2012 GREEN INFRASTRUCTURE TECHNICAL ASSISTANCE PROGRAM
CITY OF OMAHA, NEBRASKA

Support Process Development for Assessing Green Infrastructure in Omaha

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About the Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, soil and plants absorb and filter the water. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground. In most urban areas, stormwater is drained through engineered collection systems (storm sewers) and discharged into nearby water bodies. The stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape, polluting the receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, *green infrastructure* refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water. These neighborhood or site-scale green infrastructure approaches are often referred to as *low impact development*.

EPA encourages the use of green infrastructure to help manage stormwater runoff. In April 2011, EPA renewed its commitment to green infrastructure with the release of the *Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure*. The agenda identifies technical assistance as a key activity that EPA will pursue to accelerate the implementation of green infrastructure.

In February 2012, EPA announced the availability of $950,000 in technical assistance to communities working to overcome common barriers to green infrastructure. EPA received letters of interest from over 150 communities across the country, and selected 17 of these communities to receive technical assistance. Selected communities received assistance with a range of projects aimed at addressing common barriers to green infrastructure, including code review, green infrastructure design, and cost-benefit assessments. The City of Omaha was selected to receive assistance in developing a process for assessing green infrastructure.

For more information about Green Infrastructure, visit http://www.epa.gov/greeninfrastructure.

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Principal EPA Staff

Kerry Herndon, USEPA Region 7
Mandy Whitsitt, USEPA Region 7
Tamara Mittman, USEPA
Christopher Kloss, USEPA

Community Team

Jim Theiler, CSO and Sanitary Wet Weather, City of Omaha
Nina Cudahy, Stormwater Program Coordinator, City of Omaha
Marty Grate, Environmental Services Manager, City of Omaha
Kirk Pfeffer, Design Division Manager, City of Omaha
Selma Kessler, Stormwater Plans Review, City of Omaha
Pat Nelson, Omaha CSO Program Management Team
Perrin Niemann, Omaha CSO Program Management Team

Consultant Team

Carol Hufnagel, Tetra Tech
Dan Christian, Tetra Tech
Anne Thomas, Tetra Tech
John Kosco, Tetra Tech

Cover photo credits: Tetra Tech

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Executive Summary

The City of Omaha, with approximately 415,000 residents, covers an area of 130 square miles that includes approximately 43 square miles of combined sewer area. The city is currently implementing a combined sewer overflow (CSO) control program based on a Long Term Control Plan (LTCP; City of Omaha 2009 and 2014a) approved by the State of Nebraska in 2009 and updated in 2014. The city's CSO Control Program is estimated to cost approximately $2 billion (in 2012 dollars).

The goal of this project was to help the city compare green and gray infrastructure so that it can understand costs and benefits. The city also wanted to understand the costs associated with routinely treating the first ½ inch of runoff from all municipal projects, and assess how other municipalities address runoff from municipal projects.

The project team reviewed the city's current process for evaluating green infrastructure in CSO projects and made recommendations to improve the comparison of green and gray infrastructure. The team also reviewed the city's design criteria to compare it to the requirements from other cities. The cost/benefit approach was applied to an example 87-acre project area. A gray to green project cost comparison found, for this 87-acre area, that green infrastructure was 2 percent less than gray infrastructure assuming green infrastructure implemented throughout the project area.

Finally, the project team reviewed design standards and design details from 16 municipalities across the United States to assess which programs had design criteria for rights-of-way. Only five of the reviewed municipalities specifically addressed rights-of-way, with most requiring the area to follow the same post-construction requirements as other projects (with some exceptions). The project team also collected information on treatment requirements and design standards from these municipalities.

1 Project Summary

The City of Omaha, Nebraska sought to implement cost-effective stormwater management practices and green infrastructure more broadly as part of its municipal projects, and in the new and redevelopment projects within its jurisdictional control. This project was intended to aid the city in the development of processes and tools to improve consistency in decision making and reduce barriers for inclusion of these practices.

The analysis documented in this report was primarily conducted in 2012 - 2013. Subsequent to the efforts documented herein, the city implemented activities to more broadly evaluate the potential for green infrastructure as part of the CSO control program. Those results were published in the document “Conceptual Green Infrastructure Project Development Technical Memorandum,” October 2014. The findings of this report were also included in the Long Term Control Plan Update, completed in 2014.

1.1 Project Goals and Objectives

Omaha’s primary goal for this study was to facilitate additional green infrastructure implementation as part of its CSO Control Program and other municipal projects. The city found that green infrastructure is often excluded because it is not shown to be cost effective or because the normal implementation process for a project does not have a clear point when green infrastructure is considered. This study was designed to answer the following questions to achieve Omaha’s green infrastructure implementation goals:

1. How can the city compare the green and gray infrastructure so that it a) provides a more comprehensive understanding of costs and benefits, and b) can be communicated to the ratepayer or taxpayer?
2. What are the costs associated with routinely treating the first ½ inch of runoff from all municipal street or sewer projects? How do other municipalities retrofit established streets with green infrastructure?

1.2 Background

Omaha, population approximately 415,000 people, covers an area of 130 square miles that includes approximately 43 square miles of combined sewer area., It is currently implementing a combined sewer overflow (CSO) control program, based on a Long Term Control Plan (LTCP; City of Omaha 2009 and 2014a) approved by the State of Nebraska in 2009 and updated in 2014.[1] The city’s CSO Control Program is estimated to cost approximately $2 billion (in 2012 dollars).

Traditionally, Omaha’s stormwater management has been focused on water quantity control. Stormwater practices that address both quantity and quality more recently have been incorporated into the city’s practices. This shift is due to a number of reasons, including the city’s sustainability objectives, Municipal Separate Storm Sewer System (MS4) requirements, and the desire to apply a variety of cost-effective options for CSO control. This has led to a change from the traditional emphasis on flood control to a stormwater quality and green infrastructure approach. This results in the need for various decision-making methodologies to support the goals of more localized management of stormwater. Each project

[1] See http://omahacso.com/resources/ltcpdocs/.

type has a unique decision-making process. These project types include public and private projects, new development and redevelopment, CSO- and non-CSO-related activities.

The City of Omaha evaluated the potential for green infrastructure as part of their CSO LTCP and subsequently began to incorporate green infrastructure into a series of projects. Many of the projects implemented include regional stormwater management areas, which provide detention and water quality treatment to tributary areas of between 30 and 300 acres. Also, projects at specific city-owned parcels (e.g. at wastewater treatment plant (WWTP) and pump stations) have included green infrastructure. As of 2012, 14 of 29 sewer separation projects also included green infrastructure components (since 2012, the city has implemented a significant number of additional green infrastructure practices including large regional practices as all as traditional LID practices). As seen in Table 1 below, parcel-based projects tend to be larger and more comprehensive, given the larger area with which to implement green infrastructure practices. Sewer separation projects may be limited to modifications within the right of way. Appendix A provides a list of all CSO projects under the LTCP, including an explanation for projects where green infrastructure is not included.

Table 1. Stormwater Management Incorporated into the Omaha CSO program

CSO Project Type	Number of Projects with Green Infrastructure / Total Number of Projects (for that CSO Project Type)	Description*	Type of Practices Implemented
Parcel-Based Projects (WWTP, pump station, etc.)	4/4	Includes two pump stations, a WWTP and a CSO facility.	Bioretention, rain gardens, permeable pavement, dry detention, vegetated swales, other.
Sewer Separation Projects	14/29	7 new regional and LID practices in parks. 5 expansions and modification of existing stormwater detention for additional flow and water quality benefits. 4 additional projects in rights-of-way or on non-park parcels.	Regional practices: Detention basins (dry and wet), constructed wetlands, bioretention, rain gardens, vegetated swales, stream daylighting. In other areas: Curb extension bioretention and boulevard bioretention.

* Note: Some projects include multiple elements.

The city has also promoted green infrastructure through the MS4 program. This includes requirements in the City of Omaha municipal code calling for water quality control of the first ½ inch of runoff for new development or redevelopment projects. As a result, best management practices (BMPs), including green infrastructure, have been incorporated into most new or redevelopment projects on individual parcels. Municipal linear projects – such as road or utility projects – have been less consistent in incorporating green infrastructure. Exceptions to the ½ inch of runoff standard apply when imperviousness is not increased and where the runoff standard is deemed infeasible.

1.3 Report Contents

This report summarizes methods and findings for each of the questions identified under the objectives. The major emphasis of the study was on methodologies to compare green infrastructure with traditional controls to assist in decision-making and facilitate implementation. The report presents draft methodologies that the city will further evaluate and refine for the assessment of green infrastructure in Omaha (Section 2). The methods provided to assess green infrastructure within Omaha will also benefit municipalities across the country, providing insights and lessons learned in the comparison of green and gray infrastructure. Secondary activities included a review of approaches in other communities to incorporating green infrastructure practices within the right-of-way, and technical and cost information for right-of-way practices (Section 3).

2 Assessment of Green Infrastructure Costs and Benefits

2.1 Objective

The goal of this component of the study was development of a structured method for comparing green and gray infrastructure costs and benefits of city projects, particularly the city's CSO control program. With significant investments in public works infrastructure, the city is implementing cost-effective green infrastructure into CSO control projects and stormwater management practices in city parks and facility projects (i.e., parcel-based projects). A major component of the city's CSO program includes sewer separation projects within the existing combined sewer system that are a significant opportunity to use green infrastructure. Some are localized projects to protect against basement backups and others are system upgrades to remove stormwater from the combined sewer system. A method for evaluating green infrastructure will contribute to maximizing the implementation opportunities when they can be justified financially.

