aquatic habitat. Therefore, the primary focus of aquatic plant management should be to shift species composition from canopy-forming invasives that interfere with recreational use to a more desirable mix of native species.

7.3.1 General Recommendations

- Control stormwater runoff and reduce external nutrient loading to the bay to minimize algae blooms and nutrient accumulation.
- Continue water-quality monitoring to identify ecosystem changes.

- Encourage volunteers to gather data through the WDNR Citizen Lake Monitoring Network to build data showing trends for the bay over time.
- Continue annual aquatic plant surveys using the WDNR sampling protocol to accurately document changes in the bay's plant community over time.

7.3.2 Option 1. Improved Harvesting Program

A more intensive harvesting program can address problems with aquatic plants and filamentous algae in Monona Bay. The purpose of this strategy is to more effectively use the equipment and resources already available to manage biomass and better stress invasive aquatic plant regrowth in Monona Bay. This approach provides better recreational use and nuisance relief from the surface mats of plants and filamentous algae.

- Harvest larger areas of the bay several times a year to stress regrowth of CLP and EWM. Three or more harvests are most effective at reducing plant growth the following year.
- Time harvests to reduce effects on native plants and fish spawning and maximize the stress on troublesome aquatic plants by conducting early and late season cuts. For example, harvest the bay in early May to stress CLP before it sets its overwintering buds. This approach would require increased staff before summer seasonal workers are hired. Conducting another bay-wide harvest in September would stress EWM before the winter and minimize the phosphorus released as EWM decomposes later in the fall.
- More harvesting should be dedicated to the bay throughout the summer, deploying more expansive, shallow (2–3 ft) harvests to reduce the recreational use problems associated with canopies of invasive plants and filamentous algae.
- Continue to harvest deeper (5 ft) lanes in the pinwheel pattern for navigation to open water and to create "cruiser" lanes for predator fish.
- Avoid sensitive spawning locations for fish and other important habitat areas.
- Modify harvesters to better pick up filamentous algae, plant fragments, and near-shore debris.
- Install GPS units on harvesters to better track and record operations from year to year, use information to target certain areas of the bay, to better understand the effects of harvesting, and to avoid specific spawning grounds or other sensitive areas.
- Use nets to collect floating near-shore filamentous algae, plants, and trash.
- Provide clear guidance to riparian property owners about aquatic plant-management alternatives in near-shore areas. Continue permitting plant removal or herbicide applications around piers where appropriate, with a return to WDNR supervised herbicide applications or clear application standards.

7.3.3 Option 2. Small-Scale Chemical Treatment and Restoration

Another option for managing the bay's plant community is to conduct a trial of small-scale, early-spring chemical treatments that specifically target CLP and EWM. If native species do not return to these treated zones, desirable aquatic plants can be planted in small founder colonies to act as seed and propagule sources for natural colonization of the entire bay. Because the results of this approach are highly uncertain, this recommendation would be more of a long-term research project based on adaptive management and careful monitoring. Whether this idea moves forward depends on public support, and securing funding and research partners, such as from Dane County, WDNR, U.S. Army Corps of Engineers, etc.

- Apply a low-dose combination of chemical herbicides (2,4-D or triclopyr and endothall) in 20 to 30 acre blocks just after the ice melts in early spring for approximately three to four consecutive years.
- Carefully evaluate the plant community that returns to the chemically treated zones, and determine whether the treatments have adverse effects on fish or other aquatic life. If native species return, additional planting is not necessary.

- If native species do not return, proceed with establishing founder colonies using mature native plants with well developed shoots and leaves that are planted in protected enclosures. Continue to protect the plants against waterfowl, muskrats, carp, waves, and boats until they become established and begin spreading using a variety of exclosures.
- Closely monitor the results of the founder colonies to determine their effectiveness, which natives naturally repropagate, and whether the resultant plant community also grows to nuisance levels that still require periodic harvesting.
- If the colonies appear established, expand planting the subsequent year, following the same protective measures.
- If the treated areas are regularly repopulated by invasive species, and natives are not reestablishing, abandon this approach and focus on harvesting.

7.4 Water-Quality Recommendations

Because Monona Bay is in a highly urbanized environment, the collection of chemical and physical data is critical to understanding how this shallow water body is influenced by its surrounding watershed. Long-term data collection can allow lake managers to track water-quality trends and the success of various management practices over time.

7.4.1 Primary Recommendation

If adequate funding is available, the following components of a water-quality monitoring program in Monona Bay are recommended:

- Continue water-quality monitoring in the bay at the same frequency, at the same sampling sites, and for the same list of chemical and physical parameters as begun in 2005 by the City of Madison. This also includes weekly monitoring for blue-green algae at five sites within the bay. The recommended sampling regime includes the following parameters: total phosphorus, orthophosphate, nitrate-ammonia, total Kjeldahl-nitrogen, chlorophyll-a, silica, Secchi depth, pH, dissolved oxygen, temperature, and blue-green algae.
- Calculate the TSI for Secchi depth, chlorophyll-a, and total phosphorus on an annual basis and graph these results to compare with previous years. Such an index allows for the classification of nutrient enrichment or eutrophication of a lake over time.
- Provide TSI data online for public access.

7.4.2 Secondary Recommendation

If funding for water-quality monitoring in Monona Bay will not support the primary recommendation, our secondary recommendation is provided to guide a minimum level of monitoring. At a minimum, the following water-quality parameters are recommended for monitoring at the same frequency and for the same sites as begun in 2005 by the City of Madison in the bay (collection from the triangles may be omitted if resources are limited):

- total phosphorus,
- chlorophyll-a,
- Secchi depth,
- pH,
- dissolved oxygen, and
- temperature.

7.5 Education and Outreach Recommendations

Education and outreach can improve the way stakeholders use and view the bay, creating behavioral changes that improve bay conditions as well as creating motivation for public support of projects to enhance the bay.

7.5.1 Current Activities

The FOMB, the Dane County Lakes and Watershed Commission, and the WDNR support and sponsor valuable education and outreach activities. We recommend that these actions continue:

- Citizen Lake Monitoring Network Water Quality Monitoring,

- Cleanup days, and
- Internet-based education.

7.5.2 Future Activities

We developed recommendations for additional or expanded education and outreach activities by evaluating opportunities identified in the assessment of bay conditions and the results from our public survey. The WDNR, the Dane County Lakes and Watershed Commission, the FOMB, local residents and business owners, and the City of Madison have been active participants in creating and engaging in educational activities in the bay watershed. The following additional or expanded education and outreach activities would complement these existing efforts and continue to improve conditions in the bay:

- brochure and fact sheet distribution,
- rain garden and NatureMapping Workshops,
- formation of partnership with the City and posting ecologically focused informational signs around the bay and watershed-identification signs around the watershed,
- adding more trash receptacles in the watershed and modifying existing ones for increased usage,
- adding waterway markers identifying slow-no-wake and other zones, and
- continuing to expand collaboration between and among local Friends groups.

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APPENDIX 1. SOURCE LOADING AND MANAGEMENT MODEL

Table A1-1 contains the land-use and source-area information used in the Source Loading and Management Model (SLAMM). The land-use areas for each outfall basin were collected from the Dane County Community Analysis and Planning Land-Use Inventory; rooftop areas data for all buildings but single-family homes were collected from the Dane County Community Analysis and Planning Building Footprint Database.

Table A1-1. SLAMM input table 1.

	Parr St	Emerald St	BP West	BP Pavilion	N Triangle 2	N Triangle 1	BP North	Drake St	Erin St	Lowell St	South Shore	South Triangle
Total area	29.00	13.40	26.90	605.10	191.50	82.39	38.83	5.45	27.78	37.35	34.57	8.76
transportation	7.40	2.10	4.40	176.40	68.00	18.39	11.06	2.81	8.44	6.45	8.33	2.39
residential/low	6.90	8.60	12.50	164.70	14.60	10.17	8.18	1.80	7.36	30.22	16.25	5.47
rooftops	1.10	1.38	2.00	26.35	2.34	1.63	1.31	0.29	1.18	4.84	2.60	0.88
walkways	0.28	0.34	0.50	6.59	0.58	0.41	0.33	0.07	0.29	1.21	0.65	0.22
parking	0.50	0.62	0.90	11.86	1.05	0.73	0.59	0.13	0.53	2.18	1.17	0.39
driveway	0.33	0.41	0.60	7.91	0.70	0.49	0.39	0.09	0.35	1.45	0.78	0.26
landscaped	4.69	5.93	8.63	113.64	10.07	7.02	5.64	1.24	5.08	20.85	11.21	3.77
right of way	2.36	1.60	2.44	67.77	8.04	2.92	3.26	1.92	3.21	6.31	5.16	2.05
street	1.28	0.86	1.32	36.60	4.34	1.58	1.76	1.03	1.73	3.41	2.79	1.11
s/w	0.43	0.29	0.44	12.20	1.45	0.53	0.59	0.34	0.58	1.14	0.93	0.37
landscaped	0.64	0.43	0.66	18.30	2.17	0.79	0.88	0.52	0.87	1.70	1.39	0.55
Residential/hi	3.90	0.80	2.70	71.70	45.10	24.81	4.06	0.14	0.59	0.00	8.06	0.71
rooftops	1.90	0.22	0.30	22.08	21.50	3.42	1.15	0.08	0.21	0.00	1.34	0.08
walkways	0.10	0.03	0.12	2.48	1.18	1.07	0.15	0.00	0.02	0.00	0.34	0.03
parking	0.72	0.21	0.86	17.86	8.50	7.70	1.05	0.02	0.14	0.00	2.42	0.23
driveway	0.48	0.14	0.58	11.91	5.66	5.13	0.70	0.01	0.09	0.00	1.61	0.15
landscaped	0.70	0.20	0.84	17.37	8.26	7.49	1.02	0.02	0.13	0.00	2.35	0.22
right of way	1.34	0.15	0.53	29.50	24.83	7.13	1.62	0.15	0.26	0.00	2.56	0.27
street	0.80	0.09	0.32	17.70	14.90	4.28	0.97	0.09	0.15	0.00	1.54	0.16
s/w	0.27	0.03	0.11	5.90	4.97	1.43	0.32	0.03	0.05	0.00	0.51	0.05
landscaped	0.27	0.03	0.11	5.90	4.97	1.43	0.32	0.03	0.05	0.00	0.51	0.05
commercial	7.00	1.90	4.80	47.90	36.20	15.77	2.58	0.66	11.16	0.68	0.32	0.19
rooftops	1.80	0.18	1.00	17.31	20.47	5.84	0.66	0.24	7.01	0.00	0.16	0.11
walkways	0.26	0.09	0.19	1.53	0.79	0.50	0.10	0.02	0.21	0.03	0.01	0.00
parking	2.55	0.84	1.86	14.99	7.71	4.87	0.94	0.21	2.03	0.33	0.08	0.04
driveway	1.09	0.36	0.80	6.42	3.30	2.09	0.40	0.09	0.87	0.14	0.03	0.02
landscaped	1.30	0.43	0.95	7.65	3.93	2.48	0.48	0.11	1.04	0.17	0.04	0.02
right of way	2.40	0.35	0.94	19.71	19.93	4.53	1.03	0.70	4.87	0.14	0.10	0.07
street	1.68	0.25	0.66	13.80	13.95	3.17	0.72	0.49	3.41	0.10	0.07	0.05
s/w	0.48	0.07	0.19	3.94	3.99	0.91	0.21	0.14	0.97	0.03	0.02	0.01
landscaped	0.24	0.04	0.09	1.97	1.99	0.45	0.10	0.07	0.49	0.01	0.01	0.01

An analysis of Lowell Street was used to determine percentages per acre of land use for all other source areas (sidewalks, street area, driveways, landscaped area). Within ArcGIS, polygons were drawn around each source, and the total area of that source was determined. Then the total source area was divided by the particular land-use area. For example, all the single family residential walkways in Lowell Street add up to 1.12 acres, approximately 4 percent of the total single family residential acreage. It is assumed that approximately 4 percent of all single family residential acreage in the other outfall basins would be walkways. A similar method was used to determine the percentages of street, sidewalk, and landscaped area in the right of way.

