Estimating Benefits and Costs of Stormwater Management

Part I: Methods and Challenges

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ENVIRONMENTAL FINANCE CENTER
AT SACRAMENTO STATE

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About the EFC at Sacramento State

The EPA Region 9 Environmental Finance Center is operated by the Office of Water Programs (OWP) at California State University, Sacramento (Sacramento State). The EFC at Sacramento State assists state and local governments, tribal communities, and non-profits in EPA Region 9 with financial planning, asset management, and data analysis. The goal of the EFC is to support these entities in building the capacity to sustainably fund environmental and public health programs for residents.

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Low Impact Development (LID)
Stormwater Management

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1. Introduction

Municipal stormwater (drainage) infrastructure was originally built to control flooding, conveying runoff away from city streets quickly. In some cities, especially in drier climates, drainage infrastructure also collects runoff even when it does not rain, largely from over-irrigation. In the past, stormwater management was typically a secondary concern to water supply and wastewater management. In the US today, however, stormwater management efforts are growing as municipalities recognize the need for institutionalized stormwater programs. The reasons vary. For some, regulatory requirements drive investments to deal with combined sewer overflows, pollution, flooding, and erosion in local streams and rivers. For others, urban water planners hope to benefit from integrating management across water sectors.

> *Stormwater utilities* are established entities within a municipality with the directive and authority to fund stormwater activities, hire personnel and contractors, and manage dedicated revenues.
>
> *Stormwater programs* are the collection of activities that a city undertakes to manage stormwater, which can include permit compliance, operations, maintenance, and stormwater projects.
>
> *Stormwater projects* are devices designed and installed to manage stormwater in a city, such as bioretention basins, swales, or storage tanks.

Stormwater management is one need among many in municipalities. Schools, road maintenance, personnel, and many other expenses all compete for limited local funds. In addition, stormwater management emerged later than many municipal needs. Stormwater management duties have expanded beyond flood control to incorporate larger cross-cutting goals ranging from protecting and restoring local watersheds to creating new green spaces in otherwise concrete-dominated urban areas. Other goals hope to recharge local groundwater basins that provide water supply. The change in approach is significant for cities, counties, and water utilities.

In many municipalities, planning procedures and funding structures are not prepared for this new era of stormwater management. Many municipalities have no dedicated funding streams for stormwater programs, instead relying on general funds that get allocated among the many services that municipalities provide. Others have established utilities with dedicated funding streams. However, for all types, limited information exists on the full range of costs in urban stormwater, which can include everything from new projects with green infrastructure (GI) and stormwater control measures (SCMs; also called best management practices or BMPs) to regular activities required by stormwater permits. Greater clarity is essential for building effective capacity for managing stormwater in cities.

About this guide

This guide aims to clarify complex economic and public administration topics so that the concepts can be put to practical use in municipal planning. The US Environmental Protection Agency's Region 9 (EPA Region 9) Environmental Finance Center (EFC) at Sacramento State created the guide as part of a project to provide improved resources for determining benefits and costs of urban stormwater operations. As Part I of the project, the guide focuses on methods for benefit-cost analysis (BCA) of individual projects, as well as estimating cost projections across the suite of activities and infrastructure that stormwater utilities undertake. The intent is to provide a comprehensive description of methods and resources that municipalities can use in creating and managing their utilities. It focuses on guidance that is relevant to EPA Region 9 (California, Arizona, Nevada, Hawaii, the Pacific territories, and tribal lands).

Part II of the project will collect, synthesize, and disseminate data on costs and (to the extent available) benefits for local stormwater programs and projects in EPA Region 9 municipalities. There are a growing number of resources available to

> Benefit-cost analysis (BCA) and cost-benefit analysis (CBA) refer to the process of estimating the total value of a project based on projected positive outcomes and expenses. While both terms are common, some researchers distinguish between the terms by noting that BCA is more contemporary and reflects recent approaches to comprehensively include benefits. Throughout the guide, we use the term benefit-cost analysis.
>
> While BCA is common and increasingly used for stormwater planning, other methods are available that incorporate benefit assessments, including systems analysis, risk modeling, and ecosystem services analysis (Diringer et al, 2019).

assist in assessing stormwater costs, but many focus on project construction and maintenance. Often, they draw on data from larger municipalities (Phase I) where construction and labor costs are higher. They may not address local and regional differences in costs, leaving smaller communities (Phase II) with limited information to get programs up and running. There exists a knowledge gap in assessing stormwater program costs for water quality compliance. These costs, combined with the costs for existing and future stormwater projects, define the long-term revenue needs that are critical to developing sustainable funding sources. Together, the two reports offer new resources for communities in EPA Region 9 and across the country.

Figure 1: Urban storm drains are typical of 20th Century approaches to stormwater management (left), while more recent green infrastructure approaches seek to retain water on landscapes for multiple benefits (right) (Sources: Wikipedia, EPA via Flickr)

Funding needs in cities

Local governments have multiple spending priorities. Continuing responsibilities for social services and infrastructure, long-term liabilities for pensions and benefits, and limited local revenues all contribute to the collection of expenses faced by cities and counties. As stormwater permit compliance requirements expand and smaller cities begin actively managing stormwater, growing stormwater spending requirements compete against other services that local governments provide.

To address shortfalls, an increasing number of cities throughout the US are pursuing sustainable funding sources for stormwater, assembling funds from general municipal budgets, grants, loans, and dedicated fees. Funding needs vary across stormwater program duties, with periodic or one-time opportunities as well as regular, ongoing expenses. New infrastructure projects incur large costs for planning, design, and construction. These costs can be spread over time through debt financing, which allows governments to allocate upfront project costs over time, or projects can be managed on a "pay-as-you-go" basis, with projects completed as new funds are acquired. Planning and construction costs for new projects can come from existing funds, grants, loans, and bonds. Bonds and grants often do not provide any funds for on-going operations and maintenance costs. Program costs, such as those for collecting water quality samples or conducting outreach campaigns, are regular and predictable but often require funding raised at the local level, including stormwater parcel fees or municipal funds.

Thus, municipal stormwater management requires periodic large investments along with regular funding for program activities. This all occurs within an era of local government budget constraints. Developing tools that reduce the time and resources that municipal stormwater managers spend on developing cost estimates can have cascading benefits for municipal budgets.

Figure 2: Pollutant transport from storm drains as a result of untreated stormwater discharge (left) and signage to increase public awareness of storm drain connectedness (Source: Draper City, UT, Timothy Valentine on Flickr)

Are municipal stormwater budgets growing?

Municipalities throughout the US are identifying new funding for stormwater management requirements. Momentum is building to understand funding gaps (the difference between funding needs and available funding) for stormwater management.

Studies have not examined how stormwater expenditures vary across cities, including comparisons between stormwater funding and other sectors of local government. Additionally, there is little information on how spending on stormwater compares to inflation, especially in a time of strained local government budgets. Collecting more and better data on stormwater utility funding and operations would help fill current knowledge gaps regarding the state of stormwater spending and future needs.

Stormwater management strategies

Most stormwater systems have traditional components that emphasize drainage (capture and conveyance), while more recently cities have integrated green infrastructure (alternatively called low-impact development in the US) to promote retention and infiltration. The nomenclature is not standard across communities or regions. Some sources categorize these components as grey devices used for capture and conveyance or green devices that capture, retain, and infiltrate. The term stormwater control measures (SCMs) is advocated to refer to all types of stormwater infrastructure and devices used in municipal systems.

Common drainage infrastructure can include gravity and force mains (large pipes), smaller lateral line pipes, catch basins and inlets, detention basins, culverts, manholes, valves, and pumps. Each of these will have descriptive characteristics, such as date of installation (age), material, size, flow capacity, and depth.

Green infrastructure includes many types of SCMs designed to retain water in the landscape and reduce downstream discharges. Potential green infrastructure devices include bioretention and biofiltration, detention and infiltration basins, media filters, porous pavement, green streets, biostrips, and bioswales. Projects can come in many designs and sizes, from small on-site devices in front yards to large regional projects capturing runoff from small watersheds. For example, bioretention planters can have various media and gravel depths and may or may not have underdrains; the differences in these features results in different facility costs. Table 1 lists some common types of green infrastructure for managing stormwater, along with some practices to promote environmental restoration in streams and waterways.

Table 1: Types of stormwater management infrastructure

Infrastructure	SCM/Restoration Type
Infiltration devices (including LID & green streets)	Bioretention planter or bioretention facility
	Biostrip or vegetated filter strip
	Bioswale (swale, vegetated swale)
	Green roof
	Green street
	Infiltration basin, gallery, or trench
	Porous pavement, pervious pavement
	Rain garden
	Disconnected impervious surfaces, disconnected downspouts
	Tree planting and preservation
	Alternative driveways
	Wet pond or wetland
Non-infiltrating devices	Rain barrel or cistern
	Detention basin
	Lined (non-infiltrating) planter, stormwater planter (flow-through), tree box biofilter
	Media filter, sand filter
	Vortex separator or drain inlet insert
Restoration practices	Stream bed and bank stabilization
	Riparian buffer enhancement and protection
	In-stream enhancement
	Floodplain reconnection

Estimating stormwater management costs can occur for projects and programs at local or regional scales. At the project scale, projects have associated costs that are estimated as part of design and planning processes. At a regional program scale, stormwater management costs involve the infrastructure systems of many components, along with activities for maintenance, monitoring, and administration. For all these, assessment methods typically use a “bottom-up” approach that applies unit costs for activities, materials, and labor to the quantity needed in developing a total cost.

