United States Environmental Protection Agency

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.

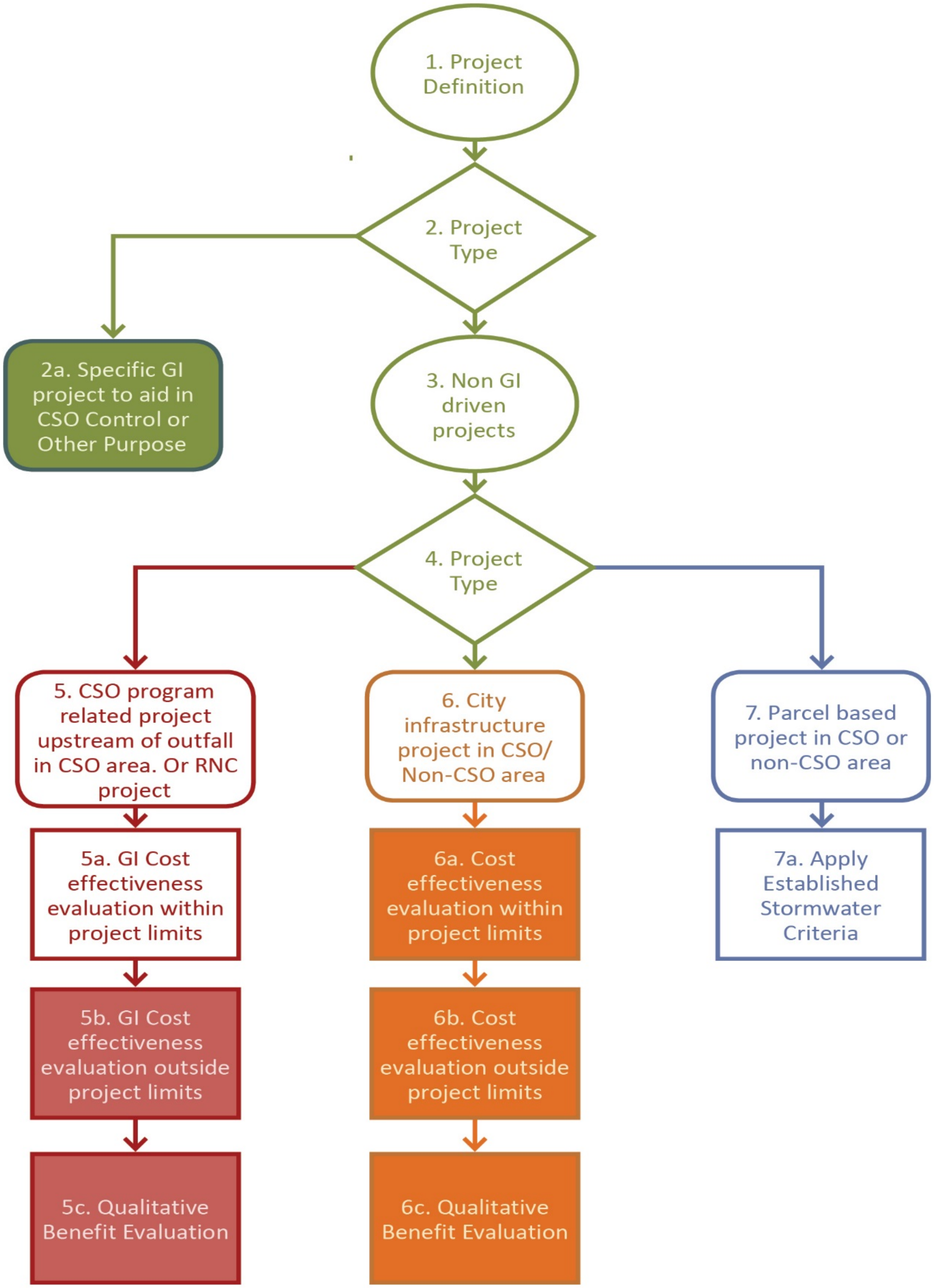

Figure 1. Project Type Gap Analysis

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.

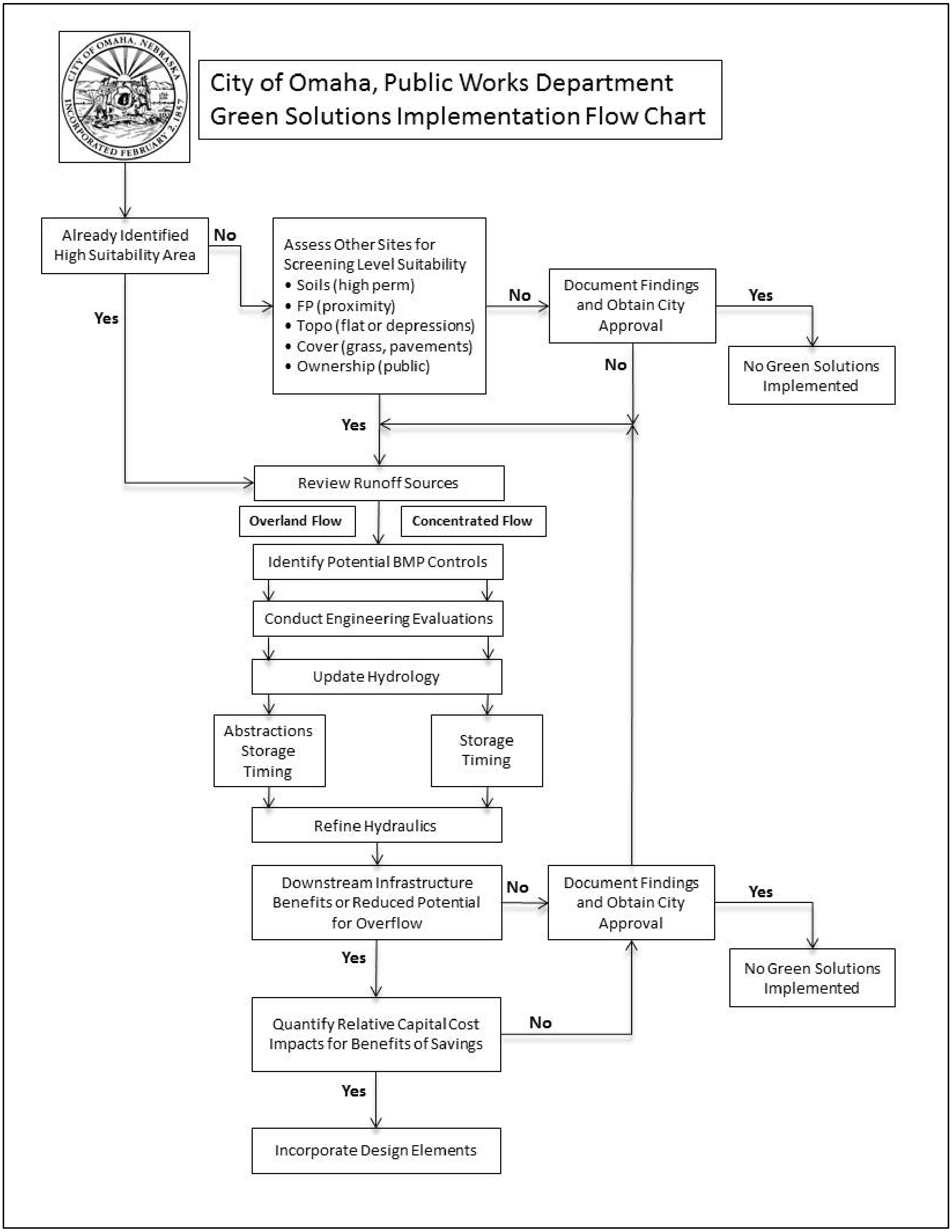

Figure 2. Original Flow Chart for Incorporation of Green Solutions into Combined Sewer Separation Projects

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.

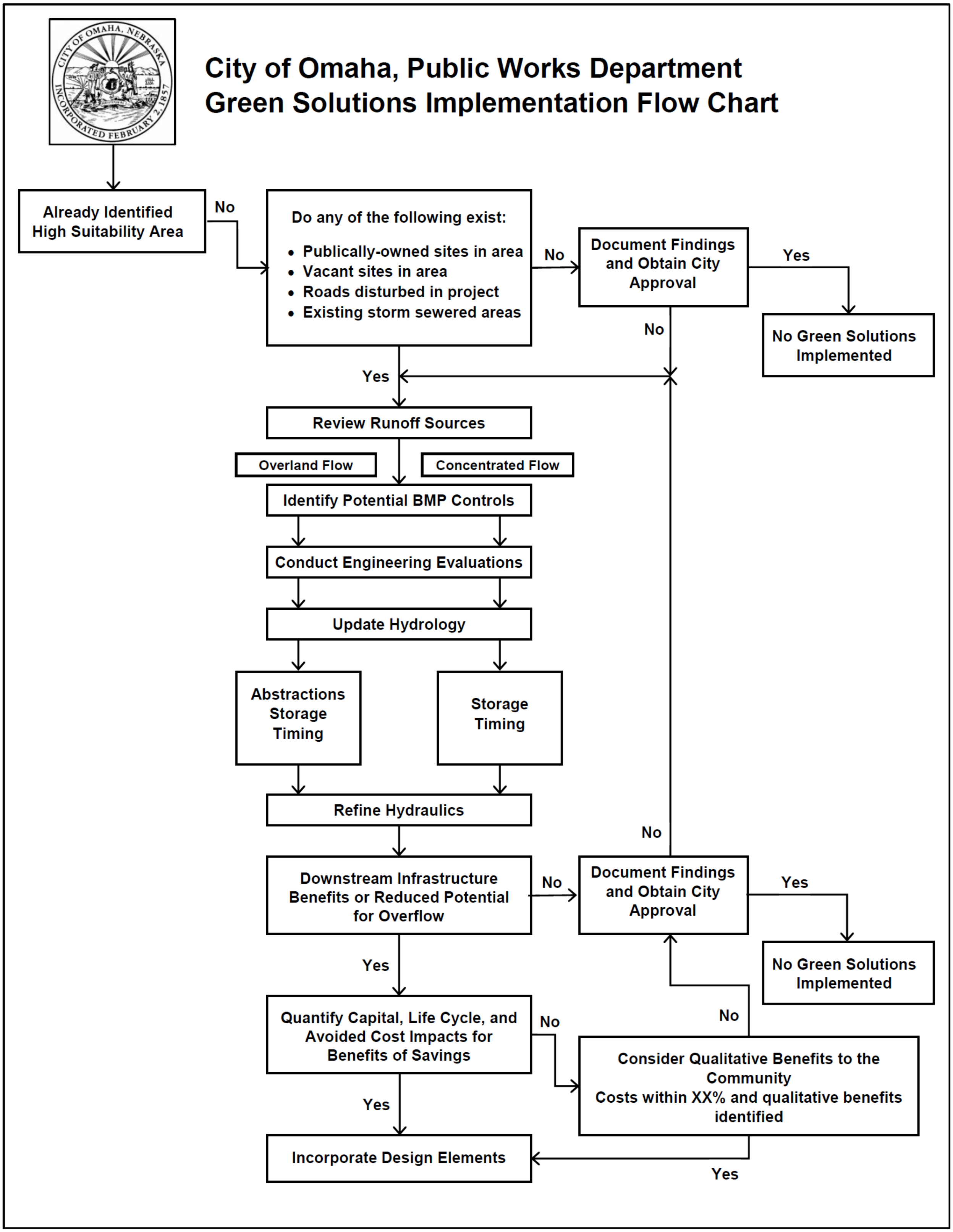

Figure 3. Modified Green Infrastructure Evaluation Flow Chart

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.

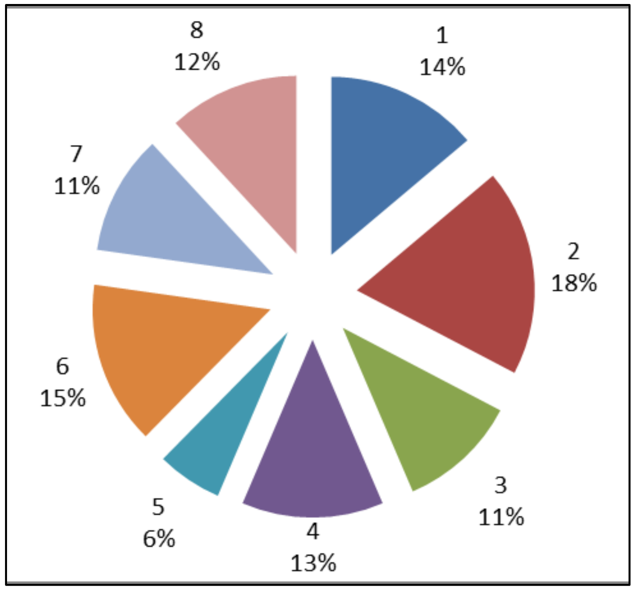

Figure 4. Median Weights of Non-Monetary Criteria (reference Table 4)

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.

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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Appendices

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Appendix A
Green Infrastructure in Coordination with Long Term Control Plan Projects

LTCP Project Name	OPW No.	CSO Study Basin	Reviewed for GS?	Green Solutions Selected for Design	Comments	Benefits (Including costs)
20th & Poppleton Sewer Separation (RNC)	51661	Leavenworth	NA	Buried detention/infiltration	Buried detention/infiltration Basin is provided to reduce the peak discharge from the drainage area to the interceptor. (Project is under construction, but detention is complete.)	Flow rate reduction
24th Street & Ogden Street Sewer Separation Project	51497	Minne Lusa	NA	Dry detention	This project included sewer separation that directed separated storm flows to the existing Pershing detention basin. (Project is complete.)	Water Quality
26th and Corby Sewer Separation Phase 1	51778	Burt Izard	Yes	Bump outs with bioretention areas	24th Street will have bump outs to provide increased pedestrian safety and traffic calming. As part of this, bioretention areas will be evaluated for use inside the bump outs as low-cost green infrastructure.	Water Quality
36th Street Sewer Separation	51698	Bridge Street	No		Located along an unimproved road section with narrow ROW and steep side slopes. No feasible alternatives.	
39th & Fontenelle Sewer Separation (RNC)	51817	Minne Lusa	No		No feasible alternatives.	
42nd & Q Sewer Separation	52257	Papio Creek South	Yes	Vegetated swales and bioretention gardens	Approximately 26 acres of runoff from residential area diverted to Hitchcock Park. Conceptual design includes vegetated swales and biorentention gardens ultimately draining to the existing pond in Hitchcock Park. During the initial stages of the preliminary design, it appears draining the swales and biorentention gardens to the pond may be cost prohibitive, and it was decided that the storm sewer discharge from the vegetated swales and bioretention gardens would drain back into the storm sewer system.	The elimination of a storm sewer pipe parallel to 42nd Street from Orchard Avenue to P Street will be attained. This will save approximately $50,000 on construction costs. In additon to the savings, the storm water from the neighborhood to the east of Hitchcock Park will be detained and some level of pre-treatment will be attained.
42nd Street & X Street Sewer Separation Project	50986	Papillion Creek South	NA	Dry detention	This project included sewer separation for a small drainage basin. Stormwater was routed through a dry detention facility to reduce peak flows to the existing creek and provide water quality benefit to the discharge. Coordinated with Omaha Public Schools for stormwater control. (Project is complete.)	Flow rate reduction and water quality
48th & Burt Area (RNC)	51796	Saddle Creek	Yes		Green Solutions were studied and determined to be unfeasible. Reasons they were unfeasible included topography, existing land use density, and the downstream constraints the project will connect to.	Flow Reduction and water quality.
49th & Caldwell Sewer Separation (RNC)	52193	Saddle Creek	Yes	Currently under preliminary design.	Evaluating bioswales, rain gardens, etc. No Green Solutions found that were considered feasible. Reasons for elimination included land availability, land ownership, topography, existing trees and vegetation, and cost.	
Aksarben Village Phase A	51151	Papillion Creek North	Yes	Dry Detention, Rain Gardens, Vegetated Swale	Approx. 29 Acres of runoff from Residential area diverted through park. Design includes trash screening structure, two dry detention basins, seven slotted weir structures, vegetated swale, and 3 bioretention gardens. Bioretention gardens include native grasses and wildflowers. Vegetated swales and dry detention basins include native grasses. (Project is currently under construction. The Green Infrastructure Project portion is complete.)	Flow rate reduction and water quality
Bohemian Cemetery Sewer Separation	51777	Saddle Creek	Yes	Dry Detention, Open Channel Conveyance	Dry detention basins include micro-pools and wetlands for additional water quality improvement. Approximately 700 lf of open channel will be created in lieu of storm pipe. All grasses and trees are native species. (Currently under construction)	The detention basins provide reduced peak discharge from major storm events and water quality benefits. The open channel provides water quality benefits and aquatic and riparian habitats. There was essentially no cost savings associated with the Green Solutions vs. installing conduits, however, the implementation of these green solutions provided the project with grant funding through the Papio-Missouri River Natural Resources District and the Nebraska Environmental Trust.
Cole Creek CSO 204 Sewer Separation Project	51995	Cole Creek Basin	Yes		No cost effective Green Solutions were identified. Reasons for elimination included land availability, land ownership, topography, and cost. The only sites extensively reviewed within the study area were at the extreme upstream and downstream portions of the basin and no cost savings could be realized from the construction of Green Solutions. No economical alternatives within this established residential area.	

LTCP Project Name	OPW No.	CSO Study Basin	Reviewed for GS?	Green Solutions Selected for Design	Comments	Benefits (Including costs)
CSO 211 Sewer Separation (Pacific St. from 63rd to 66th St.)	51686	Papillion Creek North	Yes		No feasible or cost effective green solutions were found for this project. The site is on a 7 to 10 percent slope with dense residential development on one side of the street and well-established City park on the other side.	
Gilmore Avenue Sewer Separate	52184	Ohern/Monroe	Yes	Detention Basin with constructed wetland, bioretention, and bioswales.	Four areas of Green Infrastructure are in the design process - a detention basin with constructed wetlands to improve level of service in Gilmore and South Barrel; bioretention area in Albright park for reduction in infrastructure, water quality, and education; detention/bioretention under HWY 75/JFK Freeway to inprove level of service in the South Barrel and improve water quality by treating the first flush from the freeway. Options are being evaluated for treatment of saline runoff; and Highland Elementary School - bioswale and bioretention. The bioswale will improve level of service downstream, improve water quality, educate, and treat snow and snow melt runoff.	Flow Reduction and water quality.
JCB Conveyance Sewer / JCB & Miami Sewer Separation Project/Adams Park Detention Improvements	52078 / 52165 / 52390	Minne Lusa	Yes	Dry Detention, Constructed Wetland	Past and proposed separated stormwater is to be discharged into an 13.5+ acre wetland complex to be constructed in the western portion of Adams Park. The wetland will receive stormwater flows from a 378-acre watershed consisting of predominantly residential development. The wetland concept will include emergent wetland areas that are frequently inundated, wet meadow areas that are inundated less frequently and upland areas for peak storage of larger storms. The volume above the emergent wetland zone is essentially dry detention providing peak flow attenuation for large storms up to the 100-year, 24-hour event. This facility will also provide capture and treatment for smaller events enhancing stormwater quality. Trails and interpretive and educational elements will ultimately be incorporated into the wetland by the Parks and Recreation Dept.	Peak stormwater flow attenuation, capture of water quality event, park amenity. Cost: $5.1M (est)
Leavenworth Lift Station Replacement	51874	Leavenworth	Yes	Filter Strips, Grass Pavers, Gravel Surface Storage, Rain Gardens, Vegetated Swales, Disconnected Roof Drains		Flow Reduction and water quality.
Martha Street Sewer Separation Phase 1 / Residential	51880	South Interceptor	Yes		No Green Solutions found that were considered feasible. Reasons for elimination included land availability, land ownership, topography, existing trees and vegetation, and cost.	
Martha Street Sewer Separation Phase 1 Lauritzen Gardens / Gardens Grading / Martha to Riverview Ph 1	52134 / 52187 / 52188	South Interceptor	Yes		Green Solutions will not be incorporated into the Project. The majority of the project will be installed using trenchless construction methods due to site constraints. The south portion of the Phase I project that will be constructed by open cut methods will be located on NDOR and BNSFR right of way. The segment on the NDOR ROW is located under the Interstate 80 Missouri River. The area under the bridge is currently used for storm water detention. The BNSFR property in the area of the sewer construction is currently used as an intermodal facility. Both areas are not conducive to the implementation of Green Solutions. The north portion of the Phase I project that will be constructed by open cut methods will be located in an area used by the Gardens for maintenance and storage. Construction of Green Solutions will require the Gardens to relocate these operations.	
Miller Park to Pershing Detention Basin Sewer Separation	51941	Minne Lusa	Yes	Grass Swale. Rain Gardens and Filter Strip. Diversion of stormwater pond overflows to the Pershing Detention Basin.	A 160 LF grass swale was incorporated into the project that will divert stormwater runoff from the combined sewer and replace the need for 40 LF of 30" RCP and a manhole. Green Solutions information is from Study Phase. Expansion and updates to the existing Miller Park pond, including a trash screening structure, during LTCP development are considered Green Solutions improvements.	WQ Improvement and $9000 savings. Flow Reduction and water quality.

LTCP Project Name	OPW No.	CSO Study Basin	Reviewed for GS?	Green Solutions Selected for Design	Comments	Benefits (Including costs)
Minne Lusa Stormwater Conveyance Sewer / Pershing-Storz Detention Basin Improvements / Gunderson Demolition	52004	Minne Lusa	Yes	Dry Detention, Wetlands, Community Recreation, Property Restoration	The proposed concepts include enhancements to the existing dry detention basins, including upgraded storage capacity, wetlands construction and improvements to the existing rugby fields. Furthermore, a former industrial facility on a 2-acre site has been demolished to restore the site with full vegetation. A future project may further enhance this site with bioretention gardens, permeable sidewalks, trees, bushes and grasses.	Benefits include use of dry detention to reduce construction of concrete conveyance conduits, ehancement of wetlands, improvements to community recreation facilities, and restoration of vacant industrial facilities for green space use.
Missouri Avenue/ Spring Lake Park	51997	South Interceptor	Yes	Multi-use pond, constructed wetland with submerged gravel beds, constructed stream segment, infiltration basin, bioretention garden, six water-quality basins with high-flow bypasses, mechanical separation manholes to trap oil and remove large-sized sediment.	The treatment train created by the mechanical separtion manholes, six water-quality basins, constructed stream segment, constructed wetland with submerged gravel beds, infiltration basin, bioretention garden, progressively treat stormwater from the contributing watershed to remove sediment and cleanse stormwater before it reaches the multi-use pond. Re-establishment of a fishing lake within the basin to provide stormwater detention. Water quality basins and wetland upstream of the wet pond for water quality benefit. All plantings will be of native species.	The multi-use pond will be utilized to attenuate flows, provide recreational opportunities, expand habitat diversity and reduce project costs by allowing reuse of exisiting downstream combined sanitary/storm pipes to convey separated storm flows. All green infrastructure practices within the project are designed to demonstrate their ability to create a synergery to improve water quality and protect the multi-use pond which is sited on the location of a historic pond which was lost to siltation from the contributing watershed. The total estimated cost savings for the project by including green infrastructure is $4,500,000. Flow reduction and water quality.
Missouri River WWTP Improvements	51875 / 52200	South Interceptor	Yes	Dry Detention, Vegetated Swales	The Green Solutions provide water quality treatment for the first 0.5-inch of runoff for the planned Project facilities, as well as some of the existing facilities at the MRWWTP.	Flow Reduction and water quality.
Nicholas Street Phase 1 (10th Street to 16th Street)	51892	Burt Izard	Yes		Since this project includes the extension of downstream trunk sewers that are designed to provide maximum capacity, green solutions are not appropriate to reduce the trunk sewer sizes or the length of sewers required. However, green solutions should be evaluated during future re-development of the area to provide for required storage. The City of Omaha has developed a Master Plan for this area entitled “North Downtown: Omaha’s New Urban Neighborhood”. However, because it is not yet clear how the area will be re-developed, no specific green solutions are recommended for incorporation into the Nicholas Street Sewer Extension – Phase I project. During design of future separation of the northern portion of the basin, green solutions should be evaluated to replace “unintentional” storage areas into green storage facilities.	
Nicholas Street Phase 2 Sewer Extension	52297	Burt Izard	Yes	Currently in preliminary design. Considering pervious pavements and bioretention.	Evaluating rain gardens, bioswales, bio-retention, pervious pavement, etc. Green infrastructure for this project will not reduce pipe sizes or reduce project cost. The goal for green infrastrucutre for this project is to provide water quality storage.	Water Quality
Ohern/Monroe Industrial Lift Station, Force Main & Gravity Sewer	51956	Ohern/Monroe	Yes	Bioretention Facility, Permeable Underground Storage System, and Grass Swales	Bioretention and a permeable underground storage system were used to maintain pre-project runoff conditions. Grass swales were used to reduce the quantity and size of storm sewers on site.	Reducing costs of on site storm sewers. Improving quality of runoff.

LTCP Project Name	OPW No.	CSO Study Basin	Reviewed for GS?	Green Solutions Selected for Design	Comments	Benefits (Including costs)
Paxton Boulevard Stormwater Conveyance Sewer and 33rd & Taylor Sub-Basin Sewer Separation	52077	Minne Lusa	Yes	Fontenelle Lake Expansion, Natural Stream Design in Park, Lake James Green Retrofits, and Green Solutions Along Paxton Blvd.	Green Infrastructure is planned for several locations touched by this project. Fontenelle Park Lake is planned to be expanded and a natural stream design is planned to be incorporated to convey stormwater through the park to the lake. The exact size and dimension of the expansions are still being established. Lake James will likely also be retrofitted to accommodate additional detention and bioretention/sediment forebays. The exact size is still being established. Paxton Boulevard will likely be retrofitted to incorporated green infrastructure within the ROW. The exact number and location of facilities is still being considered.	Fontenelle Park/Lake (~$3.5 million) - Will allow the downstream stormwater conveyance elements to be downsized and/or eliminated (To be determined). Sediment forebays within the Lake will help reduce sediment loads to the lake and improve water quality. A natural channel will help provide aeration to the influent stormwater and improve downstream water quality. Lake James Park (< $2 million) - Additional stormwater from the upstream areas will be delivered to the Park and existing detention facility. Multiple objectives will be balanced. No new downstream stormwater infrastructure will be built between Lake James and Fontenelle Park lake. Therefore, Lake James must be optimized to provide enough attenuation for the new inflows to ensure that the downstream infrastructure is within design standards. At the same time, costs at Lake James needs to be minimized because improvements at Fontenelle Park are more cost effective than improvements at Lake James. The $2 million value for this project is a "worst case" scenario, it is likely that the selected improvements at Lake James will be significantly less expensive than this. Paxton Boulevard (~$500,000) - When new stormwater conveyance infrastructure is constructed within Paxton Boulevard, the plan is to rebuild the street with bioretention and green solutions in the Right-of-Way (i.e., Green Street). The benefits will be reducing the size of downstream stormwater infrastructure while also reducing the amount of secondary stormwater infrastructure (i.e., inlets).
Saddle Creek Retention Treatment Basin	52049	Saddle Creek		Bioretention Ponds	The proposed concept includes bioretention and possibly a green roof. Green infrastructure will continue to be evaluated as design progresses.	Reducing costs of on site storm sewers. Improving quality of runoff.
SC 205-1; Country Club Phase 2 Sewer Separation (RNC)	50588	Saddle Creek	Yes	Rain Garden(s)	Bioretention garden selected for the intersection of Blondo Street and Country Club Avenue for water quality and neighborhood education. Other options were considered unfeasible. (Project is currently under construction.)	
South Interceptor Force Main	51873 / 52222 / 52223	South Interceptor, Leavenworth, Burt-Izard	Yes		Due to the linear nature of the SIFM project, opportunities for implementation of the Green Solutions Program on the project are limited. From Pierce Street to the Martha Street Diversion Structure, there are several small opportunities to increase the hydrologic function of the area. However, the timing for installation of these Green Solutions is better applied after completion of the SIFM to allow for future construction activities to take place without damaging any work completed. Therefore, Green Solutions in this area should be evaluated as part of the Pierce St Sewer Separation Project and the Hickory Street Sewer Separation Project. The area that will be purchased by Private parties should also be reviewed for a joint Public/Private opportunity to place Green Solutions near new railroad spurs as that development occurs in the future.	
South Omaha Industrial Area Sewer Separation (SOIASS)	51861	Ohern/Monroe	No		No feasible alternatives in establish industrial area. (Project is complete.)	
Spring Street Sewer Separation	51784	South Interceptor	No		Short 120-feet of sewer under a railroad corridor to an existing lift station. (Project is complete.)	
Webster Street Sewer Separation Phase 2	51503	Burt Izard	NA		This linear alignment is through an established industrial/commercial area along a major arterial with no feasible green alternative. (Project is complete.)	

LTCP Project Name	OPW No.	CSO Study Basin	Reviewed for GS?	Green Solutions Selected for Design	Comments	Benefits (Including costs)
Webster-Nicolas Street Separation East of 27th Street	51962	Burt Izard	Yes		Green infrastructure opportunities were evalauted as part of the 30% study phase of this project. The design team determined that sewer separation within the area containing Creighton University may not be effective and thus little, if any, sewer separation work is planned within this area. With no effective means of achieving sewer separation within the Creighton area, the benefits of any Green Solutions within this area are significantly reduced. Providing Green Solutions in the Creighton University area would, however, slightly reduce stormwater flows into the combined sewer system. No feasible alternatives within established industrial area.	

Appendix B
Technical Memorandum – Existing Practices for Green Infrastructure and Stormwater Management, City of Omaha

TETRA TECH, INC.

TECHNICAL MEMORANDUM

Date: October 19, 2012

To: City of Omaha

From: Carol Hufnagel, Dan Christian, Anne Thomas, Val Novaes: Tetra Tech

Subject: Existing Practices for Green Infrastructure and Stormwater Management, City of Omaha

Contract: EP-C-11-009

US EPA Green Infrastructure Community Partners Project

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A. EXECUTIVE SUMMARY

The City of Omaha, Nebraska desires to more broadly implement stormwater practices and green infrastructure as part of other municipal projects. This project will aid the City in the development of processes and tools to improve consistency in decision making and reduce barriers for inclusion of these practices.

Project Goals and Objectives. The City of Omaha, NE is the recipient of technical assistance from US EPA for the application of green infrastructure. The focus of the effort will be on developing processes that aid in its implementation. Of particular focus will be the assessment of approaches that improve the ability of Omaha to include green infrastructure in municipal projects. There is no current standard in the City for municipal right of way projects as it relates to stormwater management, other than drainage for flooding frequency events. The City is attempting to include control of the water quality volume in CSO projects, but this has a relatively significant financial test which is difficult to overcome.

In the context of the current technical assistance project, the intent is to work within the existing ordinances and standards that have been adopted and/ or published by the City. The goal is to develop process elements that work with the existing language to better support the implementation of green infrastructure through clarifying decision points and valuing the benefits that result from green infrastructure implementation.

Processes. The incorporation of green infrastructure is a relatively new practice in stormwater management. As a result, the criteria by which stormwater systems are designed is in the process of shifting from primarily flood control to a stormwater quality and green infrastructure approach. This shift results in the need for various decision making methodologies to support the goals of more localized management of stormwater. Each project type has its own inherent process of decision making. These project types include public and private projects, new development and redevelopment, CSO- and non-CSO- related activities.

As a result of the City's MS4 requirements and the leadership of the City in responding to these requirements, use of best management practices (BMPs), including green infrastructure, has been incorporated into most private development and redevelopment projects. Municipal projects have less defined processes for stormwater. Principal design criteria relate to design storm flow control and sizing of sewers, with the exception of CSO area projects where control of the first ½" of runoff is identified as an objective, when financially feasible.

A review of various documents pertaining to stormwater management in Omaha was conducted in order to summarize the specific requirements. Some of these documents have been adopted and others are in draft form. The documents focus on requirements to control (i.e. treat) the water quality volume (first ½" of runoff) and matching predevelopment conditions for the 2-, 10- and 100-year flood frequency events. While the documents are relatively clear for private developments, applicability to municipal projects (e.g. right-of-way corridors) is not defined.

B. DOCUMENTS REVIEWED

The information contained herein is a summary of applicable ordinances, manuals, guidelines and policies related to stormwater management and green infrastructure. The documents were reviewed to identify requirements versus recommendations as they pertain to the application of green infrastructure. The requirements and recommendations and basis for exceptions are summarized below. Documents included in the review and summarized below are the following:

- Omaha Regional Stormwater Design Manual
- Omaha Regional Stormwater Design Manual, Chapter 8, Draft (June 2012)
- City of Omaha Post Construction Stormwater Management Planning Guidance
- City of Omaha Codes and Ordinances
- City of Omaha MS4 permit and related documents
- U.S. Mayors Climate Protection Agreement
- Omaha Green Solutions Site Suitability Assessment and BMP Selection Guidance
- City of Omaha Master Plan – Stormwater Element
- City of Omaha Master Plan – Transportation Element
- Omaha's Historic Boulevards Master Plan

Documents included in the review but were not found to be significant to stormwater standards include the following:

- Omaha Regional Stormwater Design Manual, Chapter 9, Draft (June 2012)
- Green Streets for Omaha (February 2007)
- City of Omaha Master Plan – Environment Element

The following are additional documents referenced by Omaha but do not represent policy or requirements and were not reviewed:

- Manual of Best Management Practices for Stormwater Quality
  http://www.marc.org/Environment/Water/bmps.htm
- Urban Storm Drainage Criteria Manual – Volume 3
  http://www.udfcd.org/downloads/down_critmanual_volIII.htm

Table 1 and Table 2 provide an overview of the requirements as articulated in the current code, standards and references.

Table 1 lists these by reference source and Table 2 lists by project type.

Table 1: Requirements By Document Source

Document	Requirement
Omaha Regional Stormwater Design Manual (April 2006)	• Minor drainage system designed for runoff from the 10-year storm. • Major drainage system designed for runoff from the 100-year storm. • Storage facilities designed to maintain the peak rates from the 2-, 10- and 100-year storms. • NPDES NOI and SWPPP are required for land disturbance on sites of 1.0 acre and greater.
Omaha Regional Stormwater Design Manual, Chapter 8, Draft (June 2012)	• New development and significant redevelopment must 1. control the water quality volume 2. have no increase in the pre-project runoff rate for the 2-, 10-, and 100-year runoff rate
City of Omaha Post-Construction Stormwater Management Planning Guidance (November 2011)	• Develop a PCSMP that includes BMPs. • Provide water quality control of the first 0.5-inch of runoff from the site. • Maintain pre-project 2-yr runoff. • No Adverse Impact Downstream. • Additionally in CSO Permit Area: Maintain pre-project conditions for 2-, 10-, and 100-yr events.
City of Omaha Municipal Code, Chapter 32, Section 32-121 to Section 32-123	• Provide water quality control of the first 0.5-inch of runoff • Maintain the peak discharge rate during the 2-yr event to baseline conditions • For significant redevelopment projects not requiring a grading permit, control of the first 0.5-inch of runoff is not required.
NPDES Permit NE0133698 - Omaha MS4 (October 1, 2008)	• Requires implementation of control measures and other mgmt. practices to reduce pollutants in storm water discharges to the maximum extent practicable.

Document	Requirement
Amendments to the Stormwater Element of Omaha's Master Plan	Policy Group 1: • For all new developments, provide water quality control of the first 0.5-inch of runoff and maintain the peak discharge rate during the 2-yr event to baseline conditions • Encourage establishment of buffer strips along streams • Mitigate impacted wetlands at a 3:1 ratio Policy Group #2 • Peak discharge rates not to exceed 0.2 cfs/acre for the 2-year storm and 0.5 cfs/acre for the 100-year storm. • Significant redevelopment - no net increase in 2-, 10-, and 100- yr peak discharges

Table 2: Existing Project Type and Requirements

Project Type	Requirements	Reference for Requirements	Concerns/ Notes
Regional System Implementation			
Storm Drainage Systems	Minor systems designed for 10-year conveyance Major systems designed for 100-year conveyance Control flow rates to 2-, 10-, 100- year through regional retention/ storage	Omaha Regional Design Manual	Decision making on balance between opportunities for storage (impoundments) and existing conveyance capacity would involve significant cost evaluations The general philosophy used with respect to regional drainage is to prevent adverse downstream impacts, primarily from a capacity/ flooding perspective.
Drainage Systems in CSO areas	Drainage design on case by case basis in retrofit mode. Water quality control of ½" runoff.	Omaha Green Solutions Site Suitability Assessment and BMP Selection Process Guidance Document Chapter 32 municipal code	Separation projects are being implemented to improve conditions of basement flooding and other complaints. Generally seek to address local or area wide system bottlenecks cost effectively. Focus is on flooding control. In separation areas, new storm sewers are preferred as they have preference in rights of way. Once a new storm sewer is installed it typically is sized for a 10-year event.
Private Development/ Parcel Projects			
Platted Development (pre-2008)	PCSMP that includes BMPs Water quality control first ½" runoff (where reasonably practical) Pre-project 2-yr runoff rate maintained No adverse downstream impacts	Chapter 32 municipal code; Omaha Regional Stormwater Design Manual; Post Construction Stormwater Mgmt. Planning Guidance	Municipal code requirements are to prevent adverse impacts downstream. The 2-year runoff rate is considered to be related to channel protection. 10 and 100 year events are related to flood control (and are per the Omaha Regional Design Manual). The language is strictly related to flow rate and not flow volume. Coordination between stormwater and planning to ensure that concepts carry through the platting process.
Platted Development (post 2008)	PCSMP that includes BMPs Water quality control first ½" runoff Pre-project 2-yr runoff rate maintained No adverse downstream impacts	Chapter 32 municipal code; Omaha Regional Stormwater Design Manual; Post Construction Stormwater Mgmt. Planning Guidance	Municipal code requirements are to prevent adverse impacts downstream. The 2-year runoff rate is considered to be related to channel protection. 10 and 100 year events are related to flood control (and are per the Omaha Regional Design Manual). The language is strictly related to flow rate and not flow volume. Coordination between stormwater and planning to ensure that concepts carry through the platting process.
New Development or "significant redevelopment" > 1 acre (that does not require platting) in non-CSO areas	PCSMP that includes BMPs Control pre-project runoff rate for 2-, 10-, and 100-year (proposed chapter 8) events; "control the water quality volume (where reasonably practical)"; no adverse impact downstream	Chapter 32 municipal code; Omaha Regional Stormwater Design Manual; Post Construction Stormwater Mgmt. Planning Guidance	Municipal code requirements are to prevent adverse impacts downstream. The 2-year runoff rate is considered to be related to channel protection. 10 and 100 year events are related to flood control. The language is strictly related to flow rate and not flow volume. The 10- and 100- year control levels are referenced in the proposed chapter 8 of the Omaha Regional Stormwater Design Manual. Stormwater flow rate requirements for redevelopment projects are based on prior ("pre-project") land use **not** "undeveloped" land use. Where a redevelopment site is in an area where previous development was demolished/ vacated, 2004 is used as a reference year for the level of imperviousness that corresponds with the "pre-project" conditions. The ½ inch treatment requirement applies to all runoff from the property. The "where reasonably practical" language results in use of manufactured treatment devices (which are to be pre-approved) versus LID practices (which are the City's preference). The manufactured devices are generally used where space is not available.

