5.4 Site-Based Green Infrastructure Practices

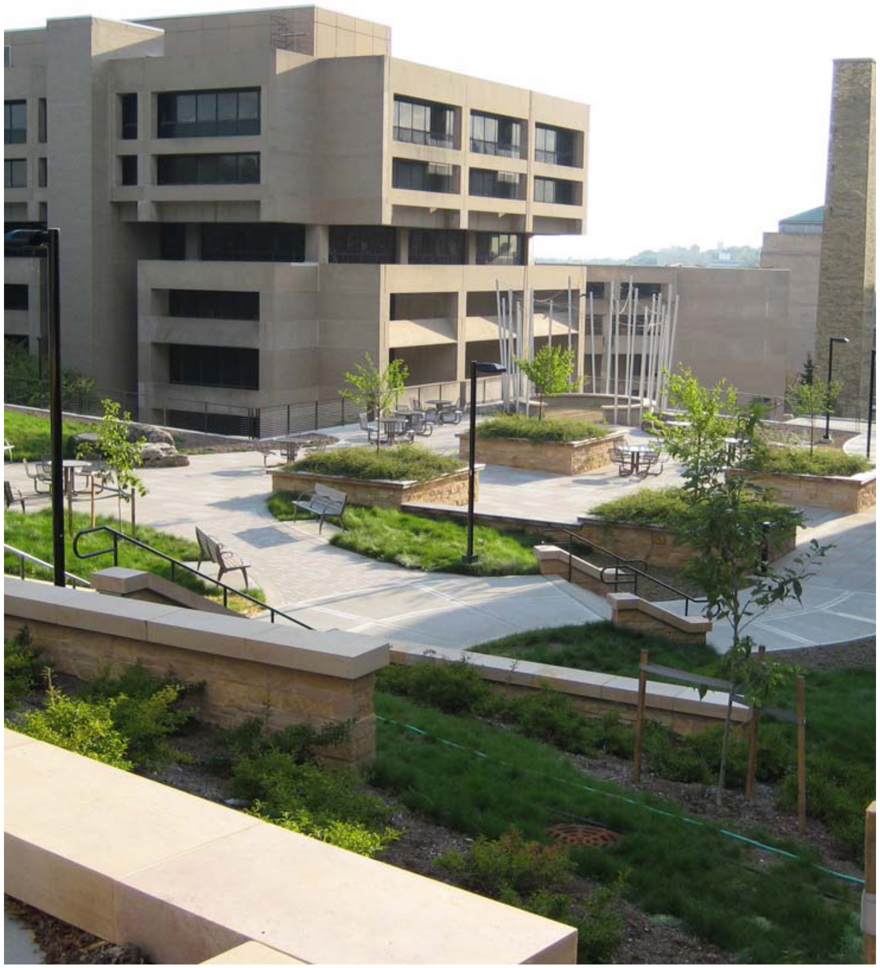

Figure 5-26 Education Building First Floor Green Roof (Over Parking)

This section summarizes recommendations for site-based green infrastructure BMPs where larger-scale practices are not feasible.

The following green infrastructure practice opportunities are discussed in general and examples are provided. As new building or site projects are planned on campus, it is intended that the design team evaluate which practices are feasible and practical for the project site, and which practices achieve the desired metrics that are being targeted.

Figure 5-1 shows some of key site-based practices that have been identified as opportunities however this figure does not represent all practices that will be needed to be installed as development projects move forward.

Land Use Modification

In general, as sites get redeveloped on campus, design teams are expected to look at ways to address the campus green infrastructure goals and meet regulatory requirements. One way to lessen the impact of a site from a stormwater management standpoint is to modify the land use, where feasible. Rooftops and sidewalks are preferable to parking lots and roads because they produce less pollutants in the runoff. However pervious surfaces are preferable from a stormwater management standpoint because runoff volume is reduced through infiltration and evapotranspiration. Since pervious surfaces such as planter beds or lawns aren't always achievable on tight building sites, the impacts of impervious surfaces can be lessened by incorporating permeable pavements and green roofs. The vegetated rooftop that was built over the surface parking lot behind the Education Building is a great example of a previous land use modification on campus. In addition to improving the volume, rate, and quality of the stormwater runoff from this site, the roof provides outdoor gathering space and better views for occupants of the building.

Water Reuse and Harvesting

Southern Wisconsin has historically not had a strong market for harvesting and reuse of rain water because municipal water is relatively inexpensive and abundant compared with other parts of the country, providing little incentive for building owners and developers to install harvesting systems. In addition, plumbing codes in Wisconsin are typically not favorable towards the beneficial reuse of rain water within buildings, even for non-potable uses (landscape irrigation is typically allowed).

However there is a movement in the green building industry for owners to collect and reuse rain water for irrigation and gray water systems within the building (i.e. toilet flushing, cooling towers, etc). So-called Living Buildings go beyond LEED and require a more holistic approach to water usage.