Greater clarity is emerging on the unit costs of various types of GI and SCMs to complement existing knowledge about the costs of traditional capture and conveyance stormwater infrastructure. However, fewer examples exist to help benchmark stormwater program costs, which include all the activities necessary for permit compliance (illicit discharge enforcement, education and outreach, water quality monitoring, etc.) along with maintaining existing infrastructure and building new projects. Utilities and regulators need further guidance to help predict costs and evaluate the cost estimates they receive.

The EFC groups municipal stormwater program expenses into three categories:

- Operations and maintenance of existing assets—Costs associated with operations and maintenance (O&M) of the existing infrastructure system must be estimated. This includes both drainage (gray) and water quality (green) assets. The frequency and extent of maintenance activities drives the cost estimates. Activities are outlined via a level of service (LOS) that the municipal utility provides for residents. An LOS plan describes how often inspections, repair, and replacement occur, and detail the labor and material needs for each. A higher LOS implies more proactive maintenance actions. Unit costs for materials and labor are applied to the LOS to estimate overall annual O&M costs.
- Permit compliance—Municipal stormwater systems must comply with National Pollutant Discharge Elimination System (NPDES) permit requirements outlined by state or federal regulators. These include specific activities such as construction site runoff control, illicit discharge detection, pollution prevention, public education, and water quality monitoring, as well as associated materials and equipment. Permit compliance activities should also include labor costs for program administration and staff.
- Future buildouts—Municipalities also invest in additional infrastructure to meet water quality standards established by the Clean Water Act. The extent (or existence) of plans for future infrastructure varies widely across communities. In some parts of western North America, municipalities are planning for significant investments in new centralized and distributed stormwater devices for water quality, drainage, and water supply goals. Within EPA Region 9, for instance, some southern California communities have outlined infrastructure investment plans to invest in future urban stormwater systems that meet NPDES requirements, including total maximum daily loads (TMDLs) of discharges to receiving waters. Some are planning stormwater capture projects for direct use

or groundwater recharge. In addition to addressing water quality and water supply needs, new infrastructure may reduce flood risk or mitigate runoff from new development. Table 2 presents examples of each cost category.

Table 2: Categories of costs and examples and considerations in stormwater management

Cost Category	Examples and Considerations
O&M for existing assets	• Labor, materials, and equipment costs related to inspections, repairs, and replacements for infrastructure. • Typical systems include drains, sewer pipes, gutters, and other components that must be maintained. • O&M for new items, including green and gray infrastructure, may be included.
Permit compliance	• Compliance costs vary by state and jurisdictions, but can include activities such as: o Water quality testing and monitoring o Construction site runoff control o Detection and elimination of illegal discharges o Construction and post-construction measures for new and re-development o Pollution prevention o Outreach education, and public involvement o Reporting • Many of these activities include labor and equipment/materials costs. • Some activities, such as preventing stormwater contaminants at municipal sites, may also require labor and capital.
New infrastructure and future buildouts	• New infrastructure could address needs for: o Conveyance through gray infrastructure for drainage o Capture and use (i.e., capture for infiltration and recharge or direct use) o TMDLs or other water quality standards • Project costs should include capital costs, contingencies, permits and approvals, and long-term operations and maintenance. • Once built, new infrastructure O&M costs become part of the expenses associated with existing assets.

Each category of stormwater utility expenses can have direct costs (infrastructure or compliance activities) and indirect costs for labor and management, rent, equipment, and benefits that are attributable to a department/utility. Organizations recover indirect costs in many ways. In a municipality, such expenses could be paid through general funds if all employee expenses are centrally managed. In other cases, the stormwater program may be responsible for individual employee and office costs. Managers should consider both direct and indirect costs when developing asset management and funding plans. Chapter 3 provides further information on cost categories and guidance for incorporating indirect costs into project and program estimates.

Categorizing permit compliance and O&M activities

While costs for permit compliance and O&M are considered separately in the categorization just discussed, in some cases, municipalities combine costs. Most municipal stormwater programs must conduct routine maintenance and comply with NPDES permits. Such O&M activities assist with preventive and corrective maintenance and can include anything from opening manholes to investigating pipe conditions to walking drainage canals and evaluating structural integrity. Other example activities include visual inspections, cleaning and debris clearing, and data management. Whether a municipality counts these as permit compliance or existing system O&M depends on several factors. For example, cities may choose to incorporate O&M costs as permit compliance because they must do O&M as a requirement for compliance. Alternatively, cities may have an existing funding source to maintain drainage systems and prefer to categorize maintenance under the existing system O&M category. Categorizing costs ultimately depends on the method that makes sense for the responsible entity. For NPDES compliance, required activities can be categorized according to common components of NPDES permits, often referred to as minimum control measures, as shown in Table 3.

Figure 3: Stormwater capture devices for runoff management: green streets with curb cutouts (left) and infiltration swales (right) (Sources: BASMAA, OWP).

Table 3: Categories of permit compliance costs and associated activities

Cost Category	Typical Activities
Construction site stormwater runoff control	• Develop/update best management practices handbooks/resources • Issue grading permits • Reviewing stormwater pollution prevention plans • Issue of enforcement actions • Send winterization letters • Develop/maintain database to track inspections and enforcement actions
Illicit discharge detection and elimination	• Investigate calls reporting potential illicit discharge • Issue enforcement actions
Industrial and commercial management	• Conduct inspections • Develop/update handbooks and resources • Issue enforcement actions
Pollution prevention and good housekeeping for municipal operations	• Street sweeping • Drainage system maintenance • Pump station cleaning • Public facility maintenance
Post-construction stormwater management for new and re-development	• Develop/update handbooks and resources • Review plans and issue permits • Issue enforcement actions • Develop/maintain database to track new infrastructure
Public education, outreach, involvement, and participation	• Develop integrated pest management (IPM) • Public service announcements and advertisements
Water quality monitoring	• Preparing quality assurance plans and sampling plans • Sample collection • Sample laboratory analysis • Data analysis and reporting
Overall stormwater program management	• Program effectiveness assessment • Annual reporting • Permit compliance administration • Budget planning and asset management

Avoiding duplicate costs

To assemble an accounting framework for tracking the costs of stormwater program elements, utility managers make choices about where to record costs for activities and capital investments. In recording and tallying costs, a utility should ensure that "double-counting" does not occur.

As an example, under the pollution prevention and good housekeeping for municipal operations cost category of minimum control measures for permit compliance (Table 3), one potential activity is drainage system maintenance, including clearing drains or removing sediment from a collection chamber before a rainfall event. These tasks could also be incorporated as costs under existing system operations and maintenance. The program manager should choose which category to use in recording the expense and document this procedure for future efforts.

Municipal stormwater programs often report costs through annual reports to regulators. These help detail the costs of minimum control measures in permit compliance as well as compliance with water quality regulations (e.g., TMDLs). Where required by permits, stormwater program managers may find it advantageous to track costs for all permit-required activities as part of the permit compliance category to help facilitate reporting.

Other constraints, such as municipal budgeting procedures or debt reporting requirements, could also influence how a stormwater manager chooses to keep track of costs. No matter the approach, managers should fully document the methods and maintain consistency to enable comparisons across years. Standardizing practices through a method developed in collaboration with colleagues in charge of finances will help in establishing a long-term structure that can last throughout personnel changes.

Assessing costs and benefits are critical steps for estimating the financial needs of a municipal stormwater program. A number of existing sources provide guidance on these activities for urban stormwater management. Most, however, are tailored to assess benefits and costs for individual projects, especially GI. Municipalities can also have a host of stormwater program needs that span monitoring, coordination, education, and routine maintenance. Cities need more guidance to better assess the costs and benefits of stormwater management activities on the way to solidifying successful programs. This section provides insight on various methods and approaches.

Figure 4: Rain garden stormwater capture device on the campus of Sacramento State University, an example of green infrastructure (Source: OWP)

The analysis of benefits and costs is part of asset management, a process to identify and prioritize current and future costs for managing a system. Asset management supports planning for long-term investments across many types of systems, from factories to municipal infrastructure. In stormwater, an asset management program that includes programmatic activities and infrastructure needs includes basic steps:

1. Creating an inventory of current assets
2. Defining an LOS for maintenance
3. Estimating program and infrastructure costs
4. Conducting a financial capability analysis
5. Developing funding sources

Throughout the process, public engagement is critical. Asset management is a tool to support sustainable and adequately-funded stormwater programs, which may ultimately require new fees or taxes. When stormwater managers engage residents, businesses, and elected leaders regarding the value of drainage, watershed quality, and flood risk management, it enables future conversations for funding. Asset management helps to understand current system needs and annual costs for activities. Communicating this with residents, utility managers, and elected leaders helps communicate the value of stormwater programs.

There are many resources to assist in getting started on asset management, including tools developed by Environmental Finance Centers for conducting asset management and developing sustainable funding sources for municipal stormwater. For instance, the EFC at Sacramento State created an open-source toolkit for stormwater system asset management.

