INDUSTRY CORNER

THE COST OF MANAGING STORMWATER

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INTRODUCTION

Stormwater has long been recognized as a substantial contributor to water quality impairments. Development has increased the area of impervious surfaces and disrupted the natural flow path for precipitation. In developed areas, large volumes of untreated stormwater runoff increase erosion and pollutant transport to surface waters. Regulators have designed programs to address the water quality impacts of stormwater and regulated entities are in the process of figuring out how to comply with these measures.

Financial burden often is cited as a major reason for slow implementation and lack of compliance with stormwater regulations (NRC, 2009). Regulated entities have argued that the permit requirements are overly burdensome and unrealistic; however, it is still too early to determine the full financial burden of stormwater regulation. Although the regulations were enacted several years ago (and continue to evolve), many entities are still in the early phases of the implementation process and are trying to determine how to integrate stormwater controls into existing infrastructure. In addition, municipalities often have limited information about the cost of retrofits.

The cost of compliance with stormwater regulation is one of the major unknowns facing municipalities and other regulated stormwater dischargers. Regulated entities should expect to incur high costs associated with stormwater controls, especially in areas that are already highly developed. Exactly how high these costs might be is uncertain. This makes it very difficult for decision makers to plan and budget for stormwater controls. As a result, many municipalities have delayed implementing these measures despite increasing pressure from regulators. Entities soon will have to begin financing and implementing stormwater controls. This paper illustrates the lack of, and uncertainty with, cost data available to planners and decision makers and provides an example where a regulated entity applied a localized analysis to cost effectively achieve stormwater reductions and compliance goals.

KEYWORDS

urban stormwater, MS4, TMDL, phosphorus, stormwater control, stormwater neutral, water quality, cost-effectiveness

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IMPLEMENTATION OF STORMWATER REGULATIONS

Congress expanded the Clean Water Act in 1987, adding amendments (enacted as Section 402(p)) that granted the U.S. Environmental Protection Agency (EPA) authority to regulate stormwater. Under this new authority, stormwater discharges into surface waters were incorporated into the existing National Pollutant Discharge Elimination System (NPDES) program. The NPDES program uses permits to regulate point sources discharging into surface waters. The EPA's stormwater program is designed to allow authorized states to issue NPDES permits for stormwater discharges.

Stormwater regulations were implemented in two phases and greatly expanded the NPDES program. In 1990, the EPA issued Phase I rules, which required NPDES permits for municipal separate storm sewer systems (MS4s) serving populations of more than 100,000. Nine years later, Phase II rules were issued, extending the permit requirement to smaller MS4s in urbanized areas. Stormwater discharges from industrial activities and construction sites also were required to be covered under NPDES permits. Stormwater dischargers make up the majority of NPDES-permitted entities and the program now regulates more than 500,000 MS4s. Comparatively, only about 100,000 non-stormwater entities are regulated under the NPDES program (NRC, 2009). Stormwater permits currently tend to have inherent flexibility due to the language of the regulations, which requires reductions to the "maximum extent practicable."

The EPA is in the process of making required stormwater discharge limits more stringent by including quantifiable goals in NPDES permits. Related to these efforts, the agency is exploring how to incorporate numeric water quality-based effluent limits in MS4 permits when the regulated entity is discharging to waters with a Total Maximum Daily Load (TMDL) (Hanlon and Keehner, 2010). A TMDL specifies the maximum amount (i.e., mass load) of a pollutant that a body of water can receive and still meet water quality standards. TMDLs also allocate pollutant loadings among point and non-point sources (USEPA, 2012). Under Section 303(d) of the Clean Water Act, bodies of water not meeting standards set under the Act are required to have TMDLs. Numeric effluent limits in MS4 permits could reduce flexibility currently provided in MS4 permits and increase the cost of compliance. Meeting numeric standards would require substantial retrofits to existing stormwater infrastructure in highly developed urban areas.

