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Implementation Work Group Report

Advancing Green Infrastructure and Low Impact Development in Raleigh

May 3, 2016

TETRA TECH

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EXECUTIVE SUMMARY

Raleigh City Council has voiced strong commitment to improving the health of local streams, lakes, and the Neuse River by promoting use of green infrastructure and low impact development (GI/LID) for addressing the main source of pollutants and damaging flows in Raleigh's streams – stormwater runoff from developed land. Council adopted a number of GI/LID policies as part of the City's 2030 Comprehensive Plan and the Raleigh Strategic Plan. However, there are multiple barriers to effective and efficient implementation of GI/LID, many of which reflect practical considerations such as knowledge of GI/LID practices, tools to support and evaluate development designs that incorporate GI/LID practices, and a program that ensures proper operations and maintenance of GI/LID practices once they are constructed. Pursuant to the strategic GI/LID Work Plan that Council endorsed in March 2015, the purpose of this Implementation Work Group Report is to summarize City efforts to date in developing tools and approaches that will advance the City's capacity to implement GI/LID.

The Implementation Work Group and its Stormwater BMP Maintenance Focus Group held seven meetings to review ideas and provide input to recommendations for developing a GI/LID cost-effectiveness tool. The Work Group focused on three tasks:

- Evaluate options for a GI/LID cost-benefit tool that can be used by staff and development applicants and recommend next steps
- Develop site planning fact sheets that show how GI/LID can be incorporated into different types and scales of development
- Develop guidelines for the City's maintenance of GI/LID practices specifically and for stormwater management measures generally

GI/LID cost-benefit tool. Based on research and input from the Implementation Work Group, Tetra Tech prepared two documents related to options for a GI/LID cost-benefit tool. The first is a white paper on GI/LID Triple Bottom Line (TBL) benefits for potential inclusion in the tool. The TBL is a framework used to explore the environmental, societal, and economic impacts of development and infrastructure projects. A TBL approach could help Raleigh focus on making decisions that simultaneously support greater economic prosperity for the region, create a higher quality of life for all, and protect the area's environmental resources. In the context of GI/LID, the TBL is used to identify benefits beyond any required water quality or hydrology improvements.

The second document is titled *Cost-Benefit Tool Concept Memorandum* and describes tool design characteristics selected by the Work Group, and how the spreadsheet tool could be used within the development planning process. A GI/LID Cost-Benefit tool could play a role during every stage of the City's development process, including promoting GI/LID during the initial phases, considering alternatives in the final review, and measuring credits for incentives. The City could also use the tool to evaluate its own stormwater retrofit design options. For developers, the tool would help bridge the information gap between conventional practices and GI/LID practices and facilitate the promotion of sustainable development. Public benefits of the tool include more efficient, informed decision-making by the City and developers, direct access to data, and the economic, social, and environmental benefits associated with GI/LID. The tool's development will require collaboration, stakeholder feedback, and planning for updates and maintenance to ensure the tool's success.

GI/LID fact sheets. With input from the Work Group, Tetra Tech developed pictorial GI/LID fact sheets, tailored to Raleigh's setting and consistent with the City's Unified Development Ordinance (UDO), for five development types:

- Commercial
- Mixed-Use
- High-Density Residential
- Medium-Density Residential
- Low-Density Residential

The fact sheets were designed for outreach and educational purposes during pre-site plan meetings with developers and their designers. Each fact sheet shows multiple BMP options and configurations to convey examples of how to treat stormwater runoff with GI. The fact sheets cite examples of how developers realized cost savings and other benefits from implementing GI/LID.

Maintaining City-owner stormwater BMPs. With guidance from the Implementation Work Group, Tetra Tech prepared a memorandum on the subject of Maintenance of City-Owned Stormwater BMPs. This memorandum documents the City's current maintenance approaches, identifies challenges, and explores potential new and revised policies for BMP maintenance with a specific focus on BMPs on City properties and in City rights-of-way. Work Group recommendations in this memorandum are supported by information gathered through staff and contractor interviews and the input of a separate Stormwater BMP Maintenance Focus Group. With strong consensus of the Focus Group, a conceptual model for a dual responsibility maintenance framework was recommended with the Stormwater Management Division as the primary responsible management entity to be supported by maintenance specialists from parks and transportation operations. The Work Group felt that the recommended model would clarify responsibilities and assist with consolidated financial support for the anticipated increase in BMP maintenance workload as the number of GI practices grow with GI/LID implementation.

Sections 1 through 6 of this report provide details on these outcomes, and Appendices I through IV provide documentation of the efforts of this Work Group.

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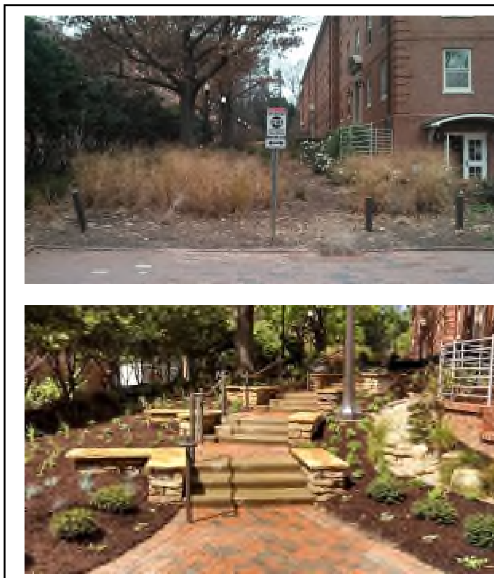
1.0 INTRODUCTION

Raleigh City Council has voiced strong commitment to improving the health of local streams, lakes, and the Neuse River by promoting use of green infrastructure and low impact development (GI/LID) for addressing the main source of pollutants and damaging flows in Raleigh's streams – stormwater runoff from developed land. At various times since the early 2000s, City staff, the Stormwater Management Advisory Commission (SMAC), the Environmental Advisory Board (EAB), the Planning Commission, and Council have discussed whether and how to advance the use of GI/LID on City projects and on private land development projects.

In February 2013, SMAC presented recommendations to Council for advancing GI/LID with an overall theme of communicating to the land development community that "Raleigh welcomes LID". In response, Council directed City staff to evaluate SMAC's recommendations and report to Council about actions needed to implement them. On staff's recommendation, the City retained the services of Tetra Tech, Inc. to provide technical expertise and experience with implementing GI/LID on a municipal scale and to facilitate a process for how the City should approach advancing GI/LID.

From late 2013 through 2014, a Work Plan for Advancing Green Infrastructure and Low Impact Development in Raleigh (GI/LID Work Plan) was developed using a deliberative and collaborative process involving City staff from numerous operations and stakeholders from the City of Raleigh citizen boards and councils, development organizations, environmental and conservation organizations, and citizens' advocacy organizations.

In March 2015, Council endorsed the GI/LID Work Plan. Six of the Work Plan tasks were divided into two categories and assigned to two related work groups made up of City staff and external community stakeholders:



NCSU Central Campus before and after installation of GI/LID shows how this approach can beautify a site.

Code Review Work Group:

- Review the City code for barriers and recommend revisions.
- Review potential incentives for implementing GI/LID and recommend new incentives.
- Prepare design templates for streets to accommodate GI/LID while maintaining essential City functions.

Implementation Work Group:

- Evaluate options for a GI/LID cost-benefit tool that can be used by staff and development applicants and recommend next steps.
- Develop site planning fact sheets that show how GI/LID can be incorporated into different types and scales of development.
- Develop guidelines for the City's maintenance of GI/LID practices specifically and for stormwater management measures generally.

Recent updates to the City's Strategic Plan further endorse GI/LID and underscore the importance of this Work Group's activities in advancing the City's goal.

This Implementation Work Group Report documents the Implementation Work Group process, findings, and recommendations and provides a summary of the documents produced under its three tasks.

Findings and recommendations of the GI/LID Code Review Work Group are provided in a separate report.

2.0 WORK GROUP MEETINGS

The Implementation Work Group included representatives of City departments, non-profit organizations, and industry as well as interested citizens. The group was charged with attending meetings, reviewing information and draft documents, and providing feedback on the City's advancement of GI/LID relating to a cost-benefit tool, GI/LID fact sheets, and an improved stormwater BMP maintenance program (***Figure 1***).

Figure 1. The Implementation Work Group considers fact sheet format during their first meeting.

The Work Group held five meetings during which they provided input to City staff and Tetra Tech:

- **Meeting #1:**
  - **Cost-Benefit Tool:** Tetra Tech presented information on existing GI/LID cost-benefit tools, and the group provided feedback on which tool components would be most useful

and relevant for the City. How existing tools could be applied and adapted was also discussed.
    - **GI/LID Fact Sheets:** The Work Group discussed the format and focus options for GI/LID fact sheets.
    - **BMP Maintenance:** In preparation for information gathering and interviews with City staff and contractors regarding the City's BMP maintenance program, Tetra Tech asked the Work Group for feedback on interview questions. The Work Group provided input on both interview questions and general considerations for conducting interviews and ultimately building a new BMP maintenance framework.
- **Meeting #2:**
    - **Cost-Benefit Tool:** Tetra Tech presented information compiled in the GI/LID Triple Bottom Line white paper and discussed ideas for the cost-benefit tool design. The group provided feedback on the TBL information as well as the tool design.
    - **GI/LID Fact Sheets:** Tetra Tech provided example GI/LID fact sheets from other cities, and the Work Group provided feedback on preferences for overall fact sheet layout and content.
- **Meeting #3:**
    - **Cost-Benefit Tool:** Tetra Tech garnered input on the cost-benefit tool concept, and the group discussed how a cost-benefit tool could be used during each step of the development review process.
    - **GI/LID Fact Sheets:** The Medium-Density Residential fact sheet was reviewed along with preliminary versions of the other site planning fact sheets. The Work Group provided feedback on the format of the fact sheets and graphics as well as the information presented within them.
    - **BMP Maintenance:** Tetra Tech led the Work Group through a discussion of each major setting for BMP maintenance, and the Work Group provided feedback on challenges and potential solutions. Based on this discussion, a focus group was formed to evaluate these issues in more detail.
- **Meeting #4:**
    - **Cost-Benefit Tool:** The Work Group provided final review and consideration of the cost-benefit tool concept.
    - **GI/LID Fact Sheets:** Breakout groups took turns reviewing each GI/LID fact sheet and providing verbal and written comments to Tetra Tech.
- **Meeting #5:**
    - **Cost-Benefit Tool:** Tetra Tech reviewed the Work Group's progress and final recommendations.
    - **GI/LID Fact Sheets:** The Work Group provided final review of the GI/LID fact sheets.
    - **BMP Maintenance:** Tetra Tech presented the BMP Maintenance Focus Group findings and recommendations and received feedback.

At the first meeting, the Work Group was given binders with introductory information and handouts. At subsequent meetings, additional pages were provided for the binders with supplemental information and draft documents for review. The Work Group reviewed the following documents:

- **Cost-Benefit Tool:** Triple Bottom Line White Paper and Cost-Benefit Tool Concept Memorandum

- **GI/LID Fact Sheets:** Fact sheets depicting GI/LID options for Commercial, Mixed-Use, High-Density Residential, Medium-Density Residential, and Low-Density Residential developments
- **BMP Maintenance:** Maintenance Program Review and Model Options

The following sections summarize Implementation Work Group results and recommendations.

3.0 GI/LID TRIPLE BOTTOM LINE WHITE PAPER

Early in the Work Group's discussions on a cost-benefit tool concept, Tetra Tech compiled and presented information on GI/LID Triple Bottom Line (TBL) benefits for potential inclusion in the tool. The TBL is a framework used to explore the environmental, societal, and economic impacts of development and infrastructure projects. A TBL approach can help a community focus on making decisions that simultaneously support greater economic prosperity for the region, create a higher quality of life for all, and protect the area's environmental resources. In the context of GI/LID, the TBL is used to identify benefits beyond required water quality or hydrology improvements.

The concept of TBL fits well within the City's approach to sustainability. Raleigh's commitment to sustainability focuses on interdependent relationships between economic strength, environmental stewardship, and social equity (http://www.raleighnc.gov/sustainableraleigh). The TBL addresses each of these goals by evaluating the economic, environmental, and social benefits of GI/LID. Benefits associated with GI will contribute to Raleigh's efforts to incorporate new technologies and become more resilient.

TBL benefits can vary depending on city-specific conditions as well as public preferences and perceptions. For this white paper (Green Infrastructure/Low Impact Development, Triple Bottom Line Benefits for Raleigh, Appendix I), Tetra Tech identified TBL benefits that had readily available data and estimation methods and that were most relevant to conditions in Raleigh. The following benefits were selected:

- Improved water quality
- Green jobs and reducing the social cost of poverty
- Property value benefits of green space
- Reduced infrastructure costs
- Reduced energy use and heat island effect
- Carbon sequestration
- Improved air quality
- Flood mitigation
- Habitat
- Mental health
- Reduced crime/improved public safety

The white paper provides a review of the most recent literature on the TBL benefits that can be achieved using GI/LID. The literature included journal articles, case studies, and technical reports that provide evidence of these benefits and estimate associated monetary values. Within the white paper, available monetized benefits were documented and potential valuation methods are summarized.

Available literature provided a strong case for the economic, social, and environmental benefits of GI in Raleigh. Local studies were available on several TBL benefits, including a property value study (Henderson 2005) that observed about a 2 percent increase in property value due to public open space. Relating to reduced infrastructure costs, the U.S. EPA North Carolina campus in Research Triangle Park experienced $500,000 in construction costs saved by using green infrastructure (***Figure 2***, USEPA, 2001). A Mecklenburg County study found that air quality benefits from the urban forest represent nearly $40 million dollars in avoided costs relating to respiratory illness and other externalities (American Forests, 2010). A demonstration of the i-Tree tool suite estimates that four trees on single-family residential lot in the North Carolina piedmont can provide $1300 in TBL benefits, reflecting energy savings, reduced social cost of carbon, and air quality benefits over 20 years. Tetra Tech also reviewed information on how a number of cities were finding ways to create jobs through GI (e.g. City of Philadelphia's partnership with PowerCorpsPHL, ***Figure 3***). Details on these and the other TBL benefits are provided in the white paper.

Figure 2. EPA Campus, Research Triangle Park, where GI saved over $500,000 in construction cost (USEPA, 2001)

Figure 3. Example of Green Jobs Creation: PowerCorpsPHL
Philadelphia Water Commissioner Howard Neukrug and Philadelphia Water Environmental Scientist Alex Warwood with PowerCorpsPHL workers; Source: PowerCorpsPHL

This information was presented to and discussed by the Work Group, and the white paper was revised to reflect the Work Group's discussions and input. The TBL information was compiled to support the potential development of a cost-benefit spreadsheet tool that evaluates stormwater management designs in terms of cost and TBL benefits in addition to stormwater performance measures. The concept memo for this tool is summarized in the next section.

4.0 COST-BENEFIT TOOL

The cost-benefit tool report (Green Infrastructure/Low Impact Development, Cost -Benefit Tool concept for Raleigh, Appendix II) describes how a spreadsheet tool would be used within the development planning process and draws from the Work Group's feedback, including ideas for the format of the tool and its components. A conceptual design of the tool is described upfront, and later sections describe how the tool would be used and how it would benefit the City, developers, and the public. Finally, key elements for success in tool development and implementation are discussed. The cost-benefit tool report proposes the following tool design characteristics:

- **Excel spreadsheet-based**[1] – The tool would be developed as an MS Excel file, either as part of an existing tool or as a stand-alone file.
- **Ability to interact with existing tools developed by the North Carolina Department of Environmental Quality: Storm-EZ Permitting Tool and Jordan Nutrient Loading Accounting Tool** – Several options are possible, including having the tool exist as additional spreadsheets or "tabs" in these existing tools. The cost-benefit tool could also exist as a separate file that draws output from these existing tools.
- **Calculate estimated costs from relatively simple user inputs –** Inputs would include square feet of GI/LID area, cubic feet for storage, etc. Costs reported would include upfront costs, operation and maintenance costs, and life-cycle costs.
- **Optional component for calculating co-benefits of GI/LID** – As discussed further in the cost-benefit tool report, the monetary co-benefits could be turned on or off, depending on a user's interest in these calculations.
- **Provide a summary report for comparison across scenarios (*Figure 4*)** – The tool would provide a summary report of estimated costs and benefits. Each development scenario would have a summary report, and these reports can be compared across the scenarios to facilitate selection for design.
- **Allow user-defined costs** – Developers, designers, and other users may need help with some GI costs but not others. The tool would provide the option to enter preferred cost data for each type of GI/LID.

[1] During tool development, the use of a spreadsheet format would be evaluated in more detail, considering current technology and platform options, including compatibility with mobile applications.

The cost-benefit tool report provides example screen shots to illustrate the proposed tool (***Figure 4***).

From the City's perspective, the GI/LID cost-benefit tool can play a role during every stage of the development process, including promotion of GI/LID during the initial phases, consideration of alternatives in the final review, and measuring credits for incentives. The City could also use the tool to test its own stormwater retrofit design options (***Figure 5***). For developers, the tool would help bridge the information gap between conventional practices and GI/LID practices and facilitate promotion of sustainable development. Public benefits of the tool include more efficient, informed decision-making by the City and developers, direct access to data, and economic, social, and environmental benefits associated with GI/LID.

The GI/LID cost-benefit tool would provide the City and its stakeholders with valuable information and a method to facilitate advancement of GI/LID. The tool's design will require collaboration, stakeholder feedback, and planning for updates and maintenance to ensure the tool's success. Designed as a "living tool," the GI/LID cost benefit tool would allow the City to adapt to changing priorities and trends in GI/LID. More details are provided in the Cost-Benefit Tool Concept for Raleigh report, Appendix II.

Cost-Benefit Summary Report Site 1

Cost Estimates over Project Life-Time	
Construction Costs	$565,000
Design and Engineering Costs	$141,250
Operation and Maintenance Costs over Proj	$339,000
Total Life-Cycle Costs	$1,045,250

Monetary Co-Benefits over Project Life-time	
Job Creation	$1,000
Property Value	$8,500
Air quality	$50
Carbon Sequestration	$40
Energy savings	$800
Habitat	$76
Total Monetary Benefits	$10,466

Figure 4. Example of Cost-Benefit Summary Report

Figure 5. Examples of Past City of Raleigh GI/LID projects:

Fire Station Rainwater Harvesting (left);
Fred Fletcher Park Water Garden and Wetland (right). Source: City of Raleigh
https://www.raleighnc.gov/home/content/PWksStormwater/Articles/CompletedProjects.html

5.0 GI/LID FACT SHEETS

With input from the Work Group, Tetra Tech developed five GI/LID fact sheets (Appendix III) tailored to Raleigh's physical setting and consistent with the City's Unified Development Ordinance (UDO). The fact sheets were designed for outreach and for educational purposes during pre-site plan meetings with developers and their designers. The GI/LID fact sheets show multiple BMPs and configurations to treat stormwater runoff at variety of sites.

The Work Group reviewed multiple versions of the fact sheets and provided extensive comments that helped shape the final drafts. The Work Group's first assignment was to review information on land use, zoning, and impervious surface and select a workable list of development types to reflect in the fact sheets. The Work Group settled on the following categories:

- Commercial
- Mixed-Use
- High-Density Residential
- Medium-Density Residential
- Low-Density Residential

Then Tetra Tech developed draft fact sheets for each development category and worked closely with the Work Group to refine each setting. The fact sheets provide illustrations of sites, buildings, and example GI BMP options that show how GI/LID can be incorporated into development sites. The illustrations are meant to reflect current requirements of the UDO. Callout bubbles explain features and show photos of real-life GI/LID examples. Each fact sheet cites examples of how developers have realized cost savings and other benefits from implementing GI/LID.

6.0 REVIEW OF STORMWATER BMP MAINTENANCE

The City anticipates that use of GI/LID will continue to grow, both through the need to meet regulatory stormwater management goals as well as through the City's efforts to remove barriers and promote the multiple benefits of GI/LID. With this growth will come a need to address widespread and long-term maintenance needs of both privately- and publicly-owned GI/LID devices. The Stormwater BMP Maintenance Review and Model Options Memorandum (Appendix IV) documents the City's current maintenance approaches, identifies challenges, and explores potential new and revised policies for stormwater BMP maintenance with a specific focus on BMPs located on public property and in City ROWs.

