AutoCASE™ Beta Testing Project

Evaluation of GI/LID Benefits in the Pima County Environment

Report Prepared for:

The Pima County Regional Flood Control District &
Pima Association of Governments with the Cooperation of the City of Tucson

Report Prepared by:

Impact Infrastructure, LLC
INFORMING IMPACT INVESTMENTS

Stantec

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AutoCASE Beta Testing Project

FOREWORD

Green Infrastructure/Low Impact Development (GI/LID) are key design strategies that will allow our region to build value-added community benefit into upcoming infrastructure projects. Understanding the economics is as important as understanding the planning and technical mechanics of GI/LID stormwater-water infrastructure design solutions. This cost-benefit report, tailored with data specific to the arid southwest, is a tool to evaluate the spending of public funds for GI/LID solutions.

We hope design and construction professionals will review this information, make recommendations and apply GI/LID practices whenever feasible. GI/LID practices are essential tools to make our region more resilient and adaptable to changing natural weather conditions while also improving the quality of life for our residents.

City of Tucson
Irene Ogata, Urban Landscape Manager, Office Of Integrated Planning

Pima County RFCD
Evan Canfield, Civil Engineering Manager; Akitsu Kimoto, Principal Hydrologist

Pima Association of Governments
Claire Zucker, Director Sustainable Environment; Mead Mier, Lead Watershed Planner; Josh Pope, GIS Manager

Background:

In October 2010, the City of Tucson and Pima County completed a joint *Water-Wastewater Infrastructure, Supply and Planning Study, 2011-2015 Action Plan for Water Sustainability*. As part of the Action Plan, Phase 2 Goals and Recommendation included "Goal 5: Increase the use of rainwater and stormwater to reduce demands on potable supplies"; with a subgoal "5.1: Develop design guidelines for neighborhood stormwater harvesting." As the City and County developed a GI/LID Working Group to assist with development of the *Low Impact Development and Green Infrastructure Guidance Manual* (GI/LID Guidance Manual), the effort became a regional effort. A GI/LID resolution was adopted by the Pima Association of Governments' (PAG) Regional Council of Governments in 2012.

In the summer of 2013, a five person team of the GI/LID working group was able to attend a Climate Leadership Academy on Adaptive Water, Resource and Infrastructure held in Philadelphia, PA. This team brought a wide background of regional knowledge on water conservation, drought, transportation infrastructure, stormwater quality planning, heat impacts and tree resilience, and flood mitigation design performances.

The Academy was put together by the Institute for Sustainable Communities (ISC) and included teams from 11 different communities across the United States. Traveling to Philadelphia, the Tucson team highlighted desert southwest issues (heat, drought and flooding), in contrast with the other communities attending the Academy (excessive rainfall, combined sewer-stormwater overflow systems). Our team's efforts were leading the way for unique arid southwest applications as well as other regions beginning to face climate change.

One of the reasons for developing the GI/LID Guidance Manual was to provide a tool for professional designers, including engineers, landscape architects, planners, developers and non-profit organizations, to utilize and better understand design configurations and the benefits of GI/LID. Economic comparisons and assessments of environmental and social impacts of GI/LID needed to be a part of the Guideline in order to provide information about GI/LID benefits. This comparison then provides a framework for how our community can plan and adapt to become more resilient utilizing GI/LID in stormwater-management.

John Williams II, Chairman and CEO of Impact Infrastructure, LLC (II, LLC) was a part of the Academy's Resource Team and presented an automated business case evaluator, AutoCASE™, for infrastructure projects. AutoCASE™ was currently in the beta stage of testing for stormwater infrastructure. Through discussion with Mr. Williams, we found that this tool could provide an affordable cost-benefit analysis into the GI/LID Guidance Manual and that data could be added to calibrate it to be arid southwest region specific.

PC RFCD and PAG provided the funding to contract with II, LLC and Stantec to beta test AutoCASE™ in this region. We were able to add arid southwest specific data and request additional concepts that were not part of the original software design which resulted in a more comprehensive analysis for our region. They evaluated the multibenefits and determined Sustainable Net Present Value (a cost-benefit calculation that also considers environmental and societal benefits) for seven common GI/LID practices as well as a suite of practices used at two different sites to illustrate how the costs and benefits of GI/LID can be considered in our community.

AutoCASE™ Beta Testing Project

Executive Summary

The water scarcity and urban heat island issues facing the City of Tucson and Pima County will also need to be addressed by most areas of the country in the coming decades.

Despite efficient water use, best practices in stormwater management, and water re-use, the population in Pima County is growing and renewable water resources are diminishing due to drought across the Colorado River Basin. It is with this background that the Pima County Regional Flood Control District (PCRFCD), in collaboration with the City of Tucson, has been hosting Low Impact Development (LID) and Green Infrastructure (GI) discussions for desert regions. Together, a working group has developed a Guidance Manual to facilitate the adoption of GI/LID practices in Pima County and the City of Tucson. The City of Tucson and other jurisdictions in Pima County coordinated efforts through the Pima Association of Governments (PAG[1]).

Using green infrastructure for stormwater management has many benefits; stormwater is naturally cleaned of pollutants, flooding is reduced, urban heat island effects are reduced, and property values are enhanced. These are benefits that are quantified and monetized in the AutoCASE™ for Stormwater Management (beta) software. The LID manual-related work was done by Stantec Consulting Services, Inc. and analytical work associated with the use of AutoCASE™ software (an automated business case analysis tool) was done by Impact Infrastructure, LLC. The services were funded under two contracts from PAG and Pima County with Stantec Consulting Services, Inc. As beta test clients the City, PCRFCD and PAG evaluated several GI/LID features from the LID Manual to understand their full economic, social and environmental value (Table 1). Two sample sites were also studied, a commercial site and a road re-design that incorporated some of the GI/LID features. The local team representing the concerns of the Tucson metro area suggested additional benefits of GI/LID features not previously included in AutoCASE™ in terms of traffic calming, reduced accidents, road surface life, as well as desert based water concerns. These incremental benefits were also estimated and added to the overall value.

There are several local characteristics that make the City of Tucson and Pima County, hereafter the Tucson region, unique when compared to other areas that have used GI/LID features to manage stormwater. The Tucson region does not have combined sanitary sewers/storm sewer systems and so does not suffer from combined sewer overflow problems that give other

[1] Pima Association of Governments (PAG) is metropolitan planning organization which coordinates the local jurisdictions in PAG's nine-member Regional Council composed of representatives from the local, state and tribal governments. PAG's programs and committees focus on regional planning issues, such as stormwater quality, economic vitality, drought planning, and transportation infrastructure. As a partner on this project, PAG can inform and disseminate information to all its regional partners and leaders.

regions cause to implement GI/LID; however, the desert environment does experience monsoons with potential for severe flooding and also seeks the beneficial use of stormwater for irrigation. The development of AutoCASE™ was significantly enhanced, as a result of this study, by including these unique regional aspects. AutoCASE™ was made more useful to desert regions through this process by calculating the cost and benefit based on these conditions common to the arid Southwest.

The Institute for Sustainable Infrastructure (ISI), through its Envision rating system, is giving credit for projects such as those stormwater management initiatives being undertaken in the Tucson region. This study used AutoCASE™ to make the business case for the GI/LID features in the Guidance Manual. The value estimated was mapped to the Envision rating categories and this report provides the Tucson region guidance on how Envision may be used in the future.

The business case analysis provides a comprehensive assessment and takes a broad perspective, looking at the value to the community, government, and the environment. The analysis makes the case that these investments pay back in more than cash terms, and the benefits cited above all have value to a wide range of stakeholders. Details on the AutoCASE™ methodology are provided in Appendix IV of this report.

This report demonstrates that the approach used in AutoCASE™ can calculate comprehensively defined value using regionally specific values and that the calculations can be run inexpensively as the design changes. By not considering these normally omitted costs, benefits and risks, the benefits may not be realized, resulting in potential negative impacts on the community.

Finding of the study and recommendations are summarized below.

- GI/LID features are not equal in terms of their financial and sustainability benefits. Broader consideration of value, beyond capital and operating costs, to include flood risk, safety, heat island mitigation, property value, and environmental benefits allow for an objective comparison.
- Stormwater Harvesting Basins, Xeriscape Swales and Infiltration Trenches have a greater than 50% probability of achieving a positive Sustainable Net Present Value (SNPV), which indicates the overall societal, environmental and economic benefits will exceed the costs of the project, after adjusting for the opportunity cost of capital[2].

[2] Most costs, such as capital expenditures, are paid early in a project's life, while most benefits, such as reduced air pollution or traffic calming, are accrued over the life of the project. A Net Present Value (NPV) calculation discounts value by a greater factor as the value is realized further into the future. Therefore, a NPV of zero would imply that the nominal benefits significantly outweigh the costs

- While Pervious Pavement had a negative SNPV, Concrete and Asphalt Paving have highly negative SNPV. This is partly due to capital expenditure costs, and partly due to the benefits that Pervious Pavement brings. These benefits offset some of its cost, unlike concrete and asphalt.
- In terms of sustainability metrics, GI/LID features, when combined into designs for a representative commercial site and a roadway re-design, are beneficial.
    - Implementation of the selection of practices at the commercial site has an 80% probability of achieving a positive SNPV. The inclusion of GI/LID features shows that the value of the site is significantly higher when compared with the base case of using concrete. There is a large difference in social and environmental value. The LID features selected have multiple social and environmental benefits. All help to reduce flood risk in the area during extreme storm events. Other benefits include a reduction in carbon emissions and air pollution, increasing local property values, reducing heat mortality, and a lower requirement for on-site irrigation.
    - The re-design of a ½ mile segment of Silverbell Road to incorporate new trees, bio retention, and water harvesting basins reveals that the SNPV of the project is a highly positive SNPV. The most substantial benefits are reduced heat stress mortality and traffic calming due to the installation of a roundabout and curb extension. These benefits are measuring direct impacts on human life, either in terms of reduced heat island effects or reduced likelihood and severity of traffic accidents.
- Ignoring the multi-benefits of GI/LID features would mean making incorrect decisions. GI/LID features have a payback to governments, the environment, the economy and the community. A large benefit of approach used to value GI/LIDs is the ability to allocate the full value of a project amongst relevant stakeholder groups so that all parties can understand how they are affected.

Recommendations:

- The City of Tucson, Pima County, and PAG (the Tucson region) should continue to measure the full value of its GI/LID initiatives and use this information to make decisions. This approach will be a useful tool in demonstrating the full value of GI/LID practices as projects are planned and designs are developed.
- The Tucson region should consider the use of Envision to communicate those benefits to outside stakeholders.

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Introduction

Project Background

The Pima County Regional Flood Control District (PCRFCD), in collaboration with the City of Tucson, has been creating a Low Impact Development and Green Infrastructure Guidance Manual to facilitate the adoption of GI/LID practices in Pima County, the City of Tucson, and Pima Association of Governments (PAG) member jurisdictions. As a partner on this project, PAG can inform and disseminate information to all its regional partners and leaders with a regional planning perspective.

In other parts of the country with combined sewer systems, GI/LID practices are cost-effective because they enhance the potential for reducing or eliminating the risk of sewer overflows. The GI/LID solutions are often funded as mitigation for overflows. In contrast, in the Tucson region, roadways are often used as stormwater conveyance pathways, and the stochastic monsoon events cause considerable flooding concern. Furthermore, the potential for contaminant migration in stormwater to perennial waterways or groundwater tends to be more limited in the Tucson environment because water bodies are few and groundwater is deep. In contrast, stormwater management in the Tucson region has particular importance because use of stormwater can offset the need for potable water. Furthermore, vegetation watered with stormwater has the potential to decrease energy use and improve the quality of life by helping to mitigate effects from the urban heat island. Additionally, the increasing rareness of perennial desert waters and the high ecological value of habitat along intermittent and ephemeral waterways make them particularly important to protect from contamination and erosion.

Project Purpose

The goal of this beta testing project was to evaluate GI/LID costs and benefits in the Pima County environment. AutoCASE™ uses economic and risk analysis to evaluate costs and multi-benefits using Autodesk's AutoCAD Civil 3D files of GI/LID practices to inform business cases. Because the motivating factors for use of GI/LID are different in Pima County than in other parts of the country, there was a need to evaluate the costs and multi-benefits of these features in this environment.

AutoCASE™ History

For decades, cost-benefit analysis has helped municipal, state/provincial, and federal governments to justify infrastructure investments and communicate the benefits of these investments. Cost-benefit analysis can be used to prioritize spending and allocate funding to projects that are the most cost-effective and create the most public value. With multiple-account cost-benefit analysis, governments can communicate the benefits of infrastructure spending to different groups. One description is as follows:

> "Cost–benefit analysis (CBA) is the systematic and analytical process of comparing benefits and costs in evaluating the desirability of a project or program – often of a social nature. CBA is fundamental to government decision making and is established as a formal technique for making informed decisions on the use of society's scarce resources. It attempts to answer such questions as whether a proposed project is worthwhile, the optimal scale of a proposed project and the relevant constraints. CBA can be applicable to transportation projects, environmental and agricultural projects, land-use planning, social welfare and educational programs, urban renewal, health economics and others."[3]

For example, a new Low Impact Development (LID) or Green Infrastructure (GI) stormwater management system may lead to reduced flood risk, increased regional aesthetic value, increased recreational opportunities, reduced carbon emissions, better air quality, and an increase in property value; detailed cost-benefit analysis can reveal these benefits so that government leaders can communicate these benefits to stakeholders.

Impact Infrastructure has two powerful risk analysis based cost benefit tools that can be integrated into feasibility, planning, and design stages of infrastructure projects. The first is the Business Case Evaluator (BCE) – a free, Excel-based model. The second is AutoCASE™ - a web-based engine, database, and reporting application for evaluating sustainable infrastructure, with an interface into Autodesk's powerful design and visualization software.

Business Case Evaluator

The Business Case Evaluator is a free Excel spreadsheet. The Model, its Documentation, and an Example is available from the Institute for Sustainable Infrastructure (ISI) or Impact infrastructure (II).

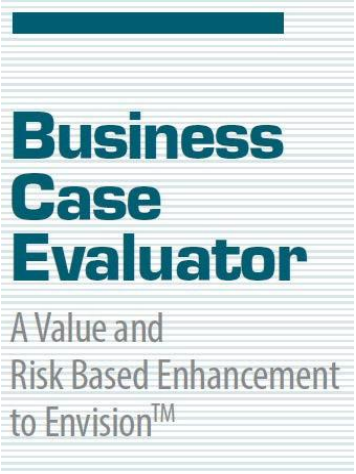


Figure 1 BCE Manual

3 E.J. Mishan and Euston Quah, Cost-Benefit Analysis, 5th edition (New York: Routledge, 2007).

In September of 2013, founders from Impact Infrastructure, LLC presented the Business Case Evaluator (BCE) for Stormwater Management at the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design to industry membership of the program's Sustainable Infrastructure Advisory Board and members of the ISI.

The BCE is an economic companion tool to the Envision™ Rating System, and its primary purpose is to produce risk-adjusted, dollar-based metrics for infrastructure projects based on their costs, benefits, and sustainable design features.

The BCE also breaks down the value of a project among different stakeholder groups, showing which groups (e.g., government, residents, local businesses, and the environment) will be affected and to what degree. In addition, the BCE maps the value of a project to Envision™ credits, showing how the value gets distributed within the Envision™ Rating System.

AutoCASE™

AutoCASE™ is a web-based database and model that is integrated with Autodesk's AutoCAD Civil 3D software. It has a multi-user, scalable architecture with many advanced features and analysis capabilities above and beyond those offered by the BCE.

Figure 2 AutoCASE™ Start Screen

AutoCASE™ builds on the BCE for Envision™. It is a web-based application that can be run through a project's life cycle, beginning with the earliest stages, including the early feasibility or planning stages. It can be run with minimal information, drawing on standard but regionally-specific inputs and best practice data.

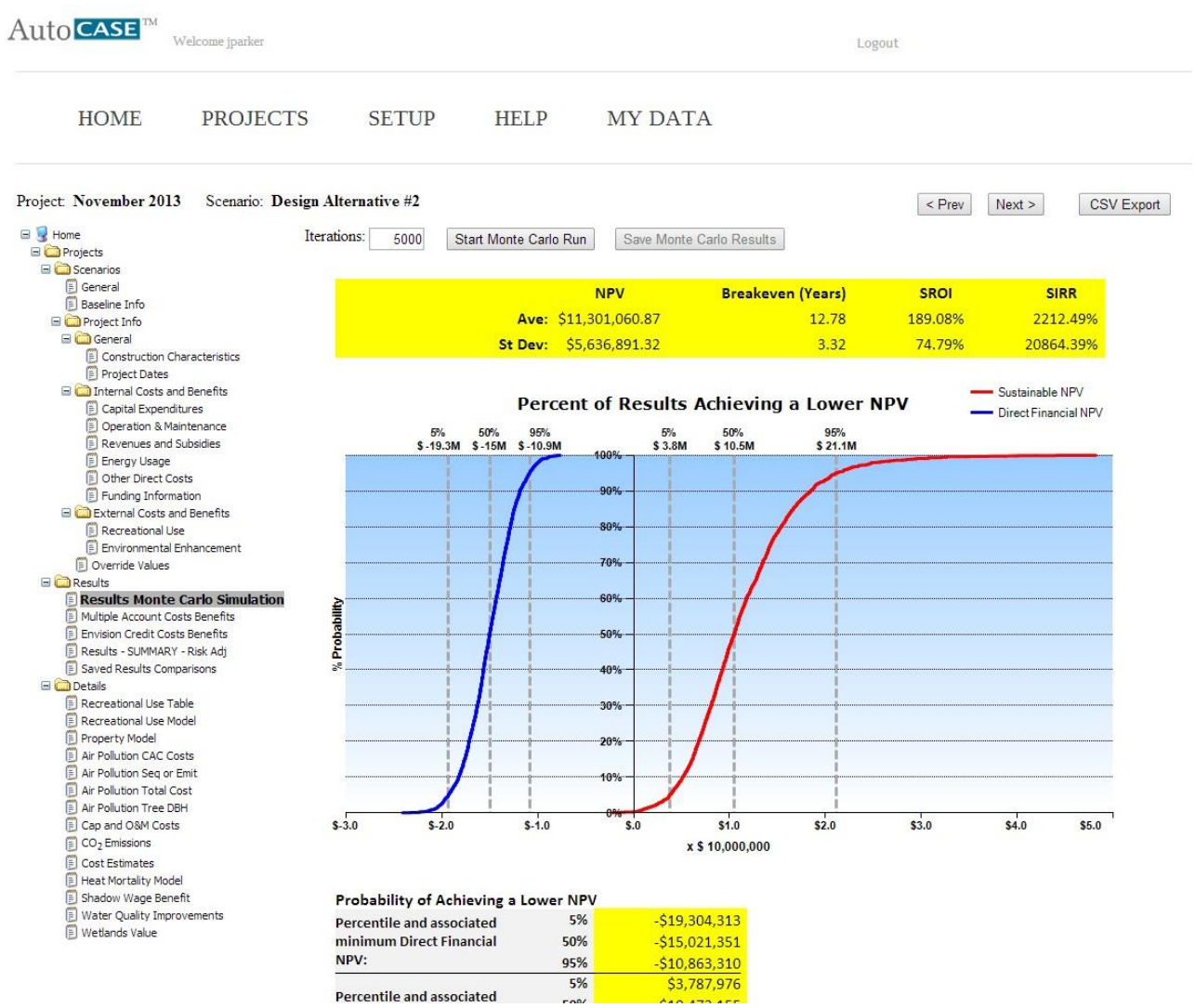


Figure 3 Example of the probability curves for the SNPV of an early stage planned project.

Note on Figure 3: Shown above is an example of the probability curves for the SNPV (Sustainable Net Present Value) of an early stage planned project. The first curve is the Direct Financial NPV (Net Present Value), which only includes the direct costs and benefits such as capital expenditures, revenues, etc., and does not include other costs and benefits such as air pollution, carbon emissions, water quality benefits, etc. The second curve is the Sustainable NPV and incorporates all costs and benefits in the model, including impacts on the local economy, society, and the environment.

AutoCASE™ enables integration with Autodesk's AutoCAD Civil 3D software to extract design information from a project and incorporate that information into its associated business case. This means that as an engineer or planner/designer is working on the design of a project, AutoCASE™ can update the project's business case and financial metrics in *real time*.

Figure 4 Shown above is an example of selecting the green infrastructure design feature of porous pavement from within AutoCAD Civil 3D.

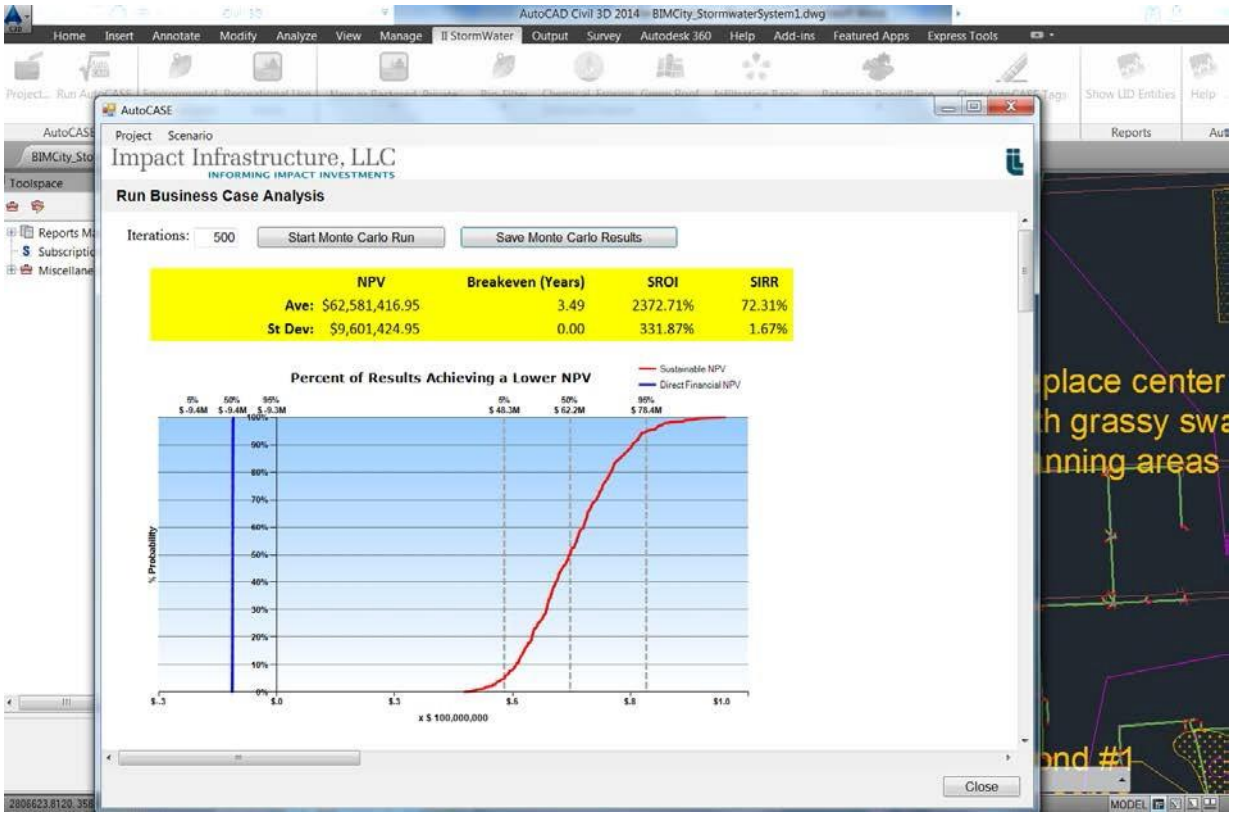


Figure 5 Shown above is an example of the same probability curves for the SNPV of the project as shown for the early stage project but now linked to the design drawing of the project.

Once all of the project's GI/LID features are selected and any additional relevant information is entered into AutoCASE™, the project's Sustainable Net Present Value (SNPV) can be calculated with the click of a button.

AutoCASE™ was released in beta (preliminary version) to Pima/Tucson at the beginning of the project (January 2014). Access was given to 16 users and a training session was held in Tucson in April 2014 to some 20 participants. A combination of AutoCASE™, the BCE, and other models developed specifically at the request of Tucson/Pima were used for this project.

The data used for this study were input into a version of the BCE that was modified for the arid Southwest. This version added traffic calming and pavement life extension benefits. The delivered spreadsheets (ii_BCE_Arid_Southwest_2.0.1_July_2014.zip) were based on the July 2014 version of Envision's™ Economic Companion Tool - the Business Case Evaluator for Stormwater Management (version 2.0.1). The BCE model and Manual are included in the package of files.

Individual GI/LID Practices

Data Collection for Individual Practices

Individual green infrastructure and low impact development practices were researched and reviewed as described in the non-regulatory *Low Impact Development and Green Infrastructure Guidance Manual*, and the draft Detention/Retention Manual, March 2014. Approximately 61 resources, along with the aforementioned manuals, were consolidated at a Stantec FTP site with access available to Pima County, City of Tucson, and PAG staff participating in the AutoCASE™ project. A full list of references can be found in the annotated bibliography at the end of this report. These resources were a fraction of the GI/LID information that is currently available nationally; therefore, our research focused on regional applicability and limited the document/data research to the specific GI & LID practices analyzed in the AutoCASE™ beta test project. Details of the AutoCASE™ methodology are provided in Appendix IV. The following nine GI/LID practices were selected for the AutoCASE™ application.