APPROACHES TO REGULATORY COMPLIANCE

Even without numeric limits, MS4s currently are experiencing additional pressures to reduce stormwater discharges. The Chesapeake Bay provides an illustrative example in this regard. In 2010, the EPA issued a TMDL for the Chesapeake Bay, which set limits on the amount of nitrogen, phosphorus, and sediment that can enter the Bay. States discharging stormwater to the Bay were required to develop Watershed Implementation Plans (WIP) and allocate loads to all non-point sectors including urban stormwater. The WIPs outline a plan for achieving the loading limits of point sources and non-point sources. Maryland's Phase II WIP, submitted to the EPA on March 30, 2012, requires stormwater load reductions of 20.3% nitrogen and 30.3% phosphorus over the 2010 loading conditions (MDE, 2012).

Limiting, or "capping", the amount of nutrients and sediment discharged to the Bay has major implications for growth and new development in the region. Any new or expanded stormwater discharges must still receive treatment. Any new load still existing following treatment must be fully offset in order to meet the Maryland stormwater WIP requirements. This effectively becomes a net zero discharge for new stormwater (i.e., for new development). Maryland has committed to creating an offset program by the end of 2013 to address these discharge requirements. Estimated costs for addressing Bay-wide urban stormwater reduction requirements are on the order of billions of dollars (RTI International, 2012).

An example illustrating successful stormwater compliance with TMDLs is found in the Midwest. Western Michigan University (WMU) is a student-centered research institution located in Kalamazoo, Michigan. It is subject to a phosphorus TMDL developed to address water quality impairments in a downstream impoundment. In 2001, the Michigan Department of Environmental Quality issued the TMDL, which required urban stormwater dischargers to reduce phosphorus loading by 50% from the 1998 load. During the past decade, WMU has installed stormwater retrofits as part of campus redevelopment activities and other capital projects. Assessing TMDL compliance required collection, analysis, and reporting of pollutant loading information. The cost of compliance was also a critical factor for the university.

WMU took a unique approach to addressing these requirements. In 2011, the university was awarded state and federal grant funding to evaluate its progress toward TMDL compliance. As part of this project, the 1998 baseline phosphorus load was calculated, enabling the campus to set a quantitative target for load reductions. During the planning process, it became apparent that existing practices already had reduced WMU's phosphorus load by approximately 38% from the 1998 baseline. This reduction corresponded to a total treatment area of approximately 54% of the 807-acre campus footprint. Figure 1 shows the increase in stormwater treatment area on campus from 1998 to 2011. Additional phosphorus reductions achieved by off-campus stormwater control measures funded by WMU were applied as "offsets" to help WMU meet its TMDL requirement. The combined on-campus and off-campus practices brought WMU into compliance with its 50% phosphorus load reduction TMDL goal.

WHAT IS THE COST OF COMPLIANCE?

When stormwater amendments were passed and regulated entities had to address new requirements, Congress provided no direct financing mechanisms for implementation (NRC, 2009). Some federal funding was available as loans through the Clean Water State Revolving Fund (CWSRF). For the most part, states, municipalities, and other newly regulated entities were left shouldering the burden for addressing treatment and control of existing stormwater discharges. Local governments may fund stormwater projects through state and federal grants, tax revenues, or the creation of stormwater utilities; however, with a few exceptions, governments have been reluctant to pursue either option. In some cases, taxation is not possible given legal restrictions on the power of local entities to levy taxes. Establishing a stormwater utility can be a viable alternative, but can take substantial time, effort, and resources. Generally, states have relied on the collection of stormwater permit fees or redirection of general funds to finance what often amounts to minimal program implementation (NRC, 2009).

As regulators increase pressure to implement stormwater controls, it is becoming increasingly clear that the cost of compliance is extremely high and variable. An example from Wisconsin illustrates the potential range of costs municipalities might face in the near future. Regulated municipalities in Wisconsin were mandated to achieve a 20% reduction in stormwater discharges of total suspended solids (TSS) by March 2008. Data were collected on nine permitted municipalities in the southeastern portion of the state in order to assess the

