GREEN STORMWATER INFRASTRUCTURE ECONOMICS IN THE BOISE URBAN AREA

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Cover photo by Steve Bly. Bioretention photo on page 3 courtesy Idaho Rivers United.

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EXECUTIVE SUMMARY

Stormwater infrastructure is of growing interest in urban areas as communities face significant costs to modernize stormwater management to better deal with flooding and water pollution. Stormwater infrastructure is also of interest because of the contribution it can make to community redevelopment, quality of life, and climate resiliency. In the Boise urban area, millions of dollars will be spent on improving stormwater management to achieve pollutant reductions required by the Clean Water Act and meet other community goals. There are a number of techniques and best management practices now available for managing stormwater including both green and conventional stormwater infrastructures. In general, stormwater managers have been moving towards stormwater infrastructure that can retain and infiltrate stormwater onsite. Stormwater infrastructure needs to be chosen carefully because each type of infrastructure comes with different costs and provides different benefits.

This study examines the economics of stormwater infrastructure by conducting a cost-effectiveness analysis of four types of green stormwater infrastructure (GSI) and two conventional infrastructure analogues. As GSI provides additional benefits beyond stormwater capture, the social benefits of GSI are also examined. Cost-effectiveness was measured for annual gallons of captured stormwater and for annual pounds of reduced pollutants of total suspended sediment (TSS) and total phosphorous (TP).

Six scenarios were modeled for redeveloping existing urban right of ways and alleys to retain and infiltrate stormwater onsite. Cost-effectiveness was based on the assumption that all six scenarios were required to capture the same amount of annual stormwater. Four GSI scenarios were modeled: bioretention, trees with suspended pavement systems, permeable pavers, and bioswales. Two conventional infrastructures incorporating best management practices were modeled that utilized infiltration trenches and seepage beds to capture stormwater: conventional trees without suspended pavement systems and conventional paved alleys. Costs included construction, materials, and annual maintenance. The additional benefits provided by the modeled infrastructure types were also analyzed.

Stormwater discharge
Photo courtesy Idaho Rivers United

Bioretention Photo by Jeff Adams

Local context including available space, prominent uses (e.g., traffic, pedestrian, parking), and soil depths heavily influence the appropriate choice of stormwater infrastructure. Beyond site-specific contexts however, several differences in cost-effectiveness for stormwater infrastructure were found:

- Among GSI types in the Boise urban area, permeable pavers are the most cost-effective means of capturing stormwater ($5/1,000 gallons) and reducing pollutants (8$/lb. TSS and $1,700/lb. TP).
- Bioretention units have the highest pollutant reduction rates and are the second most cost-effective means of capturing stormwater ($17/1,000 gallons) and reducing pollutants ($27/lb. TSS and $5,000/lb. TP).
- Comparing GSI to conventional best practices, GSI has higher initial costs but longer lifespans.
- Combined GSI and combined conventional infrastructure had equivalent cost-effectiveness for capturing stormwater ($18/1,000 gallons), but GSI was 21% more cost effective in reducing TSS and 24% more cost effective in reducing TP.

GSI provides additional benefits beyond capturing stormwater that are greater than the benefits found in conventional stormwater infrastructure. The majority of these benefits come from the “green” in GSI in terms of vegetation. The following findings come from the analysis of social benefits:

- GSI suspended pavement tree systems provide the greatest amount of social benefits of all stormwater infrastructures.
- The greatest social benefits of GSI in the Boise urban area are increased water quality, groundwater recharge, increased property values and avoided energy costs and emissions.
- Parks along the Boise River provide recreation and additional benefits while functioning as large natural stormwater infrastructure.

Overall, GSI was found to be as cost-effective as conventional practices at capturing stormwater and more cost-effective at reducing pollutants. Adding in the additional social benefits provided by GSI indicates that GSI provides greater total economic value than conventional alternatives. Because stormwater carries more than just the two pollutants analyzed in this study, the cost effectiveness of GSI is underestimated for total pollutant reduction. With many additional social benefits provided by GSI, stormwater managers should consider the importance of each social benefit in choosing stormwater infrastructure.

SECTION 1
INTRODUCTION

Stormwater discharge
Photo courtesy Idaho Rivers United

As the Boise urban area grows and land is developed or re-developed, millions of dollars will be invested in managing stormwater to protect public safety and water quality.

Green Stormwater Infrastructure (GSI) helps reduce runoff through infiltration and retaining stormwater onsite. It also provides opportunites for green-scaping in communities.

The Boise River is a critical resource in the Boise urban area. The river provides many benefits including water for drinking and domestic uses, recreation opportunities, irrigation, and fish and wildlife habitat. The quality and quantity of these benefits depends on how clean the river is. Water quality can be adversely affected by stormwater that carries bacteria, nutrients, sediment, and other pollutants into the river. Stormwater can also cause flooding and other public hazards. As the Boise urban area grows and land is developed or re-developed, millions of dollars will be invested in managing stormwater to protect public safety and water quality.

In order to improve water quality in public waters, stormwater managers are looking to reduce stormwater discharge through re-development of urban roads, alleys, rights-of-way and buildings. Likewise, regulatory mandates stemming from the United States Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) permit #IDS-027561 for the Boise area limit pollutants to the maximum extent practical (MEP). The permit encourages the use of green stormwater infrastructure (GSI) to reduce runoff through stormwater infiltration and onsite retention. GSI urban re-development techniques include bioretention areas, tree systems, and permeable pavers. Additionally, GSI provides for green-scaping opportunities in urban areas and numerous ancillary benefits.

The Boise urban area has storm sewers in place for conveying stormwater to the river or to a retention site. Storm sewers serve to reduce flooding and ponding on city streets and in neighborhoods. A number of U.S. cities, including those in the Boise urban area, have been transitioning away from drain only sewer systems to retain-onsite since the 1970s (Debo and Reese 2002). When retain-onsite options are limited in re-development areas, off-site wetlands, and open spaces can be used to help offset the effects of urban stormwater runoff.

This report provides information on two important issues stormwater managers face when deciding on stormwater infrastructure investment. The first is the cost-effectiveness of implementing GSI. While guidance from the Phase 1 EPA permit suggests a need for greater GSI, managers must have data to determine how much green and how much conventional stormwater infrastructure is optimal. Two urban subwatershed plans are being developed by co-permittees and represent the first opportunity for system wide evaluation of what types of GSI, and how much GSI, should be incorporated into the re-development of urban areas. Since the ultimate goal is to reduce the amount of stormwater, along with the sediment and pollutants conveyed into the river, cost-effectiveness is a critical factor.

The other economic issue concerns the suite of benefits provided by GSI. There are many benefits generated when GSI is implemented, and communities can use stormwater infrastructure investments to improve urban vibrancy and climate resilience. The type and quantity of benefits provided by GSI vary based on unique geographies, climates, populations and local water demands. This high-quality information on the social, ecological, and economic benefits of GSI in the Boise urban area will allow local decision makers to appropriately value this infrastructure and wisely invest limited stormwater management funds.

1.1 Background on Green Stormwater Infrastructure Economics


Stormwater discharge   Photo courtesy Idaho Rivers United

Many urban areas in the U.S. are turning to green stormwater infrastructure (GSI) to protect public safety and water quality because it offers a larger suite of social, ecological, and economic benefits than traditional stormwater infrastructure. Research has shown that greater use of GSI can increase stormwater management efficiency and provide environmental improvements and many ancillary benefits. GSI can also extend the life of and/or decrease operation and maintenance costs of necessary traditional infrastructure.

Cost-effectiveness of GSI

Economic evaluations of GSI, often referred to as "low impact development," have been conducted to determine costs and benefits from managing stormwater with green as opposed to traditional infrastructure of gutters and pipes. GSI economic research questions have focused on the fiscal costs of implementation and the avoided costs associated with limiting pollutants. But, stormwater managers have traditionally focused on structural engineering as opposed to economics (EPA 2007) and state and municipal agencies responsible for stormwater management have only recently begun to consider the total economic value of stormwater infrastructure.