Selected GI/LID Practices
Water Harvesting Basins

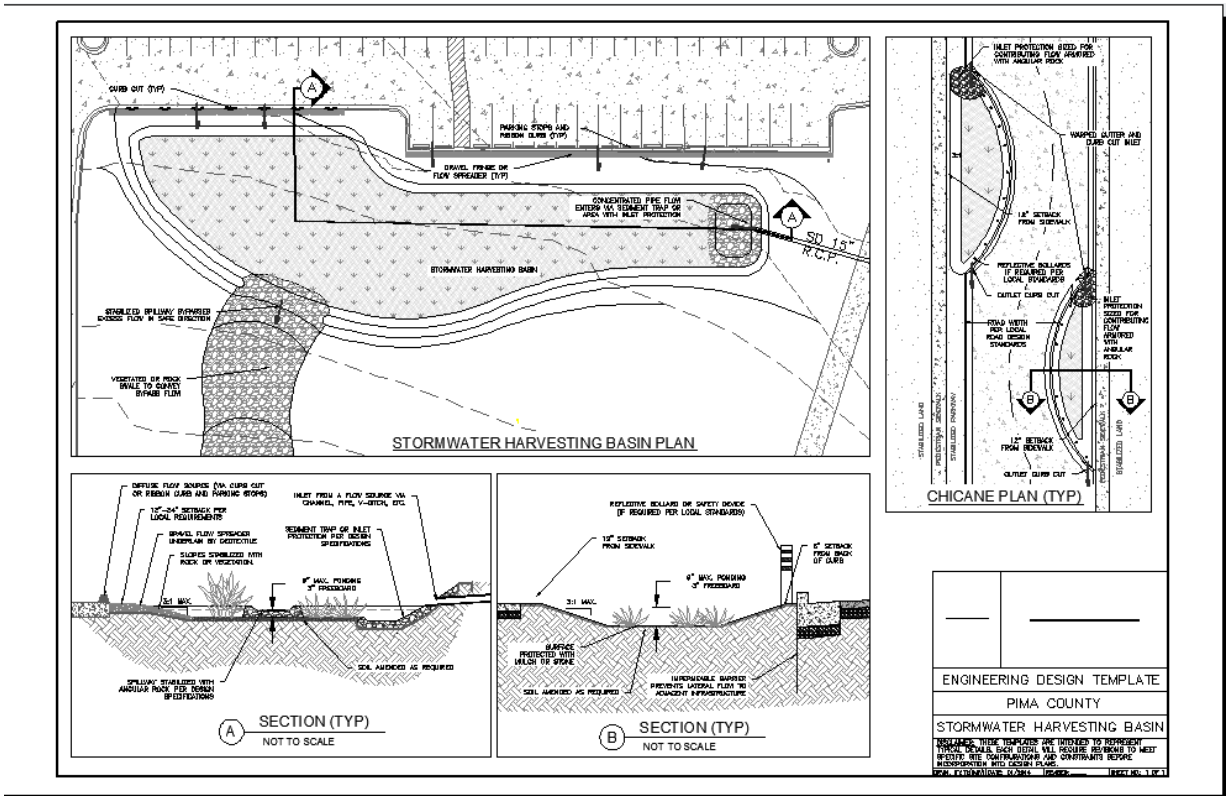


Figure 6 Water Harvesting Basin Design

Figure 7 Water Harvesting Basin Example (Photo credit: Lester Grant McCormick)

Bio Retention Basin

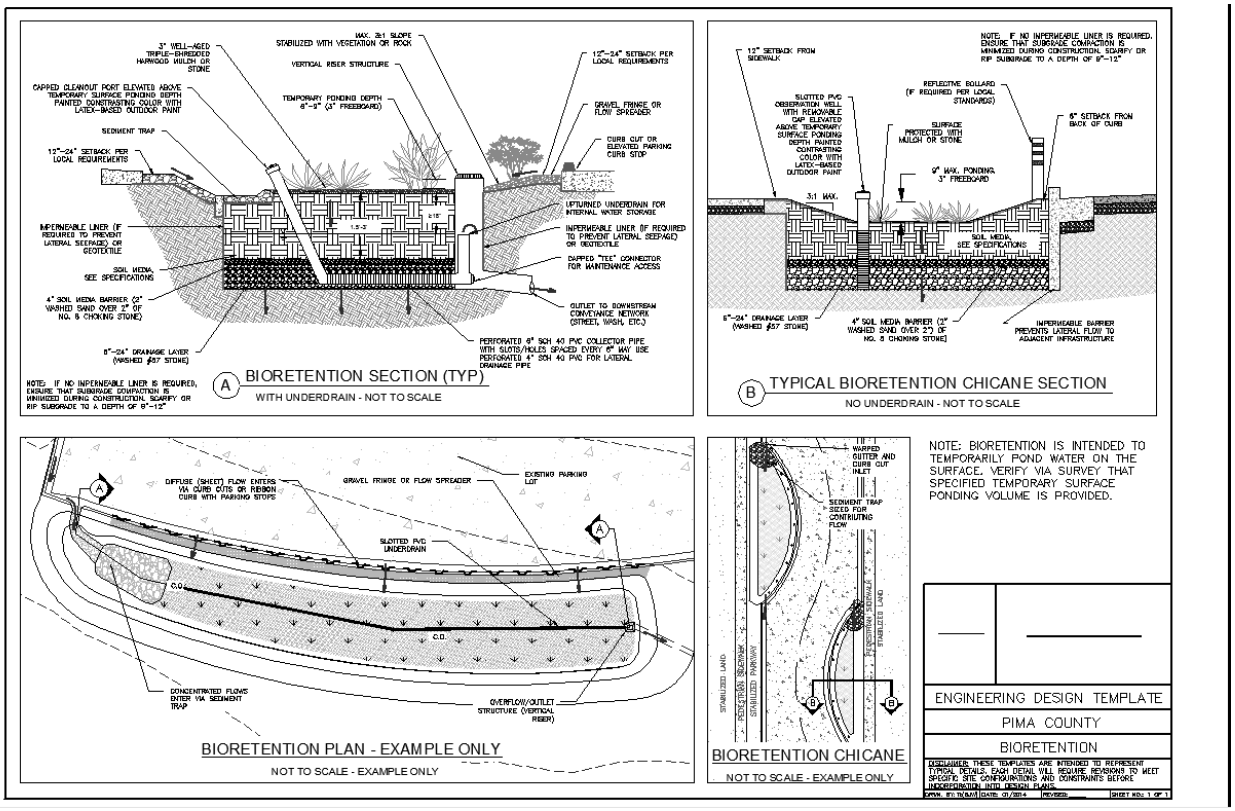


Figure 8 Bio Retention Basin Design

Figure 9 Bio Retention Basin Example (Source: Pima County and City of Tucson Low Impact Development and Green Infrastructure Guidance Manual October 2013 – Draft p.8)

Xeriscape Swale

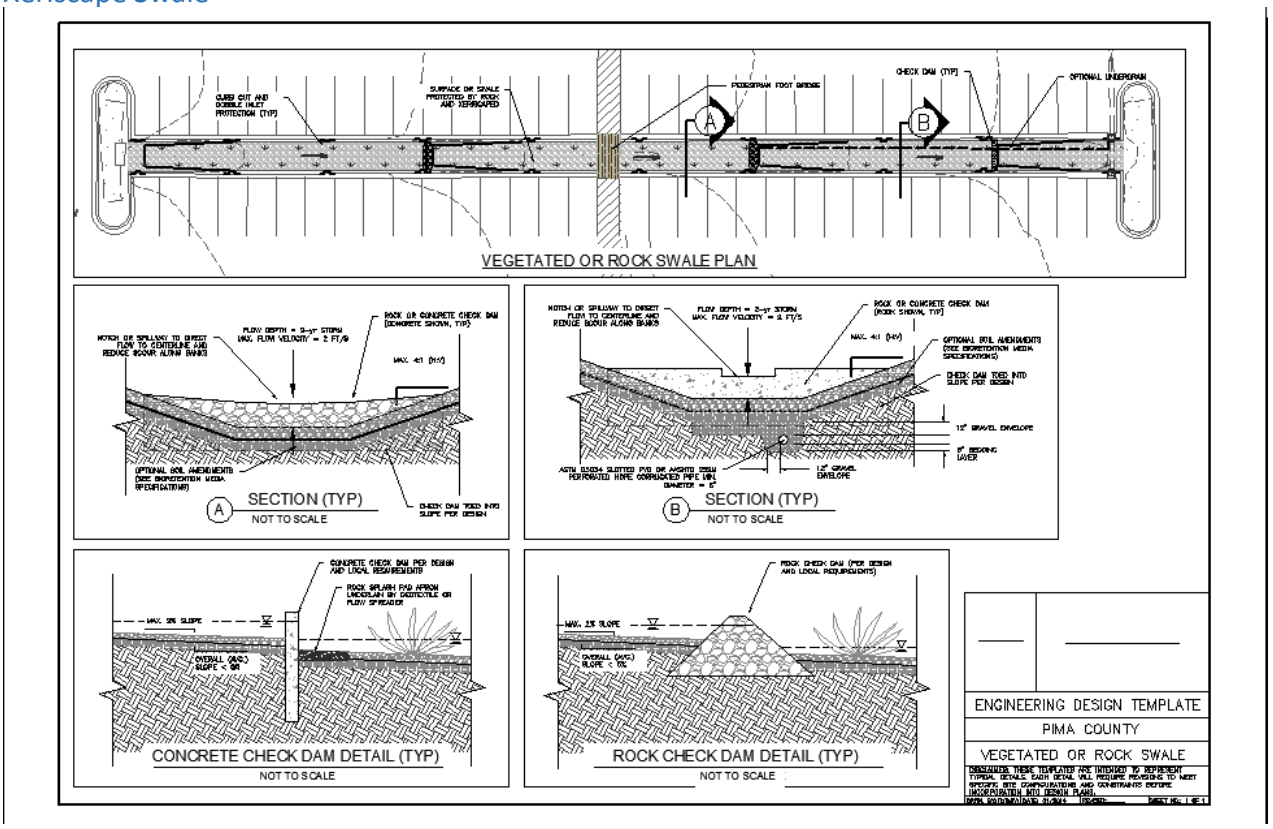


Figure 10 Xeriscape Swale Design

Figure 11 Xeriscape Swale Example (Photo credit: Sandy Bolduc, Pima County)

Cistern

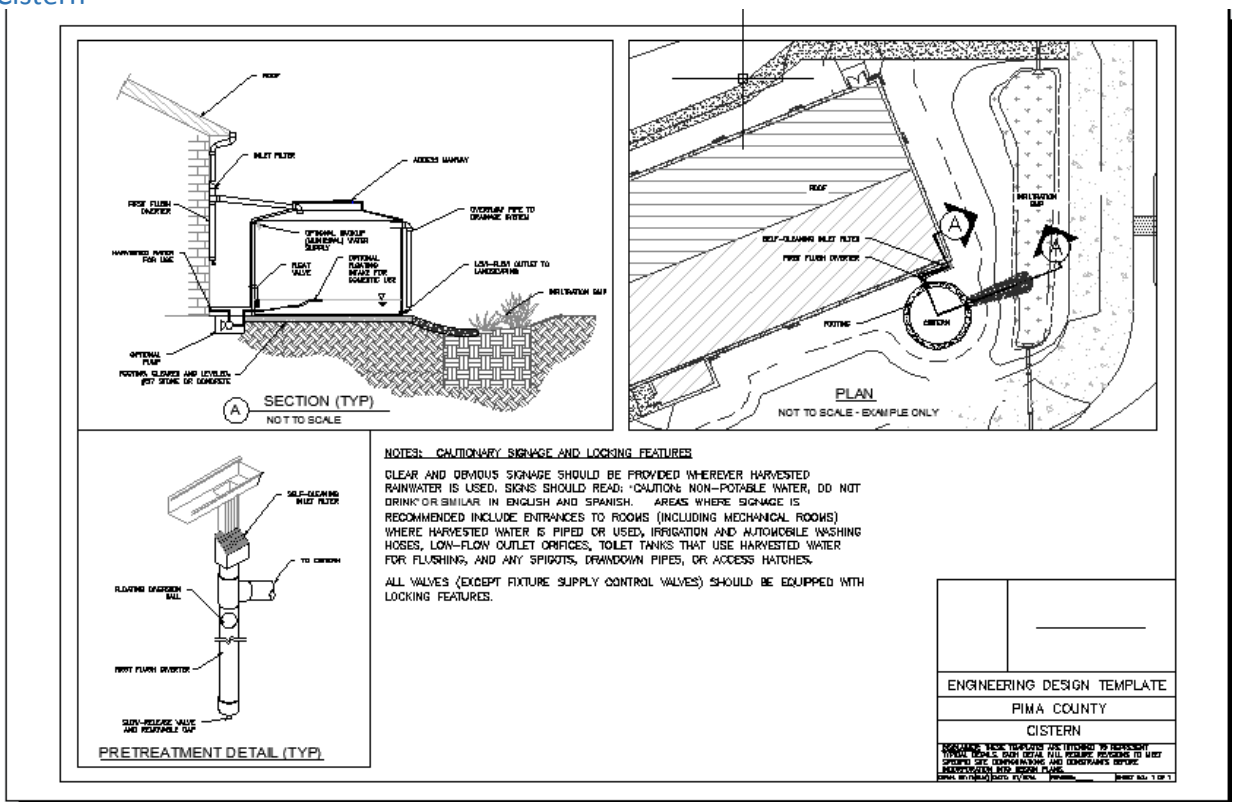


Figure 12 Cistern Design

Figure 13 Cistern Example (Photo credit: Evan Canfield, Pima County)

Infiltration Trench

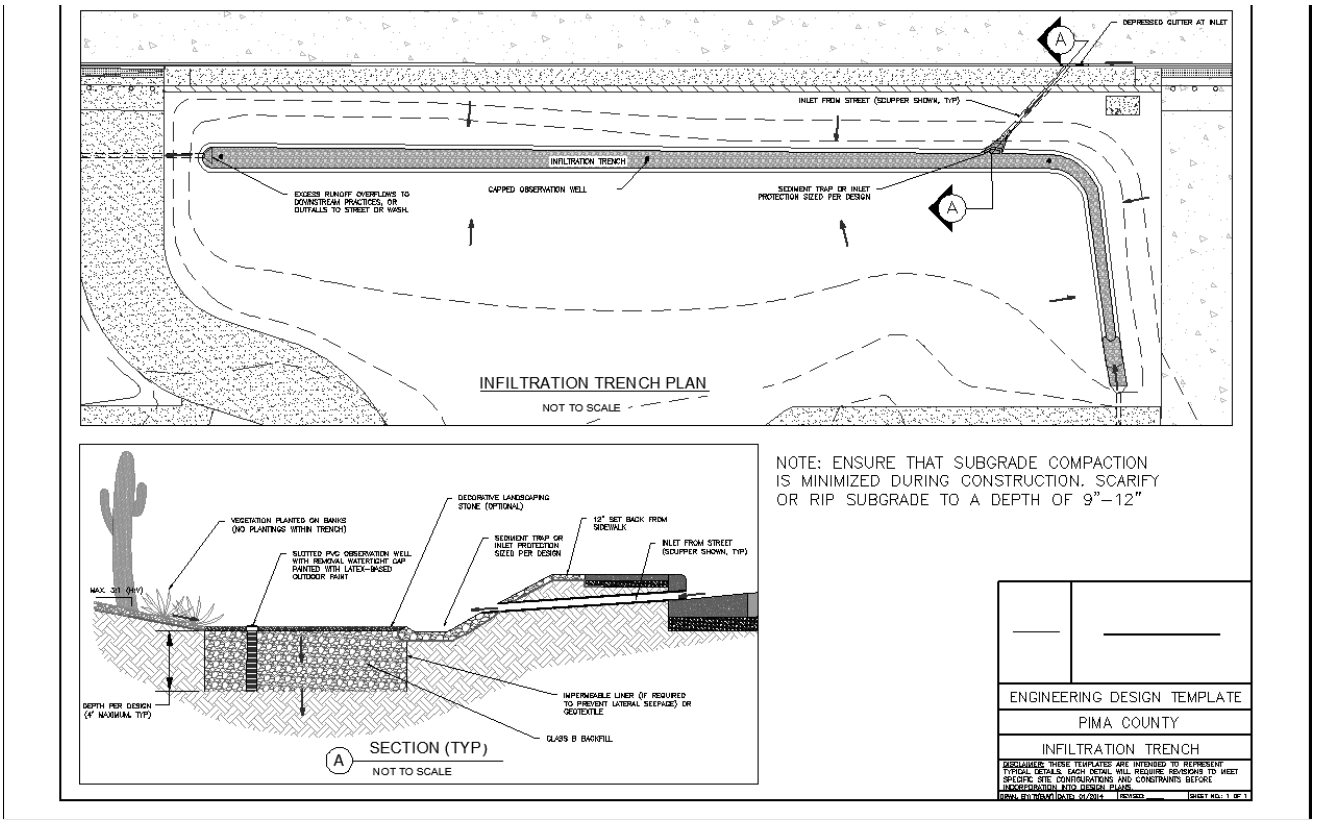
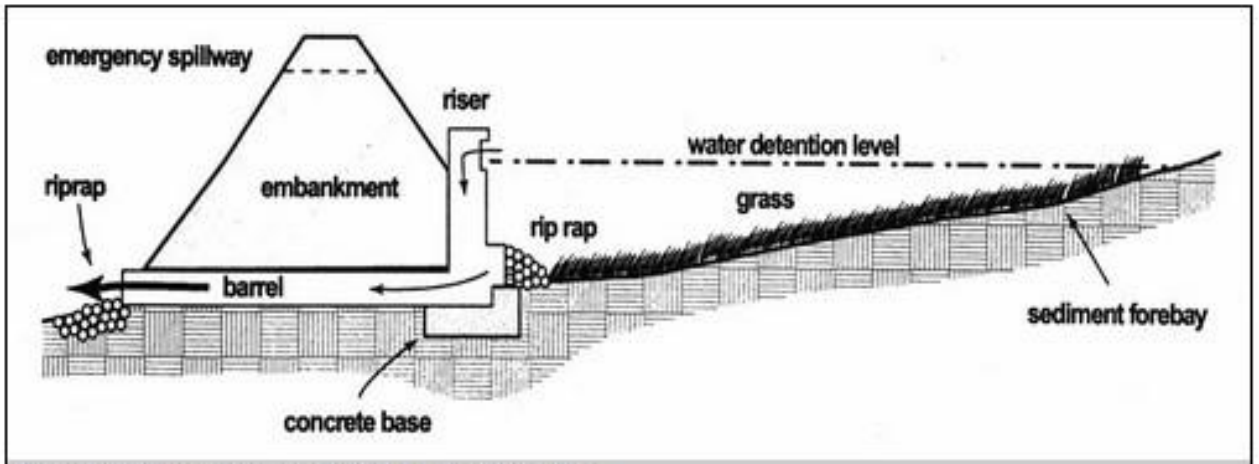


Figure 14 Infiltration Trench Design

Figure 15 Infiltration Trench Example (Photo credit: Laura Mielcarek)

Detention Basins (or Extended Detention Basins)



Example profile view of a dry pond design.

Figure 16 Detention Pond Design

Pervious Pavers

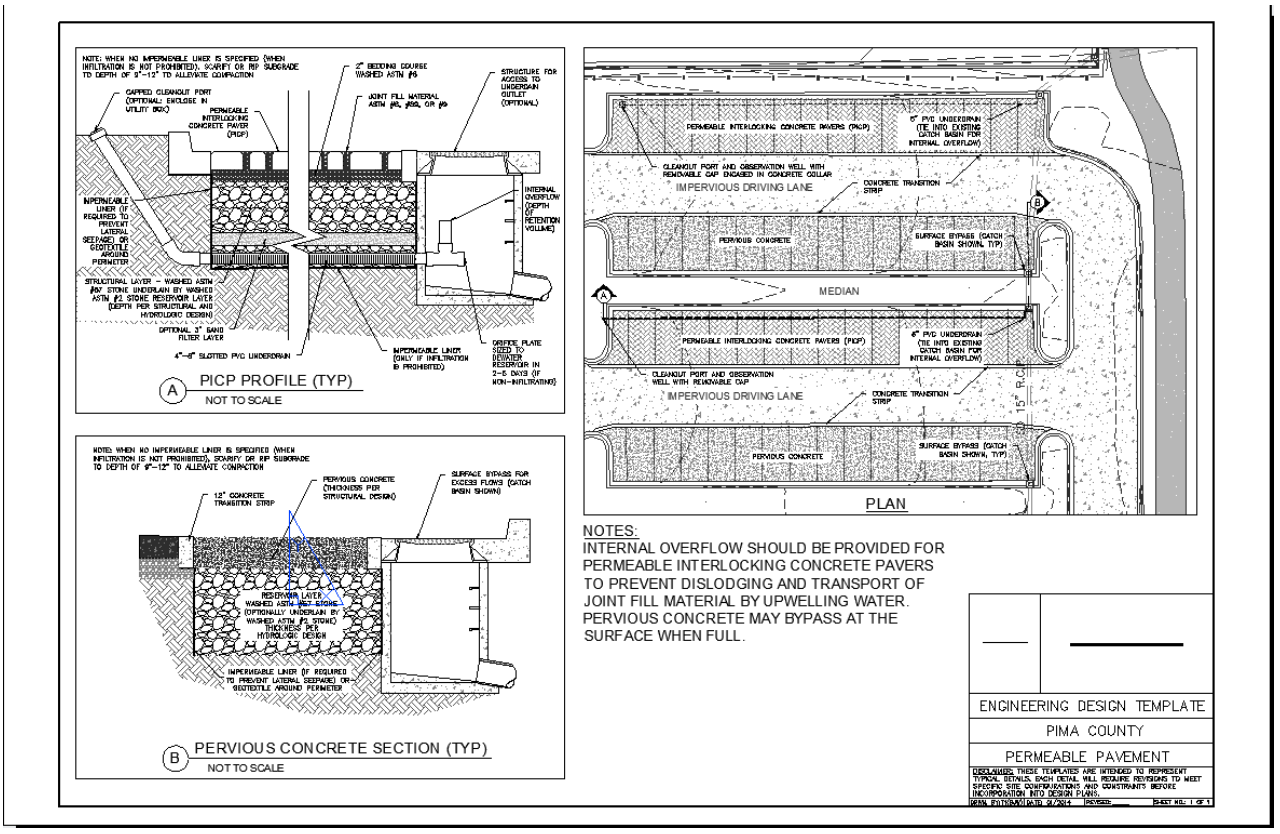


Figure 17 : Pervious Pavers Design

Figure 18 Pervious Pavers Example (Photo credit - Belgard Pavers)

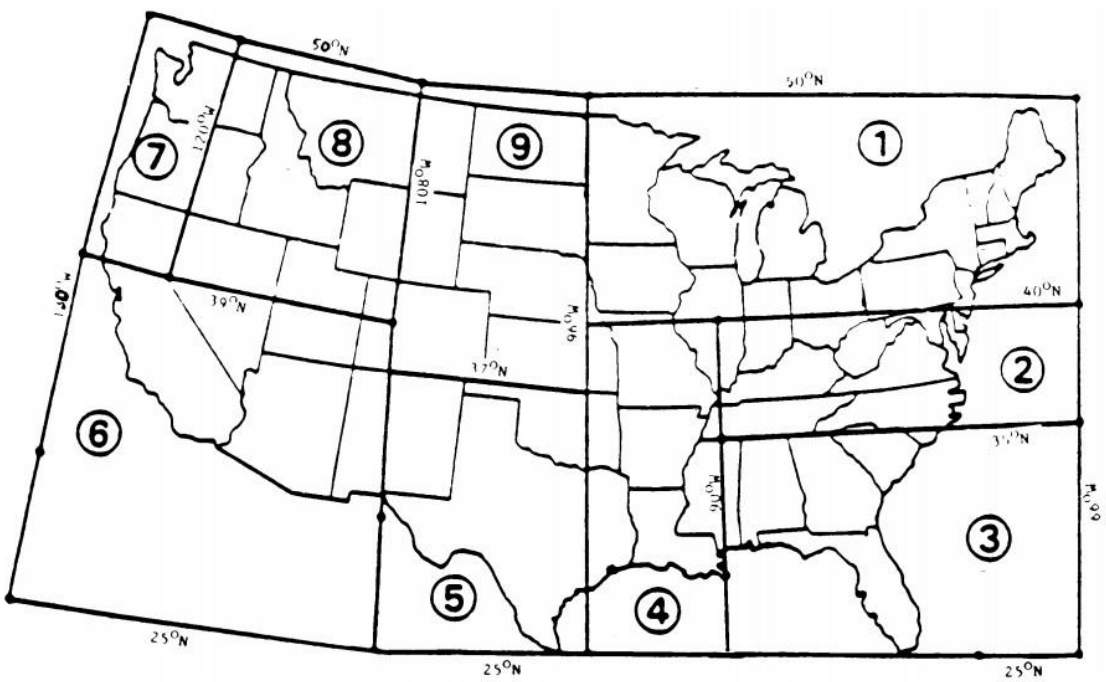
Initial parameters

The individual GI/LID's were, to the extent possible, evaluated on a consistent basis using the same area (1,000 square feet or 0.02296 acres).

