MSD

Metropolitan Sewer District

DESIGN MANUAL

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT
700 WEST LIBERTY STREET
LOUISVILLE, KENTUCKY 40203-1911

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1.1 PURPOSE OF THE MSD DESIGN MANUAL

This MSD Design Manual is a guide for the planning and design of stormwater systems, flood protection works, sanitary sewers, erosion control structures, small sanitary pump stations, small wastewater treatment plants and associated activities for the Louisville and Jefferson County Metropolitan Sewer District. The guidelines and general design procedures in this manual are approved by the MSD Board.

This Manual:

a. Enumerates design standards that have been authorized by the MSD Board and/or KRS 76 to facilitate MSD's compliance with local, state and federal regulations.

b. Identifies submittal requirements and procedures for the review of infrastructure projects within the MSD service area.

c. Serves as a reference document for professional consultants in the design of infrastructure projects within the MSD service area.

1.2 DESCRIPTION AND USE OF THE MSD DESIGN MANUAL

The Manual identifies a single set of standards, submittal requirements and approval procedures to be used in the planning and design of projects within the MSD service area.

This Manual is not intended to serve as a step-by-step design methodology nor can this Manual address every situation, which may arise. The application of sound engineering/surveying principles and judgment combined with the information contained herein are necessary to complete the planning, design, and preparation of related construction documents for stormwater, sanitary sewer, and/or wastewater projects.

Approval of plans by MSD shall not relieve the designer or developer from required compliance with the provisions of this manual unless a written variance is received from MSD.

1.3 STRUCTURE OF THE MSD DESIGN MANUAL

The Manual contains 18 chapters. A general table of contents is found at the beginning of the Manual. To facilitate use of the Manual, a detailed table of contents can be found at the beginning of each chapter for text and exhibits.

The Manual is structured as follows:

a. Chapters 2 and 3 describe MSD's general planning and design approach, required submittals and approval procedures.

b. Chapters 4 through 7 detail MSD standards regarding drafting (manual and computer-aided), construction drawings, record drawings, surveying and easement documents.

c. Chapters 8 through 14 relate to the specific design of sanitary sewers, stormwater systems, erosion control structures, native revegetation, and tree preservation.

d. Chapters 15 and 18 relate to small pump stations, small wastewater treatment plants, odor control, and geotechnical procedures.

1.4 MSD Web Page

The MSD Web Page can be accessed at http://www.msdlouky.org. **The Design Manual is available under the "Reports and Documents" → "Design and Construction Documents" path.**

MSD **no longer distributes hardcopy versions of the manual. Printable PDF versions of the respective chapters are available for download.**

1.5 UPDATES TO THE MSD DESIGN MANUAL

The Manual is intended to be a dynamic document. As design criteria and technology evolve, the Manual will require revisions and improvements. As changes are made, **updates will be posted to the website version. MSD no longer maintains a registered holder list where updates are mailed to manual owners.** . It will be **the designer's** responsibility to **stay updated on the manual.**.

Comments and suggestions concerning the content and format are welcomed from the users of the Manual. Exhibit 1-1 may be used for this purpose.

MSD DESIGN MANUAL
COMMENT FORM

FROM: Name: ______________________________ Date: __________

Company: ______________________________

Street: ______________________________

City: ______________ State: ______ Zip: __________

The Louisville and Jefferson County Metropolitan Sewer District is most interested in your comments regarding this MSD Design Manual. Please indicate your responses below and return this form to us.

1. List any specific errors detected (with page numbers): ______________________________

2. List any recommended revisions for future editions: ______________________________

3. List any general comments: ______________________________

Return to: Louisville and Jefferson County
Metropolitan Sewer District
700 West Liberty Street
Louisville, KY 40203–1911
Attn: Design Manual Comments

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GENERAL INFORMATION

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CHAPTER 2
GENERAL INFORMATION

2.1 PURPOSE

This chapter:

a. Provides an overview of the Louisville and Jefferson County Metropolitan Sewer District's planning and design approach relating to sanitary and stormwater sewers and their appurtenant facilities.

b. Defines MSD's process for submittal, review and approval of construction documents for sanitary sewer facilities and stormwater facilities.

c. Provides information relating to area utility and public works agency coordination.

d. Provides direction relating to the preparation of opinions of capital, operation, and maintenance costs.

2.2 DESIGN APPROACH

Proposed construction or expansion of sanitary sewer or stormwater facilities within Jefferson County shall be in compliance with MSD's approved countywide 201 Facilities Plan, **approved** action plans, the Sanitary and the Stormwater Drainage Master Plan, **MSD's Wastewater/Stormwater Discharge Regulations**, and guidelines defined in the MSD Design Manual. Additionally, plan development will need to conform to the Louisville and Jefferson County Erosion Prevention and Sediment Control (EPSC) and Floodplain Ordinances and the **other applicable land use planning documents**. Any person, company, corporation, or other entity proposing to develop land or to install new or replacement sanitary sewer or stormwater facilities in Jefferson County must prepare planning and design documents in accordance with the standards and requirements of this Manual for review and approval by MSD. Planning and Construction Documents must be prepared and signed by both a Professional Engineer and Land Surveyor, currently licensed in the Commonwealth of Kentucky. The service level of proposed facilities should be in accordance with standards referenced in these documents. Design standards shall also be those referenced herein.

2.3 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit to MSD for their review and approval, a concept plan and design documents as specified in subsequent chapters of this Manual. Design documents may include, but are not limited to, calculations, plans and specifications. Approval by MSD will be required prior to authorization of any succeeding phase.

Submittal of concept plans shall be prepared in report format (8.5” x 11”) and shall be spiral bound, three-ring bound or bound in some other permanent manner. Appended to or included in the submittals shall be maps, figures, and drawings as necessary.

2.4 SUBMITTAL REVIEW AND APPROVAL

The design of new sanitary sewer facilities or an expansion to existing facilities in Jefferson County, whether privately owned or MSD-owned, requires the approval of:

a. MSD
b. Kentucky Division of Water
c. **Louisville-**Jefferson County Health Department

The design of new stormwater facilities or an expansion to existing facilities in Jefferson County, that will become a part of or impact the MSD stormwater infrastructure or other public entity, requires the approval of MSD. Construction within blue-line streams and regulatory floodplains also requires the approval of and permit by the Kentucky Division of Water. The U.S. Army Corps of Engineers approval may also be required. Work within federal and state highway rights-of-way requires approval and/or a permit by the Kentucky Transportation Cabinet. Cities not within the MSD service area are to be informed of improvements by MSD.

Sanitary sewer and stormwater facilities shall be designed according to the appropriate sections of this Manual. Construction documents (plans and specifications) shall be reviewed by MSD prior to submittal to other review agencies.

2.5 UTILITIES/AGENCIES COORDINATION

The Design Engineer shall coordinate the design of all sanitary sewers and of all stormwater facilities improvements with all utilities and/or appropriate public works agencies actively involved in the provision of service in Jefferson County. Contact shall be made with such agencies and preliminary plans provided no later than the initial design submittal to MSD. MSD should be given a copy of all correspondence with utilities and public works agencies. A listing of contact persons, their respective agencies, and the number of plan sets required is included in Exhibit 2-1.

2.6 OPINIONS OF COST

Opinions of probable cost shall be based on the best professional judgement of the Design Engineer. The Design Engineer should use recent bid tabulations, and information from suppliers and contractors in formulating opinions of cost.

Opinions of capital cost shall be in the Construction Specification Institute (CSI) format and shall be grouped by category. Opinions of capital cost should include a construction contingency, allocations for planning and design, and a cost for necessary land, easement, or right-of-way acquisition. The amount or percentage of these contingencies and allocations are dependent upon project specifics and the stage of project development. Opinions of operation and maintenance cost shall include costs for labor, utilities, maintenance and repair.

2.7 PERMIT REQUIREMENTS

A summary of requirements for permits is shown as Exhibit 2-2. The Exhibit contains individual lists for drainage projects, pump station/structural projects, and pipeline projects. The list should not be considered all-inclusive, and the designer will need to confirm all permit requirements as a part of the preliminary scope of the project. The following is a brief summary and the applicability of the three major permits that impact projects in the MSD service area.

a. **Section 404 - Nationwide Permit No. 12 of 33 CFR Part 330** from the U.S. Army Corps of Engineers. Conditions of this permit may require Item b. A permit is required for discharges of soil, sand, gravel or dredged material into a blueline stream if the Average Annual Flow of the stream is greater than 5 CFS. In Jefferson County, this usually requires a drainage area of about 3.5 acres but Design Engineers must inquire from the U.S. Army Corps of Engineers if a certain stream requires this permit.

b. **Section 401 - Application for Water Quality Certification** from the Commonwealth of Kentucky, Natural Resources & Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Water Quality Branch. This application is required when more than 200 lineal feet of blueline stream is impacted.

c. **Application for Permit to Construct Across or Along a Stream** from the Commonwealth of Kentucky, Natural Resources & Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Floodplain Management Section - Water Resources Branch. This application is required if the drainage area for the impacted stream is one square mile or greater.

Electrical Service Department
Louisville Gas & Electric Company
820 West Broadway
Louisville, KY 40202
Phone: 627-3162
FAX: 627-2650
2 sets

Gas Department
Louisville Gas & Electric Company
820 West Broadway
Louisville, KY 40202
Phone: 627-3019
FAX: 627-3789
2 sets

ATT
3719 Barddstown Rd.
Louisville, KY 40218
Phone: 454-9854
Fax: 454-2320
2 sets

Relocations Process Owner
Louisville Water Company
550 South Third Street
Louisville, KY 40202
Phone: 569-3600
2 sets

Louisville - Metro Department of Public Works
444 S. Fifth Street suite 400
Louisville, KY 40202
Phone: 574-5810
2 sets

Texas Gas Transmission Corp.
10327 Gas Light Way
Louisville, KY 40299
Phone: 491-0251
FAX: 491-0251
(call prior to transmitting)
2 sets

Insight Communications
11505 Electron Drive
Louisville, KY 40299
Phone: 357-4376
2 sets

Kentucky Transportation Cabinet
District 5
8310 Westport Road
Louisville, KY 40202
Phone: 210-5400
FAX: 210-5494
2 sets

Jefferson County Public Schools
P.O. Box 34020
Louisville, KY 40232-4020
Phone: 473-3011
FAX: 473-3976
2 sets

MSD Stormwater Department or
Planning Department (Sanitary)
700 West Liberty Street
Louisville, KY 40203-1913

REQUIRED PERMITS FOR DRAINAGE PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a Stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream, in a floodplain, or when impounding water.
		2. Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	Kentucky Division of Water	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Necessary only at the direction of Corps of Engineers.
		4. Stormwater Discharge Permit	Application/ **NOI (Notice of Intent)**	Kentucky Division of Water	For all projects disturbing >**1 acre**
		5. Water withdrawal Permit	Application/ Letter	Kentucky Division of Water	When necessary to withdraw more than 10,000 gpd of water from a blueline stream
		6. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		7. Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: To be submitted at 80% design stage.
		8. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		9. Building Permit for Temporary Office	Site Plan	Louisville Metro – Code Enforcement or City of Louisville Public Works	For any temporary office/trailer.
		10. Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic.
		11. Planning Commission Approval	Site Plan(s)	Louisville Metro – Planning Commission	For all projects.
		12. MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects.
		13. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept of Public Works	For any project which requires obstruction of a roadway.
		14. Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and Corps of Engineers	When encroaching on the floodwall right-of-way.

MSD
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Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 2-2
REQUIRED PERMITS

EFFECTIVE DATE: JUNE 30, 2009

REQUIRED PERMITS FOR PUMP STATION/STRUCTURES PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a Stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream, in a floodplain, or when impounding water.
		2. Section 404 – Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401, Clean Water Act – Water Quality Certification	Application / Erosion Control Plans	Kentucky Division of Water	Any activity that requires a Section 404 permit from the Army Corps of Engineers will require a Water Quality Certification from the DOW, if a total of 200 linear feet of impact is proposed.
		4. Water Withdrawal Permit	Application/Letter	Kentucky Div. of Water	
		5. Temporary Discharge Permit	Letter detailing source, treatment analysis, location of discharge	Kentucky Division of Water	For WTP Eliminations, UST dewatering, pump tests, etc.
		6. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		7. Encroachment Permit	Application	Louisville Metro – Dept. of Public Works	When encroaching on county right-of-way: To be submitted at 80% design stage.
		8. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		9. Building Permit for Temporary Office	Site Plan	Louisville Metro – Dept. of Public Works	For any temporary office/trailer.
		10. Lane Closure Permit	Application	Louisville Metro – Dept. of Public Works	When necessary to close lanes of traffic.
		11. Health Dept. Approval	Plans	Louisville / Jefferson Co. Health Department	For all projects.
		12. Planning Commission Approval	Site Plan(s)	Louisville / Jefferson Co. Planning Com.	For all projects.
		13. MSD Water Management Approval	Plans/Plan Review Application	MSD	Reviewed internally for all projects.
		14. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept. of Public Works	For any project which requires obstruction of a roadway.
		15. Building Permit	Application/Plan/ Specs	Louisville Metro - Code Enforcement Board	Necessary for all pump stations and waste treatment plants.
		16. Certificate of Occupancy	Plans/Specs	Louisville Metro - Code Enforcement Board	For any project with a building.
		17. Community Facilities Review	Plans/Letter	Louisville Metro Planning Commission	For waste treatment plants.
		18. Air Contaminant Source Permit	Application and Location/Details	Air Pollution Control District	For any fuel tanks.
		19. Fire Marshall Approval	Site Plan(s)	State Fire Marshall	For any enclosed buildings.

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REQUIRED PERMITS FOR PIPELINE PROJECTS

SUBMITTED	APPROVED	PERMIT	REQUIRED SUBMITTALS	AGENCY	WHEN REQUIRED
		1. Construction Along a stream	Application, HEC2 analysis or floodplain verification	Kentucky Division of Water	For any construction along or across a blueline stream or in a floodplain.
		2. Section 404 - Nationwide Permit No. 12 of 33 CFR Part 330	Letter and Locations of Crossings	Corps of Engineers	For discharges of soil, sand, gravel or dredged material into a blueline stream. Also when constructing on a stream with a flow >= 5 cfs. May require DOW Water Quality Certification.
		3. Section 401 – Clean Water Act, Water Quality Certification	Application/ Erosion Control Plans	Kentucky Division of Water	When impacting more than 200 linear feet of a regulated stream and/or; impacting one acre or more of regulated wetlands area. Necessary only at the direction of Corps of Engineers.
		4. Storm water Discharge Permit	Application/ Site Plan(s)	Kentucky Division of Water	For all projects
		5. Water Withdrawal Permit	Application/Letter	Kentucky Division of Water	When necessary to withdraw more than 10,000 GPD of water from a blueline stream.
		6. Temporary Discharge Permit	Letter detailing source, treatment, analysis, location of discharge	Kentucky Division of Water	For WTP eliminations, UST dewatering, pump tests, etc.
		7. Construction Permit	Plans/Specs	Kentucky Division of Water	For all projects
		8. Encroachment Permit	Application	Kentucky Transportation Cabinet	When encroaching on state right-of-way: to be submitted at 80% design stage.
		9. Encroachment Permit	Application	Louisville Metro – Dept of Public Works	When encroaching on county right-of-way.
		10. Encroachment Permit	Application	Appropriate city	When encroaching on city right-of-way.
		11. Building Permit for Temporary Office	Site Plan	Louisville Metro - Code Enforcement Board	For any temporary office/trailer.
		12. Parking Meter Permit	Application	Louisville Metro	When necessary to remove meters from service
		13. Lane Closure Permit	Application	Louisville Metro	When necessary to close lanes of traffic.
		14. Health Dept. Approval	Plans	Louisville / Jefferson Co. Health Dept.	For all projects
		15. Traffic Control Plan Approval	Plans/Plan Review Application	Louisville Metro – Dept of Public Works	For any project which requires obstruction of a roadway.
		16. Floodwall Encroachment Permit	Application/Plans	MSD Infrastructure Dept. and Corps of Engineers	When encroaching on the floodwall right-of-way.

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GENERAL PLANNING INFORMATION

CHAPTER 3
GENERAL PLANNING INFORMATION

3.1 PURPOSE

This chapter:

a. Documents Louisville and Jefferson County Metropolitan Sewer District's philosophy for a regional (watershed) approach for the provision of sanitary sewer and stormwater service in the MSD service area.

b. Identifies the sources of planning and design information for development of sanitary sewer and stormwater drainage infrastructure in the MSD service area.

c. Identifies the goals of the Facilities Plan, Area Action Plans and the Stormwater Drainage Master Plan.

3.2 PLANNING APPROACH

MSD's regional approach for the planning, design, construction, operation and maintenance of sanitary sewer and stormwater facilities is structured to ensure a level of service that protects the general health, safety, and welfare of the citizens of the MSD service area. This approach will also further MSD's efforts to satisfy local, state and federal regulations as they relate to water quality.

MSD's 201 Facilities Plan and approved Area Action Plans provide the framework for planning and design of sanitary sewer facilities in the MSD service area. The Sanitary Master Plan, the Stormwater Drainage Master Plan, **MSD's Wastewater and Stormwater Discharge Regulations,** and the Watershed Master Plan provide the required technical information necessary for the regional planning and design of sanitary and stormwater facilities in the MSD service area. The Design Engineer should use these documents for planning and as reference documents for the development of sanitary and stormwater facilities in the respective MSD service areas.

3.3 FACILITIES PLAN/AREA ACTION PLANS (SANITARY)

The original master plan prepared for MSD for sewering portions of Jefferson County, Kentucky outside the City of Louisville dates back to 1964. In 1973 and 1974, updates of that plan and the area's 201 Facilities Plan were prepared to conform to the requirements of the Federal Water Pollution Control Act Amendments of 1972. The 201 Facilities Plan was deemed by EPA to be substantially complete in May 1975. The 201 Facilities Plan designated MSD as the local agency to implement the approved program, which became known as the Master Plan Expansion Program.

The goal of the Master Plan Expansion Program was to provide the best solutions, both cost-effectively and environmentally, to the problems of wastewater collection and treatment in Jefferson County. The Master Plan Expansion Program covers a 300-square mile portion of Jefferson County.

Since the 201 Facilities Plan was approved, MSD has initiated and completed the development of the watershed area action plans to address the problems in areas without sanitary sewer service and to facilitate growth in the MSD service area. Action plans are considered to be updates to the 201 Facilities Plan. **The MSD/OCSD Regional Wastewater Facilities Plan 2000 – 2020, dated January 2002 now overrides the original North County Action Plan, dated February 1987.** A list of the remaining area action plans and the date they were adopted by the MSD Board is as follows:

Action Plan	Adopted
Upper Pond Creek	November 1989 (Updated 1998)
Cedar Creek	May 1990 **(Updated July 2000)**
Mill Creek	May 1993
Floyds Fork	July 1993
Regional WCWTP	**Updated March 2002**

3.4 STORMWATER DRAINAGE MASTER PLAN

In order to improve and enhance stormwater drainage services to the City of Louisville and Jefferson County, Agreements of Interlocal Cooperation between MSD, the City of Louisville, and Jefferson County were signed to clearly identify MSD as the responsible agency for providing flood and stormwater services. These agreements became effective January 1, 1987, and supplemented where needed, the powers MSD already possessed pursuant to the Kentucky Revised Statutes, Chapter 76. To facilitate this transition and provide regional guidelines for management of the overall program, the Stormwater Drainage Master Plan (SWDMP) was prepared.

The goal of the SWDMP is to provide a regional approach to develop a consistent level of drainage service and maintain or improve water quality across the County. The Watershed Plan Report of the SWDMP includes the technical information and recommendations to manage the 11 designated watersheds both area-wide and on a local level to meet this goal.

3.5 REGIONAL FACILITIES

In June of 1996 the MSD Board adopted a revised policy for regional wastewater and stormwater facilities serving more than a single development. MSD realized that in some cases regional facilities are more appropriate, cost effective, and assure proper operation and maintenance compared to on-site detention facilities.

The requirement to build or participate in the cost of regional facilities shall be determined concurrently with the review by MSD of the developer's proposed development plans and by an analysis of the development's impact on the general community. This impact includes watershed, other development, existing service facilities, and its conformance with MSD's master plans.

3.6 FLOODPLAIN ORDINANCE

With the issuance of **Louisville Metro's** Floodplain Ordinance, it is important that before planning/design begins on any lot with possible floodplain or minimum opening impacts, the builder must obtain a determination from MSD on the need for a floodplain permit and clarification on exactly what restrictions apply. Construction in the local regulatory floodplain without a valid permit is a violation of the ordinance and is subject to possible fines. Per the ordinance, **"No Development"** is permitted in the local conveyance zone. The conveyance zone is further defined in Section 10.4.

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CHAPTER 4
CADD STANDARDS

4.1 GENERAL

MSD has adopted CADD standards to provide consistency with respect to plan and document development and for compatibility with respect to the sharing of data and document storage. MSD operates in the AutoCAD environment. Emphasis has been placed on developing standards that are in line with current industry procedures, but can be easily adapted to change with industry advancements.

Development plans for sanitary sewer and stormwater construction shall be prepared in a neat and professional manner **and shall conform to the standards detailed in this chapter.** It is very important that information be presented in such a manner that it will be legible when the plans are scanned, reproduced, or reduced. The following section presents the standards that shall be adhered to on all MSD and Private Development plans. **Private Development Plans, with the exception of lateral extensions, do not have to comply with the final plan submittal requirements of section 4.2.2.** The standard **Layer Names, Colors, Text Heights,** Line Weights, Standard Symbols, and Standard Abbreviations are shown in **Exhibits 4-1 through 4-7** at the end of this chapter**, and will be available on MSD's website at some point in the future.**

It should be noted that the sample sheets shown in Exhibits 4-8 thru 4-17 have not been updated to incorporate the new standards. This will be done in conjunction with making the drawing template, standards and exhibits available in digital form on MSD's website. As previously mentioned, this will be done at some point in the future.

4.2 CADD Structure

4.2.1 CADD Environment

<u>**General**</u>

- **The electronic files will be shared and referenced by many different individuals. Therefore, this chapter outlines the minimum standards, conventions, and formats necessary to ensure a usable electronic file data set to all users.**

- **It must be stressed that while the CADD Standards are to be applied to the deliverable files for design plans, they should not be used to restrict the user's options or workflows during plan development. Interim drawings for public meetings, reviews, etc. may deviate from**

the suggested workflows and standards if needed for particular display or presentation requirements.

- **All drawings shall be in AutoCAD format, compatible with the current version that MSD is running. The project manager should check with MSD for version information before any CADD work begins.**

- **In addition to hard copy drawings, , all final drawings are to be submitted in digital format per the requirements of this chapter.**

- **Model space shall be used for all drafting. Paper space shall be used for borders, viewports, and plotting. Modelspace contains the model at "real life" size. Printing is from paperspace at 1:1 scale for full-size prints**.

Scales

The appropriate scales for original plans are 1" = 50' horizontal with vertical scale of 1" = 5' and 1" = 20' horizontal with vertical scale of 1" = 2'. Other scales may be allowed with prior approval of MSD for the purpose of clarity. A graphic scale is required. In addition, crossings of state highways may require additional sheets at differenct scales. Coordination between MSD project manager and KYTC – District 5 will be necessary.

AutoCAD **Template File**

An AutoCad template will be created to incorporate the standards as described in this chapter. This file will contain the standard layers, linetypes, fonts, symbols (blocks), and sheets and can be downloaded from the MSD website at some point in the future.

Standard Layers and Line Types

The standard MSD layers are presented in Exhibit 4-1. All drawing elements shall be placed on one of these layers. The color and line style attributes for all drawing elements shall be set to "By Layer". **Custom Linestyles are also shown in exhibit 4-1.**

Standard Symbols

The standard symbols presented in Exhibit 4-3. These symbols will be pre-loaded as blocks in the future MSD standard template file.

Standard Sheets

The standard sheet size is 24" x 36" for all sanitary and stormwater projects. The sheets are presented in Exhibit 4-4 and will also be pre-loaded as blocks into the future MSD standard template file.

Pen Size Assignments

The chart in exhibit 4-5 shows the relationship between colors and pen sizes (weights). The corresponding ctb file will be made available through MSD's website at some point in the future.

Screening

For screening options - See Exhibit 4-4. The intent is for existing features (topography) to be screened.

Text Fonts, Sizes, and Weights

All fonts, sizes, and weights will be preset attributes in the future MSD template drawing file. The standard font style on MSD projects is "simplex.shx".

The text heights used are synonymous with the Leroy Scale of hand drafting. The following chart shows the height for each text style used. In general, Upper and Lower Case shall be used to denote existing text and UPPER case shall be used to denote proposed text.

TEXT STYLE	HEIGHT (inches)	Notes
L60	0.06	For existing text on plats where space is limited. (Upper & Lower Case)
L80	0.08	All existing text. (Upper & Lower Case)
L100	0.10	For Proposed Item Annotation where space is limited (UPPER CASE)
L120	0.12	For Proposed Item Annotation / Construction Notes. (UPPER CASE)

L140	**0.14**	**For Note Titles & Other Misc. Labels (UPPER CASE)**
L175	**0.175**	**Misc. Titles / Labels (UPPER CASE)**
L200	**0.20**	**Misc. Titles / Labels (UPPER CASE)**

4.2.2 Submittal of Final Plans

General

- **Every sheet in the final plan set shall have a corresponding AutoCAD file. That is, one AutoCAD file per plan sheet. A one to one relationship between the design file content and the plotted sheets shall be maintained.**

- **No external references shall be allowed for the final submittal. Paper space shall be used to represent the actual sheet at a 1:1 scale. All sanitary and storm projects performed for MSD shall be submitted digitally per the requirements of section 4.2.1.**

- **All mapping features and all design features in plan view located in model space of the CAD drawings shall maintain their true coordinate location values. Please reference Chapter 6, "Surveying" for additional details on coordinate systems. Detail sheets do not have to be shown in true coordinate location.**

- **A one-to-one relationship between the design file content and the plotted sheets shall be maintained. i.e., there is no "hidden" information that is turned "off" or "frozen" to make the final plot.**

- **The AutoCad files are submitted as a supplemental deliverable to the stamped and signed mylars, to be used at MSD's discretion.**

- **An AutoCAD (dwg) version of each sheet is submitted per the requirements of this section. The stamped and signed mylars take precedence over the CAD files should any discrepancies airse between the CAD file and the mylars.**

File Naming

At the completion of the plans, the CADD files are to be delivered with the following naming sequence:

AAAAA-SBBB.dwg

where:

AAAAA = Record Number

BBB = sheet number. Use zeroes as necessary.

The "S" stands for sheet(s) and it is not to be changed.

Example: The digital AutoCAD file for Sheet 47 of Drawing Record Number 12345 would be named as follows: 12345_S047.dwg

The files shall be stored in a parent folder named for the Record Number and name of the project and be delivered to MSD on a CD or DVD media format.

A final set of plans shall be printed on 24"x36" paper. This set of plans shall be stamped, signed and dated by the professional engineer of record.

4.3 STANDARD AND TYPICAL DRAWINGS

4.3.1 Definitions

a. Standard Drawings – Details issued by MSD that indicate the acceptable procedure, dimensions, or timetable for a particular facet of construction. The details are not to be modified and can be made a part of the plan set by referencing the respective drawing number on the front Title Sheet. The Standard Drawings are not included in this Design Manual**, but can be found on the MSD webpage under the "Inside MSD" link.** If changes are made to a particular Standard Drawing, the detail ceases to be a Standard Drawing and becomes a Special Detail. The Special Detail will then need to conform to the requirements of Section 4.3.6.

b. Special Details – There are numerous exhibits and design aids found in other chapters of this manual. The details will vary from project to project. Use of the details is encouraged; however, the detail, in its final form, will need to conform to the requirements of Section 4.3.6.

c. Typical Drawings – Examples of typical sheets illustrating the format and information required on MSD contract plans are provided as reference. The respective sheets and exhibit numbers are listed below.

Exhibit	Title
4-8	Sample Title Sheet
4-9	Sample Plan Index Sheet
4-10	Sample Drainage Map (Sanitary Collector System)
4-11	Sample Drainage Map (Storm Collector System)
4-12	Sample Horizontal and Vertical Control Map
4-13	Sample Plan Sheet
4-14	Sample Profile Sheet
4-15	Sample Cross Section Sheet
4-16	Sample Property Acquisition Summary Sheet
4-17	Sample Apportionment Map

4.3.2 Title Sheet Requirements

A MSD Sample Title Sheet can be found on Exhibit 4-7. For each MSD project, t**he title sheet shall have at least the minimum information listed on it:**

a. Contract No., Budget ID No. and Record No.

b. Name of Project -

c. Index of Drawings -

d. Name and Address of Engineer -

e. Design Segment Designation (where applicable)

f. Sheet____of____

g. For sanitary interceptor and major storm sewer contracts, the proposed sewers for which the plans are drawn shall be shown.. The stations at the extremities of the project shall be shown and identified with leaders and arrows. For example: BEGIN PROJECT MC-1, STA. 5+42.00 and END PROJECT MC-1, STA. 10+51.03.

h. To notify the Contractor of the procedure required for the location of utilities prior to construction, the following note should be placed on the Title Sheet.

"**NOTE: CAUTION EXISTING UTILITIES**"
"THE INFORMATION SHOWN ON THESE DRAWINGS CONCERNING TYPE AND LOCATION OF UNDERGROUND UTILITIES IS NOT GUARANTEED TO BE ACCURATE OR ALL-INCLUSIVE. LOCATION, SIZE, AND MATERIAL SHOWN ON UTILITIES ARE FROM AVAILABLE RECORDS SUPPLIED BY THE RESPECTIVE UTILITY COMPANY. Kentucky 811-Before You Dig (BUD) MUST BE NOTIFIED 2 BUSINESS DAYS PRIOR TO ANY EXCAVATION FOR VERIFICATION OF LOCATION, SIZE AND MATERIAL, Dial 811 or 1-800-752-6007.

i. Other Agency's Standard Drawings pertaining to project (MSD & KYTC) with standard drawing number and description.

j. Revision Block with date & comments

4.3.3 Title Block Requirements

All sheets included in the plans, except the Title Sheet and the MSD Standard Drawings, shall contain a title block, which conforms to the sample shown in the **Exhibit 4-7.**. Information in the Title Block should include the project title indicating sanitary or drainage plans, what type of sheet, and the specific information on the sheet.

4.3.4 Plan Index Sheet Requirements

A Plan Index Sheet shall be prepared to identify the location of the work shown on each Plan Sheet. A Sample Plan Index Sheet is shown on Exhibit 4-8. The Plan Index Sheet shall include a reference to the location of the profile for the sewer lines on each plan sheet if the profile is on a separate sheet. For most projects, the Plan Index Sheet may be shown on the Project Map, which is located on the Title Sheet.

4.3.5 Apportionment Map Requirements

An Apportionment Map shall be prepared for Guaranteed Maximum Assessment apportionment (sanitary collector sewer) projects at a minimum scale of 1" = 100' on a standard size plan sheet. Exhibit 4-16 shows a Sample Apportionment Map. The information shall include, but not be limited to, the following:

a. County Tax Block and Lot Number

b. Property Lines and Dimensions

c. Address of Property

d. Street Names

e. Sewer Sizes

f. Approval and Title Block

g. North Arrow

h. Record Number followed by Letters AM (11732AM)

Those Design Engineers who have sanitary collection system contracts, which contain property that is to be served by a sanitary interceptor, shall include that property on their Apportionment Maps. The property served by the interceptor will be assessed on the collector system.

4.3.6 Special Details

The Design Engineer should show any proposed construction that is not covered by the MSD Standard Drawings as a detail on a Special Detail sheet. The detail should clearly and accurately depict the proposed construction Junction chambers, special pipe bedding, railroad crossings, pump stations, select erosion control measures, and modifications to MSD Standard Drawings are typical examples of items that may require a Special Detail.

Pump station generic details that shall be modified for each project are shown as exhibits in Chapter 15.

4.3.7 Drawing Number Convention (Projects using Multiple Disciplines)

The drawing number shall consist of two parts: The 1st part is the letter corresponding to the discipline. The second part is the numerical page number in that subset.

<u>List of Disciplines</u>
General (G)
Civil/Site (C)
Process (D)
Structure (S)
Architectural (A)
Mechanical/HVAC (M)
Electrical (E)
Instrumentation & Control (I)

Examples: G-1, G-2, S-1, S-2, etc.

4.4 PLAN, PROFILE, AND CROSS-SECTION FORMAT

4.4.1 General Criteria

The plan view of proposed sewer or drainage construction generally should be shown on the same sheet as the profile with the plan view located at the bottom of the sheet and the profile at the top. Samples of the plan and profile sheets can be found in Exhibits 4-12 and 4-13. However, if drafting efficiency can be achieved, the plan view may be shown on a separate sheet from the profile. In this case, the plan sheet and profile sheets shall be cross-referenced. The entire profile for each line shall be shown on one sheet when possible. A profile sheet with profiles for more than one plan sheet can be accepted. Profiles shown on sheets separate from the plan views should follow the plan views in a logical order. The information, which appears, on both the plan and profile views shall, at the minimum, include:

a. The location of all proposed manholes, cleanouts, inlets, catch basins and all associated stations shall be shown.

b. House numbers for all residences and businesses shall be shown and drawn parallel with the streets in the plan view.

c. All existing pipes, culverts and appurtenances shall be hatched.

d. The sizes,locations, and invert elevations, if applicable, of the following items shall be shown:

- Stubs
- Drop Inlets
- Stacks
- Borings and Soundings
- Catch Basin Inlets
- Downspout Connections
- Property Service Connections

e. All existing pipes, culverts, conduits, and utilities of any nature, crossing the proposed improvement location, shall be plotted and labeled in the plan and profile.

f. A beginning and ending contract note and station shall be shown on the Title Sheet and in the plans for all interceptor sewers, major through channels and major storm sewers.

g. **Match lines shall be used for transitioning coverage from one sheet to the next.** A cross-reference shall be shown on each sheet to identify the location of the attendant profile or plan sheet

h. **No overlap of plan coverage from one sheet to the next is permitted.** Match lines are **to be used** in plan view with proper referencing station and attendant sheet number.

i. Title Blocks are required for all sheets except cross-sections. Cross-section information to be used should be similar to that shown in Exhibit 4-14.

j. One-hundred-foot stations shall be shown.

k. Plan sheets must include a north arrow.

4.4.2 Plan View

In addition to those items listed in Section 4.5.1, the information to appear in the plan view shall include, but not be limited to, the following:

a. Locations of future connections (PSC, stubs, etc.).

b. The delta angle of all PI's, except where more than one line intersects at the same manhole or inlet. In those instances, the angles relating all lines shall be shown. When the delta angle is shown, its direction shall be noted (left or right), as the stations increase. All angles shall be shown to the nearest second.

c. The location of the centerline shall be referenced by dimensions to the easement lines and to the appropriate property lines.

d. When it is necessary to orient the alignment to a general locality, indicate the name and direction of the nearest street intersection with a distance to that intersection.

e. Bench marks shall be accurately plotted and labeled on the plans. A description and location of each bench mark, including its station and offset relative to the proposed line, shall be plotted and labeled. When bench marks cannot be plotted with the plan coverage, their location and description should still be shown on the plans where it would have appeared.

f. The precise location of all soundings and borings.

g. Houses, fences and drives shall be shown for a minimum of 50 feet beyond the right-of-way or to the fronts of the houses for lines located in the street or rights-of-way. Trees, steps, walks and other topographic features shall be shown to the extent that they may be pertinent to the improvement location or construction. These items must be field located. LOJIC mapping may be used outside critical areas to supplement the base topography. Trees shall be shown with a designation of size and type **with the dripline depicted graphically**.

h. Property lines, lot lines, easement lines and other boundary lines shall be shown a minimum of 75 feet beyond any proposed or existing right-of-way. In instances where additional information might be required, the limit shall be extended.

i. Property Service Connection symbols for sanitary sewers, as shown in Exhibit 4-2, shall be shown near the lot line where service is expected to be required. For consistency, the symbol should be shown approximately 20 feet behind the property line. If a specific location for the connection needs to be shown, an arrow shall be added to the symbol indicating the desired location of service and a note shall be shown in the area indicating the station of the proposed Property Service Connection.

j. Generally, only the outside lines of a pipe shall be shown on the plans. However, a thin centerline shall be shown within these outside lines where any of the following conditions exist:

1. A distance is shown from a point or line to the centerline of the pipe.

2. The delta angle is shown.

3. The angle of intersection is shown.

Pipes larger than 24 inches in diameter should be drawn to scale to depict the true impact limits.

k. Existing ditches with a bottom width of 4 feet or less should be drawn using the centerline of the ditch. If the ditches and channels have a bottom width greater than 4 feet, each side of the ditch should be drawn and its width be noted. Where ditch paving exists, the width of the paved area shall be shown.

l. Existing and proposed sewers, their direction of flow, size, and MSD Record Number shall be shown. The Deed Book and Page Number shall be shown for existing Sewer or Drainage Easements, which are impacted by sewer construction.

m. All water lines, gas lines, oil lines, electric and telephone conduits, fiber optic cables, and any other underground or overhead utilities shall be shown with the size or primary voltage and ownership identified.

n. All existing or proposed sewers, manholes and catch basins.

o. When sanitary sewers are to be in existing streets, the front dimension and bearing, if possible, of each lot shall be shown. When sanitary sewers are to be placed in easements or rights-of-way, property line dimensions adjacent to the proposed sewer construction shall be shown.

p. Highways, street names, alleys, or major streams and ditches shall be shown. The width and type of all surfaces shall be indicated.

q. Street right-of-way widths shall be shown adjacent to and after the street name. For example: ROBIN ROAD (50' R/W) or ROBIN ROAD (R/W varies) - if the width is not uniform.

r. The name of **all baselines** shall be shown. The pipe size and direction of flow shall be noted **on all pipes**, above the pipe and between all manholes.

s. The general notes and a legend of the standard symbols used throughout the plans shall be shown on the Plan Index Sheet or on the first plan sheet if the plan index is shown on the Title Sheet.

t. Stations shall be shown above each 100-foot station on 50-scale and 20-scale plans and above each 500-foot station on 100-scale plans. For example: 1+00, 5+00, etc. All horizontal curve data shall be shown on the plans, if applicable.

u. The phrase, "Do Not Disturb", shall be used to indicate existing conditions or facilities, which are to remain in place during construction. The phrase or abbreviation, "DND", shall be shown adjacent to all such items on the plans. If used, "DND" must be shown and defined in the legend. Likewise "DNR", "Do Not Remove", may be used to indicate existing conditions or facilities which are to remain in place during construction but which some level of disturbance is anticipated. The size and type of items, which are within the construction area, must be clearly identified. This information is critical to assist in the easement acquisition process.

v. The resurfacing limits will be shown for all projects receiving final resurfacing.

w. Where applicable, add the following: storm sewer pipe and PSC charts

4.4.3 Profile View

In addition to those items listed in Section 4.4.1, the information to appear in the profile view shall include the following as a minimum:

a. Stations and grid elevations shall be shown. . The grid shall be set up on a 2-inch square basis. The vertical scale for 50-scale plans shall be 1" = 5' and for 20-scale plans shall be 1" = 2'.

b. The limits, by station, shall be shown for all concrete caps, cradles and encasements, tunnels, and bored segments.

c. When a line located in an easement crosses a public right-of-way, the limits of that right-of-way, including its width, shall be shown.

d. Information relative to whether the line will be constructed in an easement, right-of-way, or existing MSD property shall be shown. directly above the profile grid.

e. The type of backfill used, when not identified in the general notes, shall be placed directly above the profile grid with a leader and arrow defining the limits of each type of backfill.

f. The ASTM or AASHTO designation (whichever applies) and pipe classification shall be shown below the pipe profile if different from the designation and classification shown in the General Notes or Standard Specifications.

g. The pipe size, grade, and distance between the centerline if the manholes shall be indicated between all manholes. This information shall be parallel to and shown above smaller pipes; however, on pipes of sufficient diameter, this information should be placed inside the pipe. Grades shall be shown as a percent, i.e., 0.50%.

h. Invert elevations shall be shown to the nearest hundredth of a foot and at the following locations:

   1. All breaks in the grade.

   2. Breaks necessary for profile continuation onto another sheet.

   3. Centerline of standard manholes with continuous grade.

4. Other conduits critical to the pipe gradient.

5. Intersecting pipe.

6. All locations necessary to substantiate the profile grade.

7. Both pipe invert edges when there is a drop or slant inlet.

8. Other conditions shown on the typical drawings.

9. Each catch basin or surface inlet connection.

10. Labeled similar to: IE 479.48.

i. Manholes shall be indentified by station, line and manhole number. Proposed manhole rim elevations shall be shown to the nearest tenth (Rim El. 424.9±) in earth areas and to the nearest hundredth in paved areas. Surface inlet grates shall also be shown to the nearest hundredth (Gr. El. 418.76).

j. The water surface elevations of ponding and/or 100-year flooding areas shall be shown.

k. Borings indicating depths and type of soils encountered shall be shown if not shown on a separate soils sheet.

l. The results of all soundings shall be shown using the proper symbol.

m. The vertical height of manhole collars shall be shown.

n. The flow line of all ditches having impact on sewer depth or location which are deeper than one foot shall be plotted and labeled as flowline ditch, left or right. On large channels, it may be necessary to show left and right tops of bank.

o. Existing ground profile including street grades or other improvements shall be shown as dashed lines. Proposed ground profile, including any proposed street grades or improvements, shall be shown as a solid line. See Exhibit 4-2.

p. If basements exist, the basement floor elevation shall be shown for sanitary plans. For houses without basements, the first floor elevations shall be shown. When an existing basement floor elevation absolutely cannot be obtained, a first floor elevation shall be obtained and a basement elevation estimated. When the basement elevation is estimated, this fact shall be duly noted in the profile by using the word "Assumed" adjacent to the elevation. House numbers or lot numbers shall be indicated on the profile along with elevations indicated above.

q. In order to show on which side of the sewer a house is located, houses on the left (when facing up station) shall be drawn using a solid line, and houses on the right (when facing up station) shall be drawn using a dashed line as shown in Exhibit 4-1.

r. Any stacks to be shown on the profile, such as for interceptor sewers, shall be shown solid on the left side and dashed on the right side and should be labeled pipe size stack and left or right.

s. Any underground telephone conduit, water lines, gas lines, etc. shall be shown when crossing proposed MSD facilities.

4.4.4 Cross-Sections

The information to be shown on cross-sections shall be, but not limited to, the following:

a. Horizontal and vertical scales shall be equal. Generally a scale of 1" = 5' shall be used, however, 1" = 10' may be used in special circumstances. Any other scale to be used requires prior approval of the MSD Project Manager.

b. Pre-printed colored grid sheets shall not be used because they cannot be scanned on computer for record.

c. Cross-sections shall be required for all proposed ditch projects as well as roadway or alley construction.

d. Cross-sections should show the existing and proposed ground lines, utilities, fences, structures, property lines, easement lines, and right-of-way lines.

e. Cross-sections shall be shown looking up station and shall be placed on the sheet progressing from bottom of sheet for lower station to top of sheet for higher station and left to right if more than one row of cross-sections is presented on one sheet.

f. Cross-sections shall generally be on even 50-foot stations along the improvement centerline or baseline.

g. If cross-sections are required on a project, pipe crossings may be shown on a cross-section rather than creating a separate profile for each pipe crossing.

h. Half-sections shall be shown for all driveways and a minimum of one half-section between driveways.

i. All water lines, gas lines, telephone conduit, and others shall be shown in the cross-section. .

j. Existing ground shall be shown as dashed lines and proposed grade shall be shown with solid lines.

4.4.5 General Notes

General Notes are notes common to the complete set of plans and shall be shown on the first plan sheet, if space permits, or Title Sheet, if necessary. The type of backfill, pipe material and classification may be shown in the General Notes if the majority of the pipes on a particular project have these items in common. Additionally, a Legend shall be shown on the first plan sheet, which defines the standard symbols used in the plans.

4.4.6 Certification

4.4.6.1 Basement Elevation Certification (Sanitary Projects Only)

The registered Land Surveyor shall place the following certification on the preliminary plan cover sheet, or other appropriate location, prior to the request for a field review. The certification should also be placed on the first plan sheet or other appropriate location in the final plans prior to their submission to MSD for approval.

CERTIFICATION

I hereby certify that the houses shown on these plans, which have basement facilities controlling the elevation of the sanitary sewer, have been entered and controlling elevations determined under my supervision, and that these elevations are correct to the best of my knowledge and belief.

____

Surveyor’s Signature, L.S. # and Date

4.4.6.2 Surveyor’s Certification

The following certification paragraph and signature is to placed on all sanitary and drainage projects. This note will need to be adjusted if survey procedures deviate from the language as shown.

CERTIFICATION

I hereby certify that the topography for this plan was located under my supervision, and that the property lines shown hereon were obtained from recorded deeds or plats, and that only the property corners noted as monumented were located in the field.

____

Surveyor’s Signature, L.S. # and Date

NOTE: ON SANITARY PROJECTS THE CERIFICATIONS CAN BE COMBINED AS A SINGLE NOTE IF APPLICABLE.

Reference is made to Section 6.3.7 of the Manual - Surveying for information on field references.

CERTIFICATION

I hereby certify that the topography for this plan was located under my supervision, and that the property lines shown hereon were obtained from recorded deeds or plats, and that only the property corners noted as monumented were located in the field.

____

Surveyor's Signature, L.S. # and Date

NOTE: ON SANITARY PROJECTS THE CERIFICATIONS CAN BE COMBINED AS A SINGLE NOTE IF APPLICABLE.

Reference is made to Section 6.3.7 of the Manual - Surveying for information on field references.

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

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EXHIBIT 4-1 STANDARD LAYERS

PAGE 1

EFFECTIVE DATE: JUNE 30, 2009

NAME	DESCRIPTION	COLOR	LINETYPE	LINETYPE EXAMPLES
BM	BENCH MARK	50	CONTINUOUS	
BORDER-0	BASE SHEET LAYER	12	CONTINUOUS	
BORDER-1	BASE SHEET LAYER	20	CONTINUOUS	
BORDER-2	BASE SHEET LAYER	40	CONTINUOUS	
BORDER-3	BASE SHEET LAYER	50	CONTINUOUS	
BORDER-4	BASE SHEET LAYER	150	CONTINUOUS	
BORDER-ROLL	BASE SHEET LAYER	2	CONTINUOUS	
DRNA	DRAINAGE AREA	230	HIDDEN	
E-ASPH	EXISTING ASPHALT	12	HIDDEN	
E-BASE	EXISTING BASELINE	130	CONTINUOUS	
E-BLDG	EXISTING BUILDING	32	CONTINUOUS	
E-CONC	EXISTING CONCRETE	12	HIDDEN	
E-CONT-MJR	EXISTING MAJOR CONTOUR	22	HIDDEN2	
E-CONT-MNR	EXISTING MINOR CONTOUR	12	HIDDEN2	
E-CONT-TXT	EXISTING CONTOUR TEXT (L80)	12	CONTINUOUS	
E-CRST	EXISTING CRUSHED STONE	172	HIDDEN4	
E-DTCH-E	EXISTING EARTH DITCH	102	FLOW LINES	
E-DTCH-P	EXISTING PAVED DITCH	102	DASHED2	
E-ESMNT	EXISTING EASEMENTS	102	PERM ESMT	
E-FENC	EXISTING FENCES	12	FENCE	X X
E-FLTS	EXISTING FAULTS	7	CONTINUOUS	
E-GRND	EXISTING GROUND (TOP OF BANK)	22	EXIST SHOULDER	
E-PL	EXISTING PROPERTY LINES	162	CONTINUOUS	
E-PL-CH	EXISTING PROPERTY LINE CHORD	162	HIDDEN2	
E-ROAD	EXISTING EDGE OF ROAD, PAVEMENT	162	EXIST EDGE PVMT	
E-RR	EXISTING RAILROADS	32	CONTINUOUS	
E-RW	EXISTING RIGHT OF WAY	115	RIGHT OF WAY	
E-SANI *	EXISTING SANITARY SEWERS	102	HIDDEN 2	
E-SPOT	EXISTING SPOT ELEVATION (L80)	195	CONTINUOUS	
E-STRM *	EXISTING STORM SEWERS	102	EXIST PIPE OR STRUCT	
E-STRP	EXISTING PAVEMENT STRIPING	16	CONTINUOUS	
E-TOPO	EXISTING TOPOGRAPHY	12	CONTINUOUS	
E-U-CBTV	EXISTING OVERHEAD CABLE TELEVISION	12	OHC	OHC
E-U-CBTV2	EXISTING UNDERGROUND CABLE TELEVISION	12	CABLETV	CTV
E-U-ELEC	EXISTING OVERHEAD ELECTRIC	22	OHE	OHE
E-U-ELEC2	EXISTING UNDERGROUND ELECTRIC	12	ELEC	UGE
E-U-GAS *	EXISTING GAS	92	GAS	G G
E-U-TELE	EXISTING OVERHEAD TELEPHONE	92	OHT	OHT
E-U-TELE2	EXISTING UNDERGROUND TELEPHONE	92	TELE	UGT
E-U-WATR *	EXISTING WATER	172	WATER	W W
E-VEG	EXISTING VEGETATION, TREES, SHRUBS	12	CONTINUOUS	
FILE-INFO	FILE INFORMATION	7	CONTINUOUS	
GL	GRID LINE	252	CONTINUOUS	
GT	GRID TEXT (L120)	7	CONTINUOUS	
HT	HATCH	92	CONTINUOUS	
P-ASPH	PROPOSED ASPHALT	215	CONTINUOUS	
P-ASPH-HT	PROPOSED ASPHALT HATCH PATTERN	182	CONTINUOUS	
P-BASE	PROPOSED BASELINE	230	CONTINUOUS	
P-BLDG	PROPOSED BUILDING	230	CONTINUOUS	
P-CONC	PROPOSED CONCRETE	214	CONTINUOUS	
P-CONC-HT	PROPOSED CONCRETE HATCH PATTERN	188	CONTINUOUS	

* SEE EXHIBIT 4-2 FOR ADDITIONAL EXPLANATION.

MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
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40203-1913

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STANDARD LAYERS

EFFECTIVE DATE: JUNE 30, 2009

NAME	DESCRIPTION	COLOR	LINETYPE	LINETYPE EXAMPLES
P-CONT-MJR	PROPOSED MAJOR CONTOUR	210	CONTINUOUS	
P-CONT-MNR	PROPOSED MINOR CONTOUR	200	CONTINUOUS	
P-CONT-TXT	PROPOSED CONTOUR TEXT (L100)	210	CONTINUOUS	
P-CRST	PROPOSED CRUSHED STONE	213	CONTINUOUS	
P-CURB	PROPOSED CONCRETE CURB	40	CONTINUOUS	
P-DSTB	PROPOSED DISTURB LIMITS	89	DOT2	
P-DTCH-E	PROPOSED EARTH DITCH	210	FLOW LINES	
P-DTCH-P	PROPOSED PAVED DITCH	210	CONTINUOUS	
P-EPSC	PROPOSED SILT CONTROL DEVICES	50	CONTINOUS	
P-FENC	PROPOSED FENCE	210	FENCE	x x x
P-FLOW	PROPOSED DRAINAGE DIRECTIONAL FLOW ARROW	20	CONTINUOUS	
P-GRND	PROPOSED GROUND	210	CONTINUOUS	
P-PERM	PROPOSED PERMANENT EASEMENTS	210	PERM ESMT	
P-PL	PROPOSED PROPERTY LINE	245	CONTINOUS	
P-ROAD	PROPOSED EDGE OF ROAD, PAVEMENT	240	CONTINOUS	
P-RW	PROPOSED RIGHT OF WAY	233	RIGHT OF WAY	
P-SANI *	PROPOSED SANITARY SEWERS	210	CONTINUOUS	
P-SF	PROPOSED SILT FENCE \ TREE PROTECTION FENCE	50	SF	SF
P-SPOT	PROPOSED SPOT ELEVATION (L80 w/o obliquing)	40	CONTINUOUS	
P-STRM *	PROPOSED STORM SEWERS	211	CONTINUOUS	
P-STRP	PROPOSED PAVEMENT STRIPING	52	CONTINUOUS	
P-TEMP	PROPOSED TEMPORARY EASEMENT	190	TEMP ESMT	
P-U-CBTV	PROPOSED OVERHEAD CABLE TELEVISION	200	PROP OHC	OHC
P-U-CBTV2	PROPOSED UNDERGROUND CABLE TELEVISION	200	PROP UGC	UGC
P-U-ELEC	PROPOSED OVERHEAD ELECTRIC	201	PROP OHE	OHE
P-U-ELEC2	PROPOSED UNDERGROUND ELECTRIC	201	PROP UGE	UGE
P-U-GAS *	PROPOSED GAS	205	GAS	G
P-U-TELE	PROPOSED OVERHEAD TELEPHONE	203	PROP OHT	OHT
P-U-TELE2	PROPOSED UNDERGROUND TELEPHONE	203	PROP UGT	UGT
P-U-WATR *	PROPOSED WATER	200	WATER	W
P-VEG	PROPOSED VEGETATION, TREES, SHRUBS, ETC.	205	CONTINUOUS	
PAPER	PAPER	7	CONTINUOUS	
PNTS	POINTS MADE FROM LDD / CIVIL 3D	7	CONTINUOUS	
PRELIM	PRELIMINARY	7	CONTINUOUS	
SL	STATION LABELS (L140)	7	CONTINUOUS	
SNDG	ROCK SOUNDINGS	55	CONTINUOUS	
TX0	TEXT L60	12	CONTINUOUS	
TX1	TEXT L80	20	CONTINUOUS	
TX2	TEXT L100	40	CONTINUOUS	
TX3	TEXT L120	50	CONTINUOUS	
TX4	TEXT L140	70	CONTINUOUS	
TX5	TEXT L175 AND ABOVE	80	CONTINUOUS	
XREF	EXTERNAL REFERENCE	7	CONTINUOUS	

* SEE EXHIBIT 4-2 FOR ADDITIONAL EXPLANATION.

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EXHIBIT 4-2

STANDARD LINETYPE EXHIBITS AND MISCELLANEOUS FEATURES

EFFECTIVE DATE: JUNE 30, 2009

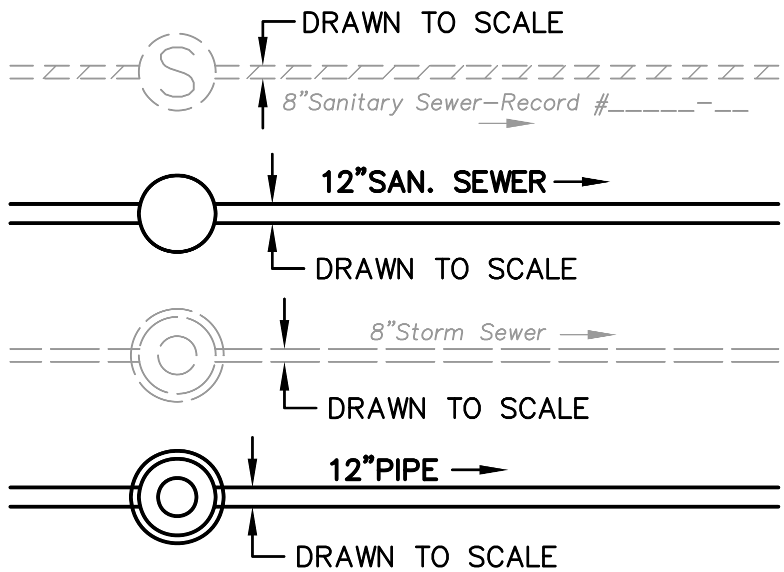
LINETYPES

EXISTING SANITARY SEWER

PROPOSED SANITARY SEWER

EXISTING STORM SEWER

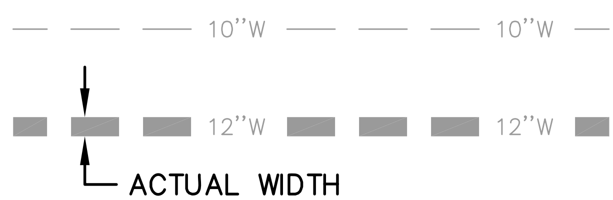
PROPOSED STORM SEWER



APPLIES TO GAS AND WATER

EXISTING UTILITY UP TO 10"

EXISTING UTILITY 12"AND LARGER SHOWN WITH ACTUAL WIDTH ASSIGNED TO LINE,



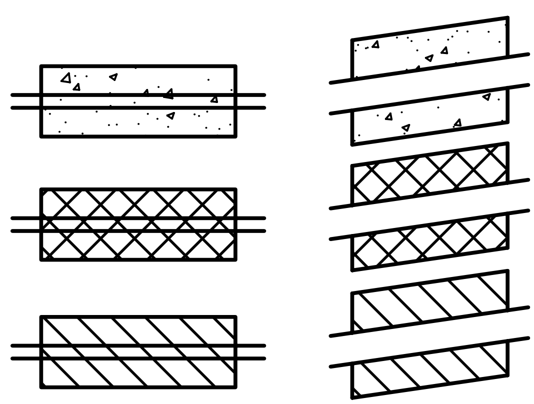
MISCELLANEOUS FEATURES

PLAN PROFILE

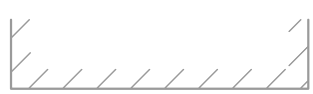
CONCRETE ENCASEMENT

TUNNELING OR PIPE JACKING

BORE & JACK OR DIRECTIONAL DRILLING



EXISTING BUILDINGS IN PLAN (FIELD LOCATED)



EX BUILDINGS IN PROFILE LEFT AND RIGHT OF BASELINE

LEFT RIGHT

SYMBOLS	DESCRIPTION	FILE NAME (.dwg)
	*Existing Tree (with size, type & drip line diameter)** * When locating tree sizes for plan views, measure diameter of trunk at breast height (in inches) and measure actual diameter of Drip line to the nearest foot.	MSDATREE.dwg
	Existing Pine or Spruce W/Size	MSDPINE.dwg
	Existing Bush W/Size	MSDSHRUB.dwg
Wooded Area	*Edge of Woods*	
	Existing Traffic Sign	MSDSIGN.dwg
○*MB*	*Existing Mailbox*	MSDMB.dwg
□*PB*	*Existing Paperbox*	MSDPB.dwg
	Contract Bench Mark	MSDBM.dwg
	Existing Guy Anchor	MSDANCHOR.dwg
	Existing Power Pole	MSDPP.dwg
	Existing Pole W/Light	MSDLS.dwg
	Existing Light Post	MSDLTSTD.dwg
□ *EPED*	*Existing Electrical Pedestal*	MSDELECPED.dwg
E	*Existing Electrical Manhole*	MSDEMH.dwg
T	*Existing Telecommunications Manhole*	MSDTMH.dwg
□ *TPed*	*Existing Telecommunications Pedestal*	MSDTPED.dwg
○ *CATV–PED*	*Existing Cable T.V. Pedestal*	MSDCPED.dwg
● 437.2±	*Overhead Power Lines (Profile)*	
○*GM*	*Existing Gas Meter*	MSDGM.dwg
○*GV*	*Existing Gas Valve*	MSDGV.dwg
○*GLM*	*Existing Gas Line Marker*	MSDGLM.dwg
	Existing Fire Hydrant	MSDFH.dwg
○*WM*	*Existing Water Meter*	MSDWM.dwg
○*WV*	*Existing Water Valve*	MSDWV.dwg
W	*Existing Water Manhole*	MSDWMH.dwg
○ *WLM*	*Existing Water Line Marker*	MSDWML.dwg

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SYMBOLS	DESCRIPTION	FILE NAME (.dwg)
CO	*Existing Sewer Clean-out*	MSDCO.dwg
S	*Existing Sanitary Manhole*	MSDSMH.dwg
M.H.	*Existing Storm Manhole*	MSDSTMH.dwg
	Existing Catch Basin (Single)	MSDCB.dwg
	Existing Catch Basin (Double)	MSDCBD.dwg
	Existing Catch Basin (Round)	MSDCBR.dwg
Steel	*Bridge (type of bridge shall be noted)*	MSDBRDG.dwg
R.P.	*Railway Pole*	MSDRP.dwg
	Railroad Rails (Profile)	MSDRR.dwg
P.L. (PIPE)	*Existing Property Line Pipe (TYPE)*	MSDPLP.dwg
⊠	*Right Of Way Marker*	MSDRWM.dwg
3	*Parcel Number*	MSCPN.dwg
C-3	*Consent and Release Parcel Number*	MSDCRN.dwg
S•	*Sounding Location (Plan)*	MSDSND.dwg
	Sounding To Rock or Refusal (Profile)	MSDSNDRK.dwg
	Sounding No Rock (Profile)	MSDSNDNRK.dwg
B-0	*Boring Location And Number. Geotechnical borings were drilled utilizing a truck-mounted drill rig. Borings were taken to a depth of one foot below flow line or until refusal.*	
	PROPOSED EMBANKMENT OR EXCAVATION SLOPE	
	PROPOSED STORM MANHOLE	MSDPSTMH.dwg
	PROPOSED DOUBLE CURB INLET	MSDPDCI.dwg
	PROPOSED CATCH BASIN DOUBLE	MSDPCBD.dwg
	PROPOSED SANITARY MANHOLE	MSDPSMH.dwg

SYMBOLS	DESCRIPTION
⊘	*Denotes 4" property service connection to be constructed to property or easement line as directed.*
⊗	*Denotes 4" Y or T branch with stopper. Property service connection is not to be constructed.*
⊘▬	*Denotes 4" property service connection to be constructed from stack at sewer to property or easement line as directed. (See note below)*
⊗▬	*Denotes 4" Y or T branch with stopper to be constructed from stack at sewer. Property service connection is not to be constructed. (See note below)*
$\boxed{\oslash}$	*Denotes a 4" property service connection (PSC) to be constructed. The PSC is <u>not</u> available for connection until the capacity charge, applicable at the time, is paid.*

Note: ***The following must be added to the general notes:***

All stacks must conform to the requirements of section 8.14 of the MSD Design Manual.

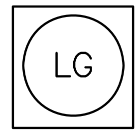
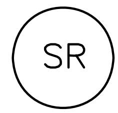
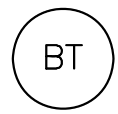
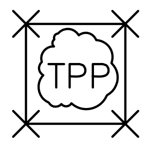
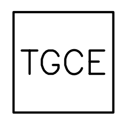
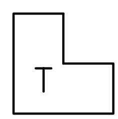
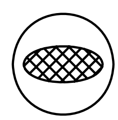
4" connections are for single family only all others are 6".

SYMBOLS	DESCRIPTION
	*Denotes 6" property service connection to be constructed to property or easement line as directed.*
	*Denotes 6" Y or T branch with stopper. Property service connection is not to be constructed.*
	*Denotes 6" siamese property service connection to be constructed to property or easement line as directed.*
	*Denotes 6" property service connection to be constructed from stack at sewer to property or easement line as directed. (See note below)*
	*Denotes 6" Y or T branch with stopper to be constructed from stack at sewer. Property service connection is not to be constructed. (See note below)*
	*Denotes a 6" property service connection (PSC) to be constructed. The PSC is <u>not</u> available for connection until the capacity charge, applicable at the time, is paid.*

Note: ***The following must be added to the general notes:***

All stacks must conform to the requirements of section 8.14 of the MSD Design Manual.

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES

DESCRIPTION	SYMBOL
SITE PREPARATION:	
LAND GRADING:	
SURFACE ROUGHENING:	
BULLDOZER TRACKED:	
TREE PRESERVATION AND PROTECTION:	
TEMPORARY GRAVEL CONSTRUCTION ENTRANCE/EXIT:	
BENCH TERRACING:	
TOPSOILLING:	

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
SURFACE STABILILIZATION:	
TEMPORARY SEEDING:	TS
PERMANENT SEEDING:	PS
SODDING:	SO
MULCHING:	M
DUST CONTROL:	DC
EROSION CONTROL BLANKET:	ECB
TURF REINFORCEMENT MAT:	TRM

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
OUTLET PROTECTION:	
OUTLET STABILIZATION STRUCTURE:	OS
INLET PROTECTION:	IP
GRAVEL AND WIRE MESH INLET SEDIMENT FILTER:	GWI
FILTER FABRIC DROP INLET PROTECTION (TEMPORARY):	FDI
BLOCK AND GRAVEL INLET PROTECTION (TEMPORARY):	BGDI
STONE BAG INLET PROTECTION:	SIP
SEDIMENT TRAPS AND BARRIERS:	
TEMPORARY SEDIMENT TRAP:	TS

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
SEDIMENT TRAPS AND BARRIERS (CONT):	
SEDIMENT BASIN:	SB
SILT FENCE (SEDIMENT FENCE):	SF SF
DITCH CHECK:	DC DC DC
TEMPORARY SEDIMENT BASIN:	
REINFORCED SILT FENCE:	RSF RSF
STREAM PROTECTION:	
TEMPORARY STREAM CROSSING:	TSC
RIPRAP:	RR
VEGETATED FILTER STRIPS:	VFS VFS VFS

MAPPING SYMBOLS AND NOMENCLATURE FOR EROSION AND SEDIMENT CONTROL PLANS FOR LAND DISTURBING ACTIVITIES (CONT.)

