Retrofitting a Major Retail Mall for Stormwater Volume Reduction

Completed tree trench in Northwest tree grove (Spring 2012).

Numerous cities and metropolitan areas in the US are faced with the challenge of trying to meet pollutant reduction goals for Impaired Waters in fully developed urban areas. Stormwater projects in urban areas are limited by extensive infrastructure, established land uses and little to no vacant land to use for conventional stormwater projects. This requires the often expensive and disruptive prospect of retrofitting urban areas to meet our water quality goals.

The Ramsey-Washington Metro Watershed District (District) is a 56-square mile watershed on the east side of the Twin Cities Metropolitan area in Minnesota. The District includes part or all of 10 cities including the City of St. Paul. The District has 11 lakes-2 of which are impaired by excess nutrients (phosphorus). The District is an urban and suburban watershed (95% developed), 40% of which is comprised of impervious streets, highways, parking lots and driveways. The District has completed numerous water quality improvement projects within its boundaries since 1975. Although our past projects have been largely successful in removing particulate phosphorus from the runoff to our lakes, small particulate and dissolved phosphorus are a continuing problem that degrade our lakes' water quality.

Above: Tree trench with side wall filter fabric (also gets wrapped over the top of the trench), first course of rock, and perforated pipe. Below: Top layer of rock with soil being washed into rock.

Project Need

Kohlman Lake is at the upstream end of the four lakes in the Phalen Chain of Lakes- a significant recreational amenity in Twin Cities Metropolitan Area. The Kohlman Lake TMDL (Total Maximum Daily Load) report, finalized in 2007, calls for the reduction of phosphorus from both its watershed and the sediment in the lake bottom. In monitoring and modeling Kohlman Lake's watershed, the District has identified runoff from impervious surfaces to be the major watershed source of phosphorus - more than 70% of the phosphorus loading from the lake's watershed comes from the 40% of the land area that is highways, streets, parking lots, and driveways.

Even before the Kohlman Lake TMDL report, the District had already defined stormwater volume reduction as a District-wide goal. This required that the District implement new rules that required volume reduction on all new construction and redevelopment, including reconstruction of highways and streets. However, we found that this alone would not meet our phosphorus reduction goals for Kohlman Lake within our 20-year time frame. We still needed to look at retrofitting our watershed's impervious areas wherever possible with rain gardens, infiltration basins and other feasible best management practices (BMPs). In our evaluation of the Kohlman Lake watershed, one particularly impervious feature stands out - Maplewood Mall. The 70-acre Maplewood Mall site is located one mile east of Kohlman Lake. Its parking lot covers approximately half of the total site and is 97% impervious. The District determined that retrofitting the Mall parking lot to intercept, filter and/or infiltrate the first inch of stormwater runoff would result in a large reduction in dissolved and particulate phosphorus to Kohlman Lake.

Process and Goals

In 2008, the District began discussions with Simon Property Group, the owners of Maplewood Mall, to explore their willingness to allow the District to retrofit stormwater BMPs on their property. Simon Property Group was very interested in the District's ideas for their parking lot and was willing to collaborate. We ultimately developed an agreement that allowed the District to install BMPs on the Mall's privately owned property without purchase of property or easements. Obviously, the District was very concerned about getting adequate assurance from Simon Property Group that any installed BMPs would be maintained and protected. The District ultimately provided assurance of continued maintenance of the BMPs and Simon Property Group provided guarantees of protection and replacement if mall building or parking alterations were required.

The project was designed to be constructed in four phases over several years, as project funding was made available through grants and the District's Capital Improvement Program funds. Phase I of the project included installation of large rainwater gardens at each of the five entrances to the Mall parking lot from adjacent roads. This project was completed with District funds in 2009 and 2010. Phases II and III include BMPs in the northeast and northwest quadrants of the Mall. This construction began in July 2011 and was completed in June 2012. Phase IV covers the southern half of the Mall property. Construction began in June 2012 and is expected to be completed by November 2012. The total project cost (including design and construction) will be approximately $6.5 million, of which the District received approximately 60% grant funding from State of Minnesota Clean Water Funds and U.S.