Capital and O&M costs used AutoCASE's database of costs that is made up of information from Philadelphia, Maryland and the International Stormwater BMP Database (July 2007 Database Release) but it a) excluded Philadelphia as a source of data because it has combined sewer overflow (CSO) problems and b) used costs specific to low rainfall areas of: AZ, Southern CA, Southern Utah, NV and Western NM.

Pt. 122, App. E **40 CFR Ch. I (7–1–12 Edition)**

APPENDIX E TO PART 122—RAINFALL ZONES OF THE UNITED STATES



Not Shown: Alaska (Zone 7); Hawaii (Zone 7); Northern Mariana Islands (Zone 7); Guam (Zone 7); American Samoa (Zone 7); Trust Territory of the Pacific Islands (Zone 7); Puerto Rico (Zone 3) Virgin Islands (Zone 3).

Source: Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality, prepared for U.S. Environmental Protection Agency, Office of Water, Nonpoint Source Division, Washington, DC, 1986.

[55 FR 48073, Nov. 16, 1990]

Figure 19 US Rainfall Zones. Source: NPDES Phase I regulations, 40 CFR Part 122, Appendix E (US EPA, 1990).

Water Harvesting Basin

- 1,000 square feet (.02296 acres)
- 18,856 cubic feet capacity
- Input in model as "Infiltration Basin"
- Expected Capital Expenditure (CapEx) cost of $5,171/acre
- Annual Operation and Maintenance (O&M) cost expected at $21/acre/year
- Residual capacity of basin – empty/negligible

Bio Retention Basin

- 1,000 square feet (.02296 acres)
- CapEx expected at $68,519/acre
- Annual O&M cost at $1,179/acre/year

Xeriscape Swale

- 1,000 square feet (.02296 acres)
- Expected CapEx cost of $16,982/acre
- Annual O&M cost expected at $540/acre

Cistern

- Price:
  - Low - $1,600 for 350 cubic feet tank
  - Medium - $2,600 for 350 cubic feet tank
  - High - $5,200 for 350 cubic feet tank
- Capacity: 350 cubic feet
- Average residual capacity at start of rainfall event – 37.7%
- Roof area – 3000 square feet

Infiltration Trench

- 1,000 square feet (.02296 acres)
- Expected CapEx cost of $117,221/acre
- Annual O&M cost expected at $518/acre

Detention Basin (or Extended Detention Basin)

- 1,000 square feet (.02296 acres)
- 45,345 cubic feet capacity
- Expected CapEx cost of $54,352/acre
- Annual O&M cost expected at $614/acre
- Residual capacity of basin – empty/negligible

Pervious Pavers

- 1,000 square feet (.02296 acres)
- Expected CapEx cost of $199,172/acre
- Annual O&M cost expected at $2,614/acre

Curb Extensions (new and retrofit chicanes, medians, traffic circles, and road diets with inlets to gather street water)

- One roundabout on Silverbell Road and one chicane on Cerada De Beto
- Cost per Vehicle Mile Travelled (VMT) of approximately $0.48 social costs due to prevalence and severity of car-pedestrian crashes (see Appendix II for details)
- 10,000 cars per day using roundabout on Silverbell Road
- 500 cars per day using chicane on Cerada De Beto

Tree Benefits

- Expected number of trees planted
- Diameter at breast height (D.B.H.) of trees – assumed to be 2”
- Lifespan average 25 years (max. 40 years)
- Increased pavement longevity due to shading - $0.66/ft² ($7.13/meter^2) over 30 year period
- Medium trees (e.g. Chilean mesquite trees) are 20-40 ft. tall[4]. Medium trees save 180 kWh in electricity and 58 kBTU per year in natural gas due to a reduced need for air conditioning near the site containing the trees.
- Small trees (e.g. Sweet acacia trees) are < 20 ft. tall. Small trees save 74 kWh in electricity and 2 kBTU per year in natural gas due to a reduced need for air conditioning near the site containing the trees

Water Costs

- Reduced need for irrigation due to use of LID features and cisterns
- Financial cost of water - $2.77 per CCF (Commercial rate of $2.22/CCF + CAP charge ($0.48/CCF) + Conservation charge ($0.07/CCF)[5]

[4] Canopy areas are in Figure 5 in McPherson et al. "Desert Community Tree Guide: Benefits, Costs, and Strategic Planting." Arizona State Land Department Natural Resources Division. July 2004

[5] http://www.tucsonaz.gov/water/rates/potable

- Social cost of water - $5.29[6] per CCF, leading to a marginal social cost of water of $5.29 - $2.77 = $2.52 per CCF

Arid Southwest Specific Interest

Reduced Water Use

- *Reduced irrigation due to the use of Cisterns:* Reduced irrigation required as a result of using cisterns is dependent on the capacity of the cistern, the roof area feeding into the cistern, the flow rate, and the rainfall patterns in the region. Using daily rainfall data from 1895 to 2000, assuming a 350 cubic foot cistern, flow rate at the rate of required water from irrigated plants, and a roof area of 3,000 square feet, the reduced irrigated water was calculated.
- *Reduced irrigation due to the use of Water Harvesting Basins:* Using Tucson's Commercial Rainwater Ordinance, it was determined that plants being planted at the Silverbell Road site would require 20 inches of water per square foot of plant canopy each year (assumed low water requirement plants). The water required by irrigation was calculated as the difference between the total water requirement of 20 inches and the average annual precipitation in Tucson of 12 inches. Therefore, the volume of reduced irrigation in any given year is equal to 8 inches multiplied by the surface area of new vegetation on the site.

Energy Savings

- *Tree Energy Savings:* Trees provide shade and reduce temperatures on hot days. This reduction in temperatures reduces the need for air conditioning, thereby reducing both the direct costs of energy, as well as the externalities produced by using energy. The trees relevant to Silverbell Road were determined to be both "Small" and "Medium" sized trees, as described by a study by McPherson et. al; medium trees save 180 kWh in electricity and 58 kBTUs in natural gas each year, while small trees

[6] The total social value of water is taken as the sum of the current gross margin plus the cost of water extraction and purification from alternative water sources. The cost of water from alternative sources was found in "Arizona's Next Century: A Strategic Vision for Water Supply Sustainability" (http://www.azwater.gov/AzDWR/Arizonas_Strategic_Vision/documents/OpportunitiesandChallengesforArizona.pdf) . It was assumed that the cheapest sources would be used first.

save 74 kWh and 2 kBTUs in energy each year[7]. Based on current rates, it is assumed that the direct cost of electricity is $0.10/kWh and $0.001/kBTU.

Operation & Maintenance

- *Direct costs of water:* Tucson's water rates were used: $2.77/CCF
- *Social marginal cost of water:* The social marginal cost of water was taken to be the difference between the current cost of water and the cost of water if current sources run dry. Future and alternative sources of water include primarily desalination plants[8], which are much more expensive sources of fresh water than direct extraction from ground sources such as aquifers. Using these costs and the implied current gross margins, the Social Cost of Water was calculated as $5.29, implying a Social Marginal Cost of Water of $2.52/CCF.
- *Overall Reduced Irrigation Costs:* The reduced costs for both direct costs and indirect costs were determined for each site by multiplying the relevant cost per CCF by the CCFs saved as a result of using LID features. This calculation produced annual values which were extrapolated out to 40 years from now. As a final step, the value of reduced irrigation for years 1-3 was subtracted from the overall benefit, as it is expected that reduced irrigation will not become a realized benefit until year 4.
- *O&M costs for trees:* $11/year[9].

Supplemental Local Costs Data

- *Capital Expenditures (CapEx) and Operations and Maintenance (O&M) costs:* To estimate the capital expenditure and O&M costs, AutoCASE™ uses a database of real project costs for each LID feature. To better cater the results to the Tucson region specifically, the database being used was narrowed down to EPA Region 6 data, providing data for regions with low rainfall.

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[7] McPherson et al. Op. Cit.

[8] http://www.azwater.gov/AzDWR/Arizonas_Strategic_Vision/documents/OpportunitiesandChallengesfor_Arizona.pdf

9 McPherson et al. Ibid.

Arid Southwest Additional Costs/Benefits Evaluation

Flood Mitigation Benefit

Flood mitigation benefits were analyzed from three primary components: rainfall analysis, analysis of value at risk and total flood risk mitigated.

Rainfall Analysis

- Historical rainfall data in the Tucson region was used to model expected future rainfall on each site for the next 100 years. Using the historical data, expected rainfall (in inches) for each year can be equated to the storm repeat rate. The storm repeat rate describes how often a storm of that strength is expected to appear. For example, a 25 year storm is a storm that would be expected to occur once every 25 years or more. The storm repeat rate is used in the next step to estimate the value at risk.

Analysis of Value at Risk

- Using historical property damage due to flooding for the state of Arizona, a function is used that relates storm repeat rate to percent of expected property damage. This function is applied to each year in the 100 year forecast to determine the percent property damage expected and, hence, the value of the damage.

Total Flood Risk Mitigated

- The sites being analyzed are incorporated by estimating the reduced on site flooding in a storm event. This reduction in flooding may be the result of higher infiltration rates, greater on-site storage capacity, or increased grey infrastructure capacity, thereby removing water from the site at a faster rate. This reduction in flooding on the site is then compared to the total projected flooding in the City of Tucson. The ratio is equivalent to the flood risk mitigated. Multiplying the flood risk mitigated by the total value at risk due to flooding produces the value of flood risk mitigated for each year. Discounting these values back (to factor in the social cost of capital) and summing produces the total NPV of the reduced flood risk.

Transportation – Traffic Calming Benefits

- Both roundabouts and curb extensions have been shown to reduce the prevalence and severity of crashes. To quantify the benefits of these features, the variables included the following: current crash rates and severity of crashes, distance of mitigated risk, and number of cars passing by feature each day. The current crash rates and severity of crashes were found in Arizona's 2012 Motor Vehicle Crash Costs document[10]. The distance of mitigated risk was conservatively assumed to be 5 meters on either side of a roundabout and, similarly, 5 meters for the curb extension. The number of cars passing by each feature was found to be 10,000 per day (two-way traffic count) for Silverbell Road and the roundabout, while the number of cars was estimated at 500 per day for Cerada de Beto and the curb extension[11]. More details on the calculation of the traffic calming benefit can be found in Appendix II: Traffic Calming Assumptions and Calculations.

Heat Island Benefit

- Green infrastructure reduces the severity of extreme heat events by creating shade, by reducing the amount of heat absorbing surfaces, and by emitting water vapor to cool the air. This cooling effect can reduce heat stress-related fatalities in the city during extreme heat wave events.
- The benefits of GI/LID on urban heat island is estimated by valuing the reduced mortality associated with lowering the air temperature. The methodology is described below and also in Appendix VII: Heat Island Benefit Calculation.
- Heat Stress and Related Premature Fatalities Avoided Methodology – "Arizona is one of the hottest places on earth from May to September. Heat-related illnesses are common during the summer. Year after year, nearly 2,000 people visit Arizona emergency rooms because of heat-related illnesses. Some heat-

[10] "2012 Motor Vehicle Crash Facts for the State of Arizona". The Arizona Department of Transportation. Accessed June 5, 2014. http://www.azdot.gov/docs/default-source/mvd-services/12crashfacts.pdf?sfvrsn=2

[11] "2012 Traffic Volumes in Metropolitan Tucson and Eastern Pima County". Pima Association of Governments. Accessed June 6, 2014. http://www.pagnet.org/documents/rdc/gis/maptrafficcount2012.pdf

related illnesses could even be fatal. Over 1,500 deaths from exposure to excessive natural heat have occurred in Arizona from 2000 to 2012[12]." These events may be more frequent and severe in the future due to climate change. "The urban heat island (UHI) effect compromises human health and comfort by causing respiratory difficulties, exhaustion, heat stroke and heat-related mortality. Various studies have estimated that trees and other vegetation within building sites reduce temperatures by about 5°F when compared to outside non-green space. At larger scales, variation between non-green city centers and vegetated areas has been shown to be as high as 9°F."[13]

- The approach used in AutoCASE™ is to link GI/LID to reduced temperatures by:
    - Determining the total acres of increased vegetation, and dividing by the total acres in the town/city that the project is being built in to calculate an overall percentage increase in vegetation.
    - Linking 10% increase in vegetation to reductions in temperatures (0.39 to 0.70°F, according to multiple studies determining the impacts of GI/LID projects on urban temperatures)
    - Calculating the overall reduction in temperature as a result of the project
- Then, linking reduced temperatures to avoided deaths by:
    - Calculating the reduction in the average annual mortality rate based on local weather, the local, Tucson region, mortality rate, and the local temperature threshold at which the impacts of heat on mortality can be detected (called the Minimum Mortality Temperature, or MMT).
        - Calculating the change in the days each year when the city is over the MMT, as well as the change in the average temperature for the days that are still over the MMT after the project is implemented.

[12] Arizona Department of Health Services - http://www.azdhs.gov/phs/oeh/heat/extreme.htm

[13] Center for Neighborhood Technology, 2010, The Value of Green Infrastructure A Guide to Recognizing Its Economic, Environmental and Social Benefits http://www.cnt.org/media/CNT_Value-of-Green-Infrastructure.pdf

MMT has been found to correlate with latitude, so more southern locations have a higher MMT and more northern locations have a lower MMT.

- Using the change in days over MMT and the change in the temperature for days over the MMT to calculate a new average annual mortality rate.

- AutoCASE™ uses local weather patterns extrapolated from history – daily data from 1981- 2010 - for approximately 1,500 weather stations across the United States. The data were used to determine a distribution of temperature values for each city for every month of the year. Data for three weather stations in the Tucson region were tested for use in this project. Since there were no material differences in the results the AutoCASE™ default of the closest weather station was used.

- Finally, AutoCASE™ calculates the annual lives saved from the project by using the Value of Statistical Life to quantify the benefit of reduced heat mortality rates. The value of a statistical life seems to be widely used in the regulatory impact analysis and cost benefit studies for federal government cost benefit analyses (e.g. safety improvements in rail and roadways). A range of $5-$13 million with a median around $9 million seems to be accepted.

Results for Individual GI/LID Practices

The analysis of individual GI/LID features shows that the three LID features with a probability of achieving a net social benefit (when their social and environmental benefits outweigh the costs) that is greater than 50% include Infiltration Trenches, Xeriscape Swale, and Water Harvesting Basins. This can be seen in Figure 20.

In contrast, traditional features like Concrete and Asphalt have a highly negative SNPV, indicating that the costs far outweigh any benefits. For that reason, Pervious Pavers provide a significantly improved SNPV, even though its SNPV is also negative.

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Table 1 Summary Results for Individual GI/LID Features (per 1000 sq. ft., Cistern is for 350 cubic feet) – Median (50th percentile) Results

	Net Present Values – Median (50th Percentile)								
	Costs		Benefits						
	CapEx Cost	O&M Costs	Flood Risk Reduction	Property Value Uplift	Heat Mortality Risk Reduction	Reduced CO_2 Emissions	Reduced Other Costs	Direct Financial NPV	**Total SNPV**
Bioretention	($2,096)	($377)	$169	$49	$515	$0	$0	($2,473)	**($1,740)**
Pervious Pavers	($2,496)	($834)	$168	$51	$513	$0	$0	($3,330)	**($2,597)**
Detention Basin / Extended Detention	($1,215)	($194)	$234	$50	$514	$0	$0	($1,409)	**($612)**
Water Harvesting Basin*	($132)	($7)	$200	$52	$518	$0	$0	($139)	**$631**
Cistern	($2,685)	$0	$95	$0	$0	$0	$448	($2,685)	**($2,142)**
Xeriscape Swale	($383)	($173)	$159	$51	$512	$0	$0	($556)	**$167**
Infiltration Trench	($701)	($167)	$200	$50	$515	$0	$0	($868)	**($102)**
Pavement	($10,817)	$0	($424)	$0	$0	$0	$0	($10,817)	**($11,241)**
Concrete	($14,106)	$0	($379)	$0	$0	($1,346)	$0	($14,106)	**($15,831)**
	*Entered as Infiltration Basin								

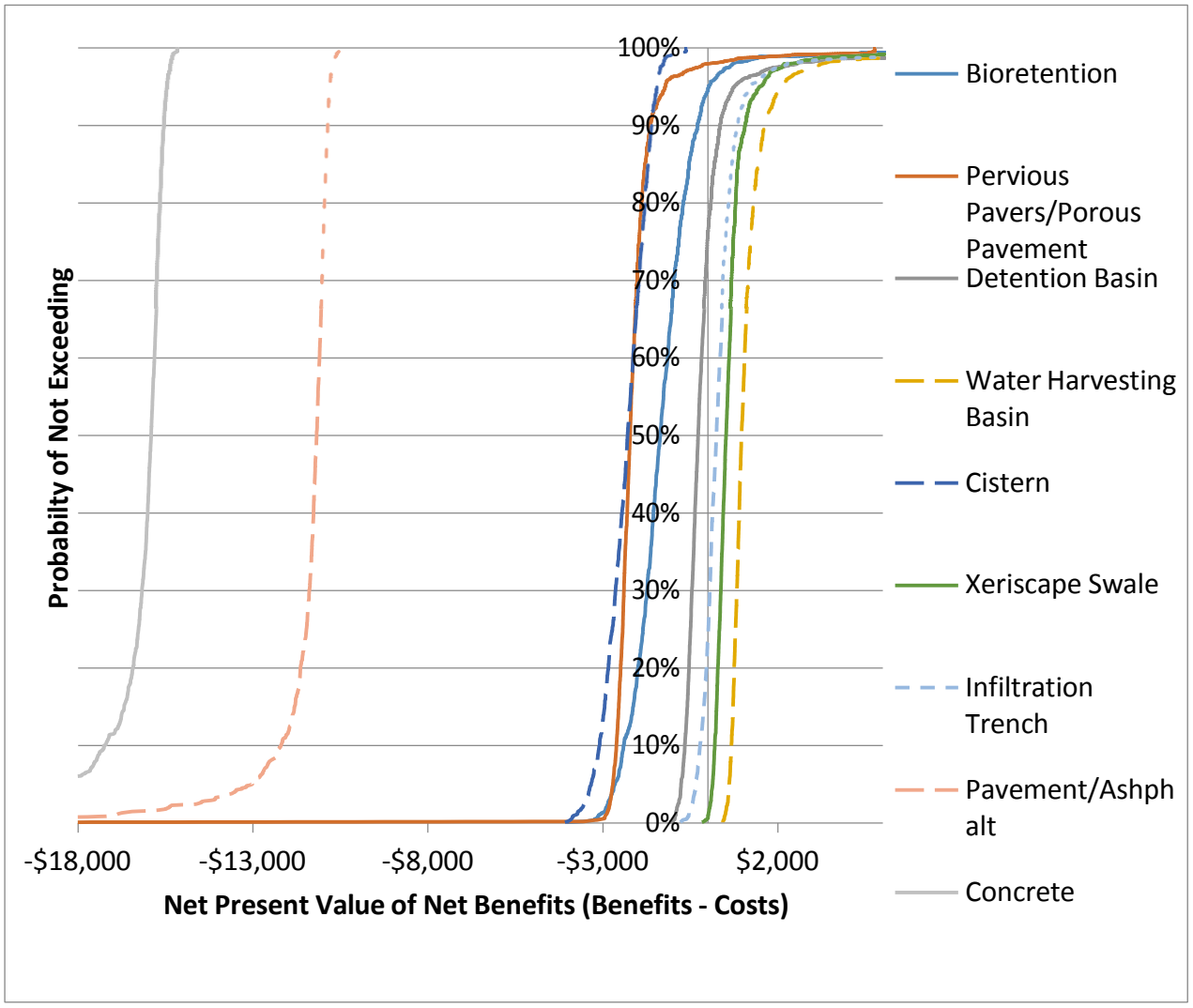


Figure 20 Probability Curves for the Sustainable Net Present Value (SNPV) of Individual GI/LID Features.

Note on Figure 20*:* These curves include all of the costs and benefits (internal or direct cash value which is made up of any revenues or subsidies minus capital and operating costs – such as reduced irrigation costs, in addition to external or non-cash benefits such as reduced flooding, property value increase, reduced heat mortality, reduced emissions, and increased water quality) of the features. The steepness of the curve shows the certainty around the estimate – the steeper the curve, the more certain, the wider the curve, the more risk in the estimate. The curves allow for probability statements about the estimates to be made – for example, there is a 90% probability that the SNPV of pavement/asphalt will not exceed -$10,900, there is a 50% probability that the SNPV will not exceed -$11,200, and there is a 10% probability that the value will

not exceed $12,200. The curves are generated from a 1,000 iteration Monte Carlo simulation. More information can be found in Appendix IV.

Site Specific Evaluations – GI/LID Clustered Scenarios

Initial Parameters

The initial parameters and suggested categories for review included the following GI/LID practices:

- **Permeable Pavers** (pollutant removal & water quality improvement)
- **Urban Heat Island Effect** (provide shade for heat mitigating effect)
- **Green Roof** (reflective shading materials and vegetation)
- **Traffic Calming** (Curb Extensions, Chicanes, Traffic Circles, Lane Widths)
- **Street Trees** (Streetscapes)
- **Protected Bike Lanes** (safety and business booster)
- **Water Harvesting Basins/Infiltration Basin** (retention of rainwater, meeting water supply needs)
- **Bio Retention Basin** (water conservation & water quality improvement)
- **Xeriscape Swale/or Grass Swale** (runoff collection, infiltration & conveyance)
- **Cistern** (water conservation, reduced irrigation needs)
- **Infiltration Trench** (runoff storage & infiltration)
- **Detention Basin or Extended Detention Basin** (runoff storage & flood risk reduction)

Commercial property

A 7.3 acre commercial property for a gas station/convenience store in the northeast edge of the City of Tucson was chosen for analysis. Green Infrastructure modification to the site designs were added for purposes of scenario testing only and are not associated with any current proposed changes at the existing site. The site shown is for illustration purposes only. The site is surrounded by suburban land uses.