Certainly from an educational and interpretive standpoint there is great value in water reuse and harvesting, and some cost savings could be realized over the life of a building. However the costs associated with designing, installing and operating rain water capture systems (typically above-ground or buried cisterns) and the associated infrastructure for distribution typically makes them cost prohibitive. Given budget constraints on most campus projects, these types of systems often get eliminated early on during the design process. Still, as buildings become progressively more sustainable, water needs to be part of the larger picture, and the market may become more favorable as cisterns become more mainstream (they already are in parts of the country where water is a scarce commodity).

Figure 5-27 Cisterns at Chesapeake Bay Foundation, Virginia Beach, Virginia

Figure 5-28 Rain Water Harvesting System, Brock Center, Virginia Beach, Virginia

Figure 5-29 Green Street, Normal, Illinois

Figure 5-30 Green Street, West Union, Iowa

Green Streets

Some of the highest concentrations of polluted runoff in urban areas comes from streets and the UW–Madison campus is no exception. As surface parking areas are replaced with structured parking, the primary source of sediment loading from campus will be streets, roads, and driveways. Green Streets can be an effective approach to managing runoff from high-pollutant load areas while offering aesthetic and educational value. Essentially BMPs are integrated into the streetscape whether they be rain garden planters, permeable pavements, or suspended pavement root enhancement systems (like Silva Cells) which allow urban street trees to grow to their full potential and provide stormwater detention and treatment as well.

There are a few issues that need to be considered when designing Green Streets, however. Salts from road de-icing (especially chlorides) can potentially lead to groundwater contamination if infiltrated. The City of Madison has avoided infiltrating runoff from streets where road de-icers containing sodium chlorides are applied. On campus, this would entail almost all streets. One solution to this is to utilize planters with salt-tolerant plant species and under-drains and liners that prevent the runoff from infiltrating into the groundwater. The plant roots absorb some of the stormwater through evapotranspiration and the soil medium helps filter the remaining runoff (TSS and metals), before it is discharged back to the storm sewer system (and ultimately the lakes). However it is important to note that dissolved chlorides have been shown to remain in the runoff even after flowing through a biofiltration practice.

Another issue to be addressed in design is accommodating pedestrian movements through Green Street spaces. Green street planters are typically suppressed below adjacent grades, making them potential trip hazards in areas where there is heavy pedestrian usage. Design details should be developed to strategically locate steps and curbs so they are visible and do not act as hazards.

Green Streets proposed for the master plan include Observatory Drive, N. Charter Street, N. Mills Street, W. Dayton Street, and Linden Avenue. Figure 5-31 shows the proposed extents. All but Linden Ave are City of Madison streets so these streetscape improvements would need to be designed in coordination with the city and implemented in accordance with their street reconstruction schedules. To date, conversations with the city have indicated that they are amenable to Green Streets as long as they are addressed to meet the concerns regarding infiltration of chlorides and other street construction standards.