DESCRIPTION	SYMBOL
RUNOFF CONTROL MEASURES:	
PERMANENT CLEAN WATER:	→ PCW →
TEMPORARY CLEAN WATER:	→ TCW →
TEMPORARY SEDIMENT LADEN:	→ TSL →
ROCKFILL:	RF
RUNOFF CONVEYANCE MEASURES:	RCM RCM RCM
GRASS–LINED CHANNELS:	GC GC GC
SOD LINED CHANNELS:	SC SC SC
RIPRAP–LINED CHANNELS:	RRC RRC RRC
TURF REINFORCED CHANNELS:	TRC TRC TRC
PAVED CHANNELS:	PC PC PC
TEMPORARY SLOPE DRAINS:	TSD TSD TSD
PIPE SLOPE DRAINS:	PSD PSD PSD
RUNOFF CONVEYANCE MEASURES (CONT):	
STONE BAG CHECK DAM:	SBCD ▶ SBCD ▶ SBCD
OTHER RELATED PRACTICES:	
SUBSURFACE DRAIN:	SSD SSD
CONSTRUCTION DEWATERING:	

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EXHIBIT 4-4
PEN SIZE ASSIGNMENTS

EFFECTIVE DATE: JUNE 30, 2009

STANDARD ASSIGNMENTS

PEN SIZE	*COLOR*	*COLOR RANGE 1*	*COLOR RANGE 2*	*COLOR RANGE 3*	*COLOR RANGE 4*
0.18mm	1, 9, 250	10-19	90-99	170-179	
0.25mm	2, 251	20-29	100-109	180-189	
0.30mm	3, 252	30-39	110-119	190-199	
0.35mm	4, 253	40-49	120-129	200-209	160-169
0.50mm	5, 254	50-59	130-139	210-219	
0.60mm	6, 255	60-69	140-149	220-229	
0.70mm	7	70-79	150-159	230-239	
0.90mm	8	80-89		240-249	

SHADING

All pens in the following ranges ending with the number 2 except "2" will plot shaded as follow

COLOR	**PLOTS**
12-172	40% of black
182	6% of black
192-242	40% of black
188	2% of black
16	30% of black

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EXHIBIT 4-5
STANDARD ABBREVIATIONS

EFFECTIVE DATE: JUNE 30, 2009

DESCRIPTION

LG&E	Louisville Gas & Electric Company
PUE	Public Utility Easement
ATT	AT&T
Conc	Concrete
Asph	Asphalt
Culv	Culvert
Hdwl	Headwall
Hdw	Headwater
RCP	Reinforced Concrete Pipe
CMP	Corrugated Metal Pipe
CIP	Cast Iron Pipe
VCP	Vitrified Clay Pipe
PE	Polyethylene
DIP	Ductile Iron Pipe
PVC	Polyvinylchloride
HERCP	Horizontal Eliptical Reinforced Concrete Pipe
HDPE	High Density Polyethylene
HP	High Pressure
MH	Manhole
CB	Catch Basin
CI	Curb Inlet
TG	Top Of Gratr Elevation
I.E.	Invert Elevation
BM	Bench Mark
TBM	Temporary Bench Mark
CSB	Crushed Stone Base
R.R.	Railroad
R/W	Right-of-Way
DND	Do Not Disturb
DNR	Do Not Remove
TBR	To Be Removed
TYP.	Typical

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EXHIBIT 4-6
STANDARD BORDER
MSD PROJECTS

EFFECTIVE DATE: JUNE 30, 2009

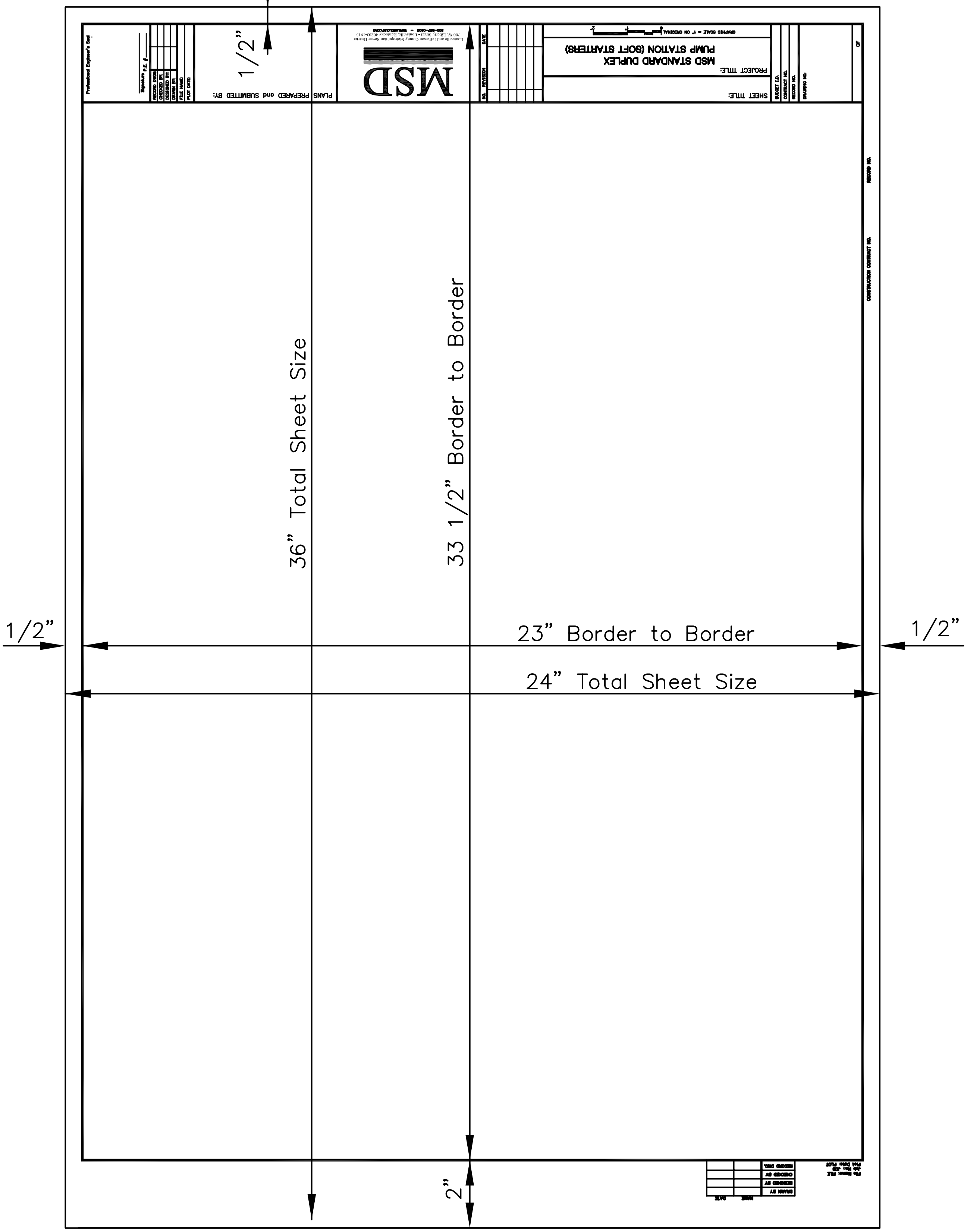

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EXHIBIT 4-7
STANDARD TITLE BLOCKS
MSD PROJECTS

EFFECTIVE DATE: JUNE 30, 2009

SHEET TITLE:
MSD STANDARD TITLE BLOCK

PROJECT TITLE:
MSD STANDARDS
SAMPLE DRAWINGS

GRAPHIC SCALE = 1" ON ORIGINAL 0 1" 2"

TITLE BLOCK

LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT

DESIGN
APPROVED: ______________________

APPROVED FOR
CONSTRUCTION: ______________________
DIRECTOR OF ENGINEERING DATE

MSD APPROVAL BLOCK

NO.	REVISION	DATE

REVISION BLOCK

MSD

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EXHIBIT 4-8

STANDARD TITLE SHEET

EFFECTIVE DATE: JUNE 30, 2009

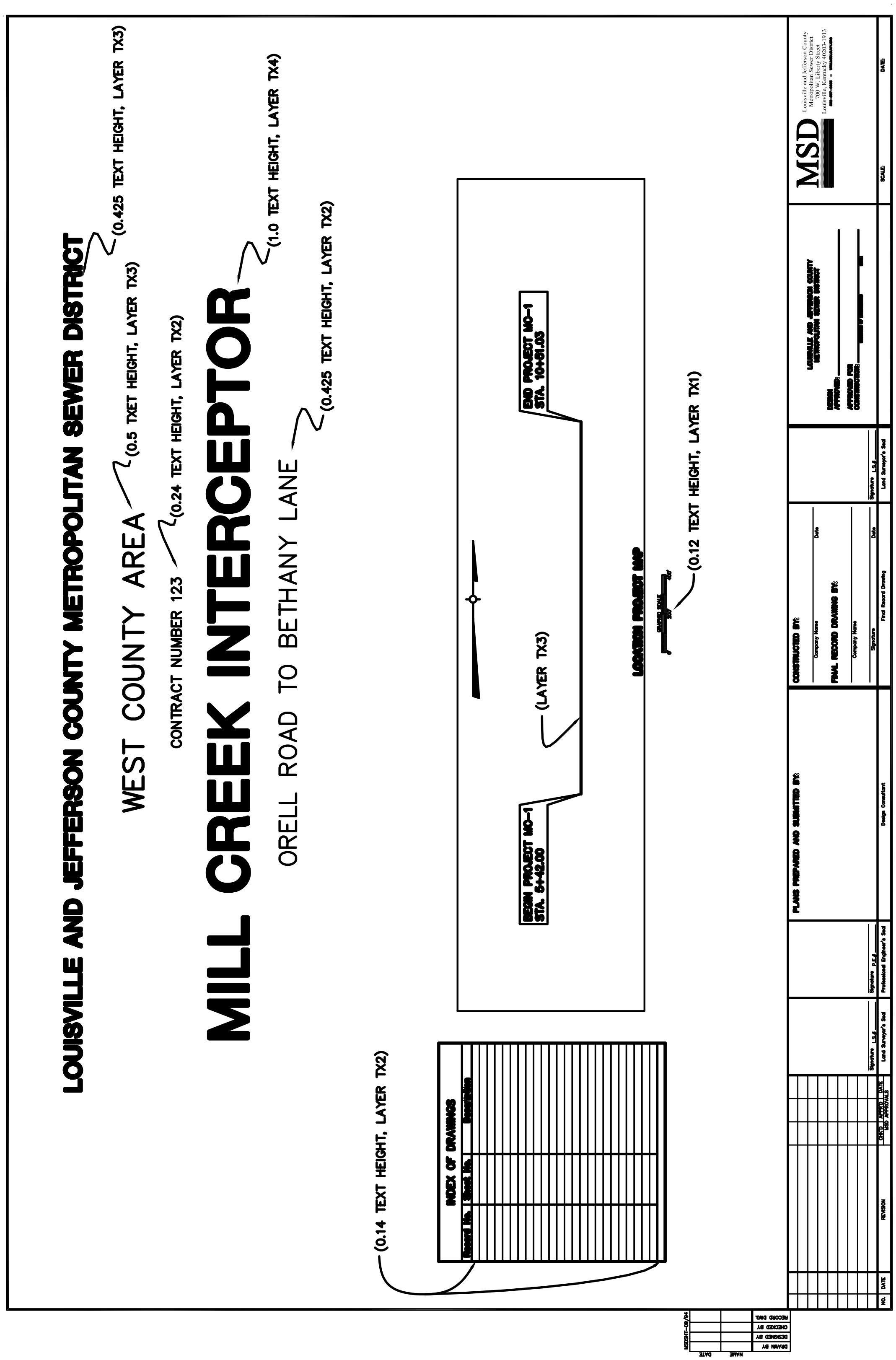

EXHIBIT 4-9
SAMPLE PLAN INDEX SHEET

EFFECTIVE DATE: JUNE 30, 2009

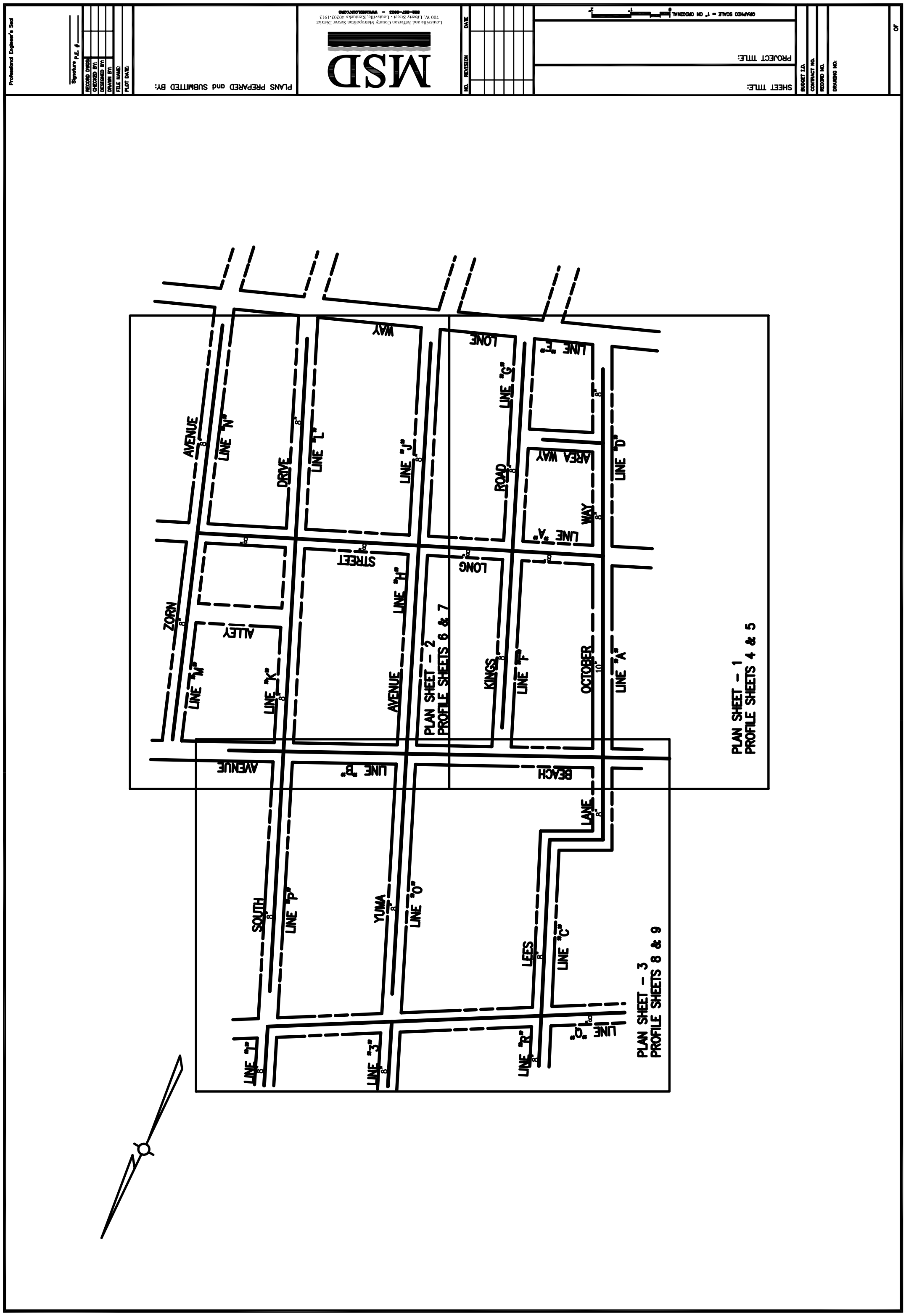

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EXHIBIT 4-10
SAMPLE DRAINAGE MAP
(SANITARY COLLECTOR SYSTEM)

EFFECTIVE DATE: JUNE 30, 2009

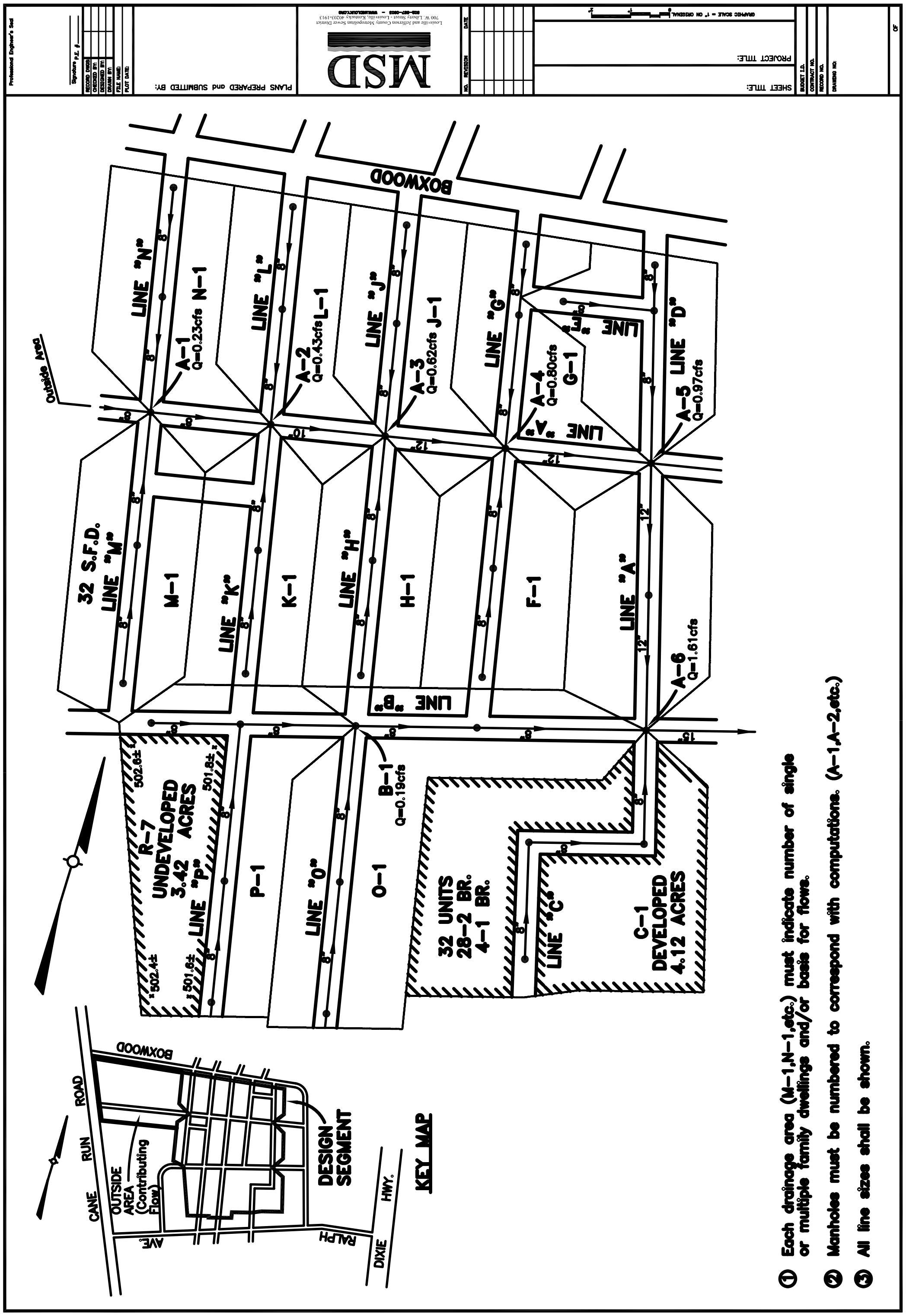

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EXHIBIT 4-11
SAMPLE DRAINAGE MAP (STORM COLLECTOR SYSTEM)

EFFECTIVE DATE: JUNE 30, 2009

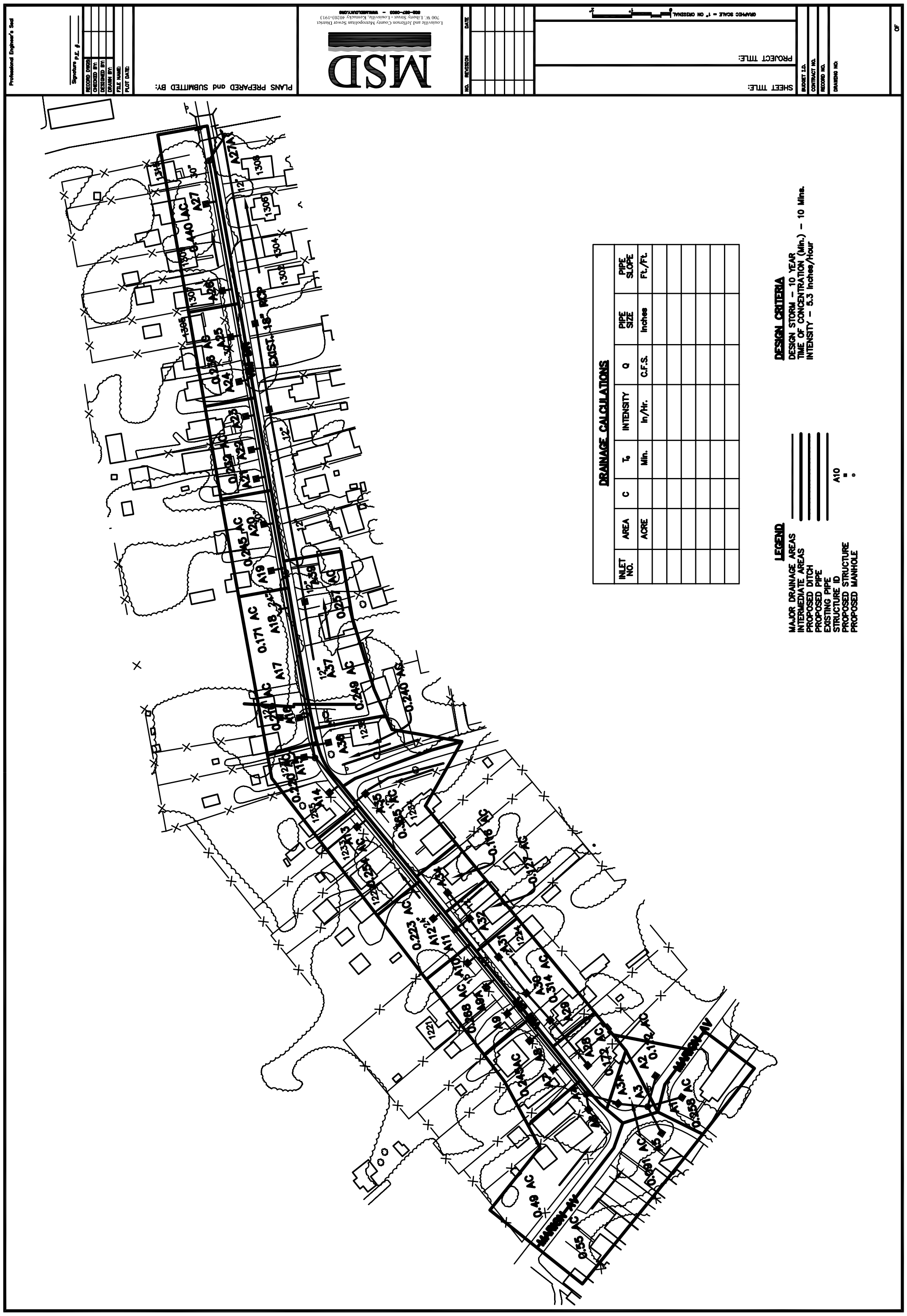

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EXHIBIT 4-12
HORIZONTAL & VERTICAL CONTROL MAP

EFFECTIVE DATE: JUNE 30, 2009

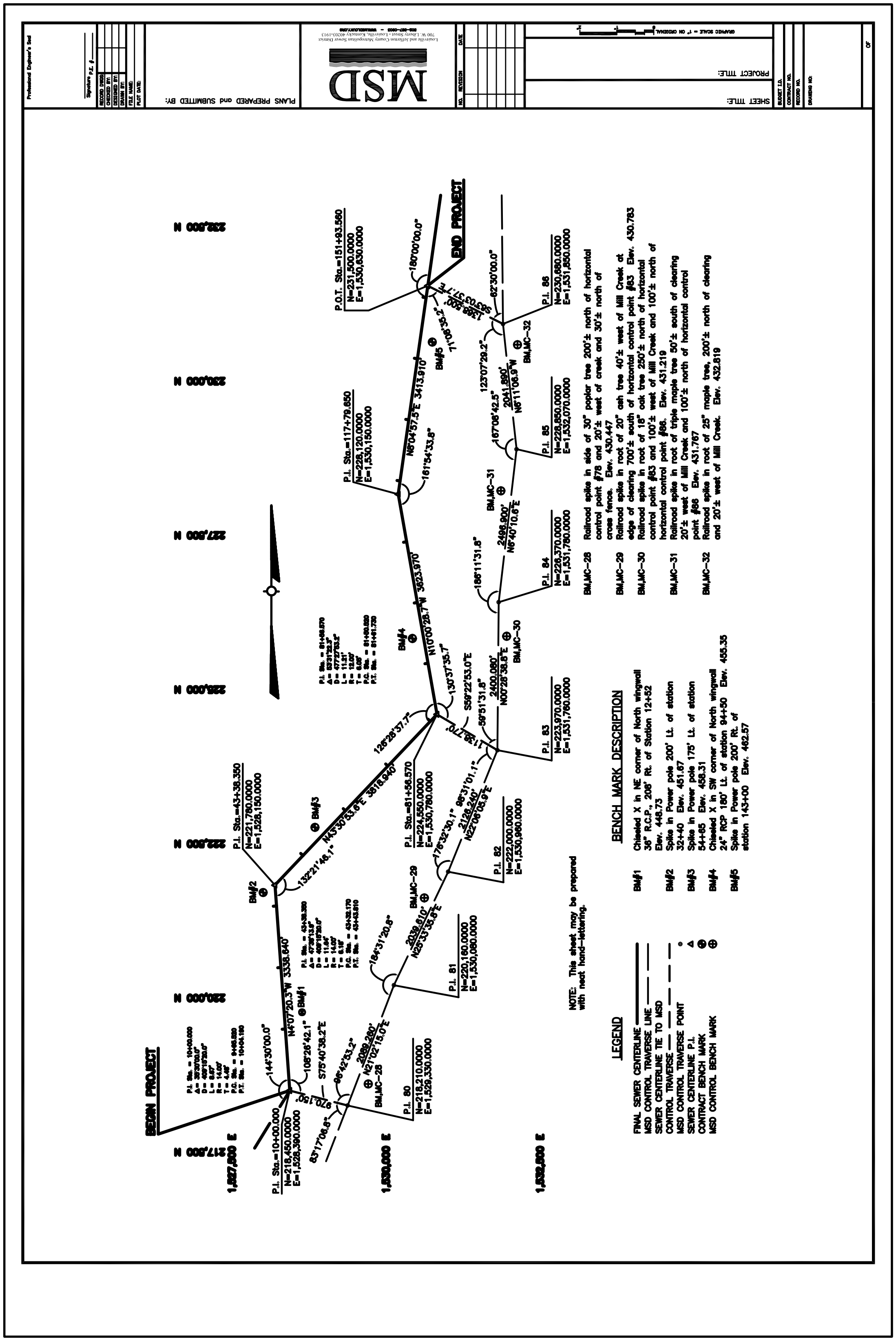

EXHIBIT 4-13
SAMPLE PLAN SHEET

EFFECTIVE DATE: JUNE 30, 2009

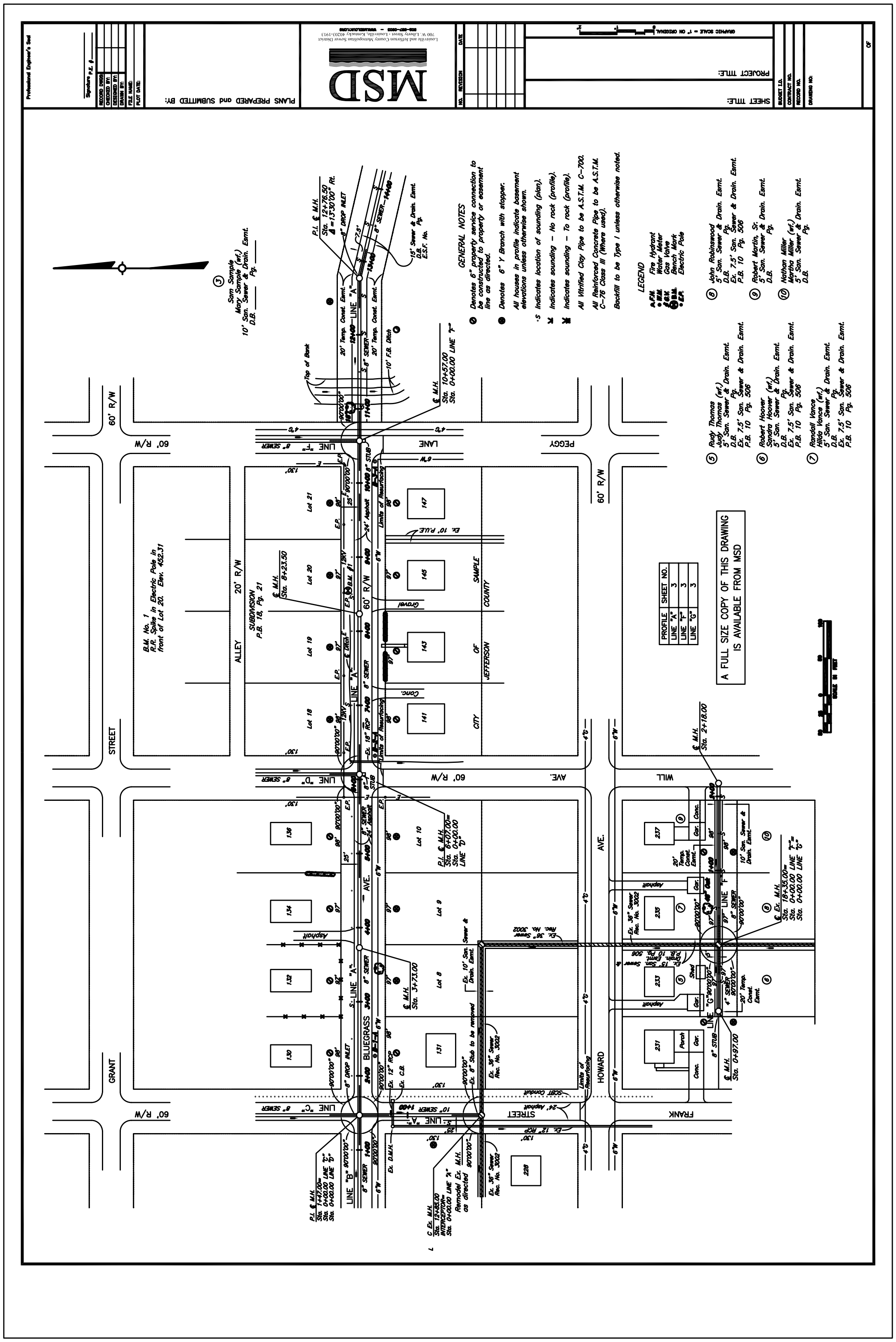

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EXHIBIT 4-14
SAMPLE PROFILE SHEET

EFFECTIVE DATE: JUNE 30, 2009

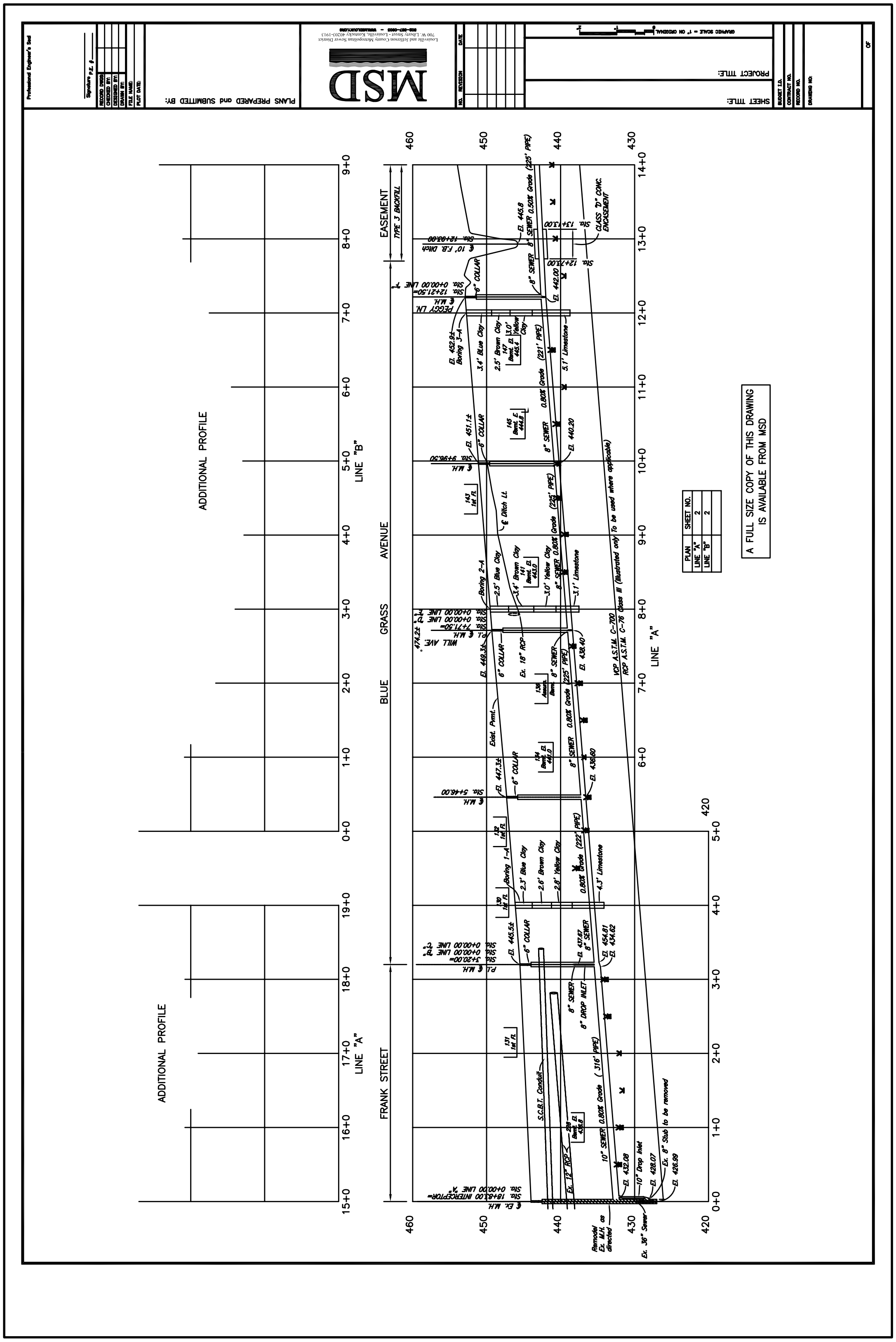

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EXHIBIT 4-15
SAMPLE CROSS SECTION

EFFECTIVE DATE: JUNE 30, 2009

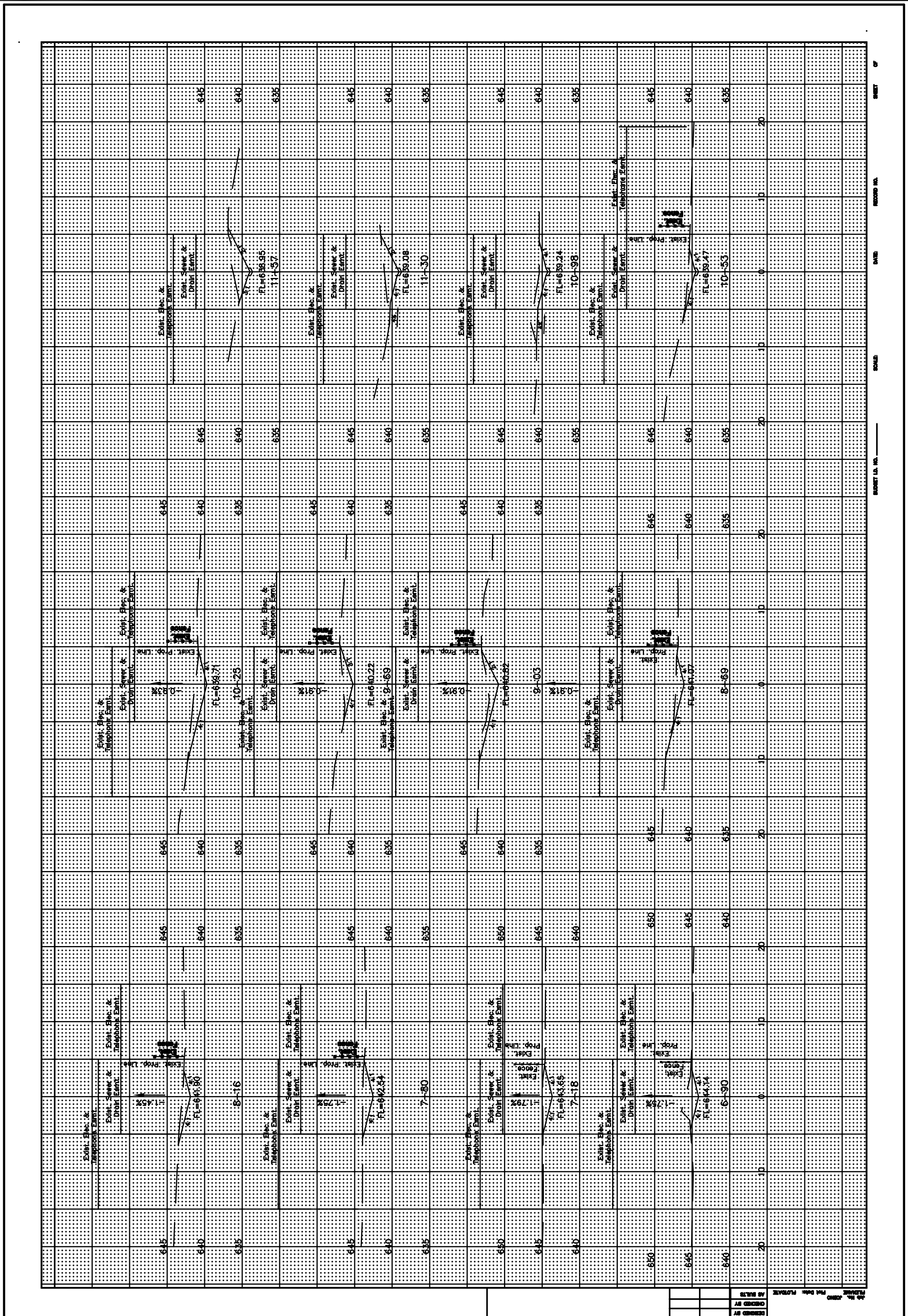

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EXHIBIT 4-16
PROPERTY ACQUISITION SUMMARY SHEET

EFFECTIVE DATE: JUNE 30, 2009

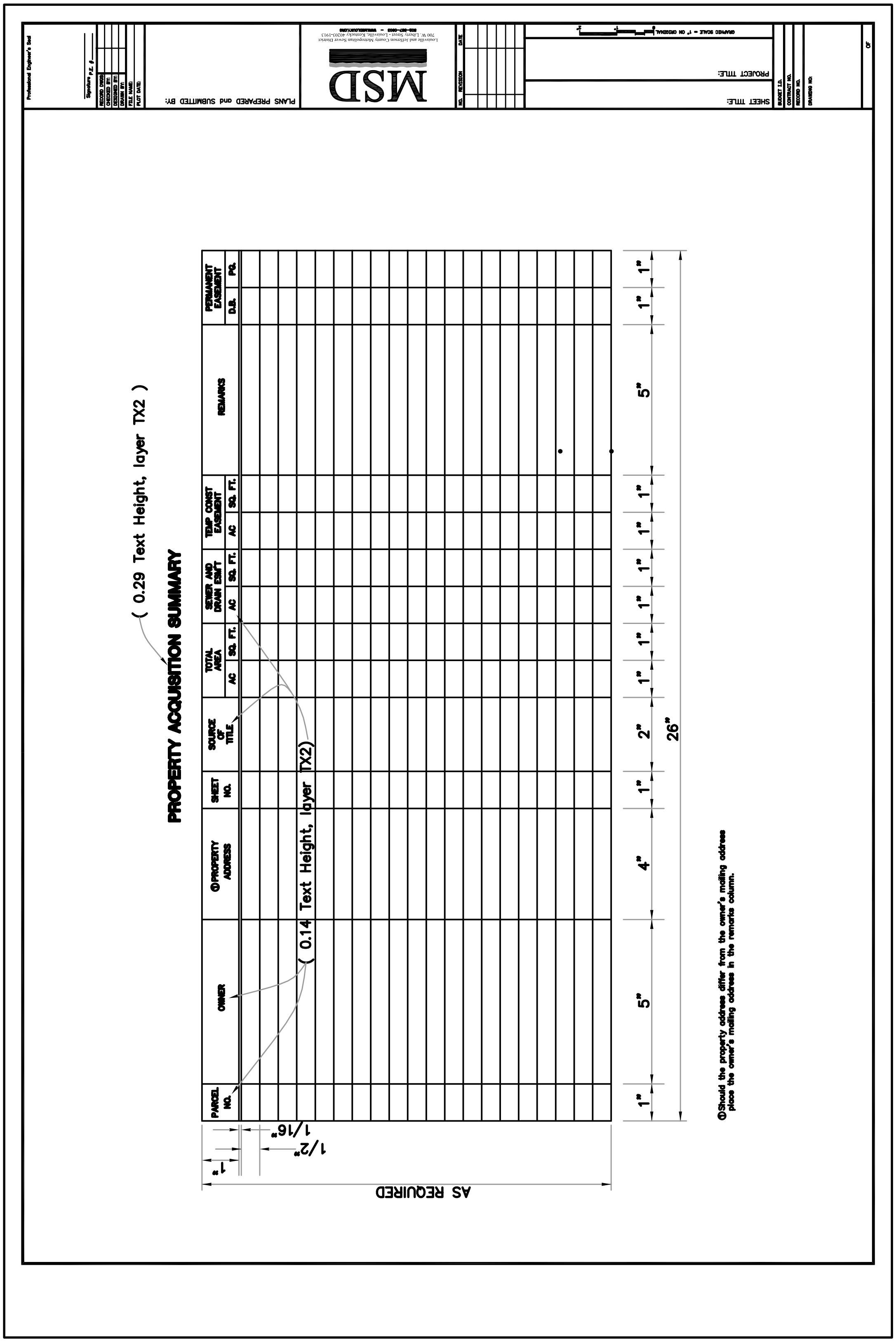

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EXHIBIT 4-17
SAMPLE APPORTIONMENT MAP

EFFECTIVE DATE: JUNE 30, 2009

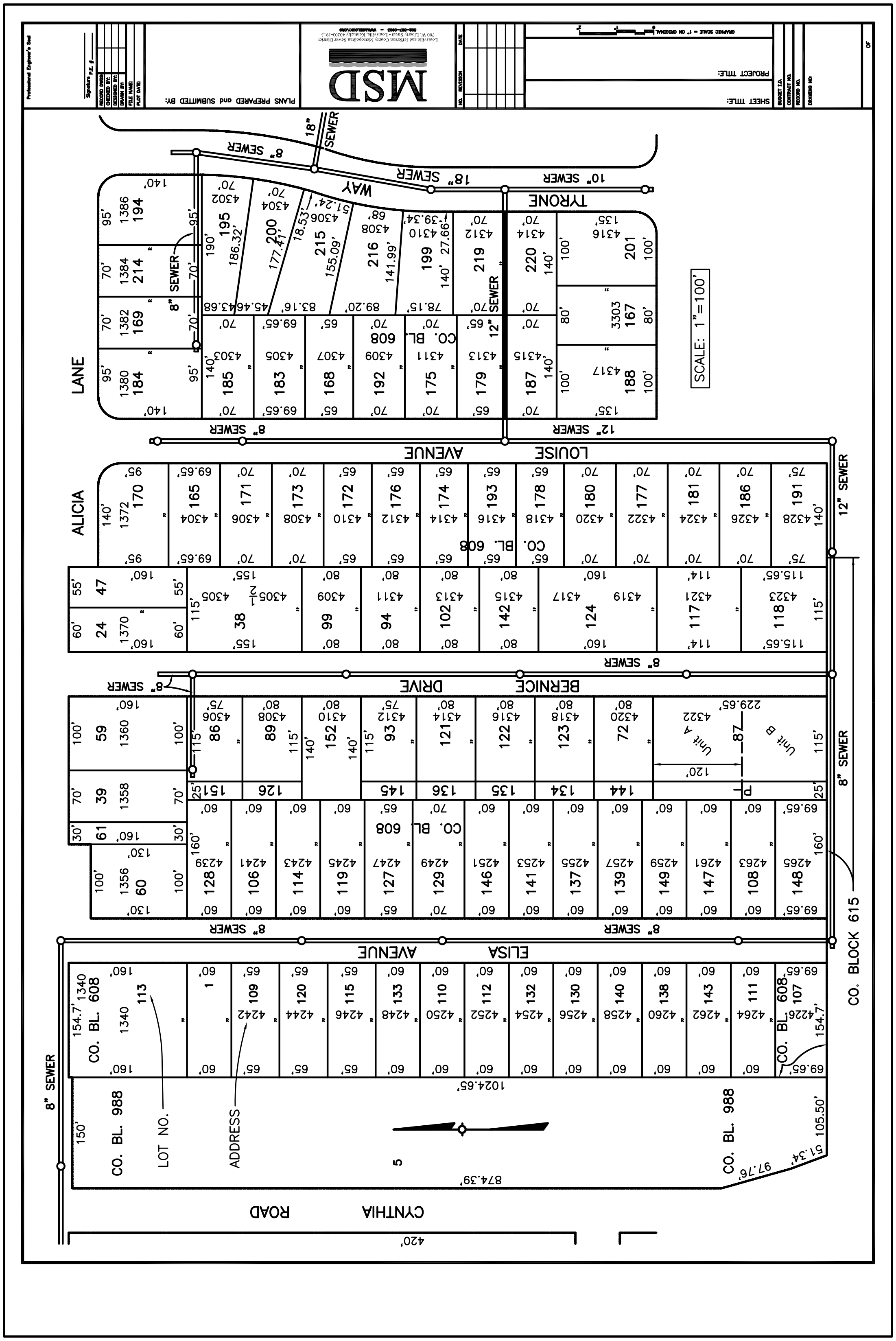

TABLE OF CONTENTS

CHAPTER 5
FINAL RECORD DRAWINGS

CHAPTER 5
FINAL RECORD DRAWINGS

5.1 PURPOSE

This chapter establishes the procedures that must be followed by Design Engineers, Land Surveyors, Contractors, Developers, and MSD concerning Final Record Drawings to ensure that all proposed **wastewater treatment and conveyance** plans correctly depict the facilities as constructed. **The final record drawings are the "Bid Plans" that have been revised to identify changes that occurred during construction.** This chapter also applies to MSD drainage projects, but not privately developed drainage plans.

5.2 GENERAL

On MSD projects, the Final Record Drawings will be prepared by MSD, or the project design engineer/consultant, based on record information provided to MSD by the contractor. At the completion of the project, the contractor will be responsible for providing MSD a set of "Red Line Drawings" and "As-Built Survey Information". The information will be incorporated into the "Bid Plans" design AutoCAD files to become the "Final Record Drawings" file. The Final Record Drawings are then saved in PDF format, with the file name format in accordance with the requirements of Chapter 4. The file will contain a "FRD" reference, differentiating it from the original "bid plans" file.

Note - On private development projects, the project owner will be responsible for preparing the Final Record Drawings, subject to the same requirements as a MSD project.

Red Line Drawings

As the project progresses, the Contractor shall maintain a record of all deviations in location or elevation of any installation from that shown on the Plans. The information will be compiled in a red-lined format on a copy of the Bid Plans. At the completion of the project the information is submitted to MSD. The information should be recorded in a clear and concise format, allowing for an easy transfer of information. For development projects four copies of proposed red line changes on the plans must be submitted for review and approval prior to execution of the changes. Approved changes will be shown on the as-builts.

As-Built Survey Information

The Contractor's Licensed Professional Land Surveyor-will be responsible for "as-builting" the items listed below. The survey information will be compiled in an

electronic fashion, compatible with the .dwg format, and submitted to MSD. Location and elevations shall be tied to the project survey control.

5.3 PROCESS

On MSD projects, the noted as-built information will be provided to MSD as soon as possible after completion of the project. Final payment to the contractor will not occur until the as-built information is provided.

On private development projects, final project acceptance will not occur until the completed Final Record Drawings are reviewed by MSD's Inspection Department for verification of information. Once verified, the plans are returned to Engineering Records for final review and acceptance. If the plans are accepted they become Final Record Drawings. If they are rejected the above process is repeated until accepted.

Reference is made to Chapter 4 for a detailed explanation of the documentation requirements. The as-built information is assigned to a specific layer within the drawing file. Predetermined font and pen sizes have also been established. The parameters are preset if the MSD standard drawing template file was used to generate the base drawing file.

5.4 DRAWING INFORMATION

Where constructed information differs from the **bid** information, the **plans will reflect** a line through the **bid** information and **show** the corrected information near the crossed-out original data. Original information shall under no circumstances be **removed** from the original plans. <u>No red line markings will be accepted</u>. A check mark should be placed beside the original plan information, which has been verified to be correct as constructed. **MSD will not accept Final Record Drawing that have color ink other than black or have plan information overlayed on aerial photos.**

5.5 AS-BUILT ITEMS

The following construction items, at a minimum, should be reviewed and verified to produce the Final Record Drawings:

5.5.1 Alignment Changes

5.5.1.1 Changes in Location

a. Manholes
b. Catch Basins or Surface Inlets
c. Headwalls
d. Retaining Walls
e. Slope Protection
f. Channel Linings

g. Pump Station Wet Wells
h. Pump Station Valve Vaults
i. Air Release Valves
j. Property Service Cleanouts

5.5.1.2 Changes in Elevation

To the nearest hundredth

a. Inverts
b. Rims
c. Surface Inlet Grates
d. Paved Ditches

To the nearest tenth

e. Turf Ditches
f. Miscellaneous Structures

5.5.2 Structure Changes

5.5.2.1 General

a. Manhole collar sizes
b. All revisions in pipe sizes, lengths, slopes, and angles
c. Identify pipe material if different from the plans

5.5.2.2 Pump Stations and Wastewater Treatment Plants

a. All revisions in pipe sizes
b. All revisions to electrical controls
c. All revisions to exhaust and ventilation systems
d. Pump modifications
e. Changes in elevation for inverts and level controls
f. Equipment layout modifications
g. Building modifications

5.5.3 Miscellaneous Changes

5.5.3.1 Property Service Connections

a. Size
b. Length
c. Depth at R/W or Property Line
d. Sewer Station
e. End Location, if the PSC is not perpendicular to the sewer

5.5.3.2 Changes in Lot or Unit Designations

a. Lot Numbers
b. Tract Numbers
c. Apartment Unit Designations
d. Condominium Unit Designations
e. Patio Home Designations

5.5.4 General

a. Any unverified data shall show +/- thereby indicating that information has not been verified.

b. The following stamp will be inserted into each plan sheet after all as-built information has been added.

c. For Private Development see the Record Drawings section of the Lateral Extension Procedures on the MSD Web site.

Final Record Drawing
By______________________Date_____________________
Contractor____
Record Drawings have been prepared based on information provided by the Contractor in accordance with the specifications.

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CHAPTER 6
SURVEYING

6.1 PURPOSE

This chapter describes the various field surveys for design, construction and approvals required for MSD projects. Private development requiring MSD approval and/or acceptance of constructed facilities shall also follow these guidelines. Project engineers and field survey crew chiefs should familiarize themselves with this and all other chapters of this Design Manual prior to the start-up of any field survey effort. Familiarity with this Manual will enable the field survey crew to obtain the necessary field information for design and construction and also minimize the occurrence of improper activities.

6.2 GENERAL

6.2.1 Conduct

The members of the survey crew are normally the first representatives of a firm or organization to come in contact with the property owners or residents along the route of the proposed improvement. It is imperative, therefore, that the survey crews conduct themselves properly, both on the project and in the surrounding community. **Survey vehicles should be adequately identified with their corresponding firm name. All survey crew members shall obtain an identification badge from MSD, and wear the badge at all times and be visible to the public.**

Their work should be explained to the property owners and to the public, as necessary, but the survey crew should carefully refrain from outlining any plans or policies, which might be misconstrued. If approached, the survey crew should <u>not</u> convey any project specific information to the property owners. The property owner should be referred to the respective MSD **Project Manager** if he/she has project specific questions. The crew must be courteous at all times when talking with the public and the crew members must maintain a **written** record of the names of owners or residents with whom they converse. During these conversations, **the survey crews should inquire about** the location of survey corners or monuments located on the owner's property.

6.2.2 Right of Entry

When it is obvious that the survey work will require entry onto private property, the owner shall be contacted, the survey work described, and permission to enter obtained. No project specific information should be conveyed to the property owner. Efforts to contact property owners shall include telephone calls and the leaving of letters and a door hanger for those who are not at home. A sample copy of the current MSD Insert Card as shown on Exhibit 6-1 shall also be presented to the property owner. Copies of these may be obtained from the MSD **Project Manager**. It should be explained in the notice that field inspection and soils investigation personnel might require entry from time to time during the course of the project. In the event that the owner does not grant permission and it is evident that the survey work will be delayed, MSD should be notified, in writing, immediately. It is the responsibility of MSD to take whatever course of action deemed necessary to obtain legal right of entry in accordance with state statutes.

6.3 HORIZONTAL AND VERTICAL CONTROL

6.3.1 General

When required, centerline and/or baselines shall be established using acceptable survey procedures. These survey lines shall be established in the general vicinity of the anticipated sanitary sewer or storm drainage system location, within the public right-of-way or easement limits and parallel to the expected location of the improvements. **When horizontal and vertical control monuments have been established in the area of the survey, all centerlines, and/or baselines, and level circuits shall be referenced to these monuments.** These monuments or coordinated positions and/or benchmarks **published by NGS or Louisville/Jefferson County Information Consortium (LOJIC) Geodetic Control Network** shall be shown and identified on the plans.

Trees are not to be used for surveying purposes except in remote areas where there is no other practical alternative. No spikes or nails are to be driven into a tree as described previously. Trees shall not be "blazed" under any circumstances, and only water-based paint may be used if it is necessary to mark a tree.

6.3.2 Guidelines

Horizontal and vertical control shall be established according to the guidelines defined by these publications:

a. **Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-003, FGDC-STD-007.1 through FGDC-STD-007.5 or the current** Federal Geodetic **Data Committee standards.**

b. All pertinent statute laws and regulations.

6.3.3 Datum

All control shall be related to existing monuments that have been **published by**

NGS or referenced on Louisville/Jefferson County Information Consortium (LOJIC) Geodetic Control Network and must reference the appropriate datum as indicated below:

a. Horizontal control shall be referenced to the Kentucky State Plane Coordinate System, North Zone/NAD **HARN** (1983).

b. Vertical control shall be referenced to the **North American Vertical Datum 1988**

6.3.4 Placement

All horizontal control shall be located within the easement or public right-of-way whenever possible. Each monument should be placed to avoid movement caused by construction or other activities. Every horizontal control marker that is not being specifically set for individual project control points should be set at maximum intervals of one-half mile on all projects.

A vertical control marker that is not being specifically set for individual project control points should be placed similarly to horizontal control marker at maximum intervals of one-quarter mile.

6.3.5 Monuments

All horizontal and vertical control markers shall be MSD approved and be of ferrous materials where applicable.

6.3.6 Project Control and Bench Marks

Project horizontal control shall be as described in this chapter. Project vertical control shall be referred to as bench marks. Bench marks shall be established at a maximum interval of 500 and must maintain a minimum distance of 25 feet from the improvement centerline. Each bench mark should be placed to avoid movement caused by construction or other activities.

All bench marks must conform to specifications for quality as referenced in Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-007.4. Sidewalks, steps (unless massive), small concrete slabs and similar structures are not acceptable. Each project must contain at least one bench mark, which conforms Federal Geodetic Data Committee (FGDC) endorsed standards FGDC-STD-007.4.

6.3.7 Survey Control Point References

With the advent of GPS and the coordinate control capabilities of most survey equipment, field references for horizontal survey control points are no longer required. All control information is identified on the Horizontal and Vertical Control Map, Exhibit 4-14.

All bench marks are to be field located and shall be referenced to the centerline of sewer by line designation, station, and offset. In addition, these other field references, such as addresses, etc., should be referenced the same in field notes, plans, and any other pertinent documents submitted. **If a spike in a power pole is used as a benchmark, the field notes, plan sheets, and the horizontal and vertical control sheet shall list the power pole number.**

6.3.8 Vandalized Survey Project Points and Bench Marks

MSD will not assume the responsibility for any damage done to project centerline control points and bench marks until after the final plans, contract documents, and field notes with proper references have been accepted by MSD. Any damage done to those points up to that time will be repaired or replaced by the Land Surveyor at the Land Surveyor's expense. It is advised that these points are accurately field referenced at the earliest possible time.

6.3.9 Horizontal and Vertical Control Review

MSD retains the right to request any corresponding field notes either digital or hard copies that pertain to the horizontal and vertical control for the project together with horizontal and vertical closure statements for their review.

The control data sheets, as shown in Exhibit 6-2, shall be submitted for each newly set horizontal and vertical control monument.

6.3.10 Horizontal and Vertical Control Map

A horizontal and vertical control map is required for all sanitary sewer surveys and major storm drainage projects as designated by the MSD Project Manager. This map shall be prepared on a standard plan sheet and shall be included in the final plans. The final horizontal and vertical control map, similar to Exhibit 4-14, shall include final stations, station equations, all curve data, and the final location and description of bench marks. In addition, the following information shall be shown.

6.3.10.1 Horizontal Information

a. Coordinate ties with adjacent projects.

b. Final coordinates of all horizontal control points, PI’s , beginning and ending stations.
c. All bearings, coordinates, angles and point designations on MSD baselines in the design segment.
d. Source of horizontal datum. **(List the bearing and distance of the control line, and the deflection angle of the proposed centerline.)**

6.3.10.2 Vertical Information

a. New bench marks - their designations, locations, description and elevation.
b. **Existing Vertical Control Monuments as referenced in 6.3.3** - their designations, elevation and location.
c. Source of vertical **datum**. (If a spike in a power pole is used for a bench mark, list the power pole number and the height of the spike above the ground, and house number(s) of adjacent homes.

6.4 DEGREE OF ACCURACY

6.4.1 General

The specified criteria for surveys will vary accordingly to their function. All surveys are subject to the guidelines indicated in Section 6.3, Horizontal and Vertical Control.

The instruments used shall meet the specifications indicated in these guidelines or in following sections. All instruments shall be certified to National Institute of Standards and Technology (NIST) standards and manufacturer's specifications. NIST, the instrument manufacturer, or a certified instrument repairs facility must perform the certification.

All **instruments** should be serviced regularly by a certified repair facility and checked at a National Geodetic Survey baseline. EDM instruments should be calibrated by a certified repair facility annually. Field notes of all calibration checks **can be requested by** MSD's Survey Supervisor.

Instrumentation for second order leveling as defined by the Federal Geodetic Control Subcommittee (FGCS) of the FGDC shall be used for any projects requiring second order, class II specifications.

6.4.2 Accuracy Criteria

6.4.2.1 Sanitary Interceptor or Through Drainage System

Horizontal surveys will adhere to Second Order, Class II specifications, except that the error of closure shall equal or exceed 1:50,000.

Vertical control will adhere to Second Order, Class II specifications.

6.4.2.2 Sanitary Collector or Local Drainage Systems

Horizontal surveys will adhere to Third Order, Class I specifications, except the adjustments being made by either the Least Squares or Compass Rule Method.

Vertical control will adhere to Third Order specifications, except the error of closure will be equal to or exceed Second Order, Class II requirements.

6.5 FIELD PROFILE AND TOPOGRAPHY

6.5.1 Field Profile Requirements

Profile elevations shall be determined along sanitary sewer or through drainage system centerlines at 25-foot intervals, where possible, or at 50-foot intervals on paved streets, and at all necessary intermediate breaks. Profiles shall delineate existing structures, roads, streams, etc. Elevations shall be established to the nearest one-tenth of a foot on natural terrain and to one-hundredth of a foot on artificial surfaces.. Cross-sections shall be taken at critical locations when it is necessary to determine what effect open cuts or trenching might have on other facilities such as structures, utilities, pavements, fences, trees, or landscaping. Sufficient original ground elevations must be determined in order to establish the slopes necessary to adequately serve the property. The MSD Project Manager may modify these requirements to suit specific projects.

Roadside ditches within 30 feet, parallel to the sewer, and greater than 1.5 feet in depth shall be shown in profile with the sewer. These ditches and other elevations critical to design and/or construction must be shown on the plans.

6.5.2 Sanitary Service Connection Survey

A sanitary service connection survey shall be made along each street to properly determine the controlling elevations for design of a particular sanitary sewer line. The form found in Exhibit 6-3 shall be used in accomplishing this survey. The following information shall be shown on the form for each unit surveyed:

a. Type of structure.

b. Basement facilities present.

c. Size, type and location of service line.

d. Elevation of the lowest possible living area floor.

e. Any additional information that may be required for design of the sanitary sewer line.

All elevations should be determined by actual field measurements; however, if a unit cannot be entered, an estimated lowest living area floor elevation shall be made from a known elevation from some other point on the unit. In this case, the elevation must be clearly marked as being estimated. Should an estimated elevation control or have the potential to control the vertical elevation of the sewer, the MSD Project Manager shall arrange provision for entry and actual determination of the service elevation.

The completed forms shall be submitted along with the preliminary plans for review. They need not be included in the final plan submission but shall be included with the original drawings submitted at the conclusion of the project.

6.5.3 Topographic Requirements

In addition to the topographic requirements established in Chapter 4, the following information shall be obtained in the field:

a. All topography critical to the design of the improvement shall be located and recorded in the field notes.

b. Topography generated from aerial photography (including LOJIC planimetric and topographic base mapping) shall be identified and field checked for any errors or omissions. Omitted topography shall be located by field survey and appropriately recorded. This work is the specific responsibility of the Engineer or Land Surveyor, even though the aerial photography may have been provided from other sources. All topography within the project construction limits and/or easements and rights-of-way shall be field located.

6.5.4 Survey Information Needed for Trees

a. Species of Tree (Use the Audubon Society Field Guide to North American Trees, Eastern Region)

b. Size (DBH - Diameter at Breast Height)

e. Dripline (Diameter)

f. Encroachment Allowed within the Dripline

g. Location

1. All trees 6 inches in diameter or greater within the temporary or permanent easement shall be located and the species given within 30-feet of the centerline for pipe projects or 15 feet outside the top of slope for ditches.

2. All trees less than 6 inches in diameter shall be located and species given, when within an existing or proposed sewer and drainage easement.

3. When trees are grouped together, at a very close interval, locate the approximate center of the grouping and list the most dominant species of the group.

6.5.5 Soundings

Soundings shall be taken to a depth of 2 feet below the invert of the proposed improvement or to rock, whichever is encountered first. Soundings shall be taken on 50-foot stations in areas where rock is encountered and 100-foot stations where rock is not encountered. In areas of rapidly changing rock elevation, additional rock soundings will be required to identify the rock surface at a minimum of 25-foot stations. All soundings shall be documented for location, surface elevation, rock elevation (depth), and depth of sounding not encountering rock (no rock).

6.6 SPECIAL SURVEYS

6.6.1 Property Surveys

Where the relationship of the improvement location and adjacent property line is critical, the location of existing property lines and other boundaries shall be established by a property survey sufficient to define the easement. All property surveys shall comply with the "Minimum Standards of Practice for Land Surveying in Kentucky", latest revision, as set forth and enforced by the Kentucky Revised Statutes. Property lines, boundary lines, easements, etc. shall be referenced by stations and offsets from the centerline or baseline to the nearest one-hundredth of one foot, by measurement of the angles at the PI with the centerline, and by other means of comparable accuracy. Surveys shall ascertain the names of owners, lessees or tenants, sources of title and date of acquisition and shall be verified from the appropriate Jefferson County records. Copies of all field notes can be requested to be submitted to MSD.

6.6.2 Utility Surveys

All publicly and privately-owned surface and subsurface utilities affected by the proposed improvement shall be located and identified by field survey and by use of maps supplied by the utilities. Locations, elevations, and other pertinent data as may be required for possible relocation or adjustment shall be secured for all such utilities to the limits of information currently available. Overhead power lines near the intended improvement alignment, or those which may be a construction hazard, should be shown on the plans using the proper symbol and labeled with their primary voltage.

6.6.3 Railroad and Highway Surveys

When the centerline of improvements crosses a railroad or highway, all existing and proposed railroad tracks, roadways, and affected structures shall be tied to the improvement centerline. The topography shall be provided on either side of the proposed crossing to the extent required by the affected reviewing agency. **. An attempt to contact the railroad owners shall be made prior to the survey work in the railroad R/W.** Typical information shall include, but not be limited to, the following sections.

6.6.3.1 Railroads

a. Top of rails - 300 feet minimum in either direction locate horizontally and vertically at 50-foot intervals.

b. Angle between centerline of tracks and centerline of improvement.

c. Name and address of railroad company.

d. Location of railroad right-of-way and easements (source of record where possible).

e. Horizontal and vertical information relative to transmission lines, such as telephone or electric.

f. Stations on the centerline of each track.

g. Mile post locations, measured from centerline crossing.

6.6.3.2 Highways

a. Station on centerline of highway and each edge of pavement, or front face of curb, as may be appropriate.

b. Angle between highway centerline and centerline of improvement.

c. Location of highway rights-of-way and easements (source of record where possible).

d. Location of any crossings, parallel utilities, or drainage structures, which may be in conflict with the improvement construction.

e. Number and width of lanes and the type and condition of the surface.

Additional information relative to requirements in the vicinity of railroads and highways may be found in Chapter 8, Sections 8.18, 8.19 and 8.20.

6.7 STAKING SANITARY SEWER AND THROUGH DRAINAGE SYSTEM CENTERLINES

6.7.1 Preliminary Centerlines

Improvement centerlines shall be staked for a preliminary field review by using highly visible temporary markers. These markers shall be placed on the centerline at convenient locations, such as fence lines, streets, and borders of timber areas. Intermediate markers shall be placed as necessary to maintain continuous visibility. Plastic flagging shall be used on the markers to increase their visibility. Approximate stations and line designation shall be placed on the markers. The method of designating the centerline in urban areas may be modified as required to provide the information previously noted, including the use of paint on streets. Final staking of improvement lines and the assignment of final line designations before a preliminary field review is not encouraged. These requirements are subject to revision by the MSD Project Manager to suit specific projects.

6.7.2 Final Centerlines

6.7.2.1 Staking

Prior to acceptance of the final plans, the centerline shall be staked at PI's and as needed to maintain line of sight for purposes of easement acquisition, bidding, MSD field reviews, etc. Stations and line designation shall be clearly marked with an indelible marker on 1" x 2" x 18" (minimum) flat stake adjacent to the PI. Guard stakes of 1" x 1" x 48" (minimum), marked "Centerline Sewer" shall be provided at all PI's, manholes, structures, and other control points.

Stake markings shall include the designation of the sewer, such as Line "A” and the station of the point for which the guard stake is provided.

Points in pavement areas shall be identified by painting the necessary information adjacent to the permanently located point. PK nails or spikes are to be used for final centerline staking. Where necessary, offset stakes shall be utilized to identify points in streets, highways, and railroads.

6.7.2.2 Monuments

Iron pins shall be placed at all PI's and POT's necessary to establish the centerline, beginning and ending stations of the contract, and at those points specifically requested by MSD. These points shall be field referenced, per MSD specifications, so they may be located or reestablished at a later date. Iron pins shall be placed at all other manhole locations but do not need to be field referenced. Iron pins shall be made of or contain ferrous material and be a minimum of 30 inches in length and 5/8 inches in diameter. . In lieu of iron pins, railroad spikes, 6 inches minimum length, or PK nails shall be used in bituminous pavements and a scribed cross ("X") shall be used on concrete surfaces.

6.7.2.3 Centerline Verification

The Design Consultant shall verify the improvement alignment by obtaining field angles and distances along all segments of the improvement centerline. This shall include tying the final centerline alignment by traverse into the MSD control baseline. The alignment shown on the Horizontal and Vertical Control Map described in Section 6.3.10 shall be the final approved alignment.

6.7.2.4 Acceptance

The Design Consultant shall verify, in writing, that the alignment shown on the final construction plans has been located correctly in the field. This shall include returning to the field and verifying that all permanent points are intact and reestablishing all damaged or missing points. This must be accomplished before MSD will accept the original drawings, contract documents, and authorize final payment to the Design Engineer.

6.8 Certification Notes

Example Surveyor Certification notes can be found in section 4.5.6. A certification note, placed on the project title sheet, is required for all projects and should reflect the specific type of survey performed.

MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

502–587–0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-1
IDENTIFICATION CARD
SUMMARY SHEET

EFFECTIVE DATE: JUNE 30, 2009

MSD

Metropolitan Sewer District

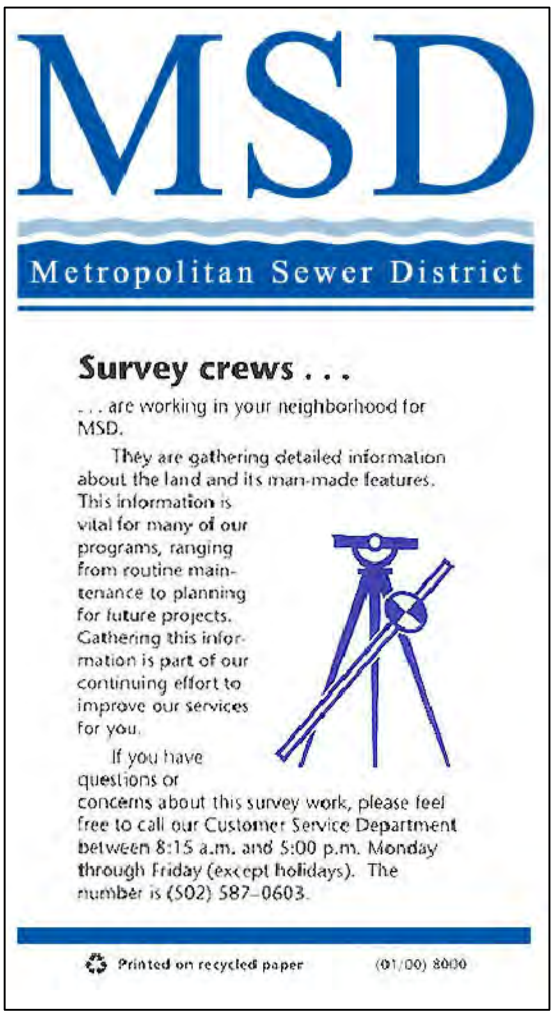
LOOK INSIDE

FOR A MESSAGE FOR YOU

Our representatives were in your neighborhood today. Please look inside this envelope for specific information – perhaps including a special telephone number – that will explain the situation.

If you have any questions about our programs, please contact the MSD Customer Service Department at 587–0603 between 8:15 a.m. and 5 p.m. Monday through Friday (except holidays).

Printed on recycled paper (01/00) 64000



MSD

Metropolitan Sewer District

Survey crews . . .

. . . are working in your neighborhood for MSD.

They are gathering detailed information about the land and its man-made features. This information is vital for many of our programs, ranging from routine maintenance to planning for future projects. Gathering this information is part of our continuing effort to improve our services for you.

If you have questions or concerns about this survey work, please feel free to call our Customer Service Department between 8:15 a.m. and 5:00 p.m. Monday through Friday (except holidays). The number is (502) 587–0603.

Printed on recycled paper (01/00) 8000

MSD

Metropolitan Sewer District

We're sorry we missed you!

One of our representatives was here today to investigate your recent request for service. This visit will help determine what can be done about the situation.

We are continuing to review your request, and we will get back in touch with you soon.

☐ If this box is checked, it means we need to talk to you to obtain more information. Please call

____

____

at ____________________________

Thank you for bringing your concern to our attention!

Printed on recycled paper (03/98) 8000

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-2
SAMPLE CONTROL DATA CARD

EFFECTIVE DATE: JUNE 30, 2009

MSD

Louisville and Jefferson County
Metropolitan Sewer District

CONTROL DATA

JEFFERSON COUNTY, KENTUCKY
KENTUCKY STATE PLANE COORDINATE SYSTEM,
NORTH ZONE

NO. OF STATION 28 X FB
ELEVATION OF STATION 456.244 (NAD 1983)
DATE STATION ESTABLISHED 2-1-93

1983 Horizontal Datum

N-Coordinate	**E-Coordinate**
1239123.1234	287912.5678

Grid Distance and North Azimuth to Objects Observed

Object	**Grid Distance – Ft.**	**North Azimuth**
29 X FB	1321.48	218°15'33"

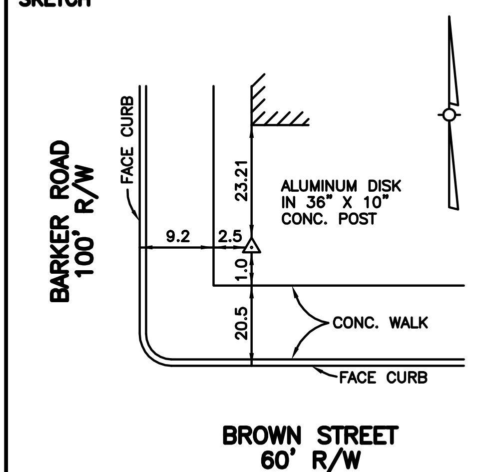
TRY AND MAKE OBSERVATION > 100'

DESCRIPTION AND REFERENCES:

Monument is aluminum disk set on a concrete post 36" X 10" flush with the ground.

To reach station from intersection Brown Street and Barker Road, City of Louisville, County of Jefferson, proceed 21.5' north of north face curb of Brown Street and 11.7' east of east face curb of Barker Road to aluminum disk set in concrete post.

SKETCH



Control set by: ____________ **Date** ____________

MSD Louisville and Jefferson County Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 6-3
SERVICE CONNECTION SURVEY FORM

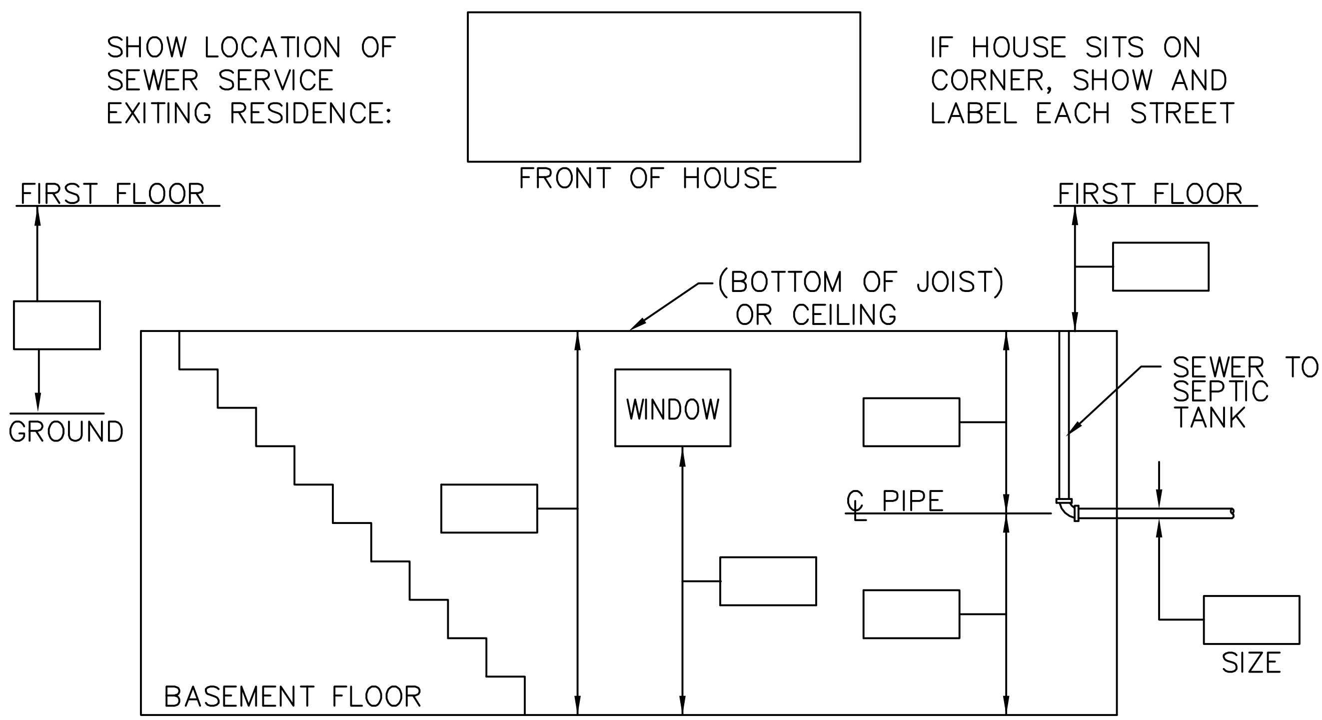
EFFECTIVE DATE: JUNE 30, 2009

____

PROPERTY OWNER: ______________________________

SHOW LOCATION OF SEWER SERVICE EXITING RESIDENCE:

IF HOUSE SITS ON CORNER, SHOW AND LABEL EACH STREET



TYPE OF STRUCTURE:

Basement ______ BiLevel ______ TriLevel ______ Slab on Grade ______ Crawl Space ______

Other ______________________________

BASEMENT FACILITIES:

			DISCHARGE TO: Septic Tank (Gravity)	Sanitary Pump
Sink	Yes ______	No ______	______	______
Shower	Yes ______	No ______	______	______
Toilet	Yes ______	No ______	______	______
Washer	Yes ______	No ______	______	______
Sump Pump	Yes ______	No ______	______	______
Sanitary Pump	Yes ______	No ______	______	______
Floor Drain	Yes ______	No ______	______	______
Other	Yes ______	No ______	______	______

COMMENTS: ______________________________

____

____

Date: ______________ Survey By: ______________

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CHAPTER 7
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CHAPTER 7
EASEMENTS

7.1 PURPOSE

All public sanitary sewers, storm drains, and open channels must be constructed in public rights-of-way, easements, publicly owned, or MSD- owned properties. No approval will be given for construction or improvement of any public sewer, storm drain, or channel without provision of suitable permanent easement or right-of-way. MSD will acquire and record all easements for MSD funded projects. The developer on private development projects will be responsible for acquiring all easements. Document recording will be the responsibility of MSD.

7.2 EXISTING EASEMENTS

Each existing easement to be used shall be shown on the plans submitted for review and approval. The information shown on the plans shall include the Deed Book and Page Number of the recorded instrument. All restrictive clauses as to the use of the easements, i.e., for utility purposes, drainage, sanitary sewers, etc., shall be noted on the plan adjacent to the pertinent easement. Construction of sanitary sewers or drainage systems will not be permitted in existing exclusive gas, electric, water, or telephone easements unless a sanitary sewer and Drainage Easement is acquired overlapping the existing easement with prior approval of MSD and the affected agency.

There are existing drainage easements in MSD's service areas. These drainage easements generally do not provide for the construction of sanitary sewers. In order to use these easements for sanitary sewer construction a new easement will be required to convert the existing Drainage Easement into a Sanitary Sewer and Drainage Easement. Construction plans and easement plats shall be prepared accordingly and the proposed new easement should be shown in the same manner as an entirely new easement.

The plats for Drainage Easements, in some cases, were recorded by previously assigned parcel numbers. The new plat converting these parcels will be assigned new parcel numbers. The parcel numbers for the existing Drainage Easements, as well as the Deed Book and Page Number or Plat Book and Page Number, shall be shown in the "remarks" column on the Property Acquisition Summary Sheet when these are available.

7.3 DEFINITIONS

The following terms define the methods under which MSD currently acquires interest in property for the purpose of constructing, operating, and maintaining wastewater treatment, drainage facilities and sanitary sewers:

7.3.1 Fee Simple Title

For the purpose of constructing major aboveground structures, MSD will normally acquire all rights to the required property in fee simple and permanently retain ownership. This generally refers to large pumping stations, wastewater treatment plant sites, and major detention basins.

7.3.2 Sanitary Sewer and Drainage Easement

For the purpose of constructing facilities (sanitary sewers, storm drainage systems, etc.), MSD will acquire the right to construct facilities within the limits of easements. They will have the right to operate and maintain those facilities within the same limits and also have reasonable ingress and egress over each affected property to the easements for construction, operation, maintenance and reconstruction. These easements are permanent in nature and are referred to as Sanitary Sewer and Drainage Easement. See Section 7.6 for the proper terminology to be used on easement plats and acquisition documents.

The limits of Sanitary Sewer and Drainage Easement shall be set for permanent structures. Existing structures shall not be within the easement area, unless the sewer construction actually requires the removal of such buildings or structures.

A property owner generally is restricted from constructing any facility within the limits of the easement that might interfere with the maintenance and operation of the facility.

7.3.3 Temporary Construction Easement

A temporary construction easement will be required adjacent to all new Sanitary Sewer and Drainage Easements when necessary for construction operations. Temporary construction easements shall be required for structure removal, access roads, stockpiling, and other construction activities when necessary. Structure removal includes the removal of treatment plants, pump stations, etc. Sufficient area shall be supplied for movement of equipment and materials to accomplish the intended activity within the Temporary Construction Easement. If at all possible, Temporary Construction Easements will not be acquired on adjacent private property when the proposed facility lies within a dedicated right-of-way or an existing Sanitary Sewer and Drainage Easement. Only under certain unusual conditions will a Temporary Construction Easement be acquired from a parcel if a new permanent easement is not being acquired from that same parcel. Accordingly, no plats shall be prepared showing Temporary Construction Easements only, without the prior approval of MSD. "Consent and Release" may be used in lieu of temporary easement. A "Consent and Release" form is shown on Exhibit 7-4. Temporary Construction Easement lines may be drawn through permanent structures; however, the Contract Documents shall contain language, which clearly indicates that all such permanent structures shall not be disturbed during construction. After the project is completed and the property is restored to its prior condition, all rights to the property are relinquished.

7.4 EASEMENT WIDTHS

Whenever possible, the total easement width, permanent and temporary, should be sufficient to permit the contractor to have flexibility in the method of construction.

<u>Suggested</u> minimum widths of Sanitary Sewer and Drainage Easements and Temporary Construction Easements using trench construction are tabulated below; however, <u>in no case shall these guidelines be a substitute for sound engineering judgement:</u>

Table 1. Minimum Easement Widths

Size of Pipe	Sanitary Sewer and Drainage	Temporary	Total
8" - 12" & Property Service Connections 8" or Less	15'	**20'** on each side	**55'**
15" - 48"	15'	20' on each side	55'
54" - 72"	20'	25' on each side	70'
84" and larger	30'	30' on each side	90'

7.5 CONSTRUCTION PLAN REQUIREMENTS

7.5.1 General

Construction plans shall be prepared in a manner, which will show clearly, and correctly, the information necessary for the acquisition of each parcel of land required. They must accurately show the location of each parcel and its relationship with surrounding areas. The alignment, as shown on the construction plans and easement plats, must agree with the alignment staked in the field. The information shown must be authentic and thoroughly checked since it will become legal evidence regarding the parcels of land required. The plans shall carry appropriate certifications and seals indicating that the surveying has been accomplished under the supervision of a Land Surveyor registered with the Commonwealth of Kentucky. They shall also meet the Minimum Standards of Practice for Land Surveying in Kentucky and the following guidelines:

a. An effort should be made to parallel property lines with the facility when topographic features permit.

b. Easements shall be referenced to property corners and/or known landmarks to the degree that they can be accurately reestablished prior to construction.

c. In residential areas, all topographic features, such as trees, shrubs, sheds, etc., which are located within the easements shall be properly identified on the plans. When undeveloped wooded areas are encountered, only those trees of unusual size or nature need to be specifically identified on the plans. Any items within these easements, which are definitely not to be disturbed during the construction, shall be clearly noted "Do Not Disturb" (DND). Items, which remain, but disturbance is necessary for construction shall be noted "Do Not Remove" (DNR).

7.5.2 Easement Description Criteria

The construction plans shall show the following information for each parcel from which easements are to be acquired:

a. Property owner's name of record, address, and spouse's name, if married. If a Property Acquisition Summary Sheet is included in the plans, this requirement will not apply.

b. Subdivision name, section number and lot number (when a deed has not been recorded) or Deed Book and Page Number.

c. Existing rights-of-way and easements.

d. Existing Sanitary Sewer and Drainage Easements, their Deed Book, Page Number, and MSD Record Number, if available.

e. Property lines with label.

f. Parcel numbers.

In addition, the Deed Book and Page Number for the new easement shall be added to the plans when the information is made available by MSD. Therefore, the abbreviations "D. B. and Pg." shall be added to the plans adjacent to the new easement with enough space to the right of each for this information to be added at a later date.

7.6 EASEMENT PLAT CRITERIA

7.6.1 General

Sanitary Sewer and Drainage Easements

Easement plats shall be prepared for each property having a Sanitary Sewer and Drainage Easement or other type of acquisition. The phrase "Sanitary Sewer and Drainage Easement" shall be used on all plats and acquisition documents. Easement plats, in general, shall be prepared on 8.5" x 14" sheets. A sample plat can be found on Exhibit 7-1.

All plats shall have the title block in the lower right corner of the plat and the Land Surveyor's Certification and Seal in the lower left corner. No other format should be submitted and none will be accepted.

Permanent easement on all plats is to be hatched for clarity. Temporary easements are not to have hatching, cross-hatching, or shading.

Release of Existing Easements

Any release of easement is to have its own plat and the area of easement to be released is to be crosshatched. No plat containing both easement dedication and release of easement will be accepted. The MSD Director of Engineering must approve the release of easement and the applicable fees must be paid. All other requirements of easement plats shall apply to easement release plats. A sample “Release of Easement Plat” is shown on Exhibit 7-2. The easement release (“Quitclaim”) requirements and procedures are found on the MSD web page.