There are three objectives for this cost/benefit analysis and evaluation:

1. Consider costs and benefits from the perspective of the funding source used for project implementation. These sources generally are wastewater ratepayers (for CSO projects) or taxpayers (for road or stormwater projects). City departments need to be able to demonstrate that investments are made wisely and are consistent with the core mission of the funding. As a result, the identified financial benefits of green infrastructure in this study were more limited than have been included in many triple bottom line analyses (a triple bottom line analyses incorporates economic, social, and environmental benefits). Additional social, environmental and financial benefits remain important, but are not quantified. These benefits may trigger additional investment when the additional costs are relatively small or where other funding sources are available.
2. Clarify the process by which decisions are made. While Omaha has implemented a number of green infrastructure projects, at the time of this report the city was primarily limited to green infrastructure regional practices. The city is interested in a broader application of green infrastructure, which could require a change in the city's financial and technical decision-making process to ensure that the impacts of selecting green infrastructure are perceived as beneficial. The natural inclination in any decision-making process is to maintain the status quo in the absence of a clear reason to change. Without a convincing reason to implement green infrastructure, the tendency has been to exclude or limit its application. Therefore a study objective was to better understand the decision points where the choice for green infrastructure was being limited.
3. Develop processes that work within the existing framework of ordinances, standards and policies that have been adopted by the city. These elements of city governance can require relatively long lead times to modify. Retaining consistency with current language will simplify the ability to move from concept to practice. The current standards include various exceptions that apply when imperviousness is not increased or when green infrastructure is "infeasible." Since many city projects (such as road or utility projects) do not impact the amount of imperviousness, and when there is a lack of clear financial benefit demonstrated, green infrastructure implementation is either limited or not included on the project. Thus, better quantification of financial benefits will enable greater green infrastructure implementation.

2.2 Methodology

In order to define an approach that would facilitate greater implementation of green infrastructure, city staff conducted several workshops with various city staff in the environmental sector of city operations to understand concerns and define objectives. Participants reviewed the current processes and identified methods that would more comprehensively value the costs and benefits associated with green infrastructure. A case study was performed to test the proposed methodology. Participants also identified future actions. The following sections describe the steps in the process.

2.2.1 Definition of Goals and Objectives

Goals and objectives were developed early in the study and continually revisited. Goals and objectives were developed in the context of the city's varied responsibilities that include ensuring compliance with regulatory requirements (e.g. CSO control and MS4), making wise investments with ratepayer/taxpayer funds, and retaining consistency with existing processes. These were incorporated into the previously identified objectives.

2.2.2 City of Omaha Document Review

Prior to developing a process to evaluate green/gray cost effectiveness for the City of Omaha, a better understanding of the local city standards and processes was required. In order to accomplish this, a variety of city documents were reviewed and their application was discussed with city staff.

Thirteen documents identified by the city were reviewed for stormwater-related requirements and recommendations, as well as policies and procedures applied in the CSO program. Of these, six contained authoritative requirements. The six documents were primarily based on the authority of the Municipal Code Section 32, Article V (City of Omaha 2015) and the *Papillion Watershed Management Plan*. (Papillion Creek Watershed Partnership 2009) The document with the most extensive definition of requirements is the city's *Post-Construction Stormwater Management Planning Guidance* (City of Omaha 2011). The primary criterion relative to green infrastructure is treatment of the first ½ inch of runoff. Generally this is applied to development projects that occur after 2008. This has not been treated as a requirement for city projects implemented in the right-of-way, although it is identified as an objective for sewer separation projects. Appendix B contains a technical memorandum detailing the document review.

2.2.3 Local Community Concerns

City staff are expected to perform their responsibilities in a manner that considers the following:

- Ensures compliance with regulatory programs (CSO and MS4).
- Provides value to the ratepayer/ taxpayer.
- Considers the long-term performance of constructed infrastructure.

The city staff work to balance these responsibilities, and this is reflected in a measured approach to green infrastructure. One of the primary concerns relates to funding sources and availability of funds for green infrastructure. The city is currently implementing a $2 billion (2012 dollars) CSO control program that has resulted in a significant increase in wastewater rates. Typical residential rates increased from approximately $10 to $37/month between 2006 and 2014. These rate increases have been applied to customers throughout the wastewater service area, which includes both the City of Omaha and areas served outside the city. While still below the national average, the rate of increase has resulted in scrutiny relative to the use of funds in the program. Funding sources for projects also include a mix of sources based on the project purpose. This results in a need to understand and justify expenditures relative to the core mission of the project funding source. Specifically, CSO program projects need to use funds primarily to benefit the CSO program objectives. The cost/benefit evaluation needs to objectively compare the options and inform decision makers on the relative costs and benefits that are provided in the alternatives.

For MS4 compliance, the city has a modest stormwater fee that finances staff efforts associated with the program. It does not fund capital projects. Therefore, green infrastructure implementation on MS4 projects is funded through non-stormwater sources. One source of funds the city has used is grant funds from the State of Nebraska. This includes a grant program that assists MS4 communities. These funds have been used by Omaha for demonstration projects and water quality features, as well as more traditional stormwater management projects.

2.2.4 Project Types

A variety of project types are implemented in the City of Omaha. The city is responsible for CSO Program projects and other city infrastructure projects (such as road improvements, streetscape and traffic enhancement projects). Private entities implement development or redevelopment projects including those at the site or subdivision scale. As part of the study, a review of various project types and how green infrastructure is considered was evaluated. A gap analysis identified where green infrastructure implementation could be expanded.

2.2.5 Process Approaches

The city has an established process for evaluating green infrastructure for CSO projects. Guidance is provided for sewer separation projects in the Omaha *Green Solutions Site Suitability Assessment and BMP Selection Process Guidance Document* (City of Omaha 2014a). Because the area of focus for the cost/benefit evaluation was on sewer separation or linear project efforts, this was the primary guidance document considered. The process described in this document was used as a foundation for a broader assessment.

Since the existing process may not consider all costs and benefits, a review of the existing methodology was undertaken to better understand which elements either encouraged or discouraged the use of green infrastructure in projects. Aspects considered included the following:

- Clear guidance for evaluating green infrastructure by project type.
- Design criteria that are used to assess green infrastructure.
- How costs and avoided costs over the project life-cycle are identified.
- Methodology to account for semi-quantitative or qualitative benefits.

2.2.6 Project Costs

In order to develop a comprehensive cost-benefit analysis, all direct, indirect and avoided costs associated with a given project need to be identified. The study identified the various cost components. These were quantified for the specific case study. Additional discussion about costs can be found in section 2.4.1.

2.2.7 Qualitative Benefits

Qualitative benefits associated with a project may influence the alternative selection if the financial analysis is relatively comparable. As used in this study, the term "qualitative" does not suggest that a cost cannot be quantified. It is intended to indicate that the value of the benefit is either difficult to determine or is not directly relevant to the core mission of the funding source. Qualitative benefits were based on prior work by the city. As part of the LTCP development and implementation, community values were defined and considered in the evaluation of alternatives. These community values relate to some of the qualitative project benefits. In addition, the triple bottom line values used in methods such as *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits* from the Center for Neighborhood Technology (CNT) and American Rivers (2010) were consulted to consider whether additional items were relevant in Omaha.

2.2.8 Case Study

An example project was evaluated in order to test the process that was developed. For this case study, specific financial data were determined. The case study helped to identify information that would be needed for a more consistent application of the process. The case study drew from one of the CSO LTCP sewer separation projects, 26th and Corby Phase I. It was also supported by information from the program management team (PMT) for the city's CSO program. This case study provided an opportunity to test the process and evaluate process strengths and weaknesses.

2.2.9 Future Steps

Comparison of costs and benefits across multiple projects will require that the city have a structured way of comparing the information. Much of the information required is outfall specific and difficult to quantify. Future steps relate to development of a standard method of quantifying these benefits so they can be considered in the project level analysis. A series of potential tools could assist in the analysis. The content of these tools is described. Not all information can be simplified, and the ability to define the process in an easy-to-apply tool may be limited.

2.3 Results

2.3.1 Project Type Gap Analysis

Green infrastructure can be a fundamental driver in the identification of a project or it can be included as an enhancement to a project that has been identified to achieve a different primary purpose. Various categories of projects were considered along with the method of assessing green infrastructure. Figure 1 shows the various project types and differences in how projects are approached.

The primary project types were identified based on the project purpose. Projects could include those where green infrastructure is the main goal (both for CSO control or another objective), as well as projects where stormwater management/green infrastructure was not the primary purpose, but rather an enhancement. These project types include CSO program-related projects, such as sewer separation (see item 5 in Figure 1 below); city infrastructure projects not directly related to the CSO control program (item 6); and parcel-based projects through private or public development (item 7). Shaded items on the figure identify processes that either need to be developed or could be strengthened.