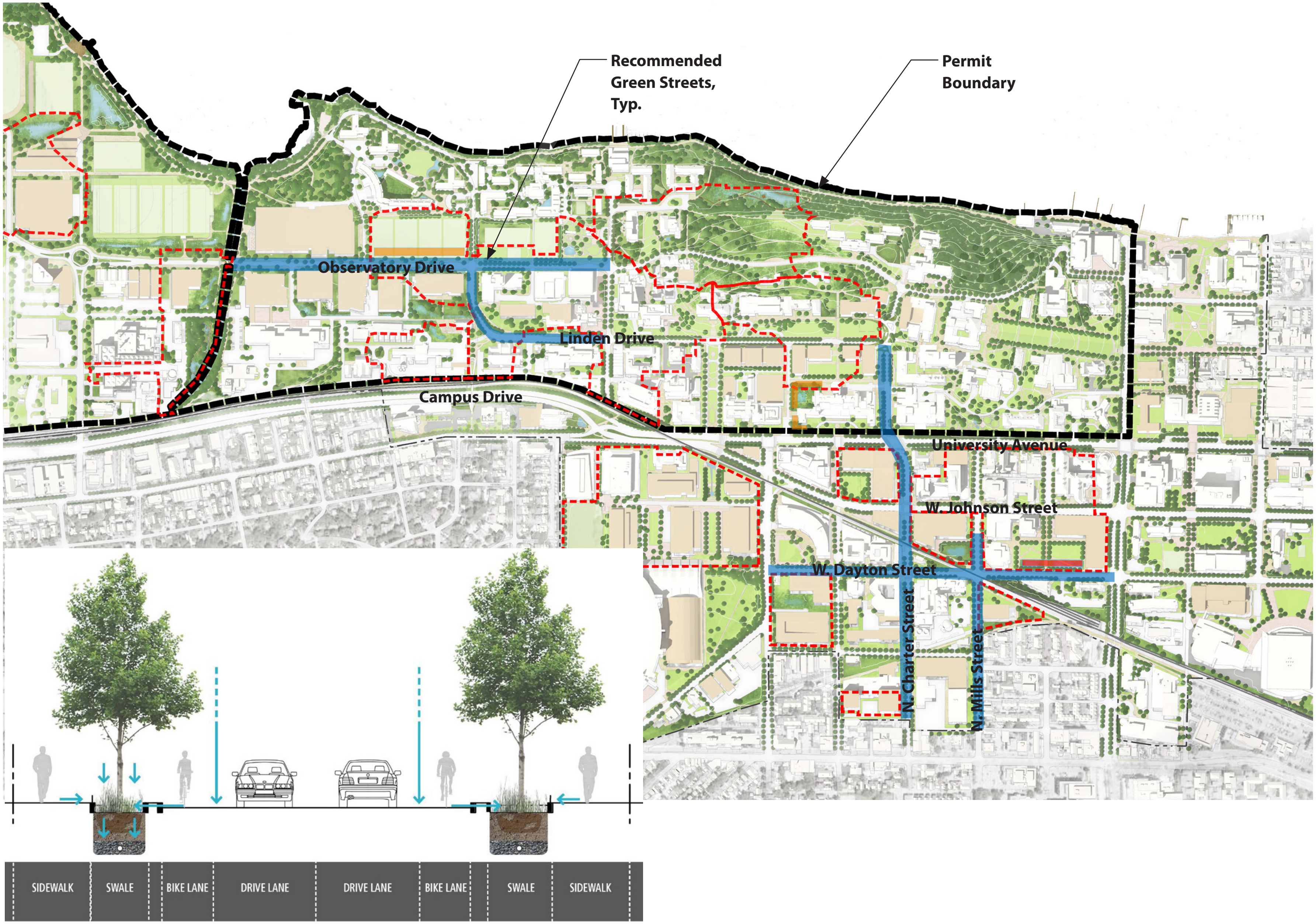

Figure 5-31 Recommended Green Street Locations & Example Green Street Cross Section

Figure 5-32 Permeable Paver Patio, Carson Gulley Commons

Figure 5-33 Permeable Asphalt, Evanston, IL

Figure 5-34 Permeable Concrete, Evanston, IL

Permeable Pavement

There are a number of different permeable pavement applications on campus, and many have been installed within recent years. Most permeable pavement used on campus has been permeable pavers used in plaza areas such as around residence halls. Permeable concrete has been installed in a few locations such as bike parking and in Lot 92. Some permeable pavements have had less success. Permeable asphalt in Lot 34 for example was removed after it failed to perform.

Where there is low risk of failure (such as in non-traffic areas), it is recommended that UW–Madison investigate different types of pervious pavement to become more familiar with the costs and performance. Permeable pavement technology has advanced significantly since the first pervious asphalt was installed on campus, and permeable pavers come in many different forms now.

Surface parking lots and driveways, especially the parking stalls, should be considered for permeable pavement installations. UW–Madison typically has preferred to not use pervious pavements where there is vehicular traffic or where there are heavy sediment loadings due to maintenance and durability concerns. Permeable pavement is generally not recommended for loading docks or other areas experiencing point loads and excessively heavy vehicles, such as fire lanes.

Pervious pavements help achieve several stormwater management goals including a reduction in impervious surfaces, and TSS removal. When designed in accordance with WDNR Technical Standard 1008, permeable pavement with an underdrain can receive a TSS removal credit of 65% and a TP removal credit of 35%.

Snow removal can be more challenging when permeable pavers are used (as with any unit paver) however overall permeable pavement has been shown to cause less icing in the winter compared with normal pavement as snow melt infiltrates rather than ponds.

Maintenance recommendations for permeable pavements are described later in this chapter but in general require more maintenance than typical pavements. Installation costs are also higher.

Green Roofs

Green roofs have been implemented on a variety of different building projects on campus including extensive (shallow) and intensive (deeper) systems. In keeping with Division of Facilities Development (DFD) policy, most green roofs on campus have been installed on accessible or visible roof areas (roofs that can be seen by other floors of that building or adjacent buildings). This policy recognizes that resources are often limited and the investment of a green roof is best made where the most benefits can be gained; not only stormwater management and heating/cooling benefits to the building but also visual green for building occupants or usable open space. Examples include green roofs at WIMR and the Education Building.

Green roofs can play a specific role when it comes to stormwater management. The DNR's stance on green roofs is that green roofs play a neutral role in management of TSS: green roofs can leach as much sediment and phosphorus from plant matter as than they help capture. However there is much evidence that shows that green roofs reduce runoff volumes over an average year of rainfall because the plant medium takes up small rainfall events. The majority of rainfall in Madison comes in small rainfall events, so the overall volume of runoff from campus would be reduced if the number of green roofs were significant enough.

While there are a dozen or so green roofs on campus currently, the impact of these is likely negligible relative to the amount of impervious area on campus. Volume reduction is important, however, for addressing issues such as increased flooding in the Yahara Lakes, so every little bit counts.

Whenever feasible, intensive rather than extensive green roof systems should be considered as they provide the most storage and volume reduction, as they allow for deeper rooted plants. They also have more soil medium to hold runoff and become saturated less frequently. A saturated green roof acts just like a regular roof as the holding capacity goes down to zero. Therefore for large storm events green roofs do not contribute to a significant reduction to peak flow rates.