This chapter highlights a few of the many methods available to incorporate benefits and costs into stormwater planning. Traditional risk assessment approaches often combine costs and benefits, such as the cost of building infrastructure to reduce risks from natural hazards (earthquakes, floods, etc.) and the estimated benefits from avoided damages. Life-cycle assessment methods evaluate the environmental (and potentially economic) effects of a policy or project across the expected lifetime, looking to quantify resource consumption and disposal. Benefit-cost analysis is a common method used to quantify the net economic value of outcomes for a project and assess the viability of projects or activities. Finally, systems analysis uses mathematical modeling of systems processes to evaluate best options. Outcomes can be based on reducing overall costs, increasing benefits, or meeting several objectives (Diringer et al. 2019).

All of these approaches are useful and this list is not comprehensive. Many of these methods require expertise that may be beyond the current capacity of municipal stormwater planners. Larger agencies have more capacity to hire staff or work with consultants to undertake more comprehensive studies. Smaller agencies, however, can still use tools to incorporate benefits into planning.

Benefit-cost analysis: A helpful tool

For this guide, we focus on introducing details and providing demonstrations for one particular approach, benefit-cost analysis (BCA), which is widely used for decision-making in public agencies. In the past, deciding between project designs or policy solutions tended to focus on costs and efficiency. Today, more planning studies attempt to quantify benefits, including difficult-to-monetize benefits that accrue from activities such as stormwater management. Benefits can include both direct, such as reduced flooding, and indirect, such as increased land values. BCA is particularly relevant in sustainability planning, where important goals can include non-monetized benefits across economic, environmental, and social systems. Some of these may even be hard to quantify.

Typical BCA studies require monetizing expected costs and benefits to assess the net effect. Sectors such as urban planning and operations have developed better benefit valuation methods to include in planning studies. However, not all benefits can be quantified. Recognizing that the dollar value of some benefits can be difficult or impossible to estimate, using BCA in tandem with other assessments of benefits without dollar values can offer more flexibility for planning and help justify spending on new projects or activities. Thus, while BCA is a well-known tool, incorporating benefits into project planning can involve some quantifications with and without dollar values.

Assessing costs

Cost assessments for municipal operations and infrastructure planning focus on current costs for existing infrastructure and program activities, or future costs for upcoming projects. Estimates must account for the changing costs of activities over time and inflation rates.

Ways to categorize costs

Costs are categorized in different ways depending on the ultimate use of the assessment. The categories overlap and are not exclusive. Some common ways to group costs include:

- Direct and indirect—Direct costs can include labor, materials, and supplies. Indirect costs may cover supervisor salaries, depreciation or use allowance on buildings or equipment, insurance, and other broader costs of work that are necessary, but not immediately attributable to a project or service.

- Fixed and variable—Fixed costs are stable every year. Variable costs change over time. Debt payments for infrastructure are fixed, while maintenance needs or energy bills are examples of costs that can change significantly from year to year after accounting for inflation.
- Construction, operations, and maintenance—Project cost estimates must consider the upfront costs of construction, as well as annual costs for operating and maintaining systems and eventual replacement.
- Capacity and operations cost—Water sector project cost estimates often report two metrics: capacity costs and operations costs. These are typically reported as a unit cost (dollars/cubic foot per second or dollars/acre-foot). The two approaches measure different concepts. The unit cost of capacity is the cost per maximum size or volume, such as gallons of water. The unit cost of capacity for a wastewater treatment plan might be reported in dollars per gallons per day ($/gallons/day), where the gallons per day is the maximum volume of sewage that could be treated in a day. Alternatively, the unit cost of operations estimates the cost per unit of average output over time. For a wastewater treatment plant, the value might be in dollars per gallons ($/gallons), where gallons are the total volume of sewage treated in a year that includes periods both at and below capacity. The capacity cost estimates the premium paid for available extra capacity above and beyond typical operations, as many water, wastewater, and stormwater projects must be sized to account for periods of peak flow, which results in unused capacity during other times. Operational costs, on the other hand, estimate average costs over time. Operational costs can be annualized over the expected life of the project to consider changes in technology and long-term financing needs. Capital unit costs based on capacity are typically higher.

Direct costs for stormwater management might include expenses for maintaining infrastructure, constructing new devices, or monitoring water quality.

Indirect costs for stormwater management could include health and retirement benefits, rent for office space, and equipment costs.

Figure 5: Building a bioretention planter stormwater control measure (Source: OWP)

- Average and marginal—Average costs are the total cost of delivering a service, divided by the total number of units of service delivered. Marginal costs, on the other hand, estimate the change in cost for producing an additional unit of service. Traditionally, utilities considered that larger projects can lower average unit costs based on efficiencies in scale. Incorporating a broader set of benefits and costs can reveal more parity between larger and smaller projects.
- Real and nominal—Real costs are adjusted for inflation. The costs of a project in future years can be directly compared to the cost in a current year. Nominal costs, on the other hand, are not adjusted for inflation and are reported as the amount that must be spent in that year, which can be useful when comparing costs to revenues.

Each of the categorization schemes above provides unique information. Evaluating fixed and variable costs allows for understanding the extent to which funds must be available to deal with the fluctuations in spending associated with variables costs. Likewise, in public finance purposes, nominal costs are often useful in describing the actual amount that will need to be spent at a future period in time, which can be more intuitive for public officials and residents.

Cost assessment methods

Best practices for cost assessments vary. Many organizations, such as federal government agencies, state auditing agencies, and professional organizations like the American Society of Civil Engineers (ASCE) publish guides and books with information on stormwater and GI. Some organizations and municipal departments also have internal guidance documents. For instance, the US Army Corps of Engineers regularly updates its guidebook, Civil Works Cost Engineering, which outlines processes to estimate costs of engineering projects. In 2011, a group of experts published the textbook *Economic Incentives for Stormwater Control*, which presents concepts and methods for assessing costs and benefits in stormwater systems, including construction, operations, and maintenance.

Engineering cost assessments often use a line-item approach, also referred to as a bottom-up approach, which compiles the costs for each material or service and sums them to arrive at a total cost estimate. The unit costs for each item, such as wages ($/hour), materials ($/linear foot of pipe or $/manhole), or activities ($/inspection), can be multiplied by the estimated number of units needed in a given period, such as a year, to arrive at a total cost.

Newly constructed projects must also consider soft costs such as contingency funding, insurance, non-standard engineering work, permits, and costs for mobilization (i.e., starting up equipment or moving equipment to a site). Some soft costs such as insurance are necessary, while others such as contingency funding help reduce the risk of cost overruns. As an example of soft costs, the City of Los Angeles Stormwater Capture Master Plan (LA City 2015) included some estimates of soft costs for stormwater infrastructure projects in the LA metropolitan area as a percentage of project capital costs, as shown in Table 4. The soft costs are based on expert opinions from the engineering design contractor.

Table 4: Projected soft costs for new stormwater infrastructure construction projects in Los Angeles (Source: Adapted from Geosyntec 2014)

	Percent of Capital Costs		
Soft Cost	*Low Cost Scenario*	*High Cost Scenario*	**Notes**
Contingency	20%	30%	—
Specialized engineering	NA	15%	Applied to complex direct use only
Material cost	40%	80%	Applied to complex direct use only
Utility realignments	NA	3%	Applied to subregional and high cost curb extension projects only
Mobilization	NA	Base cost: $2,000; Additional: 10%	—
Permitting	NA	5%	—
Engineering and planning	Small scale SCMs: 10%; Non-small BMPs: 20%	35%	Small scale BMPs: simple rain garden, dry well, simple direct use BMPs

For infrastructure projects or program activities, engineering cost methods can use straightforward construction costs. More complete methods that offer systematic estimates also include O&M costs. For most projects, costs are projected over the expected lifetime of the project, using debt financing to pay large upfront capital costs, while making regular payments to the financier over a loan term of several decades. Annualizing costs requires making assumptions about the future cost of money.

Accounting for time

Infrastructure planning must typically incorporate a way to evaluate the changing cost of money over time. Typically, a dollar spent today yields more goods and services than a dollar spent in the future.

Planning activities include discount rates or inflation estimates to compare current and future costs. National or regional estimates of economic activity such as the Consumer Price Index (CPI) can help identify an inflation rate, while the selection of discount rates for public infrastructure such as stormwater involves many factors.

Discount rates are applied through a formula that evaluates the present value or net present value of estimated benefits and costs over the lifetime of the project. The present value of project costs, for example, is the sum of costs over time when incorporating a discount rate:

$$PV = \sum_{y=0}^{n} \left(\frac{Costs_y}{(1+r)^y} \right)$$

In the equation above, *y* represents the year (ranging from 0 to the expected last year of operation) and *r* represents the discount rate.

The net present value is the difference between the present value of costs and returns (monetized benefits) over the same time period. Project solutions with larger net present values are generally more favorable, depending upon each solution's ability to also address non-monetary goals.

As a simple approach, the net present value (NPV) of a project or program over time would be:

$$NPV = \sum_{y=0}^{n} \left(\frac{Benefits_y}{(1+r)^y} - \frac{Costs_y}{(1+r)^y} \right)$$

Discount rates are also sometimes converted to discount factors (DF) that incorporate the rate and year, using the following equation:

$$DF = \frac{1}{(1+r)^y}$$

The discount factor is a decimal value less than one that is applied to the estimated benefits and costs from a project for each year.