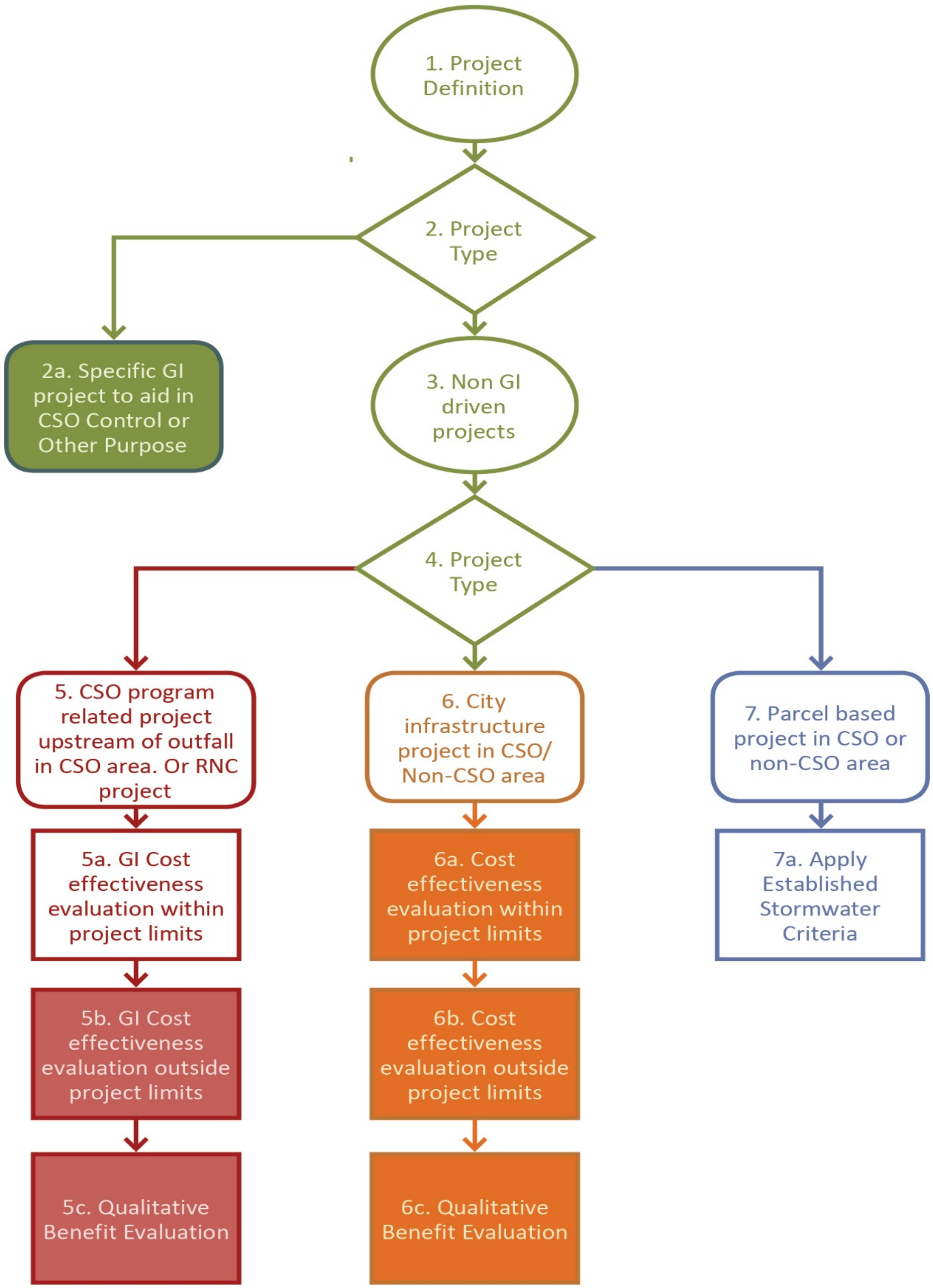

Figure 1. Project Type Gap Analysis

Stand-alone stormwater management/green infrastructure projects to support CSO control were identified as part of the LTCP. Additional stormwater management projects can be identified to support the LTCP throughout its implementation. Due to the effort required to develop an LTCP, most communities do not attempt to make significant changes to the projects described in the LTCP, unless it is part of a formal adaptive management process or it results from a wholesale review of the LTCP approach. This can be problematic for integrating green infrastructure into the community, as a number of otherwise appropriate projects may be installed before planners are able to consider green infrastructure as part of the solution. In the City of Omaha, this barrier was addressed by the commissioning of a green infrastructure study with the specific intention of identifying additional green infrastructure projects and potential projects. In June 2013, the city selected a consultant to review portions of the CSS and evaluate whether there are additional opportunities to reduce the CSO volumes, magnitudes, or durations through the implementation of green infrastructure. A summary of this analysis is included in section 3.3.2 of the 2014 LTCP update.

Sewer separation projects implemented within combined sewer areas are evaluated for green infrastructure. Two limitations of this analysis were identified that hamper the use of green infrastructure. The first is that full financial benefits associated with green infrastructure are not quantified. Financial analysis is typically limited to the local project costs using a green infrastructure or more traditional approach. The analysis is developed and documented by the project design engineer who is not able to fully identify the costs and benefits associated with the project. Therefore, the potential for green infrastructure to reduce costs in downstream projects are not defined. While qualitative benefits are considered, there is not a specific approach to document or value these, limiting the influence of qualitative benefits. The effective outcome is that decision makers do not have complete information to use in making decisions about green infrastructure implementation. Activities to enhance the process of quantifying benefits are identified in items 5b and 5c in Figure 1.

The second limitation is related to the methodology of the cost/benefit analysis. The sizing of green infrastructure is based on a different criterion than what is used for evaluation of benefits. Size of green infrastructure practices is based on controlling runoff from a 1-inch precipitation event. However, the assessment of benefits is tied to the *Omaha Regional Stormwater Design Manual*, which is based on managing flows from a 10-year event (City of Omaha 2014b). The general effect of this is that green infrastructure provides minimal beneficial impact on the storm sewer design included in the project. Since the completion of this EPA project in 2012, the city has worked to improve the evaluation of green infrastructure and its benefits associated with CSO control, which has broadened the beneficial review of green infrastructure.

City infrastructure projects (e.g. roadways) do not have a systematic approach for the evaluation of green infrastructure based on a consideration of project cost, broader costs or non-financial benefits. Process elements to address this gap are shown in items 6a, 6b, and 6c in Figure 1.

The proposed approach is intended to address the identified gaps as summarized in Table 2 below. The questions that are pertinent to green infrastructure consideration include the following:

- Is green infrastructure routinely evaluated for inclusion in the project?
- Is green infrastructure the default choice for stormwater management prior to application of a financial test?
- Are the benefits associated with green infrastructure quantified only for the project area or are they quantified for downstream impacts?

- Is the design criteria for green infrastructure clearly identified and is its performance evaluated relative to that criteria?
- Is there a consideration of other benefits from green infrastructure?

Table 2. Gap Analysis for Green Infrastructure Evaluation

Project Type	Primary Purpose	Green Infrastructure Routinely Evaluated	Green Infrastructure Default Stormwater Management Approach	Comprehensive Financial Benefits?	Clear Design Criteria for Green Infrastructure?	Assessment of Other Community Benefits Included?
Green Infrastructure Stand Alone project for CSO Control (2a)	CSO control	Not applicable (N/A)	N/A	Yes	May include: 1-inch storm, 2-year and 10-year control level, as well as water quality (0.5” runoff)	Unclear
CSO Program-Related (5b, 5c)	Sewer separation (CSO Control or Combined Sewer Renovation)	Yes	No	Financial evaluation in project area only. Expand to outside of project limits (item 5b, Figure 1)	May include: 1-inch storm, 2-year and 10-year control level	Unclear. Formalize. (item 5c, Figure 1)
City Infrastructure Project (6a, 6b, 6c)	Various (e.g. transportati on)	No	No	No. Include analysis (items 6b and 6c, Figure 1)	No structured process	Include. (item 6d, Figure 1)
Parcel-Based Project (public or private)	CSO or non-CSO	Yes	Yes	Not required	½ inch of runoff management	Not Required

2.3.2 Process Approaches

As part of the CSO LTCP, the city developed a process for assessing green infrastructure as an enhancement to CSO control projects. The primary process was included in a flow chart entitled “Incorporation of Green Solutions into Combined Sewer Separation Projects” (City of Omaha 2014a). As part of this study, the process (Figure 2) was reviewed to better understand any barriers to implementation of green infrastructure. Modifications were developed to enhance the process, including clarification of design criteria, more comprehensive financial evaluation, and better description and utilization of qualitative benefits.

