CLASIC

CASE STUDY

Community Life-Cycle Analysis for Stormwater Infrastructure Costs

Downtown Fort Collins

Colorado

CLASIC Case Studies showcase the variety of ways that the online tool can assist communities with stormwater project planning and decision-making.

CASE STUDY HIGHLIGHTS

- How to mix technology for best cost efficiency
- How to weigh co-benefits (relative and monetized)
- Analysis of 300+ acre 50% impervious downtown area

Background and Project Purpose

Fort Collins has a population of 170,000 and is located in Northern Colorado along the Colorado Front Range. It is in a transition zone between the mountains and plains, intersected from northwest to the Southeast by the Cache La Poudre river which is a wild a scenic river mostly fed by snowmelt in the northern mountains of Colorado.

The study area within Ft Collins was selected to develop feasibility level scenarios to reduce runoff to the Cache La Poudre and determine what types, mixes, and how much green infrastructure could reduce 0.6 inches to 1 inch events. This would help reduce street flooding, improve green space and provide Ft Collins with a way to potentially incorporate different stormwater practices throughout the study area.

CHALLENGE

Outdated infrastructure, stormwater and flooding problems.

Fort Collins is about 57 square miles of mostly developed urban and suburban neighborhoods. The area that is most susceptible to flooding by the Poudre River is in the downtown area and the residential neighborhood surrounding downtown (See Figure 2 blue area).The downtown Fort Collins area is significantly developed with undersized stormwater systems, the Cache La Poudre floodplain in mostly restricted within the banks of the floodplain as the river is fairly incised as it travels across the City.

The river transitions from a mountain stream with a steeper gradient on the West side of the City to a plains agricultural setting on the East side of the City. The need to address flooding and stormwater quality issues in the downtown area was identified in the early 1990s. The Downtown Stormwater Improvement Plan (DSIP) will address the five major stormwater projects remaining in the downtown area.

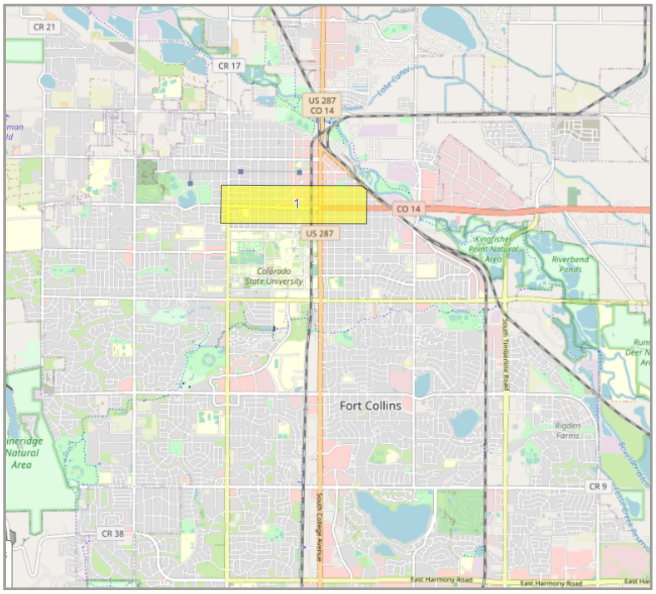

Figure 1 Downtown Ft Collins, Colorado study area in yellow. area in yellow.