A recent EPA technical report (EPA 2014a) examined the value of energy, air quality, and climate-related benefits and avoided infrastructure and treatment costs of implementing GSI to avoid combined sewer overflows (CSOs) in Lancaster, PA. The study found GSI implementation to be cost-effective, with the range of benefits exceeding the cost of implementation. Another report (Odefey et al. 2012) took the opposite approach and examined the economic costs of stormwater as a substantial source of U.S. water pollution. A 2007 EPA study (EPA 2007) synthesized 17 case studies of GSI (called Low Impact Development—LID) and found general reductions in capital costs in stormwater infrastructure and improved environmental performance.

Advanced models have been developed for assessing the cost-effectiveness of GSI and LID for reducing CSOs, particularly in northeastern cities such as New York and Philadelphia (CHM2HILL 2011). The low impact development rapid assessment (LIDRA) model (Montalto et al. 2007) was developed to examine the cost-effectiveness of using low impact development as means to reduce CSOs. The concepts and some of the calculations of LIDRA (Montalto et al. 2007) and other economic analyses help inform this assessment of Boise urban area GSI cost-effectiveness. But most of these studies focus on CSOs, meaning that many of the avoided costs associated with green infrastructure are reduced wastewater treatment facility operational and energy costs; costs not relevant in the Boise urban area.

Benefits of GSI


Downtown Boise

Photo by Steve Bly

Using soils and vegetation to infiltrate and evapotranspire stormwater creates cascading benefits, whereas traditional stormwater infrastructure typically only serves one purpose—conveying water elsewhere. By reducing stormwater runoff and pollutants entering local waterways, costs associated with water pollution are avoided. Additionally, the vegetation that often plays a role in GSI spurs other benefits not found in traditional stormwater infrastructure. These avoided costs and extra benefits of GSI are largely nonmarket services, or social returns on stormwater investments.

The extensive direct and indirect benefits of GSI have been described in Wise et al. (2010), CNT (2010), Detwiler (2012), Odefey et al. (2012), and EPA (2014b). The benefits of GSI can be separated into four broad categories: water-related, environmental, public health, and social. In addition to improving water quality, GSI creates environmental benefits such as carbon sequestration and urban cooling. These environmental benefits provide further public health and social benefits including increased safety and avoided health costs.

It is important to understand the bundled nature and co-dependency of the benefits provided by GSI, especially for accounting purposes. For example, a water-related benefit resulting from the removal of a pollutant also translates into potential public health and environmental benefits. Or a reduced need for water treatment results in both an avoided financial cost for a treatment plant and reduced energy emissions. GSI does not get equal consideration because of the difficulty in accurately monetizing these environmental benefits (EPA 2007). But the complexity of many nonmarket benefits associated with GSI, and the proper accounting of these benefits, should not deter decision makers from considering supplemental benefits when considering stormwater management. In the methods section, some clarity is provided on accounting for these myriad benefits.

GSI Economic Lessons Learned

Millions of dollars are being spent in order to achieve nutrient and pollutant reductions in stormwater entering public waterways. For example, over $18 million has recently been invested in water treatments for nutrient reduction in Lancaster, PA (CHM2HILL 2011). And we know that millions will be invested in redeveloping Boise urban areas to reduce stormwater pollutants from entering the Boise River. GSI can play a large role in urban redevelopment and in achieving pollutant reductions.

From the literature, we found a few basic premises and lessons learned from other cities. The most important economic considerations for stormwater managers in the Boise urban area include:

- GSI serves multiple purposes, as opposed to traditional infrastructure that is singular in purpose to convey stormwater away (Ranran et al. 2013).
- Being multi-purpose, the benefits of GSI are more diverse and greater than traditional stormwater infrastructure (CHM2HILL 2011).
- Mimicking natural conditions can lead to substantial avoided costs (Benedict and McMahon 2002).
- GSI can be competitive cost-wise to traditional nfrastructure depending on sewer systems (CSSs

vs. MS4s) and how costs are compared (EPA 2007).

- Scaling up with connected GSI to establish green stormwater infrastructure can yield economies of scale (EPA 2014).

The majority of economic analyses of GSI were conducted in places that had CSOs or represented some of the most problematic stormwater pollutant loading. The Boise urban area is ahead of the curve when compared to most cities in terms of already embracing GSI and making sure that all new development is required to retain stormwater onsite. The co-permittees on the Boise Phase I NPDES permit, and the stormwater managing entities such as Ada County Highway District and the City of Boise, deserve credit for understanding stormwater pollutant problems and for prioritizing the supplemental benefits afforded by GSI. Additionally, current stormwater BMPs such as infiltration trenches, provide almost the same stormwater capture as GSI, but treat fewer pollutants and do not produce as many additional social benefits. This study quantifies the current choices in stormwater management under proposed urban redevelopment and other scenarios that require reductions of pollutants to the Boise River.

Permeable paver alley Photo courtesy Idaho Rivers United

Bioswale Photo by Jeff Adams

SECTION 2

BOISE STORMWATER INFRASTRUCTURE

The Boise region is classified as a semi-arid climate and averages approximately 11.5 inches of precipitation a year (ACHD 2014). The majority of precipitation falls from November to May and high volume storms are rare. The traditional stormwater infrastructure in the Boise urban area includes municipal separate storm sewers (MS4s). Figure 1 shows a portion of the EPA Phase I permit area, the MS4 outfalls into the Boise River, and examples of existing GSI infrastructure.