In these equations, the discount rates help incorporate inflation, interest rates, and uncertainty of future conditions over time. Identifying a proper discount rate to use in an analysis involves assumptions and insight. In general, a lower discount rate yields greater present values of costs and benefits in future years, while a higher discount rate downplays future present values of costs and benefits from the project. The overall effect of *r* on NPV depends on how present benefits and costs compare.

Accounting for time in cost estimates: A simple example

Discount rates and inflation rates help incorporate the changing cost of money into analysis. A discount rate can estimate the present value of a future amount of money. Inflation rates, on the other hand, help estimate the future nominal value of a current amount of money. The present value (PV) and future value (FV) of money can be related using a discount rate, r:

$$FV = PV \times (1+r)^{y}, \quad \text{or} \quad PV = FV \times (1+r)^{-y}$$

The result is the future value (FV) of money or present value of money (PV) in year t.

As a simple example, suppose a municipality must decide whether to invest in a stormwater project now to meet a regulatory requirement and save $500 in monitoring costs (nominal) each year for 4 years. The project would cost $1,500. Is it a good investment?

Using a discount rate of 5% can estimate the present value of the savings in each year after the initial investment:

Year	1	2	3	4
Present Value of Savings	= \$500 × $(1.05)^{-1}$ = \$476	= \$500 × $(1.05)^{-2}$ = \$454	= \$500 × $(1.05)^{-3}$ = \$432	= \$500 × $(1.05)^{-4}$ = \$411

The total present value of savings equals $1,772, so the municipality would see an overall benefit by investing in the project under these terms.

The discount rate used affects the projected costs or savings.

In stormwater management, benefits from a project can include monetized values of expected returns, but often such benefits are hard to calculate. It is more common in stormwater to compare present values of traditional grey and newer green infrastructure options. Table 5 below shows an example of calculating the discount factor, present value (benefits and costs), and net present value of a project based on a 4% discount rate. Using this method, the net present value of the project over time is negative ($-9,557). This occurs because the expected returns to the project (monetized benefits) are less than the initial and annual estimated costs. In stormwater management, which is responsible for providing a service without a direct line of revenue, this may often occur without more detailed calculations to evaluate potential benefits. Projects with negative net present value in terms of monetary returns can still be justified in stating their purpose in reducing flood damages or meeting permit compliance requirements. For many benefits, such as flood risk reduction, methods are available to estimate non-monetary benefits (i.e., averted flood damages) that result from well-designed systems, but may involve detailed calculations. A more detailed discussion of ways to evaluate benefits is provided later in the chapter.

Table 5: How to apply a discount factor to projected costs and returns (benefits) for a project over time.

Project Age	*Expected Yearly Cost*	*Expected Yearly Benefit*	*Discount Factor (Discount Rate = 4%)*	*Present Value of Costs*	*Present Value of Benefits*
Initial	$10,000	$0	0.935	$9,350	$0
1	$200	$0	0.873	$175	$0
2	$300	$50	0.816	$245	$41
3	$300	$300	0.763	$229	$229
4	$100	$200	0.713	$71	$143
5	$50	$200	0.666	$33	$133
			Sub-total	$10,103	$546
			Net Present Value	$-9,557	

For stormwater planning and financing, selecting a discount rate depends on: 1) the expected life (years) of the project, 2) initial costs and long-term returns (benefits) of the project, 3) the interest rate associated with funding the project, and 4) long-term economic forecasts for inflation. In general, many public infrastructure projects include a discount rate of 3–6%, while private sector projects often use a higher discount rate of 7–15%. One factor influencing this difference is the lower rate of borrowing (interest) that governments can capitalize on to fund projects because they are generally viewed as more secure investments by lenders. Recent studies in stormwater management tend to use a discount rate of 3–4% for municipal projects (Nordman et al. 2018).

Life-cycle costs

A comprehensive approach to estimating engineering costs is to use a life-cycle cost estimation method. Life-cycle costs are the compiled costs to build, operate, maintain, and ultimately dispose of infrastructure and its associated materials. The costs are assessed over the lifetime of the infrastructure or operations, requiring assumptions for discount rates or inflation. Life-cycle costs allow for an improved comparison between options, especially during project planning for green or gray infrastructure. For stormwater, life-cycle cost assessments could include capital construction (with soft costs), energy, operations, repairs, replacement, and disposal with leftover residual value.

Filling in data

Engineering cost assessments can use a variety of data sources to populate the estimates of unit costs for activities or projects. For instance, utilities use internal data to help estimate the unit cost of activities. Not all agencies have internal data, however, and may instead use existing statistical methods to estimate the marginal costs of a project or activity.

Example equation for estimating construction costs of a retention basin project

Volumetric unit costs for detention basins:
The 2003 version of the California Stormwater Quality Association (CASQA) BMP Handbook drew on previous research (Brown and Schueler 1997) to identify an equation (exponential) that related volume and construction costs for detention basins.

$$C = 12.4V^{0.760}$$

C is the total costs for construction, while *V* is the total retention volume. The cost function is an example of a non-linear function. While cost equations such as this are helpful, using dated numbers can result in inadequate estimates of contemporary costs (Source: CASQA BMP Handbook 2003, Errata 5-06).

Linear and non-linear cost curves are common methods to assess the total cost of a project. Cost curves relate the size or capacity of a type of stormwater control measure with the total cost based on understanding unit costs for construction and/or maintenance. A linear cost curve means that the total cost of a project increases in proportion to size or capacity. A non-linear cost curve on the other hand means that the total cost does not increase proportionately to the size. In many cases, the unit cost of construction decreases as projects get larger based on economies of scale.

Cost equations often focus on a particular type of stormwater infrastructure and quantify the design variables and costs in terms of unit volume for mitigated runoff. Estimates can also be based on actual historic costs (adjusted for inflation) of either similar activities (analogy costs) or the actual activity when available. Cost assessments often mix methods with internal and external data when developing program or project cost estimates.

Managing uncertainty

Engineers use a variety of methods to deal with uncertainties in estimating costs. Many of these influence the soft cost considerations noted earlier. For instance, an engineer may be conservative in estimating costs for a project with more uncertainty, recognizing a higher risk of expenses. Cost estimates can use contingencies or include extra costs for especially difficult tasks in more demanding or riskier projects (see different contingencies shown in Table 4). Reporting cost ranges can help address uncertainties in estimates.

Experience is helpful in gauging the validity of cost estimates. Without relevant past budgeting experience, however, it can be difficult for a municipal stormwater manager to assess cost estimates from bidders. Moreover, benchmarks often do not exist for stormwater projects or programs. Part II of this project aims to develop more openly accessible cost information that helps stormwater programs evaluate needs more effectively in the early stages.

Assessing benefits

Economic methods to assess benefits have existed for decades, but are growing in use for municipal and infrastructure financing. By relying on better data and resources, benefit assessments can be significantly more holistic.

In sustainability research and practice, benefits should include outcomes that are both monetary and non-monetary. This includes economic, environmental, and social outcomes (triple bottom line). In the past, environmental and social benefits were often considered secondary to economic benefits. Moreover, while some outcomes can be converted to dollars, other important social or environmental outcomes are not easily monetized. Assessing outcomes of all three types together at the planning stages of projects or programs allows managers to understand tradeoffs in various outcomes. Assessments can include both monetary and non-monetary goals as a yardstick for evaluation. Such holistic analysis approaches can uncover opportunities to increase outcomes that advance economic, social, and environmental goals.

Many accessible sources of information provide guidance to assess monetary and non-monetary benefits of GI, including those related to stormwater. For example, the Center for Neighborhood Technology developed a guide, The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits, to assist municipalities in evaluating the monetary and non-monetary values of GI benefits (CNT 2011). This includes detailed example calculations and summarizes various econometric methods to estimate these values. This section reviews this tool and other good sources to describe:

- Benefits applicable to green and gray infrastructure
- Methods to assess, quantify, and, in some cases, monetize benefits

Stormwater projects can achieve an array of benefits that are specific to the goals, design, and location of a project. Table 6 outlines some of the many potential social and environmental benefits that can be included in triple bottom line analysis. While the metrics for benefits are primarily non-monetary, each benefit can also be valued in monetary terms for incorporating economic considerations.

Often, BCA will calculate the individual benefits and costs for various solutions and resultant outcomes. For instance, the costs of building a retention basin can be compared to the benefits it provides for flood protection, land values, water quality from decreased pollutant loads, and others. If monetized, summing the total economic value of benefits and costs from a project or program yields an assessed total. This "bottom-up" approach helps in thinking through the potential ramifications—good and bad—for a project.

Figure 6: Curb cutout for an infiltration swale (Source: Flickr, Aaron Volkening)

Table 6: Some potential benefits for stormwater management as described in Stormwater Resource Plans through CA State Water Resources Control Board guidelines.

