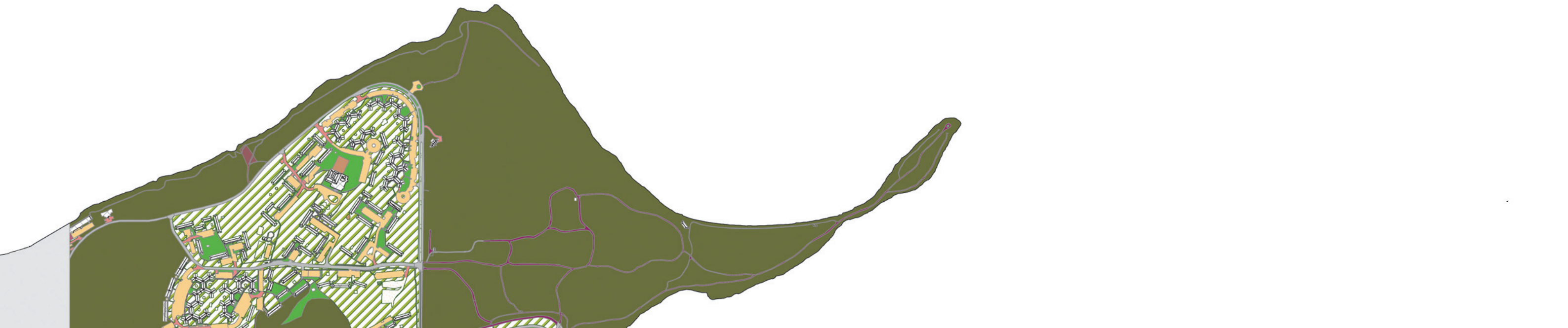
Innovating Stormwater Management on the University of Wisconsin–Madison Campus



2004

Water Resources Management Workshop 2003
Gaylord Nelson Institute for Environmental Studies
University of Wisconsin–Madison

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The Water Resources Management workshop 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.

The conclusions and recommendations are those of the graduate student authors and do not necessarily reflect the official views or policies of any of the cooperating agencies or organizations, nor does the mention of any trade names, commercial products, or companies constitute endorsement or recommendation for use.

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Preface

This report is a result of the 2003 Water Resources Management (WRM) practicum. WRM is a master's level graduate degree program within the University of Wisconsin–Madison's Gaylord Nelson Institute for Environmental Studies. The capstone of this program is a spring and summer project in which an interdisciplinary team of students and staff work with agency personnel, citizen groups, and/or private sector representatives on the analysis of a contemporary, problem-oriented water-resource issue. The practicum brings together students with diverse backgrounds and areas of specialization to work together as a team.

Funding for the 2003 workshop was provided by the Wisconsin Department of Natural Resources (DNR) under the Wisconsin Nonpoint Source Water Pollution Abatement Program, Urban Nonpoint Source and Stormwater Management Grant Program. The workshop is part of a larger project intended to improve stormwater management and reduce polluted runoff on the University's main campus. The project is under joint direction of a faculty team and Facilities Planning and Management (FPM) staff.

The goals for this project are as follows:

1. Protect and enhance the quality of Lake Mendota and other lakes, streams, groundwater, and wetlands in the Yahara Lakes Watershed.

2. Prioritize projects and problem areas for implementation of management solutions.

3. Assist the University to meet and go beyond regulatory requirements for stormwater management.

4. Establish the University as an innovator in urban stormwater management.

5. Illustrate cost-effective and straightforward solutions.

6. Suggest maintenance and monitoring opportunities in cooperation with research and education programs at the University.

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Acknowledgments

The 2003 WRM Workshop gratefully acknowledges the assistance from the following people:

Perminder Ahluwalia, Dick Baker, Jeremy Balousek, Jim Bertolacini, Gary Brown, Carolyn Betz, Barbara Borns, Quentin Carpenter, Peggy Chung, Kevin Connors, Daniel Einstein, Carol Enseki, Sue Fafard, Alan Fish, Greg Fries, Sally Hanson, John Harrington, Steve Harmon, John Harrod, Ann Hayes, Peter Heaslett, Carol Holden, Wayne Kussow, Steve Lacy, Sara Lorence, Mary Anne Lowndes, Dave Liebl, Jim Miller, John Paine, Aicardo Roa, Eric Rortvedt, Sally Rowe, Robert Scott, Gary Simonson, Tom Sinclair, Gene Turk, Chris Velie, Joy Zedler, Paul Zedler

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Executive Summary

Stormwater runoff from urban areas has been recognized as a major source of degradation to aquatic systems. It contributes to flooding and erosion of land, and to the pollution and eutrophication of waters. Recent innovations in stormwater management techniques provide ways to alleviate these effects. However, there is no single, cookbook approach to their application. Every urban area has its own physical layout, hydrologic environment, institutional structure, and set of community values. This report provides an evaluation and recommendations for stormwater management on the University of Wisconsin–Madison (UW–Madison) campus.

The UW–Madison is an ideal place to implement a comprehensive and ambitious plan. Stormwater runoff from the campus has direct and immediate effects on the Yahara Lakes, which are highly valued by local communities for their ecological, recreational, and aesthetic qualities. Moreover, the UW–Madison can strengthen its expertise and leadership in resource management by testing and demonstrating new stormwater-management practices. This forward-looking leadership will become increasingly valuable as the population of the Yahara Lakes watershed increases over the coming years, placing greater stresses on the lakes.

This report is organized into five major sections. First, we present a physical assessment of the campus landscape and stormwater infrastructure. Second, we examine the regulatory and institutional context within which stormwater management takes place, focusing particularly on regulatory changes that will impact UW–Madison's management needs. Third, we advocate the general adoption of performance-standards-based management policies by the University. Fourth, we recommend best management practices (BMPs) within several management areas, among which are construction erosion control, building design, and green area management. Finally, we examine several case studies, which are problem areas and opportunities for mitigation. We offer a plan of action for several sites, among which are the Kohl Center, Muir Woods, and Tripp Hall.

The following are some highlights of our findings and recommendations.

Our ***physical assessment*** of the campus included a detailed land use/land cover classification, a delineation of stormsewer drainage areas (sewersheds), and an estimation of stormwater runoff and pollutant loading quantities. We found that *42 percent* of the UW–Madison campus is covered by impervious surfaces such as streets, buildings, and parking lots. *Seventy-eight percent* of the campus area drains to Lake Mendota; the other *22 percent* drains to Lake Monona. The average annual runoff depth for the campus area as a whole is 0.54 feet. This runoff transports about *ninety tons of suspended solids* into the Yahara Lakes each year. Our assessment makes it clear that stormwater management on campus must include system-wide and site-specific considerations.

The ***regulatory and institutional context*** within which stormwater management takes place has undergone rapid and fundamental changes since Wisconsin's Polluted Run-off Management Rules went into effect in 2002. Despite exemptions from many of these rules, the University has strong motivations for meeting and even exceeding their standards and requirements. Progress toward this goal has been made through the UW–Madison's section of a new joint municipal stormwater-discharge permit. We recommend that the UW–Madison cultivate an integrated systems approach to storm-water management, which will include adopting performance standards and allowing off-site mitigation.

Performance standards set numerical targets for processes such as water infiltration and sediment delivery, which have direct effects on water resources. They allow flex-ibility in the choice of management technique, as long as the target process rate is met. Many of the standards in Wisconsin's NR 151 only apply to construction sites more than 1 acre in size. We recommend that the UW–Madison apply these standards to all projects, regardless of size, to mitigate the cumulative effects of many small projects. For example, sediment export from redeveloped areas must be reduced by *80 percent* as compared to no runoff controls, both during and after construction. All redevelop-ment must also infiltrate *90 percent* of predevelopment infiltration volume, on the basis of annual rainfall. Furthermore, all redevelopment must employ BMPs to make peak runoff comparable to predevelopment conditions for the 2-year, 24-hour storm event.

To ensure that this approach is carried through, the University should formally adopt the standards. The standards should be part of each project from concept through construction and should be promoted by the campus project staff during planning and design. Additionally, the University should establish a preferred BMP list, develop mechanisms for faculty awareness of campus construction projects, and clarify enforce-ment and administrative authority between various agencies and staff.

Best management practices are a group of techniques that have been found to be the most effective, practical means of reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals. They can be used not only to meet performance standards associated with redevelopment, but also to reduce the impacts of everyday activities on our water resources. We review current stormwater BMPs and make specific ***recommendations*** for their application to the UW–Madison campus. Construction-erosion control practices focus on preventing sediment loss by exposing it only when necessary, by removing it from equipment, and by covering it. Building and parking lot design practices focus on minimizing impervious area and on infiltrating stormwater on site. Green area management focuses on improving infiltra-tion capacity and preventing excessive fertilizer and pesticide use. Pedestrian facilities design focuses on adapting sidewalk and path patterns to existing traffic patterns, implementing pervious-surfaced paths, and minimizing sand and salt applications where feasible.

Our ***case studies*** include examples of specific locations on campus where various components of our recommendations could be implemented. These include infiltration practices, erosion control, soil-compaction remediation, green space maintenance, and construction-project plan review. For example, we describe how soil compaction prevents water infiltration on the lawn of the Kohl Center, and then provide remediation alternatives with associated costs and benefits for comparison.

Just months after the conclusion of our study, on October 2, 2003, the University officially agreed to a new stormwater management policy. The policy requires each new development or redevelopment project to produce no more runoff than that which would have occurred under predevelopment soil and land cover conditions. A significant aspect of the policy is that instead of exempting sites with no infiltration potential due to uncontrollable factors, such as a high water table, it will allow for compensatory mitigation elsewhere on campus. This is an example of the overall systems approach that the UW–Madison's master plan endorses and that we feel is vital to the effective management of stormwater.

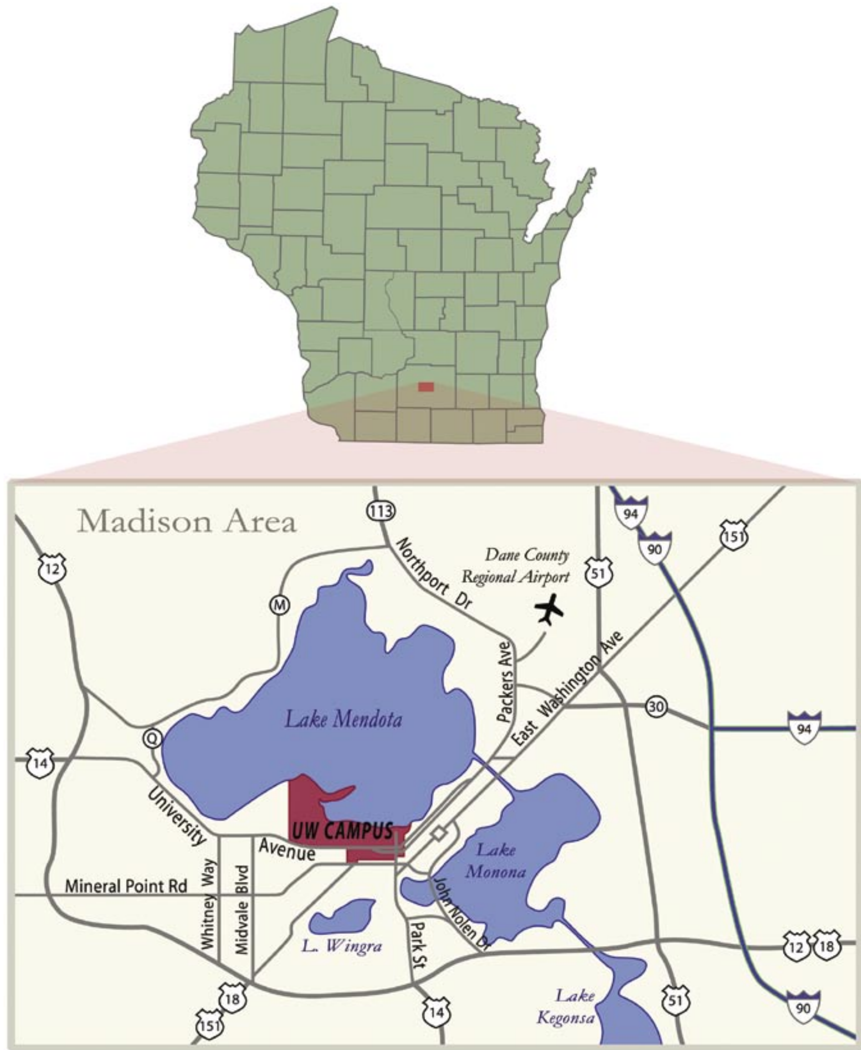

Figure 1.1. *The University of Wisconsin–Madison campus with respect to the Madison area.*

Chapter 1: Introduction

The University of Wisconsin (UW) campus in Madison lies along the shore of Lake Mendota, which, along with Lake Monona, forms the isthmus of land that is the city's downtown (Figure 1.1). Two of the University's best known features, the Memorial Union Terrace and Picnic Point, take full advantage of the natural beauty of the lake. The view of the sunset from the Terrace on a summer evening is unparalleled and certainly a fond memory for generations of UW alumni. The lakes are also a regional mecca for boaters and anglers, who can enjoy relative solitude in the midst of an urban environment. Mendota and Monona are fundamental features of Madison, and have earned a cultural status that transcends their physical attributes. Despite their value, these lakes have been degraded by agricultural activities in the watershed and by urbanization.

Lakes Mendota and Monona are part of the larger Yahara Lakes watershed, which includes Lakes Waubesa and Kegonsa. This watershed covers 325 square miles in Dane and Columbia Counties. In pre-settlement times, this area was a mix of woodland, prairie, and wetland; now it is largely agricultural, urban, and suburban. This change in land cover caused changes in the quantity and quality of stormwater runoff. Urban areas, such as the UW campus, allow much less precipitation to infiltrate the ground than do natural areas. This is due to impervious surfaces, such as streets and roofs. Water runs off impervious surfaces and eventually enters the lakes, carrying nutrients, pollutants, and sediments that degrade water quality.

Excessive stormwater runoff has caused the Yahara Lakes to become eutrophic, a state characterized by high nutrient concentrations and dense plant growth. Although lakes naturally become eutrophic as they age, excessive import of nutrients greatly accelerates the process. In the past, nutrient loading came from direct discharge of sewage effluent into Lakes Mendota and Monona (Wisconsin Department of Natural Resources, 2000). Today, the vast majority of the phosphorus entering Lake Mendota comes from the surrounding land area (Lathrop and others, 1998).

In the Yahara Lakes, this results in frequent algae blooms, especially in the summer months (Figure 1.2). The blooms interfere with boating and swimming on the lake and adversely affect the lake ecosystem. Along with nutrients, toxic substances including oils, heavy metals, and pesticides are carried to the lakes by stormwater. Pesticides are particularly toxic to fish because they bioaccumulate in the food chain. Bacteria, frequently from animal waste, are also transported in stormwater and have caused beach closings on several Madison-area lakes.

Stormwater runoff during periods of wet weather has caused flooding of Lake Mendota. This has occurred because downstream water bodies are not able to accept the excess water that drains into Lake Mendota from its increasingly impervious watershed.

Figure 1.2. *Algae bloom in Lake Mendota, circa 1990 (photograph by Brett Johnson).*

Flooding results in significant damage to shoreline land and property. For example, the direct cost of responding to the 2000 floods for UW was $41,800 (Catherine Bruner, Facilities Planning and Management, written communication, May 14, 2003). Additional indirect costs were incurred from changing bus routes and redesigning a road to prevent flooding in the future. Traditional stormwater-management practices, such as detention ponds, do not address increased flooding due to increases in stormwater-runoff volume.

The percentage of urban land in the Yahara Lakes watershed is expected to increase, which will cause an increase in flood frequency and total runoff volume. A recent study on the effects of urbanization on stream flow in Madison illustrates the impact of impervious area on stream-level fluctuations during precipitation events. Figure 1.3 compares Garfoot Creek, a stream in a rural watershed, to Spring Harbor, which has a completely urbanized watershed. Garfoot Creek levels fluctuate very little in response to precipitation; Spring Harbor is quite variable, with high peak flows after storms and low base flow between rains. Although the magnitude of the fluctuation in water levels in the Yahara Lakes would not be as great, the same trend will occur, resulting in more frequent flooding.

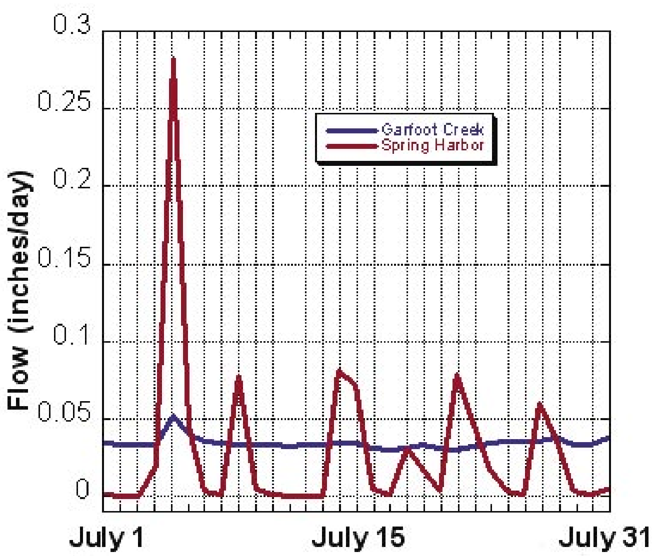

Figure 1.3. *Flows for Garfoot Creek and Spring Harbor during July 1995. Spring Harbor's flow is variable because it is entirely fed by short-duration stormwater runoff events from its urban watershed. Rural Garfoot Creek's steady flow is the result of groundwater input. As their watersheds urbanize, the Yahara Lakes levels are likely to become more like Spring Harbor's (U.S. Geological Survey data, retrieval source and date unknown).*

A third problem is sediment, which is eroded from construction sites and disturbed pervious surfaces and carried off of impervious surfaces, such as streets and parking lots. It has been estimated that 23 percent of the sediment entering Lake Mendota comes from construction activities located on only 0.3 percent of the watershed land area (Wisconsin Department of Natural Resources, 2000).

Figure 1.4. *Gully erosion at Angler's Cove below a stormsewer outfall.*

Another type of erosion is gully erosion, which can result from increased runoff from urban impervious surfaces. Gully erosion is unsightly and is costly and difficult to mitigate effectively. An example of gully erosion on campus is Angler's Cove (Figure 1.4). The transported sediment diminishes water clarity and significantly reduces water depth in harbors and channels during periods of low water, which is problematic for fish and boaters. The stormwater outflow known as Willow Creek has created a sediment bar in Lake Mendota at its mouth (Figure 1.5).

Lower water depths caused by sedimentation are made worse by diminished groundwater discharge to lakes. This occurs because increased impervious area in urban environments prevents natural infiltration of precipitation to recharge groundwater. In Madison, the groundwater aquifers are under additional stress due to pumping for municipal water supply. After use, the treated wastewater flows out of the watershed via a surface stream; therefore, water entering the sanitary sewer does not recharge in the area from which it was extracted. The net result of these factors is a steady lowering of groundwater levels, and an associated decrease in groundwater discharge to the lakes.

The Yahara Lakes are at a critical point in their history. Dane County, which today is mostly rural, is expected to develop rapidly in the next 20 years, though not uniformly. The Lake Mendota watershed was about 19.8-percent developed in 1996 and is projected to increase to about 21.6-percent developed by 2020 (Wisconsin Department of Natural Resources, 2000). The Lake Monona Watershed, on the other hand, was already 45-percent developed by 1990, and projected to grow to 57-percent developed within 20 to 40 years (Dane County Regional Planning Commission, 1992). If new developed areas rely on conventional stormwater-management practices, the impacts on the lake could be devastating. The most serious visible impact would be increases in the frequency and severity of damaging floods. Fortunately, stormwater-management practices that can prevent increases in lake flooding and more effectively protect lake-water quality are emerging. These practices can be applied in new and existing developments. New state and county regulations have the potential to spur the implemen-

Figure 1.5. *"Island" at the mouth of Willow Creek created by sediment delivered by stormwater runoff.*

tation of these emerging practices. But the new state regulations are somewhat timid, largely because of a lack of documented examples of effective practices in Wisconsin.

The UW is in an excellent position to accelerate the basin-wide adoption of effective stormwater-management practices, and thereby to protect and even improve the conditions in the Yahara Lakes. Through the cooperative efforts of faculty, staff, and students, the UW can conduct research to evaluate and demonstrate the effectiveness of emerging practices as well as to innovate new practices. Grant monies are available to conduct such research and to construct specific projects. Furthermore, the UW can commit to the long-term goal of reducing its damaging impacts on the lakes. In doing so, the UW would provide critical leadership that would help inspire and assist the watershed stakeholders to take action. In particular, UW leadership would improve the climate for stronger stormwater regulations and would also energize stakeholders to take actions beyond the regulatory requirements.

The UW has made strong commitments to the environment and open spaces in its Comprehensive Master Plan (University of Wisconsin–Madison, 1996). It recently formalized this commitment. On the basis of the preliminary recommendations of this report, the Campus Planning Committee adopted a "policy that ensures that *the amount of runoff from newly developed and redeveloped areas be no greater than the amount that occurred under native conditions."* (The resolution is included in Appendix 7.) The University also professes the "Wisconsin Idea," whereby the University shall vigorously share advances in science and knowledge with the people of the state, the country, and the world (University of Wisconsin–Madison, 2001). Innovations in stormwater management from UW research will benefit a shared resource, helping to support this commitment.

In this report, we describe the problem of stormwater management on the University campus and provide the information to implement an effective management system. This report includes discussion of past, current, and future stormwater regulations, common best management practices available and how to implement them, campus land assessment using geographic information system tools, and specific recommendations and priorities for making adjustments. We intend for this plan to serve as a tool for those administering and implementing stormwater-management practices. In particular, we hope that the UW Facilities Planning and Management Department can use this document in their comprehensive approach to management.

On the basis of the problems, context, and opportunities discussed above, we established the following goals for this report:

1. Protect and enhance the quality of Lake Mendota and other lakes, streams, groundwater, and wetlands in the Yahara Lakes Watershed.

2. Prioritize projects and problem areas for implementation of management solutions.

3. Assist the University to meet and go beyond regulatory requirements for stormwater management.

4. Establish the University as an innovator in urban stormwater management.

5. Illustrate cost-effective and straightforward solutions.

6. Suggest maintenance and monitoring opportunities in cooperation with research and education programs at the University.

References

Dane County Regional Planning Commission. (1992). Yahara–Monona Priority Watershed Plan.

Lathrop, R.C., S.R. Carpenter, C.A. Stow, P.A. Soranno, and J.C. Panuska. (1998). Phosphorus loading reductions needed to control blue-green algal blooms in Lake Mendota. Canadian Journal of Fisheries and Aquatic Sciences, 55:1169-1178.

University of Wisconsin–Madison. (1996). Comprehensive Master Plan – Summary Report. Retrieved July 15, 2003, from http://www.fpm2.wisc.edu/planning/UWMASTERPLAN/chancletter.htm.

University of Wisconsin–Madison. (2001). Connecting Ideas: Strategies for the University of Wisconsin-Madison. Retrieved November August 15, 2003, from http://www.chancellor.wisc.edu/strategicplan/amplify.html.

Wisconsin Department of Natural Resources. (2000). Nonpoint Source Control Plan for the Lake Mendota Priority Watershed Project. DNR, WDATCP, Dane Co. LCD, Columbia Co. LCD. Publication WT-536-00 REV. Retrieved July 15, 2003, from http://www.dnr.state.wi.us/org/water/wm/nps/pdf/mendota.pdf.

Chapter 2: Physical Assessment and Modeling

Stormwater routing

Physical assessment of the UW–Madison campus was a key component to developing the conclusions and recommendations of this plan. The purpose of the assessment was to describe the physical features of the campus in great detail to facilitate the analysis of current stormwater practices and recommend implementation of new management solutions. The University currently routes stormwater via pipes and overland channel ditches to Lake Mendota, Lake Monona, or Willow Creek, which eventually flows into Lake Mendota. To understand the quality and quantity of the runoff routed to the lakes, we delineated the land use of the campus in detail. This information allowed us to estimate runoff volume and pollution loading and identify areas with potential for new stormwater-management practices.

We also completed a detailed investigation of stormwater pipes to delineate stormwater sewersheds of the campus. A stormwater sewershed is a geographic area in which all of the precipitation drains to a common stormsewer pipe or outlet. Stormwater sewersheds are comparable to watersheds, except that they drain to a particular stormsewer outlet instead of a particular point on a stream, and they sometimes cross land-surface topographic divides with underground water-carrying pipes. We delineated the sewersheds for the UW campus to 1) estimate runoff quantity and quality and 2) provide a tool to the University to use in the planning of future construction and in the design of stormwater-mitigation measures. This information is especially useful to identify the source of problems from a specific outlet and for use in planning for redevelopment and construction projects.

Physical assessment methods

Methods: Campus land use/land cover classification

Using a geographic information system (GIS), we combined existing data from a previous campus mapping project (Bundy and others, 1997) with information from the Facilities Planning and Management (FPM) database. The existing data were converted from AutoCAD format to ArcGIS shapefiles to facilitate modeling. Because the existing land-use data did not include much of the pervious areas on campus, many of the pervious areas were digitized using the boundaries of existing data and a 1999 color orthophoto of the campus. The land-use data were verified visually, in the field, by the WRM practicum students using 1:1,400-scale maps. In cases where the data were incomplete—for example, when a building was missing from the campus mapping project and FPM data—the boundaries were inserted into the GIS as approximations. As soon as accurate spatial data are obtained, these approximations should be updated. The campus land-use map is shown in Plate 2.1.

The land-use data were divided into the categories listed in Table 2.1. These categories were selected based on the ability to identify them on an orthophoto and in the field as well as their importance in modeling stormwater quantity and quality.

Table 2.1. List of categories used in campus land-use characterization

Land-use categories			
athletic court	drive	mulch	sand
athletic field	garden	non-University	sidewalk
barnyard	grass	parking lot	structure
building	gravel	path	trees
bushes	loading dock	planter	under construction
coal	marsh	railroad track	water
cropland	mixed vegetation	road	woods

Methods: Sewershed delineation

The FPM provided us with an AutoCAD file of the stormsewer network. We converted this to ArcGIS format to facilitate analysis. We identified all stormsewer outfalls and color-coded the stormsewer pipe networks contributing to each outfall. We then created a mosaic of 1:2,000-scale maps of the campus with additional data layers, including pavement, buildings, and topographic lines. Using these maps, we visually estimated stormsewershed boundaries from the ground, and drew them on the detailed maps. Finally, we digitized these lines to add them to the campus GIS dataset.

Sewershed boundaries were estimated for each outfall into a lake (Plate 2.2). However, we anticipate that these data will be largely used for estimating runoff volumes at sites for potential stormwater-management practices. We estimated subsewershed boundaries for several such sites (see Chapter 5, Case Studies). Using the process outlined above, runoff volumes can easily be estimated for any future mitigation sites.

The main difficulty with sewershed delineation in a highly developed area occurs when the roof of a building lies on a boundary. In these cases, we examined campus building plans or visually examined downspouts and roof shapes to identify the correct boundary. However, these boundaries are highly prone to error and should be considered only as approximations. Whenever a specific stormwater-mitigation practice is designed, the contributing area should be estimated with more precision.

Stormwater-modeling methods

Methods: Runoff quantity estimates

Runoff-quantity estimates are necessary for designing effective stormwater-management practices and are a useful tool for evaluating progress toward runoff-management goals. To estimate the quantity of runoff, a modified TR-55-based (U.S. Department of Agriculture, 1986) model was programmed as a macro in ArcGIS for use with the UW–Madison campus land-use data. The model uses the Natural Resources Conservations Service (NRCS) curve-number method, which relies on land use and soil type, for determining runoff for a given precipitation event. A table of the curve numbers that we used is in Appendix 1. The modified model calculates average annual runoff volumes and depths based on a method developed by Brander and others (2004). Average annual rainfall is calculated by dividing the long-term April 15 through October 15 rainfall data into daily (24 hour) events and grouping these events using a 0.05-inch interval. The long-term runoff volume is calculated using the rainfall-event data, the appropriate curve number for each land-use polygon, and multiplying the result by the area of the polygon. The average annual runoff volume is the long-term runoff volume divided by the number of years in the rainfall record. The model sums the average annual runoff volumes generated for each polygon of the land-use data within each sewershed. The runoff depth is the runoff volume of the sewershed divided by the area of the sewershed. The following equation is used to calculate average annual runoff volume for each sewershed:

$$Q = \sum_{1}^{m} \left(\frac{\sum_{1}^{e} \frac{(P-I)^2}{(P-I)+S}^{*}}{n} \times A \right)$$

* for P > I, otherwise 0

Where

Q = the average annual runoff volume generated within the sewershed in acre-inches

P = daily event rainfall in inches

S = 1000/CN –10

I = 0.2S (initial abstraction)

A = the area of the land use polygon in acres

n = the number of years in the event rainfall record

m = the number of polygons within the sewershed

e = the number of daily events in the event rainfall record (for this case e = n*184 because there are 184 days between April 15 and October 15)

CN = NRCS curve number.

This is not a continuous model; it does not simulate ongoing changes in soil-moisture conditions, nor does it account for seasonal variations, including frozen ground and snowmelt. The runoff calculation results are only applicable to time periods from April 15 through October 15. (The average rainfall for this time period is 19.88 inches in Madison, Wisconsin.) Nevertheless, the average annual runoff, as calculated here, is important as an indicator of the quantity of water added or taken away from the regional surface-water and groundwater systems.

The runoff data calculated for each sewershed were saved to a table. The table included the identification number, area (acres), volume (acre-ft) of runoff produced, and average runoff depth (ft) for each sewershed as well as the pollutant loading values discussed in the following section.

Methods: Runoff quality estimates

Runoff quality generally depends on the types of surfaces on which the runoff is generated and the surfaces over which the runoff flows. We estimated runoff quality by multiplying the quantity of runoff generated on each surface by the pollutant-loading coefficients (Appendix 2) used in the SLAMM program (http://winslamm.com/). The pollutant coefficients are multiplied by the amount of runoff to determine the average quantity of pollutants generated within each sewershed per year.

Results of physical assessment and modeling

Results: Land-use characterization

The results of our land-use characterization are highlighted in Figure 2.1 and listed comprehensively in Appendix 3. Approximately 41 percent of the campus is covered by impervious surfaces, more than half of which is buildings and parking lots. Almost half of the remaining area (approximately 23%) is covered by woods, making it the largest single land-use type.

The different land-use types are not distributed evenly throughout the campus. For instance, 66 percent of the land east of Willow Creek is impervious, compared to 15 percent for the area to the west. A more practical example of this uneven distribution is that Lake Monona's contributing areas are 74-percent impervious; the areas draining into Lake Mendota are only 34-percent impervious. As areas on campus are developed and redeveloped, the amount of land within each of our land-use characterization categories is likely to change.

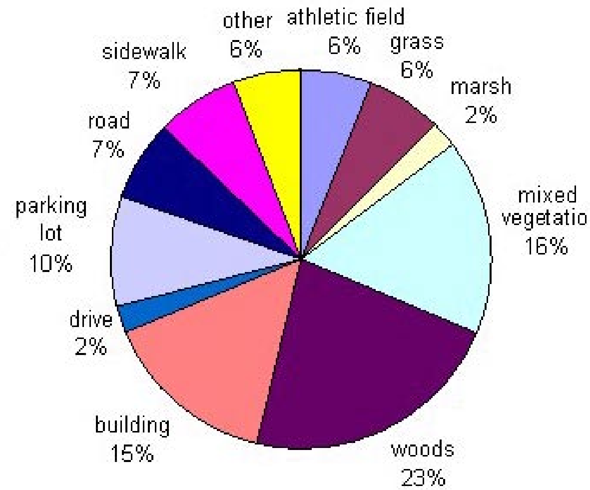

Figure 2.1. *Major land-use types on campus. Approximately 41 percent of the campus is impervious.*

Results: Sewershed delineation

On the basis of outfalls into the lakes, we divided the campus into 34 sewersheds (Plate 2.2). Sewersheds 1 and 2, which make up 22 percent of the campus area, drain to Lake Monona via City of Madison pipes, entering at Monona Bay. The remaining sewersheds drain to Lake Mendota. The areas within sewershed 18 first drain into Willow Creek, which flows into Lake Mendota. We grouped all the unsewered areas into sewershed 3, which represents 22 percent of the campus area. Runoff from these areas drains across the land surface directly to Lake Mendota. The areas on campus that either drain into the sanitary sewer or into wetlands do not contribute to stormwater runoff and were therefore excluded from the calculations. Detailed sewershed size and land-use composition data are included in Appendix 4.

Results: Runoff modeling

The total estimated annual runoff volume produced by the UW–Madison campus is 553 acre-ft. That is equivalent to an average of about 0.5 foot of water over the entire campus. Sewersheds whose land use is largely impervious produce a disproportionate amount of the total. For example, sewershed 3, which is 74-percent wooded, produces an annual runoff depth of 0.17 ft; sewershed 22, which drains only roofs, produces 1.10 ft of runoff annually. Plate 2.3 illustrates the runoff variability across the campus. Runoff quantities by sewershed are listed in Appendix 4.

Approximately 90 tons of suspended solids are carried from the UW campus to the Yahara Lakes each year. The amount of suspended solids depends on land use and runoff volume and therefore varies among the sewersheds. Annual loads ranged from 331 pounds per acre for sewershed 23 to 58 pounds per acre for sewershed 3. Appendix 4 contains a detailed list of loading estimates by sewershed for a range of commonly monitored particulate and dissolved pollutants.

Data availability

The land-use characterization and sewershed delineation that we completed will no doubt be useful for future studies on the UW–Madison campus. These data will be made available through UW Facilities Planning and Management.

References

Brander, K. E., K.E. Owen, and K.W. Potter. (2004). Modeled impacts of development type on runoff volume and infiltration performance: Journal of the American Water Resources Association, 40(4):961-970.

Bundy, J., J. Chen, C.L. Chou, N. Dahman, R. Fayram, A. Hassan, E. Guney, S. Leisz, J. Marsolek, D. Mezera, F. Scarpace, L. Seidl, and A. Vonderohe. (1997). The Campus Map Project at the University of Wisconsin–Madison, *in* ACSM/ASPRS Annual Meeting and Exposition Technical Papers. Seattle, Washington, p. 257-263.

Natural Resources Conservation Service. (1986). Urban Hydrology for Small Watersheds: U.S. Department of Agriculture Technical Release 55.

Chapter 3: Stormwater Regulations and the University of Wisconsin–Madison Campus

Regulatory context

Performance standards that regulate and promote innovative design of stormwater-management systems can help reduce polluted runoff and improve water quality. Over the past several years, the Wisconsin Department of Natural Resources (DNR), Dane County, the City of Madison, and surrounding communities have adopted new policies to manage stormwater (see Appendix 5). These regulations and standards involve managing the *quantity* and *quality* of stormwater drainage. To control sediment and pollutant loading, new standards at all levels of government require construction sites to retain soil particles on-site. Additional city and county standards control the temperature of water runoff from sites and the potential water pollution by oil and grease. Other requirements state that post-development peak water-discharge rates cannot exceed predevelopment rates for certain storm events. Although not all of these ordinances apply to the University campus, they are useful illustrations of reasonable standards for this region and serve well as comparisons to the state standards and standards proposed here for the University.

As a state institution, the UW–Madison is not subject to Dane County or City of Madison stormwater ordinances. However, it does fall under the jurisdiction of Wisconsin's newly adopted Polluted Runoff Management Rules, a set of nine administrative rules including NR 120, 151, 152, 153, 154, 155, 216, 243, and ATCP 50. The University has been subject to municipal stormwater-discharge permitting from the DNR since 1995, under Chapter NR 216, Wis. Adm. Code.

Polluted runoff management rules

Wisconsin's Polluted Runoff Management Rules are a set of nine state administrative rules that includes enforceable standards to regulate polluted runoff from agriculture, construction sites, and developed urban areas. These new statewide rules, touted as the strongest in the nation, went into effect on October 1, 2002, with delayed implementation for some of the standards. In addition to the standards, the new rules contain suggested best management practices to meet the standards and grant programs to help fund implementation.

The goals and measures for these new rules are laid out in Chapter NR 151, Wis. Adm. Code, *Runoff Management*. The performance standards included in Chapter NR 151 for agricultural and nonagricultural land uses are intended to be minimum standards of performance necessary to achieve water-quality standards. The urban, or nonagricultural, performance standards include standards for construction erosion and sediment control, design standards for post-construction performance of new and redevelopment construction projects, and performance standards for developed urban areas, some of which are required to have a Wisconsin Pollutant Discharge Elimination System (WPDES) stormwater discharge permit under NR 216.

Although the University of Wisconsin is regulated by NR 151 and 216, a number of exemptions (included in Appendix 6) in the rules could be applied to most of the planned development on campus in the next ten to fifteen years. Despite these exemptions, the University has strong motivations for meeting and even exceeding the performance standards in NR 151 and the requirements of NR 216.

Although Chapter NR 151 of the state administrative code establishes minimum performance standards for agricultural and urban land uses, Chapter NR 216 requires that certain municipalities and institutions (such as the UW–Madison) apply for and meet the requirements of a WPDES stormwater discharge permit. Together, Chapters NR 151 and NR 216 lay the foundation for strong stormwater management across the state if these programs are adequately funded and given the resources needed to implement them.

Stormwater discharge permits

In response to the 1987 Amendments to the Clean Water Act (CWA), the U.S. Environmental Protection Agency (U.S. EPA) developed the National Pollutant Discharge Elimination System (NPDES) Stormwater Program to address urban sources of stormwater that adversely affect the quality of the Nation's waters. The two-phased national program uses the NPDES permitting mechanism to require implementation of controls designed to prevent harmful pollutants from being washed by stormwater into local water bodies. The NPDES is implemented by the State of Wisconsin as the WPDES.

Phase I of the NPDES Stormwater Program began in 1990 and required all operators of medium and large municipal separate stormsewer systems (MS4s) to obtain a discharge permit and develop a stormwater-management and pollution-control program. Phase I municipalities are those that have municipal separate stormsewer systems and service incorporated areas with a population of 100,000 or more. In Wisconsin, this applied to the cities of Madison (including the UW campus) and Milwaukee.