Table A1-1. Continued.

	Parr St.	Emerald St	BP West	BP Pavilion	N Triangle 2	N Triangle 1	BP North	Drake St	Erin St	Lowell St	South Shore	South Triangle
Total area	29.00	13.40	26.90	605.10	191.50	82.39	38.83	5.45	27.78	37.35	34.57	8.76
transportation	7.40	2.10	4.40	176.40	68.00	18.39	11.06	2.81	8.44	6.45	8.33	2.39
institutional	0.10	0.00	2.20	127.70	24.60	12.68	0.00	0.00	0.00	0.00	0.00	0.00
rooftops	0.00	0.00	0.64	52.99	15.51	0.50	0.00	0.00	0.00	0.00	0.00	0.00
walkways	0.01	0.00	0.12	5.98	0.73	0.97	0.00	0.00	0.00	0.00	0.00	0.00
parking	0.04	0.00	0.55	26.15	3.18	4.26	0.00	0.00	0.00	0.00	0.00	0.00
driveway	0.02	0.00	0.23	11.21	1.36	1.83	0.00	0.00	0.00	0.00	0.00	0.00
landscaped	0.04	0.00	0.66	31.38	3.82	5.12	0.00	0.00	0.00	0.00	0.00	0.00
right of way	0.03	0.00	0.43	52.55	13.54	3.64	0.00	0.00	0.00	0.00	0.00	0.00
street	0.02	0.00	0.30	36.78	9.48	2.55	0.00	0.00	0.00	0.00	0.00	0.00
s/w	0.01	0.00	0.09	10.51	2.71	0.73	0.00	0.00	0.00	0.00	0.00	0.00
landscaped	0.00	0.00	0.04	5.25	1.35	0.36	0.00	0.00	0.00	0.00	0.00	0.00
industrial	2.00	0.00	0.00	6.90	0.00	8.57	0.00	0.00	0.00	0.00	0.00	0.00
rooftops	1.61	0.00	0.00	1.44	0.00	2.89	0.00	0.00	0.00	0.00	0.00	0.00
walkways	0.02	0.00	0.00	0.27	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00
parking	0.19	0.00	0.00	2.68	0.00	2.78	0.00	0.00	0.00	0.00	0.00	0.00
driveway	0.08	0.00	0.00	1.15	0.00	1.19	0.00	0.00	0.00	0.00	0.00	0.00
landscaped	0.10	0.00	0.00	1.37	0.00	1.42	0.00	0.00	0.00	0.00	0.00	0.00
right of way	0.69	0.00	0.00	2.84	0.00	2.46	0.00	0.00	0.00	0.00	0.00	0.00
street	0.48	0.00	0.00	1.99	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00
s/w	0.14	0.00	0.00	0.57	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00
landscaped	0.07	0.00	0.00	0.28	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
park	0.00	0.00	0.00	9.30	0.00	0.00	11.08	0.00	0.24	0.00	1.61	0.00
walkways	0.00	0.00	0.00	0.80	0.00	0.00	1.108	0.00	0.02	0.00	0.16	0.00
parking	0.00	0.00	0.00	0.90	0.00	0.00	0.55	0.00	0.01	0.00	0.08	0.00
landscaped	0.00	0.00	0.00	0.00	0.00	0.00	9.41	0.00	0.21	0.00	1.36	0.00
right of way	0.00	0.00	0.00	0.00	0.00	0.00	4.41	0.00	0.10	0.00	0.51	0.00
street	0.00	0.00	0.00	2.80	0.00	0.00	2.64	0.00	0.06	0.00	0.30	0.00
s/w	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.02	0.00	0.10	0.00
landscaped	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.02	0.00	0.10	0.00

APPENDIX 2. WATER-QUALITY SAMPLING RESULTS

Table A2-1. Results of water-quality sampling, 2005.

Secchi (ft)	6/8/05	6/22/05	7/6/05	7/27/05	8/17/05	9/7/05	9/22/05	10/4/05	10/19/05
10 (N.Tri)	NA	NA	3.7	4.3	4.3	4.1	3.5	4.9	4.3
11 (S.Tri)	NA	NA	3.4	5.6	2.7	3.7	4.3	4.4	3.5
12 (Bay)	NA	NA	4	3	2.3	2.2	2.1	2.2	2.9
13 (Bay)	NA	NA	6	5.5	3.2	2.8	2.4	2	2.8
14 (Bay)	NA	NA	5.9	8	2.6	2.2	1.9	1.6	3.1
15 (Bay)	NA	NA	4.7	3.5	2.3	3.1	2.4	1.8	3
16 (Bay)	NA	NA	5.5	6	2.5	2.7	2.3	1.7	3.4

Phosphorus (mg/L)	6/8/05	6/22/05	7/6/05	7/27/05	8/17/05	9/7/05	9/22/05	10/4/05	10/19/05
10 (N.Tri)	NA	NA	NA	8.73	8.85	8.61	8.52	8.24	8.36
11 (S.Tri)	NA	NA	NA	9.14	9.09	9.04	8.62	8.48	8.42
12 (Bay)	NA	NA	NA	NA	9.26	9.23	8.84	8.9	8.54
13 (Bay)	NA	NA	NA	NA	9.44	9.38	9.05	9.17	8.57
14 (Bay)	NA	NA	NA	9.45	9.2	9.41	9.12	9.19	8.54
15 (Bay)	NA	NA	NA	9.44	9.72	9.72	9.15	9.22	8.84
16 (Bay)	NA	NA	NA	9.59	9.55	9.62	9.09	9.19	8.52

Chlorophyll-a (g/L)	6/8/05	6/22/05	7/6/05	7/27/05	8/17/05	9/7/05	9/22/05	10/4/05	10/19/05
10 (N.Tri)	0.34	1.9	3.4	2.34	2.45	3	2.1	2.26	0.342
11 (S.Tri)	0.4	2.2	2.9	2.58	2.51	2.44	2.19	1.88	1.63
12 (Bay)	0.24	2.9	4.3	2.64	3.33	2.16	2.19	1.87	1.93
13 (Bay)	0.2	ND	1.4	1.62	1.95	2.61	1.78	1.28	1.34
14 (Bay)	0.29	ND	2.3	1.77	2	2.6	2.03	1.31	1.53
15 (Bay)	0.32	1.6	1.8	1.21	2.37	0.78	0.476	0.62	0.947
16 (Bay)	0.08	2.7	1.9	1.71	2.1	1.85	0.67	0.712	0.959

Ortho-phosphorus (mg/L)	6/8/05	6/22/05	7/6/05	7/27/05	8/17/05	9/7/05	9/22/05	10/4/05	10/19/05
10 (N.Tri)	0.078	0.16	<0.15	0.05	0.039	0.043	0.048	0.048	0.069
11 (S.Tri)	0.072	<0.15	<0.15	0.054	0.054	0.048	0.034	0.046	0.053
12 (Bay)	0.089	0.26	<0.15	0.143	0.101	0.086	0.086	0.078	0.059
13 (Bay)	0.077	<0.15	<0.15	0.062	0.074	0.067	0.064	0.074	0.071
14 (Bay)	0.089	0.18	0.15	0.057	0.054	0.079	0.086	0.102	0.068
15 (Bay)	0.188	0.17	<0.15	0.086	0.115	0.082	0.073	0.086	0.076
16 (Bay)	0.065	0.17	<0.15	0.053	0.081	0.082	0.086	0.098	0.065

Table A2-1. *Continued.*

Nitrogen-Nitrate (mg/L)	**6/8/05**	**6/22/05**	**7/6/05**	**7/27/05**	**8/17/05**	**9/7/05**	**9/22/05**	**10/4/05**	**10/19/05**
10 (N.Tri)	ND	—	<0.15	0.003	0.003	ND	ND	0.007	0.004
11 (S.Tri)	ND	—	<0.15	0.003	ND	ND	ND	ND	ND
12 (Bay)	ND	—	<0.15	0.003	0.003	ND	ND	ND	ND
13 (Bay)	ND	—	<0.15	0.003	ND	ND	ND	ND	ND
14 (Bay)	ND	—	<0.15	0.007	0.003	ND	ND	ND	ND
15 (Bay)	ND	—	<0.15	0.009	0.002	ND	ND	ND	ND
16 (Bay)	ND	—	<0.15	0.009	0.003	ND	ND	ND	ND

Nitrogen-Ammonia (mg/L)	**6/8/05**	**6/22/05**	**7/6/05**	**7/27/05**	**8/17/05**	**9/7/05**	**9/22/05**	**10/4/05**	**10/19/05**
10 (N.Tri)	ND	<0.061	<0.061	0.021	0.89	0.87	ND	ND	ND
11 (S.Tri)	ND	<0.061	<0.061	ND	1.07	1.07	ND	ND	ND
12 (Bay)	ND	<0.061	<0.061	0.08	1.57	1.52	ND	ND	0.071
13 (Bay)	ND	<0.061	<0.061	ND	1.26	1.3	ND	ND	ND
14 (Bay)	ND	<0.061	<0.061	ND	1.22	1.51	ND	ND	ND
15 (Bay)	ND	<0.061	<0.061	ND	1.65	1.65	ND	ND	ND
16 (Bay)	ND	<0.061	<0.061	ND	1.43	1.62	ND	ND	ND

Nitrogen-Kjeldahl (mg/L)	**6/8/05**	**6/22/05**	**7/6/05**	**7/27/05**	**8/17/05**	**9/7/05**	**9/22/05**	**10/4/05**	**10/19/05**
10 (N.Tri)	1.12	0.74	1.4	0.82	ND	ND	0.88	0.82	0.99
11 (S.Tri)	1.05	0.88	0.97	0.76	ND	ND	0.82	0.84	1.07
12 (Bay)	1.27	0.92	1.1	1.76	ND	ND	1.36	1.37	1.23
13 (Bay)	1.05	0.68	1.5	0.77	ND	ND	1.19	1.41	1.29
14 (Bay)	1.22	0.71	1.1	0.73	ND	ND	1.47	1.72	1.4
15 (Bay)	1.54	0.62	1.5	1.08	ND	ND	1.31	1.49	1.45
16 (Bay)	0.98	0.65	1	0.79	ND	ND	1.49	1.89	1.27

pH	**6/8/05**	**6/22/05**	**7/6/05**	**7/27/05**	**8/17/05**	**9/7/05**	**9/22/05**	**10/4/05**	**10/19/05**
10 (N.Tri)	ND	< 0.20	< 0.20	ND	ND	ND	ND	0.079	0.016
11 (S.Tri)	ND	< 0.20	< 0.20	ND	ND	ND	ND	ND	ND
12 (Bay)	ND	< 0.20	< 0.20	0.126	ND	ND	ND	ND	ND
13 (Bay)	ND	< 0.20	< 0.20	ND	ND	ND	ND	ND	0.038
14 (Bay)	ND	< 0.20	< 0.20	0.031	ND	ND	ND	ND	ND
15 (Bay)	ND	< 0.20	< 0.20	ND	0.017	ND	ND	ND	ND
16 (Bay)	ND	< 0.20	< 0.20	ND	ND	ND	ND	ND	0.021

Silica (mg/L)	**6/8/05**	**6/22/05**	**7/6/05**	**7/27/05**	**8/17/05**	**9/7/05**	**9/22/05**	**10/4/05**	**10/19/05**
10 (N.Tri)	15.7	11	17	23.7	17.2	17.3	17.7	15.2	32
11 (S.Tri)	10	7.4	16	18.9	21.3	23.2	7.94	15.4	18.6
12 (Bay)	19.3	12	17	87.4	45.5	38.2	24.3	23	25.8
13 (Bay)	8.5	4.2	3.6	20.8	30.8	30.4	21.6	17.6	19.8
14 (Bay)	24	1.5	7.5	14.3	23.3	41.7	24.8	21.7	17.7
15 (Bay)	20.2	2.6	2.5	24.9	41.3	32.6	21.8	16.6	19.6
16 (Bay)	8	1.9	4.2	40.6	36.3	34	20.2	18.7	17.9

Table A2-2. Results of water-quality sampling, 2006.

