EARTH ECONOMICS

User Guide: Green Infrastructure Benefits Valuation Tool

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

EARTH ECONOMICS

Version: 1.01, updated 11/20/2018

Acknowledgments

The report and the associated tool were developed by Rowan Schmidt and Jordan Wildish of Earth Economics. Major guidance and editing was provided by Paula Conolly of the Green Infrastructure Leadership Exchange and Wing Tam of the LA Sanitation department in the City of Los Angeles. Design support was provided by Cheri Jensen of Earth Economics. The authors are responsible for the content of this report. Generous support for this project was provided by the Kresge Foundation.

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

User Guide: Green Infrastructure Benefits Valuation Tool

Contents

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

About the Green Infrastructure Benefits Valuation Tool

Why Consider Green Infrastructure?

Water, wastewater, and stormwater utilities in the United States made significant investments in water infrastructure throughout the 20th century to meet the pressing public health needs and evolving environmental regulations of the times. Today utilities face a new set of challenges, including aging infrastructure, obsolete technologies, increased demand, climate change, and increasingly stringent environmental standards.

These issues are often compounded by increasing costs and stagnant or decreasing revenues. Traditional engineering solutions focused on the planning and construction of new system capacity cannot address these complex level-of-service and reliability issues by themselves. This massive investment need provides an opportunity to meet environmental and infrastructure challenges using a new generation of approaches, including green infrastructure.

In the context of water, wastewater and stormwater utilities, green infrastructure (GI) refers to the use of vegetation and soil to manage water. The term can encompass a range of natural environments (including forests, wetlands, floodplains, riparian buffers, parks, and green space) as well as human-built infrastructure (constructed wetlands, rain gardens, green roofs, bioswales, retention ponds, and permeable pavement). In contrast, "grey infrastructure" generally refers to more conventional systems of water transport, storage, and treatment that involve pipes, pumps, and tanks. In an economic sense, green infrastructure and grey infrastructure are "complements," and both are required to deliver wastewater and drinking water services.

GI provides a number of direct benefits that support utility service delivery, as well as broader community benefits. Benefits can include reducing water treatment needs, improving water quality, reducing flooding, increasing groundwater recharge, reducing energy use, improving air quality, reducing the urban heat island effect, providing recreational opportunities, and providing wildlife habitat.[1] The particular benefits that a utility or community values will certainly vary significantly across the country, but in almost all cases green infrastructure provides multiple benefits that extend beyond the borders of the utility and its mission.

---

[1] The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. 2010. The Center for Neighborhood Technology and American Rivers. Accessed at http://www.cnt.org/repository/gi-values-guide.pdf

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Most agencies require economic analysis to show the business case for significant infrastructure investments. In the past, methods, requirements, and common practice for economic analysis have been narrowly focused on built infrastructure such as pipes, pumps, and bridges, with little regard for the broader environmental and social costs and benefits. However, economics has evolved over the past decades, and methods and data are now increasingly available for quantifying and valuing the co-benefits of GI. For example, the economic analysis for a riparian wetland built for flood control can now quantify the many ecosystem benefits (flood protection, habitat, recreation, carbon sequestration, etc.) as well as local benefits to the economy via jobs and improved health for neighboring residents. This more comprehensive view allows decision makers to compare built and green infrastructure options in an "apples-to-apples" manner, and strike the best balance of investment in each.

The Purpose of this Tool

An increasing number of resources and tools are now available to support quantification and valuation of the GI benefits. However, some of the existing resources and tools are focused on specific geographies, benefits, or GI asset types, and others require significant investments in staff time, data, or economic expertise.

In other words, there appears to be a "gap" in the available resources, for agency staff who are looking for a tool to provide a quick, screening assessment of the potential costs and benefits of different GI investment options. This gap may be filled in the future by a comprehensive GI valuation tool, which is being developed through a Water Research Foundation-funded project, but this tool will not be ready for some time.

In the meantime, this User Guide and associated Tool is intended to fill this gap, by providing a framework, methods, and values to support rapid screening-level analysis of the costs and benefits associated with a range of GI investments. While every effort was made to allow for local/custom data inputs, this tool cannot replace a comprehensive local economic analysis, and should not be used as the basis for large investment decisions. Rather, it is intended to help educate agency leaders, generate internal discussion about the costs and benefits of GI options, and serve as a starting point for more detailed analysis.

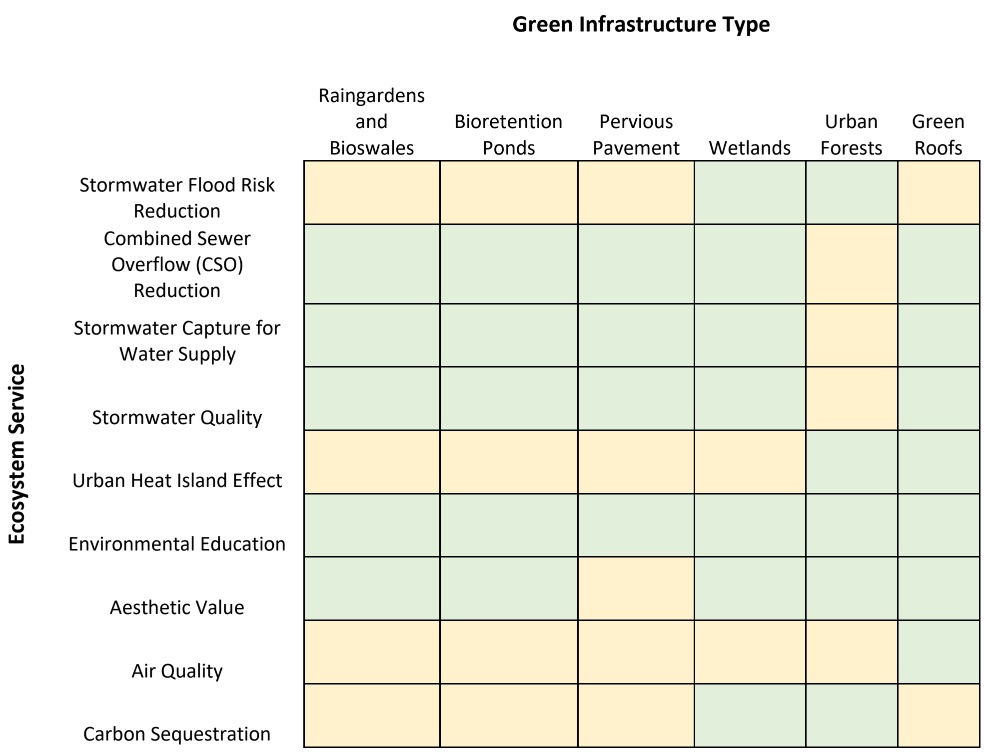
It should be emphasized that all values in this tool presented estimates, based on best available research, and actual benefits may differ significantly from these estimates. Local biophysical,

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

demographic, engineering and economic data should be used wherever possible, and the Tool allows for custom inputs where this data is available.

Within this tool, rapid valuation methods were developed for nine benefits across six GI asset categories, based on responses to a survey conducted by the Green Infrastructure Leadership Exchange. Identified and valued benefits are summarized in Figure 1 below. As shown in Figure 1, valuation methods were not available for all benefits across all GI asset categories. Benefits that are not valued in this tool do not indicate a benefit of zero, but rather than satisfactory research could not be identified to value this benefit. Because of these gaps and the additional benefit categories not included in this study, the estimated benefits should be considered an underestimate of the true benefits provided by these assets.

Figure 1. Gaps in Services Valued Within this Tools (green cells indicate available research, orange cells indicate gaps)



Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

How to use this tool

This guide provides descriptions, instructions, and best practices for each type of green infrastructure, and each associated ecosystem service valued within the tool. The guide can be used to provide context and background for the calculations generated in the associated spreadsheet. This guide is divided into sections by green infrastructure type. Each green infrastructure section includes the calculations, sources, and descriptions of all ecosystem services valued for that infrastructure type.

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Raingardens and Bioswales

Raingardens and Bioswales capture precipitation and stormwater runoff that would otherwise flow into sewer systems or waterways. Raingardens and Bioswales are vegetated sections of permeable ground, often strategically placed in low points, surrounded by impermeable surfaces. Research on these green infrastructure assets has demonstrated their potential to provide flood protection, reduction in combined sewer overflow (CSO) events, aquifer recharge, water quality improvements, heat island reduction, educational benefits, aesthetic value, air quality, and carbon sequestration.[2] [3] The following sections describe methods to estimate the value several of these benefits, along with values that can be applied to your local context and guidance on how to adjust the values within The Tool.

Benefit: Combined Sewer Overflow (CSO) Event Reduction

Background: Raingardens and Bioswales help mitigate the risk of CSO events by reducing the amount of water entering the sewer system.

Valuation Method: The marginal value of reduced CSO risk provided by Raingardens and Bioswales is calculated in the Tool using on the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Raingardens and Bioswales is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Raingarden can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Raingardens and Bioswales capture more than 90% of rainfall falling on their surface.[4]
3) **Number of CSO events.** CSO likelihood is estimated as a function of inches of rainfall per rainfall-day, with the default values based on state-level data. Areas with more heavy rain events have a greater risk of CSO events.

---

[2] Asleson, B. C., Nestingen, R. S., Gulliver, J. S., Hozalski, R. M., & Nieber, J. L. (2009). Performance Assessment of Rain Gardens 1. *JAWRA Journal of the American Water Resources Association*, *45*(4), 1019-1031.

[3] Dussaillant, A. R., Wu, C. H., & Potter, K. W. (2004). Richards equation model of a rain garden. *Journal of Hydrologic Engineering*, *9*(3), 219-225.

[4] Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

4) **Cost savings from using green infrastructure.** Every unit of water that does not enter the utility's system reduces the marginal capital and O&M costs for that utility. The national meta-analysis used for the Tool found that conventional CSO event prevention, using storage tanks, costs more than $1 per liter stored over the lifetime of the infrastructure,[5] or an annualized value of $0.04 per liter stored per year.

Example calculation: The following example calculation shows how the value of a Raingarden can be calculated for a hypothetical city in Connecticut.

$$
\begin{aligned}
\$152.32\ Value\ of\ CSO\ Capture \\
&= 0.95\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\
&\times \$0.04\ Per\ Liter\ Avoided\ Cost\ of\ Conventional\ Storage \\
&\times (450\ Sq.Ft.of\ Raingarden + 350\ Sq.Ft.Additional\ Drainage\ Area) \\
&\times 5.03\ Estimated\ Number\ of\ CSO\ Events\ Per\ Year
\end{aligned}
$$

In the above example, the "*Stormwater Captured per Rainfall Day*", and "*Avoided Cost of Conventional Storage*" values are static. The "*Sq. Ft. of Raingarden*" and *"Sq. Ft. Additional Drainage Area"* values are entered by the user, and the "*Estimated Number of CSO Events Per Year*" value can either be entered by the user or set to a default value (based on state average precipitation).