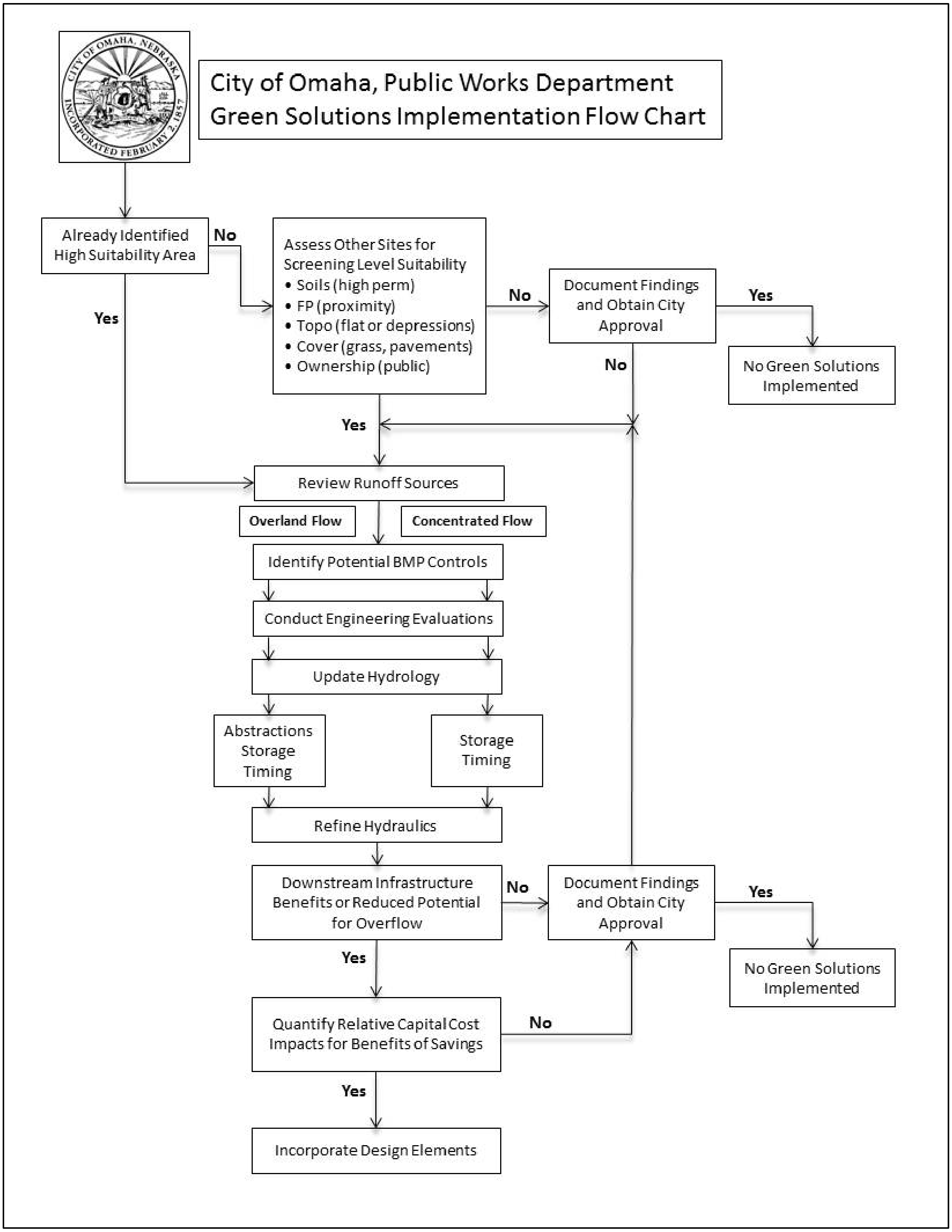

Figure 2. Original Flow Chart for Incorporation of Green Solutions into Combined Sewer Separation Projects

The most developed process is that used for evaluation of green infrastructure in CSO control projects. This process is not currently applied to non-CSO city projects (such as road projects), but could be. Areas for enhancement in the existing approach include the following.

2.3.2.1 Policy

Two fundamental policy items should be addressed in the approach to green infrastructure evaluation. These include the following:

- Ability of Green Infrastructure to Reduce or Replace CSO Facilities. Appendix O of the 2009 LTCP (titled *Green Solutions Guidance*) stated that "[t]he incorporation of Green Solution projects into the LTCP [was] not anticipated to have a significant impact on the structural CSO controls proposed since these are designed to address large events." In other words, green solutions were expected to enhance rather than modify structural controls. Appendix B recognized the ability of green solutions to result in downsized facilities, however the benefits are not quantified from a cost perspective. It is the recommendation of this review that the city affirm the ability of green infrastructure to reduce required downstream CSO controls. Where questions exist related to the ability to ensure long-term performance, or where the extent of implementation is unclear, these concerns should be clarified and reasonable safety factors applied. However, these safety factors should be approached in a manner that is consistent with safety factors applied to other technologies.
- MS4 Application to New Stormwater Discharges. Appendix O indicates that "there is the potential to maximize [green solutions] benefit by making sure the projects conform to the city's municipal separate sewer system (MS4) program requirement." The MS4 requirement is generally to treat the water quality volume (first ½ inch) of runoff from new development. This standard has not been applied in all city-owned projects. It is recommended that the city consider all newly separated stormwater (e.g., that which discharges through a stormwater outfall) as new development. For these flows, treatment of the first ½ inch of stormwater runoff from the tributary area should be considered a fundamental part of the project.

2.3.2.2 Opportunity Identification

Current language for site location of green infrastructure indicates, "Site location criteria will generally focus on sites that may be suitable for BMP implementation by virtue of their proximity to runoff sources, their ability to capture and control large areas or the fact that they may present attractive ownership potential." Practices that can control larger areas are preferred: "Very small basins (such as single lots) may be suitable for some local controls but aren't likely to have a material runoff reduction." Publically owned sites are also more feasible: "The ownership of the site will have a significant influence on the site suitability." The net result is that the primary green infrastructure implementation has been larger practices in parks, rather than distributed green infrastructure practices or those that require work on private property.

Recommendation: Revised language that would help facilitate greater inclusion of distributed green infrastructure includes:

- Clarify potential and interest in implementing green infrastructure on private property where property owners can act as partners.
- Clarify street right-of-ways as potential locations for green infrastructure practices.

2.3.2.3 Hydrologic Evaluation

The *Green Solutions in Facility Design Guidance Document* (City of Omaha 2014a, Appendix B) identifies a 1.0 inch event as the design criteria for green infrastructure, and then refers the engineer to the *Omaha Regional Stormwater Design Manual* (City of Omaha 2014b) to assess the runoff reduction benefits. The hydrologic evaluation in the *Manual* is based on larger storm events than used for CSO control, primarily the 10-year event. The 10-year event drives the sizing of storm sewer at the project level and therefore cost savings within the project are difficult to quantify.

Recommendation: Revised language is suggested to clarify that the hydrologic objective for stormwater management within the project is CSO control or water quality management. The CSO control objective (control of the 1.0 inch storm event) would directly support downsized CSO facilities at the downstream end of the system. These provide a direct cost benefit to the CSO program. The stormwater objective (½ inch of runoff control) should apply whenever stormwater is being removed from the combined system (see Policy discussion above). This is to provide water quality treatment of newly separated stormwater that previously received some treatment at the WWTP.

2.3.2.4 Cost Identification

The current approach includes a definition of life-cycle costs at the project level with and without green infrastructure. Possible increases in level of service, reduction in gray infrastructure outside of the project area, and community enhancement benefits are considered qualitatively. Typically, green infrastructure must be shown to be cost effective or cost neutral to be included in the project. The CSO program *Green Solutions in Facility Design Guidance Document* (City of Omaha 2009) recognizes that "[green solutions] will reduce the overall runoff and result in smaller downstream infrastructure and fewer sewer overflows" (p2), however, the value of this benefit is not defined. Without a comprehensive cost accounting of the benefits, decision makers cannot fully appreciate the total financial benefits associated with green infrastructure.

The project design consultant is assigned the responsibility of developing the financial analysis, including the full life-cycle cost of green infrastructure and other infrastructure within the project area. If gray infrastructure within the project area is reduced through the use of green infrastructure, this can be assessed quantitatively. However, some of the complete cost effectiveness evaluation would require an assessment of costs outside of the immediate project area. The project design consultant is not in possession of the information necessary to quantify these potential cost savings. As a result, these potentially significant financial benefits are not included in the cost/benefit analysis. Impact of green infrastructure on downstream infrastructure is therefore limited to a qualitative assessment, which carries much less weight in the decision-making process.

Recommendation: Revised language is suggested to expand the financial analysis beyond the costs of the specific separation project. The objective is to identify comprehensive costs with and without green infrastructure. These costs include capital, life-cycle and avoided costs.

2.3.2.5 Qualitative Benefits

The city has considered community enhancement and other environmental and social benefits in CSO project definition, but has no specific criteria to determine whether this justifies funding of green infrastructure practices that are not otherwise cost effective. Qualitative benefits could be considered based on the public works mission of the city, or broader benefits.

Public Works Benefits. Some public works benefits associated with green infrastructure are difficult to quantify. Examples include the benefit provided by green infrastructure toward the level of service. Green infrastructure helps to control a portion of the runoff volume. This is not apparent in standard flow calculations because the peak of the hydrograph occurs after the storage capacity associated with green infrastructure is full.

Recommendation: Revised language is suggested to identify and score the aspects of green infrastructure that are relevant to the public works and wastewater core mission. Specifically, drainage enhancements (which may provide additional basement backup protection), traffic calming (through curb extensions) and reduced infrastructure (through road narrowing) are examples of improvements that may be provided by green infrastructure and are relevant to public works.

Community Benefits. Community benefits beyond the mission of public works include such items as aesthetic and property value improvements. Broader social and environmental benefits (e.g. triple bottom line considerations) relevant to Omaha should be listed for consideration. The financial benefits of these items can be quantified with TBL calculators, such as the one developed by CNT and American Rivers (2010). However, community benefits are expected to be considered primarily from a qualitative perspective. In the event that the financial evaluation is relatively close, the community benefits associated with green may warrant consideration of additional project investment.