In addition to the Implementation Work Group, a separate Stormwater BMP Maintenance Focus Group was formed. To support the group discussions, Tetra Tech reviewed the City's current approach to stormwater BMP maintenance and gathered information through staff and contractor interviews. During the interviews and meetings, Tetra Tech worked with Work Group members and City staff to identify where policies create uncertainty or ambiguity in the City's ability to ensure long-term function of stormwater best management practices (BMPs) including GI/LID practices. Many of the issues relate to how requirements are communicated among parties and how funding is allocated. Examples of these issues include but are not limited to:

- Unclear policy regarding the maintenance of BMP's within the right-of-way (ROW); current ROW maintenance policies are not directly applicable.
- Inconsistent policy for maintaining retrofit BMPs on City properties.
- Case-by-case funding allocation for maintenance of BMPs in the ROW.

Exploration of these issues provided an opportunity to evaluate the City's overall approach to BMP maintenance across all City-owned property settings. These settings, categorized as noted below, are subject to different existing maintenance protocols:

- **Regulated City:** BMPs on City-owned parcels covered by an approved Stormwater Management Plan.
- **City Retrofit:** BMPs installed by the Stormwater Management Division to address existing development.
- **BMPs in ROW:** BMPs installed in City ROW.
- **Non-regulated City:** BMPs installed as part of green building, public education or other initiatives.

There are a variety of approaches to BMP maintenance being implemented and administered by communities across the country who struggle with the same issues that Raleigh is facing. Freehan (2013)[2] surveyed eight local governments and developed a list of "models" that described the general approach to oversight and responsibility within these programs. Tetra Tech conducted further research on these communities and interviewed staff to gain an understanding of how each community's BMP

[2] Freehan, Caitlin. 2013. A Survey of Green Infrastructure Maintenance Programs in the United States. 2013 Hixon Fellowship Final Report. Accessed March 2016. http://hixon.yale.edu/sites/default/files/files/fellows/paper/feehan_hixonpaper20131.pdf

maintenance program varies in structure and organizational elements. Several broadly defined models emerged from this research relevant to BMPs on public property:

- **Central Responsibility:** The stormwater management agency has responsibility for all implementation and funding of maintenance.
- **Dual Responsibility:** One agency (e.g., parks and recreation) has responsibility for all maintenance with oversight from another agency (e.g., stormwater management).
- **Distributed Responsibility:** The agency that constructs and owns the BMP is responsible for its maintenance. The stormwater management agency typically inspects and provides oversight.

Tetra Tech compiled the above information into a draft memorandum that was shared with the Stormwater BMP Maintenance Focus Group. The Focus Group held two meetings. The first meeting covered the challenges identified with current City BMP maintenance and the broad maintenance program models developed from the case study information. The Focus Group generally felt that the dual responsibility model would help address their concerns about departmental responsibilities and funding. They envisioned a program in which the Stormwater Management Division would provide oversight and the Parks, Recreation, and Cultural Resources Department would perform a large portion of the maintenance. Tetra Tech developed a conceptual model of the Focus Group's vision, which was reviewed during the second meeting, refined, and presented to the Implementation Work Group (***Figure 6***). The Stormwater BMP Maintenance Memo documents the above process in detail and provides several organization charts illustrating the conceptual model.

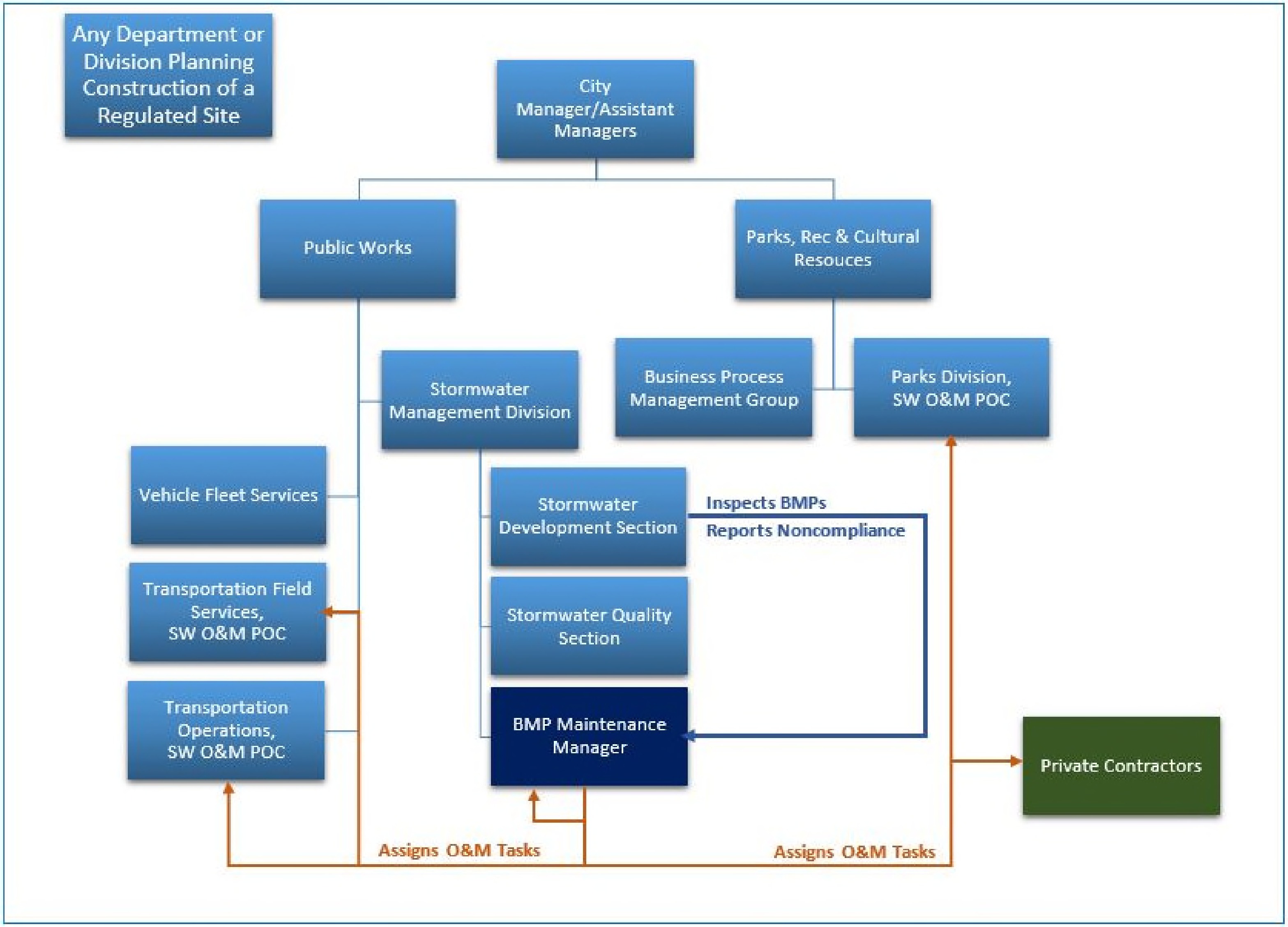


Figure 6. General Concept of Dual Responsibility for Stormwater BMP Maintenance

7.0 CONCLUSIONS AND NEXT STEPS

The City recognizes the important potential of broad use of GI/LID for reducing negative impacts of stormwater runoff from developed land, the main source of pollutants and damaging flows in Raleigh's streams. The City also recognizes additional benefits resulting from use of GI/LID, including conserving and protecting water supply sources and open space, creating more bikeable and walkable streets, reducing urban heat island effect, and improving air quality.

Development and use of Raleigh-specific educational and outreach material that highlight the benefits of GI/LID approaches to stormwater management and show how GI/LID can be implemented into the urban setting are key components for ensuring the development community is provided resources for making decisions about GI/LID adoption. These components, when coupled with functionally efficient internal City policies for maintenance of GI/LID practices can serve as foundational components for building municipal capacity for widespread use of GI/LID.

This report with recommendations of the Implementation Work Group, along with a companion report with recommendations of the Code Review Work Group, will be reviewed by the City's Stormwater Management Advisory Commission, and will be presented to City Council for consideration and direction to staff regarding implementation of the recommendations.

APPENDIX I GI/LID TRIPLE BOTTOM LINE BENEFITS

Green Infrastructure/ Low Impact Development

Triple Bottom Line Benefits

Source: NC State University

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EXECUTIVE SUMMARY

The Triple Bottom Line (TBL) is a framework used to explore the environmental, societal, and economic impacts of development and infrastructure projects. The concept of TBL fits well within the City of Raleigh's approach to sustainability. Raleigh's commitment to sustainability focuses on interdependent relationships between Economic Strength, Environmental Stewardship and Social Equity (http://www.raleighnc.gov/sustainableraleigh). The Triple Bottom Line (TBL) directly addresses each of these goals, by evaluating the economic, environmental and social benefits of green infrastructure and low impact development.

The purpose of this white paper is to provide a review of the most recent literature on the TBL benefits that can be achieved using green infrastructure and low impact development. The benefits discussed represent examples that have readily available information and are relevant to the City of Raleigh. Appendix A provides a broader list of benefits that can be associated with green infrastructure.

The literature review focused on identifying relevant data on the monetary value of TBL benefits, including avoided costs, public willingness to pay, and other valuation measures. Monetized TBL estimates can help the City of Raleigh and interested developers identify green infrastructure designs that provide the greatest value across multiple benefits. As part of Tetra Tech's GI/LID assistance to the City of Raleigh, this information was compiled to support the potential development of a cost-benefit spreadsheet tool that evaluates stormwater management designs in terms of cost and TBL benefits in addition to stormwater performance measures. The first phase of this support (Phase 1) involves this TBL white paper and a subsequent memorandum discussing the tool's design. If the City of Raleigh decides to move forward with the spreadsheet tool, it would then be developed in Phase 2.

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APPENDICES

APPENDIX A: TBL BENEFITS UNIVERSE 24

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
GI	Green Infrastructure
LID	Low Impact Development
TBL	Triple Bottom Line
USEPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program

1.0 INTRODUCTION

The Triple Bottom Line (TBL) is a framework used to explore the environmental, societal, and economic impacts of development and infrastructure projects. A TBL approach can help a community focus on making decisions that simultaneously support greater economic prosperity for the region, create a higher quality of life for all, and protect the area's environmental resources to ensure continued prosperity and a high quality of life long into the future. We consider achieving TBL benefits to be essential to building a stronger, more resilient Raleigh. In the context of green infrastructure and low impact development (LID), the TBL is used to identify benefits beyond any required water quality or hydrology improvements.

A strong case for triple bottom line benefits can be made for communities where green infrastructure has already been tested and implemented on a wide scale. American Rivers collected data on current green infrastructure practices in North Carolina, and found that North Carolina has almost 2,000 documented examples of green infrastructure in more than 100 municipalities and counties across the state. Urban metropolitan regions like Charlotte, the Triangle and the Triad have the highest density of green infrastructure practices within the state (Raabe 2012). American Rivers has also produced an interactive map showing the location of green infrastructure. Extensive national and local information is available on green infrastructure. Most recently, the University of North Carolina's Environmental Finance Center (EFC) has collaborated with the U.S. EPA to publish case studies and innovative financing approaches for green infrastructure projects (UNC Environmental Finance Center 2015).

The concept of TBL fits well within the City of Raleigh's approach to sustainability. Raleigh's commitment to sustainability focuses on interdependent relationships between Economic Strength, Environmental Stewardship and Social Equity (http://www.raleighnc.gov/sustainableraleigh). The Triple Bottom Line directly addresses each of these goals, by evaluating the economic, environmental and social benefits of green infrastructure and low impact development. Benefits associated with green infrastructure will contribute to Raleigh's efforts to incorporate new technologies and become more resilient.

The U.S. Environmental Protection Agency (USEPA) maintains a website with green infrastructure tools and examples from throughout the U.S. (http://water.epa.gov/infrastructure/greeninfrastructure/), and EPA (2013) describes case studies on quantifying benefits of green infrastructure. Several on-line tools exist that facilitate the calculation of benefits, including USDA's i-Tree tools <https://www.itreetools.org> and the Green Values National Stormwater Calculator <http://greenvalues.cnt.org/national/calculator.php>. Communities can use these resources to explore the breadth of triple bottom line benefits. This white paper describes how available tools and data can be used to communicate the value of TBL benefits.

TBL benefits can vary depending on city-specific conditions as well as public preferences and perceptions. For this white paper Tetra Tech identified TBL benefits that had readily available data and estimation methods, and that were most relevant to conditions within the City of Raleigh. A more comprehensive list of TBL benefits is included in Appendix A. The selected benefits are:

- Improved Water Quality
- Green Jobs and Reducing the Social Cost of Poverty
- Property Value Benefits of Green Space
- Reduced Infrastructure Costs
- Reduced Energy Use and Heat Island Effect
- Carbon Sequestration

- Improved Air Quality
- Flood Mitigation
- Habitat
- Mental Health
- Reduced Crime/Improved Public Safety

The purpose of this white paper is to provide a review of the most recent literature on the TBL benefits that can be achieved using green infrastructure and low impact development. The literature includes journal articles, case studies, and technical reports that provide evidence of these benefits and estimate associated monetary values. Within this white paper, available monetized benefits are documented and potential valuation methods are summarized.

This information was presented to and discussed by the City of Raleigh GI/LID Implementation Workgroup, and this white paper was revised to reflect the workgroup's discussions and input. As part of Tetra Tech's GI/LID assistance to the City of Raleigh, this information was compiled to support the potential development of a cost-benefit spreadsheet tool that evaluates stormwater management designs in terms of cost and TBL benefits in addition to stormwater performance measures. The first phase of Tetra Tech's support (Phase 1) involved this white paper and a subsequent memorandum discussing the tool's design. If the City of Raleigh decides to move forward with the spreadsheet tool, it would then be developed in Phase 2.

2.0 IMPROVED WATER QUALITY

One of the main goals of GI/LID is to improve water quality, and pollutant load reduced by GI/LID is often estimated during planning and design phases. Pollutants of concern often include nutrients (nitrogen and phosphorous) and sediment. Beyond load reduction estimates, monetary valuation can measure the effect that improved water quality has on public perceptions, property values, and other social and economic considerations.

In valuations, water clarity is often used as a surrogate measure for water quality. While only an approximate measure, water clarity strongly correlates with the presence of phosphorous, nitrogen and TSS pollution. Suspended particulates directly decrease water clarity, while high concentrations of nitrogen and phosphorous lead to eutrophication, which results in algae blooms and decreased dissolved oxygen.

Economic losses from algal blooms can include increased costs for drinking water treatment, reduced property values for streams and lakefront areas, commercial fishery losses, and lost revenue from recreational fishing, boating trips, and other tourism-related businesses. Low dissolved oxygen specifically has caused decreased harvests of commercial fish species in the Neuse River and Pamlico Bay in North Carolina (Huang 2012). Algal blooms caused significant economic losses to the tourism industry in many coastal states including North Carolina (Anderson et al., 2000).

While available literature describes the impacts of green infrastructure on water quality, many studies are site-specific and do not provide general guidelines for measurement and valuation. The Center for Neighborhood Technology suggests that water quality benefits of green infrastructure are best evaluated by considering watershed-scale green infrastructure implementation, accompanied by hydrologic modeling, to estimate changes in sedimentation and pollutant loads resulting from a green infrastructure program (CNT and American Rivers, 2010).

Several valuation studies have been conducted in North Carolina that estimated the value of improving or protecting water quality based on the public's perceptions. One study used stated preference methods to estimate the economic value of protecting water quality in the Catawba River basin of North and South Carolina at its current level. Interviews were completed with 1,085 randomly selected households. Respondents expressed a mean willingness to pay of $139 for a management plan designed to protect water quality at its current level over time. Aggregation of this mean willingness to pay value amounted to an annual economic benefit of over $75 million for all taxpayers in Catawba basin counties (Kramer et al. 2002).

Phaneuf et al. (2013) studied the change in recreational value in Falls Lake due to more stringent chlorophyll and nutrient criteria. Based on an estimated 0.9 million trips to the lake each year, the annual benefits from the updated nutrient policy were estimated at $13.76 million. Over 20 years using a 5 percent discount rate, the present value of the stream of benefits was estimated at $171.52 million.

Literature is also available on the effect of water quality on property values, which relates to green infrastructure as well as other water quality improvement measures. Poor et al. (2007) investigated the value of ambient water quality using statistical methods for estimating property value trends from observed data (hedonic analysis) in the St. Mary's River Watershed in Maryland. The study estimated that a one unit (mg/L) increase in total suspended solids (TSS) has a negative impact on average housing prices within the watershed of $1086. Correspondingly, a one-unit change (mg/L) in the dissolved inorganic nitrogen, a contributor to eutrophication, also has a negative impact on average housing prices in the watershed of $17,642. (Poor et al. 2007).

For the City of Raleigh, improved water quality achieved through GI/LID can be valued from several different perspectives. The value of improved water quality achieved through green infrastructure can be estimated using water quality modeling and available valuation literature. However, as referenced by CNT (2010), ambient water quality improvement is best evaluated at a watershed-scale due to the data and modeling requirements of such an analysis. The value of improved ambient water quality would be less feasible to estimate for a site-scale cost benefit tool.

Another possibility is to estimate the value of pollutant reductions achieved prior to stricter requirements. For example, the city could investigate the cost difference between reducing nutrient loading in new development versus retrofitting that development later to address future, more stringent nutrient reduction requirements. This type of analysis would be most useful if the city wished to promote additional nutrient reduction beyond what is currently required. Several existing cost-benefit tools use this concept to value reduced stormwater runoff achieved through tree planting or GI with the assumption that benefits achieved now will reduce stormwater infrastructure costs in the future (Maco and McPherson, 2016; CNT, 2009).

3.0 GREEN JOBS AND REDUCING THE SOCIAL COST OF POVERTY

Like many innovative practices that are part of the "green" industry, GI and LID can create jobs for local low-income individuals, providing direct, indirect, and induced economic benefits. While design of green infrastructure requires certain skilled individuals, such as architects, designers and engineers, its implementation also yields jobs in construction, operation, maintenance, and installation – termed "green jobs." In the United States, between July 2007 and January 2009, there was a 31 percent increase in people being hired specifically for green jobs, and some predictions anticipate 6.9 million green jobs by 2020 (Dunn 2010).

Green jobs not only stimulate local economies through additional employment but also can reduce government costs. Maintenance of landscaping and other green infrastructure features provides jobs for unskilled workers who may otherwise be unemployed. Unskilled workers are often hired locally whereas skilled workers are more likely to be hired from outside the local economy, which is considered a job transfer instead of a job creation. Through job creation, government costs are reduced because employed persons generally require less government assistance or intervention compared to unemployed persons. Since training will occur with GI/LID jobs, the unskilled workers will have an opportunity to learn landscaping and other skills and advance in the field.

A number of management efforts throughout the United States are taking advantage of the job creation benefits of green infrastructure (for stormwater management and other co-benefits). These efforts include urban greening initiatives in Philadelphia, Pennsylvania; Lawrence, Massachusetts; and Stamford, Connecticut (USEPA 2009b; Schilling and Logan 2008; Dunn 2010) and funding for green collar jobs in several California cities (Rangwala 2008). The urban greening efforts in Lawrence and Philadelphia have led to the creation of more stable neighborhood environments and established innovative programs that provide jobs, skills training, and local fresh food for residents through the reclamation of vacant properties.

The City of Philadelphia (2009) conducted a detailed estimate of job creation and reduction in social costs as part of their green infrastructure plan. They estimated that spending over $100 million dollars over 20 years on GI operation and maintenance would provide 250 permanent jobs for unskilled workers and save about $2.5 million dollars in social costs annually, or $10,000 per new green infrastructure job created per year. This estimate is based on local and national studies and accounts for the social costs of health services and crime related to persons in poverty. This is a conservative estimate as the literature review by the City of Philadelphia (2009) illustrated a range of estimates for the cost of poverty from $15,000 to $45,000 per person per year.

Philadelphia’s job creation estimates are already being realized. PowerCorps PHL, an AmeriCorps program, provides job training opportunities for young adults in Philadelphia. Beginning in 2013, the program enrolled 100 individuals per year, ages 18 to 26. The members work 6-months full-time with City departments and then are provided three months job placement support. As of 2015, PowerCorps crew members are being hired by companies in the green services industry (Figure 3-1; City of Philadelphia, 2015).