In this example, the Raingarden is estimated to provide **$152.32** in CSO prevention benefits per year.
The likelihood of a CSO event is highly local and depends on a city's rainfall, local hydrology of drainage basins, existing infrastructure in those basins, and other factors. The avoided costs as a result of avoiding these events are also highly local to the agency. In the Tool itself, many of the inputs can be customized, including rainfall, value of CSO reduction, and the number of CSO events per year.

Exceptions: This benefit should not be valued in cities (or portions of cities) that do not have combined sewers.

[5] Ibid

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Benefit: Stormwater Capture for Water Supply

Background: Raingardens and Bioswales allow water to permeate into the water table which would otherwise runoff to storm drains or into rivers. Groundwater consumption constitutes 20%[6] of all water withdrawals in the US, and increasing groundwater levels through permeable green infrastructure can help to recharge aquifers.

Valuation Method: The amount of water captured from Raingardens and Bioswales is calculated in the Tool using the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Raingardens and Bioswales is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Raingarden can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Raingardens and Bioswales capture more than 90% of rainfall falling directly on their surface.[7]
3) **Value, per liter of captured stormwater.** Captured groundwater was valued using EPA research on market and water rights values of groundwater recharge from stormwater retention.[8] The values determined in that study and used as default values in the Tool, averaged around $120/ acre-ft. This value is likely conservative for many urban areas in the US. It is appropriate for cities in water scarce regions to apply higher acre-ft values for captured water, to better reflect local conditions.
4) **Number of rainfall days at Raingarden site.** The average number of rainfall days, by state, is provided within the tool. For a more localized analysis, users can input the average number of rainfall days per year in their city or region.

Example Calculation: The following example calculation shows how the value of a Raingarden can be calculated for a hypothetical Raingarden in Connecticut

---

[6]"Groundwater Use in the United States" (2015) USGS Water Science School. Retrieved from: https://water.usgs.gov/edu/wugw.html

[7] Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.

[8] "Estimating Monetized Benefits of Groundwater Recharge for Stormwater Retention Practices " (2016) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

$$
\begin{aligned}
\$9.85\ Value\ of\ Stormwater\ Captured \\
&= 0.95\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\
&\times (450\ sq.ft\ of\ Raingarden \\
&+ 350\ sq.ft.\ Additional\ Drainage\ Area) \\
&\times 123.5\ Rainfall\ Days, per\ year \\
&\times \$0.000105\ Market\ Value\ of\ Stormwater\ Per\ Liter
\end{aligned}
$$

In the above example, the Raingarden provides **$9.85** in water supply benefits, per year. The "*Stormwater Captured per rainfall Day*" value is static. The "*Square Footage of Raingarden*" and *"Additional Drainage Area"* values are input by the user, and the "*Rainfall Days, per year*" and "*Market Value of Stormwater Per Liter*" values can either by input by the user or estimated within the tool.

Exceptions: This benefit should not be valued for Raingardens and Bioswales that do not drain to an aquifer used for drinking water.

Benefit: Stormwater Quality

Background: Raingardens and Bioswales capture pollutants as water flows through them.[9] Water quality improvements associated with these infrastructure installations were estimated using research compiled in the BMP database.[10] Raingardens and Bioswales demonstrated significant water quality improvements across a wide variety of metrics including Total Suspended Solids, Fecal Coliform bacteria, heavy metals, and nutrient run-off.[11] Valuing water quality changes can be challenging, because values are very specific to local pollutants, the water treatment goals/capacity of the agency, and other factors. The values presented here and in the tool are intended to be general estimates based on best available data and should be used for screening-level analysis only, not for investment decisions.

[9] Jayasooriya, V. M., & Ng, A. W. M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. *Water, Air, & Soil Pollution*, *225*(8), 2055.
[10] Clary, J., Jones, H. (2017) "International Stormwater BMP Database". International Stormwater BMP Database.
[11] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Valuation Method: Valuing decreases in specific pollutants is challenging, because cities and regions vary in their specific pollutant concerns. Raingardens and Bioswales have been shown to reduce pollutant loads by 25-100%[12], on par with many conventional treatment methods.[13]

1) **Volume of flowing into a BMP.** Average water capture for Raingardens and Bioswales is estimated by calculating the amount of water flowing into the BMP from adjacent drainage. Rainfall directly falling onto the BMP does typically contain significant pollutants, so only flow from adjacent drainage areas is included in this valuation.
2) **Percent of rainfall captured by BMP.** Research indicates that more than 90% of rainfall hitting a Raingarden is captured by the green infrastructure asset.[14]
3) **Cost of Conventional Surface Water Treatment, Per Liter.** Average cost of conventional treatment, adjusted to 2017 currency year.[15]

Example Calculation: The following example calculation shows how water quality improvements can be valued for a hypothetical Raingarden in Connecticut.

$$\begin{aligned}\$46.75\ Value\ of\ Stormwater\ Quality \\ &= .95\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\ &\times \$0.0005\ Per\ Liter\ Avoided\ Cost\ Of\ Treated\ Effluent \\ &\times (450\ Sq.Ft.of\ Raingarden + 350\ Sq.Ft.of\ Additional\ Drainage) \\ &\times 123.5\ Number\ of\ Rainfall\ Days\end{aligned}$$

In the above example, "*Liters of Stormwater Captured per Rainfall Day*" and *"Runoff Capture Efficiency"* are provided by the tool. *"Per Liter Avoided Cost of Treated Effluent"* and *"Number of Rainfall Days"* can be either inputted by the user, or generated using estimates within the Tool. *"Sq. Ft. of Raingarden"* is inputted by the user.

In the above example, the Raingarden provides **$46.75** in Stormwater Quality improvements, per year.

---

[12] Ibid
[13] "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution" (n.d). US EPA.
[14] Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.
[15] Rogers, C. (2008) Economic Costs of Conventional Surface-Water Treatment: A Case Study of the Mcallen Northwest Facility. Texas A&M University

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Exceptions: Cities which do not incur surface water treatment costs may not wish to value this benefit.

Benefit: Environmental Education

Background: Green infrastructure is often used as a tool for environmental and scientific education.[16] Many green infrastructure assets are utilized for field trips and class activities, and provide unique educational opportunities.

Valuation Method: The educational value of Bioswales and Raingardens is calculated in the Tool using the following inputs:

1) **Value of education, per student-hour.** Using data on per-student expenditures[17] and hours of educational time per year[18], the financial cost per student, per hour of education, was calculated for every state. This represents the public's "willingness to pay" to education.
2) **Average educational visitations to public green space.** Research conducted by Earth Economics in 2017 identified that public urban green spaces receive, on average, approximately 29 student-hours of educational use, per acre, per year. Educational use is highly variable across green infrastructure assets, and this value is intended to be used as a conservative estimate when more specific data in not available.

Example Calculation: The following example calculation shows how the educational value of a Raingarden can be calculated for a hypothetical Raingarden in Connecticut:

$$\$6.27\ \textit{Educational Benefits} = \$15.54\ \textit{Cost of Education per Student Hour} \times ((29\ \textit{Student Hours Per Acre Per Year} \div 43{,}560\ \textit{Sq. Ft in an Acre}) \times 600\ \textit{Sq. Ft in Raingarden})$$

[16] "Teach, Learn, and Grow: The Value of Green Infrastructure in Schoolyards" (2017) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/green-infrastructure/teach-learn-grow-value-green-infrastructure-schoolyards

[17] "2014 Public Elementary – Secondary Education Finance Data" (2014) United States Census. Retrieved from: https://www.census.gov/data/tables/2014/econ/school-finances/secondary-education-finance.html

[18] "Schools and Staffing Survey" (2008) National Center for Education Statistics. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

In the above example, the "*Sq. Ft. in Raingarden"* values are entered by the user, and the "*Cost of Education per Student Hours* ", and "*Student Hours Per Acre Per Year"* values are generated by state-based averages.

In this example, the Raingarden is estimated to provide **$6.27** in education benefits, per year.

Exceptions: Green infrastructure installations not used for educational purposes should not include this benefit.

Benefit: Aesthetic Value

Background: Raingardens and Bioswales are attractive and desirable natural features. Low Impact Development (LID) including Raingardens and Bioswales, have been shown to improve sales values of adjacent homes by 3.5%-5%. [19] The complete aesthetic value of these developments cannot be measured, however sales price premiums are a commonly used and accepted method to estimate a portion of the aesthetic premium placed upon these developments. ae

Valuation Method: The aesthetic value of Raingardens and Bioswales in measured using the following steps:

1) **Average Home Value.** Average state home values are provided in the tool, and can be supplanted with more localized sales numbers, as available.
2) **Price Premium of BMP.** The 3.5% price premium figure is applied to all homes surrounding green installation.[20]
3) **Number of Homes Adjacent to BMP.** Users are asked to estimate the number of homes, if any, which are directly adjacent to the BMP.

Example Calculation

The following example calculation shows how the aesthetic value of a Raingarden can be calculated for a hypothetical Raingarden in Connecticut:

[19] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.
[20] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

$$\$648.04\ Aesthetic\ Benefits = (\$240{,}700\ Average\ Home\ Value\ \div 13\ Home\ Sales\ Interval) \times 3.5\%\ Home\ Price\ Premium\ of\ BMP\ \times 1\ Home\ Adjacent\ to\ BMP$$

In the above example, the "*Home Adjacent to BMP*" value is entered by the user, and the "*Average Home Value*" are generated by state-based averages but can the supplanted by user data. The remaining values are static within the Tool.

In this example, the Raingarden is estimated to provide **$648.04** in aesthetic benefits, per year.

Exceptions: Raingardens that are not visible to adjacent homes and/or have no public access may not wish to include this benefit.