Stormwater Phase II, promulgated by the U.S. EPA in 1999, extended the Phase I program by requiring additional municipalities, not regulated in Phase I, to implement programs and practices to control polluted stormwater runoff. Under Phase II, operators of small MS4s were required to apply for NPDES permit coverage by March 10, 2003. The expansion of the NPDES stormwater-permit program now includes many of the smaller municipalities surrounding Madison. However, the DNR designated most of these Dane County communities under its Phase I to be brought into the WPDES permitting program earlier than required by Phase II (U.S. Environmental Protection Agency, 2000a).

In Wisconsin, the DNR has permitting authority for the WPDES stormwater program. Chapter NR 216 establishes criteria and procedures for the issuance of stormwater discharge permits for construction sites, industrial facilities, and municipalities (Wisconsin Department of Natural Resources, November 2002). As part of the State's polluted runoff-management rules, Chapter NR 216 was revised to incorporate the urban performance standards contained in Chapter NR 151. Further revisions of Chapter NR 216 are currently being made to bring the state into full compliance with the Federal Storm Water Phase II program (Wisconsin Department of Natural Resources, 2003).

UW–Madison stormwater discharge permits

The University's first stormwater discharge (WPDES) permit application was filed jointly with the City of Madison and the Wisconsin Department of Transportation in 1995. The WPDES permit (Permit No. WI-SO58416-1) authorized the UW–Madison to discharge stormwater and also contained important conditions to improve the quality of discharges. For example, the permit required the UW–Madison to implement practices, evaluate its use of salt and sand on campus, and to improve this practice to reduce salt discharge to the Yahara Lakes.

This initial permit helped facilitate many of the University's first efforts at reducing polluted runoff. Major components included the establishment of a comprehensive stormwater-management program and the legal authority to control illicit discharges to stormsewers. The overall program effectiveness is assessed through monitoring and compliance components. The University also expanded the responsibilities of the Senior Environmental Health Specialist to coordinate stormwater management and provide annual reports to the DNR.

Some of the University's accomplishments during the effective years (1995 through 2003) of this permit include the following:

- coordinating with the City of Madison to assess compliance with local stormwater ordinances for UW properties within the City of Madison;
- improving and implementing a salt-reduction policy;
- evaluating and improving their leaf collection, street/parking lot sweeping, and catch-basin cleaning policies;

- reviewing and updating policies on campus pesticide, herbicide, and fertilizer usage;

- creating an inspection schedule for evaluating existing structural controls on campus and a plan for incorporating new controls;

- developing a program to detect and respond to illicit discharges on campus; and

- continuing implementation of Spill Response and Prevention Plan.

In January 2003 the UW–Madison submitted an application for a new joint municipal stormwater-discharge permit under Chapter NR 216. Because the DNR designated other communities under its Phase I regulations, the permit group was expanded to include 18 surrounding municipalities, plus UW–Madison. Co-applicants on this permit are the Cities of Fitchburg, Madison, Middleton, Monona, Sun Prairie, Verona; Villages of Deforest, Maple Bluff, McFarland, Shorewood Hills, Waunakee; Towns of Blooming Grove, Burke, Madison, Middleton, Westport, Windsor; and Dane County. This application is currently being processed by the DNR. (Contact Jim Bertolacini, Storm Water Management Specialist, at jim.bertolacini@dnr.state.wi.us or 608/275-3201, with any questions about this new permit.)

The pending permit will build on the accomplishments of the original permit by incorporating and expanding on existing policies and programs. Monitoring will continue as a collaborative effort with the other applicants under the permit. In addition, the permit will add the following components to the UW–Madison part of the permit (University of Wisconsin–Madison, January 2003):

- Oversight of construction-site erosion and sediment control by a University Landscape Architect, in addition to existing oversight by the Division of State Facilities (DSF) within the Department of Administration (DOA). Erosion controls are to be written into all project specifications and will be reviewed by DSF when they review the project as a whole. The *Wisconsin Construction Site Best Management Practice Handbook,* 2001 Revision, is the reference manual for University projects. This reference is currently under revision and the new version (technical standards accessible as an online resource) will replace this as the reference manual for University projects when it is completed. Progress on the reference can be accessed now through http://www.dnr.state.wi.us/org/water/wm/nps/stormwater/techstds.htm.

- Although fines cannot be assessed by the University or DSF for not controlling erosion on construction sites, contractors may be pulled off the job and/or placed on a no-bid list, according to the new permit application. A DSF staff person raised some concern about the legality of this provision for the state, so it is uncertain what will be included in the final permit (Katherine Kalscheur, Wisconsin Department of Administration, oral communication, November 11, 2003). A long legal process does exist for removing a contractor from a state project. References can be requested from a bidding contractor, but they cannot be singled out for erosion and sediment-control performance. If a problem escalates to a conflict, it could involve the UW System, DNR, and DOA. For this reason, a memorandum of understanding is needed between these agencies on how to resolve such conflicts. The Wisconsin Department of Commerce, due to its role in regulating public building construction, should also be party to such a memorandum of understanding.

- A Public Education and Outreach Program on stormwater pollution prevention. This is now required of all permitted municipalities under Chapters NR 151 and NR 216. All municipalities in this permit group played a role in developing the comprehensive Joint Storm Water Permit Group Information and Education Plan, which can be accessed online at http://www.co.dane.wi.us/commissions/lakes/pdf/stormwater/jointstormwaterpermit.pdf.

- Stormwater best management practices are suggested, but not required, to be included in all new building specifications as part of the preliminary planning stage.

- All future and existing parking ramps located on campus will be equipped with maintained oil/sand interceptors.

The new permit will explicitly implement Chapter NR 151 standards.

Benefits of adopting performance standards

The UW–Madison is typically a leader in innovation. The new state polluted-runoff standards and this stormwater-management planning project provide the University with an opportunity to continue to be on the leading edge. As a major landowner in the community, it is the University's duty and responsibility as part of a joint municipal stormwater permit (with the City of Madison and 17 other local municipalities) to enact strong stormwater standards to protect the surrounding water resources. Adopting strong standards is a proactive measure that will demonstrate that the University is committed to protecting water resources.

Although not required to meet all the new state requirements, the University will set a positive example for the City of Madison and surrounding communities by voluntarily adopting the proposed standards. In this way, they will be meeting the intent of new U.S. EPA federal guidelines (CWA Phase II), DNR Polluted Runoff Rules (Chapter NR 151) and the recommendations of the Dane County Lakes and Watershed Commission (Priority Watershed Report). Finally, to meet the 40-percent reduction of suspended solids by 2013, as required by Chapter NR 151, the University must change its current stormwater-management practices. A summary of the relevant requirements under Chapter NR 151 is included in Appendix 6.

Integrated systems approach

Stormwater management within the University watershed has traditionally been handled on a localized, piecemeal basis with the goal of minimizing localized flooding and erosion by conveying the runoff to the lake in as expeditious manner as possible (Potter, 2003). This type of approach does not typically attempt to minimize the generation of runoff or address pollutant loading (Land-of-Sky Regional Council, 2002). Because runoff quantity and pollutant loading are not addressed by this localized approach, many of the water quality and flooding problems that exist on the UW campus are exacerbated.

We propose that the University adopt a systems approach to managing stormwater on campus. A systems approach takes into account the cumulative effects of multiple construction, redevelopment or new development, and projects occurring within the same land area. Such an approach to managing campus construction and stormwater projects examines the range of effectiveness associated with each single best management practice, along with the overall costs and effectiveness of implementing the practices for the whole of campus. Looking at the entire campus as an entity opens up opportunity for maximizing practices used in combination and enabling the most effective placement of stormwater-management practices, which would otherwise not be considered (U.S. Environmental Protection Agency, 2003).

The systems approach is rooted in the Campus Master Plan developed in 1996. One of the key recommendations of that document was to maintain a balance between the University's natural and manmade environments by preserving key natural features while promoting quality growth and redevelopment. Being proactive in preventing problems will save the University money in the long run. A new systems approach is less expensive than the current approach of retrofitting and reactive solutions.

Off-site mitigation opportunities

Mitigation, or the alleviation, of stormwater impacts on water quality and quantity from urban development is the aim of the new polluted runoff performance standards. Under these new rules, the performance standards are qualified with the phrase "to the maximum extent practicable" to accommodate limitations in technology, site conditions, or economic feasibility. Although time will likely resolve technological limitations and the economics of stormwater management, projects are usually constrained by geographical limitations and cost.

A systems approach allows for and emphasizes a flexible, more accommodating approach to meeting the proposed performance standards. Chapter NR 151 does not directly address off-site mitigation of stormwater impacts, primarily because large, landholding institutions, such as the UW–Madison, were not considered when the new rules were written (Mary Anne Lowndes, Wisconsin Department of Natural Resources, oral communication, June 26, 2003). However, because redevelopment is exempt from post-construction infiltration requirements in the new rules, the University has ultimate discretion and flexibility as to how it meets the requirements of our proposed infiltration standards. Some other cases also exist where University projects would be exempt from infiltration or other new standards (see Appendix 6 for more details). We recognize that it may not be feasible to achieve the standards we are proposing on all redevelopment sites. Spatial constraints or existing design/infrastructure problems may limit the ability to manage infiltration and total suspended solids. However, compensating for these limitations can occur off-site at other locations around campus. Mitigation credits can be given to restoration, enhancement, or creation of areas that improve groundwater infiltration off-site while reducing stormwater impacts in the watershed overall. Example sites for off-site mitigation when onsite mitigation is not feasible have been included for a number of stormwater impacts in Chapter 5, *Case Studies.*

Proposed stormwater performance standards

The performance standards we outline here build on the performance standards in Chapter NR 151, eliminating the loopholes that would leave UW–Madison largely exempt from the letter of the law. For example, the infiltration standard for non-residential development under Chapter NR 151 is 60 percent. The City of Middleton requires no increase over predevelopment runoff from a defined storm, that is, a 100-percent infiltration rate. The UW–Madison would become a leader in stormwater management because these proposed standards go beyond the requirements of the University under the rules, where estimated to be feasible and cost-effective.

Our proposed standards include three components: construction-site erosion and sediment control, post-construction site-design standards, and urban area performance standards.

Construction-site erosion and sediment control

Stormwater runoff from construction sites is a major concern. Pollutants commonly discharged from construction sites include sediment, fertilizers, pesticides, oil and grease, and other construction chemicals and debris. The main pollutant of concern is sediment. According to a DNR report (2000), more than 22 percent of the total sediment loading to Lake Mendota comes from construction activity occurring within the watershed. To date, stormwater runoff from construction sites has been regulated under the WPDES stormwater discharge permit program. However, unlike most nonpoint sources, which by definition are typically difficult to locate explicitly, construction activity and sedimentation of lakes and streams are directly linked. According to the U.S. EPA, construction sites contribute 10 to 20 times more sediment per acre than agricultural lands. In just a very short time, construction sites can deposit more sediment into lakes and rivers than can be deposited naturally over several decades (U.S. Environmental Protection Agency, 2000b).

University buildings are public buildings and places of employment (commercial buildings) and therefore erosion and sediment-control authority for construction of these buildings actually falls to the Department of Commerce, not the DNR, in accordance with s. 101.1205 of the Wisconsin Statutes. The DNR has requested that Commerce require the implementation of appropriate Chapter NR 151 standards where they have authority over erosion and sediment control. Commerce has not yet responded to DNR as to when they will have Commerce rules revised in accordance with Chapter NR 151 (Eric Rortvedt, Wisconsin Department of Natural Resources, written communication, August 21, 2003). The Wisconsin Department of Transportation has already revised its Chapter Trans 401 (erosion control and stormwater-management rule for transportation projects) to be consistent with Chapter NR 151.

Under Wisconsin's Chapter NR 151, construction sites that involve at least 1 acre of land-disturbing activity must develop and implement an erosion-control plan that incorporates BMPs to reduce sediment loads (s. NR 151.11). Because the majority of construction sites on campus fall under this 1-acre threshold, they are not required to meet these requirements. However, the cumulative effect of multiple sub-threshold construction sites is still the major source of sediment entering the lakes.

Therefore, we propose that *all* land-disturbing construction activity that occurs on the UW campus, *regardless of size*, meet the following performance standards:

1. ***Implement BMPs that achieve a reduction of 80 percent*** of the annual sediment load carried in runoff until the construction site has undergone final stabilization.

- Best management practices used to control erosion and sedimentation may be used alone or in combination to meet this requirement. As with Chapter NR 151, flexibility will be allowed in choosing the BMPs to meet these standards. (Further discussion of BMPs can be found in Chapter 5 and in Appendix 13.)
- Credit toward meeting the sediment reduction shall be given for limiting the duration or area of land-disturbing activity. Methods for calculating credit toward these standards would be consistent with those outlined in the polluted runoff rules.
- The 80-percent reduction specified here is the same as that specified in Chapter NR 151.

2. ***All construction projects, regardless of size, shall include erosion and sediment controls*** to do all of the following to the maximum extent possible:

   - *prevent tracking* of sediment from the construction site onto roads and other paved surfaces;
   - *prevent the discharge of sediment* as part of site dewatering; and
   - *protect separate storm drain inlet structures* from receiving sediment.

   These controls are required only for construction sites of 1 acre or more under Chapter NR 151.

3. Erosion and sediment-control BMPs shall be directly included and written into all University construction contracts, regardless of size. Projects that involve more than 1 acre of activity must develop and implement a formal erosion-control plan showing how they will reduce sediment loads, as required under Chapter NR 151.

Site-design standards (post-construction)

As mentioned in the 1996 Master Plan, the UW–Madison is experiencing a period of intense redevelopment and growth as it struggles to renew the campus built environment. As existing infrastructure ages, the University will put up new buildings, replace and redevelop other facilities, and upgrade current systems. The Master Plan identifies 50 potential building sites with a capacity of 4.7 million gross square feet of new space. Most of these sites are located in the west and south parts of campus. Given the current rate of growth, the Master Plan recommends adding an additional 3.0 million gross square feet of new space over the next 30 years of development (University of Wisconsin–Madison, 1996).

As the University plans for, and designs, facility upgrades and redevelopment projects, it should also reexamine and assess the potential stormwater impacts of these projects. Innovative, cost-effective techniques to reduce stormwater runoff should be directly incorporated into all redevelopment designs. These techniques, or BMPs, can greatly reduce the amount of pollutants and total runoff entering the Madison lakes.

Site-design standards are applied differentially depending on the type of development in question. "In-fill area" development refers to development of an "undeveloped area of land located within existing urban sewer service areas, surrounded by already existing development or existing development and natural or man-made features where development cannot occur" and redevelopment is "where development is replacing older development" [s. NR 151.002 (18) and (39)]. Development on the main campus typically falls into these two categories because of the built nature of the campus and surrounding area.

Under the new Polluted Runoff Rules (Chap. NR 151), the state is imposing building design standards for new development and redevelopment projects to manage stormwater (s. NR 151.12). These post-construction design standards fall into three main categories: total suspended solids, peak discharge, and infiltration. Although projects must meet the 1-acre size threshold and most redevelopment activities are exempt from the standards, these new requirements will greatly reduce stormwater impacts across the state.

By incorporating and adopting stormwater design standards into all redevelopment projects on campus, regardless of size, the UW–Madison can establish itself as a leader in stormwater management. These measures will also demonstrate to the surrounding communities that the University is committed to protecting surrounding water resources. We recommend that the University adopt the following design standards for all future construction projects located on campus:

Total suspended solids

- Best management practices shall be designed, installed, and maintained to control total suspended solids (TSS) carried in runoff from post-construction building sites. These BMPs should reduce the total annual suspended solids by 80 percent for all new development or redevelopment projects, regardless of size.

- At least 40 percent of this reduction must be met on-site; off-site mitigation may account for the remaining 40 percent reduction. Off-site mitigation should occur within the same watershed as the project, either the Lake Mendota or Lake Monona watershed.

Peak discharge

- Best management practices shall be employed to maintain or reduce the peak runoff discharge rates, to the maximum extent practicable, as compared to pre-development conditions for the 2-year, 24-hour design storm event. Generally, this requirement can be met through infiltration BMPs and should be evaluated for each drainage channel separately.

- Discharge will be managed to avoid erosion of open channels and conveyance systems, including outfalls.

Infiltration

- Best management practices shall be designed, installed, and maintained to infiltrate sufficient runoff volume such that post-development infiltration volume shall be at least 90 percent of the predevelopment infiltration volume, on the basis of average annual rainfall. That is, no more than a 10-percent decrease in infiltration would be allowed. If this is not feasible, off-site infiltration may be utilized to meet this requirement as part of the project stormwater plan. See Appendix 7 for recent developments on this recommendation.

Urban area performance standards

The developed urban area performance standards contained in Chapter NR 151 apply to UW–Madison as well as all Wisconsin municipalities with an average density of 1,000 people per square mile or greater (s. NR 151.13). Theses include stricter WPDES permit requirements for the University and surrounding communities. Municipalities required to be permitted through the WPDES stormwater program, under Chapter NR 216, must comply with the following additional requirements by March 10, 2008:

- Implement a public information and education program that promotes the proper use and reuse of leaves and grass clippings, proper use of lawn and garden fertilizers and pesticides, proper management of pet wastes, and prevention of oil dumping and other chemicals into stormsewers.

- Implement a program for the collection and management of leaf and grass clippings, including public information about this program.

- Implement a nutrient-management plan for the application of lawn and garden fertilizers, based on appropriate soil tests.

- Implement a system for the detection and elimination of illicit discharges to stormsewers.

Table 3.1. Summary of proposed performance standards

Construction-site erosion and sediment control

- Erosion and sediment-control BMPs must be written into all campus construction contracts, regardless of size. Formal, written plans must be included for projects greater than 1 acre.
- All projects must employ BMPs that achieve a reduction of 80 percent of sediment load carried in runoff (as compared to no controls).
- All projects must employ controls to prevent sediment tracking, discharge into waters, and discharge into stormsewers.

Total suspended solids

- All redevelopment (regardless of parking area and road size) must achieve an 80-percent reduction in TSS as compared to no runoff controls. At least 40 percent of this reduction must be met on-site.

Peak discharge

- All redevelopment must employ BMPs to make peak runoff comparable to predevelopment conditions for the 2-year, 24-hour storm event.
- Discharge must be managed to avoid erosion of open channels and conveyance systems

Infiltration

- All redevelopment must infiltrate 90 percent of predevelopment infiltration volume, on the basis of annual rainfall.

All theses elements will be incorporated into the pending UW–Madison joint-municipal WPDES discharge permit.

The second major requirement of the urban area performance standard includes important performance measures to assess progress toward improving stormwater runoff quality. By 2008, permitted municipalities must show a 20-percent reduction in TSS in runoff that enters waters of the state as compared to no controls (s. NR 151.13(2)(b)1). Additionally, by 2013, permitted municipalities must show a 40-percent reduction in TSS within municipal boundaries (s. NR 151.13(2)(b)2). Accomplishment of this requirement will be assessed through credits earned for BMP implementation relative to estimated TSS rates without controls.

Funding opportunities

Protecting and enhancing Lakes Mendota and Monona are the strongest reasons for setting strong standards for polluted runoff management on the UW–Madison campus, but adopting strong performance standards that go beyond state minimum requirements could help leverage the funds necessary to implement the appropriate BMPs.

Because reducing polluted runoff to the nation's waters is a high priority at all levels of government, funding is frequently available directly and indirectly to institutions like the UW–Madison that propose innovative solutions to these complex problems. The DNR Urban Nonpoint Source and Storm Water Management Grants Program is a state-level grant program that facilitates implementation of the NR 151 non-agricultural performance standards.

The U.S. EPA has several federal grant programs to help implement related Clean Water Act (CWA) programs. A stream and wetland restoration project at Auburn University in Alabama was funded through the Wetland Program Development Grants under CWA 104(b)(3) funding authority. The U.S. Environmental Protection Agency Five-Star Restoration Grants could also be a source of funding for stormwater management on campus, depending on the project. Some examples of other federal grant programs pertaining to polluted runoff management are possible funding sources for projects on the UW–Madison main campus (Table 3.2); others might be applicable to projects at the University's agriculture research stations. Funding opportunities also exist for research in this area.

The State of Wisconsin and Dane County have funding programs of their own and may also be good partners in seeking funds for polluted runoff management projects from these or other sources. The campus could pursue these funding opportunities along with other funding used for construction projects.

Federal grant programs are not the only available funding for stormwater management. In many cases, the cost of the stormwater-management BMPs may be just a small fraction of the total cost of a building project. This small cost may be much less than the potential costs of repairing or retrofitting, which might be needed if inappropriate designs are used. Research and educational opportunities in experimental stormwater designs might merit the additional cost because they lend themselves to the University's fundamental purposes and to the Wisconsin Idea. In other instances, the proposed infiltration or other polluted runoff control approach might draw significant public interest and funds could be solicited from private donors through the University Foundation.

These are just a few examples of funds that might be leveraged through the University's adoption of strong performance standards. Many funding possibilities for University stormwater management can be explored.

Implementation and enforcement

Polluted runoff-management standards are pointless if they are not effectively adopted and enforced. In the State of Wisconsin, the DNR usually has the authority for imple-

Table 3.2. Grant programs that fund polluted-runoff-management projects (excerpted from U.S. Environmental Protection Agency, August 2003)

Program name	Overview	FY 2003 funding levels
Five-Star Restoration Program	The EPA supports the Five-Star Restoration Program by providing funds to the National Fish and Wildlife Foundation and its partners, the National Association of Counties, NOAA's [National Oceanic and Atmospheric Administration] Community-based Restoration Program and the Wildlife Habitat Council. These groups then make subgrants to support community-based wetland and riparian restoration projects. Competitive projects will have a strong on-the-ground habitat restoration component that provides long-term ecological, educational, and/or socioeconomic benefits to the people and their community. Preference will be given to projects that are part of a larger watershed or community stewardship effort and include a description of long-term management activities. Projects must involve contributions from multiple and diverse partners, including citizen volunteer organizations, corporations, private landowners, local conservation organizations, youth groups, charitable foundations, and other federal, state, and tribal agencies and local governments. Each project would ideally involve at least five partners who are expected to contribute funding, land, technical assistance, workforce support, or other in-kind services that are equivalent to the federal contribution. (Web site: http://cfpub.epa.gov/fedfund/program.cfm?prog_num=29)	$ 496,750
National Integrated Water Quality Program	The National Integrated Water Quality Program (NIWQP) provides funding for research, education, and extension projects aimed at improving water quality in agricultural and rural watersheds. The NIWQP has identified eight "themes" that are being promoted in research, education and extension. The eight themes are (1) Animal manure and waste management (2) Drinking water and human health (3) Environmental restoration (4) Nutrient and pesticide management (5) Pollution assessment and prevention (6) Watershed management (7) Water conservation and agricultural water management (8) Water policy and economics. Awards are made in four program areas - National Facilitation Projects, Regional Coordination Projects, Extension Education Projects, and Integrated Research, Education and Extension Projects. Please note that funding is only available to universities. (Web site: http://www.usawaterquality.org/default.html)	$ 12.4 million
Science to Achieve Results	The Science to Achieve Results (STAR) program is designed to improve the quality of science used in EPA's decision-making process. STAR funds are provided for research in the following six areas: (1) Safe Drinking Water (includes source water protection), (2) High Priority Air Pollutants, (3) Research to Improve Human Health Risk Assessment, (4) Research to Improve Ecological Risk Assessment, (5) Emerging Issues, and (6) Pollution Prevention and New Technologies. The STAR program is intended to facilitate cooperation between EPA and the scientific community to help forge solutions to environmental problems. Research topic solicitations vary and are advertised in the Federal Register and through the Internet, university and scientific organizations, direct mail, and other avenues. (Web site: http://cfpub.epa.gov/fedfund/program.cfm?prog_num=52)	Not available

Table 3.2. *continued*

Program name	Overview	FY 2003 funding levels
Sustainable Agriculture Research and Education	The Sustainable Agriculture Research and Education (SARE) program of the U.S. Department of Agriculture works to advance farming systems that are more profitable, environmentally sound and good for communities through an innovative grants program. More specifically, SARE funds scientific investigation and education to reduce the use of chemical pesticides, fertilizers, and toxic materials in agricultural production; to improve management of on-farm resources to enhance productivity, profitability, and competitiveness; to promote crop, livestock, and enterprise diversification and to facilitate the research of agricultural production systems in areas that possess various soil, climatic, and physical characteristics; to study farms that have are managed using farm practices that optimize on-farm resources and conservation practices; and to promote partnerships among farmers, nonprofit organizations, agribusiness, and public and private research and extension institutions. Click on program name and check the link in the Primary Internet box for more information about grant opportunities and program results. (Web site: http://cfpub.epa.gov/fedfund/program.cfm?prog_num=54)	$ 18.5 million
Water Quality Cooperative Agreements	These EPA grants are provided to help states, Indian tribes, interstate agencies, and other public or nonprofit organizations develop, implement, and demonstrate innovative approaches relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution. This includes watershed approaches for combined sewer overflow, sanitary sewer overflows, and storm water discharge problems, pretreatment and sludge (biosolids) program activities, decentralized systems, and alternative ways to measure the effectiveness of point source programs. The estimate of funds available for fiscal year 2003 includes $20 million that has been requested for a new Watershed Initiative (WSI) program. Details for that program are currently being developed. If funds are appropriated for this program separate guidelines will be developed for the submittal, review, and approval of WSI projects. (Web site: http://cfpub.epa.gov/fedfund/program.cfm?prog_num=60)	$ 18,835,000 (estimated) ($15,000,000 requested for the New Watershed Initiative)
Watershed Processes and Water Resources Program	The Watershed Processes program sponsors basic and mission-linked research that address two areas: (1) Understanding fundamental processes controlling a) source areas and flow pathways of water, b) the transport and fate of water, sediment, nutrients, dissolved matter, and organisms (including water-borne pathogens), within forest, rangeland, and agricultural environments as influenced by watershed characteristics and contaminant origin, and c) water quality. (2) Developing appropriate technology and management practices for improving the effective use of water (consumptive and non-consumptive) and protecting or improving water quality for agricultural and forestry production, including the evaluation of management policies that affect the quantity and quality of water resources. (Web site: http://cfpub.epa.gov/fedfund/program.cfm?prog_num=96)	$4.2 million

mentation and enforcement of policies to protect the environment. Depending on the circumstances, that authority is delegated to other departments in the state government. For example, the DSF is responsible for large capital maintenance and improvement contracts on the UW campus, so DNR rules regulating construction-site erosion and sedimentation, including any stormwater-management elements designed into campus projects, would be implemented by the DSF. The administrative responsibility for planning, designing, and carrying out campus capital projects is complex. A rough schematic of how this works is included in Appendix 8.

The UW–Madison is in a unique situation as explained in the regulatory context and standards sections. Specifically, state projects involving buildings are not subject to local building codes and permitting for these projects go through the Department of Commerce. Until Commerce modifies its administrative rules to include Chapter NR 151, the new DNR standards will be enforced on state building projects. The UW–System will need to take the initiative internally to adopt the standards proposed earlier and to adjust its administrative processes to facilitate effective implementation and enforcement of those standards. Making this happen will require cooperation between the UW–System, the DOA, and the Department of Commerce.

UW–Madison administration, FPM, and the Department of Administration, in collaboration with the DNR and the Department of Commerce, should take the following steps to implement the polluted runoff management standards proposed in this report. The University should:

1. Formally ***adopt the proposed standards.***
   - *Establish a mechanism specifically for incorporating practices* within current project design processes to mitigate the impacts of development on stormwater runoff. This can occur on two levels. First, the standards can be disseminated to FPM and the Physical Plant staff responsible for conceptual development of a project in the form of guidelines. Second, the more formal process of changing administrative rules can be initiated to incorporate these standards into the UW–System administration. That will benefit not only the Madison campus, but also the rest of the UW campuses in the state. Staff should keep in mind that onsite mitigation should be considered first, and then off-site mitigation options could be examined, starting with the list of potential sites included in *Case Studies,* Chapter 5 of this report.
2. ***Make policy changes*** to adjust administrative processes to facilitate implementation and enforcement of those standards. This step should include the following:

- *Amending the University's process for implementation and monitoring* to incorporate the proposed standards for the UW–Madison main campus. The proposed standards are best incorporated during the project design phase. Thus, the Physical Plant and FPM will be responsible for including these standard specifications in project designs. The standards need to be part of each project from concept through construction and need to be promoted by the campus project staff during planning and design. The goals should be specifically stated in the program description for each project and money to meet these goals should be included in each project budget from the inception of the project. This is a change in the way many designers and program planners think. The information should also be conveyed to the campus staff who work on small projects—delegated to the campus by DOA per campus request.
- *Clarifying with the DNR what standards and requirements apply* to campus and where they have the power of enforcement. If the University, the DOA, and the DNR know explicitly what can be enforced by whom, attention to implementation of those standards and requirements will be examined more closely by all involved parties.
- *Streamlining the construction-site inspection functions* of the University's Landscape Architect (LA). The LA should be able to talk directly with the construction-site manager to resolve any problems with erosion and sediment controls. This can be written into contracts under the special conditions section of the contract where lines of communication are designated. The LA could also have a role in reviewing construction plans and specifications during design. If the LA is not written into the contract for direct communication, any concerns or problems can be reported to the FPM project manager or the DSF Construction Representative, as is currently the process. The simplest step to help the LA know what projects are taking place and what is required is to give the LA access to the DSF project database, known as WiscBuild. (Further discussion is included in the Chapter 4 in the *Construction Erosion Control* section.)
- *Empowering the FPM Senior Environmental Health Specialist* to have a greater role in implementation and enforcement of the proposed performance standards and the WPDES permit requirements. The details of how this person can best facilitate implementation and enforcement should be worked out through further discussions.
- *Developing a mechanism for faculty awareness of campus construction projects* to identify potential educational and research opportunities through those projects. This will strengthen the instructional and research capabilities of the UW–Madison, and will also identify unique project opportunities

where additional funding might be available because of the instruction or research element of the project.

- *Setting up a supplemental preferred BMPs list* to augment the State's Construction Site Best Management Practices Handbook between 10-year revisions (Wisconsin Department of Natural Resources, 2001). Some resources on BMPs are included in Appendixes 13 and 14.
- *Developing a memorandum of understanding* (MOU) between the DNR, DOA, UW–System, and the Department of Commerce concerning construction-site erosion and sediment control. This MOU must include the Department of Commerce because it holds authority over erosion and sediment control for construction sites on campus. Also, the MOU should take into consideration stormwater management throughout the UW System because these problems are not unique to the Madison campus and uniform administration of stormwater standards makes sense institutionally.

3. ***Inventory the campus*** for mitigation sites and site specific BMPs. Graduate projects assistants involved with the project (Bob Lisi, Katherine Owen, and Lisa Young) already plan to further research BMPs and make the list more useful to campus, as well as inventory all runoff reduction opportunities for compensatory mitigation then rank them according to prioritization criteria.

4. ***Annually update and modify*** stormwater-management practices, including the following:
   - Add new technologies to the supplemental preferred BMPs list.
   - Add changes recommended through permit related monitoring efforts.
   - Keep up to date and effectively use the University's "no bid" list established under the new WPDES permit.
   - Ensure that housekeeping practices like street sweeping, catch-basin cleaning, and deicing are adequately funded so the intent of protecting surface water quality is not compromised.
   - Give the FPM responsibility for maintenance of the sewershed delineation completed as part of this project. As new construction is completed, the hydrology of campus is altered, and the database needs to be updated to reflect these changes. More information about long-term monitoring can be found in the next section.

The Grant Steering Committee for this project and the Graduate Project Assistants will continue to work with UW–Madison to develop the details for implementing the steps outlined above and identifying any further steps necessary to protect the waters of Wisconsin.

Long-term monitoring

It is necessary to provide tools to UW–Madison to not only implement the recommended stormwater standards based on NR 151, but to monitor their reductions in runoff and pollutants. To function well, a monitoring system will need the capability to track the location and construction-completion date of all land-use changes and BMPs, and any changes in runoff and pollutants, such as suspended solids. Other inputs and outputs for the system can be incorporated depending on the requirements and requests of the University staff using the system. The monitoring system will also provide the framework for assuring that all construction on campus meets the standards, either on site or through off-site compensatory mitigation.

The Water Resources Management Workshop has laid the foundation for creating a long-term monitoring system for University staff to use. The first step in creating this model was developing the land-cover classifications, sewershed delineations, initial runoff estimates, and pollutant loadings, as described in Chapter 2. The final model is supported by GIS data on pervious and impervious surfaces. Cassandra Garcia, Master's student in Environmental Monitoring, completed this model as her graduate thesis in December 2003. Information about this model will also be included in the Project Assistant report, which should be complete by the end of 2005.

David Liebl reminds the University that, "stormwater-management practices will need to be reviewed site-by-site on a regular basis. The amount of construction and landscaping that takes place on campus means that even the exemplary sites can become degraded in a few years (reduced infiltration from compaction is a good example). Ongoing inspection and evaluation of stormwater-management infrastructure and practices should become part of routine campus maintenance" by FPM and Physical Plant staff (written communication, October 3, 2003).

References

Land-of-Sky Regional Council. (2002). Storm Water Control: Principles and Practices, Asheville, NC. Retrieved July 15, 2003, from http://h2o.enr.state.nc.us/su/PDF_Files/Land_of_Sky_factsheets/FactSheet_2.pdf.

Potter, K.W. (2003). Managing Storm Water at the Source. Wisconsin Academy of Sciences, Arts and Letters, 90:67-73.

U.S. Environmental Protection Agency. (2000a). Storm Water Phase II Final Rule:

An Overview (EPA Publication No. 833-F-00-001). Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2000b). Storm Water Phase II Final Rule: Small Construction Program Overview (EPA Publication No. 833-F-00-013). Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (Updated August 2003). Catalog of Federal Funding Sources for Watershed Protection. Retrieved August 6, 2003 from http://cfpub.epa.gov/fedfund/.

U.S. Environmental Protection Agency. (2003). National Menu of Best Management Practices for Storm Water Phase II. Retrieved July 15, 2003, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm.

University of Wisconsin–Madison. (1996). Comprehensive Master Plan – Summary Report. Retrieved July 15, 2003, from UW–Madison, Facilities, Planning and Management Web site: http://www2.fpm.wisc.edu/planning/UWMASTERPLAN/chancletter.htm.

University of Wisconsin–Madison. (January 2003). Group Application for a Municipal Storm Water Discharge Permit Under Sections NR 216.03(1) and NR 216.06, Wis. Adm. Code. Submitted to the Wisconsin Department of Natural Resources by UW–Madison and co-applicants.

Wisconsin Department of Natural Resources. (2000). Nonpoint Source Control Plan for the Lake Mendota Priority Watershed Project. DNR, WDATCP, Dane Co. LCD, Columbia Co. LCD. Publication WT-536-00 REV. Retrieved July 15, 2003, from http://www.dnr.state.wi.us/org/water/wm/nps/pdf/mendota.pdf.

Wisconsin Department of Natural Resources. (2001). Wisconsin Construction Site Best Management Practice Handbook. Publication WT-222-2001 Rev.

Wisconsin Department of Natural Resources. (November 2002). Wisconsin's Runoff Rules: A summary prepared by the Wisconsin Department of Natural Resources Runoff Management Section.

Wisconsin Department of Natural Resources. (2003). Municipal Storm Water Management, Proposed NR 216 with Phase II Revisions. Retrieved July 15, 2003, from http://www.dnr.state.wi.us/org/water/wm/nps/rules/nr216/nr216_revisions.htm.

Chapter 4: Recommendations

Construction erosion control

Construction activities are defined as any renovation or redevelopment activity that involves disturbing the soil through grading or excavation (Wisconsin Department of Natural Resources, 2000). Runoff from construction sites can carry a high percentage of sediments if it is not properly managed. The soil erosion that can accompany construction activities poses a serious water-quality concern within the watershed. These sediments can significantly reduce the capacity of stormwater-conveyance systems, which could lead to localized flooding. In addition, water-quality improvements could be negated by pollution from construction site runoff (Wisconsin Department of Natural Resources, 2000).

Approximately 437 acres of land within the Lake Mendota watershed are in transition from rural to urban uses each year. This accounts for only 0.5 percent of the total land use per year. However, despite being a relatively small percentage of the total land use, these transitional areas account for 22 percent of the total sediment load and 18 percent of the total phosphorus load into Lake Mendota. Erosion control in place for Dane County requires developers to implement BMPs to comply with the 7.5 tons/acre/year construction-site erosion-control standard adopted by Dane County, to reduce the direct discharge of runoff from construction sites by 80 percent, and to maintain peak stormwater flows to predevelopment conditions for 1-, 2-, and 10-year storm events (Wisconsin Department of Natural Resources, 2000).

Despite the fact that standards and regulations are in place for construction-site erosion control, at the state and county level, several issues still significantly limit the effectiveness of these regulatory tools on the UW campus. The following discussion is based on communications with Peggy Chung, of UW Facilities Planning and Management, during May and June 2003. One of the major problems is that erosion-control standards are not clearly defined in construction contracts. Planners must consider many things during the project conception and design, and establishing adequate management practices to address erosion control in many cases is overlooked. Although the contractors are required to follow all state regulations to provide adequate erosion-control measures, some aspects of the construction, such as the scope of the project, are usually not considered when deciding upon the erosion-control practices in the contracts. Installation and maintenance of erosion-control practices can be poor because the language of these contracts is typically vague.

A second limitation in controlling erosion on construction sites is inadequate enforcement of existing standards. Enforcement of erosion-control standards is typically only done when there is a complaint, and even after a complaint is made, it is can be unclear who is responsible for the problem because of the number of subcontractors involved in the project (Wisconsin Department of Natural Resources, 2000). Agencies such as DOA and the DNR, which are responsible for enforcing erosion-control standards, are understaffed and cannot adequately monitor the problem. The FPM is responsible for approving areas on campus where development will occur, and the DSF contracts an architect to create a design on the basis of the project description and requirements. Even though FPM project managers remain involved with the project throughout construction, once the contracts have been signed it becomes very difficult to alter existing practices to better address the erosion problems that may occur. This is because the property then legally belongs to the contractor, and regulatory agencies cannot enter the property without permission from the construction-company representative. Because of the many representatives typically involved in construction projects, the lines of communication to address erosion problems can be long, increasing the time it takes to respond to observed problems.

Two avenues exist for improving these lines of communication.