Some additional examples of green infrastructure job creation estimates include (Green for All 2012):

- Philadelphia’s $1.6 Billion investment in stormwater infrastructure has the potential to generate 8,600 green collar direct jobs (GSP Consulting and Ecolibrium Group 2010).
- In Northeast Ohio, 31,000 direct jobs could be created during 2012-2016 from a $3 billion investment in stormwater infrastructure (Green for All 2011).
- Montgomery County, Maryland expects to employ 3,300 workers over three years building a network of green stormwater controls (Chesapeake Bay Foundation 2011).
- PlaNYC anticipates the creation of 266 total jobs from investing $23 million in green roofs and 1,446 direct jobs from a $346 million investment in watershed protection programs (The Louis Berger Group 2008).
- Installing green roofs on 5% of Chicago’s buildings would create 7,934 jobs from an investment of $403 million (American Rivers and Alliance for Water Efficiency 2008).

Figure 3-1. Example of Green Jobs Creation: PowerCorpsPHL
Philadelphia Water Commissioner Howard Neukrug and
Philadelphia Water Environmental Scientist Alex Warwood with
PowerCorpsPHL workers; Source: PowerCorpsPHL

Several methods are available to estimate green infrastructure job creation benefits within the City of Raleigh. Economic modeling can be used to determine the number and type of jobs expected from both the construction and maintenance of proposed green infrastructure projects. The economic model IMPLAN (IMpacts for PLANning), can be used to estimate jobs and associated economic benefits generated for each green infrastructure project. IMPLAN is a software model that uses an input-output dollar flow table. For a specified region, the input-output table accounts for all dollar flows between different sectors of the economy. Using this information, IMPLAN models the way a dollar injected into one sector is spent and re-spent in other sectors of the economy, generating waves of economic activity, or “economic multiplier” effects. The model uses national industry data and county-level economic data to generate a series of multipliers, which in turn estimate the total implications of economic activity (City of Richmond, 2010).

Economic modeling may not be possible due to limited funding, and the City may prefer to estimate job creation directly. An estimate of annual labor hours in maintenance per unit for each major type of green infrastructure could be developed, and these hours could then be translated into number of jobs created per unit of green infrastructure. Tradeoffs in accuracy and value exist between the direct estimate versus the model estimate. While the estimate of direct jobs would likely be more accurate, this estimate would not include any indirect or induced economic benefits, including additional jobs created indirectly, that modeling would provide.

The reduced social cost of poverty can be estimated by multiplying jobs created by an assumed per capita social cost avoided. Reduced social cost can be based on national estimates of the cost of poverty and a city or county’s population of low income households. Once an estimate of the City’s share of social costs is estimated, this can be converted to social costs per unemployed person using U.S. census data on unemployed persons. As discussed above, this approach was used by The City of Philadelphia (2009) to estimate a $10,000 per capita social cost avoided. Another approach would be to directly estimate the City of Raleigh's annual budget that is attributable to poverty and divide that value by the number of unemployed persons in poverty within the City. The development of a Raleigh-specific value was out of scope for this phase of the project but could be considered in Phase 2 of the project.

4.0 INCREASED PROPERTY VALUE

A number of studies have estimated the effect that green infrastructure and similar practices have on surrounding property values. Many aspects of green infrastructure can increase property values, including improved aesthetics, drainage, and recreational opportunities. One of the better documented benefits is the effect that the additional plants and trees associated with green infrastructure have on property value due to their aesthetic nature. Increases in property value not only benefit individual property owners but also can lead to increased tax revenue and general economic improvement, including increased jobs.

When estimating the effects green infrastructure on property values using literature values, it is important to attribute property value increases only to those green infrastructure projects that provide aesthetic amenities similar to those studied in the literature. Property value decreases have been associated with some stormwater management facilities, where only structure or function are emphasized. In Texas, Lee and Li (2009) found that some dry basins had negative impacts on property values while some wet basins had positive impacts. Additionally, if green infrastructure is poorly maintained or non-functioning, it will likely detract from property values.

Recent study findings support estimates for increased property values due to green infrastructure. Madison and Kovari (2013) examined the general impacts that green infrastructure can have on property values for industrial, commercial and residential properties in Wisconsin. The study found that incorporating green infrastructure as part of a tax increment financed development ensured timely payoff for the overall investment. In one location, the study found that green infrastructure improvements had a strong positive impact on the surrounding properties values.

In a study conducted on the economic benefits of open space in Wake County, North Carolina, researchers found that homes in Wake County sell for significantly more money if they are located closer to any type of open space. In general, larger open spaces were found to have a greater impact on sale price. Using these results, it was calculated that an average home in Raleigh would be worth approximately $4,220 more if it were within 1500 feet of a public open space than it would if it were located farther than 1500 feet from a public open space. This difference represent s a 2.09% change in property value, and would generate an additional $42 annually in county property taxes per house (Henderson 2005).

Table 4-1 summarizes several recent studies that have estimated the effect that green infrastructure with vegetation or related practices (tree planting, open space, etc.) have on property values. Available studies were selected from cities that are similar in population to Raleigh, and studies from New York, Los Angeles, and Chicago were excluded based on population. The majority of these studies addressed urban areas, although some suburban studies are also included. The studies used statistical methods for estimating property value trends from observed data (hedonic analysis).

Table 4-1. Studies Estimating Percent Increase in Property Value from Tree Planting, Low Impact Design with Vegetation, or Community Gardens.

Source	Percent increase in Property Value	Notes
Ward et al. (2008)	3.5 to 5%	Estimated effect of LID on adjacent properties relative to those farther away in King County (Seattle), WA.
Shultz and Schmitz (2008)	0.7 to 2.7%	Referred to effect of clustered open spaces, greenways and similar practices in Omaha, NE.
Wachter and Bucchianeri (2008)	7 to 11%	Estimated the effect of tree plantings on property values for select neighborhoods in Philadelphia. The percent price differential is identified within 4000 feet of tree plantings.
Anderson and Cordell (1988)	3.5 to 4.5%	Estimated value of trees on residential property (differences between houses with five or more front yard trees and those that have fewer), Athens-Clarke County (GA).
Espey and Owasu-Edusei (2001)	11%	Refers to small, attractive parks with playgrounds within 600 feet of houses, Greenville (SC).
Hobden, Laughton and Morgan (2004)	6.9%	Refers to greenway adjacent to property, Surrey (British Columbia).
Sander et al. (2010)	0.29% to 0.48%	A 10% increase in tree cover within 328 feet increases average home sale price by $1371 (0.48%) and within 820 feet increases sale price by $836 (0.29%). In a model including both linear and squared tree cover terms, tree cover within 328 to 820 feet increases sale price 40 to 60%, Ramsey and Dakota Counties (MN).
UNC study	2.09%	An average home in Raleigh would be worth approximately $4,220 more if it were within 1500 feet of a public open space than it would if it were located farther than 1500 feet from a public open space. This difference represents a 2.09% change in property value, and would generate an additional $42 annually in county property taxes per house.

The reported percent increases in property values (***Table 4-1***) were averaged to estimate an approximate range of property value increase due to green infrastructure in the City of Raleigh. Where ranges were available, averages were calculated for the low end and high end. For studies that provided a single value that value was included in both the low and high end averages.

Based on these results and average values calculated from the data shown in Table 4-1 above, the City of Raleigh could reasonably expect a 4-6 % increase in residential property values based on relative proximity to green infrastructure that would have similar amenities to open spaces, greenways, tree cover, and parks. While any type of green infrastructure has the potential to provide aesthetic amenities, this particular property value increase is based on the presence of aesthetic vegetation. The application of literature values on property value increases due to green infrastructure assumes that the subject designs include vegetation that will improve community aesthetics.

Some of the studies in Table 4-1 were not based on a specific distances between an aesthetic amenity and a property. As a conservative estimate, the lowest distance threshold in Table 4-1 of about 300 feet (based on 328-foot distance from Sander et al. (2010) could be used as an approximate distance to attribute property value increases to green infrastructure in the City of Raleigh. This threshold would be appropriate for residential and other relatively small parcels. If this method were applied to a large parcel, the estimate may need to be adjusted based on best professional judgement of how much of the parcel owner's benefit from available views of the subject green infrastructure. A sliding scale property value change by distance could also be developed from the available literature.

5.0 REDUCED INFRASTRUCTURE COSTS

Green infrastructure provides an opportunity to reduce the costs of grey infrastructure, like stormwater inlets, culverts, and curb and gutter. As green infrastructure provides infiltration, evapotranspiration, and storage, it reduces the need to control stormwater runoff, which then reduces the need to maintain existing or to build new grey infrastructure. Some types of green infrastructure can also be used in place of grey stormwater conveyance, including vegetated swales. One cost-benefit analysis by the City of Seattle estimated that natural drainage designs can reduce street drainage costs by about 24 to 45 percent compared to traditional designs (Seattle Public Utilities 2008).

The potential for cost savings can depend on the design options for a particular development. However, it is widely recognized that the use of swales can reduce construction costs over the use of curb and gutter. CWP (1998) estimated that traditional structural conveyance systems cost two to three times more than grass swales. For the construction of the USEPA North Carolina campus in Research Triangle Park, several green infrastructure techniques (grassy swales, water quality ponds, and bioretention) were used in place of curb and gutter and oil-grit separators, saving an estimated $500,000 in construction costs (USEPA, 2001). Using an enhanced swale design, Seters et al (2013) demonstrated that curb and gutter was not necessary, resulting in an estimated savings of $5,500 to treat a 2000-$m^2$ section of pavement.

The difference between the life-cycle cost of vegetated swales and curb and gutter can be estimated locally by assuming a generic road cross-section design and estimating the costs of each conveyance type per linear foot of road. The life cycle cost estimates should include construction, design, engineering, and maintenance costs. RS Means (2015) provides data on the cost of curb and gutter and associated stormwater conveyance structures. These data are fairly detailed and costs can vary depending on the materials, design, and methods assumed. For example, the cost for purchasing the materials and installing concrete curbs and gutters ranges from $4.57 to $20.60 per linear foot depending on how the structure is installed, whether wood or steel forms are used, and other details (RS Means, 2015).

Recent per linear foot costs of vegetated swales are not readily available and require the development of location-specific assumptions. The development of Raleigh-specific cost estimates for curb and gutter and vegetated swales was out of scope for this white paper but could be considered in Phase 2 of this project.

In addition to the specific comparison of curb/gutter to swales, individual development designs may realize cost savings from green infrastructure through the reduced size of culverts, pipes, and other components of the stormwater conveyance system. This cost savings is often site-specific, but can be estimated at the planning-level when both a conventional and green infrastructure site design have been developed. Such an analysis may also be considered for Phase 2.

6.0 REDUCED ENERGY USE AND HEAT ISLAND EFFECT

Green space helps lower ambient air temperatures and, when incorporated on and around buildings, helps shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. In addition, diverting stormwater from wastewater collection, conveyance, and treatment systems reduces the amount of energy needed to pump and treat the water. Reduced energy demands in buildings, and increased carbon sequestration by added vegetation also result in reduced carbon dioxide emissions, a benefit discussed in the next section.

In the U.S., the increase in air temperature due to heat island effect is responsible for 5 to 10 percent of urban peak electric demand for air conditioning use, and as much as 20 percent of population-weighted smog concentrations in urban areas (Akbari 2001). Trees and other vegetation planted near buildings and pavement can affect energy consumption by shading, providing evaporative cooling, and blocking winter winds. Green roofs and bio-retention areas also reduce the amount of heat absorbing materials and emit water vapor, all of which cool hot air and reduce the urban heat island effect. In addition to energy savings, reducing the heat island effect also can reduce the number of extreme heat days and help prevent illness and mortality due to extreme heat events.

A study in Milwaukee demonstrated that urban trees can provide a significant energy savings in summer cooling with some increase in energy demand for heating in the winter depending on the extent and location of tree shading (USDA 2008b). Accounting for the increase in heating costs, trees in Milwaukee were estimated to reduce overall energy related costs from residential buildings by $864,000 annually (USDA 2008b).

Green roofs have insulating effects that can reduce the penetration of summer heat and the escape of interior heat in winter (Banting 2005). Green roof vegetation can provide important evaporative cooling effects that decrease energy needed for cooling during the summer. A study of Chicago found that green roofs can lower heating and cooling demands up to 30 percent (Gilligan 2005; ***Figure*** 6-1). These reduced energy demands in buildings result in energy savings for households and businesses and a decrease in the region’s carbon footprint. Gillagan (2005) also demonstrated that mature tree canopy can reduce air temperatures by about 5 to 10 degrees F through mitigating the heat island effect and lowering the temperature in nearby buildings.

Figure 6-1. Green roof on Chicago City Hall
Source: Conservation Design Forum
[CC BY-SA 4.0 (http://creativecommons.org/licenses/by-sa/4.0)],
via Wikimedia Commons.

Figure 6-2 Green roof at WakeMed in Raleigh
Source: Leslie Herndon, Greenscape Inc.

Green roof benefits depend on a variety of factors, including soil media depth, species, and climate. Green roof applications in the North Carolina piedmont have seen less success in vegetation growth compared to the green roofs studied in Gillagan (2005). For example, ***Figure 5-2*** shows the vegetation growth on an established green roof within the City of Raleigh. While energy savings from green roofs has not yet been studied in North Carolina, it is likely that the benefits would be less than those measured in Gillagan (2005) due to differences in climate and success of vegetation growth. Research on successful green roof species is ongoing and may result in identification of more successful green roof species for the piedmont's climate in the future. Green roofs if deeper soil media are also likely to provide greater heating and cooling benefits due to the temperature regulating properties of soil.

USDA's i-Tree tool suite (http://www.itreetools.org/eco/overview.php) can be used to calculate the energy saving benefits of trees used in green infrastructure. The science-based, peer-reviewed tools are adaptations of the Urban Forest Effects (UFORE) model, developed by USDA (2008a,b). These tools provides other TBL calculations which are discussed in later sections.

Tetra Tech used the i-Tree Design tool to demonstrate the potential energy savings from using trees in green infrastructure. The growth of four white oak saplings (6-inch diameter at breast height assumed) were simulated next to a house in the North Carolina piedmont. One tree was placed on each side of the house at about a 20-foot distance. The i-Tree Design tool estimated that these three trees would save about $1,000 in energy costs over a 20-year time period. The benefit values vary depending on the species, initial size, and placement of the tree in relation to a building. A general energy savings estimate, per tree or per square foot of green infrastructure, could be developed if these assumptions can be generalized across potential development designs.

7.0 CARBON SEQUESTRATION

Green infrastructure vegetation helps reduce the amount of atmospheric carbon dioxide through direct carbon sequestration and by reducing energy use in buildings, consequently reducing carbon dioxide emissions from fossil-fuel based power plants. In 2005, total carbon storage (in terms of atmospheric CO_2 reduced) in urban trees in the United States was approximately 2.57 billion tons, with net sequestration estimated at around 88 million tons per year of CO_2. A 2006 study found that about 15,000 street trees in

Charleston, SC, were responsible for an annual net reduction of over 1,500 tons of CO_2 worth about $1.50 per tree based on average carbon credit prices, for a total of about $2,250.92 (USEPA, 2009).

To convert to a monetary value, the reduced CO_2 estimates are multiplied by the most recent estimate of social cost of carbon published by the U.S. government's Interagency Working Group on Social Cost of Carbon (USEPA, 2015). Double counting of values may occur from reporting the social cost of carbon, which includes some consideration of energy use, along with a direct estimation of energy use differences.

The social cost of carbon (SC-CO_2) is an estimate of the economic damages associated with a small increase in carbon dioxide (CO_2) emissions, typically one metric ton, in a given year. This dollar figure also represents the value of losses or harms avoided for a small emission reduction (i.e. the benefit of a CO_2 reduction).

The 2009-2010 interagency group recommended a set of four SC-CO_2 estimates for use in regulatory analyses (Table 7-1). The first three values are based on the average SC-CO_2 from three integrated assessment models, at discount rates of 5, 3, and 2.5 percent. The discount rates account for the time value of money: the money allocated to pay costs in the future can be used for other investments in the current year, reducing the overall financial impact of the future costs compared to present costs. SC-CO_2 estimates based on several discount rates are included because the literature shows that the SC-CO_2 is highly sensitive to the discount rate and because no consensus exists on the appropriate rate to use for analyses spanning multiple generations. The fourth value is the 95th percentile of the SC-CO_2 from all three models at a 3 percent discount rate, and is intended to represent the potential for higher-than-average damages (USEPA 2015).

Table 7-1. Social Cost of CO_2, 2015-2050
(in 2014 Dollars per metric ton CO_2; Interagency Working Group on Social Cost of Carbon, 2015)

Year	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$12	$40	$62	$117
2020	$13	$47	$69	$140
2025	$16	$51	$76	$150
2030	$18	$56	$81	$170
2035	$20	$61	$87	$190
2040	$23	$67	$93	$200
2045	$26	$71	$99	$220
2050	$29	$77	$106	$240

USDA's i-Tree Design tool (http://www.itreetools.org/eco/overview.php) can be used to calculate the carbon sequestration benefits of green infrastructure with trees. As described above in Section 6.0, four white oak saplings placed next to a piedmont NC house (one on each side), provides a demonstration of the i-Tree tool output. The aforementioned 20-year scenario produced a value of $250 that represents the reduced social costs gained from the trees' carbon sequestration. The i-Tree design tool bases the carbon sequestration output on the 2010 social cost of carbon but could be updated to reflect the most recent values.

8.0 IMPROVED AIR QUALITY

Poor air quality can affect human health (e.g., cause or worsen respiratory diseases) and damage other environmental resources such as water, aquatic life, and trees. Urban trees can help improve air quality by reducing air temperature, removing pollutants from the air, and reducing energy consumption (USDA 2008b). Street trees are an example of green infrastructure that can provide this benefit (Figure 8-1).

The Milwaukee urban forest study estimated that trees and shrubs in the City remove 496 tons of air pollution annually, based on field data as well as recent pollution and weather data (USDA 2008b). This is equivalent to 74 pounds of pollution removed each year per acre of the City's tree canopy. These air quality improvements can reduce the incidence and severity of respiratory illness.

A similar study in North Carolina, found that urban forest in Mecklenburg County removes 14.9 million lbs. of air pollutants annually. Considering avoided costs associated with air quality, including respiratory illness, this reduction in air pollutants was valued at almost $40 million per year based on values developed by the State Public Service Commissions (American Forests, 2010).

If data on the removal of air pollutants by green infrastructure are available, the value of reduced air pollution can be calculated directly by using literature values on the monetized dollar per ton of pollutants reduced developed from multiple energy-decision-making studies (Nowak et al 2006). USDA's i-Tree software suite provides readily available methods for estimating the air quality benefits of green infrastructure related to tree planting. The tools require data on existing or planned trees, and then tree growth and reduction of air pollutants is simulated. The output includes the monetary value of air pollution reduced based on avoided costs from reduced public health impacts and other externalities.

Using the 20-year oak sapling demonstration as described in Sections 6.0 and 7.0, four oak trees placed on each side of a piedmont NC house result in an estimated value of $50 in improved air quality. A similar approach for monetizing air quality benefits could be used to estimate potential benefits for green infrastructure within the City of Raleigh.

Figure 8-1. Street trees in New York City

"GerritsenAvenue0004". Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:GerritsenAvenue0004.jpg#/media/File:GerritsenAvenue0004.jpg

9.0 FLOOD MITIGATION

Changes in the landscape from urban development can alter the hydrologic regime in a watershed, which is seen through increased runoff and flooding during and after storm events. Flood damage is very costly to property owners as well as cities and states. Climate change predictions indicate that extreme storm events are likely to increase in magnitude and frequency in the future, increasing the likelihood of localized flooding and other hazards (USGCRP, 2014). Green infrastructure can help mitigate flooding by capturing stormwater runoff before it becomes concentrated flow and redirecting it through retention, infiltration, and evapotranspiration of trees and other vegetation.

Medina (2011) demonstrated the long-term flood protection benefits of green infrastructure in a 13.2 square-mile southeastern U.S. watershed with 39 percent impervious surface. An investment of $330 million in green infrastructure retrofits was estimated to avoid damages of between $5 and $7 million a year, around a 40 percent savings. Savings are similar to an Illinois watershed (Johnston et al 2006) where on-site storage of stormwater reduced flood losses by $6,700 to $9,700 per acre.