Recommendation: The city could formalize a series of benefits and a relative value (expressed as project cost percentage) that would trigger implementation of green infrastructure. This could be applied as follows (values are for illustration only):

Table 3. Potential Investments for Qualitative Benefits

Community and Public Works Benefit Ranking	Implement Green Infrastructure if within XX percent of base project value
High	5%
Medium	3%
Low	1%
None	0%

In summary, the existing process flow diagram is displayed in Figure 2. The modified process flow chart with recommended revisions is included in Figure 3.

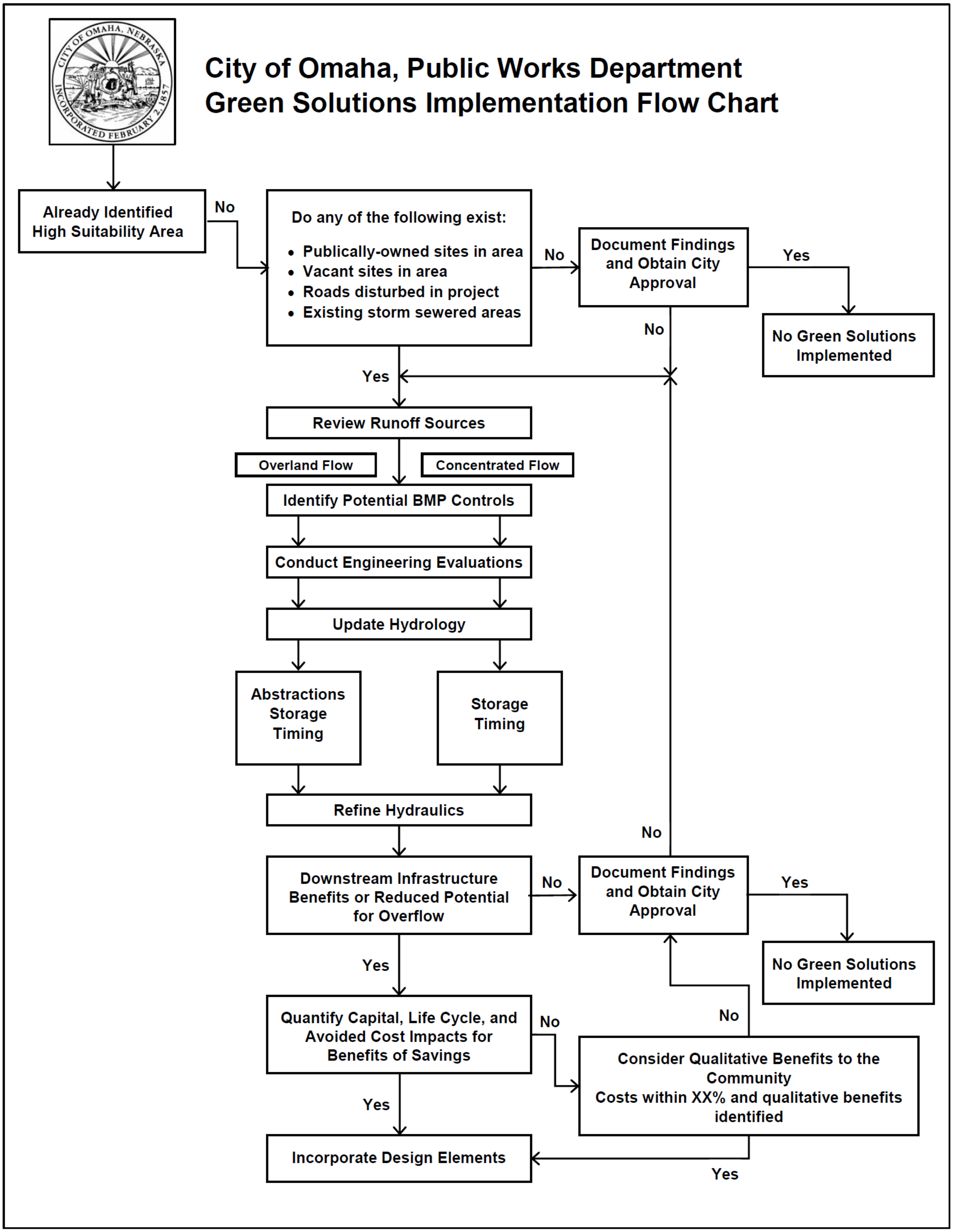

Figure 3. Modified Green Infrastructure Evaluation Flow Chart

2.3.3 Design Criteria

Green infrastructure could be (and has been) applied for CSO control, stormwater quality, and design storm flow management. The design criteria as applied in Omaha are contrasted with other design criteria used elsewhere in the country. The city specifically requested input on stormwater criteria that are applied (or could be applied in the future) as comparison against current standards.

2.3.3.1 CSO Control Criteria

Omaha's LTCP is based on a presumptive level of control per EPA policy.[2] In general, the city estimates in their LTCP that overflow control measures proposed in the 2009 LTCP achieve frequency targets of 4-6 overflows/year and 85% annual volume control. As part of the green solutions guidance document, the 1.0 inch rainfall event was identified as a "knee of the curve" level of control for green infrastructure.[3] This precipitation event is also estimated to represent an 85% volumetric control. In several of the CSO communities that have emphasized green infrastructure (e.g., Philadelphia, Cincinnati), the control level has been defined by a percentage control rather than frequency targets. In other communities with significant green infrastructure (e.g., Louisville, Kansas City) CSO control levels are based on frequency targets.

2.3.3.2 Stormwater Quality Criteria

The city's post construction stormwater standards are based on treatment of the first ½ inch of runoff. The preference is for this treatment to be accomplished using various stormwater BMPs that also control volume. As green infrastructure is implemented, the city recognized that this standard may change in the future. A range of potential control levels should be considered from a water quality perspective. These could range from control of various rain events. One standard that has been discussed is control of the 85th or 90th percentile precipitation event. For Omaha, the 90th percentile event is approximately 1.5 inch.

2.3.3.3 Channel Protection

The channel protection criterion is intended to prevent detrimental impacts on receiving channels and streams. Detrimental impacts include erosive flows that destabilize the streambanks. The criterion applied for channel protection is the two-year storm event. For this size storm, flows following the project are to be less than or equal to the pre-project flow rate.

2.3.3.4 Drainage Design

Conveyance design standards are intended to reduce the risk of flood damage or inconvenience. A series of criteria are identified in the *Omaha Regional Stormwater Design Manual (*City of Omaha 2014b). The criterion is for no adverse impact. The design event is the 10-year storm for most sewers.

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[2] EPA's CSO Control Policy is at http://water.epa.gov/polwaste/npdes/cso/CSO-Control-Policy.cfm. The "presumptive" approach is one of two alternatives a city must select in developing an LTCP; the CSO program must meet one of a series of performance measures and is therefore "presumed to provide an adequate level of control." (59 FR 18692, April 19, 1994).

[3] The knee of the curve is "an analysis to determine where the increment of pollution reduction achieved in the receiving water diminishes compared to the increased costs." (59 FR 18693) It is a way to compare the cost of control alternatives with their respective performance.

2.3.4 Project Cost Development

In order to compare the financial impact of green infrastructure as an either partial or complete replacement of more traditional alternatives, all relevant costs within or external to the project need to be quantified. The development of costs is challenging since the relationship between the project level capital components and the downstream facilities is complex. In the combined sewer system (CSS), the hydrologic control of stormwater (project objective) cannot be directly related to changes in downstream CSO facilities. The rate of change is unique for each level of control. For example, as stormwater is managed through green infrastructure, some CSO control facilities may be reduced in size. Ideally, if green infrastructure is implemented throughout a large portion of the tributary area, the CSO facilities may be avoided altogether. Sizing of CSO control facilities is related to multiple factors, including the regulatory control criteria, the extent of implementation of green infrastructure and the unique hydrologic and hydraulic conditions that determine the behavior of the sewer system. Facility sizing may relate to total volume, flow rate or a combination of the two. Some of the complexities involve the following relationships:

- The non-linear relationship between stormwater runoff control and CSO control. For example, removal of 100 gallons of stormwater does not translate into 100 gallons of CSO reduction. The ratio is dependent on the system, the type of stormwater control implemented, and the control target.
- The non-linear relationship between CSO facility size and cost. There are economies of scale that result in the marginal cost of construction of CSO facilities being much less than the average cost. This needs to be recognized in a credible cost comparison between gray and green infrastructure.

2.3.4.1 Cost Components

Each alternative considered for a particular project results in a variety of cost elements. These cost elements include capital, operation and maintenance, and avoided costs. To define a full life-cycle cost, all cost elements need to be considered. Cost components include the following:

- **Green infrastructure** (distributed): Application of low impact development or site-scale practices near the source of flow generation. Capital and operation and maintenance (O&M) costs would be relevant. Costs are dependent on the sizing criteria, the type of practice, and whether green infrastructure is implemented as part of another project or as a retrofit. Funding for green infrastructure may be either public or private or shared.
- **Regional stormwater practices**: Larger stormwater management practices include those such as previously identified in the LTCP and identified as cost effective. Capital and O&M costs would be incurred. Costs are dependent on land availability and configuration, sewers required to transport flows, any partial sewer separation required, type of practice, and land ownership.
- **Local capacity improvements for basement backup protection**: Local separation or combined sewer replacement to protect basements from sewage backup. Cost components include capital cost. O&M costs are related to pipe length rather than size. A cost savings includes the reduction in property damage due to basement backup, but this is not a quantified cost.
- **Local capacity improvements for storm drainage**: When sewers are separated, newly constructed storm sewers are sized based on the *Omaha Regional Stormwater Design Manual* (City of Omaha 2014b). Absent sewer separation, stormwater capacity improvements are rarely implemented due to lack of funding source. Cost components include capital cost. O&M costs would be associated with length of pipe. Cost savings include the reduction in property damage or inconvenience due to flooding, but this is not a quantified cost.