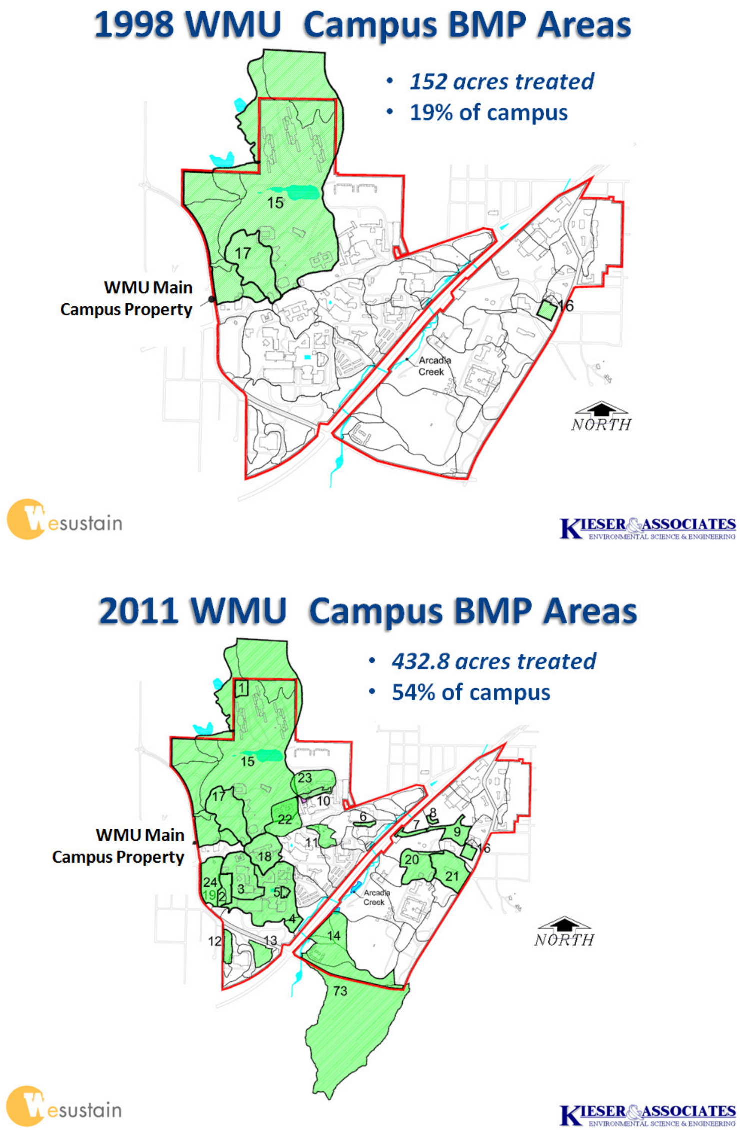


FIGURE 1. Map comparing extent of WMU stormwater controls in 1998 and 2011.

cost of compliance. For these entities, the implementation of six basic stormwater control measures in 2007 cost an average of $162,900 and ranged from $11,600 to $479,000 (NRC, 2009). The average population of these cities was 17,700, with a range between 6,000 and 65,000 (NRC, 2009). Larger municipalities can expect to incur substantially higher costs.

Total costs for stormwater control implementation consist of several components. Each project is associated with up-front planning, design, and capital costs. Control measures also incur annual operation and maintenance (O&M) costs. All costs will vary depending on the specific practice installed. In some cases, the construction costs might be relatively low, but the maintenance costs might be comparatively high. Both sets of costs should be considered when deciding which practices to implement when these capital and O&M costs vary widely. Additional costs to consider include stormwater program administration, permitting costs, monitoring, and enforcement. Opportunity costs associated with alternative uses of the land (measured in terms of land price) also should be taken into account.

The full cost burden also depends on the specific circumstances of each community. For example, a community that has prior experience with stormwater controls might be able to apply this experience to reduce costs. In addition, familiarity with the stormwater control regulations might result in lower costs if the community took advantage of the built-in flexibility in the regulations and implemented least-cost control measures (GAO, 2007). Other communities might face higher control costs if they are subject to more stringent water quality regulations (GAO, 2007). Even if such stringent regulations are not currently in place, future permits could impose tighter standards, thus increasing future costs.