Another approach to valuing flood mitigation involves the use of hedonic analysis (Section 4.0) to estimate the difference in property value across levels of flood hazard risk. In coastal Carteret County, NC Bin et al. (2008) found that location in the 100-year correlated with 7.8 percent lower property values than location outside of the floodplain. Previous studies have cited value differences of between 2 and 5 percent (CNT and American Rivers, 2010). A Raleigh-specific estimate was out-of-scope for this phase of the project but could be investigated in Phase 2. For the City of Raleigh, the value of damage avoidance (Medina, 2011) is a more feasible approach compared to property value differences (Bin et al., 2008). The property value approach would either require a local hedonic analysis or the use of Bin et al. (2008), which studied already designated floodplains; GI/LID is more likely to provide mitigation for flooding outside the 100-year floodplain. With further analysis of flood risk and available literature, it may be feasible to estimate an average value for reduction in flood damages from green infrastructure.

10.0 HABITAT

Vegetation in the urban environment provides habitat for birds, mammals, amphibians, reptiles, and insects. Even small patches of vegetation such as green roofs can provide habitat for a variety of insects and birds. During spring and fall migration, millions of birds pass through North Carolina including the Piedmont Region (Audubon North Carolina, 2014). These birds often make stopovers to find food and water. Well-planned green infrastructure that incorporates water features and native plant species can help facilitate migration through urban centers.

Green roofs have been observed to attract wild bird populations, including the green roof of the Ford Motor Company's River Rouge Assembly Plant in Dearborn, Michigan (Coffman and Davis 2005) and the large-scale green roofs at O'Hare International Airport in Chicago, Illinois. Hummingbirds, blue jays, crows, swallows, pigeons, sparrows and signs of hawks or owls have been observed on green roofs in Portland, Oregon (Liptan and Strecker 2003, Fernandez-Canero and Gonzalez-Redondo 2010).

Green space can provide habitat for other wildlife as well. A study conducted in Spartanburg, South Carolina concluded that high density of white-footed mice and the lack of invasive species suggests that urban greenways may provide suitable habitat for small mammal communities (Poarch et al. 2014). A study conducted in Melbourne, Australia suggests that amphibians often inhabit stormwater retention ponds and that incorporating certain design and vegetation features may determine habitat suitability for various species (Hamer 2012). Large scale green infrastructure, such as parks and urban forests, also help to facilitate wildlife movement and connect wildlife populations between habitats.

The public's willingness to pay (WTP) for terrestrial wildlife and aquatic habitat protection has been studied in urban locations, and literature values can be used to estimate the monetary value of habitat provided by green infrastructure under conditions similar to the study sites. Through a meta-analysis of 39 studies, Woodward and Wui (2001) suggests a public WTP for wetland habitat ranges from $100 to $1000/acre/year. Breffle et al 1998 estimated the public's willingness to pay to preserve a 5.5-acre parcel of undeveloped land in Boulder, CO. Benefits considered included views, open space, and wildlife habitat, and the results were reported separately by differing household income and distance from the parcel. The resulting WTP measured ranged from $206 to $234 per acre for residents within 0.1 mile radius of the property, and WTP decreased as distance from property increased. These values included the range of ecosystem services studied, and the WTP associated with habitat alone would be expected to be lower than the whole WTP estimate.

Studies like Woodward and Wui (2001) and Breffle et al (1998) can be used to support the selection of an approximate monetized value for habitat provided by green infrastructure. To develop a defensible valuation estimate, it is important to define the type of green infrastructure that would provide habitat, and then identify the design assumptions for that green infrastructure. For instance, if a bioretention area is estimated to have a habitat value, assumptions should be developed in terms of the vegetation planted and maintained in the bioretention cell to ensure that a habitat value is applied appropriately. For example, a bioretention cell planted with one species of grass is expected to have a much lower habitat value than one planted with a diversity of species (Figure 10-1).

Figure 10-1. Bioretention area in a suburban neighborhood with a diversity of plant species.
Source: Maryland Department of Environmental Protection

11.0 MENTAL HEALTH

Studies have shown that green spaces can improve human health. Researchers have found that people with access to green space enjoy better health and lower mortality rates. Even somewhat passive contact with nature, such as viewing it from a window, can lower blood pressure and anxiety levels. While air quality benefits discussed in Section 8.0 address human respiratory health, another TBL benefit is improved mental health.

A study at Texas A&M examined how window views from a hospital room affected recovery time in surgical patients. Researchers matched patients with similar demographics and surgical procedures but different window views—one facing a brown brick wall of an adjacent building, and the other looking at a small stand of deciduous trees. Those looking at the trees had fewer negative nurses' evaluations and post-surgical complications, used weaker pain killers, and remained in the hospital a shorter time—by 8.5%—compared to patients looking at a building wall (Ulrich 1984).

Attention restorative theory postulates that exposure to nature reduces mental fatigue, with the rejuvenating effects provided by a variety of natural settings, including community parks and views of nature through windows. Wolf (1998) found that desk workers who can see nature from their desks experienced 23 percent less time off sick than those who cannot see any nature, and desk workers who can see nature also reported a greater job satisfaction.

More recently, Karden et al (2015) conducted research in Toronto, CA suggesting that people who live near a higher density of street trees perceive greater health. The respondents also reported significantly less cardio-metabolic conditions (controlling for socio-economic and demographic factors) in neighborhoods with a higher density of trees.

Relevant monetary valuations of the mental health benefits of green infrastructure were not available. However, green infrastructure designs could be given a subjective rating in terms of how well views can contribute mental health benefits. For example, green infrastructure would be rated “high” if it provides pleasing views of natural vegetation while green infrastructure or conventional development designs that do not provide these amenities would be rated “low” for this TBL benefit. Green infrastructure could also be rated in terms of how many people will be able to benefit from the views of natural vegetation.

12.0 REDUCED CRIME AND IMPROVED PUBLIC SAFETY

Research on green space and its effect on crime and public safety has been conducted throughout the U.S. and provides relevant evidence that GI and LID could contribute to reduced crime and improved public safety. A study of 98 vegetated and un-vegetated apartment buildings in Chicago showed that vegetated spaces cut crime by half and reduced litter and graffiti. Besides mitigating violence by reducing stress and anxiety, green spaces increase a neighborhood’s collective surveillance. Vegetated landscapes invite more people to use them, ensuring more surveillance that can prevent crime in outdoor spaces (Barton, 2009).

In investigating the link between green space and its effect on aggression and violence, 145 adult women were randomly assigned to architecturally identical apartment buildings but with differing degrees of green space. The levels of aggression and violence were significantly lower among the women who had some nearby nature outside their apartments than those who lived with no green space (Kuo 2001b). The stress reduction effects of trees are likely to also have the effect of reducing road rage and improving the attention of drivers (Wolf 1998; Kuo 2001a). In a Portland, Oregon study, Donovan and Prestemon (2012) found that smaller, view-obstructing trees are associated with increased crime, whereas larger, canopy trees are associated with reduced crime.

Relevant literature values for monetized benefits of reduced crime due to green infrastructure were not available. Similar to the suggested approach in Section 11.0, green infrastructure designs could be given a subjective rating in terms of how the vegetation is designed and maintained to reduce crime and improve public safety. For example, green infrastructure that will eventually provide canopy trees or well-maintained landscaping (non-view obstructing) could be rated “high” in terms of its contribution to public safety while green infrastructure or conventional development designs that do not provide these amenities would be rated “low” for this TBL benefit.

13.0 CONCLUSION

The available literature provides a strong case for the economic, social, and environmental benefits of green infrastructure within the City of Raleigh. Local studies were available on several TBL benefits, including a property value study (Henderson 2005) that observed about a 2 percent increase in property value due to public open space. The U.S. EPA North Carolina campus in Research Triangle Park experienced $500,000 in construction costs saved by using green infrastructure (USEPA, 2001), and in Mecklenburg County, air quality benefits from the urban forest represent nearly $40 million dollars in avoided costs relating to respiratory illness and other externalities (American Forests, 2010). A demonstration of the i-Tree tool suite estimates that four trees on single-family residential lot in the NC piedmont can provide a total of $1300 in TBL benefits, reflecting energy savings, reduced social cost of carbon, and air quality benefits over 20 years (Sections 6.0 through 8.0). The benefits discussed represent examples that have readily available information and are relevant to the City of Raleigh. Appendix A provides a broader list of benefits that can be associated with green infrastructure.

The monetary valuation of TBL benefits can be a useful tool in evaluating green infrastructure for use on a development site. With the careful development of assumptions, “per unit” monetized values can be developed that are relevant across a wide variety of designs. This white paper briefly discussed the feasibility of monetizing each TBL benefit. For some TBL benefits, available information might not to be defensible to City of Raleigh stakeholders based a number of factors, including political views, perceptions, and lack of local or relevant studies. For other TBL benefits, available information might present a readily defensible case for additional green infrastructure benefits. Prior to selecting TBL benefits to monetize as part of a cost-effectiveness tool, it will be important for the City of Raleigh, with Tetra Tech’ support, to consider the defensibility of each TBL benefit and select those benefits that will have the best overall support in terms of available literature and stakeholder acceptance.

When monetizing multiple benefits, it is also important to avoid double counting values by using two different methods to calculate the same or similar benefit. For example, increase in property values due to green infrastructure could represent several benefits, including quality of life, scenic views, habitat, mental health, and public safety. If increased property value is used as a monetized TBL benefit in a cost-effectiveness tool, it will be important to evaluate whether that value represents other TBL benefits, like habitat, that are being estimated separately.

With defensibility and double-counting addressed, monetized TBL estimates can help the City of Raleigh and interested developers identify green infrastructure designs that provide multiple benefits beyond water quality and quantity. Tetra Tech’s subsequent memorandum discusses how TBL benefit information could be incorporated into a GI/LID cost benefit tool and how the calculations would benefit developers, the city, and the public.

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APPENDIX A: TBL BENEFITS UNIVERSE

Table A-1. Universe of Green Infrastructure Triple Bottom Line Benefits (Wallace, 2012; USEPA 2013)

Potential Green Infrastructure Benefits
Environmental
Improved Air Quality
Improved Water Quality
Increased Groundwater Recharge
Increased Carbon Sequestration
Reduced Greenhouse Gas Emissions
Wildlife Habitat
Improved Human Health
Reduced Urban Heat Stress
Reduced Sewer Overflow
Reduced flash flooding frequency/magnitude
Energy savings from reduced heating and cooling
Water supply conservation
Economic/Financial
Job Creation
Increased Property Value
Economic Development generated from Environmental and Social Green Infrastructure Benefits
Reduced Infrastructure Costs
Social
Improved Aesthetics
Enhanced Sense of Community
Reduced Crime and Increased Public Safety
Public Education
Increased Recreational Opportunities

APPENDIX II GI/LIDCOST-BENEFIT TOOL CONCEPT

Green Infrastructure/ Low Impact Development

Cost-Benefit Tool Concept

Source: Leslie Herndon, Greenscape, Inc. (left) City of Raleigh-Stormwater Management Division (right)

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EXECUTIVE SUMMARY

The City of Raleigh and its partners are considering the development of a spreadsheet tool to estimate life cycle costs and benefits of green infrastructure (GI) and low impact development (LID). This Cost-Benefit tool would facilitate the City of Raleigh's advancement of GI/LID throughout the City's programs and practices. Among the defining features of GI/LID are the additional benefits, or co-benefits, that contribute to the public's well-being, the local economy, and the natural environment. The tool would interact with existing stormwater performance tools and provide cost and co-benefit estimates with relatively simple user inputs. A summary report would provide a comparison across scenarios. The tool design would also allow for user-defined costs and updates to fit changing needs and priorities.

From the City's perspective, the GI/LID Cost-Benefit tool can play a role during every stage of the development process. Once a developer begins the design review process, the tool would function to promote the consideration of GI/LID in the design. The City could promote the use of the tool throughout the process. The City could also use the tool to run example scenarios that demonstrate how GI/LID can be incorporated or apply the tool to the City's own development planning and design. If the City offers GI/LID incentives in the future, the tool could be used to measure credits for those incentives.

A GI/LID cost-benefit tool would present valuable new information relevant to a developer's bottom line. The cost estimating component would likely benefit most developers, while the co-benefit component would directly benefit the subset of developers who market their projects as sustainable (e.g., LEED certification). The tool can help facilitate the flow of information to other developers and increase the volume of sustainable development practices including GI/LID.

The public stands to benefit from a GI/LID cost-benefit tool through more efficient, informed decision-making, direct access to data, and the economic, social, and environmental benefits associated with GI/LID. Ultimately, when the public asks "How much does it cost?" and "How will it benefit me?" the tool will help provide those answers.

This memorandum describes the proposed concept of the tool, including basic design features and proposed uses. To ensure the tools success, the tool design would involve collaboration among the City, developers, and tool developers. The design process would include formation of a technical committee, peer review of cost data, City staff training, designation of a tool administrator, and a plan for data updates and maintenance.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
GI	Green Infrastructure
LID	Low Impact Development
TBL	Triple Bottom Line
USEPA	U.S. Environmental Protection Agency
USGBC	U.S. Green Building Council
USGCRP	U.S. Global Change Research Program

1.0 INTRODUCTION

The City of Raleigh is exploring ways to advance the use of green infrastructure (GI) and low impact development (LID) throughout the City's programs and practices. GI, as it relates to stormwater management, involves the use of existing landscape features and additional structural and non-structural practices to control and treat stormwater as close to the source as possible. The application of LID often involves GI practices. LID seeks to maintain pre-development hydrology on developed land to provide flood control, water quality, groundwater recharge, stream base flow, stream channel protection, and ecological integrity, among other benefits. Both approaches (GI/LID) treat stormwater runoff as a resource to be incorporated into the urban environment.

Among the defining features of GI/LID are the additional benefits, or co-benefits, beyond stormwater regulatory goals, that contribute to the public's well-being, the local economy, and the natural environment. While co-benefits can be estimated for any stormwater infrastructure, GI/LID tends to offer the greatest number and value of co-benefits. Literature values for GI/LID co-benefits are discussed in detail in the Raleigh GI/LID Triple Bottom Line White Paper (Tetra Tech, 2016).

In late 2013, in response to City Council direction and recommendations of the City's Stormwater Management Advisory Commission (SMAC), City staff began a process for developing a plan for advancing green infrastructure (GI) and low impact development (LID) in Raleigh. The City retained consulting firm Tetra Tech to facilitate staff work sessions, share their national experience assisting other communities with GI/LID implementation, and provide technical services to advance GI/LID in Raleigh. In November 2013 an internal City staff Task Force was formed to support scoping for advancing GI/LID in Raleigh.

The Task Force then identified 60 challenges to implementing GI/LID and prioritized which challenges to address in Tetra Tech's work plan. City staff and Tetra Tech also obtained feedback from separate focus group meetings with representatives of SMAC, a homebuilders' association, a citizen's advocacy group, and an environmental advocacy group. Based on this input, the development of an LID cost-effectiveness tool was one of the highest-priority work items identified by the Task Force and other stakeholders.

Among the challenges to using GI/LID, the lack of local, reliable cost data may prevent developers and other interested parties from seriously considering GI/LID opportunities on development sites. Costs of more conventional stormwater devices are better understood. Developers tend to use past development projects to develop cost estimates, and they are unlikely to have cost data on GI/LID if they have not yet implemented it. The City can address this challenge by providing reliable GI/LID cost data and a tool that facilitates the cost calculations.

The term "cost-effectiveness" was originally used to describe the potential tool. Tetra Tech is recommending the term "cost-benefit" instead based on recent discussions with City stormwater staff. Cost-effectiveness is measured by a ratio of cost to a particular benefit, like pollutant load reduced ($ per lbs Total Nitrogen reduced). City staff has indicated that design scenarios would most likely be compared in terms of total costs because both scenarios must meet the same pollutant load reductions and hydrology requirements. The tool's benefit component would report co-benefit monetary values or other measures in addition to the regulatory requirements.

The City of Raleigh and Tetra Tech formed an Implementation Workgroup to provide feedback as the City and Tetra Tech make progress on a proposed cost-benefit tool among other project work items. The Implementation Workgroup has met twice since the project kick-off. During the first meeting, Tetra Tech reviewed and described the publically available tools that calculate a variety of GI/LID cost and benefit values. ***Table 1-1*** summarizes the outputs provided by each of these tools (the tool names are hyperlinked to websites for more information). The outputs include hydrology and water quality performance, cost estimates, and quantified co-benefits (either monetary benefits or other quantifiable metrics). While several tools provided a variety of outputs, no one tool produced the full suite of outputs considered.

Tetra Tech discussed how the tools varied in terms of functionality and discussed the pros and cons of each tool. The workgroup identified Storm-EZ and Jordan Nutrient Loading Accounting Tool as existing tools that provide hydrology and water quality outputs. In general, the group recommended that Tetra Tech investigate tool options that would use one or both of these existing platforms. The proposed tool would involve the addition of cost estimate and co-benefit calculation components in addition to the existing hydrology and water quality calculations. The workgroup also indicated that the tool was more likely to be used by stormwater professionals, either representing the City or developers, and for this reason, they preferred a spreadsheet format over an on-line format.

Table 1-1. Outputs provided by Publically Available GI/LID Cost and Benefit Tools

Tool Name	Cost		Nutrients	Hydrology	Sediment	Ecological/Other Benefits
Storm-EZ				X	X	
Jordan Nutrient Loading Accounting Tool			X	X		
Upper Neuse Site Evaluation Tool (SET)	X		X	X	X	
SUSTAIN	X		X	X	X	
WERF BMP Cost Tools	X					
CNT's Green Values® Calculator	X			X		X
NRDC Calculator	X			X	X	X
USDA i-Tree Software Suite						X

During the second Implementation Workgroup meeting, Tetra Tech reviewed available literature values for GI/LID co-benefits and presented several example "screen shots" of a potential tool. The workgroup requested that Tetra Tech define in more detail how the tool would be used by the City and developers. Some members raised the concern that stormwater design tends to occur late in the development planning process, and developers would be unlikely to change development layout and incorporate LID at this stage, even if it offered lower construction costs compared to conventional.

The proposed tool concept described in this memorandum considers how the tool would be used within the development planning process and draws from the workgroup's feedback, including ideas for the format of the tool and its components. A conceptual design of the tool is described upfront, and then the later sections describe how the tool would be used and how it would benefit the City, developers, and the public. Finally, key elements for success in tool development and implementation are discussed.

2.0 WHAT WOULD THE TOOL LOOK LIKE?

Preliminary feedback from the Implementation Workgroup led Tetra Tech to explore options for a tool that would take advantage of existing hydrology and water quality tools and focus on facilitating calculations for stormwater professionals. Tetra Tech proposes that the cost-benefit tool would have the following characteristics:

- **Excel spreadsheet-based**[1] – The tool would be developed as an MS Excel file, either as part of an existing tool or as a stand-alone file.
- **Ability to interact with the Storm-EZ and Jordan Nutrient Loading Accounting Tool** – Several options are possible, including having the tool exist as additional spreadsheets or "tabs" in these existing tools. The cost-benefit tool could also exist as a separate file that draws output from these existing tools.
- **Calculate estimated costs from relatively simple user inputs –** Inputs may include square feet of GI/LID area, cubic feet for storage, etc. Costs reported would include upfront costs, operation and maintenance costs, and life-cycle costs.
- **Optional component for calculating co-benefits of GI/LID** – As discussed further in this memo, the monetary co-benefits could be "turned off" depending on a user's interest in these calculations.
- **Provide a summary report for comparison across scenarios** – The tool would provide a summary report of the estimated costs and benefits. Each development scenario would have a summary report, and these reports can be compared across the scenarios to facilitate the selection of a final design.
- **Allow user-defined costs** – Developers and other users may need help with some GI costs but not others. The tool would provide the option to enter a cost estimate for each type of GI/LID.

Spreadsheet tools are typically organized into separate sheets (tabs). Some tabs may provide background information or references, while others solicit input from the user. Results, or "output," are often provided in separate tabs. The following tabs, at a minimum are proposed for the GI/LID cost-benefit tool:

- **Info** – Introduces the tool, provides basic instructions for how to use the tool, defines the purpose of each tab, and indicates who to contact for more information.