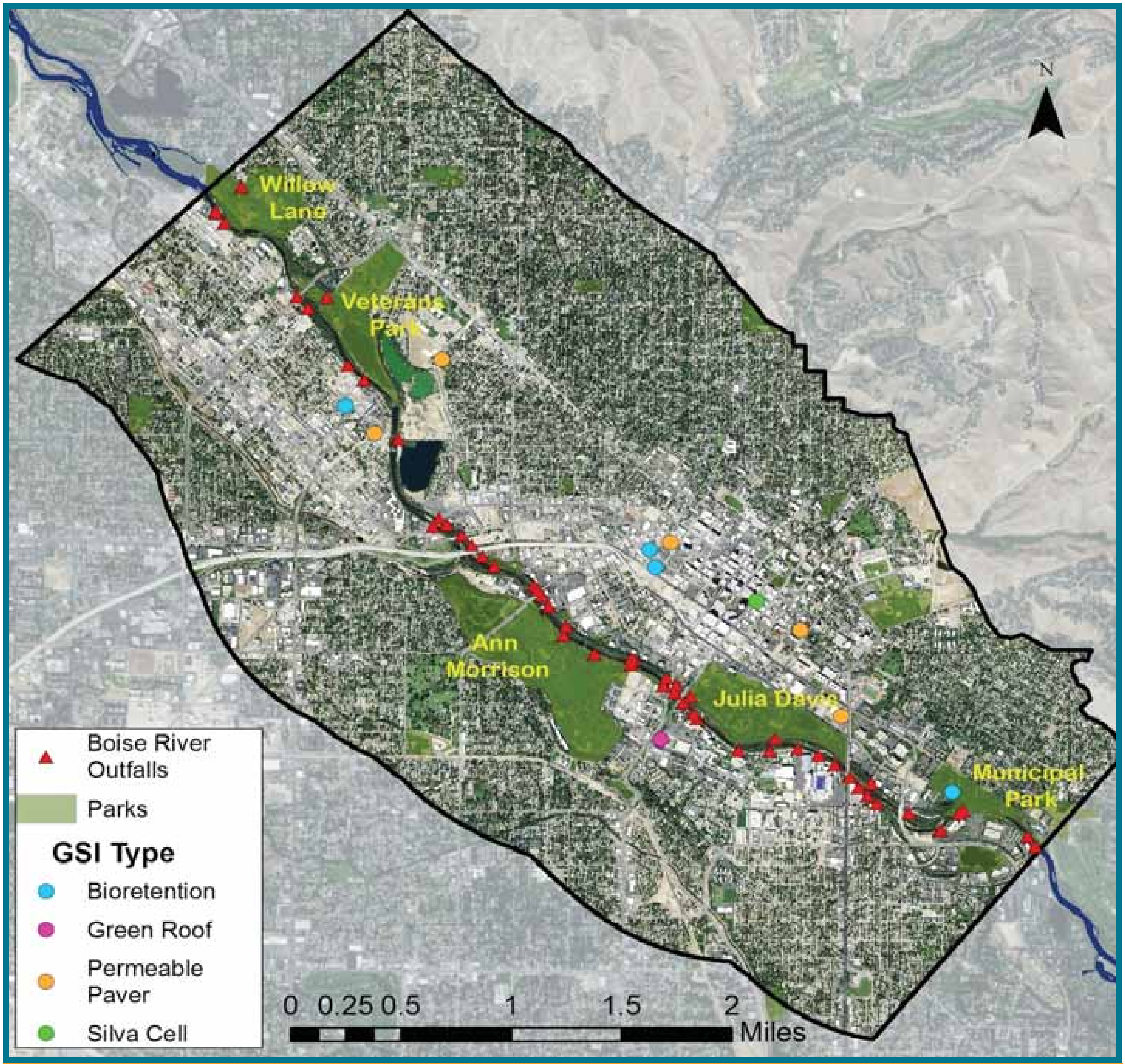


Figure 1: Boise River Downtown MS4 Outfalls and Existing GSI

The Boise River runs through the urban core of Boise. Much of the stormwater coming out of downtown Boise carries pollutants into the Boise River. But with the placement of GSI and with parks and open space acting as large natural infrastructure, the water quality of the Boise River is much better than in the past, when the River was deliberately used to pass pollutants downstream. Major public parks along the Boise River such as Julia Davis, Ann Morrison, Marianne Williams, and Kathryn Albertson provide natural stormwater filtering and infiltration functions. These green spaces along the Boise River provide a much needed function in a dense urban area with lots of impervious asphalt, concrete and hard packed dirt. This green space also provides numerous other benefits in terms of recreation, aesthetics, wildlife habitat, and serves as a cooling agent in the summer.

2.1 Boise Urban Core GSI

The City of Boise practices "retain onsite" stormwater management for new commercial development and has large areas of natural infrastructure in open space, parks, and wetlands along the Boise River in the urban core. In their Phase I permit 2014 Annual Report, Ada County Highway District (ACHD) lists GSI projects in the Boise urban area including a handful of permeable paver and bioretention projects (see Figure 1). Most GSI projects are relatively new. There is little performance monitoring and limited cost data for GSI implemented on private lands.

This report focuses on four types of GSI: tree-systems, bioretention areas, permeable pavers, and bioswales. These four types have been identified by ACHD as appropriate GSI for the Boise urban area and are representative of broader GSI options for urban stormwater re-development. Brief descriptions of examined GSI types are provided below. For full descriptions of these GSI types, please see ACHD's Green Stormwater Infrastructure Guidance Manual (June 2014). A recent technical report on green infrastructure in Milwaukee (CHM2HILL 2013) also has detailed design drawings and specifications for these GSI types.

Bioswale Photo courtesy Idaho Rivers United

Bioretention Photo courtesy Idaho Rivers United

Bioretention

Bioretention units are designed to capture stormwater in vegetated depressions, allowing stormwater to infiltrate into receiving vegetation and soils. Bioretention units can be adapted to many different sizing constraints. This design flexibility afforded by bioretention units makes them a popular GSI choice. Bioretention typically provides the greatest water quality improvements of all GSI (CHM2HILL 2013). The high capture rate of pollutants makes bioretention units a good option for urban areas.

Tree Systems

Tree systems can be considered as one type of bioretention unit. GSI tree systems in right-of-ways consist of engineered soils and suspended pavement systems that provide volume for tree roots and stormwater capture that slowly infiltrates into the ground or is evapotranspired.

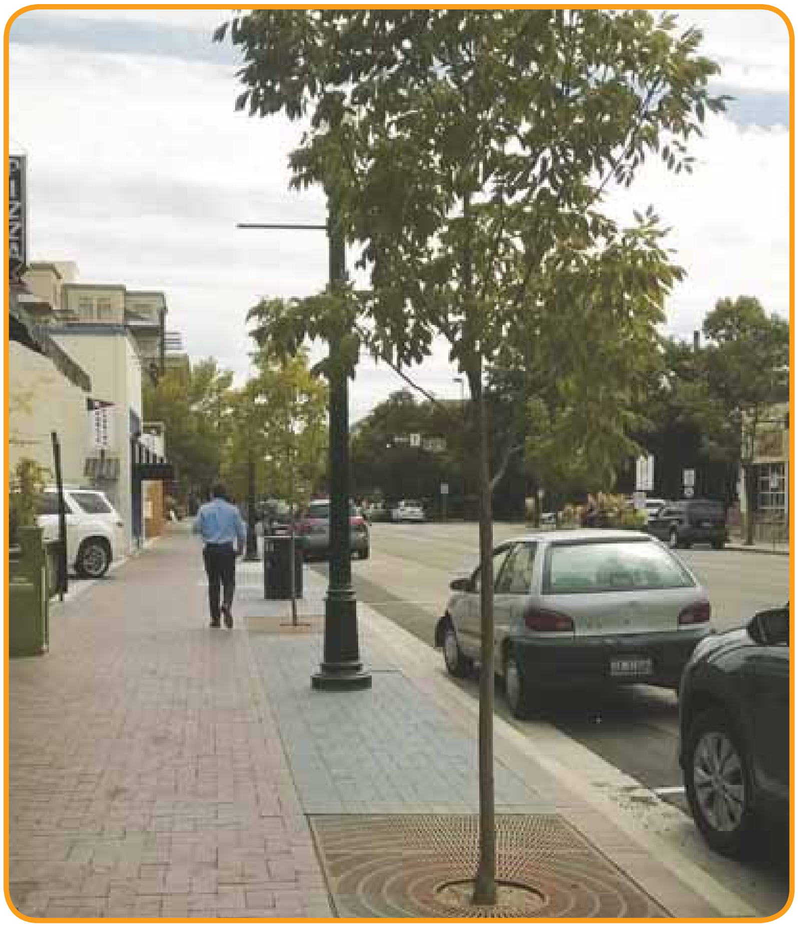
Permeable pavers Photo by Evan Hjerpe

The importance of trees and tree canopy in urban areas has been realized for decades. Trees sequester carbon, bring aesthetic beauty to heavily developed areas, and can improve air quality. Trees with suspended pavement systems provide the most social benefits of all GSI types.

Permeable Pavers

Permeable pavers can be used in areas that need to support low to medium amounts of vehicle traffic such as alleys and parking lots. As opposed to impervious surfaces such as asphalt and continuous concrete, permeable pavers allow for onsite infiltration in between placed pavers. With proper soil/aggregate mixes and appropriate maintenance, permeable pavers can effectively capture stormwater and reduce the need for seepage beds or off-site stormwater retention.

Permeable pavers are typically denoted as Green Stormwater Infrastructure, but are an exception in that there is no inclusion of "green" vegetation. Permeable pavers will not generate biophysical services such as biodiversity or carbon sequestration associated with other types of GSI. But, because permeable pavers slow and diffuse stormwater drainage onsite, they do generate biophysical services such as greater pollutant reduction/dispersion, groundwater recharge, and temperature reduction as compared to asphalt.



Silva cells Photo courtesy Idaho Rivers United

Silva cells Photo courtesy Idaho Rivers United

Bioswale Photo by Jeff Adams

Bioswales

Bioswales are vegetated depressions that collect and convey and, potentially, infiltrate stormwater. Commonly bioswales capture a portion of stormwater and convey the rest of the stormwater to another treatment or into existing MS4s. ACHD standards include both an infiltration bioswale and a conveyance bioswale.

Bioswales are most appropriate where site conditions dictate long skinny infrastructure that does not allow for deep soils and full retention.