Urban Trees

Urban Trees, whether as a component of a larger green infrastructure installation or a standalone feature provide a variety of both public and private benefits. Urban Trees have demonstrable benefits to water capture and flood risk reduction, property value, heat island reduction, and public health.[21] Unlike traditional infrastructure assets, Urban Trees appreciate in value over time as trees grow and mature.[22]

Benefit: Stormwater Flood Risk Reduction

Background: Urban Trees capture and retain stormwater, reducing the risk of flooding and reducing the cost of flood interventions.[23] The value of stormwater capture is estimated at approximately $7 per tree, for fully grown and mature trees.[24]

Valuation Methods: The value of flood risk reduction for Urban Trees is estimated as a function of the following:

---

[21] Tyrväinen, L., Pauleit, S., Seeland, K., & de Vries, S. (2005). Benefits and uses of urban forests and trees. In *Urban forests and trees* (pp. 81-114). Springer, Berlin, Heidelberg.
[22] McPherson, E. G., & Peper, P. J. (2012). Urban Tree growth modeling. *Journal of Arboriculture & Urban Forestry. 38 (5): 175-183*, *38*(5), 175-183.
[23] Ibid
[24] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

1) **Stormwater Capture Value.** Reductions in the stormwater were valued using research conducted by the Forest Service on Urban Trees in 5 cities across the US.[25] On average, a mature Urban Tree reduced stormwater costs by $7.32, per tree, per year (adjusted to 2017 currency year).
2) **Tree Age Adjustment.** To account for tree age, and adjustment factor is calculated based on average tree height by age.[26]

Example Calculation: The following example calculation shows how stormwater reduction value can be calculated for a hypothetical 10 year old Urban Tree:

$$\$4.77\ Per\ Tree = \$7.32\ Stormwater\ Reduction \times Age\ Based\ Adjustment\ Factor\left[\frac{\left(3.2463 \times ln(10\ Years\ )\right) + 2.3009}{15}\right]$$

Exceptions: Cities for whom stormwater protection is not a concern may not wish to include this value.

Benefit: Urban Heat Island Reduction

Background: Urban Trees reduce the heat island effect in urban areas by providing shade and evapotranspiration. The heat island reduction of urban vegetation is significant, estimated at 1-4.7˚ C in densely vegetated areas. [27] This heat reduction not only reduces the health impacts of heat stress, but reduces the energy costs associated with building cooling as well.

Valuation Method: The value of heat island reduction created by Urban Trees is calculated as a function of the following:

3) **Heat Island Reduction.** Reductions in the heat islands effects were valued using research conducted by the Forest Service on Urban Trees in 5 cities across the US.[28] On average, a

[25] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. *Journal of forestry*, *103*(8), 411-416.
[26] McPherson, E. G., & Peper, P. J. (2012). Urban Tree growth modeling. *Journal of Arboriculture & Urban Forestry. 38 (5): 175-183*, *38*(5), 175-183.
[27] Solecki, W. D., Rosenzweig, C., Parshall, L., Pope, G., Clark, M., Cox, J., & Wiencke, M. (2005). Mitigation of the heat island effect in urban New Jersey. *Global Environmental Change Part B: Environmental Hazards*, *6*(1), 39-49.
[28] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. *Journal of forestry*, *103*(8), 411-416.

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

mature Urban Tree reduced building energy costs by $11.1, per tree, per year (adjusted to 2017 currency year).

4) **Tree Age Adjustment.** To account for tree age, and adjustment factor is calculated based on average tree height by age.[29]

Example Calculation: The following example calculation shows how the heat island value can be calculated for a hypothetical 10 year old Urban Tree:

$$\$7.23\ Per\ Tree = \$11.1\ Energy\ Cost\ Reduction \times Age\ Based\ Adjustment\ Factor\left[\frac{\left(3.2463 \times ln(10\ Years\ )\right) + 2.3009}{15}\right]$$

In the above example, the "*Energy Cost Reduction*" value is static. The "*Age Based Adjustment Factor*" is generated based on user inputted tree age.
In this example, the Urban Tree is estimated to provide **$7.23** in urban heat island reduction value per year.

Exceptions: Cities with minimal cooling needs should not value this benefit. Trees in non-urban areas should also not be valued.

Benefit: Aesthetic Value

Background: Urban Forests are aesthetically desirable.[30] Although much of the aesthetic benefits provided by these installations are subjective and challenging to value, research on the impact on Urban Trees on property values allows a portion of the aesthetic value of trees to be valued. [31]

Valuation Method: The aesthetic benefits created by tree installations are calculated as function of the following:

---

[29] McPherson, E. G., & Peper, P. J. (2012). Urban Tree growth modeling. *Journal of Arboriculture & Urban Forestry. 38 (5): 175-183*, *38*(5), 175-183.

[30] Tyrväinen, L., Pauleit, S., Seeland, K., & de Vries, S. (2005). Benefits and uses of urban forests and trees. In *Urban forests and trees* (pp. 81-114). Springer, Berlin, Heidelberg.

[31] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. *Journal of forestry*, *103*(8), 411-416.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

1) **Home Value Increase** The 3.5% price premium figure is applied to all homes surrounding green installation.[32]
2) **Median Local Home Values**. Median home values, at the state level[33] are provided within the tool, however users may add more localized home values, as available.

Example Calculation The following example calculation shows how aesthetic benefits can be calculated for a hypothetical Urban Forest in Connecticut:

$$\$1{,}944\ Aesthetic\ Benefit\ of\ Urban\ Forests = (\$240{,}700\ Average\ Home\ Value\ \div 13\ Year\ Home\ Sales\ Interval) \times 3.5\%\ Home\ Price\ Premium\ of\ BMP\ \times 3\ Home\ Adjacent\ to\ BMP$$

In the above example, the "*Home Value Increase"* value is static. The "*Median Local Home Values"* can be generated with the Tool based on state averages, or manually inputted by the user.
In this example, the tree installation is estimated to provide **$1,944** in aesthetic benefits, per year.

Exceptions: Trees that are not adjacent to built infrastructure (commercial or residential) should not value this benefit.

Benefit: Carbon Sequestration

Background: Trees are a primary driver of carbon sequestration. The carbon sequestered and stored by Urban Trees contributes to climate change mitigation. The carbon sequestration capacity of trees has been well studied and quantified. For the purposes of generalizable analysis, only average values are supplied within this Tool. Supplemental values can be calculated using the USFS online "Tree Carbon Calculator" which allows users to calculate carbon sequestration by tree size, age, geographic location, and species.
Valuation Method: The carbon sequestrations benefits created by Urban Trees are calculated as function of the following:

1) **Amount of carbon sequestered**. On average, Urban Trees sequester approximately 0.09 tons of CO_2, per tree, per year.[34]

[32] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.
[33] "United States Home Values and Prices" (2018). Zillow Group.
[34] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. *Journal of forestry*, *103*(8), 411-416.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

2) **Social cost of carbon dioxide.** The value of sequestered and is quantified using the EPA's Social Cost of Carbon per ton ($39 in the current year)[35]. The value is based on the infrastructure and health costs associated with increased heat intensity, more extreme natural disasters, and sea level rise.
3) **Tree Age Adjustment.** To account for tree age, and adjustment factor is calculated based on average tree height by age.[36]

Example Calculation: The following example calculation shows how carbon sequestration values can be calculated for a hypothetical 10 year old Urban Tree:

$$\$2.29\ Carbon\ Sequestration\ Benefit\ Per\ Tree = 0.09\ Metric\ Tons\ of\ CO_2\ Sequestered \times \$39\ Social\ Cost\ of\ Carbon \times Age\ Based\ Adjustment\ Factor[\frac{(3.2463 \times LN(10\ Years)) + 2.3009}{15}]$$

In the above example, the "*Metric Tons of CO_2 Per Year*" and "*Social Cost of Carbon*" values are static. The "*Age Based Adjustment Factor*" is generated based on user inputted tree age.
In this example, the Urban Tree is estimated to provide **$2.3** in carbon sequestration benefits, per year.

Green Roofs

Vegetated roofs are an emerging strategy to add green infrastructure into building development. Green Roofs can contain a variety of vegetation installations, ranging from gardens beds to native grasses or mosses.[37] Green Roofs are gaining favor among building developers and users as a cost-effective way to add the water capture, aesthetic, and urban heat island reduction benefits of green infrastructure into urban design. Within this Tool, values for Green Roofs are calculated differently than other Green Infrastructures assets. Research on Green Roofs is very limited. Whereas other installations (such as trees or bioswales) may present very differently by location, Green Roof installations are largely consistent in functionality. Thus, many benefit categories that include state level data inputs for other asset types are able to be localized for Green Roofs.

[35] "The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions" (n.d.) United States Environmental Protection Agency.
[36] McPherson, E. G., & Peper, P. J. (2012). Urban Tree growth modeling. *Journal of Arboriculture & Urban Forestry. 38 (5): 175-183*, *38*(5), 175-183.
[37] Berndtsson, J. C. (2010). Green Roof performance towards management of runoff water quantity and quality: A review. *Ecological Engineering*, *36*(4), 351-360.

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Benefit: Combined Sewer Overflow (CSO) Event Reduction

Background: Green Roofs help mitigate the risk of CSO events by reducing the amount of water entering the sewer system. Green Roofs are typically designed to capture most or all of the water that falls on the roof's surface and would otherwise runoff into the storm water system.

Valuation Method: The marginal value of reduced CSO risk provided by Green Roofs is calculated in the Tool using on the following inputs:

1) **Volume of water falling on roof.** Average water capture for Green Roofs is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day.
2) **Percent of rainfall captured by roof.** Research demonstrates that Green Roofs capture approximately 60% of rainfall falling on the asset.[38]
3) **Number of CSO events.** CSO likelihood is estimated as a function of inches of rainfall per rainfall-day, with the default values based on state-level data. Areas with more heavy rain events have a greater risk of CSOs.
4) **Cost savings from using green infrastructure.** Every unit of water that does not enter the utility's system reduces the marginal capital and O&M costs for that utility. The national meta-analysis used for the Tool found that conventional CSO event prevention, using storage tanks, costs more than $1 per liter stored over the lifetime of the infrastructure,[39] or an annualized value of $0.04 per liter stored per year.

Example calculation: The following example calculation shows how the value of a Green Roof can be calculated for a hypothetical city in Connecticut.

$$
\begin{aligned}
&\$46.62\ \textit{Value of CSO Capture} \\
&\quad = .58\ \textit{Liters of Stormwater Captured Per Rainfall Day} \\
&\quad \times \$0.04\ \textit{Per Liter Avoided Cost of Conventional Storage} \\
&\quad \times 400\ \textit{Sq. Ft. of Green Roof} \\
&\quad \times 5.03\ \textit{Estimated Number of CSO Events Per Year}
\end{aligned}
$$

[38] Berghage, R., et. Al (2009) Green Roofs for Stormwater Runoff Control. National Risk Management Research Laboratory
[39] Ibid

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

In the above example, the "*Stormwater Captured per Rainfall day*", *"Runoff Capture Efficiency"* and "*Avoided Cost of Conventional Storage"* values are static. The "*Sq. Ft. of Green Roof*" values are entered by the user, and the "*Estimated Number of CSO Events Per Year*" value can either be entered by the user or set to a default value (based on state average precipitation).