Benefit Category	Benefits	Non-Monetary Metric
Water quality	Prevent or reduce pollutant discharges	Load of total suspended solids (TSS) reduced
	Prevent or reduce hydromodification	Volume of runoff reduced
Water supply	Augment water supply	Volume captured and infiltrated into groundwater basins
	Reduce water demands	Volume captured that results in reduced demand on other sources
Flood management	Prevent or reduce localized flooding	Peak flow reduction for design storm
	Prevent or reduce regional flooding	Size of area with flood mitigation
Climate change adaptation and resilience	Support water supply reliability	Additional volume of water available for supply
	Address increased precipitation volumes and intensities	Rate of peak flow reduced for the identified design storm
	Provide infrastructure redundancy	Volume of new redundant capacity
	Provide infrastructure longevity	Months or years of expected additional component life
Environmental	Protect or restore habitat	Size of area of wetland, riparian zone, or habitat
	Support biodiversity	Number of additional habitat acres for sensitive species
	Improve instream flow rates	Rate of instream flowrate improved
	Improve instream flow temperatures	Water temperature (°F or °C) improved or percent canopy cover increased
	Reduce urban heat island effects	Reduced air surface temperatures
	Reduce greenhouse gas emissions and air pollutants	Mass of greenhouse gas emissions sequestered or reduced
Community	Support permit compliance	Achieved permit needs with regulator
	Create jobs	Number of new jobs
	Provide recreational opportunities	Size of space created/enhanced
	Improve mental and physical health	Quantified improvement in community health, such as reduced hospital visits
	Provide educational opportunities	Number of outreach materials provided, events conducted, or participants
	Increase property values	Dollar value increase in property values
	Improve aesthetics	Size of public space created
	Improve community involvement	Number of hours volunteered or participants

An important consideration is the prevention of miscounting or double-counting benefits or costs. If a city institutes a parcel tax to fund new green infrastructure, this is a transfer of funds from one sector of society (residents and businesses) to another (government), not a cost. The resultant green infrastructure will have some set of associated costs such as reduced economic activity and potential benefits such as improved water quality in downstream watersheds and increased land values. The dollar values to consider in the benefit-cost analysis would be the effects of the new tax (positive or negative) rather than the dollar values of the tax itself.

One way to accrue benefits for stormwater management activities is by capitalizing on money already being spent by other departments. If a street-sweeping program is in place in another municipal department and the stormwater program funds some additional activities, a benefit would be the cost-savings that are realized by the stormwater program for investing in existing resources that, overall, cost less than a stand-alone program.

Methods for quantifying the social and environmental (non-monetary) benefits and economic (monetary) benefits are described in the next sections.

Methods of quantifying benefits

Benefit assessments for stormwater projects can determine monetary or non-monetary quantifications. In California, recent stormwater grant programs through the California State Water Resources Control Board require applicants to identify and quantify potential benefits of projects. The resulting quantifications were used to rank projects or populate a numeric scoring system to tally benefits for proposed projects in a region. In many cases, benefit assessments for small and medium-sized projects will be non-monetary. For example, the metrics for quantifying benefits identified in Table 3 are quantitative, but not monetary.

Many regions throughout the state are developing stormwater resource plans that standardize methods for quantifying benefits as part of assessment project feasibility for new stormwater projects. In the American River Basin, for example, the American River Basin Stormwater Resource Plan (ARB SWRP 2018) provides a detailed appendix with methods and equations useful for quantifying the non-monetary benefits of projects (State Water Board 2019). The Natural Resources Agency also provides many tools for estimating benefits in non-monetary metrics.

For quantifying monetary benefits, economic methods are available to estimate the dollar value of some of the benefits listed in Table 3. In some cases, the monetary outcomes result directly from a project and are easily quantified in dollars. For other benefits, however, the process of monetizing outcomes requires advanced methods.

While such methods are well established, they can be complex and difficult to apply. Lack of data and the limited reach of experienced economist practitioners has inhibited application of such methods for infrastructure planning. This is changing. Recent sources offer excellent summaries of methods and applications for quantifying benefits of green infrastructure and urban water management (Ando and Netusil 2018, City of Phoenix 2018, CNT 2011, USEPA 2013). Drawing on these sources and others, the following sections summarize available methods for quantifying benefits and identifying monetary and non-monetary metrics.

Identifying monetary and non-monetary metrics

As shown in Figure 7, decisions for public investments must sometimes compare monetary and non-monetary cost and outcomes. In water resources management studies, this approach is often called multi-objective decision making, but the approach is used across many fields. When considering a multi-objective approach to assess a stormwater management project, the assessment criteria to decide if the project is a priority investment might include monetary cost estimates as well as non-monetary objectives for volumetric reductions in runoff to streams, increased green space, greater availability of groundwater recharge for pumping, and water quality improvements. Existing literature provides examples for estimating the economic value of all these benefits, but their applicability to a project or region is often tenuous. Instead of seeking monetary benefits to compare to costs, the project assessment could include non-monetary outcomes for these benefits.

Averted costs

Averted costs are costs that are avoided or no longer necessary once investing in a project. In other words, if the policy or infrastructure did not exist, what would have been spent? Averted costs can be compared to the actual cost of the project or program. While useful to incorporate into BCA, it is not a method to value benefits and does not relate to stakeholder preferences for project outcomes.

As an example, a recent study evaluated the cost effectiveness of past investments in water conservation in Los Angeles. The study specifically noted how averted costs such as not building new infrastructure to expand supplies were important to make the overall program a net gain beyond the assessed costs for conservation program spending (CWEP and AWE 2018).

Use and nonuse values

In BCA, benefits are often quantified as monetary metrics so they can be included in assessments of NPV. Monetary metrics are categorized as use values or non-use values.

Use values represent the amount that can be earned, saved, appreciated, perceived, or otherwise attributed to the resource by an individual or society. Use values include several types, but for stormwater, the most relevant are benefits such as recreation and landscapes or services such as flood control, water storage, and water quality. Non-use values, on the other hand, quantify the amount that an individual attributes to a resource for the sake of its existence or provision. Non-use values are perceived based on knowing they exist or valuing that it can be passed to future generations.

As an example of use values in stormwater, a property owner who installs rain catchment barrels and uses the water collected for irrigation could reduce the amount he or she pays for water from the municipal water system. The property owner in this case directly experiences the benefit, or value, as an economic gain.

The property owner who installs rain barrels may also enjoy a benefit of knowing that the reduction in stormwater runoff from the rain barrels is helping protect endangered fish populations for future generations. The water quality improvements that support the fish could be either a use or non-use value, depending on whether the resident directly uses local watersheds for recreation or other activities. Non-use values can be difficult to monetize.

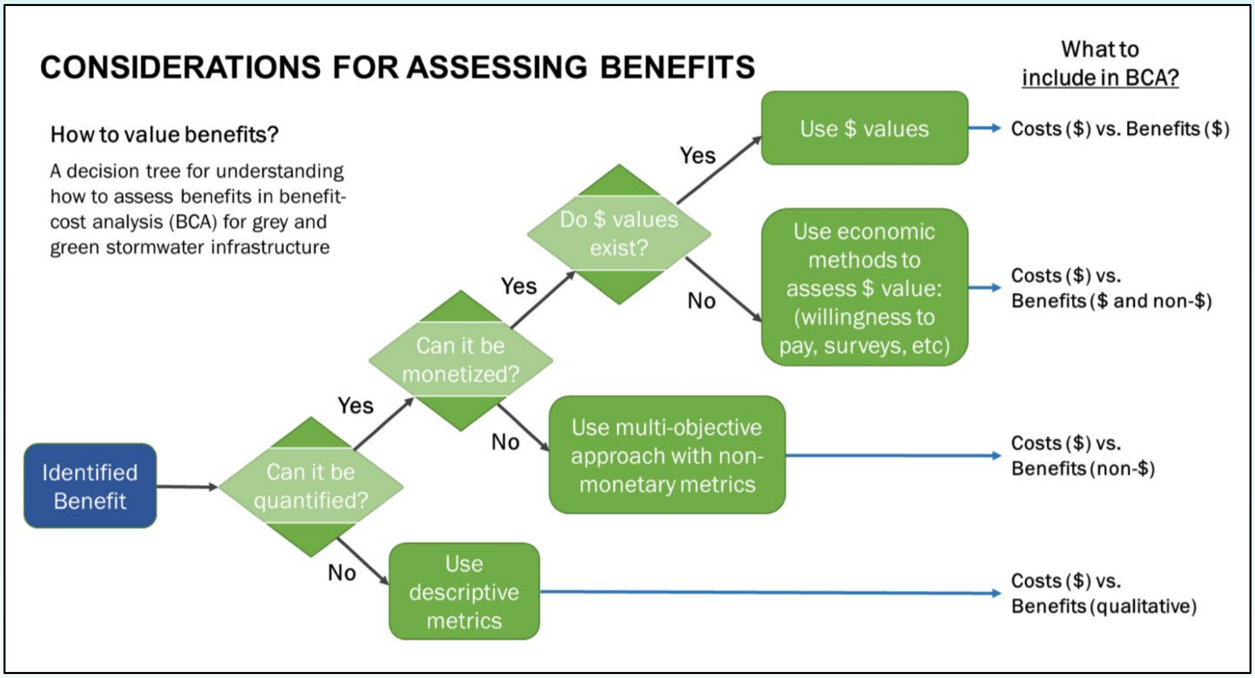

Figure 7: A decision tree for applying methods to assess benefits in benefit-cost analysis

Assembling Benefits and Costs

Example 1: Capturing and infiltrating stormwater in a retention basin

A college campus wants to build infiltration basins to reduce stormwater runoff. The project team decides to build 3 basins that cover 1,700 square feet (ft^2) each and cost $\$80/ft^2$. Each will capture 0.75 acre-feet (ac-ft) per year (y) of water. The new basins are expected to eliminate the need for construction of a new storm sewer pipe and drop inlets. In addition, the project is expected to recharge groundwater and beautify the parking lot.