In terms of economic performance, bioswales are difficult to compare directly to other GSI types. Because bioswales blend the functions of onsite infiltration and conveyance, they serve a unique niche among GSI.

SECTION 3
METHODS

Economic analysis of stormwater infrastructure in the Boise urban area can provide valuable information about the optimal amount, type and location of green stormwater infrastructure. Two economic questions about GSI in the Boise area are the cost effectiveness and the associated benefits. To answer these questions, this report looks at the costs of different stormwater infrastructures and compares them based on the amount of stormwater captured and pollutants reduced. While all stormwater infrastructures serve to mitigate flooding, GSI provides additional social benefits. The additional benefits are evaluated in order to illustrate that the total economic value of GSI stormwater infrastructure can be much greater than its cost-effectiveness of improving water quality.

Bioretention Photo by Idaho Rivers United

3.1 GSI Cost-Effectiveness

Urban streets and right-of-ways come in all shapes and sizes. Stormwater management needs are determined by site-specific features of the buildings, parking lots, alleys, sidewalks, and open space in the vicinity. Thus, these features will determine the optimal use of GSI. This physical context ultimately determines the drainage/catchment area and the physical dimensions (i.e., width, length, depth) and constraints that define the parameters of the stormwater infrastructure.

To estimate the cost-effectiveness of stormwater infrastructure, four types of GSI were examined and contrasted with two conventional infrastructures that utilized modern best practices. The incorporation of local data is paramount for modeling stormwater management options. To develop an economic model for GSI in the Boise urban area, a hydrologic model for the region that includes annual precipitation, local soil types, and a

Permeable Pavers
Photo courtesy Idaho Rivers United

To estimate the cost-effectiveness of stormwater infrastructure, we examine four types of GSI and contrast them with conventional stormwater infrastructure. Incorporating local data is paramount for stormwater management models.

Silva Cell installation Photo courtesy Idaho Rivers United storm retention goal of the first 0.6 inches of precipitation is used. The basic hydrologic model is then applied to the four types of GSI: tree systems, bioretention areas, permeable pavers and bioswales; and two types of conventional infrastructure: a paved alley with an infiltration trench and a seepage bed and a paved sidewalk with trees, an infiltration trench and a seepage bed.

Two measures of cost-effectiveness are provided: 1) per annual gallons of stormwater captured and 2) per pound of reduced pollutants—specifically Total Phosphorous and Total Suspended Sediment. Each modeled stormwater infrastructure was specified to drain 20,000 square feet of impervious surface from hypothetical right-of-ways, alleys, or parking lots. Costs were gathered from numerous industry and literature sources and include construction, materials, and future maintenance. Costs for permitting, design, and dealing with existing gas and utility lines were not included and are considered to be similar for all stormwater infrastructures. Costs of land and space necessary for GSI and conventional infrastructure were also treated as being similar. However, EPA (2007) and Weiss et al. (2007) found that property costs were generally cheaper for GSI because GSI can be implemented as part of the right-of-way or parking lot, where much of the conventional infrastructure requires additional space for large detention ponds. Please see Appendix A for full cost-effectiveness modeling details.

3.2 GSI Benefits

The Center for Neighborhood Technology and American River's 2010 Guide for valuing green infrastructure (CNT 2010) provides guidance for evaluating benefits of GSI. The Guide includes two main steps for valuing benefits of implementing GSI: 1) Quantify the biophysical or social units of change; and 2) Assess a market value for it, if possible. While this might seem straightforward, the biophysical or social units of change differ depending on the particular specifications of individual GSI types and unique regional contexts. To accurately calculate the range of benefits provided by Boise urban area GSI, every potential biophysical service and social benefit would need to be studied. In the absence of the resources to conduct these types of studies, stormwater managers can use the information and methods in this report to account for the value of GSI. Possible GSI benefits in the Boise urban area are delineated, economic valuation methods are provided, and a few potentially useful market ranges are referenced.

3.2.1 Biophysical Services

All stormwater infrastructures create benefits in terms of site-scale flood mitigation and conveyance of stormwater associated with impervious surfaces. Thus, the additional benefits provided by choosing GSI over traditional stormwater infrastructure are examined in this report. In general, it is the "green" in GSI that provides the additional benefits. Plants and vegetation that accompany most GSI provide a range of biophysical services that yield social benefits. Along with plants, the soil types and infrastructure depths allow for further biophysical services.

These biophysical services lead to, or support, multiple social benefits. The supporting service typically contributes to a social benefit that is measured separately.

Bioretention and Permeable Paver Installations

Photos courtesy Idaho Rivers United

The following biophysical services are most evident in reviews of GSI:

- Waste absorption/Pollutant reduction
- Groundwater recharge
- Carbon sequestration
- Temperature reduction
- Biodiversity/Habitat Provision

Economic valuation of these biophysical services by themselves has been primarily limited to quasi-market and non-market valuation methods. The majority of GSI economic valuation has centered more on measuring the social benefits afforded by these biophysical services. For example, GSI structures absorb waste through pollutant bioremediation. That biophysical service yields social benefits to communities—clean and plentiful drinking water. The economic value of having clean and plentiful drinking water is often measured in terms of drinking water purification costs avoided. For accounting purposes, it is important to remember that the social benefits valued typically include the value of the supporting biophysical services.

When applied to an individual modeled GSI type, the biophysical services discussed above can be very difficult to measure and monitor. But at scale, large tracts of connected GSI can provide substantial biophysical services that support significant social benefits.

3.2.2 Valuing Social Benefits of GSI

GSI performs biophysical services that render social benefits for the Boise urban area. The social benefits are changes in societal welfare due to choosing to implement GSI as opposed to some other stormwater infrastructure. Social benefits of GSI include the following:

- Clean drinking water
- Water supply
- Clean air
- Aesthetics and recreation
- Pedestrian and vehicle safety
- Reduced Heat Island effect
- Education and community engagement
- Compliance credits

In order to accurately estimate the monetary value of additional social benefits afforded by GSI, extensive research is required to calculate the changes in biophysical services with and without GSI and then calculate how the scale of biophysical service change translates into economic value. If stormwater managers want to pursue a dollar quantification of social benefits associated with GSI in the Boise urban area, the following steps are necessary:

- For each type of GSI, each of the five listed biophysical services would need to have monitoring data collected and incorporated into separately analyzed energy and chemical exchange models that account for local biophysical conditions. These studies would determine the size or amount of changed biophysical services afforded by GSI.
- For each type of GSI, each of the eight listed social benefits would also need their own study to investigate the local economic value generated. These study methods are presented immediately below and would determine the economic value of each benefit.
- All the biophysical services and social benefits calculated for each type of GSI would then need to be compared to an alternative, such as the status quo, to determine the difference in services and benefits with and without GSI.

This approach is extremely expensive, requiring numerous studies and expertise, and has rarely been done for GSI. Of the handful of studies that have calculated one or two of these benefits, a transfer of these benefit values to the Boise urban area (i.e., benefits transfer) would be an inaccurate measure of the real regional value as these primary studies were based on different contexts, comparisons and locations. For example, the social value of a tree in Chicago is an extremely poor approximation of its value in Boise. There are no off-the-shelf dollar values of the social benefits of GSI examined in this report that would provide any accuracy for the Boise urban area. In lieu of monetary quantification of the social benefits of GSI, we provide alternate approaches for incorporating GSI benefits into stormwater planning.

Market Based Methods

The first place to look for a correlating economic value associated with benefits of GSI is typically the marketplace. For example, groundwater recharge services

Bioswale Photo courtesy Idaho Rivers United

associated with GSI can lead to more available water for domestic uses. In most municipalities, water consumers are charged a market price for each unit of water consumed. Thus, with more water available under GSI implementation, the value of this water can be assigned the going market values. The difficulty for applying these methods to Boise urban area GSI implementation stems from the limited local experience with GSI and the limited monitoring data to quantify how much groundwater is recharged with GSI as compared to another stormwater infrastructure option.