Figure 21 Commercial site location from Google Maps

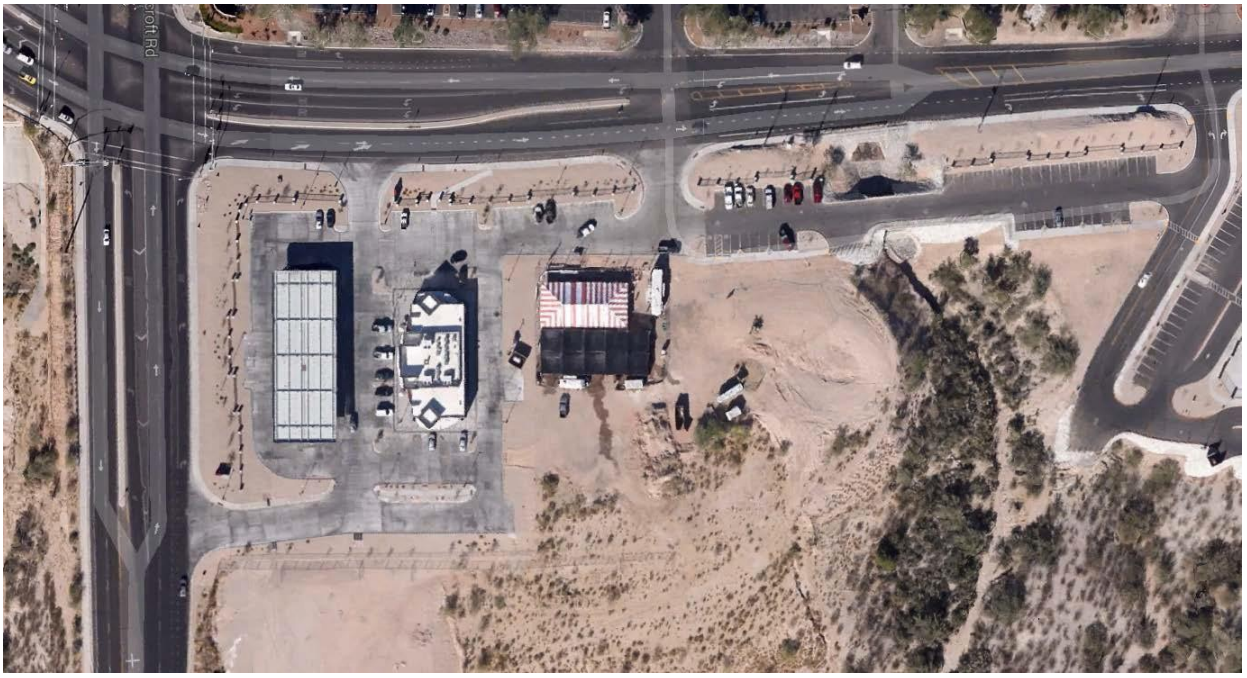


Figure 22 Commercial site from Google Maps

Figure 23 Commercial Site Detail from Google Maps

The plans for the property were modified to include green infrastructure features (these modifications were added for purposes of analysis only and are not associated with any proposed changes):

- Water Harvesting Basins
- Bio Retention Basin
- Cistern
- Pervious Pavers
- Detention Basins (or Extended Detention Basins)

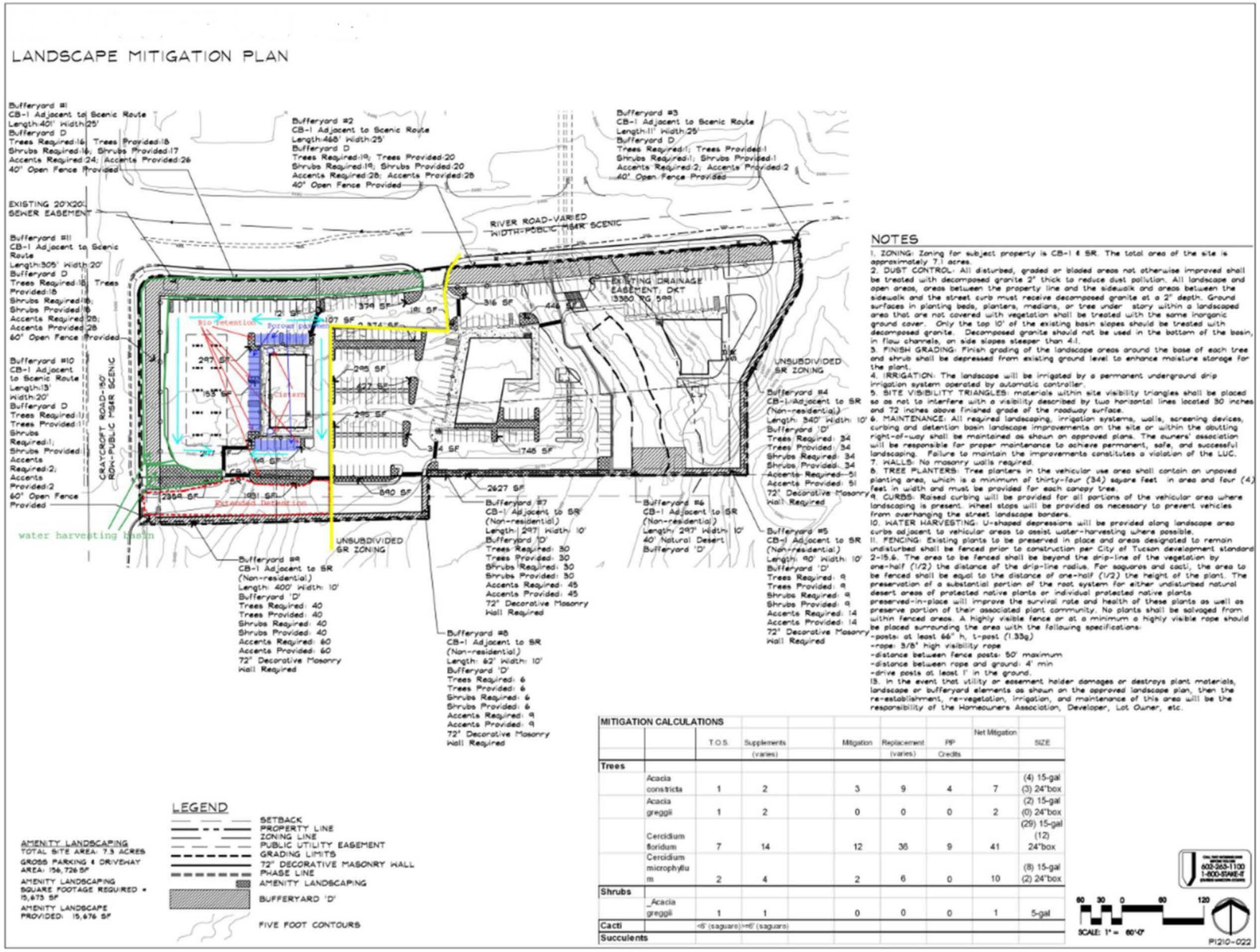


Figure 24 Commercial Site Design

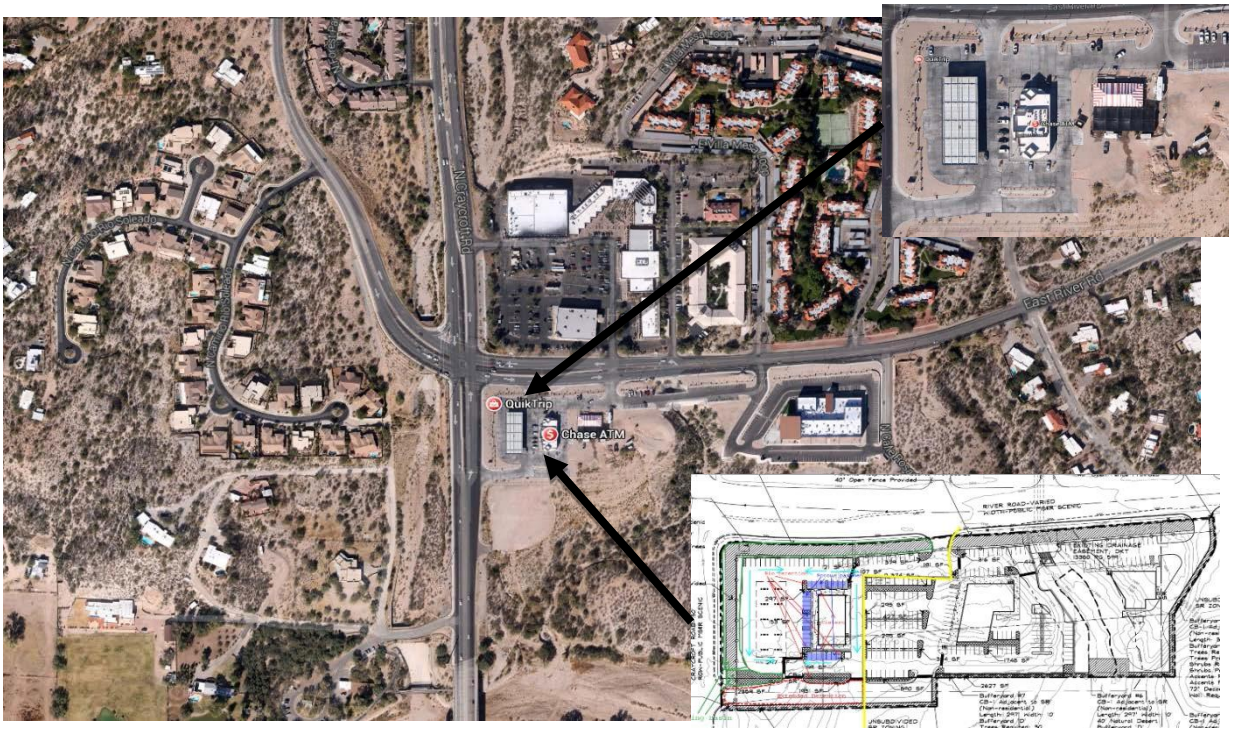


Figure 25 Commercial Site location, site and plan

Transportation Corridor project

Silverbell Road from Grant Road to Goret is being re-designed. The four northerly sections of Silverbell Road from Goret Road north were chosen for the beta test. The intersection of Silverbell Road and Goret Road (2501-2519 W Goret Rd Tucson, AZ 85745, USA) is at coordinates 32.2629394, -111.0211001.

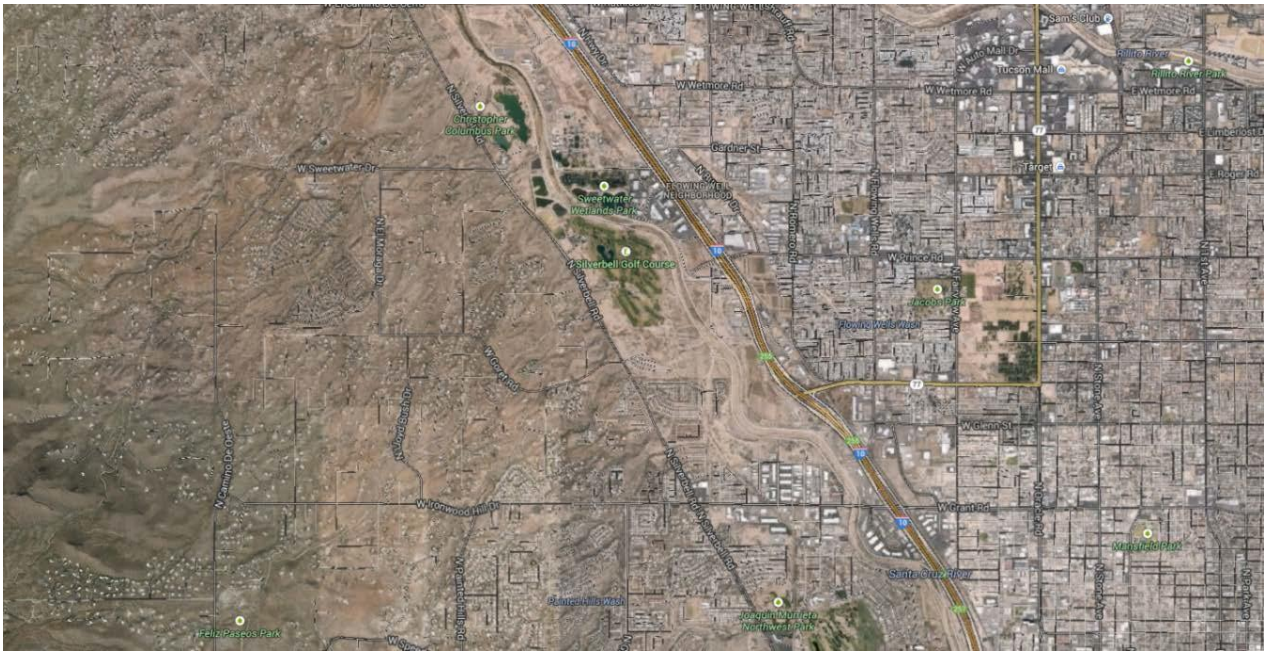


Figure 26 Silverbell Road Location from Google Maps

Figure 27 Silverbell Road Site from Google Maps

Figure 28 Silverbell Road Site Detail from Google Maps

The following Green infrastructure features were added to the design for purposes of analyses and are not associated with any proposed changes:

- Water Harvesting Basins
- Infiltration Trench
- Curb Extensions (new and retrofit chicanes, medians, traffic circles and road diets with inlets to gather street water)
- Trees

Figure 29 Silverbell Road Sections and Google Map View

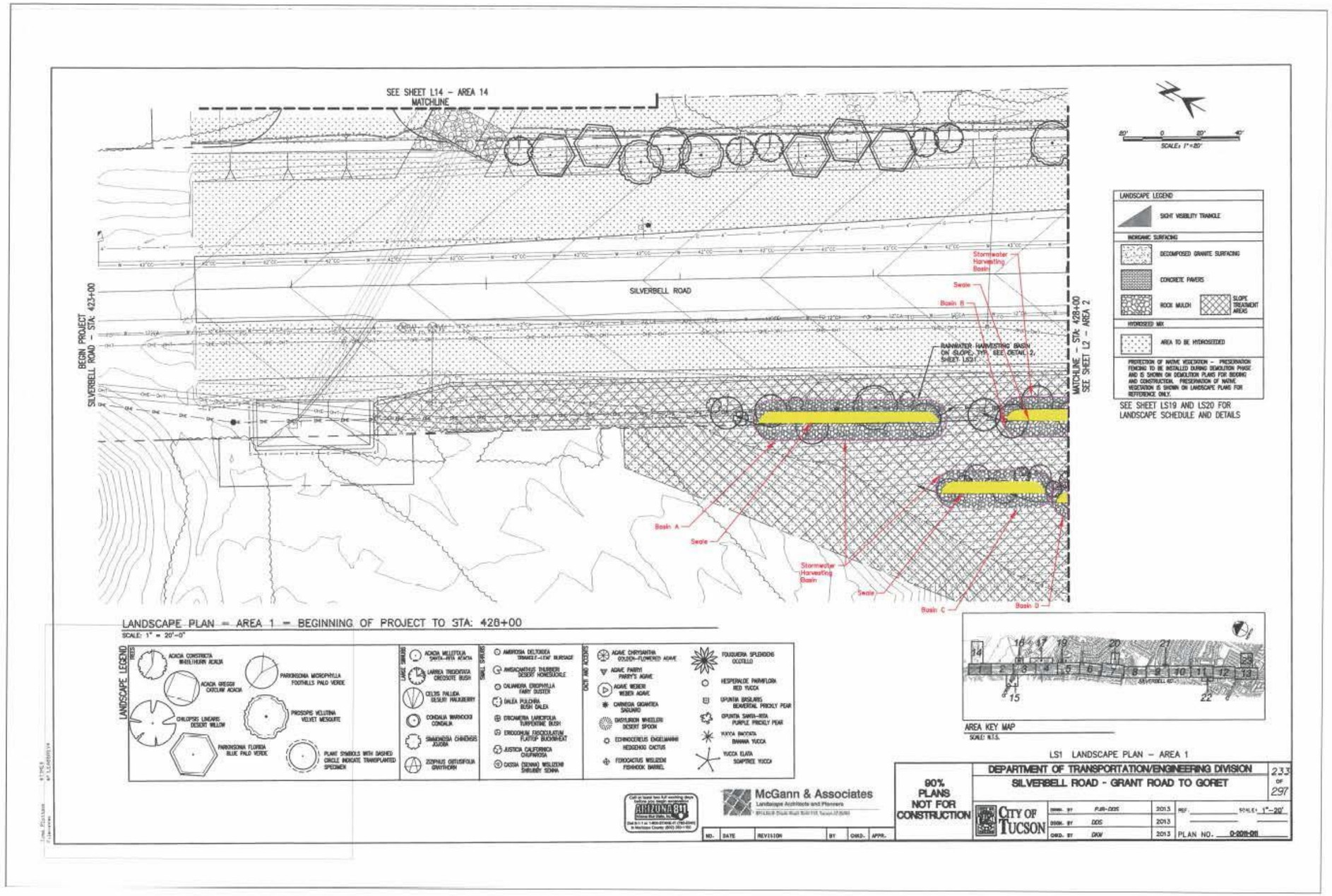


Figure 30 Silverbell Road Section 1 Design

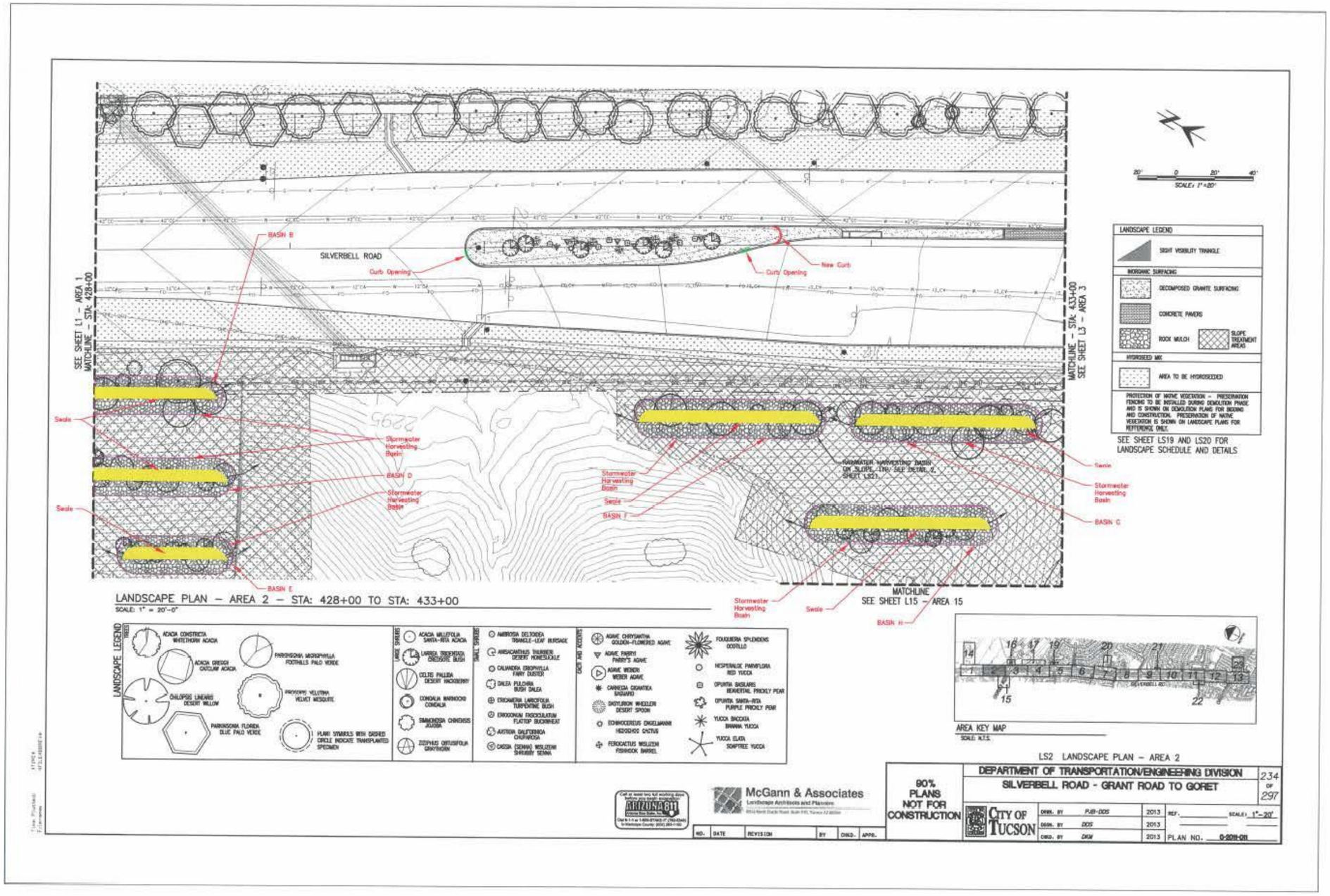


Figure 31 Silverbell Road Section 2 Design

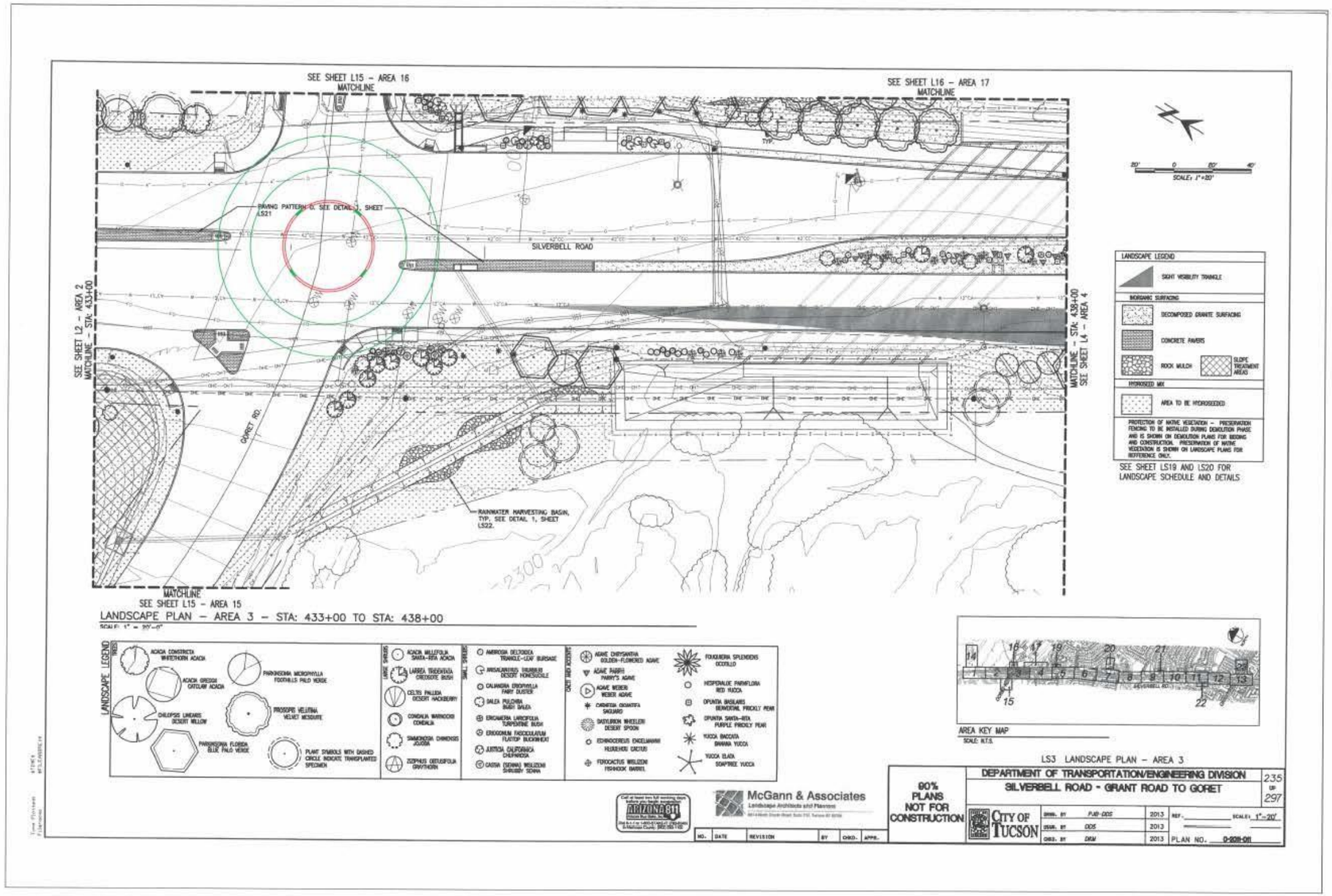


Figure 32 Silverbell Road Section 3 Design

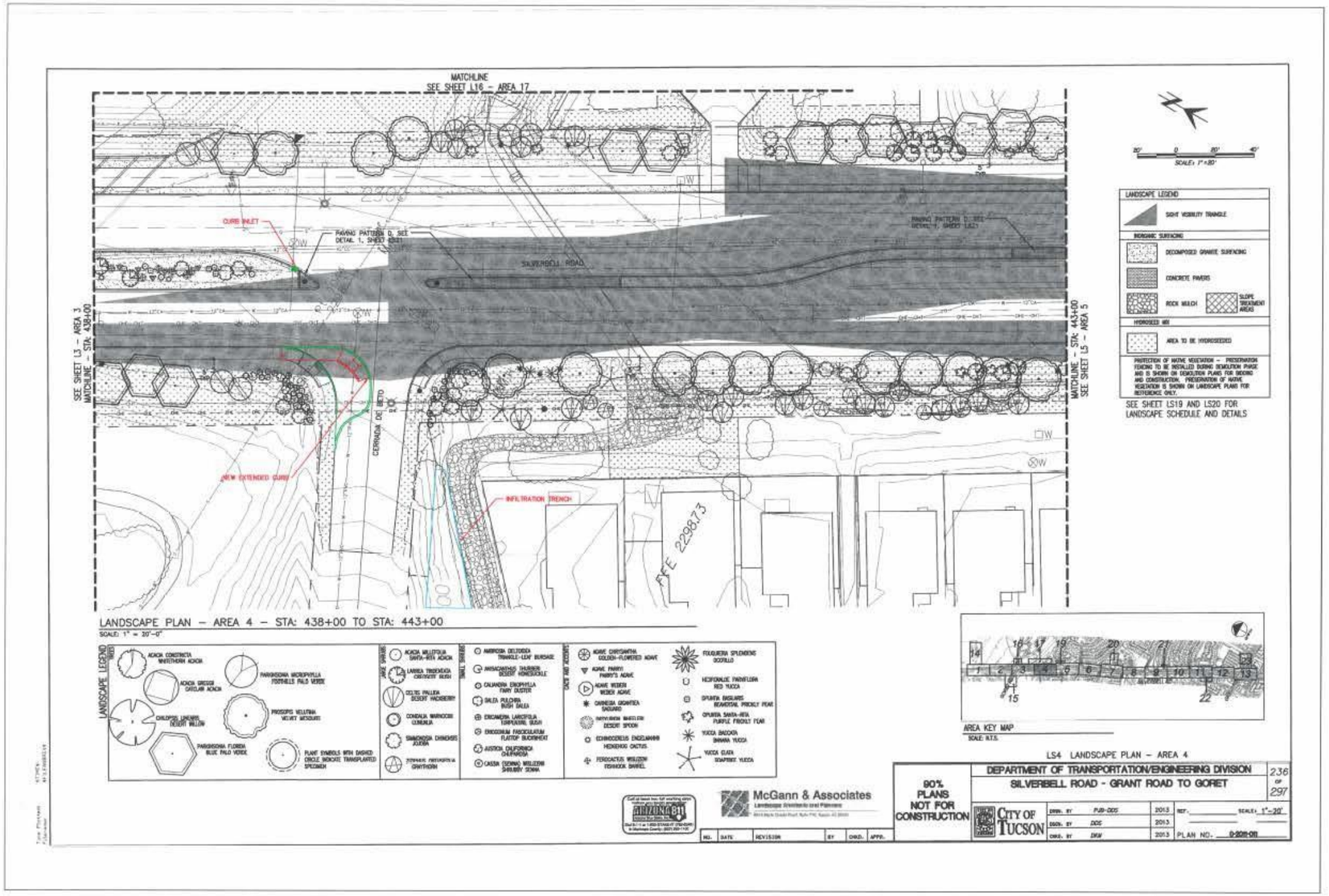


Figure 33 Silverbell Road Section 4 Design

Results for Site Specific Evaluations

The commercial site (a gas station and convenience store), was modified to incorporate rainwater harvesting cisterns, trees, bio retention, detention basins, and porous paving in some parking spots. The addition of the green infrastructure features is for analysis purposes only and do not reflect any proposed changes to the existing development.