- The LA can be written into the project contract as allowed to communicate directly with the contractor about erosion- and sediment-control measures. This can be handled in the special conditions section of a contract.

- The LA should be given access to the DSF database of projects on campus, known as WiscBuild.

A limiting factor for construction-erosion control is that no universal solution to controlling erosion exists. The best alternative(s) for controlling erosion are highly site-specific. To control erosion adequately, contractors must be aware of all the viable management practices available, which practice(s) would be most applicable to their particular site, and how best to install these practices. Contractors may be unaware of some of the more innovative management alternatives for controlling erosion and sedimentation and may lack the technical expertise to properly install and maintain some of the more familiar BMPs. A system needs to be created that provides a BMP information database that contractors can consult when bidding for a construction contract.

Popular best management practices for erosion control

Silt fencing. Silt fencing is a geotextile fabric that is attached to posts that are installed downslope of construction projects to filter out sediment from stormwater runoff, and is the most popular form of sediment control on construction projects. Some of the advantages of silt fencing from a contractor's point of view are that it is relatively inexpensive, it is a familiar erosion control technique, and it is usually specified in construction contracts (Kasperson, 2000). However, it is important to note that using silt fencing alone is not usually enough to control construction runoff. Silt fencing is most effective when used in combination with erosion-control measures such as revegetation, erosion matting, and use of polymers, which bind exposed soil. When additional erosion control is not implemented, silt fences cannot usually hold up after heavy rain events (Kasperson, 2000). In addition, silt fences can be ineffective if they are not properly installed or maintained. The layout, slope, or ground surface of a site can make silt-fence installation difficult (Kasperson, 2000).

Figure 4.1. *Ineffective silt fence near Chamberlin Hall.*

Several different types of materials used for silt fences are appropriate for different types of runoff velocities and sediment sizes, but contractors may not be familiar with the type of material that would be most effective for a particular project (Peggy Chung, Facilities Planning and Management, oral communication, June 2003). Examples of improper silt-fence installation and maintenance can be found on campus; Figure 4-1 shows an ineffective silt fence near Chamberlin Hall. This silt fence was installed on a concrete surface with sand bags placed intermittently to hold it in place. Sediment-laden runoff was not adequately controlled. Other technologies exist for silt fencing on hard surfaces, but are not yet standard practice.

Inlet protection. Inlet protection typically consists of a geotextile fabric that is installed within stormwater inlets to prevent sediment from entering these inlets. Inlet protection should be done on every construction project. However, it is important to realize that this is a last line of defense, and should be used in combination with other erosion and sediment-control practices. Many construction projects use inlet protection as a primary source of sediment control, and this is simply an inadequate way to address the problem of erosion control. Another issue that is common is improper use and maintenance of the inlet-protection material. Silt-fence material is in many cases used as inlet protection; however, the material used is woven in such a way that it quickly becomes clogged with fine sediment and becomes ineffective (Figure 4.2). The type of material that should be used is filter fabric, which allows fine sediment and water to go through and prevents flooding. After inlet protection is installed, it is very important to clean the material after rain events so that it can be effective for future rain events (Peggy Chung, Facilities Planning and Management, oral communication, June 2003).

Figure 4.2. *Poorly maintained inlet protection and defective silt fence near Chamberlin Hall.*

Figure 4.3. *Area near University Hospital where a tracking pad would be useful.*

Tracking pads. Tracking pads can be an effective tool for sediment containment, but are typically not used in campus construction projects. The most common form is a stone-tracking pad, which removes sediment from the tires of vehicles by allowing the tires to sink in to the stone base slightly. This action, combined with the rolling motion of the tires, knocks loose much of the sediment from a vehicle's tires before it leaves the site. Tracking pads are generally used on construction sites at any point of entry or exit and must be installed as soon as the drive area has been graded and before any framing above the first floor decking has begun on the structure (Dane County Erosion Control and Stormwater Management Manual, 2002). These can also be made of rubber rather than stone. Figure 4.3 shows a construction project in which a tracking pad would be useful; Figure 4.4 shows an example of an existing rubberized washing pad, similar to a rubber tracking pad, used to help minimize the amount of sediment leaving the site from exiting vehicles. Further description of tracking pads can be found in Appendix 13.

Straw logs. Straw logs can be a useful method of sediment control in situations in which silt-fence installation is inappropriate. Straw logs are sturdier than silt-fence material and can be used in paved areas that do not allow silt fence poles to be installed (Peggy Chung, Facilities Planning and Management, oral communication, June 2003). These logs also allow water to pass through while trapping sediment in the straw material, which is an advantage on sites

Figure 4.4. *Example of a rubberized washing pad in action. Picture taken from* http://www.epa.gov/owow/images/NonPtPics/14.GIF.

with high runoff velocities. One disadvantage is that straw logs are typically more expensive than silt-fence material. Straw logs also tend to break down over time, so they would have to be replaced in situations where long-term sediment containment is necessary. More durable technologies might be considered for long-term sediment control when appropriate.

Figure 4.5. *Large uncovered dirt pile near Chamberlin Hall.*

Berms. Berms consist of raised landscapes that act as a barrier for stormwater runoff. On larger construction projects, the use of berms may be the most effective method of sediment control. Berms are sturdier than more temporary practices, such as silt fences, and they are also easier to maintain once they are installed (Kasperson, 2000). However, site conditions can make the use of berms an expensive and labor-intensive sediment containment procedure. In addition, most of the construction projects on campus are renovation projects on existing buildings in an urbanized setting, which would make the use of berms an impractical alternative.

Revegetation and erosion matting. Erosion-control practices are usually only effective if they are used in combination with erosion-control practices that stabilize the exposed soil within a construction site, thus minimizing the burden placed on sediment-control methods such as silt fences. The lack of adequate erosion control during construction is a major problem on campus. Figure 4.5 shows a large pile of dirt that is uncovered and will no doubt significantly contribute to sedimentation after a major rain event. Such piles should be covered with some sort of material so that the dirt does not wash away after major storm events. Within a reasonable amount of time following project completion, contractors should revegetatate large areas of soil that are left barren by construction projects. In addition, erosion matting should be used where appropriate to stabilize the soil as the plants are growing. Finally, efforts should be made in the planning process to minimize the amount of loose material located on the construction site.

Future BMPs. In addition to these management practices, it is important to remember that future technologies may considerably improve erosion control in years to come. Contractors generally take steps to control construction-site erosion; however, giving them timely access to the latest erosion-control practices and allowing flexibility in the planning process will significantly improve the problem of construction-site erosion control.

Key stormwater problems associated with construction projects on campus

- Erosion and sediment control is not always clearly defined in construction contracts.
- Erosion and sediment control is a low priority concern for some contractors.
- Regulatory agencies are inadequately staffed, which makes enforcement of existing standards difficult.
- Lines of communication for dealing with construction stormwater problems are long, increasing time to respond to observed problems.
- Best management practices specified in construction contracts do not adequately reflect site-specific issues, such as the scope of the construction project and the physical character of the site.

Key recommendations for controlling erosion on construction projects

- Stormwater issues need to become a higher priority for construction activities on campus.
- The scope of a particular project, the physical characteristics of a site, and other site-specific issues need to be clearly addressed in the planning and design process to properly implement effective best management practices.
- Commonly used sediment control methods, such as silt fence and inlet protection, need to be properly installed and maintained, and should be used in combination with erosion-control methods that help stabilize the sediment within a site.
- Although silt fencing is the most popular management strategy for dealing with construction stormwater issues, it is not a universal solution. Other management practices need to be considered when looking at the site-specific character of a site.
- Efforts should be made to ensure that the latest best management practices are specified in construction contracts to help contractors address site-specific stormwater issues on their site.
- Project planners should incorporate existing stormwater standards and be provided with the latest technical information to help them design to those standards.
- Efforts should be made to monitor construction projects after major rain events to ensure that they are complying with existing standards.
- The Landscape Architect's job should be expanded to include assisting in developing of and monitoring implementation of CSEC plans.
- The Landscape Architect needs to be given access to WiscBuild, the DSF database of projects that has contact information and project details. This would improve communication among all parties involved in erosion- and sediment-control enforcement.

Building design

The amount of impervious surface created with the construction of a new building is a major challenge to stormwater mitigation. However, several design strategies can be incorporated that will significantly improve infiltration and water quality. By utilizing certain BMPs, and creating space-efficient building designs, contractors can maximize green-space and increase infiltration.

One of the most important strategies that can reduce stormwater runoff in building design is to decrease the overall footprint on the landscape. To achieve this, buildings should be designed to utilize vertical rather than horizontal space. Additional stories should be used whenever possible to limit the amount of impervious surface coverage. Neighboring buildings should share driveways whenever possible, and pervious pavement can be used to increase infiltration on these driveways (Dane County Lakes and Watershed Commission, 2002).

When designing a building, several minor considerations can drastically improve water quality and reduce the amount of surface runoff. Typically, buildings will get more ice on the north side in the wintertime. Therefore, using the south side of buildings for the main entrance is a good way to limit salt application and improve water quality (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). Building designs should also utilize pre-existing conditions that will help increase infiltration. Predevelopment vegetation should be maintained to the greatest extent possible. Natural buffers that exist between buildings and natural water bodies should also be maintained. Any natural drainage pathways that exist on a site should be utilized to help divert stormwater runoff and prevent gully erosion (Dane County Lakes and Watershed Commission, 2002). Green roofs are another building design technology, which help reduce runoff and pollutant loading (see Appendix 13).

Certain best management practices can be especially effective at reducing the amount of stormwater coming from buildings. When soil permeability is decreased through construction activities, deep tilling and chisel plowing should be used to restore the natural permeability. The application of organic matter in the upper layers of the soil will increase water-holding capacity and maximize infiltration. Other best management practices, such as rain gardens and grass swales, should be considered as ways to deal with surface runoff on-site whenever possible.

Because the UW–Madison campus is constantly growing, it is important to find ways to manage growth in a way that will mitigate the effects of stormwater runoff. By utilizing BMPs and space-efficient design strategies, many of the stormwater issues that go with new development can be overcome.

Key recommendations for building design on campus

- Buildings should utilize vertical, rather than horizontal space.
- Neighboring buildings should utilize shared driveways whenever possible, and can increase infiltration by using pervious pavement for these driveways.
- Main entrances to buildings should be located on their south sides to limit salt application in winter months.
- Building designs should utilize pre-existing vegetation for infiltration purposes whenever possible.
- Natural buffers between buildings and natural water bodies should be maintained.
- Best management practices, such as chisel plowing and deep tilling, can be used to improve the natural permeability of compacted soils.
- Other BMPs, such as rain gardens and grass swales, can be utilized to improve infiltration around building sites.

Parking lots

A major limitation to effective stormwater mitigation on campus is the high degree of impervious surface, which is a typical characteristic of urban environments. Parking lots tend to contribute greatly to this limitation by adding large amounts of impervious surface, and providing a source of pollutants, including oil, grease, and heavy metals. However, minimizing the amount of paved surface and incorporating vegetated infiltration areas in parking-lot design can help improve water quality and reduce stormwater runoff volume.

Parking-space design should be done in the most space-efficient way possible. Angle parking can reduce driving-lane width; stall dimensions can also be reduced. The use of at least 30 percent dedicated compact car spaces can be used to achieve this goal (Barr Engineering, 2001). Although this does not fit with current vehicle demographics, parking-permit practices can be tailored to encourage compact vehicle use.

Probably the most effective way the UW–Madison can limit impervious surface in parking lot design is to implement BMPs that incorporate pervious material into the lots. Porous pavement, pavers, and aesthetic gravel can all be used in parking lots that receive relatively low vehicular traffic. These BMPs are discussed further in the *Pedestrian design* section of this chapter. Decreased impervious surface area can also be achieved through shared parking lots. Neighboring businesses that have peak parking demand at different times should be encouraged to share lots. An effective example is Luther's Blues Restaurant, which directs people to park in lot 20.

In addition to minimizing the extent of paved areas, another strategy to reduce stormwater runoff on parking lots is to utilize vegetative areas. Grasses, forbs, shrubs, and trees help reduce the effect of stormwater runoff by removing water through evapotranspiration and by creating root channels in the soil that increase infiltration. Stormwater from parking lots can be conveyed to these vegetated areas through curb cuts or vegetated islands can be added within the parking lot. These plantings also provide an aesthetically pleasing stormwater-management alternative.

Generally, shallow-rooted turf grass is not overly effective at reducing stormwater runoff. Therefore, deep-rooted perennial plantings should be used whenever possible. The use of trees is also encouraged to help intercept rainwater and provide shade over parking areas, which reduces the heat-island effect. Canopy cover should be at least 50 percent of the paved surface. Because growing conditions are usually less favorable than normal under parking lot conditions, trees should be planted closer together.

Although established plantings will require less maintenance than paved surface, proper care should be taken to ensure plant survival. Planted areas should be weeded monthly during the first few years to help establish a healthy landscape. After that, weeding should only be necessary once or twice during the growing season. Plants should be watered as often as possible. However, because FPM would be responsible for watering, and they have a relatively small staff, drought-resistant species should be used. Typically, irrigation systems are required if stormwater runoff does not provide an adequate water supply. Snow should be plowed away from vegetated areas to help reduce sand and salt accumulation. Finally, during the construction process it is important to avoid driving on designated planting areas to avoid compaction, which would limit infiltration capacity and plant survival.

Despite the obvious advantages of modifying parking designs to reduce paved surfaces and incorporate vegetated infiltration areas, some significant challenges still must be overcome. Municipalities may have rigid parking requirements that are not open to flexibility. Also, space allocated in parking-lot design may not be sufficient enough to allow for vegetated infiltration areas. Finally, soil conditions on the site may not be favorable for infiltration or plant survival.

Not all these limitations can be overcome on every site. Physical aspects of the site, such as soil composition, cannot easily be altered. However, all parking-lot designs should take stormwater runoff into account, and incorporate these recommendations whenever necessary. It is important for institutions, such as the UW–Madison campus, to make their parking requirements flexible enough to encourage innovative design strategies.

The UW–Madison campus also has several parking ramps, which have the potential to be major concerns in stormwater management, due to the large number of cars they accommodate. On all parking ramps, runoff from all levels goes into stormsewers. The

City of Madison requires all but the uppermost level to drain into the sanitary sewer. Although the University is exempt from city requirements, this design is an effective control on pollutant loading. The University should design all future parking structures in accordance with this requirement.

All parking ramps are also required to have oil and grease separators as part of their design. Vegetated infiltration areas can also be an effective BMP for dealing with the runoff from parking ramps. Whenever possible, runoff should be conveyed to these areas.

Managing campus green areas

Within the UW–Madison, three separate entities are involved with managing campus green areas: FPM Operations, the UW Athletic Department, and the Department of Sports Recreation. Although each entity is responsible for maintaining and managing campus green spaces for different purposes and needs, we recommend that they work together to ensure that campus green areas promote maximum surface-water infiltration and reduce excess nutrient runoff.

Urban soil compaction and stormwater

Stormwater infiltration can be severely hindered by compacted soils. Soil compaction occurs when soil particles are pressed together, creating a dense mass, and thereby reducing the amount of pore space. A comparison of pore space between normal (not compacted) and compacted soils is show in Figure 4.6. This pore space, which facilitates the movement and storage of air and water, is necessary for plant growth and soil organisms (Natural Resources Conservation Service, 2000). The surface of a compacted soil is more likely to seal, which means water has a harder time moving down through the soil.

Soil compaction occurs at two levels (Figure 4.7). Surface compaction contributes to increased runoff and the establishment of new vegetation. Subsoil compaction significantly slows infiltration and blocks root growth.

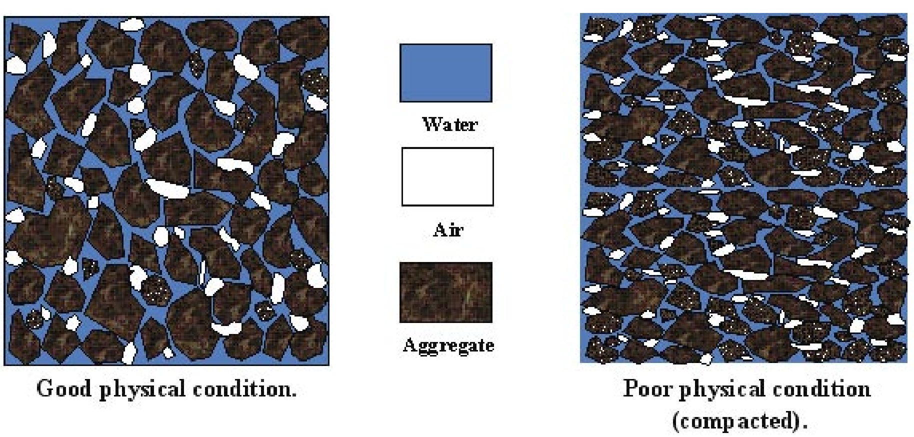

Figure 4.6. *Comparison of two different types of soils. Compacted soils have less pore space preventing infiltration. Used with permission from A. Roa-Espinosa, Urban Conservationist, Dane County Land Conservation Department (1998).*

Key recommendations for parking-lot design on campus

- Parking requirements for buildings should be re-evaluated to ensure that parking-lot area does not exceed parking demand.
- Stall dimensions can be reduced by devoting 30 percent of the stalls to compact vehicle parking and providing overflow parking on pervious surface.
- Parking-space design should be done in the most space-efficient manner possible.
- Neighboring buildings that have different peak parking times should utilize shared parking lots.
- Best management practices, such as porous pavement, can be effectively utilized to decrease the extent of impervious area used for parking lots.

Key recommendations for utilizing vegetated infiltration areas for parking-lot runoff

- The use of vegetative infiltration areas can significantly improve infiltration of stormwater runoff from parking lots as well as provide increased aesthetics.
- A combination of deep-rooted perennial plantings and various native trees will provide the best infiltration potential.
- Weeding of vegetated areas should be done monthly for the first three years. After native plants are established, weeding should only be necessary once or twice a growing season.
- Because the availability of staff to water plants on campus is limited, drought-resistant species should be utilized for parking-lot infiltration areas.
- The use of heavy machinery in creating vegetated infiltration areas should be avoided to reduce the effects of compaction.

Key recommendations for managing stormwater on parking ramps

- The UW–Madison should design future parking structures in accordance with the City of Madison requirement for all runoff from parking ramps to be conveyed to the sanitary sewer system, with the exception of the uppermost level.
- Oil and grease filters, oil and grease separators, sand filters, or in-line treatment devices are required to deal with the water-quality concerns associated with parking ramps.
- Runoff from the uppermost level of parking ramps is conveyed to stormsewers; vegetated infiltration areas can be an effective BMP for dealing with this runoff.

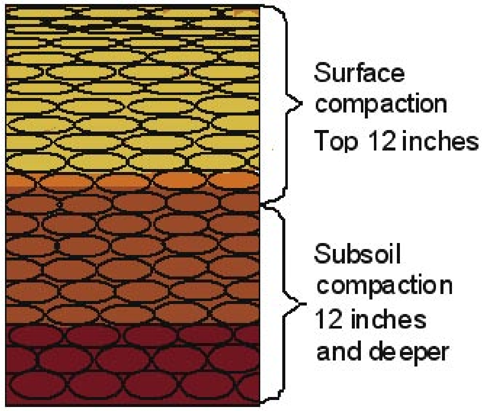

Figure 4.7. *Illustration showing surface and subsoil compaction. Used with permission from A. Roa-Espinosa, Urban Conservationist, Dane County Land Conservation Department (1998).*

Bare soil, weeds, increased runoff, and puddling after heavy rains are the most obvious signs of a soil-compaction problem (Turgeon, 1996). Water quality may be affected indirectly by compaction. Compaction can increase runoff and erosion, resulting in more sediment in streams, lakes, and drainage ditches. Nitrates, phosphorus, other nutrients, and pesticides move into these waterways with the eroded soil, resulting in lower water quality.

Urban soil compaction occurs during building or road construction when heavy equipment is used to reshape or grade lots prior to placing sod. In many cases compacted or nutrient-depleted fill material is used to regrade and landscape the green areas surrounding construction sites. Most recently, this has taken place in the green areas surrounding the new Rennenbohm Hall of Pharmacy building on West Campus and at the Kohl Center (Figure 4.8) (Robert Scott, UW Facilities Planning and Management, oral communication, July 2003).

Infiltration tests at these sites yielded minimal water flow. Soil compaction can also occur after construction from uncontrolled vehicle, bicycle, or foot traffic (Natural Resources Conservation Service, 2000).

When soil compaction becomes excessive, green areas begin to fail (Figure 4.8). Compacted green areas prevent groundwater infiltration and have a greater potential for soil erosion and water runoff. Additionally, they lose their ability to grow plants and turf grasses (Turgeon, 1996).

Numerous practices can help avoid soil compaction or reverse it after it occurs. These practices include selective grading, special construction equipment, reforestation, mechanical loosening, and the use of soil amendments (Center for Watershed Protection, 2000a). Although a certain amount of soil compaction may be inevitable with construction activities, there is consensus among soil scientists that avoidance techniques are more effective than remediation. This is especially true when compaction extends several feet below the surface (Center for Watershed Protection, 2000b).

Preventing soil compaction

Proper planning during construction projects and subsequent management and maintenance of campus green areas can help avoid and reduce the soil-compaction problems. The following recommendations can help prevent soil compaction:

- During construction, divide large areas into sections to be consciously compacted for roads and foundations, and sections for lawns and landscaping.

Figure 4.8. *Lawn in front of Pharmacy Building, left. Kohl Center front lawn, below.*

- Disturb only areas needed for construction.
- Avoid wheel traffic and tillage of wet soils; use wider tires, dual tires, or tracks; minimize tractor weight.
- Soil that will support lawns can be protected by sub-soiling (deep tilling) and by stockpiling topsoil that will be returned to the site after construction.
- Control vehicle and pedestrian traffic over campus green areas through proper landscape design of pedestrian walkways or trails and vehicle access routes.
- During special events, lay down metal or wood mats for better distribution of weight for vehicular traffic or involving high volume of people in concentrated areas.
- Do not use compacted fill material in areas intended for lawns.

Alleviating soil compaction

Where soil compaction already exists, steps can be taken to alleviate the compaction and reduce the impacts on water quality and quantity. The following recommendations can help alleviate soil compaction:

- Regularly compacted turf grasses should be aerated annually. The current University equipment for turf aeration does not adequately serve this purpose. The University should upgrade this aeration equipment to a GA 60 type aerator (Wayne Kussow, UW Soil Science, oral communication, June 20, 2003).

- Where compaction is severe and turf is dead or dying due to compaction, areas should be reseeded or completely re-sodded.

- Irrigation management should be adjusted to promote healthy green space vegetation. Frequent, low rates of water are necessary because compacted soil holds little water. Over-irrigation wastes water and may lead to environmental pollution from lawn chemicals, nutrients, and sediment.

- Partial or total soil replacement may be needed. Replace dense soil with loose soil or haul in topsoil.

- Increasing or applying organic matter can help improve root penetration and increase water absorption. Use of mulch, compost, or manure amendments with bulking agents, such as aged crumb rubber from used tires or wood chips, are cost-effective alternatives (U.S. Environmental Protection Agency, 1997).

- Sub-soiling is another practical alternative to help alleviate compacted soils (Figure 4.9). Sub-soiling is a process of deep tilling (ripping) the construction area soil to a depth ranging from 12 to 18 inches to 2 to 3 feet. A dozer pulling two shanks can be used to break up soils. Sub-soiling enhances or reestablishes the soil-profile structure to conditions prior to urban development. It allows for rapid infiltration and breaks up the formation of sheet and rill flow before it reaches scouring velocities (Roa-Espinoza, 1998). When considering sub-soiling, its drawbacks must be kept in mind. Sub-soiling is only effective when the soil is suffi-

Figure 4.9. *Subsoiling, using a dozer, penetrates the surface and can help alleviate soil compaction. Used with permission from A. Roa-Espinosa, Urban Conservationist, Dane County Land Conservation Department (1998).*

Key stormwater problems associated with soil compaction

- Stormwater infiltration is severely hindered and surface runoff significantly increased from otherwise pervious surfaces.
- Vegetation failure can result from reduced soil moisture, difficulty of growing through compacted soils, and typically nutrient poor soils used after construction.
- Soil erosion can increase due to surface runoff and loss of healthy vegetative cover.
- Increased sedimentation and pollutant loading can result from increased erosion, runoff volume, and poor vegetation cover quality.

Key recommendations for preventing soil compaction

- During construction, divide large areas into sections to be consciously compacted for roads and foundations, and sections for lawns and landscaping.
- Disturb only areas needed for construction.
- Avoid wheel traffic and tillage of wet soils; use wider tires, dual tires, or tracks; minimize tractor weight.
- Soil that will support lawns can be protected by sub-soiling and by stockpiling topsoil that will be returned to the site after construction.
- Control vehicle and pedestrian traffic over campus green areas through proper landscape design of pedestrian walkways or trails and vehicle access routes.
- During special events, lay down metal or wood mats for better distribution of weight for vehicular traffic or involving high volume of people in concentrated areas.
- Do not use compacted fill material in areas intended for lawns.

Key recommendations for alleviating soil compaction

- Aerate compacted turf grasses annually.
- The University should upgrade its aeration equipment to a GA 60 type aerator.
- Where compaction is severe and turf is dead or dying due to compaction, areas should be reseeded or completely re-sodded when success is indicated.
- Irrigation management should be adjusted to promote healthy green space vegetation.
- Partial or total soil replacement may be needed. Replace dense soil with loose soil, or haul in topsoil.
- Increasing or applying organic matter can help improve root penetration and increase water absorption.
- Sub-soiling is another practical alternative to help alleviate compacted soils. Caution should be used here to be sure that sub-soiling will have the desired results.

ciently dry and depends on the soil type (F.W. Madison, University of Wisconsin–Madison, Department of Soil Science, oral communication, June 2003). Existing utilities in redevelopment situations may make sub-soiling infeasible.

Pesticide management

In 1997 the Campus Chemical Safety Committee of the UW–Madison passed a campus-wide Pesticide Use Policy. This policy was also a requirement of the original 1995 WPDES stormwater discharge permit. The policy has two primary objectives: first, to inform UW–Madison students, faculty, staff, and visitors of campus pesticide use, and second, to minimize pesticide-contaminated runoff from University lands into lakes, ponds, and streams (University of Wisconsin–Madison, 1997).

Because of the hazards associated with pesticides, and the need to maintain costly, high-tech equipment, most turf pesticide application at the UW–Madison is performed by outside contractors (Robert Scott, UW Facilities Planning and Management, oral communication, July 27, 2003). Campus applicators are required, under the policy, to use the most advanced available practices that maximize effectiveness, safety, and minimize environmental impact.

Routine or preventive use of turf pesticides is discouraged, and practices to minimize risk (such as spraying on the weekends or during off-peak times) are required. Additionally, applicators must inform the campus community of their intentions. The applicator posts signs notifying the public of plans to spray and must notify the Central Answering and Response Service (CARS); CARS then notifies people who have chemical sensitivities, who are included on the Americans with Disabilities Act (ADA) list (University of Wisconsin–Madison, 1997).

As with fertilizer application, turf pesticides are banned from areas along the Lake Mendota shoreline and from other sensitive areas such as student housing green areas (Robert Scott, UW Facilities Planning and Management, oral communication, July 27, 2003).

The UW–Madison is currently doing an excellent job with pesticide management. This approach to pesticide management on campus minimizes impacts on the local water resources. The ban of pesticide use from areas along the shoreline is especially important to this end.

Key stormwater problems associated with pesticide use

- Health concerns are related to some pesticides.
- Water quality may be diminished by pesticides carried to lakes and streams by stormwater runoff.

Key recommendation for current pesticide management

- Maintain the ban on turf pesticides from residence hall green spaces and campus shoreline natural areas.

Nutrient management

The sources of phosphorus in the urban landscape are diverse and include lawns, rooftops, streets, driveways, sidewalks, and parking lots (Bannerman and others, 1993). State and local governments are increasingly looking at lawn fertilizers as a major source of phosphorus pollution. The Minnesota State Legislature recently passed a new law to limit the application of fertilizers containing phosphorus in the Twin Cities metropolitan area (Minnesota Office of Environmental Assistance, 2002). Similar ordinances were approved by the Madison City Council (Wisconsin State Journal, Feb. 4, 2004) and the Dane County Board (Dane County, 2004) in early 2004.

Research conducted by the DNR staff has shown that phosphorus loading to Lakes Mendota and Monona is a leading cause of their impairment. The majority of this phosphorus is from lands with agricultural uses, but the urban percentage is still significant. Approximately 25 percent of the phosphorus loading to both lakes is from existing urban areas or areas currently developing (Wisconsin Department of Natural Resources, 2000; Dane County Regional Planning Commission, 1992). Although the Lake Mendota watershed is predominantly rural, the total developed areas in both watersheds are approximately equal. To improve the lakes' condition to support aquatic life and recreational uses, the Lake Mendota Priority Watershed Report recommends that the concentration of spring total phosphorus be reduced to less than 0.074mg/L. To achieve this concentration, total phosphorus input loading to the lake from the surrounding watershed must be reduced by about 50 percent (Wisconsin Department of Natural Resources, 2000).

Ongoing research by Bannerman and Horwatich (2000) in Madison has shown that 40 to 50 percent of urban stormwater phosphorus comes from lawns that have been treated with fertilizer containing phosphorus. This suggests that the recent phosphorus bans by the City of Madison and by Dane County will reduce the phosphorus load to the lakes. However, the issue is complicated by the importance of a healthy lawn. Both phosphorus bans allow the application of fertilizer if a soil test indicates a phosphorus deficiency. However, if lawns are not tested periodically, their quality could deteriorate as a result of phosphorus deficiency, leading to increased runoff. On plots at the UW's O.J. Noer Turfgrass Research and Education Facility, Kussow (1999) observed that runoff and phosphorus loss was much greater from unfertilized plots than from fertilized plots, presumably because the fertilized turf secured soil particles more effectively and provided better conditions for water infiltration. Kussow recommends that regular soil tests combined with knowledge of the grasses being maintained will lead to the healthiest turf and the lowest sediment- and nutrient-loading levels from the landscape (Wayne Kussow, UW Soil Science, oral communication, June 20, 2003).

Since 1995, nutrient management, specifically phosphorus reduction, has been a con-

Key stormwater problem associated with nutrient application

- Phosphorus loading to Lakes Mendota and Monona is a leading cause of their impairment.

Key recommendations for nutrient management

- Continue efforts to optimize fertilizer use to meet, but not exceed the needs of turf grasses.
- Continue the use of practices to reduce phosphorus loading to the lakes, including avoidance of sidewalks and roads, establishment of a fertilizer-free area around the Lake Mendota shoreline, and the use of soil testing to determine application schedules.
- The FPM should work together with UW Athletics and the Department of Sports and Recreation to ensure consistency in nutrient management across campus.

dition of the UW's WPDES stormwater discharge permit. The new polluted runoff rules also contain tighter requirements for nutrients. Under the urban area performance standard contained in Chapter NR 151, the application of lawn fertilizers must be done in accordance with a site-specific nutrient application schedule (s. NR 151.13).

Interviews and conversations with FPM operations staff indicate that the University is already using this procedure to apply fertilizer. Over the past 10 years, the University has significantly reduced its usage of phosphorus-containing fertilizers because most soils on campus contain sufficient amounts of the nutrient (Robert Scott, Facilities Planning and Management, oral communication, July 27, 2003). The FPM utilizes BMPs when applying fertilizers. These include the avoidance of sidewalks and roads, the establishment of a fertilizer-free area around the Lake Mendota shoreline, and the use of soil testing to determine application schedules. The FPM should be commended for their efforts and should encourage the continued use of these practices to reduce phosphorus loading to the lakes. Additionally, we recommend that FPM work together with UW Athletic Department and the Department of Sports and Recreation to ensure consistency across campus.

Preservation of campus green space

As the UW–Madison continues to grow and develop, it must do so while preserving, and in many cases restoring, the green spaces that contribute so much to the campus community. Although the 1996 Campus Master Plan proposes creating an additional 11 acres of "open space," this is not necessarily equivalent to preserving green space. Open space, such as Library Mall and the proposed Murray Mall development, contributes to the quality of campus, but they are not synonymous with green space because much of these areas is impervious. Green spaces on campus include lawns, vegetated medians around parking lots and sidewalks, and campus natural areas. They are usually a component of open-space plans and are essential for the management of campus stormwater because they promote infiltration. Preservation or a net increase of green space requires planners to think about greater efficiencies in space, taller buildings, and higher densities.

Although implementation of the Master Plan has proceeded since 1996 with the construction of new Pharmacy, Biotechnology, and Engineering buildings, and the expansion of the Chemistry building and the UW Hospital, few resources have been dedicated to the creation or restoration of campus green space. According to UW–Madison administrators, the Murray Mall redevelopment project is now in the beginning planning stages (Gary Brown, Facilities Planning and Management, oral communication, July 27, 2003). This is an excellent opportunity to include the design recommendations included in this report, such as the use of permeable pavers and the creation of green, porous areas for stormwater management.

Finally, we urge the UW–Madison to adopt a "no-net-loss-of-green-space" policy, which means that the UW could not reduce the total amount of open space, but could move elements in the design of a project, such as parking lots and roads, to achieve a better balance.

Key stormwater problems associated with loss of green space

- Green, vegetated areas are essential for the management of campus stormwater because they promote groundwater infiltration. Reductions in the total area of green space mean reduced infiltration opportunities and the associated increase in polluted runoff and decrease in groundwater recharge.

Key recommendations for preservation of green space

- During the planning stages of projects like the Murray Mall redevelopment, green space design BMPs and minimization of impervious surfaces should be incorporated.
- The UW–Madison should adopt a "no-net-loss-of-green-space" policy.

Pedestrian design

The major modes of transportation on college campuses across the county and at UW–Madison are walking and biking. Pedestrian design on the UW–Madison's campus is not only paramount for transportation but also for stormwater management. Sidewalks, plazas, and stairways add more impervious area causing more runoff. Narrow sidewalks, poorly located sidewalks, and badly placed bicycle parking can cause pedestrians to walk on lawns and landscaped areas, causing compaction, unsightly dirt/mud paths, and soil erosion. Deteriorating sidewalks contribute to ice pools, erosion, and sedimentation. Carefully designed and located sidewalks, plazas, and stairways are necessary to minimize runoff, prevent compaction, and avoid erosion problems.

Recommendations for current pedestrian facilities

Many old sidewalks around campus are deteriorating, causing erosion, safety hazards, and ponding water. Facilities Planning and Management staff is currently prioritizing sidewalks to replace (Christian Velie, Facilities Planning and Management, oral communication, July 21, 2003). After field reconnaissance is finished, FPM staff will produce a plan and accompanying maps for long-term sidewalk replacement. Because campus areas (such as Athletics, Housing, University, etc.) are under a variety of management groups, the campus needs to explore creating a plan to ensure that all areas budget sufficient funds to replace sidewalks (Christian Velie, Facilities Planning and Management, oral communication, July 21, 2003).

Other existing pedestrian facilities may not be a safety hazard or a top priority, but their stormwater impacts could be minimized. Clearly, all facilities containing safety hazards on the FPM long-term sidewalk replacement plan should be reconstructed before campus planners should look at these issues in further detail. In the future, FPM staff should inventory excessive facilities, under-designed sidewalks, convenience paths, and planting strips to create a plan to minimize the impacts of these areas.

Excessively wide sidewalks and rarely used courtyards produce unnecessary runoff and increase the costs of snow removal and maintenance. For example, Steenbock Library's stairways and courtyards are rarely used (Figure 4.10), and the 20-foot wide sidewalk at the Rennebohm Hall of Pharmacy rarely sees enough foot traffic to justify its width. A 5-foot square patch of concrete produces 37 gallons of runoff from a 24-hour storm with a recurrence interval of one year in Madison, Wisconsin. If the patch of concrete is directly connected to the lakes, all 37 gallons will flow into the lakes and contribute to the flooding problem. Additionally, excess concrete areas contribute to the urban heat island effect in the summer, adding to air conditioning costs. The needless redundancy of concrete areas on campus can be seen by the fact that the UW–Madison closes many courtyards and stairways during the winter months to reduce snow-removal labor costs and salt application (Einstein and Wold, 1998). Campus planners should look at reducing the size of these facilities by replacing excess concrete with turf or landscaping. If removing concrete is not possible, placing planters with trees and bushes can reduce the negative impacts listed above and improve aesthetics (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). Planters should be designed with a minimum 1-foot wide ledge and about an 18-inch height so people can sit on the planter edges.

Figure 4.10. *The extensive and rarely used concrete patio at Steenbock Library contributes excess runoff into the watershed.*

Figure 4.11. *Example of a dirt convenience path at Computer Aided Engineering Building causing compaction and erosion problems. This would be an excellent location to add more bushes or a chain link fence located far enough back not to hinder snow removal.*

Although excessively wide sidewalks, patios, and stairs cause considerable stormwater run-off, minimal pedestrian facilities also cause a host of problems. If sidewalks are too narrow for the volume of pedestrian traffic, the grassy areas adjacent to the sidewalk are trampled. For example, the volume of pedestrian traffic along Johnson Street by the Meiklejohn House and Cousin's Subs (between Orchard Street and Charter Street) requires a wider walking area than the existing 5-foot, 4-inch-wide sidewalk. Pedestrians have trampled the 2-foot wide planting strip between the sidewalk and the curb into sandy dust. During rainfall, a significant amount of this sand erodes into the stormsewers. Erosion can also be caused adjacent to narrow sidewalks from snow removal. The University employs John Deere Gator utility vehicles, broom tractors, and pickup trucks with mounted 8-foot plows for mechanical snow removal (Rowe and Reinhardt, 1999). These reduce the need for salt and reduce snow-removal costs from shoveling. On Old University Avenue in front of the UW Foundation Building, the sidewalk is only 5-feet, 4-inches wide, and grass on edge of the sidewalk has been stripped during snow removal. For snow removal and passage of maintenance and emergency vehicles, the minimum sidewalk and handicap ramp width should be 8 feet, or narrower equipment could be used on narrow sidewalks. After all sidewalks with safety concerns are replaced, the FPM should inventory narrow sidewalks and complete a plan for their augmentation or replacement with wider facilities.