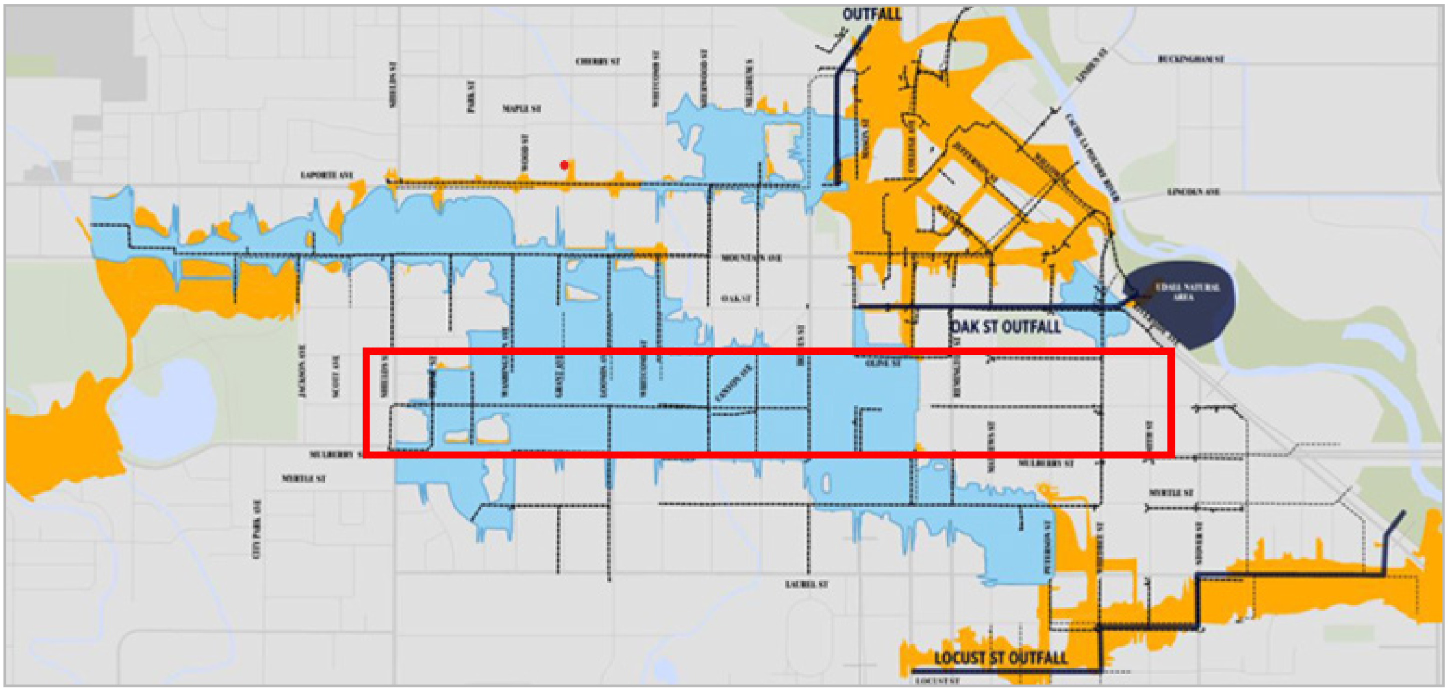

Figure 2 The Howes Street, Oak Street and Locust Street projects were constructed in the late 1990s and early 2000s in the downtown area. Blue indicates the floodplain and the orange is the areas that were removed from the floodplain.

The DSIP is a system of five large pipe projects designed to address the flood risk and improve stormwater quality in downtown Fort Collins. The mains will run along Maple, LaPorte, Oak, Magnolia, and Myrtle. The study area in Figure 1 delineates the current stormsewer catchment that will drain to the Magnolia line. The project scenarios for CLASIC and CBT designed to treat and reduce runoff included a mix of green and gray practices described on page 3.

KEY INPUTS

CLASIC defaults were used for the input selection. Once the study area was delineated in the tool, national databases from the NLCD (2016), SSURGO, climate data, precipitation and evaporation, from EPA BASINS model. CLASIC includes default values for water quality based on land use. Other defaults for are described in the guidance document. The management area in Figure 1 is 394 acres with 35% impervious surface.

GSI Scenarios

The three stormwater management alternatives were analyzed for the 0.6 inch precipitation depth. This is the depth over the captured impervious area that area of the stormwater practices are sized to capture. The runoff volume to generate by a 0.6 event is approximately 300,000 ft^3. Therefore, the scenarios were developed with this target runoff volume reduction.

- The Baseline Scenario created captures 80% of the impervious area and runoff of 300,000 ft^3. This Scenario included simulation of a medium pond with a forebay that would cover approximately 2.1 acres (91,500 ft^2).
- Scenario 2 utilized a mix of medium sized sand filters (38), medium sized raingardens (57) as well as permeable pavers. This scenario captured 312,436 ft^3. The sand filters and raingardens were assumed to be installed in currently pervious areas as opposed to impervious areas and would cover approximately 2.1 acres (95,000 ft^2). The permeable pavers would cover approximately 13.8 acres (601,638 ft^2).
- Scenario 3 utilized a mix of green infrastructure and reduced pond size (green/gray). The pond captured 200,000 ft3, the other infrastructure captured 117,018 ft3, for a total of 317,018 ft^3. The mix of green was similar to above with 6.9 acres of permeable pavers, medium sized sand filters (19) and medium sized raingardens (4) covering approximately 0.53 acres (23,000 ft^2).