In conclusion, green roofs should be considered and evaluated on all new building projects on campus, especially where there are visible or accessible portions of the roof which could double as visual or programmable open space. Intensive green roofs can be counted as "pervious surface" and may reduce the campus' share of city stormwater utility fees. However green roofs don't provide any reduction credits towards the TMDL or permit goals.

Green roofs typically cost more than standard roofs and require more maintenance.

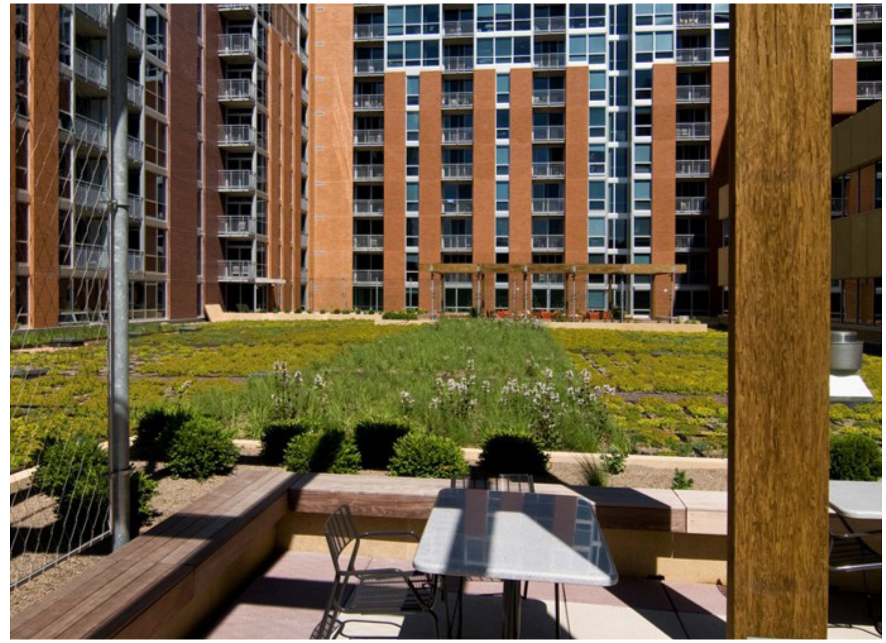

Figure 5-35 Green Roof, University Square

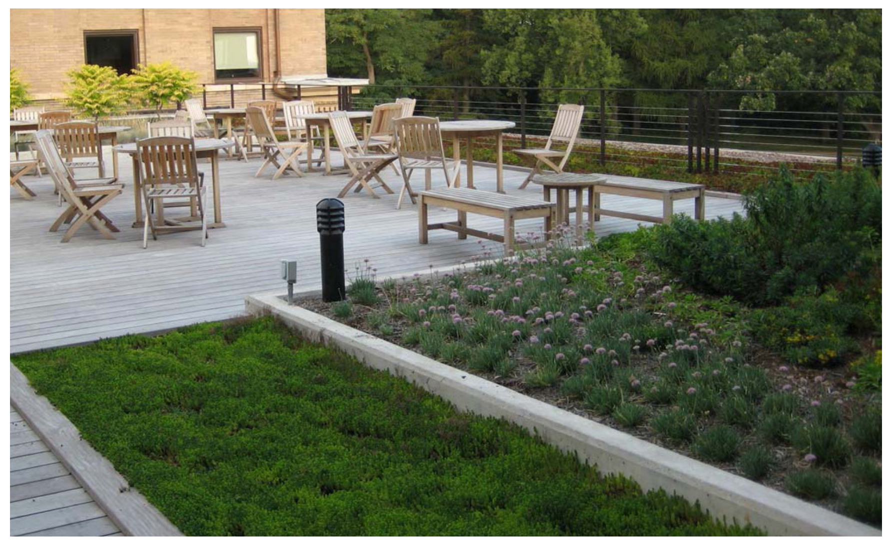

Figure 5-36 Third Floor Green Roof, Education Building

Infiltration and Biofiltration

Infiltration and biofiltration practices are among the most prevalent types of BMPs on campus. Infiltration practices include depressed planters or swales which are designed to collect runoff and promote groundwater recharge and evapotranspiration through deep-rooted plants and engineered soil. Biofiltration practices are similar but may restrict infiltration and collect treated runoff at the bottom of the practice in an underdrain which is connected to the storm sewer system. Infiltration practices provide volume reduction as well as treatment of TSS and other pollutants, and peak flow reduction. Biofiltration practices provide a more limited volume reduction because much of the runoff is still collected and conveyed downstream.

Infiltration and biofiltration practices can be designed as traditional rain gardens with side slopes, or they can be incorporated into more urban and hard-edged planters. Planters allow for a larger footprint of treatment and may fit better into tight sites, such as between bike racks or in narrow beds where slopes aren't feasible. However they are more expensive to construct and may be more difficult to maintain. UW–Madison has installed several of these urban planter-style BMPs on campus and this is likely the form that most new BMPs on campus will take in the future due to other demands for open space.