[1] During tool development, the use of a spreadsheet format would be evaluated in more detail, considering current technology and platform options, including compatibility with mobile applications.

- **Project Input** – The user enters basic site information. Some of this information could be pulled from the Jordan Tool or Storm EZ. The user would also select which components to use (Cost, Co-benefit, of both).
- **Input Tabs** – The user enters sizing information, basic infrastructure quantities, number of trees associated with the stormwater infrastructure, and other required inputs. Co-benefit inputs can be made optional or turned on and off on the info tab.
- **Report Tab** – A sharable, printable sheet that reports the cost estimates and co-benefits results using formatted tables and graphics.

Figure 2-1 provides example illustrations of an input tab and a report tab. The list of BMPs is provided as an example and would be finalized during tool development. Common conventional stormwater devices would be included as well as GI/LID devices. While focused on achieving the above design goals, the tool would also be developed with multiple users in mind. The tool is proposed as a "living tool," that can be updated to fit changing needs and priorities.

Cost Input **Site 1**

Quantites (LF = linear feet SF = square feet CF = cubic feet)

Site Element	Input Quantity	User-Defined Unit Cost
Bioretention (SF)	210	
Permeable Pavement (SF)	410	
Greenroof (SF)	70	
Grassed Swale (LF)	65	
Rainwater Harvesting (CF)	312	

Cost-Benefit Summary Report Site 1

Cost Estimates over Project Life-Time	
Construction Costs	$565,000
Design and Engineering Costs	$141,250
Operation and Maintenance Costs over Proj	$339,000
Total Life-Cycle Costs	$1,045,250

Monetary Co-Benefits over Project Life-time	
Job Creation	$1,000
Property Value	$8,500
Air quality	$50
Carbon Sequestration	$40
Energy savings	$800
Habitat	$76
Total Monetary Benefits	$10,466

Figure 2-1. Examples of Cost-Benefit Tool Input (top) and Report Tabs (bottom)

3.0 HOW WOULD THE CITY USE THE TOOL?

City of Raleigh stormwater staff are familiar with GI/LID and consider GI/LID opportunities on a regular basis. However, the City lacks quantitative cost and benefit data on GI/LID practices that could facilitate site-level decisions. Further, a spreadsheet tool that calculates costs and benefits would help save calculation time during the site design or plan review process. The City could use the tool in many ways relating to the City's different roles as both a regulator and a developer.

As a regulator, the City could integrate the consideration and use of the tool within its stormwater design review process. The use of the tool and any recommended GI/LID practices would be voluntary for the developer. The following review steps present opportunities to introduce developers to the tool, demonstrate how it can be used, and suggest GI/LID alternatives to developers by using the tool:

- **Due Diligence:** The developer meets with multi-departmental staff to discuss the feasibility and scope of a potential site development project. The session is free and optional, and no site plans are reviewed.
- **Sketch Plan Review:** A discussion of site plan design takes place between the developer and multi-departmental staff prior to a formal site plan submittal. The developer may receive regulatory-based guidance intended to reduce future review cycles, expedite project timelines, and open lines of communication with staff. The session is optional and requires a fee.
- **Pre-Application Conference:** The developer meets with City staff to ensure that all plan submittal requirements have been met. Note: This step is optional for the developer unless required specifically by the Unified Development Ordinance (UDO).

- **Administrative Review:** As the first step in the approval process before any permits can be issued, the developer submits plans and other required documents to the City. Multi-departmental staff, including stormwater, review the plans and provide comments to the developer. When all issues are resolved, the developer receives an approval letter, with conditions of approval if necessary.
- **Final Site Review:** The developer submits more detailed plans to the City for review, which include a hard copy of the stormwater design and cost estimates. Three rounds of City comments and revisions by the developer take place, followed by an in-person meeting. Once all issues are resolved, the revised final site plan is submitted for permitting.

Considering that the City may revise these steps in the future, the City can promote the tool during any review step that involves direct communication with the developer. The tool's role would vary depending on if a developer chooses one or more of the optional in-person meetings. During the Due Diligence meeting and other steps preceding a site plan drawing, the City can provide information on how to obtain and use the tool. The City also can demonstrate the tool using a plan from another site or a hypothetical scenario.

The tool demonstration would occur as early as possible during the development review process, ideally during the sketch plan review. Even if the developer is not using the tool for this particular site, the City's use of the tool can help promote consideration of GI/LID and interest from the development community. By an input-output of real data, the tool can help "ground" the developer's concept of GI/LID in relation to more familiar approaches.

The City is currently considering options to provide incentives to developers for using GI/LID. Potential options include expedited review for development permits, reduced parking requirement for preservation of healthy, specimen trees, and cost share in priority areas. If the City decides to implement incentives in the future, credits for the incentives could be tied to the tool output. For example, a developer might receive a reduction in parking requirements if the design includes GI/LID with tree-related benefits, including air quality, carbon sequestration, and energy savings.

Within its role as a developer of GI/LID, the City implements stormwater management devices that meet regulatory requirements and provide multiple community benefits. Some past examples of GI/LID developed by the City include the Fire Station Rainwater Harvesting and Fred Fletcher Park Water Garden and Wetland projects (Figure 3-1). The use of GI/LID for City stormwater projects is expected to grow as available undeveloped land decreases and climate change leads to more extreme rainfall events. Distributed GI/LID practices that have multiple functions or fit within small spaces will help mitigate for limited available land, especially in downtown areas. GI/LID practices that help mitigate runoff at the source could be considered as alternatives to increasing storm event capacity using centralized structural solutions. Climate change predictions indicate that extreme storm events are likely to increase in magnitude and frequency in the future, increasing the likelihood of localized flooding and other hazards (USGCRP, 2014). Green infrastructure can help mitigate flooding by capturing stormwater runoff before it becomes concentrated flow and redirecting it through retention, infiltration, and evapotranspiration of trees and other vegetation.

Using the proposed cost-benefit tool, the City could test options early in the design process to determine which GI/LID practices would be more affordable and provide multiple benefits to the community. The tool could be designed with multiple development scales in mind and could even support cost and benefit estimates for larger neighborhood, watershed, or City-wide plans. Similar to the private developer process above, the tool could be used throughout the design process to test options and provide quality assurance. The calculation of co-benefits would help the City estimate how well a development is achieving its sustainability goals.

From the City's perspective, the GI/LID Cost-Benefit tool can play a role during every stage of the development process. Once a developer begins the design review process, the tool would function to promote the optional consideration of GI/LID in the design. The City would promote the voluntary use of the tool throughout the process and demonstrate its use with a different or hypothetical development site with similar characteristics. These demonstrations may occur too late for the developer to start using the tool on a current site, but they would serve to promote the consideration of GI/LID for a future site. In this way, the City can facilitate the consideration of GI/LID throughout the development process.

Figure 3-1. Examples of Past City of Raleigh GI/LID projects: Fire Station Rainwater Harvesting (left); Fred Fletcher Park Water Garden and Wetland (right). Source: City of Raleigh https://www.raleighnc.gov/home/content/PWksStormwater/Articles/CompletedProjects.html

4.0 HOW WOULD A DEVELOPER BENEFIT FROM THE TOOL?

A development's net worth depends on the timeframe for design and construction, among other factors. If new information could affect a development venture, it needs to be readily accessible and comprehensible during the design process. Developers also need a demonstration of how this new information directly affects their project. A tool raises the likelihood that developers have the information in-hand to make an informed decision about whether to implement GI/LID.

For commonly-used stormwater devices, developers tend to have cost data at their fingertips and are well-equipped to estimate planning level stormwater costs for their preliminary plans. The developers may have very little knowledge of GI/LID costs except for commonly-used devices like bioretention. The tool would provide a way of "leveling the playing field" for GI/LID and more conventional stormwater by providing a direct method for estimating costs. User defined cost could also be entered if a developer had their own cost-estimate for a particular device.

The Implementation Workgroup noted that developers typically design their stormwater system during the final phases of design. At that stage, the development layout has already been finalized and can rarely be revised. The fixed nature of the layout limits the developer's options in terms of implementing GI or LID. For example, the street layout could not be revised to minimize the use of impervious surface. Despite this limitation, the tool could help the developer test the remaining GI/LID options. Since many GI/LID practices can be integrated into small spaces, the developer could use the tool to find out how additional lots might be saved by integrating stormwater management into lots (cisterns, bioretention, etc.), buildings (green roofs, vertical bioretention, etc.), and roads (bioswales, curb bumpouts, permeable pavement, etc.).

The tool would also provide the option of considering co-benefits. Within the current real estate industry, it can be difficult to visualize why a developer would have interest in co-benefits of GI/LID. Many of the co-benefits are directed toward society, including habitat values, air quality improvement, and carbon sequestration. Even the site-level benefits, like energy savings and property value increases, would more likely benefit property owners than developers. However, some developers promote sustainable development and green building through co-benefits. One way to market green infrastructure, Leadership in Energy and Environmental Design (LEED) is an internationally-recognized green building certification system developed by the U.S. Green Building Council (USGBC). Between 2002 and 2015, over 700 LEED certified projects were completed in North Carolina, totaling nearly 80 million square feet (***Figure 4-1***; USGBCNC, 2015). Over a hundred of these developments are located in the City of Raleigh (USGBC, 2015). Developers use LEED certification to promote their development to potential buyers or renters, and a tool providing co-benefit calculations would help these developers test designs that can increase their opportunities for LEED certification.

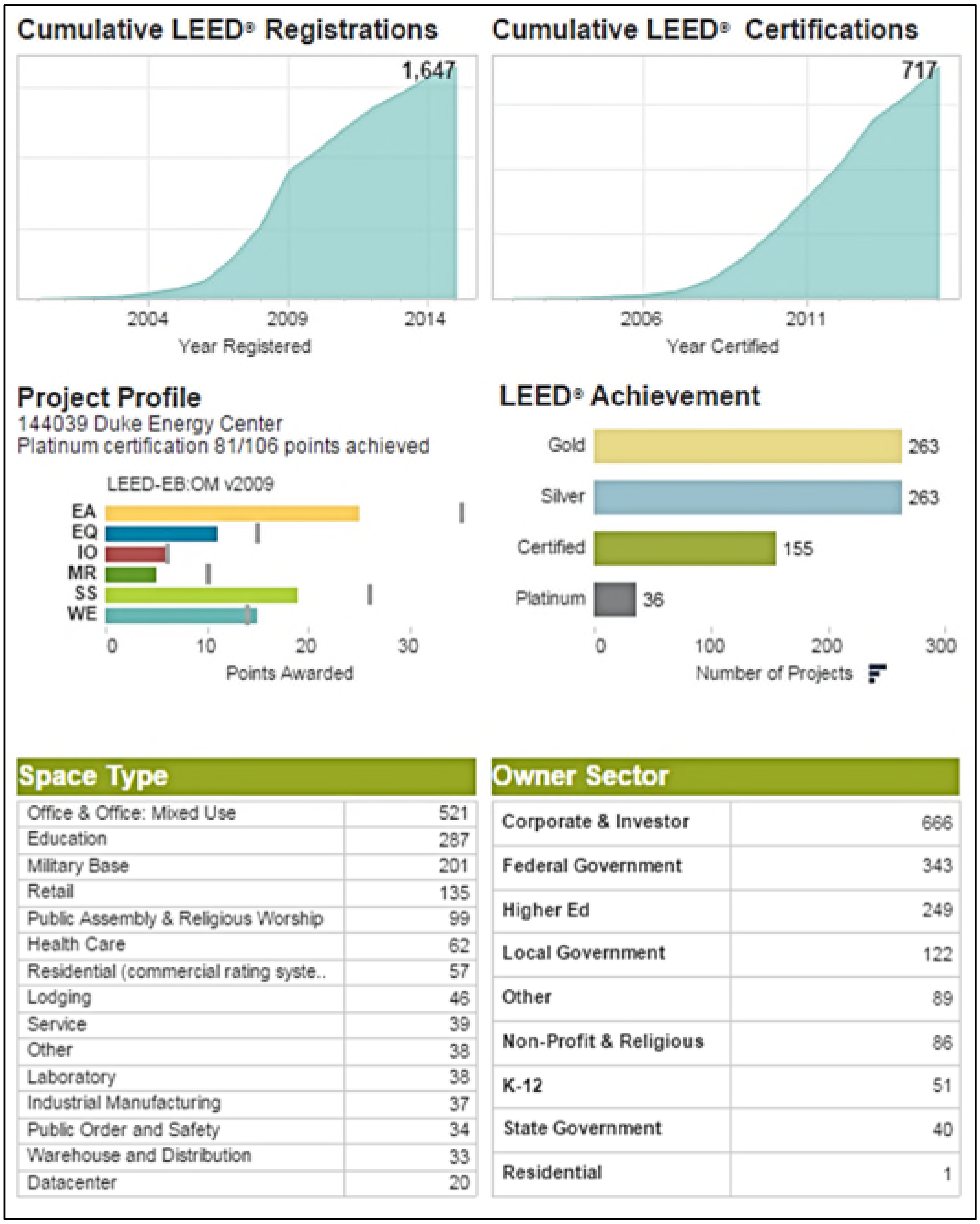

Figure 4-1. NC LEED Registrations and Certifications, excerpt from State Market Brief (USGBCNC, 2015)

While some green infrastructure receives credit through LEED building certification, the LEED neighborhood certification (LEED-ND) provides an opportunity to earn credit for a wide variety GI/LID practices. LEED-ND provides credits for water efficiency, stormwater management, heat island reduction, and site design for habitat or wetland and waterbody conservation. Since this particular certification began in 2009, two developments have received the LEED-ND certification in North Carolina: Celadon in Charlotte and East 54 in Chapel Hill. The East 54 development received the LEED-ND Gold rating and participated in the LEED-ND pilot program. East West Realty promotes the East 54's sustainable features on its website: http://www.east54.com/about.php?page=goinggreen

In general, a GI/LID cost-benefit tool would present valuable new information relevant to a developer's bottom line. The cost estimating component would likely benefit most developers, while the co-benefit component benefits developers who wish to market their projects as sustainable. The tool can help facilitate the flow of information to other developers and increase the volume of sustainable development practices including GI/LID.

5.0 HOW WOULD THE PUBLIC BENEFIT FROM THE TOOL?

The public can benefit from the cost-benefit tool in a variety of ways. Under the current development market, developers might overlook cost-effective GI/LID opportunities because the City and developers lack data to make informed decisions about costs and benefits. By helping to identify cost-effective opportunities for GI/LID, the tool would facilitate an increase in GI/LID within the City of Raleigh. New opportunities for GI/LID implementation would provide multiple economic, social, and environmental benefits to the community, as described in the GI/LID TBL White Paper. The tool may show that GI/LID is less cost-effective on some sites compared to conventional methods, or it might show that certain GI/LID practices are more cost-effective than others at a particular site. Under each of these circumstances, the tool would provide the City and developers a method for making an informed decision, which can lead to more efficient use of tax revenues as well as more secure investments in the community.

The focus of the tool, as proposed, is for use by professionals within the stormwater engineering field, either representing the City or a development company. However, other spreadsheet tools with a similar purpose and scope have been made publically available. Both the WERF tools and the UNRBA Site Evaluation Tool were available for public download. Interested residents could use the tool to test their own ideas for GI/LID at the site scale if they have a basic understanding of Excel.

Beyond single development designs, the tool could be used for broader planning efforts or for education and outreach. For example, the data could be used to compare stormwater retrofit scenarios within a watershed plan, or to inform the public of the estimated costs and benefits of capital improvement project that involves GI/LID. The inputs to the tool can be designed to be relatively scale independent so that scenarios could involve a single lot, a development, or an entire watershed. The tool data set could also be used independently for custom analysis, with the advantage that the tool's data will have been compiled, vetted, and fully documented – providing a readily available resource.

The public stands to benefit from a GI/LID cost-benefit tool through more efficient, informed decision-making, direct access to data, and the economic, social, and environmental benefits associated with GI/LID. Ultimately, when the public asks "How much does it cost?" and "How will it benefit me?," the tool will help provide those answers.

6.0 WHAT DOES THE TOOL NEED TO SUCCEED?

To succeed, the cost-benefit tool should be customized for the people who are most likely to use it, and promoted and maintained by those who will be using it on a daily basis. Several key elements for successful tool development and release are:

- **Formation of a technical committee:** This committee would include representatives of developers, stormwater design engineers, City staff, and other stakeholders. The group would meet regularly during tool development and would be involved in brainstorming tool design elements, reviewing preliminary versions of the tool, and tool testing and refinement.

- **Peer-reviewed cost data:** compiled from available local data, maybe need to be supplemented with non-local data; reviewed by technical committee and other identified peer reviewers. Well vetted – representative of ballpark, average costs.
- **Plan for training of City staff:** Since City stormwater staff will be the "ambassadors" for the tool, it will be important that they understand the major assumptions used, the degree of uncertainty in the cost and benefits data, and how to use the tool itself.
- **Designation of tool administrator:** To maintain the tool over years of use and allow for adaptation to changes in technology, real estimate markets, or other aspects, a City staff member should be designated who will train new staff on the tool, receive feedback from users, and manage periodic updates of the tool and its data.
- **Planning for data updates and maintenance**: For the most success and to allow for adaptation for changing needs, regular evaluation and updates should be scheduled and budgeted. For example, the City would conduct an annual review of tool usage and results, followed by recommendations for revisions or updates.

Overall, the tool has the greatest likelihood of success if the design and implementation steps focus on adaptability and reliability. During tool development, additional priorities may emerge as well.

7.0 SUMMARY

The GI/LID Cost-Benefit tool would facilitate the City of Raleigh's advancement of GI/LID throughout the City's programs and practices. Among the defining features of GI/LID are the additional benefits, or co-benefits, that contribute to the public's well-being, the local economy, and the natural environment. The tool would interact with existing stormwater performance tools and provide cost and co-benefit estimates with relatively simple user inputs. A summary report would provide a comparison across scenarios. The tool design would also allow for user-defined costs and updates to fit changing needs and priorities.

From the City's perspective, the GI/LID Cost-Benefit tool can play a role during every stage of the development process, including promotion of GI/LID during the initial phases, consideration of alternatives in the final review, and measuring of credits for incentives. For developers, the tool would help bridge the information gap between conventional practices and GI/LID practices and facilitate the promotion of sustainable development. The public benefits of the tool include more efficient, informed decision-making by the City and developers, direct access to data, and the economic, social, and environmental benefits associated with GI/LID.

The GI/LID Cost-Benefit tool would provide the City of Raleigh and its stakeholders with valuable information and a method to facilitate the advancement of GI/LID. The tool's design will require collaboration, stakeholder feedback, and planning for updates and maintenance to ensure the tool's success. Designed as a "living tool," the GI/LID cost benefit tool would allow the City of Raleigh to adapt to changing priorities and trends in GI/LID.

8.0 REFERENCES

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APPENDIX III GI/LID FACT SHEETS

APPENDIX IV STORMWATER BMP MAINTENANCE REVIEW AND MODEL OPTIONS MEMORANDUM

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MEMORANDUM

To:	City of Raleigh GI/LID Operations & Maintenance Focus Group
Cc:	Trevor Clements, Tetra Tech Jason Wright, Tetra Tech Heather Fisher, Tetra Tech Kevin Boyer, City of Raleigh
From:	Jonathan Smith, Tetra Tech
Date:	5-3-2016
Subject:	Review of Maintenance of City-Owned Stormwater BMPs and Maintenance Model Options

1.0 INTRODUCTION

The City of Raleigh is exploring ways to advance the use of green infrastructure (GI) and low impact development (LID) throughout the City's programs and practices. GI/LID involve the use vegetation and porous materials to treat stormwater at the source. GI/LID devices tend to have vegetation, be relatively small and distributed, and contain less structural components than more conventional stormwater devices. These elements require routine maintenance to uphold the desired performance and aesthetic quality of the device.

The City of Raleigh anticipates growth in the use of GI/LID, both through the need to meet regulatory stormwater management goals as well as through the City's efforts to remove barriers and promote the multiple benefits of GI/LID. With this growth will come a need to address widespread and long-term maintenance needs of both privately and publicly owned GI/LID devices.