Project Type	Requirements	Reference for Requirements	Concerns/ Notes
New Development or "significant redevelopment" > 1 acre in CSO areas	PCSMP that includes BMPs Control pre-project runoff rate for 2-, 10-, and 100-year events; "control the water quality volume"; no adverse impact downstream	Chapter 32 municipal code; Omaha Regional Stormwater Design Manual; Post Construction Stormwater Mgmt. Planning Guidance	Municipal code requirements are to prevent adverse impacts downstream. The 2-year runoff rate is considered to be related to channel protection. 10 and 100 year events are related to flood control. The language is strictly related to flow rate and not flow volume. The 10- and 100- year control levels are referenced in the proposed chapter 8 of the Omaha Regional Stormwater Design Manual. Stormwater flow rate requirements for redevelopment projects are based on prior ("pre-project") land use **not** "undeveloped" land use. Where a redevelopment site is in an area where previous development was demolished/ vacated, 2004 is used as a reference year for the level of imperviousness that corresponds with the "pre-project" conditions. The ½ inch treatment requirement applies to all runoff from the property. The "where reasonably practical" language results in use of manufactured treatment devices (which are to be pre-approved) versus LID practices (which are the City's preference). The manufactured devices are generally used where space is not available.
Significant redevelopment >5000 SF but less than 1 acre	PCSMP that includes BMPs Control pre-project runoff rate for 2-year events; no adverse impact downstream	Chapter 32 municipal code; Omaha Regional Stormwater Design Manual; Post Construction Stormwater Mgmt. Planning Guidance	
Private property "rehabilitation"	None		Rehabilitation projects are generally maintenance in nature. They do not include changing grades, tapping sewers or adding entrances (off of streets). An example would be a mill and resurface on a parking lot.
Right-of-Way or linear project			
Municipal Project (transportation) In CSO area Not in CSO area	There are no requirements for municipal projects in CSO areas No requirements		• In routine City projects, either in CSO or stormwater areas, there is no inherent requirement to control flow rates to predevelopment, including projects that increase imperviousness (such as road widening). • Nebraska Department of Roads (NDOR) has a requirement for control of the first ½" of runoff from a water quality perspective. Actual implementation of this requirement will be occurring for more recent NDOR funded projects.
Municipal CSO project	Water quality control of ½" runoff	Based on Chapter 32 municipal code	• CSO projects included an initial evaluation of green infrastructure benefits if 1" of rainfall capture was achieved. This was used in the planning process and is not an implementation criterion. The initial CSO project evaluation was primarily focused on regional facilities. As projects are implemented, treatment of a ½" water quality volume is considered as an objective, but is not a requirement. • Where sewer separation projects are resulting in flow to new stormwater outlets, the evaluation of the ½" water quality volume does not change (versus those projects where flow recombine downstream). Consideration of enforcing the ½" water quality control volume for new storm outlets may receive greater attention based on receiving water (e.g. Papillion Creek versus Missouri River). .

C. EXISTING POLICIES, PROCEDURES AND GUIDANCE

Below is a summary of each document reviewed. The summary includes a reference to the authority from which the document draws, and applicable exceptions to the requirement, and an excerpt of the requirement from the document. This section is divided into two sections; 1) document with stormwater-related requirements, and 2) documents with stormwater-related recommendations.

1. DOCUMENTS WITH STORMWATER-RELATED REQUIREMENTS

a. Omaha Regional Stormwater Design Manual (April 2006)

http://www.cityofomaha.org/pw/images/stories/pdfs/Stormwatermanual.pdf

Authority: SW Manual to be adopted by Omaha City Council. Regulations are located in Municipal Code Section 32 Article V, although the code references this document.

Exceptions: “The standards should not be construed as rigid criteria. The criteria are intended to establish guidelines, standards and methods for sound planning and design. The City may set aside these criteria in the interest of the health, safety, convenience, order and general welfare of the community. In the planning of drainage improvements in built-up areas, it is recommended that the design approaches presented be adjusted to optimize the benefit to cost ratio.” (Page 1-7)

Requirement Excerpt:

Page 1-4

1.5.2.1 Minor Drainage System

The minor drainage system is typically thought of as storm drains and related appurtenances, such as inlets, curbs and gutters. For residential areas, downtown areas, and industrial/commercial areas in Omaha, the minor drainage system design will provide capacity and management for the 10-year return frequency storm runoff, under assumed ultimate upstream development conditions.

During design, the hydraulic grade line for all enclosed systems shall be determined to ensure that inlets act as inlets, not outlets. All easements for newly constructed storm drainpipe should be a minimum of 30 feet wide. In situations where the engineer can clearly demonstrate that an easement less than 30 feet is adequate, the City may consider such a request. Easements wider than 30 feet may be necessary for storm drainpipe and surface water flowage where a drainageway must be designed and maintained to carry stormwater flow in excess of the storm drainpipe capacity.

1.5.2.2 Major Drainage System

The major drainage system is designed to convey runoff from, and to regulate encroachments for, large, infrequently occurring events. When development planning and design do not properly account for the major storm flow path, floodwaters will seek the path of least resistance, often through individual properties, thus causing damage. An assured route of passage for major storm floodwaters should always be provided such that public and private improvements are not damaged. For subdivisions in Omaha, this need is to be provided for both in watershed headwaters settings and along major drainageways.

The 100-year return frequency storm under assumed ultimate upstream development conditions shall be the major drainage system design storm for all new developments. Runoff from major storms should pass through a development without flooding buildings or homes. Overland flow routes can be provided using streets, swales, and open space.

Page 2-5

2.4.2 Frequency Design Criteria

Cross Drainage: Cross-drainage facilities transport storm runoff under roadways. The cross-drainage facilities shall be designed to convey (at a minimum) the 50-year runoff event with a minimum of two (2) feet of freeboard as defined in Chapter 4. The allowable depth of an overtopping event (for greater than a 50-year storm) is limited as indicated in Chapters 3 and 4 of this manual. The flow rate shall be based on upstream ultimate builtout land-use conditions as defined in the policies of the adopted Papio Watershed Plan.

Storm Drains: A storm drain, and attached piping shall be designed to accommodate the peak flow rate from a 10-year storm event. The design shall be such that the storm runoff does not: increase the flood hazard significantly on adjacent property; or encroach onto the street or highway so as to cause a safety hazard by impeding traffic, emerging vehicles, or pedestrian movements to an unreasonable extent.

Based on these criteria, a design involving temporary street or road inundation is acceptable practice for flood events greater than the design event but not for floods that are equal to or less than the design event. Thus, if a storm drainage system crosses under a roadway, the design flood must be routed through the system to show that the roadway will not be overtopped by this event. The excess storm runoff from events larger than the design storm may be allowed to inundate the roadway or may be stored in areas other than on the roadway until the drainage system can accommodate the additional runoff.

Omaha Regional Stormwater Design Manual 2 - 5

Page 2-6

Inlets: Inlets shall be designed for the peak flow rate from a 10-year storm event.

Detention and Retention Storage Facilities: Storage facilities should be designed to provide sufficient storage and release rates to manage the 2-, 10-, and 100-year design storm events to be consistent with the policies and requirements of the adopted Papio Watershed Plan.

Page 1-5

1.5.7 NPDES Construction Site Activities

A NPDES notice of intent and a Stormwater Pollution Prevention Plan (SWPPP) shall be required before land disturbance or vegetation removal activities occur on any site 1.0 acre or greater in size (see Chapter 9). Structural and non-structural best management practices (BMPs) may be required to address stormwater quality enhancement.

b. Omaha Regional Stormwater Design Manual, Chapter 8, Draft (June 2012)

Authority: Municipal Code Section 32, Article V and Municipal Code Section 53-11, Cluster Subdivisions

Requirement Excerpt:

Page 8-2

8.2.1.1 Community Objectives and Performance Standards

Community objectives and performance standards control the infrastructure necessary to sustain a development. Stormwater quality goals are often supported by defining ways to achieve community performance standards with design criteria that accentuate community values while minimizing health and safety concerns. Additional considerations include:

- ***Building Density / Lot Size*** –Zoning regulations and subdivision regulations often dictate allowable building densities and lot sizes for specific land uses and, consequently, the stormwater volume, rate, and pollutant load. Impervious area reductions, stream buffer zones, and stormwater BMP sites may be accommodated by regulations in Municipal Code Section 53-11 Cluster Subdivisions that allow clustering to protect open spaces.

Page 8-3

8.2.1.2 Environmental Objectives and Performance Standards

Environmental objectives and performance standards typically are framed by local, regional and state environmental regulations, and permit requirements. Many environmental objectives also achieve community objectives, enhancing the overall quality of life of residents. This section discusses how to establish environmental objectives and performance standards based on these regulations, permit requirements, and other considerations that typically affect projects in the Omaha region.

In the Omaha region, stormwater management regulations include those that make up the National Pollutant Discharge Elimination System (NPDES) for Municipal Separate Storm Sewer Systems (MS4), Construction Sites, Industrial Permits, and Combined Sewer Overflow (CSO) permit. The NPDES program regulates the quality of stormwater runoff. Post-construction stormwater management plan (PCSMP) requirements evolved as a program requirement in the MS4, but it applies throughout Omaha's corporate limits plus a 3 mile extra territorial jurisdiction (ETJ), i.e., it applies to areas covered by both the MS4 AND the CSO permit.

The PCSMP requirements apply to new land development and significant redevelopment that discharge to the City's MS4 or combined sewer system. New land development includes development projects in areas not previously built to urban uses (including but not limited to farmland, pasture, woodland, and green space). Significant redevelopment includes development projects in areas that are currently built to urban and suburban land uses, and are being revitalized with rehabilitation of existing structures, or demolition of existing structures and construction of new ones. These developments are required to control the WQCV.

In addition to controlling the WQCV, new development or re-development projects must maintain a "No Adverse Impact" condition. "No Adverse Impact" for the purpose of meeting the post-construction stormwater requirements is defined as no increase in the pre-project runoff rate for the 2-, 10-, and 100-year runoff rate for post project conditions. The only exception to this requirement is in cases where the project discharges *directly* to one of the existing regional detention facilities associated with the Papillion Creek Watershed (i.e., Zorinsky Lake, Glenn Cunningham Lake, or Lake Wehrspann) or to the Missouri River. Other demonstrations of a "No Adverse Impact" may be possible on a case-by-case basis.

The design, implementation, and maintenance guidelines provided in this Chapter are intended to assist developers in meeting the performance standards outlined in Municipal Code Section 32 Article V and are primarily aimed at providing control of the WQCV. Many of the BMPs discussed here can also be used to provide peak flow attenuation in order to achieve a "No Adverse Impact" condition. Chapter 2, Chapter 6 and Chapter 8 should be referenced when using BMPs for treatment of the WQCV and peak flow attenuation. BMPs not included in this document may be used in new development and redevelopment projects as long as they are preapproved by the City and are designed to control the WQCV.

Projects discharging to the combined sewer system (generally those east of 72nd Street) must control runoff such that there is no net increase in runoff from pre-development con ditions as they existed in October 2002 for 2-, 10-and 100-year storm events. In addition, the City of Omaha may require stormwater detention in areas where there is not adequate downstream sewer capacity. The applicant should meet with the City of Omaha Public Works Department to verify these requirements for each individual development.

c. City of Omaha Post-Construction Stormwater Management Planning Guidance (November 2011)

http://www.omahastormwater.org/images/stories/Development/PCSMP%20Guidance%20Document%20FINAL%207-23-09.pdf

Authority: Chapter 32, Article V of the Omaha Municipal Code
"No Adverse Impact" - Chapter 32, Article VII of the Omaha Municipal Code
CSO Areas: CSO Permit

Requirement Excerpt:
Page 2

Stormwater Management Guidance Summary

Stormwater Management Requirements in CSO Permit area (refer to attached figure ES-2)

- PCSMP (control first ½" of runoff)
  - Reference: Chapter 32, Article V of the Omaha Municipal Code.
  - Refer to Table 1 for specific requirements
  - The PCSMP requirement exists in the CSO areas because once the sewers are separated; the area will then fall under the MS4 permit.
- Maintain pre-project conditions (as they existed in 2002) for 2-, 10- and 100-yr events.
  - This is a result of the requirement in the CSO Permit. One of the 9 minimum controls is "no increase in the magnitude, duration, or frequency of overflows". By maintaining pre-project runoff conditions, this provides engineers and the City a quantifiable means to ensure this requirement is met.

Stormwater Management Requirements MS4 Permit area (areas outside CSO service area)

- PCSMP (control first ½" of runoff and maintain pre-project 2-yr runoff conditions.)
  - The PCSMP program is a result of the requirement in the City's MS4 permit to establish a Post Construction Stormwater Management Program.
  - Reference: Chapter 32, Article V of the Omaha Municipal Code.
  - Refer to Table 1 for specific requirements.
- Maintain "No Adverse Impact" condition
  - This policy is outlined in the Land Use element in the City of Omaha Master Plan. http://www.cityofomaha.org/planning/comprehensive-plan (Land Use Element, p 10 and 63). The policy is based on the NRD's recommended practice for the Papillion Creek Watershed.
  - The No Adverse Impact approach "assures that the action of one property owner or a community does not adversely impact the properties and rights of other property owners, as measured by increased flood peaks, flood stage, flood velocity, erosion, sedimentation and costs now and costs in the future."
  - Reference: Chapter 32, Article VII of the Omaha Municipal Code.

Table 1: Post-Construction Stormwater Management Plan (PCSMP) Applicability	
Development	**Requirement**
(1) For all developments with a preliminary plat approved by City Council on or after July 1, 2008 (2) For any replat in a preliminarily platted subdivision approved by City Council before July 1, 2008 that significantly increases the amount of impervious area (if required by the Planning Director)	PCSMP that includes BMPs. Provide water quality control of the first ½" of runoff from the site. Maintain pre-project 2-yr runoff. No Adverse Impact Downstream
(1) For all developments with a Preliminary Plat approved by City Council before July 1, 2008 (2) For all development or significant redevelopment that disturbs 1 acre or more and does not require preliminary platting	PCSMP that includes BMPs. Where reasonably practical, provide water quality control of the first ½" of runoff from the site. Maintain pre-project 2-yr runoff. No Adverse Impact Downstream
Significant redevelopment that adds or replaces less than 1 acre but more than 5,000 SF of surface area [1,2,3] Includes: (1) The expansion of a building footprint (2) Addition or replacement of a structure (3) Replacement of impervious surface that is not part of a routine maintenance activity (4) Land disturbing activities related to structural or impervious surface	PCSMP that includes BMPs. Maintain pre-project 2-yr runoff. No Adverse Impact Downstream
Significant redevelopment involving an outlot parcel that is part of existing development	PCSMP with BMP's. Water quality control of the first ½" of runoff for *impervious area.* Maintain pre-project 2-yr runoff conditions. No Adverse Impact Downstream

[1]Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of facility or emergency redevelopment activity required to protect public health and safety.

[2]Control of the first ½" of runoff in these cases is not required, however, the applicant must demonstrate that best management practices are included.

[3]Projects that disturb more that 5000 sq ft, but result in less impervious area are addressed on a case by case basis as far as whether a PCSMP is required

d. City of Omaha Municipal Code, Chapter 32, Section 32-121 to Section 32-123
http://library.municode.com/index.aspx?clientID=10945&stateID=27&statename=Nebraska
(Accessed September 18, 2012)

Authority: Omaha ordinance

Exception: "Systems designed to accommodate only one single family dwelling unit, duplex, triplex, or quadraplex, provided the single unit is not part of a larger common plan of development or sale, are exempt from the requirements in this chapter to submit a PCSWMP." (Section 32-123)

Requirement Excerpt:

Sec. 32-121. - Requirement for all new development and redevelopment projects.

Land development and significant redevelopment projects with the potential to add pollutants to stormwater or to affect the flow rate or velocity of stormwater runoff after construction is completed must include provisions for the management of the increased post construction runoff in a post-construction stormwater management plan.

(Ord. No. 37395, § 1, 6-13-06)

Sec. 32-122. - Post-construction stormwater management plan.

For all developments that have not had a preliminary plat approved by the city council prior to July 1, 2008, the post-construction storm water management plan, at a minimum, shall include low impact development (LID) BMPs to provide for water quality control of the first one-half inch of runoff from the site and shall maintain the peak discharge rates during the two-year storm event to baseline land use conditions, measured at every drainage outlet (storm water discharge) from the new development or significant redevelopment, and include the BMP or BMPs selected, the BMP design, schedules and procedures for inspection and maintenance of the BMPs. Provisions for BMPs are set forth in the Omaha Regional Stormwater Design Manual. The director may also require this minimum control level for replats that significantly increase the amount of impervious area in a preliminarily platted subdivision, which was approved by the city council prior to July 1, 2008.

For all developments with plats preliminarily approved by the city council prior to July 1, 2008 and for any sites requiring a permit under section 32-101 and for significant redevelopment projects, the post-construction storm water management plan, at a minimum, shall include the BMP or BMPs selected, the BMP design, schedules and procedures for inspection and maintenance of the BMPs, and for any sites requiring a permit under section 32-101 and where it is reasonably practicable, include BMPs for water quality control of the first one-half inch of runoff from the site. Provisions for BMPs are set forth in the Omaha Regional Stormwater Design Manual. For significant redevelopment projects that do not require a permit under section 32-101 or that involve replacement of building structures without significant disturbance of existing parking or other pervious areas, BMPs for water quality control of the first one-half inch of runoff from the site shall not be required. For significant redevelopment projects involving an outlot parcel that is part of a greater existing development, the calculation of the area requiring control of the first one-half inch of runoff shall be based only on the impervious area of the project site that is being added or disturbed within the outlot parcel.

(Ord. No. 37395, § 1, 6-13-06; Ord. No. 38222, § 2, 8-26-08; Ord. No. 38544, § 1, 10-20-09)

Editor's note—

At the direction of the city, the amendment to § 32-122 by Ord. No. 38486 has not been codified, as the ordinance is currently under review.

e. NPDES Permit NE0133698 - Omaha MS4 (October 1, 2008)

Authority: Federal Water Pollution Control Act 40 CFR 122.269d)(2)(iv) and the Nebraska Environmental Protection Act Title 119, Chapter 10 004.02D

Requirement Excerpt:

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D. Compliance to the Maximum Extent Practicable

Pursuant to state regulation Title 119, Chapter 10 004.02D and federal regulation 40 CFR 122.26(d)(2)(iv). This permit requires implementation of control measures and other management practices to reduce pollutants in storm water discharges to the maximum extent practicable. Narrative effluent limitations (a narrative description of the program elements and measurable Best Management Practices (BMP) goals) requiring implementation of BMPs will be used to reduce pollutants and protect water quality to the maximum extent practicable. Program elements will include management practices, control techniques, and system design and engineering methods and such other provisions that are appropriate.

f. Amendments to the Stormwater Element of Omaha's Master Plan (Interoffice Memorandum, Planning Department, June 15, 2009)

Authority: Adopted by City Council

Requirement Excerpt:

Policy Group #1 – Water Quality Improvements (renamed from Pollution Control)

- Water Quality Low Impact Development (LID) is required for all new developments
- Control of the first half inch of stormwater runoff
- No net increase in peak discharge for the 2 year storm event
- Encourage establishment of buffer strips and riparian corridors along streams
- Mitigate impacted wetlands at a 3:1 ratio
- Water quality basins as identified in the Watershed Management Plan

Policy Group #2 – Peak Flow Reduction

- Regional detention basins as identified in the Watershed Management Plan
- Maximum LID as identified in the Watershed Management Plan.
- Peak discharge rates not to exceed 0.2 cfs/acre for the 2 year storm event and 0.5 cfs/acre for the 100 year storm event
- Significant redevelopment no net increase in 2, 10 and 100 year peak discharges

Policy Group #3 – Landscape Preservation, Restoration, and Conservation

- Natural features and stormwater management techniques to be placed in public right of way or easement
- 3:1 plus 50 foot creek setbacks along streams as identified in the Watershed Management Plan

Policy Group #4 – Erosion and Sediment Control and Other BMPs

- No significant changes

Policy Group #5 – Floodplain Management

- Limit filling in the floodway fringe to 25% of total floodplain area per development application. Remaining fringe area to be designated as a floodway overlay zone.

Policy Group 6 – Stormwater Management Financing

- Water Quality LID funded by development
- Water quality basins and regional flood control reservoirs to be funded 1/3 from development fees and 2/3 from NRD funds (not a change from 2006 policy)
- Stormwater utility encouraged for on-going operation and maintaining city and county NPDES Best Management Practices

b. Changes to the Watershed Management Plan

The watershed map showing the long term plan for managing water has been modified to reflect the changes in the Policies, most notably that:

- Low Impact Development (LID) for water quality will be required for all new development and significant redevelopment across the watershed.
- In the jurisdictions of Douglas and Washington County, Maximum (enhanced) LID will be used for flood control.
- Up to 14 additional regional flood control reservoirs and 12 additional water quality basins may be evaluated for construction in the future.

2. Documents with Stormwater-Related Recommendations

a. Omaha Green Solutions Site Suitability Assessment and BMP Selection Process Guidance Document

Guidance Summary: 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 CSO's and economic benefit to rate-payers. Identify and implement natural system enhancements that contribute to the control of CSO's, improve water quality and/or create valuable community enhancements. This document applies to infrastructure improvement projects. Seven goals were developed to support the implementation of the vision statement.

Implementation of Green Infrastructure is envisioned as part of the CSO project process in locations where cost savings can be accomplished. Figure 2 of the document identifies the thought process to be implemented for considering green infrastructure in CSO programs. This process applies well to regional detention facilities that store large volumes and significantly reduce the size of downstream pipes.

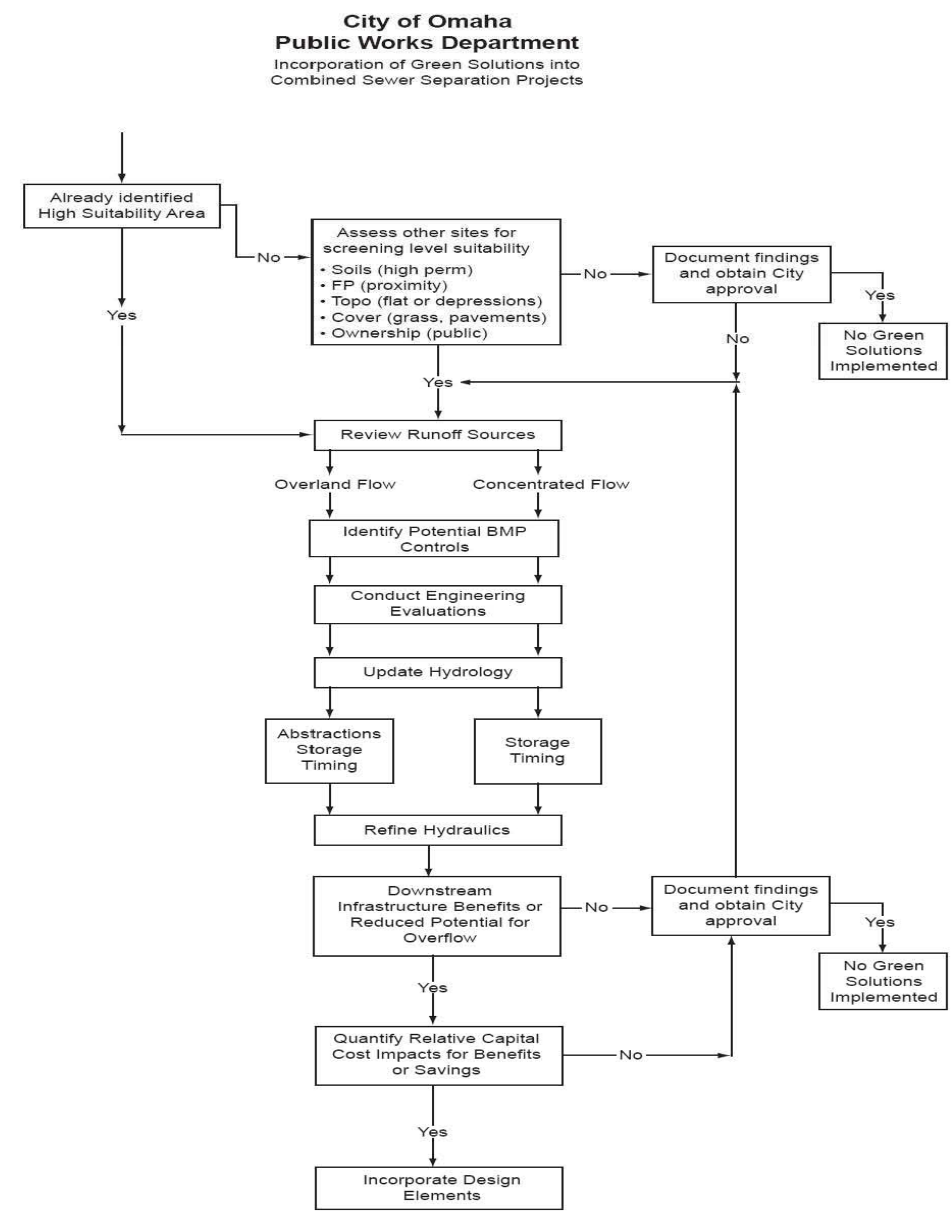

Figure 2: Green Solutions Implementation Flow Chart

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b. U.S. Mayors Climate Protection Agreement (As endorsed by the 73rd Annual U.S. Conference of Mayors meeting, Chicago, 2005)

Guidance Summary: Adopt and enforce land-use policies that reduce sprawl, preserve open space, and create compact, walkable urban communities. Maintain healthy urban forests; promote tree planting to increase shading and to absorb CO_2. Strive to meet or exceed Kyoto Protocol targets for reducing global warming pollution by taking actions on our own operations and communities.

c. Omaha Master Plan – Transportation Element (Jim Suttle, Mayor, Report #304)

Guidance Summary: In the Project Ideas Section, projects were grouped into major categories. Applicable categories for LID within the ROW include:

1. Cross Section Modification - most commonly road diets
2. Publicly-led new Street projects - Projects most commonly associated with development projects.
3. Pedestrian Corridor Projects - Typically consist of streetscape projects.
4. Pedestrian Crossing - Site-specific projects refer to pedestrian crossing improvements not necessarily associated with a larger interstection project.
5. Intersection Projects - Vehicle-based safety, operational and capacity projects, but also pedestrian-based crossing improvements.

d. Omaha's Historic Boulevards Master Plan (Draft – August 2012)

Guidance Summary: These principals apply to boulevard projects. The guidelines are meant to provide project managers, city staff and consultants with a design decision-making tool to ensure the preservation of, or expectations for, improvements within the historic Omaha Boulevard's System. [Note that some of the principals in this document may work against some of the efforts to incorporate LID into projects.]

Guiding Principles:
1. Preservation of Existing trees is paramount
2. Preserve existing center medians, curb radii intersections and islands
3. Preserve current horizontal and vertical alignments of Boulevards
4. Implement way-finding and identification throughout the system
5. Preserve and enhance the long, linear expanse of parkway lawn
6. Make use of the pavement width or narrow roadway over time
7. Prevent placement of overhead power lines within or adjacent to ROW
8. Restore historical connections

e. Omaha Master Plan – Environment Element (Jim Suttle, Mayor, Report #302)

Guidance Summary: The focus of this document is on five broad topics including Natural Environment, Urban Form and Transportation, Building Construction, Resource Conservation, and Community Health. Each of these topics is a section within the document and was developed soliciting public and advisory committee input. The document is primarily a compilation of goals and objectives surrounding the five topics. The subject of stormwater surfaces several times throughout the document expressing the following guiding principles:

1. Use natural treatment solutions to address water quality.
2. Improve water quality in the metropolitan area to meet or exceed state and federal regulations.
3. Base stormwater management plans on the characteristics of each watershed.
4. Encourage the use of green roofs, green walls, and rainwater harvesting techniques to reduce runoff volume and improve water quality.
5. Optimize the on-site retention and re-use of storm water generated from building sites.
    a. Encourage the use of narrower streets and permeable paving.
    b. Utilize rain gardens and open drainage systems to reduce volume and speed of runoff and to improve water quality.
    c. Encourage the use of green infrastructure to meet federal CSO mandates.
    d. Provide for rainwater harvesting in the City code.
    e. Ensure that stormwater and erosion controls are installed and maintained during construction.
    f. Ensure that City staff levels are adequate so that storm water site plan review and on-site inspection occur in a timely manner.
6. Educate the public about stormwater management practices including how to install rain gardens, rain barrels, green roofs, and cisterns.

D. DISCUSSION/CONCLUSION

Of the thirteen documents reviewed for stormwater-related requirements and recommendations, six contained authoritative requirements. The six documents were primarily based on the authority of the Municipal Code Section 32, Article V and the Papillion Watershed Management Plan. The document with the most extensive definition of requirements is the City of Omaha Post-Construction Stormwater Management Planning Guidance (November 2011). Generally, the documents do not contradict each other but some provide more detailed information as to which scenarios the requirements apply.

E. BARRIERS AND ACTIONS

As part of the review of documents and the project kick-off meeting, a discussion regarding various barriers to implementation of green infrastructure was held. A summary of various barriers and current status is included as Table 3.

Table 3: Barriers, Goals and Actions

Barrier	Description of Barrier	Current Status/ Action to Date	Goals or Required Objectives to Achieve	Short Term Actions Required	Long Term Actions Required
Funding/ Economics (municipal projects)	• Cost justification for including green infrastructure/ stormwater quality management has no way to assess value outside of project capital costs. • Limited dedicated stormwater funding sources. No specific source of funds for capital projects.	• Adopted concept of including green if cost neutral or otherwise feasible.	• Increase incorporation of green infrastructure on projects though a consideration of broader/ longer term benefits.	• Develop a stronger business case for the value of doing green based on a variety of direct, tangible benefits (examples include: reduced CSO facility size [potentially], reduced flow rates to downstream storm sewers that lack capacity, reduced pavement maintenance [street diets], and improved capacity of local sewers [if new sewers can be avoided]). Consider this based on a 20 – 30 year present value consistent with bonding cycles. Consider life-cycle cost including O&M. [Task 2] • Define broader set of economic and non-economic benefits that are clearly understandable to the community [Task 2]	• Add additional specifics to process for evaluating green versus gray • Consider implementation of highly effective retrofit projects targeting impervious areas.
Political	• External ratepayers are highly sensitive to expenditure of sewer funds on project elements not seen as essential • Requirements are very difficult to modify – developed regionally for MS4 program • Prefer redevelopment within the City to sprawl in undeveloped areas.	• Accomplished adoption of standards calling for BMPs	• Green infrastructure adaptation defensible to ratepayers.	• Need to be able to demonstrate value of SW mgmt./ green infrastructure to the broader stakeholder [Task 2]	• Need to be able to demonstrate cost neutrality, provide supportive funding or lesser requirements

Clarity of Requirements	• No requirement for municipal projects located within the right-of-way.
	• A primary requirement is to limit flow increases relative to a 2004 base year.
	• Historic requirements relate to flood control rather than stormwater quality/ green infrastructure. Tends to drive design
	• Redevelopment versus rehabilitation triggers are not clear to the public
		• PCSMP adopted as routine expectation; BMP adopted as routine expectation; ½" water quality volume treatment adopted as routine expectation
		• CSO program adopted policy of ½" runoff treatment
		• NDOR has ½" water quality treatment requirement
			• Develop standard for municipal right of way projects
			• Reduce or eliminate "off-ramp" language (define "feasibility")
			• Identify requirements to meet longer term/ variety of objectives
			• Clarify standards for redevelopment to higher level of control than "existing conditions".
				• Consider requirements that would apply to municipal projects with increased imperviousness (e.g. road widening). [Task 3, 4]
				    ○ Review definitions
				    ○ Clarify standards
				    ○ Work within existing requirements; modify process only
					• Revise standards, expectations to meet future requirements such as various levels of control

Barrier	Description of Barrier	Current Status/ Action to Date	Goals or Required Objectives to Achieve	Short Term Actions Required	Long Term Actions Required
Internal Understanding/ Concerns	• Internal appreciation of the need for SW mgmt. is lacking • NDOR funding and the EIS process limit the ability to make changes • Maintenance and who pays for maintenance (e.g. parks projects, streets). Internal road engineers generally skeptical of LID practices.	• Closer coordination between design division and stormwater manager has improved incorporation of green infrastructure	• Better definition of stormwater requirements for road projects	• Better definition of downstream stormwater capacity assessment required for reconstruction projects. • Clarify critical timelines for NDOR funded projects that involve EIS and which projects are beyond the point at which modifications can be made. [Task 3, 4]	• Develop design templates [started under Task 4] • Revisit some NDOR funded projects if early (enough) in project definition • Define street width for various streets and triggers for implementation
Process	• Lack of coordination between stormwater and planning • Platting process – changes that occur and are not sufficiently reviewed before approval • Electronic documents review is not fully implemented and is currently cost prohibitive.	• Moving toward more of an electronic plan review process	• Maximize implementation of green infrastructure	• Develop description of process [Task 3]	• Continue to move toward electronic system • Revise process to increase participation
Standards	• Design standards are built around flood protection. Tiered (dual) system of standards for water quality and flood protection is not understood/ embodied in practice. • Process for changing standards is long, requires consensus and is political	• The City has worked to update standards to better incorporate green infrastructure	• Standards require no net increase in runoff. Goal is to decrease runoff rate.	• Clarify design standards based on downstream capacity limitations [Task 3] • Clarify design standards (dual water quality and flood protection) and how they apply to municipal right-of-way projects. [Task 3] • Attempt to work within established standards to frame process. [Task 3	• Implement ordinance for right-of-way projects to comply with standards comparable to parcel projects. • Redo Papillion Watershed Management Plan to better address water quality. Currently based on flood control. This plan influences the standards adopted inside and outside of the Papillion Watershed.
Post Construction Requirements for Private Development	• Exception language for redevelopment where imperviousness is not increased	• Requirements established based on flow control to the 2004 baseline year.	•	• Clarify current practice and requirements. [Task 3]	•

Appendix C
Green/Gray Cost Comparison Process Table

Objective	Screening Level	Refinement Level	Items that Need Better Definition to Support Analysis
Identify characteristics of tributary area under assessment	Gross characterization of area (imperviousness/ perviousness); identification of obvious opportunities for stormwater control (e.g. large parcels; already separated stormwater) Larger subareas	Better definition of impervious by land use type such as: - Parking lots - Residential properties - Large roof areas - Local streets - Major streets Segregate impervious area into directly connected and not directly connected areas More thorough identification of already separated areas	GIS layers to support development; such as the impervious area types identified; directly or indirectly connected impervious area.
Identify volume of control required for CSO performance target	Look at volume required for area of interest (in total) Assume 85% volumetric control annually	Look at volume required by sub area within area of interest Various levels of CSO control (to develop a curve)	Good surrogate event for the 85% criterion – may vary by CSO area dependent on the flow to treatment (area specific) Volume of storage for other control types
Identify benefit for conveyance level of service of CSO control	Look at existing and future level of service of downstream conveyance with green infrastructure provided (model analysis using available model representation); define conveyance upgrades required for level of service with/ without green	Look at conveyance capacity at a more local level. Define conveyance upgrades required for level of service with/ without green	Refined understanding of hydrology/ flow response within combined areas
Define types of controls for green infrastructure management of CSO	Identify large site specific controls Identify control types by land type (e.g. parking, roof, street) Quantify for total study area	Refine quantification for subareas Define “subtypes” of green control (for example – streets could be permeable pavement or bioretention)	Develop standardized concepts to achieve various levels of control