Pedestrians on college campuses are notorious for forging their own paths through lawns and landscaping. Steady foot traffic on grass and landscaping leads to compaction, the inability for the soil to grow plants, and subsequent soil-erosion problems. Many of these dirt/mud "convenience paths" or "cow paths" can be seen around campus in newly constructed areas and older areas of campus. Figure 4.11 shows one example of these convenience paths.

Another example of a poorly designed area is the bicycle parking area on the east side of the Mechanical Engineering Building (Figure 4.12) that is surrounded by dirt or mud. All cyclists must ride and then walk through the mud on rainy days, so there is a great deal of compaction and erosion in this area. Increased cleaning costs are incurred as cyclists track mud into the building. The FPM should inventory all convenience

Figure 4.12. *The bicycle parking located at Mechanical Engineering Building that has no sidewalk connecting the parking to the main sidewalk or to the building entrance.*

paths and create a plan for each site to construct a sidewalk, build a deterrence, or allow it to remain if no problems are caused.

The popularity of scooters combined with the lack of planning on campus is a severe problem. Scooters leak oil and are driven over and parked on grass, causing erosion and compaction. The campus needs to prepare a scooter plan to retrofit old buildings with designated scooter parking, access points from the street to the scooter parking to avoid accidents with bicyclists and pedestrians, and a possible parking-permit program.

In addition to turf trampling because of narrow sidewalk widths, pedestrians tend to trample the planting strip, the area located between the sidewalk and street, when crossing the street midblock. On the west side of Union South the planting strip had to be converted to gravel due to the high volume of pedestrians crossing Randall Street midblock. During wet periods, this gravelly area can become muddy and small gravel pieces are eroded. The FPM should inventory planting strips and create a plan for their replacement with a solid surface if necessary.

Recommendations for new projects

Site planning for new buildings is a very important part of a project that many times is overlooked. Designers need to carefully locate and size sidewalks, plazas, and stairways to minimize runoff, prevent compaction, avoid erosion problems, and prevent unnecessary future maintenance costs.

Designers need to look closely at the size of concrete areas and their likely pedestrian traffic and decide if the corresponding excess runoff is justifiable. All concrete areas, including stairways and sidewalks, have maintenance costs associated with cracking and buckling over time; minimizing unnecessary concrete can reduce these costs.

Most important, new buildings should be designed to avoid redundant stairways. Stairways are eight times more expensive than sidewalks to replace (Christian Velie, Facilities Planning and Management, oral communication, July 21, 2003). Time and labor-intensive hand shoveling is the only way to remove snow from stairways. Runoff from above staircases can meander to the outside and create gully erosion where turf meets the outer stairway structure. This can be avoided if a small concrete flume is constructed on the outside of the stairway structure adjacent to the turf (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). Accessibility and meeting ADA requirements are the final important reasons to minimize stairways.

Sidewalks leading from bicycle parking, scooter parking, and main sidewalks to building entrances need to be thoughtfully located. Pedestrians on college campuses will walk the shortest distance between two points, whether a sidewalk exists or not. Designers need to provide a sidewalk along paths of shortest distance between two locations or erect a sufficient deterrent such as a fence. Small- and large-scale trip planning must be considered. For example, a direct path from the bicycle parking and from far-off apartments to the door must be provided. Designers should not only think of paths being at 90-degree angles; college campuses must be designed with many diagonal paths. Maintenance vehicles and bicycles also need a sufficient turning radius at sidewalk, path, and road intersections. Although high, dense bushes are effective in deterring pedestrians from creating a path, they can be a security hazard providing a hiding place for potential criminals. Plantings can be up to 24 inches tall and the University has the option to erect chain-link fences if mulch beds along with plantings are put in. Yet designers should refrain from paving the entire area around a building for ease because it adds unnecessary runoff and maintenance costs as described above. Additionally, as stated previously, for snow removal and passage of maintenance and emergency vehicles, the minimum sidewalk width should be 8 feet.

Except for low pedestrian traffic areas (mostly west campus), designers should provide a solid surface in place of the planting strip (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). This surface could be constructed of concrete, asphalt, durable gravel, permeable pavement, or pavers. The sidewalk should not be moved directly next to the street; this area is necessary for snow storage, temporary maintenance vehicle parking, and a margin of safety separating pedestrians from vehicles. If midblock crossings are deemed a safety hazard, designers should consider placing a fence, like those on University Avenue, to encourage pedestrians to cross at designated crosswalks.

Designers should place trees between buildings and sidewalks instead of in the planting strip to avoid heat retention of the sidewalk, constricted space for root development, and maintenance problems associated with salt-laced runoff. If trees must be placed in the planting strip, they should be placed in raised planters. Additionally, any strip of turf less than 3 feet wide is extremely difficult for UW Grounds to maintain (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). In general, the smaller the lawn area between two impervious areas, the more likely pedestrians are to trample it.

The University should experiment with alternatives to concrete and asphalt in designs for new buildings and retrofitting older facilities. If an alternative works well, it can be widely implemented in new construction and redevelopment projects and added to the list of recommendations for designers. More detailed information on BMPs can be found in the BMP Appendixes 13 and 14.

Key stormwater problems associated with pedestrian design

- Pedestrian facilities add more impervious area causing more runoff.
- If facilities are not sufficient, pedestrians walk on lawns, planting strips, and landscaped areas, causing compaction, unsightly dirt/mud paths, and soil erosion.

Key recommendations for current pedestrian facilities

- The UW–Madison needs to explore creating a plan to ensure that all areas budget sufficient funds to replace deteriorating sidewalks.
- Campus planners should look at reducing the size of excessive patios, sidewalks, and stairways by replacing excess concrete with turf or landscaping. If this is not possible, planters with trees and bushes should be placed on the excessive patios at existing buildings.
- The minimum sidewalk and handicap ramp width on campus should be 8 feet.
- After all sidewalks with safety concerns are replaced, the FPM should inventory narrow sidewalks and complete a plan for their augmentation or replacement with wider facilities.
- The FPM should inventory all convenience paths and create a plan for each site to construct a sidewalk, build a deterrence, or allow it to remain if no problems are caused.
- The campus needs to prepare a scooter plan to retrofit old buildings with designated and marked scooter parking, access points from the street to the scooter parking to avoid accidents with bicycles and pedestrians, and a possible parking permit program.
- The FPM should inventory planting strips and create a plan for their replacement with a solid surface if necessary.
- The University should experiment with alternatives to concrete for pedestrian design, including pervious pavement, pavers, and gravel.

Key recommendations for pedestrian facilities for new projects

- New buildings should be designed to avoid redundant stairways, extensive rarely used courtyards, and unnecessarily wide sidewalks.
- Designers should refrain from paving the entire area around a building for ease because it adds unnecessary construction costs, maintenance costs, and runoff.
- The minimum sidewalk width on campus should be 8 feet.
- Designers also need to ensure that the width of sidewalks is sufficient for the volume of pedestrians expected.
- Except for low volume pedestrian traffic areas, designers should provide a solid surface, such as concrete, pervious pavement, pavers, etc., in place of the planting strip.
- If midblock crossings are deemed a safety hazard, designers should consider placing a fence to discourage pedestrians from crossing midblock.
- Designers need to place sidewalks along paths of shortest distance between locations or erect sufficient deterrents such as a chainlink fences or 24-inch-high hedges.·
- Designers should not think at 90-degree angles; college campuses must be designed with many diagonal paths.
- Maintenance vehicles and bicycles need a sufficient turning radius at sidewalk, path, and road intersections.
- The University should experiment with alternatives to concrete for pedestrian design, including pervious pavement, pavers, and gravel.

Deicing and snow removal

Snow removal, necessary for safety, causes many environmental concerns. Salt application, used to deice surfaces, has associated health risks and corrodes infrastructure. Sand, used to provide traction, is a safety and environmental hazard after the spring snowmelt. The UW–Madison has already taken steps towards reducing environmental problems by creating the Salt Best Management Practice in 1999, but more steps need to be taken to minimize environmental and safety hazards, most importantly an increased budget for snow removal and deicing. It may seem intuitive that reducing sanding and salting will reduce environmental hazards (groundwater and lake contamination) and costs, but safety must be maintained to a reasonable level. The biggest cost for reducing environmental hazards is labor.

Applying salt (sodium chloride) for deicing and snow removal on sidewalks, parking lots, and roads contributes to polluted runoff. Approximately 45 percent of applied salt is carried overland by snowmelt into the Yahara Lakes and 55 percent infiltrates and slowly percolates to groundwater (Madison Department of Public Health, 2000). Salt is water-soluble and breaks down into its components, sodium and chloride. Chloride damages plants, paved surfaces, and automobiles. High levels of chloride are toxic to fish and plants. Sodium levels above the U.S. EPA recommendation limit, 20 mg/L, in drinking water negatively affect people with high blood pressure and heart disease (Maine Health and Environmental Testing Laboratory, 2002).

According to the Madison Department of Public Health (2000), the sodium content in one of Madison's municipal drinking wells is above the recommended level. Chloride and sodium levels in area groundwater have steadily increased since salt application began in 1959 and are predicted to continue to increase. However, current levels for most wells are still below the recommended limit. On average, chloride and sodium concentrations are higher in the Yahara Lakes than in the groundwater (Madison Department of Public Health, 2000). Some Madison groups are suggesting that municipal wells be moved closer to the lakes due to concern about groundwater drawdown. Because groundwater near the lakes mimics lake water quality, drinking water from these wells will have a higher concentration of pollutants. If these levels become too high, wells will be moved away from the lakes, causing more drawdown. This problem can only be fixed with minimizing salt use and increased groundwater recharge (K.W. Potter, University of Wisconsin, Department of Civil and Environmental Engineering, oral communication, July 2, 2003). Although salt does have negative environmental impacts, it is inexpensive, easy to apply, effective, and improves safety. Until other substances become available that are more effective and inexpensive, salt will continue to be used on campus. The campus goal is to keep surfaces free of ice while using a minimal amount of salt.

In addition to salt, abrasives (such as sand) are important for safety. Sand provides traction for cars and pedestrians. The University applies a mixture of salt and sand or pure salt or sand depending on the situation. Salt is not effective below 15°F (Rowe and Reinhardt, 1999). If low temperatures are predicted, a mixture of mostly sand with some salt should be used instead of a pure salt application. The salt and sand mixture is only effective if the sand is dry. If the sand is moist, it can freeze (i.e., if sand is stored outside and it snows), and actually cause more safety concerns and ice formation (Daniel Einstein, Facilities Planning and Management, oral communication, April 30, 2003). The sand expected to be used the upcoming winter should be moved to a dry storage facility in the fall. Sand causes environmental and safety concerns during the spring snowmelt and spring rains as excess is washed into stormsewers. Sand can cause problems by blocking or disrupting stormsewer flow and causing sedimentation in lakes and streams. Figure 4.13 shows sand accumulating near a stormsewer inlet following the spring snowmelt. Sand left on pavement in the spring is a serious safety hazards for cyclists. Sand increases breaking time, decreases traction, which in turn causes cyclists to slip and crash, and adds wear-and-tear to bicycles. The best way to combat these environmental and safety concerns is to sweep the streets soon after the spring snow-melt. The Grounds Department does street sweep and hand sweep in areas where street sweeping is not possible. Unfortunately, in the past years the staffing budget has not been large enough for sufficient and timely removal of sand immediately after the spring snowmelt. The street-sweeping budget must be increased to ensure sand does not cause these post-snowmelt problems.

Figure 4.13. *Sand used for traction in the winter accumulating near a stormsewer inlet at Camp Randall. To avoid sedimentation of stormsewers and lakes, an increased budget for street sweeping and hand sweeping of the sand must be provided to the numerous campus departments that have this task.*

The University's 1999 Salt Best Management Practice was created to comply with the existing DNR Stormwater Permit requirements. In addition, Environmental Services' staff conducted different experiments to learn more about salt alternatives and innovative ways to reduce salt runoff into the 1918 Marsh and the lakes. The Salt Best Management Practice recommends practices to different campus groups and areas requiring special attention including the following:

- most salt appliers,
- environmental services staff,
- facility managers and designers,
- pedestrians,
- walkways, and
- patios and wide stairways.

The University has conducted numerous experiments with salt application in the past including the following (Einstein and Wold, 1998):

- Refraining from shoveling and salting patios and redundant stairs and placing "closed for winter" signs in these areas.

- Acquiring John Deere Gator Utility Vehicles for mechanical snow removal, stopping ice formation before it starts.
- Premixing the sand and 5 percent salt mixture in the fall.
- Attempting to hydrologically disconnect runoff from the snow-storage pile for west campus parking lots to the 1918 Marsh by constructing a new berm. The berm currently in place was underdesigned and frequently fails; it only delays meltwater from entering the 1918 Marsh.
- Environmental Services staff still experiment with salt alternatives, including calcium magnesium acetate (CMA), calcium chloride (CaCl), and other new products.

For more information on the University's Salt Best Management Practice, different experiments, and implementation of practices at the UW–Madison, please refer to the Salt Best Management Practice in Appendix 9 (http://www.fpm.wisc.edu/chemsafety/Saltbmp.htm) and the Salt Reduction Status Report (http://www.fpm.wisc.edu/campusecology/landscape/salt.htm).

Managing snow-storage piles is another important aspect of stormwater control. The berm separating the snow storage pile for the parking lots on west campus from the 1918 Marsh needs to be redesigned and/or relocated to stop frequent spillovers. The current berm design is supposed to clean water by allowing it to infiltrate. This ground is not suited for infiltration in the winter. The water table is high, the ground can be frozen, and this area becomes saturated and snowmelt overtops the berm. An option that allows the sun's natural heat to melt the south snow-pile face and UW Grounds to clean out litter that accumulates from snow removal of the parking lots should be evaluated. The new berm should not rely solely on infiltration; other options possibly involving vegetative filtration should be investigated. New technologies developed by the Forest Products Laboratory could improve performance.

The University's efforts to reduce salt application while keeping sidewalks, parking lots, and streets safe should be applauded. To further improve and maintain stormwater-friendly snow removal and deicing methods, an increased budget for staff, materials, and snow-pile management is required. This will ensure a mindset of "planning ahead" instead of "crisis response."

To further reduce costs in shoveling, salt application, and "closed for winter" signs, new buildings and major renovations should be designed with snow removal in mind. Three key recommendations were made in the Salt Best Management Practice for designers. 1) Excessive sidewalks, stairways, and plazas should be avoided to minimize snow removal labor costs. 2) If possible, main building entrances should be located on the south side of the building to utilize the sun's ability to melt ice so less salt is needed (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). 3) If possible, buildings should be located and sized to minimize shadows on sidewalks and streets on the north side of the building. Tall buildings located just to the south of roads create a shadow for the entire winter and require additional salting (i.e., Rennebohm Hall of Pharmacy shades Highland Avenue). This is a tradeoff to consider when trying to reduce a building's footprint, and thereby the total impervious surface.

Mechanical removal of snow on sidewalks and handicap ramps requires an 8-foot width (UW–Madison, 1999). Mechanical snow removal on narrow sidewalks causes turf to be stripped and creates erosion problems. Areas designated for snow storage adjacent to sidewalks, stairways, parking lots, and streets must be provided in all new building designs. Many old stairways lack on-stair snow storage because snow piles cannot impede access to hand railings (Robert Scott, Gene Turk, Gary Simonson, and Catherine Bruner, Facilities Planning and Management, oral communication, July 21, 2003). Additional guidelines for careful design of pedestrian facilities and sidewalks can be found in the previous section, *Pedestrian design.* The overall campus goal for snow removal is maximize safety while using a minimal amount of salt and sand.

Key stormwater problems associated with snow removal

- Salt, used for deicing, breaks down into sodium and chloride that cause environmental, health, and corrosive concerns.
    - Chloride damages plants, paved surfaces, and automobiles.
    - Sodium levels above the U.S. EPA recommendation limit in drinking water (20 mg/L) negatively affect people with high blood pressure and heart disease.
    - These levels are rising in the Madison area in surface water and groundwater.
- Sand, used for traction, has environmental and safety concerns:
    - Sand can cause problems by blocking or disrupting stormsewer flow and through sedimentation in lakes and streams.
    - Sand left on pavement in the spring is a serious safety hazard for cyclists.
    - If the sand is moist, it can freeze and cause more safety concerns and ice formation.

Key recommendations for snow removal

- The UW–Madison Salt Best Management Practice must continue to be followed. The University Administration can show its support for the BMP by increasing budget for snow removal, deicing, and post-snowmelt street sweeping.
- The berm separating the snow-storage pile for the parking lots on west campus from the 1918 Marsh should be redesigned and/or relocated.
- New buildings and major renovations should be designed with snow removal in mind.
  - Minimize excessive plazas, sidewalks, and stairways.
  - If possible, main building entrances should be located on the south side of the building to use the sun's ability to melt ice.
  - If possible, buildings should be located and sized to minimize shadows on sidewalks and streets to the north.
  - Minimum sidewalk and handicap ramp width for mechanical snow removal should be 8 feet.
  - Snow storage should be provided adjacent to sidewalks, parking lots, and streets.
- A sufficient amount of sand for the winter must be kept in a dry storage facility starting in the fall. Periodically, the University should evaluate the adequacy of existing sand and salt storage facilities for providing dry storage.
- An increased budget for street sweeping, hand sweeping, and snow removal must be provided to keep all streets, bicycle paths, and sidewalks free of sand after the spring snowmelt and to reduce the need for salting and sanding. How much the budget should be increased would be determined with input from the Physical Plant and FPM staff.

University agricultural practices

Polluted runoff from urban land uses is the predominant concern on the UW–Madison main campus; however, urban uses are only part of the landscape. Agricultural land uses continue to dominate in Wisconsin and in the Yahara Lakes Watershed, and due to total land area, still generate more pollutant loading than urban landscapes.

The DNR Chapter NR 151 addresses agricultural practices in Subchapter II – Agricultural Performance Standards and Prohibitions. Standards are included for sheet, rill, and wind erosion; manure-storage facilities and management; and nutrient management. The details of cost-share requirements and applicability are also included in this subchapter. A brief summary of the agricultural performance standards and prohibitions is in Table 4.1.

Although the UW–Madison main campus is predominantly urban, a few agricultural areas are on campus. The most obvious is the Babcock dairy barn where 80 to 88

Table 4.1: Summary of Chapter NR 151, Agricultural Performance Standards, adapted from the Wisconsin Department of Natural Resources NR 151 Subchapter II Fact Sheet (Wisconsin Department of Natural Resources, July 2002, Wisconsin Administrative Code, 2002).

Category	Standard
Sheet, rill, and wind erosion	■ Erosion from cropped fields "must meet the tolerable soil erosion rate ("T") for those fields," from the Revised Universal Soil Loss Equation II (RUSLE II) *(NR 151.02)*.
Manure storage facilities	■ Statewide standards for new and refurbished manure storage facilities *(NR 151.05)*. ■ "Facilities are required to maintain one foot of freeboard or adequate freeboard storage to contain the 25-year, 24-hour storm, whichever is greater" *(151.05(2)(a))*. ■ Current facilities that threaten "public health, fish, and aquatic life or that violate groundwater standards must be upgraded, replaced or properly abandoned" *(NR 151.05(4))*.
Clean water diversions	■ The diversion of runoff away from feedlots, manure storage areas, and barnyards within water-quality management areas (areas 1,000 feet from a lake, 300 feet from a river or a site susceptible to groundwater contamination) *(NR 151.06)*.
Nutrient management	■ A nutrient management plan must be developed and followed for agricultural fields *(NR 151.07(3))*.
Manure management Prohibitions	■ The following are prohibited: 1. manure overflows from storage facilities, 2. unconfined manure piles near water bodies, 3. direct runoff from feedlots or stored manure into waters, and 4. unlimited livestock access to waters *(NR 151.08)*.

cows are kept at any given time (Jerry Guenther, University of Wisconsin–Madison, Department of Dairy Science, oral communication, July 23, 2003). The cows are kept in concrete yards, behind the barn or milking facilities or in interior stalls. Manure from these animals is stored until it can be taken to the University's Agricultural Research Station west of Middleton, where it is composted or spread on the fields. The barnyards and the interior stalls drain to the City of Madison sanitary sewer system. Liquid manure from the stalls is pretreated through a settling tank. A brief inspection of the barnyards revealed one spot where the rain runoff flows into an overgrown weedy depression rather than to the sanitary sewer drain. However, it appears that this runoff infiltrates on-site rather than continuing as surface runoff to Lake Mendota.

Besides the Babcock Dairy, farm animals are sometimes found in the Stock Pavilion, the Horse Barn, the Veterinary School buildings, and other agricultural research facilities in the area. The only other land use on campus that might be considered agricultural rather than urban is the Eagle Heights community garden. However, only the new location of the F.H. King Gardens is zoned agricultural. Any new garden should be designed so that no new erosion results.

Off the main campus, the University has a number of agricultural research stations where all agricultural performance standards should apply. Although this falls outside of the geographic scope of our project, the potential impact on stormwater from these agricultural practices is too significant to ignore.

Some steps have already been taken by the University to clean up agricultural runoff from its research stations under the Lake Mendota Priority Watershed Project (PWP), where cost sharing was available starting in 1997. For example the "University's Arlington Experimental station was one of the 10 *worst* polluters in the Lake Mendota watershed and was *required* to do something to clean up their act as part of the priority watershed project" (Carolyn Betz, Wisconsin Department of Natural Resources, oral communication, October 9, 2003). Although the minimum standards were met under the PWP, this leaves the Arlington station below the new standards under Chapter NR 151.

The University should be sure that their agricultural facilities on and off the central campus meet these new state agricultural performances standards for preventing polluted runoff. To this end, a full assessment of current agricultural practices and impacts of University properties should be made to identify noncompliance with Chapter NR 151. Then the University of Wisconsin should develop a plan to bring its facilities into compliance with these standards to demonstrate the feasibility and possibilities of doing so for farmers throughout the state.

Key stormwater problems associated with agricultural practices

- Agricultural land uses continue to dominate in Wisconsin and in the Yahara Lakes Watershed, and, due to total land area, still generate more pollutant loading than urban landscapes. Of particular concern is pesticide, nutrient, and sediment loading.

Key recommendations for meeting agricultural standards

- Any new gardens or other agricultural uses on the UW–Madison main campus should be designed so that no new erosion results.
- The University should be sure that its agricultural facilities on and off the central campus meet the new state agricultural performances standards for preventing polluted runoff through a full assessment of current agricultural practice compliance and water quality and quantity impacts of University properties away from the UW–Madison main campus.

References

Bannerman, R.T., D.W. Owens, R.B. Dodds, and N.J. Hornewer. (1993). Sources of pollutants in Wisconsin stormwater. Water Science Tech. 28(3-5):241-259.

Bannerman, R.T. and J. Horwatich. (2000). Sources of Phosphorous within the Urban Landscape. Wisconsin Department of Natural Resources: Presentation given at the UW–Madison on December 8, 2000.

Barr Engineering. (2001). Minnesota Urban Small Sites BMP Manual. Metropolitan Council: Minneapolis, MN. Retrieved from http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm.

Center for Watershed Protection. (2000a). Can Urban Soil Compaction Be Reversed? Technical Note #108 from T.R. Schueler & H.K. Holland (Eds.), *Watershed Protection Techniques* (pp. 666-669). Ellicott City, MD: Center for Watershed Protection.

Center for Watershed Protection. (2000b). The Compaction of Urban Soils. Technical Note #107 from T.R. Schueler & H.K. Holland (Eds.), *Watershed Protection Techniques* (pp. 661-665). Ellicott City, MD: Center for Watershed Protection.

Dane County. July 18, 2003. County Exec. Falk Seeks County-Wide Phase-Out of Phosphorus-Containing Lawn Fertilizers to Improve Lake Water Quality. Press Release as retrieved http://www.co.dane.wi.us/DaneDept/press/default.asp?frmPRID=286 on October 20, 2003.

Dane County Lakes and Watershed Commission. (2002). Dane County Erosion Control and Stormwater Management Manual. Madison, Wisconsin. Retrieved from http://www.co.dane.wi.us/commissions/lakes/stormwatermanual.shtml.

Dane County Regional Planning Commission (DCRPC). (1992). Yahara-Monona Priority Watershed Plan.

Einstein, D., and P. Wold. (1998, March 19). Salt Reduction Status Report. University of Wisconsin–Madison Environmental Management. Retrieved from http://www.fpm.wisc.edu/campusecology/landscape/salt.htm.

Kasperson, Janice. (2000). Holding Something Back: Sediment Containment Measures. Erosion Control, 7(4).

Kussow, W.R. (1999). Contributions of nitrogen and phosphorous to surface and groundwater from a Kentucky bluegrass lawn. P. 12-16. In: Proc. Turfgrass Field Day for Homeowners. O.J. Noer Turfgrass Research and Education Facility, Verona, WI.

Kussow, W. R. (2003). Where is Phosphorous Run-Off Coming From? *Turf News*, pp. 48-56, March/April 2003.

Madison Department of Public Health. (2000). 2000 Roadsalt Report. Madison, Wisconsin. Retrieved from http://www.ci.madison.wi.us/health/pubnews/2000roadsalt.html.

Maine Health and Environmental Testing Laboratory. (January 25, 2002). Sodium. Augusta, Maine. Retrieved from http://www.state.me.us/dhs/etl/sodium.htm.

Minnesota Office of Environmental Assistance (MOEA). (2002). New phosphorus lawn fertilizer law aims to protect Minnesota lakes and rivers. MOEA Fact Sheet Series. Retrieved on July 15, 2003 from, http://www.moea.state.mn.us/campaign/download/phosphorus.pdf.

Natural Resources Conservation Service. (2000). Urban Soil Compaction – Soil Quality Urban Technical Note No. 2. United States Department of Agriculture Publication 334-844-4741 X-177, Soil Quality Institute, Auburn, AL. Retrieved on July 15, 2003, from http://soils.usda.gov/sqi/files/u02d.pdf.

Roa-Espinosa, Aicardo. (1998). An Introduction to Soil Compaction and the Subsoiling Practice. Madison, WI., Dane County Land Conservation Department. Retrieved on August 7, 2003, from http://www.co.dane.wi.us/landconservation/papers/subsoil2.doc.

Rowe, S.M and P.A. Reinhardt. (1999, December). University of Wisconsin–Madison Salt Best Management Practice. Retrieved from http://www.fpm.wisc.edu/chemsafety/Saltbmp.htm.

Turgeon, A.J. (1996). Turfgrass Management. (pp. 150-152). New Jersey: Prentice Hall.

United States Environmental Protection Agency. (1997). Innovative Uses of Compost Erosion Control, Turf Remediation, and Landscaping (EPA Publication No. 530-F-97-043).Washington, DC: U.S. Environmental Protection Agency. Retrieved on August 7, 2003, from http://www.epa.gov/compost/erosion.pdf.

University of Wisconsin-Madison. (1997). Pesticide Use Policy. Retrieved August 7, 2003, from UW–Madison, Facilities, Planning and Management Safety Department's Web site: http://www.fpm.wisc.edu/chemsafety/pesticide%20use.HTM.

Wisconsin Administrative Code. (2002) Chapter NR 151, Runoff Management Final Rule, Retrieved July 15, 2003, from http://www.dnr.state.wi.us/org/water/wm/nps/rules/NRrules.html.

Wisconsin Department of Natural Resources. (2000). Nonpoint Source Control Plan for the Lake Mendota Priority Watershed Project. DNR, WDATCP, Dane Co. LCD, Columbia Co. LCD. Publication WT-536-00 REV. Retrieved July 15, 2003, from http://www.dnr.state.wi.us/org/water/wm/nps/pdf/mendota.pdf.

Wisconsin Department of Natural Resources. (July 2002). Wisconsin's Runoff Management Rules, NR 151 Subchapter II Fact Sheet, Agricultural Performance Standards and Prohibitions. Retrieved July 20, 2003 from http://www.dnr.state.wi.us/org/water/wm/nps/pdf/rules/NR151SubIIAgFactSheet.pdf.

Chapter 5: Case Studies

Given that the UW–Madison campus covers more than 930 acres, consists of hundreds of buildings and parking lots, and has a population of more than 50,000 people, it is not surprising that the campus has a variety of stormwater issues. Stormwater runoff from impervious surfaces, soil compaction, and green space management are just a few of the issues the University must deal with as it strives to remain a good steward of the environment now and in the future.

The face of the campus is in a continual state of change. Over time, new structures are being built, old ones are torn down or renovated, landscaping is being maintained or updated, and gardens are being created or replanted. It is during these projects that better stormwater control practices should be implemented, either as part of a new project or as a retrofit to an existing one. In this way, new problems can be prevented and old ones fixed. This is referred to as *mitigation*.

Intriguing examples of mitigation exist on other campuses in the United States. Just two are mentioned here. Villanova University, in Pennsylvania, retrofitted a detention basin and converted it into a stormwater wetland. Unlike a detention basin, this new stormwater wetland treats runoff quality and quantity. Evergreen State College, in Olympia, Washington, took a more comprehensive approach with the aim of limiting runoff as much as possible. Their study resulted in recommendations for design of new structures and retrofitting of existing development. Their recommendations included green roofing, pervious surfaces for roads and parking lots as well as a new approach to design of walkways and landscaping. Brief summaries of both projects are provided in Appendix 10.

A number of methods can be used to reduce a project's impacts on stormwater control. Ideally, a project should be designed with stormwater-management practices written into the plans. If this is not feasible, the University could rectify the impact by repairing, rehabilitating, or restoring the affected environment. If the impacts cannot be reduced or eliminated in the project design, and if the impacted environment cannot be restored, then the University could compensate for the impact by restoring an environment that has been impacted by a different project. This last option, called *compensatory mitigation*, should only be used if the first two options are not possible to implement.

The large size and variety of land uses on the campus provide a number of mitigation possibilities. In March 2003 a survey that asked for the location of stormwater problem sites was sent to a group of University faculty and staff. On the basis of these responses as well as input from our faculty advisors and fellow practicum participants, we compiled and organized a group of potential mitigation sites according to the major stormwater issue found at that site. This group contains many, but not all, of the potential mitigation sites on the UW–Madison campus. Practicum participants sampled the sites using coring and infiltration techniques (Appendix 11).

Soil coring involves pushing a soil probe into the soil. At regular intervals (approximately 12 inches), the probe is removed from the ground and the soil sample is examined. Samplers note the depth of the sample, the depths of different soil layers, the soil texture and color, and anything else that can be used to distinguish soil layers.

Infiltration rates were measured using an amoozemeter. This involved digging a small hole of known dimensions, keeping it filled with water to a specified depth, and recording the amount of water that soaked into the ground during each time interval. An amoozemeter is used to determine the saturated conductivity of the soil, which is necessary information for applying stormwater BMPs, such as rain gardens and detention ponds.

In addition to these two methods, data collected by students in other University classes were used. Appendix 11 notes which method was used to collected data at each site. A map of the different types of sites and the sampling locations is shown in Figure 5.1. Additional sites can be added in the future.

Infiltration sites

Infiltration sites have a ready supply of water that is conveyed by channels and pipes to the Yahara Lakes instead of being allowed to percolate down through the soil. Allowing water to infiltrate will reduce the quantity of water that reaches the lakes during and immediately after a storm event. In addition, the water quality of the lakes will improve as nutrients, sediments, and other pollutants are filtered out by the soil. A number of BMPs can be used at these sites to increase infiltration, including installing rain gardens, planting trees and native vegetation (Appendix 12), conducting deep tilling, installing a subsurface drain, and placing pervious pavement and pavers where there is vehicle or pedestrian traffic. (For more information on these BMPs, see Appendix 13.)

Horseshoe Curve

Horseshoe Curve is located on the northeast side of campus to the west of Helen C. White Hall and to the north of the Education Building. This site is mainly covered by grass with some trees. Currently, water from Observatory Drive as well as the parking lot behind the Education Building (Lot 10) is being routed by curbs and stormsewers on Observatory Drive to Lake Mendota. Initial soil probe samples found 4 to 6 inches of silt loam over a 14- to 16-inch layer of fine sand and silt, with some clay accumulation. A hard clay layer was encountered at a depth of 22 to 24 inches. (More

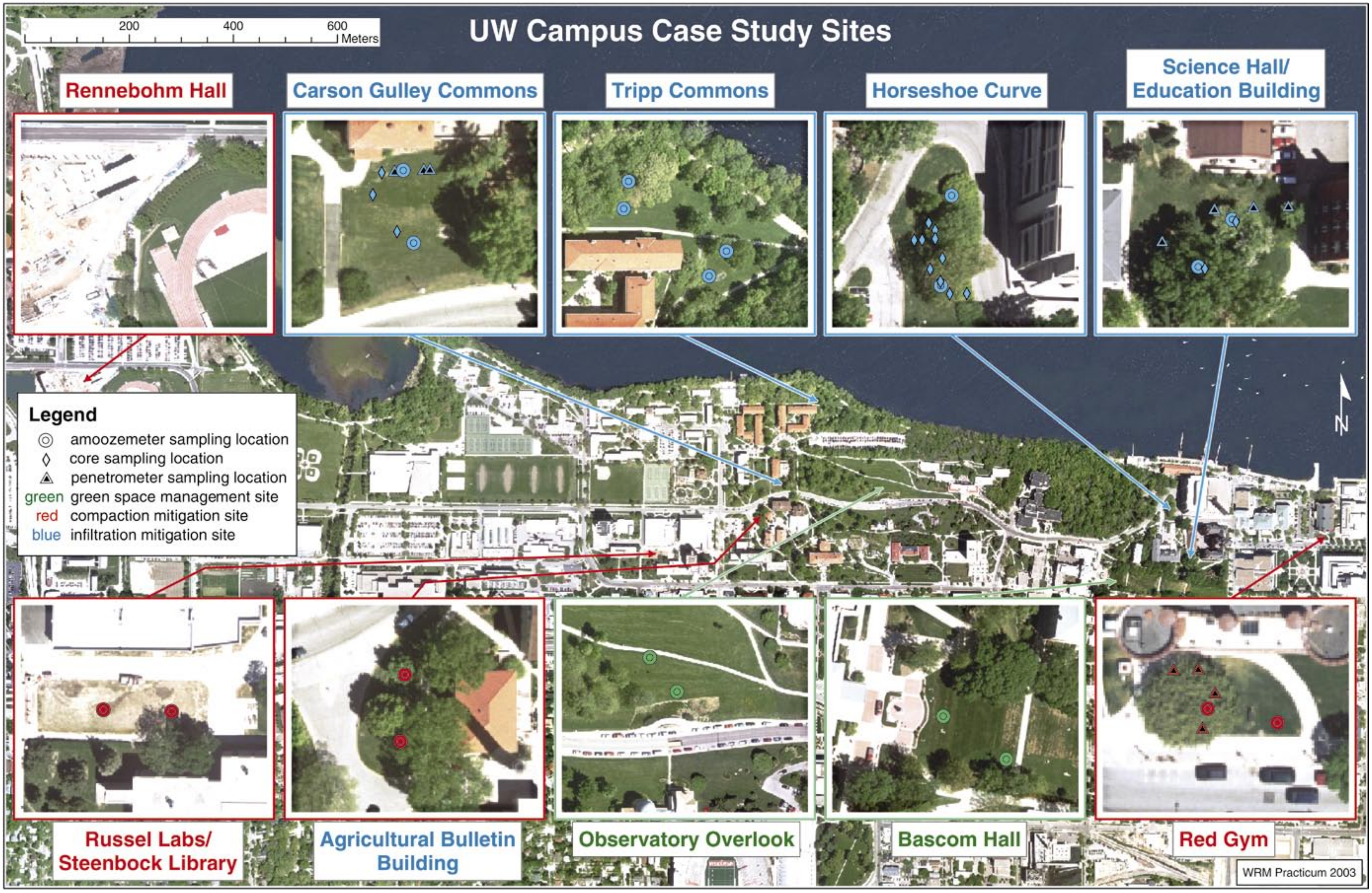

Figure 5.1. Map of University of Wisconsin–Madison campus case study sites. The sites are categorized by the type of management practice recommended.

detailed sampling data can be found in Appendix 11.) Additional testing with a larger soil probe is needed to determine the thickness of the hard clay layer. Infiltration tests indicate a moderately high infiltration rate (0.5–1.0 inches/hour). On the basis of the sample data collected, we determined that the University should install a rain garden at this site. The recent removal of the Quonset hut from the southern edge of this site should allow for a larger rain garden, although the soil here has not been tested. Plans for the renovation/expansion of the adjacent Education Hall should take advantage of this large site to deal with roof and parking lot runoff.

Science Hall/Education Building

A grassy area between Science Hall and the Education Building on the northeast side of campus is another infiltration site. Roof water from the Education Building and runoff from Bascom Hill could provide an adequate water source for a rain garden in this area. Soil samples on this site found approximately 6 inches of silt loam over a 3 to 9 inch layer of fine sand. Under this was a layer of fine sand and clay. Test results determined infiltration at the site to be moderately high (0.24–0.33 inches/hour). (For more detailed sampling results, please see Appendix 11.) One concern with this site is the location of buried utilities. Steam tunnels, electric lines, stormsewers, and water lines crisscross the site, leaving only limited space to construct a rain garden. A calculation of the maximum usable area needs to be made to determine whether this is a feasible mitigation site.

Carson Gulley Commons

Located in the north-central part of campus to the northeast of the intersection of Babcock and Observatory Drives, Carson Gulley Commons has a series of stormsewer inlets and outlets, with water sometimes flowing through underground pipes and sometimes flowing over grassed areas. Although these grassed areas allow for some infiltration, most of the water flows to Lake Mendota via the drainage channel by Tripp Hall. Buried utilities at the site could limit implementation of additional infiltration practices, such as a small pond or rain garden. In addition, tests indicate the soil has a moderately low to moderately high infiltration rate (0.16–0.25 inch/hour). The soil profiles taken at this site consisted of a very heterogeneous mixture of soil textures (see Appendix 11). This indicates that the soils on this site consist of unconsolidated fill material, which would make infiltration predictions on this site especially difficult.

Lot 43

Lot 43 is a surface parking lot located southeast of the Natatorium recreational facility on Observatory Drive. The parking lot was regraded and asphalt surfaced to direct stormwater runoff through three cuts in the curb bordering the northern perimeter of the lot for deposit on a vegetated median separating the lot and the sidewalk. Soil drilling identified 5 feet of highly impermeable clay underlain with approximately 2 feet of a mixture of sand and clay followed by pure, fine sand from 7 feet through the water-table level at 11 feet. The clay layer should be replaced with a more porous growing medium to utilize the vegetated space as an infiltration zone for the runoff collected from the parking lot. Rain gardens would be an appropriate design for promoting infiltration in this space and an effective example of using vegetated areas to manage runoff from parking lots.