Surrogate Market Methods

Economic valuation methods known as "revealed preference" methods are used when the commodity being valued is not directly traded in the markets. In these cases, economists look to proxy, or surrogate, markets that can shed light on the commodity in question. The two most well known revealed preference methods are hedonic pricing and travel cost. A good example related to GSI comes from the beautification of right-of-ways and urban areas that are above and beyond what could be achieved by traditional stormwater infrastructure. This beautification, or aesthetic enhancement, has a positive spillover effect on neighboring properties. And while property buyers consider a number of building and lot characteristics that influence prices (e.g., size of building, location, etc.), these property attributes are bundled together. One of these attributes is the aesthetics of the property and surrounding properties. With hedonic pricing methods, economists can isolate the aesthetical contributions of surrounding properties on overall value.

Simulated Market Methods

When dealing with existence and bequest values of green or open space, or other intrinsic values inherent in stormwater infrastructure such as community engagement opportunities, there are typically no market prices with which to establish economic values. In these cases, economists utilize "stated preference" methods to determine economic value. Stated preference methods include contingent valuation and choice experiments that have people participate in simulated hypothetical marketplaces. For example, Poe et al. (2001) conducted a meta-analysis on contingent valuation studies for protecting groundwater and found an average willingness to pay of $531-$736 per household.

Generalizing Previous Findings

Two means of generalizing the value of social benefits are benefits transfer methods and meta-analyses. Benefits transfer methods include applying estimates, or estimate functions, from another study site to the proposed study site. Given the limited information on GSI performance and the relatively nascent development of GSI, along with limited research funds, benefits transfer options are intuitively appealing. But, with the vast range of site dependent characteristics of stormwater infrastructure (e.g., hydrologic regimes, native soils and plants) and unique demographics, benefit transfer of GSI benefits from other studies is likely an inadequate estimate of the benefits found in Boise urban area GSI. Furthermore, there are very few primary studies that have quantified the social benefits of GSI.

Meta-analysis, or synthesizing many primary studies, provides opportunities to generalize studies and apply averages to the proposed study site. While meta-analyses offer a more refined means of benefit transfer, there needs to be many primary studies to synthesize. Unfortunately, there are not many social benefits studies of GSI and, apparently, no meta-analyses on the social benefits of GSI. This report incorporates components of both benefits transfer and meta-analyses by synthesizing and averaging cost data from other places, but does not incorporate benefits determined in other places.

SECTION 4
RESULTS

4.1 Cost-Effectiveness of GSI

The annual costs of GSI and conventional infrastructure are estimated based on their ability to capture equivalent amounts of annual stormwater. For two GSI types, tree systems and permeable pavers, the cost-effectiveness of conventional tree systems and paving that utilize infiltration trenches and seepage beds is examined. Table 1 illustrates the findings.

Looking at the four GSI types, permeable pavers are found to be the most cost-effective means of capturing stormwater and reducing pollutants. But permeable pavers are not appropriate in all locations. Bioretention units were also a very cost-effective means of reducing stormwater pollutants. Suspended pavement tree systems were found to be the least cost effective for infiltrating stormwater, but as discussed in the following sections, GSI tree systems provide the greatest social benefits. Conveyance bioswales were the least cost-effective at reducing total phosphorous, because they only infiltrate a portion of stormwater and convey the rest elsewhere. Figure 2 (p. 18) illustrates the cost-effectiveness of GSI types.

In comparing costs of stormwater infrastructure, the report finds that implementation costs of GSI can be two to three times greater than conventional (BMPs) alternatives used to capture stormwater onsite. Higher costs for GSI make sense as GSI techniques include additional or less common materials and vegetation. But GSI has a much longer lifespan than conventional infrastructure. Based on industry and stormwater management sources (e.g., ACHD Stormwater Manual 8200), all four GSI types were modeled at a 25 year lifespan, while the two conventional types were modeled with a 10 year lifespan. Determining an annualized present value for stormwater infrastructure shows that GSI is about the same in cost-effectiveness as conventional infrastructure at capturing and infiltrating stormwater onsite.

Table 1: Cost-effectiveness for Stormwater and Pollutant Capture

GSI Type[a] (cost level)	Surface Area (sq. ft.)	Total Cost (Present Value)	Annual Cost (Present Value)	$Cost[b]/ 1,000 gallons SW	Cost/lb. of TSS Reduced	Cost/lb. of TP Reduced
Bioretention	1,150.00					
(Low)		$36,634	$1,465	$11		
(Medium)		**$53,381**	**$2,135**	**$17**	**$27**	**$5,043**
(High)		$70,129	$2,805	$22		
Tree System	1,532.13					
(Low)		$76,462	$3,058	$24		
(Medium)		**$99,742**	**$3,990**	**$31**	**$50**	**$10,052**
(High)		$123,023	$4,921	$38		
Permeable pavers	1,265.82					
(Low)		$9,459	$378	$3		
(Medium)		**$15,603**	**$624**	**$5**	**$8**	**$1,685**
(High)		$25,435	$1,017	$8		
Conveyance Bioswale	4,000.00					
(Low)		$33,592	$1,344	$10		
(Medium)		**$73,786**	**$2,951**	**$23**	**$42**	**$11,154**
(High)		$150,304	$6,012	$47		
Conventional Infrastructure						
Conventional Tree System[c]	1,532.13					
(Low)		$17,467	$1,746.72	$14		
(Medium)		**$26,345**	**$2,634.50**	**$20**	**$40**	**$8,297**
(High)		$35,460	$3,546.03	$27		
Conventional Paved Alley[d]	1,265.82					
(Low)		$14,502	$1,450.19	$11		
(Medium)		**$19,920**	**$1,992.00**	**$15**	**$30**	**$6,273**
(High)		$25,576	$2,557.58	$20		

[a] Each GSI Type and Conventional Infrastructure is modeled for 20,000 sq. ft. of drainage area, estimated to capture 128,961 gallons of annual Boise area stormwater.

[b] Costs include materials, construction, and maintenance and are annualized present value over a 25 year time horizon for all GSI and a 10 year lifespan for Conventional infrastructure. A 3% annual discount rate was used for all costs. See Appendix A for calculations and assumptions.

[c] Conventional tree system includes traditional paved sidewalk, trees without suspended pavement systems, infiltration trench, and seepage bed.

[d] Conventional paved alley includes asphalt, infiltration trench, and seepage bed.

When looking at pollutant removal, GSI becomes much more cost-effective compared to conventional infrastructure (Figure 3, p. 18). It costs approximately 20 percent more for conventional infrastructure to reduce sediment, and approximately 24 percent more to reduce phosphorous. It is notable that the report only analyzes the effectiveness of reducing two pollutants—sediment and phosphorous. There are many more pollutants contained in stormwater including Ecoli, temperature, heavy metals, etc. The cost-effectiveness estimates are under-estimates for total pollutant reduction.

In terms of maintenance, slightly greater annual maintenance costs for GSI were found when compared to maintenance for conventional infrastructure. While Houle et al. (2013) found lower maintenance costs for GSI as compared to detention ponds and other conventional stormwater infrastructure, these findings of greater maintenance costs are in line with results from EPA (1999). However, with the nascent development of GSI techniques, there is limited data for comparison's sake. Additionally, documented maintenance costs for traditional stormwater infrastructure reflect economies of scale due to the much greater prevalence and history of these maintenance practices. As GSI proliferates, the authors suspect both the construction costs and maintenance costs will decrease per installation unit as both developers and markets get used to GSI projects.

4.2 Social Benefits of Boise Urban Area GSI

The biophysical services provided by GSI support social benefits. In some cases, the biophysical services hold economic value as a supporting service (e.g., carbon markets and increased groundwater availability).