In some areas of campus (such as West Campus) infiltration is limited due to poor infiltrating or hydric soils and high groundwater tables. In addition, infiltration practices may be restricted in wellhead protection areas.

Figure 5-37 Biofiltration Planter, University of Michigan, Ann Arbor, Michigan

Figure 5-38 Infiltration Planter Between Bike Racks, Wis. Institute for Medical Research

Bioswales and Vegetated Swales

Bioswales and vegetated swales are a form of green conveyance which also provide filtration and evapotranspiration of runoff. They can be very effective at removing TSS and other pollutants from street runoff. A bioswale is constructed with engineered soil and an underdrain system much like a biofiltration area, An example of a bioswale on campus is along University Bay Drive, which significantly reduces the TSS load from that area.

Bioswales and vegetated swales are most effective where there is ample green space along a parking lot or road . Most of campus has curb and gutter and hardscape adjacent to the street (sidewalks or small terraces) so there are limited opportunities but since bioswales and vegetated swales are a relatively inexpensive and effective BMP, they should be used whenever feasible to keep stormwater above grade rather than in a pipe.

Figure 5-39 Bioswale, University Bay Drive

Figure 5-40 Biofiltration Area, Lot 61

Figure 5-41 Co-Gen Ponds

Figure 5-42 Nielsen Pond

Wet Detention Basins

Wet detention basins like Nielsen Pond represent more traditional methods of treating stormwater. They are highly effective at treating TSS from large tributary areas. Nielsen Pond provides a significant amount of TSS reduction from the UW Hospital and surrounding area.

However there is limited potential for additional wet detention basins on campus due to their space requirements. Smaller footprint BMPs that treat pollutants at the source rather than the end of pipe better represent the green infrastructure approach that this plan recommends.

Some members of the campus community have expressed concern over mosquitos breeding in detention ponds. Research has shown that well maintained detention ponds do not contribute significantly to mosquito breeding grounds, and no evidence has been shown on campus that mosquitos preferentially breed in the detention ponds over other bodies of water such as nearby Lake Mendota. They typically prefer stagnant water and shady spots so these conditions should be avoided in the design of wet detention basins.

Constructed Wetlands

Constructed wetlands utilize natural ecosystem processes to treat stormwater and provide additional benefits such as habitat and wildlife viewing. The western area of campus features a number of natural and constructed wetlands that provide a great amenity to the university setting. Constructed wetlands are designed to filter and take-up pollutants in runoff, dampen peak flows, and reduce volume through evapotranspiration and infiltration.

Constructed wetlands are recommended as larger multi-site practices at two campus locations in particular: Observatory Hill (former Lot 34) and along Willow Creek. In both cases we recommend the creation of boardwalks and viewing areas for respite from daily activity, passive recreation, connection to nature, and as a living laboratory. Students and faculty could take advantage of the proposed wetlands for educational and curriculum opportunities. Interpretive signage is recommended for informing and educating visitors such as school children as well.

Figure 5-43 Wetlands at Sears Headquarters, Hoffman Estates, Illinois

Figure 5-44 Constructed Wetlands at Milliken State Park, Detroit, Michigan

Figure 5-45 StormTrap Underground Detention Chamber, Lot 45

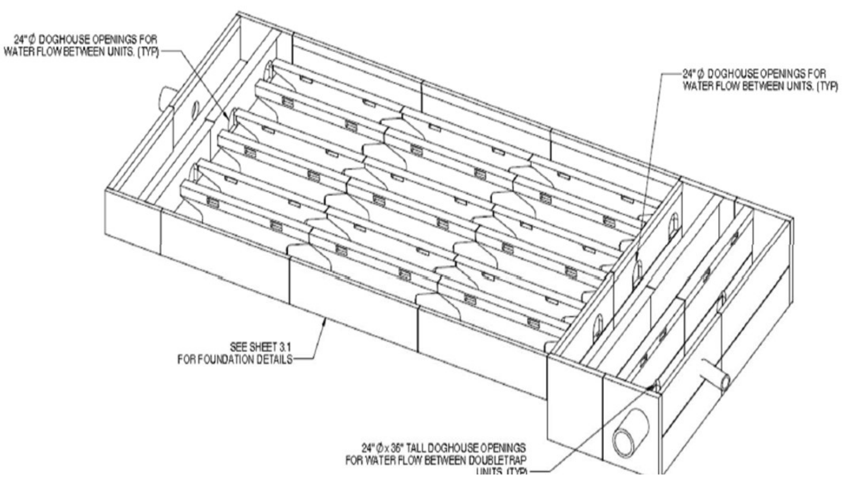

Figure 5-46 Sample Isometric Shop Drawing of a StormTrap Chamber

Underground Detention

In many areas on campus development density and demands on land space are extremely high and stormwater management features are not easily accommodated on the site. In addition, existing stormwater systems on campus which may drain fairly large areas are too deep to daylight for at-grade treatment. In these cases, underground detention and treatment chambers are an alternative to at-grade BMPs such as ponds or rain gardens.