CHALLENGES WITH STORMWATER RETROFITS

Areas with substantial existing development are likely to face the highest costs for retrofitting existing stormwater controls. Retrofits in urban areas often present a number of design and treatment limitations. Overall, retrofit construction costs can be two to seven times more than new installations (NRC, 2009). Retrofits require site-specific, individualized designs, which increase the time and cost of implementation. An example of a space constraint is illustrated in Figure 2. In addition, retrofits often perform at lower efficiencies, due to compromises in the design to meet space limitations. More frequent maintenance is also typically required in order to maximize performance. In some settings, the high costs and reduced efficiencies of retrofits might make alternative compliance options desirable. For example, a permit manager could implement stormwater controls elsewhere in the permit footprint in order to locally offset stormwater impacts.

The costs of retrofits can be illustrated using an analysis performed for WMU. A treatment cost-effectiveness assessment evaluated current stormwater controls and prioritized future stormwater treatment efforts at the university. Costs can also be expressed in terms of unit costs, such as dollars per pound of nutrient reduction or dollars per acre of treated area. On average, the practices at WMU cost approximately $38,900 per acre of treated area. In contrast, a cost analysis in Maryland's Phase II WIP estimates the cost per acre of impervious area treated by SCMs at $12,500 (MDE, 2012). This comparison also illustrates the wide variability in control costs, as was noted in the Maryland WIP.

FIGURE 2. Examples of space constraints when installing stormwater retrofits at Western Michigan University, Kalamazoo, Michigan.

ACTUAL CONTROL COSTS ARE EXTREMELY VARIABLE

Wide variability in stormwater control costs makes it very difficult for decision makers to plan for necessary financial outlays associated with implementation and compliance. Limited or highly variable cost information is available to assist planners in estimating the potential total cost of program implementation. In addition, it can be complicated to compare the costs of other programs given the inherent site-specific nature of stormwater controls. Practice design and performance depends on several factors, including soil, climate, topography, regulatory requirements, and local economics (NRC 2009).

Various efforts have been undertaken to compile data on stormwater control costs and some information is available in published literature; however, these data typically focus on construction costs of specific measures (NRC 2009). More detailed information generally is lacking. In addition, the amount of information available varies depending on practice type. Relatively more information exists regarding conventional stormwater control options, such as detention basins and wet ponds, compared to newer, smaller-scale options (NRC, 2009).

The EPA attempted to quantify the costs associated with implementing stormwater regulations by analyzing the program costs for selected cities; however, a review found that the cost data collected by the EPA were not complete or consistent (GAO, 2007). In addition, the GAO concluded that it was not possible to verify the accuracy of the EPA's analysis given the inherent variation and uncertainty of stormwater control costs.

To illustrate this substantial variation and uncertainty, the authors of this paper gathered cost data from manuscripts presented as part of the inaugural 2012 Water Environment Federation (WEF) Stormwater Symposium in Baltimore, Maryland. Although several manuscripts mentioned total project costs, very few described the unit costs of volume or water quality parameter reductions.

At the WEF symposium, Behr and Montalto (2012) presented a project that involved developing a decision-making model to address uncertainty. For this model, the authors gathered cost data in order to assess and incorporate variability. They found that stormwater control costs were extremely variable, even within a single city. For example, the authors noted that implementation costs of New York City's stormwater management plan ranged from $217,800 to $3,092,760 per acre. In addition, operation and maintenance costs were more difficult to predict than capital costs.

Another set of authors presented information on the benefits of redirecting downspouts to route stormwater onto pervious surfaces to enhance infiltration (Beckman and McCarthy, 2012). The authors assessed the redirection project in Saint Paul, Minnesota, over a two-year period (2010–2011) and calculated the unit costs associated with stormwater volume and total phosphorus (TP) reduction. The results of the analysis are presented in Table 1.

In an assessment of stormwater control costs presented by Ellwood (2012) at the WEF Symposium, the author noted a distinct lack of detailed cost data despite the growing number of databases. The author reviewed two well-known stormwater control databases (the International Best Management Practice Database and the UNHSC-NEMO Innovative Stormwater Management Inventory) to assess

TABLE 1. Unit costs associated with a downspout redirection project in Saint Paul, Minnesota (Beckman and McCarthy, 2012).