Secchi (ft)	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
10 (N.Tri)	5.5	5.2	7	6.4	9.6	3.7	4.2	4.2	2.4
11 (S.Tri)	5	6	7.7	7.3	10	2.9	2.4	2.1	2.2
12 (Bay)	5	5	7.8	5.8	7.2	1.7	1.9	2.1	2.2
13 (Bay)	6.5	5.5	6.5	6	7.3	2.1	1.9	2.3	2.1
14 (Bay)	7	5.9	5.7	11.5	14	2.1	2	1.8	2.3
15 (Bay)	4.5	5.5	5.3	5.4	7	2.1	1.9	2.1	2.2
16 (Bay)	5.5	4.5	6.3	6.5	6.5	2	1.9	1.9	2.2

Phosphorus (mg/L)	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
10 (N.Tri)	0.052	0.066	0.033	0.043	0.054	0.062	0.049	0.07	0.086
11 (S.Tri)	0.037	0.063	0.059	0.058	0.051	0.062	0.076	0.085	0.063
12 (Bay)	0.032	0.081	0.051	0.041	0.053	0.129	0.148	0.081	0.078
13 (Bay)	0.034	0.079	0.043	0.073	0.038	0.114	0.101	0.08	0.08
14 (Bay)	0.035	0.063	0.05	0.036	0.041	0.096	0.097	0.092	0.06
15 (Bay)	0.081	0.079	0.034	0.036	0.039	0.092	0.109	0.086	0.081
16 (Bay)	0.086	0.069	0.045	0.039	0.051	0.106	0.094	0.099	0.059

Chlorophyll-a (g/L)	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
10 (N.Tri)	19.2	9.15	4.55	14.7	19.3	24.7	15.1	19.9	28
11 (S.Tri)	12.5	8.5	12.1	13.7	21.2	32	24.9	17.9	18.7
12 (Bay)	14.2	11.6	5.74	4.83	11.5	49.6	26.8	17	17.4
13 (Bay)	13.7	9.68	6.42	19.1	8.23	47.4	18.8	18.6	19.3
14 (Bay)	6.59	7.39	6.39	5.52	11.3	45.1	24.7	20.2	13.7
15 (Bay)	22.6	25.4	4.18	7.14	9.4	48.3	31.5	15.2	17.1
16 (Bay)	19.8	7.95	8.47	4.78	12.9	51.5	23.4	14.2	15.4

Ortho-phosphorus (mg/L)	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
10 (N.Tri)	0.016	0.02	0.011	ND	ND	ND	0.003	0.02	ND
11 (S.Tri)	0.006	0.014	0.007	0.009	ND	ND	0.002	ND	ND
12 (Bay)	0.003	0.007	0.013	0.007	0.006	ND	0.004	ND	ND
13 (Bay)	0.006	0.011	0.007	0.005	0.002	ND	0.003	ND	ND
14 (Bay)	0.017	ND	0.004	0.004	ND	ND	0.003	ND	ND
15 (Bay)	0.03	0.003	0.004	ND	ND	ND	0.003	ND	ND
16 (Bay)	0.036	0.003	0.006	0.006	0.003	ND	ND	ND	ND

Nitrogen-Nitrate (mg/L)	5/31/06	6/14/06	6/28/06	7/11/06	7/26/06	8/23/06	9/6/06	9/20/06	10/4/06
10 (N.Tri)	0.037	ND	ND	ND	ND	ND	ND	ND	ND
11 (S.Tri)	ND	ND	ND	ND	ND	ND	ND	ND	ND
12 (Bay)	0.038	ND	0.091	0.032	ND	ND	ND	ND	ND
13 (Bay)	ND	ND	ND	ND	ND	ND	ND	ND	ND
14 (Bay)	ND	ND	ND	ND	ND	ND	ND	ND	ND
15 (Bay)	ND	ND	ND	ND	ND	ND	ND	ND	ND
16 (Bay)	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table A2-2. *Continued.*

Nitrogen-Ammonia (mg/L)	**5/31/06**	**6/14/06**	**6/28/06**	**7/11/06**	**7/26/06**	**8/23/06**	**9/6/06**	**9/20/06**	**10/4/06**
10 (N.Tri)	ND	ND	0.015	0.019	ND	ND	ND	0.087	ND
11 (S.Tri)	ND	ND	0.016	0.078	ND	ND	ND	ND	ND
12 (Bay)	ND	0.025	0.028	ND	0.024	ND	ND	ND	ND
13 (Bay)	ND	ND	0.023	ND	ND	ND	ND	ND	ND
14 (Bay)	ND	ND	ND	0.034	ND	ND	ND	ND	ND
15 (Bay)	ND	ND	ND	ND	ND	ND	ND	ND	ND
16 (Bay)	ND	ND	0.015	ND	0.018	ND	ND	ND	ND

Nitrogen-Kjeldahl (mg/L)	**5/31/06**	**6/14/06**	**6/28/06**	**7/11/06**	**7/26/06**	**8/23/06**	**9/6/06**	**9/20/06**	**10/4/06**
10 (N.Tri)	0.78	0.78	0.81	0.89	0.76	1.08	0.96	0.85	1.27
11 (S.Tri)	0.74	0.78	0.98	0.98	0.78	1.17	1.29	1.25	1.15
12 (Bay)	0.73	0.91	0.74	0.68	0.6	1.67	1.81	1.28	1.21
13 (Bay)	0.75	0.87	0.75	4.77	0.69	1.56	1.46	1.17	1.21
14 (Bay)	0.72	0.84	0.84	0.76	0.76	1.59	1.47	1.46	0.93
15 (Bay)	1.11	1.05	0.72	0.72	0.62	1.46	1.85	1.31	1.31
16 (Bay)	0.93	0.85	0.78	0.68	0.8	1.47	1.42	1.43	0.96

pH	**5/31/06**	**6/14/06**	**6/28/06**	**7/11/06**	**7/26/06**	**8/23/06**	**9/6/06**	**9/20/06**	**10/4/06**
10 (N.Tri)	8.71	9.26	8.97	8.44	8.61	8.82	8.51	8	8.25
11 (S.Tri)	9.11	8.97	9.12	8.74	8.7	9	8.36	8.39	8.28
12 (Bay)	9.3	9.5	9.58	8.87	8.83	9.15	8.72	8.56	8.39
13 (Bay)	9.19	9.45	9.8	8.97	9.23	8.57	8.48	8.33	8.25
14 (Bay)	9.37	9.39	9.69	9.3	9.15	9.48	9.15	8.81	8.68
15 (Bay)	9.38	9.54	9.81	9.05	8.77	9.51	9.06	8.48	8.45
16 (Bay)	9.72	9.55	9.73	9.33	9.1	9.31	8.51	8.65	8.46

Silica (mg/L)	**5/31/06**	**6/14/06**	**6/28/06**	**7/11/06**	**7/26/06**	**8/23/06**	**9/6/06**	**9/20/06**	**10/4/06**
10 (N.Tri)	0.263	0.469	0.391	1.31	1.5	1.97	2.16	2.26	0.53
11 (S.Tri)	ND	1.07	0.619	1.09	1.58	2.55	2.62	2.85	1.04
12 (Bay)	0.474	1.47	1.14	0.877	1.35	2.71	3.76	3.63	2.78
13 (Bay)	0.082	1.39	0.854	0.935	1.23	3.47	3.46	3.04	2.99
14 (Bay)	0.092	1.85	0.951	0.645	1.1	2.49	2.93	3	2.1
15 (Bay)	0.464	1.82	0.1	0.476	1.91	1.79	2.91	3.92	2.29
16 (Bay)	0.129	1.75	1.52	0.542	1.78	2.98	3.2	3.31	2.58

APPENDIX 3. SEDIMENT RESULTS

Table A3-1. Trace metal and nutrient results for three cores from Monona Bay: core A (offshore the Brittingham Park outfall), Ccore B (middle of Monona Bay), core C (southwest corner of Monona Bay). (Source: 2006 WRM Workshop)

Sample number	Depth cm	Hg mg/kg	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	S mg/kg	Zn mg/kg	B mg/kg	Mn mg/kg	Fe mg/kg	Cu mg/kg	Al mg/kg	Na mg/kg	Pb mg/kg	As mg/kg	Ti mg/kg	Solids %
A2-4	3	0.417	870	1609	188815	15817	9575	362	9	489	12466	138	9226	497	241	32	272	17.76
A8-10	9	0.456	864	1601	187012	16172	10612	377	10	460	12806	146	9439	424	255	37	246	23.08
A14-16	15	0.495	815	1574	197706	16652	7457	389	8	497	12875	158	9574	357	271	37	249	29.07
A18-20	19	—	718	1383	205795	15568	7204	358	19	487	12201	148	8605	398	263	45	230	31.76
A24-26	25	0.049	628	344	263994	12804	3508	32	13	435	3778	28	2106	502	22	19	81	32.47
B2-4	3	0.305	833	2050	91395	37489	4227	518	15	381	14769	132	12270	386	224	6	328	38.46
B10-12	11	—	784	1956	102128	37441	3930	566	15	393	15477	156	11966	395	321	8	311	40.87
B18-20	19	0.545	818	2050	122659	34786	4072	638	21	470	17356	178	12739	564	430	19	333	37.65
B28-30	29	—	1033	1946	118335	30949	3808	759	20	567	21910	196	13158	393	735	31	373	38.52
B36-38	37	0.653	1202	2236	125988	27700	3973	802	19	491	22464	220	14788	392	760	35	397	36.96
B44-46	45	—	1115	2459	116592	23662	4535	607	23	429	18527	227	16424	362	623	68	380	40.16
B52-54	53	—	1014	2121	93870	21289	4536	534	19	369	17647	215	14534	311	536	84	357	47.06
B58-60	59	—	840	2069	133136	15181	5061	506	12	403	15644	416	13918	351	402	61	370	39.60
B62-64	63	—	445	139	274046	4701	7565	10	15	469	6040	14	749	450	4	24	26	30.49
B74-76	75	—	388	171	236594	4635	9239	19	20	378	6546	17	960	379	4	14	25	29.27
C2-4	3	0.357	845	1613	155269	22942	8373	352	20	432	11959	117	9288	461	247	17	274	16.11
C12-14	13	0.409	739	1633	156079	24352	5971	399	18	439	12411	141	9902	387	320	30	327	28.13
C24-26	25	0.849	1003	2574	154797	18039	6600	470	13	463	15961	416	16090	359	398	110	413	30.39
C34-36	35	—	765	1920	155597	16792	4686	319	8	438	11830	536	11940	288	198	103	326	35.56
C38-40	39	—	227	548	60306	11122	1501	68	0	170	3794	127	3284	150	27	50	127	68.91

Table A3-2. Polycyclic aromatic hydrocarbon results (in mg/kg) for cores A, B, and C from Monona Bay.