- **Major trunk sewer conveyance improvements: some major trunk sewers have inadequate capacity for design conditions**. Absent new stormwater outlets for CSO control, stormwater capacity improvements are rarely implemented due to lack of funding source. Cost components include capital and O&M costs. A cost savings includes the reduction in property damage or inconvenience due to flooding, but this is not a quantified cost.
- **CSO Control**: Sewer separation (direct stormwater discharge to new outlets), storage facilities (such as tanks or tunnels), and treatment facilities (such as retention treatment basins (RTBs)). Includes capital and O&M cost. Capital costs are highly dependent on extent and size (sewers, tunnels), overall volume (basins) or type and rate of treatment (treatment facilities). O&M costs for sewers are based on length as previously indicated. O&M for tunnels is primarily related to pumping costs.
- **Pumping and wastewater treatment**: Captured combined sewage will be conveyed through the collection system for treatment. These costs include system upgrades and operations for the captured flows. WWTP improvements included in the LTCP are primarily headworks improvements, wet weather treatment for flows in excess of secondary capacity, and dewatered tunnel flows. It is generally assumed that the sizing of these facilities would not change due to green infrastructure implementation. Therefore, the cost component used in this analysis is O&M. This is a unit rate that is primarily comprised of power and chemical expense associated with treatment.

2.3.5 Project Qualitative Benefits

In addition to quantifiable cost differences between alternatives, there are other environmental and social benefits that can be considered in a more comprehensive analysis. The city is interested in considering specific triple bottom line benefits that would be accepted by the community at large and rate payers specifically. As with the process approach, non-financial benefits applicable to city projects were based on prior work included in the LTCP.

2.3.5.1 Prior City Benefit Tool

Previously, the city developed a process for considering non-monetary benefits as part of the CSO LTCP, which were developed with public input. The benefits were evaluated through the implementation of a Decision Tool (2009 LTCP p 3-25). This Decision Tool included the non-monetary benefits identified in Table 4 (Table 3-9 of 2009 LTCP).

Table 4. Non-Monetary Benefits (Table 3-9 of 2009 LTCP)

Category	Description
1. Water Quality Improvement	Water quality improvements in the receiving streams above and beyond the minimum requirements to comply with state and federal regulations. This criterion also includes consideration for stormwater quality regulations that may be required in the future. The water quality parameters include bacteria, TSS, and floatables.
2. Reduction of Combined Sewer Backups into Basements and Existing Odors	This category emphasizes those alternatives that in conjunction with addressing the effects of CSOs on receiving streams, would either reduce the number of sewer backups and/or reduce odors that occur at different locations within the system.

Category	Description
3. Reduction of Street Flooding	This category emphasizes those alternatives that in conjunction with addressing the effects of CSOs on receiving streams, would reduce the backup of stormwater on to the city’s streets.
4. Minimizing Community Disruption	The minimization of community disruption that would occur during construction of CSO solutions, including: • Minimizing neighborhood and business disruption • Minimizing community traffic impacts
5. Simplicity of Solutions	The simplicity of operations and maintenance of the proposed facilities and the reliability of the facilities to function during wet weather events. This category emphasizes proven technologies that are locally applicable.
6. Opportunities for Infrastructure/Utility Improvements	The potential for replacement of aging infrastructure, including: • Street and sidewalk improvements • Burying overhead power lines • Water main, gas main and sewer replacements
7. Compatibility with Community	The long-term compatibility of an alternative with the community, considering aesthetics and other benefits of the proposed facilities such as: • Consistency of solutions with existing zoning • Historic preservation of community • Remediated contamination • Compatibility with neighborhood • Restoration of property after project • Aesthetics of solution (footprint, noise, odors, traffic, and proximity) • Safety
8. Opportunities for Community Enhancements	This criterion includes the potential enhancements for the community through construction of the projects. Enhancements could include green space/parks, streetscapes, structures and other amenities and support of future development in the community. Examples include: • Coordination with future development • Potential hiking/biking trail routes • Potential green space and parks • Enhancement of streetscapes

In the Decision Tool process, relative weights for each Non-Monetary Benefit were developed for the CSO areas by the Community Basin Panel. Weights were applied by the Basin Advisory Panels for each basin area. A review of these weighting factors suggests that values were relatively consistent, although specific rankings were higher or lower based on unique characteristics of the individual basins. For example, “reduction of sewer backups” and “infrastructure improvements” received higher weight in the Minne Lusa basin and “reduction of street flooding” was scored highest in Saddle Creek.

Median weighting for all basins is shown in Figure 4.

Alternatives were assessed by assigning a ranking of 1 – 5 for each benefit category (5 being highest potential benefit). Once the total benefit score was determined, it was divided by the present worth cost of the alternative to determine a normalized project benefit value.

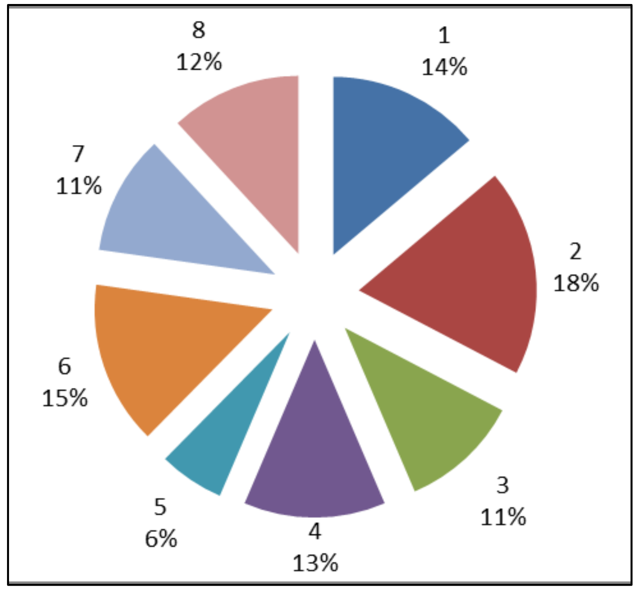

Figure 4. Median Weights of Non-Monetary Criteria (reference Table 4)

2.3.5.2 City Sustainability Criteria

Sustainability criteria were considered In the LTCP, and these criteria relate to non-financial goals. These goals are discussed in the Omaha *Green Solutions Site Suitability Assessment and BMP Selection Process Guidance Document* (City of Omaha 2014a).

The City of Omaha has adopted broad sustainability goals as part of the implementation of the CSO Control Program. It is the city's intention to incorporate the concepts embodied by the goals into projects implemented as part of the LTCP. The following Vision Statement has been established:

"The City of Omaha CSO Control Program will apply the principles of sustainability in a fiscally responsible manner to add meaningful and lasting social, environmental, and economic benefits to the implementation of the LTCP and serve as a model for the application of sustainability in the design, construction, and operation of infrastructure." (City of Omaha 2009)

The process identified seven specific goals to support the implementation of the vision statement. Three of the goals can be applied to infrastructure improvement projects. Those are listed in Table 5.

Table 5. Non-Monetary Benefits (Program Sustainability Goals)

Category	Description
1. Incorporate Resource Efficiency	Incorporate resource efficiency (e.g., energy efficiency, reduced construction waste, reduced hazardous waste generation, recycling of concrete and asphalt) into project design, construction and operation to reduce energy and material use, reduce waste and provide economic benefit to rate-payers.
2. Incorporate Multiple Benefits	Identify and implement opportunities for design practices that encourage innovative thinking to produce multiple benefits, such as enhance environmental protection, contribution to the control of CSOs and economic benefit to rate-payers.
3. Natural Systems Enhancements	Identify and implement natural system enhancements that contribute to the control of CSOs, improve water quality and/or create valuable community enhancements.

2.3.5.3 Additional Benefit Considerations

As part of the EPA technical assistance project, other potential benefits were discussed. These benefits were based on various triple bottom line calculators or tools such as published by CNT. These benefits are identified in Table 6.

Table 6. Additional Non-Monetary Benefits (Triple Bottom Line Goals)

Category	Description
1. Environmental Benefits	Additional environmental benefits such as air quality improvements, climate change mitigation, energy savings, salt/ deicer use reduction, increased infiltration, additional water quality benefits, ecosystem, habitat and wetland improvements
2. Social Benefits	Recreation, aesthetic improvements, urban heat island reduction
3. Financial Benefits (Indirect)	Energy savings, salt/ deicer use reduction, property value improvements, landscape job creation

2.4 Sample Project Process Application

The cost/benefit approach was applied to the 26th and Corby Phase I project area. This is an 87-acre project area within the CSO number 107 tributary area.

The purpose of the 26th and Corby Phase I Project is primarily to provide basement backup protection for homes in the area. The design consultant (Tetra Tech) prepared project costs for this area. The baseline alternative did not include a mechanism for stormwater management (other than conveyance). The green infrastructure alternative assumed permeable pavement or bioretention to control stormwater runoff from the critical CSO event.