Costs

With the simplification that the total upfront project cost is:

$$3 \text{ basins} \times 1{,}700 \text{ ft}^2 \times \$80/\text{ft}^2 = \$408{,}000$$

Annual operations and maintenance activities include weeding, inspections, and cleaning accumulated sediment and trash. Estimated annual O&M costs are $\$0.90/ft^2$ (Piza and Clary 2017). The total O&M cost is:

$$3 \text{ basins} \times 1{,}700 \text{ ft}^2 \times \$0.90/\text{ft}^2 = \$4{,}590/\text{y}$$

Benefits

An estimated one-time monetary benefit for the campus is the averted cost of installing new pipes that cost $350/linear foot (lin ft) to install, as well as storm drain inlets that cost $10,000/inlet. The total savings is:

$$(3 \text{ pipes} \times 200 \text{ ft} \times \$350/\text{lin ft}) + (10 \text{ drain inlets} \times \$10{,}000/\text{inlet}) = \$310{,}000$$

The campus can also claim a credit through the local water agency for the estimated value of groundwater recharged to a drinking water aquifer:

$$3 \text{ basins} \times 0.75 \text{ ac-ft/y} \times \$350/\text{ac ft} = \$787.50/\text{y}$$

Finally, a series of non-monetary benefits include campus beautification and the improvement of downstream aquatic habitat by reducing runoff.

Net Cost/Benefit

The net present value (NPV) of the project is the difference between costs and benefits when incorporating time. This estimate requires a discount rate (4%) and the project's expected lifetime when well-maintained (30 years).

The net present value equation is:

$$NPV = \sum_{y=1}^{n} \left(\frac{Benefits_y}{(1+r)^y} - \frac{Costs_y}{(1+r)^y} \right)$$

Using the nominal values for benefits and costs for the infiltration basins project and expanding the summation, the calculation becomes:

$$NPV = \left(\frac{(\$310{,}000)_{y0}}{(1+0.04)^0} - \frac{(\$408{,}000)_{y0}}{(1+0.04)^0} \right) + \left(\frac{(\$787.50)_{y1}}{(1+0.04)^1} - \frac{(\$4{,}590)_{y1}}{(1+0.04)^1} \right) + \ldots.$$

At the outset, the campus incurs the upfront construction costs but accrues the benefit of averted costs. In each year after, the value of costs and benefits are converted to future dollars through the denominator, $(1+0.04)^y$.

A simple table with the year, cost, benefit, and net cost/benefit solves the calculations:

Year	Cost	Benefit	Net Cost/Benefit
0	$408,000	$310,000	-$98,000
1	$4,413	$751	-$3,656
2	$4,243	$728	-$3,515
	……		
30	$1,415	$242	-$1,172
TOTAL (NPV)	$487,370	$323,617	-$163,752

While the project still has negative total and annual costs, incorporating benefits and the averted cost of unneeded stormwater pipe infrastructure results in a more appealing project. The total NPV of costs is $163,752, which is substantially smaller than the estimated construction and O&M cost.

Willingness to pay and willingness to accept

Willingness to pay (WTP) and willingness to accept (WTA) indicate the price or value a person assigns to a product. For benefits related to stormwater infrastructure, WTP and WTA can be estimated for both use and nonuse benefits.

Willingness to pay estimates the amount of money a person would pay to receive a benefit. The benefit could be for direct use, but for green infrastructure, in many cases, assessments instead estimate the value of nonuse benefits such as knowing that water quality is improved or knowing that future opportunities exist for recreation.

Willingness to accept, on the other hand, estimates the amount of money a person would have to receive to accept some loss that they value. For example, if a homeowner values a lawn with grass but the local water utility is trying to reduce outdoor water use or fertilizer runoff, the utility might consider providing a rebate or payment to the homeowner to motivate them to replace a lawn. In practice, while WTA considerations are relevant for governance and public financing issues, WTP methods are more common in stormwater and green infrastructure cost analysis.

Figure 8: Streams and environmental habitat (Source: US Geological Society)

Valuing non-market goods

Non-market goods have no available market price. For instance, while residents may value access to a regional park, it has no readily available monetary value because shares of park access are not traded or exchanged in a market setting.

To compensate for the lack of economic valuation data for non-market goods, economists have developed methods to estimate the monetary value of benefits for non-market goods. This can apply to both use and non-use values. The methods include several intense computations and complex methods that require good data.

Without data and resources, monetary valuation of benefits may not be applicable for many assessments.

First, "revealed preference" techniques identify values of non-market goods by extracting a monetary value based on other data. A common method is hedonic pricing. which derives the market value of an environmental good, such as flood protection or views from a property, by analyzing differences in the market prices of assets. For these cases, the asset is a property. In theory, properties with less flood risk or better scenic views would have a higher market price, a direct use benefit to property owners whose monetary value could be estimated. Statistical analysis and correlations between explanatory factors such as taxes, proximity to other amenities, or size, support an estimate of the dollar amount of the benefit.

Figure 9: Kayakers on the American River in California (Source: US Bureau of Land Management)

An increasingly popular revealed preference technique uses a "difference-in-difference" approach. In this method, assets are matched with other similar assets and market prices compared. The intent of comparing nearly identical assets with a different single characteristic is to determine the difference in market prices. As an example, to assess the economic value of scenic views for properties in a region, a house with the amenity of interest (scenic view) is matched with other very similar houses based on characteristics (size, number of bedrooms, locations, and other factors) across a large set of properties. The only difference among the properties is one has the scenic view. The difference in market price would be the market value of the scenic view amenity. Such techniques are increasingly popular for a variety of strategies in resource management and sustainability, ranging from green streets and turf replacement to energy efficiency and on-site low impact development, to name a few applications.

Second, "stated preference" techniques ask people to directly value benefits of interest. Contingent valuation is a stated preference technique for estimating the value that people place on a good by asking direct questions to help identify an economic value. For example, a survey could ask residents if they would pay an amount for water quality benefits. Respondents would answer yes or no, depending on their preference. Another method, choice experiments, surveys people about their preference among various attributes or outcomes associated with a program or project. The survey is crafted to elicit insights with attributes designed to help a researcher derive the marginal unit value of a benefit. As a simple example, a choice experiment exercise might ask participants how much they would pay for increased tree canopy, green infrastructure in neighborhoods, or flood protection. Each of these would have stormwater benefits. The survey results could be used to derive the relative willingness-to-pay for each of these goods.

Both stated and revealed preference methods are used in analyzing environmental benefits of projects, as well as in understanding tradeoffs and financial needs for managing resources.

Finding data for benefit-cost analysis

Some stormwater management studies have leveraged existing literature to integrate benefits into a BCA, which included benefits not traditionally considered in utility projects. For instance, as part of Los Angeles County's basin study to evaluate investments in various types of stormwater capture and use infrastructure, the economic analysis surveyed monetary values of various benefits from the literature. Benefit categories included flood mitigation, water quality, recreation, habitat, aesthetics, heat island mitigation, and climate resilience (LA County and USBR 2016). For some benefits, several relevant local examples were available. To evaluate the economic value of water supply reliability, the study drew on several analyses from California (including Orange County and Santa Cruz) to develop a method that estimated household WTP for supply reliability, a benefit of stormwater capture projects. For other benefits, however, just a few examples existed to estimate unit dollar values and applicability to the study region was not clear. For instance, the study provided estimates of household WTP for ecosystem services, using national estimates compiled from a variety of sources. The analysis adapted the results of the previous studies, but noted that benefits could be quantified "for only a subset of the total potential beneficial effects associated with the infrastructure and operations" described in the engineering analysis (LA County and USBR 2016). In other words, the BCA procedure could not account for the universe of potential benefits from the projects. Attempting to attribute benefit values across locations and projects is challenging because the perceived or recognized benefits may differ significantly.

Figure 10: Merced River in California (Source: Flickr, mypubliclands)

Assembling Benefits and Costs

Example 2: Estimating benefits from a green street with property value improvements

A city wants to install green street improvements, including new trees, along several blocks. The devices will capture stormwater, reduce local flooding, and improve the street's appearance. All these benefits are expected to improve property values. The installations will cost $2,000/lin ft.

Costs

The total project cost for installing 1,000 ft of green street improvements is:

1,000 feet × $2,000/lin ft = $2,000,000

Annual operations and maintenance costs are similar to bioretention basins at $0.90/ ft^2 (Piza and Clary 2017). The project is 1,000 ft long and 5 ft wide, so the total O&M cost is:

(1,000 ft x 5 ft) × $0.90/ ft^2 = $4,500/year

Benefits

A one-time benefit for the utility includes averted costs of new pipe infrastructure that costs $450/lin ft to install, along with storm drain inlets. The total savings is:

(1,000 ft pipe × $450/lin ft) + (5 drain inlets × $5,000/inlet) = $475,000

An important benefit for the project is the newly captured stormwater that will be infiltrated through dry wells. The city currently pays $1,200/ac-ft for water supply. The project will infiltrate half the runoff from a 125-acre site that receives an average of 15 inches (in) of rain per year. Applying a coefficient (R_v = 0.9) to estimate the reduction in expected runoff volume from runoff yields a total benefit of:

(125 acres × 15 in/y × 0.083 ft/in x 0.9) × $1,200 ac-ft = $94,000/y

Finally, as newly planted trees in the green street mature, the current average property value of $200,000/home is expected to increase. Estimating an increase of 1% in property value, the total increased value is:

15 homes × ($200,000 × 0.01) = $30,000/y

While the city accrues the costs and one-time benefit, homeowners would receive monetary benefits of higher property values. The city may only see a portion of this through tax revenue.