	Sample number	**A0-2**	**A6-8**	**A12-14**	**A26-28**	**B0-2**	**B16-18**	**B34-36**	**C0-2**	**C10-12**	**C22-24**
PAH	**Depth (cm)**	**1**	**7**	**13**	**27**	**1**	**17**	**35**	**1**	**11**	**23**
1-Methylnaphthalene		< 39	< 37	< 30	< 22	42	24	65	<40	<26	< 21
2-Methylnaphthalene		< 40	< 38	< 31	< 23	63	37	110	<41	< 26	24
Acenaphthene		< 38	< 36	< 30	< 22	80	40	130	<39	< 25	39
Acenaphthylene		< 37	65	< 29	< 21	48	35	91	<38	< 24	45
Anthracene		< 46	160	71	< 26	310	170	470	<47	48	160
Benzo(a)anthracene		180	590	280	< 39	1500	630	1500	230	250	720
Benzo(a)pyrene		240	1000	390	< 21	2200	930	2000	270	330	1100
Benzo(b)fluoranthene		270	1300	510	< 21	3300	1100	2400	300	360	1500
Benzo(ghi)perylene		180	430	180	< 26	880	370	670	200	200	640
Benzo(k)fluoranthene		270	1300	550	< 22	2400	1100	2100	300	390	1100
Chrysene		250	970	410	< 32	2600	960	2000	290	340	1200
Dibenz(a,h)anthracene		< 35	130	46	< 20	350	130	270	36	51	240
Fluoranthene		330	1200	530	27	4900	1700	4100	400	460	1800
Fluorene		< 44	42	< 34	< 25	120	67	170	<45	< 29	65
Indeno(1,2,3-cd)pyrene		160	440	180	< 18	860	360	660	180	190	630
Naphthalene		< 51	< 49	< 40	< 29	64	49	95	< 53	< 34	36
Phenanthrene		130	390	200	< 22	1900	720	1800	160	170	590
Pyrene		360	1200	520	22	4500	1500	3600	420	500	1600
Total PAH*		2370	9217	3867	49	26117	9922	22231	2786	3289	11489

Table A3-3. Polychlorinated biphenyl results for cores A, B, and C from Monona Bay.

Sample	**Depth**	**Aroclor 1016**	**Aroclor 1221**	**Aroclor 1232**	**Aroclor 1242**	**Aroclor 1248**	**Aroclor 1254**	**Aroclor 1260**
number	(cm)	(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)	(µg/kg)
A4-6	5	< 130	< 130	< 130	< 130	< 130	< 130	< 130
A10-12	11	< 120	< 120	< 120	< 120	< 120	< 120	< 120
A16-18	17	< 83	< 83	< 83	< 83	< 83	89	< 83
A28-30	29	< 74	< 74	< 74	< 74	< 74	< 74	< 74
B4-6	5	< 68	< 68	< 68	< 68	< 68	150	91
B20-22	21	< 57	< 57	< 57	< 57	< 57	290	120
B38-40	39	< 120	< 120	< 120	< 120	< 120	520	310
C4-6	5	< 120	< 120	< 120	< 120	< 120	< 120	< 120
C14-16	15	< 83	< 83	< 83	< 83	< 83	150	85
C26-28	27	< 74	< 74	< 74	< 74	< 74	250	< 74

APPENDIX 4. PLANTS

Aquatic plants found in Monona Bay

Reprinted with permission from Borman, Susan, Korth, Robert, and Temte, Jo, 1997, Through the Looking Glass: A Field Guide to Aquatic Plants: *Wisconsin Lakes Partnership, 248 p.*

Eurasian water milfoil *Myriophyllum spicatum*

Exotic, invasive species.

This is a submerged plant with reddish-brown to whitish-pink stems. Stems are branching and spaghetti-like. This plant is limp when removed from the water. Plants can grow very tall, and frequently form dense surface mats. It's turbidity tolerant, grows very rapidly, and shades out other native plants. Leaves are soft, feather-like, and arranged in whorls of 4 around the stem. Each leaflet has 12 to 21 pairs of needle-like leaflets (usually more than 14). Eurasian water milfoil over winters green and begins to actively grow in early spring. In mid-summer small reddish follower spikes emerge just above the water's surface. The flower spike has whorls of flowers in the axils of short bracts. It can reproduce by seeds, but less effectively than by vegetative means. In late summer and fall the plant will self-fragment. These fragments can disperse over a great distance and start new plants. Eurasian water milfoil is readily dispersed to new locations by motor boats and trailers. Eurasian water milfoil does not produce winter buds or tubers. Waterfowl graze on fruit and foliage to a limited extent. The beds provide habitat for aquatic insects, and cover and foraging opportunities for fish.

Photo by: Elizabeth J. Czarapata. Photo from: WDNR Invasive Species Program Website: http://www.dnr.state.wi.us/invasives/photos/index.asp?SF=Common

Curly Leaf Pondweed *Potamogeton crispus*

Exotic, invasive species.

This submergent plant that has distinctive wavy or lasagna noodle-like leaves. In the spring, curly leaf pondweed can become very thick. It's a cold water specialist, one of the first plants to grow in the spring. This pondweed produces winter foliage even under the ice. It dies back around July. This mid-summer dieback can increase phosphorus concentrations in the water as it decays. This atypical release of nutrients during the height of the growing season can then lead to an increase in algae growth. Curly leaf pondweed can also form surface mats that interfere with water recreation. It can usually be found in soft substrates, and is turbidity tolerant. Its seeds and turions (vegetative over-wintering buds) are considered poor waterfowl food. The plant beds provide habitat for aquatic insects and cover and foraging opportunities for fish.

Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants: http://aquat1.ifas.ufl.edu/photos.html

Sago Pondweed *Stuckenia pectinata*
(alternately known as *Potamogeton pectinatus)*
Native species.

Sago Pondweed is a submersed aquatic plant that can be recognized by its very thin, needle-like leaves and a bushy appearance. Its leaves resemble pine needles, ending in a sharp point. Each branch is forked several times into a spreading, fan-like arrangement. Its little flowers and fruit are arranged in small whorls that are slightly spaced apart on the stalk— making it look like beads on a string. Sago is widespread in lakes and streams. It grows in a wide range of sediment types and water quality conditions. It can tolerate high turbidity, salinity, pH, and alkalinity. It can be found in areas with poor water quality conditions. Sago Pondweed is considered one of the top food producers for waterfowl. Both the fruit and tubers are heavily grazed and are critical for a variety of migrating waterfowl. Sago also provides food and shelter young trout and many other juvenile fish.

Photo: Wisconsin State Herbarium www.botany.wisc.edu/herbarium
Photographer: Robert W. Freckmann, University of Wisconsin-Stevens Point

Elodea, Common waterweed *Elodea Canadensis*
Native species.

This is a very common, submersed perennial plant in Wisconsin waters. Its green leaves grow in whorls of 3 or sometime 2. The whorls are more crowded towards the stem tips (but they look more leafy than the spiny whorls of coontail). The branching stems can form tangled mats, which can become dense and create a nuisance. It's usually found in soft substrate, and is turbidity tolerant. Elodea provides cover for fish, as well as aquatic insects and small crustaceans. Muskrats and waterfowl feed on the plant itself or the many invertebrates that live on the plant.

Photo: Wisconsin State Herbarium www.botany.wisc.edu/herbarium
Photographer: Dennis W. Woodland, Andrews University

Water stargrass *Zosterella dubia*
*(*alternately known as *Heteranthera dubia)*
Native species.

Water stargrass has slender, freely branched stems. Its narrow, alternate leaves attach directly to the stem with no leaf stalk. This plant is often confused for a pondweed, but can be easily separated from the group by its lack of a prominent midvein. Stargrass also has bright yellow, star-shaped flowers that bloom at the waters surface in summer and fall. This submersed plant can be found in a range of water depths, from shallow to several meters deep. It can grow in a wide range of sediment types and will tolerate reduced water clarity. The leaves of water stargrass are an important food source for waterfowl. This plant also offers good cover and foraging opportunities for fish.

Photo: Wisconsin State Herbarium: www.botany.wisc.edu/herbarium
Photographer: Robert W. Freckmann, University of Wisconsin-Stevens Point

Coontail *Ceratophyllum demersum*

Native species.

Coontail is one of the most common plants in Wisconsin lakes. It has stiff, plastic-like, spiny leaves arranged in whorls around the stem. The whorls are more crowded at the tip of the plant, so it resembles a raccoon's tail. It will stay stiff and plastic-like when removed from the water. It's rootless, but has modified leaves to anchor itself to the bottom sediment. It's usually found in soft substrates and is turbidity tolerant. Coontail is one of the few submersed plant species that gets its nutrients from the water column, rather than from the sediments. Coontail's ability to draw nutrients from the water has lead to some creative uses of this plant in pond management. Permeable containers of coontail are placed in ponds to reduce phosphorus levels in the water, which keeps algae at bay. Tolerance to cold water and low light conditions allow it to over winter as an evergreen plant. Coontail is important cover for fish, insects, and other aquatic life— especially during winter. Many types of waterfowl eat coontail foliage and fruits.

Photo: Wisconsin State Herbarium www.botany.wisc.edu/herbarium
Photographers: Robert W. Freckmann, University of Wisconsin-Stevens Point (in water)
Dennis W. Woodland, Andrews University (close up).

Muskgrass *Chara spp*.

Native species.

Although often confused for an aquatic plant, chara is actually a submersed alga. It's considered a pioneering plant— often the first to come in after a major disturbance such as a lake drawdown. Chara is beneficial in its ability to slow the movement and suspension of sediments. It is also known as muskgrass due to its distinct musky or skunky odor. Another identifying feature of chara is its rough, grainy texture due to calcium carbonate deposits on its surface. It has a hollow stem. It is a valuable food source for many species of ducks and provides cover for fish. It also supports many aquatic insects.

Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants: http://aquat1.ifas.ufl.edu/photos.html

Leafy Pondweed *Potamogeton foliosus*
Native species.

This is a grassy-looking pondweed. It has a slender stem that, along with its leaves, is completely submerged. The leaf tip usually tapers to a point. There are 3 - 5 veins with a midvein. Leafy pondweed blooms early in the season, with a short flower stalk and tight cluster of tiny flowers. This plant can form dense stands. Leafy pondweed is turbidity tolerant, and can be found in shallow waters and in soft substrate. Leafy pondweed provides good fish habitat. It's also an important food source for waterfowl and muskrats.