Underground detention chambers act much like a detention pond as they are designed to hold and slowly release peak runoff volumes. This helps with peak discharge rates but can also be designed to settle out suspended solids and other particulates in sumps or baffled areas. On campus most underground detention chambers would be designed for TSS removal and would therefore be designed with wet or dry sumps (WDNR requires a 3-ft wet sump for TSS removal credit). Sizing of the underground chamber would be based on diverting a portion of the runoff from a site or pipe, typically the first flush which holds most suspended sediments.

There are downsides to using detention chambers below ground. One, they are one of the most expensive BMP options available. Two, there are typically no visible components of the underground detention and therefore the education value is limited. Three, they typically do not incorporate any ecosystem services or habitat opportunities as they are often concrete or polyethylene tanks. Four, maintaining underground tanks can be challenging and expensive, especially if they are not properly designed (it could involve trained confined-space entry workers and/or purchasing specialized equipment).

The primary benefits include the ability to use the land above them for things like parking, recreation fields, plazas, etc. They can also be incorporated into parking structures (but maintaining access to them for cleaning out sediment is critical). They can also be used in areas where deep pipes need to be intercepted and it is too difficult or infeasible to daylight the pipes for treatment purposes.

Recommended locations for the use of underground chambers (especially for multi-site practices) are under the Near West Recreation Fields, on the Superblock, and in the South Campus Quad. In each of these locations, large drainage areas drain to one particular storm sewer which could be intercepted to provide district-wide sediment treatment.

Sumps and Hydrodynamic Devices

Hydrodynamic devices or separators are stormwater management practices that use cyclonic or vortex separation to control TSS and other pollutants in runoff. They are designed as flow-through structures with a settling or separation unit and often integrate screens or baffles. Hydrodynamic devices are considered structural best management practices and are often proprietary (sold and patented by private companies).

These devices come in different configurations but often function in similar ways. However, from a TSS modeling standpoint, a large manhole with a sump provides the same results for soils in Southern Wisconsin. Therefore the additional cost for the proprietary device is not warranted and the results sometimes are not as good as the manufacturer's claims for fine-sediment soils such as those on most of the UW–Madison campus.

Many proprietary devices require maintenance techniques that can be difficult for maintenance personnel to implement on campus. Another downside with these units is that they don't easily offer educational opportunities or raise awareness of green infrastructure on campus since they are not visible to the public.

There are a number of these units installed and in use on campus currently, as shown on the figures in Chapter 2. Due to their costs and maintenance requirements, UW–Madison prefers the use of standard catch basin or inlets with sumps to capture TSS from paved areas where other BMPs are not feasible. WDNR requires a minimum 3-ft sump depth to provide credit for TSS removal.