Performance

Hydrology and Water Quality

CLASIC hydrologic performance summaries are shown for the three scenarios. Scenario 1 is more an "end of pipe" or "gray" solution because it does not significantly change the hydrology to benefit the recharge or infiltration in the in the study area. Scenario 2 does decrease runoff by 50% and increases infiltration by over 20%. Scenario 3 reduces runoff by approximately 15% and increases infiltration by approximately 8%. Evaporation decreases because the stormwater practices are placed in pervious areas.

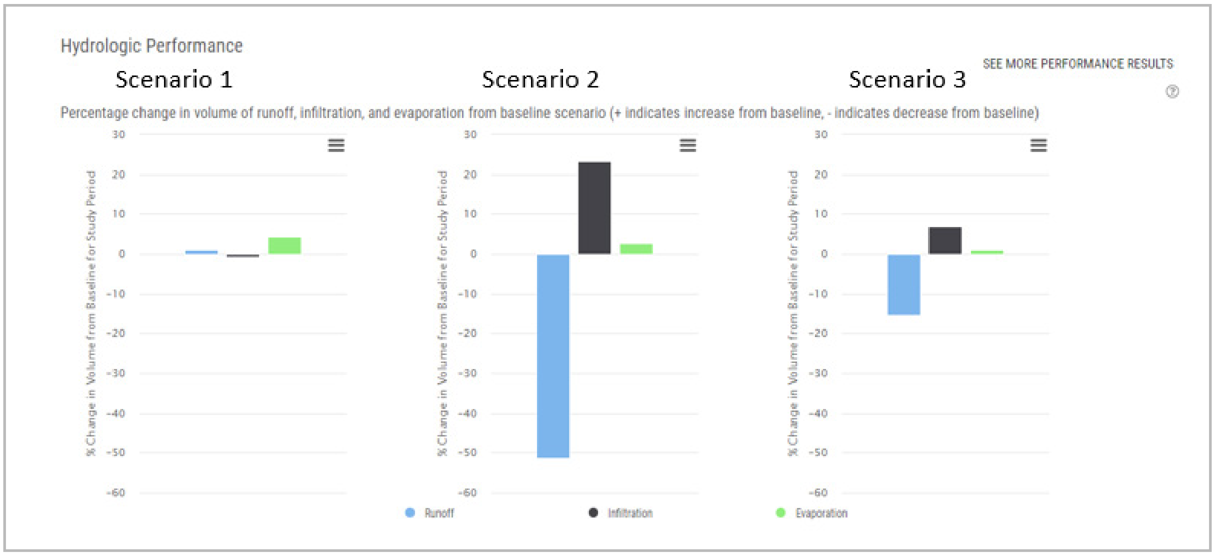

Figure 3 Hydrologic performance for Scenarios 1, 2, 3 from CLASIC output.

CLASIC output below shows modeled water quality changes are greatest for Scenario 2 compared to Scenario 1 and 3. TSS decreases by almost 60%. TN, TP and FIB (not shown) also decrease by almost 60% as well. For Scenario 1 TSS decreases approximately 15% and Scenario 3, 30%. Similar reductions are modeled for TN, TP, and FIB (not shown) for Scenarios 1 and 3.