EPA 319 water quality funding. The remainder of the funding is from District's Capital Improvement Funds and a Stormwater Revolving Fund loan.

The goal for all phases of the project is to infiltrate or filter one inch of runoff from the Mall's parking lot. The project is expected to reduce the overall phosphorus load from the site by at least 60% and sediment by at least 90%.

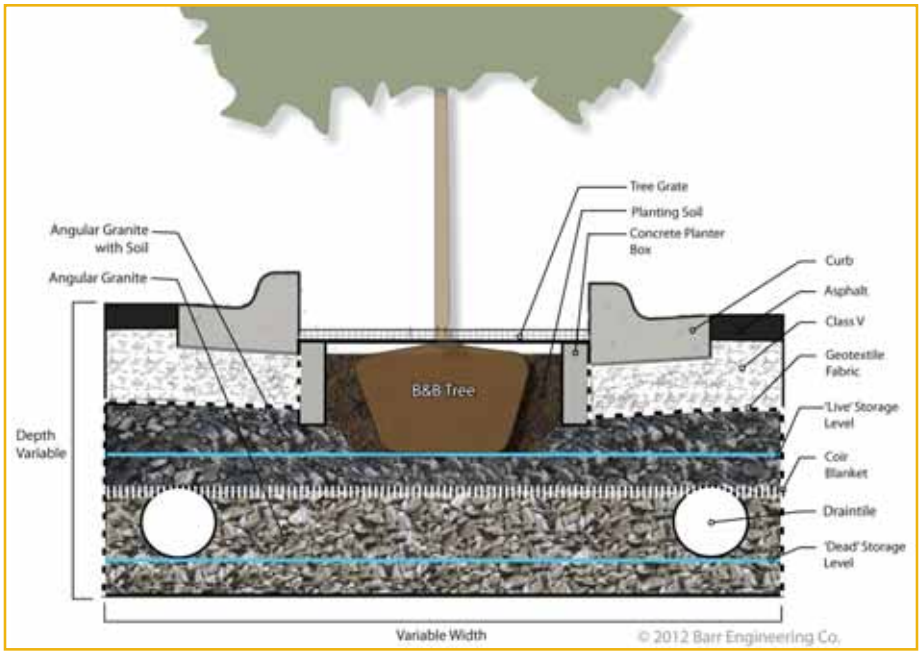
Best Management Practices

In addition to the stormwater treatment goals for the project, one of our design objectives was to use BMPs that were at least partially visible to Mall visitors. Rain gardens were an obvious first choice, as they are visible, cost-effective and provide an aesthetic improvement to the site. A notable feature of the rain gardens implemented at the Mall is the use of sand trenches "enhanced" with iron aggregate (5% by weight) that surround the garden underdrains. The iron has been proven to attract and hold dissolved phosphorus as stormwater passes over it, reducing the concentration of phosphorus in outflowing stormwater by as much as 80%. In the northwest quadrant of the Mall, an enhanced sand filter using this sand/iron aggregate mix was also constructed as a part of the project.

Tree trench with trench drain rather than swale. This trench has the class 5 installed, ready for new asphalt.

Implementation of rain gardens throughout the Mall's parking lot could only go so far- rain gardens that were big enough to intercept significant amounts of stormwater runoff from the parking lot often required reducing the number of parking spaces, and these opportunities were limited. After these opportunities were exhausted, we had to choose a different BMP that would achieve our treatment and design goals.

The primary BMPs in the project are "tree trenches" - rock-filled trenches that provide opportunities for stormwater infiltration as well as rooting space for trees to grow and take up stormwater, while not



The cross section illustrates the design of the tree trenches at Maplewood Mall.