Challenges in benefit-cost analysis

In comparing benefits and costs of green infrastructure for stormwater management, agencies can encounter many challenges that are common to economic analysis and public finance studies. In many cases, the costs and benefits included in an analysis do not accrue to the same party. This is common in municipalities, where a department may reap benefits from a task funded by another department or locality. As an example, stormwater agencies are increasingly responsible for removing trash that would accumulate and flow to local watersheds, so they invest in equipment and programs for trash containment and removal. While the municipality directly benefits by meeting regulations and avoiding fines, some benefits may instead accrue to a downstream locality, a municipal parks department, or other entity who realizes a reduced burden for trash removal. While the stormwater agency meets a regulatory requirement, it may not gain an easily identified direct, monetary benefit from the newly enacted spending. Instead, it may recognize indirect benefits of complying with stormwater permits or improved recreational watersheds that boost property values. The agency also potentially realizes lower maintenance costs associated with cleaner facilities when keeping trash out of systems. Directly attributing this to a newly installed project involves uncertainty.

Another challenge occurs in allocating the costs of required stormwater management activities or GI. Such costs may be borne across public and private entities, but dividing costs is not straightforward. For instance, stormwater flows touch streets, sidewalks, and rivers and streams. Cities divide responsibilities for managing these areas differently. As a crosscutting activity, stormwater managers may have to work with existing departments that may perceive changes in duties as additional costs for which they receive no benefits.

Private parties, too, have responsibilities for managing stormwater, but they assess costs inconsistently. Building a large new development would increase imperviousness and runoff. Cities manage this by charging developer fees or in many cases requiring developers to build new on-site infrastructure as often required in NPDES permits. In some cities, new ordinances require developers and landowners to manage stormwater on-site through small- and medium-sized devices. Yet developer fees and on-going management responsibilities can be unpopular. Getting local leaders and agencies to authorize such activities requires political will and persistence.

Finally, a lack of standardized tools and available economic data can hinder good BCA for stormwater management. Cities, too, can lack expertise or resources to undertake assessments.

3. Existing Resources

Many existing resources provide useful information for estimating the costs of stormwater projects and programs. In 2017, ASCE published a guide for maintenance costs in green infrastructure that describes many of the available tools. In 2014, Australian researchers Jayasooriya and Ng published a review of studies and models that are useful in stormwater planning economic analysis, *Tools for Modeling of Stormwater Management and Economics of Green Infrastructure Practices: A Review*.

In addition, the USEPA Water Financing Clearinghouse LID and GI Case Study Inventory is a comprehensive resource for a variety of information on stormwater studies. It lists LID and GI studies to analyze and promote the economic benefits of alternative stormwater infrastructure approaches. The list compiles case studies that track and analyze SCM capital and O&M costs (EPA 2013). The studies include a wide array of methodological approaches, ranging from simple assessments of capital costs to comprehensive evaluations of infrastructure whole-life or life-cycle costs. Many of the case studies support the cost-saving arguments of SCM-based alternatives (compared to conventional stormwater infrastructure). For example, the Capital Region Watershed District in Minnesota found considerable capital cost savings—estimated at $0.5 million—in adopting GI infiltration practices compared to traditional storm sewer conveyance systems. Similarly, a study in Western Union, Iowa, concluded that the O&M costs of permeable pavement would result in long-term cost savings, which begin accruing after 15 years and accumulate to an estimated $2.5 million in savings over a 57-year period.

The EFC at Sacramento State used these and other sources to collate the Stormwater Financing Storyboard, a set of existing tools that when used with public cost information guides from a number of sources can assist communities in early-stage stormwater program development. CASQA's Stormwater Funding Resource Portal also provides available resources for this data. Table 7 lists many of the resources, with brief descriptions provided in the next section.

Cost data for construction, operations, and maintenance

Many resources offer cost data or tools to determine costs for O&M for SCMs. Some offer construction costs as well. The following resources can be used to estimate these costs:

- ASCE EWRI Survey of BMP O&M Costs—In 2016, the American Society of Civil Engineers (ASCE) Environment and Water Resources Institute's (EWRI) Municipal

Water Infrastructure Committee (MWIC) conducted a national survey with contacts identified by the MWIC task committees to gather data on SCM O&M costs. In 2017, a book describing the data and findings from a survey of communities on maintenance cost data, project costs from cities, EPA resources, and third-party tools to estimate green infrastructure maintenance costs was published. The authors, Jane Clary and Holly Piza, asked questions on topics ranging from maintenance and labor costs to stormwater program information. A comprehensive list of questions developed to guide phone interviews is also included (Clary and Piza 2017).

The intended outcome of the survey was to generate a populated spreadsheet with itemized cost data on SCM installations. However, due to the lack of available data, the survey shifted its focus to collecting O&M cost data on bioretention devices for which national data was readily available. The median annual maintenance cost of bioretention devices was estimated at $0.687/ft^2$ with low and high costs of $0.13/ft^2$ and $2.30/ft^2$, respectively. The survey also provides average annual reported maintenance costs, which range from $250 to $3,880 with a median of $850. A tabular summary of bioretention O&M cost data is provided. According to several bioretention facilities that reported construction cost, annual maintenance costs averaged 6% of their capital costs, which falls within the estimated 5 to 7 percent range of maintenance cost as a percentage of capital cost (EPA 1999).

In compiling the book, the authors provide both newly reported survey data and a comprehensive list that notes useful existing resources. Some of these relevant sources are included in Table 7. Most existing tools and databases focus on costs for individual stormwater infrastructure projects, especially green infrastructure, which as noted earlier are one of the components of a stormwater utility program.

- University of New Hampshire Maintenance Expenditure Study—The University of New Hampshire's Stormwater Center characterized and quantified the maintenance costs of LID (i.e., SCMs) in the first two to four years of their operation (Houle et al. 2013). Physical models at a field facility—a 4.5-ha commuter parking lot with a series of uniformly sized, isolated, and parallel treatment systems—were used to examine the maintenance demands of seven different SCMs, including vegetated swales, dry/wet ponds, porous asphalt, and bioretention. System maintenance demands including materials, labor, and maintenance type and complexity were tracked and documented monthly using NYSDEC (2003) to help develop a framework for annual maintenance strategies and expenditures.

Comparing annual maintenance demands of SCMs to conventional pond systems indicated that SCMs typically have lower annual maintenance costs and higher water quality treatment capabilities due to elevated pollutant removal performance (Houle et al. 2013). Normalized installation and maintenance cost data can be found in Clary and Piza (2017). Key findings also provide insight into the structure of the maintenance regimes required by SCMs and their impact on maintenance costs. For example, vegetated filtration systems cost less and require fewer personnel hours than conventional pond systems. Also, maintenance approaches are frequently progressive. Initial maintenance activities are reactive (emergency- and/or complaint-driven) and, therefore, expensive. As maintenance programs evolve to include routine, periodic, and proactive inspections, they can reduce costs.

Houle et al. (2013) provides a platform to experiment with studies of future maintenance expenditures, addressing additional factors affecting maintenance costs such as scalability and sensitivity to temperature variation and different land uses.

- USEPA National Stormwater Calculator—The EPA developed a user-friendly tool to calculate stormwater runoff at small sites anywhere in the United States. The updated version of the tool uses the newest Stormwater Management Model (SWMM) software (v. 5.1.012) and includes definitive estimates of construction and maintenance costs, including, but not limited to, impervious area disconnection, rainwater harvesting, permeable pavement, and infiltration basins (Rossman & Bernagros 2014). They are calculated using regression equations, which are a function of fixed- and variable-cost components linked to SCM size. Various cost curves were developed based on previous cost curves and SCM costing data from a literature review. Capital and maintenance cost estimates for GI controls are accessible in Rossman and Bernagros (2014) and Clary and Piza (2017), respectively.

- University of Minnesota/Weiss BMP Cost Estimation Algorithm—The Best Management Practice Cost Estimation Algorithm is a product of collaborative research between the University of Minnesota (UM) and Peter Weiss at Valparaiso University. Initially, the algorithm generated expected costs of annual O&M as a percentage of total construction costs (Weiss et al. 2007). Following the compilation of a 20-year record of SCM construction costs and annual O&M costs by UM researchers, the algorithm is able to calculate the total present cost of SCMs in 2005 dollar terms (Clary & Piza 2017). Total present cost is defined as the current worth of a project in addition to the current worth of 20 years of annual O&M costs (Weiss et al. 2007).

  The equation calculates total present cost by converting the 20-year-old annual SCM costs to present values using municipal bond yield rates and inflation values. Total present cost is a function of the SCM size (e.g., water quality volume, swale top width). According to Weiss et al. (2007), with the exception of infiltration trenches, annual SCM O&M costs (as a percentage of construction costs) decrease as construction costs increase. Supporting information on the cost estimation algorithm can be found in Clary and Piza (2017), Weiss et al. (2007), and EPA (1999).