Photo: Kay Yatskievych. Discover Life: http://www.discoverlife.org

Small Pondweed *Potamogeton pusillus*
Native species.

Small pondweed is also a grassy-looking pondweed. It's a thin, branching plant with a flattened stem. It can be hard to distinguish from leafy pondweed. Small pondweed has a pair of glands at the leaf nodes (base of leaf attachment) that need to be seen with a field glass or microscope. Small pondweed's flowers are also different: its flowers have a longer, slender stalk and spaced whorls of flowers. It is a submersed plant, common in slow flowing waters, and is widespread in the Northern Hemisphere. This plant is an excellent source of food for waterfowl, and provides habitat for fish and wildlife.

Photo: US Army Corps of Engineers, Research and Development Center, Environmental Lab. Aquatic Plant Information System: http://el.erdc.usace.army.mil/aqua/apis/

Stiff water crowfoot *Ranunculus aquatilis*
Native species.

Water crowfoot is also known as white water crowfoot, or white water buttercup. It's in the buttercup family— its white, 5-petaled flowers indeed look like little buttercups. The flowers appear in early summer, emerging above the water's surface. This plant has long branching stems. Leaves emerge along the stems in an alternate arrangement and are stiff. They remain stiff when removed from the water. Stiff water crowfoot's leaves are divided into threadlike divisions, tight against the stem (they have almost no leaf stalk). It shows no turbidity preference. It usually grows in slow, calcareous water, and can be found over a moderate range of alkalinity, pH, and conductivity. Water Crowfoot provides a good habitat for invertebrates and fish. It is also a good food source for many kinds of waterfowl.

Photos: Wisconsin State Herbarium www.botany.wisc.edu/herbarium
Photographer: Robert R. Kowal, University of Wisconsin–Madison (flowers); Robert W. Freckmann, University of Wisconsin-Stevens Point (stem and leaves)

Wild celery *Vallisneria americana Michx.*
Native species.

Wild celery is a submersed plant with ribbon-like leaves that emerge in clusters at the base of the plant. The leaves have a cellophane-like consistency and a prominent central stripe. The leaves are up to 2 meters long and 3-10 mm wide. Wild celery is found throughout Wisconsin. It's found in water from ankle-deep to several meters. This plant is turbidity tolerant and can handle a wide range of water chemistries. Wild celery is a premiere food for waterfowl. It's a critical food source for migrating canvasback ducks. Muskrats also eat it. All portions of this plant are eaten including the tubers, rhizomes, fruit, and leaves. Wild celery beds are also good fish habitat providing shade, cover, and foraging opportunities.

Photo: Wisconsin State Herbarium www.botany.wisc.edu/herbarium
Photographer: Robert H. Read, Wisconsin Dept. of Natural Resources

Aquatic Plant Identification Resources

The aquatic plant description summaries are from the book, *Through the Looking Glass: A Field Guide to Aquatic* Plants, by Susan Borman, Robert Korth, and Jo Temte (Wisconsin Lakes Partnership, 1997, 248 p.). This book is a great reference for identifying aquatic plants and understanding their value in lakes. Learn more about it here: http://www.uwsp.edu/cnr/uwexlakes/publications/TLGDescription.asp

The following Web sites are also excellent aquatic plant identification resources:

University of Wisconsin–Madison Herbarium Website: http://www.botany.wisc.edu/herbarium/

University of Florida, Center for Aquatic and Invasive Plants Web site: http://aquat1.ifas.ufl.edu/welcome.html

APPENDIX 5. AQUATIC PLANT SAMPLING

Aquatic Plant Sampling Protocol

The sampling method used is a point-intercept approach. This is a quantitative survey conducted at predetermined sampling locations distributed evenly in a grid over the lake surface. The WDNR staff set up the points and grid resolution based upon the shape of the lake and size of the littoral zone (UW–Extension and Wisconsin Department of Natural Resources, 2006). The same 332-point grid and corresponding GPS coordinates are used each year. An evenly spaced distribution of points provides a better overview of the entire lake's aquatic plant community than transects. The grid sampling design is easy to replicate in the field using a GPS unit. It is also easy to preserve and present the spatial information with GIS technology.

The WDNR recommends this protocol on all Wisconsin's lakes for baseline sampling of aquatic plants to provide a consistent way of comparing year-to-year data within a lake and comparing data among lakes. Groups using state money (e.g., lake planning, protection, or aquatic invasive species grants) must follow this protocol (UW-Extension Lakes Program and Wisconsin Department of Natural Resources, 2006). If the WDNR protocol is consistently followed over time, better trends data will be built for Monona Bay's aquatic plant community. Future variation in the sampling data can then be more confidently attributed to actual differences in the aquatic plant community, instead of confounding variables caused by using different sampling techniques.

Aquatic plant data were collected using a rake sampler according to the WDNR protocol. The rake sampler is made of two metal garden rake heads welded together, measuring 13.8 in. (35 cm) long with 14 teeth on each side. The handle is 8 ft (2.4 m) long, and includes a telescoping extension that gives a total handle length (from tip of rake head to fully extended end) of 15 ft (4.6 m) (UW-Extension Lakes Program and WDNR. 2006). One rake sample was collected at each point by tossing the rake over the side of a motorboat and dragging the rake along the bottom for approximately 2.5 ft (0.75 m). Rake fullness ratings were recorded for plant species present: 1 = few, 2 = moderate, 3 = abundant. The rake fullness ratings reflect density of each plant species. Species that are observed within 6 ft (2 m) of the boat, but not present in the rake sample were recorded as a visual observation on the field sheets.

The WDNR generally recommends that baseline sampling be conducted between early July and mid August. Sampling within this timeframe captures species diversity and frequency (UW-Extension Lakes Program and Wisconsin Department of Natural Resources, 2006). However, changes in plant biomass often occur throughout the growing season, making this a difficult parameter to effectively capture. Curly leaf pondweed in particular creates a problem for sampling because its growth is often diminished by July 4. The WDNR highly recommends that additional aquatic plant surveys be done to evaluate specific management activities (such as herbicide treatments), to address specific species of concern, or to assess other unique factors that may important in understanding the lake's ecology (UW-Extension Lakes Program and Wisconsin Department of Natural Resources, 2006).

To learn more about Wisconsin's aquatic plant sampling protocol, visit the Web sites <http://www.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp> and <http://www.dnr.state.wi.us/org/water/fhp/lakes/aquaplan.htm>.

Biomass Weights

Aquatic plant species vary tremendously in the amount of biomass they produce. The June 2006 WRM Practicum survey also recorded biomass weights of each species found at 24 random points. This was done to better describe what the rake fullness ratings mean by providing a more tangible number—weight in grams. The 24 points were randomly chosen from the 332-point sampling grid for Monona Bay and the two triangles.

At each of these points, after rake fullness ratings were recorded for each species, the plant mass collected on the rake head was separated by species, including filamentous algae. Each species was placed in a separate container. Excess water was wrung out, and the weight for each species was recorded on the boat using a field scale. The field scale was not sensitive below 10.0 grams. At 10 of the 24 biomass weight points, after the wet wrung weights were taken in the field, plants were bagged up to record dry weights. Dry weights were obtained by placing the plant samples for each collected point in a standard lab drying oven at approximately 60° C until dry. Dry weights were then recorded using a standard electronic balance scale to provide a dry weight comparison to the wet wrung biomass weights taken in the field.

Reference

University of Wisconsin–Extension and Wisconsin Department of Natural Resources. 2006. Aquatic Plant Management in Wisconsin. Guidance dated March 16, 2006.

APPENDIX 6. PLANT STATISTICS

Individual species statistics for the Monona Bay aquatic plant surveys in 2005 and 2006

Table A6-1. Individual species statistics for the Monona Bay aquatic plant survey in 2005[1] (Sources: Genesis Bichanich, City of Madison, 2006; 2006 Water Resources Management Practicum).

	Eurasian water milfoil [2] *Myriophyllum spicatum*	Curly leaf pondweed *Potamogeton crispus*	Coontail *Ceratophyllum demersum*	Chara, *Chara* spp.	Elodea *Elodea Canadensis*	Water star-grass *Heteranthera dubia*	Leafy pondweed *Potamogeton foliosus*	Sago pondweed *Stuckenia pectinata L.*
Frequency of occurrence within vegetated areas (%)	59.08	2.64	99.01	0.33	0.33	1.32	0.33	1.65
Frequency of occurrence at sites shallower than maximum depth of plants	55.42	2.48	92.88	0.31	0.31	1.24	0.31	1.55
Relative frequency (%)	35.9	1.6	60.1	0.2	0.2	0.8	0.2	1.0
Number of sites where species found	179	8	300	1	1	4	1	5
Average rake fullness (density)	1	1	NA[3]	NA	NA	NA	NA	NA

[1] Survey dates: July 29 and August 30, 2005. Points 166–337 were surveyed on 7/29/05. Points 1-165 were surveyed on August 30, 2005. The 2005 survey was conducted by City of Madison Engineering Department and WDNR Research staff.

[2] The 2005 survey protocol only required rake fullness ratings for Wisconsin's two aquatic invasive species, Eurasian water milfoil and curly leaf pondweed. All other aquatic plants observed during the survey were recorded as present with "1" on the field data entry worksheets. Filamentous algae was not recorded in 2005. The 2006 survey protocol required rake fullness ratings for all aquatic plant species, plus filamentous algae.

[3] Not applicable

Table A6-2. Individual species statistics for the Monona Bay aquatic plant survey in June 2006[1] (Source: 2006 Water Resources Management Practicum).

	Eurasian water milfoil *Myriophyllum spicatum*	Curly leaf pondweed *Potamogeton crispus*	Coontail *Ceratophyllum demersum*	Elodea *Elodea Canadensis*	Water star-grass *Heteranthera dubia*	Leafy pondweed *Potamogeton foliosus*	Small pondweed *Potamogeton pusillus*	Stiff water crowfoot *Ranunculus aquatilis*	Sago pondweed *Stuckenia pectinata L.*	Filamentous algae [2]
Frequency of occurrence within vegetated areas (%)	81.54	35.38	96.62	0.62	0.92	2.15	0.31	1.85	1.85	73.54
Frequency of occurrence at sites shallower than maximum depth of plants	81.29	35.28	96.32	0.61	0.92	2.15	0.31	1.84	1.84	73.31
Relative frequency (%)	36.9	16.0	43.7	0.3	0.4	1.0	0.1	0.8	0.8	NA [2]
Number of sites where species found	265	115	314	2	3	7	1	6	6	239
Average rake fullness (density)	2	1	2	2	1	1	1	1	1	1
Number of visual sightings	18	55	0	0	0	2	0	1	4	28

[1] Survey dates: June 23–24 and 29–30, 2006.

[2] The 2006 survey protocol required rake fullness ratings for all aquatic plant species and filamentous algae. Filamentous algae is not included in the relative frequency statistics.

Table A6-3. Individual species statistics for the Monona Bay aquatic plant survey in 2006[1] (Source: 2006 Water Resources Management Practicum).