Objective	Screening Level	Refinement Level	Items that Need Better Definition to Support Analysis
Develop cost assessment for unit practices for green infrastructure	Apply level of control uniformly across area; define total volume controlled by practice type, such as: - Large practices - Parking lots - Local streets (differential cost if other work is performed or total cost if no other work is performed) - Roof area control	Optimize based on volume controlled/ $; requires more site specific development of practices and costing (at least to some degree)	Cost development for standardized concepts and refined costs for unique applications Better definition of design standards
Define offsetting savings for capital costs	Use a "best professional judgment" curve for offset of gray costs OR use linear curve although this is not defensible. Roughly estimate conveyance cost value	Extend to subareas within the system. Address specific known problem areas (basement or street flooding).	Develop cost curves for gray practices that are partially offset – for example smaller tunnel or reduced capacity basin
Define operational costs/ benefits for green infrastructure and gray	Ignore	Increase detail and apply definitions that are developed	Unit savings for reduced flow to treatment Definition of amount of flow removed from system through green practices (e.g. permeable pavement evaporation or bioretention infiltration or disconnected downspout infiltration).
Develop implementation programs			Develop approaches to reduce impacts of private property impervious area; Define approaches to reduce street widths over time
Product	Screening level: - Gray costs - Green costs (for comparison)		

Appendix D

Financial and Non-financial Benefits Table

Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	Financial or Enhancement
				Driver							**Funding Source**					
Public Works	Combined Sewer Overflow Control	Achieves or exceeds regulatory requirement for CSO Control as single technology employed		**X**	**X**	**X**					**X**					Financial
		Used in conjunction with other CSO controls – reduces size or cost of those facilities														
		Reduce Volume of Overflow in residual CSO discharge events														
	Basement Backup Reduction / Odors	Reduces existing basement backup (performance standard for City separation projects). *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.*	Yes			**X**				**X**		**X**				Financial
	Reduction of Surface or Street Flooding Problems	Reduces existing street flooding (performance standard for all new sewer projects). *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.*	Yes		**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**			Financial

Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	Driver							Funding Source						Financial or Enhancement
				Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	
Public Works	Improved Level of Service	Helps achieve 2-year capacity standard					**X**	**X**				**X**	**X**			Financial
		Helps achieve 10-year capacity standard					**X**	**X**				**X**	**X**			
	MS4 Permit "Requirements"	Achieves stormwater regulatory requirements; supports required elements of TMDL program		**X**				**X**					**X**			Financial
	Stormwater/ Water Quality Enhancements	*Water quality improvements in the receiving streams above and beyond the minimum regulatory 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.*	Yes; 14					**X**					**X**			Enhancement
	Reduce Streambank Erosion								**X**					**X**		Enhancement
	Wastewater Treatment	Reduces volume of wastewater to be treated at WWTP			**X**						**X**					Financial

				Driver							Funding Source					
Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	Financial or Enhancement
Public Works	Simplicity of Solutions	*The simplicity of the 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.*	Yes		**X**											Enhancement
	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 replacement.*	Yes		**X**				**X**	**X**						Enhancement
Environmental Benefits (Quantitative)	Air Quality	Sulfur Dioxide (SO_2) reduction								**X**					**X**	
		Nitrogen Dioxide (NO_2) reduction								**X**					**X**	
		Ozone (O_3) reduction								**X**					**X**	
		Particulate Matter < 10 micrometers (PM-10) reduction								**X**					**X**	
		Particulate Matter < 2.5 micrometers (PM-2.5) reduction								**X**					**X**	
	Climate Change Mitigation	CO_2 reduction								**X**					**X**	

Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	**Driver**							**Funding Source**					Financial or Enhancement
				Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	
Environmental Benefits (Quantitative)	Energy Savings	Resulting from Green Roof								**X**					**X**	
		Resulting from Tree Shading								**X**					**X**	
	Salt/ Deicer Use Reduction	Resulting from the use of Permeable Pavement.								**X**				**X**		
	Infiltration	Resulting from the volume of water directed to infiltration practices								**X**					**X**	
Societal Benefits	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*	Yes							**X**					**X**	
	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, traffics, and proximity); safety.*	Yes							**X**					**X**	

				Driver							Funding Source					
Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	Financial or Enhancement
Societal Benefits	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*	Yes							**X**					**X**	
	Recreation Increase	Resulting from the presence of substantial green space.								**X**					**X**	
	Aesthetics Increase (property value increase)	Resulting from the presence of substantial green space.								**X**					**X**	
	View Increase (property value increase)	Resulting from the presence of a green roof below a residence								**X**					**X**	
	Urban Heat Island Reduction	Resulting from the presence of vegetative cover								**X**					**X**	

				Driver							Funding Source					
Benefit Category	Benefit Type	Description	Omaha CSO Plan defined benefit?	Regulatory	CSO	WW	Drainage	Water Quality	Infrastructure	Quality of Life	All WW rates	City WW rates	SW funds	City General Funds	No source/Other	Financial or Enhancement
Societal Benefits	Landscape Job Creation (Avoided cost of social services)	Resulting from the presence of landscaping and vegetative stormwater practices								**X**					**X**	
Environmental Benefits	Water Quality Improvement	Resulting from a decrease in waterborne pollutants						**X**		**X**					**X**	
	Ecosystem Integrity	Resulting from the preservation of natural habitat						**X**		**X**					**X**	
	Habitat Improvement	Resulting from increased green space						**X**		**X**					**X**	
	Wetland Enhancement	Resulting from the increase in wetland area						**X**		**X**					**X**	

Appendix E
Design Standards Comparison Tables

Table 1: Examples of Municipalities addressing Stormwater Design Criteria within the Public Right-of-Way

Municipality	Language		Reference
NE, Kearney	9-1606 APPLICABILITY. A. This Article shall be applicable to all construction activity and land developments requiring; including, but not limited to site plan applications, subdivision applications, building applications, and right-of-way applications from the City, unless exempt pursuant to Paragraph B of this Section below. These provisions apply to all portions of any common plan of development or sale which would cause the disturbance of at least one acre of soil even though multiple, separate and distinct land development activities may take place at different times on different schedules. B. The following activities are exempt from this Article: (1) Any emergency activity that is necessary for the immediate protection of life, property, or natural resources; and (2) Construction activity that provides maintenance and repairs performed to maintain the original line and grade, hydraulic capacity, or original purpose of a facility. (Ord. No. 7573, 2-23-2010) 9-1626 POST–CONSTRUCTION REQUIREMENT OF PERMANENT BMPs. A. Land development that meets the requirements of Section 9-1606 of this Article must address storm water runoff quality through the use of permanent BMPs. Permanent BMPs shall be provided for in the drainage plan for any subdivision plat, annexation plat, development agreement, subdivision agreement or other local development plan. B. Structural BMPs located on private property shall be owned and operated by the owner(s) of the property on which the BMP is located; unless the City agrees in writing that a person or entity other than the owner shall own or operate such BMP. As a condition of approval of the BMP, the owner shall also agree to maintain the BMP in perpetuity to its design capacity unless or until the City shall relieve the property owner of that responsibility in writing. The obligation to maintain the BMP shall be memorialized on the subdivision plat, annexation plat, development agreement, subdivision agreement or other form acceptable to the City and shall be recorded with the City of Kearney Public Works Department. (Ord. No. 7573, 2-23-2010)		9-1602 http://citycode.kearneygov.org/citycode/
PA, Philadelphia	Section 600.1 Definitions (e) Development: Any human-induced change to improved or unimproved real estate, whether public or private, including but not limited to land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in these Regulations, development encompasses both new development and redevelopment. It includes the entire development site, even when the project is performed in stages. (q) Redevelopment: Any development on a site that requires demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970, with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling projects are also not considered redevelopment. Section 600.2 Regulations (a) Regulated activities under these Regulations include any development, including new development and redevelopment, that results in an area of earth disturbance greater than or equal to 15,000 square feet. The area of Earth Disturbance during the construction phase determines requirements for both the erosion and sediment controls and the post-construction stormwater management.		Philadelphia Water Department Regulations, Section 600.1 Stormwater Management, 600.1 Definitions http://www.pwdplanreview.org/WICLibrary/StormwaterRegulations.pdf

Municipality	Language		Reference
VA, Suffolk	Sec 35-5 (d) The following activities are exempt from the stormwater performance standards: (1)Permitted surfaces or deep mining operations and projects, or oil and gas operations and projects conducted under the provisions of Code of Virginia, Tit. 45.1. (2)Tilling, planting or harvesting of agricultural, horticultural or forest crops. (3)Construction of single-family residences separately built and not part of a subdivision, including additions or modifications to existing single-family detached residential structures. (4)Land development projects located within Chesapeake Bay Preservation Areas that disturb less than 2500 square feet of land area or outside of CBPA's that disturb less than 10,000 square feet of land area. (5)Linear development projects, provided that: a.Less than one acre of land will be disturbed per outfall or water shed, b.There will be insignificant increases in the peak flow rates. Insignificant increases are generally considered to be less than one cubic foot per second (cfs), however the reviewing authority's discretion will be applied.; and c.There are no existing, or anticipated, flooding or erosion problems downstream of the discharge point. (Ord. No. 07-O-097, 9-5-2007)		http://library.municode.com/index.aspx?clientId=14461
WA, Seattle	Development means any activity that requires a permit or approval, including, but not limited to, a building permit, grading permit, shoreline substantial development permit, conditional use permit, special use permit, zoning variance or reclassification, subdivision, short subdivision, urban planned development, binding site plan, site development permit, or right-of-way use permit. "Development" does not include a Class I, II, III, or IV-S forest practice conducted in accordance with Chapter 76.09 RCW and Title 222 WAC or a class IV-G nonconversion forest practice, as defined in KCC 21A.06, conducted in accordance with Chapter 76.09 RCW and Title 222 WAC and a county approved forest management plan. Site (a.k.a. development site) means a single parcel, or two or more contiguous parcels that are under common ownership or documented legal control, used as a single parcel for purposes of applying for authority from King County to carry out a development/project proposal. For projects located primarily within dedicated rights-of-way, site includes the entire width of right-of-way within the total length of right-of-way subject to improvements proposed by the project. Transportation redevelopment project means a stand-alone transportation improvement project that proposes to add, replace, or modify impervious surface, for purposes other than maintenance, within a length of dedicated public or private road right-of-way that has an existing impervious surface coverage of thirty-five percent or more. Road right-of-way improvements required as part of a subdivision, commercial, industrial or multifamily project may not be defined as a separate transportation redevelopment project. Drainage review is required for any proposed project (except those proposing only maintenance) that is subject to a King County development permit or approval, including but not limited to those listed at right, AND that meets any one of the following conditions: 1. The project adds or will result in 2,000 square feet or more of new impervious surface, replaced impervious surface, or new plus replaced impervious surface, OR... Impervious Surface Exemption for Transportation Redevelopment Projects A proposed transportation redevelopment project is exempt if it meets all of the following criteria: a) Less than 2,000 square feet of new impervious surface will be added, AND b) Less than 35,000 square feet of new pervious surface will be added, AND c) The total new impervious surface within the project limits is less than 50% of the existing impervious surface.		http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/MainBody-2009.pdf (page 1-5)
WI, Madison	(e) Municipal road or county highway projects not exempted under s. 14.47(2)(b) (projects exempted from local erosion control ordinances under state or federal statute) are exempt from s. 14.51(2)(c) (runoff rate control) where 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 s. 14.51 are met; and 4. The project does not include the addition of new driving lanes.		http://danedocs.countyofdane.com/webdocs/pdf/ordinances/ord014.pdf

Table 2: Examples of Stormwater Design Standards within the Great Plains States

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
IA, Des Moines	Iowa Statewide Urban Design and Specifications, (SUDAS) Design Manual for detention requirements. For Des Moines water quality: http://www.dmgov.org/Departments/PublicWorks/Pages/WaterQuality.aspx Chapter 106, Article III, Div. 1, Sec. 106-136 - Stormwater runoff control.	Chapter 106, Article III, Div. 1, Sec. 106-136 - Stormwater runoff control. A stormwater runoff control plan shall reduce projected runoff for a project by controlling rain events that total 1.25" or less in a 24-hour period, with the resulting volume being released at a rate that allows for a detention time of 24 hours through incorporation of stormwater management facilities.	"Emphasis should be placed on detention, storage, and the use of other BMPs to manage rainfall with a goal of not increasing erosion, sedimentation, or the discharge rate downstream from that existing prior to development"	Release rate for 2- and 5-year design storms, shall be limited to pre-developed peak rates from those same storms. 10- to 100-year storm events shall not exceed existing pre-development rate for a 5-year frequency storm. Duration of these storms is based on a critical duration of rainfall requiring the greatest detention volume.	5-year storm for local and minor collectors 10-year storm for major collectors, arterials, freeways
KS, Kansas City	No standards found online				

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
KS, Wichita	City of Wichita Code of Ordinances, Title 16 - Sewers, Sewage Disposal and Drains, Chapter 16.32 - Stormwater Pollution Prevention City of Wichita and Sedgwick County Stormwater Design Manual Volume 1 chapter 3 for water quality	The 80% TSS removal standard shall be applied to the 85th percentile storm event for the Wichita area, which is equal to 1.2 inches of rainfall. Property owners must adhere to one of the following options in order to comply with the water quality treatment requirement for redevelopments. 1. A 20% reduction in impervious area on the property; 2. Stormwater runoff from at least thirty percent (30%) of the site’s existing impervious cover and for one-hundred percent (100%) of the impervious cover for any newly disturbed area must be treated for water quality prior in accordance with the standards and criteria presented in this section of the Stormwater Manual; 3. Equivalent water quality controls must be provided at an alternative location in the same watershed as the proposed redevelopment; 4. One or more known downstream water quality or channel erosion issues located within the same watershed as the proposed redevelopment must be addressed through stream restoration and/or other off-site remedies. 5. Payment of a fee in-lieu-of water quality control and channel protection control facilities. 6. Any combination of (1) through (5).	The runoff volume from the new or redevelopment that results from the 1-year, 24-hr storm shall be detained for not less than 24 hours, or the volume difference between pre- and post must be infiltrated, reused or evaporated.	Storm water runoff peak discharge analysis and control shall be required for applicable new developments or redevelopments with the storm water quantity standards and criteria provided in the Storm Water Manual. The calculated peak discharge of stormwater runoff at each site outfall resulting from the 2-, 5-, 10-, 25- and 100-yr 24- hour storm shall be no greater than pre-development. (pg. 3-8 in Volume I of SW Manual).	Design storms range from 2- to 10-years depending on the land use.

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
MN, Minneapolis	Minneapolis Ordinance, Chapter 54. Storm Water Management Minneapolis Storm Water Management Design Manual (copies can be obtained from the Minneapolis Department of Public Works)	In general, the purpose of the storm water management ordinance is to minimize negative impacts of storm water runoff rates, volume, and quality on Minneapolis lakes, streams, wetlands and the Mississippi River by guiding future development and redevelopment activity.	Stormwater management standards are set according to the receiving water body, and for Minneapolis streams there is to be no increase in rate of runoff from a site.		Cannot find on-line.
MO, Springfield	City of Springfield Drainage Criteria Manual, Chapter 9 - Detention for Flood Control and Chapter 10-Water Quality	To minimize potential adverse impacts of urbanization and improve water quality, the City of Springfield, MO, along with many communities around the United States, encourages the widespread use of storm water Best Management Practices (BMPs) on all development sites. The purpose of this chapter is to provide guidance for selecting, designing, and maintaining BMPs.	The post-development peak runoff rate for all land development must be no greater than the pre-development peak runoff rate for the 1-, 10- and 100-year design storms.		25-year HGL to not exceed elevation of gutter 100-year HGL to meet street inundation criteria

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
MO, St. Louis	St. Louis County Phase II Storm Water Management Plan 2008-2013 St. Louis County Highways and Traffic Design Criteria Manual	See Flood Control language below.	Ponds and/or lakes will be dewatered at a rate not to exceed a 15-year design storm to protect against erosion and siltation damage to adjacent properties and roads.	Site Design Guidance - Long term storm water runoff from projects that disturb an area greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge in to the Municipal Separate Storm Sewer System (MS4), shall ensure that controls are in place that have been designed and implemented to prevent or minimize water quality impacts by reasonably mimicking preconstruction runoff conditions on all affected new development projects and by effectively utilizing water quality strategies and technologies on all affected redevelopment projects, to the maximum extent practicable. Site characteristics shall be assessed at the beginning of the construction / site design phase to ensure adequate planning for storm water program compliance. Design that promotes storm water infiltration within the site shall be emphasized.	Cannot find on-line.
NE, Lincoln	City of Lincoln Drainage Criteria Manual	Specifically, the water quality control volume (WQCV) that is <u>recommended</u> for control is the first half inch (0.5 inches) of runoff from the basin tributary to the BMP.	Detention facilities shall have release rates which do not exceed the pre-development discharge rates for the 2-, 10- and 100-year storms.		Inlet control: 5-year for residential areas 10-year for commercial, inductrial, and arterial

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
OK, Oklahoma City	Oklahoma City Municipal Code, 2010 Chapter 16-9 - Drainage and Flood Control, Detention http://library.municode.com/index.aspx?clientId=17000	No water quality criteria.	No channel protection criteria.	In drainage areas with known downstream flooding of structures, or if it is determined that development of subject property will cause or contribute to flooding or sedimentation of existing structures downstream, the developer shall install detention facilities maintaining a discharge rate not to exceed the historical runoff rate prior to development. In drainage areas where the City has no record of downstream flooding of structures and development of the subject property using a runoff coefficient of 70 percent would not cause downstream flooding of existing structures, detention will not be required. Detention storage will be required for the increased runoff resulting from development having an imperviousness in excess of 70 percent for all developments on parcels greater than two acres. The required volume for stormwater detention shall be calculated on the basis of the runoff from a 100-year frequency rainfall of an appropriate duration.	Surface water collected in streets shall be diverted to storm drains at satisfactory intervals to prevent overflow of six-inch-high curbs during 25-year frequency rain for the area and grades involved. Drainage area allowed for surface flow on streets at point of diversion shall not exceed 20 acres, regardless of flow.

Municipality	Reference	Water Quality Treatment Objective	Channel Protection	Flood Control	Conveyance
OK, Tulsa	City of Tulsa Stormwater Management Plan (accessed online: http://www.cityoftulsa.org/city-services/flood-control/stormwater-management-plan.aspx) City of Tulsa Code of Ordinances - Title 11-A - Stormwater Management and Hazard Mitigation Program, Chapter 3 - Watershed Development Regulations	Stormwater quality is of growing concern in municipal drainage management. Tulsa has geared up to meet new federal requirements for stormwater discharge NPDES permits (National Pollutant Discharge Elimination System permits). Tulsa's most serious problem with runoff quality was found to be sediment, which is being addressed through vigorous regulation of erosion from construction projects. The city is also emphasizing street sweeping, environmental monitoring, and stormwater laboratory services as part of its stormwater quality program.	New or substantially improved developments must detain the excess stormwater on site - unless they are exempted in master plans or allowed to pay a fee in lieu of on-site detention. Water from detention basins is released slowly downstream. In-lieu fees are allocated for regional detention facilities. In most instances, the city has found regional detention basins to function more satisfactorily than smaller, scattered on-site facilities. "No rise allowed" in City of Tulsa floodplain.		Cannot find on-line.
TX, Fort Worth	City of Fort Worth Integrated Storm Water Management (iSWM) Criteria Manual for Site Development and Construction, August 1, 2012	Water Quality Protection is not currently required by the CFW.	Downstream impacts due to a development must be analyzed and mitigated for the 1-, 10-, and 100-year floods for the entire Zone of Influence, as determined by the development engineer's analysis. The Zone of Influence for any proposed development must be defined by the development engineer, based on a drainage study that determines the specific location along the drainage route where "no adverse impacts" from the new development exist. Storm drainage from a development must be carried to an "adequate outfall" or "acceptable outfall."		The design storm is a minimum of the 100-year storm for the combination of the closed conduit and surface drainage system. Runoff from the 5-year storm must be contained within the permissible spread of water in the gutter. The 100-year storm flow must be contained within the ROW. Adequate inlet capacity shall be provided to intercept surface flows before the street ROW capacity is exceeded. Note: The capacity of the underground system may be required to exceed the 5-year storm in order to satisfy the 100-year storm criteria.
TX, Lubbock	City of Lubbock Stormwater Management Drainage Criteria Manual, 1997	No water quality criteria.	Lubbock does not have any specific detention/flood control criteria. They have criteria for runoff carrying capacities in the streets, storm drains, open channels, culverts and playa lakes. The playa lakes help detain stormwater. An analysis is required for the 100-year storm and at times, a 500-year storm.		Street capable of conveying the 100-year event within boundary conditions of street. 5-year event for pipes with inlets on grade and 25-year event for pipes with inlets in low points.

Appendix F
Green Infrastructure Construction Details and Photos

<u>Design Standards and Standard Details that incorporate Green Infrastructure</u>

Table 1 includes a list of green infrastructure details as well as an estimate of where each may be applied within the street right-of-way or on a site development. In most cases where a detail is denoted under Right-of-Way as well as Site Development, one detail may suffice to show both applications. Also listed are miscellaneous details that are typically a part of green infrastructure design. Specifications to consider in conjunction with the standard details are listed below the table.

Table 1 Green Infrastructure Details and Applicability

Green Infrastructure Details	**Right-Of-Way**					**Site Development**	**Block and Intersection Layout Per Street Type**
	Sidewalk	**Greenway**	**Median**	**Parking Lane**	**Travel Lane**		
Traditional Bioretention			●			●	
Bioswale		●				●	
Corner Curb Extension (Node)	●	●					●
Mid-block Curb Extension	●	●					●
Tree Box	●		●			●	
Planter Box	●					●	
Permeable Concrete	●			●	●	●	
Permeable Asphalt	●			●	●	●	
Permeable Concrete Pavers	●			●		●	
Grid Pavers						●	
Filter Strip and Level Spreader						●	
Sand Filter						●	
Cisterns						●	
Rain Barrel						●	
Green Roof						●	
Pocket Wetland						●	
ROW Widths (sidewalk, greenway, median, parking, travel lane)							●
Miscellaneous							
Curb Cut	●	●	●			●	
Sediment Sump	●					●	
Rock-lined Sediment Forebay	●	●	●				
High Flow By-Pass Structure						●	

Possible Specifications:

- Soil amendments
- Plantings
- Engineered soil mixture
- Aggregate storage
- Aggregate Filter Layer
- Structural Soil
- Modular suspended pavement (Silva cell system)
- Permeable concrete
- Permeable asphalt
- Permeable interlocking concrete pavers
- Concrete and plastic grid pavers

BIOSWALE

LEGEND:

— — — —	4" UNDERDRAIN SOCK TILE
- - - - - -	6" PERFORATED SCHEDULE 40 PVC
———	6" SOLID WALL SCHEDULE 40 PVC

American Rivers
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GREAT LAKES BIOREGION
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NCI NORTHWEST CONSULTANTS, INC.
CIVIL – STRUCTURAL – ENVIRONMENTAL
3220 Central Park West, Toledo, OH 43617
Tel. (419)841-4704, Fax (419)841-2979

TETRA TECH
www.tetratech.com
420 Madison Ave. Suite 1001
Toledo, OH 43604
PHONE: (419) 255-9500 FAX: (419) 255-9501

MARK	DATE	DESCRIPTION	BY
	11/30/09	ISSUED FOR BID	

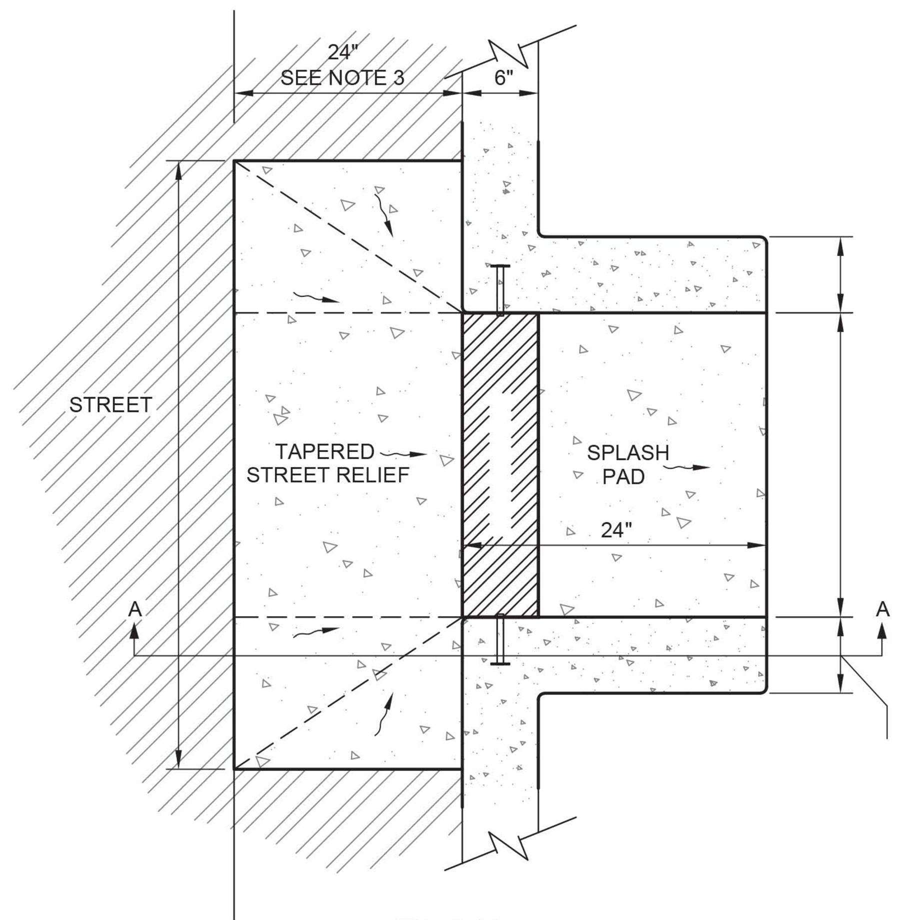
Client: CITY OF TOLEDO, OHIO
Proj. Loc.: CITY OF TOLEDO, OHIO

MAYWOOD AVENUE STORM WATER VOLUME REDUCTION PROJECT

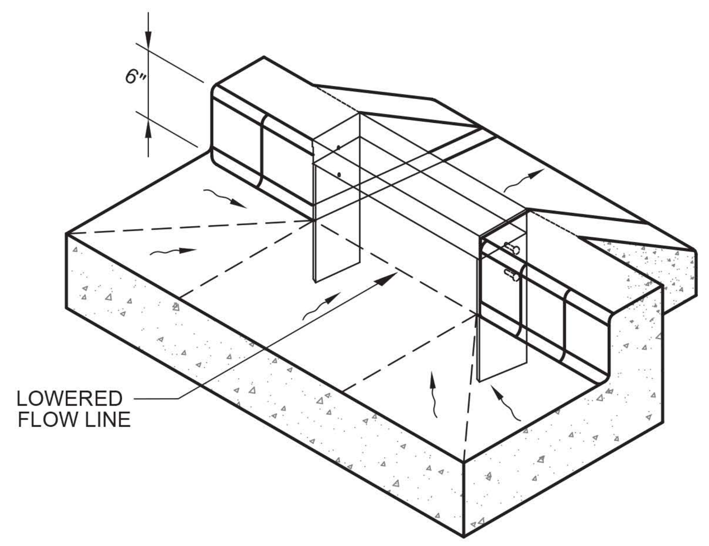
UTILITY SITE PLAN
STA. 6+50 TO STA. 13+00

Project No.:	200-06764-10001
Designed By:	A. DAVENPORT
Drawn By:	S. GOTHA
Checked By:	D. CHARVILLE

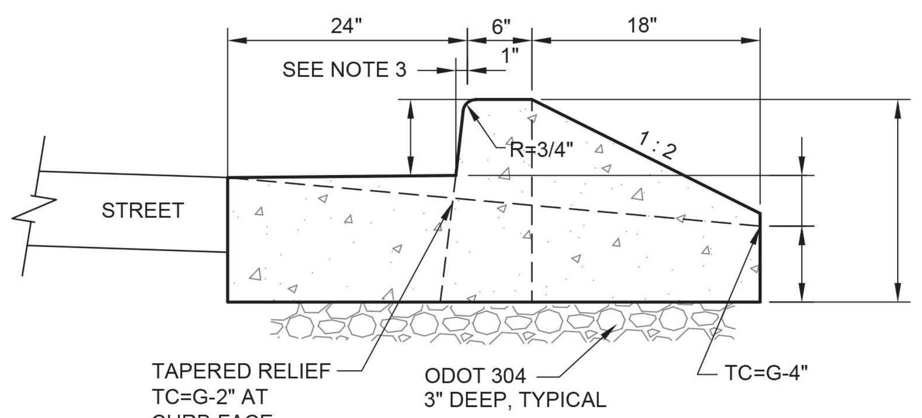
C-104



PLAN



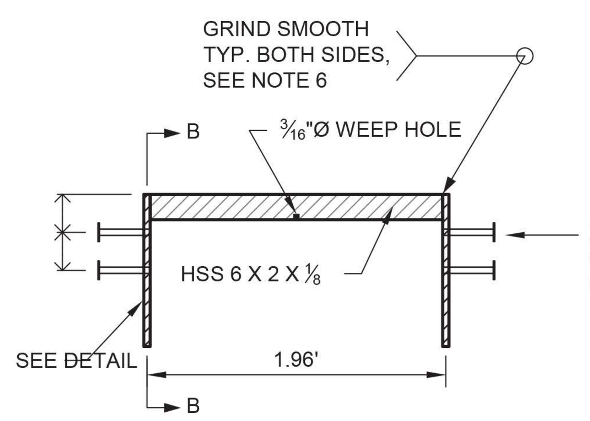
ISOMETRIC



TC = TOP OF CONCRETE

G = GUTTER

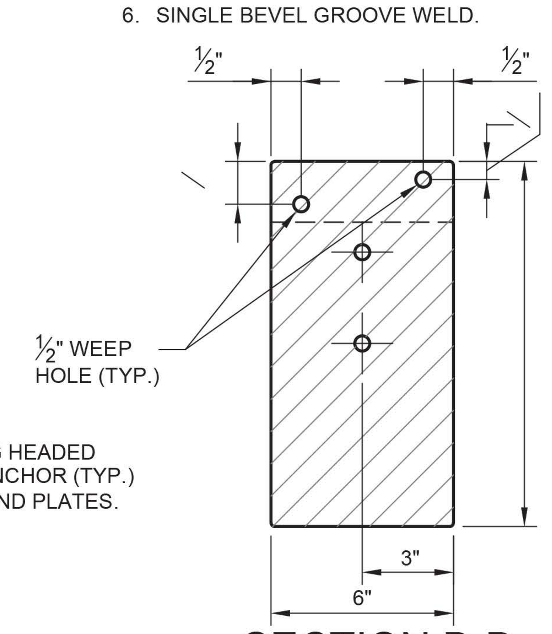
SECTION A-A



ELEVATION

NOTES:

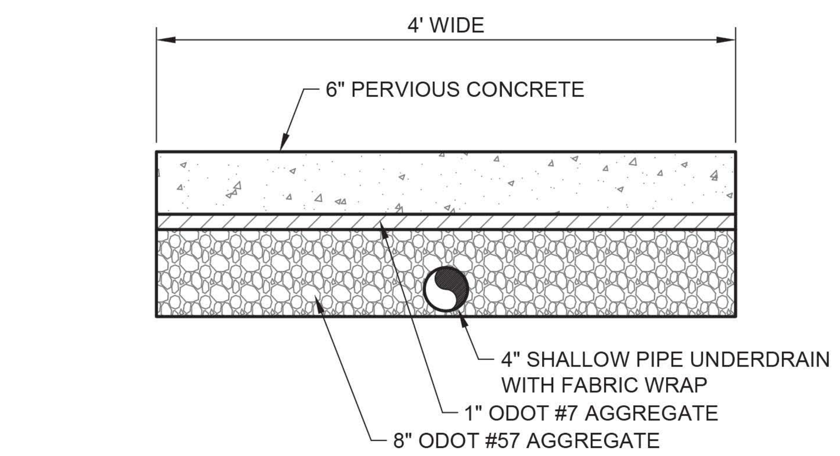
1. HEADED CONCRETE ANCHORS SHALL MEET THE REQUIREMENTS OF ASTM A-108.
2. HSS 6 X 2 X 1/8 SHALL MEET THE REQUIREMENTS OF ASTM A-500 GRADE B.
3. END PLATES SHALL MEET THE REQUIREMENTS OF ASTM A-36.
4. ENTIRE ASSEMBLY SHALL BE HOT-DIP GALVANIZED IN ACCORDANCE WITH ASTM A-123.
5. DESIGN VERTICAL WHEEL LOAD IS 8.5KIPS (1/2 OF TANDEM AXLE WEIGHT SPECIFIED IN FHWA-HOP-06-105).
6. SINGLE BEVEL GROOVE WELD.



SECTION B-B
END PLATE DETAIL

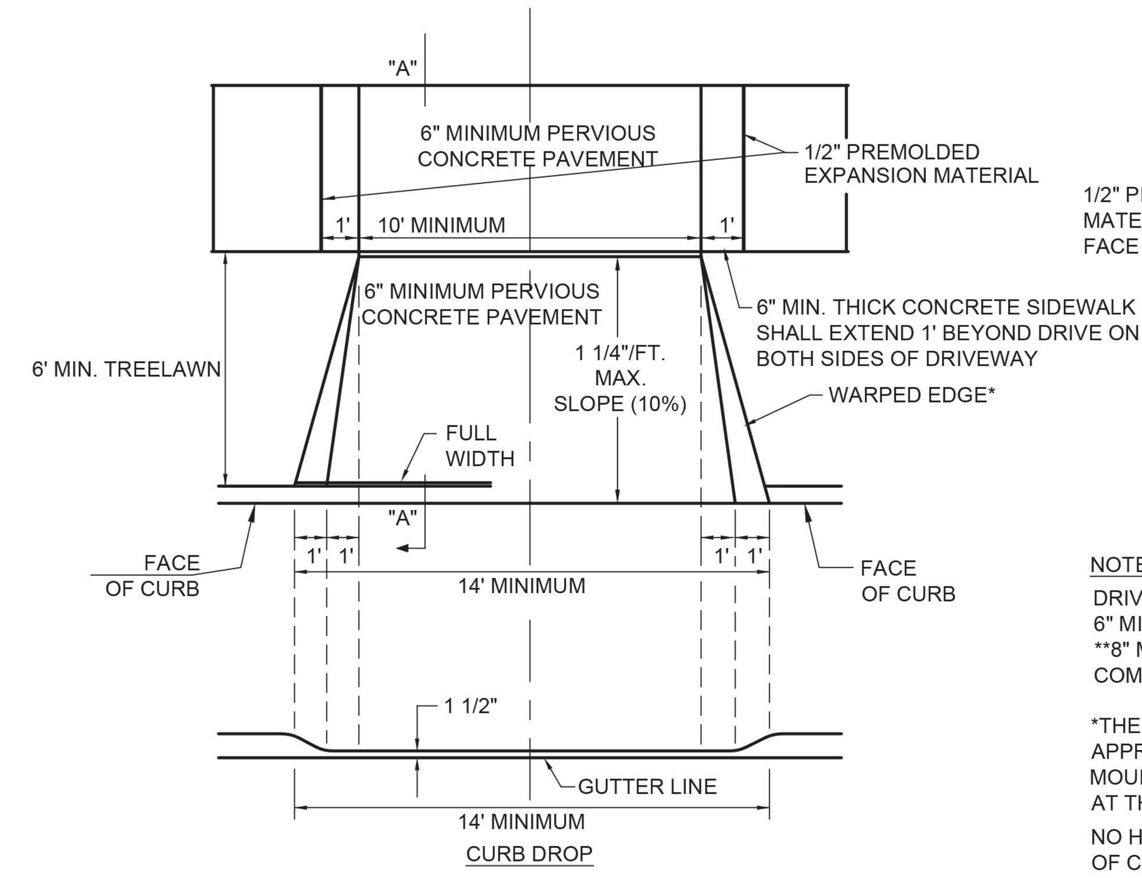
CONCRETE INLET SPILLWAY

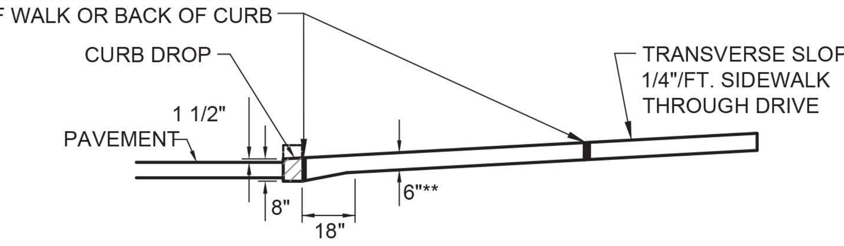
SCALE: 1" = 1'



(NON-BIOSWALE AREAS)
PERVIOUS CONCRETE SIDEWALK DETAIL

NO SCALE





CURB AND DRIVE POURED SEPARATELY

SECTION "A-A"

NOTE:

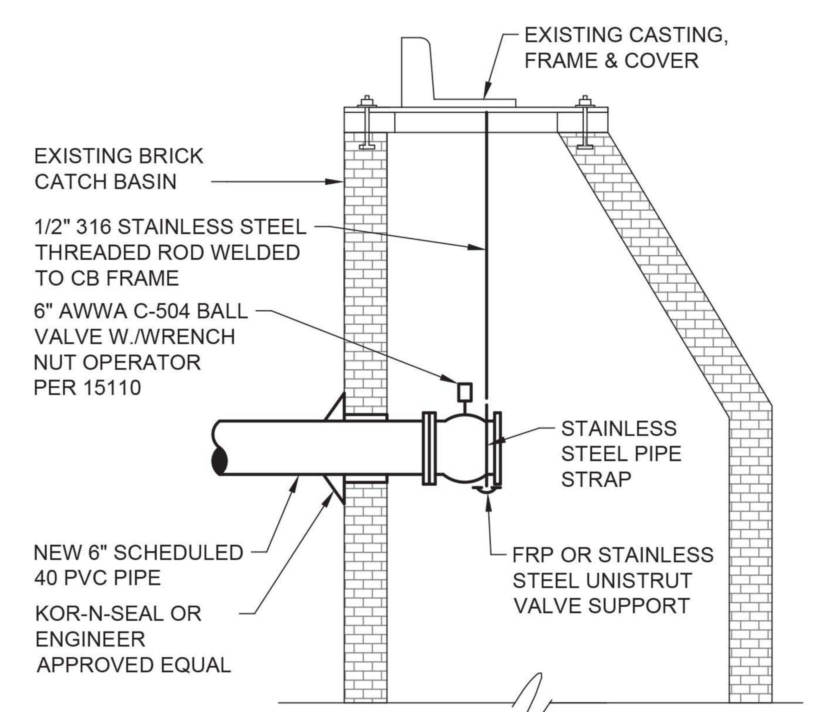
DRIVEWAY TYPICAL SECTION:
6" MINIMUM PERVIOUS CONCRETE
**8" MINIMUM CONCRETE FOR COMMERCIAL DRIVES

*THE WARPED EDGE IN THE DRIVE APPROACH SHALL BE SIMILAR TO TYPE "E" MOUNTABLE CURB AND SHALL TAPER TO 0" AT THE FACE OF THE SIDEWALK.