Year	TP Reduction ($/lb)	Volume Reduction ($/ft^3)
2010	$1,645.00	$0.0175
2011	$637.00	$0.0068

TABLE 2. Stormwater control unit costs by size of practice footprint (Ellwood, 2012).

Practice and Unit Measure	Low Unit Cost ($/unit)	High Unit Cost ($/unit)	Average Unit Cost ($/unit)
Bioinfiltration Basin (ft^2)	8	20	13
Retrofit Bioinfiltration Basin (ft^2)	19	19	19
Bioswale (ft^2)	7	17	13
Urban Planter—one project (ft^2)	17	17	17
Green Roof—Extensive/Modular (ft^2)	11	14	13
Green Roof—Extensive/Layered (ft^2)	22	28	25
Green Roof—Intensive—one project (ft^2)	35	35	35
Green Roof—Sloped—one project (ft^2)	19	19	19
Permeable Pavers (ft^2)	7	20	13
Porous Concrete (ft^2)	2	15	8
Porous Asphalt—one project (ft^2)	8	8	8
Aboveground Cistern—one project (gal)	2	2	2
Belowground Cistern—two projects (gal)	8	8	8

the extent of cost information. Despite the otherwise extensive nature of these databases, there was a lack of information regarding the costs associated with specific practices. The author gathered detailed cost data from 18 stormwater control projects around Cincinnati, Ohio, in order to assess potential control costs. This analysis excluded site-specific costs of implementation not related to the general stormwater control function to make the analysis more generally applicable. The range of costs associated with the control types based on the size of the practice is provided in Table 2.

This analysis illustrated the vast differences in costs, even among single practices. This was exemplified by costs of bioinfiltration basins, most likely due to differences in project size and costs of labor. Smaller basins tended to be more expensive because they required more manual labor and intricate placement into built environments. Porous and permeable pavement costs also varied substantially depending on the materials and design. Overall, these controls tended to exhibit economies of scale, with larger projects being relatively less expensive than smaller projects.

Ellwood (2012) also calculated unit costs to compare the project expenditures to the reductions achieved. Table 3 shows the cost per gallon of runoff captured by each practice. The author reported these values as dollars per liter; numbers were converted to English units to aid comparison with unit costs from other studies discussed herein.

Another project presented at the WEF symposium assessed the cost-effectiveness of various stormwater control practices (Baker and Doneux, 2012). The authors looked at 18 practices in a Minnesota watershed with a 60% phosphorus load reduction goal. The total project cost of $2.7 million treated a watershed area of 190 acres and provided a total dead storage volume of 3.3 million gallons. Project data were collected for 2007–2010, and the P8 Urban Catchment Model was used to simulate the storage volume and reductions in TP and total solids loads, based on the collected data. The model-projected volume, TP, and total solids reductions by control type are summarized in Table 4.

TABLE 3. Unit cost of volume reduction for various stormwater control practices (Ellwood, 2012).

Practice	Estimated Cost per Gallon Runoff Captured ($/gal)
Green roof—sloped, bioinfiltration—bioswale	$0.19
Bioinfiltration—bioswales	$0.11
Pervious paving, rain gardens, bioinfiltration	$0.15
Pervious paving, rain gardens, bioinfiltration, rainwater harvesting	$0.15
Pervious paving	$0.23
Green roof intensive & extensive, pervious paving, bioinfiltration	$0.42
Pervious paving	$0.08
Green roof—extensive, small	$1.36
Green roof—extensive, large; bioinfiltration—rain garden	$0.76
Pervious paving, bioinfiltration—bioswale	$0.11
Green roof—extensive, layered	$1.51
Pervious paving, urban planters, bioinfiltration—rain garden	$0.79
Pervious paving	$0.15
Green roof—extensive, dry wells	$0.11
Bioinfiltration—biodetention	$0.08
Pervious paving, storm separation, rainwater harvesting, bioinfiltration	$0.08
Pervious paving	$0.26

TABLE 4. Summary of annual volume, TP, and total solids reductions by stormwater control type (Baker and Doneux, 2012).