The City and Tetra Tech formed an Implementation Work Group and a separate Maintenance Focus Group on GI/LID maintenance. After initial feedback from these groups, Tetra Tech reviewed the City's current approach to maintaining stormwater BMPs. Tetra Tech worked with City staff to identify where policies create uncertainty or ambiguity in the City's ability to ensure long-term function of stormwater best management practices (BMPs) including GI/LID practices. Many of the issues relate to how requirements are communicated among parties and how funding is allocated. Examples of these issues include but are not limited to:

- Unclear policy regarding the maintenance of BMP's within the right-of-way (ROW); current ROW maintenance policies are not directly applicable.
- Inconsistent policy for maintaining retrofit BMPs on City properties
- Case-by-case funding allocation for maintenance of BMPs in the ROW

Exploration of these issues provided an opportunity to evaluate the City's overall approach to BMP maintenance across all City-owned property settings. These settings, categorized as noted below, are subject to different existing maintenance protocols:

- Regulated City: BMPs on City-owned parcels covered by an approved Stormwater Management Plan
- City Retrofit: BMPs installed by the Stormwater Management Division to address existing development
- BMPs in ROW: BMPs installed in City ROW
- Non-regulated City: BMPs installed as part of green building, public education, or other initiatives

There are a variety of approaches to BMP maintenance being implemented and administered by communities across the country who struggle with the same issues that Raleigh is facing. Freehan (2013)[1] surveyed eight local governments and developed a list of "models" that described the general approach to oversight and responsibility within these programs. Tetra Tech conducted further research on these communities and interviewed staff to gain an understanding of how each community's BMP maintenance program varies in structure and organizational elements. Several broadly defined models emerged from this research relevant to BMPs on public property.

In some situations, a single local government might consider using different models for different BMP settings. For example, a distributed approach could be used for new construction BMPs on City property, while a centralized approach could be used for BMP retrofits on City property. A decision to adopt a particular model requires consideration of current policies and procedures and how these can be improved or transitioned to a new model. Communities often elect to use "à la carte" options that could apply to any of the broadly defined models.

The purpose of this memo is to document the City's current maintenance approaches, identify challenges, and explore potential new and revised policies for BMP maintenance with a specific focus on BMPs located on City property and in City ROWs.

2.0 BACKGROUND AND DATA GATHERING

To gain an understanding of the status of maintenance procedures for stormwater BMPs within the City, Tetra Tech reviewed relevant City policies. Tetra Tech worked with City staff to identify the most pertinent ordinances and policies, and narrowed the focus to the following policies, ordinances, and standards:

Division II – Code of General Ordinances

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[1] Freehan, Caitlin. 2013. A Survey of Green Infrastructure Maintenance Programs in the United States. 2013 Hixon Fellowship Final Report. Accessed March 2016. http://hixon.yale.edu/sites/default/files/files/fellows/paper/feehan_hixonpaper20131.pdf

- Part 10A Unified Development Ordinance
  - Chapter 9 Natural Resource Protection
    Article 9.2 Stormwater Management
- City of Raleigh Street Design Manual
- City of Raleigh Stormwater Management Design Manual
- Example Stormwater Operations and Maintenance Manual
- NC DEMLR Stormwater BMP Manual

Other documents consulted in this process included:

- Managing Stormwater in Your Community: Developing a Maintenance Program. 2008. Center for Watershed Protection. Ellicott City, MD
- Elements of a Green Infrastructure Maintenance Business Plan: A Stakeholder-Driven Process to Determine the Preferred Approach to Green Infrastructure Maintenance in Southeast Wisconsin. 2015. US-EPA 832-R-15-005.

After the initial policy and procedures review, Tetra Tech interviewed a number of City staff and external stakeholders to assess current application of policy and understand informal policies. City staff interviewees represented a variety of departments with stakes in funding, implementation, and tracking of maintenance and/or long-term BMP performance validation. An external maintenance provider also was interviewed to better understand the impact of City maintenance policies on the services provided by the private sector.

The following individuals were interviewed:

- Ivan Dickey Parks, Recreation, and Cultural Resources Department: Parks Department
- Steve Halsey Public Works Department: Transportation Field Services
- George Nance Public Works: Transportation Field Services
- Susan Locklear Public Works: Stormwater Management
- Rebecca Ferres Public Works: Stormwater Management
- Mark Senior Public Works: Stormwater Management
- Leslie Herndon Greenscape Inc.: private maintenance vendor

In addition, information was collected via informal discussions with other City staff during Work Group and Focus Group meetings and via email and phone discussions to develop understanding of policies and less formal processes and to help identify challenges the City is facing or soon will be facing. The findings are summarized in the next section.

3.0 SUMMARY OF CURRENT BMP MAINTENANCE PRACTICES

The City has regulations, policies, and procedures in place to address maintenance for both conventional and GI/LID stormwater devices. Maintenance responsibilities vary depending on the owner of the device and whether it was required by stormwater regulations. The City also operates a stormwater utility that is funded through user fees. Stormwater utility funds are currently used to maintain the larger stormwater drainage system and for construction and maintenance of retrofit stormwater treatment.

An important factor impacting application and adoption of maintenance procedures is the wide variety of physical and regulatory settings in which the BMP's are placed. To facilitate discussions of maintenance policy, it is useful to categorize these settings for later reference as maintenance procedures and policies are further explored. The BMP settings are:

- Regulated BMPs on private property
- Regulated BMPs on City property
- Retrofit BMPs installed by the City
- BMPs in City row
- Non-regulated BMPs on private property
- Non-regulated BMPs on City property

The policy review and interviews identified differing approaches and challenges within each of these settings. The findings are further in the following subsections.

3.1 BMPS ON CITY-OWNED PROPERTIES

Regulated BMPs on City-Owned Properties

Development projects constructed on City property are subject to the same stormwater requirements as private development and therefore often regularly include stormwater BMPs as a part of an approved Stormwater Management Plan. Under current City policy the City entity that manages the property generally is responsible for maintaining these 'regulated' BMPs. For example, if the Fire Department builds new station that includes regulated BMPs, then the Fire Department is responsible for funding and implementing the maintenance of those BMPs. Some City departments use private contractors for BMP maintenance.

The greatest challenge has been that BMP maintenance on City property has been difficult to enforce and manage for quality and consistency. Communication across multiple departments and complicated funding mechanisms, or lack of funding transfer to responsible parties, can hinder the effectiveness of maintenance and inspections. Possible solutions include 1) adding procedures that improve communication across and within departments and 2) having the Stormwater Management Division take responsibility for maintaining all BMPs on City properties.

Challenges:

- How does the City assure quality maintenance across multiple departments?
- How does the City facilitate the availability of adequate funding across the responsible departments?

Retrofit BMPs Installed by the City

The City Stormwater Management Division has and continues to occasionally retrofit stormwater BMPs on City property to reduce stormwater impacts from existing development. These practices are not required by City code and are not subject to current maintenance policies. No formal policy has been developed to established responsibility for retrofit BMPs, and responsibility for maintenance varies on a case-by-case basis. For example maintenance responsibility for a stormwater treatment wetland installed at Fred Fletcher Park is divided between the Stormwater Management Division and the Parks, Recreation, and Cultural Resources Department. The Stormwater Management Division maintains structural components such as the embankment, inlet, and riser outlet while the Parks, Recreation, and Cultural Resources Department maintains vegetation by regular mowing and controlling invasive species.

Figure 1 Fred Fletcher Park Wetland

This category also includes BMP retrofits on private property. The City operates a cost-share program by which property owners can apply to implement a BMP retrofit on their property. Property owners maintain these BMPs for at least 10 years. BMP retrofits on private property represent a relatively small subset of retrofits at this time.

The City likely will implement a wider variety of BMP retrofits in the future as a part of efforts to restore impaired streams. As types of green infrastructure continue to diversify, and many less-structural options are available, a more formal policy could help ensure that retrofits are properly maintained. The current approach does not specifically address less-structural stormwater BMPs.

Challenges:

- What should the City's approach be for nonstructural retrofits?
- The City lacks a formal policy. Should a more formal policy be established, and what would it look like?

BMPs in City ROW

Only a few stormwater practices have been installed within the City's ROWs. One example is the curbside bioretention on Pullen Drive. The Parks, Recreation, and Cultural Resources Department maintains this BMP. Several projects now in planning or design include GI/LID in the public ROW and, as road-widening projects continue and interest in GI/LID grows, the City is likely to have a much greater number of GI/LID devices in the ROW in the future.

Figure 2 Pullen Road Curbside Planter Box/Bioretention

In discussions with Tetra Tech, the City identified several specific maintenance issues within ROWs. Snow plows have been found to damage curb bumpouts. Taller vegetation, such as shrubs, may help alert snowplow drivers to the location of the bumpouts. The City has noted this issue as a cost for maintaining curb bumpouts. City staff also noted that when roads are repaved, the new pavement can either be placed on top of the old pavement (top dressed) or be milled so that the original road elevation is maintained. If top dressing occurs, the pavement eventually becomes significantly higher than the gutter elevation. Top dressing can cause a number of issues, including a disruption in the functionality of permeable pavement. The City is moving toward milling more often than top dressing, which will help mitigate this concern.

The City has not established a formal or informal policy regarding BMPs in ROWs. However, maintenance of common ROW features is informally assigned to three departments as follows:

- **Vegetation**: per standard operating procedure 700-13, Parks, Recreation, and Cultural Resources is responsible for vegetation in the ROW, including medians of divided highways.

- **Stormwater conveyance** (culverts, ditches, catch basins): Transportation Field Services
- **Asphalt and concrete**: Transportation Field Services
- **Sidewalk and verge in residential settings**: Adjacent property owner

For curb bumpouts in the ROW of residential developments, if a curb is continuous, the property owner is responsible for maintenance. If the curb bumpout includes curb cuts, the City maintains it. Note that these responsibilities are not formalized via a memorandum of understanding (MOU), agreement, or other policy document.

The above-described division of responsibilities could be used as a starting point for a stormwater practices maintenance program for the ROW. For example, vegetation maintenance for ROW bioretention could be formally delegated to the Parks, Recreation, and Cultural Resources Department. Similar to the challenge for BMPs on City property, the program would need to address how effectiveness could be achieved across multiple departments, with considerations for training, day-to-day communication, and funding.

Challenges:

- How does the City assure quality maintenance across multiple departments?
- How does the City facilitate the availability of adequate funding across the responsible departments?
- Should the City establish a formal policy for these procedures and what should it look like?

Non-Regulated BMPs on Public Property

Public entities also incorporate GI/LID into developments toward non-regulatory goals such as green building certification (e.g., LEED). The City does not have a policy or program in place for maintaining these BMPs. Maintaining GI/LID practices helps ensure that LEED certifications remain active.

The Stormwater Management Division could play an education role, sharing information on maintenance with other departments or public entities. In some cases, managers of public green building properties may not be aware of how maintenance of GI/LID devices can affect their performance in terms of water quality and hydrology benefits.

Challenge:

- How can the City play a role in educating City property owners/managers about maintaining non-regulated BMPs?

3.2 BMPS ON PRIVATE PROPERTY

Regulated BMPs on Private Property

Over the past several decades the City has adopted stormwater ordinances to address flooding and water quality concerns. These ordinances often require that structural stormwater practices be implemented with new development and redevelopment. As these ordinances have evolved, BMP types have expanded from simple peak flow detention basins to include a wide variety of practices that provide both peak-flow reduction and water quality improvement. "Regulated BMPs" refers only to those BMP practices that are required by City ordinances.

Property owners are required to maintain BMPs on their properties. Article 9.2 Stormwater Management Section 9.2.2.G.1 requires that the land owner or person in possession or control of the land maintain all on-site stormwater control facilities required by the Stormwater Management Plan. Approved stormwater plans are required to include a maintenance manual and budget.

Figure 3 Bioretention in Commercial Development

Information provided to the development community on the appropriate content and format of stormwater plans currently is somewhat limited. Maintenance manuals vary widely in format, and the lack of consistency can act as an impediment. For example, Leslie Herndon at Greenscape Inc., who is hired by property owner's to maintain landscaping for GI/LID BMPs, indicated that she has never been given a maintenance manual by a property owner or property owners' association (POA). She said that the owners typically provide a one-page scope of services for landscaping maintenance. To streamline the process, one-page scope of work could be included in each manual, ensuring that maintenance contractors receive the necessary information about required site maintenance.

For off-site facilities and all other facilities that control more than one lot, a maintenance covenant is required that specifies the responsibilities of the developer and POA and the rights of the City to access the facilities.

The City requires annual inspections of all regulated BMPs including open spaces. The inspection must be performed and a report prepared by a North Carolina professional engineer, licensed land surveyor, or licensed landscape architect.

Private property owners fund required BMP maintenance at their expense. POAs may add a fee to property assessments to cover the maintenance. The City also collects payment to the stormwater facility replacement fund at time of recording of subdivision plat or issuances of building permit. This funding is used to maintain the public stormwater infrastructure system (culverts, conveyance, etc.) serving the development.

The City noted that property owner education is necessary for existing developments from time to time. Notably, residents in older developments have filled in swales, lacking knowledge of their function as part of the drainage system.

Challenges:

- How does the City ensure quality and consistency in maintenance manuals and budgets?
- How can communication between property owners and contractors be improved? Potential solution: one-page scope as part of the maintenance manual, to be passed on to maintenance contractors.

Non-Regulated BMPs on Private Property

In recent years many private development projects throughout the country have incorporated green infrastructure practices that go beyond the minimum requirements of local stormwater regulations. Such practices may be implemented to achieve green building certificate credits (e.g. LEED), or as part of a green marketing approach for commercial or residential projects. While such practices might be included in an approved Stormwater Management Plan, in certain situations they may not be included. In such cases, the property owner is not required to comply with any city maintenance policies or inspections related to the BMPs. Nonetheless these BMPs may represent an opportunity to protect the City's water resources, and it may be in the city's interest that proper maintenance is performed. The City could leverage its information and resources to educate property owners on effective BMP maintenance.

Under LEED certifications, the U.S. Green Building Council does not require recertification for new development. However, LEED-certified developments are randomly selected for audits that can revoke certification if credits are not maintained, so property owners do have an incentive to maintain GI/LID components that are part of a LEED certification. For retrofits of existing development with LEED certification, USGBC requires recertification every 5 years, which provides further incentive for maintenance.

Challenge:

- How can the City play a role in educating private property owners about maintenance for non-regulated BMPs?

3.3 SUMMARY OF CURRENT BMP MAINTENANCE PRACTICES

Review of the City's maintenance of stormwater BMPs identified several major challenges within each development setting. Many of these challenges relate to how requirements are communicated between parties and how responsible parties plan for funding availability. Some settings shared common challenges. While different departments may be involved in ROW BMPs, City property settings shared general challenges in terms of consistency and funding. Challenges for non-regulated settings were also similar in terms of the City's educational role. Challenges across all settings are:

Regulated BMPs on City Property (non-ROW and ROW):

- How does the City assure quality maintenance across multiple departments?
- How does the City facilitate the availability of adequate funding across the responsible departments?
- Should the City establish a formal policy for these procedures, and what should it look like?

Retrofit BMPs Installed by City:

- What should the City's approach be for nonstructural retrofits?
- Should the City establish a formal policy, and what would it look like?

Regulated BMPs on Private Property:

- How does the City ensure quality and consistency in maintenance manuals and budgets?
- How can communication between property owners and contractors be improved?

Non-Regulated BMPs on Private or Public Property:

- How can the City play a role in educating property owners/managers about maintenance for non-regulated BMPs?

The City has reached a crossroads in terms of GI/LID maintenance where basic maintenance needs are understood, and the next steps involve strengthening processes and establishing more formal policies. Experience from other local governments can provide ideas for how the City can address these challenges. While every government is unique, lessons learned from other communities can often facilitate the improvement or development of a city's own program. Tetra Tech reviewed other municipalities' BMP maintenance programs and identified several model communities of interest, as described in the following section.

4.0 GI/LID OPERATIONS AND MAINTENANCE MODEL PROGRAMS

Tetra Tech identified approaches for the City to consider based on a review of BMP maintenance programs in other local governments. Communities' BMP maintenance programs vary in structure and organizational elements. However, several broadly defined models are used. Tetra Tech identified three models for the City to consider:

- **Central Responsibility:** The stormwater management agency is responsible for all implementation and funding of maintenance.
- **Dual Responsibility:** The parks and recreation agency is responsible for all maintenance with oversight from the stormwater management agency.
- **Distributed Responsibility:** The agency that constructs and owns the BMP is responsible for its maintenance. The stormwater management agency typically inspects and provides oversight.

In some situations, a municipality might use different models for different BMP settings. For example, a distributed approach could be used for new construction BMPs on public property, while a central approach could be used for BMP retrofits on public property. It can be appropriate to use a different model for BMPs on public versus private property.

A decision to adopt a particular model requires consideration of policies and procedures and how they can be improved or transitioned to a new model. Within each model, Appendix A, Table 1 identifies the following key program elements:

- **Funding:** Process for how resources are transferred and how costs/fees are established.
- **Policy/Execution:** Policies and procedures to be followed during planning and implementation phases.
- **Inspection:** Procedures and responsibility for inspections.

Tetra Tech also found that communities use several "à la carte" options that could apply to any of the broadly defined models (Appendix A, Table 2):

- **Increase/decrease use of contractors**: Some communities find the use of contractors to be cost-effective because it can be difficult to maintain funding for full-time staff. However, other communities have found that the public are more supportive and trusting of city workers maintaining BMPs. The use of in-house staff can provide more consistency and quality assurance if a program is well-designed and operated.

- **Develop public-private partnerships:** Several communities have experienced success with public-private partnerships. Examples include Prince George's County stormwater retrofit program and City of Philadelphia's partnership with PowerCorpsPHL.
- **Hire more specialized staff**: Adding specialized and dedicated staff can help ensure quality training, communication, and oversight (e.g., Olympia Vegetation Specialist).
- **Improve asset tracking:** Several communities emphasized the importance of the use of asset tracking software in their BMP maintenance and inspection program (Lenexa, KS; Philadelphia, PA).

Appendix B provides case studies of communities that have applied these models and used at least one of the above "à la carte" options. These communities generally have experienced challenges similar to the City of Raleigh's, and their programs are evolving. In particular, the case-study cities found challenges with maintaining enough funding to sufficiently maintain BMP functionality and provide enough oversight and communication among responsible parties.

Regardless of which department is responsible, the case studies illustrate a trend across the communities surveyed. Especially in the early stages of program development, many communities address maintenance of BMPs on public property on a case-by-case basis, and then informal policies begin to develop. The communities did not have a formal policy for maintenance of public BMPs, but they were working toward this and reviewing which procedures would be appropriate as a more formal policy. It was understood that from time to time, situations would arise that required case-by-case review of who would conduct BMP maintenance.

5.0 STAFF BMP MAINTENANCE FOCUS GROUP

Once GI/LID maintenance was initially discussed by the Implementation Work group, the City decided to form a Maintenance Focus Group to consider information in more detail and propose recommendations to the Work group. The Focus Group was composed of representatives of several City departments with roles in maintaining existing BMPs and road rights-of-way. The members were:

- Leslie Bartlebaugh
- Kevin Boyer
- Ben Brown
- Ivan Dickey
- Steve Halsey
- Blair Hinkle
- Chris Johnson
- Paul Kallam
- Richard Kelly
- Susan Locklear
- Zachary Manor
- Emily Nash
- Diane Sauer
- Wayne Schindler
- Brad Stuart

The Focus Group held two meetings. The first meeting covered the challenges identified with the City's existing BMP maintenance program and the broad maintenance program models developed from the Case Study information. The Focus Group felt that the dual responsibility model would help address their concerns about departmental responsibilities and funding. They envisioned a program in which the Stormwater Management Division would provide oversight and the Parks, Recreation, and Cultural Resources Department would conduct much of the maintenance. Tetra Tech developed a conceptual model of the Focus Groups vision, which was reviewed during the second meeting, revised, and presented to the Implementation Work Group.

The envisioned conceptual model entails several organizational charts and graphics describing how a dual responsibility maintenance program would function. The first in this series, ***Figure 4*** is an excerpt of the City of Raleigh organizational chart that represents the staff, departments, and divisions most relevant to maintaining stormwater BMPs and developing a dual responsibility maintenance program. All entities function under the City Manager's office. The Public Works Department reports to the Assistant City Manager of Services, and the Stormwater Management Division as well as transportation-related divisions are included within this hierarchy. Two entities within the Stormwater Management Division would play a major role: Stormwater Engineering and Inspections would continue to inspect BMPs on City property, and the new position of BMP Maintenance Manager would function separate from Stormwater Engineering and Inspections. The Parks, Recreation, and Cultural Resources Department reports to the Assistant City Manager of Community. Several other offices under the City Manager were included because maintenance budgeting, staffing, tracking and other processes may require their involvement: Budget and Management Services, Finance, Human Resources, and Information Technology. In addition to these entities, any department or division involved in the construction and/or maintenance of a stormwater BMP would have a role.