Encroachment Plats

On occasion a permanent structure is found to be, or required to be, encroaching upon an existing easement. In such situations, an easement encroachment plat must be prepared and recorded. A sample plat is shown on Exhibit 7-3.

Easement plats should contain sufficient information to enable a Land Surveyor to locate and stake the easements in the field.

7.6.2 Plat Information

The "Easement Plat Checklist" indicates the plat requirements and should be referenced prior to all submittals to MSD. It is located on the MSD web page.

7.6.3 Property Service Connection Easement

Occasionally, a Sanitary Sewer may be located such that the permanent easement does not extend to the property line of an adjacent property to be served with a proposed property service connection. This occurs due to topographic or geographic considerations such as parallel streams. In these instances, a 15' Sanitary Sewer and Drainage Easement shall be provided from the proposed service facility easement to the property line at the most likely location of the property service connection. Sufficient Temporary Construction Easement shall also be depicted.

7.6.4 Easements on Railroad Rights-of-Way

Sanitary Sewer and Drainage Easements may be acquired on railroad rights-of-way. However, acquisition of easement on a railroad right-of-way does not eliminate the requirement of submitting a Railroad Crossing Conflict Drawing to MSD for approval of conduits crossing under rails of the affected railroad.

7.6.5 Certificates

A Certificate of Easement, Certificate of Easement Release, or Certificate of Encroachment Agreement, as applicable, must be made a part of each easement plat submittal. The certificate forms are available on the MSD web page.

It is the responsibility of the Land Surveyor to attach the proper certificate to each easement plat submitted. No changes in the format of these certificates by the Land Surveyor shall be permitted.

7.6.6 Submission

After the easement requirements have been defined, one set of preliminary plats shall be submitted for review. After incorporating any review comments, the final submittal will be in the following form:

- The original of each plat, signed in ink.
- One copy of each plat.
- One copy of each plat with the appropriate easement certification sheets attached.

Copies of all easement plats submitted shall be clearly legible and shall be made on bond, or better grade, paper using an electrostatic or equivalent copier utilizing a dry process. Plats submitted that are not clearly legible or do not meet the above requirements, will not be accepted.

Easement plats submitted shall contain a Land Surveyor's original stamp, signature and date. If MSD makes any changes or modifications to the final plans after they have been accepted by MSD, the Land Surveyor will receive a copy of the revised sheets. If any changes or revisions are necessary on the easement plats, the Surveyor shall be notified and must make the necessary revisions and resubmit the plats as previously described.

Easement location and requirements shall be determined as early as possible on all projects in order to initiate the acquisition procedures as early as possible. The estimated number of easement plats used in determining easement plat cost during the proposal period shall be given to the Acquisition Department. Adherence to this procedure should minimize the possibilities of project delays due to unavailability of required easements.

7.7 PROPERTY ACQUISITION SUMMARY SHEET

Certain property data shall be shown on the Property Acquisition Summary Sheet, as well as on the construction plan sheet and easement plat. However, a separate Property Acquisition Summary Sheet will not be required if a project has five parcels or less. In such instances, the property acquisition information in the same format may be placed on the Plan Sheet Index, on the first plan sheet if adequate space is available, or be included in the plan index on the cover sheet.

An example of the layout for the Property Acquisition Summary Sheet is shown on Exhibit 4-15. The Property Acquisition Summary Sheet shall show the following data for each parcel required for right-of-way purposes:

7.7.1 Parcel Number

Parcel numbers shall be assigned to each parcel of property to be acquired and shown on the plans. Parcel number 1 shall be assigned to the first parcel, and the remaining parcels shall be numbered consecutively from the beginning to the end of the project. Parcel numbers shall not be assigned to publicly-owned rights-of-way; however, they will be required for privately-owned rights of way, such as Louisville Gas and Electric Company, AT&T, Riverport Authority, railroad companies, private roads, etc.

Parcel numbers assigned to each tract shall not be changed after submission of the final easement plats. If it is then determined that acquisition from any parcel will not be required, that number shall be removed from the plans and the notation "NOT USED" shall be placed in the owner's block on the Property Acquisition Summary Sheet.

7.7.2 Owner's Name

The name of the current owner of the property and address, at the time of the preparation of the plans, shall be shown. These can be obtained from the Louisville and Jefferson County Property Valuation Administration Office. Final changes to the Property Acquisition Summary Sheet will be made when the property is being acquired.

7.7.3 Property Address

The address of the property served shall be shown. Should the owner's mailing address differ from that of the property, the owner's mailing address should be shown in the remark's column.

7.7.4 Plan Sheet Number

The sheet number is the number assigned to the plan sheet on which the particular parcel is shown. Some parcels, of course, will appear on more than one plan sheet and all sheet numbers must be included.

7.7.5 Source of Title

This column shall show the Deed Book and Page Number of the parcel or the subdivision name, section number and lot number when a deed has not been recorded, or such other evidence of title information as may be available.

7.7.6 Total Area of Tract

The total area of the tract from which an easement is being obtained shall be shown in either acres or square feet in the appropriate column. In general, the area of subdivision tracts shall be shown in square feet, while the area of larger tracts, generally more than an acre, shall be shown in acres.

7.7.7 Area of Easements

The area required for a Sanitary Sewer and Drainage Easement shall be shown in square feet or acres in the appropriate column. The area required for a Temporary Construction Easement shall be shown in square feet or acres in the appropriate column. Areas shall be shown to the nearest square foot or one-thousandth of an acre as appropriate.

The easement areas required on the Property Acquisition Summary Sheet shall generally be shown in square feet for easements of one acre or less and shown in acres for easements of more than one acre.

7.7.8 Permanent Easement

The Deed Book and Page Number of the newly recorded easement will be entered in the appropriate columns by MSD or the Design Engineer if the information is available prior to the submittal of final plans.

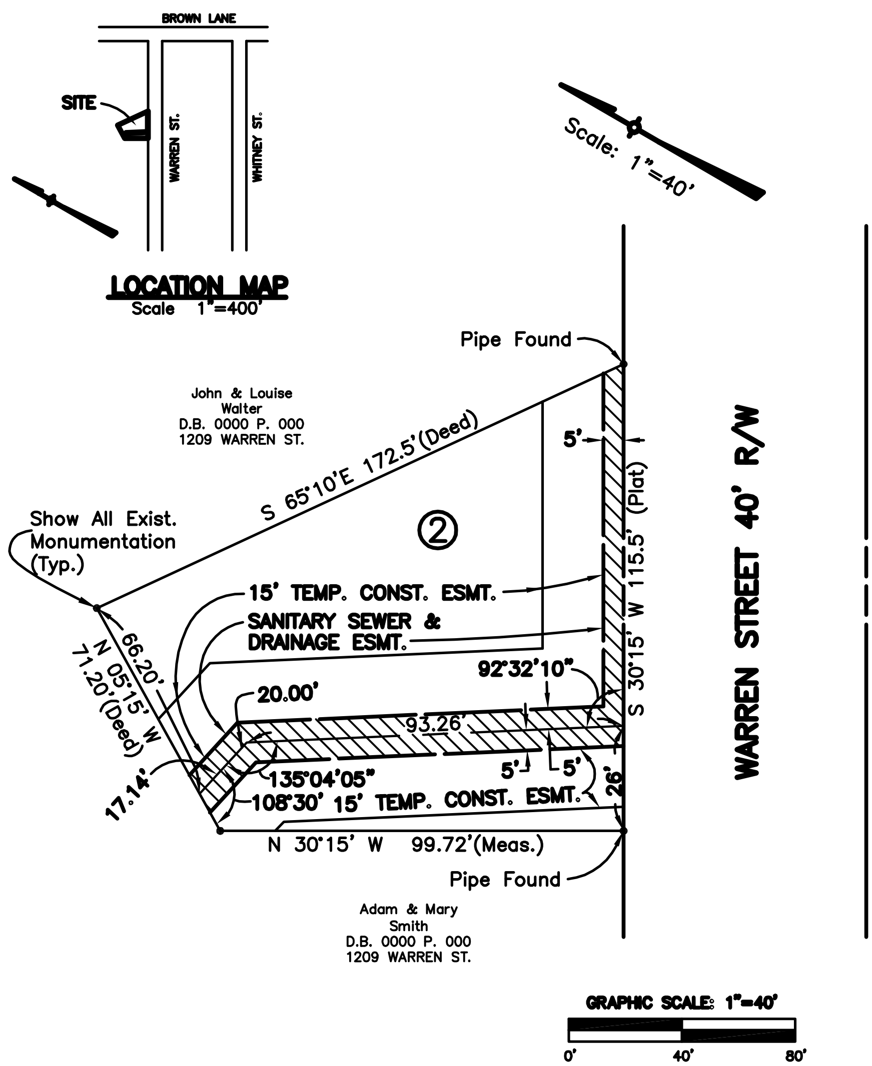
MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 7-1
SAMPLE SEWER & DRAINAGE EASEMENT PLAT

EFFECTIVE DATE: JUNE 30, 2009



PERMANENT EASEMENT = 1,502.5 SQ. FT.
TEMPORARY CONSTRUCTION EASEMENT = 4,506 SQ. FT.

The reference meridian used on this plat to determine the directions of survey lines was based on the deed bearing of the NORTH line of the tract.

Being a part of the same property conveyed to the GRANTOR by deed dated January 1980, recorded in Deed Book 4911, Page 125, in the office of the Clerk of the Jefferson County Court.

Tax Block ____________ Lot No. ____________

SAMPLE ENGINEERING COMPANY
&
ADDRESS/PHONE NO.

LAND SURVEYOR'S STAMP

I hereby certify that this plat was made under my supervision and is correct to the best of my knowledge and belief. Distances as shown on this plat have not been adjusted for closure. This easement Plat meets or exceeds the minimum standards of governing authorities.

LAND SURVEYOR'S SIGNATURE ____________ Surveyor

SANITARY SEWER & DRAINAGE EASEMENT

Property of
TOM & JANE POWERS
2001 GREEN CIRCLE WAY
LOUISVILLE, KY. 40218

Property Address
DICK & JANE DOE
1207 WARREN STREET
LOUISVILLE, KY. 40220

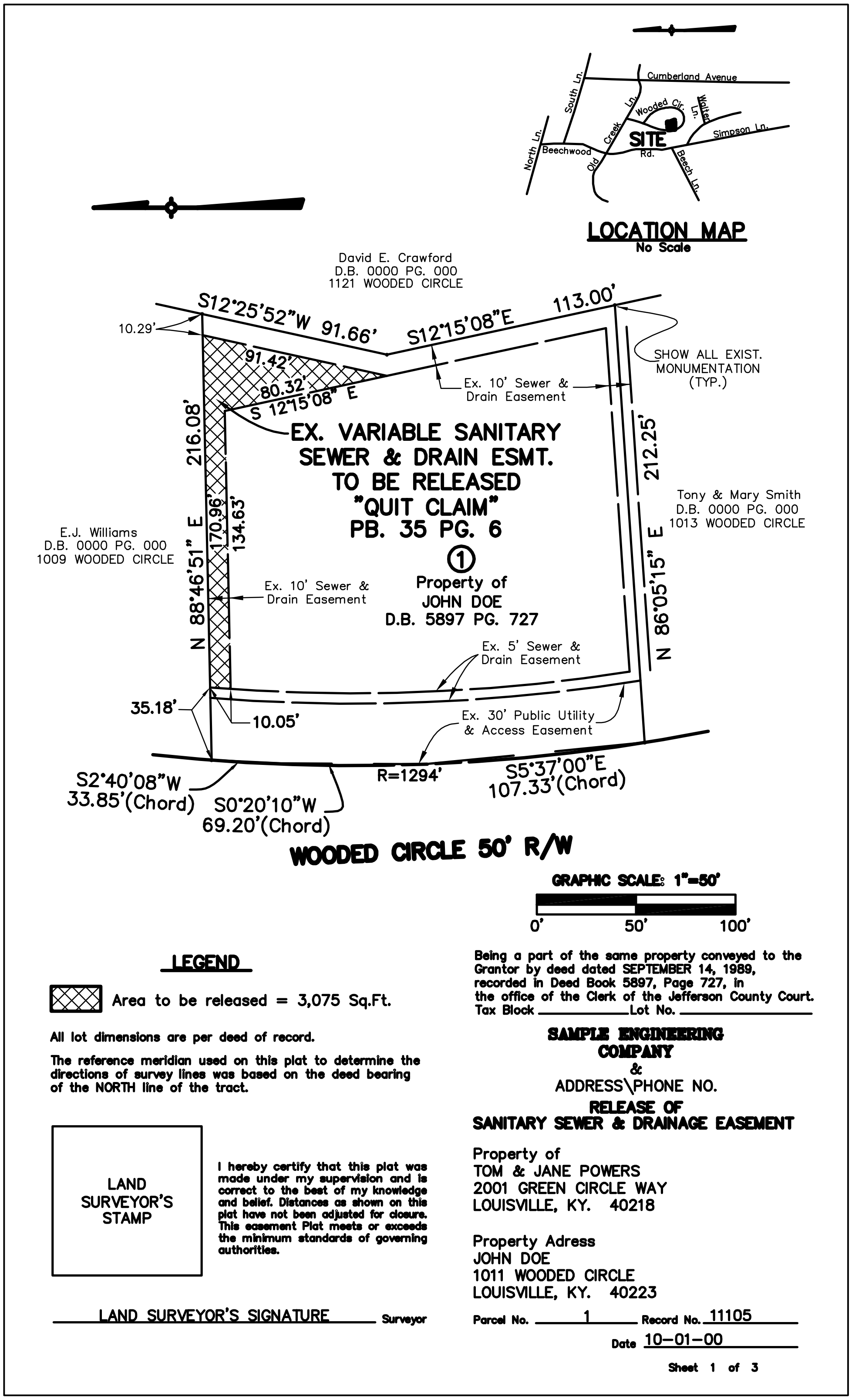
Parcel No. 2 Record No. 5199

Date 10-01-00

Sheet 1 of 3

EXHIBIT 7-2
SAMPLE RELEASE OF EASEMENT PLAT

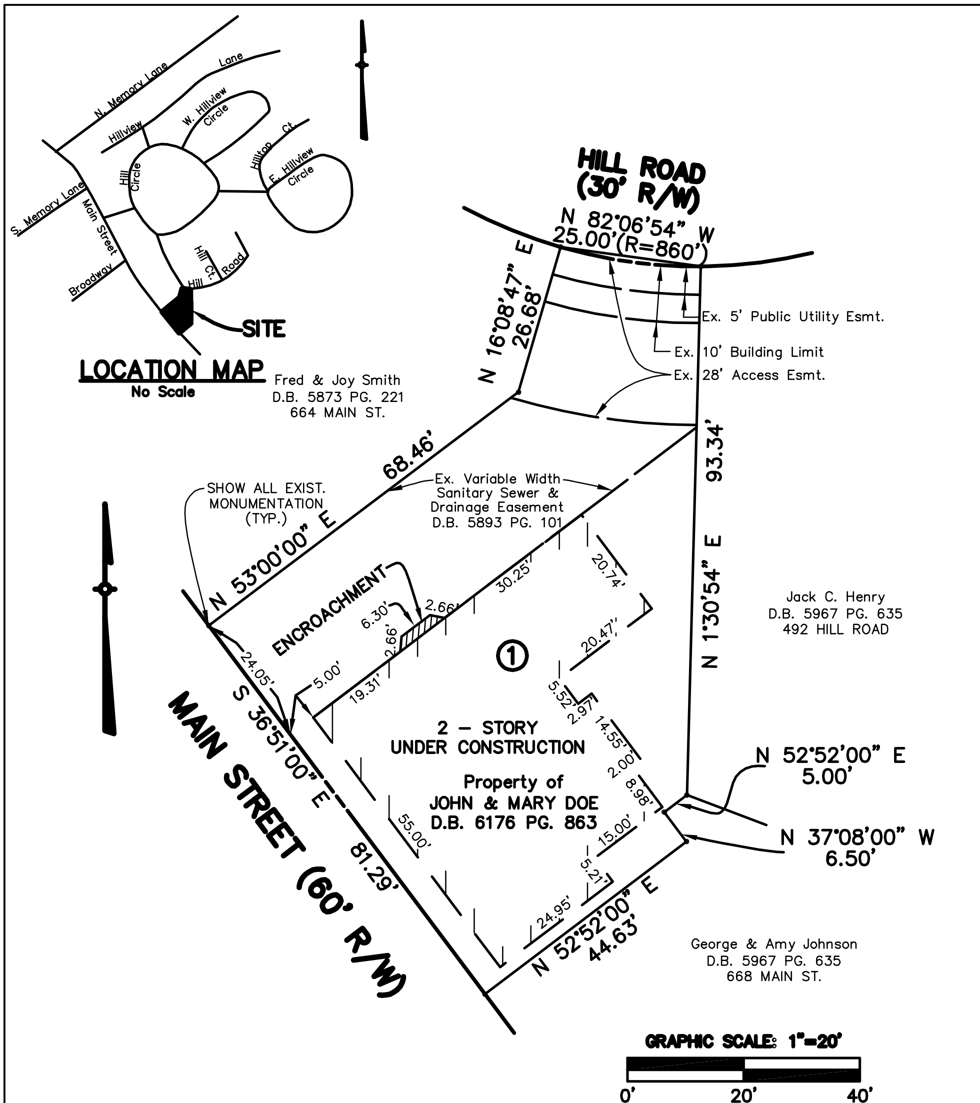
EFFECTIVE DATE: JUNE 30, 2009



MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 7-3
SAMPLE EASEMENT ENCROACHMENT PLAT

EFFECTIVE DATE: JUNE 30, 2009



LEGEND

Area of Encroachment 16.24 Sq.Ft.

All lot dimensions are per deed of record, unless noted.

The reference meridian used on this plat to determine the directions of survey lines was based on the deed bearing of the NORTH line of the tract.

Being a part of the same property conveyed to the Grantor by deed dated AUGUST 2, 1985, recorded in Deed Book 6176, Page 863, in the office of the Clerk of the Jefferson County Court.
Tax Block ________ Lot No. ________

SAMPLE ENGINEERING COMPANY
&
ADDRESS\PHONE NO.

LAND SURVEYOR'S STAMP

I hereby certify that this plat was made under my supervision and is correct to the best of my knowledge and belief. Distances as shown on this plat have not been adjusted for closure. This easement Plat meets or exceeds the minimum standards of governing authorities.

EASEMENT OF ENCROACHMENT

Property of
TOM & JANE POWERS
2001 GREEN CIRCLE WAY
LOUISVILLE, KY. 40218

Property of
JOHN & MARY DOE
666 MAIN STREET
LOUISVILLE, KY. 40211

LAND SURVEYOR'S SIGNATURE Surveyor

Parcel No. 1 Record No. 6100
Date 10-01-00
Sheet 1 of 3

MSD Louisville and Jefferson County Metropolitan Sewer District 700 W. Liberty Street Louisville, Kentucky 40203-1913 502-587-0603 — WWW.MSDLOUKY.ORG	EXHIBIT 7-4 SAMPLE CONSENT AND RELEASE FORM EFFECTIVE DATE: JUNE 1, 2009

CONSENT AND RELEASE

This Consent and release made and entered into this _______ day of _______, 20____, by and between ______________________________, parties of the first part, and

Metropolitan Sewer District

WHEREAS, the Metropolitan Sewer District deems it necessary to perform the following work in order to improve the storm drainage for the following described property, and

WHEREAS, the parties of the first part, being the owners of said property and desirous of having said work performed.

Address of Property: ____
____

Description of Work: ____
____
____

NOW THEREFORE, in consideration of the benefits accruing to said property, the parties of the first part hereby consent and agree that Metropolitan Sewer District. its agents, employees and assigns may enter ant come upon the above described property for the purpose of performing the work as described above and further expressly agree that the parties of the first part will assert no claim whatsoever, of any kind or type, against Metropolitan Sewer District, its agents, employees or assigns by reason of the performing of said work, but by these presents shall be forever barred except that Metropolitan Sewer District shall be liable for any damage to persons or property which results from its acts or omissions during the course of the project as it is performed on party of the first part's property and which occurs during such performance.

IN TESTIMONY WHEREOF, witness the signatures of the parties this _________ day of _______________, 20____.

PROPERTY OWNERS

____
Party of the First Part

____
Party of the First Part

BY: ______________________________
Louisville and Jefferson County..
Metropolitan Sewer District.

(Provide one copy for property
owner and one copy for MSD files

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CHAPTER 8
SANITARY SEWER SYSTEMS
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CHAPTER 8
SANITARY SEWER SYSTEMS

8.1 PURPOSE

This chapter establishes the minimum standards and technical design criteria for sanitary sewer systems in the MSD service area. Adherence to these will expedite review and approval of plans. Hydraulic design presented herein represents acceptable procedures not necessarily to the exclusion of other sound and technically supported design procedures. Any departure from these design requirements should be brought to the attention of MSD before submission of plans for approval and should be justified and documented. Sanitary sewer plan preparation for private development must conform to Chapter 9 requirements and in all cases plan development shall conform to the Chapter 12 EPSC requirements.

8.2 BASIC ELEMENTS

The design of sanitary sewers basically consists of the determination of the following:

a. The location of the horizontal alignment, which most efficiently provides service to existing and potential users.

b. The vertical restrictions on establishing the sewer alignment including: depths required to serve users, minimum cover, elevations of other sewers in the system, conflicts with other underground facilities, solid rock considerations, and maintaining the required hydraulic gradients.

c. The design flow generated by the existing and future users, which must be transported by the sewer.

d. The size, material, bedding and method of construction required.

e. The necessary appurtenances and special structures required.

8.3 GENERAL LOCATION CRITERIA

Sewers shall be located using sound engineering judgment to determine the most cost-effective and environmentally sensitive alignment that best serves the needs of the entire tributary area. Additionally, it is imperative that all alternatives worthy of consideration receive maximum and equal consideration with regard to environmental impact. The costs and acquisition time for easements can be significant; therefore, sewers should be located within existing easements and rights-of-way whenever feasible and practical. Sewers designed within existing pavements shall be located 5 feet from the edge of pavement on the side opposite the existing water main. Sewers designed within the rights-of-way of proposed streets and highways shall be located in the center of **one of** the proposed **traffic lanes** whenever possible. When the proposed street or highway has a curved alignment, an effort shall be made to locate the sewer a minimum of 5 feet inside the edge of pavement, unless exceptional considerations dictate to the contrary. When selecting the sewer alignment, consideration should be given to the following general location criteria:

a. Elevation requirements necessary to provide appropriate service with due consideration of sanitary facilities in basements.

b. For protection of the environmentally sensitive areas and constraints such as creeks, wetlands, trees, protected habitats, etc.

c. Existing utilities, railroads, highways, and overhead facilities.

d. Location of other existing and proposed sewerage and stormwater facilities.

e. Property values, easement needs and potential damages to the affected properties.

f. Existing and proposed high water elevations, including high water for appropriate design periods.

g. Anticipated extension of existing streets and the potential for the development of contiguous areas.

h. Continuity with adjacent design segments.

i. Maintenance of traffic.

j. Availability of materials.

k. Foundation conditions.

l. Construction cost.

The location of proposed sanitary sewers should also meet the intent of the Kentucky Administrative Regulations, specifically title 401 KAR 5:005 – "Permits to Construct, Modify, or Operate a Facility", Section 7 (Design Considerations), Paragraphs 14 and 15.

8.4 HORIZONTAL ALIGNMENT CRITERIA

8.4.1 General

With the exceptions noted hereafter, all sewers shall be constructed with a straight alignment between manholes. For alignment changes in sewers 36 inches in diameter and larger, curved monolithic sewer sections with a radius equal to four times the diameter of the sewer may be required.

8.4.2 Straight Streets

Generally, sewers shall be located in the traffic lane on the opposite side of the street from the water main and at least 10 feet from the water main; however, the centerline of the sewer should be a minimum of 5 feet from the edge of pavement. Extraordinary circumstances may require placing the sewer closer to the edge of pavement, but every effort shall be made to place the entire manhole frame and cover entirely within the pavement. In areas where this location will conflict with gas and water valves or other utilities, the sewer location shall be adjusted to avoid these conflicts. Consideration of other factors, such as the width of the pavement, depth of rock, and possible conflict with other utilities, will still be required so the sewer can be built without modification during construction. In areas where concrete pavement is encountered, consideration shall be given to placing the sewer in a location whereby one edge of the pavement to be removed would coincide with existing construction joints, which are generally in the centerline of the streets. This procedure would require that only one side of the pavement would have to be sawed for removal. In areas where lots slope abruptly away from the street, consideration shall be given to locating the sewer near the property line on the low side.

8.4.3 Curved Streets

The sewer line may be located outside the pavement if such an alignment proves to be cost-effective. The manholes may be either within the pavement or completely outside the pavement, but shall not be partially in the pavement. The existence of curbs shall be considered in evaluating the benefit of reducing the number of manholes in curved streets. In all cases, the centerline of the manhole shall be a minimum distance of 3 feet from the edge of pavement, and a minimum distance of 5 feet inside the street right-of-way line.

8.4.4 Curve Data

Curve data, based on the arc definition, shall be used for all curved monolithic sewer segments. The curve data shall be shown on the plans near the respective curve (preferably on the inside of the curve) in the following manner:

P.I. Sta. = 10+00.00	(Point of Intersection Station)
$\Delta = 35° 30' 00''$ Lt.	(Delta Angle)
$D = 409° 15' 20''$	(Degree of Curve)
$L = 8.67'$	(Length of Curve)

R = 14.00'	(Radius)
T = 4.48'	(Tangent Length)
P.C. Sta. = 9+95.52	(Point of Curvature Station)
P.T. Sta. = 10+04.19	(Point of Tangency Station)

8.4.5 Stationing

All sewer stations shall increase upstream. Every effort shall be made to begin the stationing of a sewer with Station 0+00.00 at the downstream end. When an existing sewer is to be extended, the stationing should be continued from the end of the existing sewer whenever possible. For sewers not requiring curved sections, the PI stations and deflection angles or interior angles shall be shown on the plans at all changes in alignment. The arc and tangent lengths of curved sections shall be used in determining the sewer alignment stationing.

8.4.6 Sewer Designations

The designation of the first sewer in a collection system shall be LINE "A". The next sewer upstream contributing to LINE "A" shall be designated LINE "B", and the station of LINE "B" at this point shall be Station 0+00.00. This method shall continue throughout the collection system and subsequent sewers shall be assigned appropriate designations by ascending letters. Lines beyond LINE "Z" shall continue with double letter designations starting with LINE "AA", "AB", etc. For very short segments not extending beyond one manhole, designations such as LINE "B-1" will be allowed.

8.5 VERTICAL ALIGNMENT CRITERIA

8.5.1 Sewer Depths

Sanitary sewers shall have a minimum cover of 4 feet in easements and a minimum cover of 5 feet in rights-of-way. Specific exceptions to these minimum requirements may be made with prior approval by MSD.

In developed areas, the criteria, found in Exhibit 8-2, should be used to establish the flow line of the sewer unless otherwise directed by MSD. The "Service Connection Survey" form, found on Exhibit 6-3, should be used when determining the controlling elevations of a sanitary sewer line. In instances where only a few houses on a sanitary sewer have existing basement facilities, the impact on the entire system shall be considered prior to providing gravity basement service. Additionally, in areas having substantial amounts of solid rock, consideration shall be given to the omission of basement service. This omission must be approved in writing by MSD.

In establishing the elevation of the proposed sanitary sewer, the elevations of existing or proposed interceptor sewers or the elevations of inflow pipes to existing pump stations or wastewater treatment plants and all other utilities shall be considered.

A minimum cover of 2 feet shall generally be maintained when crossing under existing streams, existing ditches, and existing or proposed channel improvements **and storm sewers**, provided the sanitary sewer line is encased in concrete **(or capped if approved by MSD)**. With respect to streams, restoration of the channel invert will conform to the applicable standard drawings (EC-01-01, EC-02-01, or EC-03-01).

The sanitary sewer elevation necessary to serve the entire tributary area shall be considered in establishing the upstream flow line of any sanitary sewer segment including the area beyond the boundary of a design section.

A separate parallel sanitary collector sewer shall be considered in lieu of individual property service connections into the interceptor sewer in areas where the sanitary interceptor sewer reaches excessive depths. The collector sewer, at a higher elevation, should end in a drop manhole or vertical stacks into the interceptor sewer. A cost-effectiveness study shall be submitted to MSD for review and approval.

8.5.2 Sewer Gradients

All sewer gradients shall be referenced to the **North American** Vertical Datum of 19**88**. When connecting into or extending existing sewer facilities that were constructed using another datum, an elevation equation should be shown on the plans. The hydraulic criteria, established in Section 8.9, should be used to determine sewer flow line elevations in manhole structures and curved segments of the sewer.

8.5.3 Flooding and Ponding Areas

In general, the top of sanitary manhole elevations shall be a minimum of 2 feet above existing, proposed, or projected 100-year high water elevations. However, when this minimum elevation causes the manhole to be above the natural ground creating obstructive mounds, the top of the manhole elevation shall be lowered to the natural ground elevation and a watertight manhole lid and frame shall be specified.

8.5.4 Minimum Water Main Clearances

The following minimum clearances between the sewer and existing or proposed water mains shall be used in establishing the sewer alignment:

8.5.4.1 Horizontal Clearance

The horizontal clearance shall be 10 feet minimum. Where this is not possible, the Design Engineer should reference the "Ten State Standards" Section 38.31 **(2004 Edition).**

8.5.4.2 Vertical Clearance

The vertical clearance shall be at least 18 inches. If at all possible, the sewer shall be located below the water main. Should it become necessary for the sewer to cross over the water main, special precautions and exfiltration testing of the sewer will be required. Such cases shall require written approval by MSD.

8.6 GENERAL PROCEDURES

The design flow for each segment of the sewer system shall be determined as the following:

a. Prepare a Drainage Map, which defines the area’s tributary to each element of the sewer.

b. Examine each area to determine its potential land use and equivalent population.

c. Determine the average daily flow based upon the equivalent population.

d. Determine the design or peak flow based upon the average daily flow and the appropriate peaking factor.

8.7 DRAINAGE MAP REQUIREMENTS

A Drainage Map shall be prepared showing the actual area to be served by the proposed project, the location of the sewers, the portion of the project area tributary to each individual sewer element, and any points of inflow which contribute additional flow from adjacent areas. The Drainage Map shall be prepared on a standard size sheet at an appropriate scale to show the entire project and adjacent future contributing areas. Two or more sheets may be used for large-scale projects. A sample Drainage Map is shown on Exhibit 4-13. The purpose of the Drainage Map is to graphically depict the basis for the design flow calculations. The Drainage Map and design calculations shall be presented for review with submittal of the preliminary and construction plans. The minimum specific information required includes the following:

a. A key map showing the general location of the project area, including any areas not within the project area that contributes to the proposed system.

b. A general layout of the proposed system with the drainage area tributary to each major element of the system defined.

c. The basis for determining the number of existing and future users and the equivalent population for each drainage area: i.e., the number of single-family or multi-family dwelling units; type and size of existing commercial, industrial and institutional users; and the number of acres of undeveloped land by zoning classification.

d. A zoning designation, such as M-1, for each drainage area.

e. A designation for each sewer line.

f. A numbering system for manholes, which shall be added to the computation sheets.

g. All proposed sewer sizes.

h. The location of estimated or actual flow entering the proposed system from outside areas, developed or undeveloped. These areas are to be shown in entirety on the Drainage Map and shall include the same types of information required for the proposed service area.

i. An adequate number of spot elevations must be obtained in areas of undeveloped land to show the natural drainage of the area if necessary.

j. LOJIC maps may be used to prepare the Drainage Map.

k. An indication of the existing system's ability to receive the proposed flow with sufficient capacity.

8.8 DESIGN FLOW

8.8.1 Collector Sewers

Collector sewers are primarily installed to receive wastewater directly from property service connections. A major change in land use within a tributary area can have a significant impact on the collector system's ability to transport the necessary flow. Collector sewers should be designed to transport the saturation population flow, which might be expected during their service life (flowing full). The appropriate equivalent population and design flows should be calculated as described in Sections 8.8.3 and 8.8.4.

8.8.2 Interceptor Sewers

An interceptor sewer is a principal sewer to which collector sewers are tributary. All interceptor sewers should be designed for saturation population (flowing full) unless otherwise directed by MSD.

For a major industrial water user or for undeveloped industrial land in the tributary area, MSD will generally specify the estimated average daily flows in determining the equivalent population (refer to Exhibits 8-2 and 8-3). Otherwise, a flow of 10 persons per acre shall be assumed for all industrially zoned land, except in areas where specific reliable information is available to more correctly analyze the anticipated flows.

8.8.3 Equivalent Population Sewer Design

8.8.3.1 Current Equivalent Population

A current equivalent population estimate shall be made using the most current aerial photographs or LOJIC maps, a field inventory, or other data sources. The equivalent population per unit factors, as shown in Exhibit 8-2, shall be combined with the land use categories of the tributary area. The factors are then multiplied by the unit count of each land use category to determine the equivalent population.

8.8.3.2 Future Equivalent Population

An estimate of the equivalent population for future development, which can reasonably be expected, shall be made and added to the current equivalent population for each drainage area (see appropriate Action Plan provided by MSD). The equivalent population for the remaining developable land shall be determined by multiplying the number of acres of land in each zoning category by the equivalent population per acre factors given in Exhibit 8-3. Design recommendations should be made relative to the land's potential development if a variance from the standards established in Exhibit 8-3 is suggested.

8.8.4 Design Flows

a. **Design** Average Daily Flow =
100 Gallons/person/day x Total Equivalent Population

b. Design Peak Design Flow =

Design Average Daily Flow x Peaking Factor (Exhibit 8-4)

8.9 HYDRAULIC DESIGN CRITERIA

8.9.1 General

Manning's Equation shall be used to determine proper pipe size and slope to transport the design flow. Design shall be for full flow at saturation conditions with the following characteristics:

a.	Roughness coefficient – n	= 0.013 (Sanitary Sewers Only – Ten State Standards)
b.	Minimum velocity – v	= 2 feet/second
c.	Minimum pipe size – D	= 8 inches
d.	Minimum allowable slopes	= (See Exhibit 8-5)

8.9.2 Hydraulic Grade Line

The hydraulic grade line should not rise above the crown of the sewer pipe. When critical, the hydraulic grade line shall be computed to show its elevation at manholes, transition structures, and junction points of flow in pipes and provide for the losses and the differences in elevation. If velocity entering a manhole is above critical, the hydraulic grade line must be computed to ensure that no service connections are surcharged. The pipe exiting the manhole must be adjusted in elevation to ensure that the energy gradient remains level across the manhole.

8.9.3 Velocity

All sanitary sewers shall be designed to carry the design flow at a minimum velocity of 2.0 ft/s (Reference paragraph 8.9.4 for exceptions). The maximum allowable design velocity shall be 15 ft/s based on the design flow. When severe topographic or unusual conditions require a design velocity greater than 15 ft/s, the hydraulic design and pipe material must be approved in writing by MSD.

8.9.4 Minimum Slopes

The minimum allowable slopes will be as required to obtain the minimum velocity as required in Section 8.9.3 above. In no case shall the slopes be less than those identified in Exhibit 8-5 (stubs shall have a minimum slope of 0.005 ft/ft). Note – For 8" pipe the minimum slope is 0.007 ft/ft (based upon pipe at one-fourth full depth) in cases where the minimum required velocity, at design flow, cannot be achieved at a lesser slope.

8.9.5 Sewer Size Changes

Sewer size changes shall only take place within a manhole or junction box structure. To ensure that the energy gradient is maintained, use the following:

a. Pipes 24" in Diameter or Smaller

1. When increasing the sewer size by 6 inches or less, crown elevations shall match at the centerline of the manhole.

2. When increasing the sewer size by more than 6 inches, the springlines of the smaller and larger sewer shall match at the centerline of the manhole. However, **if** the hydraulic design calculations **show unacceptable losses resulting in a surcharge condition**, the Design Engineer **may** match crown elevations at the centerline of the manhole by raising the elevation of the smaller sewer.

b. Pipes 27" in Diameter or Larger

Manholes or junctions involving sewers 27 inches or larger shall first be designed by matching the crown elevation at the centerline of the structure. The **hydraulic grade line shall then be determined. If the HGL shows a surcharging condition, the downstream pipe may be lowered as needed.**

8.10 HYDRAULIC COMPUTATIONS

Exhibit 8-1 is a sample computation sheet for designing interceptor and collector sewers. The procedure used in completing this form can be found at the bottom of the Exhibit. Blank computation sheets are available on the MSD web page and may be used for the computations. This computation sheet, or similar form, shall be submitted with the plans for review.

8.11 SEWER PIPE

a. The minimum allowable inside diameter for sewer pipe, other than property service connections, shall be 8 inches. All property service connections shall have a minimum inside diameter of 4 inches; however, commercial or industrial connections shall be individually considered with the minimum size of 6 inches.

b. **Pipe material will be selected from the products identified in the MSD Standard Specifications. Alternate products can be specified by the designer, but prior approval from MSD will be required. Designers will indicate “pipe” on the plan unless a particular product or group of products has been**

identified and the decision can be justified. Approved products from the specifications that are not advantageous for a particular project and <u>not allowed</u> will need to be identified in the Contract (must be approved by MSD).

c. Pipe testing and bedding requirements shall be in accordance with the MSD Standard Specifications, except for unusual conditions requiring special design and specifications.

d. Backfill classifications, materials, and methods of compaction shall be in accordance with MSD Standard Specifications, except in unusual conditions requiring special design and specifications.

e. All sewers shall be designed to prevent damage from superimposed loads during and after construction. Proper allowance for loads on sewers shall be made, based on trench width and depth. When standard strength sewer pipe is not sufficient, extra strength pipe or special construction methods shall be specified. Live and dead loads shall be determined for all sewers and calculations submitted to MSD for review. Dead load, live load and impact loading requirements must be met in the selection of pipe materials and installation methods.

f. Sewers 60 inches in diameter and larger shall be designed using the "D" loading method as specified in the "Concrete Pipe Design Manual" published by the American Concrete Pipe Association, latest revision. The cost savings using the actual "D" loading is required to meet the structural requirements, rather than standard class pipe and should be examined. If substantial cost savings can be realized, the actual "D" loading of the pipe required shall be specified and shown on the plans. However, the "D" load design shall be limited to increments of 200 feet or more, and should not vary between manholes unless unusual conditions exist. The "D" load design shall be based on a trench width approved by MSD prior to the actual design.

8.12 MANHOLES

8.12.1 Manhole Locations

Manholes shall be required at the following locations:

a. Changes in sewer grades or alignment (except approved curvilinear alignments)

b. Sewer junctions.

c. Where required, not to exceed the maximum manhole spacing.

d. Changes in sewer diameters

e. The location of the terminal manhole in each sewer line should be based on many factors including manhole spacing, driveway locations, the position of improvements on the lots being served, and the location of temporary sanitary facilities, such as septic tanks. A definitive single policy cannot be established for all circumstances, although the sewer line would normally terminate in the vicinity of the downstream property line.

f. Where vertical stacks connect to large (>48 inches) sewers an additional manhole or cleanout (if connecting sewer is 6 inches) shall be required approximately 5 feet from the stack.

8.12.2 Maximum Manhole Spacing

Size of Sewer	Distance
8" to 15" diameter	400'
18" to 30" diameter	500'
Over 30" diameter	600'

When certain conditions warrant, such as the elimination of a manhole, the manhole spacing can be exceeded with the approval of MSD and DOW.

8.12.3 Diameter

The minimum diameter of manholes shall be 48 inches, although larger diameters are necessary in special instances, such as acute angle considerations with pipe diameters greater than 24 inches. **The minimum elevation drop across new manholes and larger diameter manholes shall be 0.1 feet for changes in pipe direction greater than 45 degrees.** All manholes must be checked to ensure that sufficient wall is supplied between pipe openings to meet all precast manhole criteria. See Appendix G.

8.12.4 Watertight

Watertight manholes and covers are to be used **everywhere unless a waiver is granted by MSD**.

8.12.5 Drop Inlets

A vertical or slanting drop inlet shall be provided for a sewer entering a manhole at an elevation higher than the sewer leaving the manhole. A drop inlet will not be allowed for elevation differences less than 2 feet.

8.12.6 Manhole Collars

A 6-inch collar shall be used when it is certain the manhole rim will not be lowered in the future and a 12-inch or greater collar when lowering is anticipated.

8.12.7 Manhole Numbering

All newly constructed public or private manholes will be assigned identification numbers. It is the designer's responsibility to contact MSD to obtain the required sequence of numbers for the proposed project. The assigned number for the respective manhole will be shown on both the plan and profile sheets as part of the structure note. During construction it is the responsibility of the contractor to stamp the number into the structure rim.

8.12.8 Chimney Seals

Internal, mechanical chimney seals are required on all new MSD manholes. Chemical chimney seals are to be used only for rehabilitation and only in non-paved areas.

8.12.9 Manhole Barrel Joints

See Specification section 5.3.4 for information on the two-way sealing system required for all sanitary manhole sections.

8.12.10 Manhole Frame and Collar Connections

All standard manhole frames shall be bolted to the collar with two 1-inch diameter anchor bolts positioned 180 degrees apart and all watertight manhole frames shall be bolted to the collar with four 1-inch diameter anchor bolts positioned 90 degrees apart.

8.12.11 Manhole Personnel and Equipment Access

Personnel access is required at manholes sufficient for MSD maintenance crews to enter the area. A waiver is required in the event access cannot be provided.

8.13 STUBS

Generally, stubs shall be provided in cul-de-sacs, at points of possible future extension, and at the terminus of the sewer line, unless otherwise directed by MSD. Stubs shall be one foot long measured from outside of manhole barrel for PVC or PE pipe or one pipe length for concrete pipe. The allowable length for cul-de-sac stubs is 20 feet without specific approval from MSD.

8.14 PROPERTY SERVICE CONNECTIONS

a. The property service connection (PSC) is the section of pipe between the R/W or easement line and the mainline sewer. Standard symbols and general notes pertaining to the size, type and length of "Y" or "T" branches and property service connections are shown on Exhibit 4-2 and shall be used on the plans. The standard connection for single-family residences will be 4 inches; however, commercial or industrial connections shall be individually considered with the minimum size being 6 inches. Green metallic “locater” tape labeled “SEWER” must be installed above the PSC at a depth of not more than 30 inches. Each PSC must have a Two–Way Cleanout conforming to MSD Standard Drawing SC-02-01 installed just inside the R/W or easement line.

b. A minimum slope of 2.00% (1/4” /ft.) for property service connections shall be used for determining design elevations. However, in all cases, the invert elevation of the property service connection at the easement or property line shall be equal to or higher than the crown of the sewer. The depth of the property service connection at the R/W line will conform to Exhibit 8-8. The minimum slope for the house connection will be 1.0% (1/8”/ft.).

b. Stacks shall be used when they are more economical than the typical property service connection. Stacks shall also be used in areas where the depths of the mainline sewer, existing utilities, or other obstructions are located at elevations that prevent the use of the typical property service connections. As a rule of thumb, two guidelines must be satisfied for a stack to be used. The receiving sewer must have a minimum cover of 12 feet and the length of stack (measured vertically) must be at least 3 feet. An additional requirement is to provide the minimum 3 feet of fall between the top of stack and house discharge point as indicated on Exhibit 8-8. Example (Assume level ground) - if a receiving sewer has 12 feet of cover and the discharge point at the house is 7 feet below ground, a stack would not be used; however, if the discharge depth was 6 feet or less, a stack would be required. Obviously field conditions may dictate deviations.

c. Property service connections 6 inches in diameter and smaller may be jacked without a casing.

d. Jointless pipe shall be used for new or rehabilitated PSCs. VCP shall not be used for new or rehabilitated PSCs.

8.15 FLOATATION

All sewers and sewer structures to be constructed where high groundwater conditions exist or where flooding of the trench is anticipated shall be designed to prevent floatation or excessive pipe flexing.

8.16 ANCHORS

When sewer slopes of 20 percent or greater are encountered, the sewer shall be securely anchored by using concrete anchors or other specially designed anchoring devices to prevent slippage. The design and method used should be approved by MSD.

8.17 CONCRETE ENCASEMENTS

Concrete encasement shall extend a minimum length of 2 feet beyond the point where a 4-foot depth of cover is reached or to a point 5 feet beyond the tops of banks when crossing a ditch or stream. Concrete encasements shall be used when it is necessary to prevent floatation, when crossing streams, ditches or existing storm drains. They shall also be used where soil conditions may indicate the possibility of heavy erosion, where crossing over utilities with less than 2-feet of clearance, or in areas where the sewer has less than the required cover. The minimum length of the concrete encasement shall be 2 feet beyond the outside diameter of the storm drain or utility conduit.

8.18 TRENCHLESS PIPE INSTALLATION - DESIGN AND CONSTRUCTION REQUIREMENTS

When open cutting is not permitted, the design plans will identify an appropriate pipe installation method and required information for the contractor to bid the project. The engineer will design the trenchless pipe installation using one of the following methods:

- **Tunneling**
- **Boring and Jacking**
- **Horizontal Directional Drilling**
- **Pipe Bursting**

The contractor will have the option to offer a different method of trenchless pipe installation than the one proposed on the plans, subject to approval and acceptance by MSD. When an alternate method is proposed by the contractor he will be responsible for the final design calculations. A plan of operation and list of proposed materials will be submitted for MSD approval. Structural calculations will be required for all components. Items include: casing and carrier pipe, tunnel liner plates, the working pits, sheeting and shoring, electrical facilities, ventilation, and communications. All design calculations and plans must be signed and sealed

and submitted by a professional engineer licensed in the Commonwealth of Kentucky. The contractor will also need to coordinate their excavations beforehand with Kentucky 811- Before you Dig (BUD).

The following criteria shall be followed whenever a trenchless pipe installation is used. Any deviation from this criterion will require prior approval from MSD: Additional reference is made to the MSD Standard Specifications.

Tunneling

- Tunnels shall be constructed using steel liner plates.
- The tunnel liner shall have a minimum outside diameter of 48 inches.
- The carrier pipe shall be installed at least 4 inches above the invert of the liner, and there shall be a minimum distance of 8 inches between the top of the carrier pipe and the top of the tunnel liner.
- Tunnel liner plates and joints shall be of leak proof construction, capable of withstanding E80 loading for railroads and H25 loading for roadways.
- Liner plates shall have minimum yield strength of 28,000 psi.
- It will not be necessary to use a protective coating or cathodic protection on tunnel liners, casing or sewer pipes.
- The space between tunnel liner plates and carrier pipe shall be filled with grout or with pneumatic backstowed pea gravel or No. 9 crushed stone.

Boring/Jacking

- Steel casing pipe shall either be a minimum of 30 inches in diameter or 12 inches greater than the largest outside diameter of the carrier pipe.
- All casing pipe must have a minimum thickness of 3/8-inch unless otherwise determined by designer.
- Steel casing pipe shall have minimum yield strength of 35,000 psi.
- In boring excavation, the carrier pipe shall be encased in a ductile steel casing pipe of sufficient size to provide clearance for the proper installation of the sewer pipe. The inside diameter of the casing pipe shall be at least 12 inches greater than the largest outside diameter of the carrier pipe, joints or couplings, thus providing

a clearance of at least 8 inches between the casing pipe and the carrier pipe. The entire void between the carrier pipe and the casing pipe shall be filled with grout or with pneumatic backstowed pea gravel or No. 9 crushed stone. Any void space outside the casing pipe shall be pressure-filled with cement grout. The cement grout mixture and method of grouting is called for in the MSD Standard Specifications.

Horizontal Directional Drilling

- **Horizontal Drilling is used to install 2 inch to 30 inch diameter pipes in segments up to 1,000 feet.**

- **Completed in three phases: boring of pilot hole, enlarging of hole by reaming, and pulling of pipe through enlarged hole.**

Pipe Bursting

- **Pipe Bursting is used is used to replace existing lines that have defects that cannot be rehabilitated by normal rehabilitation methods.**

- **A static, hydraulic, or pneumatic pipe bursting tool with an expander is launched through the old pipe, fragmenting it and compacting the old pipe fragment into the surrounding soil, creating a path for the new pipe.**

Refer to Section 7 of the MSD Standard Specifications applicable specifications for the performance of trenchless pipe installation.

8.19 RAILROAD CROSSINGS

8.19.1 Criteria

The following criteria shall be strictly adhered to when the planning for sewer construction affects railroad rights-of-way and facilities (railroad companies may specify more stringent requirements):

a. Sewers shall cross tracks at an angle as close to 90 degrees as practical, but preferably never less than 45 degrees. Sewers shall not be placed under railroad bridges where there is a likelihood of restricting the required waterway area of the bridge or where there is a possibility of endangering the foundations.

b. Sewer lines crossing under railroad tracks and rights-of-way shall be constructed **using one of the trenchless methods outlined above and as** permitted by the railroad company.

c. **Sewers** under railroad tracks and across railroad rights-of-way shall extend to a point, a minimum distance of 25 feet from the centerline of the outside track or the right-of-way line, whichever occurs first.

d. Sewer lines laid longitudinally along railroad rights-of-way shall be located as far as practical from any tracks or other important structures. If located within 25 feet of the centerline of any track or should there be danger of damage from leakage to any bridge, building, or other important structure, the sewer shall be encased or shall be of a special design as approved by MSD and the affected railroad.

e. When placed along railroad rights-of-way, the top of the pipe shall have a minimum cover of 4 feet.

g. **Trenchless sewer installations** under railroad tracks and across railroad rights-of-way shall be no less than 4 feet deep measured from the bottom of the rail to the top of the **sewer installation** at its nearest point. The top of the **installation** shall not be above the invert of existing or proposed ditches.

8.19.2 Railroad Conflict Drawings

Railroad conflict drawings shall conform to the following criteria:

a. Railroad conflict drawings, as shown in Exhibit 8-9, shall be prepared on 8.5" x 11" sheets. The plan and profile may be placed on one or more sheets as dictated by the scale. The record number of the plan and/or profile sheet that shows the conflict shall be added to the conflict drawing.

b. Drawings shall be prepared to scale showing the relationship between the proposed sewer and the railroad, angle of crossing, location of utilities, original survey station of the railroad (when available), right-of-way lines, topography, and general layout. The profile established from a field survey shall show the sewer in relation to the actual ground and tracks. The limits of **installation** by station, sewer line soundings and borings, and all other pertinent information shall be shown on the drawing.

c. MSD will furnish any necessary General Notes to be placed on the plans or included in the Special Provisions.

d. Railroad conflict drawings shall be submitted along with a complete questionnaire, which shall be furnished by the railroad company.

8.20 HIGHWAY CROSSING

Sewer pipe installations constructed under State, County, or City maintained roadways, will need to confirm to the design requirements of the respective governing agency. One of the designer's first tasks will be to determine if open cutting will be allowed. Construction shall meet the following requirements (more stringent criteria may be required on a project specific basis):

a. Sewers shall cross the roadways at an angle as close to 90 degrees as practical, but preferably never less than 45 degrees. Sewers shall not be placed under roadway bridges where there is a likelihood of restricting the required area of the bridge or where there is a possibility of endangering the foundations.

b. **Sewer lines crossing under highways and rights-of-way shall be constructed using one of the trenchless methods outlined above and as permitted by the governing agency.**

c. **Sewer installations** under roadways shall have a minimum depth of 3 feet from the surface elevation to the top of the **installation**. The top of the **installation** shall not be above the invert of existing or proposed ditches.

d. **Sewer installations** under roadways shall extend a minimum of 10 feet outside the existing paving, as measured at right angles to the roadway, or to the toe of the slope when the roadway is on fill and the toe of slope exceeds 10 feet outside the existing paving. **Installations** should likewise extend to the top of slope furthest from the roadway on ditches if the top of slope is greater than 10 feet from the edge of pavement.

e. Sewer lines laid in a longitudinal direction on highway rights-of-way shall be located a sufficient distance from the edge of the pavement to allow adequate working room and to provide maximum safety to the motorist when the roadway is to remain open to traffic. Those sewer lines within the roadway right-of-way, but not located under paved areas, shall have no less than 5 feet of cover.

f. Metallic tape shall be laid in the trench above the pipe from the edge of pavement to the right-of-way line or from the end of the tunnel to the right-of-way line on all crossings of State highways.

8.21 CREEK, STREAM OR DITCH CROSSINGS

Sanitary sewer pipes for crossing a creek, stream or ditch shall be a jointless pipe and shall be encased in concrete as required in Section 8.17 Concrete Encasements.

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COMPUTATIONS FOR SANITARY SEWER DESIGN

ENGINEER ____________

Project Name____________
____
____
Record No.____________

Sheet____of____
Computed By____________
Checked By____________
Date____________

1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
LOCATION																				Invert Elev. of Sewer		REMARKS
Drain. Area Designation	Sewer Line Designation	Manhole Designation From	Manhole Designation To	Increment Total Eq. Pop.	Accumulated Total Eq. Pop.	Average Daily Flow	Peak Factor	Total Sewage Flow	Design Flow "Q"	Length	Slope	Size	"Q" Full	"V" Full	Design "Q" / "Q" Full	Design Flow Depth Ratio	Design "V" / "V" Full	Design "V"	Drop	Upper End	Lower End	
		Sta.	Sta.			GPD		MGD	c.f.s.	L.F.	ft/ft	In.	c.f.s.	f.p.s.	Ratio	d/D	Ratio	f.p.s.				

Col. 1 Drainage Area Designation
Col. 2 Sewer Line Designation
Col. 3 Manhole Designation by Station
Col. 4 Total Equivalent Population obtained from each individual drainage area analysis
Col. 5 Total Equivalent Population accumulated to this point (Col. 4 + previous Col. 5)
Col. 6 Average Daily Flow (Col. 5 x 100 Gallons per person per day)
Col. 7 Peak Factor from Exhibit 8–4
Col. 8 Total Sewage Flow (Col. 6 x Col. 7 divided by 1,000,000)
Col. 9 Design Flow (Col. 8 x 1.5472 cfs/MGD)
Col. 10 Length of Pipe measured from centerline of Manhole to centerline of Manhole
Col. 11 Design Slope
Col. 12 Pipe Size
Col. 13 "Q" Full
Col. 14 "V" Full
Col. 15 Design "Q" to "Q" Full ratio (Col. 9 divided by Col. 13)
Col. 16 Ratio of Pipe Diameter (D) to Design Flow Depth (d) in feet (Exhibit 8–6)
Col. 17 Design "V" Full to "V" Full Ratio (Exhibit 8–6)
Col. 18 Design Velocity (Col. 14 x Col. 17)
Col. 19 Difference in Invert Elevations

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EXHIBIT 8-2
DEVELOPED AREA WASTEWATER FLOWS

EFFECTIVE DATE: JUNE 30, 2009

DEVELOPMENT	POPULATION PER UNIT	AVERAGE GAL/UNIT/DAY
Single Family Dwelling	4	400
Two Family Dwelling	8	800
Apartments		
1 Bedroom	2	200
2 Bedroom	3	300
3 Bedroom	4	400
Motel Rooms	1	100

DEVELOPMENT	UNIT	EQUIVALENT POPULATION PER UNIT	AVERAGE GAL/UNIT/DAY
Schools *	Students	0.15	15
Mobile Homes	Persons	2.0	200
Nursing Homes	Bed	1.0	100
Offices	Employee	0.15	15
Laundromats	Washer	4.0	400
Non-developable Land	Acres	1.0	100
Commercial *	Acres	20.0	2000
Industrial *	Acres	10.0	1000

* Actual measured wastewater flows should be used when available – with allowance for future expansion.

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EXHIBIT 8-3
UNDEVELOPED AREA WASTEWATER FLOWS

EFFECTIVE DATE: JUNE 30, 2009

ZONING DISTRICT	DWELLING UNITS/ACRE	POPULATION PER UNIT	POPULATION PER ACRE	AVERAGE GAL/ CAP/DAY	AVERAGE GAL/ ACRE/DAY
R-E & R-1	1	4	4	100	400
R-2 *	2	4	8	100	800
R-3 *	3.5	4	14	100	1400
R-4 **	3.75	4	15	100	1500
R-5	6	4	24	100	2400
R-6	15	3	45	100	4500
R-7	30	3	90	100	9000
R-8 & R-8A	50	3	150	100	15000

ZONING DISTRICT	EQUIVALENT POP/ACRE	AVERAGE GAL/ CAP/DAY	AVERAGE GAL/ ACRE/DAY
R-9	150	100	15000
R-10	150	100	15000
Commercial	20	100	2000
Industrial ***	10	100	1000
Non-developable Land	1	100	100

* Saturation standards applicable to the design of collector or interceptor systems.

** In general, for undeveloped areas, the R-4 density is to be considered as a minimum for collection system design unless present development in the vicinity indicates that design for the actual zoning, with MSD approval, would be more prudent.

*** This figure may be adjusted by MSD if a major industrial user is anticipated.

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EXHIBIT 8-4
PEAK FACTOR CURVE

EFFECTIVE DATE: JUNE 30, 2009

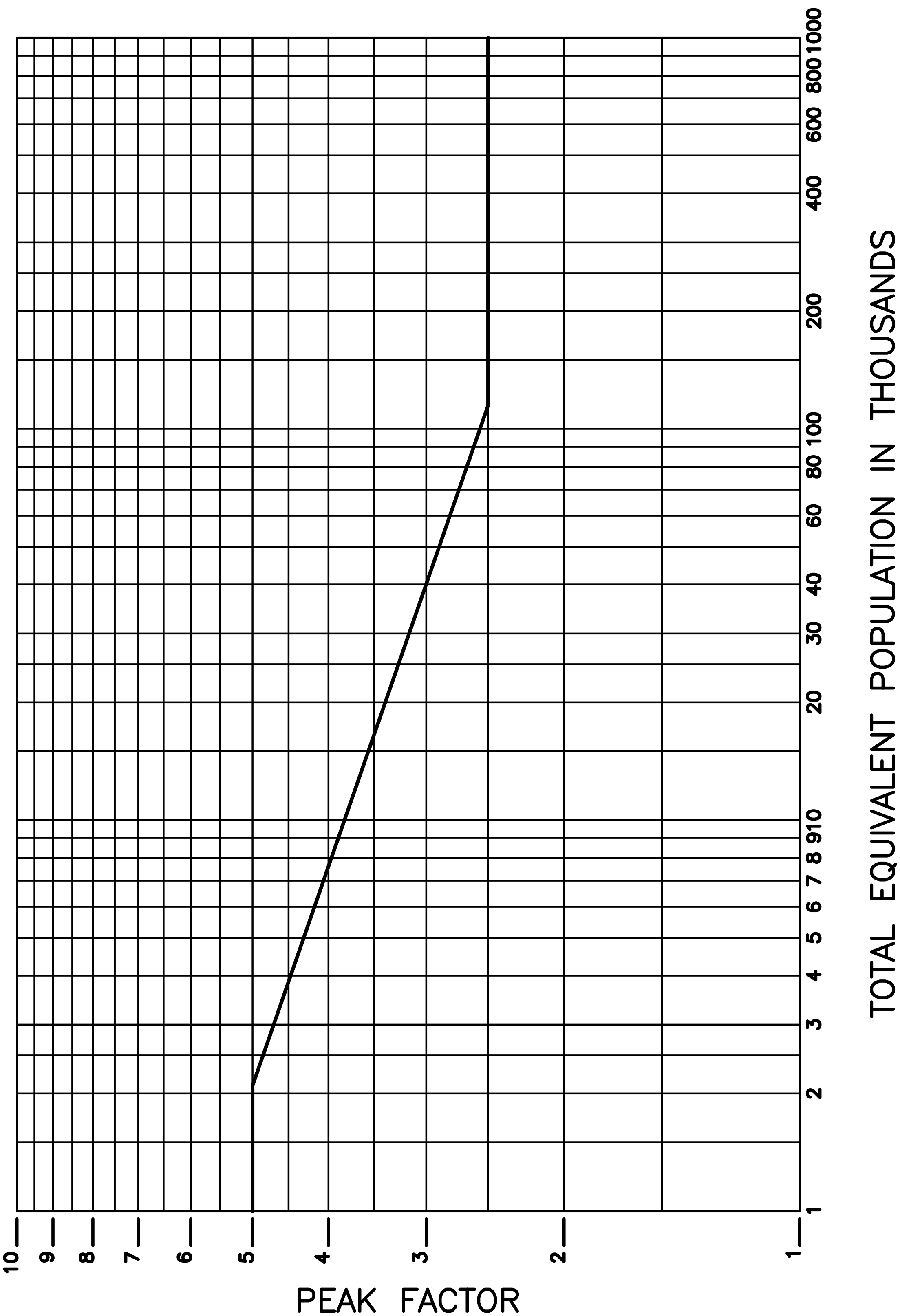

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EXHIBIT 8-5
MINIMUM ALLOWABLE SLOPES

EFFECTIVE DATE: JUNE 30, 2009

Manning's "n" = 0.013

PIPE DIA. (inches)	SLOPE (ft/ft)	VELOCITY FULL (ft/sec)
8	0.0040*	2.2
10	0.0028	2.1
12	0.0022	2.1
15	0.0015	2.0
18	0.0012	2.0
21	0.0010	2.1
24	0.0008	2.0
27	0.00067	2.0
30	0.00058	2.0
36	0.00046	2.0
42	0.00037	2.0
48	0.00030	2.0
54	0.00026	2.0
60	0.00026	2.0
66	0.00026	2.3
72	0.00026	2.4
78	0.00026	2.6
84	0.00026	2.7
96	0.00026	3.0
108	0.00026	3.2
120	0.00026	3.4
132	0.00026	3.6
144	0.00026	3.8

* If 2.0fps can not be achived with the design flow, the minimum slope will be 0.0070. ft/ft

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EXHIBIT 8-6
HYDRAULIC ELEMENTS OF
CIRCULAR SEWERS

EFFECTIVE DATE: JUNE 30, 2009

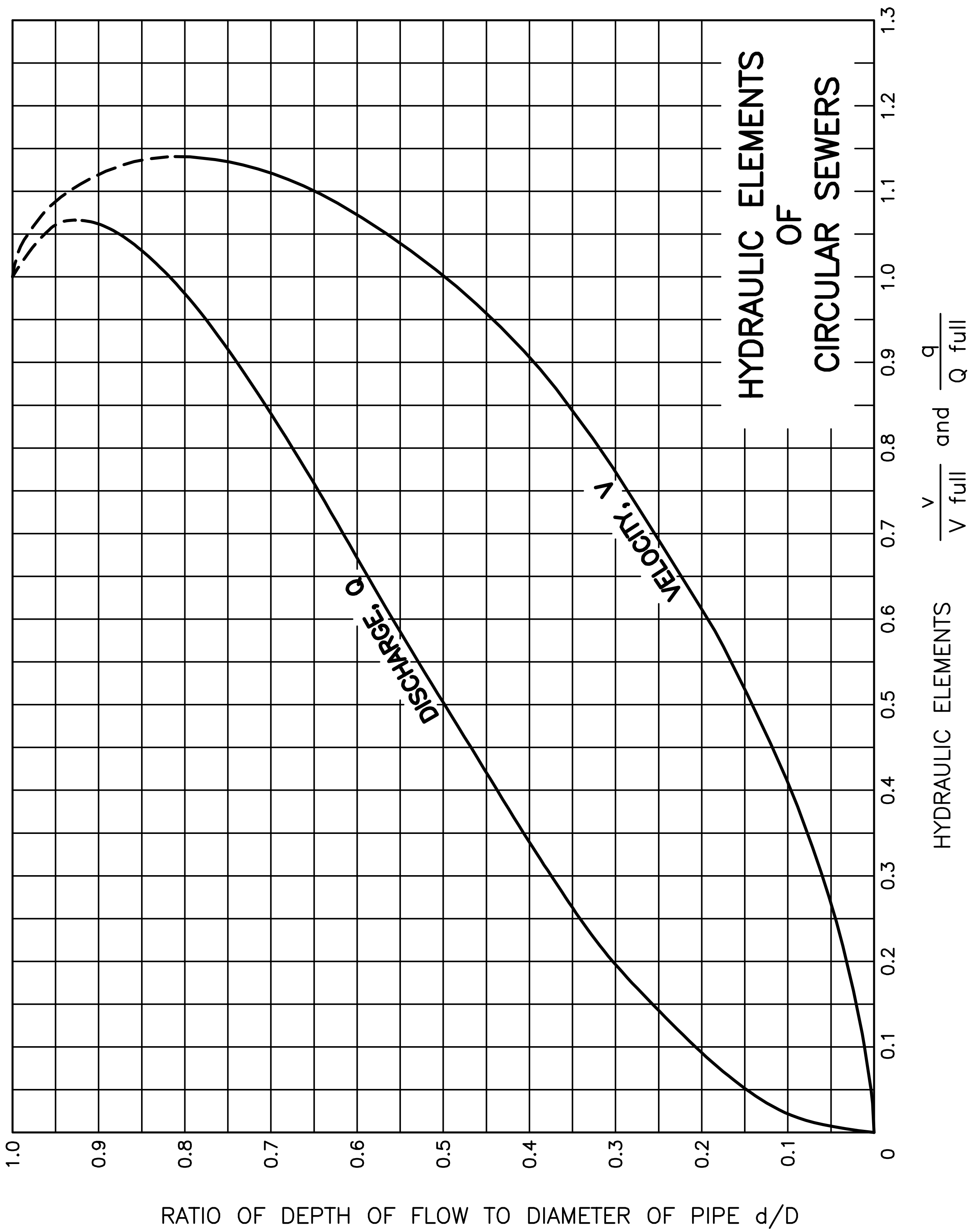

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EXHIBIT 8-7
PIPE FLOW CHART FULL (6" - 54")

EFFECTIVE DATE: JUNE 30, 2009

CAPACITY OF CIRCULAR SEWERS FLOWING FULL

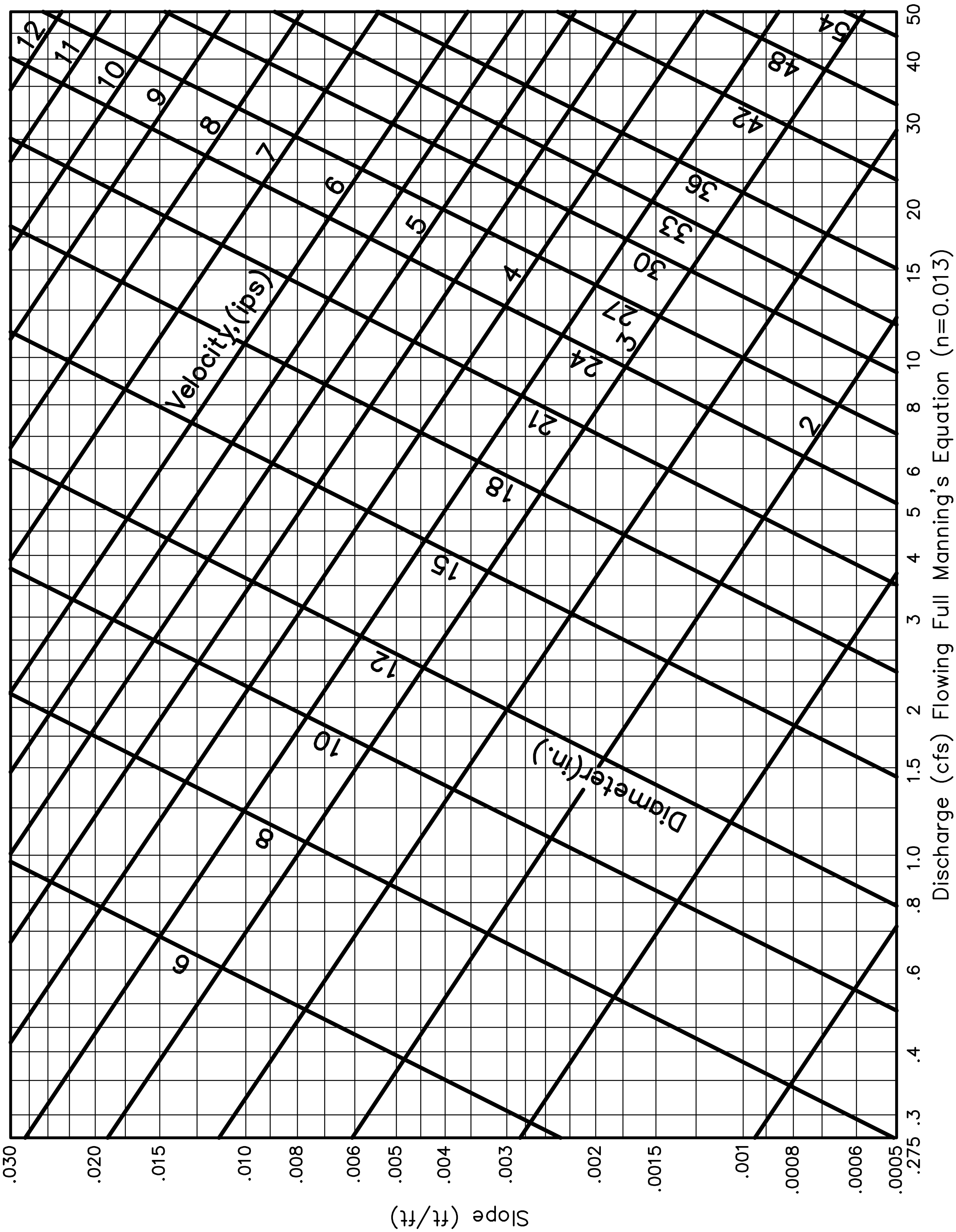

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EXHIBIT 8-7 PAGE 2

PIPE FLOW CHART FULL (21"-144")

EFFECTIVE DATE: JUNE 30, 2009

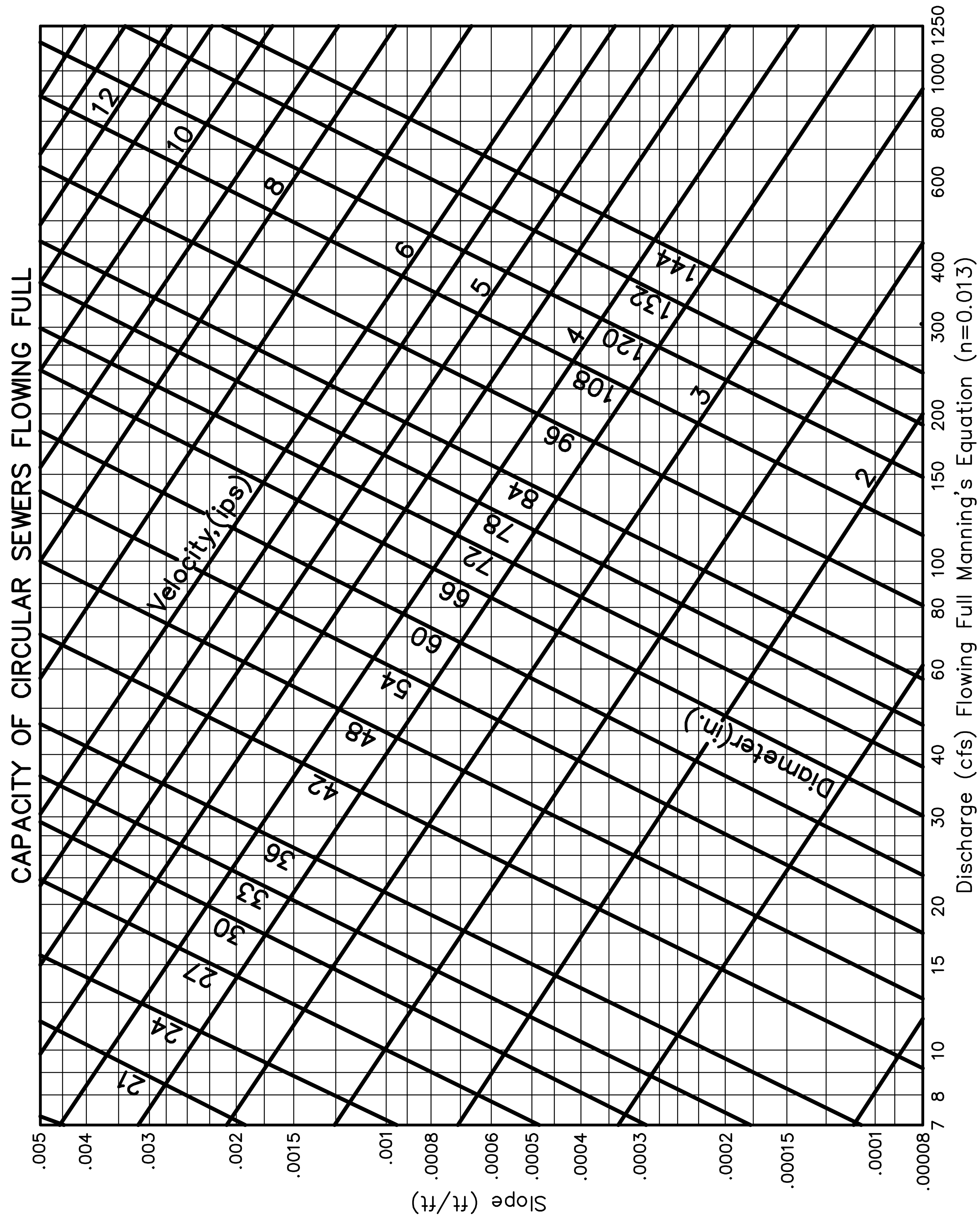

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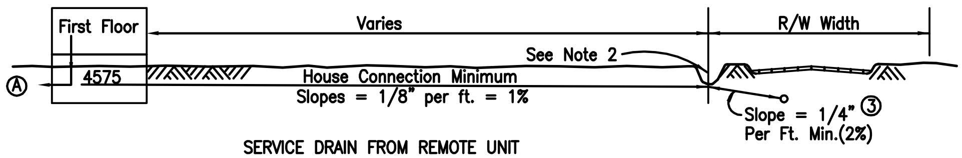
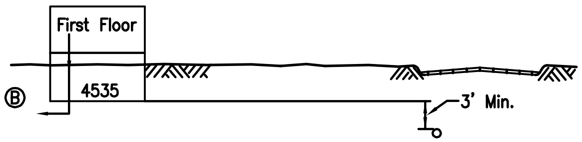
EXHIBIT 8-8
TYPICAL SERVICE CONNECTIONS

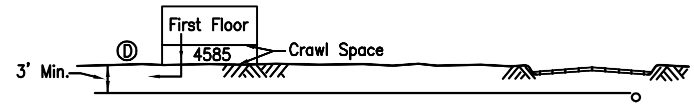
EFFECTIVE DATE: JUNE 30, 2009



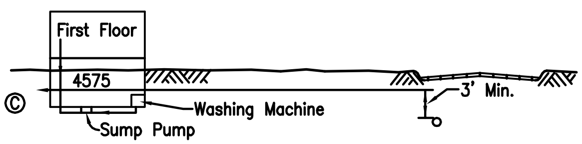
SERVICE DRAIN FROM REMOTE UNIT
When houses or other units are remotely located, consideration must be given to the amount of drop from the point of service to the sewer. The following slopes are considered minimum when not controlled by terrain, low areas, etc.



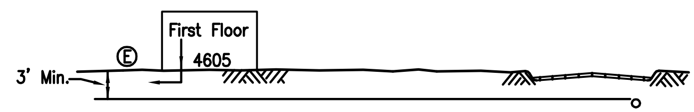
HOUSE DRAIN THROUGH BASEMENT FLOOR
When this condition controls the upper end of a sewer and no sanitary or laundry facilities exist in the basement, consideration should be given to a control depth less than 3' below the basement floor elevation.



HOUSE DRAIN THROUGH FIRST FLOOR WITH CRAWL SPACE
The crown of the sewer shall be a minimum of 3' below the ground at the point of service outlet.



HOUSE DRAIN THROUGH BASEMENT WALL
Service elevation outlets for sump pumps which do not discharge shower, laundry or sanitary facilities shall not control the sewer depth.