Reduction	Underground System	Pond	Infiltration Trenches	Rain Gardens
Volume Reduction (gal/yr)	4,235,206	6,555,428	2,592,584	2,076,920
TP Load Reduction (lbs/yr)	35.5	90.4	18.3	10.4
Total Solids Reduction (lbs/yr)	32,071	157,952	29,218	13,177

The authors also analyzed the capital and annual operation and maintenance costs for the project, as illustrated in Figure 3. The values used to generate this figure were the annual costs predicted by the model based on a 35-year project life expectancy.

Unit costs of reductions were calculated for volume, TP, and total solids reductions. These costs, as estimated by the model, are presented in Table 5. Reported values were converted to English units here.

The studies presented at the WEF symposium and discussed above illustrate both the variability in stormwater control costs and the lack of consistency in data reporting. Different studies incorporated different types of costs and conducted the analyses in different manners. Therefore, even when cost data are available to decision makers, the data might not be in the most useful format for planning and compliance assessment.

FIGURE 3. Annualized costs for stormwater controls based on model projections (Baker and Doneux, 2012).

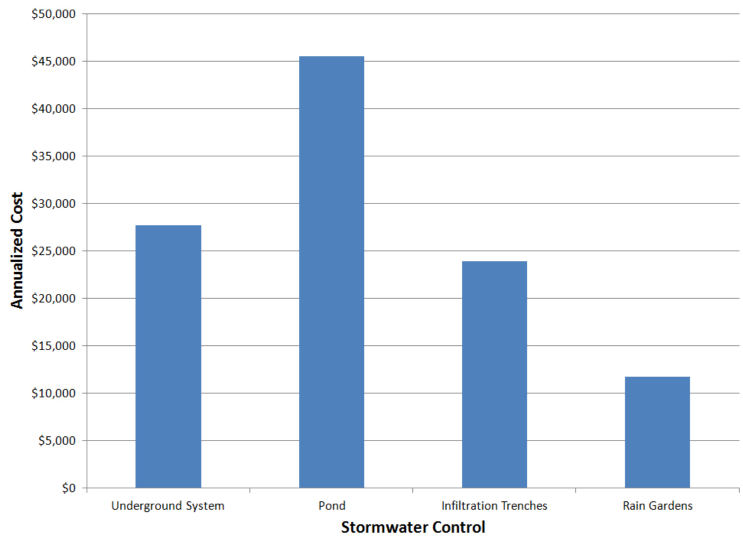


TABLE 5. Unit costs for stormwater controls based on model projections (Baker and Doneux, 2012).

Cost Description	Underground System	Pond	Infiltration Trenches	Rain Gardens
Annualized Cost	$27,755	$45,531	$23,930	$11,738
Volume Reduction Cost ($/gal)	$0.0065	$0.0069	$0.0092	$0.0056
Cumulative TP Removal Cost ($/lb)	$782	$504	$1,306	$1,129
Total Solids Removal Cost ($/lb)	$0.87	$0.29	$0.82	$0.89

HOW CAN DECISION MAKERS BETTER PLAN FOR CONTROLS?

One option for dealing with the variability and inconsistency in reported stormwater control cost data would be to conduct a localized unit-cost analysis. This would bypass the need to piece together existing data that most likely are of limited relevance. A localized analysis would allow decision makers to make choices based on a quantified metric relevant to the setting. Such efforts by WMU, as discussed briefly above and in more detail here, illustrate the application of this approach.

As a university committed to environmental sustainability, WMU set an ambitious goal to reduce beyond the 50% phosphorus load reduction required by the TMDL. The target was to achieve a Stormwater Neutral™ status for the campus. The goal of Stormwater Neutral™ is to achieve a "net zero" stormwater discharge load of a selected constituent after implementation of stormwater controls. WMU selected TP—the nutrient of concern in the watershed—as the metric for determining its "net zero" status.