- Green Values National Stormwater Management Calculator—The Center for Neighborhood Technnology (2009) collaborated with the EPA to develop a free online assessment tool to calculate and compare the costs of SCMs to conventional stormwater practices on single sites. The Green Values National (GVN) Stormwater Management calculator uses input precipitation data, runoff reduction goals, and choice of BMP to calculate the life-cycle costs of green and gray stormwater infrastructure over 5 to 100 years. Data on project lifespans and construction and maintenance costs were gathered from available literature on green and gray stormwater infrastructure. The life cycle equation is a function of construction costs, annual maintenance costs, SCM replacement frequency, annual benefits, and the service age of the SCM (CNT 2009).

  An expansive list of the definitive construction costs, maintenance costs, and component lifespan data for SCM and conventional stormwater systems are also available from the Center for Neighborhood Technnology (2018).

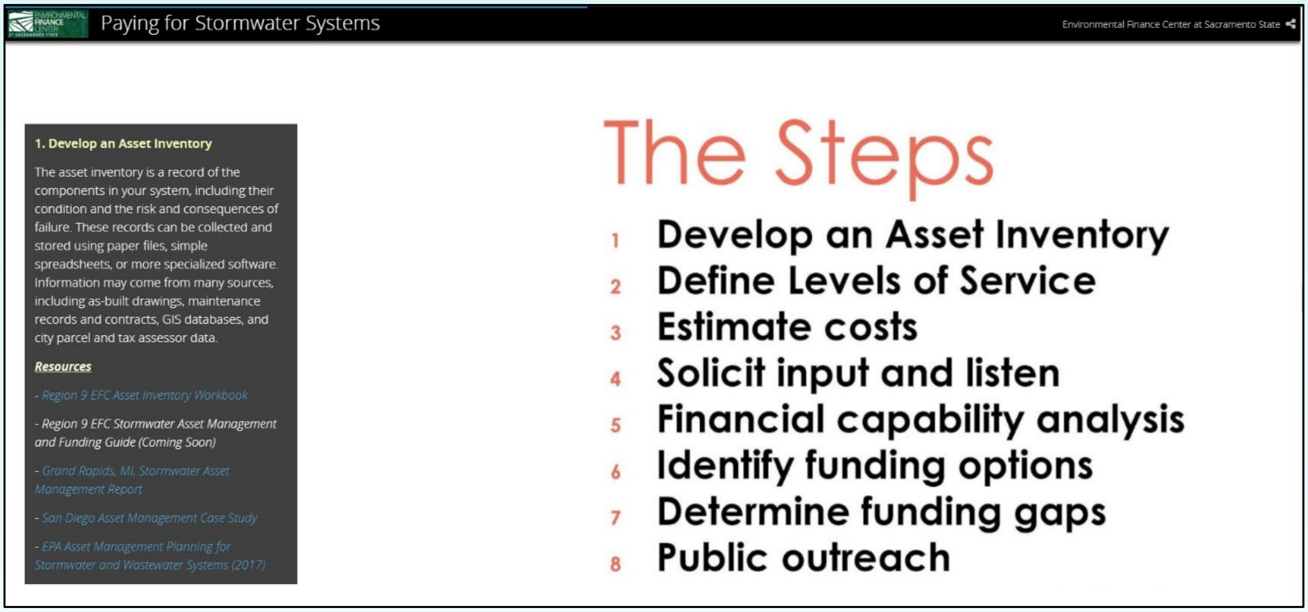

Figure 11: Web-based technical guidance on stormwater asset management for communities (Source: Environmental Finance Center at Sacramento State)

Life cycle costs

Other resources offer models or data to estimate life cycle costs. The following resources can be used when estimating these costs:

- WERF-AWWA-UKWIR Whole-Life Costs Tool—Andrews and Lampe (2005) developed a whole-life cost model to characterize the performance and whole-life costs of many SCMs, including retention ponds, extended detention basins, vegetated swales, bioretention, porous pavements, and various infiltration practices. The Water Environment and Reuse Foundation (WERF), the American Water Works Association (AWWA), and the United Kingdom Water Industry Research (UKWIR) funded the model. Researchers noted that the model supports economic assessments for stormwater management.

  The whole-life cost tool is a spreadsheet, constructed using maintenance costs collected from extensive surveys of US agencies with BMPs. Site visits to seven cities across the US supplemented surveys to identify and document differences in design elements and the factors driving variations in BMP design.

  In 2009, WERF developed an updated 2.0 version of the whole-life cost model to calculate whole-life costs of different GI measures as a function of design and maintenance options and capital and O&M costs. Outputs from the whole-life cost model indicate that differences in geography (climate, topography), aesthetic design considerations, and economics (availability and desirability of financial resources) drive the decision-making on selecting a wide array of SCMs and the maintenance costs associated with them. The size and complexity of SCMs and adequate inspection programs determine long-term maintenance expenses (Clary & Piza 2017). Average annual SCM maintenance costs for the United States—including labor, equipment, materials, replacement and/or additional planting, and disposal—can be found in Clary and Piza (2017).

- The National Cooperative Highway Research Program Whole-Life Cost Models—Taylor (2014) and the National Cooperative Highway Research Program (NCHRP) developed a comprehensive list of SCM whole-life cost models in spreadsheet format. The spreadsheet was compiled using a literature review, supported by surveys of 50 state departments of transportation on SCM costs, performance, and operation and maintenance information (Taylor 2014). SCMs include swales and bioretention facilities.

  In addition, the California Department of Transportation (Caltrans) collects real-time information on costs for maintaining stormwater controls. The process assigns maintenance codes to roadside SCMs that are located using GPS or automatic vehicle location technology. It creates necessary data systems for fine-scale calculation of long-term, life-cycle costs of post-construction for stormwater controls (Taylor 2014). Actual construction and annual maintenance costs for Caltrans BMP retrofit programs can be found in Taylor (2014).

- Denver Urban Drainage and Flood Control District's BMP-REALCOST Tool—BMP-REALCOST is an Excel-based life cycle costing model developed by the Urban Drainage and Flood Control District in Denver, Colorado (Urban Drainage and Flood Control District 2018). BMP-REALCOST determines life-cycle costs of structural SCMs in urban and suburban settings. Informal interviews with persons with SCM experience and the engineering judgement of the authors were used to inform the model's structure (i.e., the type of maintenance activities for each SCM) and assumptions (i.e., assuming a proactive and predictive maintenance regime). The model's SCM costing is a function of two factors: watershed physical properties that influence runoff quality and quantity, such as contributing areas and land use, and the specification of the SCMs applied to the watershed or development. The model provides users default cost and effectiveness values or users can input their own custom values. Entered data is analyzed to calculate life cycle costs based on the number, size, and type of SCMs required to treat average annual runoff quality and quantity for a designated watershed.

BMP-REALCOST's SCM maintenance cost equation includes a lump-sum component that is independent of size (e.g., annual inspection), as well as a size-dependent component (expressed as storage volume or design flow-rate). The model calculates average annual costs based on various inputs, including maintenance frequency, type, and equipment and labor costs. Annual maintenance costs according to BMP-REALCOST can be found in Clary & Piza (2017).

Figure 12: Low impact development device functioning during rainfall (Source: OWP)

Table 7: Summary of resources to support economic planning for municipal stormwater

Source	Description
ASCE EWRI Survey of BMP O&M Costs	A 2017 book that reports results of a survey on maintenance costs of green infrastructure and compiles many existing resources.
WERF-AWWA-UKWIR Whole-life Cost Model	A joint product from US and UK industry organizations to estimate the life cycle costs of several types of stormwater control measures, including retention ponds, detention basins, vegetated swales, bioretention, porous pavement, and others.
USEPA National Stormwater Calculator	A software tool for calculating stormwater runoff that uses the SWMM model for planning and includes tools to estimate construction costs, maintenance costs, and averted costs.
University of Minnesota/Weiss BMP Cost Estimation Algorithm	A tool for estimating the construction and annual O&M costs of stormwater capture measures, including total present costs.
University of New Hampshire Maintenance Expenditure Study	A 2013 study that characterized and quantified maintenance costs of several types of LID over a multi-year period.
The National Cooperative Highway Research Program Whole-Life Cost Models	A spreadsheet-based model covering fifty state departments of transportation to estimate life-cycle costs of stormwater capture measures.
Denver Urban Drainage and Flood Control District's BMP-REALCOST Tool	An Excel-based life cycle costing model to support life-cycle cost analysis of structural stormwater management facilities in cities.
Wossink and Hunt Empirical Cost Evaluation of SCMs in North Carolina	A 2003 study that collected empirical cost equations for O&M activities across 40 stormwater capture facilities in North Carolina.
USEPA Water Financing Clearinghouse LID and GI Case Study Inventory	A comprehensive list of LID and green infrastructure studies to provide communities with a central repository for verified studies and data.
NPDES Stormwater Cost Survey	A 2005 study in California that reports survey findings for municipal stormwater management costs to comply with NPDES requirements.
Green Values National Stormwater Management Calculator	A 2009 free tool for use in calculating and comparing costs of conventional stormwater management practices with green infrastructure and new types of stormwater control measures. Includes an expansive list of construction, maintenance, and component unit costs.

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