HOUSE DRAIN THROUGH FIRST FLOOR WITH SLAB TYPE FOUNDATION
The crown of sewer shall be a minimum of 3' below the first floor elevation

LEGEND

Ⓐ 4575 Denotes elevation and service line that drains thru basement wall with no sump pump.

Ⓑ 4535 Denotes elevation and service line that drains thru the basement floor.

Ⓒ 4575 Denotes elevation and service line in basement with a sump pump raising wastewater from basement floor.

Ⓓ 4585 Denotes elevation of ground at the point of service line outlet when house has crawl space.

Ⓔ 4605 Denotes first floor elevation.

This legend shall be used in preparation of preliminary plans. The final plans and profiles shall indicate the proper symbol and elevation for only those houses controlling the sewer.

GENERAL NOTES:
1. The intent of the sewer program is to serve only sanitary facilities in basements and not floor drains, foundation drains, window wells or other such facilities.
2. Where roadside ditches occur, the sewer must be placed at an elevation such that the property service connection at the ditch will have a minimum cover of 1' from the flow line of the ditch to top of encasement or cap.
3. Reference Section 8.14.b of the Design Manual.

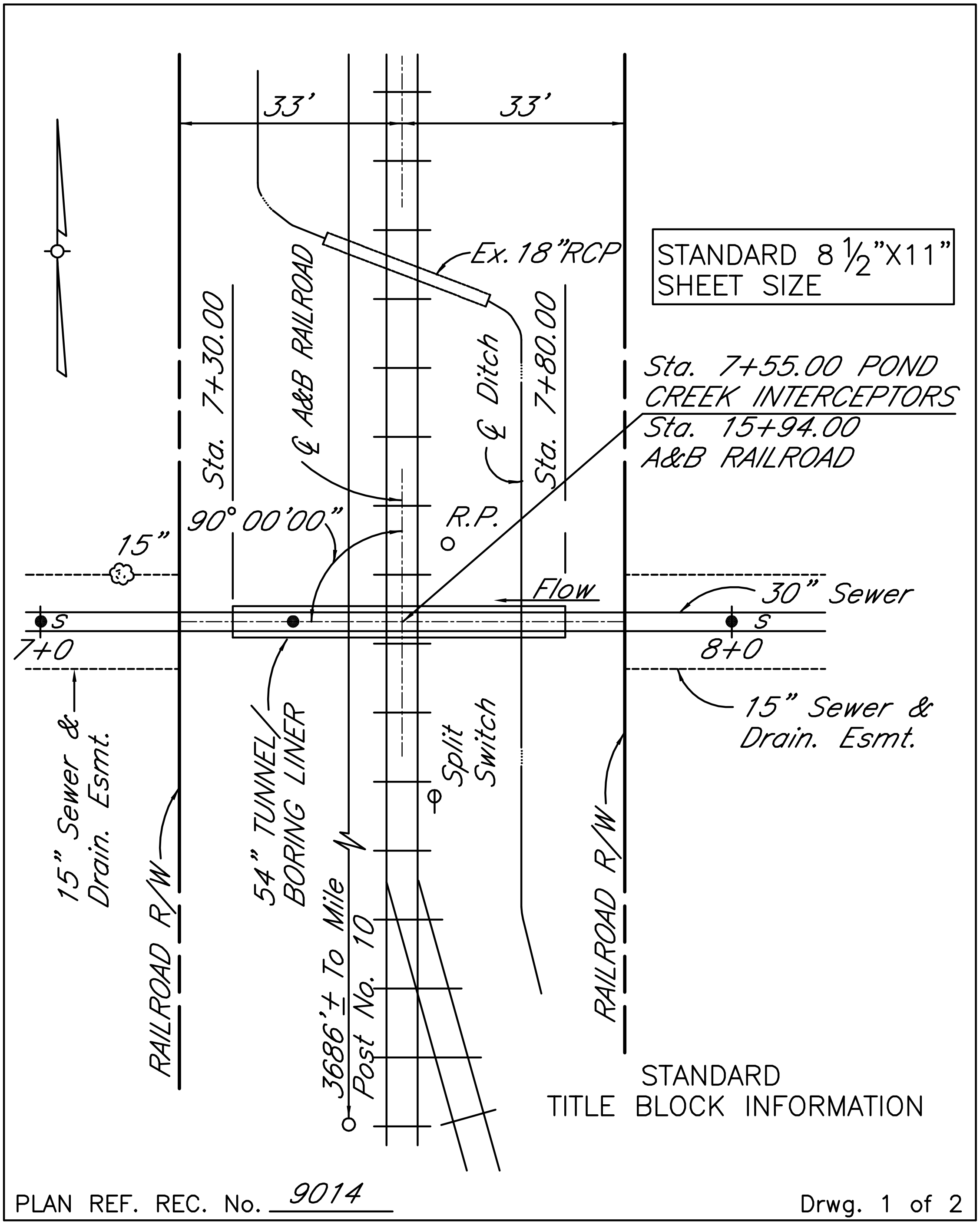
TYPICAL SERVICE CONDITIONS

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 8-9 PAGE 1

RAILROAD CONFLICT DRAWING

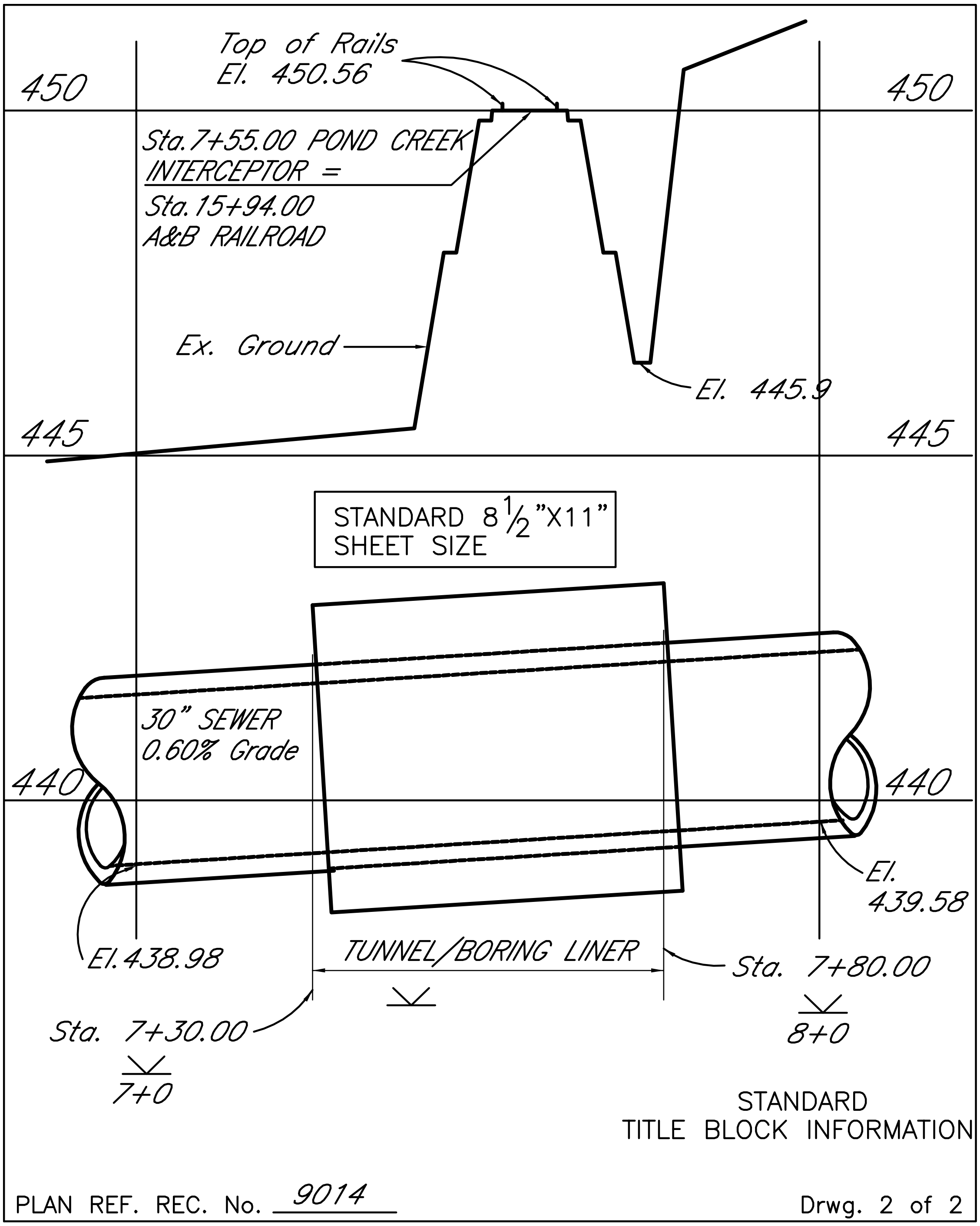
EFFECTIVE DATE: JUNE 30, 2009



MSD
Louisville and Jefferson County Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 8-9 PAGE 2
RAILROAD CONFLICT DRAWING

EFFECTIVE DATE: JUNE 30, 2009



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CHAPTER 9
DEVELOPMENT SANITARY SEWER CONSTRUCTION

CHAPTER 9
DEVELOPMENT SANITARY SEWER CONSTRUCTION

9.1 PURPOSE

This chapter establishes the minimum sanitary sewer construction plan submittal requirements and MSD procedures for submittal, construction inspection, and final approval of construction for private development **sanitary sewer** projects. Sanitary sewer systems should be designed in accordance with the applicable provisions of this and other chapters of the MSD Design Manual. Particular attention is directed to the EPSC requirements of Chapter 12. Adherence to these procedures will facilitate timely review and approval for construction.

Additional guidance and applicable forms may be retrieved from:

http://www.msdlouky.org/insidemsd/formssanitary.htm

9.2 GENERAL PROCEDURES

a. A meeting should be arranged to discuss a proposed sewer plan. The plan submittal should generally show the lot layout, sewer alignment, and drainage areas in each segment.

b. MSD will review this plan and advise as to which of the three sewer classifications will control the submittal route.

   1. **Lateral Extension (LE)**
      A MSD sanitary sewer system in which the sewer system and the treatment facility is owned and operated by MSD once constructed and approved.

   2. **Private Sewer - MSD System (PS)**
      A sanitary sewer flowing from a private property to an MSD sewer system and is treated at an MSD-owned facility.

   3. **Non-MSD System (NLE)**
      A sanitary sewer system and treatment facility owned and operated by another city, as a private individual, corporation, or agency.

c. If MSD determines that the situation is a LE or PS served by one of MSD's wastewater treatment plants, the development of design plans may proceed.

d. If MSD determines that the sewers are NLE and they are not served by a MSD owned wastewater treatment plant, a preliminary plan must also be submitted to the Jefferson County Health Department. This is to determine if the wastewater treatment plant has adequate capacity to allow for the proposed sewer expansion.

1. If the plant does not have sufficient capacity, the plant owner must apply for Waste Load Allocation (WLA) determination from the Kentucky Department for Environmental Protection, Facilities Construction Branch. Design drawings can proceed simultaneously with the treatment plant expansion plan once the WLA approval has been issued.

2. If the plant has sufficient capacity, design plans may proceed.

9.3 SUBMITTALS

Submittal requirements for construction plans are listed on the **Sanitary Sewer Document Review Checklist** on (http://www.msdlouky.org/insidemsd/formssanitary.htm). Submittal packages will be addressed to MSD's Development Plan Review Section and must include a completed copy of the checklist. <u>Variations from the checklist will require prior approval from MSD</u>. Any conditions of the Approved Preliminary Plan must be addressed at the time of construction plan submittal.

9.4 PLANS

Plan requirements for the respective sheets are identified on the **Minimum Requirements Checklist for Sanitary Sewer Construction Plans** (Same web address as above).

9.4.1 Standard Drawings / Nonstandard Details

The use of MSD's Standard Drawings is highly encouraged. When a particular drawing is utilized, a copy of the drawing is not required to be shown on the plan set. Reference can be made to the drawing by identifying the drawing number on the plan set "Title Sheet".

Nonstandard details or deviations from MSD's Standard Drawing will need to be shown within the plan set.

9.4.2 Property Service Connection Inlet Sheets

The information for all connections must be shown on a Property Service Connection Inlet Sheet. An example sheet can be found on the MSD web page. A copy of the sheet should be placed on the plans for construction and as-built reference.

9.5 PROPOSED PROJECT PLAN

An 8 ½ x 11 inch drawing identifying the limits of the proposed project must be submitted to MSD for all public and private sewer projects. In order to provide consistency of the Proposed Project Plan (PPP), the use of the template provided on the web page should be used. The PPP should be submitted with the original submission.

9.6 MSD DESIGN APPROVAL

After all MSD concerns are satisfied, a letter **certifying compliance with KAR 5:005 will be sent to the KYDOW along with copies of the approved plans. The Louisville and Jefferson County Health Department will be sent copies of the certification letter and plans.**

9.7 LATERAL EXTENSION OF BOUNDARIES AGREEMENT

For LE projects, the applicant shall submit to MSD's Development Plan Review, a "Lateral Extension **of Boundaries Agreement**". This document is a legal agreement, **required by the State**, between the developer and MSD regarding the construction of the sanitary sewerage facilities. The contract conveys the sewerage facilities to MSD, upon completion and acceptance by MSD.

9.8 NOTICE-TO-PROCEED

A formal Notice-To-Proceed letter will be issued when the following conditions are met.

a. **LE Project**

- All MSD fees are paid pertaining to the sanitary sewer project
- The "**Lateral Extension of Boundaries Agreement**" has been executed
- The "Performance Bond" has been received and accepted
- The "Maintenance Bond" has been received and accepted
- The "Certificate of **Liability** Insurance" has been received and accepted
- The "Accepted Bid Proposal" has been received and accepted
- **The KYDOW construction permit has been received**
- Easement plats have been received and are easily recorded by MSD
- Permits have been issued for work within the right-of-way
- A MSD inspector has been assigned
- Notice of Construction has been received
- Site Disturbance Permit from MSD has been issued

b. **Private Sewer Project**

- All MSD fees are paid pertaining to the sanitary sewer project

- **The KYDOW construction permit has been received**
- A MSD inspector has been assigned
- Notice of Construction has been received
- Site Disturbance Permit from MSD has been issued

9.9 INSPECTION OF CONSTRUCTION

9.9.1 General

MSD has a program of on-site inspection for the construction of all sanitary sewer systems within **District Boundaries**.

9.9.2 Inspector Assignment

Construction of sewers shall not begin in a development until an MSD inspector has been assigned to the construction site. In certain situations, which will be identified during construction plan review, full-time inspection may be required. A MSD inspector shall be present during all testing. MSD requires a 48-hour advance notice to schedule an inspector for a project.

9.10 CONSTRUCTION FIELD CHANGES

Deviations from approved construction plans as a result of unexpected field conditions will require documentation and approval by MSD. To obtain this approval, the developer's engineer shall submit four (4) copies of the marked-up (REDLINE) plans showing the proposed revisions wanting to be made. Upon acceptance of the changes, MSD will mark the REDLINE drawings approved, sign and date the approval and send the REDLINES to the construction site via the inspector. One copy will be for the contractor, two copies for the inspector and one copy for MSD's reviewer file.

9.11 RECORD PLANS

At the completion of construction, a final record (As-Built) **drawings** of the construction plans (including inlet sheet information) bearing the Land Surveyor's original seal, signature, and date, and incorporating <u>all</u> approved changes shall be submitted to MSD. Final Record Drawings shall be prepared in accordance with Chapter 5. MSD's inspector will coordinate and check the work prior to submittal to MSD. The as-builts must be completed and approved before MSD will make the sewers available for connection.

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CHAPTER 10
STORMWATER FACILITIES DESIGN
EXHIBITS

CHAPTER 10
STORMWATER FACILITIES DESIGN

10.1 PURPOSE

This chapter establishes the minimum standards for the planning and design of drainage systems and stormwater management facilities within Jefferson County. The guidelines presented must be used in connection with the Stormwater Management Master Plans contained in the Stormwater Drainage Master Plan (SWDMP), the EPSC requirements of Chapter 12, the Water Quality requirements of Chapter 18 and the Louisville Metro Floodplain Management Ordinance.

The criteria in this section shall apply to all drainage facility design in both the local and through drainage systems except where facilities have significant and immediate impact upon State or Federal property or highways. In those cases, the most restrictive of State, Federal or MSD standards shall govern.

Some requirements of this chapter may be superseded by the requirements of Chapter 18 if Green Infrastructure is incorporated into the stromwater design. These instances will be handled on a case-by-case basis.

Additional stormwater design information may be retrieved from MSD's web page. The path is as follows:

http://www.msdlouky.org/insidemsd/stormwater.htm

10.2 HYDROLOGY FOR STORMWATER FACILITIES DESIGN

10.2.1 General

This section describes the recommended procedures for calculating the runoff generated from a project site. Correct utilization of these procedures should result in the best available estimation of existing and projected runoff. The procedure will also provide the consistency of results necessary when applied to project sites throughout Louisville Metro and Jefferson County.

It is assumed that practicing Engineers involved with preparing drainage plans have adequate knowledge of the recommended procedures. There is, therefore, no attempt in this Design Manual to provide step-by-step calculation methodologies. The information provided in this chapter is geared toward assimilating the runoff calculation process with the regional planning aspects of the SWDMP. Contact MSD if there is reason to believe that these procedures are not applicable in particular project areas.

The runoff calculation procedures to be utilized depend upon the size of the proposed development or project as follows:

a. If the total tributary area to an existing or proposed stormwater facility on the project site is 50 acres or less, and no storage design is required, the method of runoff calculation shall be the **Rational Method** as described in Section 10.2.3.1.

b. If the total project drainage area is greater than 50 acres, or storage design is required, a discharge hydrograph must be calculated using the **NRCS Method** or another method that has been approved by MSD.

c. The Rational Method may be used to design through drainage channels if the drainage area of the channel is 50 acres or less; otherwise, the channel shall be designed by NRCS runoff calculation methodology or another method that has been approved by MSD.

Note: See Exhibit 10-1 for guidance in selecting the appropriate method.

10.2.2 Design Storm

10.2.2.1 Frequency/Return Period

The selection of a design storm is the basis for all runoff calculations and facility design for a project site. The facility specific requirements and associated check frequencies are found in Section 10.3. The table below summarizes the associated Return Interval for various types of analyses.

Design Storm Return Interval								
Situation		**Return Interval (years)**						
Type of Analysis	**Limiting Values**	**2**	**5**	**10**	**25**	**50**	**100**	**500**
Bridge	**ADT< 400**			●			●	
	400<ADT<1,500				●		●	
	ADT>1,500					●	●	
Culvert Capacity	**ADT< 400**			●			●	
	400<ADT<1,500				●		●	
	ADT>1,500				●		●	
Bridge Scour Analysis							●	●
Storm Sewer				●			●	
Channel Change		●		●			●	
Roadway Ditch				●			●	
Drop Inlets				●			●	
Detention or Retention Basin		●		●			●	

Note: ADT=Average Daily Traffic

Localized restrictions may be placed on some areas, based upon the hydrologic and hydraulic models developed for the area. Design criteria in such cases shall be established by MSD during the Preliminary Plan Review Process. **The elevation of the 100-year pre- and post-development discharge shall be checked for all drainage system designs to assure conformance with the guidelines of the National Flood Insurance Program and Louisville Metro Floodplain Management Ordinance.** In areas of the County not covered by a Flood Insurance Study, the Design Engineer must determine the pre-development 100-year Flood Elevation. The elevation for the 100-year post-development discharge shall be conveyed within the limits of the proposed easement.

10.2.3 Runoff Calculation Methods (Design Flow)

10.2.3.1 Rational Method

10.2.3.1.1 General

The Rational Method is the recommended runoff calculation procedure for project sites where:

a. The total drainage area is 50 acres or less.

b. Detention/Storage design is not required.

10.2.3.1.2 Calculation

a. The Rational Method shall be performed as follows:

$$Q = C \times I \times A$$

Where:

Q = Peak runoff (cu. ft. per sec.)
C = Runoff coefficient
I = Rainfall intensity (inches/hour)
A = Contributing area (acres)

b. Rainfall Intensity-Duration Curves, Exhibit 10-2, shall be utilized in the Rational Method to determine rainfall depths and storm intensities for Louisville and Jefferson County. Rainfall intensity may also be computed as described in the Kentucky

Transportation Cabinet Drainage Guidance Manual, most current edition.

c. The time of concentration (duration), Tc, shall be determined by calculating the time for a particle of water to travel from the most hydrological remote point of the project area to the point of interest. Acceptable methods to derive time of concentration are **the TR-55 (Technical Release - 55, available from the NRCS) and the Kinematic Wave method. The minimum Tc shall not be less than 10 minutes to any given inlet or analysis point.** Manning's Equation should be used to estimate any in-pipe or channel travel.

d. The runoff coefficient, C, must represent a composite of the surface condition tributary to the point under consideration.

To determine the appropriate C-Factor, the hydrologic soil group, described in Exhibit 10-4, and land use for each surface condition must be obtained. Exhibit 10-5 then combines this information with surface slope to provide the correct C-Factor for that area. The C-Factors given may be used directly when the drainage area is homogeneous. When it is not, an appropriately weighted C-Factor must be determined and reviewed by MSD.

For areas where no hydrologic soil group information can be obtained, the C-Factor should be the values for soil group C.

If the project site conditions differ significantly from those used as the basis for the C-Factor figures, the Design Engineer must develop a specific composite C-Factor for the area. To determine the composite C-Factor for the entire project site, a weighted average must be calculated based upon the percentages of the areas with different C-Factors. (NOTE: Land use regulations in Jefferson County permit the use of higher percentages of impervious surface than may be reflected in the coefficients from Exhibit 10-5. The Design Engineer should select or calculate runoff coefficients, which reflect actual proposed designs. For subdivisions, the Design Engineer should accommodate the maximum imperviousness permitted under land use guidelines.)

e. To calculate flowrates in series, (i.e. in ditch or storm sewer design) the C*A term shall be summed for all contributing drainage areas. The intensity shall be selected from the time of concentration to that point. The Tc selected shall be the larger of these two: 1) Tc for the subject inlet or analysis point based on overland flow to said inlet/anaylsis point and 2) the Tc from the previous in-line inlet or analysis point plus the travel time from the previous inlet or analysis point.

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10.2.3.2 Natural Resource Conservation Service (NRCS) Methods

10.2.3.2.1 General

The NRCS Methods are required for runoff calculation procedures for project sites where:

a. The total project drainage area is greater than 50 acres or

b. Detention/Storage design is required.

When these project conditions exist, the Design Engineer should confer with MSD to determine if there is a hydrologic or hydraulic model available for the area. If a model exists, site calculations must be performed and correlated with this data.

If models do not exist, the Design Engineer must use the NRCS Methodology in model preparation.

10.2.3.2.2 Methods

The NRCS Methods also include the TR-20 and TR-55 Methods. Detailed descriptions, example calculations, and worksheets for these methods are available in:

a. Project Formulation - Hydrology, Technical Release No. 20 User's Manual;

b. Urban Hydrology for Small Watersheds, Technical Release No. 55; and

c. A Guide to Hydrologic Analysis Using NRCS Methods.

10.2.3.2.3 Curve Number

The curve number is similar to the Rational Method C-Factor in that it is based on the surface conditions of the project site.

The appropriate figures and hydrologs in the Watershed Plans should be utilized to determine the hydrologic soil group and land use definition for the particular area. The correct CN can be determined from Exhibit 10-6.

For through drainage systems, post developed curve numbers shall be based on a fully developed watershed as zoned at the time of design.

Maps depicting the NRCS Hydrologic Soil Groups, Existing Land Use, and Projected Land Use for each watershed in Jefferson County are included in the Watershed Plans available through MSD's Stormwater Department and ERSI coverages provided by LOJIC. This information may be used to determine the appropriate surface condition factors for use in runoff calculation as described in Section 10.2.3. Contact MSD regarding any discrepancies between the maps and the proposed project site.

10.2.3.2.4 Antecedent Runoff Condition

The index of runoff potential before a storm event is termed the Antecedent Runoff Condition (ARC). The ARC is an attempt to account for the variation in CN at a particular site for various storm conditions. The CNs in Exhibit 10-6 are for average ARC, which are used primarily for design applications. Please refer to the NRCS National Engineering Handbook, Section 4 - Hydrology (NEH-4, NRCS) for a detailed discussion of storm-to-storm variations and upper and lower CN limits. ARC will normally be involved only in calibration.

10.2.3.2.5 Directly Connected Impervious Areas

Directly connected impervious areas should be considered where applicable in NRCS runoff calculations.

NOTE: Land use regulations in Jefferson County permit the use of higher percentages of impervious surface than may be reflected in the coefficients from Exhibit 10-6. The Design Engineer should select or calculate runoff coefficients, which reflect actual proposed designs. For subdivisions, the Design Engineer should accommodate the maximum imperviousness permitted under land use guidelines.

10.2.3.2.6 Rainfall Duration

The minimum design storm duration for planning and design is dependent upon the runoff method used.

a. The NRCS Method will utilize the **NRCS Type II, 24-hour rainfall distribution.** Critical storm analysis shall be performed when warranted as determined by MSD.

10.2.3.2.7 Rainfall Depth

Exhibit 10-3, shall be utilized to determine total rainfall depths for Jefferson County for use by the NRCS methods. These values are derived from Engineering Memorandum No. 2, Revised June 1, 1979, published by the Commonwealth of Kentucky, Division of Water Resources - Department for Natural Resources and Environmental Protection. MSD may require use of local rain gage data where available. The Design Engineer should inquire if MSD has such data available.

10.2.3.2.8 Rainfall Distribution

Synthetic rainfall distributions shall be used for design storm generation. When critical storm analyses are not required, the distributions shall match the NRCS Type II curve as published in NRCS Technical Report 55, with **5-minute time steps.**

In some cases MSD may require a critical storm analysis to determine the rainfall duration and distribution that produces the worst runoff conditions for a specific site. Since the NRCS Type II distribution represents a 24-hour duration storm only, it is not applicable to the critical storm analysis. This analysis will be based on dimensionless Huff Distributions as presented in *Rainfall Frequency Atlas of the Midwest* by Floyd Huff and James Angel, Midwestern Climate Center, NOAA, and the Illinois State Water Survey, A Division of the Illinois Department of Energy and Natural Resources.

10.2.3.2.9 Surface Condition Data

Maps depicting the NRCS Hydrologic Soil Groups, Existing Land Use, and Projected Land Use for each watershed in Jefferson County are included in the Watershed Plans available through MSD's Stormwater Department and ERSI coverages provided by LOJIC. This information may be used to determine the appropriate surface condition factors for use in runoff calculation as described in Section 10.2.3. Contact MSD regarding any discrepancies between the maps and the proposed project site

10.3 HYDRAULICS FOR STORMWATER FACILITIES DESIGN

This section contains the technical criteria required for the design of stormwater facilities. The Design Engineer must make adequate reference to other chapters of this manual and the MSD web page for additional design guidelines.

10.3.1 General Guidelines

10.3.1.1 Design Flows

a. Design flows must be calculated by the appropriate method described in Section 10.2. **At a minimum, the facility must have the capacity to transport the 10-year post-development discharge** except in unusual cases, such as retrofit projects. MSD will determine design criteria for retrofit projects or other unusual cases. **The water surface profile and through system capacity shall be checked for the 100-year post-development discharge. All systems must be capable of passing the 100-year design flow within the drainage easement**. Additional facility-specific requirements are found in following portions of this Section.

10.3.1.2 Combined Sewer Area

a. All development in the Combined Sewer Area (CSA) shall limit the 100 year post-developed discharge to the 10 year pre-developed discharge using the methods described in Section 10.2. **The pre-developed condition shall be defined as: *the condition of the site when either a preliminary plan or a construction plan is submitted to MSD for review*, whichever is first.**

b. The tributary area that must meet the Pre10-Post 100 requirement shall be limited to the *area of disturbance.*

Note: ***Land Disturbing Activity*** is defined by the **Jefferson County Erosion Prevention and Sediment Control Ordinance** as: "*Any land change which may result in soil erosion from water or wind and the movement of sediments into water or onto lands, including but not limited to clearing, grading, excavating, transporting and filling of land.*"

Furthermore**, the exposure of bare soil shall be considered a land disturbing activity by MSD.**

c. Development disturbing less than ½ acre and without a storm drainage system shall be exempt from the Pre10-Post 100 requirement.

d. Connections to the combined sewer system shall be no less than 6” in diameter. If calculations show that a connection should be less than 6”, the difference of the two volumes must be compensated for in the pipe system.

e. Basins connected to the combined sewer system or in a flood prone area shall be fitted with a backflow device, have an overflow above the flood elevation, and have the last storm structure be “trapped”.

f. All designs attempting to meet the Pre10-Post 100 requirement will be subject to the specifications in Section 10.3.8 and Chapter 18 of this Manual.

10.3.1.3 Allowable Pipe Materials

a. Pipe material will be selected from the products identified in the MSD Standard Specifications. Alternate products can be specified by the designer, but prior approval from MSD will be required. Designers will indicate “pipe” on the plan unless a particular product or group of products has been identified and the decision can be justified. Approved products from the specifications that are not advantageous for a particular project and not allowed will need to be identified in the contract.

10.3.1.4 Roughness Coefficients "n" (See Exhibit 10-7)

a. Concrete (Pipe or Finished): 0.012

b. Plastic (Smooth Interior Wall): 0.011

c. Corrugated Metal Pipe: 0.024

d. Sod: 0.030
e. Placed Riprap: 0.030

f. Dumped Riprap: 0.035

g. Gabions: 0.028

h. Coefficients for other approved materials shall be source documented for review.

10.3.1.5 General Pipe Design Requirements

a. Minimum velocity shall be 2 feet per second at design flow or 3 feet per second at full flow; whichever requires the greater slope.

b. Minimum pipe size shall be 12 inches except that driveway entrance pipe may be 10 inches with prior approval by MSD. Smaller pipe sizes may be approved by MSD for detention basin outlets on a case-by-case basis. Such pipes shall not be smaller than 6 inches.

c. Maximum manhole spacing
   1. Less than 18" diameter- 400'
   2. 18" to 30" diameter- 500'
   3. 33" and greater diameter- 600'

d. All pipes are to have end treatments. Design of end treatments shall consider traffic safety.

e. Stubs for storm sewers when required shall be 1 foot long measured from the outside of the manhole or surface inlet for PVC and PE pipe or one length of pipe for concrete pipe.

f. Submerged pipes are not desirable, but may be approved by MSD on a case-by-case basis.

g. When a drainage system is designed to enter a combined sewer, the last manhole or catch basin shall be trapped to prevent the possible release of harmful gases and odors.

10.3.2 Storm Sewers

10.3.2.1 Design Methodology/Design Storm

The Design Engineer may refer to the Kentucky Transportation Cabinet Drainage Guidance Manual for design methodology for storm sewers. The exception being that **all storm sewer systems will be designed for the 10-year event. The 100-year discharge elevation must be checked to ensure the system does not surcharge out of any inlets and/or manholes.** Manning's Equation is recommended to calculate pipe flow and velocity. The storm sewer hydraulic grade line shall be at least 1.0 foot below the ground surface or building drain elevation, whichever is lower, at all points for the design event. For the 100-year event, the hydraulic grade line may not rise higher than the ground line or building drain elevation, whichever is lower. Where the storm sewer hydraulic grade line exceeds the pipe crown, it must be shown on the Profile Drawing. Losses at all inlets, junction structures and bends are to be considered. Refer to MSD Standard Casting Details for all surface inlets and manhole castings. Pipes on grades greater than or equal to 20% shall have anchors at each pipe joint. The Design Engineer shall check to ensure that all pipes have sufficient cover and that all structures, inlets and manholes have sufficient dimension to receive pipes, bells, frames, and grates.

10.3.3. Culverts

10.3.3.1 Design Methodology/Design Storm

A method as described in the Kentucky Transportation Cabinet Drainage Guidance Manual should be used. The design methodology utilized must be submitted for review.

10.3.3.2 Maximum Allowable Headwater

The most stringent requirement of the following will apply:

a. Cul-de-sacs, alleys, local streets, and collectors: Use the subgrade elevation of the adjacent roadway for the 10-year discharge.

b. Major and minor arterials: Use 12 inches below the shoulder elevation of the adjacent roadway for the 100-year discharge.

c. Headwater for the 10-year discharge should not exceed 1.2 times the structure rise except as specifically approved by MSD on a case-by-case basis. For pipes 30" in diameter and larger, the headwater should not exceed 1.0 times the structure rise except as specifically approved by MSD on a case-by-case basis.

d. If a culvert has a drainage area greater than one square mile or is in a regulated floodplain the 100-year storm headwater depth shall not be greater than 1.0 times the structure rise except as specifically approved by MSD on a case-by-case basis.

10.3.3.3 General

a. Downstream channel must receive appropriate protection or energy dissipation if the design outlet discharge would cause erosive conditions.

b. Traffic safety must be considered in the design of culvert end treatments. This may include extending the culvert beyond the right-of-way limits, installing catch basins to intercept roadside swales, and installing guardrails. Designs must conform to meet the requirements of the agency responsible for road maintenance and safety.

10.3.4 Trenchless Pipe Installation

Trenchless pipe installation for storm sewers and culverts is described in Chapter 8 of this manual.

10.3.5 Conventional Channels and Ditches

This section describes the technical criteria necessary to design stormwater channels and ditches using conventional design procedures. These procedures shall be applied to roadside and rear yard ditches and highly urbanized channels. Where possible, all blueline streams (especially in undisturbed areas) shall be designed using Natural Channel Design techniques as described in Section 10.3.6. This criterion represents minimum requirements. Justification should be submitted to MSD for review and approval in cases where different slopes or other protective measures are recommended.

10.3.5.1 Design Methodology/Design Storm

Manning's Equation is recommended, except in cases where backwater conditions are significant. All calculations must be submitted for review. Software programs utilized must be approved by MSD.

a. Design Storm

1. **Channels and ditches should be capable of conveying the 10-year storm flow within their banks**. Through drainage systems shall generally be designed to collect and transport the post-development rate of runoff for the 100-year design storm. **In all cases, the 100-year discharge elevation must be checked to ensure that adjacent structures do not suffer flood damage.**

2. **All systems must be capable of passing the 100-year design flow within the drainage easement.**

b. Channel Criteria

Minimum Channel Slope - 0.5%, except in special cases such as retrofit projects or major channels.

c. Maximum Side Slope

1.	Earth	3:1 (when depth < 8.0 feet) 4:1 (when depth > 8.0 feet) 2:1 (may be allowed on case-by-case basis)	
2.	Riprap and Aggregate		1.5:1
3.	Concrete		1:1

4. No maintenance ground cover 2:1
5. Bioengineered systems on various slopes

d. Channel Depth

Channels created for new residential subdivisions shall not have a design depth of greater than 2.0’, unless otherwise approved by MSD.

e. Channel Lining

1. Channel slope 0.5% or less – Concrete. Evaluate the use of a low flow channel. As-builts may be required.
2. Channel Slope between 0.5% and 2.0% - Concrete low flow channel with durable lining for the remainder of the protected section.

3. Channel Slope greater than 2.0% - Natural vegetation and geosynthetic turf reinforcement.

4. If the design parameters are beyond the limits of natural vegetation, then a non-degradable durable material must be used. Durable channel lining is required to the depth of the 10-year storm as outlined in Section 10.3.5.3. Durable channel lining may be low maintenance ground cover, sod, soil bioengineered systems, turf reinforcement mats or concrete. Rip-Rap, Aggregate Channel Lining and Gabion Baskets are to be limited to areas immediately downstream of an outlet pipe to reduce velocities and erosion potential. The use of these materials shall be a last alternative and approved on a case by case basis. All linings must be approved by MSD on a case-by-case basis.

5. Trapezoidal or rectangular paved channels shall have bottom slopes no less than 1:12 sloping either to the center or to one side of the channel to provide self cleaning.

6. Channel and channel lining design should consider the effects of open channel junctions, curved alignment, obstructions, transitions, constrictions, changes in slope and other characteristics including the effects of subcritical and supercritical flow.

10.3.5.2 General

a. Roadside ditches on retrofit projects, which have less than a 4-foot shoulder, shall not exceed 1'-6" in depth, measured from the edge of pavement.

b. Roadside ditches and channels must have a minimum 4-foot shoulder from the edge of the pavement to the top of the bank.

c. Roadside ditches and channels in through systems must have a minimum 8-foot shoulder from the edge of the pavement to the top of the bank.

d. In areas where new sidewalks are proposed to cross-swales, ditches, or channels, a culvert meeting design storm requirements must be installed extending past the sidewalk sufficiently to allow a maximum 4:1 slope.

e. Ditches and channels adjacent to state highways may require more stringent criteria. The Design Engineer must obtain the criteria from the KYTC.

f. Cutoff walls shall be placed at the beginning and end of all paved channels.

g. Utilities and their facilities should not be located within or interfere with swales, ditches, detention/retention facilities, stormwater quality treatment devices and facilities, manholes, pipes or landscaping such as trees and bushes.

10.3.5.3 Channel Design Procedure

a. The method of designing channels and ditches as presented agrees with Hydraulic Engineering Circular HEC-15 that is based on the tractive force theory. The calculated shear stress resulting from flow in a channel is compared to the maximum permissible shear stress for the channel lining selected. If the shear force induced by the flowing water equals or exceeds the permissible shear stress of the lining, failure may occur and a more resilient lining must be proposed. This concept allows for calculation of the maximum discharge a channel can carry by equating the calculated and permissible shear[1]. The procedure is applicable to channels of uniform cross section and constant bottom slope.

The suggested step-by-step design procedure shown below is taken from the Kentucky Transportation Cabinet's Drainage Design Manual. Additional information is taken from the Federal Highway Administration's HYDRAIN software documentation manual. Obviously additional procedures and references are available and they should be utilized as designer preference dictates. However, it will be the designer's responsibility to satisfy all MSD reviews.

b. The design procedure as shown assumes steady uniform flow with the energy slope equal to the bed slope and flow calculated using Manning's equation. For conditions other than these, the designer should consult other references; one of which is HEC-11, which focuses on natural channels with irregular cross sections, varying bottom slopes, and flows exceeding 50 cfs.

The maximum shear stress on the side slopes is always less than or equal to that on the channel bottom and does not limit the design of a single, rigid, vegetative, gabion, or temporary lining, but may affect the design of composite linings[1]. The designer is alerted to this situation and should consult the previously noted references.

c. Design Procedure

1. Determine Drainage Area Contributing to the Channel.

2. Select Channel Cross Section- Side Slopes & Bottom Width

3. Determine Channel Longitudinal Grade

4. Calculate Design Flow - Adjust channel cross-section and grade as necessary for capacity. (Reference Section 10.3.1.2)

5. Select Channel Lining

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[1] Federal Highway Administration's HYDRAIN Software Documentation (GKY and Associates, Inc.).

a. Determine maximum permissible shear stress (τ_p) for the selected lining. See Table 5-3 in the KYTC Drainage Manual for a summary list of various protection measures or the manufacturer's recommendations for specific Turf Reinforcement products.

b. Estimate flow depth in the channel.

c. Determine Manning "n" for selected lining and depth of flow.

d. Calculate flow using Manning's equation and the estimated flow depth.

e. If calculated flow varies from design flow, repeat steps (b) and (d) until flows agree.

f. Calculate actual shear stress(τ_d)

$$\tau_d = \gamma \, d_n \, s,$$

Where:
τ_d = actual shear stress 1b/ft^2
γ = specific weight of water 62.4 lbf/ft^3
d_n = flow depth in ft.
s = energy slope (bed slope); ft/ft

g. If $\tau_d < \tau_p$, the lining selected is acceptable

If $\tau_d > \tau_p$, consider the following:

- Select a lining with a higher permissible shear stress
- Decrease slope
- Increase the channel width and/or flatten side slopes

10.3.6 Natural Channel Design Procedures

This section describes Natural Channel Design procedures to be utilized where possible for the design of streams especially along blueline streams and in undisturbed areas. It should be noted that Natural Channel Design techniques promote enhanced stormwater quality and aquatic habitat over conventionally designed channels and ditches and is the preferred method for the design of streams.

10.3.6.1 Design Methodology

Streams designed using natural channel design techniques shall emulate naturally formed streams. The design shall be based upon measurements from reference reaches in similar physiographical regions exhibiting similar characteristics to the desired stream. The designed stream shall exhibit characteristics consistent with stream types expected to occur within the given valley type. Both the pre-existing stream type and the designed stream shall be classified in accordance with the Rosgen Stream Classification system[2].

10.3.6.2 Design Discharge

Streams designed using Natural Channel Design techniques shall include a bankfull channel design based on the bankfull discharge (also commonly referred to as the channel forming discharge). On average, the bankfull discharge approximates a 1.5-year storm event and can range between a 0.8 to 2.0-year storm event. The bankfull discharge used for design shall be determined based on field bankfull indicators and shall be checked against regional curves developed from gauged streams within the same physiographical region as the stream to be designed. Where flooding of nearby structures may occur, the floodplain area adjacent to the bankfull channel shall be designed to convey a 100-year storm event.

10.3.6.3 Design Submittals

All parameters/information used for the basis of design shall be submitted for review. Where an existing stream is present, the design submittal should include calculations for the proposed channel as well as measurements from the existing channel. Information submitted should include reference reach data and location of reference reaches.

As a minimum, the following design parameters/information shall be included in the design submittal: longitudinal profile; cross sectional geometry for pool, riffle and cross-over reaches; stream type; drainage area; bankfull width; mean bankfull depth; bankfull cross sectional area; bankfull discharge; mean bankfull velocity; maximum bankfull depth; width to depth ratio; width of flood prone area; entrenchment ratio; ratio of pool depth to mean bankfull depth; ratio of pool width to mean bankfull width; average

[2] Applied River Morphology (Dave Rosgen, 1994)

riffle, pool, run and glide slope; average water surface slope; valley slope; meander length; belt width; radius of curvature; ratio of meander length to bankfull width; ratio of radius of curvature to bankfull width; meander width ratio; sinuosity; pool to pool spacing; ratio of pool to pool spacing to bankfull width; D50 of bed materials; D84 of material which will be transported during a bankfull event; critical dimensionless shear stresses; minimum mean bankfull depth calculated using dimensionless shear stress equations.

10.3.6.4 Channel Stabilization Methods

Methods to be utilized to stabilize channel banks below the bankfull depth should be included within the design submittal. The use of rock should be limited to areas exhibiting shear stresses above allowable shear stresses for vegetation. The use of native vegetation and soil bioengineering treatments is the preferred method to stabilize channel banks.

10.3.6.5 Aquatic Habitat Enhancements

The use of aquatic habitat enhancements should be included where possible and consistent with stream types. Enhancements may include a variety of structures consistent with stream types such as woody material, rock or wood overhangs, rock vanes, cross vanes, W-weirs, J-hook weirs, stream gravel/boulders, etc. Details for all structures shall be included with the design submittal. In most instances, it is not necessary to extend any in-stream structures or bank revetments above the bankfull depth.

10.3.6.6 Riparian Corridor Enhancements

Where practical, the design shall include enhancements to the riparian corridor on either side of the reconstructed stream. Riparian corridor enhancements shall include native plantings consistent with anticipated inundation periods. Submittals shall include a description of existing vegetation within the riparian corridor as well as proposed plantings and frequency schedules.

10.3.7 Surface Inlets and Gutter Spreads

This section describes the technical criteria necessary to design surface inlets/catch basins. Please reference HEC -12, Drainage of Highway Pavements for a more in-depth discussions and procedures.

10.3.7.1 Design Storm

Curb inlets and gutter spreads and other stormwater inlets shall be designed for the 10-year storm return period and checked against the 100 year storm for overtopping of the roadway crown.

10.3.7.2 Maximum Flow Spread on Pavement

Maximum flow spreads on pavement should be set by MSD in the preliminary stages of all projects.

a. Cul-de-sacs, Alleys, and Local Streets - 6 feet; 8 feet with 2 foot wide concrete curb and gutter

b. County Through Roads - 4 feet; 6 feet with 2 foot wide concrete curb and gutter.

c. **The gutter spread shall not cross the crown of the roadway during the 100 year storm.**

Flow spread is measured from the face of curb. Gutter grades of less than 0.50% should be avoided, if possible. In addition, the flow depth at any location along the curb shall not exceed 4 inches.

10.3.7.3 General

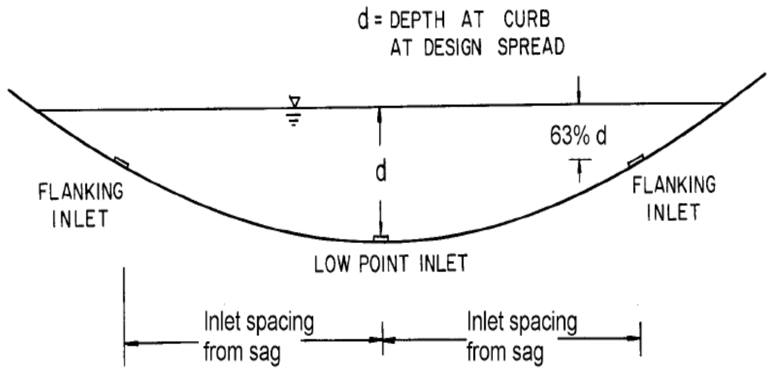
a. Inlets shall be placed immediately upstream of pedestrian walkways and intersections and designed to intercept as close to 100% of the flow as possible

b. Inlets placed at locations other than that described in Section 10.3.7.4a shall be placed at locations that prevent the allowable spread or depth at curb criteria from being exceeded. Vane grates shall be used at all inlet locations.

c. Inlets upstream of a detention basin shall have a grate elevation above the 100 year ponding elevation of the basin

d. Inlets for drains connected to the combined sewer system shall be trapped and may be designed with flow-throttling capabilities if required by MSD.

e. Inlets at sags in curb and gutter applications shall receive careful design to prevent violation of the gutter spread requirements of Section 10.3.7.3. In addition, it is good engineering practice to place flanking inlets on each side of the low point inlet when in a depressed area that has no outlet except through the system. This is illustrated in figure below.



The purpose of the flanking inlets is to act in relief of the inlet at the low point if it should become clogged or if the design spread is exceeded. Flanking inlets can be located so they will function before water spread exceeds the allowable spread at the sump location. The flanking inlets should be located so that they will receive all of the flow when the primary inlet at the bottom of the sag is clogged. They should do this without exceeding the allowable spread at the bottom of the sag. If the flanking inlets are the same dimension as the primary inlet, they will each intercept one-half the design flow when they are located so that the depth of ponding at the flanking inlets is 63 percent of the depth of ponding at the low point. If the flanker inlets are not the same size as the primary inlet, it will be necessary to either develop a new factor or do a trial and error solution using assumed depths with the weir equation to determine the capacity of the flanker inlet at the given depths.

10.3.8 Detention Basins

This section describes the technical criteria necessary to design stormwater detention basins. Detention basins are typically designed to remain empty during dry weather and to backup or detain excessive runoff generated during a storm. The designer is directed to the Detention Analysis Checklist located in the stormwater-sanitary section of MSD's web page.

10.3.8.1 Detention Basin Design

a. A minimum basin volume shall be the difference in runoff volume discharged from the project area to the basin site between the pre-development and post-development 100-year storm, or such volume to sufficiently reduce post-development discharges to pre-development rates whichever is greater. Reference Section 10.2.2.2b for the rainfall duration unique to Detention Basin Design. In cases where the volume requirement governs, the design calculations must not only show that the required volume has been created, but that the basin functions to detain the volume difference. Basin volume may also be dictated by limitations of downstream conditions or other requirements on a case-by-case basis as decided by MSD.

   In many areas of the county the increased runoff volumes can be as critical, if not more critical, than the rate of discharge. MSD will address this issue on a site-specific basis. All development submittals will be evaluated for the impacts of increased runoff and volume control. Satisfying the volume requirement may be met onsite, at approved off-site locations, or by purchase of volume in a Flood Compensation Bank if one is available in the watershed.

   In the Pond Creek watershed, the volume of increased runoff must be mitigated at a ratio of 1.5:1. The ratio may be increased on a site-specific basis as determined by MSD. See section 10.4.2 for other areas that have been identified with the 1.5:1 mitigation ratio. Check with MSD before during work in an area to find out the correct mitigation factor.

   If the basin is to be located directly on a portion of the through drainage system, volume calculations must also consider the total system flow reaching the basin. The Design Engineer must contact MSD for direction in these cases. If the basin is to be constructed on a solid or intermittent blue line stream, it must be beneficial to the stream corridor or the public.

b. Maximum basin side slopes shall be 3:1, unless retaining walls are provided.

c. Low flow channels may be grass if the channel grade is greater than 2.0%.

d. Basin design must include maintenance accessibility and responsibility.

e. Requirements of the Dam Safety Law shall be observed. **Any detention basin classified as a high hazard dam by the Kentucky Division of Water (KDOW) shall submit a dam breach analysis and emergency action plan to MSD.**

f. The Design Engineer shall address provisions for anti-seep collars, extended detention basins, wet ponds, soil bioengineering, baffles, outlet protection and length to width ratios.

g. No sanitary sewer manholes shall be placed within the detention basin.

h. Detention basins in Single Family Developments are to be placed in recorded "Open Spaces". All other detention basins must be completely within a recorded Permanent Detention Basin Easement.

i. Retention basins (permanent pools basins or wet basins) shall have a minimum depth of 5'.

j. The bottom of the detention basin shall have a minimum cross slope of 2% .

k Vegetated recessed islands, bio-swales, or micro-detention are acceptable alternatives in appropriate soil conditions and will be approved by MSD on a case-by-case basis. Such designs are subject to the specifications of Chapter 18 in this Manual.

l. No trees shall be allowed within the berm of the detention basin,

m. **Outlets connecting to the combined sewer system shall require backflow devices and the last structure shall be "trapped".**

10.3.8.2 Basin Discharge

a. Discharge control structures shall be multi-stage and capable of limiting 2, 10, 25, and 100-year post-development discharges to pre-development peak discharge rates or downstream system capacity and shall be constructed of concrete or approved alternate.

b. **The emergency spillway shall be sized to accommodate a flow equal to the design overflow of the 100-year storm post-development discharge, assuming all other outlets are completely blocked, without overtopping the dam**. Discharge must be conveyed to a public outlet of sufficient capacity. Erosion protection must be provided for the spillway and receiving stream and energy dissipation must be employed.

c. **The dam elevation shall not be less than one foot above the 100-year storm storage and overflow elevation.**

d. Appropriate downstream channel protection must be installed and the basin outlet pipe must be placed no closer than 15’ from an adjacent property line.

e. Storage, discharge, and routing calculations for the 2, 10, 25, and 100-year discharges must be submitted for review and have a Professional Engineer’s stamp and signature.

f. **The top of dam shall be at least one foot below the lowest opening of any structure adjacent to and upstream of the dam.**

g. **Detention basins shall be fully discharged, or return to normal pool elevation in the case of wet basins, within 36 hours** after the storm event unless specifically approved by MSD on a case-by-case basis.

h. **The detention basin shall be the first item of construction and must be designed to function as a sediment basin through the construction period.** The basin design must be checked for capacity due to additional runoff generated by disturbed site conditions. The detention basin may be designed with over-excavation to account for planned sedimentation during construction. Excess sedimentation shall be removed and disposed of properly to establish design capacity of the detention basin.

10.3.8.3 Parking Lot Storage

a. Parking lot storage involves shallow ponding in a specifically graded area of a parking lot.

The major disadvantage is the inconvenience to users during the ponding function. Clogging of the flow control device and icy conditions can be maintenance and safety problems. This method is intended to control the runoff directly from the parking area and is not appropriate for storing large volumes.

Parking lot storage shall generally be limited to those areas served by combined sewers, primarily in the central business district of Louisville. Parking lot storage may be approved in separate sewer areas on a case-by-case basis.

b. The general design requirements are:

1. Maximum water depth: 8 inches
2. Minimum ponding area distance from buildings: 10 feet
3. Maximum surface grade: 5.0%
4. Minimum surface grade: 1.0%
5. Maximum discharge to combined sewer system: 10-year pre-development discharge unless otherwise determined by MSD

10.3.8.4 Underground Detention

a. All applicable standards from Sections 10.3.8.1 and 10.3.8.2 shall apply.

b. **All underground detention (including oversized piping) shall be bonded.** Bond quantities shall be submitted to MSD during the review period by the engineer or contractor. The system shall be tele-inspected prior to bond release.

c. The maximum tributary area to one underground detention system shall be no greater than 25 acres.

d. No through drainage shall be allowed in an underground detention system (exceptions may be made for small amounts of offsite sheet flow).

e. All adjacent buildings and equipment shall be at least one foot above the 100 yr Water Surface Elevation

f. All underground detentions systems shall be setback no less than 50' from a septic field or water well.

g. **All underground detention systems shall have a grit removal system at the basin inlet.**

h. All underground detention systems shall be of sufficient capacity to hold the 100 year storm without surcharging.

i. All underground detention systems shall have an emergency overflow.

j. The minimum pipe size and vault height for underground storage structures shall be no less than 36".

k. **All underground detention systems shall have a Long Term Maintenance Agreement that shall be recorded.**

l. Underground detention systems connected to the combined sewer system shall require backflow devices and the last structure shall be "trapped".

10.3.9 Sinkholes

10.3.9.1 General

A sinkhole is any closed depression in a limestone region formed by the removal of water, surfacial soil, rock or other material that is connected to a cavern or underground passage. The sinkhole drainage area shall include any area that contributes surface water directly to the sinkhole.
The use of sinkholes as stormwater management facilities is not permitted, unless there are no other cost-effective alternatives. Then a submittal must be sent to MSD for approval.

10.3.9.2 Design

Specific design considerations for the use of sinkholes, when permitted, include but are not limited to:

a. **The sinkhole shall have the volume to store a 100-year, 24-hour NRCS storm with a no outlet condition**.

b. The capacity of the sinkhole outlet shall be verified by a Hydro-geologic study and dye test.

c. Protection measures for the sinkhole inlet.

d. Trash barriers.

e. Detention requirements.

f. An alternate means of surface water disposal in the event of sinkhole failure.

g. Restriction of development in floodplain areas adjacent to the sinkhole.

h. Review of construction methods and staging.

i. **The design of sinkhole structures must be supervised by a Geotechnical Engineer, licensed in the Commonwealth of Kentucky.** The engineer shall also inspect and certify the construction of the sinkhole structure and certify the ability of the sinkhole to accept anticipated flows without flooding or causing property damage in the case of failure.

j. A member of MSD's Maintenance Division must be present on all final inspections for bond release for new subdivisions.

k. Any structural failures must be fully documented and a Geotechnical Engineer, licensed in the Commonwealth of Kentucky, must supervise design of, inspect and certify construction of repairs prior to bond release.

10.4 LOCAL REGULATORY FLOODPLAIN AND CONVEYANCE ZONE

For background information on the Louisville and Jefferson County Floodplain Ordinance and the associated restrictions, refer to section 3.7. It is suggested that MSD be contacted in the early stages of any project if clarification is needed concerning requirements and restrictions. This section defines Floodplain Compensation and describes the methodologies to be used when determining the Local Regulatory Floodplain (LRFP) and Local Regulatory Conveyance Zone (LRCZ).

10.4.1 Definitions:

"Local Regulatory Flood" means the flood having a one-percent (1%) probability of being equaled or exceeded in any given year based on a fully developed watershed.

"Local Regulatory Floodplain" means any stream course or normally dry land area susceptible to being partially or completely inundated by the overflow of water from sources of public water or by the unusual and rapid accumulation or runoff of public surface waters and subject to a local regulatory flood.

"The Local Regulatory Conveyance Zone" is the channel of a river or a solid blue line stream and the land adjacent to that river or stream which, if unobstructed, will discharge a local regulatory flood without cumulatively increasing the water surface elevation more than one tenth of one foot. The conveyance zone is determined by an equal loss of conveyance (at higher elevation) occurring on each side of the channel.

"Floodplain Storage Compensation" means an artificially excavated, hydraulically equivalent volume of floodplain storage sufficient to offset a reduction in floodplain storage resulting from filling or construction within the local regulatory floodplain.

10.4.2 Floodplain Compensation

Floodplain compensation at a ratio of 1:1 is required throughout Jefferson County as part of the Floodplain Ordinance. Due to the severe flooding problems in the lower portion of the **Pond Creek watershed**, **the required ratio is 1.5:1 for any fill placed in the fully developed local regulatory floodplain. The 1.5:1 ratio also applies in Chenoweth Run of the Floyds Fork watershed and Big Run of the Mill Creek watershed.** These ratios may be increased on a site-specific basis as determined by MSD.

10.4.3 Determinations

a. MSD has approximate elevations for the LRFP in many locations. Additionally, hydraulic modeling currently exists for many streams in Jefferson County; these models may be utilized to determine the LRFP and LRCZ. If information is not available from MSD, then it will need to be defined as a part of the project.

b. Natural Resource Conservation Service Methodology (NRCS) shall be used for runoff calculation. A 24-hour Type II storm distribution with five-minute increments is required. Other distribution methods may be approved by MSD on a case-by-case basis.

c. Curve numbers (CN) and time of concentrations (T_c) shall be based on a fully developed watershed as zoned at the time of design.

d. Hydrology information may be computed using HEC-HMS, POND PACK, or Hydraflow. Hydraulic modeling should be based on HEC-RAS. In each case, other software can be utilized if approved by MSD.

10.5 HYDROLOGIC AND HYDRAULIC MODELING STANDARDS

Development of uniform modeling standards is a means by which MSD can regulate the quality of the floodplain models in Jefferson County. Successful floodplain management requires that the hydrologic and hydraulic floodplain models be updated as changes in watersheds occur. These changes include those resulting from continued development in the watershed, as well as from physical changes in the drainage system. As the watersheds evolve over time, the modeling standards provide guidance on how changes should be incorporated into the models. The implementation of a comprehensive set of modeling standards promotes consistency in floodplain modeling, standardizes MSD review effort, and provides a means to educate the engineering/development community.

Hydrologic and hydraulic modeling criteria have been established in Jefferson County through the combined efforts of MSD, U of L, the Kentucky Division of Water, KYTC, the Louisville District Army Corps of Engineers and local engineering consultants.

The following modeling guidelines are consistent with current engineering standards of practice not necessarily to the exclusion of other sound and technically supported procedures. A licensed professional engineer should justify the use of methods other than those described below in writing prior to the model submittal and review process.

Contact the MSD Development Team for surface stormwater models.

10.5.1. Software Selection

HEC-HMS is the recommended program for rainfall/runoff hydrologic simulations requiring hydrograph analysis at one or more points along a stream. HEC-RAS is the recommended program for open channel flow or floodplain calculations excluding streams with extremely low or high gradient. The most current versions of these software packages are available from the Hydrologic Engineering Center's website at www.hec.usace.army.mil. The HEC manuals offer guidance for conversions to the newer versions of their software. Other software may be accepted for floodplain analysis in Jefferson County if approved by FEMA for NFIP usage. A list of accepted models may be found at www.fema.gov. Civil site analysis, local detention basin design, water quality analysis, natural channel design, and interior drainage system design may be performed with models not on FEMA's approved NFIP list if approved by MSD prior to use on a case by case basis.

10.5.2. Hydrologic Modeling

The following methods and/or parameters should be used for single event hydrologic analyses for streams and/or detention basin calculations.

10.5.2.1. Basin Parameters

a. Subbasin Delineation. Depending on the size and location of the watershed being analyzed, and the extents of previous modeling attempts, tributary boundaries may need to be redefined or subdivided. Drainage areas must be delineated using LOJIC mapping with 2-ft contours in Jefferson County. In areas where watersheds extend into other counties and LOJIC data is not available, supplement the topographic data with 7-1/2 Minute USGS Topographic Quadrangles. Subbasin size in developable watershed areas should be 50 to 200 acres. Areas that are not expected to develop due to land use or zoning criteria, such as the Jefferson Memorial Forest, can have larger subbasin areas based on natural drainage patterns.

b. Loss Rate. The NRCS Runoff Curve Number (CN) Method, as described in TR-55 (NRCS 1986) and NEH-4 (NRCS 1985), shall be used to estimate runoff from design storms. Continuous simulations, if necessary, may use other loss rate methodology where applicable.

c. Transform. Rainfall excess shall be transformed into runoff using the NRCS Unit Hydrograph approach.

d. Base Flow. Unless modeling the Ohio River, base flow may be ignored during floodplain analyses.

e. Time of Concentration (T_c). The time of concentration shall be calculated for each subbasin using the combined travel times for sheet flow, shallow concentrated flow, and open channel flow in accordance with TR-55 (NRCS 1986).

f. Antecedent Runoff Conditions (ARC). Average ARC shall be used in all cases except for model calibration.

g. Infiltration. Runoff infiltration will be calculated using the NRCS Runoff Curve Number Method, as discussed above. CN's should be developed for both the "existing watershed conditions" (EX) and the "fully developed watershed conditions" (FD) and analyzed separately. EX CN's shall be estimated using LOJIC data for hydrologic soil groups, land cover type and treatment, hydrologic condition, and percentage of impervious area (connected or unconnected). Impervious area calculations should include LOJIC data sources for buildings, roads, and miscellaneous transportation such as sidewalks and driveways. FD CN's shall be estimated using soils data, existing zoning regulations, and lookup tables relating zoning designations with maximum impervious area limitations to CN values.

h. Channel Routing. Hydrograph routing through a subbasin or along a reach of stream shall use either the Modified Puls (low gradient) or Muskingum-Cunge (moderate to high gradient) routing techniques. Muskingum-Cunge 8-point cross sections are recommended for natural channels. Routing results in the hydrologic model must correlate with the hydraulic model for the same reach.

i. Reservoir Routing. Reservoir routing may be used for modeling storage effects at bridges or culverts, or may be used for detention facility analysis. In either case, the routing method shall use an elevation-volume-outflow relationship developed by the engineer with consideration of backwater effects on the outlet hydraulics. The initial conditions of reservoir elements shall be controlled by normal dry-weather water surface elevations. Documentation of methods used to derive the hydraulic response and storage capacity of structures associated with reservoir routing should accompany the submittal.

10.5.2.2. Meteorological Parameters

a. Rainfall Duration. All models used for hydraulics analysis shall use 24-hour duration design storms.

b. Total Rainfall Depth. Rainfall depths associated with various annual exceedence probabilities are referenced from *Rainfall Frequency Atlas of the United States*, U.S. Department of Commerce, Weather Bureau, 1961 (also known as TP-40). The 24-hour duration rainfall values used for analysis in Jefferson County are as follows (also see Exhibit 10-3):

- 2-year 3.2 inches
- 10-year 4.5 inches
- 25-year 5.2 inches
- 100-year 6.2 inches

c. Temporal Distribution. The NRCS Type II rainfall distribution (5-minute increment) will be used for design storm definition in Jefferson County.

d. Spatial Distribution. Design storms shall be applied uniformly and simultaneously to subbasins of the hydrologic simulation.

10.5.2.3. Control Specifications

a. Calculation Time Step. There are five-minute (or less) calculation steps required for hydrologic modeling.

b. Simulation Length. Hydrologic models must simulate the 24-hour design storm and describe watershed response until all elements are within 5% of their initial discharge conditions.

10.5.3. Hydraulic Modeling

Water surface profile modeling is required for analyzing impacts to blue line and intermittent blue line streams in Jefferson County. The one-dimensional, steady flow calculations performed by HEC-RAS are suitable for most watershed conditions. HEC-RAS also has the ability to calculate LRCZ boundaries.

10.5.3.1. Study Limits

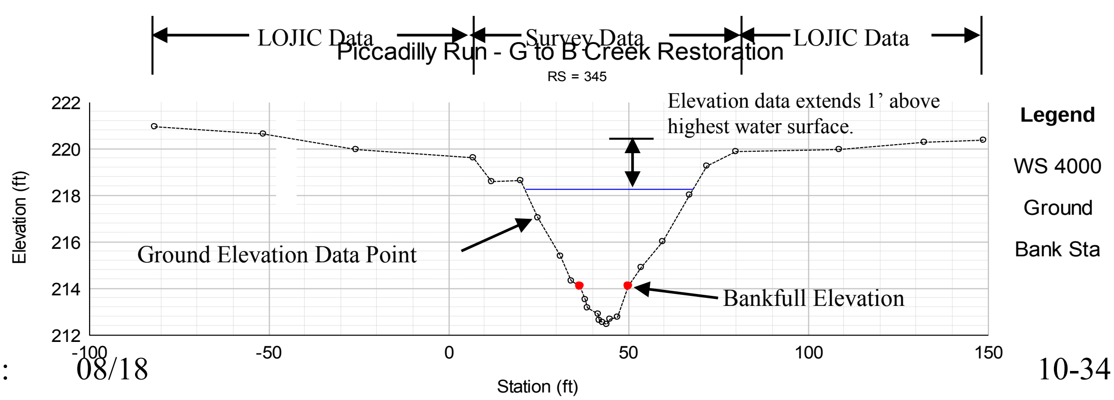
The hydraulic study should extend upstream and downstream of the impacted reach to a point that the modified profile converges with the existing condition profile for the same event. When creating new models, verify modeling extents with MSD prior to the project. GIS coverage of watershed boundaries, floodplains and conveyance zones are available with existing H-H models on the MSD web page. Changes to models typically require modification to the existing subbasins and/or cross section coverage.

10.5.3.2. Cross Sectional Geometry

a. Width. The minimum width is set by extending the left and right ends of the cross section to one foot above the LRFP elevation.

b. Spacing. Cross section locations should be based on sound engineering judgment. Higher density is required at tributary locations, slope changes, roughness changes, valley morphology changes, and at bridges or other structures. In general, cross section locations should be based on the riffle spacing of the stream being studied. Pool cross sections may be necessary for geomorphic channel design, but are not required for floodplain determination. Cross section spacing on any stream in Jefferson County should not exceed 500 feet (excluding the Ohio River).

c. Number of Data Points. A minimum of seven data points is required to describe each cross section. The maximum number of data points is limited by software constraints.



d. Source of Geometry Data. Elevation data in the active channel shall be collected with field survey and tied to the North American Vertical Datum of 1988 (NAVD 88) . The cross section geometry should have the density of points necessary to accurately quantify the area under bankfull elevation and the location of the stream thawleg. LOJIC 2-ft contour mapping may be used to supplement cross section data in the floodplain (overbanks). A licensed Land Surveyor or Professional Engineer must document the accuracy of survey information at cross sections and structures. An example of a suitable cross section is as follows:

e. Bank Stations. Bank stations in natural cross sections should be placed at the geomorphic bankfull elevation. Variations in roughness values should be included for the channel bed, left and right banks, and left and right floodplains.

f. Reach Lengths. The distances measured between cross sections at similar points are called reach lengths. HEC-RAS uses this information to compute discharge-weighted reach overbank segments. Floodplain models should use the distance measured along the stream thawleg for the centerline reach length. Left and right overbank reach lengths should be estimated as the center of mass of the floodplain discharge.

g. Roughness Values. Channel and floodplain roughness values significantly influence model accuracy. Roughness values should be reflective of the natural variations in the bed materials and overbank vegetation. Consistent with models developed in the past, Manning's n should be used to describe frictional energy losses. There are a variety of methods available for calculating Manning's n from particle size distributions of channel materials (USDA, Rosgen, and others). Listed below are some additional references available that have photographs of reaches with measured values. A listing and description of roughness values with photographs should be included in the documentation of the model development.

h.

References:

Open-Channel Hydraulics, Chow, 1959
Roughness Characteristics of Natural Channels, Barnes, Harry H., USGS, 1967
Roughness Characteristics of New Zealand Rivers, Hicks and Mason, 1991
Stream Corridor Restoration Principles, Practices, and Processes, USDA, 1998
The Reference Reach Field Book, Rosgen, 1998

i. Expansion and Contraction Coefficients. Subcritical flow contraction and expansion coefficients are used to estimate energy losses caused by abrupt changes in the flowing cross sectional area. Typical losses occur upstream and downstream of bridge or culvert crossings and flow through a narrower portion of the valley. Where contraction and expansion losses are expected to occur, contraction coefficients should vary between 0.1 and 0.3, expansion coefficients should vary between 0.3 and 0.5. FEMA requires documentation of loss coefficients higher than these ranges.

j. Ineffective Flow Areas. Effective flow, in one-dimensional modeling, is the portion of the flow traveling in the downstream direction. Portions of the cross section that are occupied by water but not flowing in the downstream direction are described as ineffective flow areas and should be specified. A definition of ineffective flow areas should be justified in the report. Ineffective flow areas in urban watersheds must reflect current development. It is typical to have ineffective flow areas upstream and downstream of bridges.

k. Levees. The use of the levee option in HEC-RAS must be used to describe a levee in accordance with FEMA regulations and justified for NFIP use. Use of the levee option in the hydraulic model for other reasons than the description of a legitimate flood control measure must be approved by MSD in advance.

10.5.3.3. Structures

a. Required Structures. Bridges, culverts, significant pedways and other stream crossings should be included in the hydraulic model. The geometry of the obstruction should be surveyed and related to NAVD 88. Normal stream debris should be reflected in the reach's roughness values.

b. Analysis Methods. Refer to *Hydraulic Reference Manual* Version 2.0 or higher (HEC). The selected method is at the discretion of the engineer but must be documented in the report.

10.5.3.4. Steady Flow and Boundary Conditions

a. Frequency of Flow Data. The hydrologic model must be sufficiently subdivided to provide flow change locations along the study reach. New flow data should be added to the hydraulic model when the flow rate changes by $\pm$10%.

b. Upstream or Downstream Boundary Conditions. Within each of the eleven major watersheds of Jefferson County, hydraulic models should be connected by junctions or downstream boundary conditions representing larger streams. Normal depth is used to represent the upstream or downstream boundary condition, or starting water surface, when the study reach is sufficiently remote from streams with existing models. If the study reach can be extended to a modeled reach then either a junction should be used or the downstream boundary of the new reach should be set at the water surface elevation of the larger tributary modeled with the same storm event. This conservative "simultaneous peak" approach is used for regulatory models to define the worst possible case of floodplain inundation. A minimum of ten cross sections should be placed between the boundary conditions and the study reach. LRCZ boundary conditions are set at the LRFP elevation plus 0.1 feet.

c. Internal Boundaries (Junctions). Where possible, newly modeled tributaries will be connected to larger streams with junctions. Under most floodplain modeling conditions in Jefferson County the energy losses occurring at locations where streams come together can be calculated with the Energy Equation option in HEC-RAS. The reach distance across junctions should be minimized to reduce errors when using this option.

10.5.3.5. HEC-RAS Methodology

a. Friction Slope. Use the HEC-RAS Average Conveyance Method.

b. Calculation Tolerances. Use the HEC-RAS Defaults.

c. Conveyance Method. The suggested method, for consistency, is to use the HEC-RAS default, which calculates conveyance in areas defined by changes in Manning's "n" values only.

d. Floodway Methodology. Floodway determinations are required for blue line or intermittent blue line streams in Jefferson County. The LRCZ is determined by using the encroachment options available in HEC-RAS. LRCZ boundaries are established by encroaching into the LRFP, producing equal loss in conveyance from both sides of the channel until the water surface has risen 0.1 feet. Floodway determination should include consideration of expansion and contraction losses at bridges and valley nick points. For additional guidelines refer to HEC-RAS and *Floodway Determination Using Computer Program HEC-2*, TD-5, USACE, 1988.

10.5.4. Submittals

10.5.4.1. The LRFP/LRCZ Report Details

The report should include the following:

a. Discussion of the reasons for development or modifications of floodplain models and the standards or assumptions made. The report should be a document including a cover letter signed by a licensed professional engineer.

b. Include a table defining the changes to LRFP and LRCZ limits containing the information provided in HEC-RAS with the standard table "Encroachment 1". HEC-RAS results should be submitted for the existing, or effective model, if available, the corrected effective model showing additional geometry information from the study reach, and the proposed model.

c. Tables of the watershed and basin parameters, i.e. time of concentrations, curve numbers for existing and fully developed conditions and watershed areas.

d. Photographs of representative reaches and all bridges or culverts in the hydraulic model.

e. A table of HEC-HMS elements that correspond to flow change locations in HEC-RAS including junction name, cross section name, the road name at road crossings, and LRFP discharge.

f. Water surface profiles for all events modeled.

g. Typical cross sections showing water surface elevations and encroachment limits.

h. Hardcopies of existing HEC data files used to generate the updated models.

i. A hardcopy summary of HEC-HMS results (standard output table).

j. Digital versions of models prepared for the analysis.

10.5.4.2. Watershed Analysis Mapping

a. Mapping shall include soils, land use, zoning, streams, buildings, roads, existing and proposed LRFP/LRCZ boundaries, hydraulic cross sections and study reach limits, at a minimum. The standard scale for paper maps is 1" = 400' or less using 2-ft contours. Contact LOJIC for digital or paper mapping**.** Contact MSD for guidance and methodology for mapping the LRCZ from model results. Encroachment stations shown on final mapping shall be represented in the final model runs.

b. Digital copies of cross section or subbasin modifications are required. Submittals may be as ESRI shapefiles or *.DXF files referenced to LOJIC coordinate systems.

10.5.4.3. Transmittal Medium

All digital materials, including HEC models, ESRI shapefiles, DXF files, digital photographs, H-H modeling parameters, etc. should accompany submittals on a CD bound into the report.

10.6 Combined Sewer Floodprone Development Requirements

10.6.1 Definitions

"Accessory structure" - A structure located on the same parcel of property as the principal structure, the use of which is incidental to the use of the principal structure. Accessory structures shall constitute a minimal initial investment, shall not be used for human occupancy, and shall be designed to have minimal flood damage potential. Examples of accessory structures are detached garages, carports, storage sheds, pole barns, and hay sheds.
"Combined Sewer Floodprone Area" – Area delineated as having a 1% annual chance or greater of flooding due to surcharging of the combined sewer system.
"Combined Sewer Floodprone Elevation" – Elevation of the 1% annual chance or greater flood as determined by hydraulic modeling of the combined sewer system.
"Critical Facility" - Any facility which if unusable or unreachable because of flooding would seriously and adversely affect the health and safety of the public. Critical facilities, to include, but not limited to schools, hospitals, nursing homes, and housing likely to contain occupants not sufficiently mobile to avoid injury or death unaided during a flood; police stations, fire stations, emergency vehicle and emergency equipment storage facilities, and emergency operations centers likely to be called upon before, during and after a flood; public and private utility facilities important to maintaining or restoring normal services before, during and

after a flood; and those structures or facilities which produce, use, or store highly volatile, flammable, explosive, toxic, and/or water reactive materials.
"Floodprone Area Storage Compensation" - An artificially excavated, hydraulically equivalent volume of storage sufficient to offset a reduction in storage resulting from filling or construction within the combined sewer floodplain area as determined by the administering agency. Such storage compensation shall be provided on the same property or at an alternate site if the administering agency so approves.

10.6.2 Determinations

a. Limits of the combined sewer floodprone area can be found on the LOJIC Online Map. Limits of this area are also available from LOJIC. The combined sewer floodprone area was determined using two dimensional hydraulic modeling software (Innovyze InfoWorks ICM) to determine the surcharge from the combined sewer system during a 1% annual chance or greater storm.
b. A 24-hour Type II Storm distribution with 5 minute increments was used. Runoff calculations are based on an assigned percent impervious for each basin. The Horton Infiltration methodology was used in pervious areas. Runoff response was based on a calibrated slope/basin dimension using the EPA-SWMM runoff methodology.
c. Mapping of the floodprone area inundation limits is based on 3-foot LIDAR data, which was used as the basis for a 2D surface flow-routing mesh in InfoWorks ICM.
d. Elevations for the combined sewer floodprone area are available upon request from MSD.