In this example, the Green Roof is estimated to provide **$46.62** in CSO prevention benefits, per year. The likelihood of a CSO event is highly local and depends on a city's rainfall, local hydrology of drainage basins, existing infrastructure in those basins, and other factors. The avoided costs as a result of avoiding these events are also highly local to the agency. In the Tool itself, many of the inputs can be customized, including rainfall, value of CSO reduction, and the number of CSO events per year.

Exceptions: This benefit should not be valued in cities (or portions of cities) that do not have combined sewers.

Benefit: Stormwater Capture for Water Supply:

Background: Green Roofs, when disconnected from storm drains, allow water to permeate into the water table which would otherwise runoff to storm drains or into rivers. Groundwater consumption constitutes 20%[40] of all water withdrawals in the US, and increasing groundwater levels through permeable green infrastructure can help to recharge aquifers.

Valuation Method: The amount of water captured from Green Roofs is calculated in the Tool using the following inputs:

1) **Volume of water falling on roof.** Average water capture for Green Roofs is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day.
2) **Percent of rainfall captured by roof.** Research demonstrates that Green Roofs capture approximately 60% of rainfall falling on the asset.[41]
3) **Value, per liter of captured stormwater.** Captured groundwater was valued using EPA research on market and water rights values of groundwater recharge from stormwater

[40]"Groundwater Use in the United States" (2015) USGS Water Science School. Retrieved from: https://water.usgs.gov/edu/wugw.html

[41] Berghage, R., et. Al (2009) Green Roofs for Stormwater Runoff Control. National Risk Management Research Laboratory

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

retention.[42] The values determined in that study and used as default values in the Tool, averaged around $120/ acre-ft. This value is likely conservative for many urban areas in the US. It is appropriate for cities in water scarce regions to apply higher acre-ft values for captured water, to better reflect local conditions.

4) **Number of rainfall days at Raingarden site.** The average number of rainfall days, by state is provided within the tool. For a more localized analysis, users can input the average number of rainfall days per year in their city or region.

Example Calculation: The following example calculation shows how the stormwater capture of a Green Roof can be calculated for a hypothetical Green Roof in Connecticut.

$$\$7.54\ Value\ of\ Stormwater\ Captured = 0.58\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \times 1000\ sq.ft\ of\ Green\ Roof \times 123.5\ Rainfall\ Days, per\ year \times \$0.000105\ Market\ Value\ of\ Stormwater\ Per\ Liter$$

In the above example, the "*Stormwater Captured per rainfall Day"* value is static. The "*Square Footage of Green Roof"* value is input by the user, and the "*Rainfall Days, per year*" and "*Market Value of Stormwater Per Liter"* values can either by input by the user or estimated within the tool.

Exceptions: This benefit should not be valued for Green Roofs that do not drain to an aquifer used for drinking water.

Benefit: Urban Heat Island Reduction

Background: Green Roofs reduce the heat island effect in urban areas by reducing the intensity of heat absorbed by the building below. The heat island reduction of urban vegetation is significant, estimated at 0.5-3˚ C for buildings with Green Roofs.[43] This heat reduction decreases building cooling costs.

Valuation Method: The value of heat island reduction created by Green Roofs is calculated as a function of the following:

---

[42] "Estimating Monetized Benefits of Groundwater Recharge for Stormwater Retention Practices " (2016) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf

[43] Santamouris, M. (2014). Cooling the cities–a review of reflective and Green Roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar energy*, *103*, 682-703.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

1) **Heat Island Reduction.** Reductions in the heat islands effects were valued using research conducted by the Green Infrastructure Foundation.[44] On average, one square foot of Green Roof reduced building energy costs by $0.23, per Sq. Ft., per year.

Example Calculation: The following example calculation shows how the heat island reduction value can be calculated for a hypothetical Green Roof:

$$\$92 = \$0.23\ Energy\ Cost\ Reduction, per\ Sq.ft., per\ year \times 400\ Sq.ft\ of\ Green\ Roof$$

In the above example, the "*Energy Cost Reduction"* value is static. The "*Sq. Ft. of Green Roof"* value is inputted by the user.
In this example, the Green Roof is estimated to provide **$92** in building energy savings, per year.

Exceptions: Cities with minimal cooling costs, and trees that are not located in dense urban should not value this benefit.

Benefit: Environmental Education

Background: Accessible Green Roofs are often used as a tool for environmental and scientific education.[45] Many green infrastructure assets are utilized for field trips and class activities, and provide unique educational opportunities.

Valuation Method: The educational value of Green Roofs is calculated in the tool using the following inputs:

1) **Value of education, per student-hour.** Using data on per-student expenditures[46] and hours of educational time per year[47], the financial cost per student, per hour of education, was calculated for every state
2) **Average educational visitations to public green space.** Surveys conducted by Earth Economics in 2017 identified that public urban green spaces receive, on average,

[44] "Making Informed Decisions: A Green Roof Cost and Benefit Study for Denver" (2017) Green Infrastructure Foundation
[45] Kudryavtsev, A., Krasny, M. E., & Stedman, R. C. (2012). The impact of environmental education on sense of place among urban youth. *Ecosphere*, *3*(4), 1-15.
[46] "2014 Public Elementary – Secondary Education Finance Data" (2014) United States Census. Retrieved from: https://www.census.gov/data/tables/2014/econ/school-finances/secondary-education-finance.html
[47] "Schools and Staffing Survey" (2008) National Center for Education Statistics. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

approximately 29 student-hours of educational use, per acre, per year. Educational use is highly variable across green infrastructure assets, and this value is intended to be used as a conservative estimate when more specific data in not available.

Example Calculation: The following example calculation shows how the educational value can be calculated for a hypothetical Green Roof in Connecticut:

$$\$4.18\ Educational\ Benefits = \$15.54\ Cost\ of\ Education\ per\ Student\ Hour * ((29\ Student\ Hours\ Per\ Acre\ Per\ Year\ \div 43{,}560\ sq.ft\ in\ an\ Acre) \times 400\ sq.ft\ of\ Green\ Roof)$$

In the above example, the "*Sq. Ft. in Green Roof*" values are entered by the user, and the "*Cost of Education per Student Hours*", and "*Student Hours Per Acre Per Year*" values are generated by state-based averages.

In this example, the Green Roof is estimated to provide **$4.18** in educational benefits per year.

Exceptions: Green Infrastructure installations not used for educational purposes should not include this benefit.

Benefit: Aesthetic Value

Background: Green Roofs are unique design features that increase building value.[48] Although much of the aesthetic benefits provided by these installations are subjective and challenging to value, research on the impact of Green Roofs on building rental values allows a portion of the aesthetic value of these assets to be measured. [49] Where aesthetic values for other types of green infrastructure can be calculated using localized price inputs, research on the property value impacts of Green Roof is too limited to allow that level of nuance.

[48] Gregoire, B. G., & Clausen, J. C. (2011). Effect of a modular extensive Green Roof on stormwater runoff and water quality. *Ecological Engineering*, *37*(6), 963-969.
[49] "Making Informed Decisions: A Green Roof Cost and Benefit Study for Denver" (2017) Green Infrastructure Foundation

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Valuation Method: The aesthetic benefits created by Green Roofs is calculated as function of the following:

1) **Property Value Increase**. Research indicates that one square foot of Green Roof increases building rental value by $0.3, per year.[50]

Example Calculation: The following example calculation shows how the aesthetic value can be calculated for a hypothetical Green Roof:

$$\$120\ Aesthetic\ Benefits\ of\ Green\ Roofs = \$0.3\ Property\ Value\ Increase, Per\ Sq.Ft., Per\ Year \times\ 400\ Sq.Ft\ of\ Green\ Roof$$

In the above example, the "*Property Value Increase*" value is static. The "*Sq. Ft. of Green Roof*" value is inputted by the user.
In this example, the Green Roof is estimated to provide **$120** in aesthetic benefits, per year.

Exceptions: Green Roofs that are not accessible or visible to occupants may not wish include this benefit.

Benefit: Air Quality

Background: Vegetated roofs capture and sequester ozone, nitrogen dioxide, and sulfur dioxide which are commonly found in high concentrations in urban areas. This pollution removal has been demonstrated to have significant benefits to human health and wellbeing in densely populated areas. [51]
Valuation Method: The air pollution reduction benefits created by Green Roofs are calculated as a function of the following:

1. **Amount of Air Pollutants Captured**: Pollutant removal from Green Roofs impacts both outdoor and indoor air quality, as many buildings have air intake units located on the roof.
2. **Value of Air Pollution:** Air pollution is valued using marginal the healthcare costs associated with incremental association to these pollutants.

Example Calculation The following example calculation shows how the air quality improvement value can be calculated for a hypothetical Green Roof:

[50] Ibid
[51] Nowak, D. J. (2002). The effects of Urban Trees on air quality. *USDA Forest Service*, 96-102.

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

$$\$14.00\ Air\ Quality\ Benefit\ of\ Green\ Roofs = \$0.035\ Air\ Quality\ Benefit \times\ 400\ sq.Ft\ of\ Green\ Roof$$

In the above example, the "*Air Quality Benefit*" value is static. The *"Sq. Ft. of Green Roof"* is inputted by the user.
In this example, the Green Roof is estimated to provide **$14.00** in air quality benefits, per year.

Bioretention Ponds

Bioretention Ponds are intended to store and filter water runoff. These ponds may appear similar to bioswales in that they are vegetated areas placed below the ground level. Bioretention ponds tend to be designed to hold water for several months a year, and may include underdrains or other built infrastructure components.[52] Although each BMP has specific characteristics, for the purpose of the analysis, "Bioretention ponds" are defined as a catch-all term that includes detention basins/ponds and retention basins/ponds. BMP's that do not hold water year round or during the entirety of the rainy season should be categorized as "Raingardens or Bioswales" or "Wetlands" when using this Tool.

Benefit: Combined Sewer Overflow (CSO) Event Reduction

Background: Bioretention Ponds help mitigate the risk of CSO events by storing excess water, reducing the amount of water entering the sewer system during a rain event.

Valuation Method: The marginal value of reduced CSO risk provided by Bioretention Ponds is calculated in the Tool using on the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Bioretention Ponds is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Pond can also be manually added in the Tool.

[52] "Bioretention Design Specification and Criteria" (n.d) Maryland Department of the Environment.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

2) **Percent of rainfall captured by BMP.** Research demonstrates that Bioretention Ponds capture approximately 80% of rainfall falling on the asset.[53]
3) **Number of CSO events.** CSO likelihood is estimated as a function of inches of rainfall per rainfall-day, with the default values based on state-level data. Areas with more heavy rain events have a greater risk of CSOs.
4) **Cost savings from using green infrastructure.** Every unit of water that does not enter the utility's system reduces the marginal capital and O&M costs for that utility. The national meta-analysis used for the Tool found that conventional CSO event prevention, using storage tanks, costs more than $1 per liter stored over the lifetime of the infrastructure,[54] or an annualized value of $0.04 per liter stored per year.