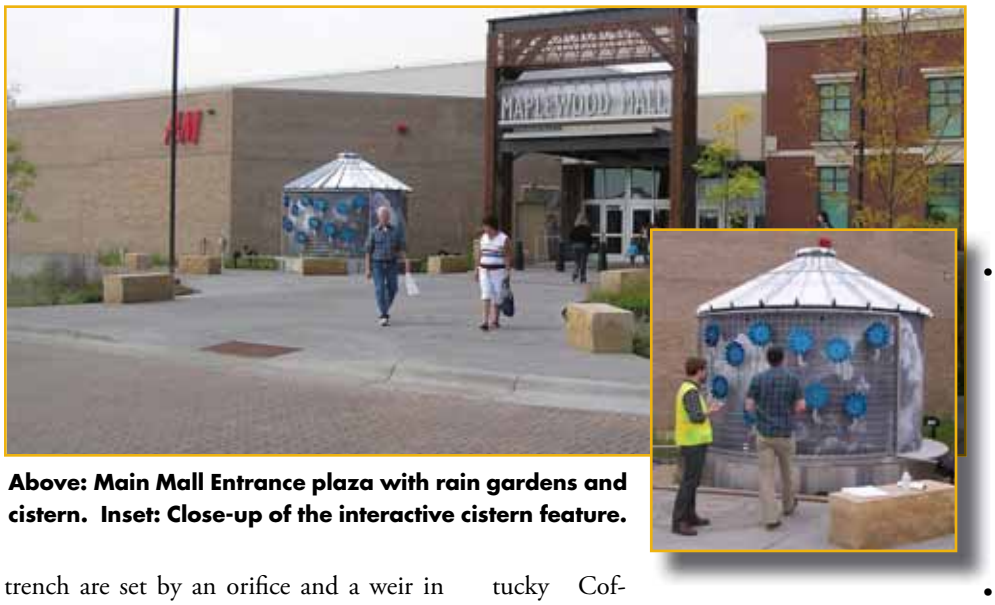
taking up parking spaces. Other alternatives like porous pavements were identified in early concept plans. However, while porous pavers were ultimately used in crosswalk areas, they were not ultimately chosen to intercept the bulk of the parking lot runoff. Concerns about the maintenance costs and longevity of a large expanse of porous pavers and/or asphalt, its inability to reduce stormwater volume at the site (when installed over clayey soils) and its relative "invisibility" to Mall visitors led us to choose tree trenches as the primary BMP for the project.

Tree Trench Design and Performance

The Maplewood Mall tree trenches utilize a design adapted from tree specialists in Stockholm, Sweden that provides a non-compacted growing environment for trees planted in highly impervious environments. This tree trench design differs from other designs due to both its heavy use of angular, load-bearing rock (angular granite), and the fact that a specified soil mix is washed into the rock after it has been compacted. In this way, the rock can support heavy traffic, but the soil in the void spaces between the rocks is non-compacted.

Stormwater from the parking lot is directed to sump catch basins that are connected to drain tile (perforated pipe) laid along a layer of angular granite that is "clear" (without soil in the void spaces). The drain tile is flat (0% slope), allowing water to fill the trench equally. As stormwater rises to the layer of angular granite that is filled with soil, water is wicked up through the soil, watering tree roots from below. After a storm event subsides, water slowly drains out of the trench and away through the greater storm sewer system for the area or infiltrates into the surrounding soil.

The dead and live storage levels in the



Above: Main Mall Entrance plaza with rain gardens and cistern. Inset: Close-up of the interactive cistern feature.

trench are set by an orifice and a weir in an Agri Drain structure that is downstream of each trench. The orifice and the weir levels are adjustable, in case the dead and live storage levels need to be changed in the future. As shown in the cross section below, the separation of the granite layer filled with soil and the clear granite layer is established with a layer of coir blanket. For the final phase of the Maplewood Mall project (Phase 4), the coir blanket layer is substituted with differently –sized angular granite layers that form a rock filter.