	Eurasian water milfoil *Myriophyllum spicatum*	Coontail *Ceratophyllum demersum*	Leafy pondweed *Potamogeton foliosus*	Sago pondweed *Stuckenia pectinata L.*	Wild celery *Vallisneria americana*	Filamentous algae [2]
Frequency of occurrence within vegetated areas (%)	73.86	96.73	0.98	0	0.33	28.10
Frequency of occurrence at sites shallower than maximum depth of plants	69.11	90.52	0.92	0	0.31	26.30
Relative frequency (%)	43.0	56.3	0.6	0	0.2	NA [2]
Number of sites where species found	226	296	3	0	1	86
Average rake fullness (density)	1	2	1	0	1	1
Number of visual sightings	25	13	2	2	1	67

[1] Survey dates: August 17–18 and 20–21, 2006. Survey conducted by City of Madison Engineering Department and 2006 WRM Practicum.

[2] The 2006 survey protocol required rake fullness ratings for all aquatic plant species and filamentous algae. Filamentous algae is not included in the relative frequency statistics.

[3] Not applicable

APPENDIX 7. STAKEHOLDER SURVEY

Dear Neighbor,

Water Resources Management graduate students from the UW are currently working to develop a management plan to improve the quality of Monona Bay. We are gathering information and opinions from users of the Bay to help us with the process. Only a small number of those who utilize and/or live near Monona Bay will receive this survey, so it is very important that you take the time to complete and return it promptly. The information that you provide will be extremely helpful to us in determining prioritized management activities for Monona Bay and it is very possible that the information you provide us will be implemented into a management strategy that will be enforced by the City of Madison.

In this survey, we are interested in learning about your recreational uses of Monona Bay, your perceptions about water quality, and your support of Monona Bay improvement activities. Participation in the survey is voluntary, and all of the information you provide will be kept confidential unless you indicate otherwise by providing your contact information for the Friends of Monona Bay citizen group. The information gathered will only be reported in aggregate form, and your name will never be used in any report that includes survey results.

The entire survey is 7 pages in length, and should take about 15 minutes to complete. We would like the survey to be filled out by **any willing adult**. Please feel free to use the last page to include any additional comments or concerns you may have.

A business reply envelope has been enclosed for your convenience. Please return the survey to us upon completion. Thank you for your time and assistance. If you have any questions, feel free to contact Caitlin Scopel, a Water Resources Management student at the UW, at coscopel@wisc.edu, or (608)-265-3402.

Sincerely,

Alison Coulson   Michelle Washebek   Caitlin Scopel

University of Wisconsin-Madison Water Resources Management graduate students

Monona Bay Survey

Monona Bay Usage

1. When did you first start using Monona Bay for recreational purposes?
*Please enter the **year** in the space below.*

____

2. How has the overall quality of Monona Bay changed since your first exposure to the Bay?
Please circle one response.

Greatly Decreased　Decreased　No Change　Improved　Greatly Improved　Don't Know

3. In the past 12 months, have you participated in any of the following activities at Monona Bay or Brittingham Park? *Please circle one response, and if you answer Yes, please enter the number of times you have engaged in each activity in the space provided.*

			If Yes, how many times
A. Fishing	No	Yes	________
B. Ice fishing	No	Yes	________
C. Boating (motor/pontoon)	No	Yes	________
D. Canoeing/Kayaking/Rowing	No	Yes	________
E. Cross country skiing	No	Yes	________
F. Sailing/Windsurfing	No	Yes	________
G. Picnicking	No	Yes	________
H. Water skiing/Tubing	No	Yes	________
I. Swimming	No	Yes	________
J. Jet skiing	No	Yes	________
K. Ice skating	No	Yes	________
L. Viewing wildlife	No	Yes	________
M. Scenic enjoyment	No	Yes	________
N. Ice hockey	No	Yes	________
O. Photography	No	Yes	________
P. Biking	No	Yes	________
Q. Walking/Running	No	Yes	________
R. Other: __________	No	Yes	________

4. Of the above activities, which *three* are most important to you? *Please enter the letter of selected choices in the spaces below.*

1.____________　2. ____________　3. ____________

Monona Bay Quality

1. How would you describe the overall water quality of Monona Bay? *Please circle one.*

Degraded	Poor	Fair	Good	Not Degraded (Excellent Natural Condition)

2. To the best of your knowledge, how would you rate the following occurrences in Monona Bay?
Please circle one number for each lettered item.

Occurrence	Not a Problem	Minor Problem	Problem	Major Problem
A. Algal blooms	1	2	3	4
B. Excessive aquatic plants	1	2	3	4
C. Sedimentation (sediment washing in Bay)	1	2	3	4
D. Erosion of banks	1	2	3	4
E. Water clarity	1	2	3	4
F. Fish kills	1	2	3	4
G. Unusual water color or smell	1	2	3	4
H. Exotic aquatic plant species	1	2	3	4
I. Too much boat traffic	1	2	3	4
J. Too much noise	1	2	3	4
K. Trash in the water and along shoreline	1	2	3	4
L. Safety	1	2	3	4
M. Goose droppings	1	2	3	4
N. Beach closings due to high bacteria counts (e.coli)	1	2	3	4

3. In your opinion, which of the following factors pose a threat to water quality in Monona Bay?
Please circle one number for each lettered item.

Item	Not a Cause	Minor Cause	Cause	Major Cause
A. Soil erosion from residential areas, construction sites, and shorelines	1	2	3	4
B. Animal waste from residential areas (e.g. pets, geese, etc.)	1	2	3	4
C. Fertilizers and pesticides from residential areas	1	2	3	4
D. Stormwater runoff from house roofs, driveways, and residential land	1	2	3	4
E. Stormwater runoff from streets, highways, and/or parking lots (e.g. road salt, automotive oils, gasoline)	1	2	3	4
F. Yard or grass clippings and/or leaves entering storm sewers	1	2	3	4
G. Displacement of natural shoreline vegetation by lawns	1	2	3	4
H. Discharge and waste from factories and/or businesses (e.g. from oil and grease spills)	1	2	3	4
I. Introduction of non-native plant and/or animal species	1	2	3	4
J. Motor boat pollution	1	2	3	4
K. Trash from stormwater outlets	1	2	3	4
L. Historical pollution trapped in Bay sediments	1	2	3	4

4. Of the items listed above (question 3, Quality section), which one do you feel contributes <u>most</u> to water quality problems in Monona Bay and why? *Please enter the letter of selected choice and a brief explanation in the space below.*

____________ Most important. Why?____

____

____

Management of Monona Bay

1. In your opinion, how would the following lake management activities affect your recreational use(s) of Monona Bay? *Please circle one number for each lettered item.*

		Increase Use	No Change	Decrease Use	Don't Know
A.	Cutting aquatic plants (plant harvesting within the Bay)	1	2	3	4
B.	Non-point source pollution control (e.g. buffer strips of natural vegetation)	1	2	3	4
C.	Dredging	1	2	3	4
D.	Stocking sport fish	1	2	3	4
E.	Stormwater sediment filters	1	2	3	4
F.	Shoreline restoration	1	2	3	4
G.	Education programs on yard care	1	2	3	4
H.	Solar Bees (water circulation systems)	1	2	3	4
I.	Stormwater management practices on your own home (eg. Rain barrels, rain gardens)	1	2	3	4
J.	Trash removal	1	2	3	4
K.	Chemical treatment of aquatic plants	1	2	3	4
L.	Other ______________________________	1	2	3	4

2. Which management activities would you be willing to support financially?
Please circle the letter of all that apply.

A. Cutting aquatic plants (plant harvesting within the Bay)
B. Non-point source pollution control (e.g. buffer strips of natural vegetation)
C. Dredging
D. Stocking sport fish
E. Stormwater sediment and trash filters
F. Shoreland restoration with native plants
G. Education programs on yard care
H. Solar Bees (water circulation systems)
I. Stormwater management practices on your own home (e.g. rain barrels)
J. Trash removal
K. More street sweeping to decrease leaves and sediment entering the Bay
L. Chemical treatments of aquatic plants
M. Other ____

3. Would you like to see restrictions on any of the following activities? *Please circle one response, and if you answer Yes please provide a brief explanation in the space provided.*

			If Yes, Why?
A. Fishing	No	Yes	___
B. Ice fishing	No	Yes	___
C. Boating (motor/pontoon)	No	Yes	___
D. Canoeing/Kayaking/Rowing	No	Yes	___
E. Cross country skiing	No	Yes	___
F. Sailing/Windsurfing	No	Yes	___
G. Picnicking	No	Yes	___
H. Water skiing/Tubing	No	Yes	___
I. Swimming	No	Yes	___
J. Jet skiing	No	Yes	___
K. Ice skating	No	Yes	___
L. Viewing wildlife	No	Yes	___
N. Ice hockey	No	Yes	___
P. Biking	No	Yes	___
Q. Walking/Running	No	Yes	___
R. Other: ___________	No	Yes	___

4. Do other user groups inhibit your enjoyment and/or use of Monona Bay? *Please circle one response.*

No

Yes → **If yes, What users and Why?** *Please identify the type of user(s) and a brief explanation in the space below.*

____

____

5. According to local scientists, there are five core management strategies that could affect Monona Bay. Please rank the strategies and outcomes listed below according to how comfortable you are with each (1=most comfortable, 5=least comfortable). *Please enter a number from 1-5 next to each strategy.*

____	Natural Biological Control : Milfoil weevils, native insects that live in and eat *only* the invasive Eurasian Water Milfoil, have been successful at controlling this nuisance plant that dominates Monona Bay, ***but*** they must be stocked in large numbers and require dense shoreline vegetation to survive over the winter.
____	Intensive Harvesting : Keeps aquatic plants at more tolerable levels, ***but*** will also decrease the potential for natural biological control.
____	Chemical Treatments : Kills aquatic plants or ceases aquatic plant growth ***with*** the risk of killing desirable plants and organisms and could potentially turn the Bay into a system with dense algae, cloudy water, and no aquatic plants.
____	Dredging : Removes nutrient rich sediment, deepens the Bay and might increase the amount of native aquatic plants, reducing the amount of unwanted milfoil, ***but*** disturbs contaminated sediment which could potentially turn the Bay into a system with dense algae, cloudy water, and no aquatic plants. Studies have shown dredging to be the most economically costly strategy.
____	No changes : Continue current management practices : County mechanically harvests aquatic plants at locations where they are at nuisance levels.

Information about Yourself

1. Which of the following educational opportunities about lake management activities would interest you? *Please circle all letters that apply.*

A. Paper Newsletters
B. Digital Newsletters
C. Volunteer programs
D. Speakers
E. Workshops
F. Websites
G. Fact sheets
H. Radio programs
I. Television programs
J. Neighborhood demonstration s
K. Brochures
L. Videos

2. Would you be interested in attending education/action meetings or participating in events to improve the quality of Monona Bay (i.e. Earth Day, Stake in the Lakes, monthly cleanups, etc.)? *Please circle one response.*

No
Yes → If willing, please provide your contact information:

Name______________________ Street address___________________________

Phone______________________Email address___________________________

3. Are you aware of the citizen's group Friends of Monona Bay? *Please circle one response.*

No
Yes

4. Do you reside in the Monona Bay watershed (Vilas, Regent, Capitol, Bay Creek, Bayview, or Greenbush neighborhoods)? *Please circle one response.*

No → Done with the survey. Thank you for your time!

Yes → Please proceed to next question.