The inclusion of these LID features shows that the value of the site is significantly higher when compared with the base case of using concrete. As can be seen in Figure 34, both the direct financial net present value (NPV) and the sustainable NPV (SNPV) are lower for the base case. This is primarily because the capital expenditure costs of concrete are higher than the green LID features selected. However, there is also a large difference in social and environmental value. The SNPV for concrete is negatively skewed because concrete is an impervious surface and can increase flood risk in a region. In contrast, the LID features selected have multiple social and environmental benefits. Cisterns, trees, bio retention, detention basins, and porous paving all help to reduce flood risk in the area during extreme storm events. Other benefits include a reduction in carbon emissions and air pollution, increasing local property values due to enhanced aesthetics, and reducing heat mortality due to mitigated urban heat island effects. Another benefit due to the use of cisterns is a lower requirement for on-site irrigation. This benefit is divided between a reduced requirement to pay for water, as well as social benefits that result from decreasing water use in water scarce areas such as the Tucson region.

One item of particular note is that the SNPV becomes positive with a probability of approximately 20%. In other words, when including the social and environmental benefits of using LID features, the net value of the project (including the upfront costs and maintenance costs) has an 80% probability of being greater than $0. This is important as most alternatives, such as the use of concrete or pavement, have high up-front costs but then fail to generate much social or environmental value, hence leading to negative NPVs. This can be clearly seen in Figure 34.

A summary of the benefits realized by the commercial site, as well as the capital expenditure and operations and maintenance (O&M) costs can be seen in Table 2.

Table 2 Summary Results for Commercial Site

Summary Results	Net Present Value of Benefits - Commercial Site
Capital Expenditures	*-$81,685*
O&M Costs	*-$26,640*
Direct Financial NPV	***-$108,325***
Reduced Flood Risk	*$6,203*
Change in Property Values	*$3,059*

Summary Results	Net Present Value of Benefits - Commercial Site
Reduced Heat Stress Mortality	*$69,162*
Value of Reduced CO2 Emissions	*$15,043*
Value of Reduced Air Pollution	*$26,088*
Reduced Direct Costs of Water	*$896*
Reduced Marginal Social Costs of Water Use	*$815*
S-NPV	***$12,941***

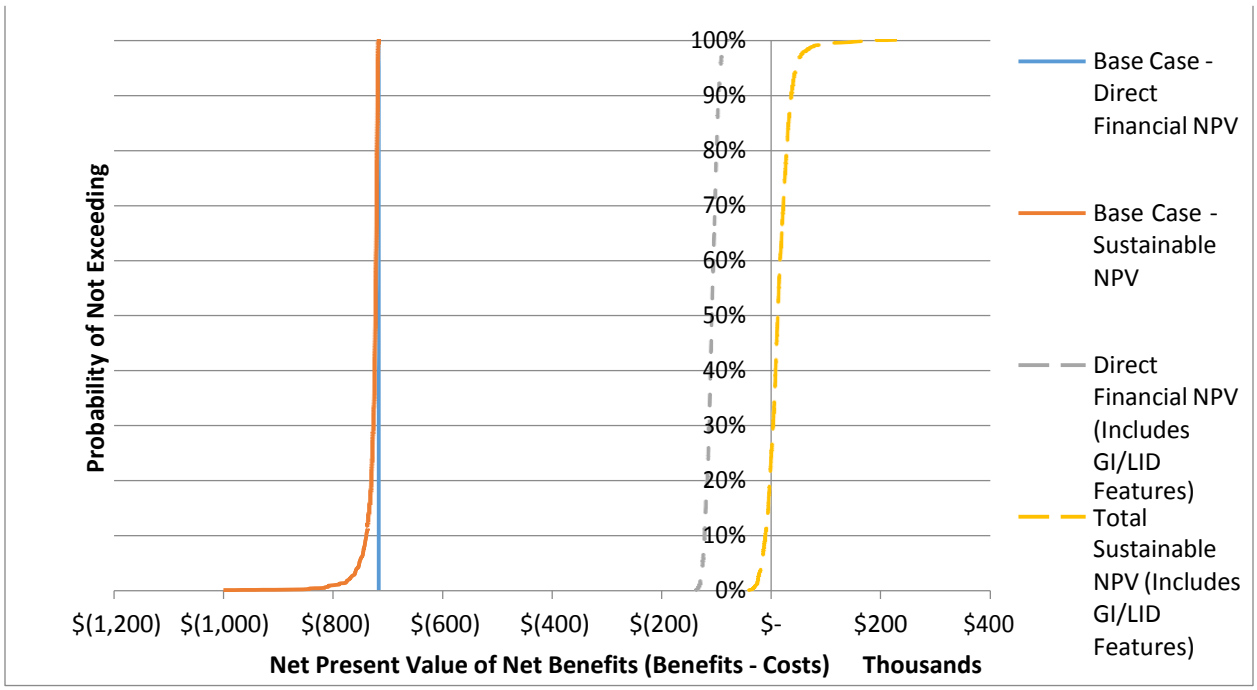


Figure 34 Probability Curves for Commercial Site

Note on NPV charts: The Direct Financial NPV includes all costs and benefits that are seen as having direct monetary impacts over the value of a project. These include capital expenditure costs and operations and maintenance costs. The Sustainable NPV combines the value of the Direct Financial NPV with the value of all of the social and environmental costs and benefits of the project. Therefore, the Sustainable NPV includes capital expenditures, operations and maintenance costs, reduced energy costs, flood risk mitigation, property value uplift, heat stress mortality reduction, reduced air pollution and carbon emissions, reduced direct costs of water, and reduced social costs of water.

The exercise of additional green infrastructure elements to a ½ mile segment of Silverbell Road included incorporating new trees, bio retention, and water harvesting basins revealed that the

SNPV of the site, including the LID features selected, leads to a highly positive SNPV. The most substantial benefits are reduced heat stress mortality and traffic calming due to the installation of a roundabout and curb extension. Unlike the other benefits, these benefits are measuring direct impacts on human life by increasing the safety of a region, either in terms of reduced local temperatures or reduced likelihood of cars hitting pedestrians. The value of life-related costs have a large value over time and, as shown in Table 3, are more substantial than the other benefits as a result.

Table 3 Summary Results for Silverbell Road

Summary Results	Net Present Value of Benefits - Silverbell Road
Capital Expenditures	*-$42,125*
O&M Costs	*-$3,897*
Direct Financial NPV	***-$46,022***
Reduced Electricity Costs	*$20,331*
Reduced Natural Gas Costs	*$57*
Reduced Flood Risk	*$25,645*
Change in Property Values	*$1,592*
Reduced Heat Stress Mortality	*$84,634*
Value of Reduced CO2 Emissions	*$12,095*
Value of Reduced Air Pollution	*$17,588*
Reduced Direct Costs of Water	*$43,823*
Reduced Marginal Social Costs of Water Use	*$39,868*
Increased Pavement Longevity Benefit	*$1,763*
Traffic Calming - Roundabouts and Curb Extension	*$117,737*
Other Benefits	*$3,412*
S-NPV	***$322,523***

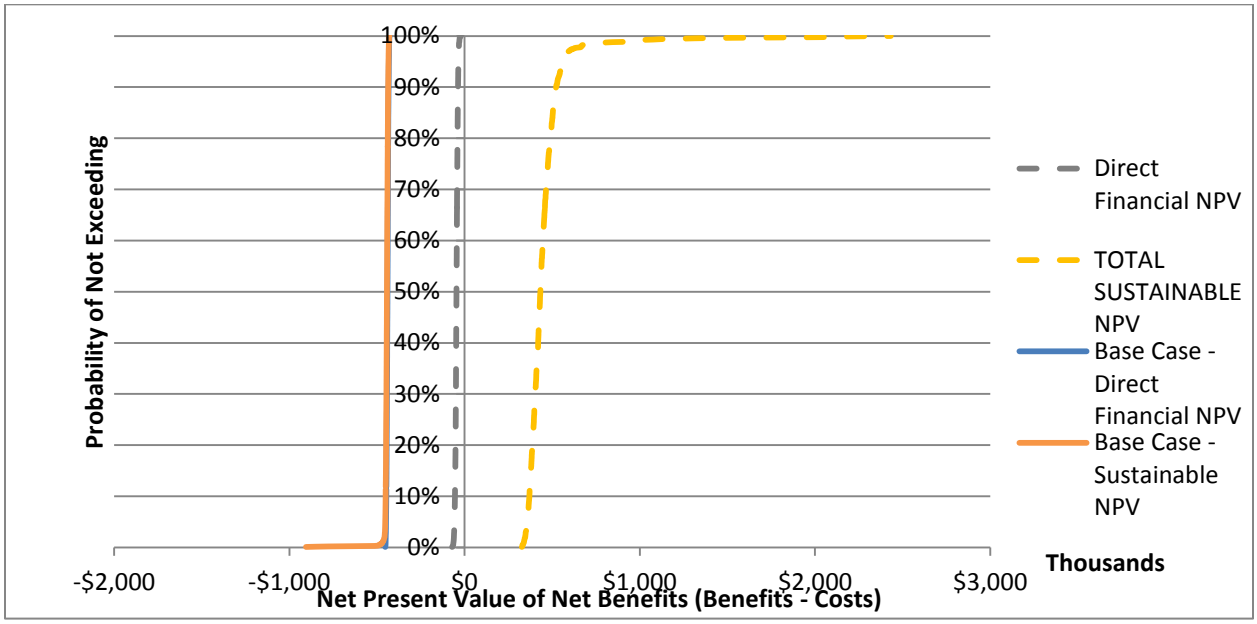


Figure 35 Probability Curves for Silverbell Road

Note on Figure 35 Probability Curves for Silverbell Road - the Base Case Direct Financial NPV and the Base Case Sustainable NPV overlap for most of their range and so are indistinguishable in the chart.

The Tucson region is a bellwether. The Tucson region is teaching the world that infrastructure money must be spent to deal with low probability, large impact events such as flooding. Because of its many benefits, including reduced loss of life, nature's green infrastructure, based on business case analysis, was determined to be the best solution. The implementation of green infrastructure elements can be an effective way to deal with problems of water quality, flooding, safety, urban heat islands, and preserving water as the precious (but undervalued) resource that it is.

AutoCASE™ Summary

Application of the Use to Pima County

Commercial Site

AutoCASE™ was implemented for a commercial site with a gas station and convenience store. The site was modified to incorporate rainwater harvesting, cisterns, trees, bio retention, detention basins, and porous paving in some parking spots. The result led to a large increase in social and environmental value for the site. The division of these benefits can be seen Figure 36.

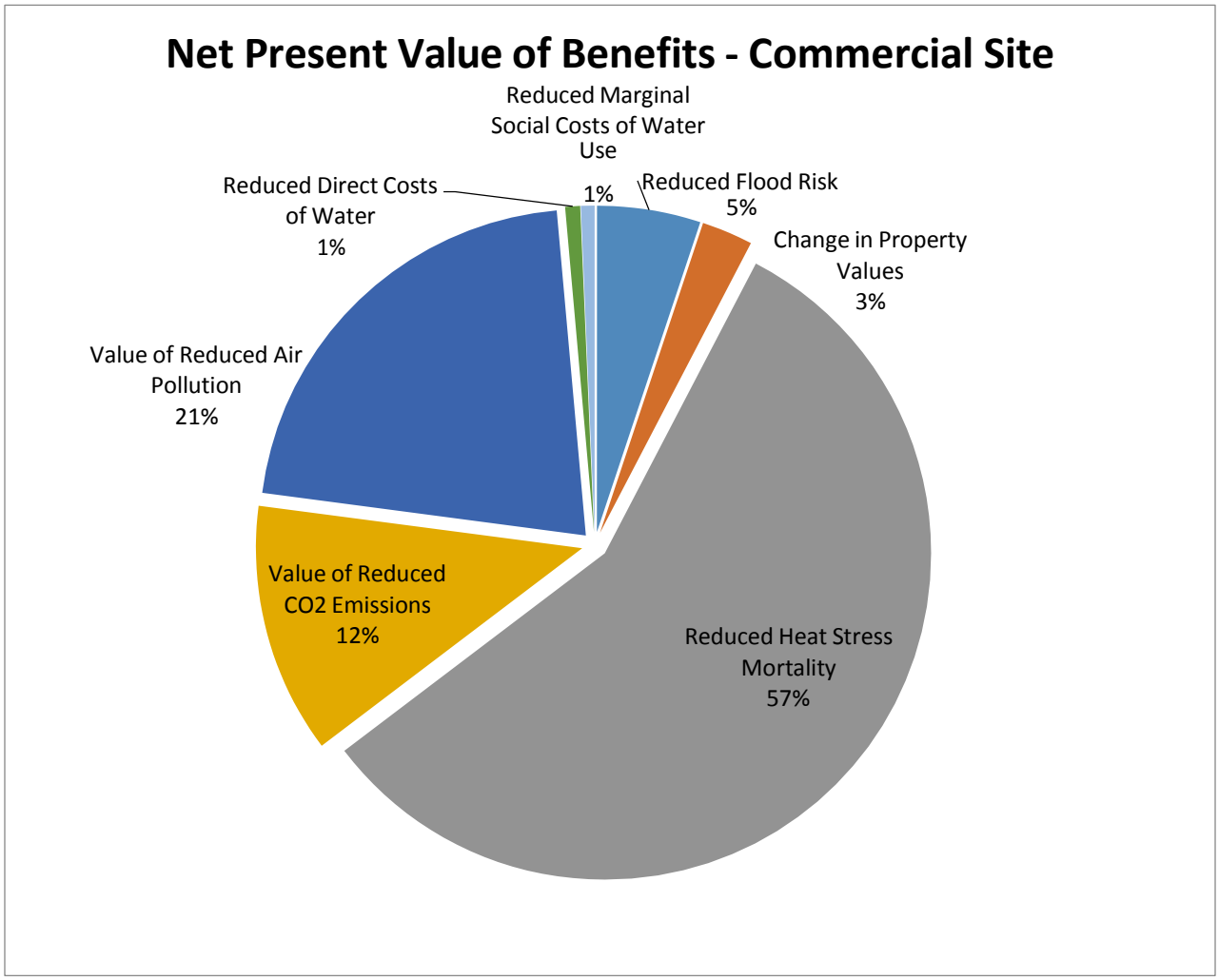


Figure 36 Benefits Breakdown - Commercial Site

As can be seen, the reduced heat stress mortality benefit is the source of most of the value due to the inclusion of LID features. This is largely due to that benefit's direct quantification of the value of increased health and safety that results from a mitigated heat island effect. In other words, the value of a human life saved from reduced temperatures is much greater than lower carbon or air pollutants emissions.

The costs of the project are in line with what would be expected; capital expenditure costs are over 75% of the total lifetime project costs, while operations and maintenance costs account for the remaining 25%. This division of costs can be seen in Figure 37.

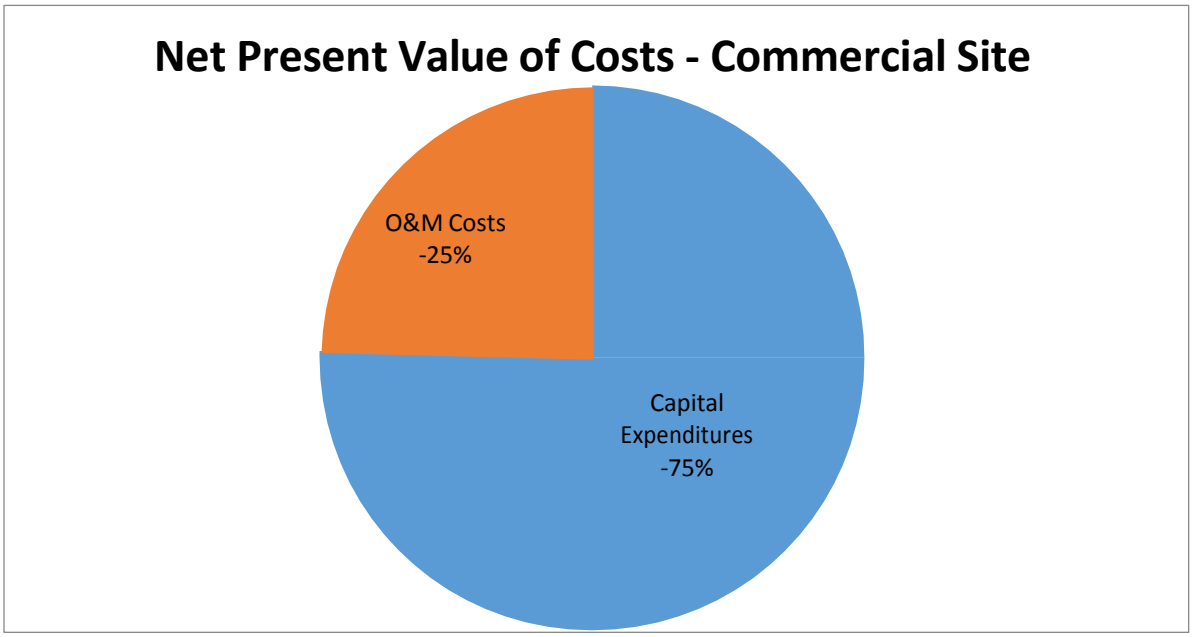


Figure 37 Costs Breakdown - Commercial Site

A large benefit of AutoCASE™ is its ability to allocate the value of a project amongst relevant stakeholder groups so that all parties can understand how they are affected. Shown in Figure 38, direct financial value is the largest proportion of value, although it should be noted that this represent negative value. In other words, this is the net costs of the project. The pie chart shows that the costs represent a smaller proportion of the project's value than the benefits, implying a net positive social value of the project. The negative financial value is the result of the capital expenditure and O&M costs, without a balancing revenue stream or decrease in costs.

When analyzing the stakeholder groups that are benefiting from the project, the government, community, and the environment are all benefiting from the use of LID practices. The government has lower use of potable water for irrigation, higher economic activity due to reduced heat mortality rates and lower health costs due to air pollution. At the same time, the community also benefits from lower mortality rates and better health, while the environment benefits from reduced pollution and carbon emissions.

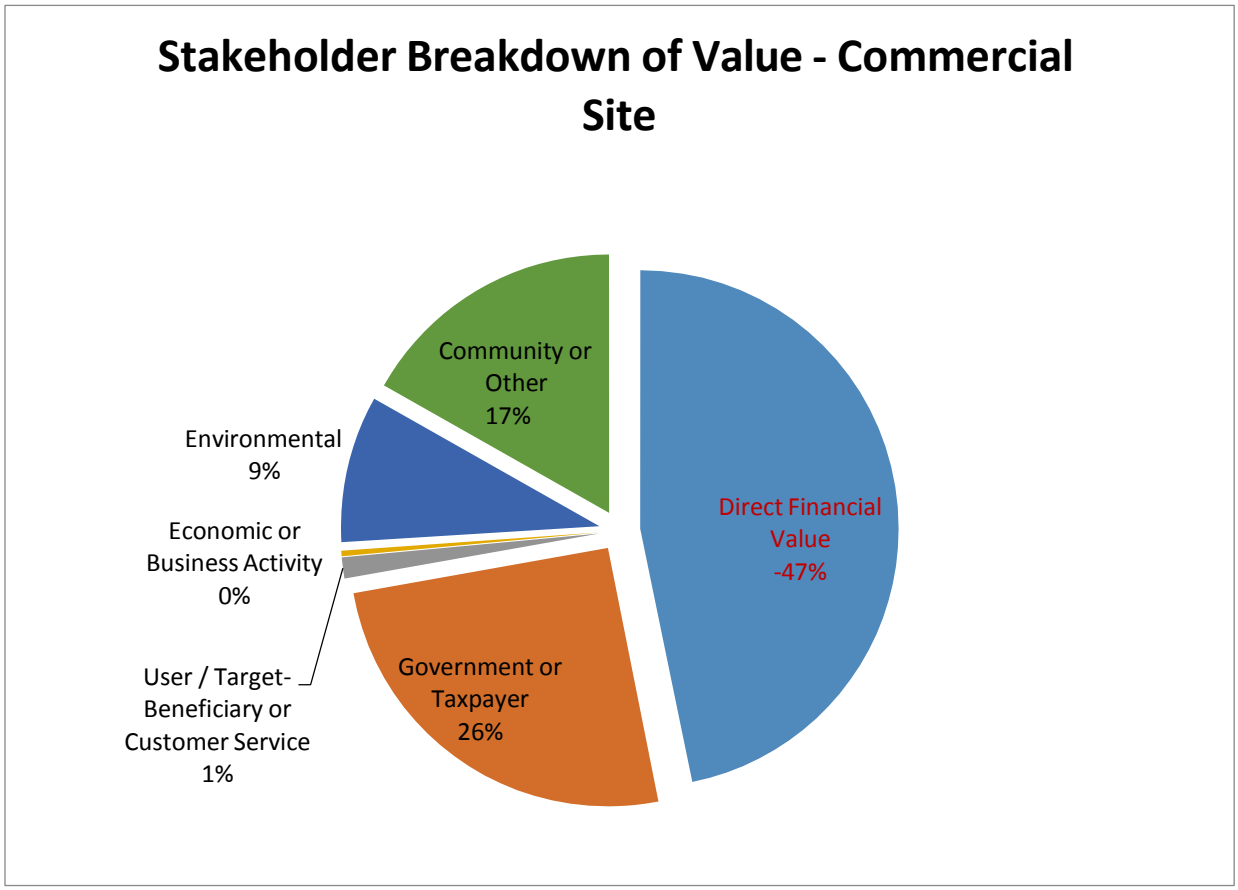


Figure 38 Stakeholder Value Breakdown - Commercial Site

Silverbell Road

At Silverbell Road, the re-design of a ½ mile segment included new trees, bio retention, and water harvesting basins. Traffic calming features, including a roundabout and a curb extension, were also included. These features are projected to produce many benefits, with the highest proportion of benefits derived from traffic calming, reduced heat mortality, and water conservation (see Figure 39). The traffic calming features translate to a lower risk of car crashes with pedestrians. Although these are rare, the social costs of these events are very high as pedestrian crashes have high damage costs[14]. Therefore, even a small reduction in the probability of these events produces a large amount of value. Similarly, reduced heat mortality is also a large portion of the benefits as it is measuring the incremental value due to a lower probability of heat-related deaths.

Water conservation due to the use of bio retention and water harvesting basins leads to a reduced need for potable water use for irrigation. In this analysis, it was assumed that the reduced need for potable water irrigation would begin 3 years into operations and would

[14] http://www.azdot.gov/docs/default-source/mvd-services/12crashfacts.pdf?sfvrsn=2

remain for the remaining 37 years of the project's effective life. As a result, reduced water costs were counted for years 3-40[15]. Going hand in hand with this is the reduced social cost of water. Since the reduction in irrigation requirements is not expected to be realized until year 3, the Social Marginal Cost of Water benefit was calculated for years 3-40.

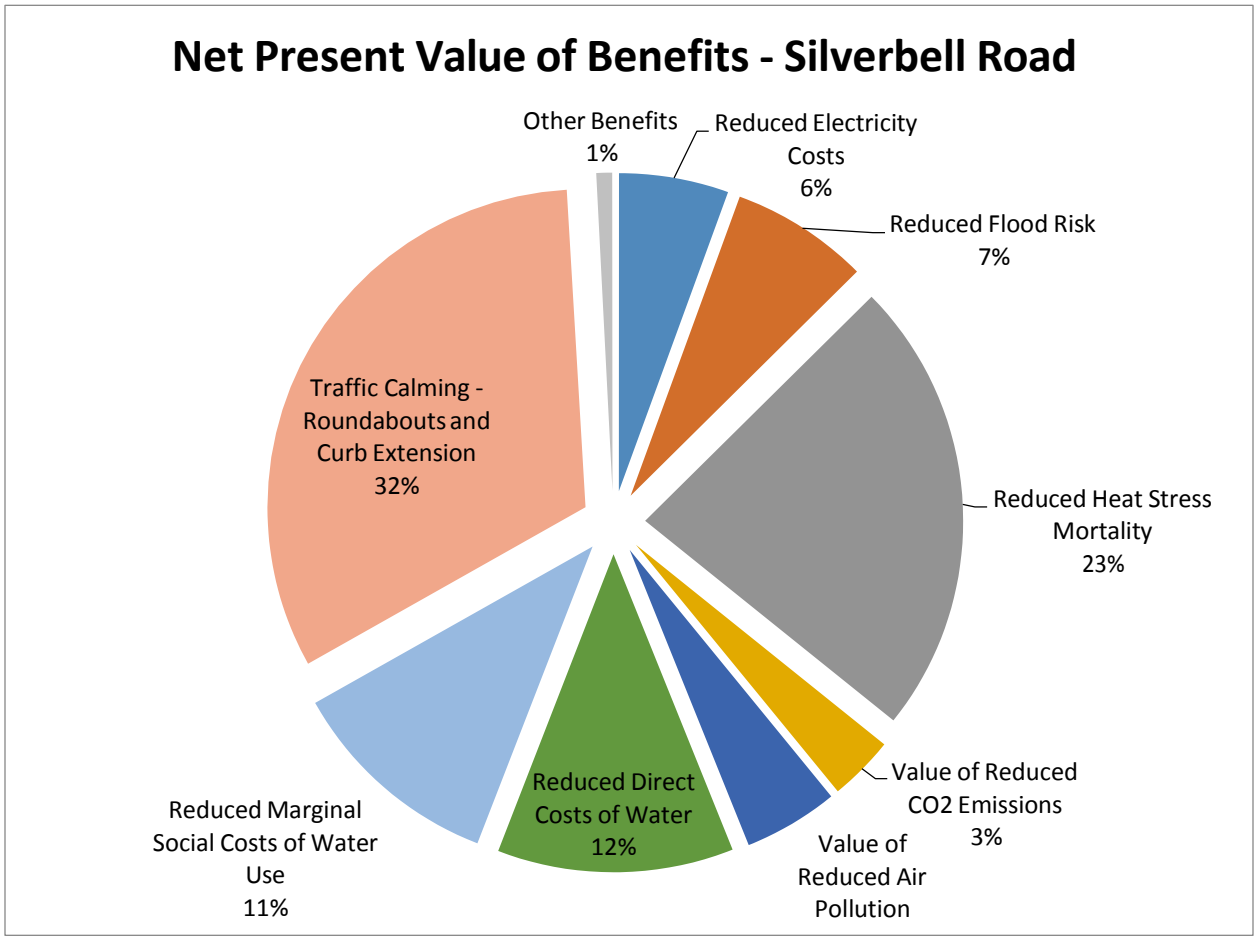


Figure 39 Benefits Breakdown – Silverbell Road

As with the costs for the commercial test site, the vast majority of the costs for Silverbell Road are due to Capital Expenditures. Operations and Maintenance costs comprise the remainder (see Figure 40 Costs Breakdown - Silverbell Road).