Figure 2: Cost-Effectiveness of GSI

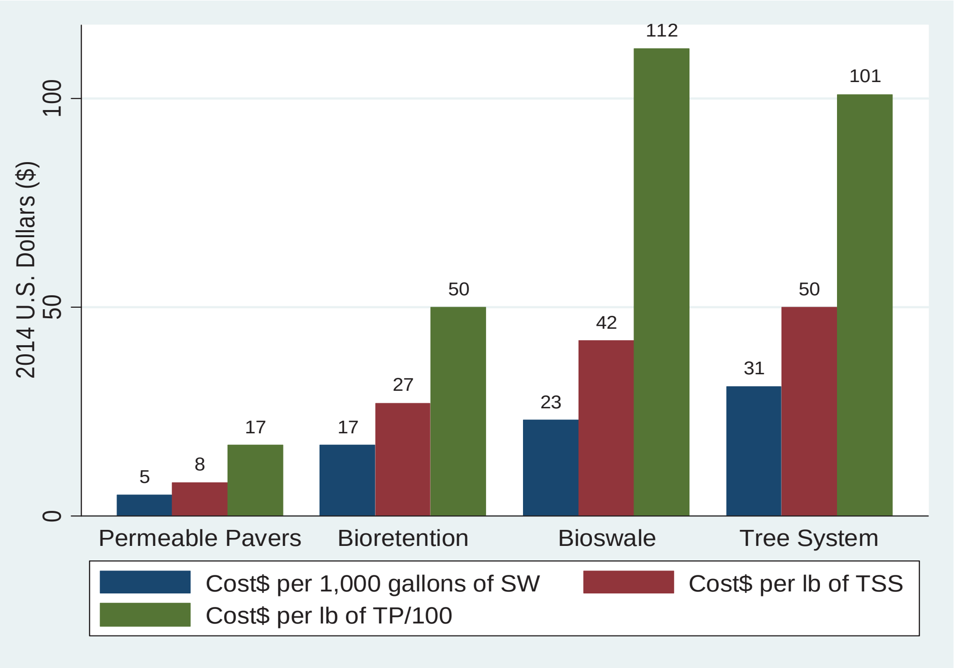
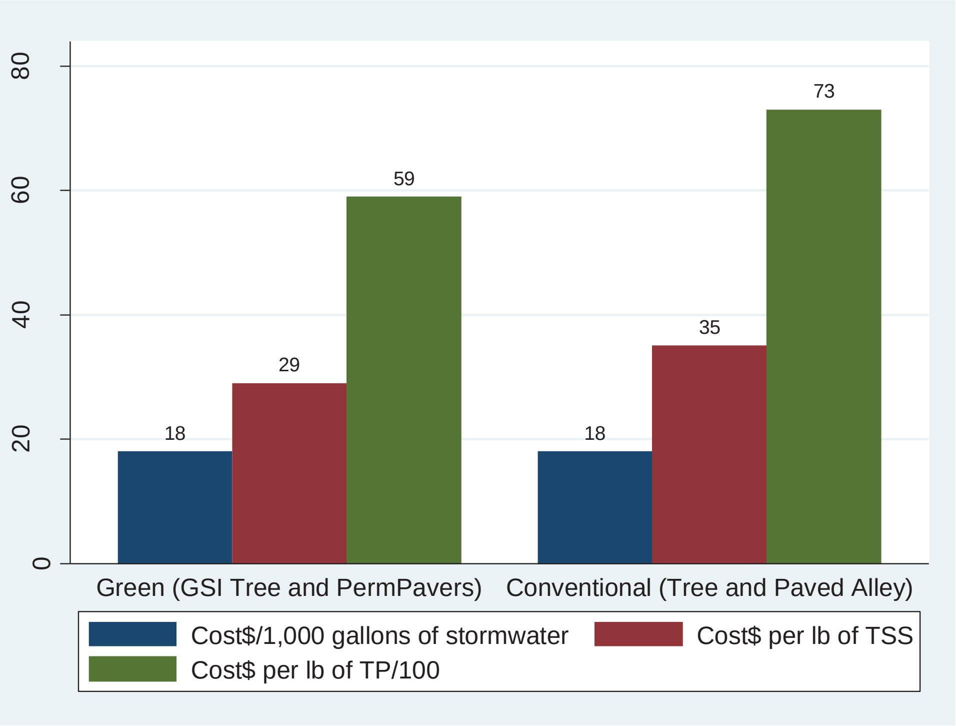


Figure 3: Cost-Effectiveness of GSI vs. Conventional Infrastructure



For example, carbon sequestration has had multiple international markets arranged and numerous economic studies on the societal value of sequestered carbon. Similarly, waste absorption occurs when pollutants are bioremediated in vegetation and healthy soils. Pollutant trading is also beginning as a matter of regulatory compliance to achieve targeted total maximum daily loads (TMDLs). Table 2 illustrates the biophysical services and resultant social benefits for each GSI type.

Table 2: Biophysical Services and Social Benefits of GSI

Benefit	Bioretention	Tree Systems	Permeable Pavers	Bioswale
Biophysical Services				
Waste absorption	YES	YES	YES	YES
Groundwater recharge	YES	YES	YES	YES
Carbon sequestration	YES	YES	NO	YES
Temperature reduction	YES	YES	YES	YES
Biodiversity/Habitat Provision	YES	YES	NO	YES
Social Benefits ($Estimate)				
Clean drinking water (Market Price, Avoided Costs)	YES	YES	YES	YES
Water quantity increases (Market Price)	YES	YES	YES	YES
Aesthetics and recreation (Property value enhancement)	YES	YES	YES	YES
Clean air (Hedonic Pricing)	YES	YES+	NO	YES
Pedestrian and vehicle safety (Avoided Health Costs)	YES	YES	YES	YES
Reduced Heat Island effect (Avoided Costs)	YES	YES+	YES	YES
Education and community engagement (Contingent Value)	?	?	?	?
Compliance Credit (Local Trading Market)	?	?	?	?

For the Boise urban area, the authors hypothesize that the following social benefits of GSI provide the greatest market value. Four example data points relevant for social benefits of GSI in the Boise urban area are provided in Table 3 (p. 20).

Increased Water Quality and Replenishment

Pollution can degrade the quality of both receiving surface waters and groundwater. Because GSI reduces pollutants to the Boise River and groundwater, it results in substantial avoided costs. By improving water quality, GSI supports beneficial uses like aquatic life and recreation. Implementing GSI also relieves polluters from additional pollution reduction costs. Groundwater recharge can also be an important consideration for choosing which types of stormwater infrastructure to employ. Onsite infiltration allows for greater groundwater recharge, an important natural process that is diminished in urban areas. Increased water quality and replenishment can be valued at its market price or for any avoided or reduced water treatment costs.

Table 3: Example Values of GSI Benefits

Social Benefit	Location	GSI Type	Units	Amount	Valuation Method	Source
Reduced Heat Island Effect	Boise, ID	Tree System	Energy savings$/ tree (West aspect)	$48/year	Avoided Cost	TVUTC Assessment (2013)
Air Quality	Boise, ID	Tree System	Lbs. of pollutant reduced/tree	3.86lbs. /year or $24/year	Permit Trading	TVUTC Assessment (2013)
Increased Property Values	Seattle, WA	All types	Property values$	3-5%	Hedonic Pricing	Ward et al. (2008)
Groundwater Protection	U.S.	All types	WTP$/ household	$531-$736	Stated Preference	Poe et al. (2001)

Increased Property Values

A recent study in Seattle found that the implementation of GSI techniques increased adjacent property values by 3 - 5 percent (Ward et al. 2008). This provides value not only to property owners, but also to municipalities in terms of increased property tax revenues. However, there have been very few investigations of this, and none for the Boise urban area. To accurately quantify the amount of increased property value attributable to Boise urban area GSI, a hedonic pricing study would need to be conducted.

Avoided Energy Costs and Emissions

Cleaner source water reduces the need for drinking water treatment. This is an oft cited social benefit of GSI (e.g., Spatari and Montalto 2011). This reduced need for water treatment can lead to avoided energy use. This is primarily a benefit to cities with combined stormwater-sewer systems and resultant CSOs. However, construction and maintenance of stormwater infrastructure takes energy and resources, causing carbon emissions that should be considered when looking at choosing stormwater management infrastructure. This added social benefit has become a large component of green building and other construction life-cycle analyses. In terms of GSI, Moore and Hunt (2013) illustrated that bioretention and permeable pavers generally have lower carbon footprints than traditional pavement.