Several calculations were completed to help WMU assess its stormwater control practices. These calculations provided the university with a quantified metric of its TP reductions. A multi-step mass balance approach was used to determine WMU's net TP loading and compare the stormwater control reductions to the 1998 TMDL baseline loading. The costs of existing stormwater control practices were also calculated. Table 6 lists the costs of different

TABLE 6. Total phosphorus (TP) load reduction and associated cost per unit of removal from different stormwater practices installed by Western Michigan University on-campus and off-campus within the watershed. Unit costs were calculated by dividing the implementation costs by the projected annual load reductions.

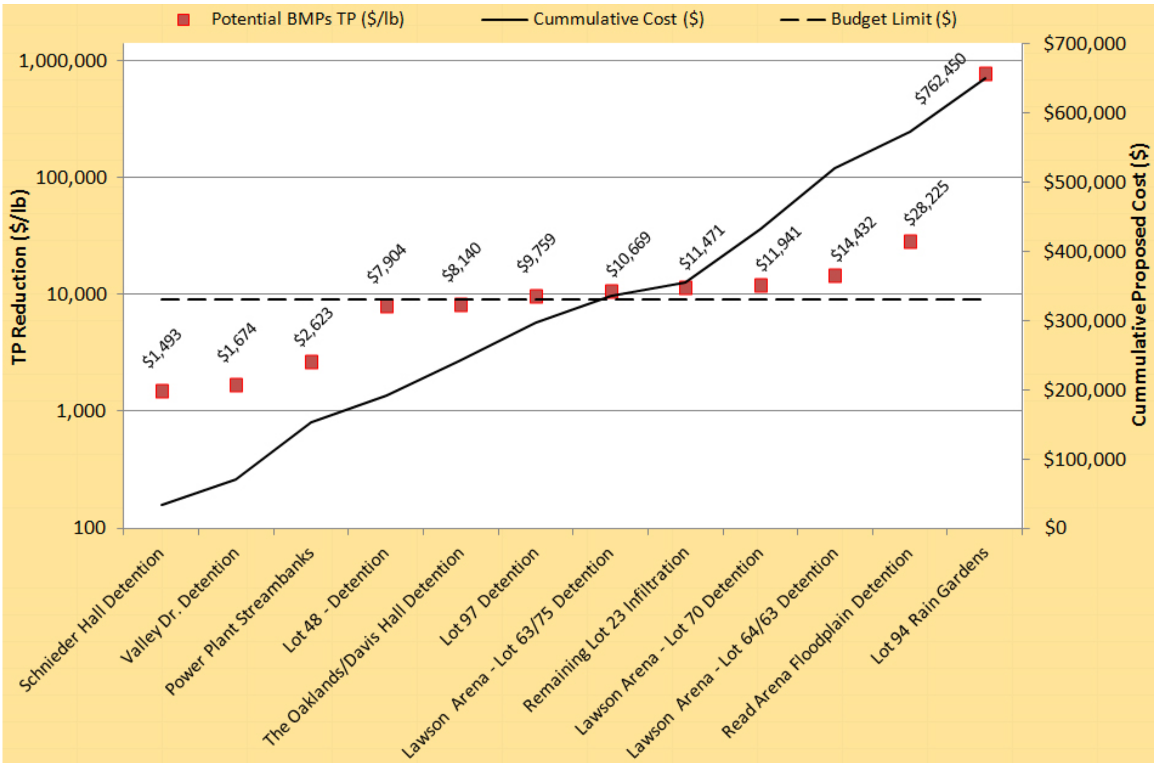
Location	SCM Type	Approximate Implementation Cost	Load Reduction (lbs TP/yr)	Cost ($/lb TP removed)
Goldsworth Valley Pond	Wetpond (outflow structure raised)	$31,000	37.3	$831
Arcadia Creek CMI	Detention Pond	$235,000	85.9	$2,736
Parking Lot 23	Detention Pond	$138,800	28.3	$4,912
Parking Lot 76	Detention Pond	$135,000	20.4	$6,618
College of Health & Human Services	Detention Pond	$110,000	13.7	$8,029
Schneider Hall	Detention Pond	$120,000	10.0	$12,000
KCMS Parking Lot	Infiltration Practice	$80,000	2.2	$36,364
Chemistry Building	Detention Pond	$586,600	14.9	$39,370
Parking Lot 95	Infiltration Practice	$400,000	9.5	$42,105
Parking Lot 55	Infiltration Basin	$244,500	5.7	$42,745
Western View	Infiltration Practice	$388,000	9.0	$43,016
Kohrman Hall	Infiltration Practice	$1,159,900	23.1	$50,212
Fieldhouse Sidewalk	Infiltration Practice	$20,000	0.4	$51,282
Oliver St. Reconstruction	Infiltration Practice	$527,300	9.2	$57,436