10.6.3 Development Standards

a. For any new residential structure or new addition located in the combined sewer floodprone area, the lowest finished floor must be elevated to at least two feet above the combined sewer floodprone elevation.
b. For any new non-residential structure or new addition, the lowest finished floor must be elevated to at least one foot above the combined sewer floodprone elevation or the structure must be dry floodproofed to at least one foot above the combined sewer floodprone elevation so that those areas including all mechanical and utility equipment and ductwork below the required elevation are watertight with walls substantially impermeable to the passage of water and structural components are used which have the capability to resist hydrostatic and hydrodynamic loads and the effects of buoyancy which capabilities shall be certified by a licensed professional engineer or architect and provided to MSD.

c. Mechanical and utility equipment and ductwork associated with a new structure or addition must be elevated to at least two feet above the combined sewer floodprone elevation or for non-residential structures, dry floodproofed to at least two feet above the combined floodprone elevation.

d. If solid foundation perimeter walls are to be used to elevate the structure to at least freeboard elevation,

    1. If flood depths are more than 1’, foundation walls must be designed by a professional engineer to withstand hydrostatic pressures from the 1% annual chance elevation, and
    2. All space within the area created by the solid perimeter walls shall be designated undevelopable space with a restriction recorded with the deed of such designation evidence of which recorded restriction shall be provided to the administering agency before approval of the floodplain permit, and
    3. The interior portion of the area shall not be partitioned or finished into separate rooms.
    4. Any openings, including vents, shall be elevated to at least the 1% annual chance elevation.

e. Accessory structures shall be exempt from section 10.6.

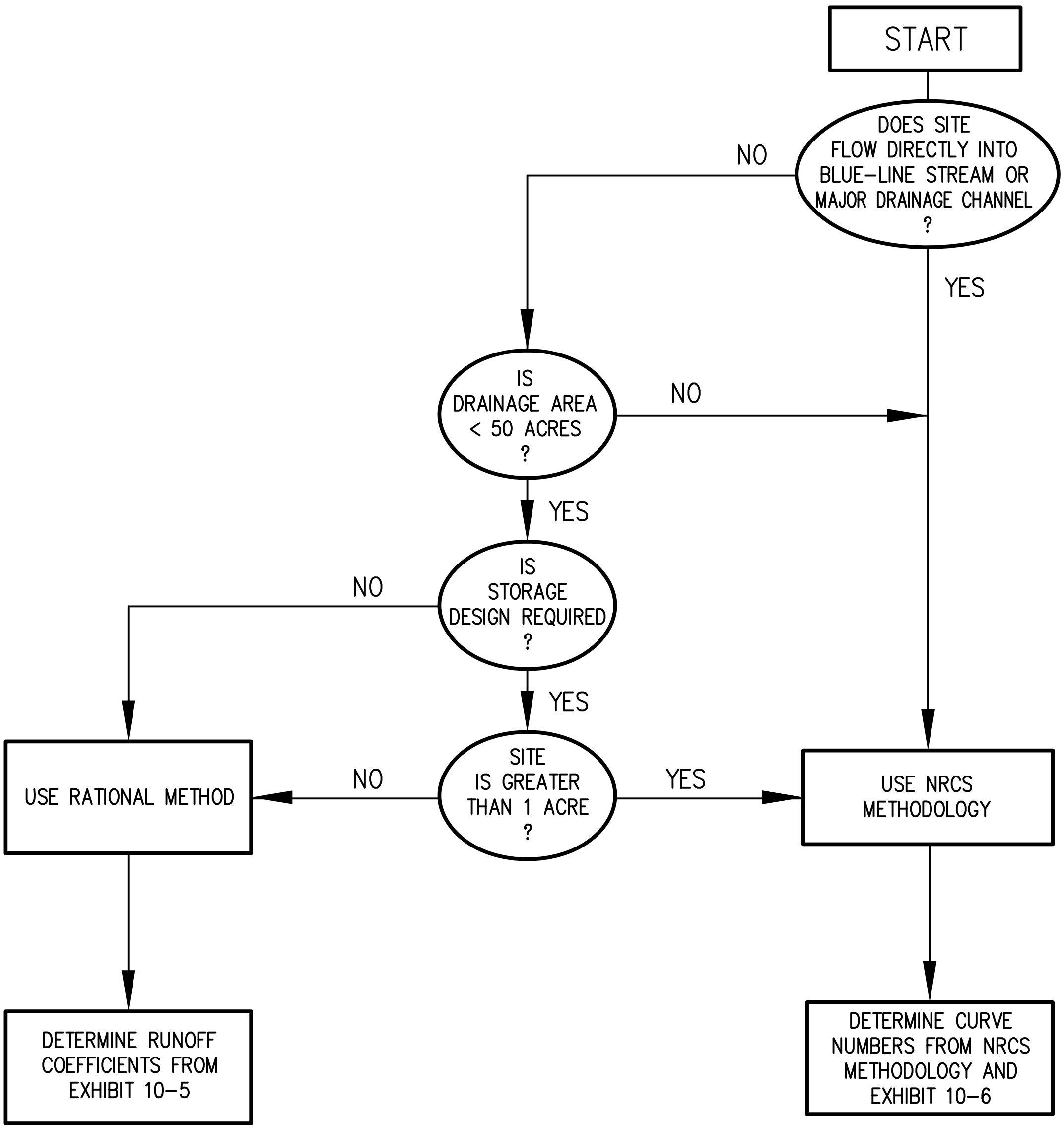
f. An elevation certificate bond shall be required for any new structure or addition located in the combined sewer floodprone area prior construction approval.

g. Any development which displaces any storage capacity for floodwaters in the combined sewer floodprone area shall provide equivalent floodprone area storage compensation.

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 10-1
HYDROLOGIC METHOD SELECTION FLOWCHART

EFFECTIVE DATE: JUNE 30, 2009



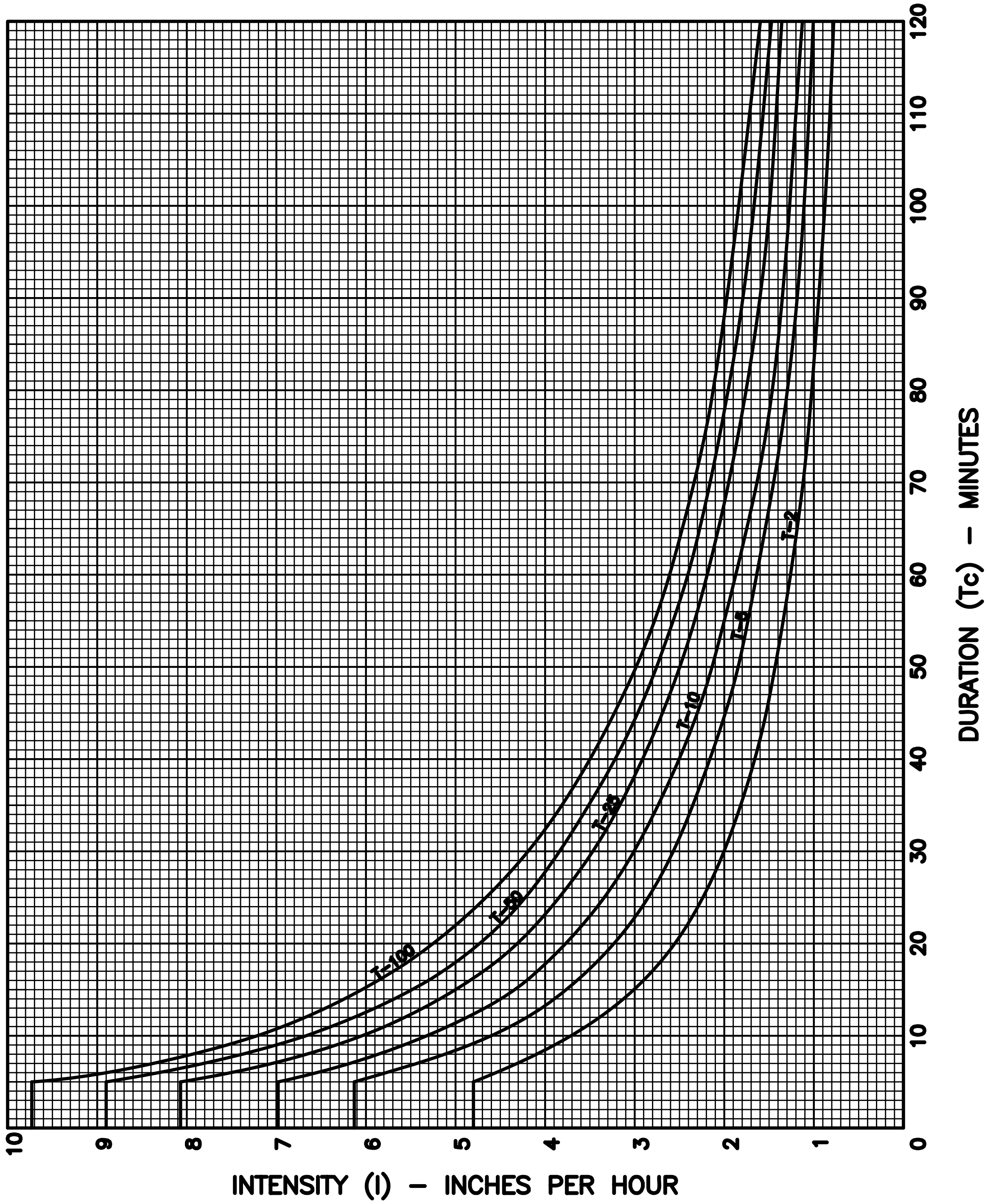
MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913

502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 10-2
RAINFALL INTENSITY-
DURATION CURVES

EFFECTIVE DATE: JUNE 30, 2009



MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 10-3
RAINFALL FOR JEFFERSON COUNTY * (INCHES)

EFFECTIVE DATE: JUNE 30, 2009

FREQUENCY (YEARS)

DURATION	1	2	5	10	25	50	100	PMP
30 min.	1.0	1.1	1.4	1.6	1.9	2.0	2.3	
1 hour	1.2	1.4	1.8	2.0	2.3	2.6	2.8	
2 hour	1.5	1.7	2.2	2.5	2.8	3.2	3.5	
3 hour	1.6	1.9	2.4	2.7	3.2	3.4	3.8	
6 hour	2.0	2.3	2.8	3.3	3.7	4.2	4.5	28.0
12 hour	2.4	2.8	3.4	3.9	4.4	4.9	5.4	33.0
24 hour	2.7	3.2	4.0	4.5	5.2	5.7	6.2 **	35.0
2 day	0.0	3.6	4.4	5.1	6.1	6.4	7.3	38.5
4 day		4.3	5.3	6.0	6.9	7.6	8.4	
7 day		5.0	6.1	6.8	8.0	8.8	9.6	

* SOURCE:
DIVISION OF WATER RESOURCES
DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
ENGINEERING MEMORANDUM NO. 2 (4–30–71), REVISED (6–1–79)

** NOTE:
RAINFALL RANGED FROM 7.5 TO 12.5 INCHES DURING THE FEBRUARY 28/ MARCH 1, 1997 EVENT.

Hydrologic Soil Group *(HSG)*is NRCS's way of summarizing soil's hydrologic effects. This classification, with land use, is one of the determinants of NRCS's Curve Number. NRCS has categorized every soil in the country into four groups, lettered A to D. Group A is the lease likely to create runoff; group D is the most likely.

The four groups are defined by NRCS soil scientists as follows:

- **Group A** soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr). This group also includes sand, loamy sand and sandy loam that have experienced urbanization but not been significantly compacted.
- **Group B** soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr). This group also includes silt loam and loam that have experienced urbanization but not been significanly compacted.
- **Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 to 0.15 in/hr). This group also includes sandy clay loam that has experienced urbanization but not been significantly compacted.
- **Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr). This group also includes clay loam, silty clay loam, sandy clay, silty clay and clay that have experienced urbanization but not been significantly compacted.

Compound classification A/D indicates that the natural soil is in group D because of a high water table which impedes infiltration and transmission, but following artificial drainage using such methods as perforated pipe underdrains, the soil's classification is changed to A.

For a specific site, *HSG* designations can be obtained by refering to a local NRCS soil survey where one is available. If the survey does not specify *HSG*s, you can look up the soil names in the complete national listing given in NRCS's *Technical Release 55.* If there is no NRCS survey at all, you can make an on-site investigation of soil charateristics, and compare them with the above definitions.

Information about HSG on this page is from page A-1 of U.S. Soil Conservation Service, 1986, *Urban Hydrology for Small Watersheds,* Technical Release 55.

RUNOFF COEFFICIENTS BASED ON LAND USE, SOIL GROUP AND SLOPE RANGE

LAND USE	%Imp	A 0–2	A 2–7	A 7+	B 0–2	B 2–7	B 7+	C 0–2	C 2–7	C 7+	D 0–2	D 2–7	D 7+
Residential													
RE, R–1, R–2	25	.31	.35	.39	.33	.38	.43	.37	.41	.48	.40	.44	.52
R–3, R–4, R–5	38	.42	.45	.49	.44	.48	.52	.47	.50	.56	.50	.53	.59
R–5A, R–6, R–7, CN, OR–1	65	.65	.67	.69	.66	.68	.71	.68	.70	.73	.69	.71	.75
R8A OR–2, OR–3, OFT	75	.73	.75	.77	.75	.76	.78	.76	.77	.79	.77	.78	.80
Commercial Business C–M, C–1 thru C–5	85	.82	.83	.84	.83	.84	.85	.84	.85	.86	.84	.85	.86
Industrial RT, M–1, M–2, M–3	72	.71	.73	.74	.72	.74	.76	.73	.75	.77	.75	.76	.79
Roofs, Driveways Streets, Etc.	100	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Open Spaces, Lawns, Parks, Etc.	0	.09	.15	.21	.13	.19	.26	.18	.23	.32	.22	.27	.37
Woodlands,	0	.09	.15	.20	.13	.18	.23	.17	.22	.26	.20	.25	.30
Pasture, Grass, and Farmland	0	.15	.20	.25	.18	.23	.30	.22	.26	.35	.25	.30	.40
Newly Graded/Disturbed,		.65	.67	.69	.66	.68	.71	.68	.70	.73	.69	.71	.75

Unclassified Areas – These are areas where the Natural Resources Conservation Service has not identified any hydrologic soil groups

		0-2	2-7	7+
<u>Residential</u>	%Imp			
RE, R-1, R-2	25	.37	.41	.48
R-3, R-4, R-5	38	.47	.50	.56
R-5A, R-6, R-7, CN, OR-1	65	.68	.70	.73
R8A OR-2, OR-3, OFT	75	.76	.77	.79
<u>Commercial Business</u> C-M, C-1 thru C-5	85	.84	.85	.86
<u>Industrial</u> RT, M-1, M-2, M-3	72	.73	.75	.77

<u>Notes:</u>

1. Where the imperviousness is significantly different from the assumed values, a weighted coefficient should be computed using the actual percent impervious.

2. Consideration should be given to whether the soil group has been changed due to soil compaction by heavy equipment or mixing of the surfaces and subsurface soils

References:

1. Rossmiller, Ronald L., The Rational Formula Revisited, Proceedings International Symposium on Urban Storm Runoff, University of Kentucky, Lexington, Kentucky, July 28 – 31, 1980.

Runoff Curve Numbers for Urban Areas
(See Section 10.2.3.2)

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type and Hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Fully Developed Urban Areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.):					
Poor Condition (grass cover < 50%)		68	79	86	89
Fair Condition (grass cover 50% to 75%)		49	69	79	84
Good Condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right of way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (previous areas only)		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1 to 2 inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c)					

Reference Table 2-2a. pg.2-5 of 210-VI-TR-55, Second Ed., June 1986

Runoff Curve Numbers for Cultivated Agricultural Lands

Cover Description			Curve Numbers for Hydrologic Soil Group			
Cover Type	Treatment	Hydrologic Condition	A	B	C	D
Fallow	Bare Soil	–	77	86	91	94
	Crop Residue Cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight Row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR and CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T and CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR and CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C and CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T and CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Table 2-2b. pg. 2-6 of 210-VI-TR-55, Second Ed., June 1986

Runoff Curve Numbers for Other Agricultural Lands

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition	A	B	C	D
Pasture, grassland, or range – continous forage for grazing.	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continous grass, protected from grazing and generally mowed for hay.	–	30	58	71	78
Brush – brush–weed–grass mixture with brush the major element.	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods – grass combination (orchard or tree farm).	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots.	–	59	74	82	86

Table 2–2c. pg. 2–7 of 210–VI–TR–55, Second Ed., June 1986

Land Use Definition	Soil Group A	Soil Group B	Soil Group C	Soil Group D	Unclassified
High Density	89	92	94	95	93
Medium Density	77	85	90	92	87
Low Density	61	75	83	87	79
Open/Undisturbed	49	69	79	84	74

The Land Use Definitions are based upon the following conditions:

High Density – 85% Impervious – Commercial

Medium Density – 65% Impervious – 1/8 Acre lots

Low Density – 38% Impervious – 1/4 Acre lots

Open/Undisturbed – Grass cover on 50% to 75% of the area

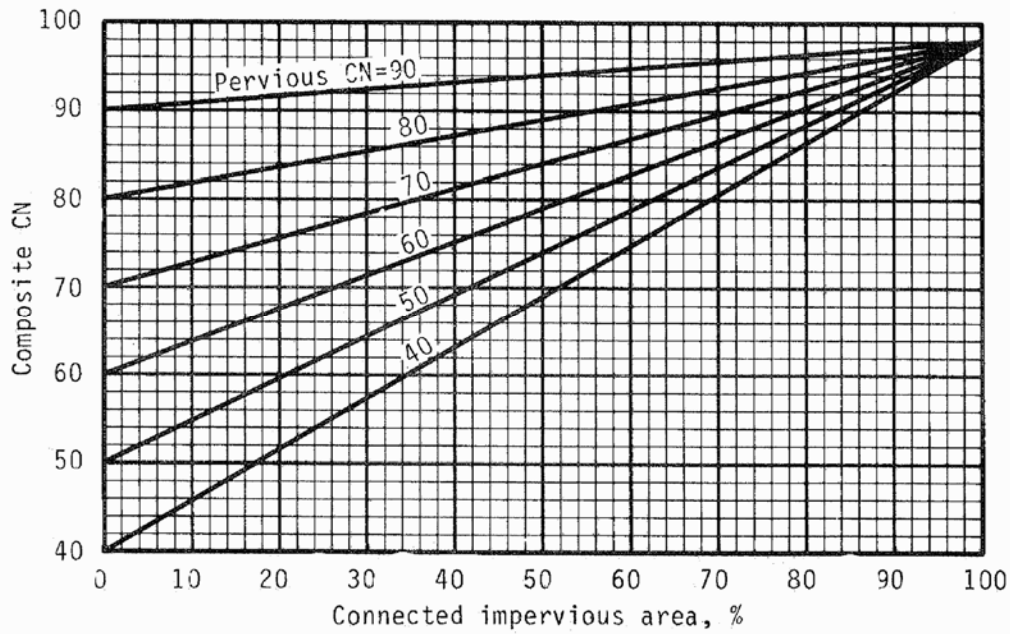


Figure 4-5 - NRCS Composite CN with connected impervious area

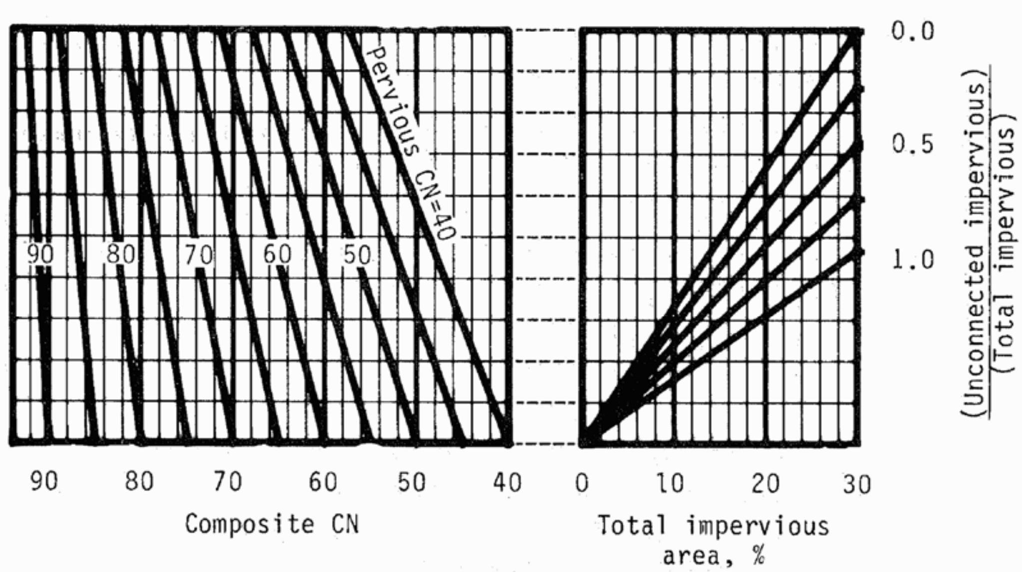


Figure 4-6 - NRCS Composite NC with connected impervious area and total impervious area less than 30%

		Manning's n Range
I.	CLOSED CONDUITS: *	
A.	Concrete pipe	0.012
B.	Smooth wall PVC	0.011
C.	Corrugated–metal pipe or pipe–arch:	
	1. 2–2/3 by 1/2 in. corrugation (riveted pipe):	
	a. Plain or fully coated	0.024
	b. Paved invert (range values are for 25 and 50 percent of circumference paved:	
	(1) Flowing full under pressure . . .	0.021–0.018
	(2) Flowing part full, depth 0.8D . .	0.021–0.016
	2. 6 by 2 in. corrugation (field bolted) . . .	0.030
D.	Vitrified clay pipe	0.012–0.014
E.	Cast–iron pipe, uncoated	0.013
F.	Steel Pipe	0.009–0.011
G.	Brick	0.014–0.017
H.	Monolithic Concrete:	
	1. Wood forms, rough	0.015–0.017
	2. Wood forms, smooth	0.012–0.014
	3. Steel forms	0.012–0.013
I.	Cemented rubble masonry walls:	
	1. Concrete floor and top	0.017–0.022
	2. Natural floor	0.019–0.025
J.	Laminated treated wood.	0.015–0.017
K.	Vitrified clay liner plates	0.015
II.	OPEN CHANNELS, NONVEGETATED LINING, (Straight Alignment): *	
A.	Concrete, with surfaces as indicated:	
	1. Formed, no finish	0.013–0.017
	2. Trowel finish	0.012–0.014
	3. Float finish	0.013–0.015
	4. Float finish, some gravel on bottom. . . .	0.015–0.017
	5. Gunite, good section	0.016–0.019
	6. Gunite, wavy section	0.018–0.022
B.	Concrete, bottom float finished, sides as indicated:	
	1. Dressed stone in mortar	0.015–0.017
	2. Random stone in mortar	0.017–0.020
	3. Cement rubble masonry	0.020–0.025
	4. Cement rubble masonry, plastered	0.016–0.020
	5. Dry rubble (riprap)	0.020–0.030

		Manning's n Range
II.	(CONTINUED)	
	C. Gravel bottom, sides as indicated:	
	1. Formed concrete	0.017–0.020
	2. Random stone in mortar	0.020–0.023
	3. Dry rubble (riprap)	0.023–0.033
	D. Brick	0.014–0.017
	E. Asphalt:	
	1. Smooth	0.013
	2. Rough	0.016
	F. Wood, planed, clean	0.011–0.013
	G. Concrete–lined excavated rock:	
	1. Good section	0.017–0.020
	2. Irregular section	0.022–0.027
III.	HIGHWAY CHANNELS AND SWALES WITH MAINTAINED VEGETATION (Values shown are for Velocities of 2 and 6 f.p.s.): *	
	A. Depth of flow up to 0.7 foot:	
	1. Bermudagrass, Kentucky bluegrass, buffalograss:	
	a. Mowed to 2 inches	0.070–0.045
	b. Length 4–6 inches	0.090–0.050
	2. Good stand, any grass:	
	a. Length about 12 inches	0.180–0.090
	b. Length about 24 inches	0.200–0.100
	3. Fair stand, any grass:	
	a. Length about 12 inches	0.140–0.080
	b. Length about 24 inches	0.250–0.130
	B. Depth of flow 0.7–1.5 feet:	
	1. Bermudagrass, Kentucky bluegrass, buffalograss:	
	a. Mowed to 2 inches	0.050–0.035
	b. Length 4–6 inches	0.060–0.040
	2. Good stand, any grass:	
	a. Length about 12 inches	0.120–0.070
	b. Length about 24 inches	0.200–0.100
	3. Fair stand, any grass:	
	a. Length about 12 inches	0.100–0.060
	b. Length about 24 inches	0.170–0.090

IV. STREET AND EXPRESSWAY GUTTERS: *

	Manning's n Range
A. Concrete gutter, troweled finish	0.012
B. Asphalt pavement:	
1. Smooth texture	0.013
2. Rough texture	0.016
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. For gutters with small slope, where sediment may accumulate, increase above values of n by	0.002

V. OPEN CHANNELS, EXCAVATED OR DREDGED **

	Minimum	Normal	Maximum
A. Earth, straight and uniform	0.016	0.018	0.020
1. Clean, recently completed	0.018	0.022	0.025
2. Clean, after weathering	0.022	0.025	0.030
3. Gravel, uniform section, clean. .	0.022	0.027	0.033
B. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides .	0.025	0.030	0.035
5. Stony bottom and weedy sides .	0.025	0.035	0.045
6. Cobble bottom and clean sides .	0.030	0.040	0.050
C. Dragline—excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
D. Rock cuts			
1. Smooth and uniform.	0.025	0.035	0.040
2. Jagged and irregular.	0.035	0.040	0.050
E. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides .	0.040	0.050	0.080
3. Same, highest stage of flow . .	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

VI. NATURAL STREAM CHANNELS: **

	Minimum	Normal	Maximum
A. Minor streams (top width at flood stage < 100 ft)			
1. Streams on Plain			
a. Clean, straight, full stage, no rifts or deep pools. . .	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as 4, more stones .	0.045	0.050	0.060
g. Sluggish reaches, winding, deep pools	0.050	0.070	0.080
h. Very winding reaches, deep pools, floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. Bottom: gravels, cobbles, few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070
B. Flood Plains			
1. Pasture, no brush			
a. Short grass	0.025	0.030	0.035
b. High grass	0.030	0.035	0.050
2. Cultivated area			
a. No crop	0.020	0.030	0.040
b. Mature row crops.	0.025	0.035	0.045
c. Mature field crops	0.030	0.040	0.050
3. Brush			
a. Scattered brush, heavy weeds	0.035	0.050	0.070
b. Light brush and trees in winter.	0.035	0.050	0.060
c. Light brush and trees in summer.	0.040	0.060	0.080
d. Med. to dense brush, in winter.	0.045	0.070	0.110
e. Medium to dense brush, in summer	0.070	0.100	0.160

VI. (CONTINUED)

	Minimum	Normal	Maximum
4. Trees			
A. Dense Willows, summer, straight	0.110	0.150	0.200
B. Cleared land w/ stumps, no sprouts	0.030	0.040	0.050
C. Same as b., with heavy growth of spouts	0.050	0.060	0.080
D. Heavy timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
E. Same as d., with flood stage reaching branches .	0.100	0.120	0.160

C. Major Streams (top width at flood stage > 100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.

	Minimum	Normal	Maximum
1. Regular section with no boulders or brush	0.025	*****	0.060
2. Irregular and rough section . . .	0.035	*****	0.100

* SOURCE:
KENTUCKY DEPARTMENT OF HIGHWAYS DESIGN MANUAL
EFFECTIVE DATE 3–77, EXHIBIT 2–507.1
MANNING ROUGHNESS COEFFICIENTS, n

** SOURCE:
KENTUCKY DEPARTMENT OF HIGHWAYS DESIGN MANUAL
EFFECTIVE DATE 01–01–93, EXHIBIT DR–05.901
MANNING ROUGHNESS COEFFICIENTS, n

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PLAN SUBMITTAL REQUIREMENTS

CHAPTER 11
PRIVATE DEVELOPMENT DRAINAGE PLAN SUBMITTAL REQUIREMENTS

11.1 PURPOSE

This chapter delineates the purpose and legal responsibility through KRS Chapter 76 and the Louisville-Jefferson County Planning Commission Development Code whereby MSD reviews and approves private development plans. Drainage systems should be designed in accordance with the applicable provisions of this and other chapters of this Design Manual and the requirements of the Floodplain and Erosion Prevention and Sediment Control (EPSC) Ordinances. Plans and specifications submitted for review should meet or exceed the minimum construction plan standards as outlined in Section 11.4. Procedures and applicable forms may be retrieved from http://www.msdlouky.org/.

The review primarily examines the development for the following:

a. Potential impacts to upstream, downstream, and adjacent properties.

b. Adequacy of drainage system outlet.

c. Public or "defined" outlet for drainage.

d. Floodplain impact.

e. Erosion Prevention and Sediment Control

f. Adherence to any applicable composite drainage master plan criteria.

11.2 PLANS SUBJECT TO REVIEW AND APPROVAL

MSD has developed checklists to assist in the submittal process. The checklist forms, which are updated periodically, can be downloaded from the MSD web page. For each situation shown below, the applicable checklist is listed. In all cases, an initial “Plan Review Application” will be submitted.

11.2.1 Preliminary Plans for the Louisville-Jefferson County Planning Commission and Board of Zoning Adjustment

a. Request for change of zoning plans.

b. Conditional use permit plans.

c. General district development plans.

d. Detailed district development plans.

e. Preliminary subdivision plans (major subdivision).

f. Board of Zoning Adjustment plans.

g. Submit **Preliminary Plan Checklist**

11.2.2 Technical Review Committee

Reviews preliminary subdivision plans that require no zoning changes.

11.2.3 Minor Subdivision Plats

Subdivision plats dividing tracts of land into two (2) or more lots not designated by the Planning Commission as a major subdivision.

11.2.4 Site Construction Plans

a. Commercial Tracts

b. Industrial Tracts

c. Fills and/or excavations not related to building construction

d. Floodplain Encroachments

e. Stream Crossings

f. Roadway Projects

g. Submit **Site Plan Review Checklist**

11.2.5 Subdivision Construction Plans (Major Subdivision)

Subdivision construction plans shall be reviewed and approved in accordance with the Louisville and Jefferson County Development Code, Metropolitan Subdivision Regulations. Submit **Subdivision Review Checklist**.

11.2.6 Record Plats

Submit in accordance with Metropolitan Subdivision Regulations.

11.2.7 Single Family Construction Plans

a. Lots located in the 100-year F.E.M.A. or Local Regulatory floodplain.

b. Lots not in a recorded subdivision or lots with sensitive features.

c. Lots in a recorded subdivision with **construction** restrictions (i.e. minimum opening elevations, lowest finished floor elevations, **steep slopes and geotechnical evaluations,** etc.) on the recorded plat.

11.2.8 Industrial Waste/Hazardous Materials Spill Prevention and Control Plans

Submit an information checklist available by contacting MSD.

11.3 LEVELS OF REVIEW

11.3.1 Preliminary Plan Approval

Plans specifically prepared for the Planning Commission or the Board of Zoning Adjustment (BOZA) showing conceptual drainage conditions which identify and address potential impacts on public sewer and drainage facilities shall be submitted for MSD review. If significant or sensitive features exist on a site, see Chapter 12, a conceptual EPSC plan will also be required. Plans must receive MSD's stamp of approval in order to be placed on the Planning Commission Land Development and Transportation Committee or BOZA docket. The **Preliminary Plan Checklist** must be submitted before MSD will review the plans.

11.3.2 Construction Plan Approval

Plans for which building or construction permits are being sought must be reviewed and approved by MSD prior to obtaining these permits. Either the MSD **Subdivision Review Checklist** or the **Site Plan Review Checklist** must be submitted**, as well as Detention Checklist and EPSC Checklist**.

11.4 MINIMUM CONSTRUCTION PLAN SUBMITTAL STANDARDS

11.4.1 Major Subdivision Plans

All correspondence and plan submittals should reference the Water

Management Number as assigned by MSD’s **Development Plan Review Team**.

Major Subdivision Plans for the development of more than four (4) lots require dedication of roadways for access.

All plans must be submitted on 24 x 36 inch sheets.

Submit “Extension of Stormwater Boundary Agreement” **with Corporate Resolution and plat showing development boundaries (**if applicable).

11.4.1.1 Cover Sheet

a. Location Map with the site outlined.

b. Title Block: Title of Subdivision, name and address of developer, name address and email address of Engineer, date of preparation, revision dates.

c. Index of Sheets and Legend

d. Engineer's and Land Surveyor's seals, signatures, and dates

e. Water Management Number: As assigned by MSD’s **Development Plan Review Team**

f. Utility Notes

11.4.1.2 Composite Drainage Plan

a. Topography: Minimum Scale 1" = 100' with existing contours at 2-foot intervals, **NAVD 88** datum. Contours to extend a minimum of 50 feet beyond property lines.

b. Proposed Development: Street rights-of-way, street names, street centerline stationing, lot lines, lot numbers, property boundary, existing drainage structures, proposed drainage structures (labeled by number or other designation) and easements with widths shown.

c. Hydrologic Designate drainage areas

Data: (in acres) to individual inlets, and off-site drainage areas (acres), which generate through drainage.

d. Pipe Chart: Pipe number, drainage area, coefficient of runoff (c), time of concentration, intensity, discharge (Q), size, length, slope, capacity, velocity, and headwater depth for both the 10-year and 100-year Qs.

e. 100-year FEMA and Local Regulatory floodplain and conveyance zone, if applicable, with flood elevations noted.

g. Identification of outlet system.

11.4.1.3 Grading and Erosion Prevention and Sediment Control Plan

a. Existing and Proposed Contours

b. Erosion Prevention and Sediment Measures (Reference Chapter 12 and **EPSC Checklist**).

c. Proposed Development: Street rights-of-way, street names, street centerline stationing, lot lines, lot numbers, property boundary, existing drainage structures, proposed drainage structures (labeled by number or other designation) and easements.

d. Grading Plan may be combined with Composite Drainage Plan provided the plan remains legible.

e. Areas of slope greater than or equal to 20% shall be identified.

f. Stream Buffers if applicable.

g. **Limits of disturbance and number of acres disturbed.**

11.4.1.4 Plan and Profile (Road) Sheets

Plan View

a. Catch Basins: Line and station number (structure number), grate type and elevation, and invert elevation.

b. Pipes: Length, size, type, slope, pipe number or designation.

c. Headwalls: Type, invert elevation.

d. Ditches and Swales: Number or designation, type, stations

e. Easements: Type, size, existing with deed book and page numbers, proposed.

f. Utilities: Existing and proposed (including sanitary sewers).

g. Other drainage structures to be labeled accordingly.

Profile View

a. Storm lines and structures to be shown on road profiles.

b. Utility and sanitary sewer crossings.

11.4.1.5 Storm Drainage Profiles (pipes, ditches, box culverts)

a. Catch Basins: Station or number, type, grate type and elevation, invert elevation, and headwater elevation (10 and 100 year).

b. Pipes: Length, size, type, class, grade, line number if applicable, HGL (10 and 100 year).

c. Ditches:

- Type
- Grade
- Flow line elevation at grade changes (P.V.I)
- Design Depth
- Mannings "n"
- Slope
- 10 and 100 year discharge depths
- **Channel Shear Stress**

d. Headwalls: Type and invert elevation.

e. Existing and proposed ground surfaces.

11.4.1.6 Standard Detail Sheet

Reference sections 4.4.1 and 4.4.6 for the incorporation of MSD Standard Drawings and Special Details unique to the project. If pre-cast structures are used from sources not on the current MSD Pre-approved source list, then shop drawings of the structures must be approved by MSD prior to construction.

11.4.1.7 Additional Submittal Items

a. **Specifications – All storm drainage construction is expected to conform to MSD Standard Specifications. Any deviations from the specifications must be noted on the plans and be approved by MSD.**

b. **Quantities** - Detailed breakdown of all items, related to storm drainage construction needed by MSD to determine the amount of the subdivision bond.

c. **Approved Preliminary Plan -** including sanitary sewer layout.

d. **Clearing and Grading Plan** - required if site clearing and grading is to precede approval.

e. **Detention Basin Calculations** - if applicable and in accordance with the provisions of Chapters 10 and 12.

f. **Highway Encroachment Permit** - (if applicable).
All construction plans for major subdivisions shall conform to Article 6 of the Louisville and Jefferson County Planning Commission Subdivision Regulations.

g. **Section 404 Permit -** (if applicable) from the U.S. Army Corps of Engineers.

h. **Application for Water Quality Certification** - (if applicable) from the Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Water Quality Branch.

i. **Application for Permit to Construct Across or Along a Stream** - (if applicable) from the Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water - Floodplain Management Section - Water Resources Branch.

j. Copy of Demolition Permit or General Permit (if applicable).

k. Copy of Approval Letter for private WWTP (if applicable).

i Request for sanitary sewer capacity.

11.4.1.8 Submittal

Two sets of construction plans and specifications are to be submitted for initial review by MSD. Variations from the Minimum Construction Plan Submittal Standards will require prior approval from MSD. Any conditions of the Approved Preliminary Plan (such as geotechnical report, state approvals, etc.) must be addressed at the time of construction plan submittal to MSD.

11.4.2 All Other Development Plans (Site, etc.)

Submit "Extension of Stormwater Boundary Agreement" with Corporate Resolution and plat showing development boundaries (if applicable).

11.4.2.1 Existing Topography Plan

This plan shall conform to Development Code Section 8.1.B.4 requirements with the following additional data:

a. Spot elevations at critical points.

b. 100-year FEMA **Floodway** and Local Regulatory floodplain and conveyance zone, if applicable, with flood elevations noted.

c. Off-site drainage area in acres, which generate through drainage.

11.4.2.2 Proposed Development and Grading Plan

This plan may be combined with the plan described in paragraph 11.4.2.1 if existing features can still be discerned. This plan shall also conform to the requirements of Section 8.1.B.4 of the Development Code with the following additional data:

a. Revised hydrologic data, runoff calculations, and detention basin design, if applicable.

b. Hydraulic data, such as pipe charts and ditch data on profiles, showing quantity of flow, velocities, and degree of protection.

c. Erosion prevention and sediment control measures and details.

d. Show public outlet and evaluate capacity of downstream facilities.

e. Proposed easements for through drainage, detention facilities, and/or offsite increase in runoff.

f. Note specific conflicts with other utilities.

g. Written explanation of any proposed deviation from Planning & Design or MSD policies, standards, or design criteria and any supplemental data that would aid the understanding of the proposed plan work.

h. The stamp of a professional engineer licensed in Kentucky shall be affixed to the plan when the proposed facilities affect public drainage, downstream properties**, Regulatory Floodplain or detention**.

11.5 INSPECTION OF MAJOR SUBDIVISION CONSTRUCTION

11.5.1 General

MSD has a program of on-site inspection for the construction of **public** drainage systems in public rights-of-way or public easements. Drainage construction may begin following MSD approval of the construction plans and issuance of a **Site Disturbance Permit.**

11.5.2 Inspector Assignment

Construction of drainage structures and pipes shall not begin in a development until a MSD inspector has been assigned to the construction site. In certain situations, which will be identified during construction plan review, full-time inspection may be required. In the event that MSD personnel are not available to provide the level of inspection necessitated by a contractor's schedule, the owner may retain (at the owner's expense) an independent inspector working under the direct supervision of a professional engineer approved by MSD. The independent inspector will be required to certify to MSD that the materials and methods of construction are in compliance with the approved plans and specifications. Arrangements for owner-provided inspection including schedule and level of effort must be approved by MSD in advance. MSD inspector shall be present during testing.

MSD requires three (3) working days advance notice to schedule an inspector for a project. To schedule an inspector, please fax the "Notice of Construction Form" to MSD.

11.5.3 Construction Plan Revisions

MSD will require the final approved construction plans bearing the Engineer's original seal, signature, and date prior to beginning storm drainage construction. Deviations from approved construction plans as a result of unexpected field conditions will require documentation and approval by MSD. To obtain this approval, the developer's engineer should submit a marked print of the plans showing the proposed revisions to MSD for review.

11.5.4 Subdivision Bond

In accordance with the Metropolitan Subdivision Regulations, MSD sets the drainage portion of the subdivision bond at 100% of the estimated construction cost consistent with past practice. When projects constructed under MSD drainage inspection are completed, they may have the drainage bond reduced to 20% of the estimated construction cost. When a subdivision is finished and at least 80% of the lots have been developed, the subdivision bond may be released following satisfactory inspections by the Board of Health, the local Fire Department, MSD and the Public Works Department.

11.5.5 Construction Initiation

Recognizing the developer's need to initiate construction in a timely fashion, MSD will allow certain construction activities to proceed prior to the approval of the entire set of construction plans. General clearing and site grading, not involving construction of drainage structures, roadway grading, nor significantly affecting existing drainage in the area, may be performed following approval of a Grading and EPSC Plan by MSD, Jefferson County Department of Public Works and the Planning Commission and the issuance of the necessary work order. A Grading Plan, prepared by a licensed engineer, must be submitted if site clearing and grading is to proceed prior to construction plan approval. The three working days notice of construction form must also be submitted before clearing and grading can begin. Erosion prevention and sediment control measures in accordance with Chapter 12 of this design manual must be clearly described on the plan and must be installed prior to initiating any construction at the project site. Application for approval of a Clearing and Grading Plan may be made at the time of construction plan submittal to MSD. A notice of violation and stop-work order may be issued for failure to implement proper EPSC measures.

11.6 FEES

11.6.1 Plan Review Fees

Only applicable to development outside MSD stormwater service area including the Cities of Anchorage, Jeffersontown, Prospect, Shively, and St. Matthews. These fees must be paid prior to MSD's approval of the plans. Additionally, fees may be required for sites with extensive review of hydrologic and hydraulic modeling.

11.6.2 Stormwater Fees

11.6.2.1 Regional Facility Fee

This is a stormwater impact fee, paid by the developer on sites where MSD has determined on-site detention will not be required. This fee allows the developer to pay a proportionate share of MSD's cost of constructing Regional Stormwater Detention Facilities. For development outside MSD's drainage service area, a twenty percent (20%) surcharge will be added to the regional facility fee.

11.6.3 Compensation Fees

Fees are applicable to sites in floodprone watersheds where runoff volume compensation is required.

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CHAPTER 12
EROSION PREVENTION AND SEDIMENT CONTROL

12.1 PURPOSE OF THIS CHAPTER

This chapter of the MSD Design Manual provides the user with the tools to meet the requirements of the **Jefferson County Erosion Prevention and Sediment Control (EPSC) Ordinance**. Some of the information contained in this chapter, such as the application forms, and checklists are available in digital format and can be downloaded from www.msdlouky.org. Sensitive Features information can be obtained by consulting the LOJIC Standard Information Map at www.lojic.org.

This chapter also establishes requirements to be used when preparing plans for minimizing soil erosion and sedimentation during and after construction of any land development, improvement or retrofit project. Guidelines on how to select and design EPSC Best Management Practices (BMPs) for specific construction activities have been developed in accordance with several references from across the country. **Sections 12.5, 12.6, and 12.7 are organized as collections of BMP sheets. Each sheet describes a particular BMP, appropriate applications, design and implementation measures, and maintenance requirements.**

12.2 OVERVIEW OF EPSC ORDINANCE AND REQUIREMENTS

The EPSC Ordinance requires that an EPSC plan be developed and be approved by MSD. A Site Disturbance Permit should also be obtained from MSD prior to initiating construction or land disturbing activities that are in excess of 2,000 square feet and are situated closer than 50 feet to a drainageway,

The Ordinance also establishes standards for the design of EPSC plans to minimize the adverse impact and offsite degradation that may result from construction site runoff.

There are two types of EPSC plans that may be required as part of an application for approval of a land disturbing activity: Concept EPSC plans and Detailed EPSC plans.

- Concept EPSC plans are a preliminary presentation of techniques, measures, and controls intended to prevent erosion and control sedimentation arising from land disturbing activities on a specific development site or parcel of land.

- Detailed EPSC plans are required at the construction plan stage for all land disturbing activities. The detailed EPSC plan shall contain the information required by the MSD **EPSC Detailed Construction Plan Checklist**, and if Sensitive Features are identified, a narrative description of how the delineated Sensitive Features will be protected when conducting the proposed land-disturbing activity must be included on the plans. Submit the MSD **EPSC Detailed Construction Plan Checklist** with the detailed EPSC plans for review and approval.

- Tree Removal only: A Site Disturbance Permit will not be required for a site where trees are removed by hand tools and the stumps are left in place. Equipment shall disturb ground cover or distub sensitive features.

12.3 SENSITIVE FEATURE IDENTIFICATION

Sensitive Features include land containing any one the following features:

- Local Regulatory Floodplain and Conveyance Zone as defined by local ordinance (Reference Section 10.4 for more details).
- Stream corridors (including blue line and intermittent) as mapped by United States Geological Survey.
- Karst features with a well-defined surface opening (such as a cave, sinkhole, vadose shaft, or other karst anomaly).
- Lakes and impoundments.
- Jurisdictional wetlands as determined by the US Army Corps of Engineers.
- Slopes greater than 20%.
- “Erodible” and “severely erodible” soils as determined by the Natural Resources Conservation Service.
- Sites with the potential to drain stormwater directly into a sensitive feature listed above (including any designated buffer area for that feature) or into a designated greenway.

12.4 EPSC PLAN DEVELOPMENT STANDARDS

EPSC plans shall be developed to achieve an 80% design removal efficiency goal. When a site is completely denuded of vegetation, the structural and nonstructural EPSC measures are designed to trap 80% of the total suspended solids (TSS) that are generated by the site. The design storm event associated with this level of control is the ***10-year 24-hour NRCS Type II storm event***. NRCS procedures should be used to determine runoff amounts. It is important to note that when a BMP is designed for this event, it will have a greater trapping efficiency for more frequent events (i.e., 2-year storm).The Rational Method may be used when using the design aids.

Each EPSC Plan must delineate the following elements:

- All Sensitive Features as defined above.
- Potential sources of sediment that may potentially leave the site
- The location and depth of all structural and non-structural BMPs necessary to achieve the 80% design removal efficiency goal and protect the Sensitive Features
- Installation and maintenance of required BMPs
- The sequencing of construction activities to be utilized on the project
- Standard EPSC notes (see exhibit)
- MSD Standard Drawing Numbers for EPSC BMPs used on the plan.

Primary BMPs receiving over one acre of contributing watershed must have calculations demonstrating that the BMP achives a Total Suspended Solids (TSS) removal efficency of 80% or greater.The following non-structural site management practices shall be utilized during construction : :

- Minimize site disturbance to preserve and maintain existing vegetative cover;
- Limit the number of temporary access points to the site for land disturbing activities;
- Phase and sequence construction activities;
- Locate temporary and permanent soil disposal areas, haul roads, and construction staging areas to minimize erosion, sediment transport, and disturbance to existing vegetation.

Detailed EPSC plans shall comply with the following standards and review criteria:

- <u>Sediment Tracking Control</u>. Stabilized construction entrances shall be located and utilized at all points of ingress/egress on a construction site. The transfer of soil, mud and dust onto public rights-of-ways shall be prevented.
- <u>Construction Dewatering Operations</u>. Whenever construction dewatering operations are required on a site, they shall be conducted according to the specifications set forth in this Manual, the Standard Specifications and Drawings.
- <u>Crossings of waterways</u> during construction shall be minimized and approved by MSD. Encroachment into stream buffers, riparian areas, and wetlands shall be avoided.
- <u>Topsoil shall be stockpiled</u> and preserved from erosion or dispersal both during and after site grading operations.
- <u>Temporary Stabilization Measures</u>. Where construction or land disturbance activity will or has temporarily ceased on any portion of a site, temporary site stabilization measures shall be required as soon as practicable, but no later than 14 calendar days after the activity has ceased.
- <u>Final Stabilization</u>. Final Stabilization of the site shall be required within 14 calendar days of construction completion.
- <u>Temporary Structural Controls</u> installed during construction shall be designed to accomplish maximum stabilization and control of erosion and sedimentation, and shall be installed, maintained, and removed according to the specifications set

forth in the MSD Design Manual, Standard Specifications and Standard Drawings. All temporary structural controls shall function as designed when controlling the peak runoff resulting from the storm event identified in the MSD Design Manual, Standard Specifications and Standard Drawings.

- All Permanent Structural Controls, including drainage facilities such as channels, storm sewer inlets, and detention basins, shall be designed according to the standards set forth in the this Manual, the Standard Specifications and Drawings.
- Show BMPs for existing and proposed grading/topography.
- If a site is over 5 acres and/or the site is to undergo significant topography changes, a series of progressive EPSC plans will be required to demonstrate the changing nature of the site. For example, if a site's current topography slopes to the east but in the proposed condition it will slope to the west, then two or more EPSC plans depicting this transition will be needed. Furthermore, other intermediate BMPs such as sediment laden or clean water diversion ditches, sediment traps, and basins may be needed as the site transitions to the final condition.
- If a change in topography necessitates the relocation of a sediment basin, an interm plan and phasing sequence will be required to show how EPSC will be mantinaed during the transition.

To encourage the development and testing of alternative EPSC BMPs, alternative management practices that are not included in the MSD Design Manual, Standard Specifications and Standard Drawings may be allowed upon review and approval. To use an alternative BMP, submit substantial evidence that the proposed measure will perform at least equivalent to a currently approved control contained in the MSD Design Manual, Standard Specifications and Standard Drawings. Evidence may include, but is not limited to, peer-review by a panel of licensed professional engineers and research results as reported in professional journals or other literature.

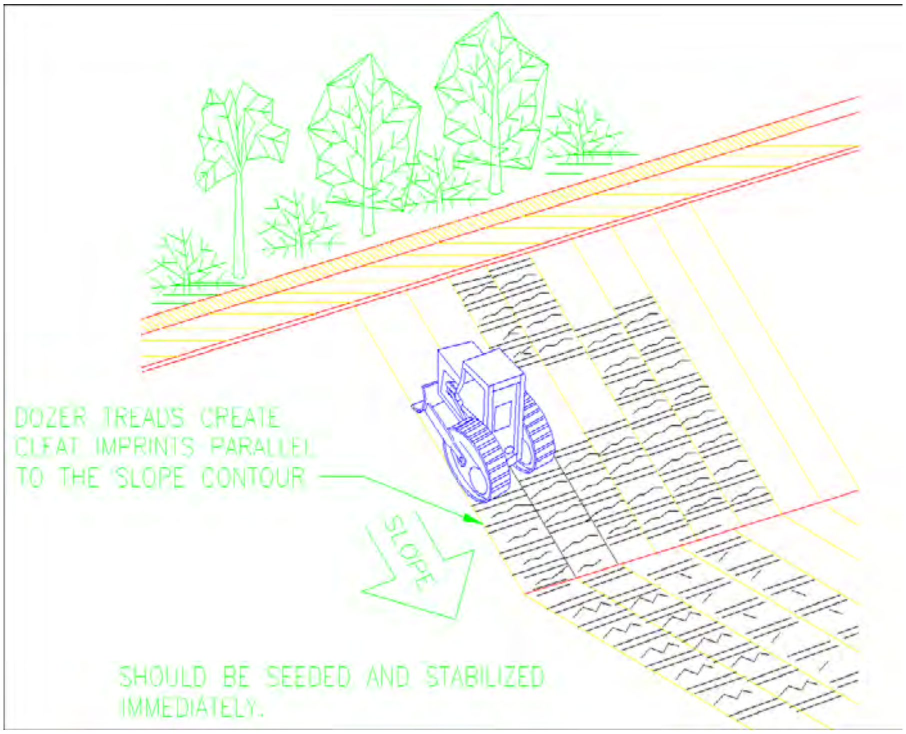
If MSD finds the alternative BMP has failed or is inadequate to contain sediment onsite, the alternative BMP shall be removed and replaced with a BMP approved by MSD and found in the MSD Design Manual, Standard Specifications and Standard Drawings.

12.5 EROSION PREVENTION MEASURES

Erosion prevention measures shall be used during and after construction site preparation in order to safely convey clean water to storm drains or adequate watercourses. One or more measures should be utilized as appropriate during the project's construction phase. Such measures may include but are not limited to: phasing and construction sequencing, surface roughening, temporary seeding, mulching, matting, and geotextile blankets. Each of these measures is discussed in the sections to follow.

In addition to site-specific erosion control measures, the grading plan should include the following general measures as a minimum:

- The finished cut and fill slopes to be vegetated should not be steeper 3H:1V.
- Cuts or fills should not be so close to property lines as to endanger adjoining property without adequately protecting such properties against erosion, sedimentation, slippage, settlement, subsidence, or other damages.
- Subsurface drainage should be provided in areas having a high water table to intercept seepage that would affect slope stability, bearing strength or create undesirable wetness.
- No fill shall be placed where it can slide or wash onto another property.
- Fill shall not be placed adjacent to channel banks where it can create bank failure, reduce the capacity of the stream, or result in downstream sediment deposition.
- All borrow and disposal areas should be included as part of the grading plan.
- Adequate channels and floodways should be provided to safely convey increased runoff from the developed area to an adequate outlet without causing significant channel aggradation, degradation, or increased off-site flooding.
- The site should be graded to direct flows to appropriate controls.



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Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Surface roughening is the creation of horizontal grooves, depressions, or steps that run parallel to the contour of the land. **The purpose is to aid in the establishment of vegetation cover from seed, reduce runoff velocity, increase infiltration, reduce erosion, and provide sediment trapping.**

The following surface roughening measures are approved for use: tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints parallel to the slope contour) as shown in Standard Drawing EC-04-**01**; stair-step grading as shown in Standard Drawing EC-05-**02**; and slope grooving (using disks, spring harrows, or teeth on the bucket of a front-end loader) as shown in Standard Drawing EC-06-**01**.

APPLICATION

- **Construction slopes where seeding, planting, and mulching to stabilize soils.**
- **Graded areas with smooth, hard surfaces, and the potential for erosion.**

APPROACH

Cut slopes with a gradient steeper than 3H:1V but less than 2H:1V should be stair-step graded or groove cut. Stair-step grading works well with soils containing large amounts of small rock. Stairs should be wide enough to work with standard earth moving equipment. Grooving can be done by any implement that can be safely operated on the slope, including those described above. Grooves should not be less than 3 inches deep or more than 15 inches apart.

Fill slopes with a gradient steeper than 3H:1V but less than 2H:1V should be compacted every 9 inches of depth. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep that can be left rough or can be grooved as described above, if necessary.

Any cut or filled slope that will be maintained should have a gradient less than 3H:1V and in no case greater than 2H:1V. Such a slope can be roughened with shallow grooves parallel to the slope contour by using normal tilling. Grooves should be close together (less than 10 inches) and not less than 1 inch deep.

Immediately seed and mulch roughened areas to obtain optimum seed germination and growth. Use erosion control blankets or turf reinforcement mats on long (>50 feet) steep (>2H:1V) slopes as necessary, or hydroseed.

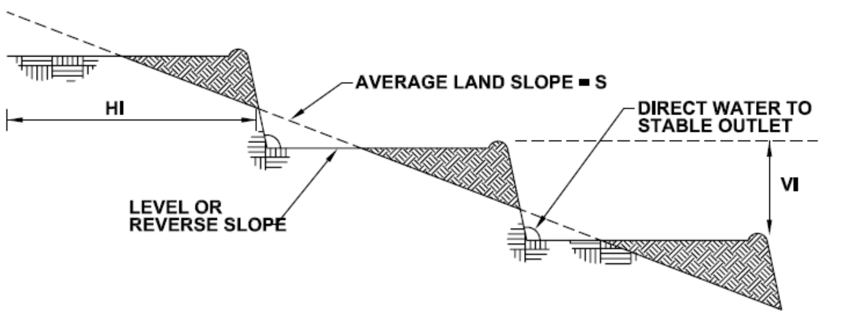
MAINTENANCE

- **Inspect roughened surfaces every seven days and within 24 hours after each rain event that produces 0.5 inches or more of precipitation for rills and washes. Fill these areas slightly above the original grade, then reseed and mulch or cover with blanket or mat as soon as possible.**

LIMITATIONS

- **Surface roughening may not be appropriate for certain soil types including sandy, steep, or shallow soils.**
- **Surface roughening, seeding, and mulching may need to be repeated after significant rain events.**
- **Excessive surface roughening may be undesirable when area is to be mowed.**

12.5.2 BENCH TERRACING — EPM-2: BT



EQUATION FOR HORIZONTAL AND VERTICAL INTERVALS

$$HI = VI \times \frac{100}{S}$$

$$VI = aS+b$$

WHERE a = 0.5 FOR LOUISVILLE
b = 1 FOR ERODIBLE CONDITION
2 FOR RESISTANT SOILS WITH GOOD COVER.

S = AVERAGE LAND SLOPE IN PERCENT
HI = HORIZONTAL INTERVAL BETWEEN TERRACES
VI = VERTICAL INTERVAL BETWEEN TERRACES

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Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Bench terraces are permanent earth embankments or ridges constructed along the face of a slope at regular intervals creating a stair-step effect. Bench terraces reduce slope lengths and direct surface **runoff** to stable outlets. **The stair-stepping effect will help vegetation establish and also trap eroding soil from the above slope.** The proper orientation of a bench terrace is shown in Exhibit 12-1 in Supplemental Section D.

APPLICATION

- **Construction slopes steeper than 3:1.**
- **Graded areas where the length of slopes needs to be reduced by terracing.**

APPROACH

Bench terraces are designed for highly erodible, steep slopes ranging from 3:1 to 1.5:1, and should not be constructed on slopes with sandy or rocky soils. They are effective only where there are suitable runoff outlets such as grassed waterways, or piped outlets.

The design of a bench terrace system involves proper spacing and location. Terrace spacing is expressed as the vertical distance between the channels of successive terraces. For each terrace, the spacing is the vertical distance from the top of the hill to the bottom of the channel, commonly known as the vertical interval or VI. Although the horizontal spacing is useful in determining row arrangement, the VI is more convenient for terrace layout and construction.

Terrace spacing is expressed by the empirical formula:

$$VI = aS + b$$

Where:

VI = vertical interval between consecutive terraces in ft.,
a = constant for geographical location (**0.5 for Louisville**),
b = constant for soil erodibility (**1 for erodible conditions, 2 for resistant soils with good ground cover**), and
S = average land slope in **percent**

The horizontal interval HI or bench width can be calculated by the formula:

$$HI = VI \times 100/S$$

Where:

HI = horizontal interval of each terrace in ft.,
VI = vertical interval between consecutive terraces in ft., and
S = average land slope in **percent**.

MAINTENANCE

- Periodically inspect seeded areas, particularly after rain events, for rills and washes.
- Remove debris from outlets and excessive silt from terraces.
- Inspect benches for **destabilizing gully** formation. Gullies may require rock placement to stabilize the area.
- Reseed and mulch as necessary.

LIMITATIONS

- Bench terracing is not applicable for sandy or rocky soils.
- Must only be used when adequate drainage channels and runoff diversions are provided.

12.5.3 TEMPORARY SEEDING

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Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	**Large Flat Areas**	**Borrow Areas**	**Adjacent Properties**

DESCRIPTION

The purpose of temporary seeding is to reduce erosion and sedimentation by stabilizing disturbed areas that would otherwise lay bare for long periods of time **(>14 days)** before they are worked or stabilized. Temporary seeding is also used where permanent vegetation growth is not necessary or appropriate.

APPLICATION

- **Apply to areas left in rough grade condition that will not be disturbed for 14 days or more**

APPROACH

Any disturbed areas that will not be worked for 14 days or more must have temporary cover applied by the 14th day. Seeded areas should be covered with mulch to provide protection from the weather. If the vegetation does not grow quickly or thick enough to prevent erosion, the area should be re-seeded as soon as possible. Seeded areas should be kept adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water, waste water, and fuel can cause **or worsen** erosion. Seed selection should be based on the requirements of the MSD Standard Specifications **and applied at recommended rates.**

MAINTENANCE

- **Inspect frequently for the first six weeks following planting to assure seed is adequately moist and to determine if vegetation is uniform and dense.**
- **Damaged areas should be repaired, fertilized, seeded, and mulched where appropriate.**

LIMITATIONS	• **Some types of grasses (e.g. annual rye) may outcompete desirable permanent vegetation.** • **Uneven application may cause patchy growth and erosion. Over application of fertilizer or lime causes stormwater runoff pollution.** **Areas to be seeded may require compaction, disking, or other activity to prepare the seedbed.**

12.5.4 MULCHING EPM-4: M

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Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	**Borrow Areas**	Adjacent Properties

DESCRIPTION

Mulching is a temporary soil stabilization erosion control method where materials such as grass, **straw, cellulose,** wood chips, wood fibers, **or other suitable materials** are placed on the soil surface. In addition to stabilizing soils, mulching can enhance the absorption of water by the soil, reduce evaporation losses, regulate soil temperatures and reduce the speed of **stormwater** runoff over an area. **Mulching is used in conjunction with seeding and hydroseeding of critical areas for the establishment of temporary or permanent vegetation.**

APPLICATION

- **Temporary stabilization of freshly seeded and planted areas, or during periods unsuitable for growing permanent vegetation.**
- **Short-term ground cover on steep slopes to reduce rainfall impact, decrease the velocity of sheet flow, and trap sediment.**

APPROACH	Erosion control mulching may be used on level areas, slopes up to 50%, and in waterways with caution. Where soil is highly erodible, nets should only be used in connection with organic mulch, such as straw and wood fiber. Mulch is an effective **temporary** ground cover when the establishment of vegetation is improbable due to severe weather conditions (winter conditions), poor soil, or steep slopes. **If using mulch for temporary ground covers without seeding, the mulch should be applied to an appropriate depth for the material used and should have greater than 95% coverage of the soil surface. On steep slopes (>2.5H:1V), or where the mulch is susceptible to movement by wind or water, the mulch should be hydraulically applied or the mulch should be anchored appropriately (e.g. covered by degradable netting).**
MAINTENANCE	• **Avoid traveling on mulched and seeded areas.** • **Periodically inspect mulched and seeded areas, particularly after rainfall events, for damage or deterioration. Replace as necessary.** • **Continue inspections until vegetation is established.**
LIMITATIONS	• **Organic mulches tend to lower the soil surface temperature, and may delay germination of some seeds.** • **Organic mulches may also affect the pH of the soil.** **Mulching of waterways may cause flow impediments at water inlets and is not appropriate for areas that receive high stream flows.**

12.5.5 EROSION CONTROL BLANKETS AND TURF REINFORCEMENT MATS — EPM-5: ECB/TRM

ECB

TRM

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	**Borrow Areas**	Adjacent Properties

DESCRIPTION

A variety of Rolled Erosion Control Products (RECPs) are available for the stabilization of seeded slopes and channel banks. MSD distinguishes between the different types of products using two categories: Erosion Control Blankets (ECBs) and Turf Reinforcement Mats (TRMs).

ECBs and TRMs are preferred alternatives to traditional hard channel protection such as concrete, riprap, gabions and revetment mattresses. These products improve the quality of stormwater discharges by creating a stronger, vegetated **armament** that filters the flow, allows infiltration, and **protects and encourages the establishment of** wildlife habitat. **This BMP prevents soil erosion, promotes seed germination, protects young vegetation and prevents seed or mulch from washing away.** The proper orientation of netting and matting is shown in Standard Drawing EC-07-**01**.

ECBs are used for the temporary stabilization of soil immediately following seeding until the vegetative cover has grown and become well established. They provide temporary protection because they degrade over time as the vegetation becomes established. Some products are effective for a few months while others degrade slowly and are effective for a few years.

TRMs are nondegradable products that enhance the ability of living plants to stabilize soils. They bind with roots to reinforce the soil matrix. TRMs are used in situations where vegetation alone will not hold a slope or stream bank. TRMs **provide potential** “green” solutions in many areas where only “hard” solutions such as riprap or concrete linings were viable in the past.

APPLICATION

- **Any area subject to erosive action particularly where permanent vegetation has been planted.**
- **Graded slopes, stormwater channels, detention structures, stream banks or swales.**

APPROACH

When designing a permanent conveyance (as described in Chapter 10) with a grassed or vegetative lining, the design should address the bare condition prior to vegetation being established. A geotextile lining may be applied to protect the conveyance during this period. It is important to use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of ECBs and TRMs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, a corresponding ECB or TRM that meets the conditions may be selected from the list of approved ECB and TRM products. This list can be found on the MSD web page.

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning’s channel roughness coefficient (n) of the TRM or ECB or final vegetation, and

Normal channel flow depth (d_n) based on peak flow rate and channel dimensions.

The governing equation for maximum velocity is Manning’s Equation:

$$V = (1.49 / n) * R^{2/3} * S^{1/2}$$

Where:

V = maximum velocity (ft/sec)
n = Manning’s channel roughness coefficient
R = Hydraulic radius of the flow based on d_n (ft)
S = Channel bed slope (ft/ft)

The governing equation for maximum channel shear stress is:

$$\tau = \gamma \, d_n \, S$$

Where:

τ = maximum shear stress (lbs/ft^2)
γ = unit weight of water = 62.4 lbs/ft^3
d_n = normal channel flow depth (ft)
S = channel bed slope (ft/ft)

MAINTENANCE

- **Inspect ECBs and TRMs periodically and especially after rain events to check for movement of blanket/mat, topsoil, or mulch and any significant erosion.**
- **Continue inspections until vegetation is firmly established.**
- **Repair or replace ECBs or TRMs that have been washed out, broken, or eroded. Repair ground surface with topsoil, re-seed, re-mulch and fertilize where necessary prior to installing new ECBs or TRMs.**

LIMITATIONS

- **Inadequate coverage or anchoring will result in erosion, washout, and poor vegetation establishment.**
- **Do not install within the wetted perimeter of a stream or drainage channel that carries water continuously.**
- **The type of ECB or TRM chosen must be appropriate for the specific project needs.**

12.5.6 FINAL STABILIZATION EPM-6: FS

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Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	**Large Flat Areas**	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Final stabilization measures include topsoiling, permanent seeding and planting of grasses, and sodding. Implementation of these items will occur after all construction activities on site have been completed.

These measures reduce stormwater runoff velocity, maintain sheet flow, protect soil surface from erosion, promotes infiltration of runoff into the soil and can improve wildlife habitat.

APPLICATION

- **Any area where soil disturbance activities have taken place.**

APPROACH

12.5.6.1 Topsoiling

When and Where to Use It

Topsoil should be used when vegetative stabilization is used, where soils are dense or impermeable, or where mulching and fertilizers alone cannot improve soil quality.

Design Criteria

Stockpiling of topsoil onsite requires good construction sequencing and planning so the stockpiles will not obstruct other operations. If topsoil is to be stockpiled, the use of temporary seeding, mulching, or silt fence to control erosion should be considered.

12.5.6.2 Permanent Seeding and Planting of Grasses

Design Criteria

The use of native species is preferred when selecting vegetation. Seedbed preparation, seed type, application rate, fertilizer rate and planting windows should be designed according to the MSD Standard Specifications.

12.5.6.3 Sodding

When and Where to Use It

Sodding is appropriate for any graded or cleared area that may erode, and where a permanent, long-lived plant cover is immediately needed. Examples of where sodding can be used are yards, buffer zones, stream banks, dikes, swales, slopes, outlets, and filter strips.

Design Criteria

Sodding should be installed per MSD Standard Specifications as shown in Standard Drawing EC-08-**01**. Sodding should not be used on slopes steeper than 2H:1V, unless the sodding is to be mowed, then it should not be placed on slopes greater than 3H:1V

MAINTENANCE

- **Inspect areas where topsoiling, permanent seeding and planting of grasses, and sodding measures have been implemented at a minimum of every seven days and within 24 hours after each storm event that produce 0.5 inches or more of precipitation.**

12.5.7 RIPRAP OR AGGREGATE EPM-7: RR

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Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Riprap is a permanent, erosion-resistant channel lining aggregate consisting of large, loose, angular stone with a filter fabric or granular underlining. The purpose of riprap is to:

- Protect the soil from the erosive force of concentrated runoff; and
- Slow runoff velocities while enhancing the potential for infiltration.

The purpose of filter fabric or granular underlining is to prevent undermining the riprap layer by migration of soil particles under seepage forces through the riprap.

APPLICATION

- **Along streams or within drainage channels as a stable lining resistant to erosion.**
- **On lakefronts and riverfronts, or any other area subject to wave action.**
- **Protection of culvert inlets and outlets to prevent scour and undercutting.**
- **In channels to reduce velocities, dissipate hydraulic energy and promote infiltration and settle sediment.**

APPROACH

The preferred method of slope and channel protection is the use of vegetation. If vegetation cannot withstand the design flows, ECBs and TRMs (see Section 12.5.5) are the preferred and suggested method of protection. When conditions are too severe for vegetation and TRMs, riprap may be used for erosion control and protection. Riprap may be used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, drop structures, at the toe of slopes, and in transitions from concrete channels to vegetated channels. Table 12-1 lists several KTC sizes of coarse aggregates along with the corresponding stone diameter.

Table 12-1. Coarse Aggregates

Aggregate Size (KTC Size No.)	Mean Spherical Diameter (d_{50}) (inches)
1	3.5
2	2.5
23	2.5
3	2.0
357	2.0
4	1.5
467	1.5
5	1.0
57	1.0
610	1.0
67	0.75
68	0.75
710	0.75
78	0.50
8	0.375

Riprap sizes can be designed by the diameter or by the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical. Table 12-2 lists some typical riprap classes and the corresponding dimensions.

Table 12-2. Weight and Size of Riprap Stones

Channel Lining Riprap Class	**Corresponding Size**
IA	Limestone with 100% passing a 5-inch sieve, and no more than 20% passing though square openings 1.5” by 1.5”
II	Limestone with 100% passing a 9-inch sieve, and no more than 20% passing though square openings 5” by 5”
III (Cyclopean Riprap)	> 80% by volume of individual stones ranging from ¼ to 1-½ cubic feet

General

Geotextile Underlining: Place a lining of geotextile filter fabric or granular filter material between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

Riprap at Outlets: Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are given in Section 12.5.8 of this chapter; Outlet Stabilization**.**

Riprap for Channel Stabilization: Riprap for channel stabilization should be designed to be stable for the condition of bank-full flow in the reach of channel being stabilized. The Federal Highway Administration (FHWA) design procedure as presented in this section should be used. This method establishes the stability of the rock material relative to the forces exerted upon it.

Riprap should extend up the banks of the channel to a height equal to the maximum 10-year flow depth, or to a point where vegetation can be established to adequately protect the channel.

Riprap placed in channel bends should extend upstream and downstream from the point of curvature at least 5 times the channel bottom width. The riprap should extend across the bottom and up both sides of the channel.

Freeboard and Height of Bank: For riprap and other lined channels, the height of channel lining above the water surface should be based on the size of the channel, the flow velocity, the curvature, inflows, wind action, flow regulation, etc.

The designer shall obtain a minimum freeboard for placement of riprap relative to the top of bank from Chapter 10.

Design of Riprap Channel Linings

Design of erosion protection within the channel should be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

For Straight Channel Sections:

The Exhibits used in this section are found in Supplemental Section D of this chapter.

1. Enter the graph of Exhibit 12-2 with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line above the point of intersection.)

2. If the channel side slopes are steeper than 3H:1V, continue with Step 3; if not, the procedure is complete.

3. Enter the graph in Exhibit 12-3 with the side slope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to read K_1.

4. Determine from the graph in Exhibit 12-4 the angle of repose for the d_{50} stone size and the channel side slope. (Use an angle of 42^o for d_{50} >10 inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Enter graph in Exhibit 12-5 with the side slope of the channel and the angle

of repose for the d_{50} stone size. Where the two lines intersect, move vertically down to read K_2.

6. Compute d_{50} x K_1/K_2 = d_{50} to determine the correct size stone for the bottom and side slopes of straight sections of channel.

MAINTENANCE

- **Check riprap and channel linings after rain events that produce greater than 0.5 inches of precipitation for slumping, displacement, scour and undermining of riprap. Replace or reposition as necessary.**
- **Remove excessive vegetative growth if stability of area is compromised.**

LIMITATIONS

- **Displacement of riprap or channel lining may occur if the slope is too steep or if riprap is improperly sized or installed.**
- **Weeds may be difficult to control.**
- **Riprap placement in waterways may require permitting with the U.S. Army Corps of Engineers and the Kentucky Division of Water.**

12.5.8 OUTLET STABILIZATION EPM-8: OS

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DESCRIPTION

Outlet **stabilization** dissipates the energy of concentrated **stormwater** flows thereby reducing erosion or scouring at **stormwater** outlets and paved channel sections. In addition, outlet **stabilization** lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including permanent turf reinforcement mats (TRMs), stone or riprap, concrete aprons, and paved sections.

APPLICATION

- **Wherever discharge velocities and energies at the outlets of culverts, pipes, conduits, channels or ditches are sufficient to erode the immediate downstream reach.**

APPROACH

The design of lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection. This causes re-concentration of the flow **which** results in large velocities when the flow leaves the apron. Outlet protection should be designed according to the following criteria:

Round Pipe Flowing Full:

1. Tailwater Depth: The tailwater depth immediately below the pipe outlet must be determined for the design capacity of the pipe. The depth may be determined using Manning's Equation. If the tailwater depth is less than ½ the diameter of the outlet pipe, it should be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than ½ the pipe

diameter, it should be classified as a Maximum Tailwater Condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition.

2. Apron Length: The required apron length, L_a, according to the tailwater condition, should be determined from the appropriate graphs provided in the following exhibits found in Supplemental Section D of this chapter:

   Minimum Tailwater Condition - Use Exhibit 12-6
   Maximum Tailwater Condition - Use Exhibit 12-7

3. Apron Width: When the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less). If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows:

   - The upstream end of the apron, adjacent to the pipe, should have a width three times the diameter of the outlet pipe (3D).
   - For a Minimum Tailwater Condition, the downstream end of the apron should have a width equal to the pipe diameter plus the length of the apron ($D + L_a$).
   - For a Maximum Tailwater Condition, the downstream end should have a width equal to the pipe diameter plus 0.4 times the length of the apron ($D + 0.4 * L_a$).

4. Bottom Grade: The apron shall be constructed with no slope along its length (0% grade). The downstream invert elevation of the apron should be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

5. Side Slopes: If the pipe discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

6. Alignment: The apron should be located so there are no bends in the horizontal alignment.

7. Materials:

   - The preferred apron lining shall be with an appropriate permanent turf reinforcement matting (TRM). The shear stress and maximum velocity should be calculated to determine which type of TRM is applicable for the situation (see Section 12.5.5).
   - When conditions are too severe for TRMs the apron may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap should be determined from the curves in Exhibit 12-6 and 12-7 according to the tailwater condition. The gradation, quality, and placement of riprap should conform to the requirements presented in Section 12.5.7.

8. Filter Cloth: In all cases, filter cloth should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the physical properties for filter cloth found in

the requirements presented in Section 12.5.7.

Paved Channel Outlets (Standard Drawing DD-05-**01**):

1. The flow velocity at the outlet of paved channels flowing at design capacity **must not** exceed the permissible velocity of receiving unprotected grass-lined channels as provided in Table 12-3.

2. The paved channel end should merge smoothly with the receiving channel section with no overfall at the end of the paved section. When the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section should be provided with a maximum side divergence of 1 in 3F with;

$$F = \frac{V}{(gd)^{0.5}}$$

Where:
F = Froude number
V = Velocity at beginning of transition (ft./sec.)
d = Depth of flow at beginning of transition (ft.)
g = Acceleration due to gravity (32.2 ft./sec.^{2})

3. Bends or curves in the horizontal alignment at the transition are not allowed unless the Froude number (F) is 1.0 or less, or the section is specifically designed for turbulent flow.