Erosion sites

Erosion is a problem on campus for two reasons. First, when material is carried away from a slope, erosion can cause slope instability, which is dangerous and can cause building failure. Second, the material that erodes from a slope can end up in one of the lakes surrounding campus, causing excessive sedimentation. Sedimentation is a major erosion problem on the UW–Madison campus because of its location between two lakes, and most surface water that flows from campus ends up in one of the lakes.

Tripp Hall

Tripp Hall is one of 31 residence halls located on the University grounds. Located along the Lake Mendota shoreline in the north-central part of campus, Tripp Hall has a large green space to the north and east of the building. An asphalt-lined stormwater drainage channel runs along the east side of the building and then crosses the Lakeshore Bike Path. From here, the stormwater runs down an embankment and into the lake. As the water from melting snow and rain events runs down to the lake, it erodes the bike path and the lake embankment.

The source of water for this drainage channel is a very large area, bordered by Elizabeth Waters Residence Hall to the east, King Hall to the south, and Babcock Drive to the west. This is an area greater than 3 acres. Land use includes a grass- and tree-covered green space, sidewalks, roads, buildings, and parking lots. Although samples would need to be collected to determine the quality of the water from the roads and parking lots, enough clean water could be diverted from building roofs and allowed to infiltrate on the grass area to the north and east of Tripp Hall. Infiltration testing of this area found moderately high infiltration rates (0.45–0.57 inch/hour).

Although there is not much of an elevation difference between Tripp Hall and Lake Mendota to allow for large-scale infiltration, any decrease in the volume of water in the drainage channel would also decrease erosion of the bike path and the embankment, improving the quality of the water entering the lake. In addition, the asphalt drainage channel could be removed and a grass swale could be installed to provide additional infiltration and slow the velocity of the stormwater. (For more information on grass swales, please see Appendixes 13 and 14.)

Muir Woods

A visual survey of Muir Woods found a number of signs of erosion. A drainpipe was found at the top of the Woods, across from Bascom Hall. Indications of erosion extended from the pipe outfall across a parcel of grass and into Muir Woods. Runoff from Muir Knoll caused erosion below the observation platform. Pooled water, soil, and vegetation debris could be seen at the bottom of Muir Woods hill.

Further investigation, however, showed that the problem was not as extensive as was first thought. The pipe at the top of the hill, originally installed as a temporary solution to a leaking water pipe under Observatory Drive by Bascom Hall, was no longer functioning. The water pipe has been repaired, so the drainpipe no longer has a source of water. The erosion seen at the outlet of the pipe had occurred in the past. As evidence, the pipe was observed on more than one occasion during and immediately after storm events. No water was observed to come out of the pipe.

In contrast, the erosion along the walking paths and from the water coming from the Muir Knoll observation platform still occurs. There are, however, two things to note about this erosion. The first is that the erosion is relatively minor. Second, the University is already planning to renovate the Muir Knoll area and the walking paths through Muir Woods. Specific plans are not yet written, but they should be reviewed by future students enrolled in environmental engineering, land resources, water resources, or other environmental-related programs offered at the University. Chapter 4 of this report provides good examples of the types of stormwater practices that should be included in these plans.

Finally, the bottom section of the Woods was redesigned during the installation of the water pipe near the Limnology Building for the future Cogeneration Plant. This redesign raised and angled the bicycle path away from the lake, reshaped the parts of the toe of Muir Woods hill, and planted or seeded vegetation along the Lakeshore Path. This was done to prevent stormwater from directly draining into Lake Mendota.

Lot 34

Lot 34 is northwest of Elizabeth Waters Residence Hall, between the Lakeshore Path and Observatory Drive. The concrete channels that direct runoff from Lot 34 provide little opportunity for infiltration or water-quality improvements before the water flows across the Lakeshore Path and into Lake Mendota. Additionally, the runoff erodes the lakeshore and the adjacent path. Runoff from the parking lot could be spread out along the entire wooded area to the north of the site instead of being contained in three narrow concrete channels. This would give the water more chance to infiltrate as well as decrease erosion. In addition, the vast expanse of asphalt at Lot 34 is an optimal building site for UW–Madison's first "green building," which will house the

Gaylord Nelson Institute for Environmental Studies. Replacing parking-lot area with rooftop area would decrease the amount of pollutants that would reach the lake. A green building would also incorporate cutting-edge stormwater-management practices as part of the design.

Compaction remediation sites

Soil compaction occurs when heavy pressure on the soil (from constant foot traffic, vehicles, construction equipment, etc.) reduces pore space and closely packs particles in the soil. Wet soil that contains a significant amount of clay is more easily compacted. Surface compaction occurs within the top 8 to 12 inches of soil because of initial contact pressure to the soil surface by truck and heavy machinery traffic during construction. Subsoil (deep) compaction is caused by total load as well as contact pressure. Loads of 20 tons can compact wet soils as deep as 2 feet, well below the root zone (Roa-Espinosa, 1998).

Soil compaction is a concern in stormwater management because dense soils lack water-storage capacity, which increases runoff and erosion rates. In urban areas that have been redeveloped, many green spaces may be acting more like impervious than pervious surfaces.

Kohl Center

During construction, the front lawn of the Kohl Center became very compacted as a result of the use of heavy machinery. Much of the area was backfilled with construction material and contains a lot of clay, which, in addition to the compaction problem, prevents most stormwater from infiltrating. Instead, water runs off the front lawn and into the street or ponds. According to Dan Wyatt (Facilities Maintenance and Operations, oral communication, June 13, 2003) a hole was recently dug on the site to install a flagpole, and compaction looked to be about 6 feet deep.

The compaction has also caused problems with the vegetation. The restricting soil has prevented the trees from spreading their roots, which has stunted their growth, and many of the trees are dying because the soils are not suitable. The tree roots do not have adequate access to oxygen, water, or nutrients. Large trees need a lot of space to stretch their roots; otherwise they die from lack of water and oxygen, which is seen on the front lawn of the Kohl Center (Stier and Chung, 2001).

The turf on the site is very thin and unhealthy. The grass was peat-grown sod, which is somewhat incompatible with the mineral soils on the site. Peggy Chung, Landscape Architect for the FPM, believes that this difference as well as the severe compaction has prevented the sod from taking root (oral communication., May 30, 2003).

According to Chung (oral communication, May 30, 2003), the grounds crew has aerated and watered the area consistently, but the grass and trees continue to do poorly. Dan Wyatt, Kohl Center Building and Grounds Superintendent, said it is difficult for the maintenance staff to water the area since there is no source of water on the outside of the Kohl Center (oral communication, June 13, 2003). Several recommendations follow as to what could be done on the site to promote infiltration and healthy vegetation. Because the site is so highly visible to the public, it would be in the best interest of the University to do something quickly to improve the site for aesthetics and to control stormwater runoff.

The most basic proposal is to excavate the trees, turf, and some of the soil and replace everything. Any excavation would need to be preceded by soil testing for contamination because the Kohl Center was built on the former site of a railroad station. Contamination might make excavation more expensive than currently estimated.

The first step is removal of the sod and topsoil to a depth of 8 inches, or 1,450 yd^3 of material, after installing the recommended sediment-control structures on the site. The site should then be chisel-plowed to an additional 12 inches to break up more of the compacted soil. Next, a layer of coarse sand should be added to the plowed soil to a depth of 3 inches, or 538 yd^3 to increase the infiltration capabilities of the top layers of the soil. A layer of compost should then be added to the sand at the same rate to add organic matter and increase the nutrient availability. The three layers would be mixed in place with a rototiller to ensure even distribution and save money from mixing off-site. Finally, a new turf of tall fescues, a heartier variety, should be used to replace the old, thin sod.

Assuming the trees would be replaced, it would be up to a landscape engineer to determine what the layout would be and which species should be used. It would be very beneficial to dig trenches around the trees in a spoke-like fashion to allow deep root penetration (Peggy Chung and Dan Wyatt, oral communications, June 2003).

Because water access has been a problem for the site, an in-ground irrigation system could be installed at the time of the excavation project. For the trees and turf to do well, an adequate amount of water is essential (Dan Wyatt, oral communication, June 2003). An irrigation system would help free staff-time that would have been spent watering the vegetation. To maintain a quality soil, the lawn should be aerated at least once a year to combat the effects of foot traffic. A final addition to the project could be to add earthworms to part of the lawn to increase infiltration. A future study could be done to look at the effects that earthworms have on soil quality. The estimated costs for each of the suggested practices is included for reference as Appendix 15.

Rennebohm Hall (Pharmacy Building)

Rennebohm Hall is part of increased expansion on the western edge of campus. Extreme surface compaction from construction methods makes breaking the ground with a shovel difficult. Because of this, the infiltration rate at the site is very low (0.012 inch/hour). Remediation might require surface and deep tilling. The front lawn's compaction problems are similar in nature to those of the Kohl Center. Rennebohm Hall, however, is a much less visible and lower profile. This might make experimental strips and educational opportunities more viable.

Red Gym

The Red Gym, officially known as the Armory and Gymnasium, is in the northeast section of campus, to the east of Memorial Union. To the south of the main entrance to the building is a semicircular area of mainly grass, with one tree. The Red Gym is home to the Admissions Office, a number of information services, and the Student Organization Office, among other things. Because of this, foot traffic on the grass area is a regular occurrence, resulting in compaction, as can be seen by soil-compaction testing with a penetrometer (see Appendix 11). Infiltration, however, was generally higher than other sites tested (0.79–1.85 inches/hour), indicating the potential for mitigation at this site. Utilities in this area are on the north and south edges of the site, leaving much of the 2,000 square feet available to work with. This site should be tilled and planted with native plants, a few more trees, or a small rain garden. To keep people from walking across the site and re-compacting the area, a chain fence can be put around the perimeter. These actions will guide people to the sidewalks as well as enhance the aesthetics for visitors to the Red Gym.

Agricultural Bulletin Building/King Hall

A small site is located to the west of the Agricultural Bulletin Building, near the intersection of Observatory and Babcock Drives. Infiltration testing returned moderately low results (0.06 inch/hour), and buried utilities could limit the size of any mitigation work to be performed at this site. Compaction testing could not be completed at this site due to equipment problems. This testing will need to be completed before recommendations can be made for this site.

Russell Labs/Steenbock Library

A small parking area in the north-central part of campus, surrounded by the Animal Sciences building, Russell Labs, Steenbock Library, and Lot 36, was converted to grass. The site still receives a lot of traffic, from reports of cars still driving onto it to foot traffic as people walk between the buildings and parking lot that surround it. The 5,500 square foot area is only partially shaded by Russell Labs and has a sanitary sewer line across the northern third of the site. This would leave enough room to till the site to alleviate the compaction. In addition, the infiltration at this site was moderately low (0.058 inch/hour). Tilling would help to improve this rate, and water from the surrounding buildings' rooftops could be used to supply irrigation to a garden. Pavers should also be installed where pedestrians walk across the site to control compaction.

Green space maintenance

Green space maintenance is very important to maintaining the function of open areas, especially in an urban environment. It is especially important that green spaces in urban environments infiltrate water adequately because available recharge areas are limited by impervious surfaces. Infiltration capacity is altered by compaction, which is caused by construction practices, vehicles, and foot traffic. Compression of soils can be reversed or mitigated by BMPs such as deep tilling. Other practices that enhance the infiltration capacity of soils include native plantings, mulching, and designating footpaths.

Bascom Hill

Bascom Hill is a large, sloping grass area on the east side of Bascom Hall. This area is used extensively by students for studying, socializing, and even classes. In addition, students walk across the grass on their way between classes. Although this area serves many functions for current students, it is also one of the first things that many prospective students and other visitors see when they come to the UW–Madison campus.

Many utilities underlie Bascom Hill, limiting the type, size, and placement of any mitigation project at the site. The FPM has expressed interest in installing a rain garden on Bascom Hill, using the roof water from Bascom Hall. Infiltration testing near the top of the hill found a moderately high rate (0.29–0.32 inch/hour). In places that receive the most pedestrian traffic, pavers can be placed to reduce compaction (Appendix 13). At least once a year, the lawn should be aerated, which would decrease compaction and increase infiltration. These practices would not limit student usage of Bascom Hill.

Observatory Hill Overlook Area

Off Observatory Drive, between Carson Gulley Commons and Elizabeth Waters Residence Hall, is an open green space with established footpaths and few utilities. It is one of the few open spaces on the Lake Mendota side of Observatory Drive where a large volume or stormwater could feasibly be routed for infiltration. The area does not have significant compaction problems; therefore, establishing an infiltration practice will be easier and more cost effective. This site presents a great opportunity for enhancing infiltration through native plantings, mulching, or installation of a rain garden. In addition, part of the large grass area below the overlook should be converted to a prairie. This would provide an excellent hands-on opportunity for students enrolled in restoration classes at the University.

Athletic field behind Nielsen Tennis Stadium

Between the Nielsen Tennis Stadium and the Lakeshore Path, the University owns a large area of green space that functions as multi-use athletic fields. Over the past few years these fields have been used to host everything from casual pick-up games and intramural recreational soccer leagues to the competitive Badger State Games. They have heavy use during the year while they are not covered with snow.

Because of the low elevation of the area surrounding the fields and the proximity to Lake Mendota, the groundwater lies very near the surface of the fields. Thus, during wet times of the year, these fields become flooded and unusable. Few of the mitigation techniques outlined in Appendix 13 would solve the flooding problem because of the high water level in the area. However, adding soil to the top of the fields to raise the level of the area will decrease future flooding, thus decreasing the amount of time that the fields cannot be used. This approach is part of the current construction of the cogeneration facility on campus (K.W. Potter, University of Wisconsin–Madison, Department of Civil and Environmental Engineering, oral communication, August 7, 2003). This solution does not alleviate flooding problems to the west of these fields.

Plan review

The mitigation sites listed above are areas that already exist on the campus. Some sites, however, are still in the planning stage. Two of these sites are the Lot 60 reconstruction and the Crew House reconstruction. Plans for both projects are being drawn up. It will be up to future University students and Practicum participants to review those plans as well as plans for any new projects, to make sure that proper stormwater-control practices are included.

References

Roa-Espinosa, Aicardo. (1998). An Introduction to Soil Compaction and the Subsoiling Practice. Madison, WI., Dane County Land Conservation Department. Retrieved on August 7, 2003, from http://www.co.dane.wi.us/landconservation/papers/subsoil2.doc.

Stier, J. and P. Chung. (2001). Renovation of Kohl Center Landscape II. Unpublished internal document.

Chapter 6: Closing Remarks

> A healthy river is the heart of a healthy ecosystem and can be the heart of a healthy community. But many of Wisconsin's rivers are not healthy, and they need our help. —*River Alliance of Wisconsin (2003)*

The UW–Madison campus is a community like any other city or town, in need of healthy lakes and rivers. The Yahara Lakes are central to the experience of the University of Wisconsin in Madison. With the campus and the city surrounded by water, it is hard to imagine one without the other. The quality of the water that is draining to the lake has the signature of poor land-use practices and it is threatening the way of life at the University and the Madison community that depends on the vitality of this water. We are all responsible for the condition of our environmental resources.

The University is in a position to exercise its responsibility for lake stewardship and lead by example for conservation and forward-looking land-use practices. This is a critical time for changes in stormwater and polluted runoff management, due to the state of the regulations and the potential changes recommended in detail in this report. It is also a time of great innovation in BMPs.

Our recommendations are consistent with the mission of the University to share and test new ideas as the center of learning for the state of Wisconsin and its forward-looking ideals. President Charles Van Hise said that the Wisconsin Idea was the goal to make a "beneficent influence of the University available to every home in the state" (University of Wisconsin Board of Regents, 1997). The University is not an entity apart from the rest of the state that can create its own isolated place; the University is designed to be a part of the state and a leader in innovation. Implementing this updated stormwater plan is part of what the Wisconsin Idea subscribes to and what the University is responsible for as a steward to the state and its resources.

The scientific motivations and recommendations for better stormwater management by the University are laid out in this report, but they can just become another dusty plan sitting on a bookshelf without implementation. Responsibility for effective stormwater management rests with a number of institutional bodies, including the Wisconsin Department of Administration's Division of State Facilities, the Wisconsin Department of Commerce, the UW System, and the UW–Madison's Campus Planning Committee, the Facilities, Planning and Management department, the Physical Plant, and faculty and students. Each has a role to play in protecting Madison's lakes.

Despite the complex institutional framework involved in coordinating and making decisions influencing stormwater management and the variety of activities that potentially impact the lakes, implementation of our recommendations is relatively straightforward. In fact, implementation has already begun. Our recommendations can be conceptualized into four categories: 1) Policy changes, 2) Planning modification, 3) Further research, and 4) Monitoring. The recommendations in each of these categories are summarized in Table 6.1. Included in the table are the chapters in which each recommendation is discussed, an approximate timeframe for implementing it, as well as the likely people or institutional body responsible for taking the action.

We realize that many of our recommendations go beyond the reach of the Madison campus, but polluted runoff is a problem that does not respect political or institutional boundaries; efforts to reduce polluted runoff must be considered on a watershed level. As a result of the institutional mosaic in which the University is situated, a number of institutional bodies will need to act to achieve polluted runoff reduction and protection of our lakes and rivers. We present to those institutions the challenge of implementing the innovative stormwater-management plan we have developed here.

References

River Alliance of Wisconsin. (2003). Organizational Web site, Join page. As retrieved on November 19, 2003, from http://www.wisconsinrivers.org/member.html.

University of Wisconsin Board of Regents. (1997). A UW-Madison Odyssey: The Wisconsin Idea. As retrieved on December 8, 2003, from http://www.news.wisc.edu/welcome/odyssey/Outreach/wiscidea.html.

Wisconsin Academy of Arts, Letters and Sciences. (Spring 2003). Wisconsin Academy Review. Madison, Wisconsin.

Table 6.1: Plan implementation.

Implementation stage	Recommended steps	Timing	Who	Discussed in Chapter
Policy changes:	Adopt recommended stormwater management standards through *resolution*.	Done October 2, 2003.	UW–Madison's Campus Planning Committee	Exec. Summary Ch. 1: Intro. Ch. 3: Standards Appendix 7
	Develop and implement *guidelines* for project planning to be used by FPM and the Physical Plant, which guide inclusion of the stormwater standards for new project design. One element of these guidelines should be a list of new stormwater management BMPs to supplement the State BMP list, which is only updated every 10 years.	Spring 2004	Developed by FPM units PAC (Project Administration Center) Major Projects Used by FPM and Physical Plant project planners.	Ch. 3: Standards Ch. 4: Recommendations-Construction Erosion Control
	Initiate the process for developing new *administrative rules* for the UW System and the Department of Administration's Division of State Facilities to officially adopt the recommended stormwater-management standards and formalize their inclusion in system wide project planning.	Spring 2004	Initiated by Civil Engineer of Department of State Facilities (DSF) Civil Engineer UW System Applies to DFS and the UW System.	Ch. 3: Standards Ch. 4: Recommendation - Construction Erosion Control
	The State needs to finish incorporating its new polluted runoff control standards into other agency administrative rules. Specifically adoption of *NR 151* into the *Department of Commerce's administrative rules* would expand their applicability and enforcement on public building projects.	When possible	Wisconsin Department of Commerce.	Ch. 3: Standards
	Evaluate *current levels of funding* for Facilities Planning and Management and the UW Madison Physical Plant specifically for carrying out current policies, which reduce pollutant loading in stormwater, erosion, and flooding. In particular, concerns were raised about funding for street sweeping, deicing and snow removal, and inspection, cleaning of catch basins, and for stormwater management in campus construction projects. Make every effort to ensure that these efforts are adequately funded so the public does not have to pay elsewhere for the impacts of polluted runoff.	When possible	Evaluation of funding by FPM and UW–Madison Physical Plant. Changes to funding level ?	Ch. 3: Standards Ch. 4: Recommendations
	Complete a *Memorandum of Understanding* between the UW System, the Wisconsin Department of Natural Resources, the Wisconsin Department of Administration (DSF), and the Wisconsin Department of Commerce concerning construction site erosion and sediment control and stormwater management more generally throughout the UW System.	When possible	UW System WI Dept. of Administration, DSF WI Dept. of Natural Resources WI Dept. of Commerce	Ch. 3: Standards

Table 6.1: Plan implementation, *continued*

Implementation stage	Recommended steps	Timing	Who	Discussed in Chapter
Planning modification	Implement the planning, design, and grounds management recommendations in Chapter 4 of this report. These recommendations include changes for Construction Erosion Control, Building Design, Parking Lot Design, Preservation and Management of Campus Green Areas, Pesticide and Nutrient Management, Pedestrian Design, and Deicing and Snow Removal.	Ongoing	UW–Madison, FPM and Physical Plant	Ch. 4: Recommendations
	Reserve sites for offsite mitigation and be prepared to construct best management practices on these sites when infiltration standards cannot be fully or partially implemented for new or redevelopment project onsite due to space constraints.	Ongoing	UW–Madison, FPM and Physical Plant WI Dept. of Administration, DSF	Executive Summary Ch. 2: Physical Assess. and Modeling Ch. 3: Standards Ch. 4: Recommendations Ch. 5: Case Studies
	Seek funding for new campus construction projects, with proper stormwater management in mind as a matter of course, not just something to be added if there is money left over.	Ongoing	UW- Madison FPM Project Managers	Executive Summary Ch. 3: Standards
Further research	An inventory of *potential mitigation sites*, site conditions, and recommended BMPs for each site will be completed by current Project Assistants under the same grant as this report. This will build on the mitigation Case Studies presented in Chapter 5 of this report.	Ongoing through 2005	Project Assistants working with Professor Ken Potter and Cathie Bruner	Ch. 3: Standards Ch. 5: Case Studies
	Huge potential exists for faculty and student research through development of innovative designs for stormwater management in new construction on campus. Some sort of mechanism is needed to *facilitate this collaboration*, which embodies the purposes of this academic institution.	When possible	UW–Madison FPM personnel	Preface Ch. 1: Intro. Ch. 3: Standards
	UW System agricultural practices should be examined for their compliance with the NR 151 standards and for potential ways polluted runoff can be reduced. This was beyond the scope of this report.	When possible	Civil Engineer for UW System and CALS research station UW-Madison	Ch. 4: Recommendations – University Agricultural Practices

Monitoring:	Empower the University's *Senior Environmental Health Specialist to have a greater role in implementation and enforcement* of both the proposed performance standards and the WPDES permit requirements. This position should be responsible for monitoring whether new construction projects are meeting the standards proposed for the University or not. Specific details of how to strengthen this person's role in stormwater management have not been identified.	As soon as possible	UW–Madison, FPM	Ch. 3: Standards
	Construction contracts should include a special condition allowing the University's Landscape Architect to communicate directly with someone on the construction project about possible violations of erosion and sediment-control requirements and concerns.	All new construction contracts	WI Dept. of Administration, DSF UW–Madison, FPM, Landscape Architect	Ch. 3: Standards Ch. 4: Recommendations – Construction Erosion Control
	The University's Landscape Architect should be given *access to the DSF database* of construction project contracts on campus, known as WiscBuild. This will make it easier for the Landscape Architect to know what projects are happening and who the contact people are.	As soon as possible	WI Dept. of Administration, DSF UW–Madison, FPM, Landscape Architect	Ch. 3: Standards Ch. 4: Recommendations – Construction Erosion Control
	Keep the *supplemental Preferred BMPs list updated* as they arise and until such a time as the Wisconsin BMP list is updated and the process can begin again.	As soon as possible	UW–Madison, FPM and Physical Plant	Ch. 3: Standards
	Update and maintain the sewershed delineation and land use information layers in the *GIS Runoff Model* developed for the University.	Ongoing	UW–Madison, FPM	Ch. 3: Standards
	Use the GIS Runoff Model to assess the University's *compliance with their runoff standards* on an annual or biannual basis.	Ongoing	UW–Madison, FPM	Ch. 3: Standards

Appendix 1. Table of curve numbers and pollutant coefficient groups used in the runoff analyses

Land-use category[1]	Pollution group	Curve number	Hydrologic soil group
Athletic court	Commercial roofs	98	all
Athletic field	Small landscape	69 84	B A/D and B/D
Building	Commercial roofs	98	all
Bushes	Small landscape	48 73	B A/D and B/D
Cropland	Small landscape	78 89	B B/D
Drive	Driveways	98	all
Garden	Small landscape	61 80	B A/D and B/D
Grass	Small landscape	79 89	B B/D
Gravel	Small landscape	85 91	B A/D and B/D
Loading dock	Driveways	98	all
Mixed vegetation	Small landscape	79 89	B A/D and B/D
Mulch	Small landscape	61 80	B B/D
Parking lot	Commercial parking lot	98	all
Path	Small landscape	82 89	B A/D and B/D
Planter	Small landscape	39	all
Railroad track	Small landscape	90	all
Road	Commercial streets	98	all
Sand	Small landscape	68	all
Sidewalk	Small landscape	98	all
Structure	Commercial roofs	98	all
Trees	Small landscape	79 89	B A/D and B/D
Under construction	Small landscape	86 94	B A/D and B/D
Woods	Undeveloped areas	55 60 79	B[2] B[3] B/D

[1] Barnyard, coal, marsh, non-University, and water were not included in the assessment because they do not contribute to stormwater runoff on campus.
[2] Woods west of Willow Creek
[3] Woods east of Willow Creek

Appendix 2. Concentrations of pollutants measured in runoff water from different land-use types. Numbers are the arithmetic mean of several measurements taken by the U.S. Geological Survey to calibrate the Source Loading and Assessment Model (www.winslamm.com).

Constituent (concentration)	Commercial roofs	Commercial parking lots	Driveways	Small landscape	Commercial streets	Undeveloped areas
Suspended solids (mg/L)	32.8	130	154	227	176	16
Dissolved solids (mg/L)	115	62.7	111	183	123	186.2
Phosphorus particulate (mg/Kg)	9,427	1,888	3,352	7,389	1,897	400
Phosphorus dissolved (mg/L)	0.061	0.055	0.290	1.35	0.060	0.01
Zinc particulate (mg/Kg)	3,357	844	655	160	1,152	NA
Zinc dissolved (μg/L)	1	44	166	34.0	60.2	NA
Copper particulate (mg/Kg)	1.79	99.2	89.3	14.4	141	185
Copper dissolved (μg/L)	12.9	14.4	13.0	7.4	12.0	NA
Lead particulate (mg/Kg)	748	323	244	250	209	48
Lead dissolved (μg/L)	27.1	1.72	2.925	2.83	1.9	NA
Cadmium particulate (mg/Kg)	12.45	4.65	2.88	1.51	4.81	0.043
Cadmium dissolved (μg/L)	0.73	0.48	0.25	0.30	0.38	0.04
Chromium particulate (mg/Kg)	NA	47.26	11.26	19.62	38.1	NA
Chromium dissolved (μg/L)	1.50	2.46	1.5	1.5	8.6	NA
5-Day BOD particulate (mg/Kg)	94,136	28,267	32,461	12,294	20,978	533,333
5-Day BOD dissolved (mg/L)	17.5	7.52	7.71	1.6	10.6	24
COD particulate (mg/Kg)	739,110	32,676	303,261	382,761	199,270	1,844,444
COD dissolved (mg/L)	152.3	39.0	91.8	90.5	47.9	106
Kjeldahl nitrogen particulate (mg/L)	26,482	3,907	9,466	30,516	19,477	1,503
Kjeldahl nitrogen dissolved (mg/L)	1.65	0.58	0.69	1.97	0.9	0.880
Nitrogen + nitrite dissolved (mg/L)	0.75	0.4	0.45	0.45	0.49	0.0325
Pyrene particulate (mg/Kg)	17.7	174.79	16.5	NA	17.1	NA
Fluoranthene particulate (mg/Kg)	24.8	288.95	23.1	NA	25.0	NA
Total PAH particulate (mg/Kg)	119	936.51	105	NA	73.2	NA

Appendix 3. Land-cover composition for University of Wisconsin–Madison sewersheds

Sewershed	Athletic field (%)	Bushes (%)	Crop-land (%)	Garden (%)	Grass (%)	Marsh (%)	Mixed vegetation (%)	Mulch (%)	Path (%)	Planter (%)	Trees (%)	Woods (%)	Athletic (%)	Building (%)	Drive (%)	Gravel (%)
	Land-cover categories															
Non-contributing	< 1	-	-	-	-	61	8	-	-	-	-	-	-	-	-	-
1	2	1	-	< 1	5	-	15	< 1	< 1	< 1	< 1	-	< 1	31	3	2
2	-	-	-	-	12	-	7	-	-	< 1	-	-	< 1	33	2	-
3	5	< 1	-	< 1	2	-	8	< 1	2	< 1	< 1	74	< 1	2	< 1	< 1
4	-	1	-	2	13	-	13	-	-	< 1	-	-	-	28	3	-
5	-	-	-	7	-	-	1	-	-	4	-	-	-	61	-	-
6	-	< 1	-	-	21	-	7	-	-	< 1	-	-	-	10	2	-
7	-	3	-	-	-	-	5	-	-	< 1	1	-	-	53	-	-
8	-	-	-	< 1	19	-	9	-	-	-	1	-	-	29	1	< 1
9	-	-	-	-	-	-	-	-	-	-	1	-	-	83	1	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
11	-	4	-	-	4	-	-	-	-	-	-	50	-	< 1	-	-
12	-	2	-	-	7	-	19	-	-	1	-	< 1	-	34	3	< 1
13	-	-	-	-	-	-	1	-	< 1	-	-	-	-	92	-	-
14	-	-	-	-	18	-	61	-	-	< 1	-	2	-	4	-	-
16	-	-	-	-	5	-	22	< 1	-	-	-	< 1	-	38	2	-
17	-	< 1	-	2	10	-	31	-	-	< 1	< 1	-	-	22	7	-
18	4	1	3	3	6	-	21	< 1	< 1	< 1	< 1	5	2	19	5	1
19	-	< 1	-	-	-	-	38	-	-	-	-	-	-	43	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
21	-	-	-	-	-	-	37	-	-	-	-	-	-	35	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
23	-	1	-	-	5	-	32	-	-	-	-	-	-	5	-	-
24	-	< 1	-	-	-	-	30	-	-	-	-	-	-	31	-	-
25	-	2	-	-	1	-	26	-	-	-	-	-	-	16	3	-
26	-	-	-	-	6	-	23	-	-	-	-	-	-	28	-	-
27	-	-	-	-	-	-	26	-	-	-	-	-	-	69	-	-
28	-	-	-	-	1	-	53	-	-	-	-	-	-	-	-	-
29	5	< 1	-	< 1	11	-	18	< 1	< 1	< 1	< 1	-	-	16	3	2
30	43	< 1	-	-	13	11	8	-	1	-	-	-	2	4	< 1	< 1
31	1	-	-	-	2	-	21	-	3	-	< 1	59	-	3	1	< 1
32	-	-	-	-	5	-	40	-	< 1	-	< 1	22	-	13	2	-
33	-	-	-	-	2	-	58	-	-	-	-	-	-	17	4	-
34	-	-	-	-	13	-	40	2	-	-	-	-	-	17	2	-
Total area (acres)	64.7	3.00	4.35	6.23	65.2	24.6	171	0.552	8.11	0.538	1.49	232	4.45	156	22.5	6.99
Percentage of campus	6.21	0.29	0.42	0.60	6.26	2.37	16.45	0.05	0.78	0.05	0.14	22.23	0.43	15.02	2.16	0.67

Appendix 3. Land-cover composition for University of Wisconsin–Madison sewersheds (continued)

	Land-cover categories													
Sewershed	Loading dock (%)	Parking lot (%)	Railroad track (%)	Road (%)	Sand (%)	Sidewalk (%)	Structure (%)	Under construction (%)	Water (%)	Barn yard (%)	Coal (%)	Non-University (%)	Total area (acres)	Percentage of campus
Non-contributing	< 1	-	< 1	1	1	< 1	< 1	-	10	3	4	12	24.5	2
1	< 1	14	1	12	< 1	11	1	2	-	-	-	-	202	19
2	1	6	-	15	1	19	-	4	-	-	-	-	247	2
3	< 1	2	-	2	< 1	2	-	-	-	-	-	-	228	22
4	< 1	4	-	14	-	23	-	-	-	-	-	-	37.2	4
5	-	-	-	-	-	27	-	-	-	-	-	-	0.128	< 1
6	-	14	-	12	-	34	< 1	-	-	-	-	-	4.79	< 1
7	-	< 1	-	-	-	38	-	-	-	-	-	-	1.52	< 1
8	-	10	-	14	-	16	-	< 1	-	-	-	-	5.09	< 1
9	-	-	-	-	-	15	-	-	-	-	-	-	1.58	< 1
10	-	-	-	-	-	-	-	-	-	-	-	-	0.141	< 1
11	-	-	-	21	-	18	3	-	-	-	-	-	1.36	< 1
12	-	6	-	11	-	18	-	1	-	-	-	-	7.34	1
13	< 1	-	-	-	-	6	-	-	-	-	-	-	0.848	< 1
14	-	-	-	8	-	8	-	-	-	-	-	-	5.80	1
16	-	-	-	10	-	23	-	-	-	-	-	-	2.12	< 1
17	-	3	-	7	-	17	-	-	-	-	-	-	6.94	1
18	1	15	< 1	7	< 1	7	< 1	-	< 1	-	-	-	155	15
19	-	-	-	-	-	19	-	-	-	-	-	-	0.682	< 1
20	-	-	-	-	-	-	-	-	-	-	-	-	0.142	< 1
21	-	-	-	-	-	28	-	-	-	-	-	-	0.825	< 1
22	-	-	-	-	-	-	-	-	-	-	-	-	0.097	< 1
23	-	21	-	18	-	18	-	-	-	-	-	-	1.20	< 1
24	-	17	-	9	-	12	-	-	-	-	-	-	1.30	< 1
25	-	36	-	8	-	8	-	-	-	-	-	-	1.84	< 1
26	-	20	-	11	-	12	-	-	-	-	-	-	0.973	< 1
27	-	-	-	-	-	4	-	-	-	-	-	-	0.277	< 1
28	-	-	-	30	-	16	-	-	-	-	-	-	0.739	< 1
29	< 1	22	-	10	< 1	7	< 1	5	-	-	-	-	87.9	8
30	-	10	-	5	1	1	< 1	< 1	-	-	-	-	88.4	8
31	-	3	-	4	1	1	-	-	-	-	-	-	71.6	7
32	< 1	10	-	2	1	4	-	-	-	-	-	-	58.8	6
33	-	10	-	4	1	5	-	-	-	-	-	-	2.02	< 1
34	-	16	-	4	1	5	-	-	-	-	-	-	14.7	1
Total area (acres)	2.25	101	1.84	71.2	3.25	71.2	2.03	9.58	2.52	0.637	0.940	3.04	1041	
Percentage of campus	0.22	9.70	0.18	6.83	0.31	6.84	0.19	0.92	0.24	0.06	0.09	0.29		

Appendix 4. Table of calculated stormwater runoff and pollutant loading for the University of Wisconsin–Madison campus

Sewershed	Runoff volume (acre*ft)	Runoff depth (ft)	Sewershed area (acres)	Suspended solids (lb/yr)	Suspended solids per acre (lb/acre/yr)	Dissolved solids (lb/yr)	Particulate phosphorus (lb/yr)	Dissolved phosphorus (lb/yr)	Particulate zinc (lb/yr)	Dissolved zinc (lb/yr)
1	169	0.83	202.17	48,700	241	50,300	109.2	78.4	32.2	52.0
2	21.7	0.88	24.69	6,490	263	6,730	14.41	10.6	4.27	7.28
3	39.0	0.17	228.23	13,200	57.8	14,700	34.85	38.6	5.05	6.82
4	30.5	0.82	37.22	9,440	254	9,580	20.97	16.3	5.91	10.6
5	0.124	0.97	0.13	23.9	187	38.4	0.07041	0.0459	0.0201	0.0520
6	3.97	0.83	4.79	1,520	317	1,160	2.829	2.48	0.731	1.28
7	1.55	1.02	1.52	357	234	480	0.9416	0.701	0.247	0.657
8	4.17	0.82	5.09	1,260	247	1,270	2.777	2.05	0.814	1.33
9	1.72	1.09	1.58	248	157	535	0.9007	0.466	0.285	0.714
10	0.155	1.10	0.14	13.8	98.0	48.5	0.07397	0.0257	0.0263	0.0633
11	0.654	0.48	1.36	272	200	212	0.4384	0.302	0.164	0.194
12	6.02	0.82	7.34	1,710	233	1870	4.009	3.01	1.13	2.09
13	0.915	1.08	0.85	101	119	286	0.4567	0.194	0.154	0.375
14	1.90	0.33	5.80	869	150	718	2.514	2.87	0.342	0.464
15	0.094	0.93	0.10	39.7	223	28.8	0.07510	0.0812	0.0135	0.0414
16	1.76	0.83	2.11	473	220	564	1.202	0.930	0.321	0.660
17	4.71	0.68	6.94	1,530	226	1,500	3.697	3.36	0.823	1.66
18	108	0.69	155.50	35,100	165	32,700	84.75	76.4	18.7	30.6
19	0.503	0.74	0.68	112	98.0	163	0.3614	0.305	0.0778	0.200
20	0.156	1.10	0.14	13.9	195	48.9	0.07451	0.0259	0.0265	0.0637
21	0.618	0.75	0.83	161	98.0	198	0.4575	0.410	0.0941	0.249
22	0.107	1.10	0.10	9.51	331	33.3	0.05083	0.0177	0.0181	0.0435
23	0.947	0.79	1.19	395	255	284	0.8069	0.758	0.187	0.221
24	1.11	0.85	1.30	331	295	335	0.8254	0.696	0.197	0.322
25	1.58	0.86	1.84	542	257	417	1.060	0.859	0.281	0.361
26	0.819	0.84	0.97	250	111	237	0.5508	0.423	0.152	0.231
27	0.235	0.85	0.28	30.7	301	75.2	0.1382	0.0833	0.0384	0.0931
28	0.456	0.62	0.74	222	270	162	0.4712	0.453	0.113	0.106
29	66.5	0.76	87.86	23,700	193	19,600	54.74	50.7	11.9	16.0
30	37.6	0.43	88.41	17,000	73.6	13,600	55.06	66.1	5.40	6.20
31	13.4	0.19	71.64	5,280	132	4,630	13.71	14.2	2.44	2.90
32	24.2	0.41	58.75	7,740	171	7,360	20.52	19.9	3.78	6.61
33	1.05	0.52	2.02	346	178	331	0.9281	0.901	0.175	0.300
34	8.23	0.56	14.71	2,620	241	2,400	6.477	5.86	1.38	2.12
Total	**553**	—	**1017.03**	**180,000**	—	**173,000**	**440.4**	**398**	**97.4**	**153**