5. Were you aware that activities on your property directly affect the quality of Monona Bay? *Please circle one response.*

No
Yes

6. **There are specific actions that all residents can do to reduce the amount of pollutants, sediments, and trash entering surface water bodies. Which of the following activities are you willing to do on your property or along the Bay?** *Please circle one number for each lettered item.*

		Already Do	Willing To Do	Unwilling To Do	Not Sure
A.	Keep leaves and yard wastes off street curbs	1	2	3	4
B.	Perform a soil test before deciding to apply fertilizers	1	2	3	4
C.	Apply fertilizers and pesticides only once per year	1	2	3	4
D.	Stop using chemical fertilzers and pesticides on your lawn	1	2	3	4
E.	Modify roof gutters, downspouts, or landscaping at your home (e.g. rain gardens) to divert rain water away from roads, sidewalks, and driveways to allow natural infiltration	1	2	3	4
F.	Clean up pet waste promptly	1	2	3	4
G.	Attend public meetings on how to protect water quality	1	2	3	4
H.	Obey laws against dumping of pollutants (oil, gas, etc) into streets	1	2	3	4
I.	Use compostable leaf bags for leaf collection	1	2	3	4
J.	Restrict the use of salt on sidewalks or use sand or salt alternatives	1	2	3	4
K.	Clean up trash along the shoreline	1	2	3	4
L.	Use permeable materials to construct patios, walkways and driveways	1	2	3	4
M.	Keep sprinkler water off sidewalks and streets	1	2	3	4
N.	Adopt a stormwater inlet to monitor and remove trash and debris (e.g. sticks and leaves)	1	2	3	4
O.	Adopt a stormwater outlet to remove trash and debris after storm events	1	2	3	4
P.	Report spills from outfalls or elsewhere	1	2	3	4
Q.	Restore natural shoreline vegetation	1	2	3	4
R.	Other ___________________________________	1	2	3	4

7. **How far away do you live from the Monona Bay shoreline?** *Please circle one.*

On the shore On Brittingham Park Within ¼ mile ¼ mile to 1 mile 1 mile to 2 miles Greater than 2 miles

8. **Do you own, rent or lease property on the West Shore or South Shore of Monona Bay?** *Please circle one.*

No ⟶ Done with the survey. Thank you for your time!
Yes ⟶ Please proceed to next question.

9. **If it could be shown that restoring natural vegetation would help improve water quality and help control the exotic aquatic vegetation (Eurasian Water Milfoil) *and* other Bay property owners were willing to restore their shoreline to natural vegetation, how willing would you be to restore your own shoreline?** *Please circle one.*

1	2	3	4
Not Willing	Somewhat willing	Very willing	Already restored

10. What activities do you practice on your own property to affect the quality of Monona Bay? (e.g. removing weeds from water, altering shoreline, applying herbicides to shoreline weeds)

____

____

____

____

11. Is there anything else related to the quality or management of Monona Bay that you would like to share?

____

____

____

Thank You!!!

If you have any questions or comments about this survey please contact Caitlin Scopel at coscopel@wisc.edu

Survey Results

Respondents were asked questions and picked from a list of choices. The percentages may not always add to 100 because not all participants answered every question and some questions allowed for more than one choice. These are the results of 188 returned surveys, although we received a few additional surveys after we compiled these results.

Questions on Monona Bay Usage

How has the overall quality of Monona Bay changed since your first exposure to the Bay?

Greatly Decreased	14%
Decreased	14%
No Change	11%
Improved	2%
Greatly Improved	1%
Don't Know	2%

In the past 12 months, have you participated in the following activities at Monona Bay or Brittingham Park?

Activity	Percent of total respondents saying 'Yes'
Fishing	28%
Ice fishing	10%
Boating (motor/pontoon)	29%
Canoeing/Kayaking/Rowing	32%
Cross country skiing	11%
Sailing/Windsurfing	1%
Picnicking	34%
Water skiing/Tubing	15%
Swimming	26%
Jet skiing	3%
Ice skating	22%
Viewing wildlife	69%
Scenic enjoyment	80%
Ice hockey	7%
Photography	28%
Biking	63%
Walking/Running	72%

Questions on Monona Bay Quality

How would you describe the overall water quality of Monona Bay?

Degraded	27%
Poor	47%
Fair	18%
Good	4%
Not Degraded (Excellent Natural Condition)	0%

To the best of your knowledge, how would you rate the following occurrences in Monona Bay?

Occurrence	Not a Problem	Minor Problem	Problem	Major Problem
Algal blooms	3%	15%	32%	45%
Excessive aquatic plants	3%	3%	20%	70%
Sedimentation (sediment washing in Bay)	5%	22%	35%	27%
Erosion of banks	27%	39%	19%	9%
Water clarity	7%	20%	38%	32%
Fish kills	19%	33%	23%	10%
Unusual water color or smell	6%	24%	37%	28%
Exotic aquatic plant species	12%	15%	17%	38%
Too much boat traffic	52%	28%	10%	4%
Too much noise	56%	29%	7%	3%
Trash in the water and on shore	4%	34%	24%	36%
Safety	45%	29%	13%	6%
Goose droppings	12%	30%	30%	24%
Beach closings due to high bacteria (e coli)	13%	25%	35%	18%

In your opinion, which of the following factors pose a threat to water quality in Monona Bay?

Factor	Not a Cause	Minor Cause	Cause	Major Cause
Soil erosion from residential areas, construction sites, and shorelines	10%	37%	30%	18%
Animal waste from residential areas (e.g. pets, geese, etc.)	10%	43%	29%	15%
Fertilizers and pesticides from residential areas	6%	13%	37%	38%
Stormwater runoff from house roofs, driveways, and residential land	6%	27%	37%	26%
Stormwater runoff from streets, highways, and/or parking lots (e.g. road salt, automotive oils, gasoline)	3%	15%	38%	40%

Yard or grass clippings and/or leaves entering storm sewers	12%	27%	40%	18%
Displacement of natural shoreline vegetation by lawns	27%	35%	24%	11%
Discharge and waste from factories and/or businesses (e.g. from oil and grease spills)	24%	37%	22%	9%
Introduction of non-native plants and/or animals	14%	21%	28%	26%
Motor boat pollution	22%	45%	23%	6%
Trash from stormwater outlets	7%	30%	38%	20%
Historical pollution trapped in Bay sediments	9%	34%	29%	18%

Of the items listed above, which one do you feel contributes most to water quality problems in Monona Bay?

Soil erosion from residential areas, construction sites, and shorelines	5%
Animal waste from residential areas (e.g. pets, geese, etc.)	7%
Fertilizers and pesticides from residential areas	27%
Stormwater runoff from house roofs, driveways, and residential land	10%
Stormwater runoff from streets, highways, and/or parking lots (e.g. road salt, automotive oils, gasoline)	18%
Yard or grass clippings and/or leaves entering storm sewers	3%
Displacement of natural shoreline vegetation by lawns	3%
Discharge and waste from factories and/or businesses (e.g. from oil and grease spills)	2%
Introduction of non-native plants and/or animals	15%
Motor boat pollution	3%
Trash from stormwater outlets	6%
Historical pollution trapped in Bay sediments	3%

<u>Questions on the Management of Monona Bay</u>

In your opinion, how would the following lake management activities affect your recreational use(s) of Monona Bay?

Activity	Increase Use	No Change	Decrease Use	Don't Know
Cutting aquatic plants (plant harvesting within the Bay)	64%	26%	3%	7%
Non-point source pollution control (e.g. buffer strips of natural vegetation)	44%	35%	2%	24%
Dredging	38%	31%	5%	24%
Stocking sport fish	20%	63%	5%	13%

Stormwater sediment filters	56%	27%	1%	16%
Shoreline restoration	49%	38%	2%	12%
Education programs on yard care	38%	49%	0%	14%
Solar Bees (water circulation systems)	26%	37%	6%	36%
Stormwater management practices on your own home (eg. Rain barrels, rain gardens)	35%	48%	0%	18%
Trash removal	74%	18%	0%	6%
Chemical treatment of aquatic plants	39%	19%	18%	26%

Which management activities would you be willing to support financially?

Cutting aquatic plants (plant harvesting within the Bay)	13%
Non-point source pollution control (e.g. buffer strips of natural vegetation)	9%
Dredging	8%
Stocking sport fish	3%
Stormwater sediment and trash filters	12%
Shoreland restoration with native plants	9%
Education programs on yard care	7%
SolarBees (water circulation systems)	5%
Stormwater management practices on your own home (e.g. rain barrels)	7%
Trash removal	11%
More street sweeping to decrease leaves and sediment entering the Bay	9%
Chemical treatments of aquatic plants	8%

Would you like to see restrictions on any of the following activities? (Percent saying YES)

Fishing	7%
Ice fishing	12%
Boating (motor/pontoon)	34%
Canoeing/Kayaking/Rowing	1%
Cross country skiing	1%
Sailing/Windsurfing	1%
Picnicking	1%
Water skiing/Tubing	30%
Swimming	3%
Jet skiing	51%
Ice skating	2%
Viewing wildlife	1%
Ice hockey	1%
Biking	0%
Walking/Running	1%

Please rank the strategies and outcomes listed below according to how comfortable you are with each (1=most comfortable, 5=least comfortable).

Strategy	1 (Most Comfortable)	2	3	4	5 (Least Comfortable)
Natural Biological Control	48%	16%	13%	9%	4%
Intensive Harvesting	19%	27%	28%	12%	4%
Chemical Treatments	6%	11%	16%	14%	43%
Dredging	19%	10%	17%	24%	22%
No Change	5%	16%	20%	14%	33%

Questions about the respondents

Which of the following educational opportunities about lake management activities would interest you?

Paper Newsletters	46%
Digital Newsletters	38%
Volunteer programs	32%
Speakers	22%
Workshops	21%
Websites	46%
Fact sheets	45%
Radio programs	24%
TV programs	29%
Neighborhood demonstration	33%
Brochures	24%
Videos	10%

Are you aware of the citizen's group Friends of Monona Bay?

59% of all respondents said YES
65% of watershed residents said YES
69% of people residing on or across the street from the Bay said YES

Were you aware that activities on your property directly affect the quality of Monona Bay? (Answered by those living in the watershed.)

88% said YES

Which of the following activities are you willing to do on your property or along the Bay?

Activity	Already Do	Willing To Do	Not Willing To Do	Not Sure
Keep leaves and yard wastes off street curbs	88%	9%	3%	1%
Perform a soil test before deciding to apply fertilizers	20%	49%	9%	21%
Apply fertilizers and pesticides only once per year	52%	33%	7%	8%
Stop using chemical fertilizers and pesticides on your lawn	55%	24%	10%	11%
Modify roof gutters, downspouts, or landscaping at your home (e.g. rain gardens) to divert rain water away from roads, sidewalks, and driveways to allow natural infiltration	39%	41%	8%	12%
Clean up pet waste promptly	78%	16%	2%	4%
Attend public meetings on how to protect water quality	16%	52%	20%	12%
Obey laws against dumping of pollutants (oil, gas, etc) into streets	94%	5%	1%	1%
Use compostable leaf bags for leaf collection	39%	53%	3%	6%
Restrict the use of salt on sidewalks or use sand or salt alternatives	71%	22%	4%	3%
Clean up trash along the shoreline	56%	29%	10%	6%
Use permeable materials to construct patios, walkways and driveways	32%	42%	8%	18%
Keep sprinkler water off sidewalks and streets	70%	22%	5%	4%
Adopt a stormwater inlet to monitor and remove trash and debris (e.g. sticks and leaves)	13%	50%	6%	31%
Adopt a stormwater outlet to remove trash and debris after storm events	9%	46%	11%	34%
Report spills from outfalls or elsewhere	20%	63%	3%	14%
Restore natural shoreline vegetation	8%	60%	10%	22%

How far away do you live from the Monona Bay shoreline? (Answered by those living in the watershed.)