NO HORIZONTAL SAW CUTTING OF CURB WILL BE ALLOWED.

RESIDENTIAL PERVIOUS DRIVEWAY DETAILS

SCALE: NONE

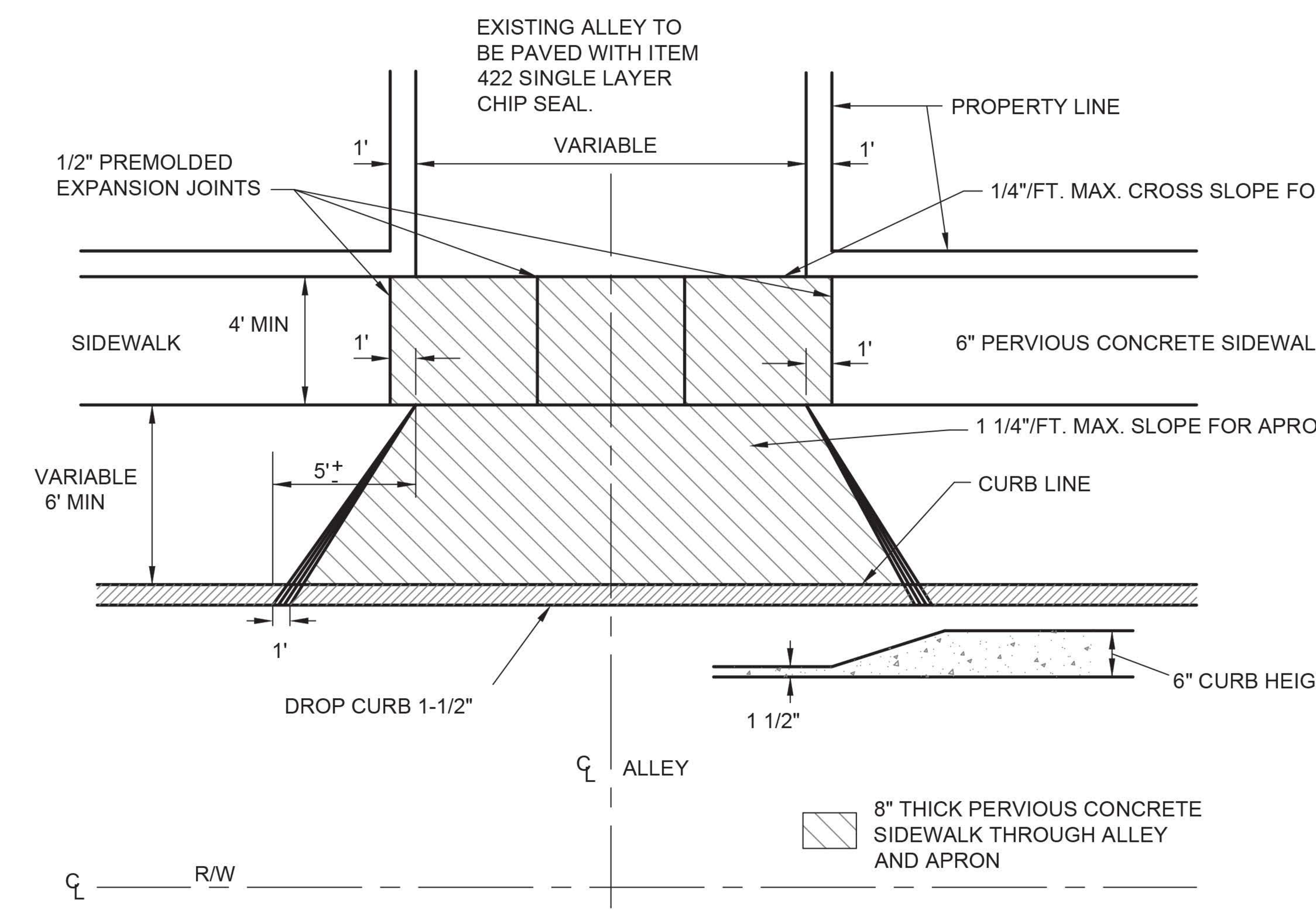


NOTES:

1. ALL HARDWARE SHALL BE 316 STAINLESS STEEL OR EQUAL.
2. WRENCH NUT OPERATOR SHALL BE ALIGNED VERTICALLY BENEATH THE GRATE PORTION OF THE CATCH BASIN.
3. CORING HOLE IN CB IS INCIDENTAL TO DRAINAGE CONDUIT CONNECTION TO CATCH BASIN.

SWALE DEWATER VALVE DETAIL

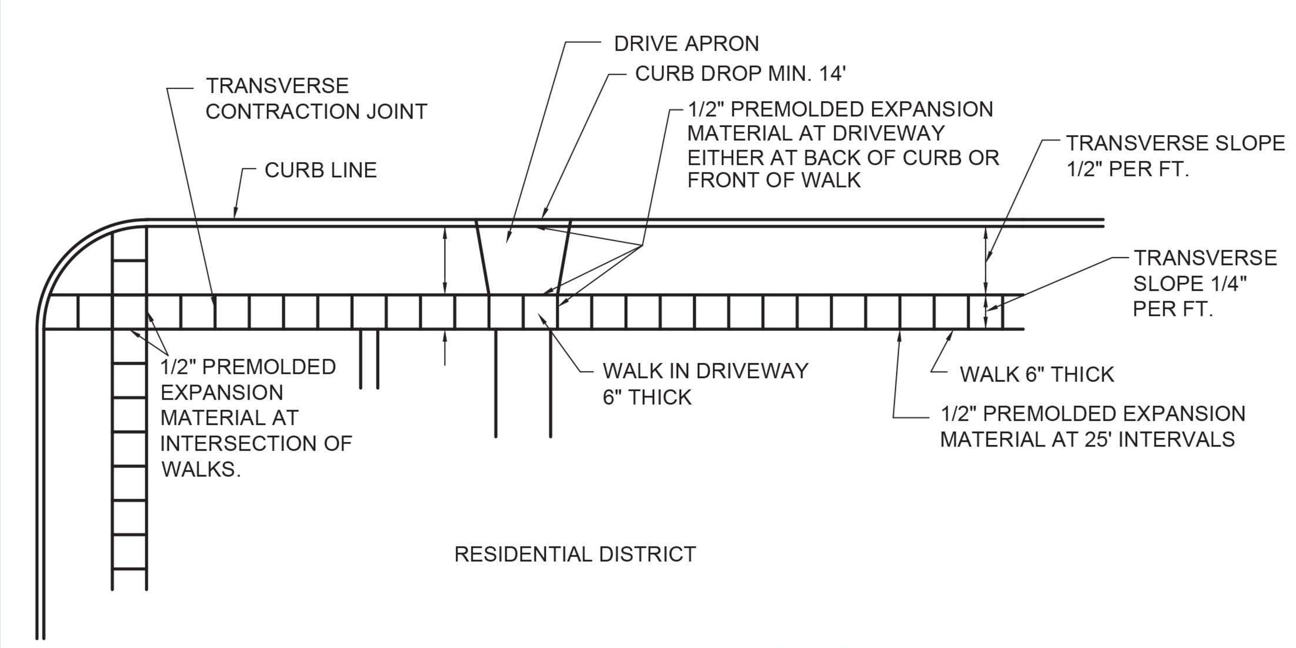
NO SCALE



8" ITEM SPCL PERVIOUS CONCRETE PAVEMENT

ALLEY PERVIOUS RETURN DETAIL

SCALE: NONE



NOTES:

1. MAXIMUM LONGITUDINAL SLOPE 1/2" PER FT.
2. REFER TO PEDESTRIAN RAMP CONSTRUCTION DETAILS.
3. MAXIMUM LENGTH OF RAMP IS 30 FT.
4. WHEREVER SIGN POSTS ARE WITHIN THE SIDEWALK, A PLASTIC SLEEVE OF THE APPROPRIATE SIZE (3"-4" TYPICAL) SHALL BE PLACED FLUSH WITH THE CONCRETE SURFACE AT THE APPROPRIATE LOCATION. ALL POLES WITH IN THE SIDEWALK SHALL BE WRAPPED WITH A 1" FLEXIBLE EXPANSION MATERIAL PRIOR TO PLACEMENT OF CONCRETE.
5. NO SIDEWALK SHALL BE PLACED DIRECTLY AGAINST ANY RIGID STRUCTURE AND/OR FOUNDATION. A MINIMUM 1/2" PREFORMED EXPANSION MATERIAL MUST BE PLACED BETWEEN THE STRUCTURE AND THE ADJACENT SIDEWALK.
6. CONSTRUCT TRANSVERSE EXPANSION JOINTS IN SUCH A MANNER THAT THE JOINT WILL BE FILLED TO WITHIN ONE-HALF INCH (1/2") OF THE SURFACE OF THE WALK, AT INTERVALS OF NOT MORE THAN TWENTY-FIVE FEET (25'), UNLESS OTHERWISE SPECIFIED BY THE ENGINEER. PLACE JOINTS AT THE GROOVED DIVISION LINES, TRULY NORMAL TO THE GRADE. WHENEVER CONCRETE SIDEWALKS ABUT OTHER WALKS, STEPS, CURBS, MANHOLES, CATCH BASINS, BUILDING FOUNDATIONS, ETC., PROVIDE ONE-HALF INCH (1/2") THICK EXPANSION JOINTS. EFFECTIVELY SEPARATE WALK AT EXPANSION END OF BRIDGE AND APPROACH. CLEAN ALL CONCRETE FROM THE TOP OF THE PREMOLDED JOINTS AND EDGE AS SPECIFIED ABOVE.
7. FINISHING: PER SPEC SECTION 02795

RESIDENTIAL PERVIOUS SIDEWALK DETAILS

SCALE: NONE

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MARK	DATE	DESCRIPTION	BY
	11/30/09	ISSUED FOR BID	

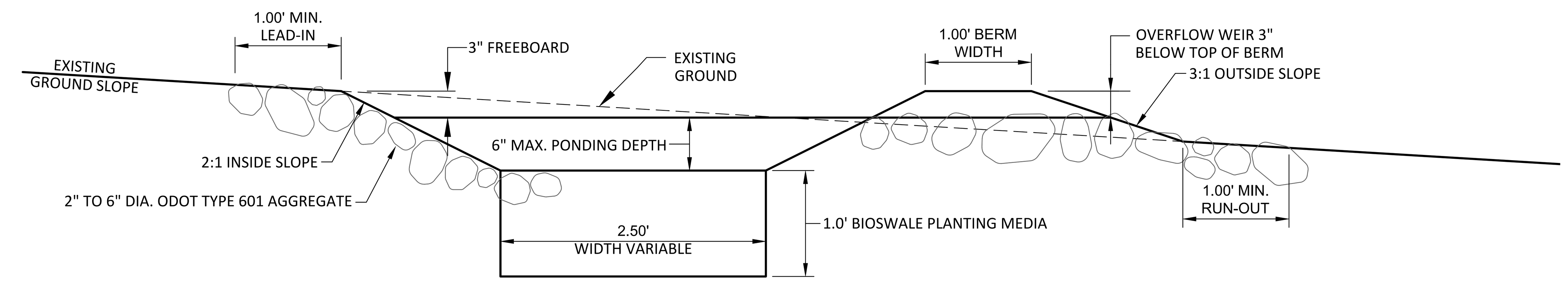
Client: CITY OF TOLEDO, OHIO
Proj. Loc.: CITY OF TOLEDO, OHIO

MAYWOOD AVENUE STORM WATER
VOLUME REDUCTION PROJECT

CIVIL STANDARD DETAILS

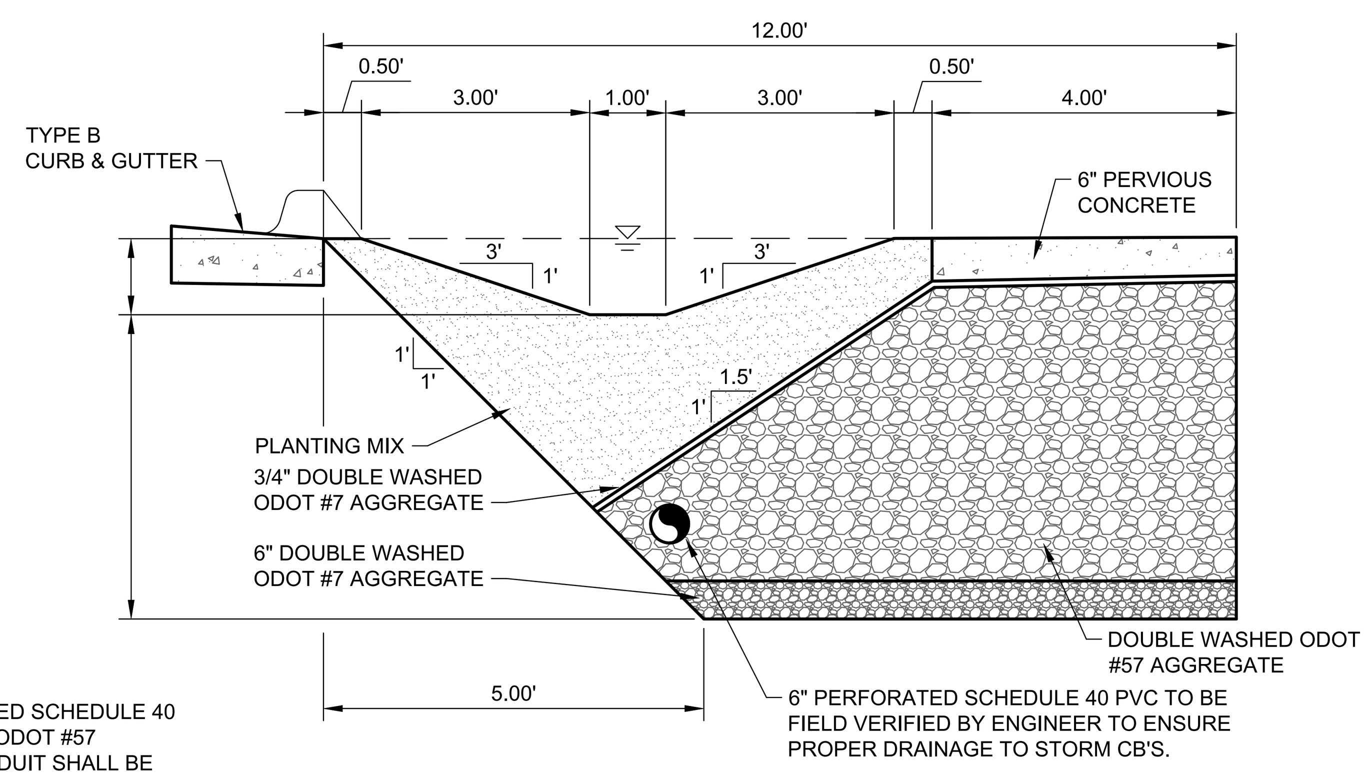
Project No.:	200-06764-10001
Designed By:	A. DAVENPORT
Drawn By:	S. GOTHA
Checked By:	D. CHARVILLE

C-503



3" FREEBOARD - BERM

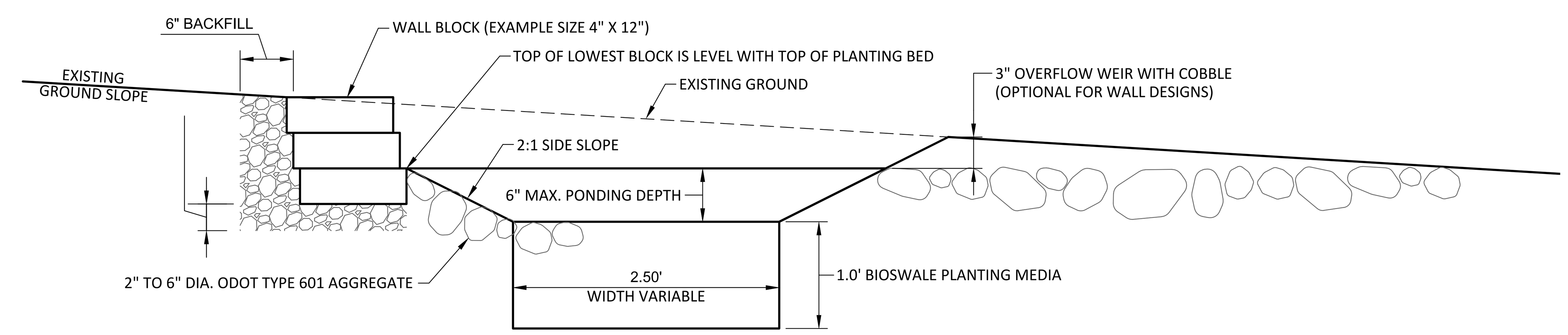
SCALE: NONE



NOTE:
POSITION OF 6" PERFORATED SCHEDULE 40 PVC CONDUIT WITHIN THE ODOT #57 AGGREGATE VARIES. CONDUIT SHALL BE POSITIONED TO DRAIN INTO THE NEAREST CATCH BASIN PER PLAN, FIELD VERIFIED AND APPROVED BY THE ENGINEER.

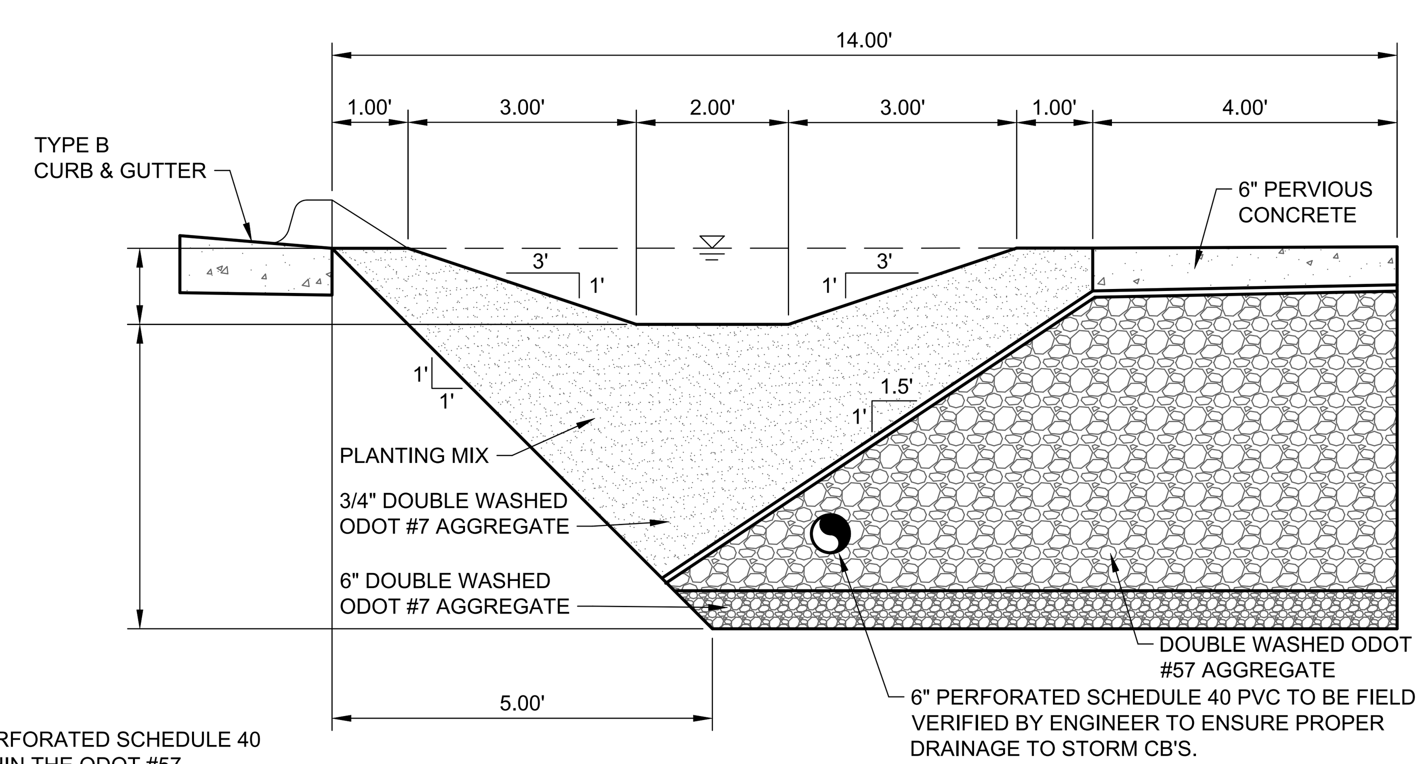
BIOSWALE CELL SECTION (TYP.)

SCALE: 1" = 2'



3" FREEBOARD - WALL

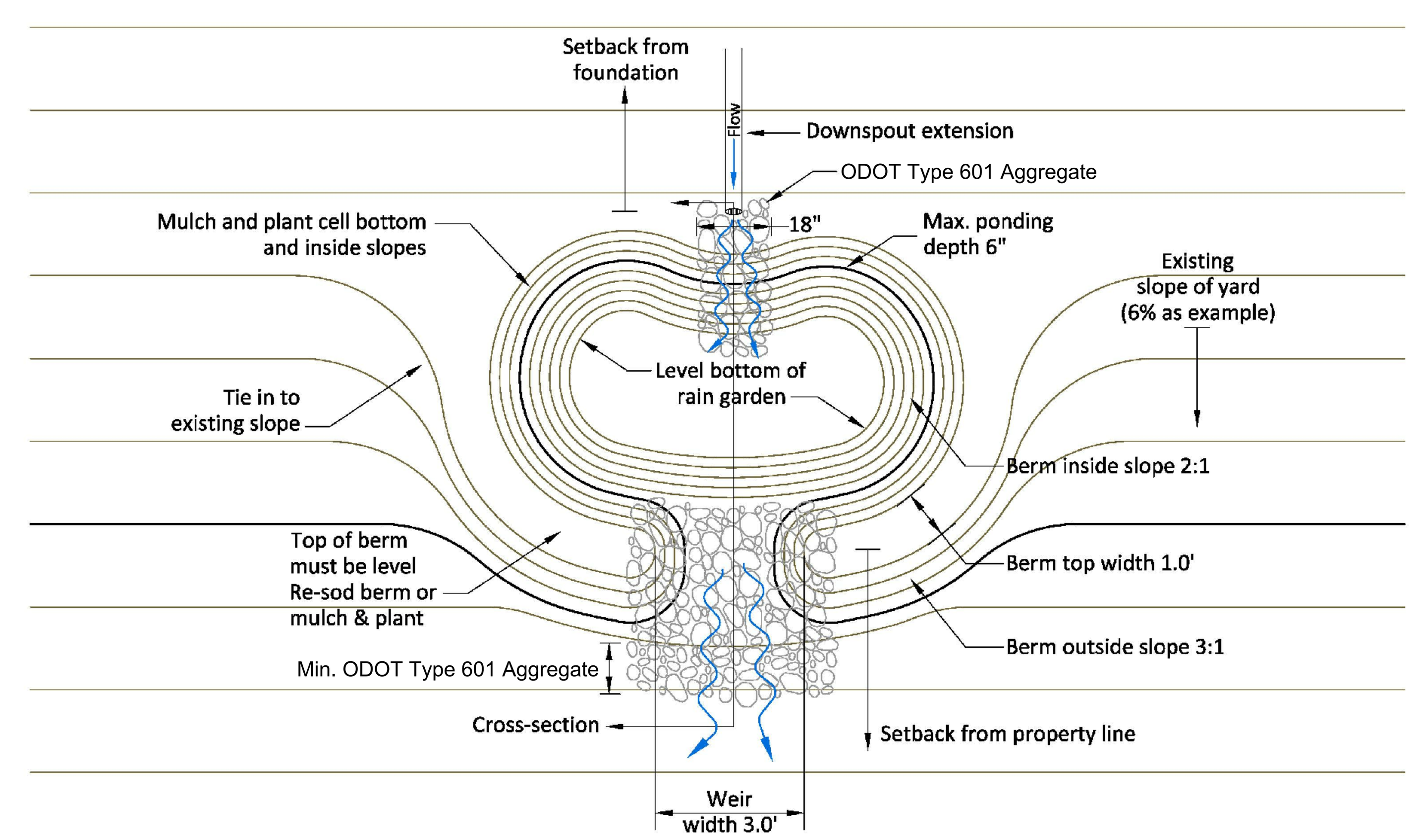
SCALE: NONE



NOTE:
POSITION OF 6" PERFORATED SCHEDULE 40 PVC CONDUIT WITHIN THE ODOT #57 AGGREGATE VARIES. CONDUIT SHALL BE POSITIONED TO DRAIN INTO THE NEAREST CATCH BASIN PER PLAN, FIELD VERIFIED AND APPROVED BY THE ENGINEER.

BIOSWALE CELL SECTION (TYP.)

SCALE: 1" = 2'



RAIN GARDEN PLAN VIEW

SCALE: NONE

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MARK	DATE	DESCRIPTION	BY
	11/30/09	ISSUED FOR BID	

Client: CITY OF TOLEDO, OHIO
Proj. Loc.: CITY OF TOLEDO, OHIO

MAYWOOD AVENUE STORM WATER
VOLUME REDUCTION PROJECT

LANDSCAPE STANDARD DETAILS

Project No.:	200-06764-10001
Designed By:	J. ZIELINSKI
Drawn By:	J. ZIELINSKI
Checked By:	D. CHARVILLE

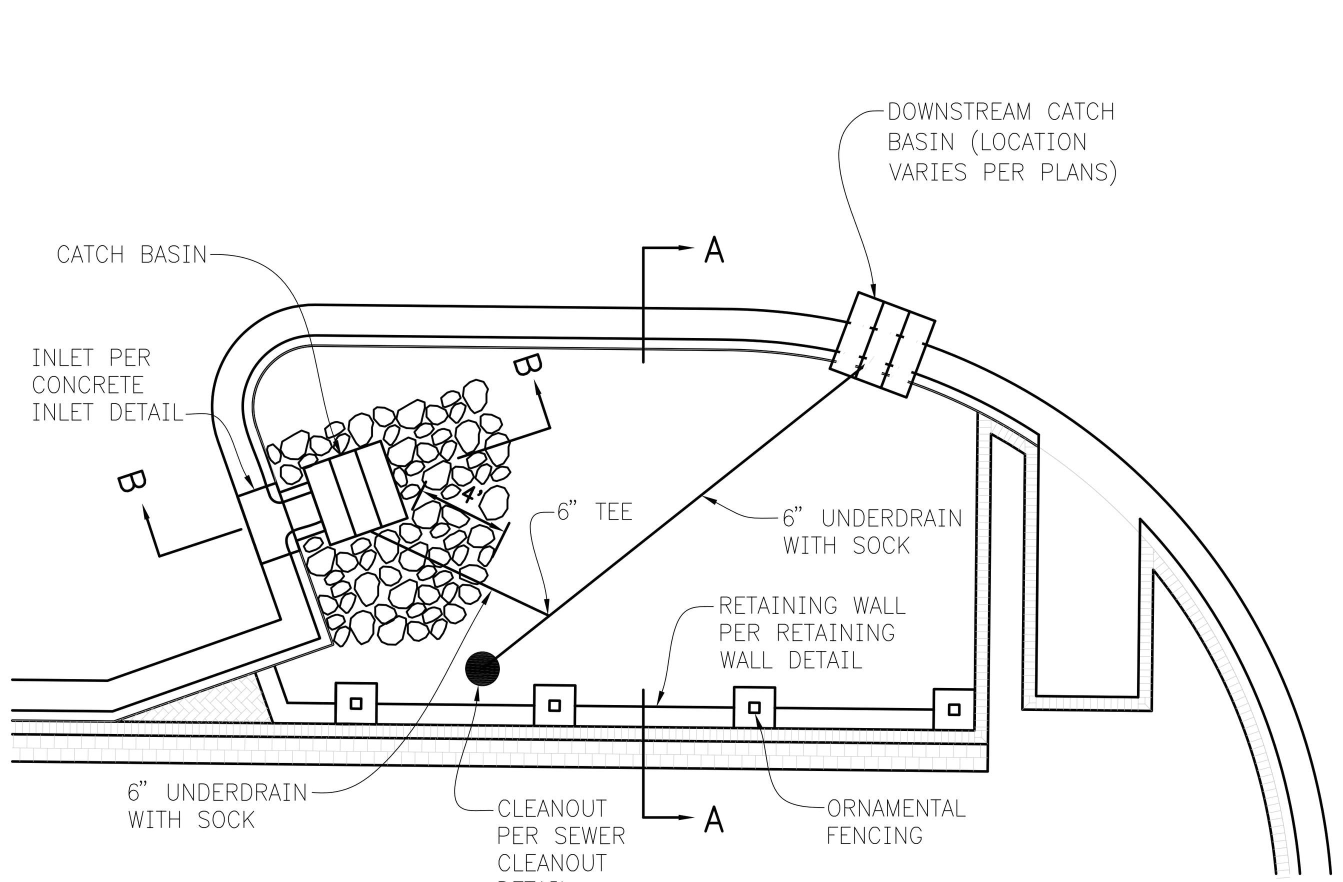
L-502

CORNER CURB EXTENTION (NODE)

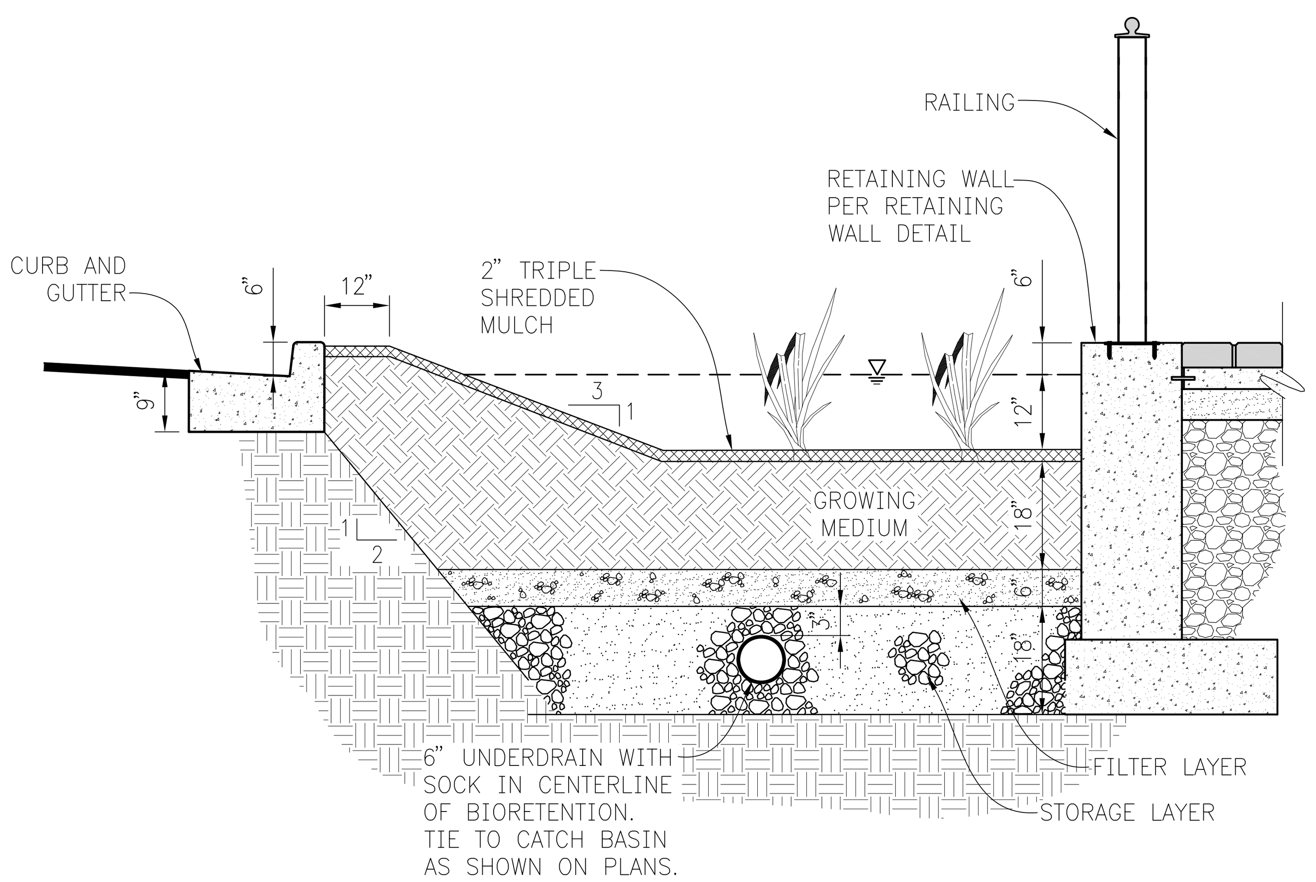
OPERATION	BY	DATE
BOARD OF WATER & LIGHT: ELECTRIC		
WATER		
CONSUMERS ENERGY - GAS		
BELL TELEPHONE		
CABLE TELEVISION - CATV		
FIRE DEPARTMENT		

OPERATION	BY	DATE
SAN. SEWER DESIGN CK.		
STORM SEWER DESIGN		
STORM SEWER DESIGN CK.		
SAN. SEWER QUANTITIES		
SAN. SEWER QUANTITIES CK.		
STORM SEWER QUANTITIES		
STORM SEWER QUANTITIES CK.		
PRELIMINARY R.O.W. CK.		