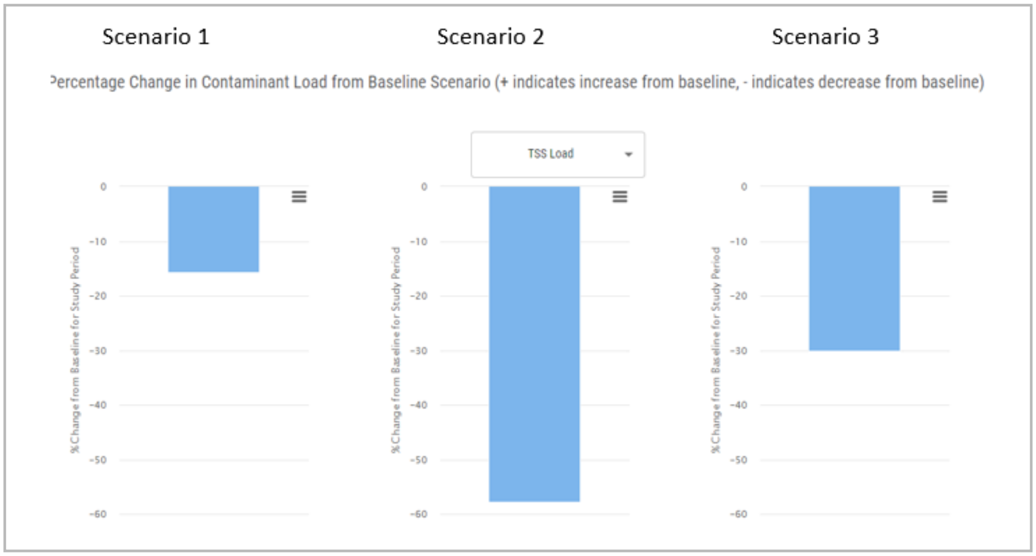

Figure 4 Pollution reduction for Scenarios 1, 2, and 3 from CLASIC output.

Costs

CLASIC generates a cost for construction, maintenance and major rehabilitation based on study period. The study period selected was 35 years to account for at least one rehabilitation period for each stormwater practice. The scenarios included a sensitivity analysis for real discount rates from 0% to 3%. Because CLASIC costs do not take into account cost flux that occurs with labor or other potential escalation, a 0% discount rate assumes discount rate is the same as the rate of increase in other construction and maintenance costs.

Table 1 shows the construction, annual maintenance, and rehabilitation costs for each alternative. Figure 5 provides a snapshot of how these costs are depicted in CLASIC Summary Tab. The average annual costs are the total costs (undiscounted) divided by the study period (35 years). The dollars per gallon shown is the total cost divided by number of gallons treated – which is around 300,000 cubic feet or 2.2 million gallons.

Table 1 Scenarios 1, 2, and 3 cost categories and present value calculations form CLASIC.

	Scenarios Present Value in $		
Cost category	1	2	3
Construction	$437,220	$10,117,731	$4,079,735
Maintenance	$932,712	$4,892,771	$2,295,069
Rehabilitation	$272,880	$4,796,761	$2,097,169
Total (35 yr, 0% discount)	$1,633,812	$19,807,262	$8,471,972
Annual Average	$46,680	$565,922	$242,056
Dollars per gallon (total cost divided by gallons of runoff captured)	$0.74	$9.00	$3.85

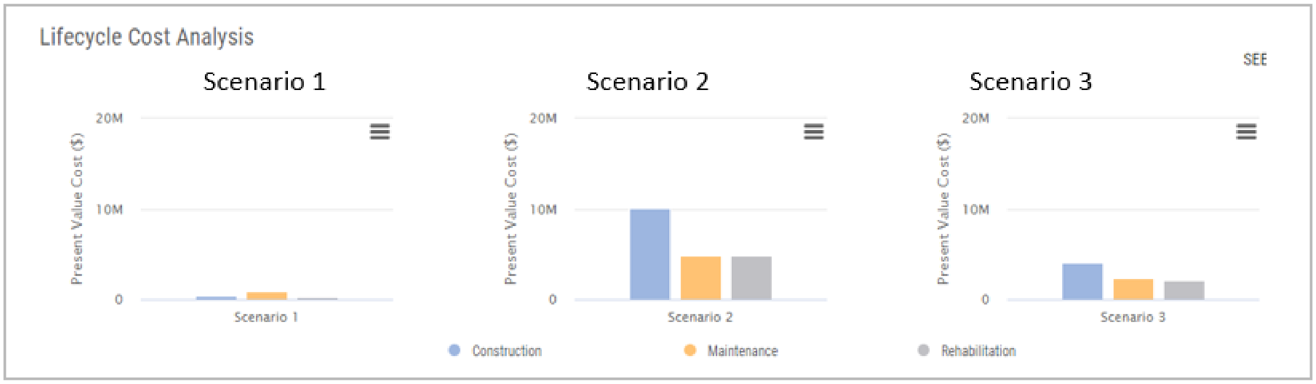

Figure 5 Lifecycle cost for construction maintenance and rehabilitation from CLASIC output.