Table 12-3. Maximum Permissible Velocities For Unprotected Grass Lined Channels

Channel Slope	Lining	Velocity (ft./sec.)**
0 – 5 %	Bermuda Grass	8
	KY-31 Tall Fescue	7
	Kentucky Bluegrass	7
	Grass-legume Mixture	5
	Small Grains	3.5
	Temporary Vegetation	3.5
5- 10 %	Bermuda Grass	7
	KY-31 Tall Fescue	6
	Kentucky Bluegrass	6
	Grass-legume mixture	4
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended
Greater than 10%	Bermuda Grass	6
	KY-31 Tall Fescue	5
	Kentucky Bluegrass	5
	Grass-legume mixture	Not Recommended
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended

***Allow velocities over 5 ft/sec only where good cover and maintenance will be provided.**
****For highly erodible soils, decrease permissible velocities by 25%.**
Source: Elementary Soil and Water Engineering, Shwab et. al. 1971

MAINTENANCE

- **Inspect outlet stabilization periodically, particularly after rain events, for erosion, sedimentation, scour or undercutting.**
- **Repair or replace riprap, TRM, or concrete structures as necessary.**

- **Remove trash, debris, vegetation, and sediment as necessary.**

LIMITATIONS

- **An easement may be necessary to maintain riprap outlet protection given that outlet protection is usually at or near the project boundary.**

12.5.9 DUST CONTROL — EPM-9: DC

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DC

Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	**Borrow Areas**	**Adjacent Properties**

DESCRIPTION

Wind erosion can occur when the surface soil is loose and dry, vegetation is sparse or absent, the wind is sufficiently strong, and when construction traffic disturbs the soil. Wind erodes soils and transports the sediment offsite in the form of fugitive dust, where it may be washed into receiving water bodies by the next **rain event**.

Fugitive dust is a nuisance for neighbors. It settles on automobiles, structures and windows and finds its way into homes. It also can make breathing difficult (for those with respiratory problems) and becomes a safety problem when it blinds motorists, equipment operators and laborers.

Dust control methods should be utilized whenever there are offsite impacts, such as periods of drought, and implemented until final stabilization is reached. **Selection of particular dust control techniques depends primarily on cost and potential environmental hazards (particularly near Sensitive Features). The effectiveness of each technique will depend on soil type, properties of chemical agent, traffic volume, climate, environmental requirements, and frequency of application.**

APPLICATION

- **Clearing and grading activities.**
- **Construction vehicle traffic on temporary or unpaved roads or construction site access paths.**
- **Sediment tracking on paved roads.**
- **Soil and debris storage piles.**
- **Areas with unstabilized soil.**

12.5.9 DUST CONTROL EPM-9: DC

APPROACH

There are many methods to control dust on construction sites including:

- Vegetative Cover - For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control.
- Mulch - Offers a fast, effective means of controlling dust.
- Sprinkling Water – Used on haul roads and other traffic routes as dust control.
- Spray-on-Adhesive - Latex emulsions, or resin in water can be sprayed onto mineral soils to prevent their blowing away and reduce dust caused by traffic.
- Calcium Chloride - May be applied by mechanical spreaders as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.
- Barriers - Broad, wind, or sediment fences can control air currents and blowing soil. These fences prevent erosion by obstructing the wind near the ground, stopping the soil from blowing offsite. Barriers are not a substitute for permanent stabilization. Perennial grass and **stands** of existing trees may also serve as wind barriers.

Spray exposed soil areas only with approved dust control agents as indicated in the MSD Standard Specifications

MAINTENANCE

- **Reapplication of dust control agents must be appropriate to the agent type and intensity of traffic areas.**

LIMITATIONS

- **Watering prevents dust only for a short period and should be applied daily (or more often) to be effective.**
- **Overwatering may cause erosion.**

12.6 TEMPORARY SEDIMENT CONTROL MEASURES

MSD emphasizes erosion prevention in EPSC plans. However, there are always instances where erosion cannot be prevented. For these situations, temporary sediment controls must be implemented to control the migration of eroded sediment off site. The following sediment control measures are applicable as temporary practices for use during construction. One or more of the measures should be utilized as appropriate during the project's construction phase. A discussion of the planned measures will be required during the Preliminary Plan Review phase for sites containing sensitive features.

12.6.1 STORAGE VOLUMES AND MAINTENANCE SCHEDULES — SCM-1: SV

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Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

This section provides the basic formulas needed for temporary sediment basin and sediment trap design.

APPROACH

Calculating the appropriate sediment storage volume is very important in sediment basin and sediment trap design. This volume is the storage occupied by the sediment deposited over the given design period. Design periods may be the life of the basin, or the time between scheduled clean outs. Using computed sediment yields from the Universal Soil Loss Equation (USLE) found in Supplemental Section B, along with the sediment bulk density, the sediment storage volume can be calculated by

$$V_S = \frac{Y_D}{W * 43{,}560}$$

Where: $\mathbf{V_S}$ is the sediment storage volume (acre-feet), $\mathbf{Y_D}$ is the sediment deposited over the design period (pounds), and **W** is the weight density (bulk density) of the deposited sediment (lbs./ft^3). **W** can be found from soil survey data (usually given in grams/cm^3) or by the equation:

$$W = W_c P_c + W_m P_m + W_s P_s$$

Where: W_c, W_m, and W_s are unit weights of clay, silt, and sand in (lbs./ft^3) taken from Table 12-4, and P_c, P_m, and P_s are the primary soil matrix percent clay, silt, and sand as listed in soil survey (used as a decimal).

Table 12-4. Unit Weight Values of Basin Sediment

Type of Basin Operation	Wc ($\#/ft^3$)	Wm ($\#/ft^3$)	Ws ($\#/ft^3$)
Sediment always submerged (Wet Pond)	26	70	97
Basin normally empty (Dry Pond)	40	72	97

R Factors and EI Values

When designing for sediment storage volume, the sediment deposited over the design period Y_D, must be calculated. This value can be obtained by converting the sediment yield calculated by the Universal Soil Loss Equation (USLE) into pounds of sediment. One of the variables used in the USLE is the R factor. R is the factor in the USLE that accounts for the damaging effects of rainfall. The R factor indicates the erosivity of the rainfall, not the average annual precipitation in a locality. The R factor is defined as the number of erosion index (EI) values in a normal year's rain. The EI index value of a given storm is equal to the kinetic energy of the storm (hundreds of foot-tons per acre) times its maximum 30-minute intensity (inches/hour). The EI values of individual storms may be summed to get an EI value for a month, six months, or for any period of time. When EI values are summed and averaged over a period of years, they become R factors.

The distribution of EI values become important when soil losses need to be calculated for a period of time less than one year, such as a construction season. The distribution of the EI values over a known period of time is used to calculate an R factor for that time period. Table 1 in Supplemental Section B of this chapter shows the distribution of EI values for Jefferson County as a percentage of the R factor for Jefferson County. MSD requires a minimum EI value of 50 for any construction period.

The following steps are used to determine the storage volume for a sediment trapping structure. All **USLE** input values are found in Supplemental Sections B and C of this chapter.

1. Determine the site sediment yield using the Universal Soil Loss Equation

$$A = R \bullet K \bullet LS \bullet CP$$

Where:
A = Average soil loss per unit area(tons/acre/specified design period)
R = Rainfall erosive index (100-ft-tons/acre x in/hr)
(EI Value for given design period * average annual R Value)
K = Soil erodibility factor (tons/acre per unit R)
LS = Length-slope steepness factor where length is the slope distance from the point of origin of overland flow to the point of concentrated flow or until deposition occurs (dimensionless)
CP = Control practice factor (dimensionless).

2. Determine the weight density **(W)** of the specific soil.

   - The Jefferson County Soil Survey gives a soil bulk density in grams/cm^3
   - Convert (grams/cm^3) to (lbs/ ft^3) by multiplying by 62.43

   W = (bulk density in grams/cm^3) x (62.43) = lbs/ft^3

3. Convert sediment yield from (tons/acre) to acre-feet of sediment storage.

   - Determine the total disturbed area **DA** (acres)
   - Determine the sediment yield in tons

Multiply **A** from step 1. * **DA** from step 3. (tons/acre * Acres = tons)

   - Convert tons to pounds to get $\mathbf{Y_D}$

$\mathbf{Y_D}$ = (tons) * (2000 lbs/ ton) = pounds

$$V_S = \frac{Y_D}{W * 43{,}560} \quad = \mathit{acre - feet}$$

4. The designer can now determine what level the required sediment storage corresponds to, and require a clean out marking stake to be installed at this elevation. The contractor shall be required to clean out the basin or trap when this level is reached. Or the designer can simply state that based on the calculations, the basin or trap will be required to be cleaned out on a time period basis such as weeks, months or years.

12.6.2 TEMPORARY SEDIMENT BASIN SCM-2: TSB

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Slope Protection	**Waterway Protection**	**Surface Protection**	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A sediment basin is an impoundment for the purpose of detaining runoff to allow excessive sediment to settle.

Temporary sediment basins should be used on sites where 5 or more acres are disturbed. A temporary sediment basin shall not be built in wetlands, any active or live streams, or in Waters of the Commonwealth. Temporary sediment basins shall be utilized until the contributing flow areas to the basin have undergone final stabilization.

Basins shall be designed to have an 80% design removal efficiency goal for total suspended solids (TSS) in the inflow. Drop inlet spillways, pipe spillways, rock fill outlets and weir spillways may be used for the design of the principal spillway. Typical sediment basin schematics are Exhibits 12-8A and 12-8B in Supplemental Section D of this chapter.

APPLICATION

- **Used for retaining stormwater from disturbed areas where 5 to 150 acres are disturbed.**
- **At locations with steep slopes, sloughing or severely eroded soils, or industrial activities that generate sediment and soil particles.**

APPROACH

- Dam Safety –Design criteria such as those used by the USDA Soil Conservation Service (previously the Natural Resources Conservation Service), U.S. Army Corps of Engineers and the Dam Safety and Floodplain Compliance Section of the Kentucky Division of Water must be followed.

- Safety, Signage, and Fencing - Ponds, which are readily accessible to populated areas, should incorporate all possible safety precautions. The inside pond slopes shall be no steeper than 3H:1V.

- General Design Criteria -The design aids located in Section 12.8.2 of this chapter shall be used to properly size the sediment basin. Sedimot III, SEDCAD and other computer models may also be utilized.

- Riser Structure Design- The outlet riser shall be properly designed to meet the discharge capacity of the 10-year 24-hour storm.

Flow control devices can operate as either open channel flow, in which the flow has a free water surface, or pipe flow in which the flow is in a closed conduit. In either situation, an increase in head on a structure increases the discharge flow rate through the structure.

The stage discharge relationship for basin outlet structures is controlled by weir, orifice or pipe flow. A given riser spillway can have a variety of stage discharge relationships depending on the head. When the water level is just above a riser crest (a very low head on the riser), the riser crest acts like a weir, and flow is weir controlled. As the water level in the basin increases, water begins flowing in from all sides including directly above the inlet, and the inlet begins to act like an orifice. As the head continues to increase, the outlet eventually begins to flow full, and pipe flow dictates. To determine which of the three flow mechanisms is controlling at a particular water level in the basin, all three equations should be utilized at each level. The minimum flow for a given stage indicates the actual discharge from the basin and the flow mechanism that is controlling at that water level.

Weir Flow:

$$Q = C\,L\,H^{\frac{3}{2}}$$

Where: Q is the discharge (cfs), C is the weir coefficient (dependent upon units and weir shape but C is typically between 3.0 and 3.2), L is the weir length (feet), which is the total length over which flow crosses the weir (L = circumference of a pipe for circular drop inlets), and H is the water head (feet).

Orifice Flow:

$$Q = C'\,a\,(2gH)^{\frac{1}{2}}$$

Where: Q is the discharge (cfs), C' is the orifice coefficient (C' = 0.6 for sharp-edged orifices), a is the cross sectional area of the orifice (ft^2), g = 32.2 ft/sec^2, and H is the head on the orifice (feet).

Pipe Flow:

$$Q = \frac{a\left(2gH'\right)^{\frac{1}{2}}}{\left(1 + K_e + K_b + K_c L\right)^{\frac{1}{2}}}$$

Where: Q is the discharge (cfs), a is the cross sectional area of the pipe (ft^2), g = 32.2 ft/sec^2, H' is the head (feet) defined as the distance from the water surface in the basin to a point 0.6 D above the invert of the outlet barrel where D is the outlet barrel diameter in feet, K_e and K_b depend on the configuration of the pipe entrance and bend (typical values are $K_e = 1.0$ and $K_b = 0.5$), K_c is the head loss coefficient due to friction ($K_c = 5087*n^2 / D^{4/3}$, where: n = Manning's roughness coefficient of the barrel and D is the barrel diameter in inches), and L is the total length of the pipe (feet).

Other required design criteria are as follows:

a. Minimum Drainage Area - 5 acres
b. Maximum Drainage Area - 150 acres
c. 80% design removal efficiency goal for TSS.
d. The required draw down time of the basin will be the time to detain flows to meet the 80% design removal efficiency. In many cases this will result in a draw down time longer than 36-hours.
e. Basin Shape - the effective flow length should be at least twice the effective flow width (L=2W minimum).
f. Sediment Volume Storage Accounted For In Design Volume
g. Outlet Riser and Barrel Requirements
   1. Discharge Capacity - 10-year 24-hour storm.
   2. Minimum Outlet Pipe Diameter of 8-inches.
   3. Required 6-inch low flow orifice at bottom of riser structure.
   4. Perforations and orifices shall be designed to keep the 2-year and 10-year 24-hour storm disturbed-state peak flow rates from the basin less than or equal to the pre-disturbance peak flow rates.
   5. Anti-Vortex Device / Trash Rack Required.
   6. Minimum one-foot elevation difference from top of riser to crest of the emergency spillway.
   7. Sediment Volume Storage Accounted For In Design Volume.

h. Embankment Requirements
   1. Maximum Upstream Slope – 3H:1V.
   2. Maximum Downstream Slope – 3H:1V.
   3. Freeboard - 12-inch minimum.
   4. Antiseep collars are required on all penetrations through the dam.
   5. Typical dam height to top width dimensions are provided below in Table 12-5.

Table 12-5. Sediment Basin Width/Height Relationship

Dam Height (Ft)	Top Width (Ft)
< 10	8
11-14	9
15-19	10
20-25	12

i. Emergency Spillway Requirements
   1. Shall be designed to discharge a flow equal to the design overflow of the 100-year 24-hour storm post-development discharge.
   2. Shall have a minimum one-foot of freeboard from the 100-year 24-hour storm water surface elevation to the top of the dam.

MAINTENANCE

- **Inspect temporary sediment basins periodically and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color and perform necessary repairs when appropriate.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level and dispose of sediment at a protected location onsite to prevent resuspension of sediment.**

LIMITATIONS

- **Sediment basins may kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **May not be effective for fine-grained soils such as silt or clay. Additional upstream controls may be necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

12.6.3 MULTIPURPOSE BASINS SCM-3: MB

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Slope Protection	**Waterway Protection**	**Surface Protection**	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Multipurpose basins are permanent detention basins that are designed for use as temporary sediment basins during the construction phase of a project.

APPLICATION

- **Modification of a permanent detention basin for the purpose of handling large amounts of silt and eroded soil.**

APPROACH

Two spillway configurations are commonly used in the life of a multipurpose basin. The first configuration is the sediment basin spillway, which is typically a CMP riser and RCP barrel configuration. When conversion of the spillway is required, this configuration makes the most sense because the riser section can be removed and the barrel section can be utilized as part of the spillway for the detention basin.

For steps on the design of the principal and emergency spillways for multipurpose basins, refer to Chapter 10. Design the sediment basin principal spillway to reduce the construction-phase conditions to pre-development levels for the 2 and 10-year 24-hour storm events. Design the emergency spillway to pass and provide flow reduction for the 100-year 24-hour storm permanent detention basin using post-development conditions.

Design the principal spillway for the permanent detention basin to reduce post-development flows to pre-development flows for the 2 and 10-year 24-hour storm events as described in Chapter 10. Design the emergency spillway to pass and provide flow reduction for the 100-year detention basin using post-development conditions.

When the sediment pond phase has expired, the temporary riser structure shall be removed and the permanent structure shall be installed. The basin shall be cleaned of deposited sediment and re-graded to meet the permanent basin contours if necessary.

General Design Criteria

a. Minimum Freeboard for both basin phases is 1 ft.
b. Design must include maintenance accessibility and responsibility.
c. Provide erosion protection for the emergency spillway and channel protection for the receiving channel.
d. Storage, discharge, and routing calculations for the 2, 10, and 100-year storm events must be submitted for review.
e. Multipurpose basins shall be fully discharged within 36 hours after the storm event unless specifically approved by MSD.
f. Multipurpose basins shall be the first item of construction.

MAINTENANCE

- **Inspect temporary sediment basins periodically and after each rainfall event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color and perform necessary repairs when appropriate.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level and dispose of sediment at a protected location onsite to prevent resuspension of sediment.**

LIMITATIONS

- **Sediment basins may kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **May not be effective for fine-grained soils such as silt or clay. Additional upstream controls may be necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

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Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Temporary sediment traps are small temporary ponds that detain sediment-laden runoff from disturbed areas allowing sediment to settle out. A temporary sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out. Sediment traps shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. Temporary sediment trap details are Exhibits 12-9A and 12-9B in Supplemental Section D.

APPLICATION

- **Any disturbed area which is less than 5 acres.**
- **Along the perimeter of a project site to prevent sediment-laden runoff from being discharged off-site or areas where runoff can enter stabilized areas or waterways.**
- **Immediately upstream from temporary storm drain inlet protection measures.**

APPROACH

A sediment trap may be formed completely by excavation or by constructing a compacted embankment. The outlet should be a rock fill weir/spillway section, with the area below the weir acting as a filter for sediment and the upper area as the overflow spillway depth.

To complete the design of the temporary sediment trap:

- Determine the required sediment storage volume.

- Determine the bottom and top surface area of the sediment storage volume using 3H:1V side slope from the bottom of the trap.

- Determine the total trap dimensions by adding the depth required for the 10-year, 24-hour design storm above the surface of the sediment storage volume, while not exceeding 3H:1V side slopes.

- General Design Criteria – the design aids located in Section 12.8.5 shall be used to properly size the sediment trap. Sedimot III, SEDCAD and other computer models may also be utilized.

- Other design requirements are as follows:
  a. Maximum Drainage Area - 5 acres
  b. Maximum Design Life - 18 months
  c. 80% design removal efficiency goal for TSS
  d. Basin Shape - The flow length should be 2 times the flow width.
  e. Embankment Requirements:
     1. Maximum Dam Height - 5 feet.
     2. Maximum Stone Height – 3.5 feet.
     3. Minimum Rock Bottom Width – 3 feet.
     4. Discharge and treatment capacity for the 10-yr. 24-hr. storm event.

MAINTENANCE

- **Inspect traps periodically and after each rain event for excessive sediment buildup, undercutting flows or seepage, slope failure, settlement and structural soundness.**
- **Regularly inspect water quality being discharged for suspended sediment and color; identify and perform repairs to improve water quality.**
- **Inspect downstream channel for erosion or sedimentation.**
- **Remove accumulated sediment whenever it reaches the designated cleanout level.**

LIMITATIONS

- **Sediment traps can kill nearby vegetation by excessive sediment or by long periods of submergence.**
- **Temporary sediment traps only remove coarse particles which settle quickly. They are not effective for fine-grained soils such as silt or clay. Additional upstream erosion control measures are necessary.**
- **Can be attractive and dangerous to children. Protective fencing or other access control measures are highly recommended.**

12.6.5 SILT FENCE **SCM-5: SF**

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SF SF

Slope Protection	**Waterway Protection**	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A silt fence is a temporary measure for sediment control. It shall be designed to have an 80% design removal efficiency goal of the TSS in the inflow. Silt fence consists of posts with **a synthetic** filter fabric stretched across the posts and a wire support fence. The lower edge of the fence is vertically trenched and covered by compacted backfill. Typical silt fence details, with and without reinforcement, are shown in Standard Drawings EF-09-**02** and EF-10-**02**.

APPLICATION

- **Any disturbed area accepting sediment-laden sheet flow conditions.**
- **Along the downstream perimeter of a disturbed site, below the toe of a cleared slope, upstream of sediment traps or basins, along streams and channels and around temporary spoil areas.**

APPROACH

- Maximum sheet or overland flow path length to the fence is 100 feet.
- Maximum slope steepness (normal [perpendicular] to fence line) 2H:1V.
- Not to be placed across channels.
- General Design Criteria - The design aids located in Section 12.8.4 shall be used to properly design silt fence.
- Standard non-reinforced silt fence shall be used when the contributing slope is less than or equal to 3% and the design life of silt fence is less than 6 months.

- Reinforced silt fence shall be required when the contributing slope is greater than 3% and the design life of the silt fence is greater than 6 months.

Land Slope	Max. Slope Distance
< 5%	100 ft.
5% - 10%	50 ft.
10% - 20%	25 ft.
20% - 50%	15 ft.

- Other design requirements are as follows:
  - a. 80% design removal efficiency goal for TSS
  - b. Maximum Slope Length - 100 feet
  - c. Maximum Slope Gradient – 2H:1V
  - d. Minimum Installed Fence Height - 18 inches
  - e. Maximum Installed Fence Height - 24 inches
  - f. Minimum Post Bury Depth – 18 inches
  - g. Maximum Reinforced Fence Post Spacing - 6 feet
  - h. Maximum Non-reinforced Post Spacing - 6 feet

MAINTENANCE

- **Inspect silt fence periodically and after each rainfall event for damage or loosened fabric, excessive sediment buildup, undercutting flows or flows around end of silt fence. Repair or replace as necessary.**
- **Remove sediment whenever it reaches one-third of the silt fence height.**
- **Maintain silt fence until disturbed areas have been properly stabilized.**
- **Silt fence should be removed within 30 days after final site stabilization is achieved or after temporary BMPs are no longer needed.**

LIMITATIONS

- **Cannot be used in continuously-flowing streams.**
- **Installation and removal may damage vegetation and channel grades.**
- **May kill vegetation by excessive sediment or by long periods of submergence.**
- **Should not be installed along the slope contour and not up or down the slope.**

12.6.5B HARD SURFACE SEDIMENT BARRIERS

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Slope Protection	Surface Protection	Enclosed Drainage	Flat Areas	Adjacent Properties

DESCRIPTION

Hard surface controls shall be used when silt fence cannot be installed due to a concrete or asphalt surface. BMPs such a fiber rolls, silt socks, and straw waddles shall not be used as a primary control and only when larger BMPs are impractical

APPLICATION

- **To be used for small, flat areas where silt fence or other BMPs cannot be used due to asphalt or other hard surface.**

MAINTENANCE

- **Inspect periodically and after each rainfall event for damage or loosened fabric, excessive sediment buildup, undercutting flows or flows around end of barrier. Repair or replace as necessary.**
- **Remove sediment whenever it reaches one-third of the height of the particular BMP.**
- **Maintain until disturbed areas have been properly stabilized.**
- **Should be removed within 30 days after final site stabilization is achieved or after temporary BMPs are no longer needed.**

LIMITATIONS

- **Not a primary control**

12.6.6 ROCK DITCH CHECK SCM-6: RDC

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DC ▶ DC ▶ DC

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A rock ditch check is a small, temporary or permanent rock fill dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows. Rock ditch checks shall be designed to have an 80% design removal efficiency goal of the TSS in the inflow. A typical rock ditch check section is shown in Standard Drawing EB-03-003

APPLICATION

- **Sediment and erosion control in small open channels (<5-acre drainages).**
- **Flow velocity reduction.**

APPROACH

- Rock ditch checks should be used only in small open channels. The checks should not be placed in Waters of the Commonwealth, unless approved by the State. The center section of a rock ditch check should be lower than the edges.

- Spacing varies with the bed slope of the ditch. The maximum spacing between the rock checks should be such that the toe of the upstream check is at the same elevation as the top of the downstream check.

- In the case of grass-lined ditches and swales, ditch checks should be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4%. The area beneath the ditch checks should be seeded and mulched immediately after dam removal. Geotextile filter fabric shall be installed under all rock fill.

- General Design Criteria - The Design Aids located in Section 12.8.3 shall be used to properly design rock ditch checks.

- Other design requirements are as follows:
  a. 80% design removal efficiency goal for TSS
  b. Maximum Drainage Area – 5 acres
  c. Maximum Height - 2 feet

- If the rock ditch check is not properly sized, the flow will overtop the structure and the Trapping Efficiency is assumed 0% when this takes place.

MAINTENANCE

- **Inspect every seven days and within 24 hours after each rain event that produces 0.5 inches or more of precipitation to check for excessive sedimentation or instability.**
- **Sediment must be removed before it reaches one-half of the device's original height.**

LIMITATIONS

- **Not for use in continuously-flowing streams.**
- **May damage vegetation and channel grades.**

12.6.7 STABILIZED CONSTRUCTION ENTRANCES

SCM-7: SCE

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TGCE

Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	**Large Flat Areas**	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A stabilized construction entrance is a temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site to reduce the amount of mud, dirt, rocks, etc. transported onto public roads by motor vehicles equipment and runoff. A diagram of a typical temporary gravel construction entrance is shown in Standard Drawing ER-01-03.

Stabilized construction entrances should be used whenever repetitive traffic will be leaving a construction site and be moving directly onto a public road. Construction entrances provide an area where mud can be removed from vehicle tires before entering a public road.

APPLICATION

- **All points of construction ingress and egress.**

APPROACH

If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road. If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried offsite. Washdown facilities shall be required as directed by MSD. Washdown areas, in general, must be established with crushed gravel and drain into a sediment trap or sediment basin. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles. Limiting traffic from the site in wet conditions is a means of controlling mud on streets.

12.6.7 STABILIZED CONSTRUCTION ENTRANCES

SCM-7: SCE

The General Design Criteria **are:**

a. Minimum Entrance Dimensions

1. Thickness - 6 inches
2. Width of entrance area - 24 feet
3. Length – 100 feet or required length for 10 tire revolutions

b. Material - #3stone size or larger. Non-woven geotextile fabric is required to underlie the stone.

MAINTENANCE

- **Maintain entrance area to ensure mud, dirt, rocks, etc. are not tracked onto roadways. Remove all mud or sediment deposited on paved roadways as necessary.**
- **Remove gravel material and filter fabric at completion of construction, or as paved surfaces are finished.**
- **Periodic top dressing of the area may be required.**

LIMITATIONS

- **Construction entrances on slopes may require diversions to prevent stormwater from leaving the site.**

12.6.8 STORM DRAIN INLET PROTECTION SCM-8: SIP

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SIP

Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Storm drain inlet protection allows sediment to settle prior to entering into a stormwater catch basin or inlet. Storm drain inlet protection can be achieved by placing a temporary filtering device around any inlet to trap sediment. This mechanism prevents sediment from entering inlet structures. Additionally, it serves to prevent the silting-in of inlets, storm drainage systems, or receiving channels.

Four different materials/methods that can be used to provide inlet protection are: filter fabric, block and gravel, gravel and stone with a wire mesh filter, and stone bags. **Straw bales are not permitted for this purpose because of plugging.** In addition, excavating immediately around the drop inlet and using gravel to restrict sediment flow can also be used to protect the inlet. Typical diagrams for each of these filter types are: Filter Fabric Inlet Protection Standard Drawing EF-01-**02**, Block and Gravel Drop Inlet Protection Standard Drawing EF-13-**01**, Gravel and Wire Mesh Inlet Sediment Filter Standard Drawing EF-14-**01**, and Stone Bag Inlet Protection Standard Drawing EF-03-**02**.

APPLICATION

- **Every storm drain inlet, catch basin, curb inlet, culvert or similar drainage structure that receives sediment-laden runoff.**
- Storm drain inlet protection is not meant for use in drainage areas exceeding one (1) acre or for large concentrated **stormwater** flows. <u>Inlet protection is to be used as a last resort for sediment control when no other means are practical.</u>
- <u>Stone bag inlet protection is not to be used in an active roadway.</u>

APPROACH

Inlet protection shall be avoided on roadways due to the potential of ponding and street flooding. Inlet protection may be installed prior to the construction of roads however, once the sub base is laid, the inlet protection shall be removed.

Inlet protection is required on all inlets that have outfalls that bypass sediment trapping structures and directly discharge off-site. General design criteria for each of the materials/methods of inlet protection are provided below.

- Filter Fabric is used for inlet protection when **stormwater** flows are relatively small (0.5 cfs or less) with low velocities and where the inlet drains a relatively flat area (slopes no greater than 5%). This practice cannot be used where inlets are paved or where inlets receive concentrated flows, such as in streets or highway medians.

- Filter Fabric Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

- Block and Gravel filters can be used where heavy flows and higher velocities are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure.

- Block and Gravel Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.3 shall be used to properly design rock ditch checks.

- Gravel and Mesh filters can be used where heavy concentrated flows are expected and subject to disturbance by site traffic. Gravel and Mesh filters should not be used where ponding around the structure might cause excessive inconvenience or damage to adjacent structures and unprotected areas. Gravel and Mesh filters have no overflow mechanism; therefore ponding is likely, especially if sediment is not removed regularly. Gravel and Mesh filters must never be used where overflow may endanger an exposed fill slope.

- Gravel and Mesh filters shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

- Stone Bag Inlet Protection is used when **stormwater** flows are relatively small (0.5 cfs or less) with low velocities and where the inlet drains a relatively flat area (slopes no greater than 5%). The immediate land area around the inlet should be relatively flat (less than 1% slope).

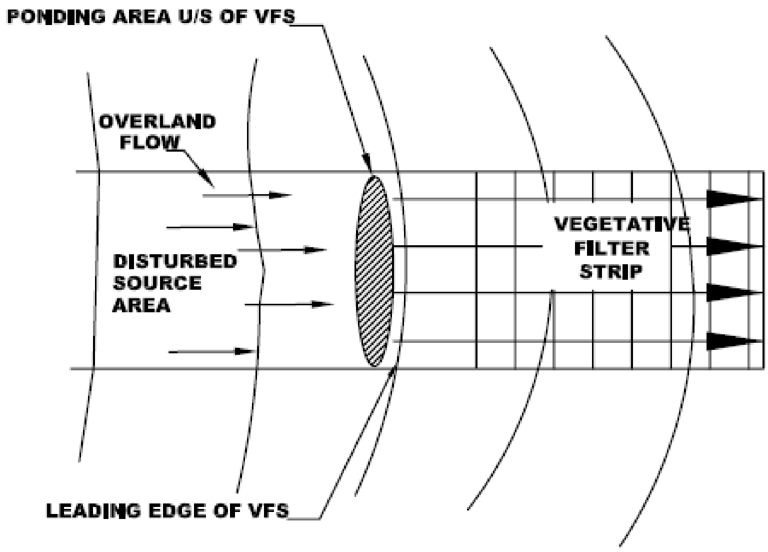
- Stone Bag Inlet Protection shall be designed to have an 80% design removal efficiency goal of the total suspended solids (TSS) in the inflow. The design aids located in Section 12.8.4 shall be used to properly design silt fence.

MAINTENANCE

- **Inspect storm drain inlet protections periodically and after every rain event to check for damage caused by large flows and clogged fabric. Repair or replace as necessary.**
- **Remove sediment when depth exceeds one-third the height of the filter or half the depth of the sediment trap.**
- **Inlet protection should be removed and the area restored once the contributing watershed has been permanently stabilized.**

LIMITATIONS

- **Some types of inlet protection may cause ponding that could encroach onto access roads, streets, parking lots, driveways or highway traffic.**



PLAN VIEW

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VFS VFS

Slope Protection	**Waterway Protection**	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Vegetated filter strips (VFS) are zones of vegetation through which sediment and pollutant-laden runoff are directed before being discharged to a concentrated flow channel. Proper orientation of VFS is shown in Exhibit 12-10 in Supplemental Section D.

APPLICATION

- **Often used in conjunction with other stormwater management practices to reduce the amount of sediment and treat runoff from impervious surfaces.**

APPROACH

In the design of VFS, the designer must select a vegetation type, a ground slope, filter strip width, and strip length. To be effective, VFS should be located on the contour perpendicular to the general direction of flow. Vegetation should be selected to be dense, turf-forming grass in order to minimize water channelization. The designer should never assume that natural vegetation is adequate for VFS. A ponding area shall be constructed at the leading edge of the VFS for bedload deposition.

The design process for VFS requires a series of detailed equations found in Design Hydrology and Sedimentology for Small Catchments, Hann et. al. 1994: pages 359-375. Software packages such as SEDIMOTII, or SEDCAD should be utilized to determine trapping efficiencies for VFS.

- The General Design Criteria to Design Filter Length are:
  a) Select a vegetation type.

  b) Select the design life and maximum allowable sediment deposition. A design life of 10 years and deposition of 0.5 feet is recommended.

c) Estimate the long-term sediment yield entering the filter strip and a 10-year 24-hour design single-storm sediment yield.

d) Determine desired Trapping Efficiency- 80% design removal efficiency is the goal of the total suspended solids (TSS) in the inflow.

e) Estimate the filter length necessary to prevent deposition within the filter greater than 0.5 feet. (Assume filter width is equal to disturbed area width but no smaller than 15 ft.)

f) Use the filter length to calculate Trapping Efficiency for the design storm.

g) Repeat (d) and (e) until **the filter length achieves appropriate removal efficiency.**

- Minimum Ground Slope = 1%
- Maximum Ground Slope =10%

MAINTENANCE

- **Inspect periodically and after significant rain events until vegetation is established. Repair or replace damaged vegetation or eroded areas.**
- **Vegetation should not be mowed shorter than three inches.**

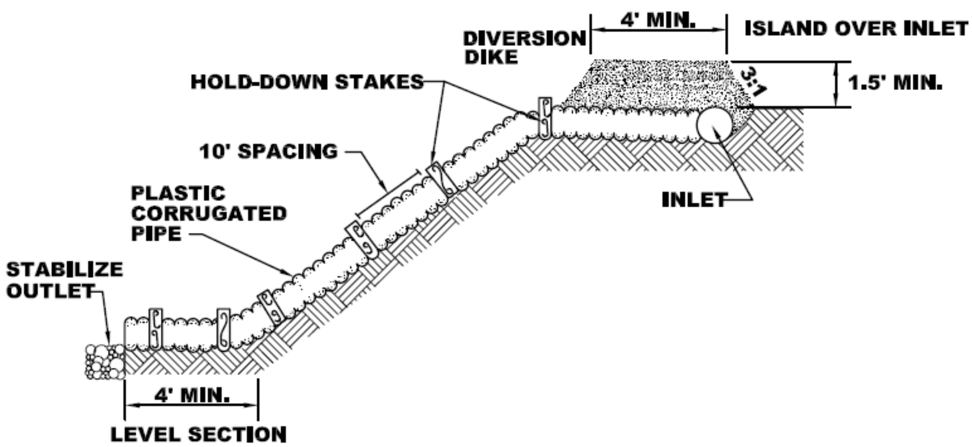
LIMITATIONS

- **Vegetated filter strips only treat sheet flow and are effective only on gentle slopes.**
- **Proper maintenance is required to maintain the health and density of vegetation.**
- **Filter strips typically require a large amount of space.**

12.7 RUNOFF CONTROL AND CONVEYANCE MEASURES

The following flow control measures are applicable as temporary and/or permanent practices for use during construction.

12.7.1 PIPE SLOPE DRAINS — RC&CM-1: PSD



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PSD PSD PSD

Slope Protection	Waterway Protection	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Pipe slope drains reduce the risk of erosion by discharging concentrated runoff from the top to the bottom of slopes. Pipe slope drains can be temporary or permanent depending on installation and material used. A typical pipe slope drain layout is shown in Exhibit 12-11 in Supplemental Section D of this chapter.

Temporary pipe slope drains, usually flexible tubing or conduit, may be installed prior to construction of permanent drainage structures. Permanent slope drains shall be buried beneath the ground surface. The inlets and outlets of a pipe slope drain shall be stabilized with flared end sections, Erosion Control Blankets (ECBs), Turf Reinforcement Mats (TRMs) or riprap. The soil around the pipe entrance should be fully compacted to prevent bypassing and undercutting of the structure. The soil at the discharge end of the pipe should be stabilized along the bottom of any swales that lead to sediment trapping structures or other stabilized areas.

APPLICATION

- Pipe slope drains are used when it is necessary for water to flow down a slope without causing erosion, especially before a slope has been stabilized or before permanent drainage structures are installed.

APPROACH

- The capacity should handle a 10-year, 24-hour storm peak flow.
- The maximum drainage area allowed per pipe is 2 acres.
- The inlet section should be securely connected to the slope drain and have watertight connecting bands.

- Slope drains sections should be securely fastened together, have **watertight** gasket fittings, and be securely anchored properly into the soil.
- Diversion channels should direct runoff to slope drains. The height of the dike should be at least 1-foot higher than the top of the inlet pipe and be compacted around the pipe with an anti-seep device.
- The area below the outlet must be properly stabilized with ECBs, TRMs, riprap or other applicable stabilization technique.
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Permanent slope drains should be buried beneath the soil surface a minimum 1.5 feet.

MAINTENANCE

- **Inspect periodically and after each rain event. Remove sediment buildup and debris from inlets and outlets as necessary.**
- **Inspect outlet for erosion and downstream scour. Repair damage as necessary.**
- **Install energy dissipaters if appropriate.**

LIMITATIONS

- **Severe erosion may result when downdrains fail.**
- **Should not be used in drainages exceeding 2 acres.**

12.7.2 TEMPORARY STREAM CROSSING RC&CM-2: TSC

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TSC

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

A temporary stream crossing is a bridge or culvert across a stream or watercourse for short-term use by construction vehicles and heavy equipment. A stream crossing provides a means for construction vehicles to cross streams or watercourses without moving sediment to streams, damaging the streambed or channel, or causing flooding. A typical layout for a temporary stream low water crossing is shown in Standard Drawing ER-02-**02**.

APPLICATION

- **Any area where construction vehicles must cross a stream or watercourse.**

APPROACH

Prior to constructing a temporary stream crossing, the owner/person financially responsible for the project must submit an Application for Permit to Construct Across or Along a Stream to the Kentucky Division of Water (KDOW). Temporary stream crossings require a Section 404 Permit from the Army Corps of Engineers that is subject to Section 401 Water Quality Certification from KDOW. If the crossing creates more than 200 linear feet of fill or more than 1/3 acre of fill, an Individual Permit may be necessary instead of a Nationwide Permit. A copy of **the Army Corps of Engineers** permit needs to be submitted with the proposed construction plans prior to receiving construction approval.

When feasible, one should always attempt to minimize or eliminate the need to cross streams. Temporary stream crossings are a direct source of pollution; therefore, every effort should be made to use an alternate method (e.g., longer detour), when feasible. When it becomes necessary to cross a stream, a well-planned approach will minimize the damage to the stream bank and reduce erosion. The design of temporary stream crossings requires knowledge of the design flows and other information; therefore, the services of a professional engineer to deal with specific state and local requirements should be considered. The specific loads and the stream conditions will dictate what types of stream crossing to employ.

Design Criteria

Temporary Bridge Crossing

- Structures may be designed in various configurations. However, the materials used to construct the bridge must be able to withstand the anticipated heavy loading of the construction traffic.

- Crossing Alignment - The temporary waterway crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15^{o} from a line drawn perpendicular to the centerline of the stream at the intended crossing location. However, every effort shall be taken to install the crossing perpendicular to the stream. All fill materials associated with the roadway approach shall be limited to a maximum height of two feet above the existing **floodplain** elevation.

- A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. The flow captured in these dikes and swales shall be directed to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

- Appropriate perimeter controls such as silt fences, must be employed when necessary along banks of stream parallel to the same.

- All crossings shall have one traffic lane. The minimum width shall be 12 feet with a maximum width of 20 feet.

Temporary Culvert Crossing

- Limit the width of fill to that only necessary for the actual crossing.

- Where culverts are installed, coarse aggregate of clean shot limestone rock, riprap, and/or concrete with **#57** stone or greater will be used to form the crossing.

- Clean shot rock and/or riprap may be used as fill for crossings that will be in place for 6 to 12 months. A concrete cap shall be constructed over the rock for crossings that will be in place for more than 12 months.

- The depth of stone cover over the culvert shall be equal to ½ the diameter of the culvert or 12 inches; whichever is greater, but no greater than 18 inches. To protect the sides of the stone from erosion, riprap shall be used.

- The culvert crossing shall be large enough to convey the flow from a two-year frequency storm without appreciably altering the stream flow characteristics. A qualified professional must design the structure.

- The maximum number of pipes as possible should be placed within the stream banks with a maximum spacing of 12 inches between pipes.

- The minimum-sized pipe culvert that may be used is 24 inches.

- All culverts shall be strong enough to support their cross-sectional area under the maximum expected heavy equipment loads.

- The length of the culvert shall be adequate to extend the full width of the crossing, including side slopes.

- The slope of the culvert shall be at least 0.25 feet per foot.

- Crossing Alignment – A temporary culvert crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15^{o} from a line drawn perpendicular to the centerline of the stream at the intended crossing location. However every effort shall be taken to install the crossing perpendicular to the stream. All fill materials associated with the roadway approach shall be limited to a maximum height of two feet above the existing **floodplain** elevation.

- The approaches to the structure shall consist of stone pads meeting the following specifications:

  1. Clean stone or concrete fill only
  2. Minimum thickness: 6-inches
  3. Minimum width: equal to the width of the structure
  4. 20-foot minimum approach length

- A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. The flow captured in these dikes and swales shall be directed to a sediment trapping structure. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

A temporary culvert crossing should be in place no longer than 24 months.

MAINTENANCE

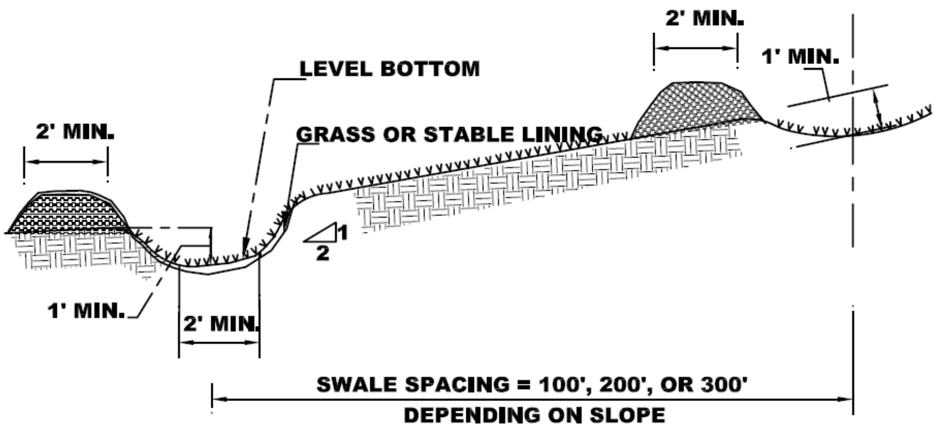
- **Inspect every seven days and after each rain event that produces 0.5 inches or more precipitation and repair any eroded areas immediately.**
- **The crossing should be removed immediately after construction. The stream bed and banks must be stabilized and restored to pre-construction conditions.**

12.7.2 TEMPORARY STREAM CROSSING RC&CM-2: TSC

LIMITATIONS

- **Temporary stream crossings may increase velocity of flows within the channel in excess of those normally encountered, resulting in stream bed and bank scour.**
- **Crossings require coordination with the U.S. Army Corps of Engineers and the Kentucky Division of Water.**

12.7.3 RUNOFF CONVEYANCE MEASURES RC&CM-3: RCM



SWALE

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RCM RCM RCM

Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties

DESCRIPTION

Dikes and berms and swales are used to divert upslope runoff from crossing areas where there is a high risk of erosion. Runoff conveyance structures may be used as temporary clean water diversions, temporary sediment-laden **water** diversions, or permanent clean water diversions. Runoff conveyance measures can be either temporary or permanent **stormwater** control structures. Typical cross sections for dikes and swales are shown in Exhibit 12-12 in Supplemental Section D.

When constructed along the upslope perimeter of a disturbed or high-risk area (though not necessarily all the way around it), clean water diversions prevent clear water runoff from flowing over unprotected **downslope** areas. Sediment-laden diversions located on the downslope side of a disturbed or high-risk area will prevent sediment-laden runoff from leaving the site before sediment is properly removed. For short slopes, runoff conveyance measures at the top of the slope reduce the amount of runoff reaching the disturbed area. For longer slopes, several dikes or swales are placed across the slope at intervals. This practice reduces the amount of runoff that accumulates on the face of the slope and carries the runoff safely down the slope. In all cases, runoff is guided to sediment trapping areas or a stabilized outfall before release.

APPLICATION

- Runoff conveyance measures are generally built around the perimeter of a construction site before any major disturbing activity takes place.
- Runoff conveyance measures are used in areas of overland flow.
- Convey stormwater to sediment trapping area.
- Convey clean stormwater around construction areas.

12.7.3 RUNOFF CONVEYANCE MEASURES RC&CM-3: RCM

APPROACH

Runoff channeled by dikes or swales should be directed to an adequate sediment trapping structure or stabilized outfall. Care should be taken to provide enough channel slope for drainage but not too much slope to cause erosion due to high runoff flow speed. Temporary runoff conveyance measures may remain in place as long as 12 to 18 months (with proper stabilization). Dikes or swales should remain in place until the area they were built to protect is permanently stabilized.

Permanent controls should be designed to handle runoff after construction is complete; should be permanently stabilized; and should be inspected and maintained on a regular basis. Refer to Chapter 10 for temporary and permanent diversion channel stabilization requirements. **Examples of runoff conveyance measures include: grass-lined channels, sod-lined channels, riprap-lined channels, turf reinforced channels, paved channels, and temporary slope drains.**

<u>Dikes and Berms</u>

- Top Width - 2 foot minimum
- Height - 18” minimum measured from upslope toe.
- Side Slopes - 2H:1V or flatter
- Grade - Limited to grades between 0.5% and 1.0%.
- Spacing

Percent Slope	< 5%	5% - 10%	10% - 40%
Horizontal Spacing (ft)	300	200	100

- Stabilization - Slopes shall be stabilized immediately using vegetation, sod, erosion control blankets, or turf reinforcement mats to prevent erosion.
- Outlet - The upslope side of the dike should provide positive drainage so no erosion occurs at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
- Other - Minimize construction traffic over temporary dikes.

<u>Swales</u>

- Bottom Width - 2 feet minimum, the bottom should be level.
- Depth - 1-foot minimum.
- Side Slope - 2H:1V or flatter.
- Grade - Maximum 5%, with positive drainage to a suitable outlet.
- Stabilization - Stabilize with erosion control blankets or turf reinforcement mats immediately.

- Spacing

Percent Slope	< 5%	5% - 10%	10% - 40%
Horizontal Spacing (ft)	300	200	100

- Outlet - riprap to stabilize outlet/sedimentation pond.

MAINTENANCE

- **Inspect periodically and after every rain event to check for erosion and accumulation of debris and sediment. Remove debris and sediment buildup as necessary.**
- **Any decrease in the berm height due to settling or erosion should be repaired immediately.**

LIMITATIONS

- **Severe erosion may result when dikes, berms or swales become unstable or or not installed properly.**
- **Concentrated flow within conveyance increases the potential for erosion.**
- **Conveyance should be designed to avoid vehicular crossings.**

12.7.4 CONSTRUCTION DEWATERING RC&CM-4: CD

Slope Protection	**Waterway Protection**	Surface Protection	**Enclosed Drainage**	**Large Flat Areas**	**Borrow Areas**	Adjacent Properties

DESCRIPTION

Construction dewatering involves removing stormwater or groundwater from bore pits, trenches, and other excavations on the construction site. Usually this removal involves the pumping of this water to an appropriate receiving area. Direct pumping to lakes and streams **is illegal** and must be avoided.

APPLICATION

- **Removal of stormwater or groundwater from bore pits, trenches, and other excavations on the construction site.**

APPROACH

The pump utilized for dewatering purposes must be properly sized. Each pump has its own unique rating curve; therefore it is not feasible to list them in this chapter. The pump rating curve is used to calculate pump design flows based on head loss through the pump system.

The sediment-laden groundwater should be pumped directly to:

- A sediment control structure (i.e., sediment basin or sediment trap);
- An infiltration trench; or
- A vegetated buffer strip or zone.

Pumping to a Sediment Control Structure:

- It is recommended that sediment basins or temporary sediment traps receive sediment-laden water from bore pits and trenches. This will ensure that the 80%

trapping efficiency goal will be upheld. Special care should be taken to ensure that the pumping of this water does not cause the sediment control structure to fail. Also, care should be taken at the outlet of the hose from the pump to ensure that erosion does not occur due to high concentrated flows.

<u>Pumping to an Infiltration Trench:</u>

- An infiltration trench is a shallow, excavated trench back-filled with stone to form a reservoir. This reservoir may contain a subsurface drainage pipe or just stone. This trench allows water to filter through the stone and then be diverted to a suitable discharge point. The soils and the depth to the water table must be suitable for this sort of **dewatering.** Typical trench depths range from 2 to 8 feet. The stone fill material consists of washed aggregate 1.5 to 3 inches in diameter.

<u>Pumping to a Vegetated Buffer Strip or Zone:</u>

- Buffer zones are capable of filtering sediment-laden water. One option is to pump the water to a discharge device that will evenly spread the water over a wooded or vegetated buffer zone. An appropriate buffer zone can be determined from Section 12.6.9.

- A plan and profile for dewatering operations with pumping to a vegetated buffer zone is provided in Exhibit 12-13 in Supplemental Section D.

A detail for an outlet structure to the buffer zone is provided in Exhibit 12-14 in Supplemental Section D. This discharge device uses Schedule 40 PVC pipes. The discharge hose from the pump is connected to a flow diffuser constructed using PVC pipe. The diffuser pipes are capped at the ends and the water is discharged through evenly spaced holes drilled into the diffuser. The size and length of the diffuser and the size and spacing of the holes are dependent upon the flow capacity of the pump being used for the **dewatering** process. The **Exhibit provides** recommended pipe sizes, pipe lengths, hole sizes, and hole spacing are based on pump discharge rates for pumps of 5 HP and less.

MAINTENANCE

- **Inspect receiving area frequently to ensure capacity is not exceeded.**

LIMITATIONS

- **If the presence of polluted water is identified, the contractor shall implement appropriate dewatering pollution controls.**

12.7.5 STONE BAG CHECK DAM IN SMALL DITCH — RC&CM-6: SBCD

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SBCD ▶SBCD ▶SBCD

Slope Protection	**Waterway Protection**	**Surface Protection**	Enclosed Drainage	Large Flat Areas	Borrow Areas	**Adjacent Properties**

DESCRIPTION

Stone **b**ag **c**heck **d**ams can reduce flow velocities in small man-made swales and ditches, which reduces the erosive potential of the flow and also promotes sediment deposition. A typical layout for a stone bag check dam in a small ditch is shown in Standard Drawing EF-12-**02**.

APPLICATION

- Stone **b**ag **c**heck **d**ams are to be placed in front and rear yard swales only. Stone bag check dams should not be built in wetlands, any active or live streams, and in Waters of the Commonwealth.
- Stone bag check dams are applicable in situations where flow velocities are too high and are causing channel scour. They should not be used as a primary sediment-trapping device. They should be used as velocity checks only as a short-term temporary solution.
- Specific conditions for use include new diversion ditches that will not or cannot be stabilized for several days, and temporary diversion channels that are eroding due to high flow rates or steep slopes.

APPROACH

The bags shall be filled with KTC No. 57 stone. The dam shall span the banks of the ditch or swale. The height of the dam on the stream centerline should equal the height of flow for the 2-year 24-hour storm event. Bags should be placed on the bank to a height at least 6 inches higher than the center of the dam.

Space **stone b**ag **c**heck **d**ams such that the crest of the downstream dam is at the same elevation of the toe of the dam located immediately upstream. Show the designed spacing

	on the EPSC plans.
MAINTENANCE	• **Inspect every 7 days and after each rain event that produces 0.5 inch or more precipitation to check for excessive sedimentation or debris and trash buildup.** • **Remove sediment, debris and trash before it reaches one-half of the device's original height.** • **Loose or displaced stone bags should be repaired to the original specifications or replaced.**
LIMITATIONS	• **Not to be used in streams or rivers.** • **Not a primary control**

12.8 ENGINEERING AIDS AND DESIGN GUIDELINES FOR SEDIMENT CONTROLS

This section presents design aids that were developed for use in designing four types of sediment control structures; temporary sediment basins (Section 12.6.2), temporary sediment traps (Section 12.6.4), silt fences (Section 12.6.5), and rock ditch checks (Section 12.6.6) for Jefferson County, Kentucky. These design aids will each be briefly described and then examples will be used to demonstrate their use in realistic problems. Settling velocity will be discussed to begin.

12.8.1 Characteristic Settling Velocity and Eroded Particle Size

A common feature of each of the design aids is that a characteristic settling velocity for the eroded soil must be obtained. For Jefferson County conditions, this velocity corresponds to an eroded size such that 15% of the sediment has particles smaller than the size specified. The procedure for empirically estimating eroded size distributions is best described by Hayes et.al (1996). Characteristic settling velocity corresponds to an eroded particle diameter that is referred to as D_{15}. This diameter represents the point on the eroded particle size distribution curve where 15% of the particles (by weight) are equal to or smaller than this size. Estimated eroded size distributions for Jefferson County soils using an adaptation of the method described by Foster et al. (1985) were developed. The procedure uses the primary particle size information reported by SCS as part of county soil surveys. This procedure may be used with USDA Soil Survey Data or site specific soil boring data. Other procedures are given by Haan et.al. (1994) for physically based estimating procedures. If D_{15} is less than 0.01 mm, then settling velocity based upon a simplified form of Stokes Law is:

$$\mathbf{V_s = 2.81d^2} \qquad (1)$$

Where: V_s is settling velocity in ft/sec and d is diameter in mm. If D_{15} is greater than or equal to 0.01 mm, then settling velocity should be found using

$$\mathbf{\log_{10}V_s = -0.34246\,(\log_{10}d)^2 + 0.98912\,(\log_{10}d) - 0.33801} \quad (2)$$

Where: V_s, is settling velocity in ft/sec and d is particle diameter in mm (Wilson et al., 1982). The characteristic settling velocity can be obtained using Figure 12.1 and the eroded particle size (D_{15}) for soils found in Jefferson County, which is provided in Supplemental Section D.

It is important to remember that the eroded size distribution is the most critical parameter in sizing sediment controls. The eroded size distributions vary greatly from primary particle size distributions that are often determined as a result of soil strength investigations for construction purposes. Primary particle sizes will yield erroneous results and should not be used. The user should note that D_{15} is often smaller for coarse textured (more sandy soils) because of the reduced clay content and the lack of aggregation.

Table 12-7. Soil Classification by Texture

Jefferson County Soil Classification by General Texture			
Texture	Coarse	Medium	Fine
Soil Type	Sandy Loam	Silt Loam	Clay Loam

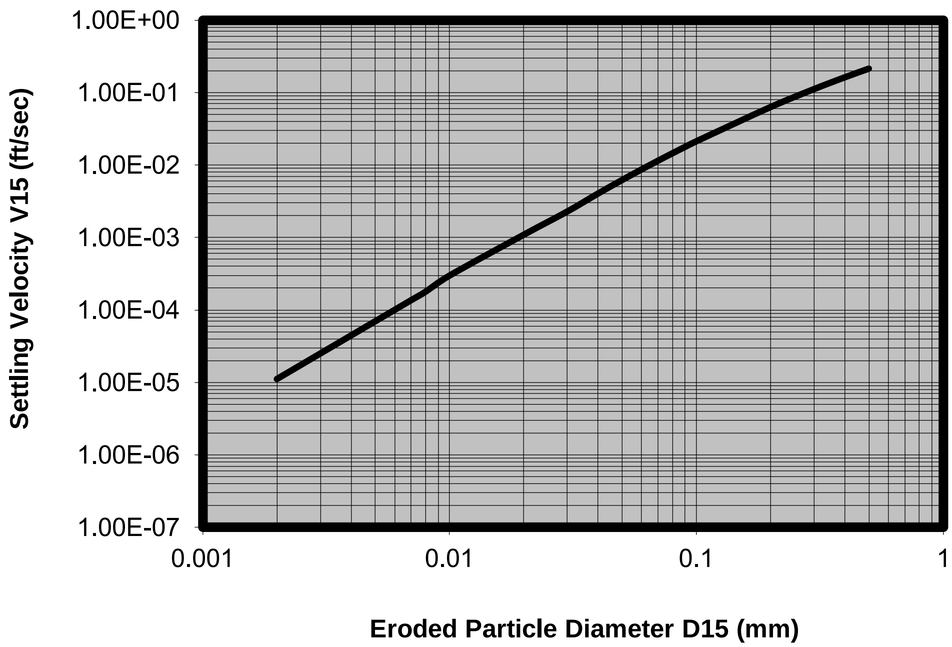

Figure 12.1. Characteristic Settling Velocity as a Function of Eroded Particle Diameter

12.8.2 Sediment Basin Design Aids

Figure 12.2 plots the basin ratio (qpo/AV_{15}) versus percentage of trapping efficiency. For basins, the ratio is defined by:

$$\textbf{Basin Ratio} = q_{po}/AV_{15} \qquad (3)$$

Where: q_{po} = peak outflow rate from the basin (cfs), A =surface area of the pond at riser crest (acres), V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Figure 12.2 is for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam) as shown in Table 12-8. The ratio should be less than or equal to the curve value at any given trapping efficiency. For example, at 80% trapping efficiency, the basin ratio equals 2.0E+**0**5 as shown in Figure 12.2. If the basin ratio q_{po}/AV_{15} intersects the curve at a point having a trapping efficiency less than the desired value, the design is inadequate and must be revised.

Basin Ratios above the design curves are not recommended for any application of the design aids. Constraints for use of Figure 12.2 are:

- Watershed area less than or equal to 30 acres
- Overland slope less than or equal to 20 %
- Outlet diameter less than or equal to 6 feet

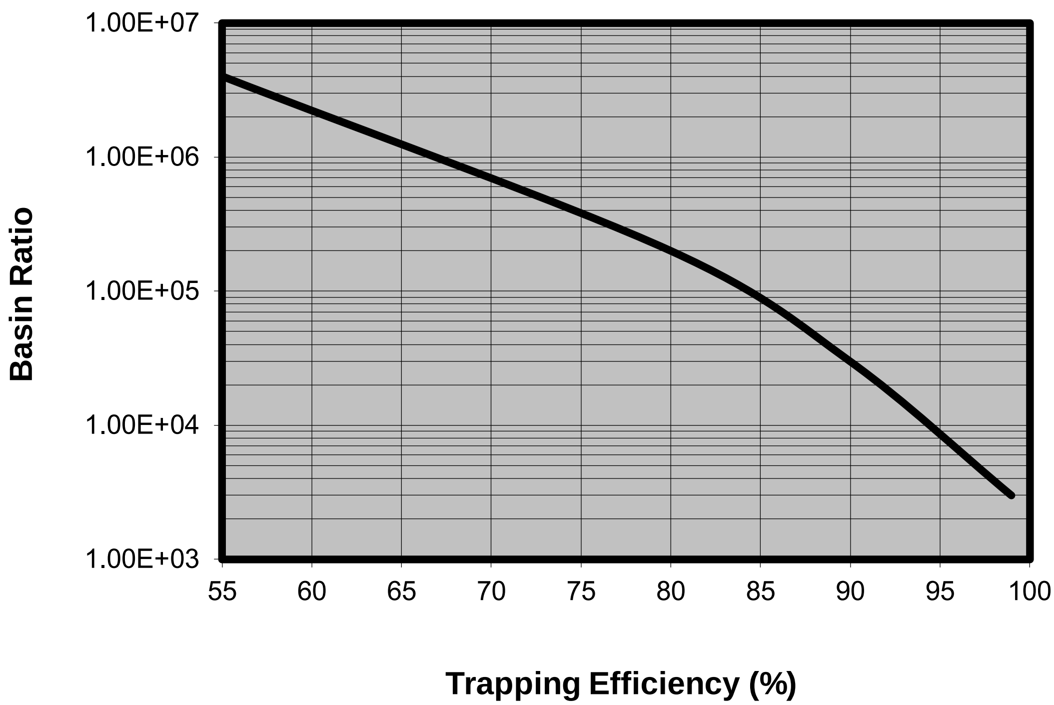

Figure 12.2. Design Aid for Estimating Trapping Efficiency of Sediment Basins.

12.8.3 Rock Ditch Check Design Aids

Design aids for rock ditch checks were developed similarly to those for **basins.** Again, the D_{15} eroded particle size is used for the calculation of the characteristic settling velocity. The ratio for ditch checks is defined by:

$$\textbf{Ditch Check Ratio} = Sq^{(1-b)}/aV_{15} \qquad (4)$$

Where: S = channel slope (%),
q = flow through the check (cfs/ft),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Table 12-8. Stone Flow Coefficient a and Exponent b

Stone D_{50} (m)	Exponent b	dl= 1m Coefficient a	dl = 2m Coefficient a	dl = 3m Coefficient a
0.01	0.6371	9.40	6.05	4.60
0.02	0.6540	7.40	4.65	3.55
0.03	0.6589	6.40	4.08	3.08
0.04	0.6609	5.85	3.65	2.80
0.05	0.6624	5.40	3.35	2.60
0.06	0.6635	5.05	3.15	2.40
0.08	0.6644	4.50	2.85	2.20
0.09	0.6648	4.28	2.70	2.10
0.10	0.6651	4.13	2.60	2.05
0.20	0.6662	3.20	2.05	1.57
0.30	0.6664	2.80	1.75	1.30
0.40	0.6665	2.50	1.55	1.16
0.50	0.6666	2.30	1.40	1.08

Coefficients *a* and Exponent *b* can be interpolated from Table 12-8 (Haan et.al. (1994) pg. 151).
D_{50} = rock ditch check average stone diameter in **meters**.
dl = average flow length through the rock ditch check in **meters**.

If the check overtops, the trapping efficiency is assumed to be zero. Figures 12.3a, 12.3b, and 12.3c can be used for estimating trapping efficiency of rock ditch checks. Table 12-8 provides guidance to determine which plot is appropriate.

Ditch Check Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figures 12.3a, 12.3b, and 12.3c are:

- Watershed area is less than or equal to 5 acres
- Overland flow length is less than or equal to 500 feet
- Overland slope is less than or equal to 15 %

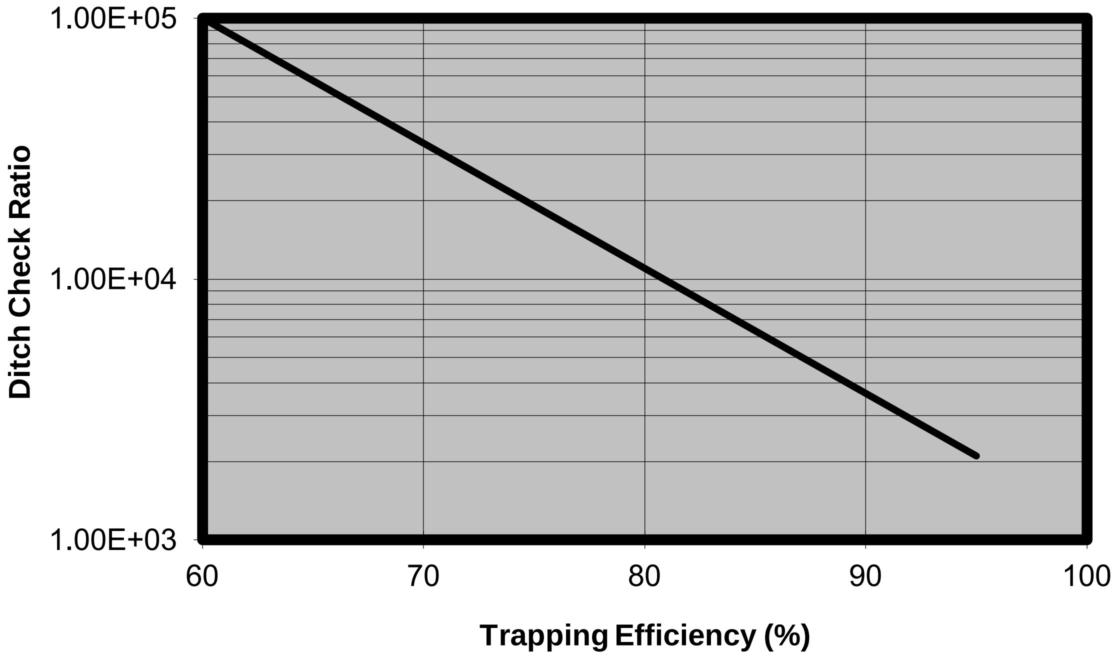

Figure 12.3a. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Fine Texture Soils.

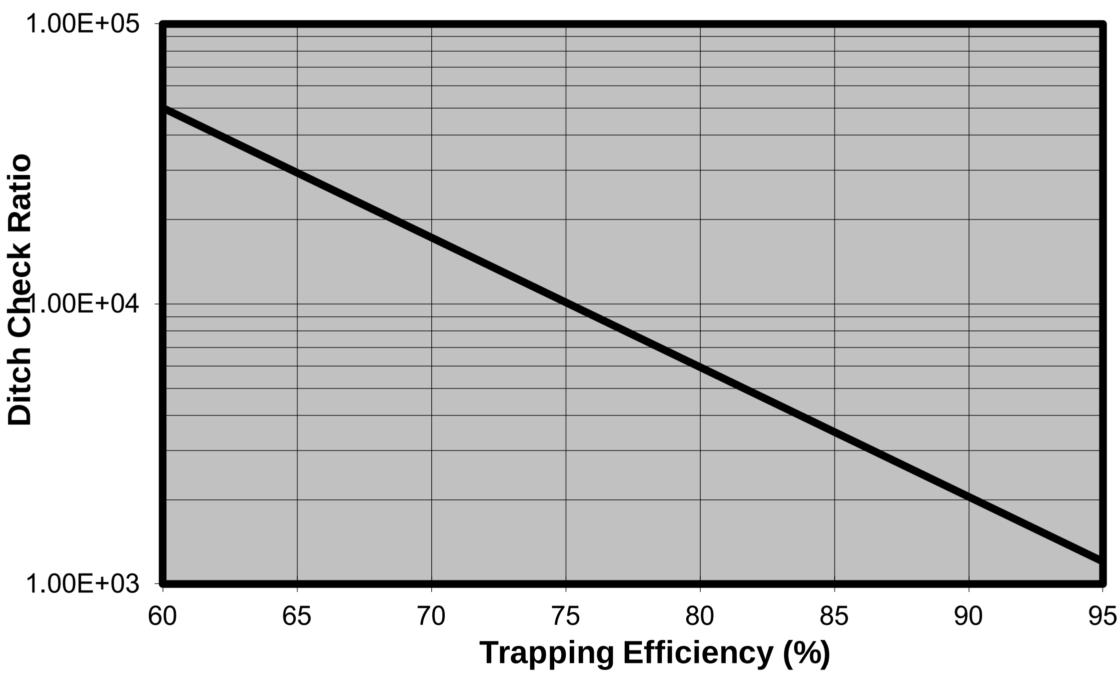

Figure 12.3b. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Medium Texture Soils.

Figure 12.3c. Design Aid for Estimating Trapping Efficiency of Rock Ditch Checks with Coarse Texture Soils.

12.8.4 Silt Fence Design Aids

The design aid for silt fences applies to silt fence placed in areas down slope from a disturbed area where it serves to retard flow and cause settling. Two conditions must be met for a satisfactory design.

- Trapping efficiency must meet the desired level of control.
- Overtopping of the fence must not occur.

One of the most important considerations in silt fence design is to specify regular maintenance. The silt fence design aid is a single line grouping all soil textures together. A similar procedure was used for development of the ratio as used for the **basins** and rock checks. For the silt fence, the ratio is:

$$\textit{Silt Fence Ratio} = q_{po}/V_{15}P_{area} \qquad (5)$$

Where:

q_{po} = peak outflow through the fence (cfs),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm),
P_{area} = potential ponding area up slope of the fence (ft^2).

The ponded area can be estimated by using the height of the fence available for flow through and extending a horizontal line from the fence to an intersection with the ground surface upslope of the fence. This is described by the available fence height times the ground slope. Multiply this distance by the available length of fence for ponding to obtain the potential ponding area. Then calculate the ratio and enter the value to Figure 12.4 to determine the efficiency. Once an acceptable trapping efficiency is determined, a calculation for overtopping must be done. The overtopping calculation must be done using the slurry flow rate through the fence. This rate must be checked against the incoming flow to determine if enough storage exists behind the fence to prevent overtopping.

Silt Fence Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figure 12.4 are:

- Watershed area is less than or equal 5 acres
- Overland flow length is less than or equal to 500 feet
- Overland slope is less than or equal to 6 %
- Slurry flow rate through the fence is less than or equal to 10 gpm / ft
- Maximum height of the silt fence is less than or equal to 3 feet

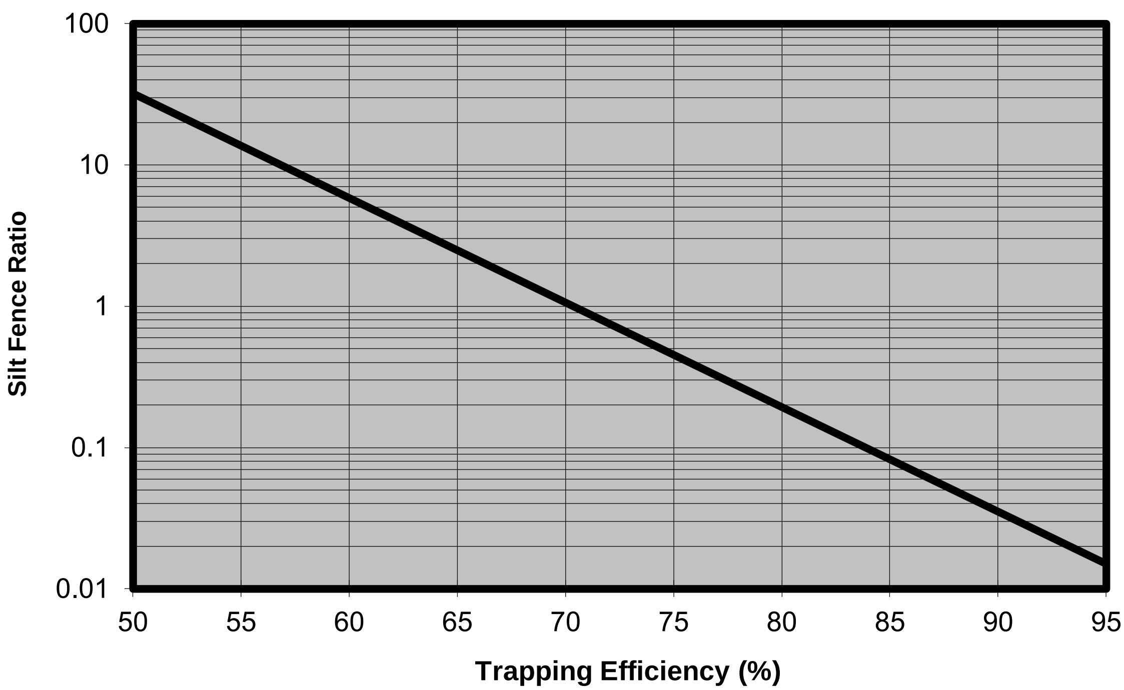

Figure 12.4. Design Aid for Estimating Trapping Efficiency of Silt Fence

12.8.5 Sediment Trap Design Aids

Sediment traps, for the purposes of this document, are small excavated **basins** with rock fill outlets. Their outlet hydraulics are different from a drop inlet structure, thus the design aid is slightly different. Trapping efficiencies for sediment traps are plotted in Figure 12.5 as a function of the sediment trap ratio:

$$\textit{Sediment Trap Ratio} = q_{po}/A/V_{15} \qquad (6)$$

Where:

q_{po} = peak outflow (cfs),
A = surface area at the elevation equal to the bottom of the rock fill outlet (acres),
V_{15} = (from Figure 12.1) characteristic settling velocity (fps), of the characteristic D_{15} eroded particle (mm).

Figure 12.5 is for soils classed as either coarse (sandy loam), medium (silt loam), or fine (clay loam) as shown in Table 12-8. The ratio should be less than or equal to the curve value at any desired trapping efficiency.

Sediment Trap Ratios above the design curves are not recommended for any application of the design aids. Constraints for the use of Figure 12.5 are:

- Watershed area less than or equal to 5 acres
- Overland slope less than or equal to 20%
- Rock fill diameter greater than 0.2 ft and less than 0.6 ft.
- Rock fill height less than 5 ft.
- Top width of rock fill between 2 and 4 ft.
- Maximum Side slopes 1:1 to 1.5:1.

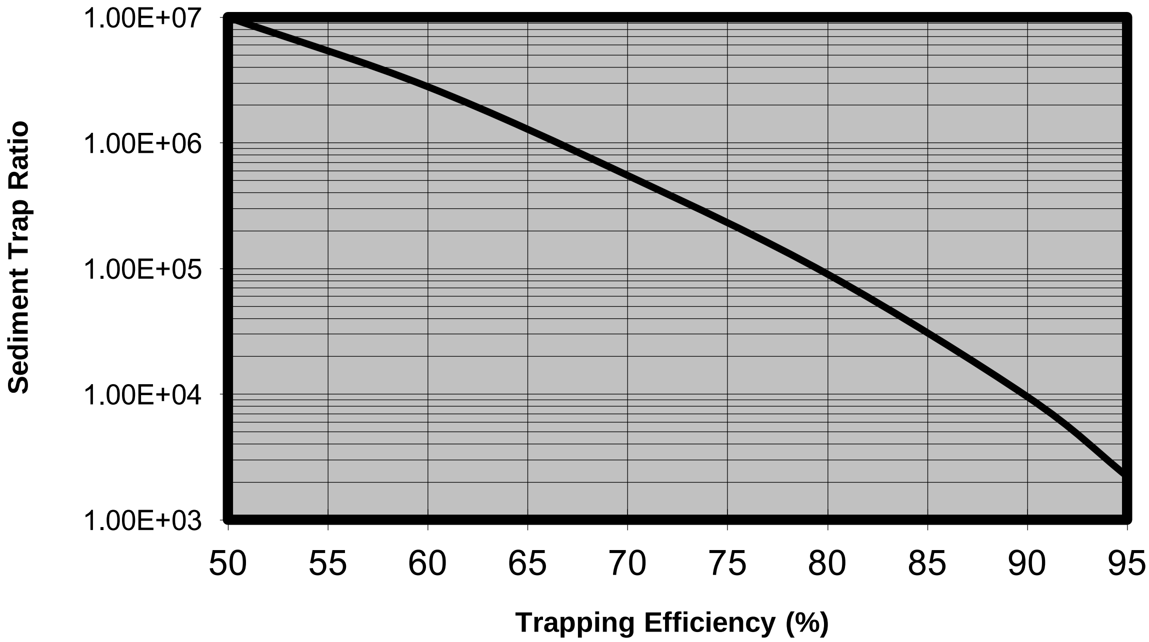

Figure 12.5. Design Aid for Estimating Trapping Efficiency of Sediment Traps.