Below the weir in the Agri Drain structure, and assuming that no flow is leaving the orifice, the tree trenches were designed to hold 0.5 inches of stormwater running off from the tributary parking lot areas. However, taking into account that water will also leave the trenches during a storm event, the depth of runoff that can fill the trenches to brimming at the tree grates is much higher- 2.3 inches, falling at the rate of a 2-yr, 24-hr event in Ramsey County.

When surcharged, the system outflows to the existing storm sewer system already in place within the Mall's parking lot. Within a given set of trenches (or "groves" as we call them), trenches are hydraulically linked to provide treatment in series. Once Phase 4 construction is complete in 2012, approximately 1 mile of tree trenches will be installed to intercept runoff from 90% of the Mall's parking lot. Over 200 trees will have been planted in the tree trenches (375 total, including rain garden and end island areas). The selected trees are fast-growing as well as winter and drought tolerant. The species include Swamp White Oak, Discovery Elm, Skyline Honey Locust, Kentucky Coffeetree, and Common Hackberry.

We expect this system of tree trenches to both reduce stormwater volume and remove sediment and phosphorus from stormwater in the following ways:

- *Sump catch basins and extended detention*: The most basic way that the tree trenches will remove pollutants is through extended detention and inlet sumps. There are 117 inlet sumps throughout the tree trench and rain garden system that intercept the water coming off of the parking lot, catching the heaviest sediments before water enters the tree trench itself. Each trench also has extended detention storage upstream of a 1-inch orifice that holds water back for up to 48 hours (depending on the trench, and the storm event).
- *Infiltration effect*: Most of the existing soils at Maplewood Mall are highly compacted silty clay. However, in some areas, localized lenses of sand have been uncovered during excavation activities. Some infiltration of stormwater may occur in these areas after right after construction, in other areas, infiltration may occur later, as tree roots penetrate the subgrade. In other areas, there may be little to no infiltration.
- *Interception*: 375 trees will be planted in the parking lot by the time Phase 4 of the project is complete. The canopies of 375 trees at maturity, assuming each is approximately 30 feet in diameter, cover an area of 6.1 acres. Various researchers document that tree canopies can intercept large amounts of rainfall over the course of a year. According to www.treebenefits.com (a product of the National Center for Tree Research, US Forest Service), an American Elm with a 12-inch trunk can intercept 912 gallons of water in a single year.
- *Wicking of water into soil in the tree trenches*: As the trenches fill with stormwater during a storm event, the water is held back in the trenches upstream of the weir. Water will wick up into the soil media, saturating it, making water available to tree roots. In this way, the soil will act as a sponge suspended in the upper half of the tree trench cross section.
- *Uptake of water from tree roots*: The trees themselves will take up water through their roots, removing water from the tree trenches. This is not something that we can quantify at present, and is something that will change over time as the trees grow.

Public Education

A key component of the project is public education. The District and Simon Property Group are very interested in capitalizing on the large number of visitors to the mall to enhance the public understanding of stormwater management and water quality issues. To accomplish this objective, we worked with the mall to modify each of the five mall entrances to add design and artistic elements to draw attention to our stormwater management improvements. Each of the entrance designs includes small rain gardens, interpretive signage and concrete stenciling to simulate the ripples of raindrops. Two of the entrances will have a water features that use roof runoff to attract attention. The main Mall entrance was expanded in size and now includes four rain gardens, more educational signage, and a 5,700-gallon cistern that can collect up to 0.5 inches of runoff from 0.4 acres (1%) of the Mall's roof. Hand pumps allow children and adults to pump water from the cistern to create a simulated rainfall that triggers water wheels and chimes and then flows to water rain gardens. A large tile mural was also commissioned for the main entrance to the Mall that depicts the proximity of natural and urban environments within the District.