Tetra Tech developed a draft process for how a dual responsibility program would function across the relevant entities. ***Figure 5*** illustrates how task assignments and reporting could proceed if the Stormwater Management Division takes overall responsibility for maintenance, with support from transportation and parks entities. The BMP Maintenance Manager would assign maintenance tasks to the Stormwater Management Division's own staff and to several transportation and parks divisions. The BMP Maintenance Manager would communicate with each division's maintenance contact. Annually for each BMP, Stormwater Engineering and Inspections would inspect and provide an inspection report to the Manager. If any noncompliance issues were reported, the Manager would assign tasks needed to address the noncompliance, and Stormwater Engineering and Inspections would follow up with the Manager on the noncompliance issues until resolved.

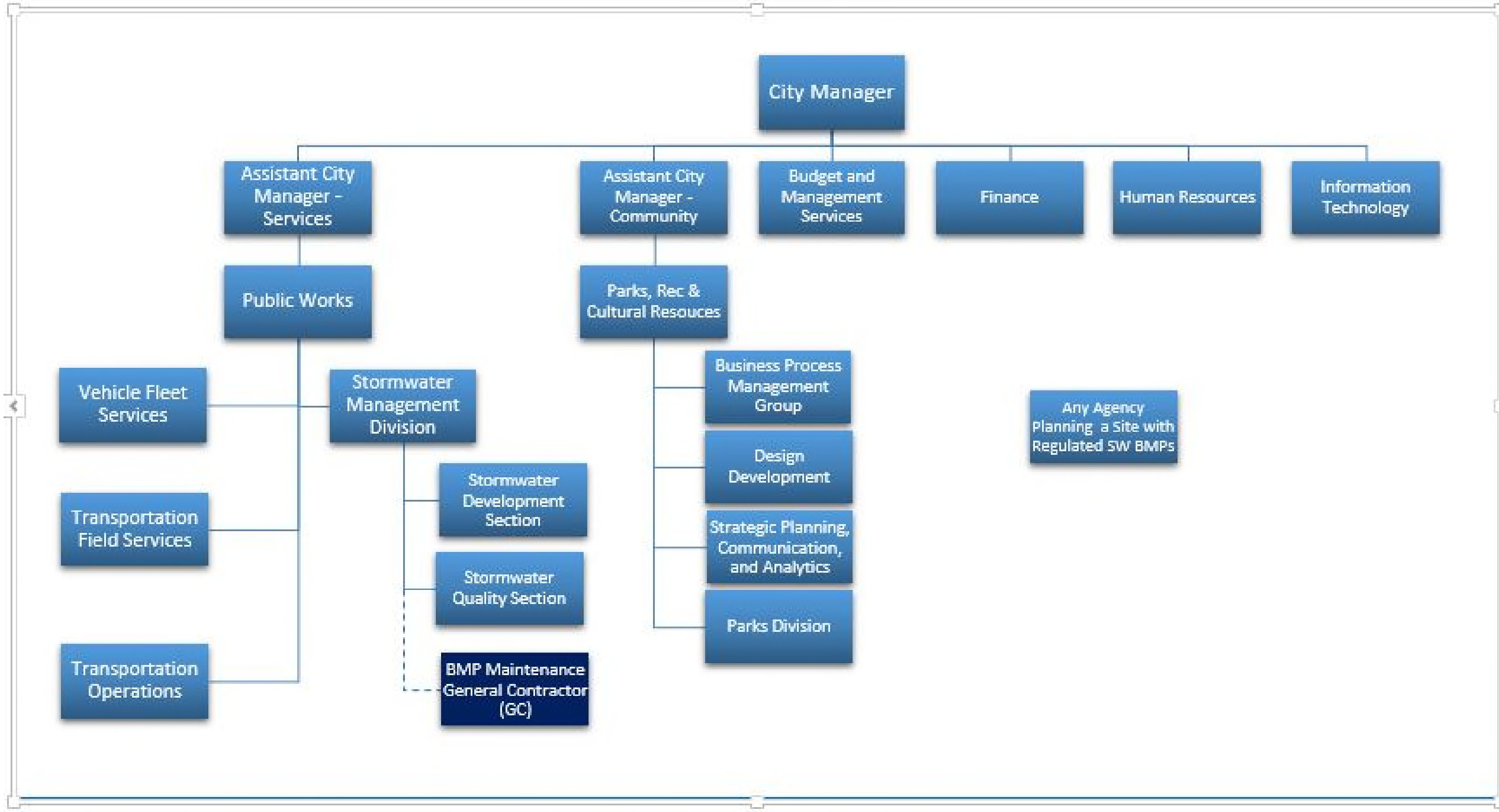

Figure 4 Overview of relevant agencies (excerpt from City of Raleigh Organizational Chart)

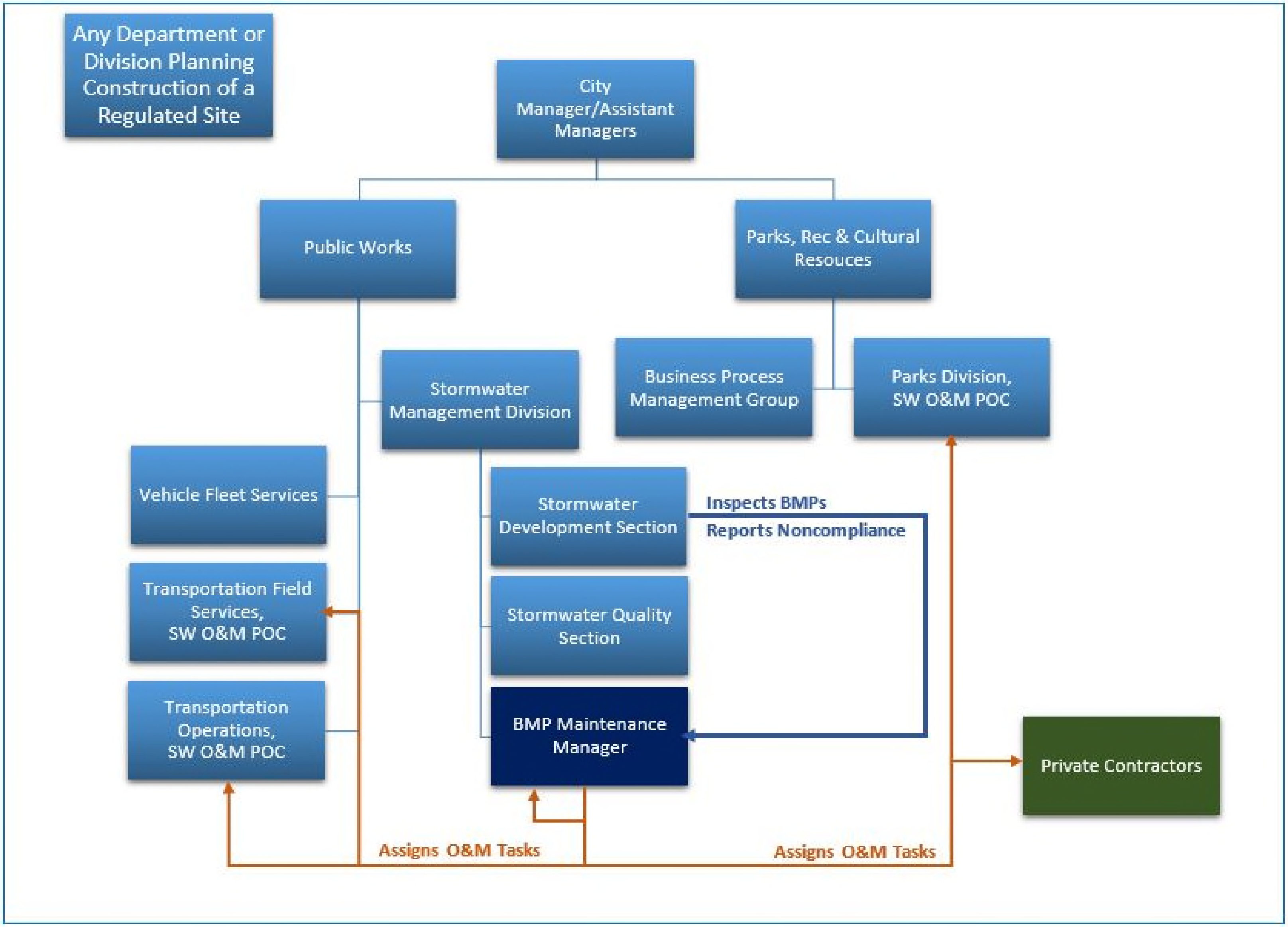

Figure 5. General Concept of Dual Responsibility O&M Operations

Tetra Tech and the Stormwater BMP Maintenance Focus Group also considered steps needed to set up a dual responsibility program. ***Figure 6*** outlines policy, funding, and staffing considerations for an effective dual responsibly program.

During **Program Set-Up**, the development of more detailed roles, policies, and procedures would help ensure an effective program. The set-up process would identify staffing needs, assign roles to current staff, and propose new positions. Memoranda of Agreement (MOAs) would outline how to manage responsibility and funding across departments. Standard Operating Procedures (SOPs) would provide detail about staff roles, procedures, and specific contact information. Documentation would also address how the BMP Maintenance Manager would distribute maintenance funds to the various divisions.

The Focus Group identified several considerations under funding. They discussed developing a separate budget line item for funding maintenance that would be funded separately from other stormwater management costs. During review of the City's current program, a concern about lack of cost estimating information was raised. Development of cost estimating guidance is included under funding considerations to address the need to accurately estimated maintenance costs and allocate adequate funding. Accordingly, the City will need a process for updating budgets and requesting additional funding as the number and variety of BMPs increase in the future.

Several staffing considerations also were identified. The major roles, discussed earlier, include the Stormwater Management Division BMP Maintenance Manager, who would oversee all BMP maintenance, and the POCs for supporting operations that would conduct on-the-ground maintenance. Current staff could be assigned these roles, or additional staff could be hired. As more BMPs are constructed, additional inspections and maintenance staff will likely be needed. Departments and divisions with stormwater BMPs also will need to plan and budget for BMP maintenance and be prepared to transfer funds to other operations that maintain the BMPs, on the ground.

Policies

- Description of purpose, goals, and objectives
- Organization: Agency/Staff roles and responsibilities, outlined in MOA and/or SOP
- Description of processes for assigning and conducting O&M
- Specific staff names and contact information
- Guidelines for task tracking procedures
- Assessment and response actions
- Links to any tracking files and/or software

Funding

- Mechanism to transfer funding for O&M outlined in MOA
- How funding will be categorized (e.g., separate line item)
- Cost estimating guidance
- Process for updating budgets and requesting additional funding

Staffing

- Stormwater Management Division "Stormwater BMP Maintenance Manager"
- O&M POCs
- Additional maintenance staff
- Additional inspection staff
- Dedicated staff time for funding and budgeting operations, planning, etc.

Figure 6. Dual Responsibility Program Set-up

6.0 CONCLUSION AND NEXT STEPS

The model programs and à la carte options outlined in Section 4 provide a template for discussing vetted next steps for the City's future maintenance of City-owned stormwater BMPs. A key consideration for discussions is which maintenance model for maintenance of BMPs on City properties (central responsibility, dual responsibility, or distributed responsibility) is most appropriate for the City given the current framework, available resources, future plans, and other considerations. Within each model, the case studies provide à la carte options to consider, including use of contractors, public-private partnerships, specialized staff, and improved asset tracking. After further discussions with the Implementation Work Group and the Stormwater BMP Maintenance Focus Group, next steps are selecting a preferred approach and developing a conceptual model for implementing the approach.

APPENDIX I: MAINTENANCE PROGRAM OPTIONS FOR BMPS ON CITY-OWNED PROPERTIES

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Maintenance Program Options for BMPs on City-Owned Properties

Common BMP settings/scenarios:

Regulated City-Owned: BMPs on City-owned parcels covered by an approved Stormwater Control Plan
City-Owned Retrofit: BMPs installed by Stormwater Management to address existing development
In ROW: BMPs installed in City or DOT ROW
Non-regulated City-Owned: BMPs installed as part of green building, public education or other initiatives

Table 1 Common Models for Maintenance: These models may be applicable for use in one or more of the common City-owned settings listed above.

MODELS & EXAMPLE COMMUNTIES	PROGRAM ELEMENT	WHAT IS NEEDED FOR RALEIGH TO APPLY THIS MODEL?
Central Responsibility: A single agency responsible for stormwater management or GI program maintains all City-owned BMPs.		
Olympia, WA Lenexa, KS Montgomery Co. , MD	Funding	• Requires transfer of maintenance resources from owning agency to the agency doing the maintenance. • Must be accompanied by the establishment of a cost basis for maintenance funding.
	Policy/Execution	• Requires formal policy for transferring maintenance responsibility to responsible agency.
	Inspection	• Stormwater Management continues/extends current inspection protocols; adjust so that different staff are maintaining versus inspecting BMPs – to ensure proper oversight.
Dual Responsibility: A single agency, typically the parks department, maintains all City-Owned BMPs, with oversight from a different agency.		
Lenexa, KS – limited, no funding transfer Montgomery Co., MD – limited New York City, NY – briefly used during first wave of bioswale implementation (CSO retrofits)	Funding	• Requires transfer of maintenance resources from owning agency to agency doing the maintenance. • Must be accompanied by the establishment of a cost basis between owning agency, Parks agency, and SW management agency.
	Policy/Execution	• Requires formal policy for transferring responsibility to responsible agency
	Inspection	• Stormwater Management continues/extends current inspection protocols.
Distributed Responsibility: City-owned BMPs are maintained by different agencies, depending on where BMPs are located (e.g., green streets maintained by Transportation Field Services).		
Charlotte, NC Durham, NC Kansas, City, MO Raleigh, NC Philadelphia, PA	Funding	• Current funding mechanisms remain as is; generally, responsible agency funds maintenance through departmental budget, drawn from the general fund/utility fund.
	Policy/Execution	• Procedures remain generally as is; communication, training, and other improvements may be considered. Policies should be developed for ROW and retrofit BMP settings.
	Inspection	• Stormwater Management continues current inspection protocol; communication, training, and other improvements may be considered.

Table 2 'à La Carte' O&M Program Options: These program options represent a range of maintenance program enhancements that the City may consider either in tandem with the maintenance models from table 1 or as stand-alone improvements.

ADDITIONAL MODEL OPTIONS	DESCRIPTION AND POTENTIAL APPLICATIONS FOR RALEIGH
Third party support	External contractor or non-profit provides maintenance with oversight from agency responsible. Currently, most maintenance on city property is outsourced except for those maintained by Parks, Recreation, and Cultural Resources. As new BMPs are built, the City may consider the use of contractors for settings in which in-house resources are not currently available. The effectiveness of third party support depends on the availability of well-trained and experienced contractors. Examples include the City of Philadelphia's partnership with non-profit PowerCorps-PHL and the Prince George's County Public-Private partnership to implement retrofit BMPs.
Hire more specialized staff	Hire more specialized and dedicated staff to help insure quality training, communication, and oversight (e.g., Olympia Vegetation Specialist). While this applies to all models, more specialized staff will likely be needed under the centralized model.
Improve planning and budgeting	Schedule meetings or use other forms of communication to ensure that responsible parties understand maintenance requirements upfront. Provide format and guidance for maintenance plans. Provide budgeting assistance when needed, including recommended unit costs or assistance with/oversight of cost estimates.
Improve asset tracking	Review current asset tracking and consider improvements to process, software, etc. The importance of asset tracking was emphasized by the Charlotte, Lenexa, and Philadelphia case studies.
Improve communication	Review and improve procedures so that specific staff are assigned to implement inspections and these staff follow-up with other specific staff members who are responsible for maintenance. Contact lists for specific staff responsible are kept up-to-date and circulated. (e.g., City of Charlotte)

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APPENDIX II: GI/LID CASE STUDY SUMMARIES

Charlotte, NC (population ~800,000 people)

The City of Charlotte has established maintenance requirements under its post-construction stormwater ordinance, adopted in 2007. Procedures for maintaining BMPs and both public and private property are outlined in the Post-Construction Ordinance, Post-Construction Ordinance Administrative Manual, and the Standard Operating Procedures (SOP) for Inspection and Maintenance of City-Owned Structural Stormwater Control Measures.

For publically owned BMPs, the City has a cross-agency coordination process by which the responsible agencies meet with the stormwater staff to discuss how required maintenance will be accomplished. Points of contact are determined for who in the responsible agency will be in charge of a particular BMP's maintenance and who within the stormwater staff will be in charge of oversight. Several meetings may take place during this initial planning phase. This process also applies to BMPs in the public ROW. Developments that were approved prior to 2007 were grandfathered, and newer transportation projects, for example, are just beginning to reach the BMP operation and maintenance stage.

CHARLOTTE, NC HIGHLIGHTS

Distributed Model

Stormwater utility funds drainage and water quality improvements.

Protocols for Maintenance on Public Property outlined in SOP.

Cross-agency coordination process helps ensure effective maintenance.

The SOP outlines which staff are responsible for inspection depending on the location of the BMP or owning department. BMPs are inspected annually.

Charlotte collects a stormwater fee to fund drainage improvements and water quality needs. The fee is made up of three components:

1. A fee set by Mecklenburg County to address drainage improvements and water quality needs of named creeks and the regulated floodplain;
2. A fee set by the City to address drainage improvements and water quality needs of unnamed tributaries, channels, pipes, catch basins and culverts;
3. A billing processing fee.

For BMPs on private property, the property owners are responsible for maintenance except for structural BMPs in single-family residential or town home developments, which the City maintains after a 2-year warranty period. In order for the City to accept the responsibility of maintenance, the residential development must have public street frontage and the stormwater BMPs must only serve the single family homes or town homes. The Post-Construction Ordinance Administrative Manual includes the operation and maintenance agreement, maintenance tasks and schedules, maintenance and inspection checklists.

Durham, NC (population ~250,000 people)

The City of Durham operates a stormwater utility, delegates maintenance to various departments for BMPs on public property, and requires private property owners to maintain BMPs. For BMPs on public properties, each department is responsible for its own maintenance. Many BMPs are maintained under the various divisions of the Public Works department, which includes the Stormwater and GIS Services Division.

The City does not have formal maintenance agreements for BMPs on public property. Inspectors designated by the Stormwater and GIS Services Division conduct the annual inspections of all BMPs on public property and send the inspections reports to the respective departments. The City is considering other approaches in order to improve success of their maintenance program. A white paper is in production that describes how a centralized approach to maintenance would be implemented and what it would cost.

BMP maintenance on private property is the responsibility of the property owner, even within the ROW. Private property owners are required to use independent contractors for inspections. The City operates their own training and certification program for inspectors. They have had some problems with inspectors allowing property owners to fix problems which are not reported in the inspection reports.

Maintenance responsibility for some BMPs is handled on a case by case basis. For example, the City has partnered with NC State University to conduct several BMP studies. In these cases, the City took over maintenance and inspections for the devices.

The funding source for maintenance varies by department. BMP maintenance performed by the Public Works department is funded by the stormwater utility. Funding for BMP maintenance in other departments, like Parks and Recreation, tends to be sourced from the General Fund.

The City has created a compliance protocol, which is currently in draft. The process includes a series of notices sent to the owner within a pre-determined schedule that communicate failure to conduct inspection, necessary repairs and other maintenance required following inspection, etc. The document also outlines procedures for enforcement.

DURHAM, NC HIGHLIGHTS

Distributed Model

The stormwater utility funds maintenance for BMPs owned by the Public Works department.

The City is currently reviewing other options for maintenance, including a more centralized approach.

The City currently has an enhanced inspection and enforcement protocol in draft form.

Olympia, WA (population ~50,000 people)

Olympia has a stormwater utility responsible for the maintenance of stormwater infrastructure and low impact development projects. All maintenance is funded through the utility by user fees. Property owners are responsible for conducting inspections and maintenance of their stormwater system each year, and submitting annual reports to the City of Olympia.