[15] Forty years is used in the analysis for all base case (concrete) and GI/LID features as an estimate of the longest-lived of these assets.

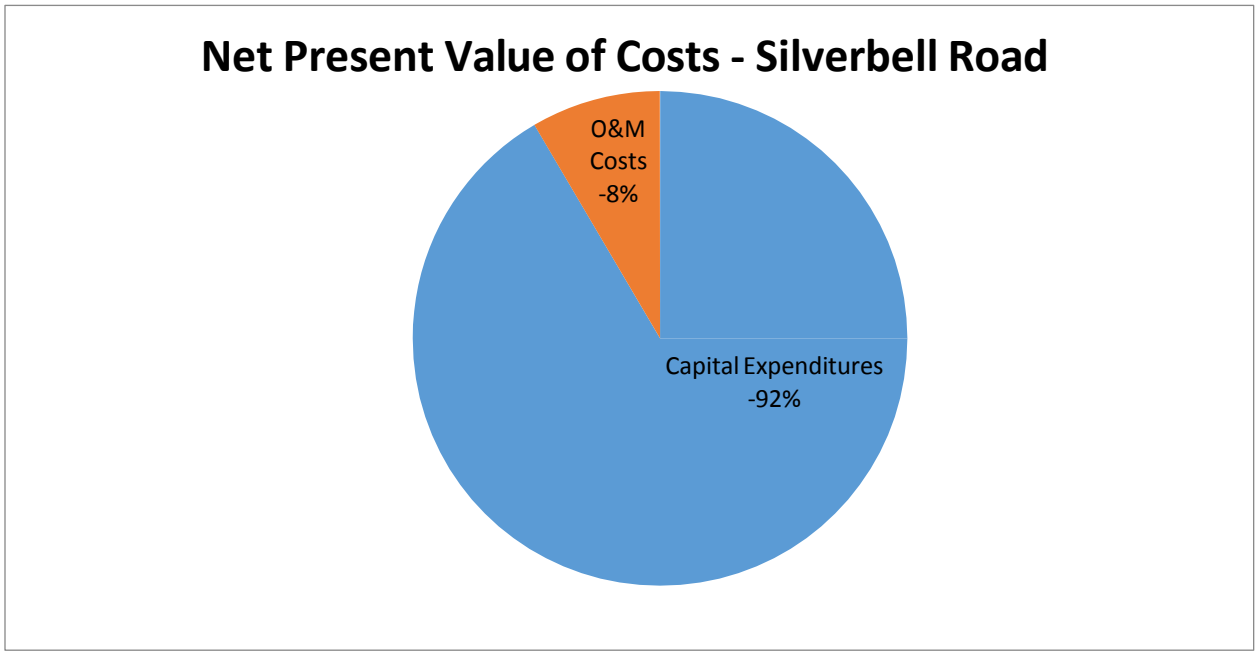


Figure 40 Costs Breakdown - Silverbell Road

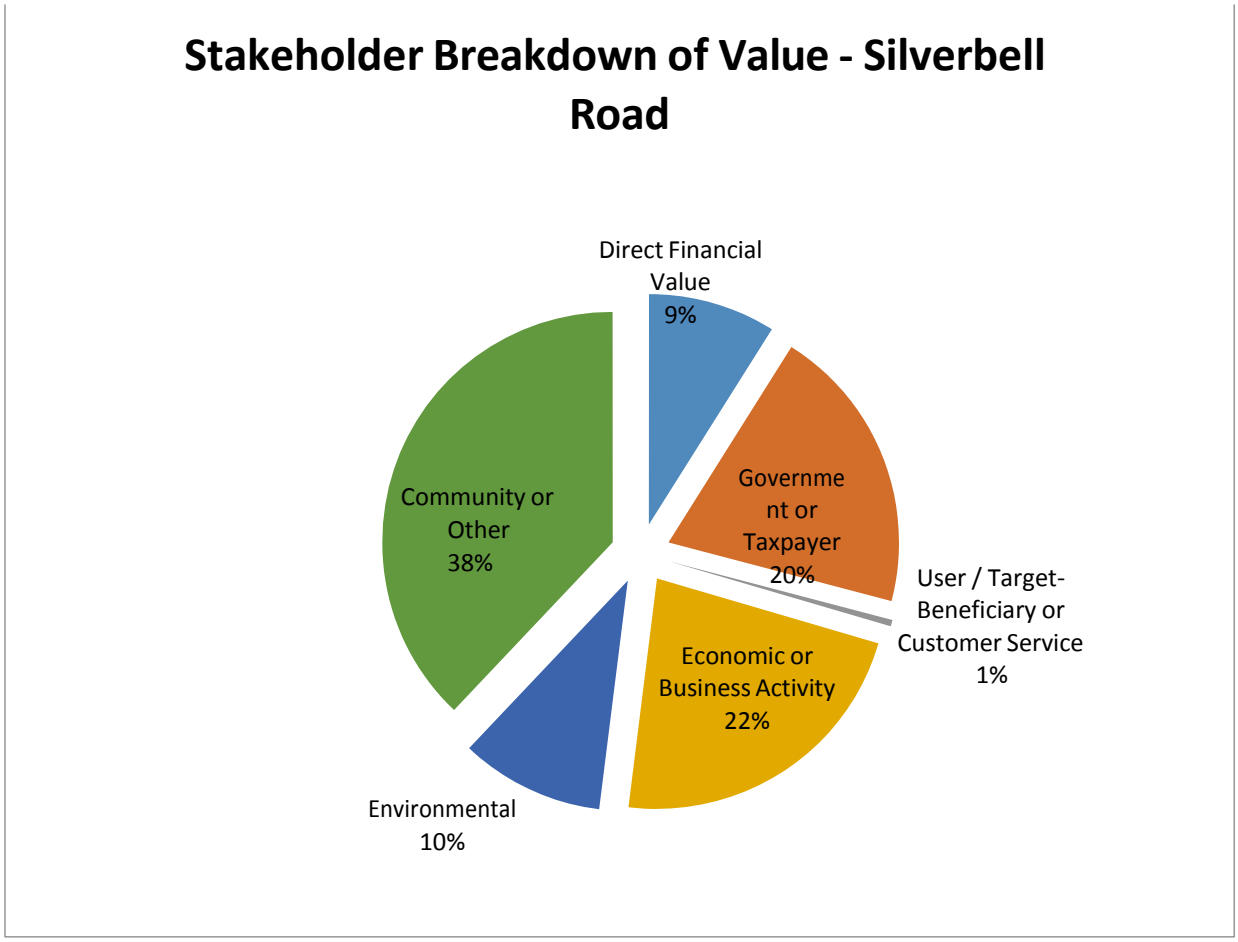


Figure 41 Stakeholder Value Breakdown - Silverbell Road

Figure 41 shows AutoCASE's division of the value from Silverbell Road between the relevant stakeholder groups. Most of the value of this project is realized by the community, the government, and the local economy. The community benefits most from the marginal social cost of water and traffic calming benefits. These benefits reduce the community's risk of water shortages as well as improving quality of life by increasing safety. The government benefits from reduced heat mortality rates of local residents, decreased local flood risk (thereby lowering costs), and reduced carbon and air pollution. Finally, the economy benefits most from the reduced social cost of water, as well as the traffic calming features of the roundabout and curb extension. The traffic calming causes increased economic activity because it is leading to a reduction in accidents, which leads to a decrease in lost economic activity; put another way, there is a net increase in economic activity when compared with having no traffic calming features in place.

Link between AutoCASE™ and Envision

Overview

One of the most valuable features of AutoCASE™ is its ability to express the value of a project in the context of the Envision™ Rating System. Envision™ allows users to rate the level of sustainability and resiliency of an infrastructure project. As an example, for a city designing a new stormwater management system, Envision™ requires the designers of the project to answer questions about the project and its local impacts and design characteristics. This may include the level of resiliency of the design, the degree of sustainable materials used, noise and aesthetic impacts on the local community, impacts on carbon emissions, and so on. At the end, the designers are given a score that is purely points based. This tells them that they achieved a certain level of sustainability, but it does not have the analytical capabilities to determine the project's true value in risk-adjusted dollar values. This is where AutoCASE™ comes in. By answering a few additional questions in AutoCASE™, planners, designers, and project owners can understand the Sustainable Net Present Value (SNPV) of the project. This metric looks at the holistic value of the project, including its impacts on society and the environment, as well as direct costs in the form of upfront and operating costs.

What Envision™ lacks in quantitative analysis, AutoCASE™ can supply, and where AutoCASE™ lacks in qualitative considerations, Envision™ has thoroughly covered. Together, they are a powerful sustainable infrastructure planning package.

How AutoCASE™ links with Envision

AutoCASE™ divides up the value of a project between the five overall credit categories within Envision™: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate. The approach to creating this link was by going through each credit and sub-credit within Envision, and, if possible, creating a link to the relevant costs and benefits within AutoCASE™. As an

example, under "Climate and Risk", CR1.1, which is the credit promoting "Reduced greenhouse gas emissions", has been linked to the Reduced CO_2 Emissions benefit within AutoCASE™. Similarly, CR2.4, "Prepare for short-term hazards", has been linked to the Flood Risk Mitigation benefit within AutoCASE™. This approach has been taken with all of the costs and benefits and credit categories in AutoCASE™ and Envision™, respectively. Some credits in Envision were unable to be mapped to benefits in AutoCASE™. An example of this is LD1.4 (in the Leadership category), "Provide for Stakeholder Involvement". Although this may be an attribute of a project running in AutoCASE™, this answer is qualitative and cannot be easily linked to a benefit quantified in AutoCASE™. As a result, this credit would not be allocated any of the project's value. Conversely, some benefits in AutoCASE™ are applicable to several credits in Envision™. An example of this is the Water Quality Enhancement benefit. This benefit is relevant to a range of credits within the Natural World category of Envision; however, it is also relevant to RA3.1 (in the Resource Allocation category), "Protect fresh water availability". As such, the value of any Water Quality Enhancement is split between the Natural World and Resource Allocation categories. The full mapping of these costs and benefits to the Envision™ credit categories can be found in Appendix III.

Envision's™ breakdown of value – Results for Commercial Site and Silverbell Road

The analysis on the commercial site produced the results shown in Figure 42. As can be seen, the majority of the value was shared between Climate and Quality of Life. This is in line with the results in Figure 36, showing that most of the value of the commercial site project is split between reduced carbon emissions (Climate), reduced air pollution (Climate), and reduced heat mortality (Quality of Life).

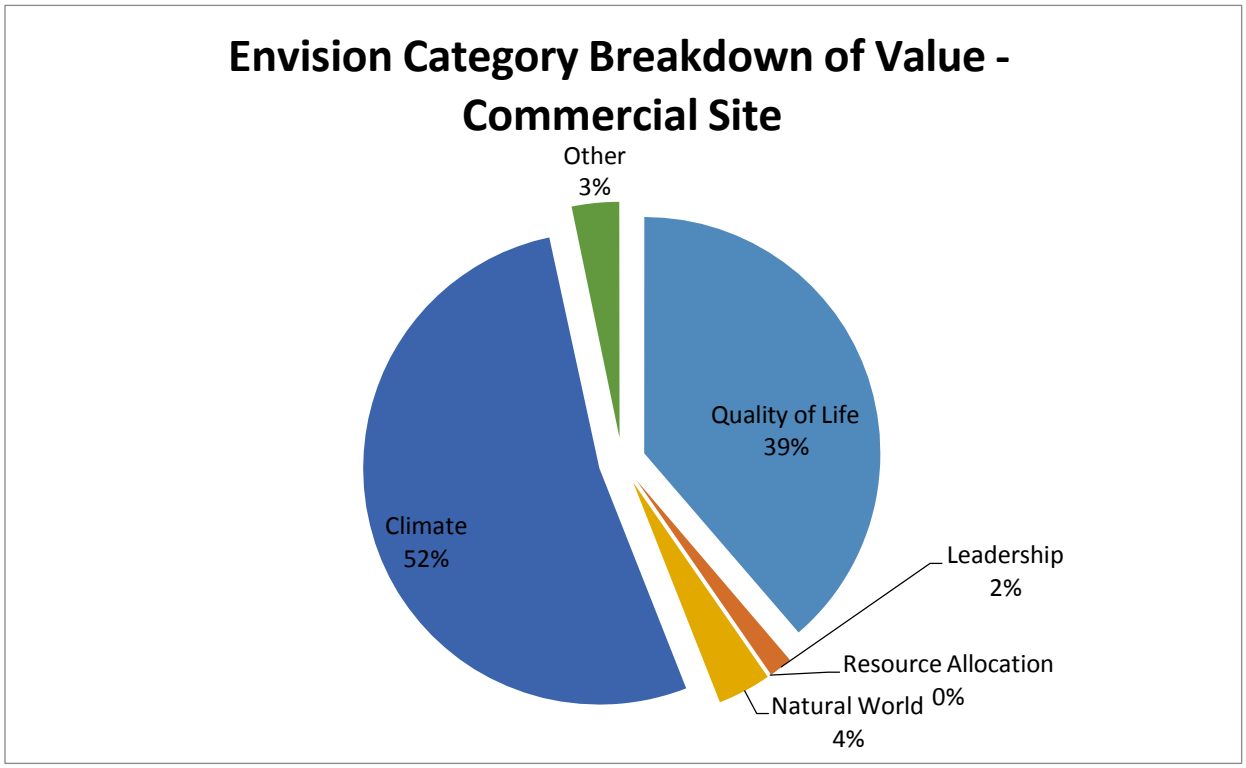


Figure 42 Envision Breakdown of Value - Commercial Site

The analysis on Silverbell Road found that Quality of Life remained the credit category realizing the highest value from the project, while the Climate and Natural World categories consisted of the majority of the remaining Envision value (Figure 43). This is in line with the results in Figure 41, as most of the value is attributed to increased pedestrian safety due to traffic calming (Quality of Life), reduced heat mortality (Quality of Life), reduced social cost of water (Natural World), and lower carbon and air pollution (Climate).

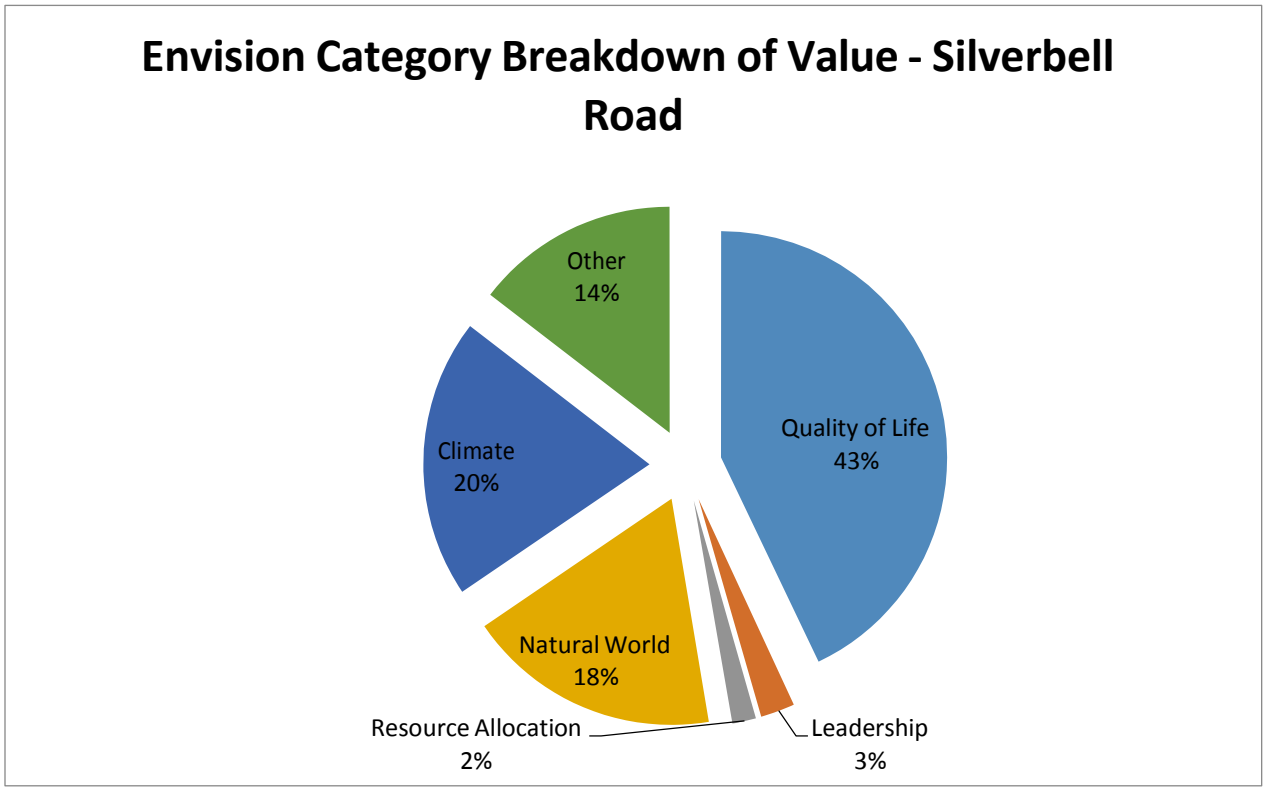


Figure 43 Envision Breakdown of Value - Silverbell Road

Findings and Recommendations

The Tucson region is a leader in advocating for and implementing green infrastructure or low impact development (GI/LID) features in stormwater management. Evaluation of the individual GI/LID features and the added elements at the two sites show that:

- GI/LID features are not equal in terms of their financial and sustainability benefits. Broader consideration of value, beyond capital and operating costs, to include flood risk, safety, heat island mitigation, property value, and environmental benefits allow for an objective comparison.
- Stormwater Harvesting Basins, Xeriscape Swales and Infiltration Trenches have > 50% probability of achieving a Sustainable Net Present Value (SNPV), which indicates the overall societal, environmental and economic benefits will exceed Net Present Value (NPV – i.e., only including direct costs and benefits such as capital expenditures, revenues, etc., and not including other costs and benefits such as air pollution, carbon emissions, water quality benefits, etc.).

- While Pervious Pavement had a negative SNPV, Concrete and Asphalt Paving have highly negative SNPV indicating that Pervious Pavement has a lower overall cost.
- In terms of sustainability metrics, GI/LID features, when combined into designs for a representative commercial site and a roadway re-design, are beneficial.
- Ignoring the multi-benefits if GI/LID features would mean making incorrect decisions. GI/LID features have a payback to governments, the environment, the economy and the community.

Recommendations:

- The City of Tucson, Pima County and PAG (the Tucson region) should continue to measure the full value of its GI/LID initiatives and use this information to make decisions.
- The Tucson region should consider the use of Envision™ to communicate those benefits to outside stakeholders.

Appendix I: Individual GI/LID Practices

Water Harvesting Basins

Table 4 Summary Results - Water Harvesting Basin - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$132*
O&M Costs	*-$7*
Direct Financial NPV	***-$139***
Flood Risk Reduction	*$200*
Property Value Uplift	*$52*
Heat Mortality Risk Reduction	*$518*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***$631***

Bio Retention Basin

Table 5 Summary Results -Bio Retention Basin - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$2,096*
O&M Costs	*-$377*
Direct Financial NPV	***-$2,473***
Flood Risk Reduction	*$169*
Property Value Uplift	*$49*
Heat Mortality Risk Reduction	*$515*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$1,740***

Xeriscape Swale

Table 6 Summary Results - Xeriscape Swale - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$383*
O&M Costs	*-$173*
Direct Financial NPV	***-$556***
Flood Risk Reduction	*$159*
Property Value Uplift	*$51*
Heat Mortality Risk Reduction	*$512*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***$166***

Cistern

Table 7 Summary Results - Cistern - Median Values (50th Percentile)

Net Present Value for a 350CF Cistern	
CapEx Cost	*-$2,685*
O&M Costs	*$0*
Other Benefits (irrigation)	*$188*
Direct Financial NPV	***-$2,497***
Flood Risk Reduction	*$95*
Property Value Uplift	*$0*
Heat Mortality Risk Reduction	*$0*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$2,402***

Infiltration Trench

Table 8 Summary Results - Infiltration Trench - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$701*
O&M Costs	*-$167*
Direct Financial NPV	***-$868***
Flood Risk Reduction	*$200*
Property Value Uplift	*$50*
Heat Mortality Risk Reduction	*$515*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$103***

Detention Basins (or Extended Detention Basins)

Table 9 Summary Results - Detention Basin - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$1,215*
O&M Costs	*-$194*
Direct Financial NPV	***-$1,409***
Flood Risk Reduction	*$234*
Property Value Uplift	*$50*
Heat Mortality Risk Reduction	*$514*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$611***

Pervious Pavers

Table 10 Summary Results - Porous Pavers - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft of LID	
CapEx Cost	*-$2,496*
O&M Costs	*-$834*
Direct Financial NPV	***-$3,330***
Flood Risk Reduction	*$168*
Property Value Uplift	*$51*
Heat Mortality Risk Reduction	*$513*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$2,598***

Curb Extensions

New and retrofit chicanes, medians, traffic circles and road diets with inlets to gather street water (see Appendix II for full calculations).

Table 11 Summary Results – Curb Extensions - Median Values (50th Percentile)

Traffic Calming - Roundabouts and Curb Extension	*$117,737*

Pavement

Table 12 Summary Results - Pavement - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft	
CapEx Cost	*-$10,817*
O&M Costs	*$0*
Direct Financial NPV	***-$10,817***
Flood Risk Reduction	*-$424*
Property Value Uplift	*$0*
Heat Mortality Risk Reduction	*$0*
Reduced CO_2 Emissions	*$0*
Reduced Air Pollution	*$0*
S-NPV	***-$11,241***

Concrete

Table 13 Summary Results – Concrete - Median Values (50th Percentile)

Net Present Value for 1,000 Sq. Ft	
CapEx Cost	*-$14,106*
O&M Costs	*$0*
Direct Financial NPV	***-$14,106***
Flood Risk Reduction	*-$379*
Property Value Uplift	*$0*
Heat Mortality Risk Reduction	*$0*
Reduced CO_2 Emissions	*-$1,346*
Reduced Air Pollution	*$0*
S-NPV	***-$15,831***
Assuming 1 foot deep = 1,000 cubic feet	
1 cubic foot = 150 lbs.	