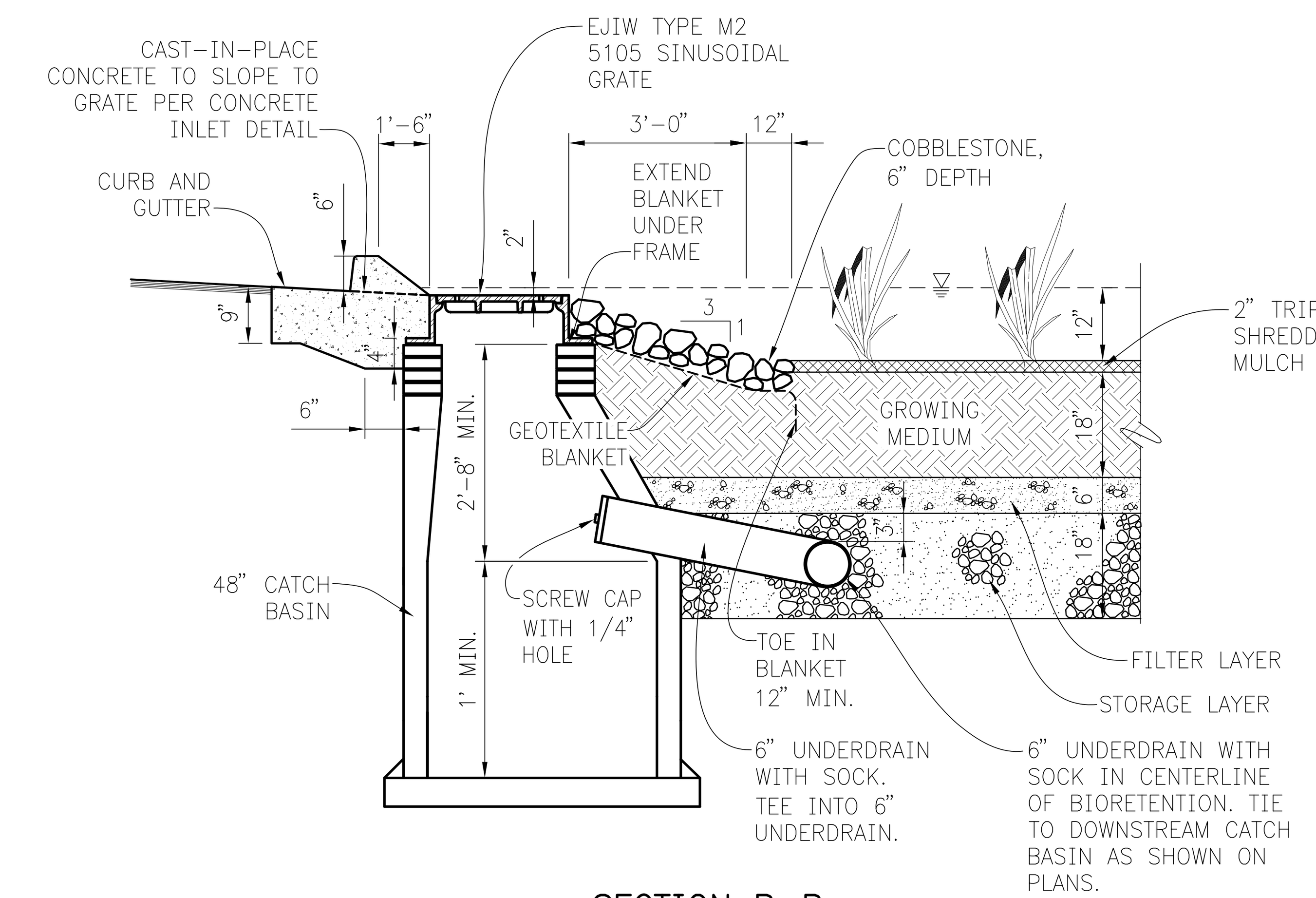
OPERATION	BY	DATE
SURVEYED		
PLAN PLOTTED		
PLAN CHECKED		
PROFILE PLOTTED		
PROFILE CHECKED		
PRELIMINARY GRADE		
GRADE INSPECTION		
SANITARY SEWER DESIGN		



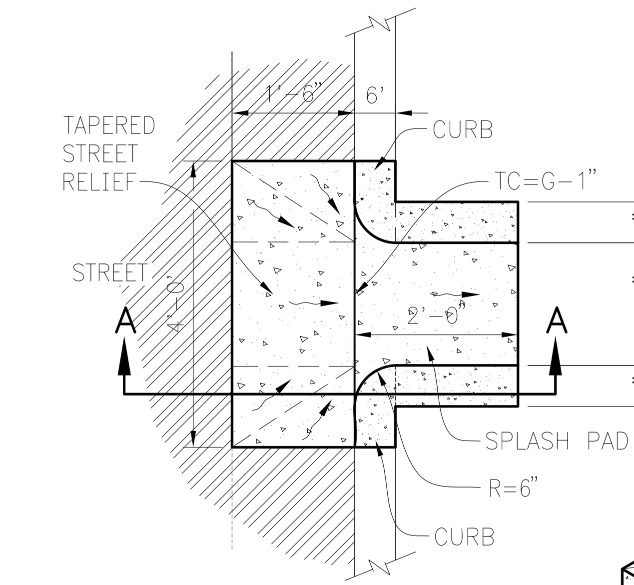
BIORETENTION DETAIL
NO SCALE



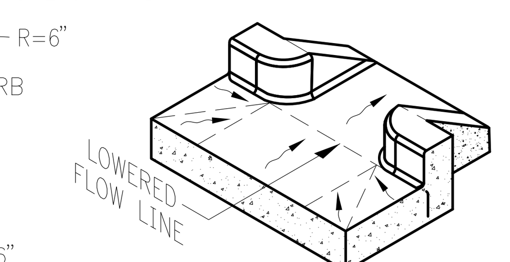
SECTION A–A
NO SCALE



SECTION B–B
NO SCALE



PLAN VIEW



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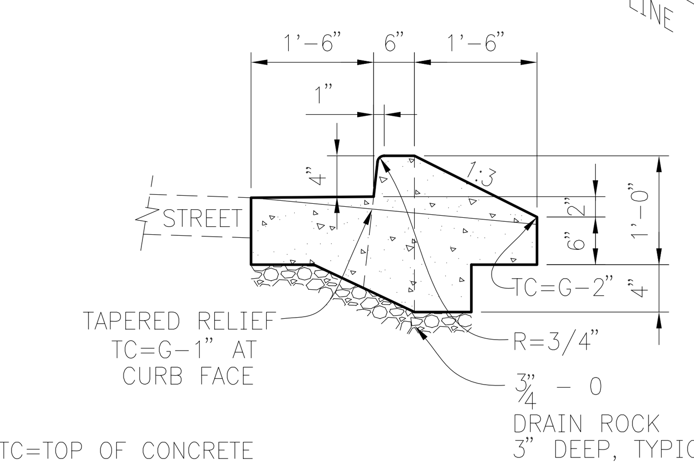
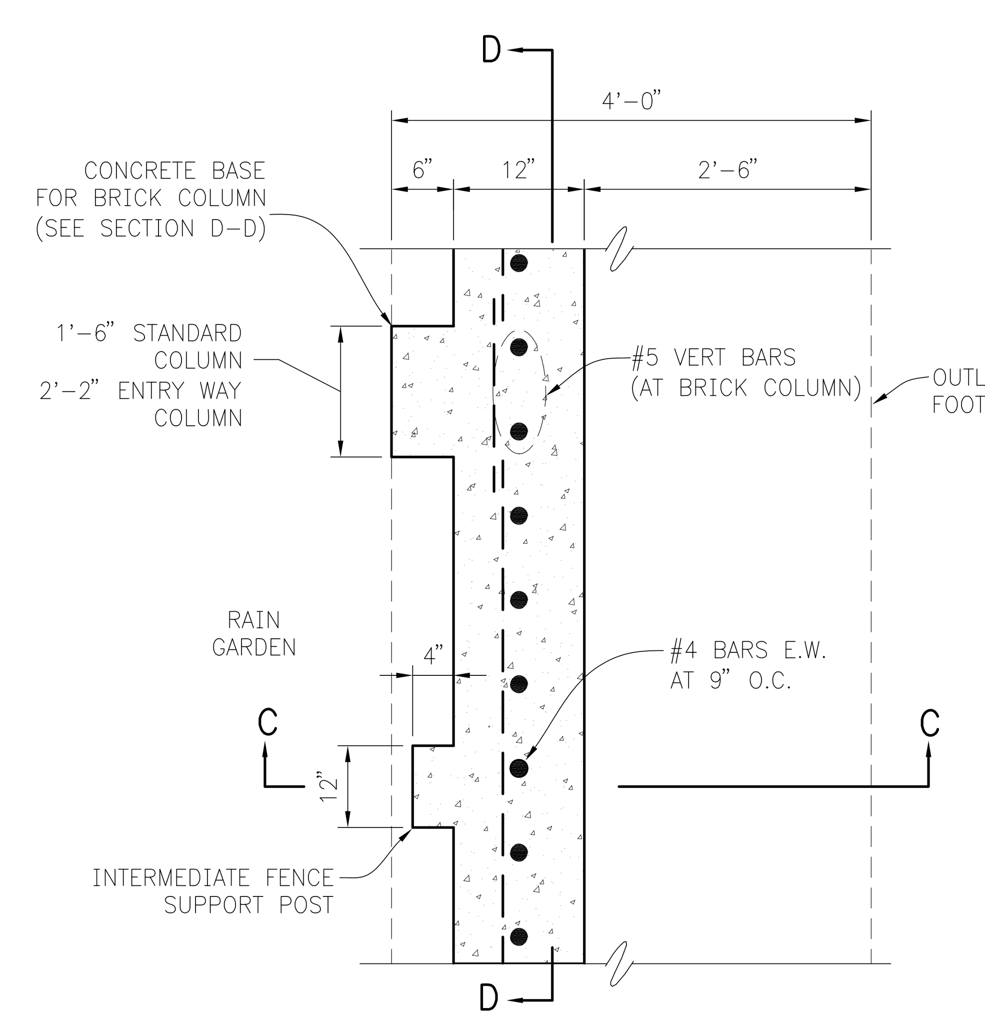


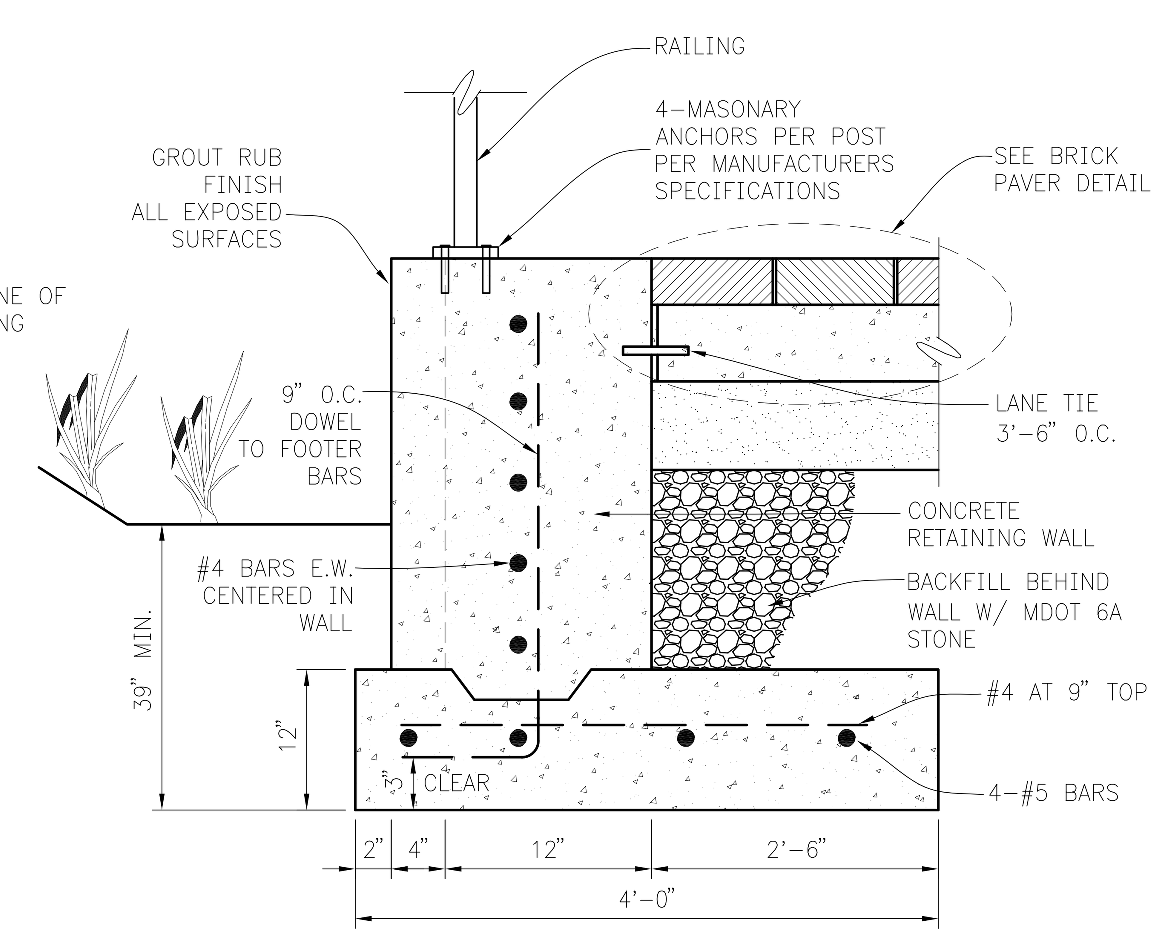
TC=TOP OF CONCRETE
G=GUTTER

SECTION A–A

CONCRETE INLET DETAIL
NO SCALE

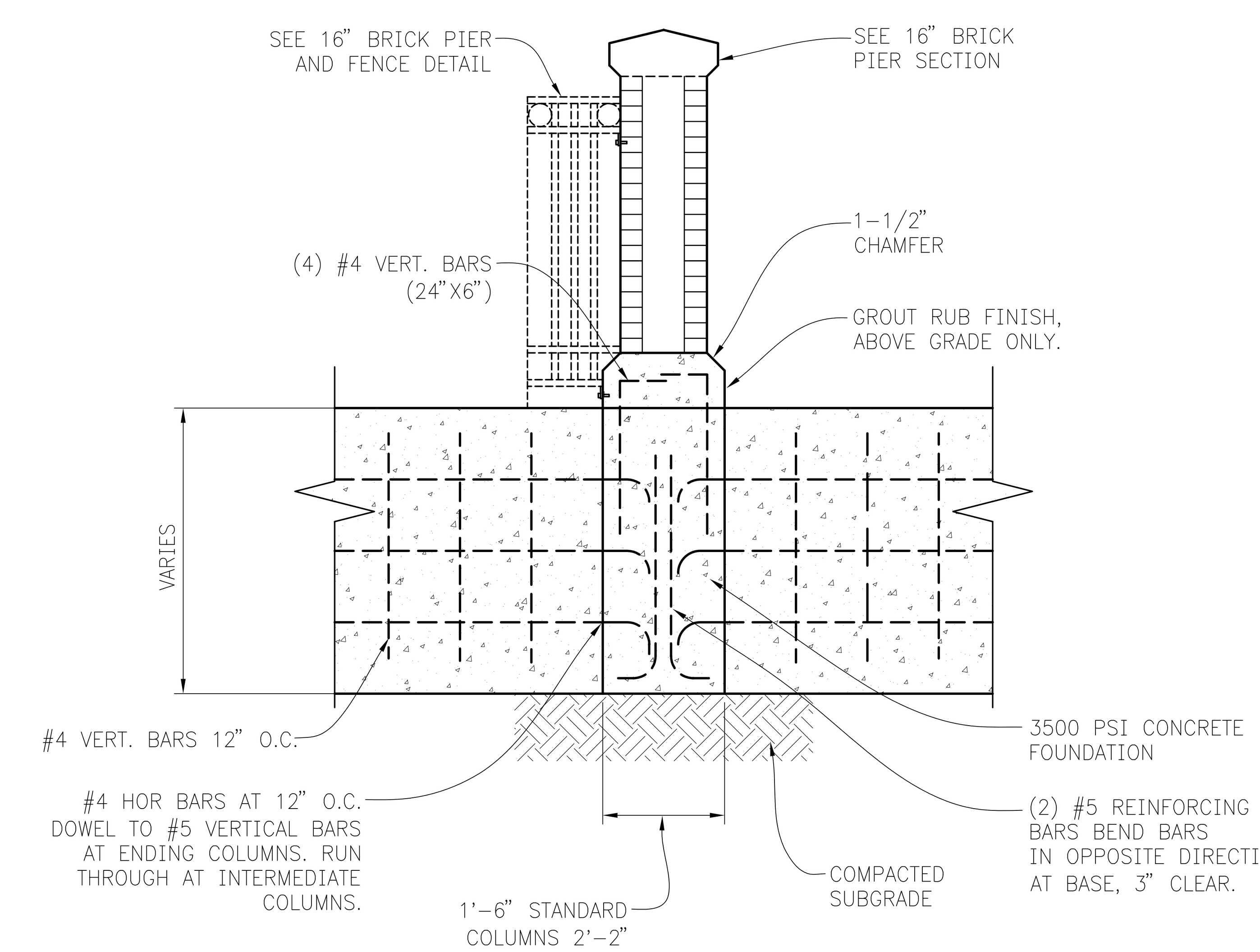


PLAN VIEW



SECTION C–C

RETAINING WALL DETAIL
NO SCALE



SECTION D–D
NO SCALE

1. FOR ENTRYWAY COLUMN WITH STREETLAMP, INSTALL 1 1/2-INCH DIAMETER CONDUIT INSIDE COLUMN TO CORED HOLE IN FINAL FOR STREETLAMP WIRING. COORDINATE WORK WITH LANSING BOARD OF WATER & LIGHT.

ISSUE	NATURE OF REVISION	DATE

PHASE V SEGMENT 2
DOWNTOWN SEPARATION (WASHINGTON/OTTAWA)

PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:
Tt CONTRACT: 200-12741-08002.S-3 DIVISION:

Virg Bernero, Mayor

TETRA TECH

DESIGNED: A. THOMAS CHECKED: N. McPHERSON
CADD DATE: 2/4/2010 Hollenbeck, Todd
PART: 132 BIORETENTION DETAILS

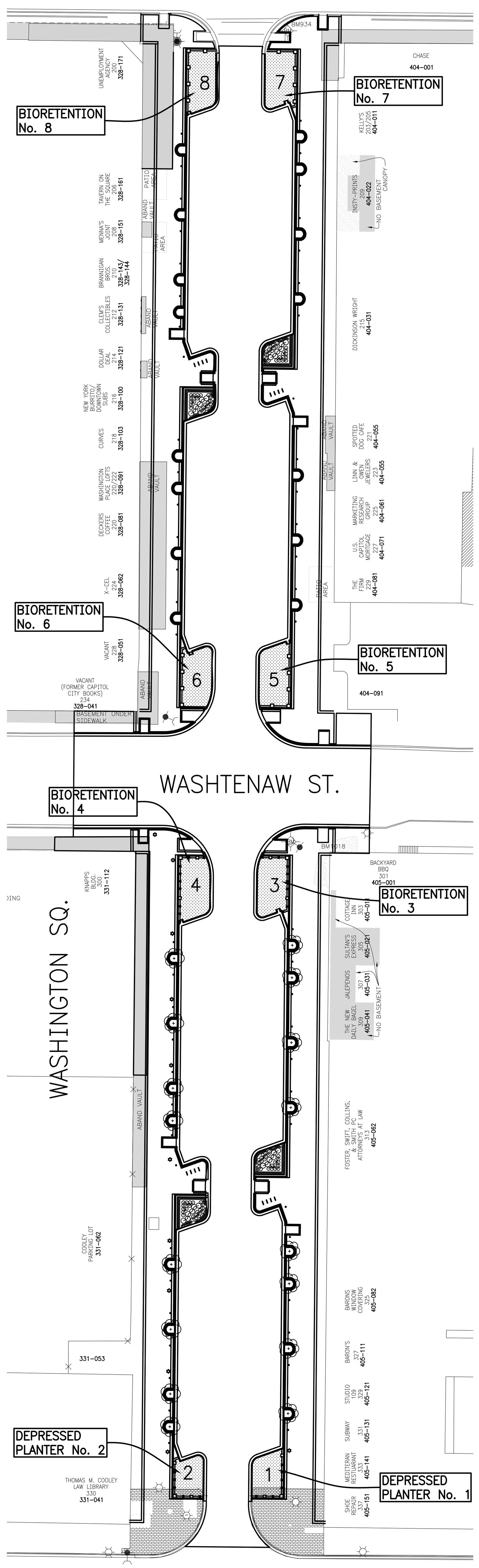
DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

BIORETENTION DETAILS

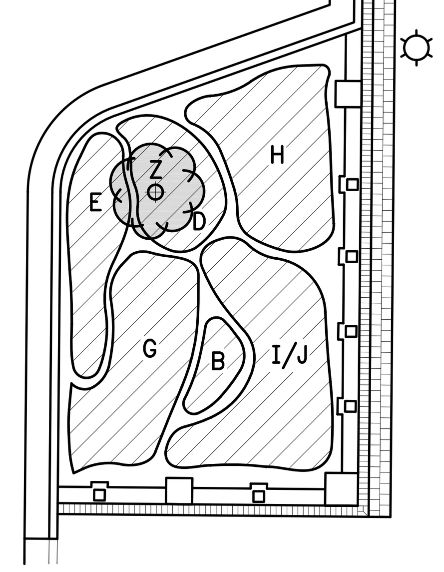
APPROVED FILE NO.
DEPARTMENT OF PUBLIC SERVICE
SCALE HORIZONTAL: AS NOTED VERTICAL: NO SCALE
PROJECT NO. PS 36321
SHEET 32 OF 58 SHEETS

PS 36321

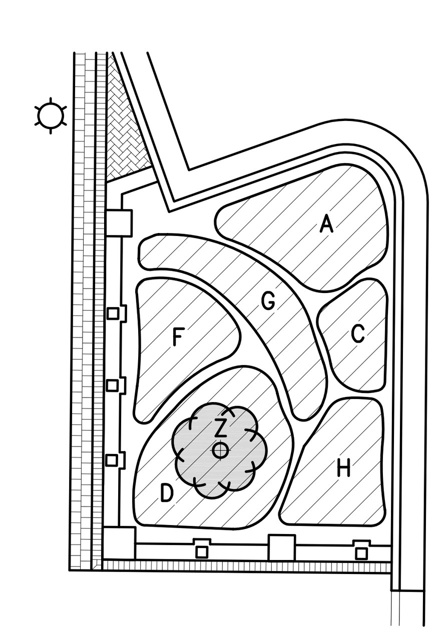
PHASE V SEGMENT 2 – DOWNTOWN SEPARATION (WASHINGTON/OTTAWA)



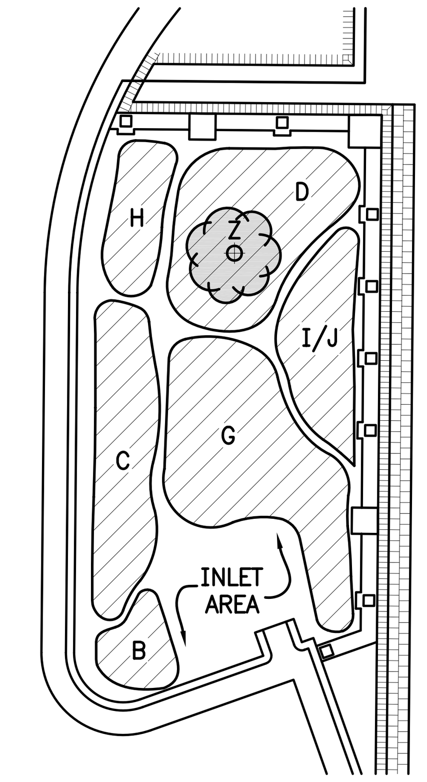
PLANTING DETAIL LOCATIONS
SCALE: 1"=50'



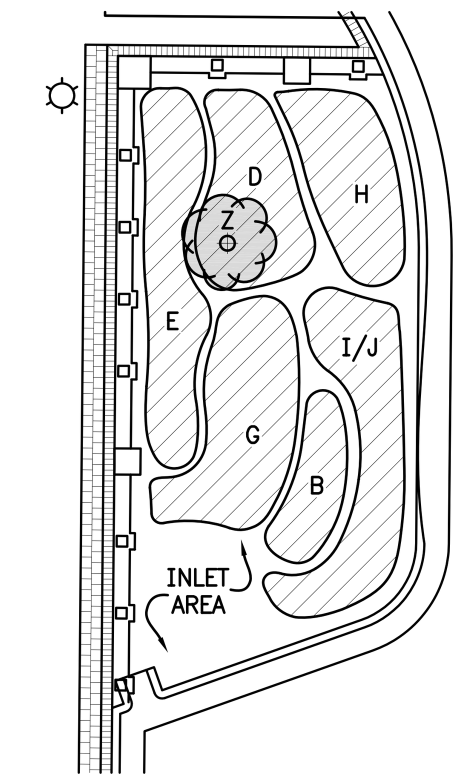
DEPRESSED PLANTER DETAIL No. 1
SCALE: 1"=10'



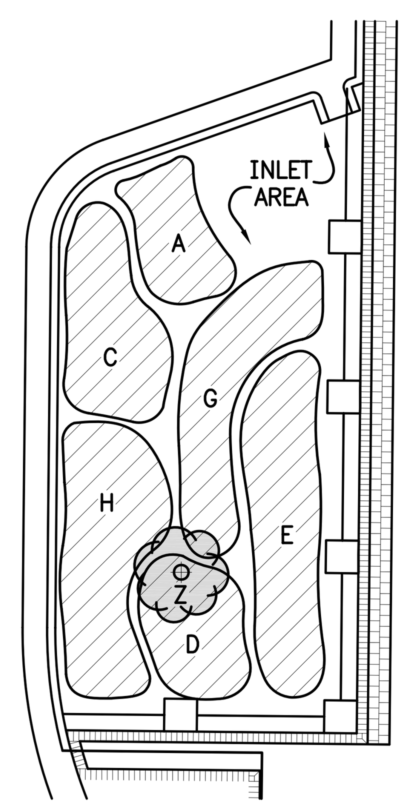
DEPRESSED PLANTER DETAIL No. 2
SCALE: 1"=10'



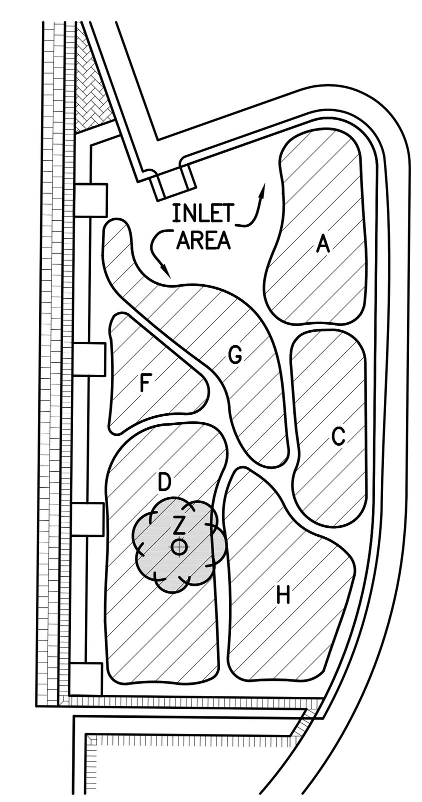
BIORETENTION DETAIL No. 3
SCALE: 1"=10'



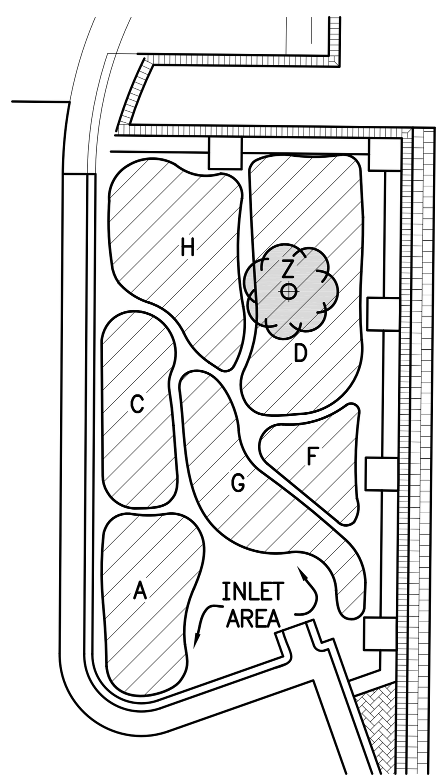
BIORETENTION DETAIL No. 4
SCALE: 1"=10'



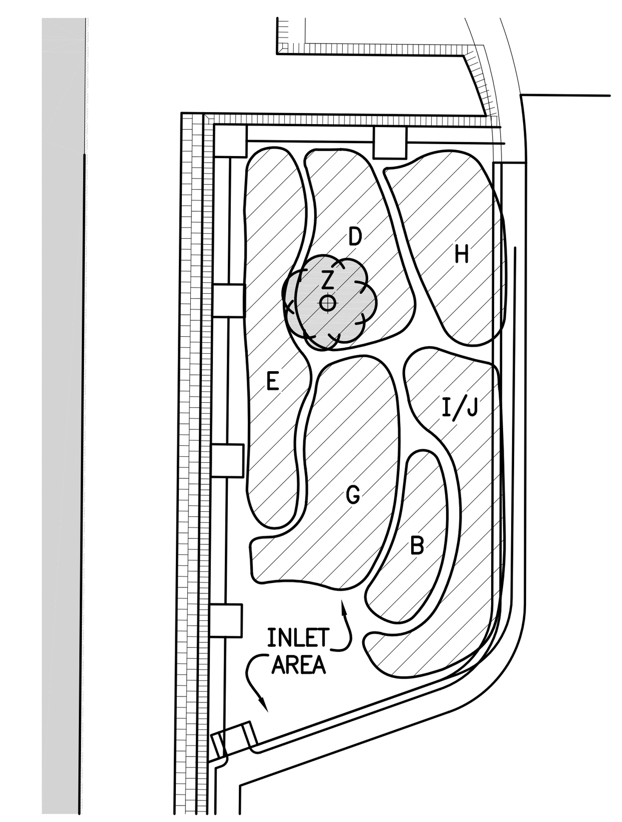
BIORETENTION DETAIL No. 5
SCALE: 1"=10'



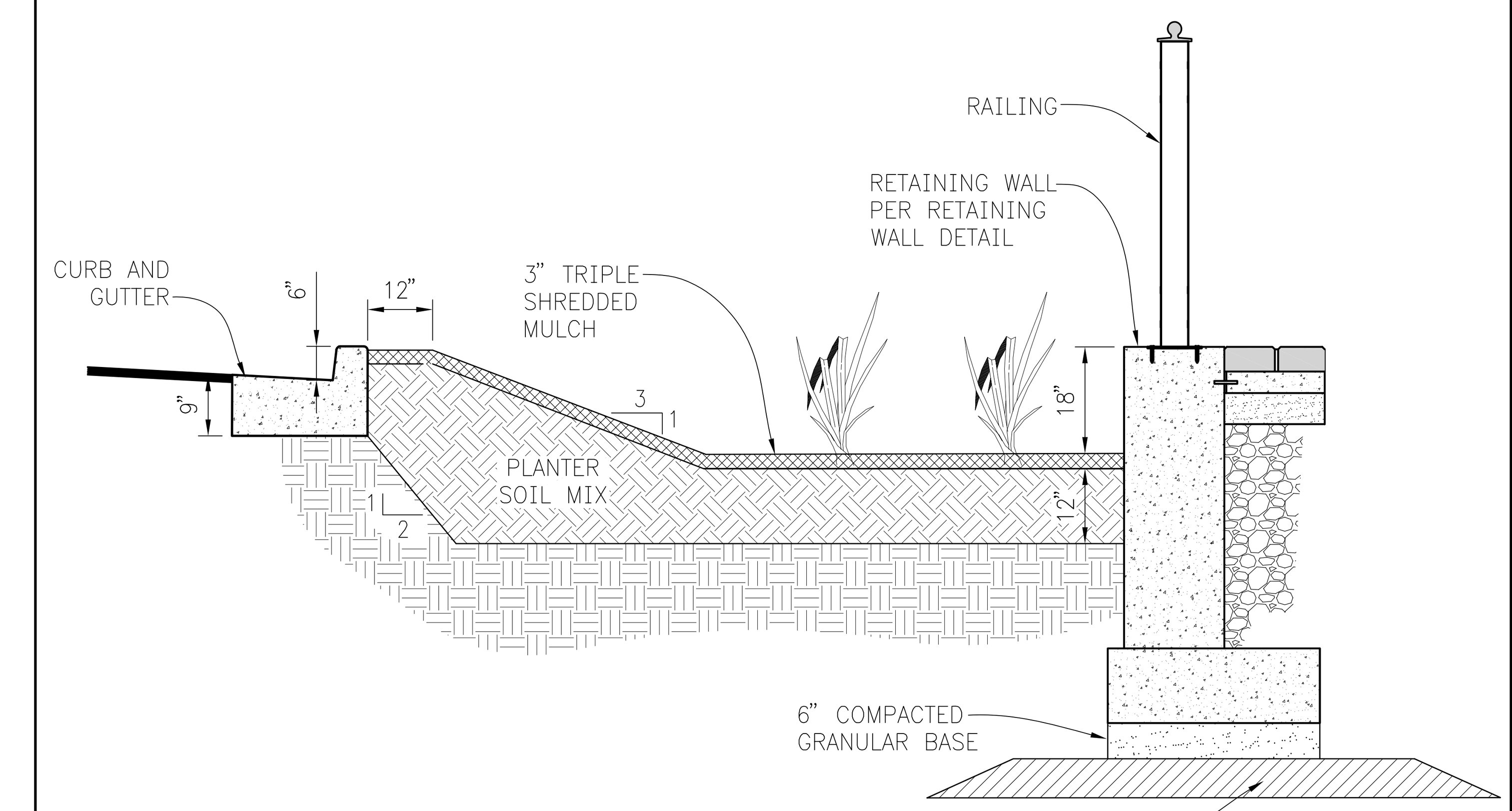
BIORETENTION DETAIL No. 6
SCALE: 1"=10'



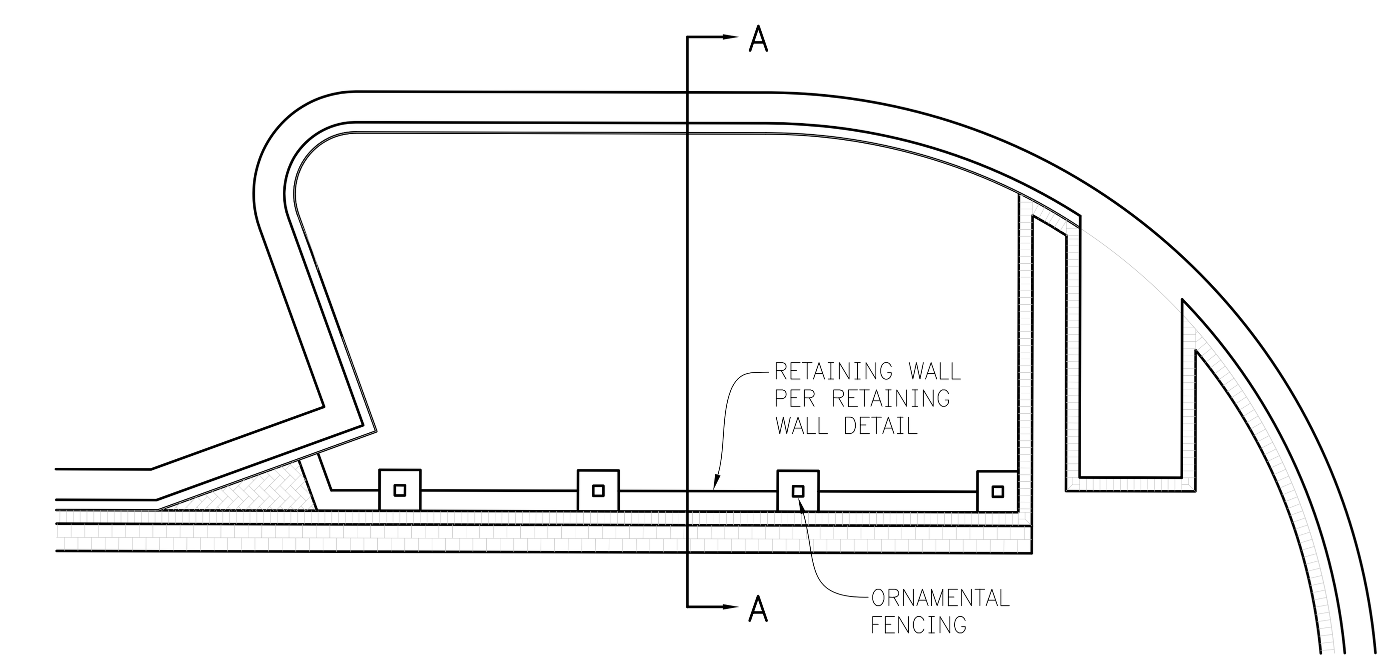
BIORETENTION DETAIL No. 7
SCALE: 1"=10'



BIORETENTION DETAIL No. 8
SCALE: 1"=10'



SECTION A–A
NO SCALE



DEPRESSED PLANTER DETAIL
NO SCALE

Plant Material List				Individual Garden Plant Quantities							
				Detail No. 1	Detail No. 2	Detail No. 3	Detail No. 4	Detail No. 5	Detail No. 6	Detail No. 7	Detail No. 8
	Total Quantity	Plug Spacing	**Common Name** **Botanical Name**								
Deciduous Tree (BB)	8		**Z** -Cleveland Select Flowering Pear Pyrus C. 'Cleveland Select'	1	1	1	1	1	1	1	1
Perennials (plug)	212	12' on center	**A** - Nodding Wild Onion Allium cernum	46	49			40	77		
	102	18" on center	**B** -Swamp Milkweed Asclepias incarnata	10		18	28			18	28
	246	18" on center	**C** -Alum Root Heuchera Americana	51	16	49		55	26	49	
	506	12" on center	**D** -Southern Blue Flag Iris Virginica		76	89	43	47	120	87	44
	312	12" on center	**E** -Rough Blazing Star Liatris aspera	39			84	103			86
	70	18" on center	**F** -Marsh Blazing Star Liatris spicata		27				43		
	348	24" on center	**G** -Switch Grass Panicum virgatum	38	26	57	43	43	41	56	44
	478	12" on center	**H** - Beardtongue Penstemon Digitalis	84	30	29	80	98	47	28	82
	68	18" on center	**I** -Three-Lobed Coneflower Rudbeckia Triloba			17	17			17	17
	68	18" on center	**J** -Yellow Coneflower Ratibida Pinnata			17	17			17	17

ISSUE	NATURE OF REVISION	DATE

PHASE V SEGMENT 2
DOWNTOWN SEPARATION (WASHINGTON/OTTAWA)
PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:
Tt CONTRACT: 200-12741-08002.S-3
DIVISION:
Virg Bernero, Mayor
TETRA TECH
DESIGNED: A. THOMAS
CHECKED: N. McPHERSON
CADD DATE: 2/5/2010 Hollenbeck, Todd
PART: 131 BIORETENTION DEPRESSED

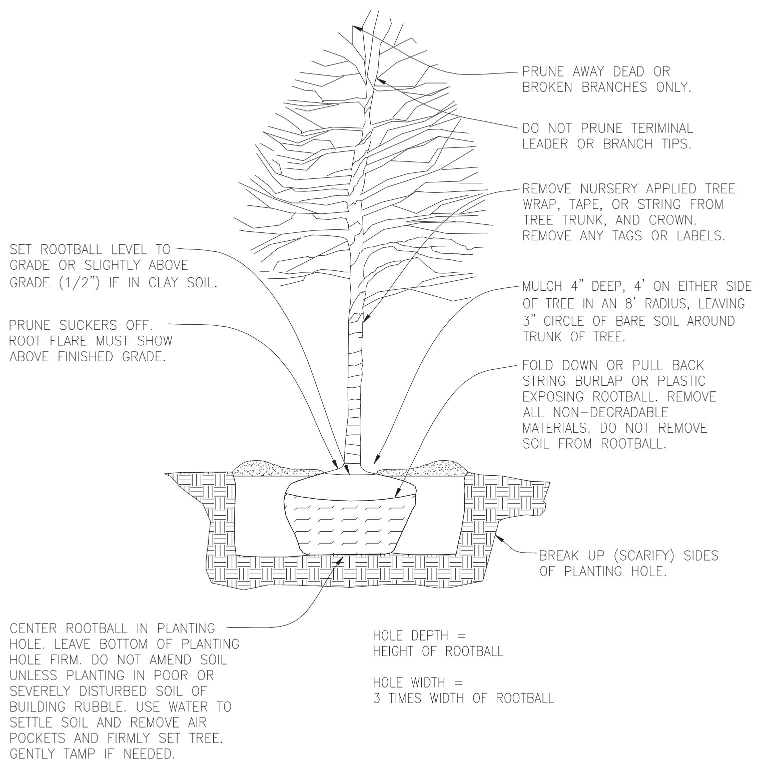
DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

BIORETENTION AND DEPRESSED PLANTER PLANTING PLANS

APPROVED
FILE NO.
DEPARTMENT OF PUBLIC SERVICE
SCALE HORIZONTAL: AS NOTED VERTICAL: NO SCALE
PROJECT NO. PS 36321
SHEET 31 OF 59 SHEETS

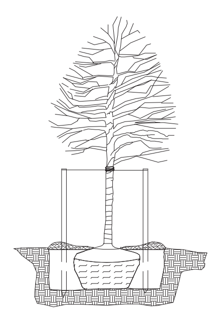
PS 36321
PHASE V SEGMENT 2 – DOWNTOWN SEPARATION (WASHINGTON/OTTAWA)

MID-BLOCK CURB EXTENSION



DO NOT STAKE UNLESS IN HEAVY CLAY SOIL, WINDY CONDITIONS, 3" OR GREATER DIAMETER TREE TRUNK, OR LARGE CROWN. IF STAKING IS NEEDED:

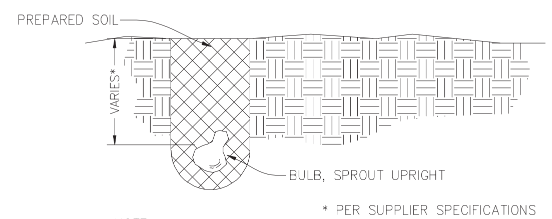
1. STAKE WITH 2"X2" HARDWOOD STAKES OR APPROVED METAL POSTS DRIVEN INTO THE SOIL ONE FOOT OUTSIDE THE ROOT BALL.
2. LOOSELY STAKE TREE TRUNK TO ALLOW FOR TRUNK FLEXING.
3. STAKE TREES JUST BELOW FIRST BRANCH WITH APPROPRIATELY SIZED EYE BOLT CONNECTED TO THE POSTS WITH ELEVEN GAGE WIRE. TWO PER TREE ON OPPOSITE SIDES OF THE TREE. DO NOT USE A ROPE OR WIRE THROUGH A HOSE.
4. REMOVE ALL STAKING MATERIALS AFTER ONE YEAR.