Appendix 4. Table of calculated stormwater runoff and pollutant loading for the UW campus (continued)

Sewershed	Particulate lead (lb/yr)	Dissolved lead (lb/yr)	Particulate copper (lb/yr)	Dissolved copper (lb/yr)	Particulate cadmium (lb/yr)	Dissolved cadmium (lb/yr)	Particulate chromium (lb/yr)	Dissolved chromium (lb/yr)	Particulate 5-day BOD (lb/yr)	Dissolved 5-day BOD (lb/yr)
1	3.14	5.85	8.99	5.82	0.14	0.24	0.761	1.3	960.59	5,500
2	0.428	0.745	1.14	0.735	0.018	0.029	0.0893	0.17	127.67	710
3	0.627	0.941	2.02	0.476	0.025	0.034	0.197	0.24	364.04	1,200
4	0.605	1.04	1.60	0.985	0.025	0.039	0.119	0.24	182.89	970
5	0.00154	0.00434	0.00535	0.00657	0.000078	0.00020	0.000100	0.00050	0.68465	4.8
6	0.0863	0.139	0.230	0.0613	0.0033	0.0041	0.0208	0.030	25.494	98
7	0.0210	0.0544	0.0701	0.0712	0.00098	0.0022	0.00171	0.0063	8.9827	56
8	0.0815	0.144	0.223	0.137	0.0035	0.0056	0.0187	0.033	24.257	130
9	0.0187	0.0604	0.0699	0.108	0.0011	0.0030	0.000722	0.0070	8.9008	74
10	0.00140	0.00544	0.00587	0.0114	0.000098	0.00031	0	0.00063	0.73860	7.4
11	0.0201	0.0217	0.0383	0.00766	0.00069	0.00062	0.00455	0.0086	4.5996	18
12	0.108	0.207	0.309	0.222	0.0047	0.0083	0.0215	0.043	34.942	200
13	0.00886	0.0321	0.0357	0.0638	0.00058	0.0017	0.000153	0.0037	4.4920	42
14	0.0387	0.0557	0.129	0.0301	0.0016	0.0019	0.0121	0.018	11.080	40
15	0.00183	0.00327	0.00520	0.000745	0.000060	0.000064	0.000247	0.00038	0.67274	1.9
16	0.0298	0.0600	0.0868	0.0718	0.0013	0.0024	0.00474	0.011	10.181	61
17	0.0843	0.159	0.254	0.143	0.0036	0.0058	0.0169	0.031	28.230	140
18	1.88	3.65	6.15	3.05	0.086	0.14	0.532	0.74	622.66	3,100
19	0.00598	0.0171	0.0234	0.0251	0.00032	0.00077	0.000630	0.0021	2.7425	18
20	0.00141	0.00548	0.00591	0.0115	0.000098	0.00031	0	0.00064	0.74406	7.4
21	0.00819	0.0211	0.0299	0.0260	0.00039	0.00084	0.000942	0.0025	3.5595	21
22	0.000965	0.00374	0.00403	0.00786	0.000067	0.00021	0	0.00043	0.50761	5.1
23	0.0221	0.0319	0.0608	0.0106	0.00088	0.0010	0.00696	0.0091	5.7803	21
24	0.0188	0.0379	0.0613	0.0372	0.00088	0.0016	0.00514	0.0076	6.1528	34
25	0.0301	0.0561	0.0953	0.0314	0.0014	0.0020	0.0105	0.012	9.0415	41
26	0.0151	0.0285	0.0456	0.0248	0.00068	0.0011	0.00422	0.0061	4.6401	25
27	0.00223	0.00809	0.00965	0.0158	0.00015	0.00044	0.000106	0.00096	1.1479	10
28	0.0140	0.0142	0.0309	0.00293	0.00050	0.00041	0.00389	0.0065	2.9416	10
29	1.25	2.26	4.05	1.47	0.056	0.084	0.413	0.51	376.99	1,700
30	0.562	1.10	2.73	0.595	0.029	0.042	0.271	0.27	195.17	680
31	0.271	0.402	0.834	0.241	0.011	0.015	0.0872	0.12	85.562	340
32	0.363	0.810	1.39	0.710	0.018	0.032	0.114	0.14	135.92	680
33	0.0170	0.0351	0.0610	0.0316	0.00081	0.0014	0.00495	0.0067	5.8646	30
34	0.134	0.281	0.478	0.237	0.0065	0.011	0.0439	0.053	45.083	230
Total	**9.90**	**18.3**	**31.3**	**15.5**	**0.44**	**0.71**	**2.77**	**4.0**	**3303.0**	**16,000**

Appendix 4. Table of calculated stormwater runoff and pollutant loading for the UW campus (continued)

Sewershed	Particulate COD (lb/yr)	Dissolved COD (lb/yr)	Particulate TKN Kjeldahl N (lb/yr)	Dissolved TKN Kjeldahl N (lb/yr)	Dissolved Plus nitrite-N (lb/yr)	Particulate pyrene (lb/yr)	Particulate fluoranthene (lb/yr)	Particulate total PAH (lb/yr)
1	9,742.18	46,100	451.1	540	260	1.40	2.25	7.57
2	1,247.00	6,110	62.32	69	34	0.114	0.176	0.619
3	3,141.18	9,250	149.9	120	41	0.269	0.433	1.44
4	1,784.06	8,620	89.27	95	47	0.132	0.199	0.724
5	5.83553	44.9	0.1998	0.46	0.22	0.000217	0.000304	0.00141
6	262.767	894	11.18	9.6	5.2	0.0376	0.0596	0.205
7	78.7630	534	2.696	5.3	2.6	0.00317	0.00444	0.0205
8	243.600	1,140	11.90	13	6.5	0.0289	0.0457	0.156
9	73.0837	666	2.538	7.0	3.3	0.00233	0.00326	0.0153
10	5.79915	64.2	0.2078	0.70	0.32	0.000139	0.000195	0.000934
11	42.1748	135	2.680	1.6	0.86	0.00275	0.00396	0.0140
12	341.427	1,770	16.06	20	9.6	0.0309	0.0480	0.170
13	36.1128	370	1.292	4.0	1.8	0.000968	0.00136	0.00643
14	164.315	451	11.69	6.8	2.6	0.00484	0.00695	0.0250
15	6.53155	23.4	0.2210	0.18	0.11	0.000336	0.000471	0.00214
16	97.0625	558	4.692	6.0	2.9	0.00409	0.00581	0.0238
17	295.765	1,340	14.33	15	7.1	0.0206	0.0314	0.116
18	7062.62	27,700	331.4	340	160	1.06	1.71	5.72
19	26.9800	178	1.149	1.9	0.88	0.000820	0.00115	0.00532
20	5.84203	64.7	0.2093	0.70	0.32	0.000140	0.000196	0.000941
21	35.1207	207	1.439	2.1	1.0	0.00122	0.00171	0.00788
22	3.98554	44.2	0.1428	0.48	0.22	0.0000954	0.000134	0.000642
23	69.6663	181	3.714	2.5	1.2	0.0117	0.0189	0.0625
24	68.7278	300	3.247	3.7	1.7	0.0103	0.0166	0.0554
25	104.426	324	3.996	4.2	2.1	0.0278	0.0455	0.149
26	49.8232	208	2.214	2.5	1.2	0.00905	0.0146	0.0487
27	10.2222	93.4	0.4248	1.0	0.46	0.000238	0.000333	0.00158
28	35.9810	84.7	2.724	1.3	0.58	0.00180	0.00261	0.00871
29	4,619.57	15,000	224.4	200	92	0.860	1.40	4.61
30	3,545.26	8,270	232.6	140	50	0.371	0.606	1.97
31	1,040.65	3,040	64.06	44	18	0.100	0.160	0.528
32	1,640.24	6,320	74.66	79	35	0.258	0.420	1.40
33	71.5617	281	3.602	3.5	1.6	0.00908	0.0146	0.0493
34	543.431	2,050	24.39	26	12	0.104	0.169	0.558
Total	**36,501.8**	**142,000**	**1,807**	**1,800**	**800**	**4.88**	**7.85**	**26.3**

Appendix 5. Comparative chart of state, county, and local stormwater-management regulations

	State of Wisconsin	Dane County	Madison	Middleton
Applicability				
	Any new and redevelopment construction on sites of 1 acre or more. Green spaces more than 5 acres where fertilizers are applied. Transportation construction sites and new urban residential roads. WPDES permitted livestock operations.	Any development that results in the cumulative addition of 20,000 square feet of impervious surface to the site. Any development that requires a subdivision plat, or a certified survey map. Redevelopment must meet new standards. Other high-risk areas as required by local approval authority.	Any development that results in the cumulative addition of 20,000 square feet of impervious surface to the site. Any development that requires a subdivision plat, or a certified survey map. Redevelopment must meet new standards. Other high-risk areas as required by local approval authority.	New residential land that requires a subdivision plat or that cumulatively creates an impervious surface area of 20,000 square feet. Land development, other than residential, requiring a certified survey map, or that creates an impervious surface area of 20,000 square feet. Redevelopment of 4,000 square feet. All downspouts, driveways, and other impervious areas shall be directed to pervious surfaces unless possibility of groundwater contamination. Any other land development that the City Engineer chooses.
Preconstruction erosion and sediment controls				
	Reduce to the maximum extent practicable 80 percent of the sediment load on an average annual basis on all redevelopment sites of 1 acre or more during construction, as compared to no controls. Transportation construction sites must adhere to a written plan to reduce sediment load in runoff by 80 percent and to manage polluted runoff.			
Erosion and sediment control: Existing and in-fill development (post-construction)				
	Existing WPDES permitted municipalities must create and follow a stormwater-management program to reduce total suspended solids by 20 percent on all existing development before March 10, 2008 and achieve a 40% reduction before March 10, 2013 (or maximum extent practicable).	For existing development, design practices to retain soil particles greater than 40 microns on the site (20 percent reduction – resulting from a 1-year, 24-hour storm event.	20 percent reduction in sediment loads for existing developments (as compared to no controls).	Existing development: retain soil particles greater than 40 microns (20 percent reduction) from a 1-year 24-hour storm event.

In-fill development sites of less than 5 acres are required to reduce total suspended solids by 40 percent post-construction, and greater than 5 acres by 80 percent (starting October 2004). After October 2012, all sites of 1 acre or more require an 80 percent reduction of TSS.			
Erosion and sediment control: Redevelopment (post-construction)			
Starting in October 2004, redeveloped sites of 1 acre or more would be required to include practices, which reduce total suspended solids by 40 percent post-construction.	Redevelopment resulting in exposed surface parking lots and traffic areas design practices to retain greater than 20 microns (40% reduction) on the entire site resulting from a 1-year, 24-hour storm event. Site's existing sediment level cannot be reduced as a result of a redevelopment.	Redevelopment resulting in exposed surface parking lots and traffic areas design practices to retain greater than 20 microns (40% reduction) on the entire site resulting from a 1-year, 24-hour storm event.	Redevelopment resulting in parking lots and traffic areas: retain greater than or equal to 20 microns (40% reduction) from 1-year, 24-hour storm event. Site's existing sediment level cannot be reduced because of a redevelopment.
Erosion and sediment control: New development (post-construction)			
Starting October 2004, new development sites of 1 acre or more would have to include practices to reduce total suspended solids by 80 percent post-construction.	Design practices to retain soil particles greater than 5 microns (80% reduction) from 1-year, 24-hour storm event.	Design practices to retain soil particles greater than 5 microns (80% reduction) from 1-year, 24-hour storm event.	Retain soil particles greater than or equal to 5 microns (80% reduction) from 1-year, 24-hour storm event.
Water quantity: Flow			
Peak runoff discharge rate for the 2-year, 24-hour design storm must be maintained or reduced from predevelopment conditions.	All stormwater facilities shall be designed, installed, and maintained to effectively: Maintain predevelopment peak runoff rates from the 2-year, 24-hour storm event (2.9 inches over a 24-hour duration), a 10-year, 24-hour storm event (4.2 inches over a 24-hour duration). Safely pass the 100-year, 24-hour storm event (6.0 inches over a 24-hour duration).	All stormwater facilities shall be designed, installed, and maintained to effectively: Maintain predevelopment peak runoff rates from the 2-year, 24-hour storm event (2.9 inches over a 24-hour duration), a 10-year, 24-hour storm event (4.2 inches over a 24-hour duration). Safely pass the 100-year, 24-hour storm event (6.0 inches over a 24-hour duration).	Peak discharge rates limited to predevelopment from 1, 2, 5, 10, 25, and 100 year – 24-hour storms.

Appendix 5. Comparative chart of state, county, and local stormwater-management regulations (continued)

State of Wisconsin	Dane County	Madison	Middleton
Water quantity: Outlets			
	Discharges from new construction sites must have a stable outlet capable of carrying designed flow at a non-erosive velocity. Outlet design must consider flow capacity and flow duration. This requirement applies to the site outlet and ultimate outlet to stormwater conveyance or water body.	Discharges from new construction sites must have a stable outlet capable of carrying designed flow at a non-erosive velocity. Outlet design must consider flow capacity and flow duration. This requirement applies to the site outlet and ultimate outlet to stormwater conveyance or water body.	Discharge velocities must be non-erosive to discharge locations, outfall channels, and receiving streams. Closed watersheds runoff discharge is limited.
Water quantity: Conveyance systems			
			Pipes shall contain peak discharge from a 10-year, 24-hour storm with no surcharge or pressurizing flow. Open channels shall contain peak discharge from a 25-year, 24-hour storm. Streets shall contain peak discharge from a 25-year, 24-hour storm event to the top of the curb. Overland drainage ways and culverts where no overflow structure exists shall contain the 100-year, 24-hour storm event. Discharges shall not exceed the capacity of the downstream receiving systems.
Oil and grease control			
Petroleum-product runoff from fueling and vehicle maintenance areas must be controlled to remove all visible sheen.	For all commercial or industrial developments where the potential for pollution by oil and grease exists, the first 0.5 inches of runoff will be treated using the best oil and grease removal technology available.	For all commercial or industrial developments where the potential for pollution by oil and grease exists, the first 0.5 inches of runoff will be treated using the best oil and grease removal technology available.	For commercial or industrial developments, the first 0.5 inches of runoff will be treated using the best oil and grease removal technology available.

Temperature control			
	Plan and practices must include provisions to reduce the temperature of runoff from all sites located within a DNR defined Cold Water Community, and Class I, II, and III trout streams – some exemptions may apply, according to County Conservationist.	Must include provisions and practices to reduce the temperature of runoff for sites located within a DNR defined Cold Water Community, and Class I, II, and III trout streams. Applicant may use approved model to justify that practices are not necessary because temperature increase at the site post-development will be zero.	Only for development in Black Earth Creek Watershed and Fredrick Springs Tributary.
Protection of wetland and special resource waters			
For new development under NR 151.12 (5)(d), protective areas (buffers) are required around lakes, streams, and wetlands. Width varies depending on the resource it is protecting.			Discharge of stormwater to wetlands without pretreatment shall be minimized. Avoid significant changes to wetland hydrology and functional values.
Off-site stormwater management			
A regional device is allowed for off-site detention, and could perhaps be applied to infiltration. The regional stormwater management mechanism must be built with the first construction project in the joint venture and cannot be a future promise.	Off-site management is allowed, provided that the off-site facility is in place, is designed adequately to provide a level of stormwater management that at least meets the ordinance standards, and the facility has a legally obligated entity responsible for its long term operation and maintenance.	Off-site management is allowed, provided that the off-site facility is in place, is designed adequately to provide a level of stormwater management that at least meets the ordinance standards, and the facility has a legally obligated entity responsible for its long term operation and maintenance.	
Nutrient management			
After March 10, 2008 fertilizers must be applied based on a site-specific nutrient-management plan where it is applied to more than 5 acres of land. Proper management of leaf and grass clippings is required, as appropriate, by March 10, 2008.			

Appendix 5. Comparative chart of state, county, and local stormwater-management regulations (continued)

State of Wisconsin	Dane County	Madison	Middleton
Manure management			
The following are prohibited: manure overflows from storage facilities, facilities, unconfined manure piles near water bodies, direct runoff from feedlots or stored manure into waters, and unlimited livestock access to waters. Statewide standards for new and refurbished manure-storage facilities.			
Infiltration			
For non-residential land uses (commercial, industrial, institutional), 60 percent of predevelopment infiltration volume or 10 percent of the post-development runoff from the 2-year, 24-hour rain must be infiltrated to the maximum extent practicable. No more than 2 percent of the site would have to be dedicated to meeting infiltration requirements.	All downspouts, driveways, and other impervious areas shall be directed to pervious surfaces, where feasible.	All downspouts, driveways, and other impervious areas shall be directed to pervious surfaces, where feasible.	Infiltration practices required in all new development: Roofs, sidewalks, and driveways shall not contribute any additional runoff volume above predevelopment condition from the 1-year storm event. Unless deep tilling or another practice is completed, the soil loss and stormwater calculations must utilize a soil-group classification one group lower than the predevelopment soil classification, i.e., A becomes B. In parking areas, more than 50 percent of impervious area must be directed to a bioretention basin prior to any additional treatment. Golf courses must use wet antecedent conditions. Stormwater shall be pretreated prior to infiltration. Stormwater infiltration is prohibited under the following circumstances: stormwater runoff is from highly contaminated source areas at manufacturing or industrial sites; stormwater runoff carried in a conveyance system that also carries contaminated,

non-stormwater discharges; stormwater runoff from active construction sites.

Fee in lieu

For any public or private development for which construction of stormwater-management practices as required by this ordinance is determined not to be feasible, the owner shall pay to the City a fee in lieu of construction.

Owner also shall pay a fee in lieu of constructing infiltration practices, where their construction is not feasible due to soil conditions, high groundwater, or other site constraints.

In order for the City to accept fees in lieu of constructing on-site stormwater-control practices as per the requirements of the ordinance, alternate off-site practices sufficient to meet the stormwater control requirements of 26.05(3)(b) must be in place downstream of the proposed development and upstream of the point of discharge to a sensitive water feature.

The requisite off-site control may be an existing practice, or may be achieved through modification of an existing practice or construction of a new practice.

Appendix 6. Comparison of proposed standards to NR 151 standards

Standard type	Proposed University of Wisconsin–Madison standards	Relevant NR 151 standards

Construction site erosion and sediment-control standards	Threshold: none – **all projects** are required to meet standards.
	• All projects must employ BMPs that achieve an **80 percent reduction of sediment** load carried in runoff (as compared to no controls), *to the maximum extent possible*.
	• All projects must employ controls to **prevent sediment tracking, discharge into waters, and discharge into storm sewers.**
	• Erosion and sediment control BMPs must be **written into all campus construction contracts, regardless of size**. Formal, written plans must be included for projects greater than 1-acre.
		Threshold: **greater than 1 acre** of land disturbing activity.
		• Written erosion-control plan must contain:
		  • The BMPs that achieve a **reduction in 80 percent of sediment load** carried in runoff (as compared to no controls – *to the maximum extent possible*)
		  • Controls to prevent **sediment tracking, discharge into waters, and discharge into storm sewers.**

Post-construction design	Threshold: none – **all projects** are required to meet standards.
	
	Exemptions: None
		Threshold: **greater than 1 acre** of land disturbing activity.
		
		Exemptions:
		  • Redevelopment with no increase in exposed parking lots or roads.
		  • Sites with less than 10 percent connected imperviousness, provided cumulative area of parking lots and rooftops is less than 1 acre.

Post-construction design – *Total Suspended Solids*	• **All development**, including redevelopment and in-fill development (regardless of parking area and road size) must achieve an **80 percent reduction in TSS** as compared to no runoff controls. • At least 40 percent of this reduction must be met on-site.	• **New Development – 80 percent reduction** as compared to no runoff controls. • **Redevelopment – 40 percent reduction** as compared to no runoff controls. • **In-Fill – 40 percent reduction** until 2012, then 80 percent as compared to no runoff controls.

Post-construction design – *Peak Discharge*	• All development, including redevelopment and in-fill development, must employ BMPs to **handle peak runoff, as compared to predevelopment conditions** for the 2-year, 24-hour storm event. • Discharge will be managed to **avoid erosion of open channels and conveyance systems**, including outfalls. • Sites where hydrology limits infiltration or retention of stormwater, **off-site mitigation may be considered.**	• BMPs must be employed for **qualifying sites** to **handle peak runoff, as compared to predevelopment conditions** for the 2-year, 24-hour storm event (incorporates soils and curve number) **Exemptions:** • Sites that do not change the hydrology of existing surface water by more that 0.01 feet (30 mm) • Redevelopment • Infill less than 5 acres
Post-construction design – *Infiltration*	• **All redevelopment must infiltrate 90 percent of pre-development** infiltration volume, based on annual rainfall. • **No cap on percentage of site** because off-site mitigation is an option on campus.	**Residential developments –** • One of the following must be met: **a) 90 percent of pre-development infiltration volume,** based on annual rainfall or, **b) 25 percent of post-development runoff volume** from the 2-year, 24-hour design storm (incorporating soil types and curve numbers) • **No more than 1 percent of project site** is required to be an effective infiltration area. **Non-residential developments** (including commercial and institutional) – • One of the following must be met: **a) 60 percent of pre-development infiltration volume, based** on annual rainfall or, **b) 10 percent of post-development runoff volume** from the 2-year, 24-hour design storm (incorporating soil types and curve numbers) • **No more than 2 percent of project site** is required to be an effective infiltration area, and this only applies to rooftops and parking areas.

Appendix 6. Comparison of proposed standards to NR 151 standards (continued)

		Exclusions: • Areas with less than 3 feet between infiltration system and groundwater – not including roof runoff. • Nonresidential runoff from parking lots and roads with less than 5 feet between infiltration system and groundwater. • Areas within 400 feet of community well. • Industrial, fuel, and maintenance areas. **Exemptions:** • Areas where soil infiltration rate is less than 0.6 inches/hour. • Parking areas and access roads less than 5,000 square feet. • Redevelopment. • In-fill development less than 5 acres. • Roads in institutional land uses.
Developed urban area performance standard	No changes – the standards proposed above will facilitate meeting the reduction of TSS requirements listed to the right for permitted municipalities, of which the UW–Madison is one. The other four requirements to the right are address in the WPDES permit.	• Municipal stormwater management programs must meet the following requirements: – 20 percent reduction of TSS in runoff (by 2008) – 40 percent reduction of TSS in runoff (by 2013). • Implement a public information and education program. • Implement a program for collection and management of leaf and grass clippings. • Nutrient management plan for application of fertilizers. • Detection and elimination of illicit discharges to sewers.

Appendix 7. Campus Planning Committee Resolution

The following resolution was introduced to the University Campus Planning Committee based on preliminary recommendations from this report. It was passed unanimously October 2, 2003.

FORMALIZING THE UW COMMITMENT TO PROTECT THE YAHARA LAKES

Ken Potter
CPC Environmental Representative

RECOMMENDED UW POLICY

The University of Wisconsin-Madison should commit to a policy that ensures that *the amount of runoff from newly developed and redeveloped areas be no greater than the amount that occurred under native conditions.*

JUSTIFICATION

The UW occupies a prominent position on the Yahara Lakes, in terms of benefits it derives as well as impacts it causes. Unfortunately, the lakes are suffering from severe problems, including

- Nuisance weeds and algae due to excessive phosphorus in storm runoff.
- Increasing flood risk due to expansion of impervious area.
- Decreasing minimum water depths due to groundwater pumping, loss of groundwater recharge, and sedimentation.

The potential severity of the latter two problems has only been recognized in the last few years. Furthermore, only recently has it been demonstrated that conventional stormwater-management practices, which rely heavily on detention ponds, provide virtually no mitigation of these problems. If the Yahara Lakes watershed, which is today predominantly rural, continues to be developed using conventional stormwater-management practices, the severity and frequency of damaging high- and low-water episodes will increase significantly.

Fortunately, there are number of emerging stormwater-management practices that enable watershed development without impacting lake levels. Many of these conservation practices facilitate the infiltration of storm runoff from impervious surfaces. Examples of such practices include rain gardens, bioretention cells, and permeable pavements. Other conservation practices, such as green roofs, reduce runoff by holding water and allowing it to evaporate. A third group of conservation practices enhances the infiltration capacity of green spaces through the use of vegetation, soil amendments, and tillage practices. These practices, when appropriately designed and sited, are comparable in cost to traditional stormwater-management practices.

Although the advantages of conservation practices have been well documented, their adoption has been slowed by the inertia associated with traditional approaches. The University is well poised to expedite this process in Wisconsin, and particularly in the Yahara Lakes watershed. In fact, the University has already begun to include conservation practices in several of its planned construction projects. The most effective University action would be to commit to a policy that ensures that runoff from each new construction project be no greater than the amount that occurred under native conditions. Implementation of this policy could be achieved by use of conservation practices on site, by improving stormwater-management practices elsewhere on campus, or by a combination of on- and off-site improvements.

Adoption of this policy would lead to a long-term reduction in the University's impacts on the Yahara Lakes, funded through the construction costs associated with building projects. More importantly, the University would be providing strong leadership at a critical stage in the development of the Yahara Lakes Watershed.

It is therefore recommend that the University of Wisconsin-Madison commit to a policy that ensures that *the amount of runoff from newly developed and redeveloped areas be no greater than the amount that occurred under native conditions.*

Appendix 8. Simple overview of University of Wisconsin–Madison project administration—November 2003

Diagram by Kathy Kalscheur

Project < $100,00

"Small" Project submitted to DFS by Campus staff; approved by DSF; Campus contact named on project request. Projects requested by Physical Plant.

Design, construction contracting, and construction oversight by campus staff. Physical Plant "Shops" staff, not operations (like grounds).

DSF Project Manager choose Design Consultant or DSF Selection Committee choose Consultant

Design by consultant contracted by DSF, bidding, and construction contract by DSF.

Project > $100,00

Campus staff develop project request or "program" — FPandM staff.

Approval by UW Board of Regents to request funding

Approval by UW-System Capital Planning and Budget to request funding

Approval to go to the State Building Commission by DSF Planning and Budget

Approval of funding project by State Building Commission.

Design Consultant selected by DSF Selection Committee.

Design by consultant contracted buy DSF, bidding, and construction contract by DSF.

NOTES:

- The DSF Selection Committee includes a representative from Campus or UW System.
- Campus contact is involved during the design of the project and reviews construction documents.
- All projects that include ground disturbing require erosion control.
- Construction contracts awarded based on competitive bidding. DOA/DSF has the authority to contract for construction contracts over $30,000 per Statute and Administrative Code.
- All DSF construction contracts per the "General Conditions" (basically one set of administrative rules for all out contracts).
- DSF Construction Representative administers the construction contract.
- Construction projects over $500,000 with more than one major discipline (general building construction/earthwork, plumbing, HVAC, electrical, other) will have a prime contractor for each discipline. The general building contractor is typically designated as the "Lead" contractor responsible for scheduling and general site matters – like erosion control.
- Each contract requires a single contact person be designated.
- All contacts – Campus, DSF project manager, DSF Construction Representative, Contractor contacts, Design contact – listed in WisBuild with email addresses, and phone numbers.

Appendix 9. University of Wisconsin Salt Best Management Practice

December 1999

Sally M. Rowe and Peter A. Reinhardt
Chemical and Environmental Safety Program
UW–Madison Safety Department

This is one of several written Best Management Practices (BMPs) that has been prepared to describe how the University of Wisconsin—Madison (University) minimizes pollutants in stormwater runoff from University lands into our lakes, ponds and streams. The University's DNR Stormwater Permit requires that BMPs be established for this purpose. This BMP focuses on salt (sodium chloride), which is used at the University to melt ice on campus streets, walks and parking lots to improve their safety.

What is a BMP? A BMP establishes benchmark practices that, when employed, represent the most reasonable and modern "best practices" for preventing pollution. It is meant to reflect community and peer institution standards for salt use. In many cases these recommendations reflect common sense and practices that are already in use. The practices described in this BMP are optional, not mandatory. Not all salt users will be able to adopt every BMP recommendation. You should consider this BMP as a goal, and are encouraged to continually seek improvements in reducing salt while maintaining the safety of our streets, parking lots and walks. Please let us know your ideas. This BMP will change as new practices are discovered and deemed practical.

Objective and Needs

The objective of this BMP is to encourage the prudent use of salt at the University. Users should apply sufficient quantities of salt to keep streets, parking lots and walks safe from ice; applications should be done carefully to minimize the amount of salt used.

This BMP addresses a dual, sometimes conflicting need. Students, faculty, staff and visitors deserve safe streets, parking lots and walks, which is often facilitated when salt is used to melt ice. However, salt is detrimental to our environment. Salt pits concrete walks and streets so that they eventually need to be replaced—often sooner than otherwise might be the case. Salt rusts and can destroy car exteriors, handrails and other items made of ferrous metals. Salt can injure and or kill grass, flowers and other vegetation along campus walkways.

Perhaps most importantly, salt dissolved in rainwater and snowmelt may drain into the storm sewer system. This system subsequently discharges into Lakes Mendota and Monona. Salt in lakes and streams is measured as the chemical pollutant chloride, and chloride, at elevated levels, is toxic to fish and other aquatic life. Winter salt use is by far the major source of chloride in our lakes. Because chloride is water soluble and does not degrade in the environment, it can accumulate in lakes and ponds. University and DNR scientists are very concerned that the salinity (i.e., chloride levels) of Lake Mendota has been rising for decades.

To protect our environment, we need to minimize the salt we use. But the need to protect our environment from the deleterious effects of salt use must be balanced with the need for safety.

Applicability

This BMP is applicable to everyone who uses salt on streets, parking lots and walks on the University of Wisconsin-Madison campus, including the Arboretum and campus natural areas. Agricultural Research Stations, UW-Extension facilities and other non-contiguous properties are not included at this time.

Private contractors who apply salt on campus streets and walks are responsible for understanding this BMP and considering its recommendations whenever practicable.

Salt Use at the University

As shown by the table below, salt is used on campus by Physical Plant staff and staff of program revenue units (e.g., Union, Housing, Athletics, University Health Services). Salt that is applied by Physical Plant is stored on campus at a Physical Plant Environmental Services shed on Herrick Dr. Two formulations are available to Physical Plant employees: pure salt and a carefully prepared sand mixture with 5 percent salt. Environmental Services staff choose between the two formulations, or they may mix the formulations, depending on their judgment.

Salt Alternatives. There are numerous deicing chemicals that can be used as an alternative to salt (sodium chloride). Campus salt users are encouraged to try them. Please report your findings so that we can keep track of alternative salt use on campus and help others who are considering salt alternatives. Physical Plant has some experience in using the salt alternatives calcium magnesium acetate (CMA) and potassium acetate; feel free to contact them to discuss your situation.

Some salt alternatives have the advantage of being usable at temperatures lower than sodium chloride's range. Salt is the least expensive deicing chemical, although lower application rates may make the more expensive alternatives cost competitive. CMA may have the least environmental impact, while other alternatives can impact the environment to some degree. Alternatives, such as chlorides of calcium, magnesium and potassium can harm concrete, corrode metal and contribute to chloride levels in the lake. Sand and other abrasives can provide safe footing in some cases. Note that salt is often mixed with sand to keep sand from freezing (sand usually contains a small amount of moisture).

Other Salt Minimization Activities. As mentioned elsewhere in this BMP, the University has made significant progress in some areas of salt reduction. Since 1995, "No Plow, No Salt" areas have been designated, removal equipment has been improved, Physical Plant's sand mixture has been reformulated, and salt alternatives have been tried. In addition, a low berm was constructed between the 1918 Marsh and the snow storage area to prevent salt-contaminated runoff from entering the Marsh. These activities have been summarized in the report, "Salt

Campus Salt User	Where They Use Salt	How They Apply Salt	Salt Formulation Used
FPandM Physical Plant	Streets Parking lots	Road Spreaders	Mixture of salt and sand Sand mixture with 5 percent salt
Environmental Services	Walks	Sidewalk spreaders	Mixture of salt and sand
FPandM Physical Plant Custodial Services	Entrances and walks—from door to main sidewalk	Hand thrown	Salt
Campus Building Managers	Entrances and walks—from door to main sidewalk	Hand thrown	Salt
Program Revenue Units	Mostly entrances and walks—from door to main sidewalk	Mostly hand thrown	Varies

Reduction Status Report," by Daniel Einstein and Peter Wold, Physical Plant Environmental Management (19 March 1998).

Best Practices for Most Salt Users

Most salt users on campus will find the following salt minimization practices reasonable and worth considering. Many of these practices can achieve the same, or better, level of safety that we are used to, but with less salt.

Trust your judgment. Because weather conditions and salt needs vary so greatly, salt users must be free to exercise their judgment. The ultimate decision of how much salt to use, and how to apply it, must be left to the user. Over time, however, you will gain a better understanding of what works best to clear walks, parking lots and streets while minimizing your use of salt. You will learn that, under some conditions, a little salt goes a long way.

It would be easy to use the same practices under all conditions, to oversalt, or to rely on traditional practices. Instead, every time you use salt, please take time to assess the conditions and your needs for that situation—then apply salt carefully. Practices to consider include:

- Prevent ice by keeping runoff from pooling; keep gutters and storm sewer drains open and clear of leaves, snow and ice. Should pooling occur, contact Environmental Services (2-7266). They will then assess the situation and take corrective action.
- Don't use salt if you expect below zero temperatures for a prolonged period; use sand instead. Salt works poorly below zero, and doesn't work at all below –6 °F.
- When possible, use fine grain salt instead of rock salt. Large pieces of salt melt ice very inefficiently. You can do the same job with a smaller amount of fine grain salt.

- Salt only walks, streets and parking lots. Don't salt grass or planting beds.
- Unless you are sure that ice is about to form, don't salt in anticipation of ice. Avoid salting dry pavement that is free of ice.
- Remove snow first; avoid salting snow.
- Use salt as necessary to clear accessible routes and other paths of travel used by people with disabilities. These routes should be given priority.
- Use salt as necessary if ice formation is likely, due to forecasted weather conditions, shade, or run-on that is likely to freeze.
- Minimize or eliminate salt use if there is a warming trend that will melt ice quickly.
- Minimize or eliminate salt use if sun exposure is likely to melt the ice quickly.
- Use less salt when the surface is level or partially clear, or when packed snow provides safe traction.
- Sweep up any excess or spilled salt. Reuse it or dispose of it in the normal trash; avoid sweeping the excess salt into the street.

Best Practices for Walkways

Many people on campus are responsible for keeping walks and entrances clear of ice and snow. Although time is always a constraint, early and frequent snow removal is the best practice to minimize salt use. Shoveling prevents ice formation that results from snow packing and the thaw/freeze cycle.

- Please do not use salt as an alternative to timely snow removal and shoveling.
- If time and weather allow, always try to shovel first—before salting.
- Ramps on an accessible route or those providing access must be totally cleared of snow, handrail to handrail; there cannot be any snow left under the handrail.

However, use salt as necessary:

- When ice is expected because of the weather forecast. For example, salt wet walkways (caused by sun or daytime temperatures) when freezing overnight temperatures are forecasted.
- To prevent ice as an interim measure between snow removals.
- When it snows and no one will be available to clear it.
- To loosen thick ice for future removal. Prompt, complete snow removal is the best way to prevent packed ice. Although packed snow provides good traction for a while, it can soon turn to thick ice, which is very difficult to remove.

Patios and Extra-Wide Walkways and Stairs

Not every inch of paved surface on campus needs to be salted or cleared of snow and ice. It is better to do a good job of clearing a narrow path than not having the time to adequately clear a large area. If you wish to close a walk or area during the winter, consider:

- Building exits must be clear and allow emergency egress.
- Check with the Building Manager.
- Post the closed area or walk with "Please Stay On Designated Path," "Closed For Winter," or "Do Not Enter: No Shovel/No Salt Area." You also may wish to cordon off the area. If you cordon off the area, the materials used to block off the area must be cane-detectable.
- Cleared paths should be at least four feet wide or, the width of the building entrance, whichever is wider. You may want to clear a wider path for areas with heavy traffic, if it will facilitate snow removal in the future, or if it will prevent ice formation from re-freezing snowmelt and run-on.
- Emergency exits should remain cleared.

University staff may decide to close certain walkways, areas and stairs in the winter. To date, these closures have been limited to the path to Picnic Point, a redundant, seldom-used sidewalk near the Willow Drive dorms, and redundant stairs at the Steenbock Library, Vilas Hall, Agriculture Hall, Educational Science, Teacher's Education, Chamberlin Hall, Lathrop Hall, Memorial Library, Wendt Library, Science Hall, Atmospheric Sciences and the new Biochemistry addition. In addition to reducing salt use, these closures save labor and money. Please contact the Physical Plant if you wish to nominate an area for winter closure.

Best Practices for Environmental Services Staff

Environmental Services staff operate the road and sidewalk spreaders used on campus to spread salt. They also are responsible for clearing snow off of parking lots, roads and major walkways. Normally, they plow only if more than one inch of snow has fallen. A salt/sand mixture is usually then applied. If less than one inch of snow falls, the salt/sand mixture is applied in lieu of plowing. Environmental Services staff should consider the following practices to minimize their salt use:

- As with walkways (see above) prompt and complete mechanical clearing of snow minimizes ice formation and the need for salt.
- Prevent ice formation by removing as much snow as possible. Environmental Services staff are encouraged to plow snow up to the curb. Curb cuts, designated paratransit drop off sites, and DIS parking stalls at the curb need to have snow removed entirely. Ridges of snow cannot be left by a plowing operation.
- When loading salt and sand into the spreaders, minimize your use of pure salt whenever possible. Use the sand mixture with 5 percent salt preferentially.

- Use the salt/sand mixture as necessary for safe intersections and hills; the application rate may be reduced for level and less-used routes.
- At snow depths of less than one inch, remove snow from DIS parking spaces, the adjacent access aisles and along a path of travel out of a parking lot.