The project team worked with the Omaha CSO Program Management Team (PMT) to define hydrologic response and approximate costs associated with reductions in downstream CSO infrastructure requirements.

2.4.1 Project Data

The 26th and Corby project area is located in the Burt Izard CSO basin. Flows from this area are tributary to CSO 107. The system is interconnected with CSO 106.

The 26th and Corby project is a local sewer separation project that is being implemented to address basement backup concerns. The project will effectively separate 87 acres of area internal to the combined area. The stormwater outlet will be an existing combined sewer. Data for the 26th and Corby Phase I project came from design memoranda that considered green infrastructure practices. At the conceptual level, the project team selected permeable pavement with a storage layer for control of the critical event that was associated with sizing of downstream CSO control facilities. Permeable pavement was assumed in locations where pavement was disturbed due to sewer construction.

Downstream CSO infrastructure data was developed by the program management team (PMT). This data included model results and assessment of reduced CSO facilities if the critical sizing event were controlled. The impact of the 26th and Corby project was assumed to be the unit impact of a broader application of green infrastructure within the tributary area. Effectiveness of green infrastructure presumes that it would be implemented broadly throughout the tributary area. The 26th and Corby project on its own is not sufficient in magnitude to result in major change to the CSO controls.

Basic hydrologic data relative to the project area and the downstream CSO controls are shown in Table 7. This analysis assumed a level of control equal to four residual overflows per year.

Table 7. 26th and Corby Phase I: Base Project Data

Description	Value	Unit
Area Tributary to CSO 107:	1413	acres
Precipitation volume (5th largest event)	0.95	inches
Total Precipitation volume (5th largest event)	36.46	MG
InfoWorks model predicted total runoff 5th largest event	0.24	inches
InfoWorks model predicted total runoff 5th largest event	9.23	MG
InfoWorks model predicted CSO volume 5th largest event	0.19	inches
InfoWorks model predicted CSO volume 5th largest event	7.20	MG
Annual runoff volume (to diversion)	286.5	MG
Total annual effective runoff volume	7.47	inches
Residual annual overflow volume (with four overflows)	40.5	MG
Net annual runoff to WWTP (following control)	246.0	MG
26th and Corby drainage area	87	acres
26th and Corby runoff volume 5th largest event	0.29	inches
Effective share of flow to tunnel (5th largest event)	0.44	MG
Annual 26th and Corby total runoff volume	18	MG
Annual runoff volume (that could reach treatment)	15.15	MG

2.4.2 Cost-Effectiveness Comparison

Four cost elements were defined and evaluated as part of the cost effectiveness comparison.

Project capital costs were based on project data for the 26th and Corby Phase I area. Regardless of green infrastructure implementation, new storm and sanitary sewers would be provided to essentially the same extent. Green infrastructure would be an additional component intended to accomplish CSO reduction. Green infrastructure costs were based on the control of the 0.95 inch event, which corresponded to the critical event associated with control of the downstream outfall. Costs were developed for project alternatives without and with green infrastructure. The effective unit cost of green practice installed volume was $1.33/gallon in this scenario. This is an incremental cost relative to construction of green practices versus traditional surface restoration. A total of 635,000 gallons of volume were included in the green infrastructure concept.

Operation and maintenance costs were determined based on relative changes in O&M for the gray and green projects in the 26th and Corby Area. The primary difference in O&M is related to additional costs for permeable pavement maintenance. All other cost differences were minor and were not included in the final calculations. A 50-year present worth was determined.

Avoided capital costs were determined based on a reduction in the size of the tunnel associated with comparable green infrastructure installation throughout the 1431 acre tributary area. Costs for this level of control were prorated to the project area under review. Present worth cost was assumed equal to construction cost. For the critical event which drives the sizing of the tunnel, approximately 78% of the stormwater runoff is converted to CSO gallons. (CSO volume for this event for this regulator is 7.2 MG out of 9.2 MG of runoff). Because the tunnel continuously directs flow to treatment during the event, the extent to which the tunnel is decreased in size is less than the CSO volume. The estimated tunnel size decrease for this condition was estimated as 5.5 MG. Thus, the effective green infrastructure to gray infrastructure installed volume ratio for this scenario is 9.2 MG/5.5 MG = 1.67.

Reduced capital costs for the tunnel for the case study were determined to be at a marginal rate of $1.03/gallon. This is because the net effect of controlling this outfall using green infrastructure would be a decrease in tunnel diameter from 17 to 16 feet. Control of this location would not significantly reduce the tunnel length, an approach that would have a much greater impact on the marginal cost.

Should sufficient control of area and volume be provided through the implementation of green infrastructure, there would be a potential for a dropshaft to be removed. With that additional capital facility reduction, the marginal capital cost for the gray infrastructure becomes $2.45/gallon.

Avoided operation and maintenance costs for wastewater collection and pumping were provided by the PMT. The value of $500/MG treated is consistent with the city's rate model. For the gray alternative the volume of flow captured in the CSO facilities would result in more flow treated. Green infrastructure enhances the evaporation and infiltration of stormwater runoff. Evaluations of installed green infrastructure with controlled underdrains have demonstrated an effective annual reduction in runoff to the sewer system of approximately 65%. Thus, the green infrastructure alternative was assumed to reduce the total volume to treatment.

Results of the analysis are summarized in Table 8 and Table 9. A proposed green/gray cost comparison process table is included as Appendix C.

Table 8. Gray/Green Project Cost Comparison (Tunnel Only)

Element	Gray Present Worth	Green Present Worth	Comments
26th/Corby Phase I	$5,596,000	$6,442,000	635,000 gallons of permeable pavement storage added
O&M of green infrastructure	$229,809	$357,480	Permeable pavement maintenance
Reduce CSO facilities	0	($410,566)	400,000 gallon tunnel reduction
Change in flow to WWTP	$39,090	($77,597)	Increased/reduced volume per option.
Total	$5,864,898	$6,311,317	Green is 108% of gray cost (present worth)

Table 9. Gray/Green Project Cost Comparison (Tunnel and Dropshaft)

Element	Gray Present Worth	Green Present Worth	Comments
26th/Corby Phase I	$5,596,000	$6,442,000	635,000 gallons of permeable pavement storage added
O&M of green infrastructure	$229,809	$357,480	Permeable pavement maintenance
Reduce CSO facilities	0	($980,210)	400,000 gallon tunnel reduction Drop shaft eliminated
Change in flow to WWTP	$39,090	($77,597)	Increased/reduced volume per option.
Total	$5,864,898	$5,741,673	Green is 98% of gray cost (present worth)

The results for the cost-benefit analyses are presented in Table 10. These summary costs demonstrate the need to look outside of the immediate project area to quantify the full benefit of green infrastructure. When looked at only at the project level, the cost of green infrastructure is calculated to be 17% greater than no green infrastructure. However, when the downstream benefits are quantified, the complete costs are more competitive and may represent a decrease.

Table 10. Gray/Green Project Cost Comparison

Element	Gray Present Worth	Green Present Worth	Relative Difference
26th/Corby Phase I Construction Cost only	$5,596,000	$6,442,000	635,000 gallons of permeable pavement storage added (apparent 15% increase in project capital cost)
O&M of green infrastructure	$229,809	$357,480	Permeable pavement maintenance (apparent 55% increase in O&M)
Total Project Life Cycle	$5,825,809	$6,799,480	Green 17% greater at project level
Total Project with downstream benefits considered	$5,864,898	$6,311,317	Green 8% greater with comprehensive costs considered
Total Comparison with green assumed implemented throughout tributary area	$5,864,898	$5,741,673	Green is 2% less with widespread implementation and comprehensive cost

The case study location was selected due to availability of information for the 26th and Corby project. This location is a particularly challenging one for green infrastructure to offset gray. This is related to the fact that the overall tributary area is large and the downstream control is shared with other outfalls. Nevertheless, the consideration of downstream benefits significantly offset the additional costs to implement green infrastructure.

2.4.3 Qualitative Comparison

A qualitative scoring of the case study project is presented in Table 11. This scoring was prepared for the base project, green infrastructure controls with an emphasis on permeable pavement and green infrastructure with an emphasis on bioretention.

Table 11. Example Qualitative Benefit Scoring

Criterion	Criteria Weight	Separation with Tunnel[1]	Permeable Pavement	Bioretention	Comments
1. Water Quality Improvement	14	1	1.25	1.25	Green solutions slightly reduce pollutant load in residual overflows
2. Reduction of Combined Sewer Backups into Basements and Existing Odors	19	1	1.25	1.25	Green solutions help to reduce peaks to downstream sewers
3. Reduction of Street Flooding	11	1	1	1	All solutions address
4. Minimizing Community Disruption	13	0	0	0	All equally disruptive to implement
5. Simplicity of Solutions	6	0	-1	-1	Concern that green infrastructure solutions are more complex
6. Opportunities for Infrastructure/Utility Improvements	15	1	1	1	All solutions address
7. Compatibility with Community	11	0	0	1	Bioretention adds aesthetic appeal
8. Opportunities for Community Enhancements	12	0	0.5	1	24th Streetscape
Totals		59	67.25	84.25	

Note 1: The base 26th and Corby project includes local sewer separation to reduce basement backup and a downstream tunnel for CSO control.

2.5 Next Steps

In developing this analysis, several challenges were encountered. These issues should be evaluated as part of future work.