Appendix II: Traffic Calming Assumptions and Calculations

Table 14 Traffic Calming Assumptions and Calculations

Crashes/injuries per 100 million Vehicle Miles Travelled (VMTs)	Pedestrian Crashes/ Injuries per 100 million VMTs	Pedal cycle Crashes/Injuries per 100 million VMTs	% of Category	Pedestrian Crashes/Injuries per 100 million VMTs	Pedal cycle Crashes/ Injuries per 100 million VMTs	Economic Cost	Product	Cost per VMT
Property damage only	*27.7*	*62.9*	*100%*	*27.7*	*62.9*	*$9,282*	*$841,423*	*$0.008*
Possible injuries	*226.0*	*293.0*	*55.52%*	*125.5*	*162.7*	*$13,056*	*$3,762,301*	*$0.038*
Non-incapacitating injuries			*35.52%*	*80.3*	*104.1*	*$23,154*	*$4,268,673*	*$0.043*
Incapacitating injuries			*8.96%*	*20.3*	*26.3*	*$71,910*	*$3,344,192*	*$0.033*
Fatalities	*21.9*	*3.0*	*100%*	*21.9*	*3.0*	*$1,448,400*	*$36,028,648*	*$0.360*

Source: http://www.azdot.gov/docs/default-source/mvd-services/12crashfacts.pdf?sfvrsn=2

TOTAL Cost per VMT: *$ 0.48*

Assumptions			Total Distance with Mitigated Crash Risks (m)	Total Distance with Mitigated Crash Risks (miles)	Cars per Day*	Vehicle Miles Travelled VMTs in Risk-Mitigation Area/Day	Daily Value of Risk	Risk Mitigated (%) **	Risk Mitigated ($)
Roundabout	*5*	*m*	*10*	*0.00625*	*10000*	*62.5*	*$30.15*	*75%*	*$22.61*
Curb Extension	*5*	*m*	*5*	*0.003125*	*500*	*1.5625*	*$0.75*	*25%*	*$0.19*

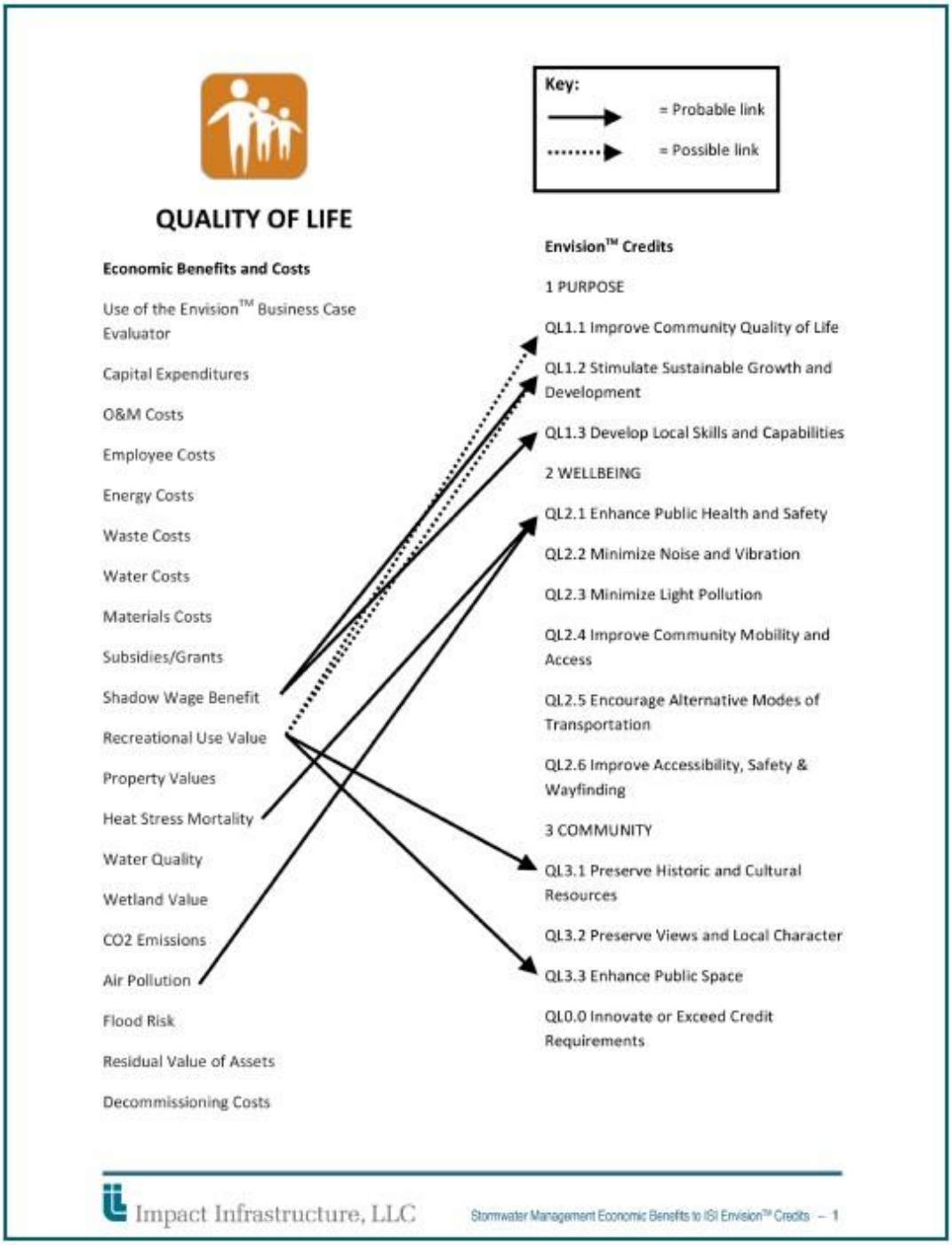
Total Daily Risk Mitigated	*$22.80*
Total Annual Risk Mitigated	***$8,323.25***
@ 6.5% real discount rate, NPV (40 yrs.):	**$117,736.69**

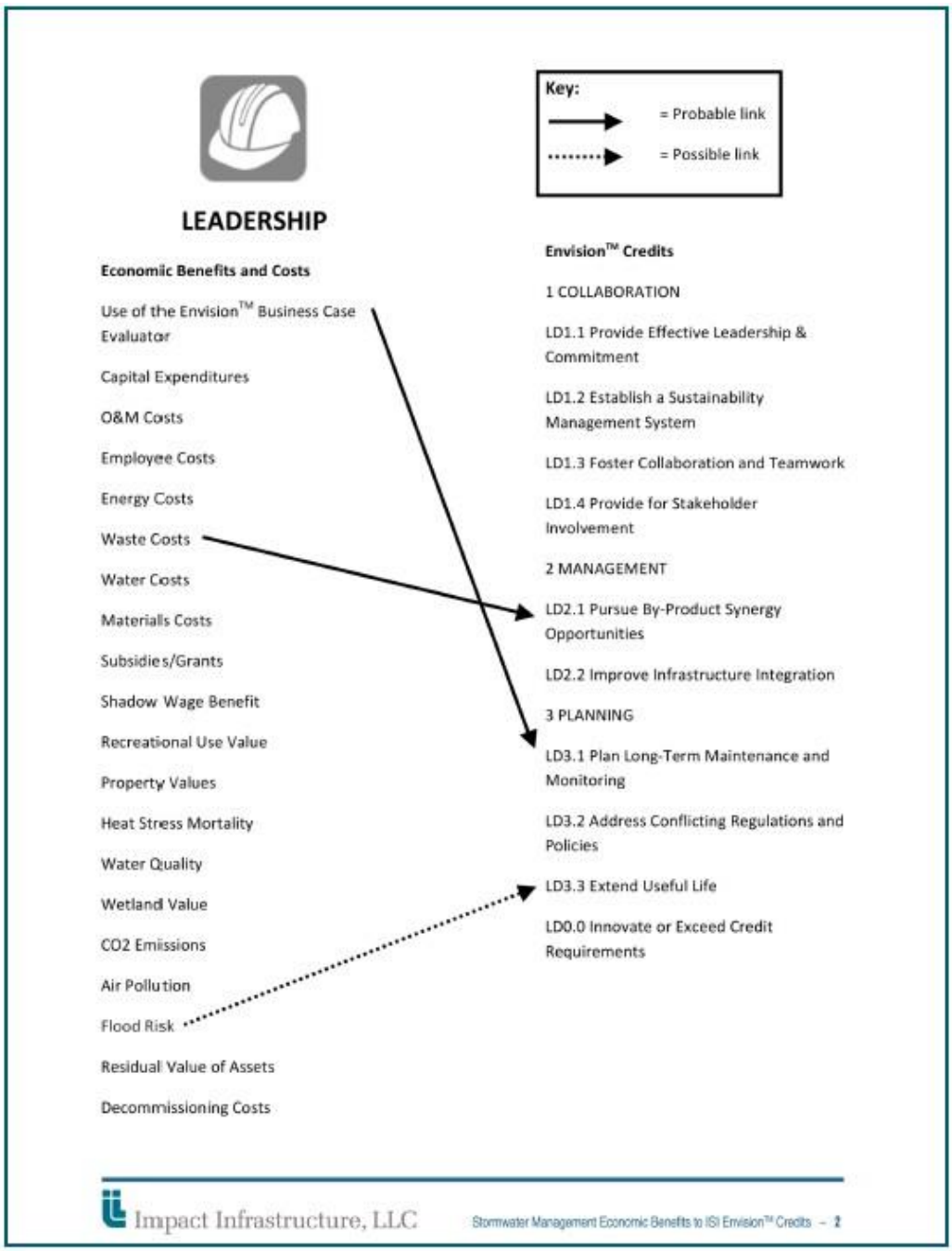
*Two-way daily traffic count- Source: http://www.pagnet.org/documents/rdc/gis/maptrafficcount2012.pdf

**Source: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447993/pdf/0931456.pdf

Appendix III: Envision™ to AutoCASE™ Mapping

AutoCASE™ costs and benefits listed on the left were mapped to Envision™ credits, listed on the right.

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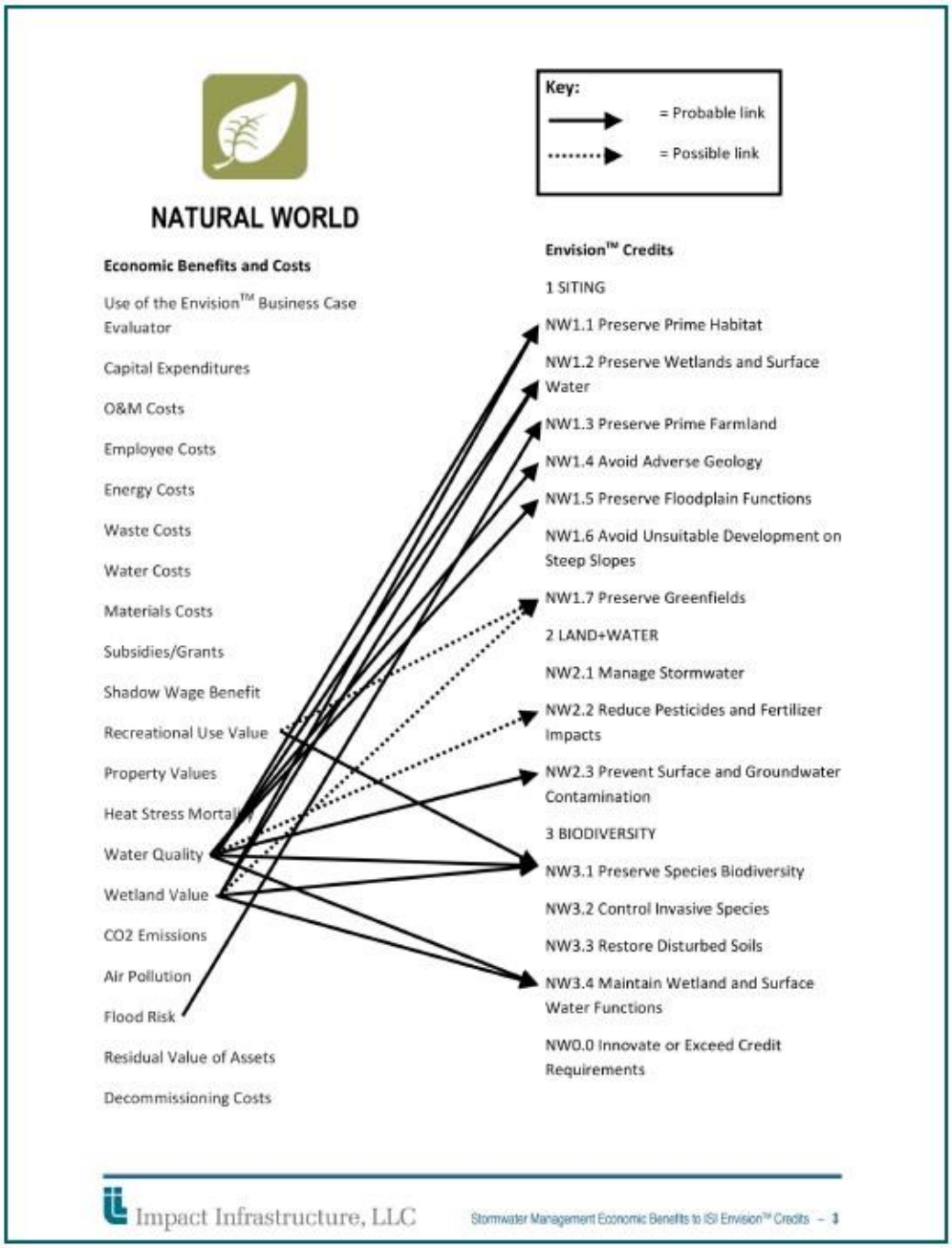
LEADERSHIP
Economic Benefits and Costs
Use of the Envision™ Business Case Evaluator
Capital Expenditures
O&M Costs
Employee Costs
Energy Costs
Waste Costs
Water Costs
Materials Costs
Subsidies/Grants
Shadow Wage Benefit
Recreational Use Value
Property Values
Heat Stress Mortality
Water Quality
Wetland Value
CO2 Emissions
Air Pollution
Flood Risk
Residual Value of Assets
Decommissioning Costs
Envision™ Credits
1 COLLABORATION
LD1.1 Provide Effective Leadership & Commitment
LD1.2 Establish a Sustainability Management System
LD1.3 Foster Collaboration and Teamwork
LD1.4 Provide for Stakeholder Involvement
2 MANAGEMENT
LD2.1 Pursue By-Product Synergy Opportunities
LD2.2 Improve Infrastructure Integration
3 PLANNING
LD3.1 Plan Long-Term Maintenance and Monitoring
LD3.2 Address Conflicting Regulations and Policies
LD3.3 Extend Useful Life
LD0.0 Innovate or Exceed Credit Requirements
Impact Infrastructure, LLC
Stormwater Management Economic Benefits to ISI Envision™ Credits – 2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NATURAL WORLD
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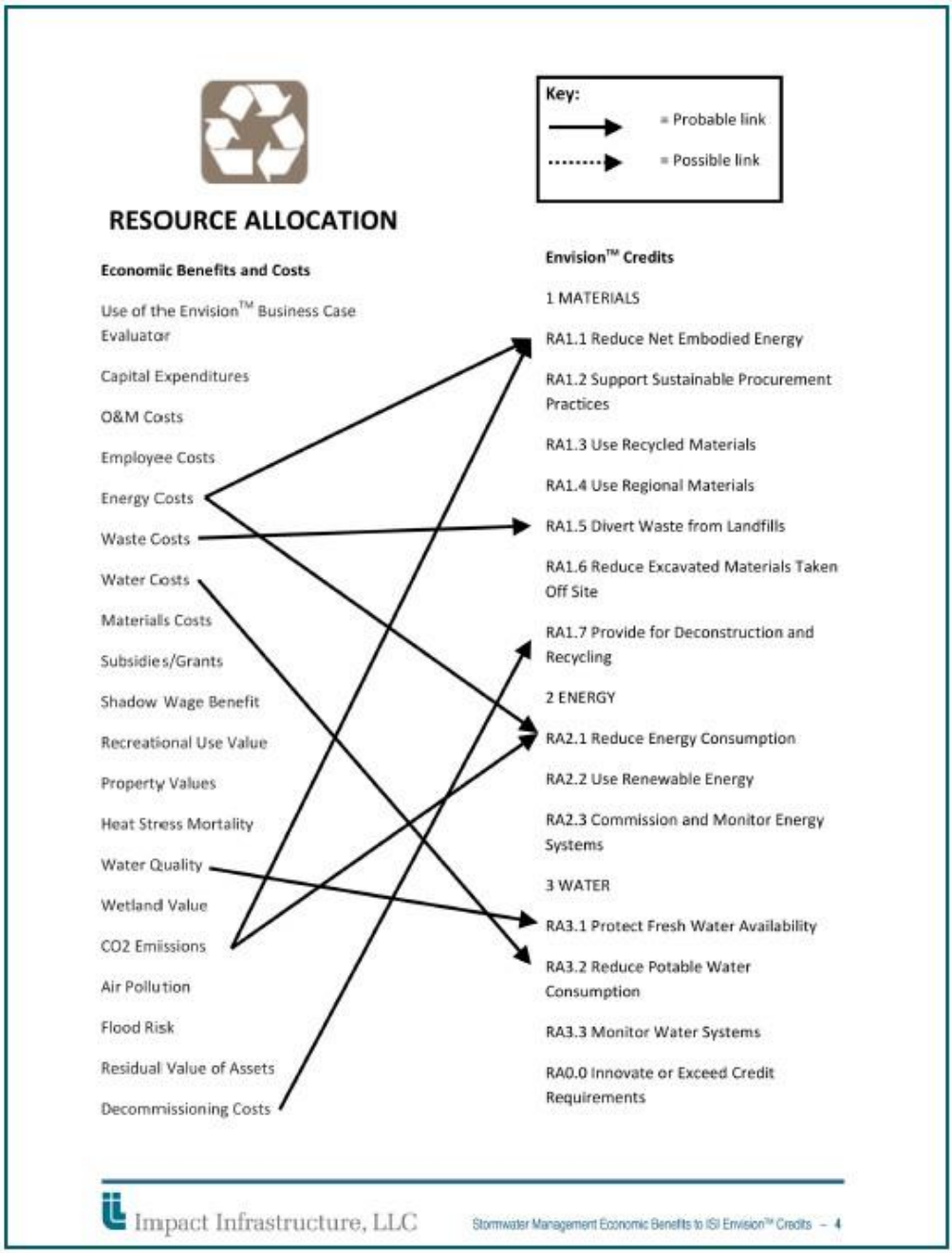
Use of the Envision™ Business Case Evaluator
Capital Expenditures
O&M Costs
Employee Costs
Energy Costs
Waste Costs
Water Costs
Materials Costs
Subsidies/Grants
Shadow Wage Benefit
Recreational Use Value
Property Values
Heat Stress Mortal
Water Quality
Wetland Value
CO2 Emissions
Air Pollution
Flood Risk
Residual Value of Assets
Decommissioning Costs
Envision™ Credits
1 SITING
NW1.1 Preserve Prime Habitat
NW1.2 Preserve Wetlands and Surface Water
NW1.3 Preserve Prime Farmland
NW1.4 Avoid Adverse Geology
NW1.5 Preserve Floodplain Functions
NW1.6 Avoid Unsuitable Development on Steep Slopes
NW1.7 Preserve Greenfields
2 LAND+WATER
NW2.1 Manage Stormwater
NW2.2 Reduce Pesticides and Fertilizer Impacts
NW2.3 Prevent Surface and Groundwater Contamination
3 BIODIVERSITY
NW3.1 Preserve Species Biodiversity
NW3.2 Control Invasive Species
NW3.3 Restore Disturbed Soils
NW3.4 Maintain Wetland and Surface Water Functions
NW0.0 Innovate or Exceed Credit Requirements
Impact Infrastructure, LLC
Stormwater Management Economic Benefits to ISI Envision™ Credits – 3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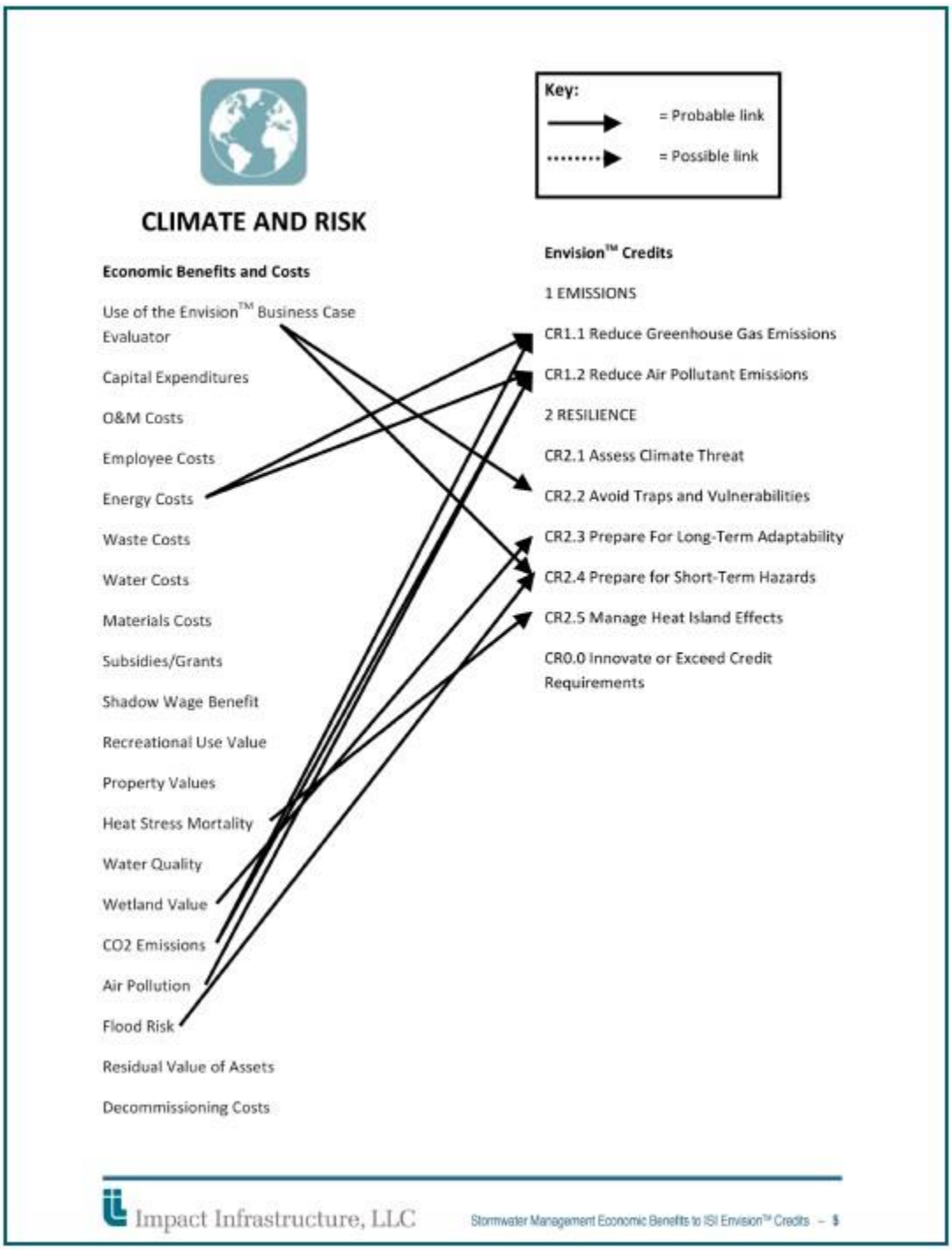
Economic Benefits and Costs
Use of the Envision™ Business Case Evaluator
Capital Expenditures
O&M Costs
Employee Costs
Energy Costs
Waste Costs
Water Costs
Materials Costs
Subsidies/Grants
Shadow Wage Benefit
Recreational Use Value
Property Values
Heat Stress Mortality
Water Quality
Wetland Value
CO2 Emissions
Air Pollution
Flood Risk
Residual Value of Assets
Decommissioning Costs
Envision™ Credits
1 MATERIALS
RA1.1 Reduce Net Embodied Energy
RA1.2 Support Sustainable Procurement Practices
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste from Landfills
RA1.6 Reduce Excavated Materials Taken Off Site
RA1.7 Provide for Deconstruction and Recycling
2 ENERGY
RA2.1 Reduce Energy Consumption
RA2.2 Use Renewable Energy
RA2.3 Commission and Monitor Energy Systems
3 WATER
RA3.1 Protect Fresh Water Availability
RA3.2 Reduce Potable Water Consumption
RA3.3 Monitor Water Systems
RA0.0 Innovate or Exceed Credit Requirements
Impact Infrastructure, LLC
Stormwater Management Economic Benefits to ISI Envision™ Credits – 4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CLIMATE AND RISK
Economic Benefits and Costs
Use of the Envision™ Business Case Evaluator
Capital Expenditures
O&M Costs
Employee Costs
Energy Costs
Waste Costs
Water Costs
Materials Costs
Subsidies/Grants
Shadow Wage Benefit
Recreational Use Value
Property Values
Heat Stress Mortality
Water Quality
Wetland Value
CO2 Emissions
Air Pollution
Flood Risk
Residual Value of Assets
Decommissioning Costs
Envision™ Credits
1 EMISSIONS
CR1.1 Reduce Greenhouse Gas Emissions
CR1.2 Reduce Air Pollutant Emissions
2 RESILIENCE
CR2.1 Assess Climate Threat
CR2.2 Avoid Traps and Vulnerabilities
CR2.3 Prepare For Long-Term Adaptability
CR2.4 Prepare for Short-Term Hazards
CR2.5 Manage Heat Island Effects
CR0.0 Innovate or Exceed Credit Requirements
Impact Infrastructure, LLC
Stormwater Management Economic Benefits to ISI Envision™ Credits – 5

Appendix IV: AutoCASE™ Methodology

To make a sensible comparison between green infrastructure, or low impact development (LID), and traditional grey infrastructure, or pipe and water processing facilities, one needs a common metric. Engineering methods can often quantify the differences in gallons of water or kWh of electricity saved; economic methods help to put a price on these quantities so that a monetary equivalent value (price x quantity) can be used in the decision-making.

Engineers have at their disposal tools to calculate water and energy saved from sustainable design. Valuation in terms of the social costs (the damage or benefit to human health, buildings, crops, animals, and the environment) of the improvements is the missing link to value the benefits of sustainable projects.

Because the economics is often similar across projects, AutoCASE™ has codified the economics and made it available to designers, engineers, and their project sponsors, public funding sources and the private investment community so that they can understand the full economic value of their projects. In this way, engineers have access to tools that help them design the project to yield optimal outcomes.

Envision™ attempts to help the design process so that the project is done right from financial and sustainability perspectives. It also helps to make sure that the right project is done.
To compare the value and make decisions regarding the right project, one also needs to understand the risks associated with the choices. The methodology combines economic cost-benefit analyses with risk analysis so that risk adjusted values are calculated, allowing informed decision making.

Sometimes the services green infrastructure provides have no price that can be directly observed as the outcome of market transactions. Economics uses several methods to value these non-market externalities. The table below shows how the various benefits from wetlands creation can be valued.

Table 1. Examples of Valuation Techniques for Wetland Services

Benefit Type	**Valuation Method**
Habitat for commercial species	Market prices for commercial species and productivity per acre
Habitat for wildlife and visual/cultural benefits	Prices paid by government agencies to protect wetlands
Wetland conservation	Opportunity costs; i.e., benefits of wetland conversion
Amenity or aesthetic value	Hedonic property price model
Recreation value	Travel cost method; Participation model using

Benefit Type	Valuation Method
	unit-day values; Contingent valuation
Water purification	Reduced treatment costs by alternative methods
Non-use and option value	Contingent valuation

Table Source: Adapted from David W. Pearce and R. Kerry Turner. 1990. Economics of Natural Resources and the Environment. Baltimore: Johns Hopkins University Press. pp. 226-235.