Example calculation: The following example calculation shows how the value of a Bioretention Pond can be calculated for a hypothetical city in Florida.

$$\begin{aligned}\$769.22\ Value\ of\ CSO\ Capture\\ &= 0.76\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day\\ &\times \$0.04\ Per\ Liter\ Avoided\ Cost\ of\ Conventional\ Storage\\ &\times (1500\ sq.ft.of Bioretention\ Pond + 2500\ Sq.Ft.Additional\ Drainage\ Area)\\ &\times 5.45\ Estimated\ Number\ of\ CSO\ Events\ Per\ Year\end{aligned}$$

In the above example, the "*Stormwater Captured per Rainfall Day*", and "*Avoided Cost of Conventional Storage*" values are static. The "*Sq. Ft. of Bioretention Pond*" and *"Sq. Ft. Additional Drainage Area"* values are entered by the user, and the "*Estimated Number of CSO Events Per Year*" value can either be entered by the user or set to a default value (based on state average precipitation).

In this example, the Bioretention Pond is estimated to provide **$769.22** in CSO prevention benefits, per year.
The likelihood of a CSO event is highly local and depends on a city's rainfall, local hydrology of drainage basins, existing infrastructure in those basins, and other factors. The avoided costs as a result of avoiding these events are also highly local to the agency. In the Tool itself, many of the

[53] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado
[54] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

inputs can be customized, including rainfall, value of CSO reduction, and the number of CSO events per year.

Exceptions: This benefit should not be valued in cities (or portions of cities) that do not have combined sewers.

Benefit: Stormwater Capture for Water Supply

Background: Bioretention Ponds allow water to gradually release and permeate into the water table which would otherwise runoff to storm drains or into rivers. Groundwater consumption constitutes 20%[55] of all water withdrawals in the US, and increasing groundwater levels through permeable green infrastructure can help to recharge aquifers.

Valuation Method: The amount of water captured from Bioretention Ponds is calculated in the Tool using the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Bioretention Ponds is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Pond can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Bioretention Ponds capture approximately 80% of rainfall falling on a roof.[56]
3) **Value, per liter of captured stormwater.** Captured groundwater was valued using EPA research on market and water rights values of groundwater recharge from stormwater retention.[57] The values determined in that study and used as default values in the Tool, averaged around $120/ acre-ft. This value is likely conservative for many urban areas in the US. It is appropriate for cities in water scarce regions to apply higher acre-ft values for captured water, to better reflect local conditions.

---

[55] "Groundwater Use in the United States" (2015) USGS Water Science School. Retrieved from: https://water.usgs.gov/edu/wugw.html

[56] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado

[57] "Estimating Monetized Benefits of Groundwater Recharge for Stormwater Retention Practices " (2016) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

4) **Number of rainfall days at Bioretention Pond site.** The average number of rainfall days, by state is provided within the tool. For a more localized analysis, users can input the average number of rainfall days per year in their city or region.

Example Calculation: The following example calculation shows how the value of a Bioretention Pond can be calculated for a hypothetical asset in Florida.

$$\$43.38\ Value\ of\ Stormwater\ Captured = 0.88\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \times (1500\ Sq.ft\ of\ Bioretention\ Pond + 2500\ Sq.Ft.\ Additional\ Drainage\ Area) \times 116\ Rainfall\ Days, per\ year \times \$0.000105\ Market\ Value\ of\ Stormwater\ Per\ Liter$$

In the above example, the "*Stormwater Captured per rainfall Day*" value is static. The "*Square Footage of Bioretention Pond*" and *"Additional Drainage Area"* values are input by the user, and the "*Rainfall Days, per year*" and "*Market Value of Stormwater Per Liter*" values can either by input by the user or estimated within the tool.

Exceptions: This benefit should not be valued for Bioretention Ponds that do not drain to an aquifer used for drinking water.

Benefit: Stormwater Quality

Background: Bioretention Ponds capture pollutants as water flows through them.[58] Water quality improvements associated with these infrastructure installations were estimated using research compiled in the BMP database.[59] Bioretention Ponds demonstrated significant water quality improvements across a wide variety of metrics including Total Suspended Solids, Fecal Coliform bacteria, heavy metals, and nutrient run-off.[60] Valuing water quality changes can be challenging, because values are impacted by the localized conditions and water treatment capacity. The values presented in the report are intended to be general estimates based on best available data and should not be considered precise costs savings values.

[58] Jayasooriya, V. M., & Ng, A. W. M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. *Water, Air, & Soil Pollution*, *225*(8), 2055.
[59] Clary, J., Jones, H. (2017) "International Stormwater BMP Database". International Stormwater BMP Database.
[60] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Valuation Method: Valuing decreases in specific pollutants is challenging, because cities and regions vary in their specific pollutant concerns. Bioretention Ponds have been shown to reduce pollutant loads by 25-100%[61], on par with many conventional treatment methods.[62]

1) **Volume of water falling on BMP.** Average water capture for Bioretention Ponds is estimated by calculating the amount of water flowing into the BMP from adjacent drainage. Rainfall directly falling onto the BMP does typically contain significant pollutants, so only flow from adjacent drainage areas is included in this valuation.
2) **Percent of rainfall captured by BMP.** Research indicates that more than 80% of rainfall hitting a Bioretention Pond is captured by the green infrastructure asset.[63]
3) **Cost of Conventional Surface Water Treatment, Per Liter.** Average cost of conventional treatment, adjusted to 2017 currency year.[64]

Example Calculation: The following example calculation shows how water quality improvements can be valued for a hypothetical Bioretention Pond in Florida.

$$\begin{aligned}\$204.65\ &Value\ of\ Stormwater\ Quality\\ &= 0.88\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day\\ &\times \$0.0005\ Per\ Liter\ Avoided\ Cost\ Of\ Treated\ Effluent\\ &\times (1500\ Sq.Ft.of\ Bioretention\ Pond\\ &+ 2500\ Sq.Ft.of\ Additional\ Runoff\ Area) \times 116\ Number\ of\ Rainfall\ Days\end{aligned}$$

In the above example, "*Liters of Stormwater Captured per Rainfall Day"* and *"Runoff Capture Efficiency"* are provided by the tool. *"Per Liter Avoided Cost of Treated Effluent"* and *"Number of Rainfall Days"* can be either inputted by the user, or generated using estimates within the Tool. *"Sq. Ft. of Bioretention Pond"* is inputted by the user.

In the above example, the Bioretention Pond provides **$204.65** in Stormwater Quality improvements, per year.

---

[61] Ibid

[62] "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution" (n.d). US EPA.

[63] Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.

[64] Rogers, C. (2008) Economic Costs of Conventional Surface-Water Treatment: A Case Study of the Mcallen Northwest Facility. Texas A&M University

Office 253.539.4801 *Address* 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Exceptions: Cities which do not incur surface water treatment costs may not wish to value this benefit.

Benefit: Environmental Education

Background: Green infrastructure is often used as a tool for environmental and scientific education.[65] Many green infrastructure assets are utilized for field trips and class activities, and provide unique educational opportunities.

Valuation Method: The educational value of Bioretention Ponds is calculated in the Tool using the following inputs:

3) **Value of education, per student-hour.** Using data on per-student expenditures[66] and hours of educational time per year[67], the financial cost per student, per hour of education, was calculated for every state. This represents the public's "willingness to pay" to education.
4) **Average educational visitations to public green space.** Research conducted by Earth Economics in 2017 identified that public urban green spaces receive, on average, approximately 29 student-hours of educational use, per acre, per year. Educational use is highly variable across green infrastructure assets, and this value is intended to be used as a conservative estimate when more specific data in not available.

Example Calculation: The following example calculation shows how the educational value of a Bioretention Pond can be calculated for a hypothetical Bioretention Pond in Florida:

$$\$7.65\ Educational\ Benefits = \$7.59\ Cost\ of\ Education\ per\ Student\ Hour \times ((29.3\ Student\ Hours\ Per\ Acre\ Per\ Year\ \div 43{,}560\ Sq.Ft\ in\ an\ Acre) \times 1500\ Sq.Ft\ in\ Bioretention\ Pond)$$

[65] "Teach, Learn, and Grow: The Value of Green Infrastructure in Schoolyards" (2017) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/green-infrastructure/teach-learn-grow-value-green-infrastructure-schoolyards

[66] "2014 Public Elementary – Secondary Education Finance Data" (2014) United States Census. Retrieved from: https://www.census.gov/data/tables/2014/econ/school-finances/secondary-education-finance.html

[67] "Schools and Staffing Survey" (2008) National Center for Education Statistics. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

In the above example, the "*Sq. Ft. in Bioretention Pond"* values are entered by the user, and the "*Cost of Education per Student Hours* ", and "*Student Hours Per Acre Per Year"* values are generated by state-based averages.

In this example, the Bioretention Pond is estimated to provide **$7.65** in education benefits, per year.

Exceptions: Green Infrastructure Installations not used for educational purposes should not include this benefit.

Benefit: Aesthetic Value

Background: Bioretention Ponds are attractive and desirable natural features. Low Impact Development (LID) including Bioretention Ponds, have been shown to improves sales values of adjacent homes by 3.5%-5%. [68] The complete aesthetic value of these developments cannot be measured, however sales price premiums are a commonly used and accepted method to estimate a portion of the aesthetic premium placed upon these developments. The improvement in home value resulting from the GI asset are annualized by dividing the home value by 13, the average home sales interval.[69]

Valuation Method: The aesthetic value of Bioretention Ponds is measured using the following steps:

1) **Average Home Value.** Average state home values are provided in the tool, and can be supplanted with more localized sales numbers, as available.
2) **Price Premium of BMP.** The 3.5% price premium figure is applied to all homes surrounding green installation.[70]
3) **Number of Homes Adjacent to BMP.** Users are asked to estimate the number of homes, if any, which are directly adjacent to the BMP.

Example Calculation

---

[68] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.

[69] Emrath, P (2013) "Latest Study Shows Average Buyer Expected to Stay in a Home 13 Years". National Association of Home Builders. Retrieved from: http://eyeonhousing.org/2013/01/latest-study-shows-average-buyer-expected-to-stay-in-a-home-13-years/

[70] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

The following example calculation shows how the aesthetic value of a Bioretention Pond can be calculated for a hypothetical Raingarden in Florida:

$$\$607.92\ Aesthetic\ Benefits = (\$225{,}800\ Average\ Home\ Value\ \div 13\ Home\ Sales\ Interval) \times 3.5\%\ Home\ Price\ Premium\ of\ BMP\ \times 1\ Home\ Adjacent\ to\ BMP$$

In the above example, the "*Home Adjacent to BMP"* value is entered by the user, and the "*Average Home Value* " are generated by state-based averages but can the supplanted by user data. The remaining values are static within the Tool.