Best Practices for Pedestrians

To maintain this balance between safety and the environment, we need the cooperation of all students, faculty, staff and visitors. Call Physical Plant CARS at 3-3333 to report unsafe areas that need to be cleared of snow and ice. Your feedback is important to improve our practices. Feel free to contact the Physical Plant, the Safety Department or your Building Manger with any concerns regarding salting practices.

Be aware, however, that it is not reasonable to expect every foot of paved surface to be free of snow and ice at all times. There are limits to University resources, the equipment we use—as well as the capabilities of salt. The University is dedicated to clearing a reasonable, safe path for pedestrians, but you must:

- Stay on cleared paths and plowed snow routes.
- Don't cut corners or make your own path.
- Use alternate routes to closed sidewalks and stairs posted "Closed for Winter."

Best Practices for Facility Managers and Designers

Facility managers and designers can help improve safety, reduce salt use, and make maintenance easier. Abrasive coatings are helpful on some campus walkways—especially those prone to being slippery. As a result, less salt and sand is needed in those areas. In planning or remodeling, facility designers should consider:

- Avoid oversized patios, walkways or stairs. This would reduce both labor needed for snow removal and the need for salt.
- Design areas to facilitate snow removal. Sidewalks and ramps should be wide enough for a mechanical broom (i.e., a minimum of seven feet, although eight feet would be preferred.)
- Provide snow storage areas adjacent to sidewalks, roads and around parking lots. These storage areas should be designed to prevent snowmelt from running across parking lots, roads and walkways.

BMP History and Review

Several University Committees, Departments and Units have reviewed and commented on this BMP. In adopting this BMP, the University hopes to balance the needs for safety and environmental protection. The University may modify this BMP at any time.

Reviewer	Action	Date
UW Building Managers	Presented	15 October 1998
UW Physical Plant, including Environmental Services, Custodial Services and Environmental Management	Review	February and March 1999
UW Safety Department, including General Safety and Chemical and Environmental Safety	Review	Fall 1998
UW Facilities, Planning and Management	Review	Fall 1998 and Winter 1999
UW Environmental Health (UHS)	Review	February 1999
UW Risk Management	Review	December 1998
Madison Fire Department Inspector (for exiting/life safety)	Review	Fall 1998
UW Arboretum	Review	February 1999
UW Chemical Safety Committee		

Appendix 10. Clean Water Act Section 319 success stories

Success Story 1: University receiving funding under CWA 319

Villanova's Stormwater Wetland Retrofit: BMP Treats runoff and provides research site

Villanova University is located in the southeast corner of Pennsylvania within a 41-acre urban watershed. The watershed consists of more than 16 acres of impervious surface, including Villanova University's parking lots, dormitories, office buildings, railroads, highways, and housing areas. An existing stormwater detention basin on the university's property was targeted as an ideal site for a 319 retrofit project.

Project goals

The purpose of the 319 project was to make a stormwater wetland out of the existing detention basin (Figure A10-1), creating a water-quality treatment facility. The existing stormwater detention basin was originally designed to reduce the increased peak flows coming from the university campus. Runoff entered the basin through sheet flow from a large parking lot and through two major pipes.

The basin was redesigned by removing the underground pipes, moving earth to create a meandering flow path (Figure A10-2), adding a sediment forebay, and modifying the structure outlet. Wetland plantings were added; plants were selected for diversity and based on their ability to thrive at different inundation levels.

Low flows would now travel through the sediment forebay to give particles a chance to settle out. Flows would continue through a meandering wetland channel, maximizing contact with the plants, and finally go through a deeper pool and the outlet structure. The flow path for larger storms would provide for the flow to pass over a berm, preventing resuspension of the sediments collected in the structure, thus using the original design for peak flow management while avoiding damage to the low-flow components.

Multiple benefits

Because it is located on the university's property, this stormwater wetland is not only aiding in the reduction of pollutants for this headwater but also serving as a permanent research and demonstration site. To date, hundreds of visitors have toured the site, and the site is being incorporated into a dem-

Figure A10-1. *An existing stormwater detention basin was targeted for a CWA 319 retrofit project.*

Figure A10-2. *A meandering channel was designed to reduce flow velocity and allow particles to settle out.*

onstration "theme park" of multiple BMPs (including signage) on Villanova's property.

The wetland project was completed at the end of 2000, and the current plan is to wait a year for the wetlands to mature before starting to collect water-quality samples. Hydrologic and hydraulic monitoring is already under way, and flowmeters and a rain gauge have also been installed to collect data. It is projected that total suspended solids will be reduced by 70 percent, total phosphorus by 40 percent, total nitrogen by 20 percent, and lead by 75 percent.

This case study was excerpted from Section 319 Success Stories: Volume III (February 2002), U.S. Environmental Protection Agency, Washington, DC. EPA Publication EPA 841-S-01-001. Available online at http://www.epa.gov/owow/nps/Section319III/PA.htm.

Success Story 2: Evergreen State College completes zero-impact study

Background

The Evergreen State College on the outskirts of Olympia, Washington, has 4,500 students on a 1,000-acre campus. The campus's storm drainage system—built before current standards—has no treatment or detention systems. In 1998 the college adopted a stormwater goal in the master plan: "For planning purposes the college should try to limit runoff on campus by minimizing hardened surfaces and maximizing undisturbed forest." Evergreen then obtained a grant from U.S.EPA Region 10 to study the feasibility of disconnecting the college's storm drains from the streams around the campus.

Prior to the study, there was no visible damage to streams in the area, in spite of the lack of stormwater treatment or detention. However, part of the campus discharges to Green Cove Creek, which the city of Olympia and Thurston County have singled out for special protection. Part of the campus also discharges to Houston Creek, a productive salmon stream. College officials also wanted to do the study to foster sustainability, to provide an example for the community, and to provide a teaching opportunity.

Description

The college hired consultants to inventory stream conditions and review existing studies on fisheries and water quality. Consultants also reviewed the college's comprehensive plan and capital improvement program and engineering studies of campus soils, groundwater, geology and infrastructure. They produced the following two kinds of analyses:

- how to introduce low development design to new structures.
- how to retrofit existing development during the course of major redevelopment projects.

The study identified five areas for the use of low impact techniques: roofs, parking, roads, walkways and landscaping.

Recommendations included the following:

- Roofs. Use of infiltration, collection, and green roof systems.
- Parking. Alternatives include adding stormwater storage under parking areas and in landscape strips, and reducing impervious surfaces through use of pervious paving.
- Roads. Use of pervious pavement, directing drainage to adjacent forests, amending the soils of side slopes, and disconnecting drainage from streams. Recommendations included new road design concepts, some of which did not require excavation of existing soils for their construction.
- Walkways. Many campus walkways serve more as architectural statements than transportation. Alternatives include removal, replacement with pervious walks, placing pervious buffers around catch basins, expanding planters, and adding grass-roofed covered walkways.
- Landscaping. While there is comparatively little formal landscaping on campus, the study recommended that some landscaped areas could be converted back to natural forest, with amendment of soils to repair compacted areas.

Results

The college has begun to implement the study by including a garden roof on its new Seminar 2 building (construction began in 2002). Soon, the college will rebuild parts of its parking lot using pervious pavement systems and may build a motorcycle parking structure with a vegetated roof. This would be a study focus for students in the environmental studies program.

Costs

The study estimated that the costs of zero-impact roads and stormwater systems would be as much as 60 percent lower than traditional high impact systems. Conversion of car parking to pervious pavers would be the same as or lower than traditional alternatives, which require expensive new treatment and detention systems. Green roofing would be more expensive, but the life-cycle cost might be lower. An important factor in choosing the pervious paving systems is that this approach negates the need to clear and grade surrounding forest areas for detention ponds. Implementing the study's recommendations has an additional benefit to the public because the drainage system could eventually be disconnected from the local stream system.

Information in this case study was excerpted from Natural Approaches to Stormwater Management: Low-Impact Development in Puget Sound (March 2003), Puget Sound Action Team, Olympia, *WA. Available online at* http://www.psat.wa.gov/Publications/LID_studies/LID_approaches.htm.

For the complete Evergreen Report, Towards Zero-Impact, Evergreen State College Campus: Opportunities for Zero-Impact Development and Redevelopment, visit http://www.evergreen.edu/facilities.

Appendix 11. Case study sampling data

			Core sample	
			Soil core/vibracore	Drill rig
Russell Labs[a]	Reading IN1: 2.358 cm/h 0.928 in/h Reading IN2: 1.933 cm/h 0.761 in/h	NA	NA	NA
Observatory Hill Overlook[a]	Reading IN1: 0.426 cm/h 0.168 in/h Reading IN2: 0.580 cm/h 0.228 in/h	NA	NA	NA
Carson Gully[a]	Reading IN1: 0.417 cm/h 0.164 in/h Reading IN2: 0.644 cm/h 0.254 in/h	Reading P1: 125 lbs/in^2 at 6.5 in Reading P2: 250 lbs/in^2 at 24 in Reading P3: 150 lbs/in^2 at 13.75 in	Sample C1 0-5" black silt loam 5-9" brown silty clay 9-25" brown clay Sample C2 0-4" black silt loam 4-18" brown and black silt loam (heterogeneous) 18-42" silty clay (heterogeneous) Sample C3 0-4" dark brown silt loam 4-15" brown silt loam at 15" mixed rocky material, could not core through	NA
Agricultural Bulletin Building[a]	Reading IN1: 0.147 cm/h 0.058 in/h Reading IN2: 22.395 cm/h (root?) 8.817 in/h	NA	NA	NA

Appendix 11. Case study sampling data (continued)

			Core sample	
			Soil core/vibracore	**Drill rig**
Tripp Hall[a]	Reading IN1: 1.289 cm/h 0.507 in/h Reading IN2: 1.386 cm/h 0.546 in/h Reading IN3: 1.450 cm/h 0.571 in/h Reading IN4: 1.143 cm/h 0.450 in/h	NA	NA	NA
Science Hall/ Education Building[a]	Reading IN1: 0.835 cm/h 0.329 in/h Reading IN2: 0.615 cm/h 0.242 in/h	Reading P1: 400 lbs/in^2 at 17 in Reading P2: 500 lbs/in^2 at 24 in Reading P3: 500 lbs/in^2 at 3-6 in	Sample C1 Could not get beyond 2” Sample C2 0-6” black and brown silt, subangular block structure 6-9” brown fine sand with gravel 9-15” light brown very fine sand 15-27” light brown clay and very fine sand Sample C3 0-6” brown silt loam, compacted 6-8” light brown sand 8-10” brown silt loam with sand	NA
Red Gym[a]	Reading IN1: 4.705 cm/h (root?) 1.852 in/h Reading IN2: 1.998 cm/h 0.787 in/h	Reading P1: 350 lbs/in^2 at 8 in Reading P2: 300 lbs/in^2 at 2 in Reading P3: 300 lbs/in^2 at 2.5 in Reading P4: 300 lbs/in^2 at 5 in	NA	NA
Bascom Hill[a]	Reading IN1: 0.727 cm/h 0.286 in/h Reading IN2: 0.808 cm/h 0.318 in/h	NA	Sample C1 0-20 cm brown loam with many pebbles Sample C2 0-20 cm dark brown loam with pebbles and cobbles	NA

Bascom Hill/Muir Woods[b] (downhill site)	Reading IN1: 0.134 cm/h 0.053 in/h	NA	<u>Sample C1</u> 0-1.7” black silt with some fibrous organic material 1.7-5.2” very dark brown silt loam 5.2-33.7” dark yellowish brown to black silty loam to silty clay loam 33.7-45.2” black loam, brown clay loam, and light yellowish brown sandy loam 45.2-52” brown clay, light yellowish brown sandy loam	NA
Bascom Hill/Muir Woods[b] (uphill site)	Reading IN1: 0.054 cm/h 0.021 in/h	NA	<u>Sample C1</u> 0-2.4” black silt loam with organics 2.4-9.3” brown to dark brown, and very dark grey silt loam 9.3-15.9” dark yellowish brown silty clay	NA

Appendix 11. Case study sampling data (continued)

			Core sample	
			Soil core/vibracore	**Drill rig**
Horseshoe Curve[a]	Reading IN1: 2.423 cm/h 0.954 in/h Reading IN2: 1.212 cm/h 0.477 in/h	NA	<u>Sample C1</u> 0-6" dark loam with organics 6-12" brown fine sand with silt 12-?" fine and medium sand, few pebbles, and silt <u>Sample C2</u> 0-6" dark loam with organics 6-12" fine sand and silts 12-20" brown fine sand <u>Sample C4</u> 0-6" silt loam with mottling 6-24" fine sand 24-?" silt and clay, subangular blocky structure <u>Sample C5</u> 0-4" organics with some silt 4-5" fine sand 5-22" dark silt, few sand grains <u>Sample C6</u> 0-20" organics with silt and some fine sand 20-22" brown fine sand with some clay <u>Sample C7</u> 0-4" dark loam with organics 4-12" fine sand with some medium sand, pebbles, and silt 12-24" light brown fine sand 24-?" fine sand and clay <u>Sample C8</u> 0-6" dark brown silt loam with some sand 6-18" light brown fine sand 18-24" light brown clayey sand	NA

			<u>Sample C9</u> 0-4” dark brown silt loam, granular 4-18” light brown sandy loam, granular 18-28” light brown lay loam with subangular blocks 28-36” light brown clay	
Lot 34	Reading IN1: 1.02 cm/h 0.401 in/h	NA	<u>Sample C1</u> 0-3.7” very dark grey silt loam 3.7-12.4” dark brown silt loam 12.4-35.5” very dark greyish brown silt	<u>Sample C2</u> 0-12.5’ dark yellowish brown silt/clay/fine sand 12.5-14’ gravel 14-17.5’ yellowish brown sandy silt with small pebbles 17.5-27.5’ yellowish brown silty sand
Rennebohm Hall (Pharmacy Building)	Reading IN1: 0.030 cm/h 0.012 in/h	NA	NA	<u>Sample C1</u> 0-2.5’ brownish yellow fine to coarse sand with pebbles 2.5-7.5’ grayish brown clay with organic lenses 7.5-12.5’ yellowish brown very fine to medium sand with possible silt 12.5-17.5’ light yellowish brown medium to coarse sand with 0.5mm pebbles 17.5-20’ light yellowish brown clayey silt with some pebbles 20-22.5’ light yellowish brown very fine silty sand 22.5-35’ yellowish brown medium to coarse sand with pebbles 35-40’ yellowish brown fine to medium sand with coarse fragments

[a] Infiltration data collected with an amoozemeter.
[b] Infiltration data collected with a double ring infiltrometer.

Appendix 12. Rain garden plant list

Mesic-dry soils (sunny)

Native species

Butterfly Flower	*Asclepias tuberosa*
Purple Prairie Clover	*Dalea purpureum*
Purple Coneflower	*Echinacea purpurea*
Bee balm	*Monarda fistulosa*
Little Bluestem	*Schizachyrium scoparium*
Spiderwort	*Tradescantia bracteata*
White False Indigo	*Baptisia lacteal*

Non-native

Yarrow	*Achillea*
Feather Reed Grass	*Calamogrostis*
Daylily	*Hemrocalis* spp.
Blazingstar	*Liatris*
Silverfeather Grass	*Miscanthus sinenis*
Garden Phlox	*Phlox paniculata*
Black-Eyed Susan	*Rudbeckia fulgida*

Mesic-dry soils (shady)

Native species

Wild Columbine	*Aquilegia canadensis*
Wild Geranium	*Geranium maculatum*
Obedient Plant	*Physostegia virginiana*
Jacob's Ladder	*Polemonium reptans*
Soloman's Seal	*Polygonatum biflorum*
Zigzag Goldenrod	*Solidago flexicaulis*
Canada Violet	*Viola canadensis*
Culver's Root	*Veronicastrum virginium*

Non-native

White Comfrey	*Symphytum grandifolia*
Tufted Hair Grass	*Deschamsia caespitosa*
Bigroot Geranium	*Geranium macrorrhizum*
Daylily	*Hemerocallis* spp.
Hosta "Royal Standard"	*Hosta* "Royal Standard"
Tigerlily	*Lilium tigrinum*

Wet soil (sunny)

Native species

Giant Hissop	*Agastache foeniculum*
Canada Anemone	*Anemone canadensis*
Marsh Milkweed	*Asclepias incarnata*
New England Aster	*Aster novae-angliae*
Turtlehead	*Chelone glabra*
Joe-Pye Weed	*Eupatorium maculatum*
Obedient Plant	*Physostegia viginianum*
Boneset	*Eupatorium perfoliatum*
Queen of the Prairie	*Filpendula rubra*

Blueflag Iris	*Iris versicolor*
Great Blue Lobelia	*Lobelia siphilitica*
Switchgrass	*Panicum virgatum*
Mountain Mint	*Pycnanthemum virginicum*
Tall Meadow Rue	*Thalictrum dasycarpum*
Culvers Root	*Veronicastrum vigrinicum*
Golden Alexander	*Zizia aurea*

Non-native

Daylily	*Hemerocallis* spp.
Siberian Iris	*Iris sibirica*
Tigerlily	*Lilium tigrinum*
Switchgrass	*Panicum virgatum*
"Heavy Metal"	"Heavy Metal"

Wet soil (shady)

Native species

Cardinal Flower	*Lobelia cardinalis*
Ostrich Fern	*Matteuccia struhiopteris*
Virginia Bluebells	*Mertensia virginica*
Sensitive Fern	*Onoclea sensibilis*

Non-native

Pink Turtlehead	*Chelone layonii*
Daylily	*Hemerocallis* spp.
Obedient Plant	*Physostegia virginicana*

Shrubs (sunny)

Black Chokeberry	*Aronia melanocarpa*
Red-Osier Dogwood	*Cornus serecia*
Low Bush Honeysuckle	*Diervilla ionicera*
Annabelle Hydgrangea	*Hydrangea arborescens* "Annabelle"
Pussy Willow	*Salix discolor*
High Bush Cranberry	*Viburnum trilobum*

Shrubs (shady)

Black Chokeberry	*Aronia melanocarpa*
Red-Osier Dogwood	*Cornus serecia*
Low Bush Honeysuckle	*Diervilla ionicera*
Annabelle Hydgrangea	*Hydrangea arborescens* "Annabelle"

Appendix 13. Best management practices

NOTE: Practice definitions in *italics* were taken from the Dane County Erosion Control and Stormwater Management Manual (2002).

Aesthetic gravel

Gravel of different colors can be placed in areas where convenience paths have formed or are expected to form. By sheltering the bare soil from precipitation, gravel reduces erosion. These areas should not be shoveled in the winter.

Deep tilling

Deep tilling, also called sub-soiling, is used to remedy compaction problems by ripping the soil perpendicular to the flow direction. In addition, deep tilling increases pore space, which promotes plant growth and water retention.

Sub-soiling can be used on a variety of sites; however, safety is an issue on steeper slopes. It is best to use deep tilling in conjunction with other practices, such as mulching, erosion matting, and seeding, because it exposes soil.

The effectiveness of the practice depends on the type of equipment used as well as the condition of the soil at the site. For example, at the Kohl Center the compaction runs deep enough that the amount of force required to pull the heavy steel shanks used in deep tilling through the soil may make the compaction problem worse. In this instance, it may be better to use a chisel plow to break up the soil. At other, less problematic sites, heavy machinery can be used to achieve a depth of 2 to 3 feet. If the soil is compacted, it is best to rip it to 1 to 2 inches below the hardpan layer, if possible.

Fiber logs

On disturbed areas with especially steep slopes, fiber logs may be the most effective alternative of sediment containment. A fiber log consists of log-shaped fabric filled with excelsior fibers. Stormwater passes through these logs, reducing the flow rate and filtering sediment. The shape of these structures allows for easier placement on steep slopes because they contour to the landscape (Construction Fabric Materials, 2002).

Like the other methods of sediment containment mentioned in this appendix, fiber logs are used as temporary structures until the disturbed area is stabilized. The fiber inside these logs is typically degradable, so it does not have to be removed from the site (Construction Fabric Materials, 2002).

Gabions

Gabions are wire baskets filled with rock, which function as outlet structures in conjunction with other BMPs. The baskets work to dissipate the energy of rushing water, reducing its erosion potential while also working as a filter for sediment and other pollutants.

Site characteristics will determine the most appropriate size of the gabions, but a general framework is at least 1 foot high, 3 feet deep. To function properly, the gabions need to extend across the full width of the waterway structure, and have slopes not steeper than 2:1. Also, geotextile fabric should be used along the bottom of the gabion to protect the structure from undercutting that could lead to failure.

The size of the clean stone in the baskets will also depend on the site. Generally, rock 1 to 8 inches in diameter is used. It is recommended that the baskets be filled by hand to prevent gaps.

Important notes:

- Wire braces should be used to reinforce the gabion structure.
- Stone and geotextile should be placed at the bottom of the structure to prevent water erosion at the base.
- Additional stone may need to be added as maintenance to offset settlement and lost stones.

Grass swales

Grass swales are gently sloping vegetated channels that convey stormwater and reduce the temperature of the water. Stormwater enters these channels and is slowed by the dense vegetation growing in the swale. As the velocity of the stormwater is reduced, the vegetation works to filter out sediments and pollutants (Dane County, 2002).

Grass swales can be used in conjunction with or instead of curb and gutter systems. They can be used on sites up to 50 acres in size, with the number and length of the swale depending on the topography of the site and the size of the draining area. Recommended lengths and widths of swales depend greatly on the physical characteristics of a site, but generally swales should be between 2 and 8 feet wide. Swales greater than 8 feet will likely result in channelized flow. Grass swales can be used on a wide variety of soil types, but should not be used on excessively coarse material, which will inhibit vegetation growth and have high infiltration rates that provide limited pollutant treatment possibilities. In situations where grass swales are designed to provide infiltration, soil permeability should be high enough to provide adequate infiltration for a short ponding period. However, not all swales are designed to provide infiltration, some are designed to filter out sediment from stormwater runoff. All swales should be designed to accommodate the volume of stormwater runoff from the 10-year storm event (Dane County, 2002).

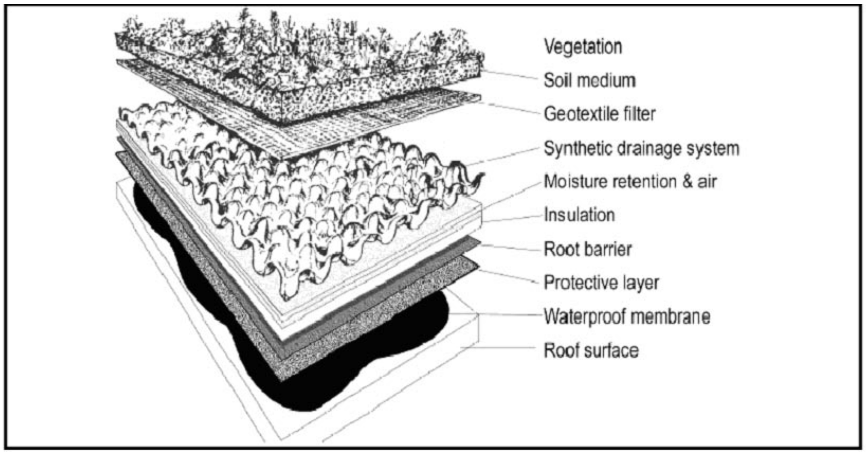

Figure A13-1. *Example of a green roof (adapted from Miller, 1998, and American Hydrotech).*

Green rooftops

Green rooftops are roof surfaces consisting of living vegetation. These structures help manage stormwater runoff by mimicking some of the hydrologic processes of natural green space, such as rainwater capture on the foliage material, root adsorption, and evapotranspiration. These processes work to reduce the amount of stormwater falling on impervious surfaces, and the water that does leave the roof is slowed and kept cooler, which is beneficial for water quality. Green rooftops are especially useful at mitigating the effects of intense, short-duration thunderstorms (Metropolitan Council, 2003). They also reduce the volume of storm runoff. However, green roofs do not provide benefit to groundwater, since the volume reduction is due to evapotranspiration.

Things to consider in green roof installation include the structural and load-bearing capacity, plant selection, waterproofing and drainage or water storage systems. Figure A13-1 provides a generalized diagram of a typical green roof design. Green roofs can be designed in a variety of different ways, but there are two general design types; extensive and intensive. Extensive systems are the simplest design alternative, with a relatively light system of drainage, and shallow soil layer (2 to 4 inches) that is planted with drought tolerant herbaceous vegetation. Intensive systems utilize deeper soils to accommodate trees and shrubs and tolerate human use. These types of roofs require higher structural load capacity.

Green rooftops are useful because they

- delay stormwater runoff,
- help reduce CO_2 levels,
- reduce heating and cooling costs by providing insulation,
- reduce urban temperatures by humidifying and cooling the surrounding air,
- provide habitat for birds and butterflies, and
- are aesthetically pleasing.

Some of the limitations of green rooftops include the following:

- Damage to waterproofing materials may result in severe water damage to building.
- They can be very expensive, particularly when retrofitting existing structure.
- Planting on sloped roofs requires special erosion control.
- Maintenance is higher than conventional roof.
- Extreme sun and wind conditions on rooftops provide challenge to plant survival.

- Weight of snow may provide structural limitations, particularly in Wisconsin's climate regime.

Infiltration trench

Infiltration trenches are depressions that collect and store stormwater until it can infiltrate into the subsoil. Sediment settles out in the device, and nutrients, metals, and organic material are adsorbed by stone and subsoil as the water infiltrates. Infiltration trenches may also be designed to reduce peak flows from a site if the storage capacity of the device is increased and an outlet structure is included in the design.

These structures are applicable on sites with highly permeable soils and drainage areas of less than 15 acres. Infiltration trenches should not be used near foundations, basements, or roads or on sites with high water tables, steep slopes, or clay soils. In addition, these devices should not be used on sites with large concentrations of soluble pollutants, as groundwater contamination may result.

Although these structures effectively treat the runoff volume from the 1-year, 24-hour storm, larger storm events quickly overwhelm the capacity of the device and render it ineffective. Trenches are also susceptible to clogging from large sediments and, as a result, they should be used in conjunction with other management practices.

Inlet protection

No best management practice can be 100 percent effective at containing sediment and pollutants on a site; therefore it is critical to protect all inlets, catch basins, culverts, and other conveyance structures to prevent pollutants from entering the water supply. The current NR 151 standard requires inlet protection around all construction sites. However, this is only meant to be a last-line of defense and should be used in combination with other sediment and erosion control practices.

Inlet protection consists of silt fence, straw bale, fiber log, or equivalent sediment barrier protection, around areas where runoff enters conveyance system structures. In addition to this, inlet insert baskets are installed in curb inlets and drop inlets. These structures consist of filter fabric supported by a metal frame (Wisconsin Department of Natural Resources, 1993). Often times left over silt fence material is used as the filter fabric. However, it is important to use a fabric that allows enough fine sediment to pass through so that the fabric will not become clogged, which would reduce the effectiveness of capturing sediment (Peggy Chung, Facilities Planning and Management, oral communication, June 2003).

In-line treatment devices

One method of removing oil, grease, and larger sediment particles is to use a stormwater interception and treatment device. These are placed along a storm drain; forcing stormwater into the mechanism, treating it, and pushing it back out along the drain. Different types of filtering devices have been used. Examples include centrifugal removal or multi-chambered filtration. In-line treatment is a newer technology that brings with it some skepticism since they do not filter fine sediments, and they can be very costly to install (Jeremy Balousek, Dane County Land Conservation Department, oral communication, June 2003).

A specific unit, called a Stormceptor (www.stormceptor.com), is made of concrete, and is used in place of a stormwater basin. It can be used in urban areas with little space required, in conjunction with other BMPs. In-line units will require at a minimum, annual removal of accumulated pollutants and sediment (Chester County, 2002).

Mulching/erosion matting

Mulching is the surface application of plant residue, wood chips, or other organic material (Wisconsin Department of Natural Resources, 1993). Applying mulching material increases the water-holding capacity and organic matter content of the soil, which helps promote the establishment of vegetative cover after seeding. In addition, mulch works to reduce erosion by reducing the impact energy of precipitation and reducing surface runoff and flow velocities. A wide variety of materials can be used for mulch, with the recommended rate of application varying depending on the type of material used. The types of materials typically used for mulching include straw (1.5–2 tons/acre), wood chips (6–9 tons/acre), wood fiber (0.75–1 tons/acre), and corncobs (5 tons/acre) (Wisconsin Department of Natural Resources, 1993).

There are a variety of different erosion mats or nets that are used to secure mulching material and seed/sod to the soil surface. Matting material can consist of polypropylene netting, excelsior retention blankets, jute matting, or coconut fiber (Wisconsin Department of Natural Resources, 1993). These mats are degradable and will eventually break down after vegetative cover is established.

Native plants

Native plantings can serve as stormwater collection areas while slowing runoff, filtering out sediments, and encouraging infiltration. Native species are adaptable to many areas and can provide an aesthetic quality as well as wildlife habitat. Although they are more costly and difficult to establish than non-native species, prairie vegetation offers a greater level of infiltration due to its deep root systems, which can stretch to 10 feet below the soil surface. The root systems help to stabilize the soil and protect water quality since fertilizers and pesticides are generally not required. Note, however, that the evapotranspiration from deeply rooted plants will be greater, reducing the amount of groundwater recharge.

Within the first year of establishment, most of the native species will only grow two to three inches. A few species may even lie dormant for several years before sprouting. During this time, the plants are establishing their root systems, and weeds and other invasives can out compete the native plants. However, once they are established, native species will flourish and quickly replace the weeds.

The species selected for an individual site will vary according to soil type, slope, aspect, and other environmental factors. A planting can be accomplished by transplants or by seed. The prior tactic is more costly, but is one to two years quicker in getting established. Either way, it is important to purchase stock from a local supplier to provide the best results.

Following planting, clean straw mulch should be used to control erosion. Heavy erosion matting should be avoided to prevent the seeds from rotting. Once established, native species will require no more maintenance than periodic mowing and supervised, controlled burning.

Oil and grease filters

Oil and grease filters are devices that are designed to remove oil, grease, sediments, trash, and other debris from stormwater by passing them through a filtering device.

They are most often used at gas stations, industrial sites, parking lots, loading areas, and anywhere hydrocarbons are likely to be present in large quantities. Because they generally operate underground, they are often used in retrofit applications where other management practices are not practical. In high flow situations, the volume of water may exceed the capacity of the filter chamber and stormwater may bypass the device without treatment. As a result, these practices are best used in conjunction with other management practices.

Oil and grease filters are available from a wide variety of vendors, so the design specifications vary depending on where the device is obtained. All devices should be designed to accommodate the specific conditions of the site, and at a minimum, should be designed to treat the first ½ inch of stormwater runoff. Because Dane County does not recognize one particular brand as being superior, and design specifications vary significantly, installations of these products should be approved by the Dane County Conservationist if there is any question about effectiveness (Dane County, 2002).

Oil and grease separators

Oil and grease separators are devices that are designed to remove oil, grease, sediments, trash, and other debris from stormwater. These three chambered, underground devices use the difference between the specific gravities of water and petroleum products to separate the two. However, other types of chemical pollutants, such as solvents and detergents, are not removed by this practice.

In low flow conditions, water enters the separator via a storm inlet and passes through the chambers of the device. As stormwater passes through the chambers, oil and grease are separated to the surface and are either skimmed off (oil) or left to settle to the bottom of the chamber (grease). The remaining effluent is then discharged to additional management practices, such as infiltration. A generalized diagram of this device is shown in Figure A13-2. In high flow situations, the volume of water may exceed the separating capacity of the device, so this practice should only be used on impervious areas of 1 acre or less.

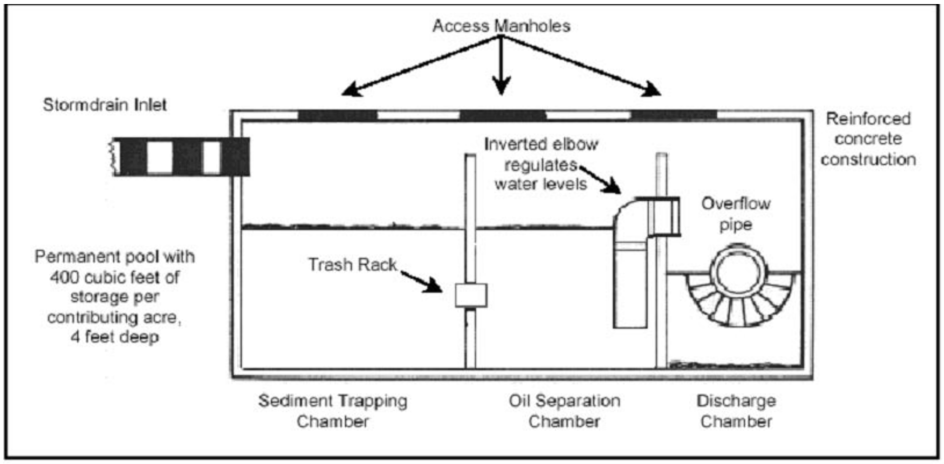

Figure A13-2. *A typical oil and grease separator (from Schueler, 1987).*

Much like oil and grease filters, the design specifications of these devices vary greatly depending on the manufacturer. However, all oil and grease separators should provide a minimum of 400 cubic feet of storage per acre of drainage area, and provide enough detention time to allow oil, grease, and sediment to separate from the stormwater. Also, separate storage areas should be provided for the separated petroleum products at the top of the chamber and accumulated solids at the bottom. All separators should be at least four feet deep and should not be installed to treat stormwater with velocities exceeding three feet per minute.

Pavers

Pavers are modular perforated concrete blocks that allow vegetation to grow in the voids and increase infiltration. Pavers, like pervious pavement, provide storage in the three feet-plus subsurface layer of gravel. Pavers are best utilized in areas of pedestrian traffic, rarely used overflow parking, and are especially useful around bus stops. The bus stop in front of the Princeton House, 1815 University Avenue, utilizes pavers. Pavers can sometimes be uncomfortably bumpy for cyclists and motorists, so they are not appropriate in areas that receive a lot of vehicular traffic (Dane County, 2002). Routine maintenance is required to clean out sediment located in the voids between the pavers.

Pervious pavement

Pervious pavement is constructed to have interconnected pores that allow water to infiltrate into an underlying gravel storage zone and then the soil. These concrete or asphalt systems are best for areas with low vehicle traffic, such as overflow parking areas and sidewalks (Dane County, 2002). The Walden Pond State Reservation in Concord, Massachusetts, installed a parking lot using this technology in 1977 that is still operable today (Keating, 2000).

Porous pavement can become clogged by sediment, including sand used for snow management. Porous pavement should not be used in areas with high sediment loads. If the pavement becomes clogged, it will only affect the ability of the pavement to infiltrate and not hinder its structural stability to hold cars and people. If porous pavement becomes clogged, it can be renewed by vacuuming or by removing the top 0.75 inches. Possible uses of porous pavement for campus include rarely used parking areas, paving on planting strips, and connecting bus stop shelters to the street. Lessons learned from a porous pavement project at Villanova University, near Philadelphia, Pennsylvania are outlined in “Villanova Urban Stormwater Partnership Lessons Learned - Porous Concrete Demonstration Site,” (Traver et al., 2003).

Polymer application

Polymers (anionic polyacrylamides) are organic, non-toxic chemicals that, when applied to exposed soil, temporarily bonds to it, preventing erosion from water and wind. It can be used on a wide variety of sites, including steep slopes and construction sites. In addition, when used with other practices (i.e. seeding) polymers can be significantly more effective.

Polymers are available commercially in both liquid and granular form. Before they can be applied, both the DNR and the Wisconsin Department of Transportation must approve them. A list of pre-approved polymers is available from the Product Acceptability List Committee on the Wisconsin Department of Transportation's Web site: http://www.dot.state.wi.us/dtid/bhc/pal.html.

Application of the polymers varies on the product used, the time of year, and the site characteristics. The manufacturer's instructions need to be followed precisely. Over application can result in a reduced effectiveness of the product. Also, some polymers may have an adverse effect on local plant and wildlife communities; as a result, these polymers must not be applied within 30 feet of any state water bodies. Reapplication is required after every 6 weeks due to the breakdown of the product.

Rain gardens/bioretention cells

Rain gardens are small depressions planted with a variety of forbs, grasses, and shrubs. Rain gardens can be established in a variety of locations such as residential or commercial green spaces, boulevard planting strips, parking lot planter islands, or below roof downspouts. They function as a type of on-site infiltration system designed to reduce the amount of stormwater runoff by slowing the flow of water and allowing it to soak into the ground. When rain gardens are installed correctly and are functioning properly, surface water runoff is used to recharge groundwater and to water trees and other vegetation. The vegetation within the rain garden can also enhance water quality as it filters out pollutants from the surface water. They are not to be used, however, to filter a large volume of pollutants or significantly contaminated surface water (Metropolitan Council, 2003).

Specifications

A rain garden in a 2-acre or less drainage area should be between 4 and 16 inches deep (Bannerman and Considine, 2003; Metropolitan Council, 2003). The soil in the rain garden should be leveled. If a rain garden is to be constructed on a sloping site it might need to be built in terraced compartments. The size and dimensions of the garden will depend on the specific location and the amount of water draining to it (Bannerman and Considine, 2003). There are many choices of plants suitable for a rain garden, but each site will differ depending on the soil type present. A list of some of the appropriate plant species can be found in Appendix 5.3.

Limitations

Rain gardens require an adequately draining soil to function. If the soil has too much clay, the water will pond instead of soaking in to the ground. A simple way for a homeowner to test the permeability of soil involves digging a hole in the proposed site about 6 inches deep and filling it with water. If it soaks in within 24 hours, the site is probably suitable; otherwise, if the water is still present, it is not a good location for a rain garden unless the soil is excavated and replaced with a more suitable mix of soil and compost (Bannerman and Considine, 2003). For a larger project in an area such as the UW campus, a more thorough soil test would be necessary to determine whether water will adequately infiltrate. It is important for rain gardens to be at least 10 feet from any building foundation to prevent water from seeping into the foundation (Bannerman and Considine, 2003).

Maintenance within the first year or two of establishment is very important. To keep the rain garden aesthetically pleasing, it is necessary to keep weeds from taking over the garden. Once the planted species are established, the maintenance requirements should be restricted to mowing in the spring, removing dead plant material, and inspecting the garden for sediment build-up. If the site is adequately maintained, the rain garden should function for over 20 years (Metropolitan Council, 2003).