Air temperature reductions attributable to GSI can lead to both an energy cost savings in buildings located adjacent to GSI and reduced emissions from power plants. For example, reduced heat island effects due to tree systems in Boise have been estimated to save $48/year for adjacent building owners (TVUTC Assessment 2013). This energy cost savings can be further evaluated based on a correlating amount of reduced greenhouse gas emissions. Other vegetation in GSI has similar, but smaller temperature effects, and the pervious nature and optional light coloring of permeable pavers provides for greater cooling than continuous concrete or asphalt. Avoided energy costs and emissions should be a benefit of GSI that is strongly considered when redeveloping urban areas.

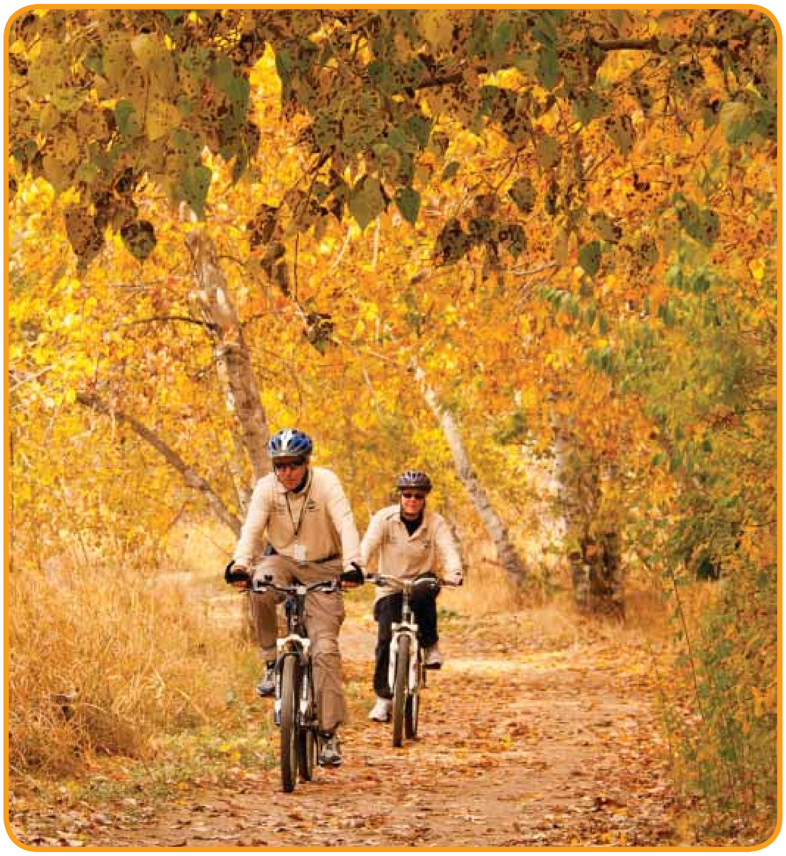
Recreation

At larger scales, GSI types that are connected as open spaces of bioswales and bioretention serve as appealing places for people to recreate. This added recreation benefits the community and likely translates into reduced health costs and increased well-being for individuals. Recreation benefits accrue according to the size of the GSI. The Boise urban area has numerous wetlands and parks, particularly along the Boise River, that serve both as GSI and as recreation and wildlife viewing landscapes. There has been little economic investigation of the values of these larger types of GSI in terms of recreational value.

Other Social Benefits

Other social benefits from GSI also generate economic value. Benefits such as increased pedestrian safety and air quality improvement are likely to be context dependent and at larger scales these benefits become substantial to communities. Similarly, Boise urban area

GSI provides opportunities for community engagement and education. Implementing GSI can help promote stormwater management awareness along with the need for water conservation and pollutant reductions. Community engagement programs in other areas, such as the Watershed Management Group (https://watershedmg.org/) in Tucson, Arizona and the Surfrider Ocean Friendly Gardens program (http://www.surfrider.org/programs/entry/ocean-friendly-gardens), are showing a growing interest from citizens to participate in stormwater management solutions both through investments on their own private property and through volunteering time at organized workshops and events to implement GSI solutions. This type of community engagement programming serves as a model for the Boise urban area and has the potential to expand the implementation and support of GSI.



Recreation on Boise River Photo by Steve Bly

Painted curb cut Photo by Jeff Adams

SECTION 5
GSI ECONOMIC APPLICATIONS

Bioretention

Photo by Jeff Adams

Assessing the economics of stormwater infrastructure in the Boise urban area has provided a means for determining cost-effectiveness and benefits for future projects and development. Currently, stormwater infrastructure development and retrofitting in the Boise urban area are planned without the consideration of the full suite of long term benefits and costs. Understanding the economics of new stormwater infrastructure can provide decision makers with an additional economics filter for viewing tradeoffs involved in stormwater management.

GSI can cost more initially than conventional infrastructure now used to infiltrate stormwater onsite. But due to longer life expectancy of GSI, GSI is as cost-effective as conventional infrastructure at capturing stormwater. GSI has higher rates of pollutant reduction, and is more cost-effective than conventional infrastructure when comparing their effectiveness at reducing pollutants. When the additional benefits provided by GSI are accounted for, GSI will generally provide greater economic value than conventional infrastructure.

The relative newness of GSI suggests that costs per unit will decrease as more GSI is implemented. As with any new markets, the costs of implementation for GSI currently suffer from inexperienced workforces and a lack of performance monitoring. As GSI practices become more prevalent and streamlined, so too will the accounting of the overall costs and benefits. And as GSI use increases, economies of scale and greater efficiencies will make GSI even more cost-effective as compared to traditional stormwater infrastructure.

The findings of this study suggest that stormwater managers should consider the additional social benefits provided by GSI to appropriately value this infrastructure and wisely invest limited stormwater management funds. If stormwater stakeholders do not have the resources to conduct the number of studies needed for quantifying the monetary value of all GSI benefits, there are means to more simply quantify the social benefits of GSI within a non-monetary economic accounting of stormwater infrastructure. Utilizing a presence-or-absence type of checklist as provided in this report, stormwater managers can assign weights to the importance of each social benefit and to the overall costs of the project. Under a multi-objective decision making framework (also known as multi-criteria optimization), different stormwater infrastructure alternatives would have different scores based on their overall weighted averages, illustrating which infrastructure type is best suited for the proposed project site.

Accurately determining the scale of value provided by the additional social benefits can be complex and takes dedicated science funding. But monetary quantifications are not always necessary to understand the economic value of alternatives. Monetary quantifications of non-market benefits, especially through the use of benefits transfer, are often at best a rough placeholder, and at worst an inaccurate interpretation leading to non-optimal and inefficient solutions. The additional social benefits of GSI have an economic value greater than zero. This suggests that stormwater managers should deliberately consider the additional benefits in some manner, be it qualitatively or quantitatively.

For instance, pedestrian and driver safety may be an important consideration when redeveloping urban areas. If so, the additional benefits of GSI include an increase in traffic safety. Because this added value is difficult to quantify in dollars, does not mean the social benefit should be ignored when determining cost-benefit ratios. Another example is neighborhood beautification and aesthetic enhancement provided by GSI that results in improved quality of life and enhanced property values. In key locations in the urban area, this added social benefit provides significant justification for choosing GSI. The final determination of optimal implementation of GSI should be based on the additional benefits GSI provides. The valuation and prioritization of benefits beyond flood mitigation differ but all of the benefits of GSI must be fully considered to make the best use of public and private funds.

SECTION 6

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Appendix A
Methods for Calculating Costs of GSI

Numerous references and projects were synthesized in order to model stormwater infrastructure costs and pollutant removal rates. For the Boise urban area, implementation of GSI is just starting and there is extremely limited tracking and monitoring data available. Costs for only three GSI projects (two permeable paver alleys and one tree system) are available. The modeled cost and performance metrics are therefore based on projects, industry sources and models from other regions.