In this example, the Bioretention Pond is estimated to provide **$607.92** in aesthetic benefits, per year.

Exceptions: Bioretention Ponds that are not visible to adjacent homes and/or have no public access may not wish to include this benefit.

Pervious Pavement

Pervious Pavement absorbs and infiltrates water that would otherwise run off of traditional pavement. Many varieties of Pervious Pavement exist, such as porous asphalt, porous concrete or the use of pavers in place of contiguous surfaces. Although all of the installations have their associated and unique benefits and functions, within the Tool they may all be considered as "Pervious Pavement".

Benefit: Combined Sewer Overflow (CSO) Event Reduction

Background: Pervious Pavement helps mitigate the risk of CSO events by storing excess water, reducing the amount of water running off pavement and into the sewer system during a rain event.

Valuation Method: The marginal value of reduced CSO risk provided by Pervious Pavement is calculated in the Tool using on the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Pervious Pavement is estimated by calculating the amount volume of water hitting its surface based on average

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

rainfall during a precipitation day. Additional areas that drain into the Pavement installation can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Pervious Pavement captures approximately 70% of rainfall falling on the asset.[71]
3) **Number of CSO events.** CSO likelihood is estimated as a function of inches of rainfall per rainfall-day, with the default values based on state-level data. Areas with more heavy rain events have a greater risk of CSOs.
4) **Cost savings from using green infrastructure.** Every unit of water that does not enter the utility's system reduces the marginal capital and O&M costs for that utility. The national meta-analysis used for the Tool found that conventional CSO event prevention, using storage tanks, costs more than $1 per liter stored over the lifetime of the infrastructure,[72] or an annualized value of $0.04 per liter stored per year.

Example calculation: The following example calculation shows how the value of a Pervious Pavement can be calculated for a hypothetical city in Iowa.

$$
\begin{aligned}
\$68.16\ Value\ of\ CSO\ Capture \\
&= 0.5\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\
&\times \$0.04\ Per\ Liter\ Avoided\ Cost\ of\ Conventional\ Storage \\
&\times (756\ Sq.Ft.ofPervious\ Pavement \\
&+ 240\ \ Sq.Ft.of\ Additional\ Runoff\ Area) \\
&\times 3.4\ Estimated\ Number\ of\ CSO\ Events\ Per\ Year
\end{aligned}
$$

In the above example, the "*Stormwater Captured per Rainfall Day*", and "*Avoided Cost of Conventional Storage"* values are static. The "*Sq. Ft. of Pervious Pavement"* and *"Sq. Ft. Additional Drainage Area"* values are entered by the user, and the "*Estimated Number of CSO Events Per Year*" value can either be entered by the user or set to a default value (based on state average precipitation).

In this example, the Pervious Pavement is estimated to provide **$68.16** in CSO prevention benefits, per year.

---

[71] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado
[72] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

The likelihood of a CSO event is highly local and depends on a city's rainfall, local hydrology of drainage basins, existing infrastructure in those basins, and other factors. The avoided costs as a result of avoiding these events are also highly local to the agency. In the Tool itself, many of the inputs can be customized, including rainfall, value of CSO reduction, and the number of CSO events per year.

Exceptions: This benefit should not be valued in cities (or portions of cities) that do not have combined sewers.

Benefit: Stormwater Capture for Water Supply

Background: Pervious Pavement allows water to permeate into the water table which would otherwise runoff to storm drains or into rivers. Groundwater consumption constitutes 20%[73] of all water withdrawals in the US, and increasing groundwater levels through permeable green infrastructure can help to recharge aquifers.

Valuation Method: The amount of water captured from Pervious Pavement is calculated in the Tool using the following inputs:

1) **Volume of water falling on the BMP.** Average water capture for Pervious Pavement is estimated by calculating the amount volume of water hitting a surface, by average rainfall during a precipitation day. Additional area flowing into the Pavement can be added within the tool. For many Pervious Pavement that additional area measured may be very significant.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Pervious Pavement capture approximately 50% of rainfall falling on the Pervious Pavement.[74]
3) **Value, per liter of captured stormwater.** Captured groundwater was valued using EPA research on market and water rights values of groundwater recharge from stormwater retention.[75] The values determined in that study and used as default values in the Tool, averaged around $120/ acre-ft. This value is likely conservative for many urban areas in the

[73]"Groundwater Use in the United States" (2015) USGS Water Science School. Retrieved from: https://water.usgs.gov/edu/wugw.html

[74] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado

[75] "Estimating Monetized Benefits of Groundwater Recharge for Stormwater Retention Practices " (2016) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

US. It is appropriate for cities in water scarce regions to apply higher acre-ft values for captured water, to better reflect local conditions.
4) **Number of rainfall days at Pervious Pavement site.** The average number of rainfall days, by state is provided within the tool. For a more localized analysis, users can input the average number of rainfall days per year in their city or region.

Example Calculation: The following example calculation shows how the value of a Pervious Pavement can be calculated for a hypothetical asset in Iowa.

$$\begin{aligned}\$3.16\ Value\ of\ Stormwater\ Captured \\ &= 0.5\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\ &\times (756\ Sq.Ft\ of\ Pervious\ Pavement \\ &+ 240\ Sq.Ft.\ Additional\ Drainage\ Area) \\ &\times 111\ Rainfall\ Days, per\ year \\ &\times \$0.000105\ Market\ Value\ of\ Stormwater\ Per\ Liter\end{aligned}$$

In the above example, the "*Stormwater Captured per rainfall Day"* value is static. The "*Square Footage of Pervious Pavement* and *"Additional Drainage Area"* values are input by the user, and the "*Rainfall Days, per year*" and "*Market Value of Stormwater Per Liter"* values can either by input by the user or estimated within the tool.

Exceptions: This benefit should not be valued for Pervious Pavement installations that do not drain to an aquifer used for drinking water.

Benefit: Stormwater Quality

Background: Pervious Pavement captures pollutants as water flows through them.[76] Water quality improvements associated with these infrastructure installations were estimated using research compiled in the BMP database.[77] Pervious Pavement demonstrated significant water quality improvements across a wide variety of metrics including Total Suspended Solids, Fecal Coliform bacteria, heavy metals, and nutrient run-off.[78] Valuing water quality changes can be challenging, because values are impacted by the localized conditions and water treatment capacity. The values

[76] Jayasooriya, V. M., & Ng, A. W. M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. *Water, Air, & Soil Pollution*, *225*(8), 2055.
[77] Clary, J., Jones, H. (2017) "International Stormwater BMP Database". International Stormwater BMP Database.
[78] Ibid

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

presented in the report are intended to be general estimates based on best available data and should not be considered precise costs savings values.

Valuation Method: Valuing decreases in specific pollutants is challenging, because cities and regions vary in their specific pollutant concerns. Pervious Pavement have been shown to reduce pollutant loads by 25-100%[79], on par with many conventional treatment methods.[80]

1) **Volume of water falling on BMP.** Average water capture for Pervious Pavement is estimated by calculating the amount of water flowing into the BMP from adjacent drainage. Rainfall directly falling onto the BMP does typically contain significant pollutants, so only flow from adjacent drainage areas is included in this valuation.
2) **Percent of rainfall captured by BMP.** Research indicates that more than 50% of rainfall hitting Pervious Pavement is captured by the green infrastructure asset.[81]
3) **Cost of Conventional Surface Water Treatment, Per Liter.** Average cost of conventional treatment, adjusted to 2017 currency year.[82]

Example Calculation: The following example calculation shows how water quality improvements can be valued for hypothetical Pervious Pavement in Iowa.

$$\begin{aligned}\$27.82\ &Value\ of\ Stormwater\ Quality\\ &= .5\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day\\ &\times \$0.0005\ Per\ Liter\ Avoided\ Cost\ Of\ Treated\ Effluent\\ &\times (756\ Sq.Ft.of\ Bioretention\ Pond + 240\ Sq.Ft.of\ Additional\ Runoff\ Area)\\ &\times 111\ Number\ of\ Rainfall\ Days\end{aligned}$$

In the above example, *"Liters of Stormwater Captured per Rainfall Day"* and *"Runoff Capture Efficiency"* are provided by the tool. *"Per Liter Avoided Cost of Treated Effluent"* and *"Number of Rainfall Days"* can be either inputted by the user, or generated using estimates within the Tool. *"Sq. Ft. of Pervious Pavement"* is inputted by the user.

In the above example, the Pervious Pavement provides **$27.82** in Stormwater Quality improvements, per year.

---

79 Ibid
80 "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution" (n.d). US EPA.
81 Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.
82 Rogers, C. (2008) Economic Costs of Conventional Surface-Water Treatment: A Case Study of the Mcallen Northwest Facility. Texas A&M University

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Exceptions: Cities which do not incur surface water treatment costs may not wish to value this benefit.

Benefit: Environmental Education

Background: Green infrastructure is often used as a tool for environmental and scientific education.[83] Many green infrastructure assets are utilized for field trips and class activities, and provide unique educational opportunities. Pervious Pavement is not a common target for educational use, however may be used for field trips as a component of Green Streets or other multi-use installations.

Valuation Method: The educational value of Pervious Pavement is calculated in the Tool using the following inputs:

1) **Value of education, per student-hour.** Using data on per-student expenditures[84] and hours of educational time per year[85], the financial cost per student, per hour of education, was calculated for every state. This represents the public's "willingness to pay" to education.
2) **Average educational visitations to public green space.** Research conducted by Earth Economics in 2017 identified that public urban green spaces receive, on average, approximately 29 student-hours of educational use, per acre, per year. Educational use is highly variable across green infrastructure assets, and this value is intended to be used as a conservative estimate when more specific data in not available.

Example Calculation: The following example calculation shows how the educational value of Pervious Pavement can be calculated for a hypothetical Pervious Pavement Installation in Florida:

[83] "Teach, Learn, and Grow: The Value of Green Infrastructure in Schoolyards" (2017) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/green-infrastructure/teach-learn-grow-value-green-infrastructure-schoolyards
[84] "2014 Public Elementary – Secondary Education Finance Data" (2014) United States Census. Retrieved from: https://www.census.gov/data/tables/2014/econ/school-finances/secondary-education-finance.html
[85] "Schools and Staffing Survey" (2008) National Center for Education Statistics. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

$$\$3.86\ Educational\ Benefits = \$7.59\ Cost\ of\ Education\ per\ Student\ Hour \times ((29.3\ Student\ Hours\ Per\ Acre\ Per\ Year \div 43{,}560\ Sq.Ft\ in\ an\ Acre) \times 756\ Sq.Ft\ of\ Pervious\ Pavement)$$

In the above example, the "*Sq. Ft. of Pervious Pavement"* values are entered by the user, and the "*Cost of Education per Student Hours* ", and "*Student Hours Per Acre Per Year"* values are generated by state-based averages.