Monitoring and Maintenance

Runoff from the project site has been monitored since before construction began in order to characterize "pre-project" volume and water quality of the stormwater leaving the site. Monitoring will continue after project completion to characterize "post-project" conditions, and to quantify the effect of the project. On a smaller scale, we are also monitoring the treatment performance of one of the larger rain gardens on the site, as well as monitoring the hydraulic performance of each of the tree trench groves to maximize their stormwater retention and infiltration efficiency.

The project will be routinely inspected and maintained by the District. The District will be working closely with Simon Property Group to coordinate maintenance schedules. Typical annual maintenance will involve rain garden weeding and replacement of mulch as well as sump catch basin cleaning. Less frequent maintenance will be completed as needed on the porous paver areas, tree trimming and tree replacement.

Agency Coordination and Approvals

This project was complex and challenging due to its size, duration and funding. Specific construction permit approvals were obtained by the City of Maplewood, NPDES Construction Site Permit, and approval of plans and specifications by grant and loan funding agencies (Minnesota Pollution Control Agency, the Minnesota Board of Water and Soil Resources the Public Facilities Authority). Also, approval of plans and specifications was obtained from the Department of Labor and Industry (MN DLI) to demonstrate compliance with the Minnesota State Plumbing Code.

Completed tree trench with concrete swale and curb and tree cage to protect trees from cars.

The Agency interests were in review of the BMPs used in the project to insure that they were properly designed and would achieve the objectives for the project. The City had grading, utility and erosion control interests. The review by MN DLI was triggered by the diversion of a Mall roof drain to our cistern (although the ultimate review involved the entire project). This review triggered a number of code issues (mostly associated with pipe and structure material selections) that required changes to the plans and health concerns about the cistern. A major concern was about locations where the tree trenches or rain gardens crossed potable water pipes. Since there were a number of crossings of this type throughout the project, plans were changed to provide solid pipe sections and to eliminate tree trench and rain garden sections for 10 feet on either side of any potable water line. Various fittings and pipe materials were also changed. The DLI also had concerns about the potential for public contact with the water pumped from the cistern, so our ultimate design minimized the potential for contact.

Project Challenges

Simon Property Group staff were very collaborative and excited about the project. They realized that our project would

result in a major aesthetic improvement in the Mall property and at no cost to them. However, there were several challenges that are probably common when working with a large commercial/retail real estate owner. First and foremost, one of the Mall's primary concerns was to maintain the required parking spaces for compliance with city ordinance requirements and the requirements established in their leases with mall tenants. This led to innovative designs that minimized the loss of parking spaces.

Another challenge was the fact that Simon Property Group wasn't the sole owner of the Mall parking lot. In addition to areas owned by Simon Property Group, each of the Mall's major tenants also owns a portion of the parking lot in front of their store. Any improvements we wanted to make in other tenants' areas had to receive the approval of that tenant. At times, this was time consuming and led to significant project delays.

Another challenge common to retrofit projects was the presence of many utilities throughout the site, both active and abandoned, that were not always well recorded. Simon Property Group was not the original developers of the site, so determining utility locations prior to locates was sometimes a challenge that resulted in delays and change orders during construction.

Public Opinion

Public comments on the project have been very positive. The only concerns expressed to date have been related to the project's cost and why the District was paying for an improvement to the Mall property. Our main message is that the Mall was not required to make any changes to their stormwater management and will likely not be required to make changes in the near future. If the District wanted to see improvements made, we needed to facilitate and fund the project. Also, we found that doing a large scale project at a single site was more cost effective than doing a large number of smaller, rain garden projects scattered throughout the District to achieve the same treatment goals. Lastly, the educational impact of doing this project at such a highly visited location made this a project that achieved not only the District's stormwater treatment goals, but its goals for public education as well.

Conclusion

This project is intended to be only the first of many retrofit projects for commercial areas in the District. The successful completion of this project is key to demonstrating these practices and developing good working relationships with the business community. Success for this project will be measured by showing we can manage stormwater from highly impervious sites in a cost-effective and aesthetically pleasing manner. **L&W**

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