For public facilities, maintenance activities are conducted by City staff. Public BMPs are owned by Olympia's stormwater utility, including BMPs in the public right of way (ROW) along the roadside. The utility maintains these for the most part but has contracted with private landscaping companies. Olympia has two maintenance crews. The stormwater operations crews are largely responsible for structural repairs and maintenance. The City also employs a seasonal vegetation crew for 6-9 months of the year. The vegetation crew is largely responsible for bioretention BMPs.

Olympia employs a full time Senior Vegetation Specialist under the environmental services group who works with the stormwater utility to perform oversight and inspections of green infrastructure BMPs. The Senior Vegetation Specialist works directly with the stormwater operations supervisor. Olympia is currently in the process of hiring another full time position to conduct inspections. All maintenance is funded through the utility by user fees. The City is raising rates gradually as requirements for green infrastructure projects increase and more BMPs are installed. The City works closely with citizen advisory committees to ensure community involvement and stakeholder support.

OLYMPIA, WA HIGHLIGHTS

Centralized Model

All maintenance of BMPs on public property are funded by stormwater utility.

Maintenance is performed either by private landscaping contractors as well as in-house crews.

The full time Vegetation Specialist performs oversight and inspections of green infrastructure BMPs

The City is raising rates gradually as requirements for green infrastructure projects increase and more BMPs are installed.

The City works closely with citizen advisory committees to ensure community involvement and stakeholder support.

For private facilities, the requirement for maintenance is established through a recorded maintenance agreement between the facility owner and the City. This agreement requires that a maintenance program be followed, records of maintenance be retained, and an annual report be provided to the City. This agreement grants the City access to the private stormwater facilities for on-going inspection and authorizes the City to provide maintenance repair if needed (at owner cost).

Overall, Olympia emphasizes the constantly changing nature of green infrastructure and low impact development from evolving regulations to advancing technologies. The City's needs change over time and their stormwater program must have built-in flexibility to keep up with new challenges. The City meets these challenges through training, outreach and education, and continued community engagement.

Kansas City, MO (population ~470,000 people)

Kansas City does not have a dedicated stormwater utility. Maintenance for green infrastructure is provided and funded through the entity that installed it, generally the Overflow Control Program or through the Department of Public Works. Private property owners are responsible for maintenance of private BMPs, which are inspected by Kanas City Water Services. Kansas City has many challenges around green infrastructure maintenance including structure and oversight as well as funding.

The Overflow Control Program (OCP) is a commitment by KC Water Services to meet regulatory requirements, as outlined in a Consent Decree with EPA, to reduce overflows from combined sewer systems and prevent overflows from separate sewer systems. As part of this program and under the consent decree KC Water Services created a largescale stormwater management system consisting of over 150 green solutions installed within the public right of way, including rain gardens, bioretention gardens, cascades for sloped areas, porous sidewalk and permeable paver systems.

Currently, publicly-owned BMPs are maintained by the entity that installed them, unless a special Memorandum of Understanding (MOU) for maintenance is executed. Over half of the BMPs were installed by Kansas City Water Services, which operates the City's stormwater program. The City does not have a dedicated stormwater utility or regional sewer authority. Required stormwater projects are managed directly through the City and Kansas City Water Services and are funded through the overflow control program under consent decree. Public works project enhancements are paid for out of the general fund which is comprised of water and sewer rate fees, and a very small stormwater fee.

As a rule, if the BMPs are City-owned and installed by Water Services, then Water Services maintains them. If the BMPs are considered City Capital Projects and installed by Public Works, then the entity who installs the BMPs is responsible for maintenance. Most departments conduct their own maintenance, while some hire private contractors. For example, the Police Department currently contracts maintenance out to a landscaping company.

Since each department maintains their own projects, the communication between departments is minimal after construction ends. Currently there isn't any one department that

KANSAS CITY, MO HIGHLIGHTS

Distributed Model

No dedicated stormwater utility

The City's program includes 150 green solutions within the public right of way, including rain gardens, bioretention gardens, cascades for sloped areas, porous sidewalk, and permeable paver systems.

Maintenance for required stormwater projects are funded through the overflow control program.

Other BMP maintenance is paid for out of the general fund, which includes water and sewer rate fees, and a very small stormwater fee.

Kansas City has found that conducting maintenance in-house provides communities with a sense of ownership and predictability.

One of its major challenges is funding availability and public support for increased stormwater fees.

oversees maintenance of all public BMPs. However, Kansas City's Green Team is developing a sustainable project inventory as a starting point.

Kansas City has found that conducting maintenance in-house provides communities with a sense of ownership and predictability. Seeing City workers maintaining BMPs provides a greater comfort level for residents and a certain degree of transparency to projects. Contracting with private maintenance providers presents challenges related to contract administration and legal agreements.

Water Services is responsible for inspection of all publicly-owned BMPs. Vegetated BMPs are assigned service levels, which set measurable expectations for appearance, weeds and pests, and mulching and erosion at each inspection.

Figure 7 roadside Bioretention

For private developments, property owners are responsible for maintenance. Kansas City has implemented a few lot easements to facilitate inspections. Implementation depends on the relationship with the property owner. Currently, all privately-owned BMPs are inspected by Water Services' Stormwater Utility Inspector.

One of the City's major challenges is funding availability for BMP maintenance. The City has already raised sewer fees as part of their CSO correction program. The public is not likely to support additional utility fee increases.

Kansas City is currently exploring frameworks and mechanisms for a more comprehensive maintenance plan. Currently they are exploring a potential non-profit partnership that would provide green job training, similar to Philadelphia's program.

Lenexa, KS (population (~50,000 people)

LENEXA, KS HIGHLIGHTS

Centralized Model with some partnerships with Parks Department and Streets Division

Ongoing O&M is currently funded by three revenue streams: the stormwater utility, a systems development charge, and erosion and sediment permit fees.

Lenexa's Stormwater Specialist provides technical assistance to facilitate the successful installation and long-term performance of BMPs.

Lenexa's Stormwater Specialist provides technical assistance to contractors, homeowners, developers, maintenance personnel and City staff to facilitate the successful installation and long-term performance of BMPs. The City has a stormwater utility and has developed an operations budget. The City of Lenexa Municipal Services Department's Stormwater Maintenance Division is responsible for the maintenance of all public Stormwater BMPs. Additional O&M responsibilities are performed by the City's Parks Division and its Streets Division. Property owners are required to maintain privately-owned BMPs, which are inspected by the stormwater superintendent.

Ongoing O&M is currently funded by three revenue streams: the stormwater utility, a systems development charge, and erosion and sediment permit fees. Stormwater fees are based on the amount of impervious area at $7.50/Equivalent Dwelling Unit (EDU). A Capital Development Charge is also assessed on new development projects with property draining to a public facility. Erosion and sediment control fees are assessed at the time of grading and site development permits.

There are currently over 200 BMPs in place to capture pollutants from public roads and right of ways. Lenexa's stormwater maintenance crews care for green infrastructure owned by the City, including rain gardens, bioretention cells, swales, green roofs and other structures. Maintenance of this entire system is the responsibility of the stormwater group members that reside in the Municipal Services Department.

The Stormwater Maintenance Division employs the Maintenance Superintendent, as well as two crews of maintenance workers. The Stormwater Superintendent is in charge of overseeing maintenance. Lenexa currently employs 14 full-time maintenance workers, who are responsible for all long-term maintenance activities. Workers are split between grey and green crews. Crews responsible for green infrastructure receive regional training, and develop the specialized knowledge base required for maintaining BMPs.

Parks is responsible for mowing, the irrigation/water reuse system, and trash pickup for all areas not maintained by the Stormwater Division. The Streets Division maintains hard surface pathways, performing snow removal and the repair and replacement of surfaces. Currently, the Stormwater Division also partners with the Parks Division to maintain Lenexa's fire station green roof. The program also partners with volunteer groups for trash clean up watershed restoration projects, as well as general green infrastructure maintenance. The vast majority of BMP maintenance is performed by Lenexa's stormwater crews who are funded through the stormwater utility. Any assistance they receive from other departments is not funded with the utility but is just charged to their normal operating budgets.

The Stormwater Superintendent is required to inspect privately-owned BMPs under City ordinance once every three years. Property owners are mandated to maintain BMPs, and under the City ordinance crews and inspectors do have the authority to access the property for inspection.

Operation and maintenance of BMPs is tracked through the City's asset management software. The Stormwater Superintendent does monthly inspections of the City's BMPs and prepares work orders for the maintenance crews.

Montgomery County, Maryland
(Population: ~1 million people)

Montgomery County has an established stormwater utility and user fee (Water Quality Protection Charge), which provides a dedicated funding source for BMP operation and maintenance. The Water Quality Protection Charge (WQPC) is a part of Montgomery County property tax bills. The WQPC is calculated based on the potential for a property to contribute to stormwater runoff. The County raises rates to stay on pace with BMP construction.

The Stormwater Facility Maintenance Program (SWMP) is responsible for inspecting and ensuring maintenance of all public and private stormwater management facilities within Montgomery County. SWMP inspects stormwater facilities at least every three years. There are more than 7,000 stormwater facilities in the County that require inspection. Maintenance responsibilities for different types of facilities are described in the Table 1.

All maintenance is contracted out, and contractors are paid from the stormwater fund. All stormwater facility maintenance contractors working in Montgomery County are required to have a Certificate of Attendance from the Department of Environmental Protection's Stormwater Facility Maintenance Contractor Training. Once contractors have been certified, they will be placed on a list of contractors approved by the County for maintenance of stormwater facilities. However, many of the County's contractors are general contractors, and have limited experience or expertise around landscaping or vegetation management.

The County solicits contracts through invitations to bid. Currently, a 1-year contract entails 10 months of maintenance at $1800 per BMP on public property and right of ways. Generally, contracting crews consist of one foreman and 3 crew. Writing contracts is challenging, because there is a certain amount of unpredictability. It is hard to know what to expect at maintenance visits, because there are so many variables (BMP types, weather, wear and tear, damage, etc.). This makes it difficult to determine exactly how often maintenance is needed and how long the contractor will have to be on site at each BMP.

Maintenance on school and parks properties is shared with the Parks Department and schools. The Parks Department maintains BMPS on park properties and generally have the equipment and expertise to provide proper maintenance. Parks maintenance is partly funded from the County's water quality protection fund (utility).Schools on the other hand are more challenging, since stormwater BMPs are generally not a priority for groundskeepers.

MONTGOMERY COUNTY, MD

Centralized Model for structural maintenance; Distributed Model for non-structural maintenance.

All maintenance by the Stormwater Facility Maintenance Program (SWMP; mostly structural) is funded by the stormwater utility.

All SWMP maintenance is contracted out.

The County has experienced challenges with BMP maintenance along roadways and educates road crews in an effort to address this challenge.

Communication between departments is largely dependent on whether the stormwater department shares maintenance or is 100% responsible. If maintenance is shared, then they give other departments access to the maintenance database, and they stay in constant communication so they know whether maintenance is being completed. The stormwater department will push concerns up the chain in each department as is necessary to make sure that work is completed.

If the stormwater department is responsible for 100% of maintenance, then there is little communication unless there is an issue. They do always have key contacts within each department so they know who to talk with if there is an issue. When stormwater maintenance contractors or inspectors are on site doing maintenance, they always let the building or property staff know they are there (like at a school) for safety reasons and to make sure not to disrupt business. The department contacts are not always the building contacts so often they need to communicate with a lot of different people.

All of the County's agreements and MOUs for shared maintenance with other departments require them to provide a list to each department of what they are inspecting and working on for the upcoming year. However, they find that frequent communication is more effective.

Table 1. Montgomery County Maintenance Responsibilities

Type of Facility	Maintenance Responsibility
Residential stormwater facility	**Structural maintenance**: DEP's Stormwater Facility Maintenance Program works with citizens to assume responsibility for structural maintenance for residential stormwater facilities if the property owner has completed the maintenance transfer process. Once the facility has completed the transfer process, DEP will assume responsibility for the structural maintenance and the owner will continue to provide non-structural maintenance to their facility. **Nonstructural maintenance**: For all facilities, nonstructural maintenance is the responsibility of the owner. This maintenance includes grass cutting, trash removal, and landscaping.
Nonresidential stormwater facility (e.g., commercial facilities)	Maintenance for most nonresidential facilities is the responsibility of the owner.
Local government stormwater facility	Montgomery County assumes responsibility for Structural maintenance and either assumes all, or shares responsibility for Non-Structural maintenance with the owner. (e.g. parks, schools, and libraries)

Figure 8 Treebox maintenance

Montgomery County's right-of-way BMPSs are very challenging to maintain due to harsh conditions. These BMPs require at least monthly maintenance. The County has worked to educate road crews and prevent improper management. Current maintenance by contractors includes mulch replenishment, weeding, pruning, and track and debris removal (*Figure 8*).

A private property owner of any stormwater management system is required to have an easement and maintenance agreement with the County for the stormwater management systems. The Easement is a legal document that describes the area the county is permitted to enter for inspection and maintenance. The Covenant, also known as the maintenance agreement, describes who is responsible for maintenance.

The County does have the authority to enforce maintenance on private property. The County issues notices where maintenance is not completed, and can issue citations with associated fees or abatement orders. The County also has the authority to go on private property and complete maintenance at the cost of the property owner. In some cases, the department performs regular maintenance on private residential properties. With residential partnerships, they must notify residents 7 days before performing work; however this can be challenging with a large number of BMPs.

The SWMP currently employs only one planning person who is in charge of inspections oversight of contracts. Inspections are required every 3 years, but requirements vary seasonally and between BMP types. All maintenance is tracked through the County's Asset Management software. Work orders are issued to contractors and contractors provide daily logs. These maintenance logs are tracked through the asset management system (EAM).

Philadelphia, PA (population ~1.5 million people)

Green City, Clean Waters is Philadelphia's plan to reduce stormwater pollution currently entering the Combined Sewer System through the use of green infrastructure. Philadelphia has over 75 retrofit GI stormwater management practices (SMPs), including pervious pavement, bioretention facilities, infiltration trenches, tree trenches, and stormwater trees. Approximately 30 percent of the SMPs are bioretention facilities in the ROW.

The Philadelphia Water Department (PWD) maintains all PWD-owned green stormwater infrastructure (GSI). GSI maintenance is funded via the PWD operating budget. Other City agencies such as Parks and Recreation are considered "private" with respect to stormwater management/billing/fees, and are thus required to manage parcel-generated stormwater onsite. As with commercial customers, agencies can and do receive stormwater credits for implementing GSI, but these credits are contingent on those agencies maintaining their own GSI. PWD and Parks and Recreation partner on a considerable number of projects where runoff from the public right-of-way is conveyed into a park (they also work with the School District in Philadelphia to implement the same model) and managed within a stormwater management practice (SMP's are Philly's analog to BMP's). In these instances, PWD maintains GSI on park facilities (i.e. rec centers, neighborhood parks) at PWD's cost.

PHILADELPHIA, PA HIGHLIGHTS

Distributed

The City is currently developing a series of contract management protocols.

PowerCorps PHL partners with the city to train maintenance crews, providing young people with job opportunities.

The Philadelphia Water Department's (PWD) Green Stormwater Infrastructure (GSI) Maintenance Group is responsible for ensuring that maintenance is completed. The City works with two contractors (one landscape and one subsurface) with oversight from PWD; PWD does preliminary subsurface inspection and delegates work to contractors. Surface maintenance is scheduled (without preliminary inspection). Due to their use of perforated pipes in GI projects, Philadelphia's GI program also includes the use of contractors that perform sewer inspections and sewer cleanings. Philadelphia's GI projects include perforated pipes connected to catch basins that require sewer inspection equipment and jet-vac trucks for maintenance. Additionally, vacuum trucks for maintaining pervious pavement are also necessary. Contractor tasks are documented and tracked in a database to be incorporated into CityWorks asset management system.

The City has a small in-house crew to perform inspections and "light" maintenance (i.e. hand weeding, pruning, trash removal, replacement/cleaning of inlet protection/pretreatment devices).

Philadelphia also has four scientist and engineering staff responsible for inspecting SMP's, managing contracts, reviewing designs (for maintainability), providing on-site oversight on tasks and tracking implementation activities (i.e. design and construction status). To better facilitate contract management processes, the Water Department is developing a series of internal contract management protocols.

PWD partners with PowerCorps PHL, an AmeriCorps program, for green infrastructure maintenance. The program provides job training opportunities for young adults in Philadelphia. Beginning in 2013, the program enrolled 100 individuals per year, ages 18 to 26. The members work 6-months full-time with City departments and then are provided three months job placement support. As of 2015, PowerCorps crew members are being hired by companies in the green services industry (***Figure 3*;** City of Philadelphia, 2015).

Figure 3. Example of Green Jobs Creation: PowerCorps PHL

New York, NY (population ~8.5 million people)

The City of New York follows a distributed model for BMP O&M. For any development conducted by public agencies or private owners and requiring stormwater BMPs, the owning entity is responsible for maintenance of the stormwater BMPs.

Relating to retrofit maintenance, the New York City Department of Environmental Protection is responsible for addressing combined sewer overflows (CSOs). This program involves extensive implementation of stormwater retrofits including green infrastructure as outlined in the City's Green Infrastructure Plan, which was developed in 2010. Within this plan, the City has prioritized the construction of bioswales throughout the CSO-regulated area.

Prior to the City's Green Infrastructure Plan, the New York City Department of Parks and Recreation (DPR) began installing green streets as a beautification effort in 1999, and through ARRA funding in the 2000s, DPR began installing bioswales with stormwater treatment. Throughout both periods, the goal was to replace underused impervious surface to provide multiple benefits. Since DPR had extensive experience with bioswales, they managed the first DEP bioswale contracts and directed DEP employees in the maintenance of bioswales (no funding transfer occurred).

After these first contracts, DEP took over responsibility for the bioswales that they funded themselves through the CSO program. An MOU had been developed to establish formal transfer of funding across departments. However, this MOU was not used and is unlikely to be used in the future. DEP found that conducting maintenance internally within DEP was more efficient. When DEP constructs a devices on another agency's property that is part of the CSO program, DEP assumes maintenance responsibility for that device.

DPR continues to implement green infrastructure in ROWs and on park land, including bioswales, wetlands, and permeable pavement. The funding for DPR's maintenance currently is drawn directly from their general departmental budget.

NEW YORK, NY

Distributed

The Department of Parks and Recreation department was involved in the initial maintenance of city's bioswale program.

The Department of Environmental Protection assumed full responsibility for the bioswale maintenance to improve efficiency.

Onondaga County, NY (population ~500,000 people)

The Save the Rain Program is Onondaga County is an initiative to improve the water quality of Onondaga Lake and its tributaries. To date, the County has advanced more than 175 distinct green infrastructure projects including green roofs, porous pavement projects, and bioretention facilities, on public and private property.

Onondaga County's Save the Rain Program utilizes four entities to conduct maintenance currently; Onondaga County Department of Water Environment Protection (WEP) "in-house" crew, Syracuse Parks Department (for GI projects in parks), Onondaga Earth Corps (a nonprofit), and several private contractors. The County is currently in the process of moving toward greater use of non-profits for maintenance work.

Public projects are maintained by in-house personnel, shared service agreements, and private contracts. Private Projects are maintained by on-staff personnel and private contracts. The County uses in-house crews for small tasks as supplement to contractors. Contractor crews are hired for maintenance of porous pavement with crews ranging from 2-12 staff. Landscaping is performed by a nonprofit crew of 8-9 workers.

ONONDAGA COUNTY, NY HIGHLIGHTS

Various Models

Funding: Distributed

Public projects are maintained by in-house personnel, shared service agreements, and private contracts.

The County is currently in the process of moving toward greater use of non-profits for maintenance work.

The County has a partnership with Earth Corps, a Youth Conservation Corps model program to support community green infrastructure program including maintenance activities. The Onondaga Earth Corps (OEC) is a youth development and employment program in the City of Syracuse. As youth work on community and environmental service projects, they learn valuable job and life skills, civic engagement, environmental stewardship and technical skills in urban forestry and other urban green infrastructure.

Figure 10 Onondaga Rain Barrel Program

Work orders are created when maintenance is required and incorporated into asset management system (Maximo). The system tracks in-house personnel hours and rates, shared direct costs, private contracts, direct costs, date base records, annual inspections, and maintenance records.