TREE PLANTING DETAIL

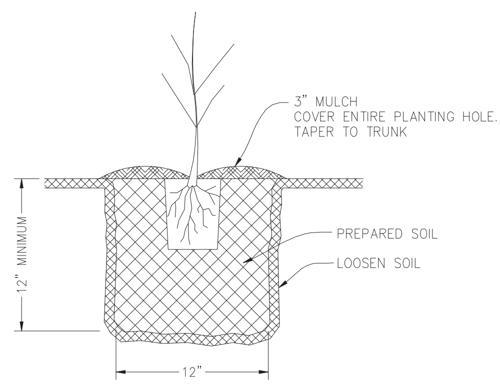
NO SCALE

TREE PLANTING DETAIL

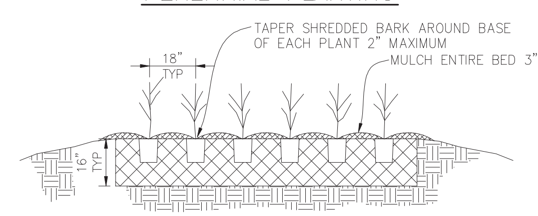


NOTE:
PLANT BULBS IN FALL BETWEEN SEPTEMBER 15 AND OCTOBER 31.

BULB PLANTING



PERENNIAL PLANTING

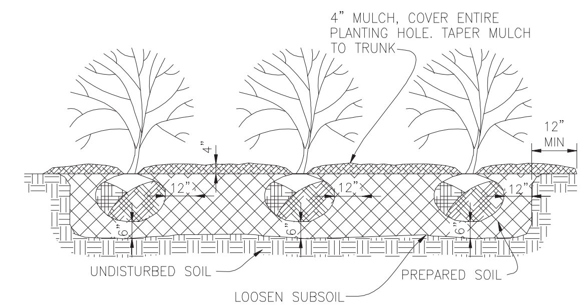


BEDDED PERENNIAL PLANTS

NOTE:
FIRST AND SECOND WATERING AND CULTIVATION SHALL INCLUDE PERENNIAL BEDS.

PERENNIAL PLANTS

NO SCALE

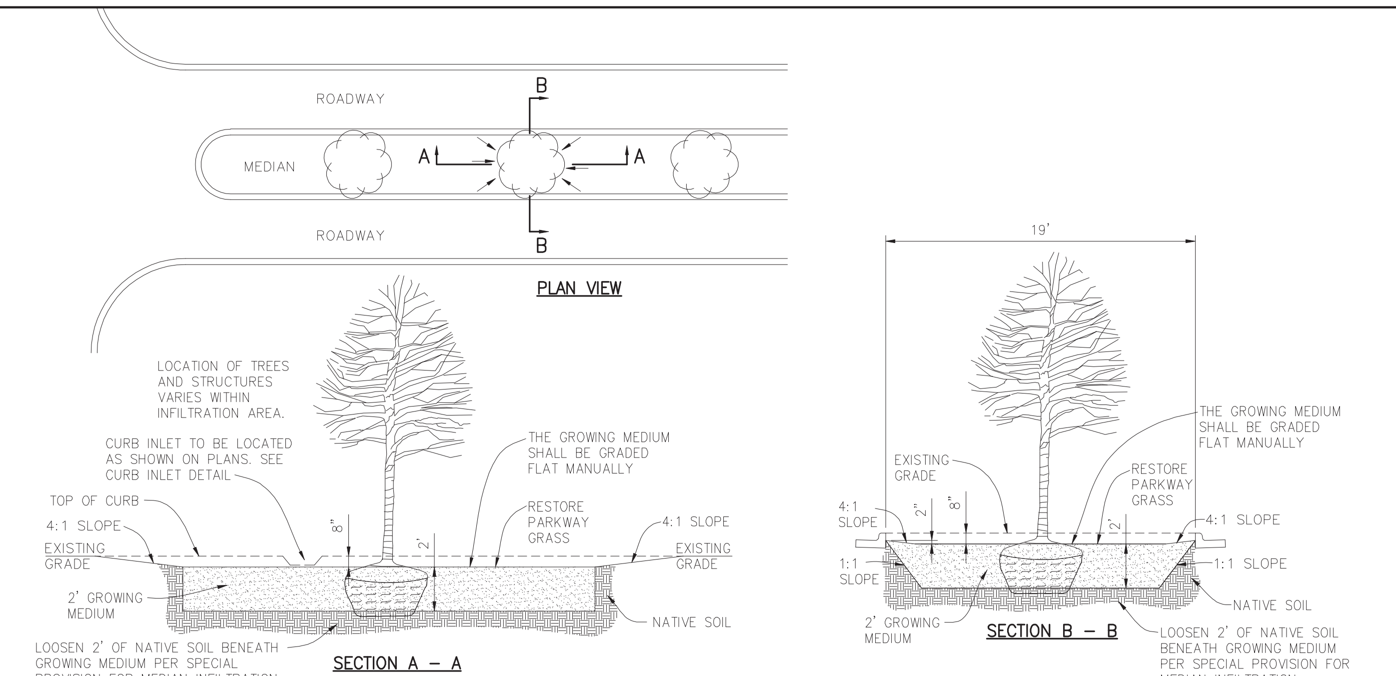


SHRUB BED DETAIL

NO SCALE

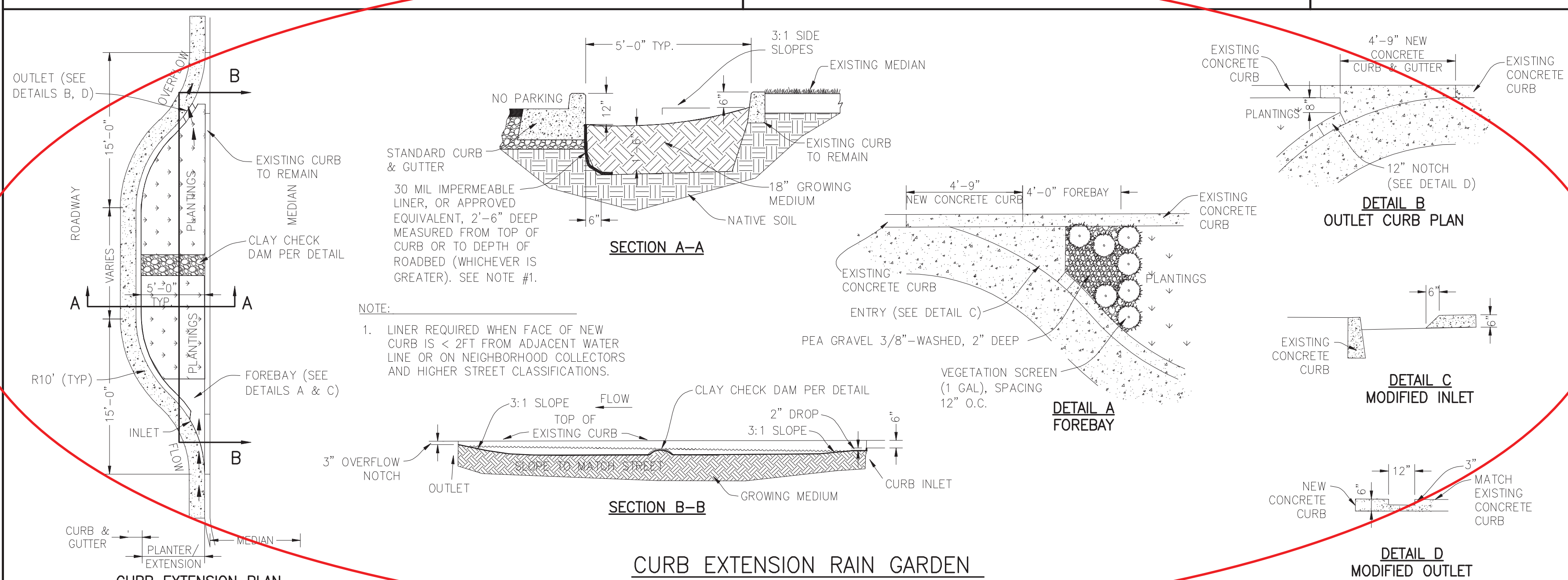
SHRUB PLANTING NOTES:

1. DIG PLANT POCKET FOR SHRUBS A MINIMUM OF 12" WIDER AND 6" DEEPER THAN THE ROOT BALL, UNLESS OTHERWISE SPECIFIED.
2. LOOSEN EARTH ON SIDES OF PLANT POCKET TO BREAK ANY GLAZING CAUSED BY DIGGING.
3. SET PLANTS AT THE SAME OR SLIGHTLY HIGHER DEPTH THAN THE NURSERY.
4. FILL PREPARED SOIL TO THE DEPTH OF THE ROOT BALL, PACK GENTLY, AND PUDDLE THE WATER.
5. LOOSEN AND REMOVE BURLAP AND ALL LACING FROM UPPER HALF OF ROOT BALL. REMOVE NON-DEGRADABLE MATERIAL.
6. BACKFILL WITH PREPARED SOIL WHICH, AFTER COMPACTION, IS FLUSH WITH SURROUNDING GROUND LEVEL.
7. COVER ENTIRE PLANT POCKET AREA WITH 4" MULCH TAPERING TO 2" AT PLANT BASES. PRUNE DAMAGED OR DISTORTED LIMBS AS NECESSARY TO BALANCE PLANT.
8. ALL LANDSCAPE BEDS SHALL HAVE 3"-4" OF HARDWOOD BARKMULCH INSTALLED. SEE DETAILS (THIS SHEET) FOR SPECIFIC DEPTHS OF PERENNIAL, SHRUB, AND TREE BEDS.
9. WHEN PLANTS ARE FURNISHED IN CONTAINERS, THE CONTAINERS SHALL BE COMPLETELY REMOVED AT THE TIME OF PLANTING.
10. FIRST AND SECOND WATERING AND CULTIVATION SHALL INCLUDE SHRUB BEDS.
11. ALL PLANTS SHALL BE SET PLUMB AND HAVE THE BEST SIDE OF THE PLANT FACING TOWARD THE MAIN DIRECTION OF VIEW.



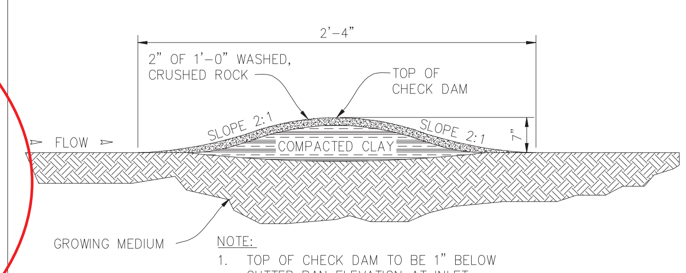
MEDIAN INFILTRATION PLAN

NO SCALE



CURB EXTENSION RAIN GARDEN

NO SCALE



NOTE:
1. TOP OF CHECK DAM TO BE 1" BELOW GUTTER PAN ELEVATION AT INLET.

CLAY CHECK DAM DETAIL

NO SCALE

ISSUE	NATURE OF REVISION	DATE

PHASE V SEGMENT 2
SUBAREA 034C SEPARATION

PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:

TI CONTRACT: 200-12741-08002-S-2 DIVISION:

c2ae TETRA TECH

DESIGNED JWB/SMB CHECKED WJK/RWF/ADF
SCALE AS NOTED CADD DATE 9/8/2009 10:12 AM

DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

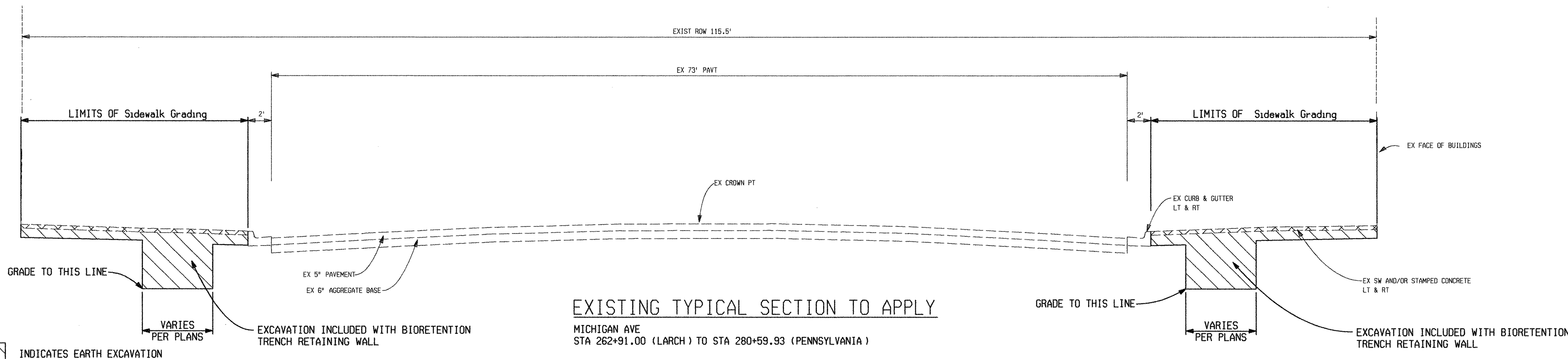
STANDARD DETAILS
PLANTING DETAILS

APPROVED
DEPARTMENT OF PUBLIC SERVICE
FILE NO.
SCALE HORIZONTAL: AS NOTED VERTICAL: AS NOTED
PROJECT NO. PS 45046
SHEET 8 OF 110 SHEETS

PS 45046

PHASE V SEGMENT 2 – SUBAREA 034C SEPARATION

PLANTER BOX

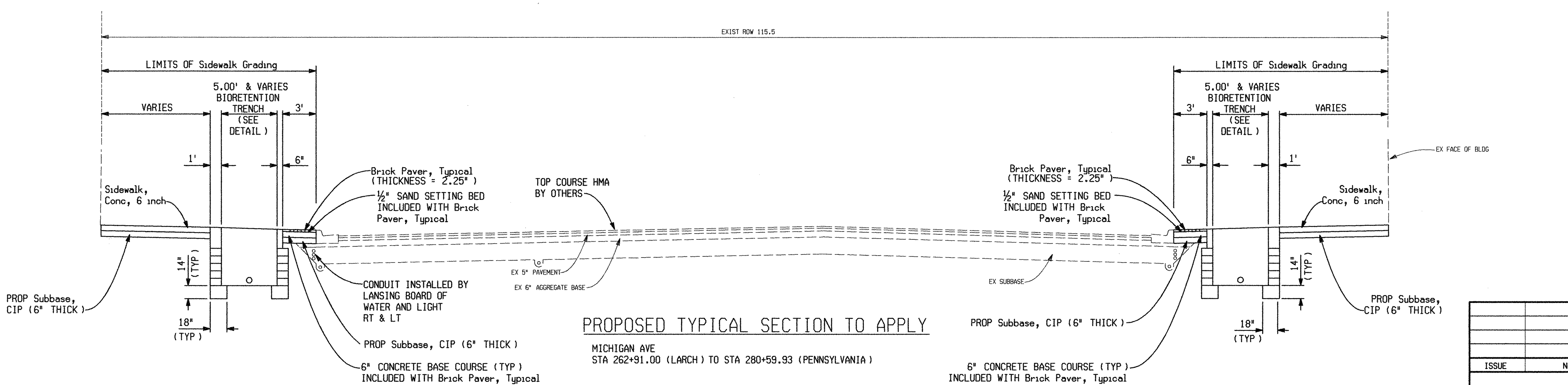


EXISTING TYPICAL SECTION TO APPLY

MICHIGAN AVE
STA 262+91.00 (LARCH) TO STA 280+59.93 (PENNSYLVANIA)

INDICATES EARTH EXCAVATION

INDICATES Sidewalk, Rem



PROPOSED TYPICAL SECTION TO APPLY

MICHIGAN AVE
STA 262+91.00 (LARCH) TO STA 280+59.93 (PENNSYLVANIA)

OPERATION	BY	DATE
BOARD OF WATER & LIGHT:		
ELECTRIC		
WATER		
CONSUMERS ENERGY - GAS		
BELL TELEPHONE		
CABLE TELEVISION - CATV		
FIRE DEPARTMENT		

OPERATION	BY	DATE
SAN. SEWER DESIGN CK.		
STORM SEWER DESIGN		
STORM SEWER DESIGN CK.		
SAN. SEWER QUANTITIES		
SAN. SEWER QUANTITIES CK.		
STORM SEWER QUANTITIES		
STORM SEWER QUANTITIES CK.		
PRELIMINARY R.O.W. CK.		

OPERATION	BY	DATE
SURVEYED		
PLAN PLOTTED		
PLAN CHECKED		
PROFILE PLOTTED		
PROFILE CHECKED		
PRELIMINARY GRADE		
GRADE INSPECTION		
SANITARY SEWER DESIGN		

ISSUE	NATURE OF REVISION	DATE

PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:
MPS CONTRACT: DIVISION:

CAPITAL CONSULTANTS DesignWorks AE

DESIGNED | CHECKED
SCALE: 1"=5' | CADD DATE: 10/5/06
PART: 45594m3.typ

DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

TYPICAL CROSS SECTIONS
MICHIGAN AVENUE

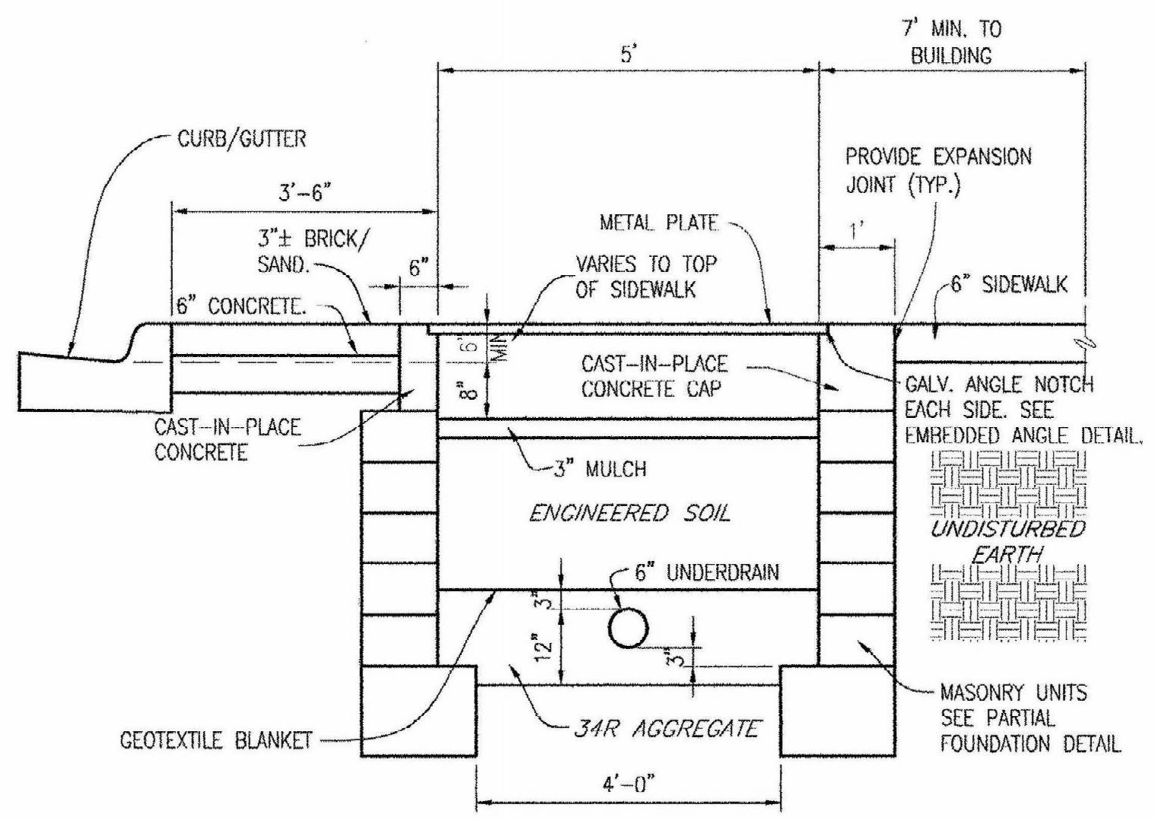
APPROVED
DEPARTMENT OF PUBLIC SERVICE
FILE NO.
SCALE HORIZONTAL: 1"=5' VERTICAL: 1"=5'
PROJECT NO. PS 36313
SHEET 6 OF 66 SHEETS

CONTROL SECTION NO. STU 33014 JOB NO. 87826A
CONTROL SECTION NO. STU 33403 JOB NO. 72114A

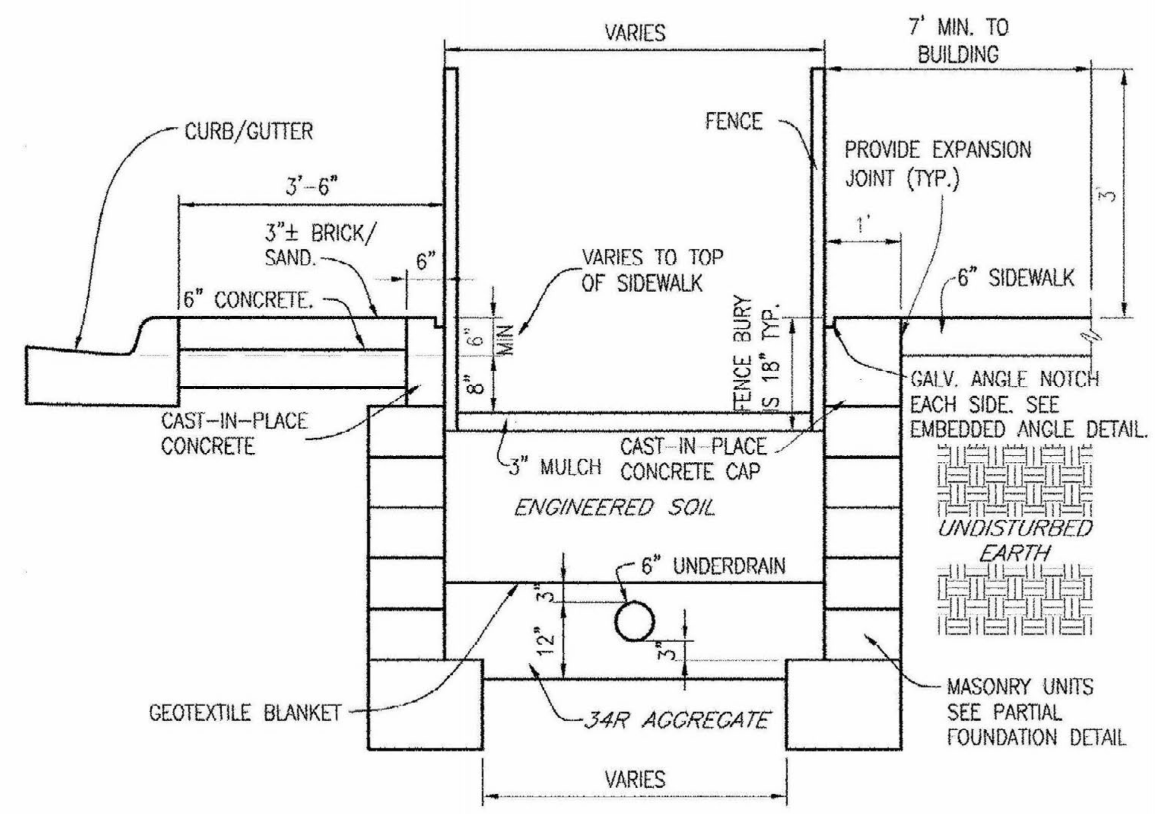
OPERATION	BY	DATE
SURVEYED		
GRADE PLOTTED		
PLAN CHECKED		
PROFILE PLOTTED		
PROFILE CHECKED		
PRELIMINARY GRADE		
GRADE INSPECTION		
SANITARY SEWER DESIGN		

OPERATION	BY	DATE
SAN. SEWER DESIGN CK.		
STORM SEWER DESIGN		
STORM SEWER DESIGN CK.		
SAN. SEWER QUANTITIES		
SAN. SEWER QUANTITIES CK.		
STORM SEWER QUANTITIES		
STORM SEWER QUANTITIES CK.		
PRELIMINARY R.O.W. CK.		

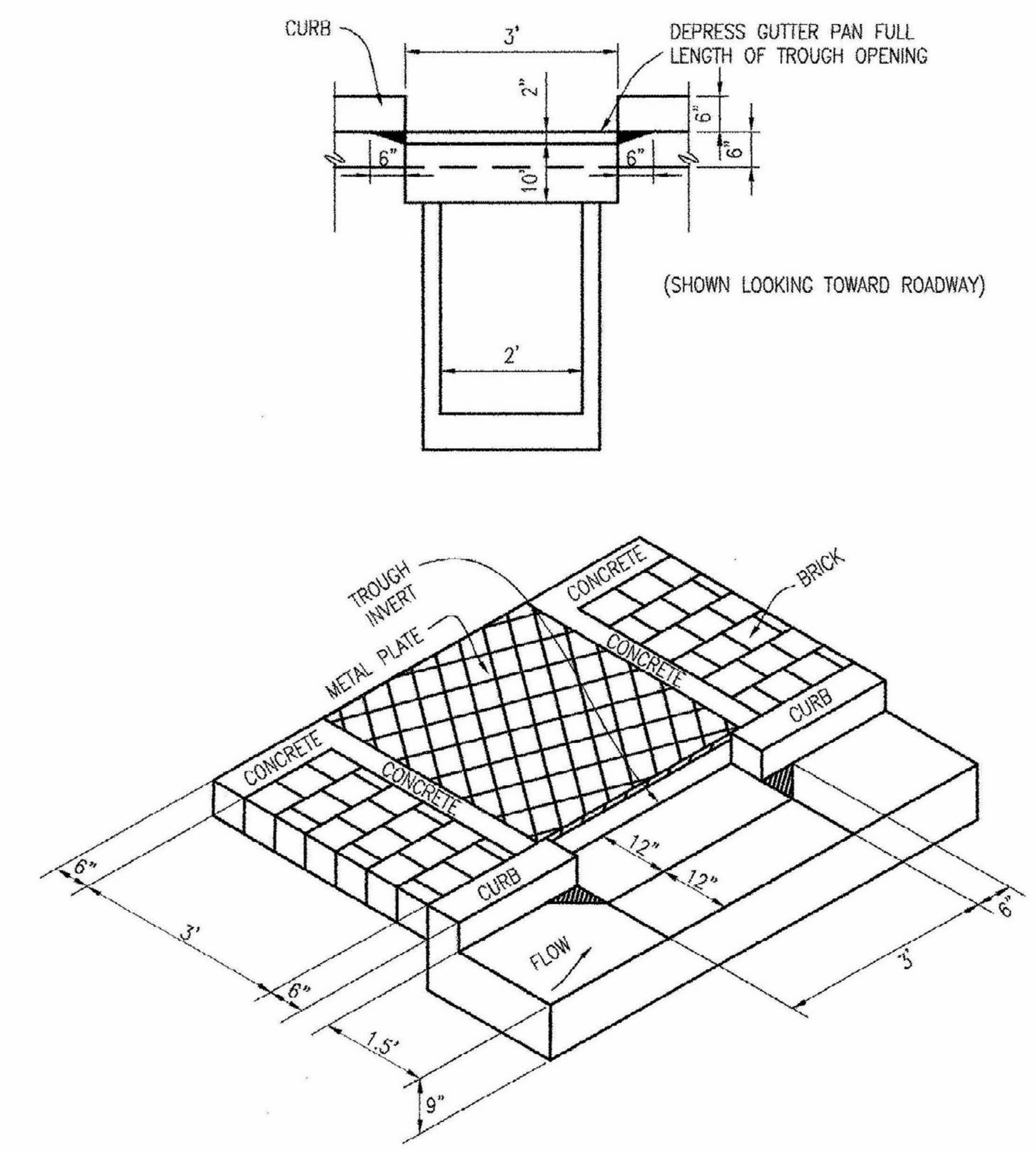
OPERATION	BY	DATE
BOARD OF WATER & LIGHT:		
ELECTRIC		
WATER		
CONSUMERS ENERGY – GAS		
BELL TELEPHONE		
CABLE TELEVISION – CATV		
FIRE DEPARTMENT		



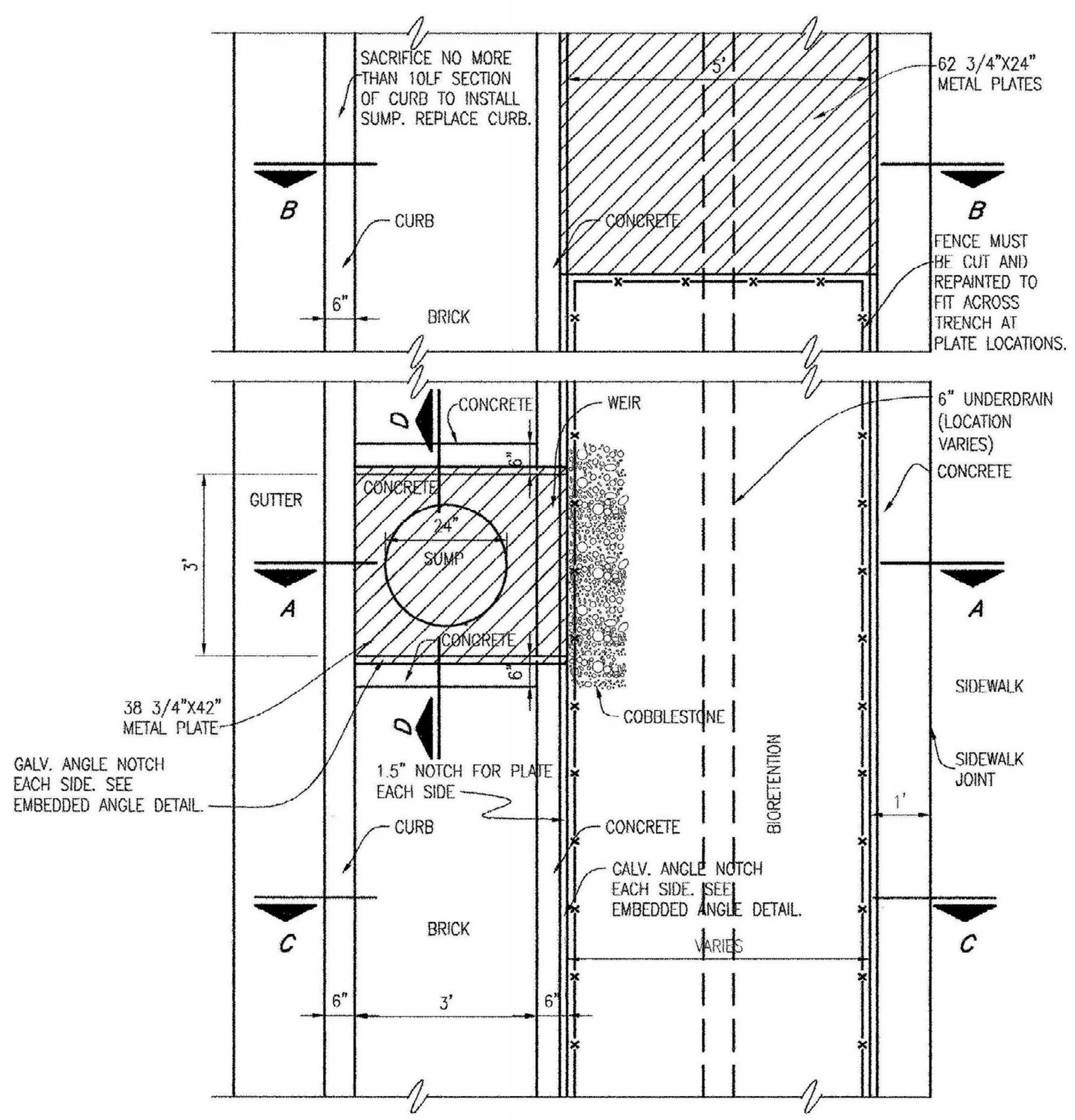
BIORETENTION DETAIL
B–B DETAIL (TYPICAL)
SCALE: 1" = 2'



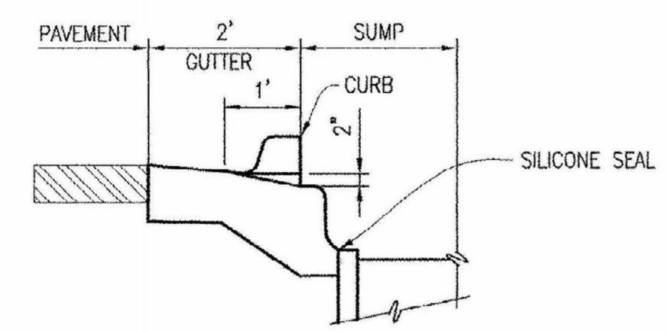
BIORETENTION DETAIL
C–C DETAIL (TYPICAL)
SCALE: 1" = 2'

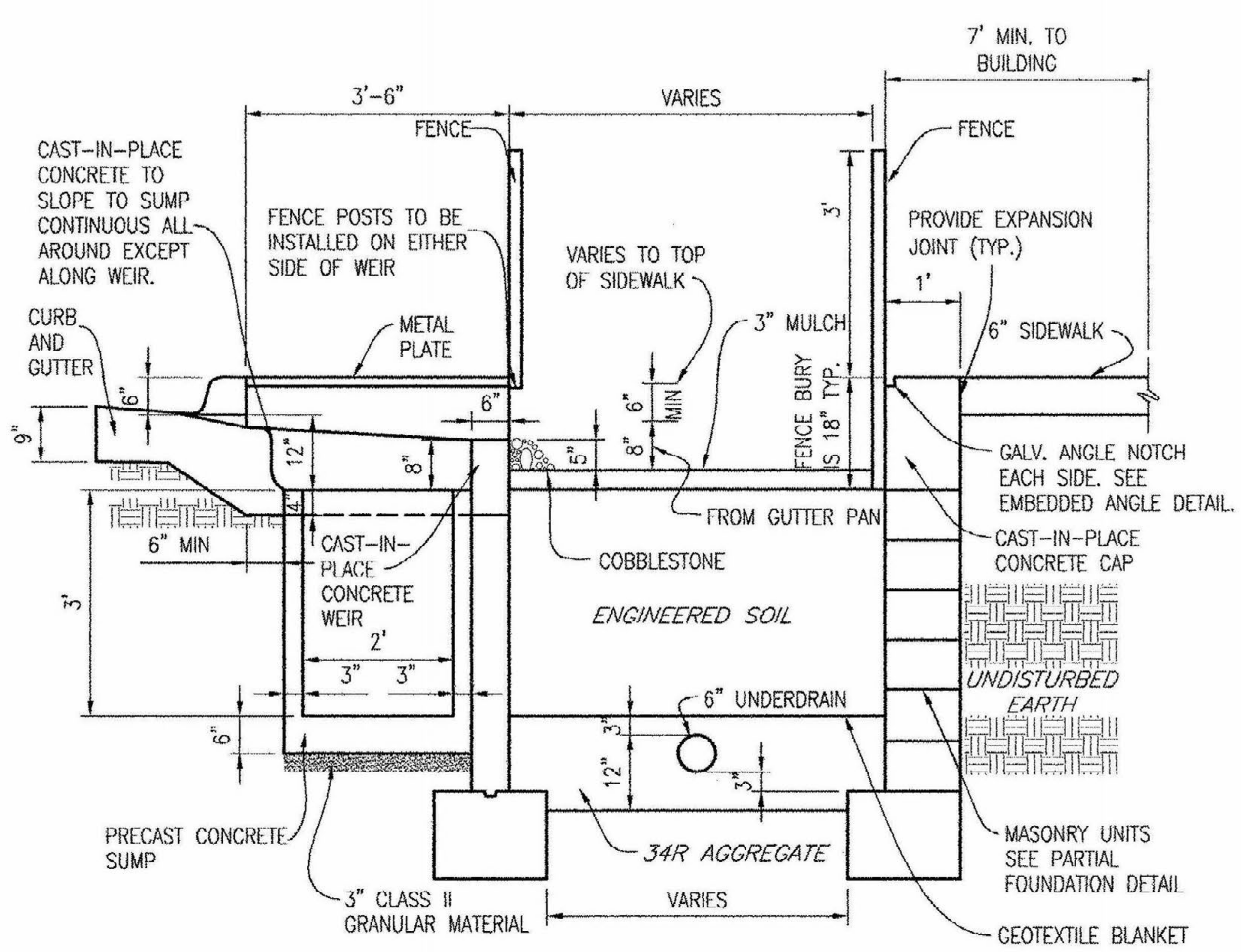


INLET DETAIL
SECTION D–D
SCALE: 1" = 2'