Benefits

Benefit Indicator Importance

CLASIC provides a relative benefit scenario analysis where the user sets levels of importance for economic, social, and environmental categories associated with stormwater practice benefits for a community. The user selects levels of importance:

1 = Not Important

2 = Somewhat Important

3 = Medium Importance

4 = Very Important

The benefit categories selected as very important (shown below) were to compare the scenarios for economic benefits of property values, potential impacts from nuisance flooding, building efficiency, and employment opportunity. The social indicators selected were for health impacts for air quality, public awareness of stormwater systems, and flooding[1]. Environmental benefits selected for importance were ecosystem services, groundwater flow increase and carbon sequestration. These are benefits also within the Framework and Tool for Quantifying the Triple Bottom Line Benefits of Green Stormwater Infrastructure, described below in the next section.

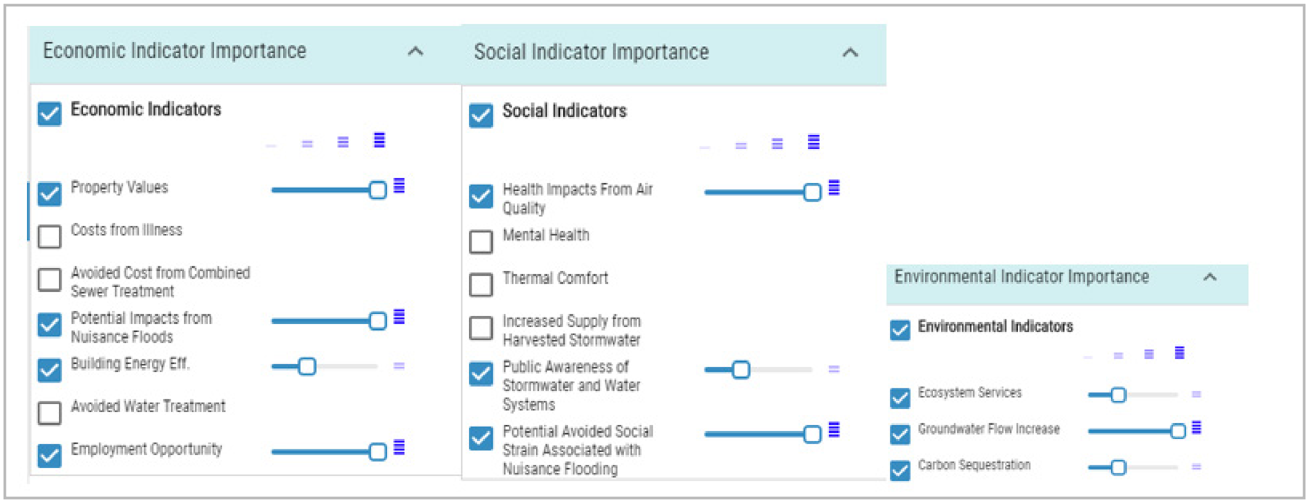

Figure 6 Benefit importance selections.

The CLASIC output on page 7 displays the dial and column graph to observe scores for the economic, social and environmental scores for each scenario. Scenario 1 has the lowest benefit score, Scenario 3 has a moderate score and Scenario 2 has the highest score. The number and distributed nature of the stormwater practices throughout the study area accounts for the benefit score being higher for Scenario 2.

[1] *Monetary values were not calculated therefore, double-counting was not considered.*