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION A

EROSION PREVENTION & SEDIMENT CONTROL BMP SELECTION PROCESSES, SUGGESTED USES, & GUIDELINES

BMP Suggested Uses

Erosion Prevention Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Erosion Prevention Measures	12.5	X	***X***	X	X	X	X	X
Surface Roughening	12.5.1	X		X				
Bench Terracing	12.5.2	X		X				
Temporary Seeding	12.5.3	X		X		X	X	X
Mulching	12.5.4	X				X	X	
Erosion Control Blankets and Turf Reinforcement Mats	12.5.5	X	X	X			X	
Final Stabilization	12.5.6	X		X		X		X
Topsoiling	12.5.6.1			X		X		
Permanent Seeding and Planting of Grasses	12.5.6.2	X		X		X		X
Sodding	12.5.6.3	X		X		X		X
Riprap or Aggregate	12.5.7	X	X	X				
Outlet **Stabilization**	12.5.8		X		X			X
Dust Control	12.5.9					X	X	X

BMP SUGGESTED USES

Temporary Sediment Control Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Temporary Sediment Control Measures	12.6	X	X	X	X	X	X	X
Storage Volumes and Maintenance Schedules	12.6.1		X		X			X
Temporary Sediment Basin	12.6.2		X	X	X			X
Multipurpose Basin	12.6.3		X	X	.X			X
Temporary Sediment Trap	12.6.4		X	X				X
Silt Fence	12.6.5	X	X					X
Rock Ditch Check	12.6.6			X				X
Stabilized Construction Entrance	12.6.7					X		X
Storm Drain Inlet Protection	12.6.8		X		X			X
Vegetated Filter Strips	12.6.9		X					X

BMP SUGGESTED USES

Runoff Control and Conveyance Measures

BMP	Design Manual Section	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
Pipe Slope Drains	12.7.1	X		X				
Temporary Stream Crossing	12.7.2		X	X				X
Runoff Conveyance Measures	12.7.3	X					X	X
Construction Dewatering	12.7.4		X		X	X	X	
Stone Bag Check Dam in Small Ditch	12.7.**5**		X	X				X

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION B

JEFFERSON COUNTY RAINFALL & UNIVERSAL SOIL LOSS EQUATION INFORMATION

Rainfall Data

Table 1. Distribution of Rainfall Erosion Index (EI Curves) for Jefferson County

Date	EI Curve Number
January 1	0.0
January 15	1.0
February 1	3.0
February 15	6.0
March 1	9.0
March 15	12.0
April 1	16.0
April 15	21.0
May 1	26.0
May 15	31.0
June 1	37.0
June 15	43.0
July 1	50.0
July 15	57.0
August 1	64.0
August 15	71.0
September 1	77.0
September 15	81.0
October 1	85.0
October 15	88.0
November 1	91.0
November 15	93.0
December 1	95.0
December 15	97.0
January 1	100.0

Minimum Value to be used is 50
Average Annual R Factor = 175

Table 2. Universal Soil Loss Equation CP Factors

Condition	CP Factor
Bare Soil	1.0
Compacted Root Raked Soil	1.2
Compacted Bulldozer Scraped Soil	1.2
Fresh Unprepared Seedbed	0.64
Temporary Seeding 0-60 Days	0.40
Temporary Seeding After 60 Days	0.05
Permanent Seeding 2-12 Months	0.05
Brush	0.35
Erosion Control Blankets	0.01-0.10

Table 3. Universal Soil Loss Equation LS Factors

% Slope	Slope Length in Feet 20	50	75	100	120	150	200	250	300	350	400	450	500	600	700	800	900	1000
0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.114	0.12	0.12	0.13	0.13	0.13	0.137	0.141	0.145	0.148	0.152
1.0	0.1	0.11	0.12	0.13	0.14	0.14	0.15	0.15	0.17	0.18	0.19	0.20	0.20	0.22	0.23	0.24	0.25	0.25
2.0	0.12	0.16	0.18	0.20	0.21	0.22	0.24	0.26	0.27	0.29	0.0	0.31	0.32	0.34	0.36	0.37	0.38	0.40
3.0	0.17	0.23	0.26	0.28	0.30	0.32	0.35	0.37	0.38	0.41	0.43	0.45	0.46	0.49	0.51	0.53	0.55	0.57
4.0	0.21	0.30	0.35	0.40	0.43	0.47	0.52	0.57	0.62	0.66	0.69	0.73	0.76	0.81	0.87	0.91	0.96	1.00
5.0	0.23	0.37	0.46	0.53	0.58	0.65	0.75	0.84	0.92	1.00	1.07	1.13	1.19	1.31	1.41	1.51	1.60	1.69
6.0	0.30	0.47	0.58	0.67	0.73	0.82	0.95	1.06	1.16	1.25	1.34	1.42	1.50	1.64	1.78	1.90	2.01	2.12
7.0	0.36	0.58	0.71	0.82	0.90	1.01	1.16	1.30	1.42	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.60
8.0	0.44	0.70	0.85	0.99	1.08	1.21	1.40	1.56	1.71	1.85	1.98	2.10	2.21	2.42	2.62	2.80	2.97	3.13
9.0	0.52	0.82	1.01	1.17	1.28	1.43	1.65	1.85	2.03	2.19	2.34	2.48	2.62	2.87	3.10	3.31	3.52	3.71
10.0	0.61	0.96	1.18	1.36	1.50	1.67	1.93	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.10	4.33
11.0	0.70	1.11	1.36	1.58	1.73	1.93	2.23	2.49	2.73	2.95	3.16	3.35	3.53	3.87	4.18	4.46	4.74	4.99
12.0	0.80	1.27	1.56	1.80	1.97	2.21	2.55	2.65	3.12	3.37	3.60	3.82	4.03	4.42	4.77	5.10	5.41	5.70
13.0	0.91	1.44	1.76	2.04	2.23	2.50	2.88	3.23	3.53	3.82	4.08	4.33	4.56	5.00	5.40	5.77	6.12	6.46
14.0	1.02	1.62	1.98	2.29	2.51	2.81	3.24	3.62	3.97	4.29	4.58	4.86	5.13	5.62	6.07	6.49	6.88	7.25
15.0	1.14	1.81	2.21	2.56	2.80	3.13	3.62	4.04	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
16.0	1.26	2.00	2.45	2.83	3.11	3.47	4.01	4.48	4.91	5.31	5.67	6.02	6.34	6.95	7.51	8.02	8.51	8.97
17.0	1.40	2.21	2.71	3.13	3.42	3.83	4.42	4.94	5.42	5.85	6.26	6.64	7.00	7.66	8.28	8.85	9.39	9.89
18.0	1.53	2.42	2.97	3.43	3.76	4.20	4.85	5.43	5.94	6.42	6.86	7.28	7.68	8.41	9.08	9.71	10.3	10.9
19.0	1.67	2.65	3.24	3.75	4.10	4.59	5.30	5.93	6.49	7.01	7.50	7.95	8.38	9.18	9.92	10.6	11.3	11.9
20.0	1.82	2.88	3.53	4.07	4.46	4.99	5.76	6.45	7.06	7.63	8.15	8.65	9.12	10.0	10.7	11.5	12.2	12.9
25.0	2.63	4.16	5.1	5.89	6.45	7.21	8.33	9.31	10.2	11.0	11.8	12.5	13.2	14.4	15.6	16.7	17.7	18.6
33.3	4.22	6.67	8.17	9.44	10.3	11.6	13.4	14.9	16.4	17.7	18.9	20.0	21.1	23.1	25.0	26.7	28.3	29.9
40.0	5.65	8.94	8.94	12.7	13.9	15.5	17.9	20	21.9	23.7	25.3	26.8	28.3	31.0	33.5	35.8	38.0	40.0
50.0	7.97	12.6	12.6	17.8	19.5	21.8	25.2	28.2	30.9	33.3	35.6	37.8	39.9	43.7	47.2	50.4	53.5	56.4
66.6	11.9	18.9	18.9	26.7	29.2	32.7	37.7	42.2	46.2	49.9	53.3	56.6	59.6	65.3	70.5	75.4	80.0	84.3
100.0	18.9	29.9	29.9	42.2	46.3	51.7	59.7	66.8	73.2	79.0	84.5	89.6	94.5	103.	112	120	126	134

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SUPPLEMENTAL SECTION C

JEFFERSON COUNTY SOIL INFORMATION

Soils Information and Eroded Size Distributions for Jefferson County, Kentucky.

PERCENT FINER FOR SPECIFIED PARTICLE DIAMETERS

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
						Percent Finer Than (mm)				
ASHTON –HSG B										
0-9	0.32	0.0063	100.0	91.9	73.5	56.0	53.1	5.5	3.4	0.0
9-44		0.0053	100.0	91.9	73.4	64.9	62.9	8.0	5.1	0.0
44-80		0.0065	100.0	85.2	51.5	42.5	42.5	7.5	4.9	0.0
BEASLEY –HSG C										
0-7	0.43	0.0048	100.0	87.4	58.6	53.8	52.7	11.7	8.0	0.0
7-29		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0
29-50		0.0046	100.0	80.9	37.3	35.5	35.5	13.7	9.8	0.0
CAPTINA –HSG C										
0-9	0.43	0.0066	100.0	93.3	78.0	55.6	51.8	4.4	2.7	0.0
9-25		0.0055	100.0	89.1	64.2	57.0	56.1	8.4	5.4	0.0
25-39		0.0063	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
39-58		0.0079	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0
58-80		0.0754	100.0	72.9	11.0	8.0	8.0	12.9	9.8	0.0
CORYDON –HSG D										
0-9	0.43	0.0052	100.0	87.3	58.4	53.2	52.6	9.9	6.5	0.0
9-15		0.0048	100.0	84.9	50.5	47.6	47.4	12.1	8.3	0.0
CRIDER –HSG B										
0-12	0.32	0.0054	100.0	93.1	77.4	67.1	64.4	7.3	4.6	0.0
12-38		0.0052	100.0	91.5	72.0	64.2	62.1	9.0	5.8	0.0
38-50		0.0239	100.0	75.1	18.1	15.5	15.5	13.1	9.8	0.0
50-96		0.0037	100.0	80.7	36.7	35.6	35.6	16.2	11.7	0.0
DICKSON -HSG C										
0- 7	0.43	0.0058	100.0	92.4	74.9	61.5	58.8	6.4	4.0	0.0
7-25		0.0054	100.0	92.4	75.1	65.4	63.1	7.5	4.7	0.0
25-45		0.0054	100.0	91.3	71.4	63.1	61.4	8.0	5.1	0.0
45-65		0.0052	100.0	82.1	41.3	38.6	38.6	11.8	8.3	0.0
DUNNING -HSG D										
0-15	0.37	0.0050	100.0	89.3	64.9	58.7	57.1	10.5	7.0	0.0
15-72		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
ELK -HSG B										
0-9	0.37	0.0053	100.0	88.8	63.3	56.8	55.8	9.1	5.9	0.0
9-42		0.0054	100.0	91.3	71.4	63.1	61.4	8.0	5.1	0.0
42-69		0.0061	100.0	85.4	51.9	44.7	44.7	8.2	5.4	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Percent Finer Than (mm)							
ENNIS -HSG B										
0-10	0.24	0.0083	100.0	85.6	52.7	34.7	34.6	5.7	3.6	0.0
10-60		0.0080	100.0	83.3	45.3	32.6	32.6	7.3	4.9	0.0
FAIRMOUNT -HSG D										
0-11	0.24	0.0044	100.0	83.1	44.4	43.0	43.0	13.9	9.8	0.0
11-17		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
GINAT -HSG D										
0-9	0.43	0.0058	100.0	89.4	65.2	54.8	53.7	7.2	4.5	0.0
9-23		0.0054	100.0	88.3	61.7	55.4	54.6	9.0	5.8	0.0
23-48		0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
48-74		0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
74-80		0.0056	100.0	90.9	70.1	60.1	58.4	7.3	4.6	0.0
GUTHRIE -HSG D										
0-8	0.43	0.0059	100.0	94.3	81.1	64.8	60.6	5.5	3.4	0.0
8-32		0.0054	100.0	92.4	75.1	65.4	63.1	7.5	4.7	0.0
32-53		0.0055	100.0	90.4	68.6	60.2	59.0	7.8	4.9	0.0
53-68		0.0055	100.0	89.5	65.6	57.9	56.9	8.2	5.2	0.0
HOLSTON -HSG B										
0-8	0.28	0.0079	100.0	87.1	57.5	37.7	37.3	5.4	3.4	0.0
8-44		0.0071	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
44-75		0.0073	100.0	81.2	38.1	31.0	31.0	9.1	6.3	0.0
HUNTINGTON -HSG B										
0-11	0.32	0.0057	100.0	89.6	65.9	56.6	55.6	7.5	4.7	0.0
11-64		0.0057	100.0	89.6	65.9	56.6	55.6	7.5	4.7	0.0
64-74		0.0079	100.0	84.2	48.0	34.0	34.0	6.7	4.4	0.0
LAKIN -HSG A										
0-11	0.17	0.0379	100.0	94.8	83.0	16.1	15.0	1.2	0.8	0.0
11-60		0.0441	100.0	92.9	76.6	14.5	14.1	1.7	1.1	0.0
60-80		0.0449	100.0	97.1	90.5	10.7	9.8	0.6	0.4	0.0
LAWRENCE -HSG C										
0-10	0.43	0.0057	100.0	93.7	79.2	65.0	61.4	6.1	3.8	0.0
10-25		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
25-50		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
50-75		0.0049	100.0	87.9	60.3	55.1	53.9	11.2	7.6	0.0
LINDSIDE -HSG C										
0-8	0.32	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
8-44		0.0054	100.0	90.0	67.1	59.3	58.1	8.2	5.2	0.0
44-60		0.0065	100.0	84.7	49.7	41.0	41.0	7.9	5.2	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP										
			Percent Finer Than							
DEPTH (in)	K	D15 (mm)	1.4	1.0	0.063	0.044	0.038 (mm)	0.004	0.003	0.001
LITZ -HSG C										
0-12	0.32	0.0093	100.0	84.9	50.5	30.9	30.9	5.6	3.6	0.0
12-24		0.0461	100.0	79.7	33.1	12.4	12.4	6.0	4.4	0.0
LORING -HSG C										
0-7	0.49	0.0061	100.0	96.4	88.0	67.8	61.9	4.1	2.5	0.0
7-28		0.0053	100.0	93.3	78.0	69.0	66.5	7.8	4.9	0.0
28-50		0.0054	100.0	93.9	80.0	68.8	65.5	7.0	4.4	0.0
50-65		0.0060	100.0	93.3	78.1	61.2	57.6	5.5	3.4	0.0
LOWELL -HSG B										
0-11	0.37	0.0050	100.0	90.6	69.1	62.0	60.1	9.9	6.5	0.0
11-23		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
23-53		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0
MARKLAND -HSG C										
0- 7	0.43	0.0051	100.0	89.8	66.6	59.9	58.3	10.0	6.6	0.0
7-28		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
28-60		0.0048	100.0	86.3	55.1	51.1	50.4	12.1	8.3	0.0
MCGARY -HSG C										
0-11	0.43	0.0052	100.0	87.9	60.1	54.7	53.8	10.0	6.6	0.0
11-39		0.0046	100.0	89.2	64.4	58.1	56.4	12.1	8.3	0.0
39-60		0.0047	100.0	88.5	62.1	56.4	54.9	12.1	8.3	0.0
MELVIN -HSG D										
0-9	0.43	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
9-30		0.0055	100.0	92.3	74.8	64.7	62.3	7.3	4.6	0.0
30-62		0.0057	100.0	90.1	67.6	57.7	56.3	7.3	4.6	0.0
MEMPHIS -HSG B										
0-9	0.49	0.0060	100.0	95.8	86.3	68.0	62.7	4.7	2.9	0.0
9-23		0.0052	100.0	92.7	76.0	67.5	65.0	8.4	5.4	0.0
23-77		0.0057	100.0	94.9	83.3	68.3	64.0	5.8	3.6	0.0
MUSKINGUM -HSG C										
0-5	0.28	0.0072	100.0	88.3	61.6	42.0	41.4	5.5	3.4	0.0
5-26		0.0074	100.0	84.7	49.8	37.2	37.2	6.8	4.4	0.0
NEWARK -HSG C										
0-7	0.43	0.0059	100.0	89.6	65.8	54.8	53.6	7.0	4.4	0.0
7-38		0.0054	100.0	90.0	67.1	59.3	58.1	8.2	5.2	0.0
38-60		0.0053	100.0	90.5	68.8	61.5	60.8	8.3	5.2	0.0
OTWAY –HSG D										
0-18	0.43	0.0046	100.0	87.9	60.1	54.9	53.4	12.7	8.8	0.0
18-36		0.0052	100.0	90.0	67.0	60.7	60.1	9.0	5.7	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP

DEPTH (in)	K	D15 (mm)	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Percent Finer Than (mm)							
PURDY -HSG D										
0-9	0.43	0.0052	100.0	92.9	76.8	68.1	65.6	8.2	5.2	0.0
9-42		0.0048	100.0	84.9	50.5	47.6	47.4	12.1	8.3	0.0
42-60		0.0048	100.0	85.6	52.8	49.4	48.9	12.1	8.3	0.0
ROBERTSVILLE -HSG D										
0-6	0.43	0.0058	100.0	93.2	77.6	63.2	59.9	6.1	3.8	0.0
6-21		0.0054	100.0	92.2	74.2	65.5	63.5	7.8	4.9	0.0
21-45		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
45-65		0.0054	100.0	88.3	61.7	55.4	54.6	9.0	5.8	0.0
ROCKCASTLE -HSG D										
0-6	0.43	0.0044	100.0	83.1	44.4	43.0	43.0	13.9	9.8	0.0
6-28		0.0045	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
SCIOTOVILLE -HSG C										
0-13	0.37	0.0059	100.0	91.2	71.0	58.1	56.0	6.6	4.1	0.0
13-34		0.0055	100.0	89.6	65.7	57.9	56.9	8.0	5.1	0.0
34-59		0.0053	100.0	90.6	69.2	61.6	60.9	8.2	5.1	0.0
59-69		0.0071	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0
SEQUATCHIE -HSG B										
0-12	0.24	0.0087	100.0	85.9	53.5	33.5	33.4	5.4	3.4	0.0
12-46		0.0060	100.0	87.4	58.5	49.5	49.2	7.4	4.7	0.0
46-72		0.0098	100.0	84.7	49.9	29.4	29.4	5.5	3.6	0.0
SHELBYVILLE -HSG B										
0-9	0.32	0.0058	100.0	94.5	81.8	66.6	62.5	5.8	3.6	0.0
9-38		0.0053	100.0	92.3	74.9	66.3	64.1	8.2	5.2	0.0
38-65		0.0043	100.0	83.8	46.8	44.8	44.5	13.9	9.8	0.0
TAFT -HSG C										
0-9	0.43	0.0060	100.0	93.3	78.1	61.2	57.6	5.5	3.4	0.0
9-24		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
24-64		0.0054	100.0	91.6	72.4	63.8	62.0	7.8	4.9	0.0
64-80		0.0066	100.0	84.4	48.8	39.6	39.6	7.8	5.2	0.0
TYLER -HSG C										
0-14	0.43	0.0058	100.0	92.5	75.5	61.5	58.6	6.2	3.9	0.0
14-18		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
18-59		0.0055	100.0	89.7	66.2	58.2	57.2	7.9	5.0	0.0
59-70		0.0061	100.0	89.6	65.9	52.9	51.5	6.6	4.1	0.0
WEINBACH -HSG C										
0-15	0.43	0.0059	100.0	89.6	65.8	54.8	53.6	7.0	4.4	0.0
15-23		0.0055	100.0	89.9	66.7	58.5	57.5	7.8	4.9	0.0
23-40		0.0055	100.0	89.9	66.7	58.5	57.5	7.8	4.9	0.0
40-52		0.0053	100.0	90.6	69.2	61.6	60.0	8.7	5.6	0.0
52-65		0.0071	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0

SOIL SERIES -HYDROLOGIC SOIL GROUP											
			Percent Finer Than								
DEPTH (in)	K	D15 (mm)	1.4	1.0	0.063	0.044	0.038 (mm)	0.004	0.003	0.001	
WESTMORELAND -HSG ZZ											
0-7	0.99	0.0058	100.0	90.1	67.6	56.5	55.1	7.0	4.4	0.0	
7-36		0.0062	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0	
36-49		0.0081	100.0	82.7	43.3	31.2	31.2	7.6	5.2	0.0	
WHEELING -HSG B											
0-14	0.37	0.0069	100.0	90.8	69.7	48.9	46.6	5.0	3.1	0.0	
14-60		0.0067	100.0	85.1	50.9	40.7	40.7	7.2	4.7	0.0	
60-72		0.0255	100.0	87.5	59.1	17.5	17.5	3.4	2.2	0.0	
WOOLPER -HSG C											
0-6	0.37	0.0052	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0	
6-15		0.0047	100.0	86.9	57.0	52.6	51.6	12.2	8.4	0.0	
15-65		0.0043	100.0	85.3	51.6	48.2	47.5	13.9	9.8	0.0	
ZANESVILLE -HSG C											
0-7	0.43	0.0052	100.0	90.6	69.1	61.8	60.0	9.3	6.0	0.0	
7-28		0.0053	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0	
28-39		0.0055	100.0	89.7	66.2	58.2	57.2	7.9	5.0	0.0	
39-60		0.0079	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0	
ZIPP -HSG D											
0-6	0.28	0.0047	100.0	88.5	62.1	56.4	54.9	12.1	8.3	0.0	
6-36		0.0044	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0	
36-60		0.0046	100.0	85.7	53.1	49.6	48.9	12.7	8.8	0.0	

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION D

EXHIBITS

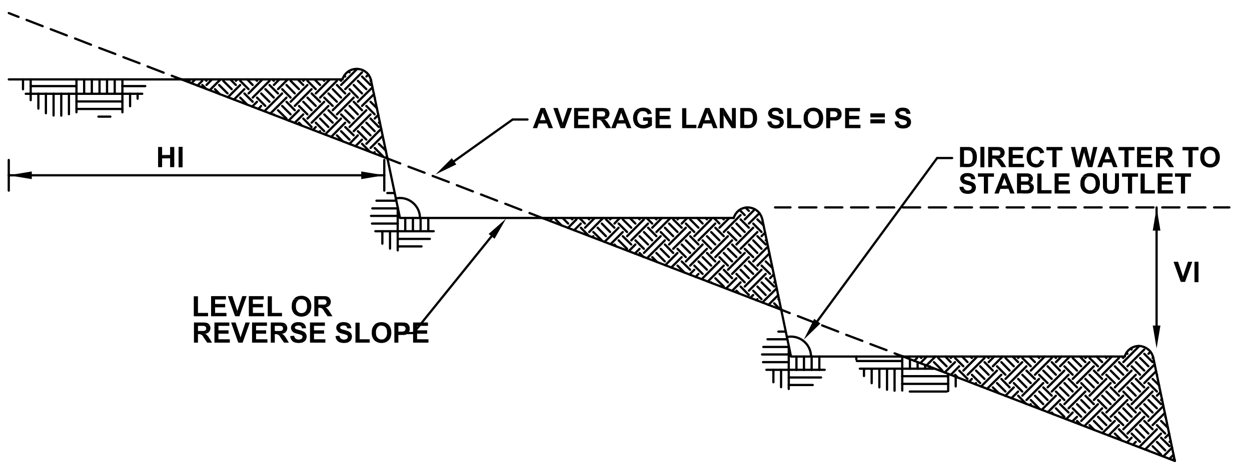
CHAPTER 12

EROSION PREVENTION AND SEDIMENT CONTROL
SUPPLEMENTAL SECTION D
EXHIBITS

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 12-1
BENCH TERRACES
FOR URBAN AREAS

EFFECTIVE DATE: JUNE 30, 2009



EQUATION FOR HORIZONTAL AND VERTICAL INTERVALS

$$HI = VI \times \frac{100}{S}$$

$$VI = aS + b$$

WHERE a = 0.5 FOR LOUISVILLE
b = 1 FOR ERODIBLE CONDITION
2 FOR RESISTANT SOILS WITH GOOD COVER.

S = AVERAGE LAND SLOPE IN PERCENT
HI = HORIZONTAL INTERVAL BETWEEN TERRACES
VI = VERTICAL INTERVAL BETWEEN TERRACES

BENCH TERRACES

Louisville and Jefferson County
Metropolitan Sewer District
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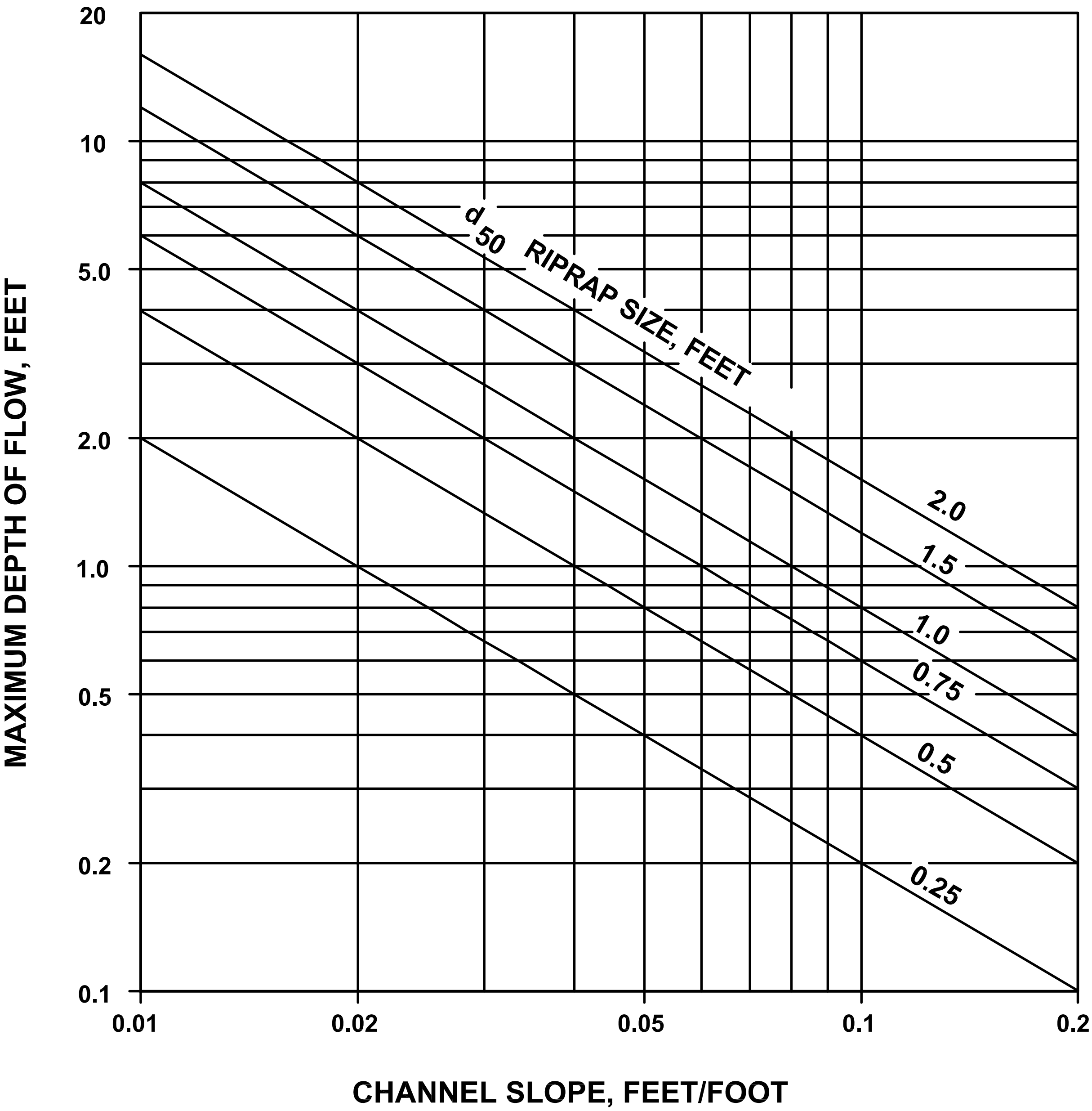
EXHIBIT 12-2
MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

EFFECTIVE DATE: JUNE 30, 2009



MAXIMUM DEPTH OF FLOW FOR RIPRAP LINED CHANNELS

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Metropolitan Sewer District
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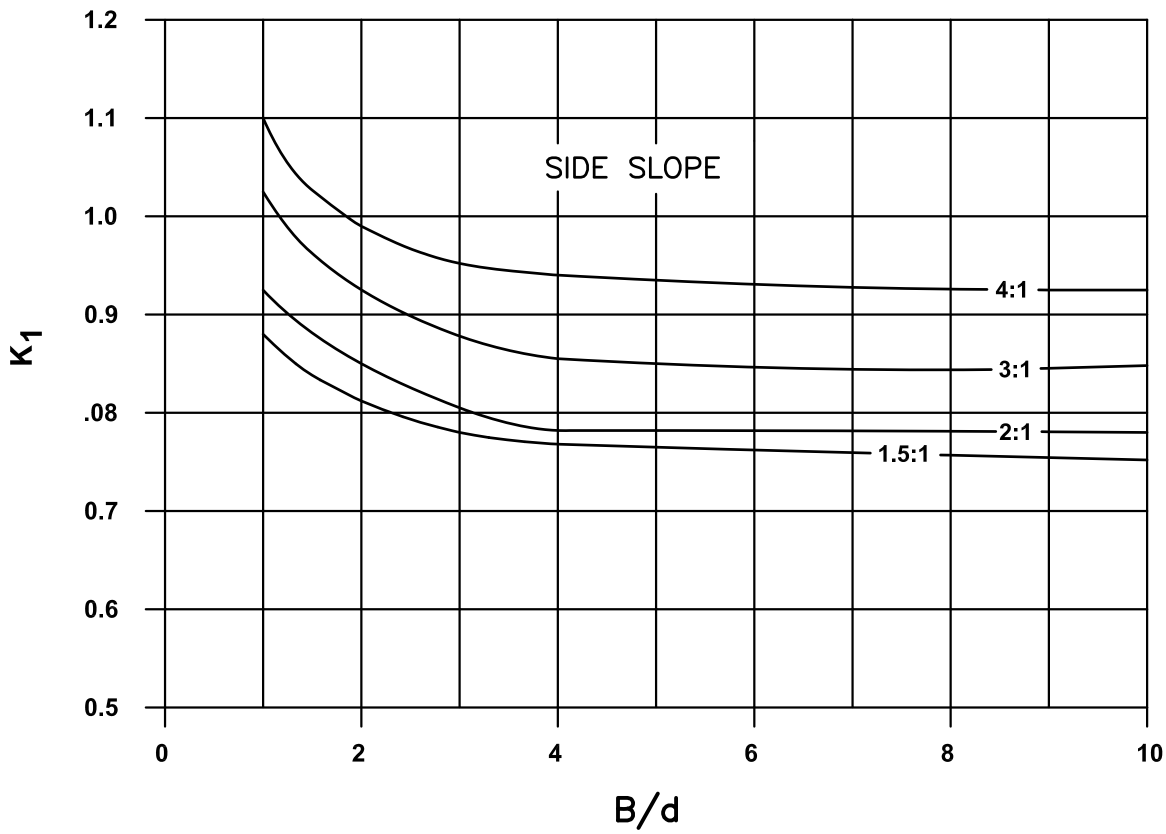
EXHIBIT 12-3
DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPAZOIDAL CHANNEL

EFFECTIVE DATE: JUNE 30, 2009



DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPAZOIDAL CHANNEL

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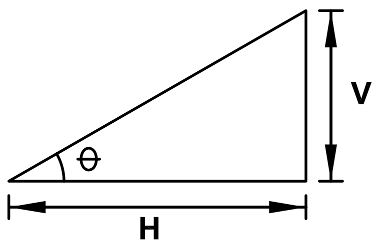
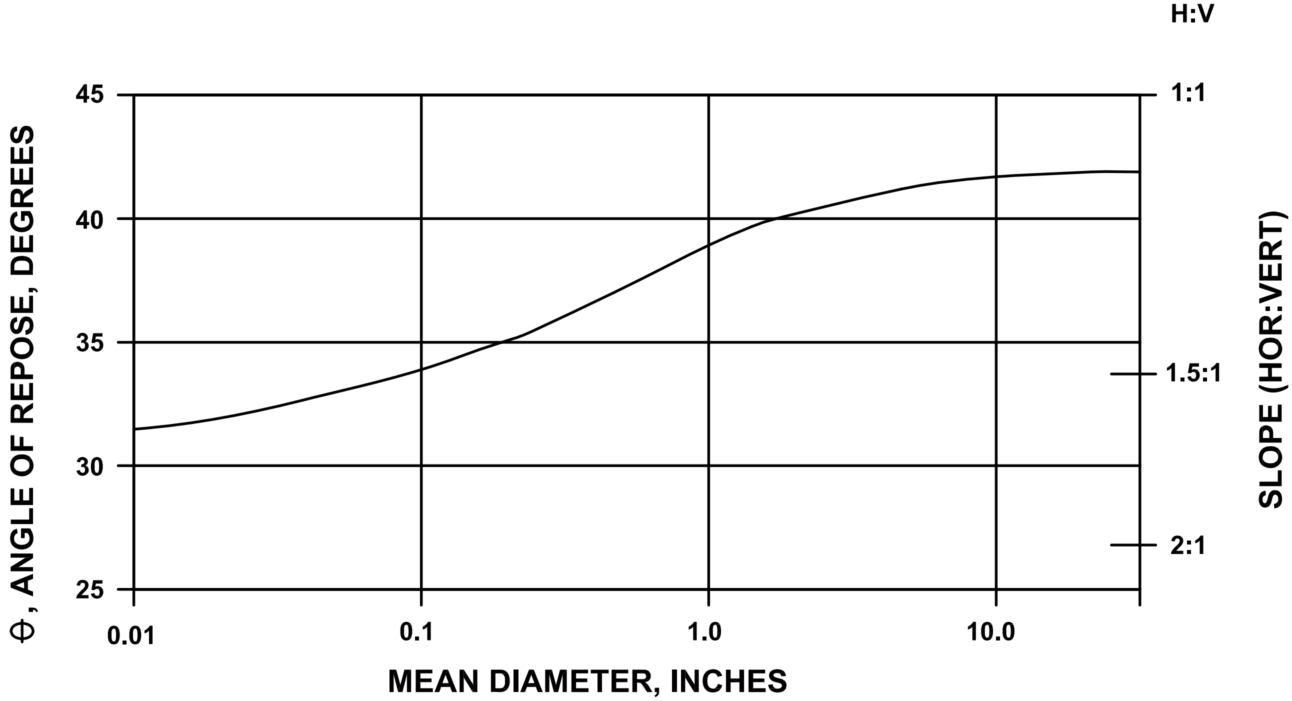
EXHIBIT 12-4
ANGLE OF REPOSE FOR RIPRAP STONES

EFFECTIVE DATE: JUNE 30, 2009





ANGLE OF REPOSE FOR RIPRAP STONES

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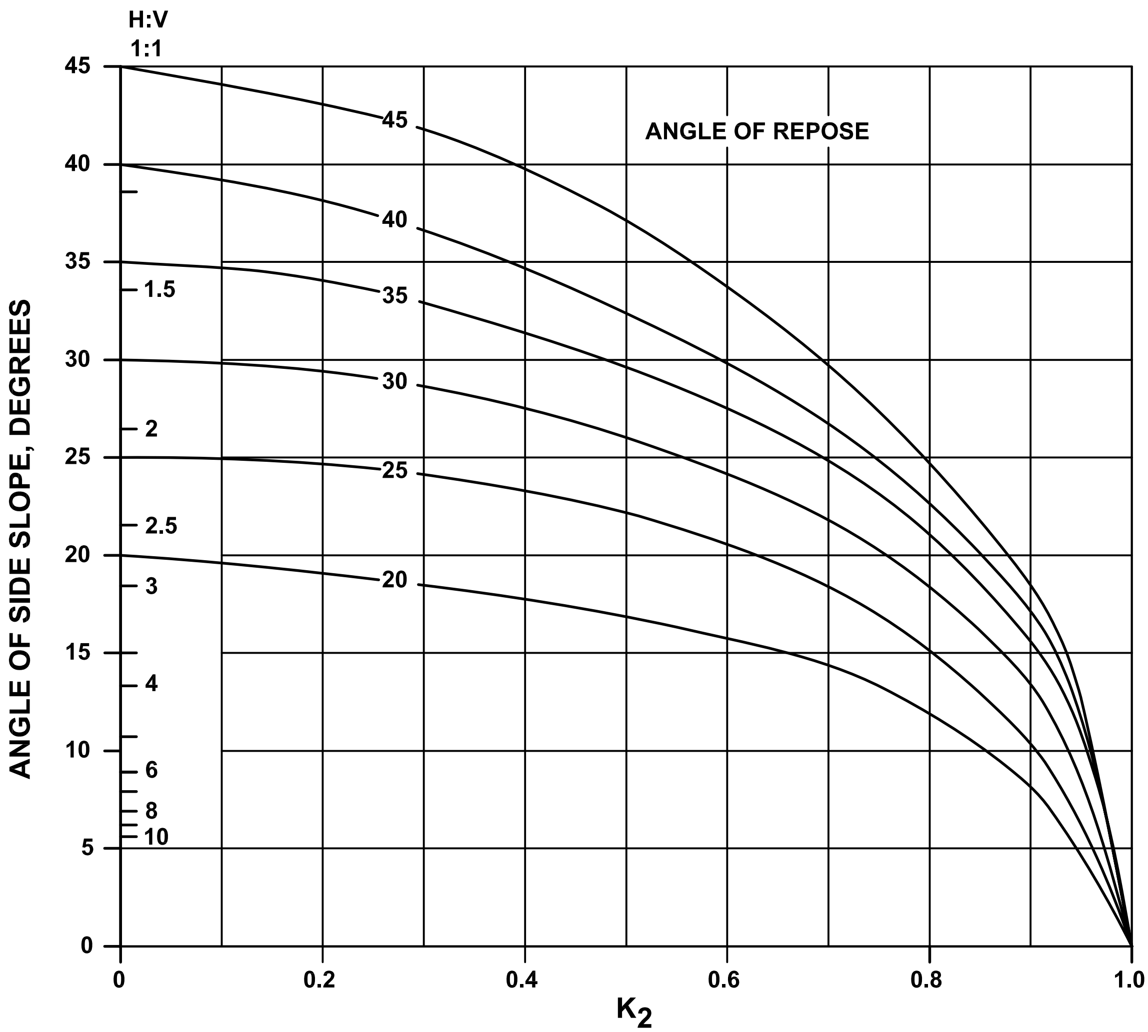
EXHIBIT 12-5
RATIO OF CRITICAL SHEAR STRESS ON SIDES
TO CRITICAL SHEAR STRESS ON BOTTOM

EFFECTIVE DATE: JUNE 30, 2009



RATIO OF CRITICAL SHEAR ON SIDES TO CRITICAL SHEAR ON BOTTOM

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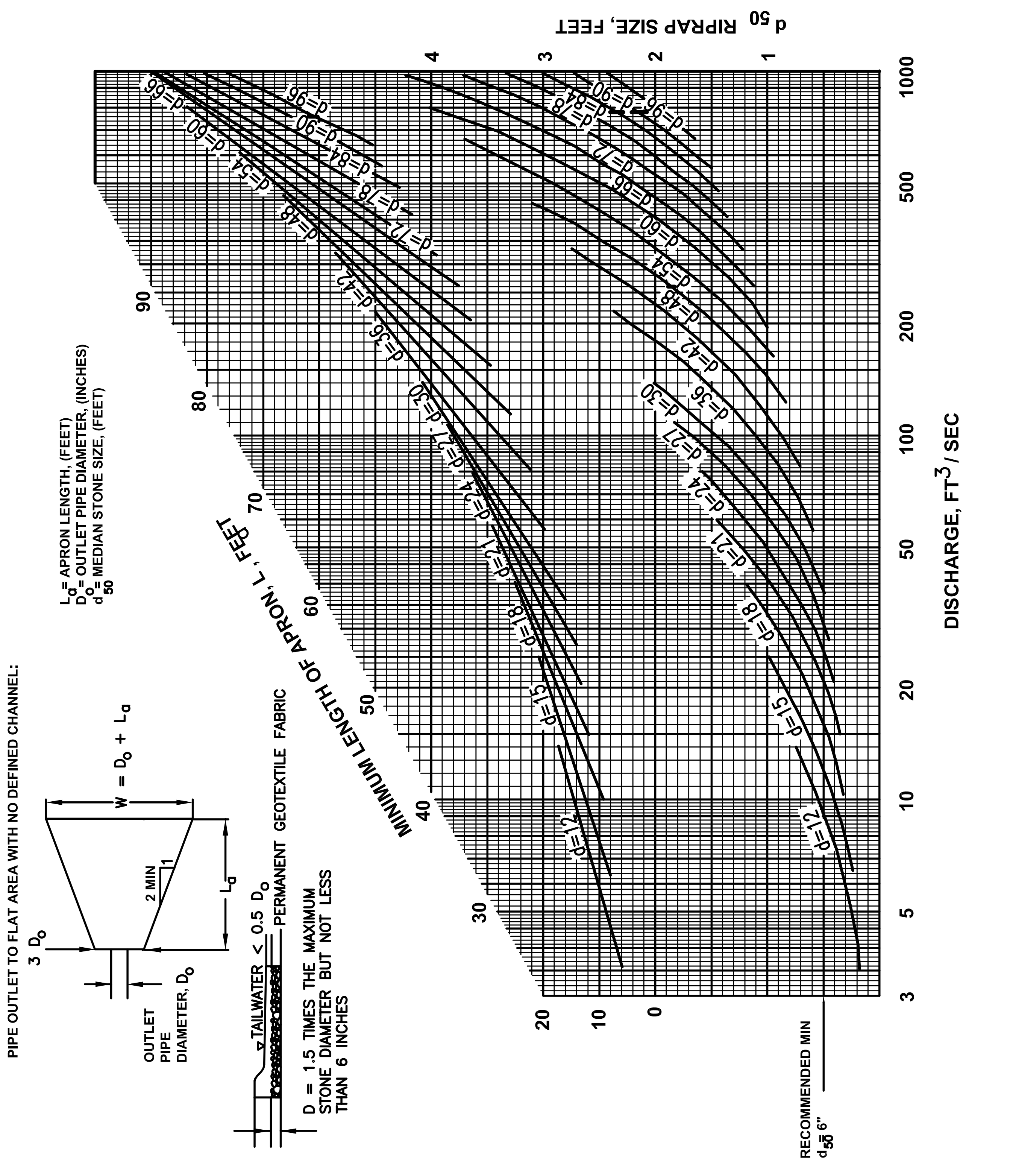
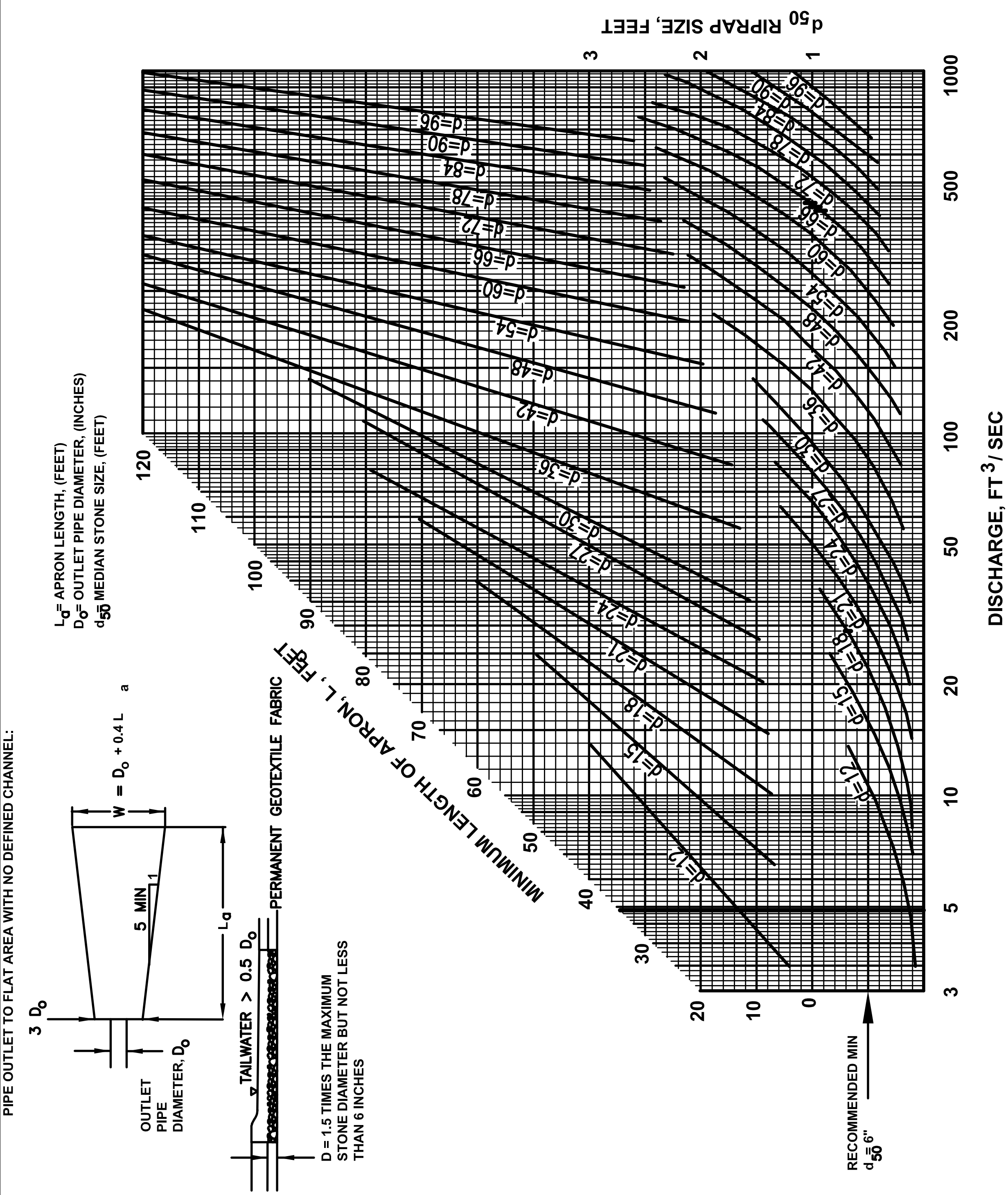
EXHIBIT 12-6
MINIMUM TAIL WATER CONDITION

EFFECTIVE DATE: JUNE 30, 2009



DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T < 0.5 DIAMETER)



DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL MAXIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)

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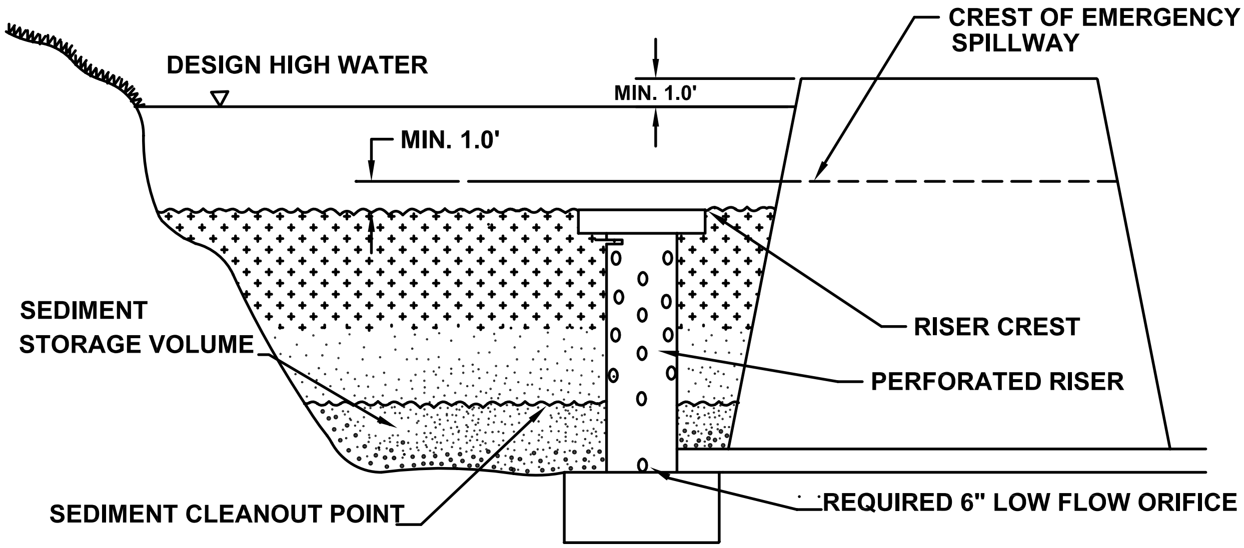
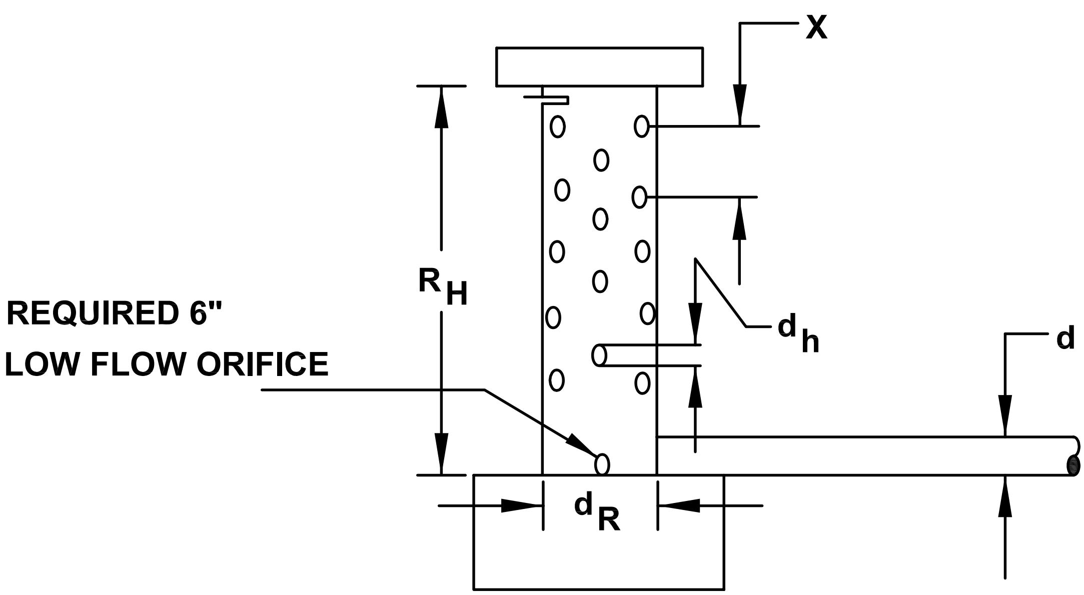
EXHIBIT 12-8A PAGE 1
TEMPORARY SEDIMENT BASIN

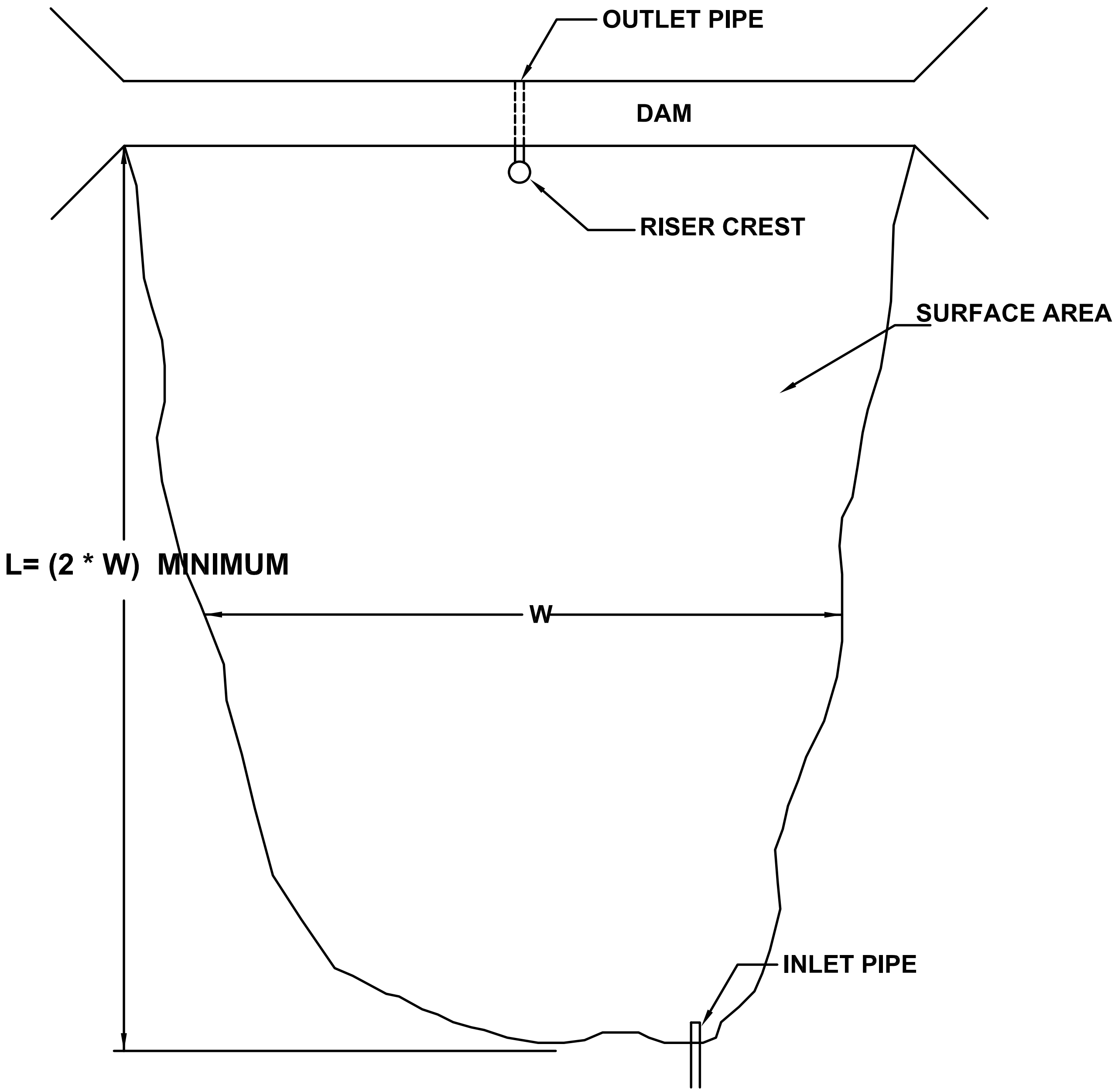
EFFECTIVE DATE: JUNE 30, 2009



DESIGN ELEVATIONS WITH REQUIRED EMERGENCY SPILLWAY



RISER PIPE DETAIL


OUTLET PIPE
DAM
RISER CREST
SURFACE AREA
L= (2 * W) MINIMUM
W
INLET PIPE

PLAN VIEW

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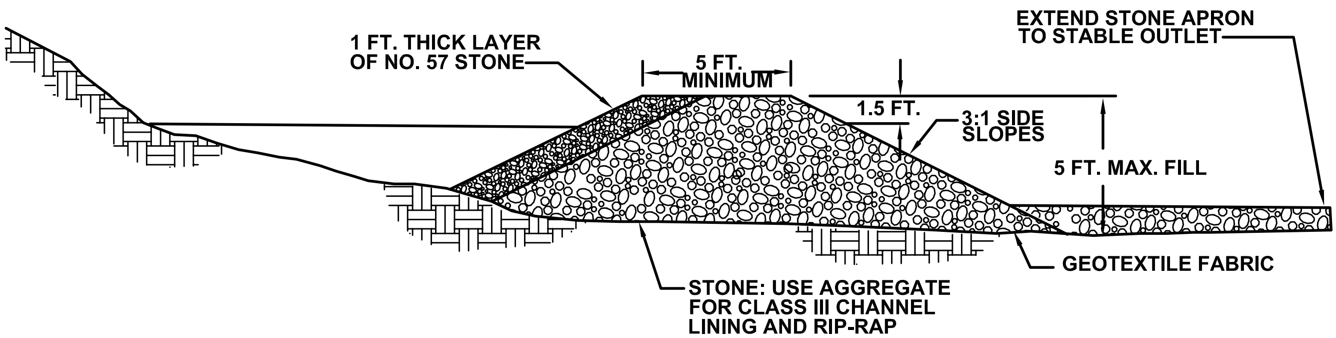
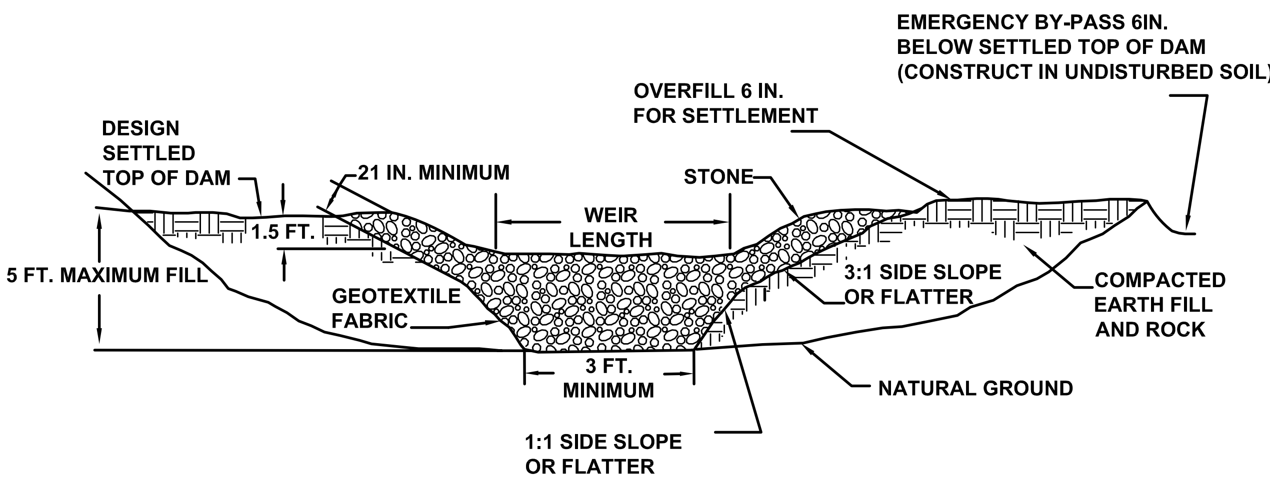
EXHIBIT 12-9A PAGE 1
TEMPORARY SEDIMENT TRAP
FOR URBAN AREAS

EFFECTIVE DATE: JUNE 30, 2009



STONE SECTION



EMBANKMENT AND SPILLWAY
ELEVATION

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Metropolitan Sewer District
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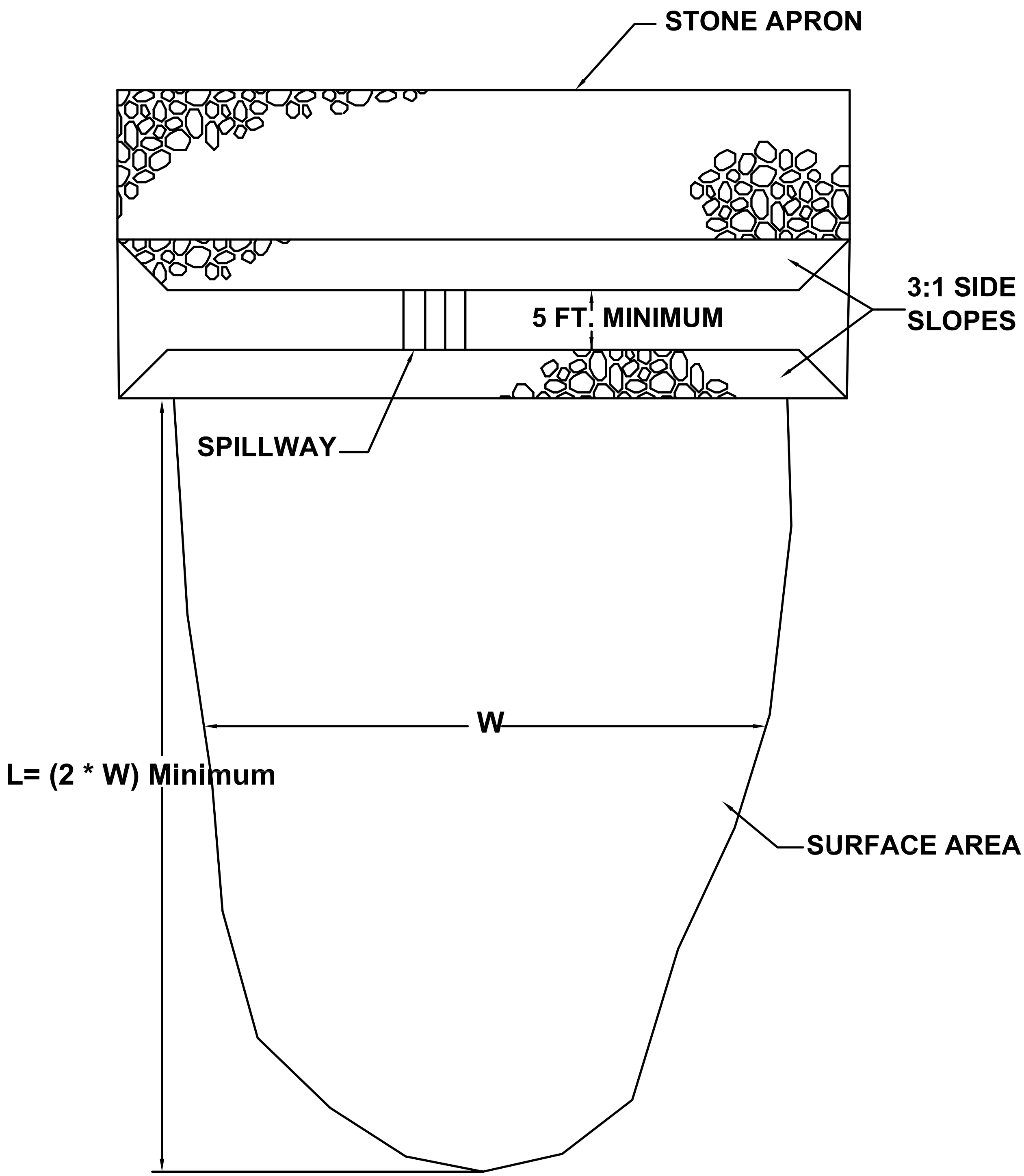
502-587-0603 – WWW.MSDLOUKY.ORG

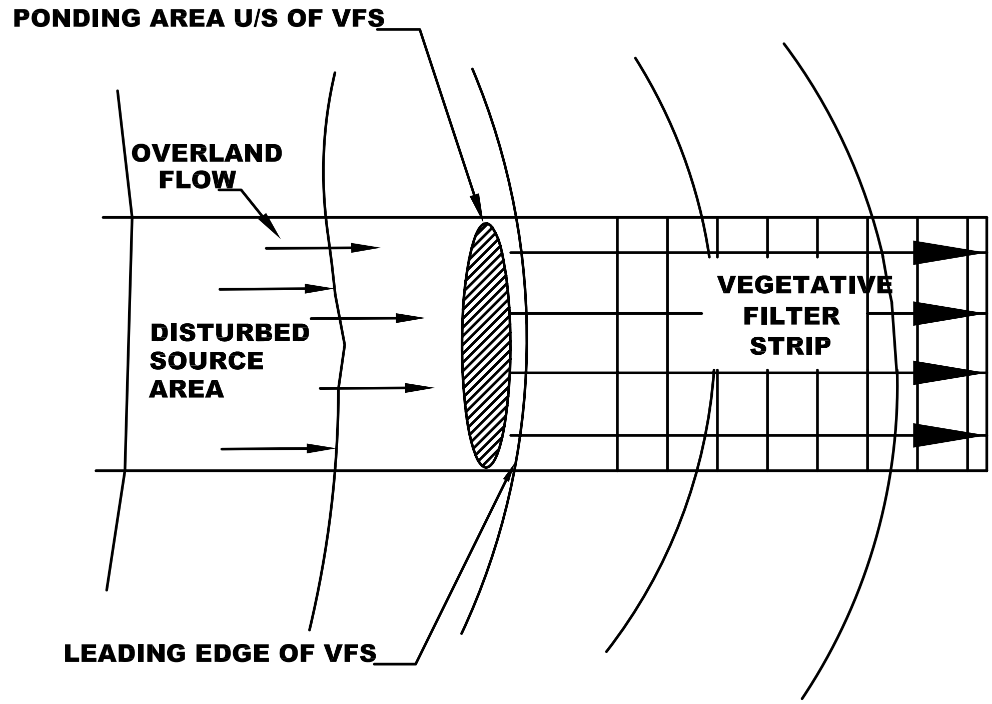
TEMPORARY SEDIMENT TRAP

EFFECTIVE DATE: JUNE 30, 2009

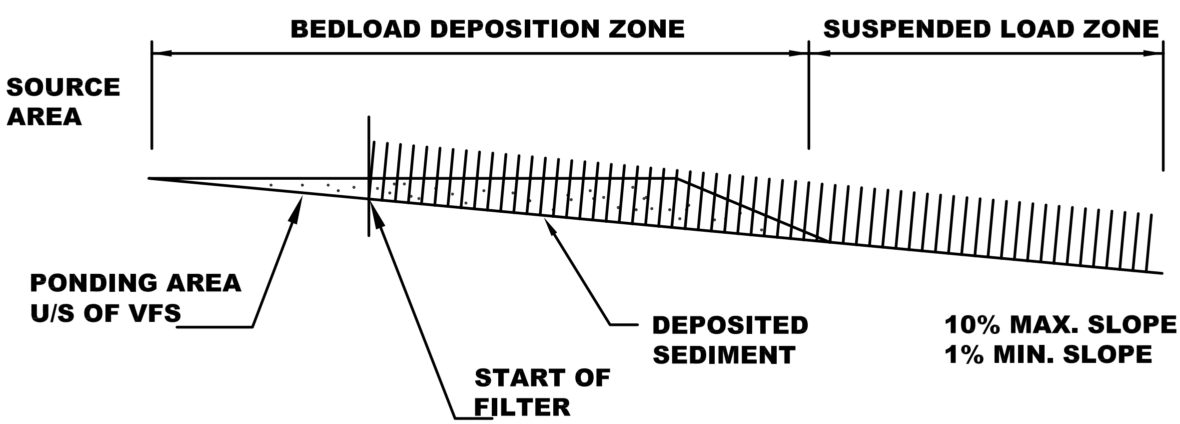


PLAN VIEW

MSD Louisville and Jefferson County Metropolitan Sewer District 700 W. Liberty Street Louisville, Kentucky 40203-1913 502-587-0603 – WWW.MSDLOUKY.ORG	EXHIBIT 12-10 VEGETATED FILTER STRIPS
	EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

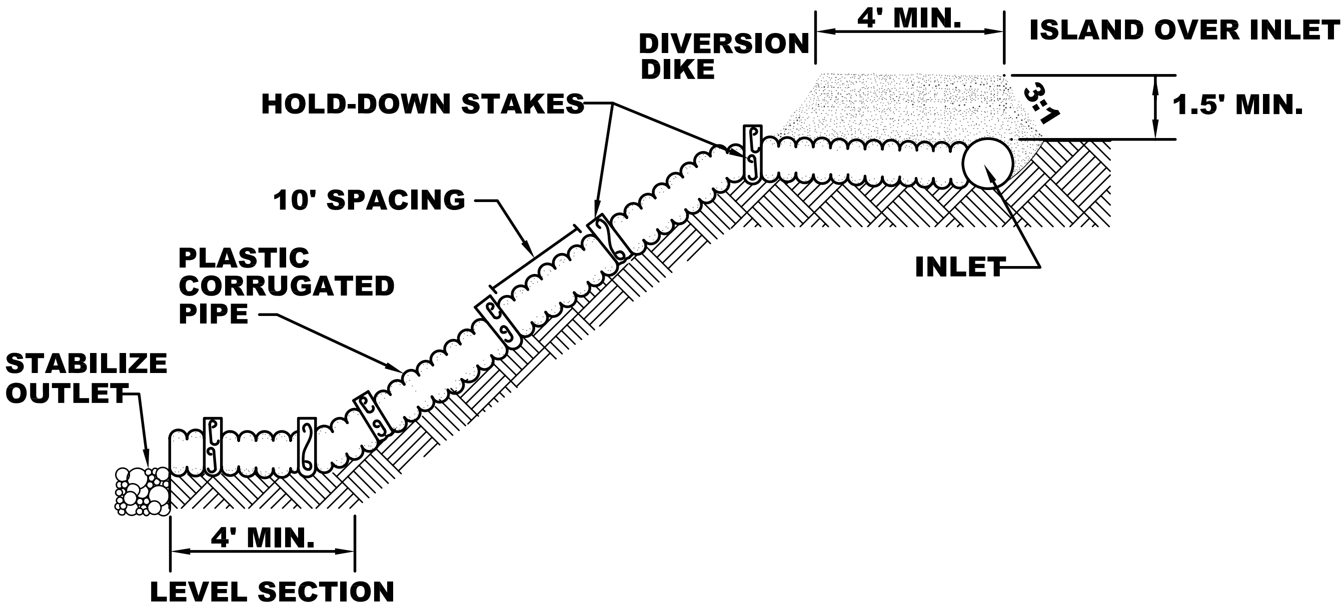


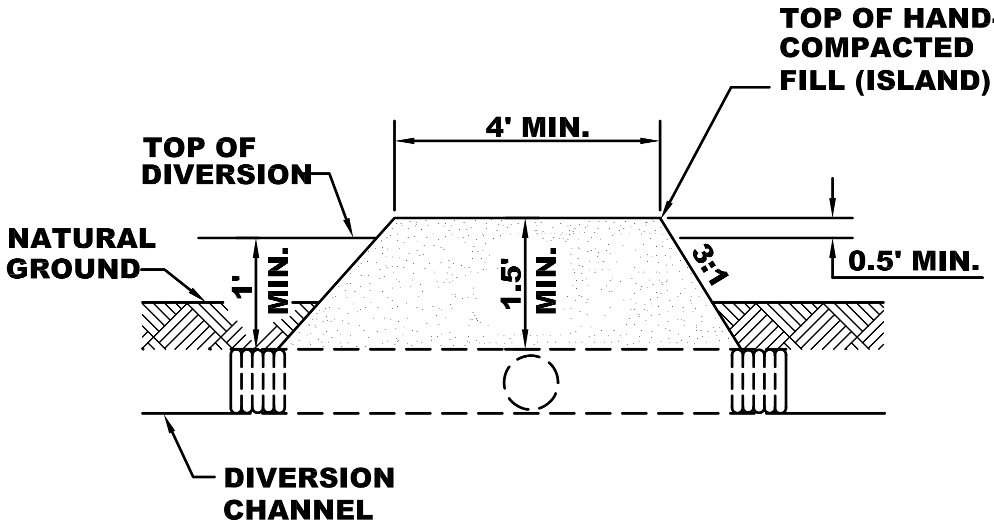
PROFILE VIEW

SCHEMATIC OF A TYPICAL VEGETATIVE FILTER STRIP

EXHIBIT 12-11
PIPE SLOPE DRAIN

EFFECTIVE DATE: JUNE 30, 2009



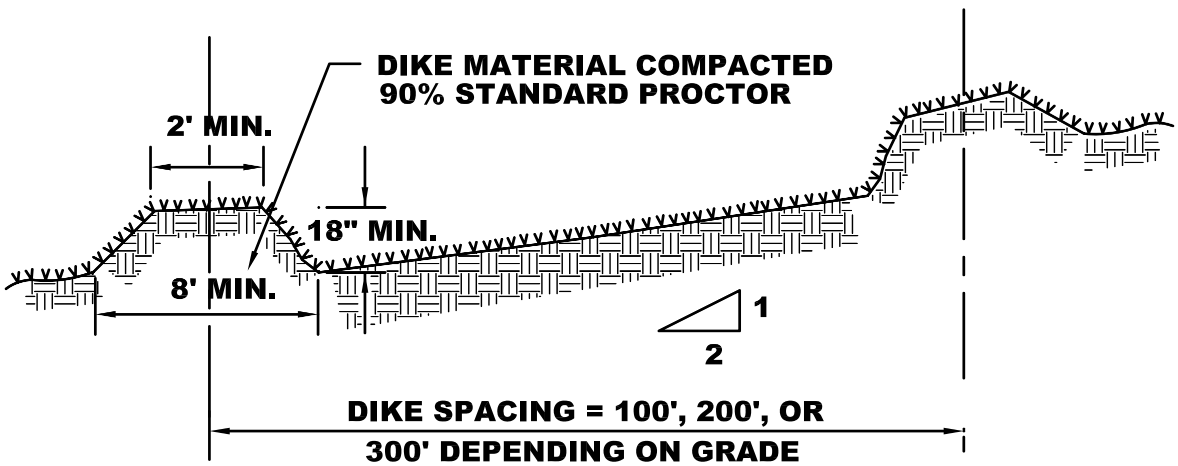


TYPICAL PIPE SLOPE DRAIN LAYOUT

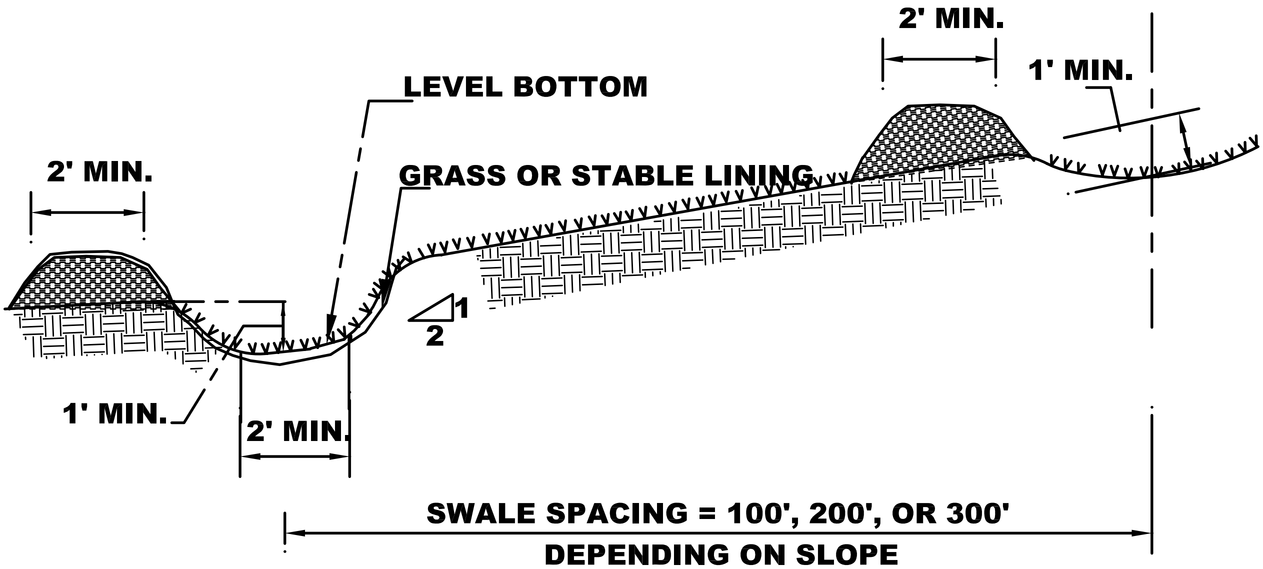
MSD Louisville and Jefferson County Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 12-12
DIKES AND SWALES

EFFECTIVE DATE: JUNE 30, 2009



DIKE

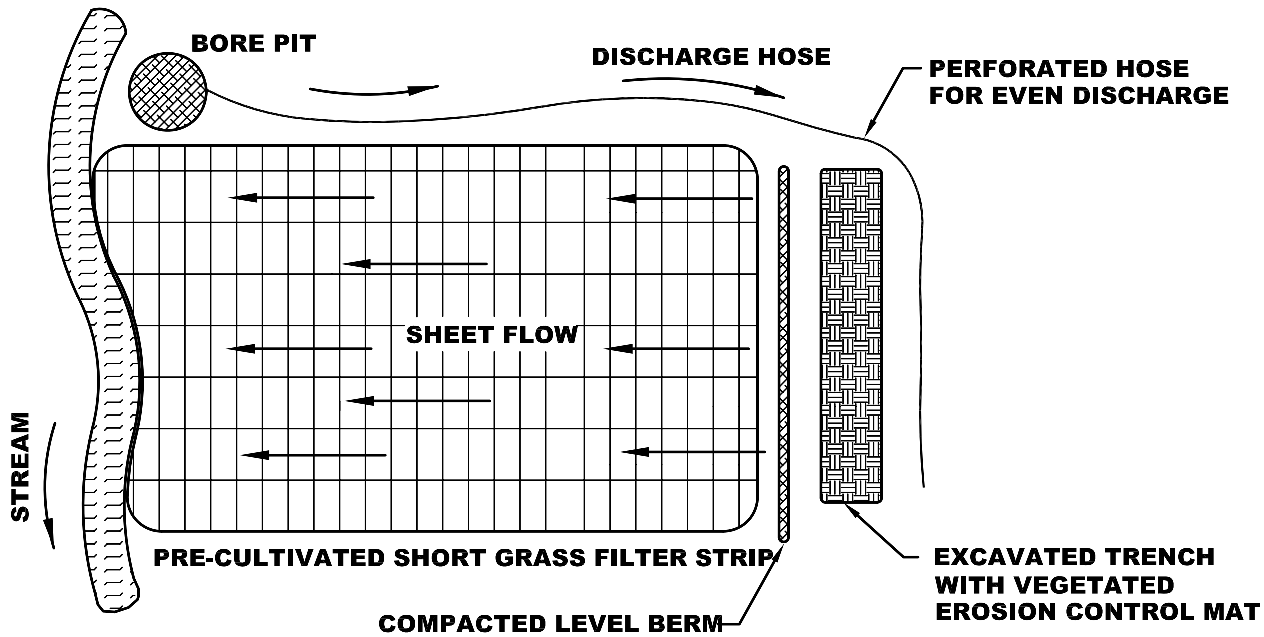


SWALE

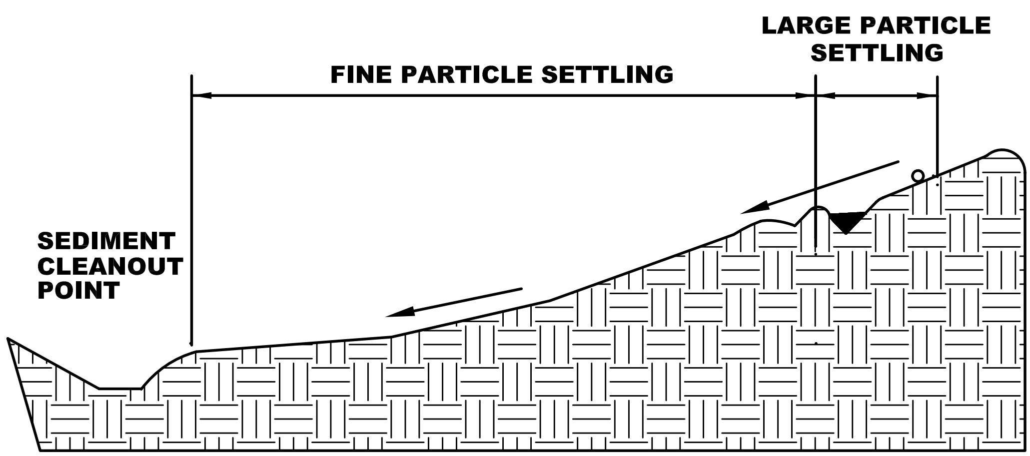
MSD Louisville and Jefferson County Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 12-13
DEWATERING OPERATIONS FOR PUMPING TO A VEGETATED BUFFER ZONE

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW



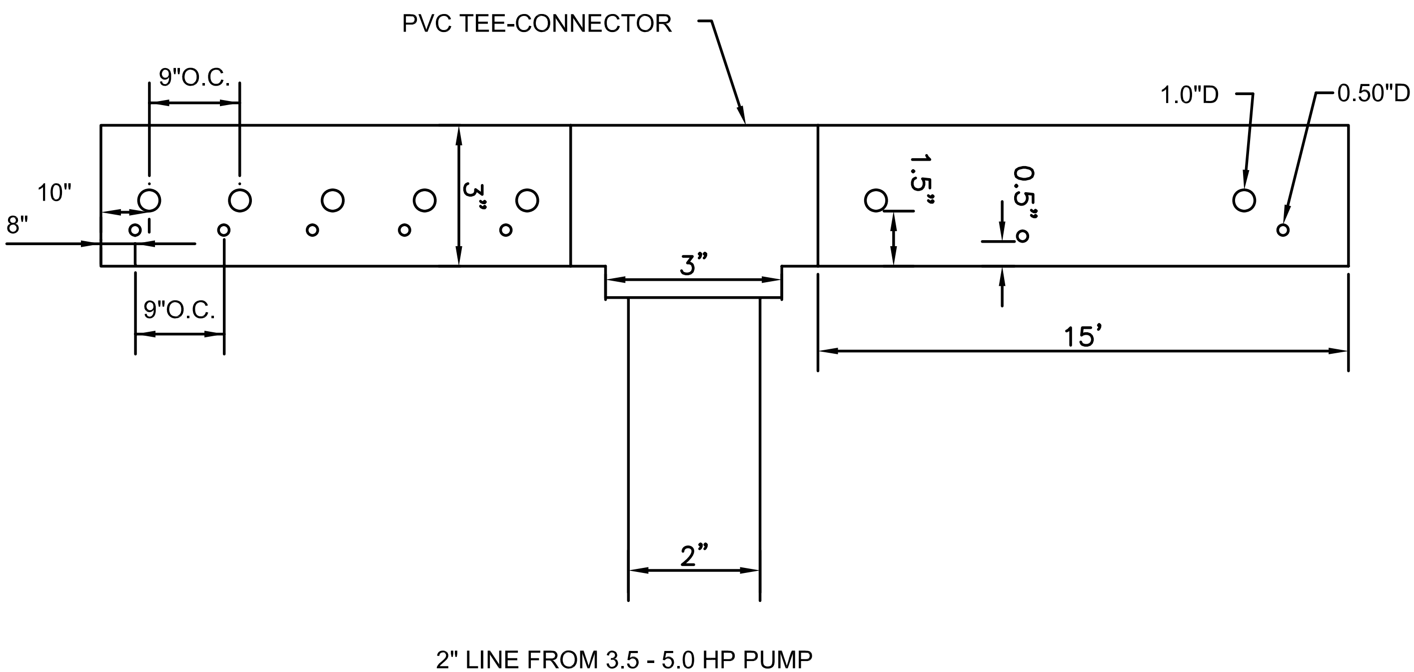
PROFILE VIEW

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 12-14
DETAIL FOR DEWATERING OUTLET STRUCTURE

EFFECTIVE DATE: JUNE 30, 2009

- TWO 15-FT. SECTIONS OF 3-INCH DIAMETER SCHEDULE 40 PVC PIPE ATTACHED TO 3" PVC TEE SECTION. EACH OPEN PIPE END SHALL BE CAPPED.
- EACH 15-FT. SECTION HAS 20, 0.50-INCH DIAMETER HOLES LOCATED 0.5 INCHES FROM THE BOTTOM OF THE PIPE LINEARLY SPACED 9 INCHES ON CENTER, WITH THE FIRST HOLE STARTING 8 INCHES FROM THE EXTREME END OF THE PIPE.
- EACH 15-FT. SECTION HAS 18, 1.00-INCH DIAMETER HOLES LOCATED 1.5 INCHES FROM THE BOTTOM OF THE PIPE LINEARLY SPACED 9 INCHES ON CENTER, WITH THE FIRST HOLE STARTING 10 INCHES FROM THE EXTREME END OF THE PIPE.