Drainage Capacity

To compare costs, four GSI types were evaluated, each one at three drainage capacities. At the low end, 5,000 square feet of drainage area was evaluated as this is the minimum drainage area triggering compliance with the NPDES Phase I permit. Larger GSI structures capable of capturing 20,000 and 40,000 square feet of drainage, or roughly a half acre and one acre were also evaluated. The costs and removal rates for the medium size, 20,000 square feet of drainage, are presented in the Results. The costs findings were linear meaning that each size of GSI had a similar ratio of costs. Economies of scale are likely present in stormwater infrastructure that would result in lower costs per square foot of drainage as project size increases, but it was not possible to verify efficiency gains in larger projects with such limited data.

Ratio of Drainage to Treatment Area

Each GSI type has a unique and varying ratio of drainage area to treatment area, or the surface area of the infrastructure. At the individual project level, this ratio is dependent on the local conditions and context. For example, a bioretention unit may be draining roads and a parking lot, where tree systems may be draining building rooftops. The ratio of drainage area to treatment area is also dependent upon the design specifics of the infrastructure in terms of depth, type of soils used, and design. Drainage and treatment sizes from multiple projects and designer specifications were reviewed and overall averages were used.

Boise Urban Hydrologic Information

The performance of GSI types was modeled to capture 0.6 inches of precipitation. It is the initial flush of a storm that carries the most pollutants. To determine average annual stormwater capacity and pollutant loads, the annual estimated precipitation for the Boise area (11.5 inches) was used. This amount of stormwater is multiplied by a runoff coefficient (0.9) for impervious surfaces and by the drainage area modeled (20,000 sq. ft.). Or:

P(precipitation) * Rc(runoff coefficient) * D(drainage area) = Captured Stormwater (gallons)

11.5 in. * 0.9 * 20,000 sq.ft. = 129,000 annual gallons of captured stormwater

All stormwater infrastructure types in our analysis were sized to capture 129,000 gallons of annual stormwater.

Pollutant Calculations

Stormwater pollutant monitoring in the Boise urban area has been ongoing since 2000. To estimate average annual pollutant loads, monitoring data from the EPA NPDES Permit year 2013-2014 was used. Pollutant loading estimates were taken from wet samples during four storms. These data were analyzed in the five subwatersheds: Lucky, Whitewater, Main, Stilson, and Americana. This data is presented in Appendix 13, Table 10, of ACHD's annual report for Permit year 2013-2014 (ACHD 2015). Samples from all four storms and all five subwatersheds were averaged. The resulting average total phosphorous load was 0.49 mg/liter. The resulting average total suspended sediment was 82.1 mg/liter.

Each stormwater infrastructure type is differently suited to reduce pollutants when capturing stormwater. The two primary means of reducing pollutants are bioremediation of pollutants through uptake in vegetation and slowly capturing, dissolving, and/or dispersing pollutants, often bound to sediments, into the soil or other substrate. Total reduced pollutants for each stormwater infrastructure type were calculated by collecting and synthesizing overall pollutant reduction rates based on ACHD Stormwater Design Manual (Section 8200) and other literature and industry sources. The following table illustrates pollutant reduction rates assumed in the model:

Table A-1: Estimated Pollutant Reduction Rates for Stormwater Infrastructure

Stormwater Infrastructure Type	Phosphorous Reduction Rate	Sediment Reduction Rate
GSI		
Bioretention	0.80	0.90
Tree System	0.75	0.90
Permeable Pavers	0.70	0.90
Bioswale	0.50	0.80
Conventional		
Conventional Tree System	0.60	0.75
Conventional Paved Alley	0.60	0.75

Calculations for cost per pound of reduced pollutant first required an estimated amount of annually reduced pollutants based on the GSI and traditional types specified to drain 20,000 square feet. Then, annual costs of stormwater infrastructure presented in Table 1 were divided by annual pounds of reduced pollutants:

Captured SW(gallons) * PL (pollution load) * Prr (pollution reduction rate) = Reduced Pollutants (lbs.)

Annual Cost ($)/Annual pounds of reduced pollutants = Cost per pound of pollutant reduction

Pollutant averages for phosphorous are noticeably lower, by about 50%, in the Boise urban area than midpoints for all U.S. stormwater referenced in CHM2HILL (2011). Reduction rates for Ecoli were also investigated, but little difference in Ecoli reduction rates for the stormwater infrastructure types were found. Generally, all types were found to be greater than 70% effective at capturing and reducing Ecoli.

Assumptions for All Modeled Stormwater Infrastructure

The use of the model to determine stormwater gallons and pollutant loads assumes the following restrictions:

- All costs include construction, raw materials, and future maintenance. Design, permitting, and administration costs are NOT included in calculations, nor are the costs for relocating existing utility and gas lines or other site specific infrastructure.

- Conveyance infrastructure to the stormwater management unit, including inlets, curb and gutters are assumed to be same for GSI and conventional infrastructure. Likewise, pretreatment sumps and observation wells are assumed to be same for GSI and conventional infrastructure.

- Sizing is based on instantaneous volume approximations for storage/treatment for Vwq (0.6 inch) event, based on listed Ratio Drainage to Treatment, while actual systems will need to be engineered to site-specific conditions based on Design Manual and BMPs.

Appendix B

Documentation for GSI Specification and Cost Sources

To parcel out GSI specifications and to build our cost model, we pursued numerous literature and industry sources. The following list provides full documentation of our sourced information for each type of stormwater infrastructure.

Bioretention Design and Effectiveness

1. Green Stormwater Infrastructure Guidence Manual - ACHD - June 2014
2. ACHD Section 8200 Stormwater Design Manual
3. Evaluation of Green Infrastructure Practices Using Life Cycle Assessment by Kevin Martin Flynn, P.E. (accessed 4.13.15 at http://www1.villanova.edu/content/dam/villanova/engineering/vcase/vusp/Flynn-THesis-11.pdf
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13. BioRetention Basin, BMP 9, Catalog of Stormwater BMP's for Idaho Cities and Counties, ID Dept of Environmental Quality, 2005

Tree System Design and Effectiveness

1. Silva Cell Operations and Maintenance Manual by DeepRoot
2. Green Stormwater Infrastructure Guidence Manual - ACHD - June 2014
3. http://www.deeproot.com/products/silva-cell/cost
4. Investments vs Returns for Healthy Urban Trees: Lifecycle Cost Analysis by The Kestral Design Group Inc/ deeproot

5. Field Monitoring of Two Silva Cell Installations in Wilmongton, North Carolina: Final Report by J.L Page, R.J. Winston, W.F. Hunt III, 2014
6. River Myrtle Streetscape, Boise ID, Preliminary Calculations by DeepRoot (dated 2.20.2015)
7. Cost Analysis of LID BMP's, Amy H. Brennan, Chagrin River Watershed Partners inc. (accessed on 4.22.15 at http://www.dot.state.oh.us/Divisions/Planning/LocalPrograms/LTAP/Notes% 20Pages%20Slide%20Presentation%20Files/Notes_Pages_CRWP_LID_Costs_20111128.pdf)
8. Email from Boise City representatives - 5.21.2015

Permeable Pavers Design and Effectiveness

1. Permeable Paver Monitoring Report - Water Year 2014 by Ada County Highway Department
2. ACHD Section 8200 Stormwater Design Manual
3. Fact sheet: Permeable Interlocking Concrete Pavement (PICP) for Municipal Officials by Interlocking Concrete Pavement Institute (http://www.icpi.org/permeable on 3.3.15)
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7. Fact Sheet: GSI Facility Permeable Pavers by Ada County Highway Department
8. PICP Manual by David R. Smith, 3rd edition (http://www.idealconcreteblock.com/tl_files/pages/designers/know-green/PICP_Manual_3rd_ edition.pdf)
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Flyfishing on the Boise River

Photo by Steve Bly

GREEN STORMWATER INFRASTRUCTURE ECONOMICS IN THE BOISE URBAN AREA

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