In this example, the Pervious Pavement is estimated to provide **$3.86** in education benefits, per year.

Exceptions: Pervious Pavement installations not used for educational purposes should not include this benefit.

Wetlands

Wetland are intended to store and filter water runoff, and provide habitat for flora and fauna. Wetlands may be used as Green Infrastructure either by preserving and maintaining natural wetland areas, or by developing Constructed Wetlands. Wetlands traditionally are meant to stay wet, though not submerged in water, for most or all of the year. Although Wetlands can be any size, these installations are typically quite large.

Benefit: Stormwater Flood Risk Reduction

Background: Wetlands capture and contain stormwater, reducing the risk of flooding and reducing the cost of flood interventions.[86] The value of stormwater capture is estimated at approximately $0.14 per square foot of wetland[87]

Valuation Methods: The value of flood risk reduction for Wetlands is estimated as a function of the following:

---

[86] Leschine, Thomas M,Wellman, Katharine F,Green, Thomas H (1997) The Economic Value of Wetlands: Wetlands' Role in Flood Protection in Western Washington, Washington State Department of Ecology
[87] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

1) **Stormwater Capture Value.** Reductions in the stormwater were valued using research conducted by the Washington State Department of Ecology.[88] On average, a Sq. Ft. of Wetland reduced flood risk by $0.14, per year (adjusted to 2017 currency year).

Example Calculation: The following example calculation shows how stormwater reduction value can be calculated for a hypothetical Wetland:

$$\$1{,}145.45\ Wetland = \$0.14\ Flood\ Reduction\ Per\ Sq.Ft.\ \times (5000\ Sq.Ft\ of\ Wetland + 3000\ Sq.Ft\ of\ Additional\ Drainage\ Area)$$

Exceptions: Cities for whom stormwater protection is not a concern may not wish to include this value.

Benefit: Combined Sewer Overflow (CSO) Event Reduction

Background: Wetlands help mitigate the risk of CSO events by storing excess water, reducing the amount of water entering the sewer system during a rain event.

Valuation Method: The marginal value of reduced CSO risk provided by Wetlands is calculated in the Tool using on the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Wetland is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Wetland can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Wetlands capture approximately 80% of rainfall falling on the asset.[89]
3) **Number of CSO events.** CSO likelihood is estimated as a function of inches of rainfall per rainfall-day, with the default values based on state-level data. Areas with more heavy rain events have a greater risk of CSOs.
4) **Cost savings from using green infrastructure.** Every unit of water that does not enter the utility's system reduces the marginal capital and O&M costs for that utility. The national

[88] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. *Journal of forestry*, *103*(8), 411-416.

[89] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

meta-analysis used for the Tool found that conventional CSO event prevention, using storage tanks, costs more than $1 per liter stored over the lifetime of the infrastructure,[90] or an annualized value of $0.04 per liter stored per year.

Example calculation: The following example calculation shows how the value of a Wetland can be calculated for a hypothetical city in Florida.

$$\begin{aligned}\$1{,}538.44\ &Value\ of\ CSO\ Capture \\ &= 0.88\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\ &\times \$0.04\ Per\ Liter\ Avoided\ Cost\ of\ Conventional\ Storage \\ &\times (5{,}000\ Sq.Ft.ofWetland + 3{,}000\ Sq.Ft.Additional\ Drainage\ Area) \\ &\times 5.45\ Estimated\ Number\ of\ CSO\ Events\ Per\ Year\end{aligned}$$

In the above example, the "*Stormwater Captured per Rainfall Day*", and "*Avoided Cost of Conventional Storage*" values are static. The "*Sq. Ft. of Wetland*" and *"Sq. Ft. Additional Drainage Area"* values are entered by the user, and the "*Estimated Number of CSO Events Per Year*" value can either be entered by the user or set to a default value (based on state average precipitation).

In this example, the Wetland is estimated to provide **$1,538.72** in CSO prevention benefits, per year. The likelihood of a CSO event is highly local and depends on a city's rainfall, local hydrology of drainage basins, existing infrastructure in those basins, and other factors. The avoided costs as a result of avoiding these events are also highly local to the agency. In the Tool itself, many of the inputs can be customized, including rainfall, value of CSO reduction, and the number of CSO events per year.

Exceptions: This benefit should not be valued in cities (or portions of cities) that do not have combined sewers.

Benefit: Stormwater Capture for Water Supply

[90] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Background: Wetlands allow water to gradually release and permeate into the water table which would otherwise runoff to storm drains or into rivers. Groundwater consumption constitutes 20%[91] of all water withdrawals in the US, and increasing groundwater levels through permeable green infrastructure can help to recharge aquifers.

Valuation Method: The amount of water captured from Wetlands is calculated in the Tool using the following inputs:

1) **Volume of water falling on BMP.** Average water capture for Wetlands is estimated by calculating the amount volume of water hitting its surface based on average rainfall during a precipitation day. Additional areas that drain into the Wetlands can also be manually added in the Tool.
2) **Percent of rainfall captured by BMP.** Research demonstrates that Wetlands capture approximately 80% of rainfall falling on the asset.[92]
3) **Value, per liter of captured stormwater.** Captured groundwater was valued using EPA research on market and water rights values of groundwater recharge from stormwater retention.[93] The values determined in that study and used as default values in the Tool, averaged around $120/ acre-ft. This value is likely conservative for many urban areas in the US. It is appropriate for cities in water scarce regions to apply higher acre-ft values for captured water, to better reflect local conditions.
4) **Number of rainfall days at Wetland site.** The average number of rainfall days, by state is provided within the tool. For a more localized analysis, users can input the average number of rainfall days per year in their city or region.

Example Calculation: The following example calculation shows how the value of a Wetland can be calculated for a hypothetical asset in Florida.

---

[91]"Groundwater Use in the United States" (2015) USGS Water Science School. Retrieved from: https://water.usgs.gov/edu/wugw.html

[92] Guo, J., Urbonas, B., MacKenzie, K. (2013) Water Quality Capture Volume for Storm Water BMP and LID Designs. Dept. of Civil Engineering, University of Colorado

[93] "Estimating Monetized Benefits of Groundwater Recharge for Stormwater Retention Practices " (2016) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

$$\begin{aligned}\$86.28\ \textit{Value of Stormwater Captured} &= 0.88\ \textit{Liters of Stormwater Captured Per Rainfall Day} \\ &\times (5000\ \textit{Sq.ft of Wetland} \\ &+ 3000\ \textit{Sq.Ft. Additional Drainage Area}) \\ &\times 116\ \textit{Rainfall Days, per year} \\ &\times \$0.000105\ \textit{Market Value of Stormwater Per Liter}\end{aligned}$$

In the above example, the "*Stormwater Captured per rainfall Day"* value is static. The "*Square Footage of Wetland"* and *"Additional Drainage Area"* values are input by the user, and the "*Rainfall Days, per year*" and "*Market Value of Stormwater Per Liter"* values can either by input by the user or estimated within the tool.

This hypothetical raingarden provides **$86.28** in stormwater capture value per year.

Exceptions: This benefit should not be valued for Wetlands that do not drain to an aquifer used for drinking water.

Benefit: Stormwater Quality

Background: Wetlands capture pollutants as water flows through them.[94] Water quality improvements associated with these infrastructure installations were estimated using research compiled in the BMP database.[95] Wetlands demonstrated significant water quality improvements across a wide variety of metrics including Total Suspended Solids, Fecal Coliform bacteria, heavy metals, and nutrient run-off.[96] Valuing water quality changes can be challenging, because values are impacted by the localized conditions and water treatment capacity. The values presented in the report are intended to be general estimates based on best available data and should not be considered precise costs savings values.

[94] Jayasooriya, V. M., & Ng, A. W. M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. *Water, Air, & Soil Pollution*, *225*(8), 2055.
[95] Clary, J., Jones, H. (2017) "International Stormwater BMP Database". International Stormwater BMP Database.
[96] Ibid

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Valuation Method: Valuing decreases in specific pollutants is challenging, because cities and regions vary in their specific pollutant concerns. Wetlands have been shown to reduce pollutant loads by 25-100%[97], on par with many conventional treatment methods.[98]

1) **Volume of water falling on BMP.** Average water capture for Wetlands is estimated by calculating the amount of water flowing into the BMP from adjacent drainage. Rainfall directly falling onto the BMP does typically contain significant pollutants, so only flow from adjacent drainage areas is included in this valuation.
2) **Percent of rainfall captured by BMP.** Research indicates that more than 80% of rainfall hitting a Wetlands is captured by the green infrastructure asset.[99]
3) **Cost of Conventional Surface Water Treatment, Per Liter.** Average cost of conventional treatment, adjusted to 2017 currency year.[100]

Example Calculation: The following example calculation shows how water quality improvements can be valued for a hypothetical Wetland in Florida.

$$\begin{aligned}\$409.31\ Value\ of\ Stormwater\ Quality \\ &= 0.88\ Liters\ of\ Stormwater\ Captured\ Per\ Rainfall\ Day \\ &\times \$0.0005\ Per\ Liter\ Avoided\ Cost\ Of\ Treated\ Effluent \\ &\times (5000\ Sq.Ft.ofWetland + 3000\ Sq.Ft.of\ Additional\ Runoff\ Area) \\ &\times 116\ Number\ of\ Rainfall\ Days\end{aligned}$$

In the above example, "*Liters of Stormwater Captured per Rainfall Day*" and *"Runoff Capture Efficiency"* are provided by the tool. *"Per Liter Avoided Cost of Treated Effluent"* and *"Number of Rainfall Days"* can be either inputted by the user, or generated using estimates within the Tool. *"Sq. Ft. of Wetland"* is inputted by the user.

In the above example, the Wetland provides **$409.31** in Stormwater Quality improvements, per year.

[97] Ibid
[98] "A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution" (n.d). US EPA.
[99] Xiao, Q., McPherson, E. G., Zhang, Q., Ge, X., & Dahlgren, R. (2017). Performance of two bioswales on urban runoff management. Infrastructures, 2(4), 12.
[100] Rogers, C. (2008) Economic Costs of Conventional Surface-Water Treatment: A Case Study of the Mcallen Northwest Facility. Texas A&M University

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Exceptions: Cities which do not incur surface water treatment costs may not wish to value this benefit.

Benefit: Environmental Education

Background: Green infrastructure is often used as a tool for environmental and scientific education.[101] Many green infrastructure assets are utilized for field trips and class activities, and provide unique educational opportunities.