BIORETENTION
PLAN (TYPICAL)
SCALE: 1" = 2'





BIORETENTION SECTION
A–A DETAIL (TYPICAL)
SCALE: 1" = 2'

ISSUE	NATURE OF REVISION	DATE

PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:
MPS CONTRACT: DIVISION:

TETRA TECH
CAPITAL CONSULTANTS DesignWorks

DESIGNED CHECKED
SCALE CADD DATE Dec/14/2006-2:36pm
PART S:\2000\05267\DESIGN\Final Design Drawings\05267Detail 9-25-06.dwg

DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

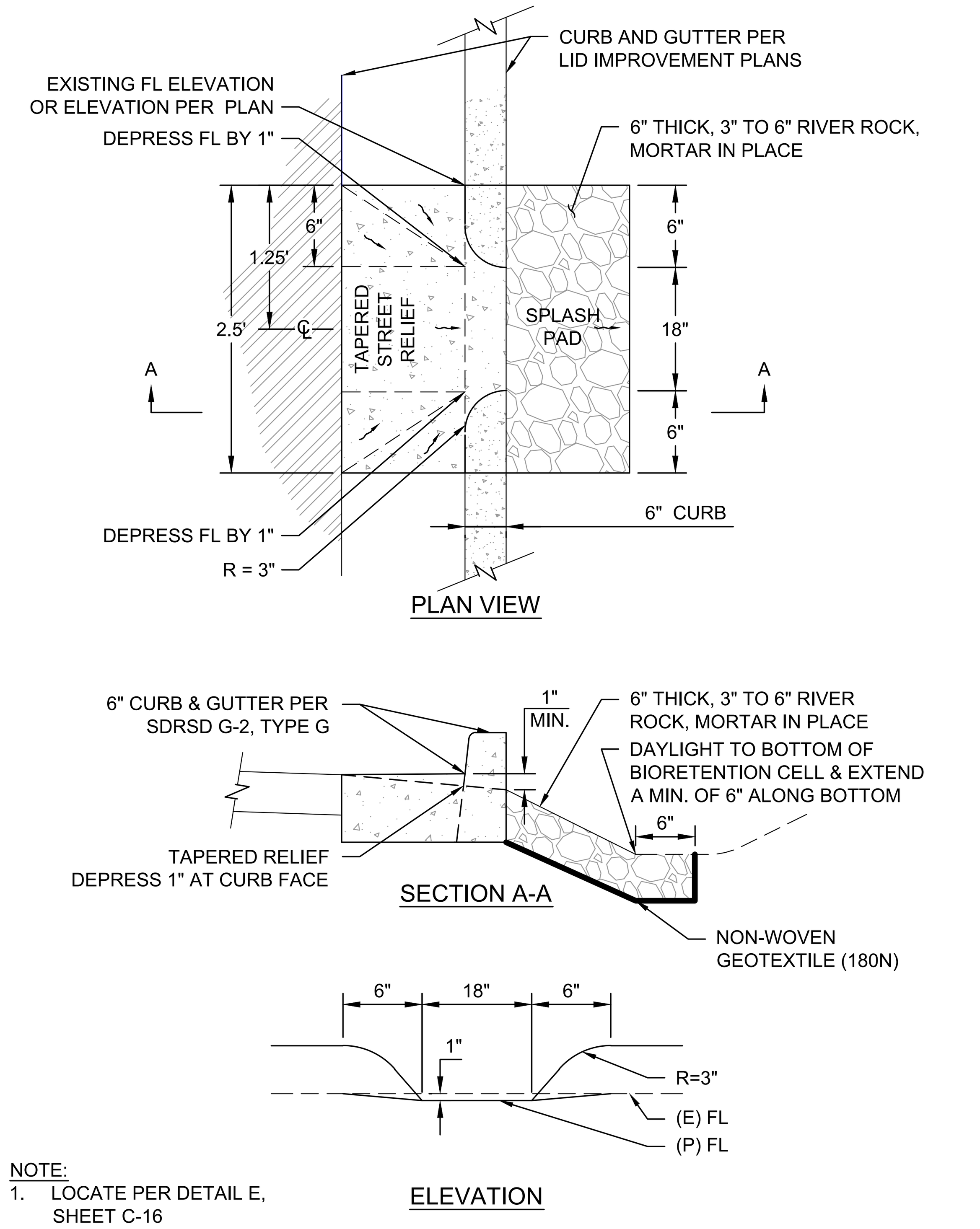
BIORETENTION
DETAILS

APPROVED
FILE NO.
DEPARTMENT OF PUBLIC SERVICE
SCALE HORIZONTAL: VERTICAL:
PROJECT NO. PS 36313
SHEET 13 OF 66 SHEETS

JOB NO. 87825A
CONTROL SECTION NO. 33014
JOB NO. 72114A
CONTROL SECTION NO. 33403


621

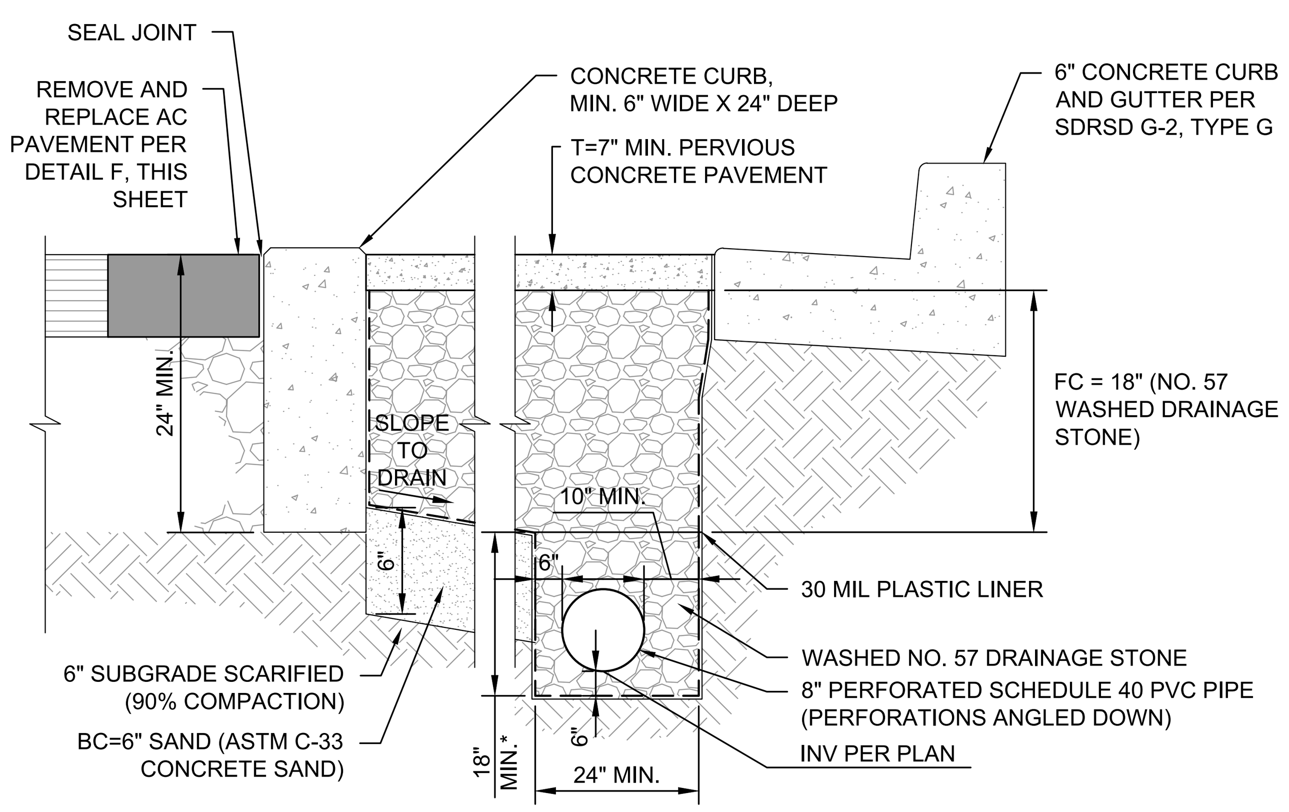
PERMEABLE CONCRETE



NOTE:
1. LOCATE PER DETAIL E, SHEET C-16

CURB OPENING WITHOUT GRATE

D / VAR — C-01, C-02 — NOT TO SCALE

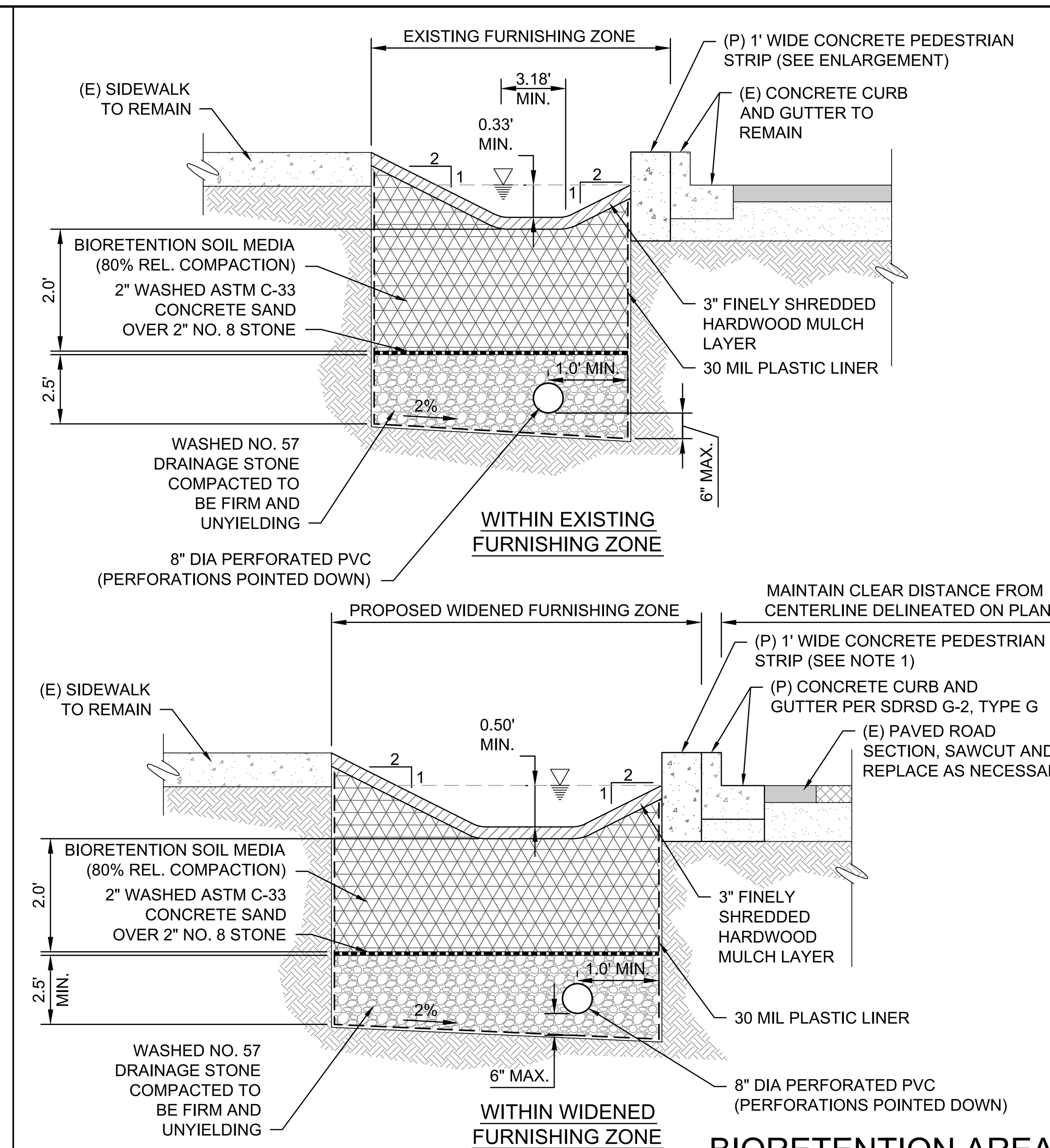


NOTE:
1. CONTROL JOINTS AT 12' INTERVALS MAX.
2. LOCATE UNDERDRAIN AS SHOWN ON THE IMPROVEMENT PLANS
3. DEPTH OF PERFORATED PVC PIPE MAY INCREASE TO TIE INTO THE PROPOSED PERFORATED PVC PIPE BENEATH THE PROPOSED BIORETENTION AREAS.
4. REFER TO DETAIL C, THIS SHEET, FOR UNDERDRAIN WITHIN A COMMON TRENCH.
5. WHERE A PIPE IS REQUIRED TO PENETRATE THE LINER, THE LINER SHALL BE CUT TO SLIDE THE PIPE THROUGH. TO SEAL THE LINER REFER TO DETAIL C, SHEET C-15 FOR TYPICAL PIPE SEALANT DETAIL.

* INCREASE DEPTH AS REQUIRED FOR UNDERDRAIN CONNECTIONS

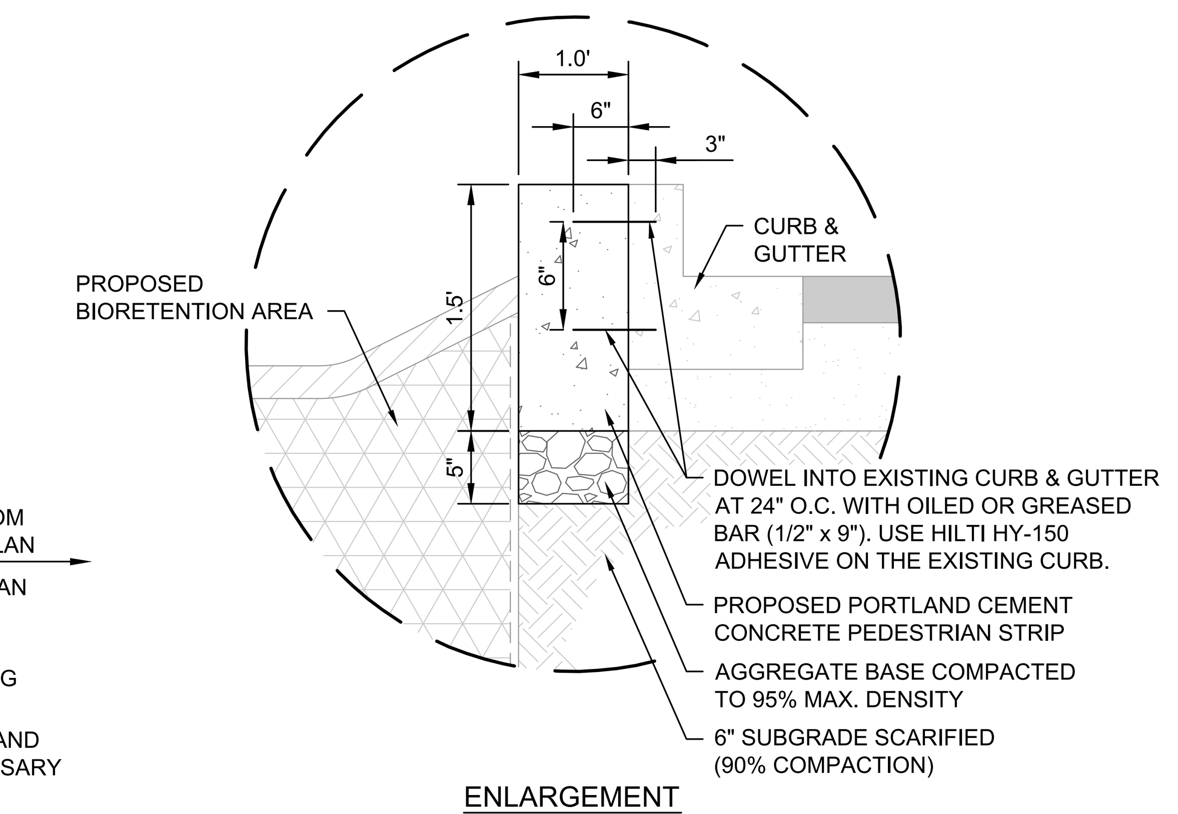
PERVIOUS PORTLAND CEMENT CONCRETE

B / VAR — G-02, C-09, C-10, C-11, C-14, C-15 — NOT TO SCALE



BIORETENTION SOIL MEDIA TABLE

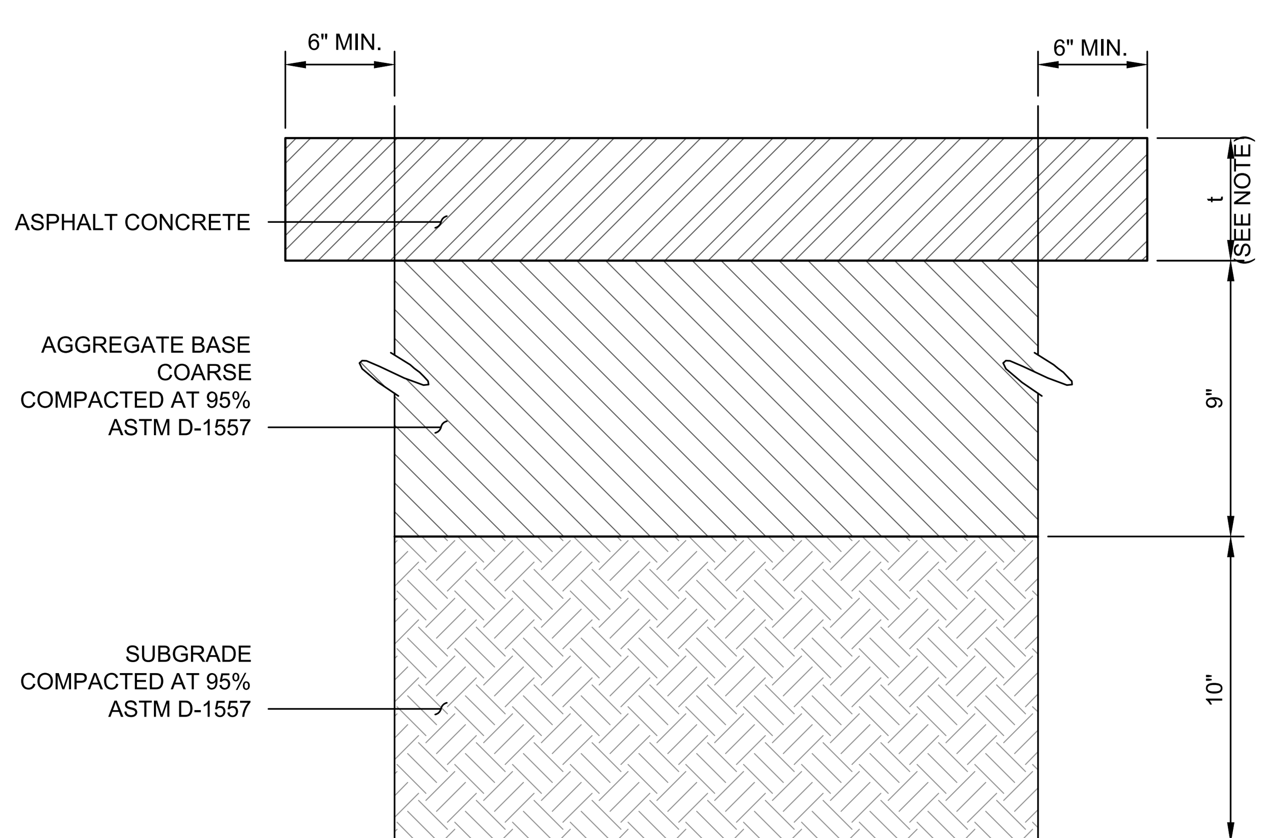
BIORETENTION SOIL MEDIA TYPE	LOCATION
TYPE A	MANITOU WAY
TYPE B	BANNOCK AVENUE
TYPE C	CLAIREMONT MESA



NOTE:
1. WHERE APPLICABLE, POUR PROPOSED 1' WIDE CONCRETE PEDESTRIAN STRIP MONOLITHICALLY WITH THE PROPOSED CURB AND GUTTER. OTHERWISE, DOWEL INTO EXISTING AS SHOWN ABOVE.
2. REFER TO HORIZONTAL CONTROL PLANS FOR HORIZONTAL CONTROL INFORMATION.
3. REFER TO UNDERDRAIN PLANS FOR INVERT ELEVATIONS OF UNDERDRAINS.
4. REFER TO DETAIL C, THIS SHEET, FOR UNDERDRAIN WITHIN A COMMON TRENCH.
5. WHERE A PIPE IS REQUIRED TO PENETRATE THE LINER, SEE DETAIL C, SHEET C-15 FOR TYPICAL PIPE SEALANT DETAIL.

BIORETENTION AREA

A / VAR — G-02, C-10, C-11, C-12, C-14, C-16 — NOT TO SCALE

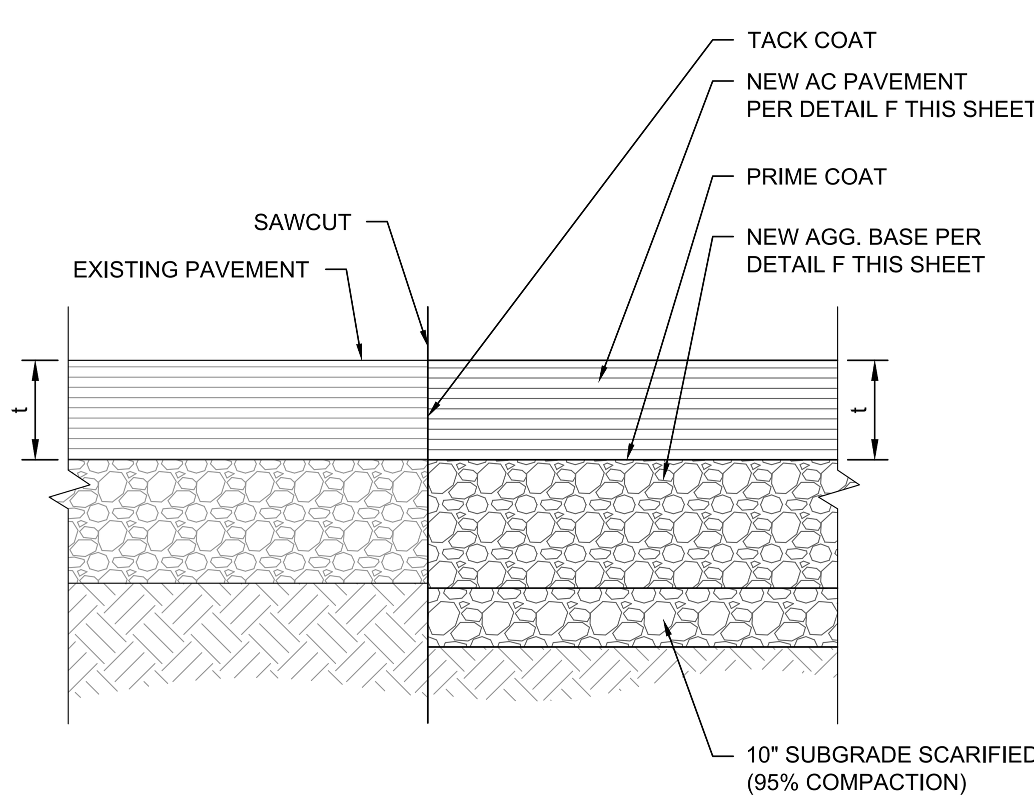


STREET NAME	t
MANITOU WAY	7"
BANNOCK AVENUE	9"
GENESEE AVENUE	15"
CLAIREMONT MESA BOULEVARD	9"

NOTE:
1. THICKNESSES ARE APPROXIMATE AND WERE OBTAINED FROM CORES AT VARIOUS LOCATIONS.
2. TRENCH RESURFACING PER SDG-107 AND SDRSD G-24

NEW AC PAVEMENT

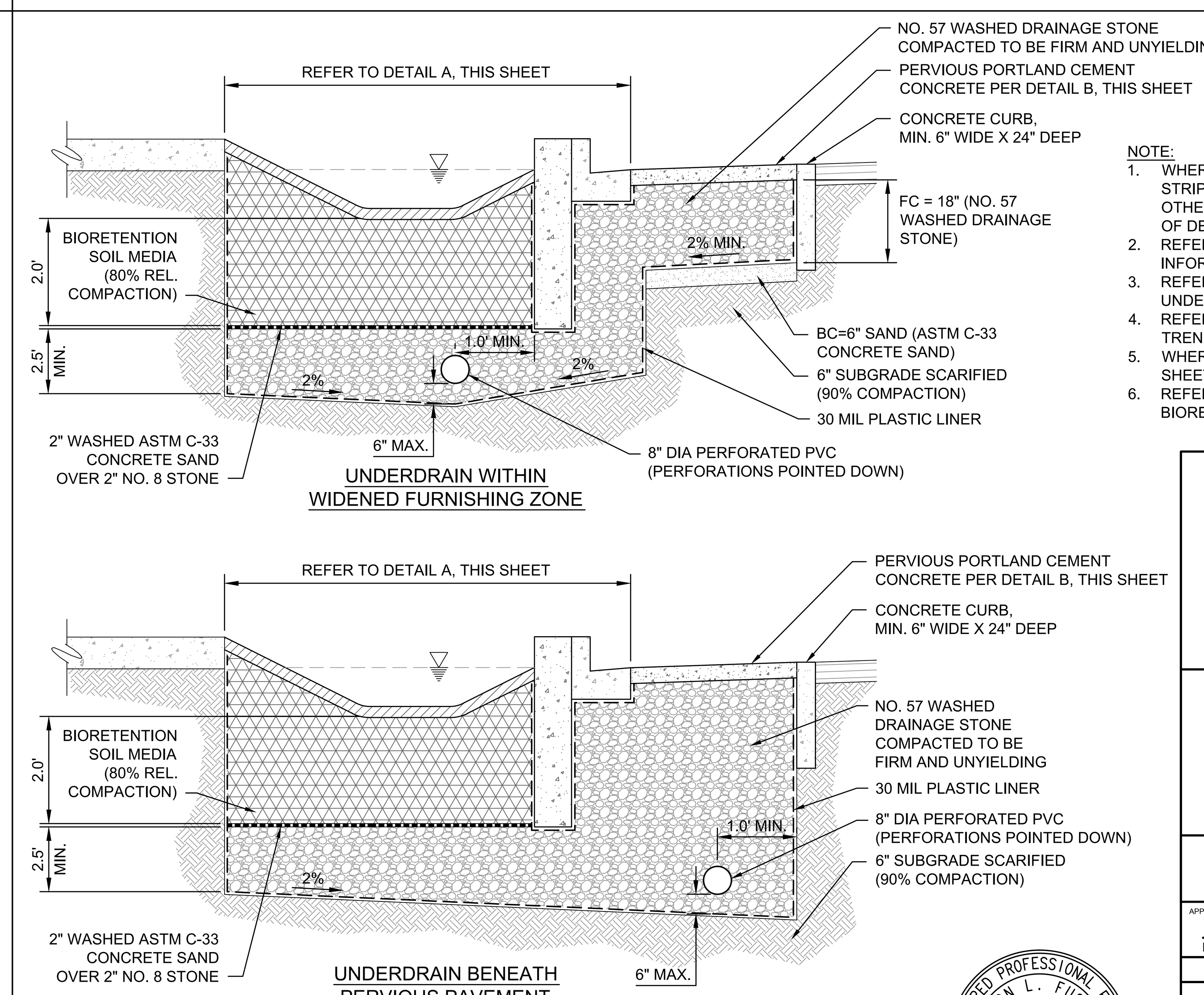
F / VAR — G-02, C-14, C-15 — NOT TO SCALE



NOTE:
FOR t DIMENSION, SEE TABLE IN DETAIL F, THIS SHEET

JUNCTURE OF NEW PVMT. TO EX. PVMT.

E / - — NOT TO SCALE



NOTE:
1. WHERE APPLICABLE, POUR PROPOSED 1' WIDE CONCRETE PEDESTRIAN STRIP MONOLITHICALLY WITH THE PROPOSED CURB AND GUTTER. OTHERWISE, DOWEL INTO EXISTING AS SHOWN IN THE ENLARGEMENT OF DETAIL A, THIS SHEET.
2. REFER TO HORIZONTAL CONTROL PLANS FOR HORIZONTAL CONTROL INFORMATION.
3. REFER TO UNDERDRAIN PLANS FOR INVERT ELEVATIONS OF UNDERDRAINS.
4. REFER TO DETAIL C, THIS SHEET, FOR UNDERDRAIN WITHIN A COMMON TRENCH.
5. WHERE A PIPE IS REQUIRED TO PENETRATE THE LINER, SEE DETAIL C, SHEET C-15 FOR TYPICAL PIPE SEALANT DETAIL.
6. REFER TO DETAIL A HEREON FOR THE TYPE AND LOCATION OF THE BIORETENTION SOIL MEDIA.

COMMON TRENCH

C / VAR — C-09, C-10, C-12, C-14, C-15 — NOT TO SCALE

C-14

PLANS PREPARED BY:

TETRA TECH, INC.
9444 Balboa Avenue, Suite 215
San Diego, CA 92123
(858) 268-5746 - phone, (858) 268-5809 - fax

BANNOCK AVENUE STREETSCAPE ENHANCEMENTS

DETAILS

CITY OF SAN DIEGO, CALIFORNIA
PUBLIC WORKS DEPARTMENT
SHEET 17 OF 35 SHEETS

WBS NO. B-10027

APPROVED: FOR CITY ENGINEER — DATE

SUBMITTED BY: JEFF SORIANO, PROJECT MANAGER

CHECKED BY: RON FOX, PROJECT ENGINEER

DESCRIPTION	BY	APPROVED	DATE	FILMED
ORIGINAL	XX/XX			

XXXX
CONTROL CERTIFICATION

234-1701
LAMBERT COORDINATES

CONTRACTOR ____ DATE STARTED ____
INSPECTOR ____ DATE COMPLETED ____

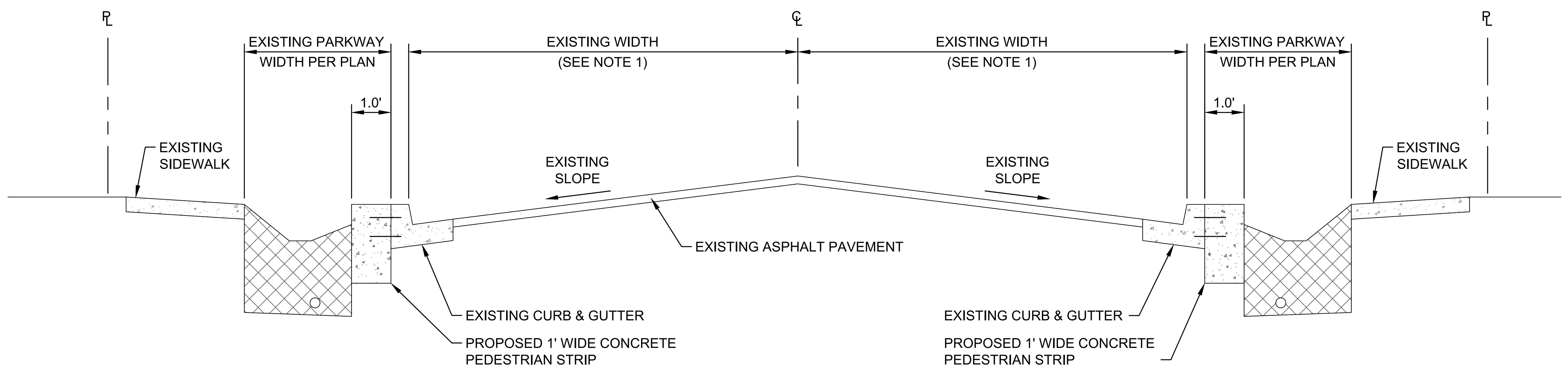
REGISTERED PROFESSIONAL ENGINEER — JASON L. FUSSEL — No. 70879 — EXP: 6-30-13 — CIVIL — STATE OF CALIFORNIA

36701-17-D

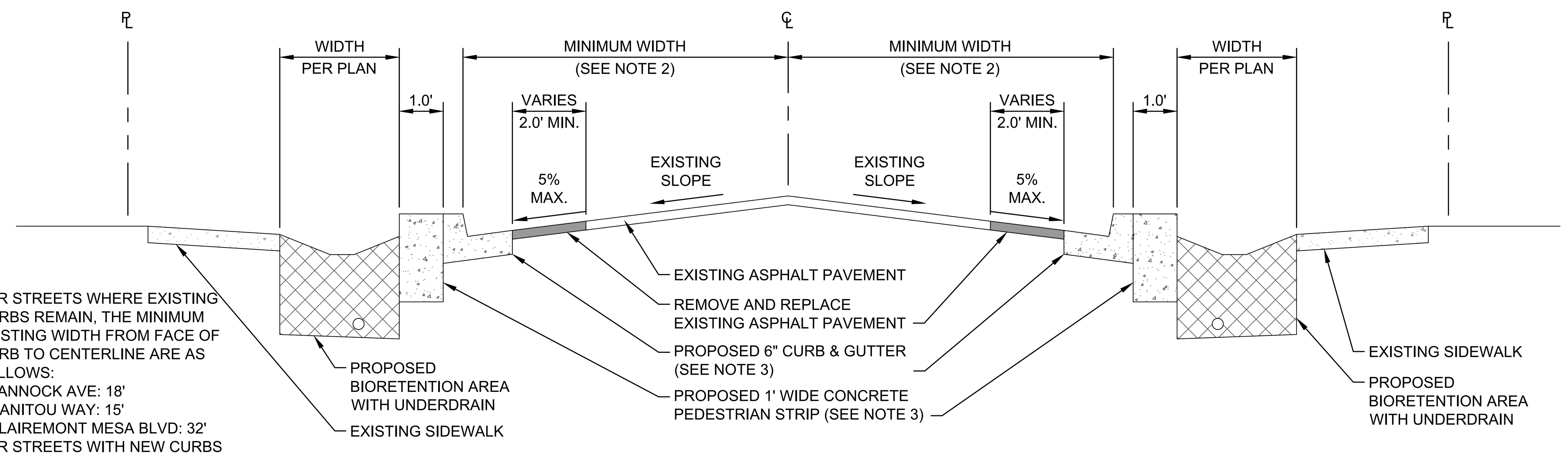
BANNOCK AVENUE STREETSCAPE ENHANCEMENTS

SHEET SIZE AND SCALE: "IF SHEET IS LESS THAN 22" X 34", IT IS A REDUCED PRINT SCALE ACCORDINGLY."