While methodologies for valuation may not vary for similar projects, often the values themselves will vary by region of the country or by income or demographics of those affected. By using meta-analyses[16] that synthesize many studies, we hope to include the most important variations in these values so that if, for example, the social cost of water is high in the South West due to scarcity, this can be captured in the analysis.

As shown in the table above, **non-market valuation methods** are used to value things that people may never use:

- **Revealed preference methods**: Infer the value of a non-market good or service using other market transactions. For example, the price of a house may be used to determine the value of transit services. Hedonic pricing methods start from the premise that the price of a good is a function of the service's characteristics. A regression model then determines the contribution of each characteristic to the market price.

- **Stated preference methods**: Contingent valuation studies survey people on how much they are willing to pay to get access to a good or service or how much they would be willing to accept as compensation for a given harm or lack of access.

- **Market-based methods are** used to measure value from the perspective of what you would have spent had you taken another approach:

- **Avoided cost analysis**: This methodology looks at "the marginal cost of providing the equivalent service in **another way. For exa**mple, rainfall retention and infiltration can offset a water utility's cost to capture, transport, treat and return each additional gallon of runoff."[17] Rather than the avoided cost of not building facilities, it may be more appropriate to consider the converse, what the cost would be of damages be if the project does not go ahead.

Risk Analysis Approach

For each set of inputs, including most values used in the methodologies themselves, high, medium and low values are collected to reflect the range of uncertainty around the inputs. Default values for coefficients or assumptions in the methodologies are taken from current literature. Using the three points, distributions can be generated around each input (either the 95% confidence interval for a normal distribution, a beta distribution, or a triangular distribution. If the distribution type is not specified, it defaults to a beta distribution). When the Monte Carlo simulation is running, a random value from each of the inputs' distributions is

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[16] "a meta-analysis refers to methods focused on contrasting and combining results from different studies, in the hope of identifying patterns among study results, sources of disagreement among those results, or other interesting relationships that may come to light in the context of multiple studies." Meta-analysis from Wikipedia, the free encyclopedia - http://en.wikipedia.org/wiki/Meta-analysis

[17] The Value of Green Infrastructure - A Guide to Recognizing Its Economic, Environmental and Social Benefits, Center for Neighborhood Technology 2010, p. 14, downloaded from: http://www.cnt.org/repository/gi-values-guide.pdf January 22nd 2013. (referred to as CNT below)

selected and plugged into the model. A result is calculated and saved, and the process repeats itself. AutoCASE™ runs 1000 iterations to produce a probability distribution of potential outcomes. These probability distributions are portrayed as the "S curves" shown throughout this report.

The AutoCASE™ business case evaluator aims to, as much as possible:

- Be **a comprehensively exhaustive list of economic benefits (where data exists)**. Avoiding double counting and correctly defining the scope of the project and the benefits, costs and risks to be counted is crucial to ensuring that the calculation is credible.

- To avoid error in the ultimate estimation of the total economic value associated with a given project, it will be important to avoid the potential error associated with counting a benefit/credit associated with a given project more than once. We have tried to avoid the temptation to create a 'grab bag' of all possible benefits/credits associated with these projects. We have focused attention on those benefits/credits that are most readily monetized and where data is available. Economists often agonize over double counting and there are some rules of thumb that have emerged in cost benefit studies. For transit, for example, hedonic house price models that attempt to capture the benefit of access to transit that is embedded in houses prices might already be accounted for in travel time savings that are also counted as a benefit. In this case 50% of the property price increase is counted as incremental to the other benefits. The 50% rule has also been used in the Philadelphia stormwater management project evaluation.

- There is a need to provide a clear definition of the boundary for measuring the 'project impact' in order to consistently measure benefit/credits across categories. For instance, is the boundary of impact spatial or non-spatial? A clear understanding/method for estimating the project boundary will be needed. This will directly impact the inclusion/exclusion of project benefits/credits.

- Measure the **risk associated with the business case costs and benefits**.

- There are often many ways to measure the same benefit. Often, meta-analyses of benefits use studies that mix several techniques. In theory, willingness to pay (WTP) and willingness to accept (WTA) should give the same results but in experiments they have shown that measures of WTA greatly exceed measures of WTP. As meta-analyses have done, we average results over several methodologies (but also capturing the range that is produced from these methodologies too). For a particular benefit, one methodology for measurement and monetization may dominate and in another a range of methodologies may be used. The objective is to use the state of the art in

measurement of these externalities. In this regard transparency trumps consistency of one particular method.

- Be a reference document that **documents the sustainable return of the infrastructure project**. The analysis is done relative to a reference case, which is equivalent to the status quo or a "do nothing" scenario. Often, refurbishment or increased operations and maintenance costs of an existing facility are required if a project does not go ahead. These expenditures should be included in the reference case. The evaluator also has the capacity for individual projects to be compared against each other, so that if a "do nothing" scenario is not a viable option, then results valuing different project options against each other may be obtained.

Each cost or benefit that is quantified in the AutoCASE™ business case evaluator has been included because it:

- Is significant on a list of costs and benefits that aims to be comprehensively exhaustive when describing the impacts of GI/LID projects
- Has substantial literature surrounding its quantification so that reliable and consistent values can be obtained, even as the model is applied across different geographical regions.

A full list of the costs and benefits that are evaluated in the AutoCASE™ app are shown in the table below:

Cost or Benefit Type	Valuation Method
Revenues	Direct revenue impacts
Capital Expenditures	Direct capital expenditure costs
Operations and Maintenance Costs (O&M)	Direct projected O&M costs
Employee Costs	Direct employee costs
Energy Costs	Direct energy costs
Waste Costs	Direct waste disposal costs
Water Costs	Direct water costs
Materials Costs	Direct materials costs
Subsidies	One-time and recurring subsidies obtained
Shadow Wage Benefit	Shadow wage conversion factor incorporating projected construction wages and wages of employees during operation, local unemployment rate, and local tax rates
Recreational Use Value	Willingness-to-pay per use x new user days per year
Property Value Benefit	Increase in local green acreage, implied

Cost or Benefit Type	Valuation Method
	property uplift percentage, average value of local homes, and number of local homes affected
Reduced Heat Stress Mortality Benefit	Increased green acreage, reduced local temperatures during excessive heat events, implied reduction in local mortality rates, leading to total lives saved and total value of lives saved
Water Quality and Habitat Enhancement	Meta-analytical function used to estimate willingness-to-pay for improvements in local bodies of water
Wetland Enhancement	Meta-analytical function used to estimate value per acre of wetlands created or restored, incorporating wetland type and functions into the estimation
CO_2 Emissions	Includes a reduction in carbon emissions due to decreased energy usage, as well as the effects of carbon sequestration as a result of increased planted vegetation
Air Pollution	Includes a reduction in air pollutants due to decreased energy usage, as well as the effects of air pollutant sequestration as a result of increased planted vegetation

Appendix V: Envision™ Ration System in the Tucson Region

AutoCASE™, Business Case Evaluator, and Envision™

The Institute for Sustainable Infrastructure's (ISI's) Envision™ Rating System shows the benefits of green infrastructure in holistic terms through a standard indicating how new horizontal infrastructure should be planned, designed, and built to incorporate sustainable and resilient designs.

The Envision™ system was developed in partnership between the ISI and the Harvard University Graduate school of Design. The ISI is a non-profit association of the American Society of Civil Engineers (ASCE), the American Council of Engineering Companies (ACEC) and the American Public Works Association (APWA). Envision™ is similar in some ways to LEED™ for buildings, although it is designed to consider the entire lifecycle of projects at a systems level within its' points-based ratings system. As a relatively new system, Envision™ plans to become the industry standard for sustainable rating systems in the infrastructure space. Simultaneously, leaders in the ISI have recognized the need for business case analysis as a partnering tool with Envision's™ points-based system which is now being more substantively addressed through its' Business Case Evaluator (BCE) and AutoCASE™.

The Envision™ system evaluates projects in 5 categories:

1. Quality of life
2. Leadership
3. Resources Allocation
4. Natural World
5. Climate and Risk

The levels of achievement in each category/subcategory range from Improved (i.e. slightly above industry standard) through Superior to Restorative (i.e. net positive impact). This recognizes that minimizing the negative impact of a project is beneficial, but reversing a trend to have the project make positive impacts is even better. Projects that receive certification through Envision™ can achieve different levels based on performance but perhaps more significantly Envision™ is intended as a tool to support planning and design processes by presenting:

- A transparent framework to compare options and make defensible choices;
- Guidance on best practices that are currently being used by owners and designers;
- Envision™ certification that can provide validation of claims of 'green' performance and associated reputational benefits; and
- An opportunity for owners to display innovation and leadership that will gain national recognition.

In order to accomplish these objectives Envision™ launched its points-based framework in 2012 but also needed to develop a companion economic tool that can be used to quantitatively

assess the comparative costs and benefits of different design alternatives, for all dimensions of a project (i.e. economic, social, environmental). This is the role served by the closely related BCE and AutoCASE™.

Implementing the Envision Rating System in The Tucson Region

The work to develop the GI/LID Guidance Manual has occurred in the broader context of sustainability commitments and planning for Pima county and the City of Tucson. Tucson, Pima County and PAG have a well-established history of advancing sustainability values within local and regional policies and planning. This is nicely summarized by a statement from the Climate Change Committee of the City of Tucson contained within Plan Tucson (2013), the City's most recent general and sustainability plan: "A modern sustainability vision for Tucson is to be the world's leader and source of innovation for more efficient, more prosperous, and healthier desert living." Following voter ratification of Plan Tucson, the Office of Integrated Planning (OIP) was formed in November 2013 which updated and integrated the previous "Framework for Advancing Sustainability (2008)" throughout.

The Sonoran Desert Conservation Plan established sustainability principles that guide land use policies and infrastructure investments to direct sustainable growth and development. The Plan also provides infrastructure sustainability strategies and measurable implementation objectives. The Sustainable Action Plan for County Operations (2008) was intended to be "an adaptive plan that will be responsive to new ideas, technologies, partnerships, and shifts in available resources, with the goal of every new adaptation taking us down an even better and more sustainable path." Among its' features the plan includes goals, principles and an action plan for a number of infrastructure aspects including Water Conservation and Management, Waste Reduction, and Renewable Energy.
In 2010, both the City of Tucson Mayor and Council and the Pima County Board of Supervisors adopted the Phase 2 Water Study Report pursuant to the City/County Water and Wastewater Infrastructure, Supply and Planning Study (2008) which nicely encapsulated the region's perspective on sustainable infrastructure: "To achieve sustainability goals, changes to the existing infrastructure must begin by improving the efficiency and flexibility of the existing built environment, including roads, parks, public services water, wastewater and stormwater systems. In addition to considering the location and form of growth, integrated planning also needs to consider the efficient allocation, distribution and use of all available water resources including stormwater, effluent, reclaimed and potable water."

With these policies and commitments in mind, it is appropriate to consider the possible use of the Envision™ framework and rating system, described earlier in this document, to assess Local GI/LID practices. Beyond this, deploying Envision™ in the context of stormwater GI/LID could serve as a pioneering pilot sector from which to evaluate its' applicability across the spectrum of Tucson and Pima County infrastructure systems.

Without repeating the earlier general description of Envision™, there are a number of prospective uses and benefits to incorporating the framework into both stormwater GI/LID

evaluations and planning. These elements are equally relevant to all civil infrastructure and perhaps most important to applying a consistent and transparent methodology to planning, design, options analysis, stakeholder engagement and defensible decision-making across an integrated infrastructure program.

Overall, Envision™ was developed to assist planners, engineers and ultimately project proponents, owners and stakeholders to understand and evaluate design options and make defensible choices through application of a simple, transparent and cost effective methodology. With this overarching intention, Envision™ intends to support an evolution from conventional design and efficiency of discreet projects to projects that meet rigorous performance expectations in accord with triple bottom line (economic, environmental and socio-cultural) objectives:

- durability;
- lifecycle efficiency and costing;
- whole system design;
- adaptive and resilient infrastructure components and integrated systems;
- close consideration of community needs, stakeholder engagement and broad partnerships;
- sustainable return on investment;
- affordability of operations and maintenance; and
- optimization of short and long range community benefits

The Envision™ framework accomplishes these objectives through reference to 55 assessment objectives (plus innovation objectives) across five overarching Credits (themes) – Quality of Life (Purpose, Community and Wellbeing), Leadership (Collaboration, Management and Planning), Resource Allocation (Materials, Energy and Water), Natural World (Siting, Land & Water and Biodiversity), and Climate (Emissions and Resilience). Each Credit is documented to include its intent, various levels of potential achievement, explanations on how to advance to higher achievement levels, criteria and documentation, sources and interrelationship with related Credits.

Envision™ is transparent to owners, design teams, community groups, environmentalists, constructors, regulators and policy makers. As a result it offers a mechanism for all of these stakeholders to discuss community priorities in civil infrastructure projects and the two pivotal related questions - “Are we doing the right project?" and “Are we doing the project right?" Use of Envision™, in either its full format assisted by a trained Envision™ Sustainability Professional (ENVSP), or by undertaking a preliminary assessment through application of the abbreviated Envision™ Checklist format provides the basis to:

- identify and understand options and tradeoffs
- engage stakeholders transparently - build public confidence

- consider sustainable implications in an organized fashion
- design to the Envision™ Framework

By incorporating the Envision™ Business Case Evaluator and/or the AutoCASE™ web-based analytic engine into the analysis it is now easily possible to meld the sustainability performance indicators of Envision™ (qualitative or quantitative) with sophisticated and flexible quantitative risk-based cost benefit analyses. Such analyses generate logical, defensible performance options, and ultimately a compelling case for optimization of sustainable infrastructure systems. Finally, the Envision™ framework, when applied either during planning or subsequently during construction or operations, presents a verifiable case for sustainable design and performance evaluation that is eligible for review by ISI and if deemed acceptable, for Envision™ Certification and Award (in four recognized levels). Such award would validate and recognize Tucson and/or Pima County for its leadership in sustainability and justify 'green' claims and commitments, with all attendant reputational benefits.

In the context of the current project, the AutoCASE™ business case analysis was applied to the GI/LID case examples. Since AutoCASE™ is mapped and synchronized to the Envision™ framework it has been easily possible to chart and produce risk-adjusted, dollar-based metrics for these infrastructure projects based on their costs, benefits, and sustainable design features. Although the scope of the project has not encompassed a formal Envision™ evaluation, the data and tools are now substantially in place to do so for one or both of the two beta test sites. Perhaps more importantly, the experience and foundation is now in place to apply Envision™ and AutoCASE™ as integrated tools on other and future Tucson or Pima County stormwater initiatives. It should be pointed out that Envision™ includes a specific Credit category (NW2.1) on Stormwater Management that is focused on LID measures (for which the GI/LID Manual will be an exceptional resource and source of validation and documentation). But greater value can be realized by application of the full suite of Envision™ Credits that are pertinent to the planning, design and sustainable performance of this and other infrastructure categories.

As stated earlier, Envision™ and the accompanying business case analysis takes a broad perspective that is relevant to all civil infrastructure both individually and as a set of interrelated systems. They look at the value to the community, government, and the environment providing the ammunition to make the case that these investments pay back in more than cash terms and the benefits have value to stakeholders and the community at large. In this way Envision™ is designed to do more than simply rate and rank projects in the built environment. It is designed as a template for planning, designing and constructing projects that contribute to the reduction of our environmental footprint while not diminishing our overall quality of life. At the same time, it helps engineers and other practitioners take into account the changes in operating conditions in ways that ensure the project will perform as specified over the entire design life. As such, Envision™ helps to create a new breed of sustainability public works staff and engineer/designers, people who have good knowledge of what it takes to design a project that truly contributes to sustainability and the ability to present these projects to decision makers and citizenry in logical, defensible fashion.

That these analyses can be integrated into well-established planning and procurement methods and accomplished at modest cost is rapidly contributing to the adoption of Envision™ across North America including jurisdictions such as New York City, Dallas, Milwaukee, Los Angeles County and Long Beach. Tucson and Pima County have taken this another step forward, having positioned themselves as pioneers in the application of AutoCASE™ as the further significant component of these evaluative processes. Therefore they are in a particularly advantageous position to establish clear leadership in the emergence of sensible sustainable infrastructure renewal that integrates sustainable and business case performance. A more complete discussion of the potential for this application with regard to stormwater GI/LID and/or infrastructure systems generally can be easily arranged.

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Appendix VII: Heat Island Benefit Calculation

The following slides, taken from a presentation given by John Wise of Stantec to the 9th Annual Urban Heat Island Workshop on May 8th 2014. The full presentation is available from http://impactinfrastructurellc.com/blog/?p=663.

Benefit Calculation - Example

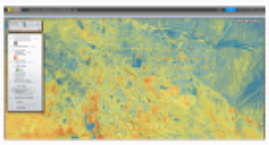
URBAN HEAT ISLAND AND MORTALITY

City of Tucson UHI Workshop - GI Benefits 8

Urban Heat Island

City of Tucson UHI Workshop - GI Benefits 9

Increased Vegetation and Reduced Mortality



- Episodes of extremely hot (or cold) temperatures are associated with increased mortality.
- The authors[1] found a strong association of the temperature-mortality *and a* relation with latitude *for East Coast Cities*.
- The model developed in this analysis is used for projecting the change in mortality as a result of reducing the heat island effect.
- We determine the percentage increase in vegetation from the GI features.
- Then we calculate the overall reduction in temperature as a result of the project based on percent increase is vegetated area.
- General association used: a **10% increase in vegetation reduces temperatures in a region by 0.39 to 0.70 ^{0}F.**[2,3]

[1] "Temperature and Mortality in 11 Cities of the Eastern United States", Curriero et al., Am J Epidemiol Vol. 155, No. 1, 2002
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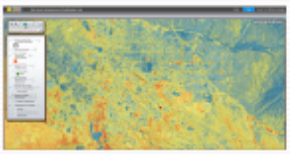
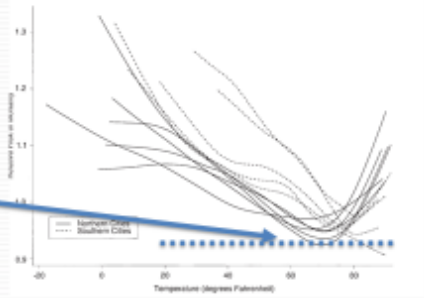
Increased Vegetation and Reduced Mortality



- We calculate the reduction in the average annual mortality rate based on local Tucson weather, the local mortality rate, and the local temperature threshold at which the impacts of heat on mortality can be detected (called the Minimum Mortality Temperature, or MMT)
- We use the change in days over MMT and the change in the temperature for days over the MMT to calculate the change in average annual mortality rate.
- We calculate annual lives saved from the project.



- Finally, we use the Value of Statistical Life to quantify the benefit of reduced heat mortality rates in dollar value.

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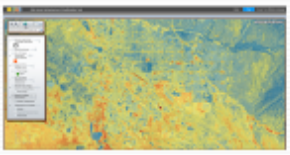
Value of a Statistical Life

- The VSL is the value that an individual places on a marginal change in their likelihood of death.
- The VSL is very different from the value of an actual life. It is the value placed on changes in the likelihood of death, not the price someone would pay to avoid certain death.
- **Empirical studies published in recent years indicate a VSL of $9.1 million (2012 $).**
  - **Low and high values of $5.2 million and $12.9 million** are also used.

City of Tucson UHI Workshop - GI Benefits 12

Summary – Heat Island Calculations



How Heat Mortality Reduction is Valued:

1. GI related to temperature changes
2. Temperature related to mortality rate changes
3. Valuing the dollar value of the VSL, a dollar value is put on the benefit the GI has in reducing the heat island effect.

- This is one of several benefits associated with GI that we quantify.
  - Example: This is one of the multiple benefits quantified for a water harvesting basin.

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Use of the Value of Statistical Life (VSL) Approach for Valuing Heat Mortality Risk

To the extent possible, Impact Infrastructure (II LLC) has followed EPA guidance for valuation of risk in AutoCASE. The EPA itself has not opined on the appropriateness of valuing the reduced risk associated with lower temperatures that come from using GI/LID. However, recent guidance indicates that Value of a Statistical Life (VSL) is the preferred methodology for valuing similar risk. According to the EPA, VSL is: "..how much people are willing to pay for small reductions in their risks of dying from adverse health conditions that may be caused by environmental pollution."
http://yosemite.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html

In their *Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants* (June 2014 http://www.epa.gov/ttn/ecas/regdata/RIAs/111dproposalRIAfinal0602.pdf), EPA reported the opinion from the Science Advisory Board Environmental Economics Advisory Committee for calculating estimates of the mortality risk benefits of their regulation air pollution health co-benefits of their proposed carbon regulation (i.e. the economic value of reductions in ambient concentrations of air pollution that lower the risk of future adverse health effects by a small amount for a large population). They stated that the VSL approach "..provides the most reasonable single estimate of an individual's willingness to trade off money for reductions in mortality risk. The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people. " (quote from http://www.epa.gov/ttn/ecas/regdata/RIAs/111dproposalRIAfinal0602.pdf with the reference given is to:
http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/0/34D7008FAD7FA8AD8525750400712AEB/$File/White+Paper+(Dec.+2010).pdf).

Impact Infrastructure has presented the valuation of heat mortality risk methodology to the EPA and had follow-up discussions with a couple of economists at the National Center for Environmental Economics in the US Environmental Protection Agency. These economists told II LLC that the method used in the AutoCASE model, while not endorsed, will be listed as a resource on the EPA website for people to evaluate GI/LID features. In our opinion, the EPA uses the same approach as II LLC for valuation of changes in risks that may cause deaths (see below) and they certainly do identify that GI/LID can reduce the risks of deaths (http://www.epa.gov/heatislands/impacts/index.htm, http://www.epa.gov/heatisland/resources/pdf/BasicsCompendium.pdf and http://www.epa.gov/heatisland/about/pdf/EHEguide_final.pdf) .

II LLC has determined that the approach EPA has used to assess acceptable levels of contaminant clean-up solutions for Superfund cannot be easily adapted to heat mortality valuation in AutoCASE. This 'Minimum Acceptable Risk' approach sets performance objectives, so all clean up solutions for a Superfund site meet a combined mortality risk of one death in one million from ingestion, inhalation, dermal contact etc.. This approach would require us to define a minimum or acceptable reduction in heat mortality risk for stormwater infrastructure. In essence the value of this acceptable reduction is a policy decision, and there are currently no

national standards for heat mortality that would allow us to pursue valuation using this approach.

Tucson and Pima could mandate an acceptable risk for heat mortality, which would then eliminate the valuation of how much people are willing to pay for reduced heat mortality from the AutoCASE assessment. However II LLC's intent is to make the decision-making process easier so that trade-offs and subjective weights (e.g. one in a million risk) do not have to be applied to trade off one risk with another. If the region regulated minimum mortality risk reductions the difference in benefits between competing technologies would be zero and they would be evaluated on their costs and other benefit categories. The AutoCASE methodology and data would stay the same but mortality benefit would be zero.

While there may be situations where EPA continues to use this Minimum Acceptable Risk approach, their guidelines for Cost-Benefit Analysis (http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/guidelines.html) and in particular Appendix B on Mortality Risk Valuation Reductions (http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-22.pdf/$file/EE-0568-22.pdf) published in 2010 suggest they have adopted the VSL approach (and expecting to continue to use it although they are looking at refining it to communicate the concept more effectively).

It is important to recognize that VSL is way to recognize a societal rather than an individual benefit. VSL is " the willingness to pay for small risk reductions across large numbers of people, but it has led to confusion because many have interpreted it as referring to the loss of identified lives" (http://www.sra.org/sites/default/files/u32/EPA-SAB_2011-VSL_Review.pdf). Therefore, our study does not place a dollar value on individual lives. Rather, when conducting a benefit-cost analysis of GI/LID practices we use estimates of how much people are willing to pay for small reductions in their risks of dying from adverse health conditions that may be caused by the heat island effect (see for example http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/mortalityriskvaluation.html). It may be more appropriate to replace the "heat island mortality benefit" term with "value of mortality risk" (proposed but not yet adopted by the EPA - "guidance on mortality risk valuation is a multi-step process ...this may take some time to complete") or a term like "value of risk reduction" to better "communicate the notion that value is derived from reducing risks rather than the risks themselves" (http://www.sra.org/sites/default/files/u32/EPA-SAB_2011-VSL_Review.pdf).

A complicating factor is that people may value heat related mortality risk mitigation differently than traffic accident risk, cancer risk or some other risk. Context-specific and aged-related risk is something that, while an area for research, the EPA has not endorsed.

Mortality rates could be included in benefit calculations such as flood risk reduction as well. However, AutoCASE does not currently use mortality rates as a factor in flood risk because the most common and best documented risk from flooding is property damage rather than mortality. The costs associated with flood risk are derived from historical property damage costs (both residential and commercial) due to flood events over a 50 year period, broken down by

state. To be completely thorough, AutoCASE should also be counting mortality rates associated with flood events, as well as impacts on the environment and economic activity. For most costs and benefits, II LLC took the approach of quantifying the most commonly, best documented, and quantified aspect of a cost and benefit. We used mortality rates and the VSL in the heat mortality benefit and traffic calming benefits as the most immediate, documented, and defensible benefit.