The most complex aspect of the cost comparison is related to the potential changes in CSO facilities that might result from implementation. For the case study, these costs were developed based on the specific project application. When considering a major CSO facility, such as a tunnel, the costs can be impacted by total volume required, length of tunnel required, number of dropshafts, etc. The overall cost of the facility cannot be expressed as a $/gallon that applies across all ranges of green infrastructure implementation. However, to perform the comprehensive analysis, an estimate of the CSO facility savings is required.

Green infrastructure can be optimized by sizing it relative to a precipitation event that is comparable to that which drives the sizing of the CSO facility. The program is currently using a 1.0 inch event as a surrogate for this critical event. The LTCP recognized that various outfalls behaved differently in terms of discharge frequency and critical event. This control target could be evaluated on an outfall by outfall basis. In addition, updates to the city's LTCP may result in a review of control levels at some outfalls. This may also modify the control target.

A listing of potential tools and the associated objectives is included in Table 12.

Table 12. Tools to Support Evaluation Process

Tool Description	Objective
Avoided Cost Definition for CSO Control Projects	Defines the step function associated with reducing the size or extent of CSO control facilities. Provides marginal cost data at various levels of implementation.
Critical Event Selection Tool	Defines "surrogate" sizing event for green infrastructure. Event is intended to be approximately equivalent to the critical event that determines the sizing of CSO control facilities. This is unique for each CSO regulator tributary area. This is a refinement on the presumed 1.0-inch event.
Green Infrastructure Costing and Performance Tool	Defines the capital and lifecycle costs for green infrastructure on a unitized basis by practice type and location. Defines the hydrologic response by practice including such items as storage effectiveness during critical events and amount of water totally removed from the system due to infiltration/ evaporation.
Avoided Operational Costs for Flow Reductions to Collection System	Methodology to evaluate the present worth of the reduced flows to treatment.
Level of Service Evaluation for Downstream Capacity	Methodology to relate green infrastructure storage volume to increased downstream level of service and apply a value.
Non-financial Benefits	Methodology to rank various non-financial benefits and relate this to increased project capital or life cycle cost. See Appendix D.

3 Design Standards and Standard Details that Incorporate Green Infrastructure

3.1 Purpose and Objectives

The City of Omaha desired to gain some perspective on and knowledge of what other municipalities have in place regarding stormwater design criteria, particularly within the right-of-way, to help guide future modifications to their own stormwater design standards. This information would provide an approach to follow for their internal projects. Additionally, they were interested in viewing construction details for green infrastructure practices previously constructed within the right-of-way and references regarding pervious concrete pavement design. This interest was related to the limited direct experience with these practices by city engineering staff and their desire to understand more specifically how green infrastructure practices are designed. This section provides this information as well as the estimated cost of incorporating green infrastructure within a standard street block. The specific objectives include:

1. Investigating and documenting municipal ordinances and standards that address the applicability of stormwater design criteria within the public right-of-way.
2. Investigating and documenting municipal ordinances and standards within the Great Plains states, which address stormwater quality, channel protection, flood control and conveyance.
3. Providing green infrastructure implementation guidance for right-of-way projects including design details and costs.

3.2 Methodology

3.2.1 Stormwater Design Criteria within the Right-of-Way

Sixteen municipalities from across the United States were selected for review relative to how stormwater management design criteria were addressed within the public right-of-way. In particular, roadway resurfacing and widening were considered. Resources used for the investigation included online ordinances and design manuals. The selected municipalities included Kearney, NE; Philadelphia, PA; Suffolk, VA; Seattle, WA; Madison, WI; Boise, ID; Lake County, IN; Muldraugh, KY; Bloomfield Hills, MI; Burnsville, MN; Scott County, MN; Urbana, OH; Harrison, OH; Concord Township, OH; San Antonio, TX; and Corpus Christi, TX.

3.2.2 Water Quality, Channel Protection, Flood Control, and Conveyance Standards

Large municipalities within the Great Plains states were selected for investigation into their stormwater quality criteria. Resources used for the investigation included on-line ordinances and design manuals. The selected municipalities included Des Moines, IA; Kansas City, KS; Wichita KS; Minneapolis, MN; Springfield, MO; St. Louis, MO; Lincoln, NE; Oklahoma City, OK; Tulsa, OK; Fort Worth, TX; and Lubbock, TX.

3.2.3 Green Infrastructure Guidance

Green infrastructure practice construction details and photos were compiled from right-of-way projects throughout the country. In addition, references for pervious concrete design were compiled. The incremental cost of incorporating green infrastructure along a city block in conjunction with road reconstruction was estimated.

3.3 Results

3.3.1 Stormwater Design Criteria within the Right-of-Way

Of the sixteen municipalities reviewed, five were found to address projects within the right-of-way. The remaining municipalities either had limited on-line information or remained silent on right-of-way projects, although several stated that resurfacing activities were exempt from stormwater requirements. The five municipalities listed below recognize right-of-way or transportation-related projects as development. Appendix E, Table 1 provides specific language from these municipalities regarding stormwater design criteria within the right-of-way.

Kearney, NE requires that right-of-way applications meet the same stormwater runoff quality requirements as all other construction activity and land developments. Projects related to maintaining the original design purpose of the facility are exempt.

Philadelphia, PA considers public or private street construction to be “new development” or “redevelopment” and must follow the same post-construction stormwater management requirements as any human-induced change to improved or unimproved real estate. Replacement of impervious surfaces is “redevelopment.” Maintenance activities including top-layer grinding and repaving are not considered “redevelopment.”

Suffolk, VA exempts linear development projects that disturb less than one acre of land per outfall or watershed; cause insignificant increases in the peak flow rates (<1 cfs); and are located upstream of areas with no existing, or anticipated, flooding or erosion problems. If the exemptions do not apply, the linear development project must follow the city’s stormwater performance standards.

Seattle, WA defines activity requiring a right-of-way permit to be “development.” A transportation redevelopment project is a stand-alone transportation improvement project that proposes to add, replace, or modify impervious surface within a public or private road right-of-way that has an existing impervious surface of 35 percent or more. Maintenance-only projects do not apply. Flow rate and water quality standards (as part of the Design Review) apply for any proposed project subject to a development permit AND meeting various other conditions. Transportation redevelopment projects must follow the flow rate and water quality drainage review requirements unless they meet the exemption criteria.

Madison, WI states that municipal road or county highway projects that are not exempted under local erosion control ordinances under state or federal statute, are exempt from runoff rate control if all of the following conditions are met: 1) The purpose of the project is only to meet current state or federal design or safety guidelines, 2) All activity takes place within existing public right-of-way, 3) All other requirements of the Stormwater Management Plan are met; and 4) The project does not include the addition of new driving lanes. As part of the Stormwater Management Plan, street reconstruction projects shall include design practices to retain soil particles greater than 20 microns on the site resulting from a 1-year, 24-hour storm event with no sediment resuspension.

3.3.2 Water Quality, Channel Protection, Flood Control, and Conveyance Standards

Of the eleven municipalities reviewed, eight of them did not have stringent water quality requirements leaving two with set requirements and one not found. The majority of the municipalities had flood control and conveyance standards. Channel protection in several municipalities was addressed by requiring the 1-year or 2-year post-development peak flow to match pre-development rates. Appendix E, Table 2 provides specific language, as applicable, regarding water quality treatment, channel protection, flood control, and stormwater conveyance for these municipalities.

3.3.3 Green Infrastructure Guidance

An assortment of green infrastructure construction details and accompanying photos are provided for reference in Appendix F to aid in the future development of Omaha's design standards. Appendix G provides additional design guidance references for pervious concrete pavement design.

The added cost of incorporating green infrastructure into a standard 350 foot city block as part of a road reconstruction project is included in Appendix H. This table provides separate costs for using pervious concrete and curb extension bioretention along a city block to capture the first ½-inch of runoff from the right-of-way only.

Providing pervious concrete in the parking lanes with eight inches of aggregate sub-surface storage is sufficient enough to store the required volume of runoff. The additional cost of constructing the pervious concrete for one block is approximately $16,000.

Incorporating a curb extension that is five feet wide by 44 feet long on each side of the street will provide sufficient storage for the required volume of runoff. The additional cost of constructing the curb extension bioretention for one block is approximately $8,000.

4 Conclusions

For cities with combined sewer systems, the ability to compare green infrastructure practices with traditional gray infrastructure practices is important in order to choose controls that both minimize costs and maximize benefits. The City of Omaha has developed a process to incorporate green solutions into combined sewer separation projects with recommendations made to improve the process to clarify design criteria, more comprehensively evaluate finances, and better describe qualitative benefits. For example, a recommendation was made to expand the financial analysis beyond the cost of the specific project to also include comprehensive costs such as capital, life-cycle and avoided costs.

The cost/benefit approach was applied to an 87-acre project area within the CSO tributary area where the primary goal was to provide basement backup protection for homes in the area. The main control was sewer separation with permeable pavement and bioretention considered as green infrastructure controls. By considering all cost elements (such as project capital costs, operation and maintenance costs, avoided capital costs, and reduced capital costs), the comparison found that the cost of a green project was approximately 2 percent less than the cost of a gray project.

To incorporate green infrastructure into CSO designs, construction details and design criteria are needed. A number of municipalities were reviewed to assess their current requirements, with comparisons of design standards (Appendix E) included in the report along with construction and design details (Appendix F).

5 References

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