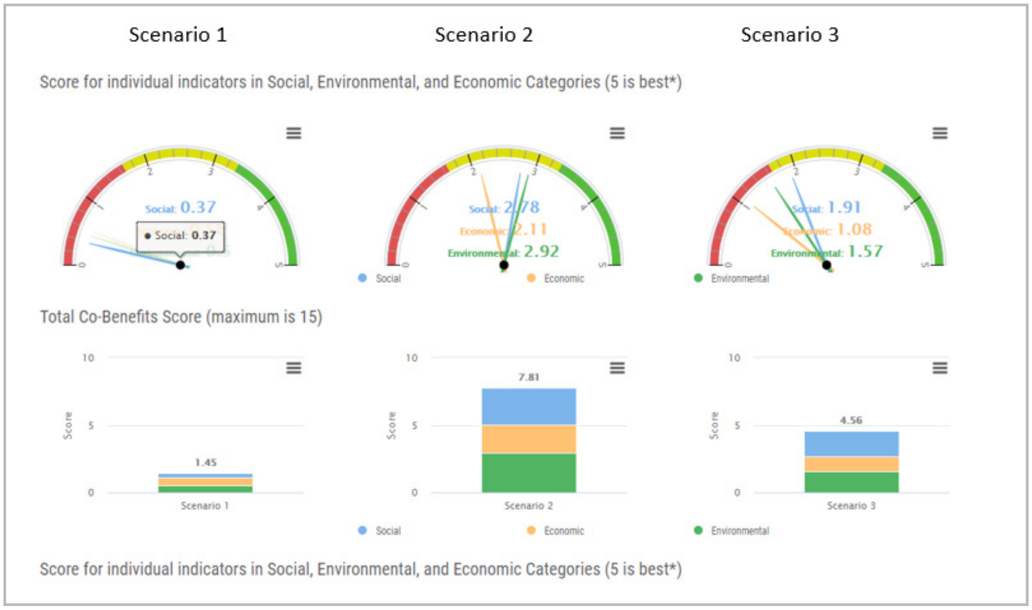

Figure 7 Benefit scores for Scenarios 1, 2, and 3 from CLASIC output.

The benefit scores are correlated with performance output and scaled with the importance level assigned by the user. Potential Impacts from to nuisance floods CLASIC uses runoff volume output and how the scenario reduces average annual precipitation that becomes runoff (in/yr). Scenario 2 reduced the most runoff so social, economic and environmental benefits are highest for this mix of stormwater practices.

CLASIC output also provides the individual scores for benefits generated as shown below. The health impact, public awareness benefits, as well as avoided social strain for nuisance flooding are shown highest as well for Scenario 2. In general the benefits are correlated with increased green space and amount of water treated or captured by the practices.

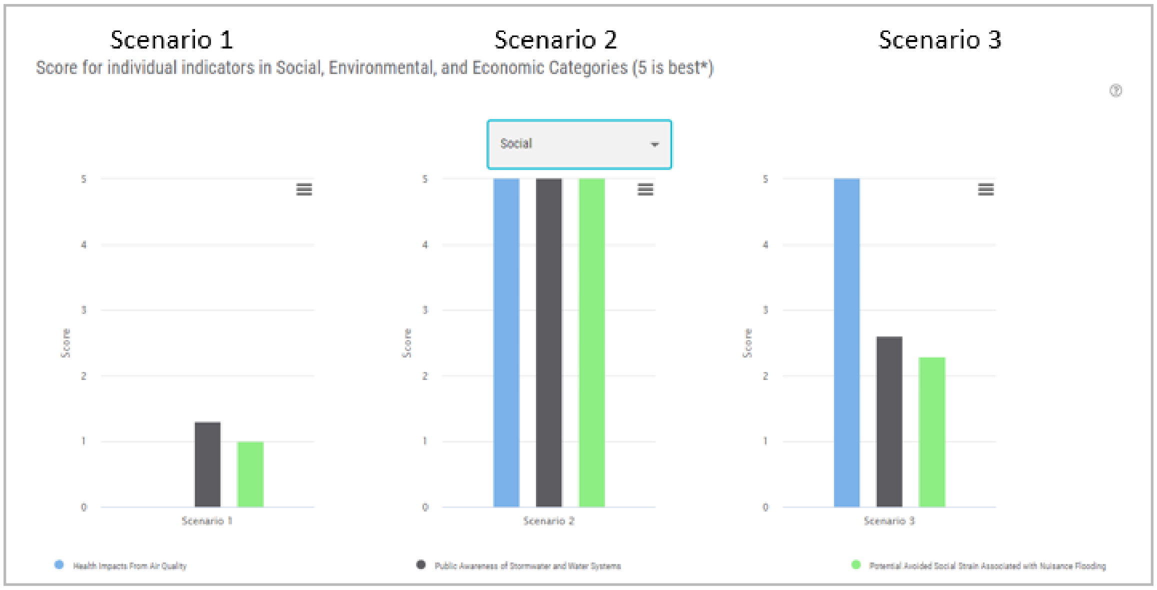

Figure 8 Individual benefit scores for Scenario 1, 2, and 3 from CLASIC output.

FRAMEWORK AND TOOL FOR QUANTIFYING THE TRIPLE BOTTOM LINE BENEFITS OF GREEN STORMWATER INFRASTRUCTURE (GSI TBL TOOL)

Using the GSI TBL Tool helps understand the monetary values associated with selected benefits for each scenario. The two tools were developed to help the user obtain information on tradeoffs for evaluating multiple options and outcomes that green stormwater infrastructure may provide to a community.