Valuation Method: The educational value of Wetlands is calculated in the Tool using the following inputs:

1) **Value of education, per student-hour.** Using data on per-student expenditures[102] and hours of educational time per year[103], the financial cost per student, per hour of education, was calculated for every state. This represents the public's "willingness to pay" to education.
2) **Average educational visitations to public green space.** Research conducted by Earth Economics in 2017 identified that public urban green spaces receive, on average, approximately 29 student-hours of educational use, per acre, per year. Educational use is highly variable across green infrastructure assets, and this value is intended to be used as a conservative estimate when more specific data in not available.

Example Calculation: The following example calculation shows how the educational value of a Wetland can be calculated for a hypothetical Wetland in Florida:

$$\$25.51\ Educational\ Benefits = \$7.59\ Cost\ of\ Education\ per\ Student\ Hour \times ((29.3\ Student\ Hours\ Per\ Acre\ Per\ Year\ \div 43{,}560\ sq.Ft\ in\ an\ Acre) \times 5000\ sq.Ft\ in\ Wetland)$$

[101] "Teach, Learn, and Grow: The Value of Green Infrastructure in Schoolyards" (2017) United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/green-infrastructure/teach-learn-grow-value-green-infrastructure-schoolyards
[102] "2014 Public Elementary – Secondary Education Finance Data" (2014) United States Census. Retrieved from: https://www.census.gov/data/tables/2014/econ/school-finances/secondary-education-finance.html
[103] "Schools and Staffing Survey" (2008) National Center for Education Statistics. Retrieved from: https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

In the above example, the "*Sq. Ft. in Wetland"* values are entered by the user, and the "*Cost of Education per Student Hours* ", and "*Student Hours Per Acre Per Year"* values are generated by state-based averages.

In this example, the Wetland is estimated to provide **$25.51** in education benefits, per year.

Exceptions: Green Infrastructure Installations not used for educational purposes should not include this benefit.

Benefit: Aesthetic Value

Background: Wetlands are attractive and desirable natural features. Low Impact Development (LID) including Wetland, have been shown to improve sales values of adjacent homes by 3.5%-5%. [104] The complete aesthetic value of these developments cannot be measured, however sales price premiums are a commonly used and accepted method to estimate a portion of the aesthetic premium placed upon these developments. The improvement in home value resulting from the GI asset are annualized by dividing the home value by 13, the average home sales interval.[105]

Valuation Method: The aesthetic value of Wetlands is measured using the following steps:

1) **Average Home Value.** Average state home values are provided in the tool, and can be supplanted with more localized sales numbers, as available.

2) **Price Premium of BMP.** The 3.5% price premium figure is applied to all homes surrounding green installation.[106]

3) **Number of Homes Adjacent to BMP.** Users are asked to estimate the number of homes, if any, which are directly adjacent to the BMP.

Example Calculation

[104] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.

[105] Emrath, P (2013) "Latest Study Shows Average Buyer Expected to Stay in a Home 13 Years". National Association of Home Builders. Retrieved from: http://eyeonhousing.org/2013/01/latest-study-shows-average-buyer-expected-to-stay-in-a-home-13-years/

[106] Bryce, W., MacMullen, E., Reich, S. (2008) The Effect of Low-Impact Development on Property Values. Proceedings of the Water Environment Federation.

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

The following example calculation shows how the aesthetic value of a Wetland can be calculated for a hypothetical Wetland in Florida:

$$\$1{,}215.85\ \mathit{Aesthetic\ Benefits} = (\$225{,}800\ \mathit{Average\ Home\ Value}\ \div 13\ \mathit{Home\ Sales\ Interval}) \times 3.5\%\ \mathit{Home\ Price\ Premium\ of\ BMP}\ \times 2\ \mathit{Homes\ Adjacent\ to\ BMP}$$

In the above example, the "*Home Adjacent to BMP*" value is entered by the user, and the "*Average Home Value*" are generated by state-based averages but can the supplanted by user data. The remaining values are static within the Tool.

In this example, the Wetland is estimated to provide **$1,215.85** in aesthetic benefits, per year.

Exceptions: Wetlands that are not visible to adjacent homes and/or have no public access may not wish to include this benefit.

Benefit: Carbon Sequestration

Background: Wetlands sequester a significant amount of greenhouse gases. The carbon sequestered and stored by Wetland contributes to climate change mitigation.
Valuation Method: The carbon sequestrations benefits created by Urban Trees are calculated as function of the following:

1) **Amount of carbon sequestered**. On average, Wetlands sequester approximately 0.25 lbs. of CO_2, per Sq. Ft., per year.[107]
2) **Social cost of carbon dioxide.** The value of sequestered and is quantified using the EPA's Social Cost of Carbon per ton ($39 in the current year)[108]. The value is based on the infrastructure and health costs associated with increased heat intensity, more extreme natural disasters, and sea level rise.

Example Calculation: The following example calculation shows how carbon sequestration values can be calculated for a hypothetical 10 year old Urban Tree:

[107] Hansen, L (2009). The Viability of Creating Wetlands for the Sale of Carbon Offsets. Journal of Agricultural and Resource Economics
[108] "The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions" (n.d.) United States Environmental Protection Agency.

$$\$25.61\ Carbon\ Sequestration\ Benefit\ Per\ Tree = 0.00013\ Metric\ Tons\ of\ CO_2\ Sequestered \times \$39\ Social\ Cost\ of\ Carbon \times 5000\ Sq.Ft.of\ Wetland$$

In the above example, the "*Metric Tons of CO_2 Per Year*" and "*Social Cost of Carbon*" values are static. The *"Sq. Ft. of Wetland"* figure is entered by the user.
In this example, the Wetland is estimated to provide **$25.61** in carbon sequestration benefits, per year.

Cost Estimates

Average costs of green infrastructure installations were included within the Tool to allow for a cost-benefit comparison. Costs, both capital and in operation and maintenance, can vary significantly between projects and between regions. The included estimates should be considered as general averages for what similar projects have cost, and not a prediction of the true cost of proposed infrastructure installation.
Within the Tool, users can approximate both capital costs (including design and site preparation costs), and annual operations and maintenance costs.

Capital Costs

Capital costs for each BMP type were estimated based on best available information, and adjusted to the 2018 currency year. In practice, project costs may be higher or lower due to local conditions, labor sourcing and a variety of other issues.

BMP	Units	Low Estimate	Median Estimate	High Estimate
Raingardens and Bioswales	Per Sq. Ft.	$3.00[109]	$8.22[110]	$28.66[111]

[109] Brown, D. (2008) "Create a Bioswale or Raingarden" American Society of Landscape Architects https://www.asla.org/uploadedFiles/CMS/Chapters/CD_Bioswale.pdf
[110] "Pricing Sheet" (n.d.) Center for Neighborhood Technology
[111] Center for Neighborhood Technology (2009) "Green Infrastructure Data Quantification and Assessment In the Calumet Region"

Office 253.539.4801 Address 107 N. Tacoma Avenue
Fax 253.539.5054 Tacoma, WA 98403

Bioretention Ponds	Per Sq. Ft.	$1.38[112]	$9.04[113]	$44.76[114]
Pervious Pavement	Price Premium Above Traditional Roof, Per Sq. Ft.	$0.5[115]	$1.95[116]	$6[117]
Urban Forests	Per Tree	$17.19[118]	$51.94[119]	$85.94[120]
Wetlands	Per Sq. Ft	$2.42[121]	$9.65[122]	$14.12[123]
Green Roofs	Price Premium Above Traditional Roof, Per Sq. Ft.	$11.79[124]	$14.31[125]	$22.56[126]

Operations and Maintenance Costs

Operations and maintenance tend to be a frequent topic of concern in green infrastructure development, as O & M costs for green installations may exceed those of their traditional counterparts. The included estimates reflect the wide range in reported O & M costs. For the sake of simplicity, these costs are calculated per Sq. Ft., although a more nuanced project based cost estimate would be better able to fixed and variable costs associated with maintaining green installations.

BMP	**Units**	**Low Estimate**	**Median Estimate**	**High Estimate**

[112] "Puget Sound Stormwater BMP Cost Database" (2012) Washington State Department of Ecology.
[113] Ibid
[114] Ibid
[115] "Pricing Sheet" (n.d.) Center for Neighborhood Technology
[116] Ibid
[117] Ibid
[118] McPherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). Municipal forest benefits and costs in five US cities. Journal of forestry, 103(8), 411-416.
[119] Ibid
[120] Ibid
[121] "Puget Sound Stormwater BMP Cost Database" (2012) Washington State Department of Ecology.
[122] Ibid
[123] Ibid
[124] "The Benefits and Challenges of Green Roofs on Public and Commercial Buildings" (2011) US General Services Administration
[125] Ibid
[126] Ibid

Office 253.539.4801
Fax 253.539.5054
Address 107 N. Tacoma Avenue
Tacoma, WA 98403

Raingardens and Bioswales	Per Sq. Ft.	$0.07[127]	$0.15[128]	$0.61[129]
Bioretention Ponds	Per Sq. Ft.	$0.25[130]	$0.3[131]	$2.78[132]
Pervious Pavement	Price Premium Above Traditional Roof, Per Sq. Ft.	$0.02[133]	$0.04[134]	$0.23[135]
Urban Forests	Per Tree	$20[136]	$25.07 [137]	$173[138]
Wetlands	Per Sq. Ft	$0.001[139]	$0.002[140]	$0.004[141]
Green Roofs	Price Premium Above Traditional Roof, Per Sq. Ft.	$0.1[142]	$0.21[143]	$0.42[144]

[127] "Pricing Sheet" (n.d.) Center for Neighborhood Technology
[128] Ibid
[129] Ibid
[130] Puget Sound Stormwater BMP Cost Database" (2012) Washington State Department of Ecology.
[131] Ibid
[132] Ibid
[133] Ibid
[134] "Pricing Sheet" (n.d.) Center for Neighborhood Technology
[135] Ibid
[136] "Pricing Sheet" (n.d.) Center for Neighborhood Technology
[137] Ping Song, X., et. al. (2017) "The economic benefits and costs of trees in urban forest stewardship: a systematic review. Urban Forestry & Urban Greening.
[138] Ibid
[139] Narayanan, A. (2005) Costs of Urban Stormwater Control Practices. US EPA.
[140] Ibid
[141] Ibid
[142] "Puget Sound Stormwater BMP Cost Database" (2012) Washington State Department of Ecology.
[143] "The Benefits and Challenges of Green Roofs on Public and Commercial Buildings" (2011) US General Services Administration
[144] "Pricing Sheet" (n.d.) Center for Neighborhood Technology