On the shore	31%
On Brittingham Park	15%
Within ¼ mile	41%
¼ mile to 1 mile	9%
1 mile to 2 miles	2%
Greater than 2 miles	2%

If it could be shown that restoring natural vegetation would help improve water quality and help control the exotic aquatic vegetation (Eurasian water milfoil) and other Bay property owners were willing to restore their shoreline to natural vegetation, how willing would you be to restore your own shoreline? (Answered by those living on or across the street from the bay.)

Not Willing	10%
Somewhat Willing	32%
Very Willing	57%
Already Restored	2%

APPENDIX 8. FACT SHEET

On the Water's Edge

Stormwater runoff carries silt and sediment that may be nutrient rich, and, when released into Monona Bay, could bury fish-spawning beds as well as fill in the areas near your pier. This could increase nearby plant and algae growth. A lawn mowed to the shoreline edge provides no buffer for the stormwater, providing fertilizers, pet waste, and lawn clippings a clear avenue to flow into the lake where they can fuel algae blooms. According to Wisconsin Department of Natural Resources research, mowed shorelines can release seven times the amount of phosphorus and 18 times the amount of sediment than properties with natural shorelines. Switching from manicured lawns to no-mow zones of native sedges and grasses, shrubs, and ground cover not only provides a buffer for polluted stormwater, but also creates new habitat for wildlife and requires less maintenance.

Vehicle Maintenance

By maintaining your car properly, you can prevent oil leaks that result in heavy metals and toxic materials traveling from your car, onto the street, and eventually our waterways. Be certain that engine fluids are never dumped into gutters or on the street because they will end up in our lakes. Make sure to recycle your used motor oil. The following local businesses in the Monona Bay watershed will take your used motor oil free of charge:

Hansen's Auto Service Center
1405 South Park Street
Telephone: 608/256.0713

Jensen Auto, Inc.
1233 Regent Street
Telephone: 608/257.9201

Valvoline Instant Oil Change
939 South Park Street
Telephone: 608/251.7959

How you wash your car can also affect our waterways. Taking your car to a car wash is the easiest way to ensure that water containing pollutants, such as oils and grease, phosphates (from the soap), and heavy metals, does not end up in our lakes. Most car washes reuse water several times before sending it to a sewage-treatment plant. If you prefer to wash your car at home, use soap sparingly, and park your car on gravel, grass, or another permeable surface while washing, so the ground can filter the water naturally.

Lawn and Garden Care

Remember that lawn fertilizers, pesticides, and herbicides can be washed into our Madison lakes through the stormsewers on a rainy day. These chemicals can kill the critters in the lakes that serve as fish food as well as cause algae blooms and even fish kills. Many homeowners do not need to treat their lawns at all. In a survey done by the Center for Watershed Protection, only 20 to 40 percent of homeowners who treat their lawns need to. Performing a soil test will tell you whether you need to use these products, and at a price of only $15, it may save you a lot of money on lawn treatment in the future! Soil tests can be done right here in Madison. For details on how to sample your soil, visit the Web site: <http://uwlab.soils.wisc.edu/madison/>

Or contact:

UW Soil and Plant Analysis Laboratory
5711 Mineral Point Road
Madison, Wisconsin 53705
Telephone: 608/262.4364

Pet Waste

When animal waste is left on the ground, rainwater or melting snow washes it down our storm drains or directly into our local lakes. This is a problem because some pet waste contains disease causing bacteria and animal waste can act like a fertilizer, promoting aquatic plant growth that can choke waterways, promote algae blooms, and rob the water of vital oxygen. One way to avoid these problems is to pick up after your pet and throw the waste in the garbage, or flush it down the toilet where it will eventually be treated at a sewage-treatment plant.

Infiltration Test

An infiltration test measures how quickly water can soak in and flow through the soil. This will help you determine whether the soil on your property is suitable for certain types of stormwater-management measures, such as a dry well or rain garden.

Rain Barrels

A rain barrel allows you to collect the rainwater that falls on your roof, collects in the gutter, and flows down your downspout. When you've collected an adequate amount of water, simply turn the spigot on and water your garden or wash your car or bicycle. If your barrel is full, the rainwater from your roof simply bypasses the barrel and flows from your gutter as it would normally. Collected rainwater is better for plants because it's not chlorinated (like tap water) and it's mildly acidic, which helps plants take up important minerals from the soil. Rain barrels help to save energy, chemicals, and tax money spent on wastewater purification. Rain barrels may also reduce your water bill, depending on how much rainwater you collect! But remember to put a screen on your barrel to prevent mosquito breeding. One rain barrel costs about $100, including installation! Or you can do it yourself for $75.

Contact Sustain Dane: 608-819-0689 or email rainbarrel@sustaindane.org for more information.

Rain Gardens

Rain gardens are a way for homeowners as well as businesses to reduce polluted runoff, simply by planting a specialized garden made up of native plants. Rain gardens capture stormwater, allowing it to slowly filter into the ground, rather than run off into the storm sewer. A rain garden allows about 30 percent more water to soak into the ground than a conventional lawn. Rain gardens don't require much space and can be built in various shapes, making them easy to add to existing buildings. You can view existing rain gardens at Edgewood College and the Willy Street Co-op grocery store. For more information, visit the Web site: <http://www.danewaters.com/private/raingarden.aspx>

Rain Gardens Partnership
2102 Linden Avenue
Madison, Wisconsin 53704
Telephone: 608/556,0570

Dry Wells and Porous Materials

Dry wells are small, excavated pits, filled with stone or gravel that temporarily stores stormwater runoff until it soaks into the surrounding soil. The stormwater can come off the roof of your house via a downspout that either indirectly or directly connects to the dry well.

Build or renovate with porous materials. Permeable pavers look like a solid surface, but allow natural drainage and migration of water into the ground by permitting water to drain through the spaces between the pavers. Porous pavers have a surface with "holes" that can be filled with plants or gravel as desired. Porous/permeable pavers provide the same advantages as traditional concrete pavers, including resistance to heavy loads, flexibility of repair, low maintenance, exceptional durability, and high quality.

A local business that supplies these materials is:

Madison Block and Stone
5813 N. Highway 51
Madison, Wisconsin 53704
Telephone: 608/249.5633
www.madisonblockandstone.com

GLOSSARY

Benthic organisms – Plants and animals that live on the bottom of a water body.

Beta-N-methylamino-L-alanine – A neurotoxin produced by cyanobacteria.

Bioturbation – The disturbance of bottom sediments by biological activity that can suspend sediments and pollutants in the water column.

Blue-green algae – Microscopic, single-cell bacteria that are naturally present in lakes and streams in very small numbers. Blue-green algae can be very abundant in warm, shallow, undisturbed surface water that receives a lot of sunlight, where they can form blooms that discolor the water or produce a scum on the surface of the water. Some blue-green algae produce toxins that could pose a health risk to people and animals when they are exposed to them in large enough quantities. They are also known as cyanobacteria.

Catch basin – A stormwater treatment device like a cistern or vault. It is placed at the point where a street gutter discharges into a sewer, to catch solid materials, which cannot pass readily through the sewer.

Cone of depression – A conical-shape depression of the water table around a pumping well. The cone is inverted, with the top representing the maximum lowering of the water table, located at the well.

Cultural eutrophication – Enrichment of a water body with nutrients (e.g. phosphorous and nitrogen) that leads to depleted dissolved oxygen levels. It is derived from human activities and they often derive from sewage, soil erosion at construction sites, agricultural and livestock holding operations.

Cyanobacteria – Technical name for blue-green algae (see blue-green algae).

Eutrophication – The process by which a water body receives excess nutrients (e.g. phosphorous and nitrogen) that stimulate excessive plant and algal growth and leads to low dissolved oxygen levels.

Exotic species – Organisms introduced into habitats where they are not native.

Fecal coliform – Toxic bacteria associated with fecal material of warm-blooded animals.

Filamentous algae – Algae with thread-like structure that can float or attach to submerged items such as aquatic plants.

Floatables – Detritus entering Monona Bay comprised of buoyant material.

Floristic Quality Index – A system that allows for comparison of ecosystems among many sites and tracking changes at the same sites over time, using a metric of plant species diversity.

Green roof – Roofs of buildings that are partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. They are installed to reduce stormwater runoff.

Groundwater recharge - The process of precipitation infiltrating into the ground to become groundwater.

Gyttja – A nutrient-rich, organic mud consisting of plankton, other plant and animal residues. It is deposited in water in a finely divided condition.

Invasive species – Organisms introduced into habitats where they are not native and are or likely are detrimental to the environment.

Isothermic – Uniform and constant water temperature.

Lentic water bodies – Water bodies with still to low velocity currents.

Macrophyte – Large aquatic plant.

Marl – Calcium or magnesium-rich mud, derived from limestone and dolomite rocks.

Morphometry – Shape and relative elevations of the bottom of a water body.

Outfall – Subsurface, concrete pipes that discharge urban storm water into a water body.

Photic zone – Water depth where light intensity falls to 1% of that at the surface; below which photosynthesis cannot occur (i.e. aquatic plants cannot grow).

Planktonic algae – Microscopic free-floating plants that suspend in the top few feet of water of a water body where light is sufficient enough for them to photosynthesize.

Porous pavement – Pavement that allows water to infiltrate into the subsurface to reduce stormwater runoff from parking lots.

Primary producer – An organism that makes organic material from inorganic material examples include plants, phytoplankton, and some bacteria.

Rain garden – A bowl-shaped garden, designed to absorb stormwater run-off from impervious surfaces such as roofs and parking lots.

Secchi depth – A measure of water clarity that corresponds to the depth of last visibility of a Secchi disk. The rule of thumb is that light can penetrate to a depth of 1.7 times the Secchi depth, thus Secchi depth is used to calculate a water body's photic zone.

Secchi disk – A circular plate divided into quarters painted alternately black and white. The disk is lowered into the water until it is no longer visible. This depth is called Secchi depth (see Secchi depth). Higher Secchi depths mean more rope was let out before the disk disappeared from sight and indicates clearer water or deeper photic zones and the converse for lower Secchi depths.

Sediment-water interaction – The physical and chemical interactions between bottom sediments and the water column of a water body. It is a determinant of the mobilization of chemicals from bottom sediments to the water column.

Sewershed – The land area drained by a sewer network and discharging into a single source.

Simpson Diversity Index – A measure of ecological diversity. It is often used to quantify the biodiversity of a habitat by taking into account the number of species present and each species' relative abundance.

SolarBees – Floating, solar-powered, water-circulation devices that are designed to control blue-green algae blooms and heavy growth of aquatic plants (e.g. Eurasian water-milfoil).

Stable State – One of two states common to shallow lakes and is characterized by clear water, submerged vegetation, and strong communities of fish and invertebrates.

Turbid – Condition where sediments or foreign particles are stirred up or suspended, causing water to be opaque or to have low transparency.

Turions – A specialized, overwintering bud produced by some aquatic plants (e.g. curly leafed pond weed) to adapt to adverse conditions such as decreasing daylength or reducing temperatures.

Watershed – An area of land that catches precipitation and drains into a water body, including both surface and ground (see sewershed).