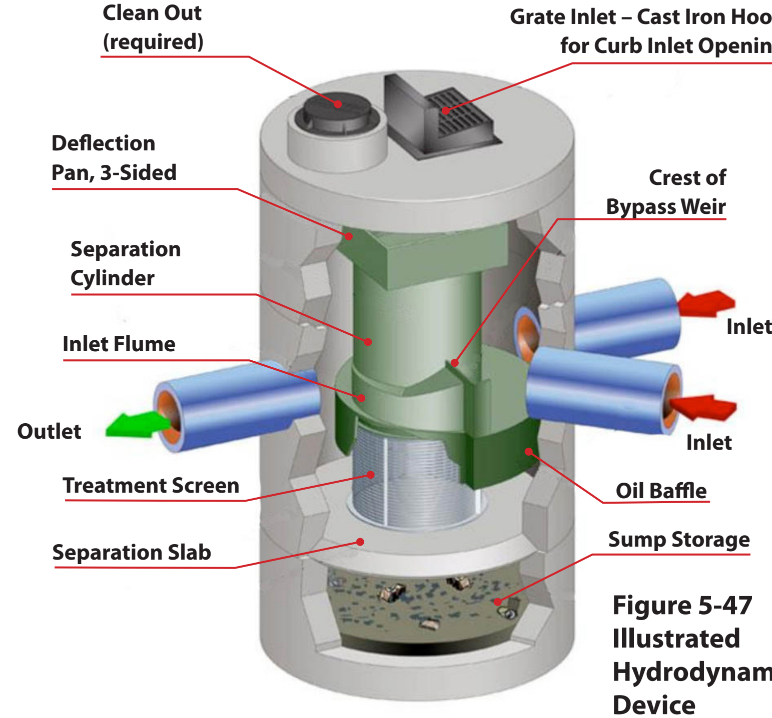

Figure 5-47 Illustrated Hydrodynamic Device

Figure 5-48 Installation of a Hydrodynamic Device, Butte, Montana

Figure 5-48 Asphalt Swale near Tripp Hall

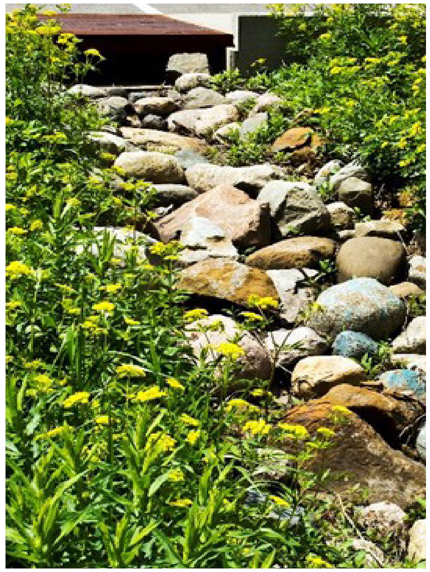

Figure 5-49 Stone Conveyance Channel

Alternative Conveyance Methods

Keeping stormwater at grade rather than in a pipe does several things: it slows down the runoff and lengthens the flow path (lengthening the time of concentration); increases the opportunity for infiltration or evapotranspiration; allows for the use of more shallow BMPs; and provides more awareness of the movement and treatment of stormwater. Conveyance methods promoted in green infrastructure practice includes stone lined or vegetated swales or channels, trench drains and flumes (with grates or plates for pedestrian or vehicle access), runnels, and other surface features. These can also be an opportunity for artful expression.

Figure 5-50 Stormwater Flume to Rain Garden with a Sidewalk Plate

Figure 5-51 Concrete Spillway

Figure 5-52 Modular Concrete Flume for Walks

Subgrade Storage and Urban Tree Canopy

Root enhancement zones or suspended pavement systems such as Silva Cell by DeepRoot allow trees to be planted in pavement areas such as in plazas and urban streetscapes without starving the trees of the soil capacity they need to thrive. The units are modular shelf-like structural units that transfer surface loads down to a compacted subbase below the root zone. Filled in the interstitial space is a planting mix that is high in sand and nutrient-rich soil for healthy growing trees.

Stormwater runoff can be directed to these systems below ground for filtration, infiltration, evapotranspiration, and detention. Directing stormwater to the root enhancement zone benefits the trees and reduces the need for supplemental irrigation.

The enhanced system results in trees that grow larger, faster and healthier than they would if planted in a typical structural soil or in a small planter with a traditional tree grate. Many studies have shown that urban trees contribute a significant amount to stormwater capture and volume reduction. The larger and healthier the tree, the more this benefit is achieved.

Suspended pavement systems have been installed with several projects on campus including Camp Randall North Lawn and on the Memorial Union Terrace.

Even where trees are not present, stormwater can be directed below grade to clear stone base layers below permeable pavement or recreational fields for added detention, infiltration and filtration.

Figure 5-53 Installation of Silva Cell Root Enhancement Zone

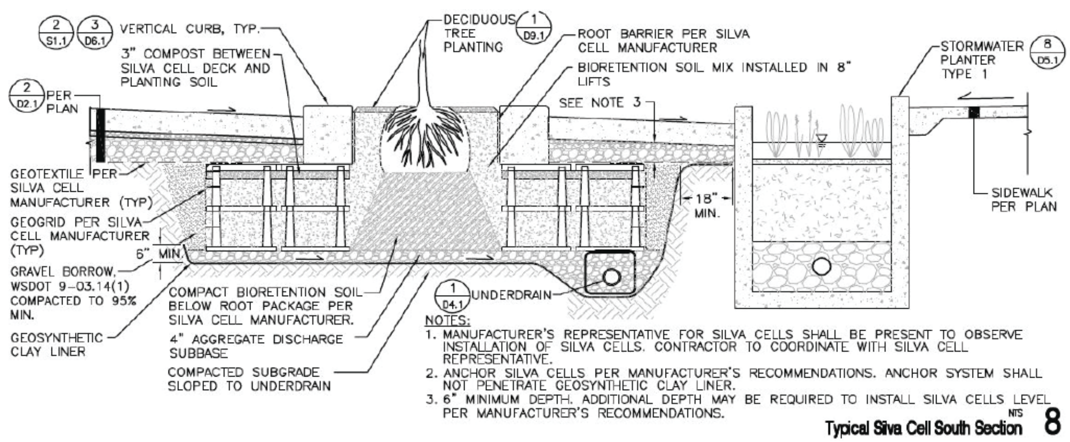

Figure 5-54 Details for a Suspended Pavement Silva Cell System with Stormwater Planters

BMP Matrix

To summarize the purpose and appropriate uses for certain BMPs a matrix of BMPs that are appropriate for urban settings such as UW–Madison's campus has been prepared (Table 5-4). The matrix is intended to summarize the primary and secondary stormwater management objectives for each BMP and their relative construction costs (low, moderate, high) as compared with their effectiveness. The matrix is intended to be a summary outlining the factors to be weighed when choosing site-specific BMPs. It is meant to be a quick reference guide to easily explain the purpose and function of many common urban BMPs.