The suite of benefit categories that can be assessed using the GSI TBL Tool are:

Benefit Categories

Financial

- ☒ Avoided infrastructure and treatment costs
- ☒ Avoided replacement costs
- ☒ Energy savings

Environmental

- ☒ Water quality improvements
- ☒ Carbon emissions reduction and sequestration
- ☒ Ecosystem benefits

Social

- ☒ Improved air quality
- ☒ Water supply benefits
- ☒ Improved aesthetics (property values)
- ☒ Reduced heat stress
- ☒ Increased recreation
- ☒ Green job creation

Other

- ☒ Other benefits (enter to the right)

To supplement the outcomes for the scenarios described in the case study, the GSI TBL Tool was used to obtain monetary value for a subset of benefits and estimated benefit-cost ratios overall for the projects. For the three scenarios, the present value of financial, social, and environmental benefits accrued over 35 years is shown below. For this case study, a discount rate is not input but could be for sensitivity analysis.

The financial benefits include avoided replacement costs and energy savings for trees added. For this case study avoided treatment costs did not apply. The avoided replacement costs were calculated for scenarios with permeable pavers. The energy savings benefit will only accrue, of course, if the pond or stormwater practice is sited near buildings or homes. The larger pond may be sited at the "end of pipe" in the Udall Natural Area, in this case the financial benefits of energy savings would not apply. For Scenario 2 and Scenario 3 it is anticipated that the green space associated with trees and green infrastructure would have energy savings overtime as these areas would be by buildings and homes. The permeable pavement included in Scenarios 2 and 3 provides the avoided replacement cost benefit for pavement, therefore the financial benefits are shown below and Scenario 1 does not accrue any financial benefits.

The social benefits for Scenarios 2 and 3 area also larger than Scenario 1. The social benefits calculated for this case study include improved air quality, property values, and increased job creation. The social benefits not included were water supply, heat stress, and recreation. Some of these benefits such as recreation and water supply may be included if the placement of the practices have recreation or water supply impacts, however for this feasibility the particular location of practices was not estimated to have benefits to these categories. Heat stress is calculated based on days where temperatures cause an increase in hospital visits. Ft Collins does not experience a significant number of days that cause heat stress, therefore for this study area, heat stress benefit would not accrue to the scenarios. Scenarios 2 and 3 have higher benefit values than 1 and the amount of increased green space is related to improved air quality, property values and job opportunity. Air quality estimation is related to air pollutant emission reductions due to reduced energy use, air pollutant uptake, and removal by vegetation. The more acres, and greener the practice, equate to higher associated health benefits. Property values are estimated from a percentage of increased residential property values from green space added. For this case study, only single family residential properties were valued, as such this is likely a very low estimate. To value the commercial benefits, more detailed information is needed and may be done at a future time. Job benefits are calculated using the total value of construction jobs and the annual value of maintenance jobs using representative wage approach. The assumptions included market wages between $17 - $20 and employment of 20-30% of underemployed or unemployed workers.

Environmental benefit estimation includes carbon, water quality, and ecosystem benefit through habitat creation. The three scenarios are largely estimated to be the same water quality benefit because the design is to treat or retain 300,000 cf of smaller storms. The different scenarios are not anticipated to have significantly different carbon or ecosystem benefits. Carbon is heavily related to significant tree increase and biodiversity of ecosystems is not substantially different between the three scenarios.