The general cost of a rain garden will depend on several factors: the size of the site, the complexity of the design, and whether the vegetation used is native or ornamental. Generally, ornamental species will cost more than native species (Ryan Shore, Dane County Land Conservation Department, oral communication, June 2003). Roger Bannerman of the Wisconsin Department of Natural Resources has compiled the following list of associated costs in installing a rain garden.

Construction	$3.00/ sq. ft.
Design	$1.00/ sq. ft.
Planting	$3–4.00/ sq. ft.
Plants	$2.50–4.50/ sq. ft.
Total cost for a simple rain garden	**$11.00–13.00/ sq. ft.**

Incorporating bio-filtration/retention

In places where the drainage area is greater than two acres, rain gardens can be used in conjunction with a bio-filtration system. These systems can take the form of a variety of different designs to retain excess stormwater and may use various biological substances to filter out pollutants. Whereas a simple rain garden may only be a few inches to a couple of feet deep, a bio-filtration system would involve more extensive excavation to retain more stormwater (Metropolitan Council, 2003).

The most cost-effective system consists of an excavated area, from 2 to 6 feet deep, depending on the site, and a well-mixed combination of soil and compost. The existing soil on the site can be re-used after it has been sufficiently mixed with compost, giving the soil a greater capacity for holding water. In some cases, a subsurface drain is situated below the soil mixture to prevent overflow. The preferred compost is that of oak leaves because they contain tannins, which bind to heavy metals. Filtering out heavy metals further enhances the properties of the bio-filtration system (Aicardo Roa-Espinosa, Dane County Land Conservation Department, oral communication, June 2003). However, it is important to use high quality compost when incorporating oak leaves to prevent inadvertently spreading oak wilt disease (Ryan Shore, Dane County Land Conservation Department, oral communication, June 2003).

The additional cost of a bio-filtration/retention system will depend on the size of the watershed, and the individual site characteristics.

For more specific information on building rain gardens refer to the following:

- *Rain Gardens: A How-To Manual for Homeowners* put out by the Wisconsin Department of Natural Resources
- *Minnesota Urban Small Sites BMP Manual* prepared by the Barr Engineering Company.
- *Dane County Erosion Control and Stormwater Management Manual*

For more information on rain garden vegetation, contact:

Mo. Fayyaz, Ph.D.
Director
Greenhouses and Botanical Garden
Botany Department
College of Letters and Science
144 Birge Hall
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Madison, WI 53706
(608) 262-2235
email: mmfayyaz@facstaff.wisc.edu

Sedimentation basins

Sedimentation basins are basins constructed to retain a permanent pond of water while also temporarily accumulating stormwater runoff. Their purpose is to reduce stormwater flow velocity while trapping sediment and other pollutants. The large volume of storage helps to reduce peak discharges from storm events, which then reduces down-stream flooding.

Sedimentation basins are often used when the contributing area is relatively large (ten acres or greater). They take up a significant amount of space, which hinders their potential use on the UW campus.

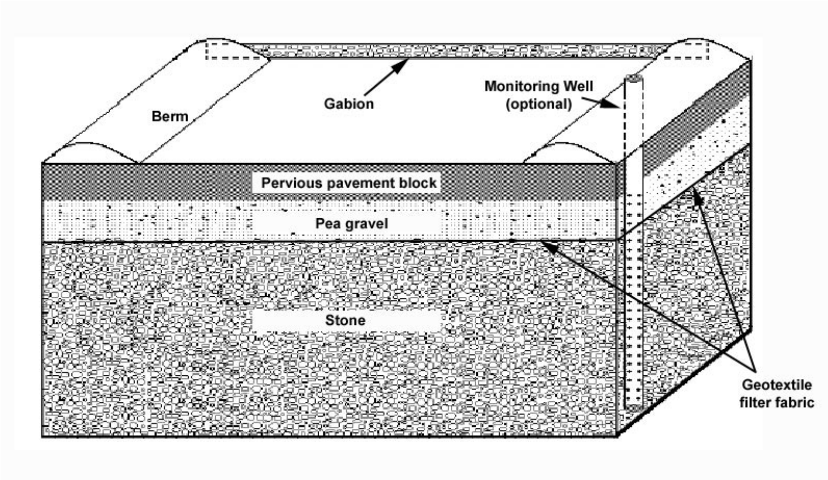

Figure A13-3. *A typical stone crib (adapted from U.S. Environmental Protection Agency, 1999).*

Important notes:

- Maintenance costs are generally 3 to 5 percent of construction cost per year.
- Sediment should be removed as necessary, usually between every 5 to 25 years, depending on the design of the basin.

Silt fence

A silt fence is a temporary structure, constructed of woven geotextile filter fabric attached to posts, which minimizes the loss of sediment from a site and prevents sheet and rill erosion. These structures intercept runoff and force it to pass through the filter fabric, reducing its velocity and allowing suspended sediments to settle out upslope of the silt fence.

Silt fences are typically used on construction sites to trap sediment on site and around soil piles and may not be used in channels, gullies, ditches, streams, or in any other area where concentrated flow may occur. These structures, which may be prefabricated or constructed on site, should be installed prior to site disturbance. Because silt fences have a high rate of failure without proper installation and maintenance, they are best used in conjunction with other BMPs.

Silt fences must be removed and disposed of after the site has been stabilized and permanent BMPs have been established.

Stone cribs

A stone crib [figure A13-3] is a basin designed to collect the first ½ inch of stormwater. The velocity of the water is reduced as it passes through the basin, promoting sedimentation. The stone also works to reduce the temperature of the water. When water enters the basin, it passes through a top layer of pervious pavement block then through a layer of pea gravel. This system functions as a filter for sediment and other particles. It is generally used concurrent with a gabion structure to collect larger debris and trash upstream of the structure.

These structures can be used in a variety of situations, especially in temperature-sensitive watersheds. They require minimal land area and are relatively cost-effective. The maintenance requirements are relatively low; however, their function is limited during larger storm events.

Stone tracking pads/washing racks

Stone tracking pads [figure A13-4] consist of paths of 3-6 inch washed stone that are at least 12 inches thick, 50 feet long, and 24 feet wide. These paths are installed at the exit and entry points of a construction site, and work to remove sediment from the tires of passing vehicles by allowing the tires to sink into the crushed stone as they are moving. Tracking pads are installed prior to any disturbance activity and are removed at the completion of the construction project. Periodic cleaning or stone replacement may be required if sediment is not being efficiently removed.

In situations where construction conditions are excessively muddy, washing racks should also be used to increase the efficiency of stone tracking pads. Wash racks consist of a heavy metal grate and water collection system that removes sediment from tires. Water that is used for this purpose must be collected on-site and placed in a settling basin, so that suspended sediment can be deposited before the water leaves the site (Dane County, 2002).

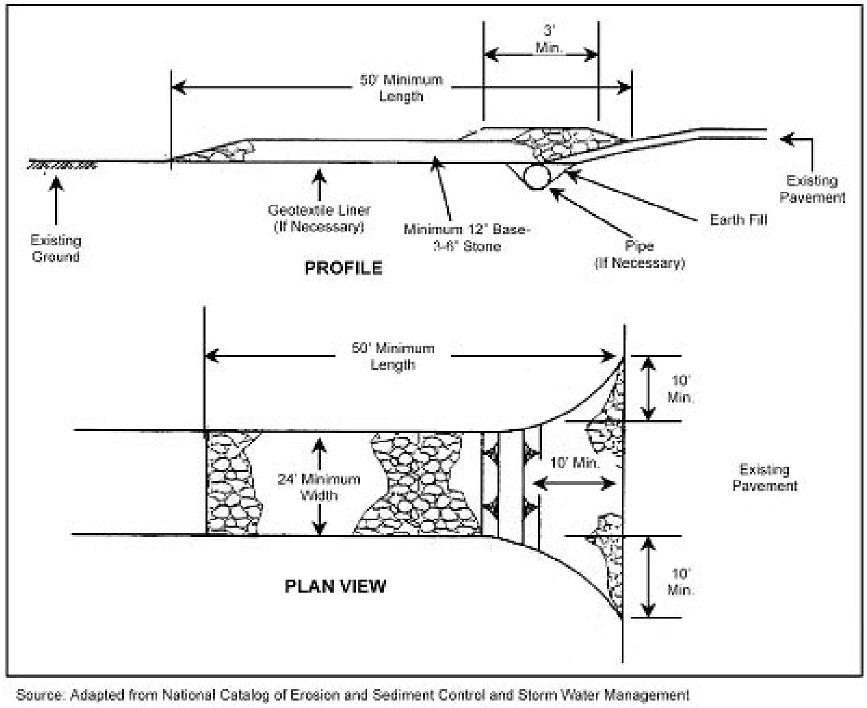

Figure A13-4. *Sketch of a stone tracking pad (Dane County, 2002).*

Straw bale fences

Straw bale fences are similar to silt fences in that they are used as a barrier for sediment leaving a disturbed site. Like silt fences, they are temporary structures, installed down-slope of the disturbed areas. Straw bale fences are generally considered less effective than silt fences because they are more difficult to manipulate. However, because straw bales are biodegradable, they are sometimes used in situations where silt fence removal is impractical (Wisconsin Department of Natural Resources, 1993). However, because straw bales break down over time, they are not suitable as a long-term management alternative.

Sweeping of parking lots and streets

Parking lot and street sweeping prevents sediment, heavy metals, and other pollutants from reaching receiving waters by removing them from the impervious areas before they can reach storm drains. Impervious areas accumulate sediment, lawn and leaf litter, trash, and other pollutants, and then stormwater carries these contaminants to waterways.

Sweeping is applicable to any impervious area where a street sweeper may travel safely. Street sweeping should be used with other practices, as smaller particles can be difficult to remove with such equipment.

There are two mechanized methods for street sweeping: broom and vacuum. Broom sweepers can remove larger particles, and are most efficient on wet surfaces. Vacuum sweepers are better at removing finer, pollutant-laden particles, but are generally not effective on wet surfaces.

Street sweeping should be performed at least twice a year. Salt, sand, as well as leaf clippings, are removed with street sweeping, which stresses the importance of timing to prevent these materials from entering the nearest storm drain.

Construction sites and areas with a high traffic volume need to be swept more frequently. Screening can separate the waste accumulated so that lawn and grass clippings can be composted.

Street sweeping can be used to meet the 80 percent total suspended solids reduction requirement. When used regularly and properly, and in conjunction with other practices, it is possible to achieve a 10 percent reduction in TSS.

In the past, the University has done a very thorough, very respectable job of street sweeping in the spring, summer, and fall. However, recent budget cuts and reprioritizing of the grounds maintenance task list by the Environmental Services Department have limited the Grounds crew's ability to devote the necessary time to street sweeping as well as cleaning up storm drains. The time that is required to do the cleaning that the Environmental Services Department feels is a priority, which is taking time away from other maintenance tasks, is the equivalent of one full-time position.

It would be in the University's best interest to invest in a new street sweeper. The current sweeper is too old and breaks down frequently. The crew believes that it is not necessary to upgrade to a more costly, high-tech version, but replacing the worn out one with a newer model would prevent downtime due to repairs.

It is highly recommended that the University restore the budget to the grounds maintenance staff to allow for adequate street sweeping and storm drain cleanup, which prevents sediment and other pollutants from getting to Lakes Mendota and Monona.

Important notes:

- Sweeping reduces amount of sediment, heavy metals, and other pollutants from reaching receiving waters, especially when used in parking lots.
- Sweeping helps to prevent storm drains from clogging.
- Sweeping improves aesthetics.
- Sweeping operations should prevent materials from being directed toward storm drains.
- Holding and disposal sites for collected materials should be located so that it is not washed back into storm drain inlets.
- Sweeping should be performed prior to storm events to maximize the amount collected.
- Routine maintenance should be performed on sweepers to keep them operating efficiently.

Disadvantages of sweeping:

- Limited effectiveness on streets with parked cars.
- Waste can contain heavy metals and other pollutants.

Subsurface drains

Tiles or pipes, installed several feet below ground, collect and convey stormwater to an outlet can be used as subsurface drains. They are usually plastic and can be perforated to allow water to move into or out of the surrounding soil. Subsurface drains are designed to function as water transport tubes only; they do not improve water quality.

The term "subsurface drainage systems" is used to denote two very different practices. In one instance, relief drains are used to lower the water table to allow the growth of vegetation or to remove surface water in the direction of the slope. The other system consists of interceptor drains, which are placed along slopes to prevent the soil from becoming saturated, and usually drain to the side of the slope.

Important notes:

- Subsurface drains need to be located at least 50 feet from trees to prevent damage to the structure by roots.
- Installation should be done when soil is as dry as possible.
- Drains should be inspected periodically to ensure they are draining properly, as they have a tendency to plug.

Tree planting

Trees help to stabilize disturbed sites while encouraging infiltration, by protecting soil from the impact of raindrops that break up soil structure and exacerbate erosion. They also act as windbreaks and provide wildlife habitat. Trees can be planted wherever mowing and other maintenance activities are difficult. While the canopy cover is developing, trees should be used in conjunction with other practices such as temporary or permanent seeding or planting native grasses and forbs.

Tree selection is site specific. Characteristics important to consider include soil type, drainage, pH, slope, maintenance, growth rate, size, and time of planting are just some of the considerations when selecting trees. Invasive or exotic species should not be used, because of their potential to crowd out essential native species, which act as food for wildlife among other things. Soil testing should be done to determine the needs of the site prior to planting.

When transplanting trees, larger trees take longer to recover and will require more care and maintenance than smaller trees. Trees are available with bare roots, with soil wrapped in burlap, container-grown, or tree spaded, and each will have different requirements for planting and care.

After following the planting instructions for the specific variety, the soil surrounding the plant should be watered and gently pressed to remove any air pockets. Be careful not to compact the wet soil too much. The area should be sloped toward the tree, creating a small depression to hold water. Mulching a two to three foot area surrounding the tree will help to discourage weed growth. A small, mulch-free ring should be maintained directly surrounding the tree to inhibit fungal growth. More information about proper methods for tree planting is readily available from state and local natural resource conservation agencies and tree suppliers.

Important notes:

- All grading and tracking should be completed before planting begins.
- Species should be adapted to the soils and climate of the area.
- Transplanted trees must be watered frequently.
- Weeds around the base should be removed as necessary.
- Fertilizer should be added at proper rates.

Vehicle washing

Removing excess sediments from cars, trucks, and other vehicles is an important step in maintaining water quality. However, proper handling of the wastewater produced in vehicle washing is critical. When washing vehicles it is important to know where the wastewater goes. Disposal of wastewater directly into natural water bodies should be avoided. The Texas Natural Resource Conservation Commission provides a good discussion of tips for preventing pollution during vehicle washing.

Washing vehicles on pervious surfaces will lessen the amount of surface runoff that typically accompanies vehicle washing. However, washing vehicles on pervious surface may cause significant compaction, so it is not recommended on areas that are especially valuable for infiltration. When vehicle washing is done on impervious surfaces, the grading should be such that all wastewater is directed into catch basins that will filter out excess pollutants.

Cleaning solutions used in vehicle washing should be kept to a minimum, which will lessen the amount of detergents, brighteners, and other pollutants in the wastewater. Many cleaners consist of biodegradable and less hazardous substances that should be used when washing vehicles. The use of abrasives should be avoided because they have a tendency to remove paint-chips and heavy metals from vehicles, which could adversely affect water quality.

Online best management resources

The field of stormwater management is constantly changing, as new technologies are developed and refined. Any effective stormwater plan should include the most cutting-edge and useful management alternatives. Below is a selection of some online resources that provide information on cutting-edge stormwater mitigation alternatives. This list should not be considered all-inclusive as information on BMPs changes regularly.

EPA: Example photographs of BMPs
http://www.epa.gov/owow/nps/ex-bmps.html

Minnesota BMP manual
http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm

Maryland Stormwater Design Manual
http://www.mde.state.md.us/assets/document/sedimentstormwater/Introduction.pdf

LID Urban Design Tools
http://www.lid-stormwater.net/

Stormwater Manager's Resource Center
http://www.stormwatercenter.net/

EPA National Management Measures to Control Nonpoint Source Pollution from Urban Areas http://www.epa.gov/owow/nps/urbanmm/index.html

EPA Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures -- Urban
http://www.epa.gov/owow/nps/urban2.html

Knoxville TN Stormwater BMP Manual
http://www.ci.knoxville.tn.us/engineering/bmp_manual/

Texas BMPs
http://www.txnpsbook.org/BMPs/URBMPS.htm

Prince George's County LID Design Strategies
http://www.epa.gov/owow/nps/lidnatl.pdf

Dane County BMPs
http://www.co.dane.wi.us/commissions/lakes/pdf/stormwater/tableofcontents.pdf

California Construction Erosion Control BMPs
http://www.dot.ca.gov/hq/construc/stormwater/BMP_Field_Manual_Master_5x8_revision5.pdf

EPA Construction Erosion Control BMPs
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/con_site.cfm

National Stormwater Best Management Practices
http://www.bmpdatabase.org/

References

American Hydrotech, Inc. n.d. The garden roof planning guide. Chicago, IL.

Bannerman, R. and E. Considine. 2003. Raingardens: A how-to manual for homeowners. University of Wisconsin–Extension. Publication GWQ037. Retrieved from http://clean-water.uwex.edu/pubs/raingarden/rgmanual.pdf.

Construction Fabric Materials. 2002. Coir Fiber Logs. Brochure.

Dane County. 2002. Dane County Erosion Control and Stormwater Management Manual. Madison, Wisconsin. Retrieved from http://www.co.dane.wi.us/commissions/lakes/stormwatermanual.shtml.

Keating, J. 2000. Porous Pavement. Stormwater 2(2) Retrieved from http://www.forester.net/sw_0103_porous.html.

Wisconsin Department of Natural Resources. 1993. Construction Site Erosion Control Handbook. Madison, WI.

Metropolitan Council. 2003. Urban Small Sites Best Management Practice Manual, Minneapolis, MN. http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm

Miller, C. 1998. "Vegetated Roof Covers" in Proceedings of the 1998 Pennsylvania Stormwater Management Symposium. Villanova, PA.

Schueler, T. 1987. Controlling urban runoff: A practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments.

Texas Natural Resource Conservation Commission. n.d. Pollution Prevention for Wastewater: Vehicle Washing Tips. http://www.twua.org/p2/Tips/Vehicle_Washing.html.

Traver, R., A. Welker, C. Emerson, M. Kwiatkowski, and T. Ladd. 2003. Villanova Urban Stormwater Partnership Lessons Learned—Porous Concrete Demonstration Site. EPA electronic document received 11/18/03, in a written communication with Carolyn Betz.

U.S. Environmental Protection Agency. 1999. Data Summary of Urban Storm Water Best Management Practices (EPA-821-R-99-012). Washington, D.C.

Appendix 14. Table of best management practices, by purpose and cross-referenced to pages where the practice is discussed in the report

Construction erosion/ sedimentation control

PRACTICE	Applicable Standard/ Problem	Applicability to Sites	Maintenance Requirement	Environmental Concerns	Special Considerations	See Page #	Average Cost
Erosion matting	Soil erosion	Widely applicable on low to moderate slopes	Low	Limited effectiveness on steep slopes	Proper installation	39 41 133	$1.50/ yd^2$
Gabion	Prevents gully erosion	Applicable to vegetated ditches and swales	Low	Does not remove smaller suspended solids	Adjoining materials may require add'l stabilization to prevent erosion	129	$50 – 100 each (size-dependent)
Grassed swale	Total suspended solids goal	Widely applicable	Low to Moderate	Restricted use for areas with high pollution potential	Pretreatment; Careful design	120	$5-6/ yd^3$
Permanent seeding	Soil erosion	Widely applicable	Moderate; Low once established	Possible erosion during establishment; Fertilizer runoff	Must match seed mix w/ season and site conditions; Requires >3" prepared top soil	141	$300/acre
Polymer application	Soil erosion at construction sites	Application on sites that are not actively being graded	Moderate	Risk of adverse impacts if over applied	Must be re-applied if site is disturbed after initial application	135	$250/acre
Silt fence	Soil erosion	Widely applicable	High	Sediment transport; High rates of failure if not properly installed and maintained; Disposal	Longevity; Proper installation	38 138	$2.00/lin ft
Sod	Soil erosion	Widely applicable	Low after establishment	Fertilizer runoff; Over-watering	May need to be staked on steep slopes; Proper selection of species; Req's >3" prepared top soil	79	$2.00/ yd^2$ ($9680/acre)
Stone crib	Thermal; Infiltration; Rate control	Widely applicable, especially in urban areas	Low to Moderate	Limited effectiveness with large storm events	Pavement blocks must have >35 percent permeability	138	$5000-$35,000
Stormwater inlet protection	Soil erosion from construction sites	Widely applicable	Moderate	Ineffective for large storm events; Limited effectiveness with large sediment loads	Must be replaced/repaired frequently	39 131	Variable: approx. $25 each
Tracking pad	Tracking problems from construction sites	Widely applicable	Low to High	None	Cost-effective; Must use >3" clear stone	40 138	$300 each

Appendix 14. Table of best management practices, by purpose and cross-referenced to pages where the practice is discussed in the report (continued)

Infiltration/green space management							
PRACTICE	**Applicable Standard/ Problem**	**Applicability to Sites**	**Maintenance Requirement**	**Environmental Concerns**	**Special Considerations**	**See Page #**	**Average Cost**
Aesthetic gravel	Infiltration; Thermal; Rate Control	Applicable on areas with very low traffic volumes	Moderate	Some small gravel pieces may erode	Occasionally need to sweep gravel pieces back on path	44 128	$10/ yd^3$
Bio-filtration/ retention systems	Infiltration; Thermal; Rate control	Applicable in smaller drainage areas; Can be retrofitted	Low to Moderate	Susceptible to clogging	Cost can be high.	135	Approx. $25/ yd^3
Deep tilling	Compaction	Widely applicable where compaction or heavy grading has occurred	Very Low	None	Following grading; Buried utilities	43, 50 81, 128	$110.00/hr
Infiltration trench (French drain)	Rate control; Infiltration; Thermal	Highly restricted to sites with small drainage areas and proper soils; Depth to water table and bedrock; Slopes	High	Potential for groundwater contamination; Restricted use for areas with high pollution potential	Recommended with careful soils evaluation and pretreatment	131	Approx. $30/ yd^3
Mulching	Soil erosion	Widely applicable on low to moderate slopes	Moderate	Limited effectiveness on steep slopes	Must be reapplied/replaced frequently and crimped	82 128 132	$200/acre
Native plants	Infiltration; Rate control	Widely applicable	Low	None	Careful selection of native species; Requires a cover crop during establishment	81 82 132	$300/ acre
Pervious pavement	Infiltration; Thermal; Rate Control	Applicable on areas with very low traffic volumes	Moderate	Potential for groundwater contamination	Limited use in cold climates; Durability; Potential to clog	43, 44 75, 134	Approx. $5/ ft^2
Pervious paving blocks	Infiltration; Thermal; Rate Control	Infiltration; Thermal; Rate Control	Applicable on areas with low pedestrian traffic volumes	Moderate	Susceptible to clogging	44, 59 74, 82 134	$10-12/ ft^2
Rain gardens	Total suspended solids goal; Rate control; Infiltration	Applicable on sites with drainage areas <2 acres	Low	Susceptible to clogging	Sufficient/suitable land areas and soil	43, 74 81, 82 135	$11.00-13.00/ ft^2

Subsurface drain	Thermal; Rate control	Widely applicable	Low	Provides limited sediment and pollutant removal	Must have stable outlet	74, 137 141	$1.15/lin. ft
Tree planting	Thermal	Widely applicable (excluding berms and streambanks)	Low	Canopy may shade out ground level vegetation	Careful selection of native species; Size; Proper spacing	141	$150-300/ tree

Water quality							
Detention basin	Total suspended solids; Rate control	Widely applicable	Low	Possible downstream warming; low bacteria removal; May attract undesirable wildlife	Sufficient/ suitable land area; Design considerations; Sediment forebay	6 74	Cost varies greatly
Green roofs	Rate control; Suspended solids goal	Applicable on buildings with high structural integrity	High	Extreme sun and wind make plant survival difficult	Cost; Building integrity; Water leakage	43 130	$15-35/ yd^2
Oil and grease filter	Oil and grease removal, 1st ½ inch of runoff	Applicable on small impervious areas (w/ <1 acre drainage)	Moderate to High	Limited pollutant removal	Cost	133	$100-300
Oil and grease separator	Oil and grease removal	Applicable on small impervious areas (w/ <1 acre drainage)	Moderate to High	Limited pollutant removal, dos not remove soluble pollutants	Cost	46 133	Cost varies greatly (from $1000 to $20,000)
Parking lot/street sweeping	Total suspended solids goal	Widely applicable	Moderate	Sediment and debris collected may be contaminated with heavy metals	Hi-Vac trucks are more efficient but more costly	76 78 139	Campus: $23-33/hr labor; $1000 for disposal

References

Barr Engineering. (2001). Minnesota Urban Small Sites BMP Manual. Metropolitan Council: Minneapolis, MN.

Dane County. (2002). Dane County Erosion Control and Stormwater Management Manual. Madison, Wisconsin. Retrieved from http://www.co.dane.wi.us/commissions/lakes/stormwatermanual.shtml.

University of Wisconsin–Madison. (2002). Structural Control Inspection Survey: Retention Facilities.

Appendix 15. Kohl Center case study and estimated costs

ITEM	UNIT	NO.	UNIT COST	TOTAL UNIT COST
Site prep	Job	1	$500.00	$500.00
Excavation	Cu. Yds	1450	$4.00	$5800.00
Earth fill* (sand and compost)	Cu. Yds	1075	$12.00	$12,900.00
Sod	Sq. Yds	6430	$2.00	$12,860.00
Additional Equipment				
Commercial Roto-tiller	hr	3	$50.00	$150.00
Chisel plow	hr	2	$110.00	$220.00
Sediment control				
Silt fence	ft	750	$2.00	$1,500.00
Tracking pad	each	1	$300.00	$300.00
Storm drain inlet protection	Each	3	$20.00	$60.00
Additional cost				
30-percent added cost due to site location	job	1		$10,000.00
Basic proposal			Total cost	$44,290.00
Secondary Projects				
Tree planting	Each	?	$450.00	variable; add 20 percent to total cost for delivery/ planting
In-ground irrigation	job	1	$30,000.00	$30,000.00
Earthworms	Acre	0.3	$1050.00	$350.00

NOTES:

*Cost of earth fill includes transportation costs. The estimated costs are derived by the Dane County Land Conservation Department as averages from engineering practices completed in 2002.

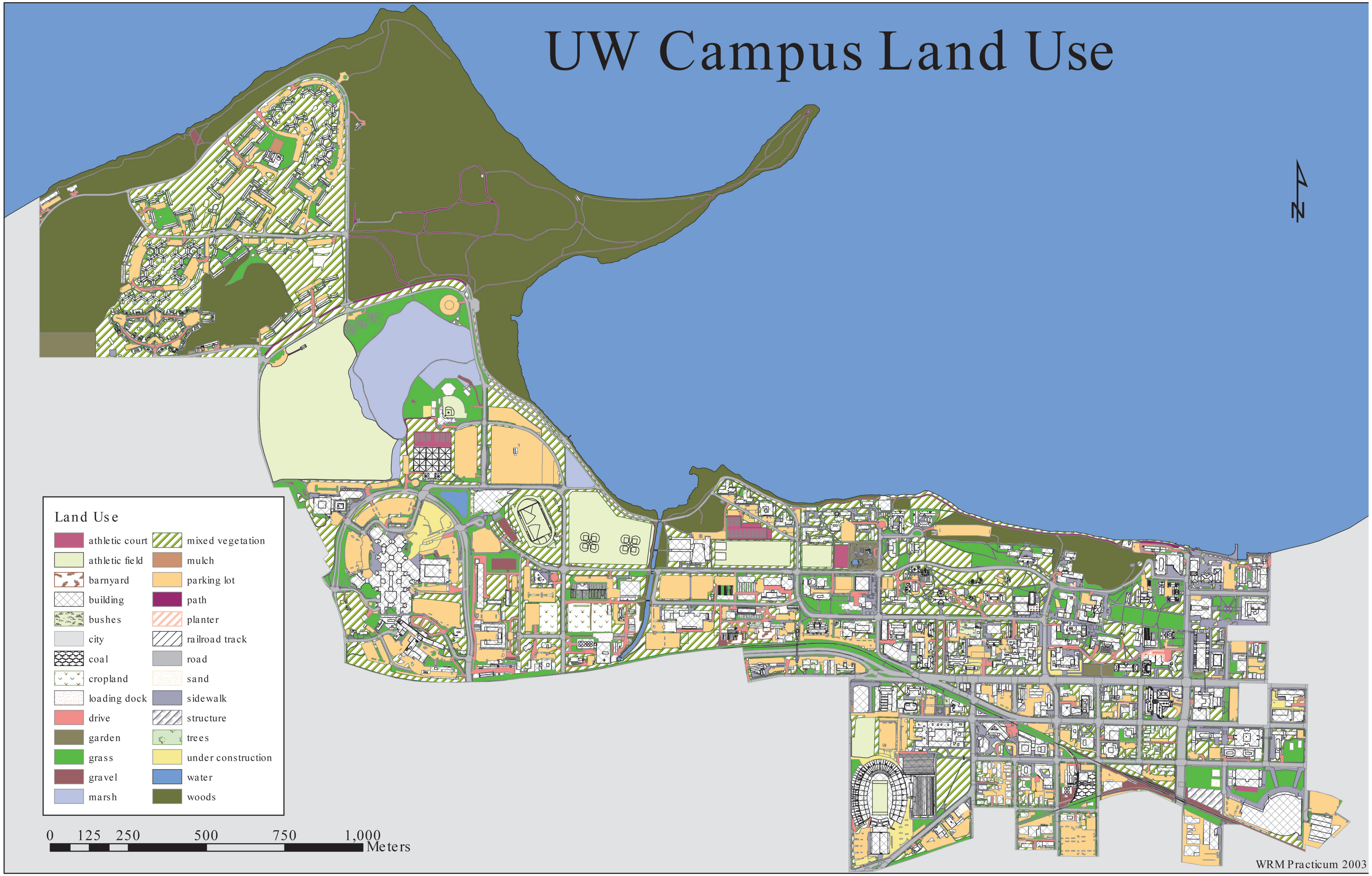

Plate 2.1. Land-use map of campus. The land-use data were verified in the field by the WRM Practicum students. These data are used in the runoff and pollution modeling.

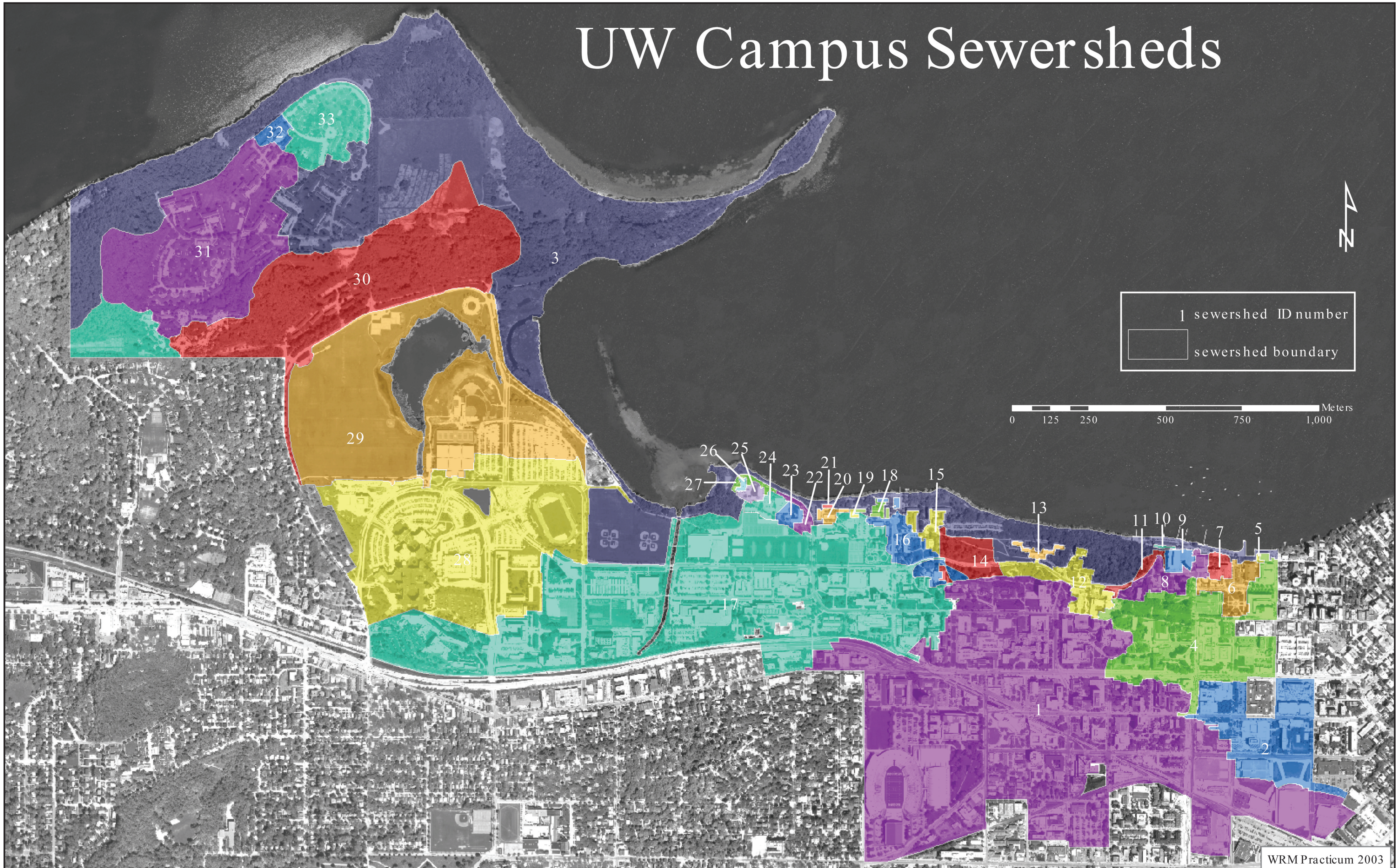

Plate 2.2. Map of UW–Madison campus sewersheds. The sewersheds were delineated based on outfalls to either of the lakes. Sewersheds 1 and 2 drain to Lake Monona, the remaining sewersheds drain to Lake Mendota.

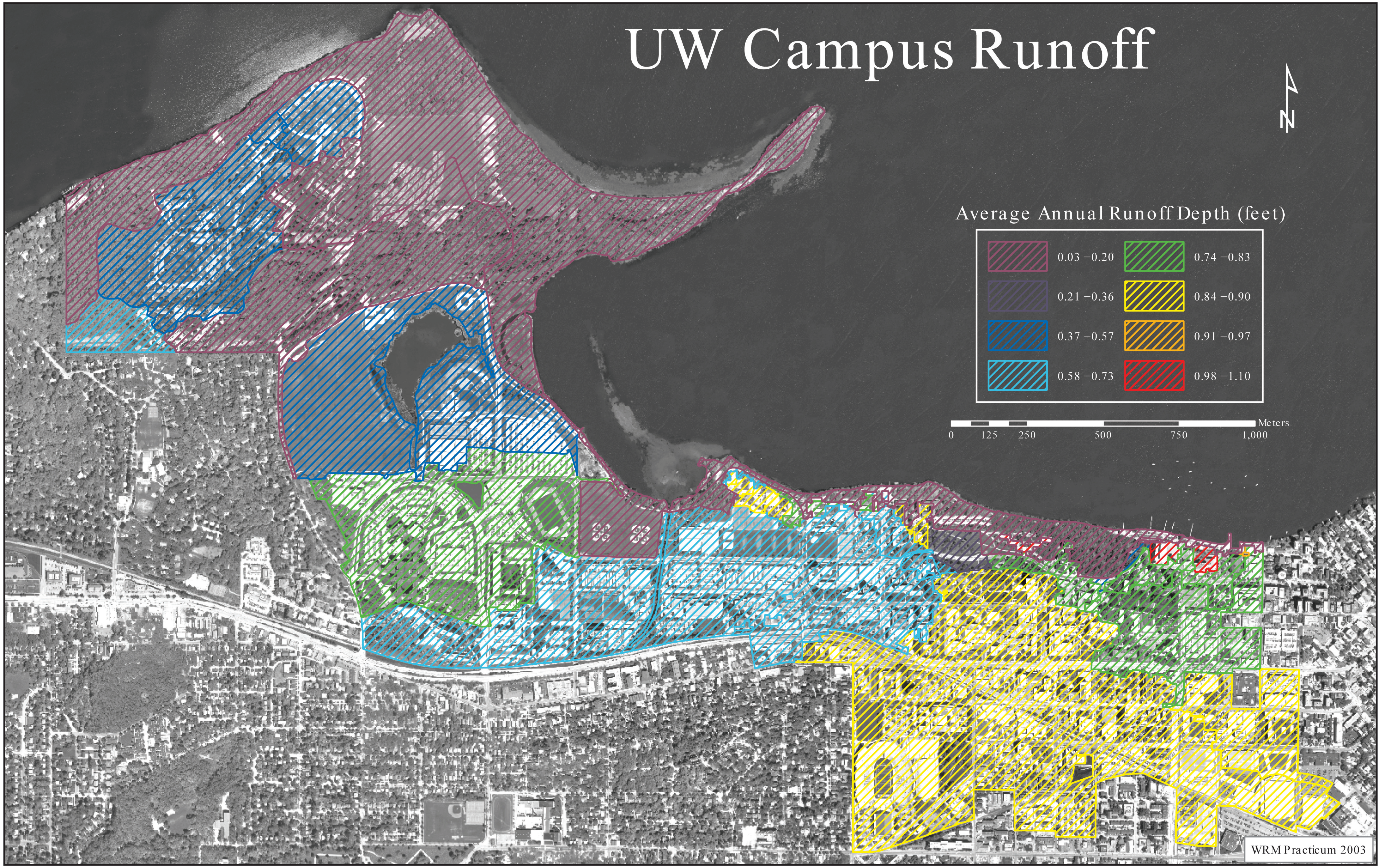

Plate 2.3. Map of runoff variability across campus. The eastern part of the campus generates much higher runoff depths than the western part due to differences in land use composition.