Urban BMP costs can vary substantially. In Dane County, Yahara WINS (the group piloting Adaptive Management) collected data on urban BMPs that were constructed between 2005 and 2013 and calculated a median average of approximately $735 per lb of TP captured (the measure they are using to evaluate the costs of urban BMPs versus rural practices). The costs for urban BMPs ranged between $100 and over $10,000 per lb of TP.

The matrix in Table 5-4 includes different stormwater management objectives along the top row. The following summarizes in more detail what is meant by each of those objectives:

Runoff Rate Reduction:

These practices detain stormwater in ponds or chambers and slowly release the water through a control structure, pipe or orifice. These practices tend to be designed to treat large infrequent events (such as 10 or 25-year events) and help dampen peak flow rates that could lead to streambank erosion or flood urban storm sewer systems.

Runoff Volume Reduction:

These practices are typically designed to infiltrate or evapotranspirate runoff to reduce the total volume of water leaving a site (not just hold it and release it later). These practices are usually designed for smaller regular rainfall events. The volume reduction is often measured on an average annual basis using typical rainfall data (which consists of mostly small frequent events rather than large storm events). Volume reduction lessens the impact of lake floods, which are getting worse in the Yahara Lakes as the watershed becomes more urbanized according to UW–Madison published studies.

Groundwater Recharge:

These practices involve infiltration and contribute to groundwater recharge using relatively clean runoff (volume reduction is also achieved).

TSS Reduction:

These practices are designed to allow suspended solids to settle out in traps, sumps, engineered soil, or pervious pavement. Many pollutants in urban runoff such as heavy metals, nutrients, and pathogens are also often captured as they attach to sediments.

TP Reduction:

Total phosphorus is typically reduced through the same methods as TSS reduction; however dissolved phosphorus tends to stay in runoff and is harder to remove than TSS so biological processes such as plant uptake help contribute to TP reduction. However some practices have been found to leach phosphorus (such as decaying plant matter on green roofs). WDNR has issued specific guidance about the use of compost in infiltration practices, which can actually increase the amount of TP in runoff. A mostly sand soil profile is currently recommended to limit phosphorus leaching from the engineered soils.

Oil & Grease Control:

These practices use filters or baffles to trap oil and grease, which can be present in runoff from streets, driveways, parking lots, loading dock areas and fueling areas. Since these pollutants float, the baffles are typically trapping the surface water and the outlet draws from the bottom.

Impervious Area Reduction:

These practices, when incorporated to a project site, may reduce the overall impervious area that is included when calculating stormwater management metrics such as TSS loading or runoff quantity. Examples include pervious pavement and intensive green roofs, which can typically be counted as permeable areas in runoff calculations. Extensive green roofs, however, are not considered by WDNR as counting towards pervious surfaces because they have a very limited holding capacity and act similarly to regular roofs when saturated.

Table 5-4 Matrix of Urban Best Management Practices

Urban Best Management Practice (BMP)	Relative Cost	Stormwater Management Objective						
		Quantity			Quality			
		Runoff Rate Reduction(A)	Runoff Volume Reduction(B)	Groundwater Recharge	TSS (C) Reduction	TP (D) Reduction	Oil & Grease Removal	Impervious Area Reduction (E)
Architectural strategies								
Cistern, rain barrels (greywater use)	$$	X	1	X	X	X	X	X
Flow-through planter	$$	X	1	X	X	X	X	X
Green Roof (extensive)	$$	X	1	X	X	X	X	2
Green Roof (intensive)	$$$	X	1	X	X	X	X	1
Site strategies – non-vegetated								
Catch basin & inlet filters	$	X	X	X	1	2	1	X
Catch basin & inlet sumps	$	X	X	X	1	2	X	X
Infiltration Trench	$	1	1	1	X	X	2	X
Infiltration Basin	$$	1	1	1	1	1	2	X
Oil & grease trap	$$	X	X	X	2	2	1	X
Open graded base under parking or rec fields	$	2	1	1	2	2	2	X
Pervious/Permeable Pavement	$$	2	1	1	2	2	2	1
Proprietary sedimentation device	$$$	X	X	X	1	2	2	X
Underground vault with wet sump, closed bottom	$$$	1	X	X	1	1	2	X
Underground vault with infiltration	$$$	1	1	1	2	2	2	X
Site strategies – vegetated								
Bioswale (or vegetated swale)	$	2	2	2	1	1	2	X
Rain Garden (bioinfiltration)	$	1	1	1	1	1	2	X
Tree canopy	$	X	1	X	X	X	X	X
Wet detention pond	$$	1	X	X	1	1	1	X
Maintenance practices								
Street sweeping	$$	X	X	X	1	2	2	X

Legend:

1	Primary purpose of BMP, most effective at objective
2	Secondary purpose of BMP, less effective
X	Not effective for intended purpose
$	Relatively low cost
$$	Moderate cost
$$$	Relatively high cost

Notes:

A – Runoff rate reduction typically addressing larger storm events (greater than 2 yr)
B – Volume reduction looking at annual average (i.e. smaller, more frequent rainfall events)
C – TSS is total suspended solids
D – TP is total phosphorus
E – Strategy may reduce the total development impervious area, lowering requirements for treatment