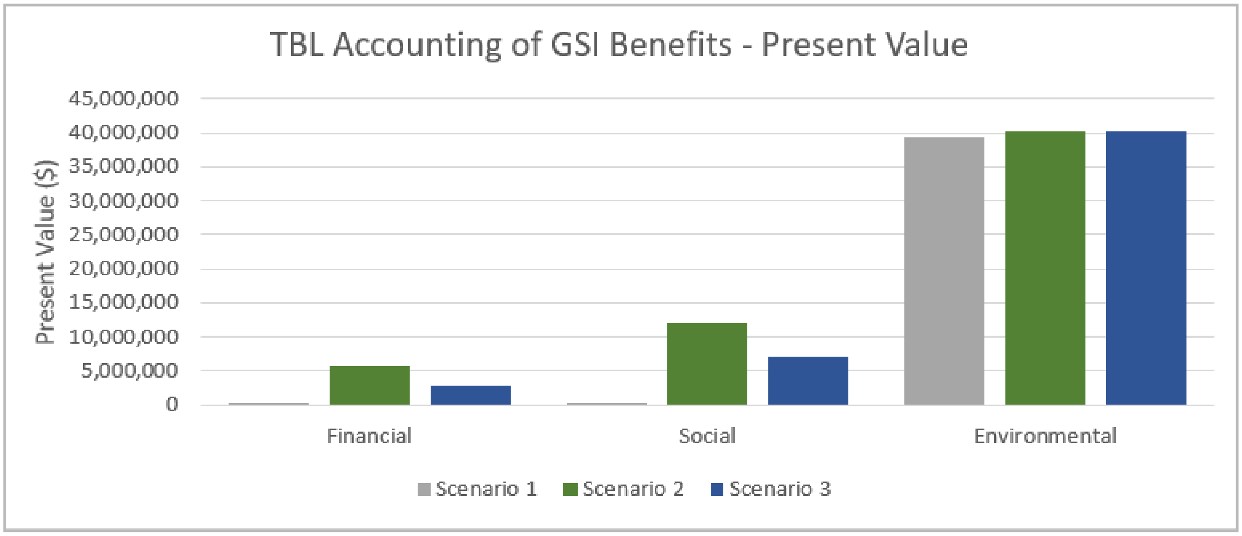

Figure 9 Output from the GSI TBL tool showing the financial, social and environmental monetary benefits for Scenario 1, 2, and 3.

One valuable output that can be calculated from the data in the tool is the benefit-cost ratio. This ratio should, in general, be above 1 for a project to have higher benefit than cost and make sense to implement from a cost stand point. The costs in this case study were derived from the CLASIC output. The three scenarios have very different Triple Bottom Line cost benefit ratios as shown in the table below. The TBL totals the benefits over the financial social and environmental categories and compares it to present value cost. The water quality benefits are similar for each scenario so may not be informative to make a comparison of benefit. Therefore you can look at just the social or just the environmental costs. In that case as shown below for both financial and social benefit cost, Scenario 3 is the only scenario over 1. This information supports that the higher costs may be justified using social and financial benefit estimates to support implementing the "hybrid" gray and "greener" scenario.

Table 2 Comparison of the TBL total and isolated benefit – Social and Financial – to demonstrate benefit/cost.

Triple Bottom Line Benefit-cost over study period (35 years, 0 % discount)			
	Scenario 1	Scenario 2	Scenario 3
Benefits	$39,589,786	$57,780,694	$49,950,902
Costs	$535,548	$159,610,385	$1,371,333
Benefit-Cost Ratio	74	0.36	36
Social only	Total over study period (35 years, 0 % discount)		
	Scenario 1	Scenario 2	Scenario 3
Benefits	$221,723	$12,056,281	$6,958,646
Costs	$535,548	$159,610,385	$1,371,333
Benefit-Cost Ratio	0.41	0.08	5
Financial only	Total over study period (35 years, 0 % discount)		
	Scenario 1	Scenario 2	Scenario 3
Benefits	$12,749	$5,571,282	$2,855,067
Costs	$535,548	$159,610,385	$1,371,333
Benefit-Cost Ratio	0.02	0.03	2

SUMMARY

The CLASIC and GSI TBL tools were used to assess a case study in Ft Collins, Colorado to determine the costs and benefits, overtime, of implementing various scenarios to address runoff to the Udall Natural Area and improve water quality in the Cache La Poudre river. Three scenarios in CLASIC provided comparison of a large pond (Scenario 1, essentially outlet treatment), green stormwater infrastructure of permeable pavement, sand filters, and raingardens (Scenario 2) and a combination of smaller quantities of green stormwater infrastructure in Scenario 2 in addition to a smaller pond (Scenario 3).

Using CLASIC and the GSI TBL tool provided comparison which showed how Scenario 2 had significant runoff reduction and infiltration compared to the two other scenarios, and also provided the highest relative benefit score. However, Scenario 2 was also the costliest over the 35 year study period. Using the GSI TBL tool provided the estimated monetary values for financial, social and environmental benefits. The environmental benefits were largely monetized as water quality and were similar for the three scenarios because all three were designed to treat the 0.6 inch storm (volume of 300,000 cf). The comparison of benefits costs using only the social and financial benefits showed that Scenario 3 had the only benefit cost ratio above 1.

The outputs of CLASIC and the GSI TBL tools can be fine-tuned to target costs and other types of green infrastructure implementation. They assist the user with multiple forms of analysis to help determine sizes, types and numbers of green practices to meet varied stormwater goals for any community.