7/27/2012 FINAL SUBMITTAL



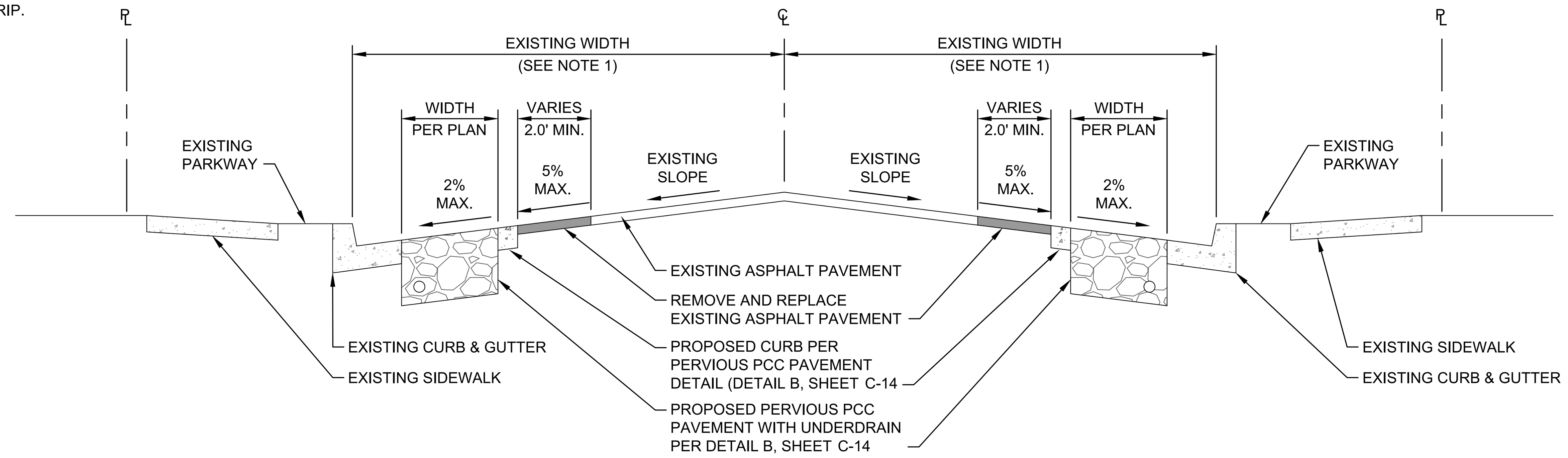
SECTION WITH EXISTING CURB AND NEW BIORETENTION AREAS



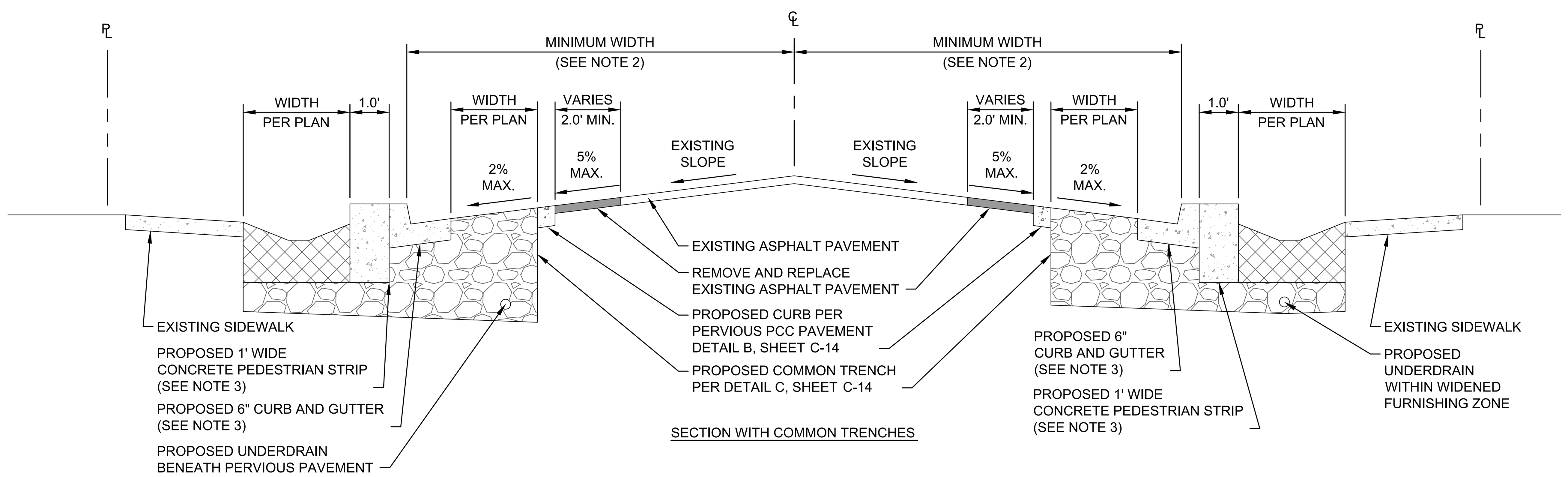
NOTES

1. FOR STREETS WHERE EXISTING CURBS REMAIN, THE MINIMUM EXISTING WIDTH FROM FACE OF CURB TO CENTERLINE ARE AS FOLLOWS:
   BANNOCK AVE: 18'
   MANITOU WAY: 15'
   CLAIREMONT MESA BLVD: 32'
2. FOR STREETS WITH NEW CURBS AND BIORETENTION AREAS, THE MINIMUM WIDTH FROM FACE OF CURB TO CENTERLINE SHALL BE 16'.
3. CURB & GUTTER MAY BE POURED MONOLITHICALLY WITH PEDESTRIAN STRIP.

SECTION WITH NEW CURB AND BIORETENTION AREAS

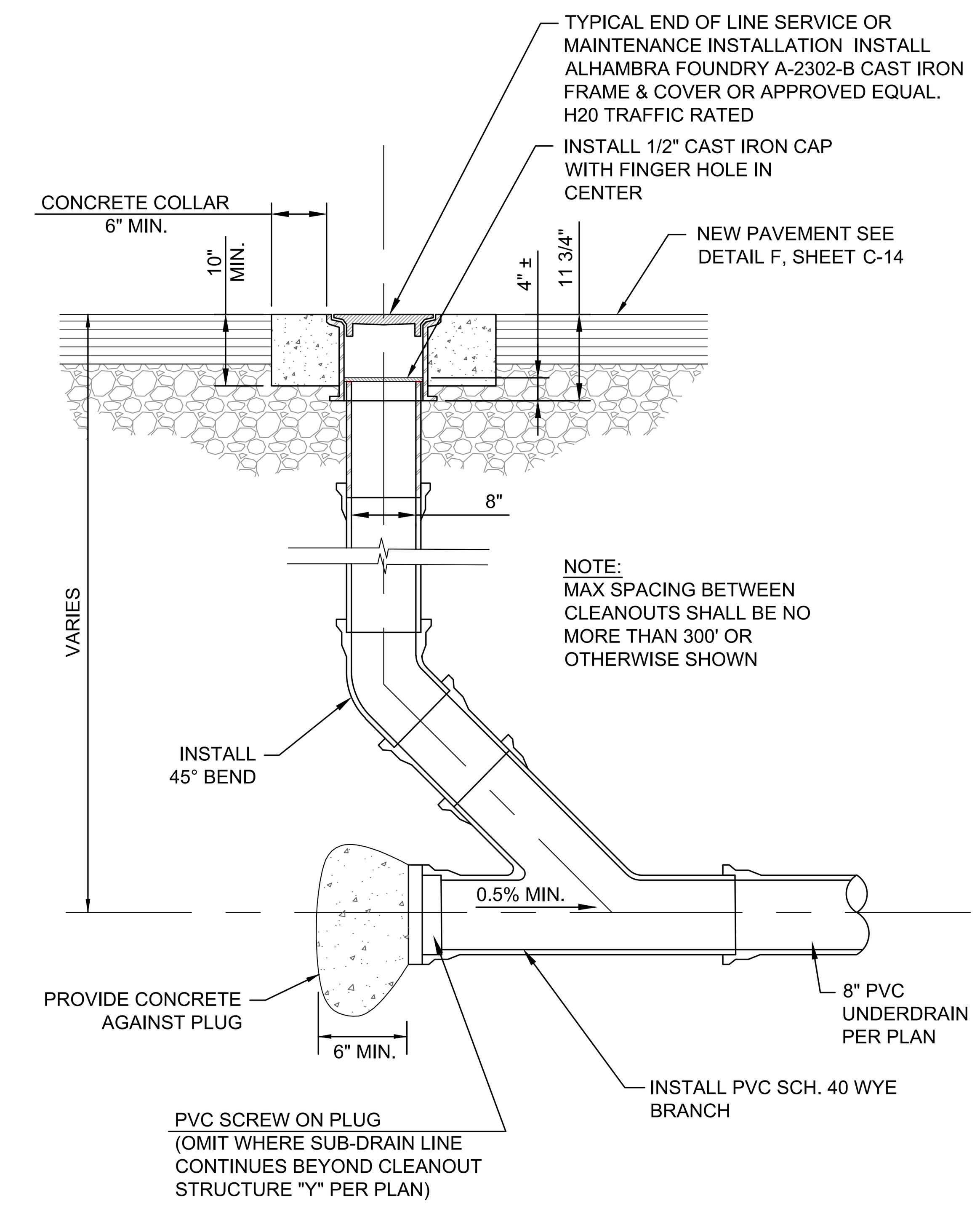


SECTION WITH PERVIOUS PAVEMENT AREAS



SECTION WITH COMMON TRENCHES

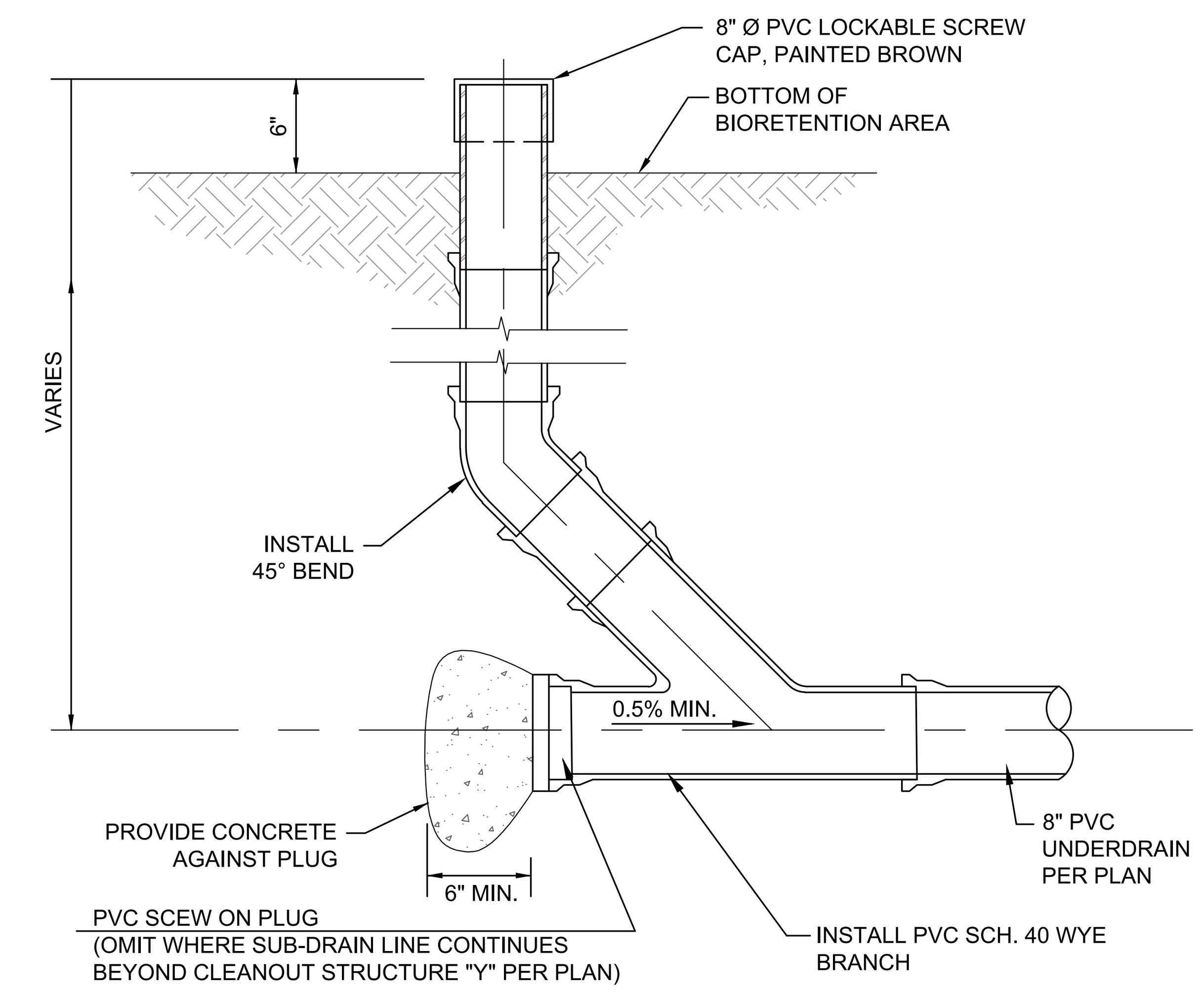
TYPICAL
ROADWAY SECTIONS (E / -) NOT TO SCALE



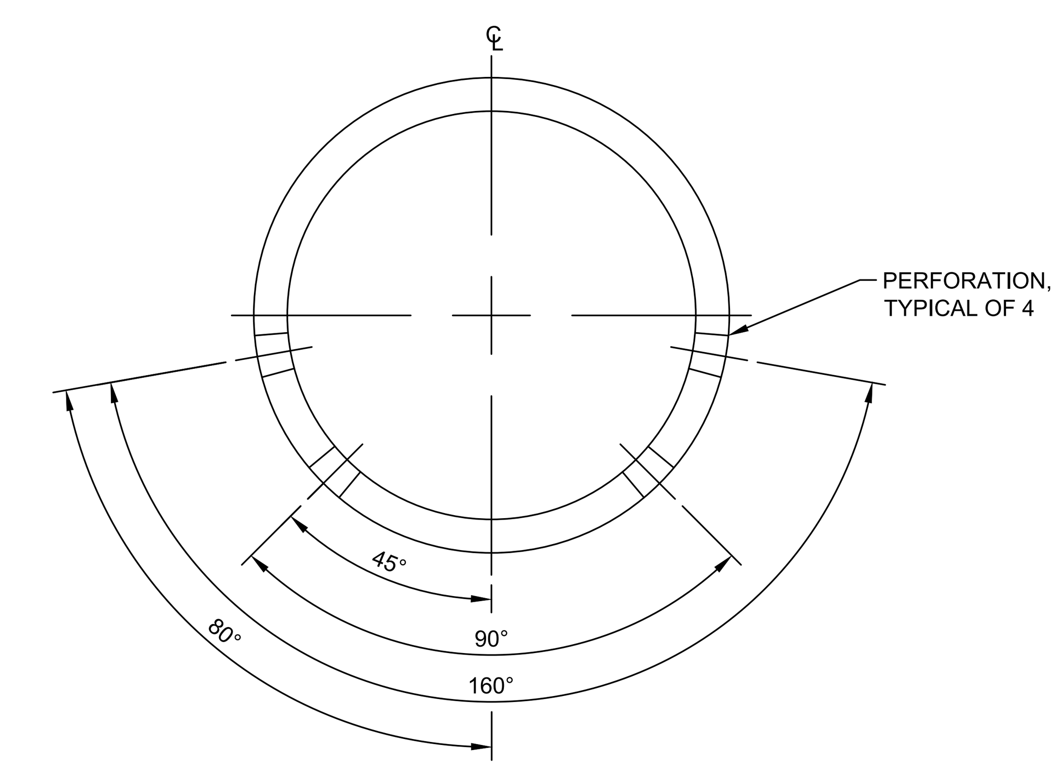
NOTES:

1. PIPES AND FITTINGS SHALL BE PROPERLY ALIGNED AND MAINTAINED WHILE CONCRETE IS BEING PLACE AND ALLOWED TO HARDEN. JOINTS FOR PIPES AND FITTINGS SHALL BE MADE PRIOR TO PLACING CONCRETE. CONCRETE FOR BEDDING, ENCASEMENT, AND WALL SUPPORT FOR PIPES AND FITTINGS SHALL BE PLACED UNIFORMLY AROUND THE PIPE AND FITTINGS AS SHOWN HEREON TO MAINTAIN PROPER ALIGNMENT, AND SHALL BE CLASS 420-C-2000.

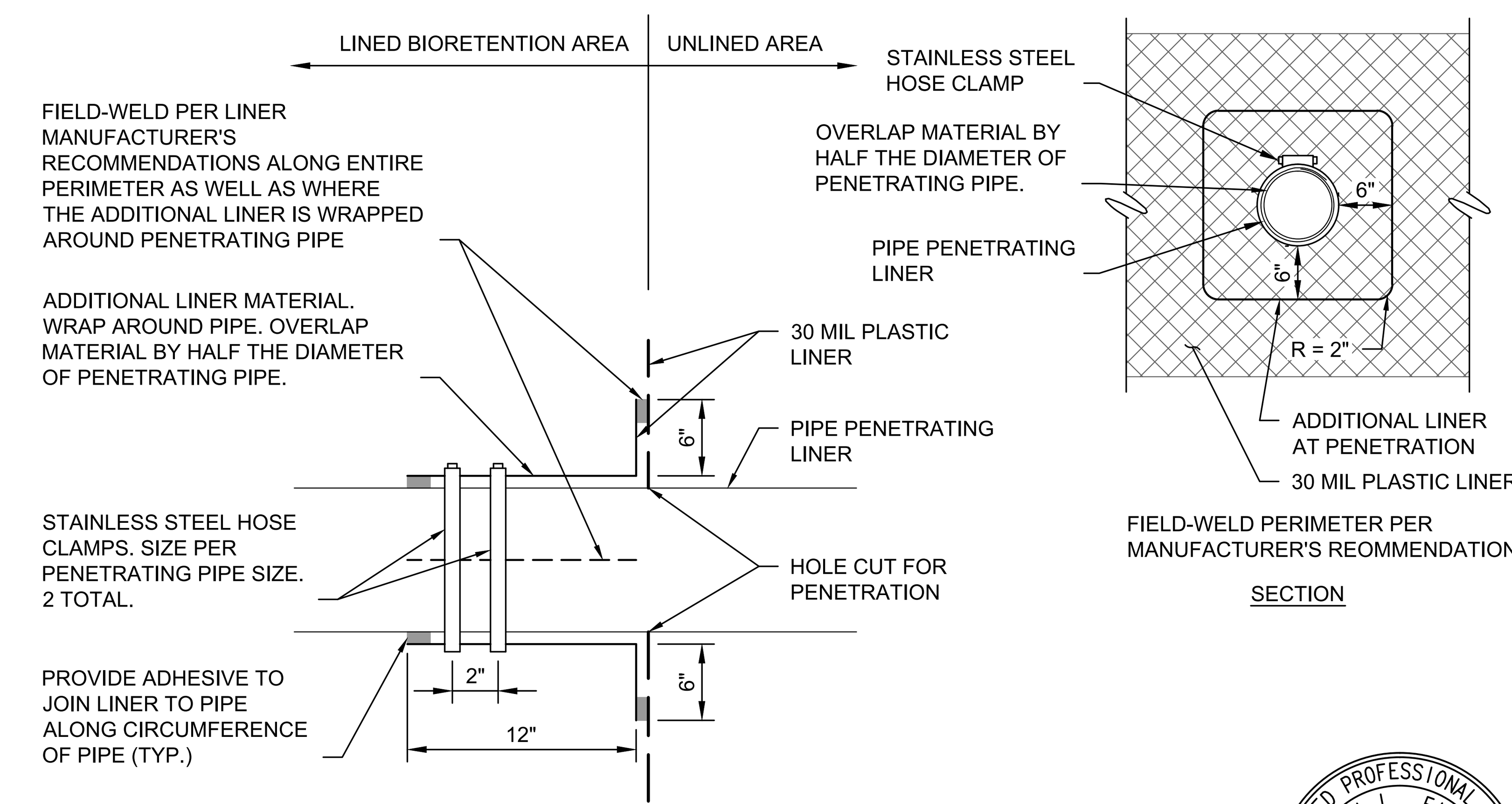
CLEANOUT IN
PAVEMENT AREA (B / VAR) G-02, C-09, C-10, C-11, C-12 NOT TO SCALE



CLEANOUT IN
BIORETENTION AREA (A / VAR) G-02, C-09, C-10, C-11, C-12 NOT TO SCALE



TYPICAL 8" PERFORATED PIPE (D / VAR) G-02, C-09, C-10, C-11, C-12 NOT TO SCALE



PIPE SEALANT (C / VAR) C-14, C-16 NOT TO SCALE

REGISTERED PROFESSIONAL ENGINEER
JASON L. FUSSEL
No. 70879
EXP: 6-30-13
CIVIL
STATE OF CALIFORNIA

C-15

PLANS PREPARED BY:

TETRA TECH, INC.
9444 Balboa Avenue, Suite 215
San Diego, CA 92123
(858) 268-5746 - phone, (858) 268-5809 - fax

BANNOCK AVENUE
STREETSCAPE ENHANCEMENTS
DETAILS

CITY OF SAN DIEGO, CALIFORNIA
PUBLIC WORKS DEPARTMENT
SHEET 18 OF 35 SHEETS

WBS NO. B-10027

APPROVED:
FOR CITY ENGINEER — DATE

SUBMITTED BY: JEFF SORIANO, PROJECT MANAGER
CHECKED BY: RON FOX, PROJECT ENGINEER
XXXX — CONTROL CERTIFICATION
234-1701 — LAMBERT COORDINATES
36701-18-D

DESCRIPTION		APPROVED	DATE	FILMED
ORIGINAL	XX/XX			

CONTRACTOR — DATE STARTED
INSPECTOR — DATE COMPLETED

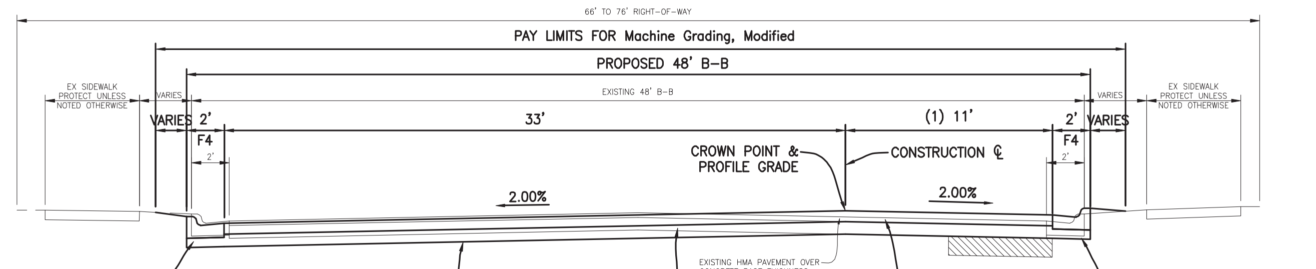
BANNOCK AVENUE STREETSCAPE ENHANCEMENTS

SHEET SIZE AND SCALE: "IF SHEET IS LESS THAN 22" X 34", IT IS A REDUCED PRINT SCALE ACCORDINGLY."

7/27/2012 FINAL SUBMITTAL

PERMEABLE CONCRETE PAVERS

PS 45046



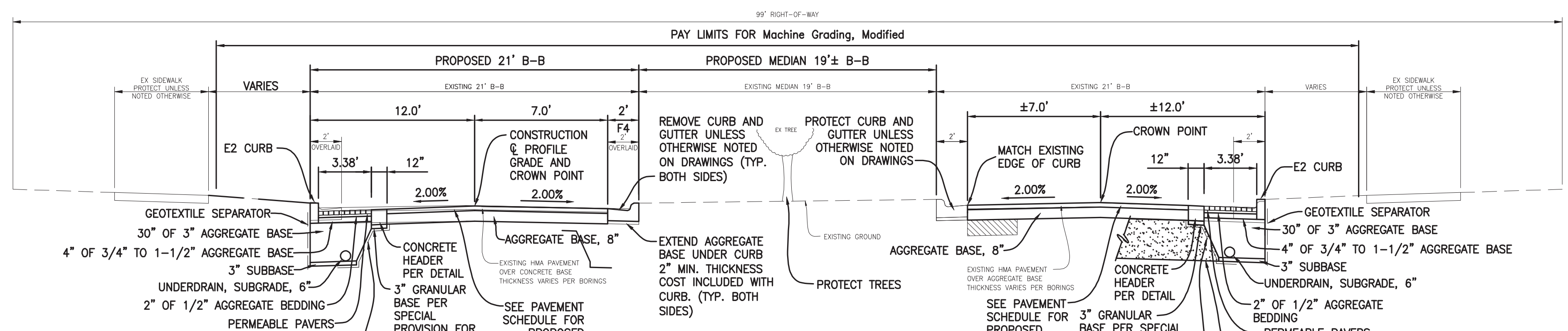
HATCHING DENOTES EXAMPLE AREA OF SUBGRADE UNDERCUT. CONTRACTOR SHALL PROOFROLL SUBGRADE IN PRESENCE OF ENGINEER PRIOR TO PLACEMENT OF AGGREGATE BASE. CONTRACTOR SHALL UNDERCUT UNSUITABLE AREAS AS DIRECTED BY ENGINEER. ENGINEER MAY DIRECT THE INSTALLATION OF GEOTEXTILES AND UNDERDRAINS AS CONDITIONS WARRANT.

PROPOSED TYPICAL CROSS SECTION
HMA OVER AGGREGATE

504

SCALE: 1"=5'
TO APPLY: • MT. HOPE AVENUE (STATION X+XX TO STATION X+XX)

(1) LANE WIDTH TRANSITION FROM X.X' AT STATION X+XX TO X' AT STATION X+XX

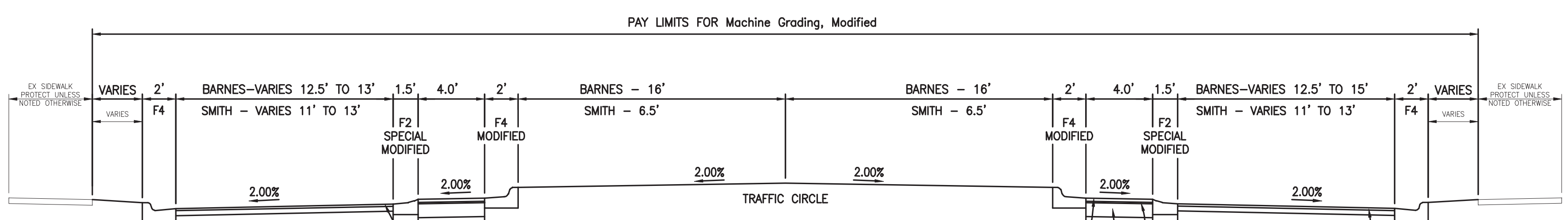


HATCHING DENOTES EXAMPLE AREA OF SUBGRADE UNDERCUT. CONTRACTOR SHALL PROOFROLL SUBGRADE IN PRESENCE OF ENGINEER PRIOR TO PLACEMENT OF AGGREGATE BASE. CONTRACTOR SHALL UNDERCUT UNSUITABLE AREAS AS DIRECTED BY ENGINEER. ENGINEER MAY DIRECT THE INSTALLATION OF GEOTEXTILES AND UNDERDRAINS AS CONDITIONS WARRANT.

PROPOSED TYPICAL CROSS SECTION
HMA OVER AGGREGATE

513

SCALE: 1"=5'
TO APPLY: • BARNES AVENUE STATION 30+00 TO STATION 38+16
(WB PERMEABLE PAVING: STATION 30+01 TO STATION 33+81; STATION 34+55 TO STATION 37+92)
(EB PERMEABLE PAVING: STATION 30+00 TO STATION 33+81; STATION 34+54 TO STATION 37+95)



PROPOSED TYPICAL CROSS SECTION
TRAFFIC CIRCLE DETAIL

514

SCALE: 1"=5'
TO APPLY: • INTERSECTION OF BARNES AVENUE AND BEAL AVENUE
• INTERSECTION OF SMITH AVENUE AND BEAL AVENUE

NOTE: EARTH EXCAVATION AND EMBANKMENT REQUIRED TO CONSTRUCT THE EARTH GRADE SHALL BE INCLUDED WITH THE PAY ITEM "MACHINE GRADING MODIFIED".

ISSUE	NATURE OF REVISION	DATE

PHASE V SEGMENT 2
SUBAREA 034C SEPARATION

PRIME CONTRACTOR:
CONSTRUCTION ADMINISTRATOR:
CONSTRUCTION OBSERVATION BY:

TI CONTRACT: 200-12741-08002-S-2 DIVISION:

c2ae TETRA TECH

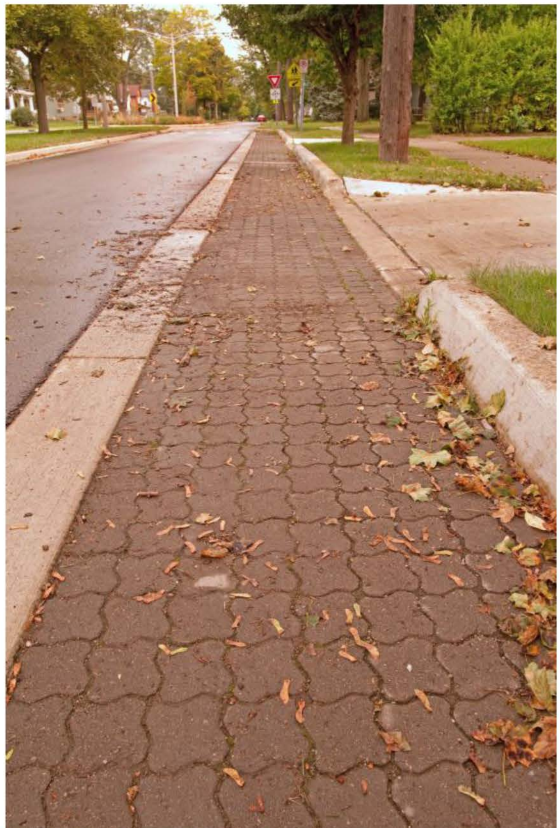
DESIGNED JWB/SMB CHECKED WJK/RWF/ADF
SCALE AS NOTED CADD DATE 10/22/2009 3:23 PM
PART R:\LA\2008\LA.08265.CSOSubarea034C\Dwgs\034C.PP.Typicals.dwg

DEPARTMENT OF PUBLIC SERVICE
LANSING, MICHIGAN

TYPICAL PAVEMENT REPLACEMENT CROSS SECTIONS

APPROVED FILE NO.
DEPARTMENT OF PUBLIC SERVICE
SCALE HORIZONTAL: AS NOTED VERTICAL: AS NOTED
PROJECT NO. PS 45046
SHEET 13 OF 110 SHEETS

PHASE V SEGMENT 2 – SUBAREA 034C SEPARATION



Appendix G
Pervious Concrete Pavement Design References

TETRA TECH, INC.

MEMORANDUM

Date: February 19, 2013

To: City of Omaha

From: Carol Hufnagel, Anne Thomas

Subject: Portland Pervious Cement Concrete (PPCC) Information

Contract: EP-C-11-009

US EPA Green Infrastructure Community Partners Project

Maintenance References:

Coughlin, J. P., Campbell, C. D., and Mays, D. C. (January 2012). Infiltration and Clogging by Sand and Clay in a Pervious Concrete Pavement System. *Journal of Hydrologic Engineering, ASCE.* 17:68-73.

North Carolina Department of Environment and Natural Resources. (October 2012). Stormwater Best Management Practices Manual, Chapter 18, Permeable Pavement. Last accessed February 18, 2013. http://portal.ncdenr.org/web/wq/ws/su/bmp-manual

North Carolina State University Cooperative Extension. (2011). Urban Waterways: Maintaining Permeable Pavements. Last accessed February 18, 2013. http://www.bae.ncsu.edu/stormwater/PublicationFiles/PermPaveMaintenance2011.pdf

Design Guidance:

Permeable pavement excerpt from the Draft City of Dublin, OH Stormwater Management Design Manual (Attachment 1)

Permeable pavement excerpt from the San Diego Low Impact Development Design Manual (Attachment 2)

Permeable pavement underdrain and outlet excerpt from Chapter 18, Permeable Pavement of the North Carolina Department of Environment and Natural Resources Stormwater BMP Manual (Attachment 3)

Cost References:
Pervious Concrete Sidewalk, 6" $6/SF for materials and installation Maywood, Toledo project

Porous Concrete, $2-$6/SF for materials and installation (no mention of thickness)
http://www.epa.gov/heatisld/images/extra/level3_pavingproducts.html#7

Pervious concrete - $118.8/CY (May, 2010) including tax. 6 inches thick = $19.80/SY.
Calculated: $3.65/SF @ 10-inch thicknesses   Wang, Y. and Wang, G. (2011) Improvement of Porous Pavement. http://www.usgbc.org/ShowFile.aspx?DocumentID=9915

Pervious Concrete - $2 – $7 /SF for 2-4 inches deep National Cooperative Highway Research Program (NCHRP), Evaluation of Best Management Practices for Highway Runoff Control: Low Impact Development Design Manual for Highway Runoff Control, Project 25-20(01), 2005 (page 10-3)

Sultan,WA residential street. (2006) 8 inches thick with 8-inch of aggregate storage
$196,000/32,000 SF = $6.13/SF   ~$7.66/Sf for 10-inch PPCC with 8-inch of aggregate storage ; $7.17/SF for only 10-inch PPCC
http://www.concretenetwork.com/pervious/design-ideas/pervious-concrete-washington.html

32nd Street SW, Seattle pervious Concrete 2005 – 8" PPCC over 18" subbase $85 - $165/SY for pavement, excavation, subbase, side barriers, and underdrains. Calculation: $9 - $18/SF; ~$8-$17 without aggregate
http://depts.washington.edu/uwbg/docs/stormwater/PorousPaveStudy.pdf

N. Gay Avenue Portland, OR, 10" PPCC over 6" subbase connected to 20ft x 20ft sewer trench below.– full street (2005) reused existing curb, 25-year storm $256,000/32,000SF = $8/SF with PPCC and aggregate (Excavation included with utility work??) Calculation: $8/SF - $0.37/SF for aggregate = $7.63/SF for PPCC only
http://www.portlandoregon.gov/bes/article/196785

Strength References:

Marks, A. Pervious Concrete Pavement – How Important is Compressive Strength?. Vol. 3, Number 3.
http://www.rmc-foundation.org/images/PCRC%20Files/Structural%20Design%20&%20Properties/PvC%20Pvmt-Compressive%20Strength.pdf

Chopra, M., Wanielista, M., Mulligan, A. M. (January 2007). Compressive Strength of Pervious Concrete Pavements. http://www.rmc-foundation.org/images/PCRC%20Files/Structural%20Design%20&%20Properties/Compressive%20Strength.pdf

Specification References:

Pervious Concrete spec ACI 522.1-08 $34.50
http://www.concrete.org/bookstorenet/productdetail.aspx?itemid=522108

Roadway Details:

Seattle, WA 32nd Street pervious concrete road.

http://www.seattle.gov/util/groups/public/@spu/@usm/documents/webcontent/spu02_020005.pdf

Aggregate Void References:

ASTM C29 Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

Roadway Performance Reference:

Schaefer, V. R., Kevern, J. T., Izevbekhai, B., Wang, K., Cutler, H. E., and Wiegand, P. (2010). Construction and performance of Pervious Concrete Overlay at Minnesota Road Research Project. *Transportation Research Board: Journal of the Transportation Research Board.* 2164:82-88.

Appendix H
Green Block Cost Calculation

Typical Residential Block with Green Infrastructure to Capture 0.5-inch of Runoff

Option 1

Pervious Concrete in Parking Lanes

							Option 1			Option 1					
Block length (Ft)	Road removed	Right-of-Way Width (Ft)	Road Width (Ft)	Drainage Area (Ac)	Storage Volume Needed, Ac-Ft	Storage Volume Needed, CF	Control type for 1/2" runoff	Volume Aggregate Reqd, CF	Aggregate Depth reqd for parking lanes (6-ft each side), Ft	Open Graded Aggregate Unit Cost (per SF)	Excavation Unit Cost (per SF)	10-inch Pervious Concrete unit cost (per SF)	6-inch underdrain unit cost (per LF)	Green component total cost	**Green component adjusted cost**
350	Full width	60	24	0.48	0.02	875	Perv. Conc., 6' on each side of street	2188	0.52	$ 0.49	$ 0.62	$ 8.00	$ 6.50	$ 42,817	**$ 15,517**

Use a min. of 8 inches of aggregate depth.

The Green Component Adjusted Cost is the additional cost per block for "Green" as part of a road reconstruction project.

Option 2

Bioretention Curb Extensions (nodes)

							Option 2		Option 2									
Block length (Ft)	Road removed	Right-of-Way Width (Ft)	Road Width (Ft)	Drainage Area (Ac)	Storage Volume Needed, Ac-Ft	Storage Volume Needed, CF	Control type for 1/2" runoff	Area of Bioretention Reqd, SF	Open Graded Aggregate Unit Cost (per SF)	Excavation Unit Cost (per SF)	Engineered Soil Unit Cost (per SF)	Vegetation Unit Cost (per SF)	Mulch Unit Cost (per SF)	Curb and Gutter Unit Cost (per LF)	6-inch underdrain unit cost (per LF)	Overflow Catch Basin and Pipe Unit Cost (per EA)	Green component total cost	**Green component adjusted cost**
350	Full width	60	24	0.48	0.02	875	Bioretention Curb Extensions	438	$ 2.22	$ 0.83	$ 2.22	$ 5.00	$ 0.42	$ 12.00	$ 6.50	$ 2,500	$ 11,538	**$ 7,886**

The Green Component Adjusted Cost is the additional cost per block for "Green" as part of a road reconstruction project.

Notes:

Assume 0.5-inch of runoff.

The green component adjusted cost for pervious concrete is the green infrastructure practice cost less what would have typically been spent on traditional concrete pavement (~$5/SF), 8-inch aggregate base ($8.50/SY), and 18 inches of excavation ($10/CY).

Cross-section design for bioretention: 6 inches of ponding, 1.5 feet of engineered soil (20% void), 3 feet of aggregate (40% void). 1 SF of bioretention = 2 CF of storage

Assume the bioretention practice is 5 feet wide from existing curb toward center of road.

The area of bioretention (438 SF) is equivalent to a curb extension approximately 5 feet wide by 44 feet long per side of the street. This could be designed as one unit or multiple smaller units at the corners and mid-block.

The green component adjusted cost for bioretention is the green infrastructure practice cost less what would have typically been spent on traditional concrete pavement (~$5/SF), 8-inch aggregate base ($8.50/SY), 18 inches of excavation ($10/CY) and concrete curb and gutter ($12/LF).

Aggregate void space is assumed to be 40% of total aggregate volume.