stormwater control projects installed on WMU's campus from 1998–2011. This table depicts the approximate implementation costs, which were estimated from WMU records, and only include construction costs associated with each project.

To achieve the Stormwater Neutral™ goal, the university faced design and space limitations that made many on-campus control practices cost prohibitive. WMU therefore informally credited university-funded off-campus stormwater control projects to "offset" phosphorus loading from campus. Though not formally invoked here, Michigan has water quality trading rules that allow a discharger to meet regulatory requirements through load reduction "credits" generated by a different discharger. These off-campus control projects amounted to an additional reduction of 229 lbs TP/year (Boyer and Kieser, 2012). In total, WMU stormwater treatment practices resulted in a 565 lb TP/year load reduction, a 74% load reduction from the 1998 baseline (Boyer and Kieser, 2012).

An additional analysis was completed to help WMU's decision-making for future stormwater control practices in addressing the remaining phosphorus load from campus. This analysis involved determining the cost per pound of TP reduced for different types of stormwater control practices, including estimates for practices recommended for future installation. Quantifying this information enables WMU to prioritize the implementation of future projects based on funding availability and treatment effectiveness. Figure 4 provides an example of how WMU can use this analysis to select stormwater controls for a grant project with a fixed budget. The projects are listed in order from lowest to highest TP treatment cost. The total

FIGURE 4. This graph illustrates the use of a cost-effectiveness analysis to evaluate future implementation of stormwater controls.



project budget is marked at $330,000. Cumulative cost is tracked for each additional practice. This type of analysis does not maximize the number of stormwater projects. Rather, by using the cost-effectiveness associated with each practice, this analysis allows for maximizing the phosphorus reductions that can be achieved within a fixed budget. Without this analysis, WMU might have selected the Lot 94 Rain Garden project, for example, due to its relatively low construction cost ($76,245) compared to the other options. However, when the treatment efficiency is factored into the analysis, this proposed rain garden is the most expensive option given the amount of phosphorus removed ($762,450/lb TP).

CONCLUSIONS

Decision makers are faced with ambiguity when planning for stormwater controls. Implementing stormwater control practices is very expensive and the cost of complying with stormwater regulation is expected to be high; however, it is often highly uncertain as to how expensive compliance will be. This uncertainty can make it difficult for a regulated entity to prepare and budget for required reductions in stormwater discharges. As a result, compliance with stormwater regulations has been rather slow. This despite recent EPA activity that indicates that the agency is beginning to push for compliance and more stringent discharge limits.

Given the high cost of stormwater controls, regulated entities would likely benefit from an evaluation approach that provides detailed local information for planning, and generates opportunities for cost savings. The first step in this process is to quantify compliance needs. This involves analyzing current stormwater loading and comparing that amount to the compliance limit. It also includes evaluating past progress toward implementing stormwater controls. As was the case with WMU, existing stormwater controls might bring an entity close to its compliance goal and therefore only a few additional practices might be necessary.

Once an entity determines the quantity of load reductions needed for compliance, it becomes important to evaluate the cost-effectiveness of potential stormwater control practices. Stormwater practices would be assessed based on the reductions achieved and cost of the project. With this information, decision makers can rank projects based on the unit cost of reductions (e.g., cost per pound of phosphorus reduced). A unit cost analysis enables an entity to select projects that will provide the maximum amount of reductions at the least cost. Compliance will still be expensive, but applying this type of analysis will allow a regulated entity to make its stormwater control investments count.

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