DEWATERING OUTLET STRUCTURE TO VEGETATED BUFFER ZONE

DESIGN MANUAL CHAPTER 12

SUPPLEMENTAL SECTION E

EROSION CONTROL BLANKETS
&
TURF REINFORCEMENT MATS

Erosion Control Blankets

A list of ECB products for each of the following classes and types is given in the MSD Standard Specifications.

Temporary Erosion Control Blanket (ECB) -Class I & II

For any ECB that has netting attached, the netting shall be photodegradable and/or biodegradable as specified for that Class and type of ECB. The weight of the netting shall not exceed 15% of the total blanket weight.

- **Class I:** Short-term Degradable Products – Defined as products composed primarily of biologically, photochemically or otherwise degradable constituents with longevity of approximately 1 year. Non-organic, photodegradable or biodegradable netting is allowed.

  Urban- Either netted with biodegradable material or non-netted, used in urban and residential areas where the slopes do not exceed 4H:1V. No minimum shear stress required, but the minimum mat thickness allowed is 9mm (3/8 inch). The product should be capable of withstanding moderate foot traffic without tearing or puncturing. Not to be used in channels.

  Type A- Maximum Product Permissible Shear Stress (0 - 1.0 lb/ft^2):
  A netted product for use on slopes 2.5H:1V and flatter where the calculated design shear stress is 1.0 lb/ft^2 or less. Not to be used in channels.

  Type B- Maximum Product Permissible Shear Stress (1.0 - 2.0 lb/ft^2):
  Double netted, used on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less.

- **Class II:** Long-term Degradable Products- defined as products composed primarily of biologically, photochemically or otherwise degradable constituents with a longevity of up to 5 years.

  Type A-Maximum Product Permissible Shear Stress (0 - 1.0 lb/ft^2):
  For use on slopes 3H:1V or, in channels where the calculated design shear stress is 1.0 lb/ft^2 or less flatter

Jute fabric used for erosion mats shall be a woven fabric of a uniform open weave of single jute yarn.

Type B- Maximum Product Permissible Shear Stress (0 - 2.0 lb/ft^2):

For use on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less. Non-organic, photodegradable or biodegradable netting is allowed.

Type C- Maximum Product Permissible Shear Stress (0 - 2.0 lb/ft^2):

For use in environmentally sensitive areas on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 2.0 lb/ft^2 or less. Only organic fiber woven mats are allowed with a maximum opening of 12 mm (1/2 inch).

Turf Reinforcement Mats

MSD Class III TRM physical properties are identified in the MSD Standard Specifications.

- **Class III:** Non-degradable Products- defined as products composed of non-degradable constituents with an unlimited longevity.

Type A- Maximum Product Permissible Shear Stress (0 – 6.0 lb/ft^2):

A TRM mat for use on slopes 2H:1V or flatter or, in channels where the calculated design shear stress is 6.0 lb/ft^2 or less.

Type B- Maximum Product Permissible Shear Stress (6.0 - 8.0 lb/ft^2):

A TRM mat for use on slopes 1H:1V or flatter or, in channels where the calculated design shear stress is 8.0 lb/ft^2 or less.

Type C- Maximum Product Permissible Shear Stress (8.0 - 10.0 lb/ft^2):

A TRM mat for use on slopes 1H:1V or steeper or, in channels where the calculated design shear stress is 10.0 lb/ft^2 or less.

Table of Contents
Chapter 13: Native Revegetation

13.1 Native Plants

Native plants for use in rain garden (Photo: Louisville & Jefferson County MSD)

13.1 Purpose

This chapter establishes guidelines to be used when preparing planting plans and implementing permanent revegetation of disturbed natural areas. Revegetation is needed after the loss of natural habitat from construction of any development, improvement, or retrofit project. Loss of habitat could take the form of deforestation, forest fragmentation, wetland disturbance, or native grassland converted to agriculture or developed land. By definition, natural areas are plant communities and habitats indigenous to the region, and include many types as upland forests, forested wetlands, stream bank buffers, dry upland or moist bottomland meadows, and emergent wetlands. Planning for native plant restoration is essential for successful revegetation and should occur before construction, during the design and planning phase.

This chapter provides guidance for revegetating and restoring natural areas. In some cases, it may be appropriate to consult a professional restoration ecologist or biologist. This may be especially true when the habitat to be disturbed is of high ecological value or is threatened within Kentucky, such as wetlands, glades, or barrens. In such cases, you may need to hire professional help to evaluate your site and design a planting plan.

13.2 General

The guidelines presented here are intended to provide:

a. an understanding of the approach to native revegetation and contributing factors;
b. an understanding of MSD's goals and objectives for native revegetation; and
c. familiarization with native revegetation planting plan procedures and elements.

13.3 Principles of Native Revegetation Planning

There are several foundational principals to follow when planning native revegetation and restoration of a project site. Following these guidelines will encourage biodiversity and help to create a balanced ecosystem in the disturbed area.

a. Relate plans proposed for the native revegetation of natural areas to existing site conditions and surrounding or adjacent natural habitats.
b. Provide restoration or buffering of environmental features such as stream corridors, wetlands, steep slopes, erodible soils, and critical habitats.
c. Always emphasize the use of native plants in planting plans. Native plants are indigenous to the State of Kentucky and distributed within the regional area of Louisville and Jefferson County. Plan for the integration of proposed native revegetation areas to other areas of existing habitat, and the revegetation of areas causing forest fragmentation.
d. Native Revegetation should be self-sufficient, low-maintenance plantings that require minimal watering, weeding, pest and disease control, fertilization, and pruning.
e. Specify diversity in native plant species selection representative of natural communities of Kentucky to establish various planting zones in planting plans.
f. Specify the required materials including plant form and size, soil amendments, seeding, protective devices, and erosion control materials.
g. Establish required planting densities and spacing. Develop any necessary Special Provisions including specific requirements for monitoring, inspection, and warranty.

Use the site characteristics checklist in Table 13.1-B to narrow the group of potential plants before any plant selection is made. Use this information in conjunction with Appendix 1 in creating a planting plan.

Although this chapter focuses primarily on revegetation areas, many of these same principles can be utilized in green infrastructure. The benefits of using Kentucky natives and cultivars equally apply in the planning of green roofs, bioswales, rain gardens, dry and wet basins, and constructed wetlands, which are further discussed in Chapter 18.

Sedum being used in a green roof application
(Photo: Courtesy of The Green Building)

13.4 Planning Approach

13.4.1 Define Planning Area—Site Constraints and Revegetation Area Extent

To begin, determine the planning area. The primary factors that determine the extent of the native revegetation area are the size of the disturbed area and limitations due to the site's physical features. Consider adding areas within the site's easement or right-of-way to help connect and expand the planting zones. Examine the possibility of creating connections between the area to be planted and existing areas of natural vegetation. Small, isolated areas of natural vegetation are difficult to protect and manage. Creating connections between existing small fragments can result in larger, more stable natural areas.

Other goals and objectives for the project site may factor into determining the type(s) and extent of the revegetation areas. These may include creating vegetative buffer zones around existing streams, managing shading, controlling erosion, preserving wildlife habitat, developing screening, and establishing greenway corridors. Some suggested minimum vegetative buffer or corridor widths for certain goals are included in Table 13.1-A.

Table 13.1-A. Minimum Buffer/Corridor Widths

Resource Protection Goal	Minimum Width
Water quality protection and Stream bank stabilization	35 feet*
General riparian corridor or greenway	50 feet*
Corridor connections for general wildlife habitat and/or sensitive forest interior dwelling wildlife habitat	300 feet **

* On each side of a centerline or stream bank edge
** Total for both sides of a stream channel or the entire width for a terrestrial corridor

As a general rule the revegetation area should be maximized to the extent possible, given site and situation constraints, and should naturally take into account cost considerations. Distinct planting zones may be as small as several hundred square feet for intentional micro-habitats such as wetland depressions, and may be as large as several acres or more for reforestation areas and large corridors. In general the

13.1-B. Revegetation Site Physical Characteristics

	Site Characteristics	Explanation/Description/Comments	Picture Taken/Reference Number
1.	Aspect		
2.	Slope		
3.	Flood Potential		
4.	Soil Type		
5.	- Soil Depth		
6.	- Internal Drainage		
7.	- pH		
8.	Existing Vegetation by class (mowed grass, un-mowed weeds, grass, shrubs, small trees, young forest, closed canopy forest, etc)		
9.	Area Size		
10.	Aesthetic or Visual constraints (line of site or road intersections, etc)		
11.	Are there overhead power lines at the site?		
12.	Are there known underground pipelines or sewers?		
13.	Are there existing invasive plant species?		

size and layout of planting zones should be clear and straightforward. Plans should be easy to understand and practical for a contractor to implement.

13.4.2 Identify Habitat Type

Once the revegetation area has been defined, identify the vegetation community type that was originally found at the site. There are a myriad of native habitat types that exist in Kentucky. Determining this native habitat may be difficult, depending on how disturbed the site has already been. Planting plan designers should look at characteristics such as soil type, aspect, topography, and existing native plant species. If the site has already been significantly disturbed, such as in a developed residential area, determining the native habitat type for that area may be impossible for a non-professional. In such cases, the designer should consult with county agricultural extension agents or the MSD restoration ecologist.

13.5 Planning Design and Planting Plan

13.5.1 Identifying Planting Zones

Now the designer is ready to look at site specifics that will help determine planting zones within the revegetation area. Planting zones account for the differences within the site that create better environments for certain types of plants. The specific land form and features of the project site will govern the planting zones and help to identify any microhabitats within the revegetation area. Depending on the size of the project site, there may be numerous planting zones defined by differences in aspect, proposed degree of shading or openness, slope, soil fertility and type, pH, drainage and moisture, hydrologic regime (flooding, inundation), existing vegetation cover, and propagule source (seed bank, root and rhizome distribution, and recolonization sources). Working with the natural planting zones of the site helps to make for a healthier, more self-sustaining ecosystem.

13.5.2 Site Constraints

Proper design of native revegetation areas must take into account site-specific constraints. The location of existing and proposed features within the project area, such as buildings, roads, bridges, culverts, head walls, outfalls, fences, sewer lines, buried and above-ground utilities, etc., must also be considered. Vegetation patterns, including trees to be retained, existing wetlands, forested areas, and other natural community types adjacent to or within the project site, must be evaluated.

13.5.3 Plan for a Changing Site

When identifying planting zones, the designer should factor in changes to the tree canopy that may affect the types of plants and seeds selected for the site. Restoration of a forest community may need to be done in steps if the tree canopy is absent. Woodland shrubs and herbaceous plants cannot be planted into an area that currently receives full sun.

Capitalize on opportunities presented by existing conditions and design within the limitations of a given site. Keep in mind the growth rates, spread, and typical mature size of the plants being chosen for the site. Plan spacing and placement so that the plants will not directly compete for resources in the coming years.

13.5.4 Use of Native Plants

MSD advocates the use of native plants for all revegetation of natural areas. Native plants are important because they have specially adapted to the specifics of the region and require much less maintenance. They are built to thrive with the soil, weather, and seasons that the area provides.

Native organisms including plants, insects, birds, mammals, and amphibians have a complex interdependence that composes a balanced ecosystem. Establishing a healthy native plant community encourages a robust population of pollinators and the animals that feed on them. The revegetated area is then better equipped for filtering air and water pollution that can result from human development.

Preserving local biodiversity can also be highly asthetically rewarding. Native plant species are one of the most visible elements of the local ecosystem, and express the uniqueness of the region, enhancing the sense of place. They often offer bright colors and pleasing scents through different seasons. Many plant species that can be used in revegetation projects attract showy pollinators, like butterflies, that add a vibrant element to what could otherwise be a mundane area.

Plant species chosen should be those that occur within the habitat type(s) identified for the site. Use of a nearby "remnant", or undisturbed habitat of the same type as the project site, may be helpful as a reference to create a plant species list.

Native plants used for restoration plantings should be native to Jefferson County, KY. The origin of the plant material should be as close to Jefferson County as possible, preferably within 200 miles. Using local sources of plant material will help to ensure the protection of genetic biodiversity and the success of the plantings.

Some non-native plants have been found to be invasive in natural areas should not be used in any revegetation project. Appendix 2 provides a list of non-native species that have been found to be invasive. Many are available for sale at local nurseries or on the internet and are to be avoided. Others establish in disturbed areas such as your project site and may out-compete native plants. Appendix 2 includes plants to avoid in your planting plan and will serve as an identification tool and how-to for detecting and removing non-native site invaders.

13.5.5 Plant Species Selection

It is not the intent of this manual to identify exact plant composition lists for all potential habitats, but rather to provide a general framework and list of plant species suitable for a variety of conditions. Included in this document is a list of potential plants for Kentucky restoration sites and green infrastructure, organized by site condition and plant type (Appendix I). This list includes species that can be planted as seeds or live plants for native revegetation.

The Appendix I provides images of the plants as well as additional information on the natural history, management, and growing tips for each species. This chapter, should be used with the Appendix I Plant Guide to design a site's planting plan.

Plant composition should include a broad diversity of native species as is appropriate to the site and should take into consideration a number of factors. Species selection should take into account the flood or saturation tolerance, the shade tolerance of the species, and the adaptability to projected site conditions. Local wildlife species require specific plants for food and shelter; these needs should be considered in the selection of plant material. For a forested area to become established, it is recommended that a minimum of four to five species of trees and three to four species of shrubs be selected. If a shrub community is desired, at least four species of shrubs should be selected.

The designer should review and incorporate items in the Native Revegetation Design Checklist, Exhibit 13-1, when creating plans for natural area revegetation. They include native seeding and native tree, shrub and herbaceous planting.

13.5.6 Writing the Planting Plan

The planting plan should consist of a design drawing, an accompanying report, and a construction time table. The plan should be multi-lingual where possible and should use symbols when necessary. The design drawing will identify the site area and size, planting zones, any natural and physical site constraints, locations for construction equipment including storage and unloading zones, and sensitive areas that should be protected from construction impact.

The written report will clarify the type of construction equipment expected including any special equipment, such as a native seed drill, and specifics of how sensitive areas will be protected. During construction, any environmental features such as stream corridors, wetlands, steep slopes, erodible soils, and critical habitats must be buffered or protected.

When protecting existing trees and natural areas, the root zones should be avoided to protect them from damage and impaction by heavy equipment. The Critical Root Zone is generally considered to be a 12" radius for every tree inch diameter. For example, a tree with a 10" diameter at 4.5' above the ground (diameter breast height, or DBH) should have at least a 10' root protection area around it. **Keep heavy equipment away from areas underneath and around trees—do not park vehicles or store equipment underneath trees!**

The plan should include instructions on how to treat soil and other site amenities and identify any potential erosion areas and control devices.

Accompanying the plan will be the planting list for each planting zone. All planting lists should include the plants' common and scientific names, size, form, spacing, quantity, and any special characteristics of the plants to be established. Both the common and scientific name of each plant should be used when placing a plant order to avoid any confusion. Any substitution by a nursery from the design specification plant list should be approved by the designer before anything is shipped.

<u>a. Seeding vs. Live Plants</u>

Planting native revegetation areas with seed, rather than live plants, provides an effective and cost-efficient method of revegetation. Seeds can easily be spread in large areas or focused sites, sprouting naturally and becoming established in a very organic presentation, mimicking the original site.

Table 13.1-C. Typical Plant Spacing and Density Summary*

Spacing (feet)	Plants Per Acre	Spacing (feet)	Plants Per Acre
1x1	43,560	10x10	435
2x2	10,890	12x12	302
4x4	2,722	15x15	194
5x5	1,742	18x18	134
7x7	889	20x20	109

Native and Cultivar plants used in a residential rain garden. (Photo: David Dods, URS)

However, some plant species may establish better by the use of live plants rather than seed and should be planted accordingly. Similarly, some site conditions, such a stream edges or wetlands, may lend themselves to the use of live plants rather than seed due to the persistent of the flow of water in the area.

b. Planting Type, Size, and Form

The planting plan should specify the size of the plants to be used. The size of plants selected is important to the success of the revegetation plan and to the overall cost of construction. There are many sizes and forms available for plants. Below is a summary of some of the commonly available plant units from native plant nurseries and seed suppliers.

Trees typically come in the following forms: container grown, balled and burlapped, and bare root stock/whips. The size of trees varies from less than a foot tall for bare root stock (seedlings) to 10-12 feet tall or more for balled and burlapped plants and larger bare root tree saplings. Project revegetation goals and cost may dictate size of trees used in the replanting, however a general rule of thumb is that smaller plants have a higher success rate at long-term establishment than larger plants and cost less to acquire. If you have the option to use them, bare root stock will establish better in the soil, require less water to help them establish, and within three to five years will often have caught up in growth with larger caliber trees planted at the same site. In order to ensure the success of bare root stock establishing, it is essential that the roots remain moist and covered at all times until seconds before being put into the ground.

Shrubs can be obtained as small as one foot or less up to four to five feet (4'-5') tall for larger container-grown plants. Shrubs may also be obtained as bare root plants or live cuttings.

Herbaceous plants (grasses, forbs/wildflowers) can be purchased as bare root stock, peat pots/plugs, or container-grown in pint, quart, and gallon(s) container size. Other typical units include multiple plant flats, two-inch (2") plugs, and four- to six-inch (4"-6") peat pots. The height of these plants is usually highly variable; however, certain plants, such as grasses, may be specified as single or multi-stem units.

If you determine that seeding is preferable for your site conditions, native seed should be specified in the form of Pure Live Seed (P.L.S) as per MSD Standard Specifications. Seeding is specified on planting plans by percent frequency of overall seeding rate, resulting in a corresponding application rate of pounds per acre (or square footage) for that particular species.

c. Spacing and Quantity

If you choose to use live plants, it is important to specify the spacing. Individual species spacing should be specified as the minimum planting distance between any two individuals of the same species. In proposed natural revegetation areas, a random planting pattern is generally recommended; however, regular, row, or cluster planting may be used if required by site conditions or project objectives. Row or cluster planting is most often used when planting an emergent wetland area or where a grove or grouping of a single species is desired (e.g., an evergreen tree copse). Examples of plant spacing details are provided in Exhibits 13-2, 13-3, and 13-4.

The actual spacing distances are highly variable and are subject to site conditions, growth rates and mature size, overall goals, and professional judgment. There are times, such as when planting an early successional woodland community, when a high density of tree saplings and a low density of shrubs are desired. A corresponding planting density may then be on the order of 435 trees per acre, corresponding to an overall on-center spacing of approximately 10 feet. For the lower density of shrubs, a corresponding density may be 222 shrubs per acre corresponding to an overall on-center spacing of approximately 14 feet. Another approach may be to emulate a later stage of succession by planting larger trees in a less dense fashion. This may correspond to trees of a 25-30 foot on-center spacing or greater. The spacing selected should take into account the size of the plants specified.

Herbaceous plant densities can result in spacing as close as 1 foot on-center in order to achieve more rapid and dense coverage, or conversely, they may be planted further apart where supplementation, or initially sparse coverage, is the objective. A summary of several typical on-center plant spacing distances and their respective planting densities is provided in Table 13.1-C.

d. Soil Conditions and Treatment

According to MSD standards, the project designer shall specify the soil salvaging, furnishing, and amendment parameters needed before, during, and after construction to ensure a more successful restoration. The planting plan should determine the existing depth of topsoil on site, the soil's suitability for salvaging and re-use, and the total depth for topsoil placement (salvaged and/or furnished). The designer shall evaluate the existing soil by having analytical tests performed to determine if the existing topsoil meets MSD Standard Specifications in Section 2.2.1. If the topsoil is deemed to be deficient, the designer must identify in the project's Special Provisions the specific amendments required (e.g., fertilizer, organic matter, lime, etc.) or the volume and depth of suitable furnished topsoil to be provided by the contractor. Soil that has been compacted during construction activity must be loosened before planting!

The designer shall also specify areas where the existing soil is, or may be, infested with noxious weeds, other invasive plants, or any parts (seeds, rhizomes, roots, etc.) of these plants. Specification of the treatment for the infested area(s) should also be identified. This shall include infested soil removal and disposal requirements or specific treatments required for noxious weed and/or invasive species control, such as use of a pre-emergent herbicide. The control or removal of exotic invasive plants on a site should precede any clearing, grading, or other type of soil disturbance to prevent the spread of the invasives. Clearing without prior control may leave living roots that will re-sprout after the area is planted and make subsequent control much more difficult. The specific measures shall be specified in Special Provisions created for the project.

All land-disturbing activities in Jefferson County are subject to the Erosion Prevention and Sediment Control Ordinance of 2000 (EPSC). To ensure EPSC compliance, the planting plan designer should consult with the MSD website and information therein regarding requirements and specifications of the EPSC . The link may be found at http://www.msdlouky.org/insidemsd/epsc.htm.

e. Specifying Protective Devices

There are certain situations where protective devices are required for plant survival and vigor. These include the use of staking and guying or tree shelters. Staking and guying is recommended for all trees greater than 1-inch caliper and is particularly crucial for open areas where trees may be subject to high winds and windfall. Staking or guying trees requires follow-up to remove these devices, often several years later. If these devices are left on trees for too long they will inhibit or impede the tree's growth.

Tree shelters are plastic shelters or tubes used to foster young trees in their early stages of development. They protect saplings from browsing by local herbivores, and can accelerate growth rates by reducing water and weed stresses. The shelter creates a sort of greenhouse effect that channels growth into the main stem and roots.

Tree shelters are recommended in situations where seedlings or very small saplings are specified. They are also recommended where there is evidence of a strong deer population or where poor soils may contribute to desiccation and plant withering. When specified, either of these protective devices should be incorporated into the planting plans in the form of notes or symbols around individual trees.

Many wetland plants, particularly emergent grasses, must be protected from predation by waterfowl. This may include the use of traditionally named "Goose" or waterfowl exclusion fencing. The materials and execution of protective device placement shall be in accordance with MSD Standard Specifications in Section 13. Planting details for these devices are included in MSD Standard Drawings.

f. Timetable

A timetable is an important component of ecological restoration. Site preparation, such as disking or spraying of pre-emergent herbicides, should be coordinated with planting times to maximize long-term success of the restoration. Certain herbaceous plants and seeds should be planted during specific times of the year to maximize establishment. Preparation of some native seeds, in the form of cold stratification or scarification, is necessary before planting and should be part of timetable planning. As contract awarding may not coincide with the ideal timing of site preparation, a timetable needs to be finalized early and followed to the letter. Disregarding the timetable often results in a failed project.

g. Creating Special Provisions

If the designer wants to use planting techniques or processes not specified in this manual, a Special Provision is necessary. This is a text document that describes the purpose and required items for implementation of the provision. Development of these Special Provisions should follow the standard outline for MSD Standard Specifications including sections for Description of Work, Materials, and Execution. The execution of these items should also include a description of the appropriate Warranty and Maintenance.

h. Identifying Maintenance and Monitoring Protocols

Maintenance can be specified in Special Provisions and/or in a maintenance schedule containing a description of activities required, the methods required, the frequency, and the time of year. (See example in Exhibit 13-7). Long-term management of exotic species should be specified as well. Maintenance protocols may be identified according to specific plant warranty standard specifications, MSD specifications, and/or the landowner stipulations. Similarly, a derivation of the maintenance schedule may be used to identify a monitoring protocol schedule in order to address the execution of specific regulatory and permit condition requirements.

When feasible, management of exotic species should be specified in Special Provisions. Examples of exotic species to be managed include: burning bush, English ivy, periwinkle, Japanese honeysuckle, and garlic mustard. A detailed list of invasive species is provided in Appendix II Invasive Species.

Maintenance concerns: 1) staking or surveying trees requires follow-up to remove these devices, often several years later; and 2) maintenance or planting plans may need to be bilingual or use symbols when necessary.

Exhibit 13-1 Native Revegetation Plan Design Checklist

The Designer should review the project site including determining/accomplishing the following:

_____ Aspect, orientation, slope/topography
_____ Drainage, soil wetness/dryness
_____ Existing shading/tree cover
_____ Likely post-construction shading
_____ Existing native vegetation composition
_____ Evidence of noxious weed infested topsoil
_____ Site constraints and infrastructure features
_____ Depth of existing topsoil
_____ Take soil samples for analytical testing
_____ Invasive plant species for removal

Determine Native Revegetation Planting Plan needs and approach including the following:

_____ MSD project requirements
_____ Permit conditions/mitigation requirements
_____ Determine project area (sq. footage/acreage)
_____ Minimum planting widths for project goals

Determine plant establishment techniques to be used:

_____ Tree and shrub planting
_____ Herbaceous planting
_____Native seeding

Designate and develop planting zones including:

_____ Zone name and number
_____ Making necessary grading changes
_____ Definition of habitat type(s)
_____ Draw plan view of zones

Create Planting Tables and Composition Tables including:

_____ Plant species by zone and strata
_____ Specify quantity per acre
_____ Seeding rate (per acre) and by species
_____ Plant spacing (overall and by species)
_____ Calculate area and required plant quantities
_____Identify plants sizes and plant stock form

Identify and incorporate Planting Details from:

_____ MSD Standard Drawings (Native Revegetation section)

Review MSD Standard Specifications for applicability and project specific modification including:

Section 12 Native Seeding

Materials

_____ Seed (Section 12.2.1)
_____ Topsoil (Section 12.2.2)
_____ Organic Fertilizers (Section 12.2.3)
_____ Mulch (Section 12.2.4)
_____ Tackifier (Section 12.2.5)
_____ Anchors for Erosion (Section 12.2.6)
_____ Erosion Control Blankets (Section 12.2.7)
_____ Water (Section 12.2.8)

Execution

_____ Schedule (Section 12.3.1)
_____ Transporting Material (Section 12.3.2)
_____ Clearing and Grubbing (Section 12.3.3)
_____ Topsoil Salvaging, Storing (Section 12.3.5)
_____ Seeding (Section 12.3.6)
_____ Fertilization (Section 12.3.7)
_____ Mulch Stabilization (Section 12.3.8)
_____ Watering (Section 12.3.9)
_____ Clean-Up (Section 12.3.10)
_____ Maintenance (Section 12.3.11)
_____ Warranty (Section 12.3.12)

Section 13 Native tree, shrub, and herbaceous planting

Materials

_____ Native Plant Material (Section 13.2.1)
_____ Mulch (Section 13.2.2)
_____ Stakes and Wire (Section 13.2.3)
_____ Tree Shelters (Section 13.2.4)
_____ Waterfowl Exclusion Fencing (Section 13.2.5)
_____ Soil Amendments (Section 13.2.6)
_____ Root gel (Section 13.2.7)
_____ Water (Section 13.2.8)

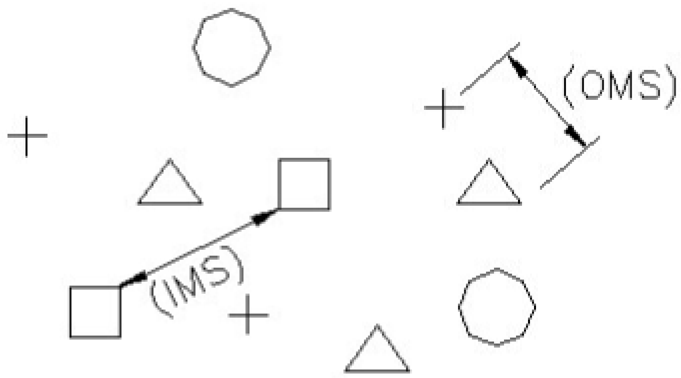
Execution

_____ General (Section 13.3.1)
_____ Planting (Section 13.3.2)
_____ Maintenance (Section 13.3.3)
_____ Warranty (Section 13.3.4)

Evaluate any additional needs and items for preparation including:

_____ Special Provisions (when necessary)
_____ Maintenance (Exhibit 17-7)
_____ Monitoring Schedule (e.g. permit conditions)
_____ Support documents (e.g. monitoring plan)

Exhibit 13-2 Plant Spacing - Random



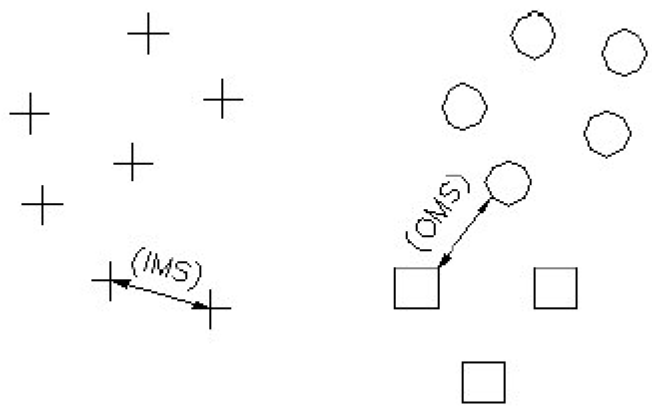
OMS-An overall minimum spacing distance (OMS) is assigned to the planting configuration (see plant schedule)

IMS-An individual minimum spacing distance (IMS) is assigned to each individual species (see plant schedule)

PLANT SPACING - RANDOM

PLAN VIEW **Not to Scale**

Exhibit 13-3 Plant Spacing - Cluster

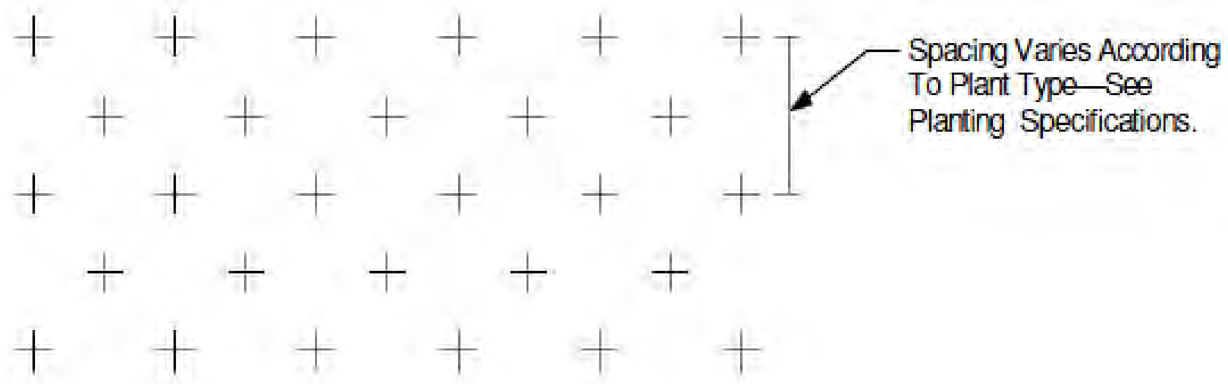


1. Plants are arranged in clusters consisting of the same species.
2. Spacing between each cluster is determined by the overall minimum spacing distance (OMS).
3. Spacing between each species within each cluster is determined by the individual minimum spacing distance (IMS).
4. Clusters, whenever possible, shall consist of odd numbers with no less than 3 and no more than 11 individuals of one species.

PLANT SPACING - CLUSTER

PLAN VIEW **Not to Scale**

Exhibit 13-4 Plant Spacing - Row



1. Space plants at even intervals-alternating rows
2. See plant schedule for specific plant spacing distances.

Exhibit 13-5 Plant Composition Table Example

COMPOSITION TABLE

Planting Area: Anywhere, Kentucky Zone: 2 Habitat: Floodplain Forest

% Comp. per Strata (per acre)	Overall Min Spacing (feet)	Total (per acre)	Vegetation Strata/ Species Name	Frequency (%)	Quantity (per acre)	Spacing Type	Individual Min. Spacing (feet)
100	12	435	TREES				
			tree name 1	15	65	RANDOM	26
			tree name 2	25	109	RANDOM	20
			tree name 3	20	87	RANDOM	22
			tree name 4	25	109	RANDOM	20
			tree name 5	15	65	RANDOM	26
100	15 ft.	194	SHRUBS				
			shrub name 1	30	58	RANDOM	27
			shrub name 2	35	68	RANDOM	25
			shrub name 3	35	68	RANDOM	25
100	N/A	40	HERBACEOUS*				
			herb name 1	20	8	SEED	N/A
			herb name 2	15	6	SEED	N/A
			herb name 3	35	14	SEED	N/A
			herb name 4	15	6	SEED	N/A
			herb name 5	15	6	SEED	N/A

*Herbaceous unit of measure is lbs

Exhibit 13-6 Planting Table Example

PLANTING TABLE

Size (acres): 1.5

Planting Area: Anywhere, Kentucky Zone: 2 Habitat: Floodplain Forest

Quantity	**Botaical Name**	**Common Name**	**Unit**	**Size**
TREES				
98	tree species 1	tree name 1	balled in burlap	1 1/2 inch caliper
164	tree species 2	tree name 2	container grown	4-5 ft.
131	tree species 3	tree names 3	container grown	4-5 ft.
164	tree species 4	tree name 4	container grown	4-5 ft.
98	tree species 5	tree name 5	container grown	4-5 ft.
SHRUBS				
87	shrub species 1	shrub name 1	container grown	2-3 ft.
102	shrub species 2	shrub name 2	container grown	2-3 ft.
102	shrub species 3	shrub name 3	container grown	2-3 ft.
HERBACEOUS				
12	herb species 1	herb name 1	LBS	SEED P.L.S 75%
9	herb species 2	herb name 2	LBS	SEED P.L.S 75%
21	herb species 3	herb name 3	LBS	SEED P.L.S 75%
9	herb species 4	herb name 4	LBS	SEED P.L.S 75%
9	herb species 5	herb name 5	LBS	SEED P.L.S 75%

P.L.S.=Minimum
Pure Live Seed
Percentage

Exhibit 13-7 Maintenance Schedule Example

DESCRIPTION	METHOD	FREQUENCY*	TIME OF YEAR
1. Inspect & replace dead or diseased plants	Follow MSD Specifications	1	March 15 to June 15 & Sept. 15 to Nov. 15
2. Prune all woody plants (corrective pruning only)	Hand tools	1	November 15 to March 1
3. Watering of plants	Water truck/ hand hose	4	June, July, Aug., Sept.
4. Mowing of permanent seed areas (As required by Special Provisions)	Hand mower or tractor	1	March 1 to May 1 or October 1 to December 1

*Per Year

Commercial Planting Plan Example — Rain Garden/Bioretention

Quantities are based on a 400 square foot area with plants on 2-foot centers.

Plant List

Fall Flowering

Common Name *(Scientific Name)*	Quantity
Smooth Blue Aster (*Aster laevis*)	42
Fox Sedge (*Carex vulpinoidea*)	25
Gray Goldenrod (*Solidago nemoralis*)	33
Total	**100**

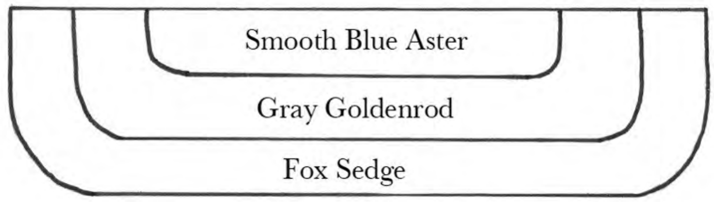


Figure 13.1-A. Typical parking lot bioretention cell (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Typical parking lot bioretention cell shown during fall blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Rain Garden/Bioretention

Quantities are based on a 400 square foot area with plants on 2-foot centers.

Plant List

Mid-Summer Flowering

Common Name *(Scientific Name)*	Quantity
Fox Sedge (*Carex vulpinoidea*)	25
Mist Flower (*Eupatorium coelestinum*)	42
Slender Mt. Mint (*Pycanthemum tenuifolium*)	33
Total	**100**

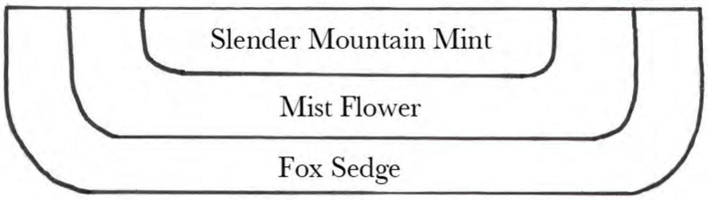


Figure 13.1-B. Typical parking lot bioretention cell (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Typical parking lot bioretention cell shown during mid-summer blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Green Roof

Quantities are based on a 5,000 square foot area with plants on 12-inch centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Stiff Aster (*Aster linariifolia*)	1,000
Poverty Grass (*Danthonia spicata*)	1,250
Gray Goldenrod (*Solidago nemoralis*)	1,075
Little Bluestem (*Schizachyrium scoparium*)	500
Prarie Dropseed (*Sporobolus heterolepis*)	1,000
Flower-of-the-hour (*Talinum calcaricum*)	175
Total	**5,000**

Typical extensive green roof shown during fall blooming season (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

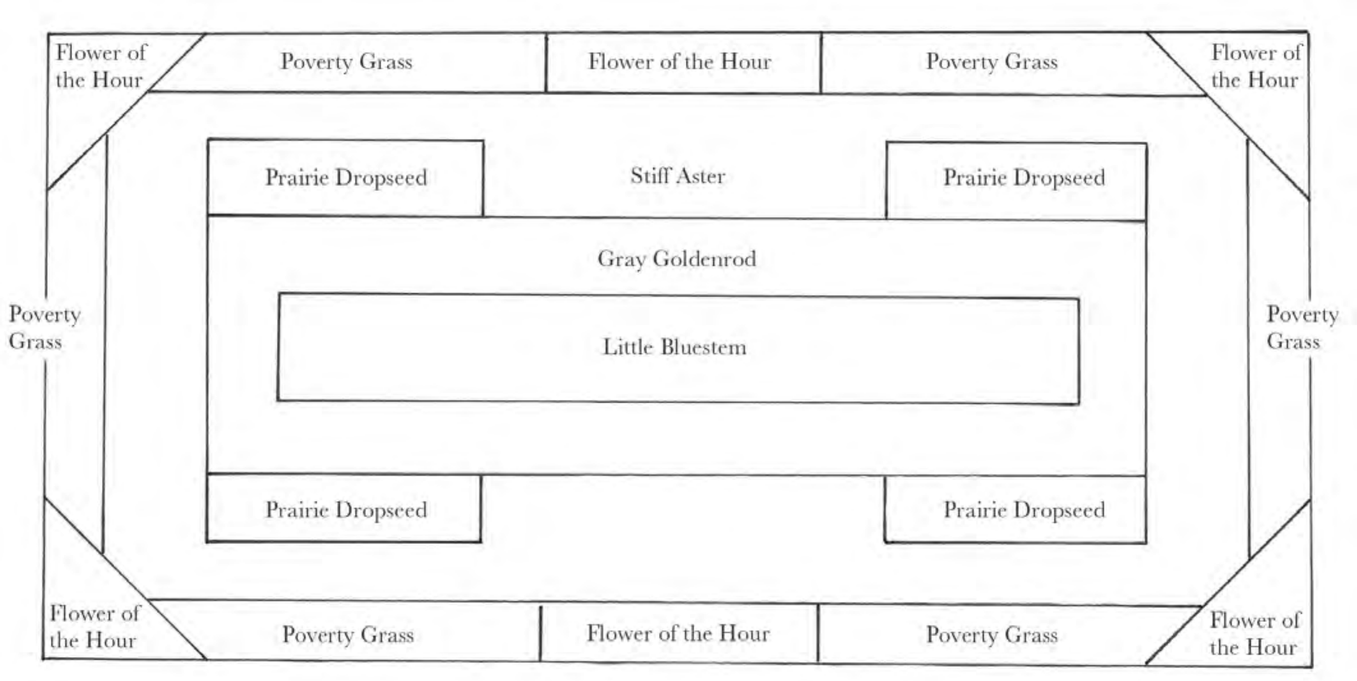


Figure 13.1-C. Typical extensive green roof (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Green Roof

Quantities are based on a 5,000 square foot area with plants on 12-inch centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Stiff Aster (*Aster linariifolia*)	1,525
Poverty Grass (*Danthonia spicata*)	1,250
Little Bluestem (*Schizachyrium scoparium*)	1,050
Prarie Dropseed (*Sporobolus heterolepis*)	1,000
Flower-of-the-hour (*Talinum calcaricum*)	175
Total	**5,000**

Typical extensive green roof shown during fall blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

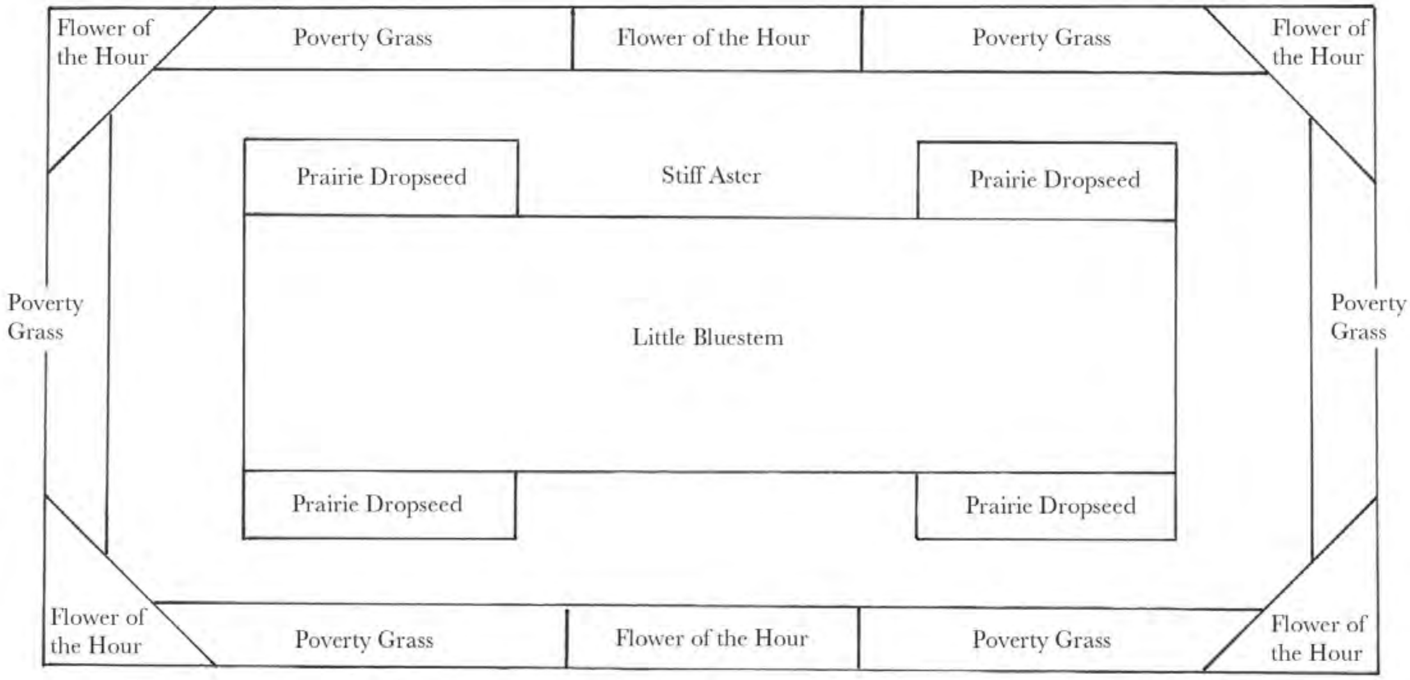


Figure 13.1-D. Typical extensive green roof (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Commercial Planting Plan Example — Rain Garden

Quantities are based on a 450 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Eastern Bluestar (*Amsonia tabernaemontana*)	15
River Oats (*Chasmanthium latifolium*)	17
Purple Coneflower (*Echinacea purpurea*)	20
Narrow-leaved Sunflower (*Helianthus angustifolius*)	11
Dense Blazing Star (*Liatris spicata*)	11
Orange Coneflower (*Rudbeckia fulgida*)	23
Little Bluestem (*Schizachyrium scoparium*)	13
Total	**110**

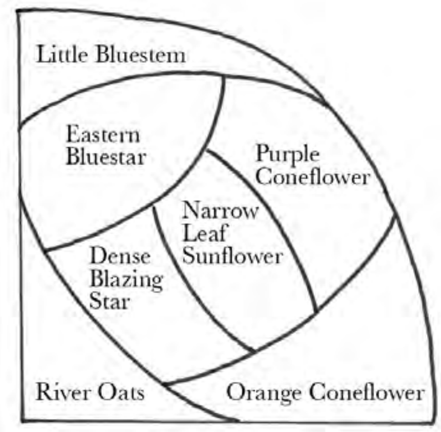


Figure 13.1-E. Typical parking lot rain garden (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Typical parking lot rain garden shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Rain Garden

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Autumn Bentgrass (*Agrostis perennans*)	9
Mist Flower (*Eupatorium coelestinum*)	13
Swamp Hibiscus (*Hibiscus moscheutos*)	9
Bee Balm (*Monarda fistulosa*)	11
Slender Mt. Mint (*Pycanthemum tenuifolium*)	21
Total	**63**

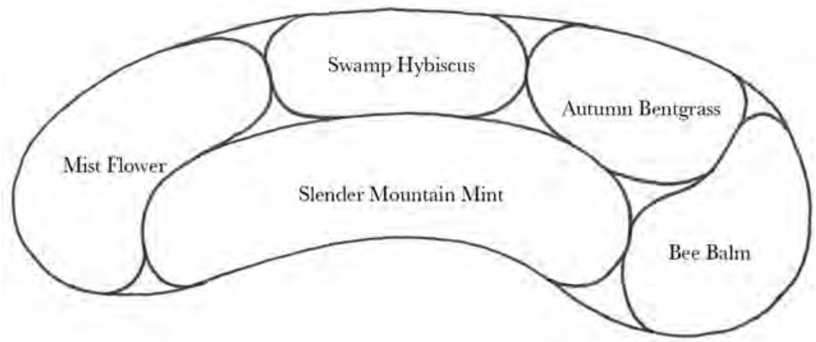


Figure 13.1-F. Typical residential rain garden (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Typical residential rain garden shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Curb Cut Bioswale

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Plant List

Common Name *(Scientific Name)*	Quantity
Fox Sedge (*Carex vulpinoidea*)	15
River Oats (*Chasmanthium latifolium*)	8
Mist Flower (*Eupatorium coelestinum*)	11
Slender Mt. Mint (*Pycanthemum tenuifolium*)	11
Total	**45**

Typical residential curb cut bioswale shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

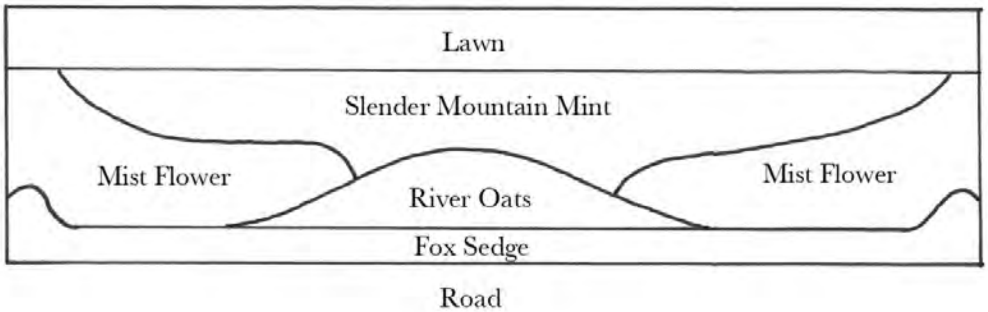


Figure 13.1-G. Typical residential curb cut bioswale (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Residential Planting Plan Example — Parkway Bioswale

Quantities are based on a 245 square foot area with plants on 2-foot centers.

Typical residential parkway bioswale shown during mid-summer blooming season. (Concept Rendering: Margaret Shea & Shea Powell, Dropseed Nursery)

Plant List

Common Name *(Scientific Name)*	Quantity
Bald Cypress (*Taxodium distychum*)	1
Pin Oak (*Quercus*)	1
Swamp Rose (*Rosa palustris*)	4
Black Chokeberry (*Aronia melanocarpa*)	3
Fox Sedge (*Carex vulpinoidea*)	19
River Oats (*Cuasmanthium latifolium*)	13
Foxglove Beardtongue (*Penstemon digitalis*)	19
Great Blue Lobelia (*Lobelia siphilitica*)	13
Sensitive Fern (*Onoclea sensibilis*)	11
Total	84

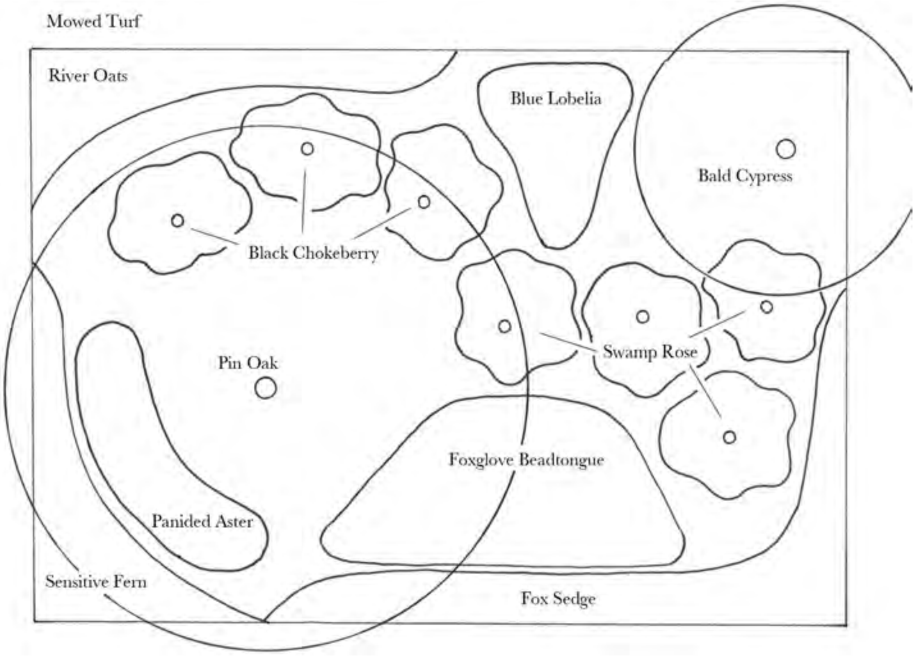


Figure 13.1-H. Typical residential parkway bioswale (Layout: Margaret Shea & Shea Powell, Dropseed Nursery)

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Appendix I: Plant List

Native plants at an educational display at the State Fair (Photo: Louisville & Jefferson County MSD)

Purpose

This purpose of this appendix is to provide guidance on selection of native or cultivar plants for use in green management practices (GMPs). For GMPs such as rain gardens, bioswales and planters, choose deep rooted native plants or non-invasive cultivars based on aesthetic preferences, plant heights, sun/shade tolerances, and the anticipated moisture zones. Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Invasive species shall not be used, and can be identified using the guide in Appendix II: Invasive Species.

The following plant characteristics are used in the Plant List and these descriptions will facilitate plant selection for your site or GMPs. Plant characteristics include:

- Site Conditions
- Form
- Nativity
- Wetland Indicator Status
- Project Uses
- Spread (Coefficient of Conservatism)
- Height
- Flower Color
- Showy in Fall
- Flowering Time
- Root Depth
- Growth Rate

Black-eyed susan (Photo: Louisville & Jefferson County MSD)

Site Conditions

A key consideration in plant selection in the site conditions where the plant will be located. Plants are commonly grouped and labeled for the following site condition categories:

- Sun
- Shade
- Partial sun
- Thrives in sun or shade

The plant list is organized first by site conditions and then by form type. When using the plant list, first determine the site conditions and then determine the type or types of plant forms that you would like to include in your planting plan.

Form

The plant form is the next plant characteristic that you should choose for your planting plan. Decide whether you would like trees, shrubs or flowers, or a combination thereof. The following are plant forms provided in the plant list:

- Trees, shrubs and vines
- Forbs/Flowers
- Grasses, sedges and ruches

Nativity

Plant nativity characterizes the plant as native, exotic (not native to Kentucky) or a cultivar of a Kentucky native species. The plant list uses the following abbreviations to indicate nativity:

- Native to Kentucky, N
- Exotic, not native to Kentucky, E
- Cultivar of a Kentucky native species, C

Wetland Indicator Status

Wetland indicator denotes the tolerance of a plant for wetland or non-wetland conditions. The wetland status of plants is determined by the U.S. Fish and Wildlife Service and is based on the occurrence of that species in wetlands in 13 separate regions of the United States. Wetland indicator categories are provided in table 13.1-A.

In selecting plant material for rain gardens and bioswales, site-specific design should be taken into careful consideration. In rain gardens with well-drained engineered soils using a high proportion of sand, species with wetland indicators of FACW or OBL will *not* be suitable. In rain gardens using native soil or using engineered soil with a higher proportion of compost, species with wetland indicators of FACW or OBL can thrive. Similar considerations should be taken for bioswales depending on their soils and length of time that stormwater will be retained in the areas.

Table 13.1-A. Wetland Indicator Categories*

Indicator Code**	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

* United States Department of Agriculture, Natural Resources Conservation Service

** A positive (+) or negative (−) sign is used for the facultative categories. The (+) sign indicates a frequency towards the wetter end of the category (more frequently found in wetlands) and the (−) sign indicates a frequency towards the drier end of the category (less frequently found in wetlands).

Project Uses

The following are defined project uses in the plant list. Please use the following key to select plants suitable for these project use categories:

- Riparian restoration, R
- Wetland restoration, W
- Bioretention/rain garden, B
- Green roof, GR
- Urban green street/green alley, U
- Upland restoration, UR

Oakleaf hydrangea (Photo: Louisville & Jefferson County MSD)

Spread (Coefficient of Conservatism)

Plant spread is designated as low, medium or high which indicates whether a plant species is faithful to a particular environment (high) or if it can grow easily in many environments (low). This scale also indicates weedy tendencies of a species or how easily it will spread when planted in a landscape. Plants that are more weedy species and tend to spread are classified as low or 0 where less weedy species that do not spread are classified as high.

The plant spread shown in the plant list is adapted from the coefficient of conservatism, a scale from 0 to 10. Each native taxon in the flora of Kentucky has been assigned a coefficient of conservatism from 10, for taxa that are associated with specific, intact, natural communities, to 0, for taxa able to withstand extensive, frequent, or ongoing site degradation.

The coefficients of conservatism can also be used to assess a species' likely behavior in a landscape planting or restoration project. Species with a high rank will be difficult to establish into highly disturbed sites. Species with low ranks will tend to be aggressive and have the potential to dominate sites where they are introduced.

Other Plant Characteristics

These remaining plant characteristics are provided in the plant list to aid in selecting plants that achieve the aesthetic goals of your GMP. To create year-round interest, select plants of varied forms, heights, flowering color and time. The following characteristics are included in the plant list:

- Height (plant height in feet)
- Flower color
- Showy in fall (yes/no indicates fall interest)
- Flowering time (Month of flowering time)
- Root depth (approximate root depth of plant in inches)
- Growth rate (slow, moderate, rapid)

Purple Coneflower (Photo: Louisville & Jefferson County MSD)

Louisville MSD Green Infrastructure Design Manual
Appendix I: Plant List

Project Uses
R =Riparian Restoration
W = Wetland Restoration
B = Bioretention/Rain Garden
GR = Green Roof
U = Urban Green Street/Green Alley
UR = Upland Restoration

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Salinity Tolerance
H = High
M = Moderate
L = Low
U = Unknown

Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Sun-Dry Site	**Grasses**											
Andropogon gerardii	Big Bluestem	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	1.6	M	
Andropogon virginicus	Broomsedge	N	FACU	UR, U, B	high	2-3	yellow	y	Aug-Sept	1.2	L	
Bouteloua curtipendula	Side-oats Grama	N	UPL	UR, GR, U	low	1.5-2.5	yellow	y	July-Aug	0.66	M	
Carex brevior	Shortbeak Sedge	N	UPL	UR, U	medium	1-2	yellow	n	May-June		L	
Carex cephalophora	Oval-headed Sedge	N	FACU	UR, B	medium	1	green	n	May	0.75	N	
Carex morrowii "Ice Dance"	Japanese Sedge	E	-	GR	-	.5-1	green	n	June-July		M	
Carex morrowii "Silver Sceptre"	Silver Sedge	E	-	GR	-	1	green	n	June-July		M	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Elymus villosus	Silky Wild Rye	N	FACU-	UR, B	medium	1-2	yellow	n	June		N	
Festuca amethystina "Superba"	Blue Fescue	E	-	GR	-	0.5	white	y	May-June		M	
Festuca glauca "Elijah Blue"	Blue Fescue	E	-	GR	-	.75-1	green	n	June-July		M	
Festuca ovina "glauca"	Blue Fescue	E	-	GR	-	1	green	y	June-July		M	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Koeleria macrantha	June Grass	N	UPL	UR, U, GR	low	1-2	yellow	n	May-June	1.6	M	
Panicum virgatum	Switchgrass	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	1	H	
Schizachyrium scoparium	Little Bluestem	N	FACU-	UR, B, U, GR	medium	2-3	yellow	y	Aug-Sept	1	H	
Schizachyrium scoparium "The Blues"	Little Bluestem	C	FACU-	B, U, GR	medium	2-4	purple	y	Aug-Oct	1	N	
Sesleria autumnalis	Autumn Moor Grass	E	-	GR	-	0.75-1	green	y	Sept-Oct		H	
Sorghastrum nutans	Indian Grass	N	UPL	UR, B, U, R	medium	4-6	yellow	y	Aug-Sept	2	M	
Sporobolus heterolepis	Prairie Dropseed	N	UPL	GR, U, B, UR	low	1-3	green	y	July-Sept	1	M	
Sporobolus heterolepis "Tara"	Prairie Dropseed	C		GR, U		1-3	brown	y	July-Sept	1	N	
Sun-Dry Site	**Forbs/Flowers**											
Adenophora confusa	Ladybells	E	-	GR	-	2-3	blue	n	May-July		L	
Allium cernuum	Nodding Wild Onion	N	NI	UR, U, GR	low	1-2	white	n	July		H	
Allium flavum	Small Yellow Onion	E	-	GR	-	1	yellow	n	July		U	
Allium schoenoprasum	Chives	E	-	GR	-	1-1.5	purple	n	April-May		U	
Allium stellatum	Prairie Onion	E	-	GR	-	1-1.5	pink	n	July-Sept		U	
Allium tanguticum "Summer Beauty"	Ornamental Onion	E	-	GR	-	1-1.5	purple	n	July		U	
Allium thunbergii "Ozawa"	Ornamental Onion	E	-	GR	-	.5-1	purple	n	August		U	
Antennaria dioica	Pussytoes	E	-	GR	-	.1-.2	white	n	May-July		U	
Armeria juniperifolia	Alpine Thrift	E	-	GR	-	.5-1	pink	y	May-July		M	
Armeria maritima	Sea Thrift	E	-	GR	-	.5-1	pink	n	April-May		M	
Sun-Dry Site	**Forbs/Flowers**											

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FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

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Arnoglossum atriplicifolium	Pale Indian Plantain	N	NI	UR	medium	3-6	white	n	July-Aug		NA	
Asclepias tuberosa	Butterfly Milkweed	N	NI	U, B, UR	medium	1-2.5	orange	n	June-Aug		M	
Symphyotrichum laeve (Aster laevis)	Smooth Blue Aster	N	UPL	U, B, UR	medium	2-4	blue	y	Sept-Oct	0.8	M	
Symphyotrichum pilosum (Aster pilosus)	Frost Aster	N	UPL	U, B, UR	0	2-5	white	n	Sept-Oct	0.8	N	
Baptisia australis	False Blue Indigo	N	NI	B, U, UR	low	3-4	blue	n	May-June		M	
Campanula rotundifolia	Harebell	E	-	GR	-	.5-1.5	blue	n	June-Sept		M	
Campanula trachelium	Bellflower	E	-	GR	-	1.5	blue	n	June-Aug		U	
Cerastium tomentosum "Silver Carpet"	Snow-In-Summer	E	-	GR	-	.5-1	white	n	May-June		M	
Coreopsis lanceolata	Tickseed	E	-	GR	-	1-2	yellow	n	May-July		N	
Coreopsis palmata	Tickseed	E	-	GR	-	1.5-2.5	yellow	n	May-July		N	
Coreopsis tripteris	Tall Coreopsis	N	FAC	U	medium	6-8	yellow	n	Aug-Sept		N	
Coreopsis verticillata "Zagreb"	Threadleaf Coreopsis	E	-	GR	-	1-1.5	yellow	n	May-June		N	
Corydalis lutea	Fumitory	E	-	GR	-	1-1,5	yellow	n	May-Sept		M	
Dalea purpurea	Purple Prairie Clover	N	UPL	GR, U, UR	low	1	purple	n	June-Sept	1.25	M	
Delosperma congestum	Hardy Ice Plant	E	-	GR	-	0.1-0.2	yellow	n	June-Sept		M	
Desmanthus illinoensis	Bundleflower	N	FAC	R, B	high	2-3	white	n	July	1	M	
Dianthus carthusianorum	Pinks	E	-	GR	-	1.5	pink	n	May-June		U	
Echinacea purpurea	Purple Coneflower	N	NI	GR, U, B, UR	low	3-5	purple	n	June-Aug	2	L	
Eryngium yuccifolium	Rattlesnake Master	N	FAC	B, U	low	3-4	white	y	July-Sept		N	
Eupatorium serotinum	Late Boneset	N	FAC	UR,U	high	2-4	white	n	July-Oct		NA	
Euphorbia cyparissias "Fen's Ruby"	Cypress Spurge	E	-	GR	-	1-1.5	yellow	n	April-June		M	
Euphorbia polychroma	Cushion Spurge	E	-	GR	-	1.5	yellow	y	May		M	
Euthamia graminifolia	Grass-leaved Goldenrod	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		L	
Geranium cantabrigiense "Biokovo"	Cranesbill	E	-	GR	-	.5-1	pink	n	May-June		U	
Geranium cantabrigiense "Karmina"	Cranesbill	E	-	GR	-	.5-1	red	n	May-June		U	
Geranium maculatum	Wild Geranium	N	FACU	UR, R	medium	1	violet	n	April-May		M	
Geranium sanguineum " Max Frei"	Cranesbill	E	-	GR	-	.5-.75	purple	n	May-June		U	
Geum triflorum	Geum	E	-	GR	-	.5-1.5	pink	n	May-July		N	
Gypsophila repens "Alba"	Creeping Baby's Breath	E	-	GR	-	.5	white	n	June-July		M	
Gypsophila repens "Rosea"	Creeping Baby's Breath	E	-	GR	-	.5	pink	n	June-July		M	
Helianthus mollis	Ashy Sunflower	N	NI	B, U, UR	low	2-4	yellow	n	Aug-Sept		M	
Heliopsis helianthoides	False Sunflower	N	NI	B, U, UR	medium	4-6	yellow	n	June-Oct		N	
Heuchera americana	Downy Alum Root	N	FACU-	UR, U	medium	1-2	white	n	June-Aug		M	
Sun-Dry Site	**Forbs/Flowers**											
Heuchera americana "Dale's Strain"	Downy Alum Root	C	-	GR	-	1-2	pink	n	June-Aug		M	

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Heuchera villosa	Hairy Alum Root	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		M	
Hypericum sphaerocarpum	St. John's Wort	N	FAC	U, UR, B	medium	1-2	yellow	n	June-Sept		L	
Iris pumila " Sarah Taylor"	Dwarf Bearded Iris	E	-	GR	-	1	blue and	n	June		U	
Knautia macedonica	Knautia	E	-	GR	-	1.5-2	burgandy	n	July-Sept		U	
Lamium maculatum "Aureum"	Spotted Dead Nettle	E	-	GR	-	1	purple	y	May-Sept		M	
Lamium maculatum "Chequers"	Spotted Dead Nettle	E	-	GR	-	1	purple	y	May-Sept		M	
Lespedeza capitata	Round-headed Lespedeza	N	FACU-	U, B, UR	low	1-2	purple	n	Aug-Sept	1.5	N	
Lewisia longipetala "Little Plum"	Bitter Root	E	-	GR	-	.5	pink	n	May-Sept		U	
Liatris aspera	Rough Blazing Star	N	NI	U, UR	low	1-3	purple	n	Aug-Sept		M	
Liatris cylindracea	Cylindrical Blazing Star	N	UPL	U, UR	low	1-2	purple	n	July-Oct		L	
Liatris ligulistylis	Meadow Blazing Star	E	-	GR	-	1-3	purple	n	July-Sept		U	
Manfreda virginica	False Aloe	N	UPL	UR, GR	medium	4	yellow	n	July		N	
Monarda clinopodia	Basal Balm	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		M	
Monarda fistulosa	Bee Balm	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	M	
Nepeta faassenii "Blue Wonder"	Catmint	E	-	GR	-	.5-1	blue	n	May-Sept		M	
Nepeta faassenii "Walker's"	Catmint	E	-	GR	-	1-3	blue	n	May-Sept		M	
Origanum laevigatum	Ornamental Oregano	E	-	GR	-	1-2	purple	n	July-Sept		U	
Parthenium integrifolium	Wild Quinine	N	UPL	U, UR	medium	2-3	white	n	July-Aug		M	
Penstemon digitalis "Husker Red	Beardtongue	C	-	GR	-	2-3	white	n	April-June		M	
Penstemon hirsutus	Hairy Beardtongue	N	NI	B, U, UR	medium	1-2	pink	n	May-June		M	
Penstemon hirsutus "pygmaeus"	Beardtongue	C	-	GR	-	.5	violet	n	June-July		M	
Petrorhagia saxifraga "Lady Marie"	Tunic Flower	E	-	GR	-	.5	pink	n	June-Oct		L	
Phlox paniculata	Phlox	N	FACU	UR, B	medium	3-5	pink	n	July-Sept		U	
Platycodon grandiflorus	Dwarf Balloon Flower	E	-	GR	-	1-2.5	blue	n	June-Aug		U	
Playtcodon grandiflorus "Sentimental Blue"	Balloon Flower	E	-	GR	-	0.5-1	blue	n	July-Aug		U	
Potentilla neumanniana "Nana"	Cinquefoil	E	-	GR	-	0.25-0.5	yellow	n	April-June		M	
Pulsatilla vulgaris	Pasque Flower	E	-	GR	-	0.75-1	violet	n	April-May		N	
Ratibida pinnata	Gray-headed Coneflower	N	NI	B, U, UR	medium	3-5	yellow	n	July-Aug	1.2	M	
Rudbeckia hirta	Black-eyed Susan	N	FACU-	B, U, UR	medium	2-3	yellow	n	June-Sept	0.8	M	
Salvia lyrata	Lyre-leaved Sage	N	UPL	B, U, UR	high	1-2	blue	n	April-June		M	
Salvia nemorosa "Rosenwein"	Rose Wine Sage	E	-	GR	-	1-1.5	rose	n	June-Sept		M	
Salvia nemorosa "Marcus"	Salvia	E	-	GR	-	0.5-1	violet	n	June-Sept		M	
Sun-Dry Site	**Forbs/Flowers**											
Saponaria lempergii "Max Frei"	Soapwort	E	-	GR	-	0.75-1.5	pink	n	March-April		U	
Sedum acre "Aureum"	Golden Stonecrop	E	-	GR	-	.25-.5	yellow	y	June-July		M	

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Sedum acre "Octoberfest"	Sedum	E	-	GR	-	.25-.5	white	y	July-Aug		M	
Sedum album "Coral Carpet"	Stonecrop	E	-	GR	-	0.25-0.5	pink	y	May-June		M	
Sedum dasyphyllum "Blue Ridge"	Stonecrop	E	-	GR	-	0.5-1	white	n	June-July		M	
Sedum floriferum "Weihenstephaner Gold"	Russian Stonecrop	E	-	GR	-	0.3'	yellow	y	July-Aug		M	
Sedum hispanicum "Diploid"	Mexican Sedum	E	-	GR	-	0.3'	white	n	July-Aug		M	
Sedum hybridum "Immergrunchen"	Stonecrop	E	-	GR	-	0.5	yellow	y	July-Aug		M	
Sedum kamtschaticum "Akibono"	Russian Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum middendorffianum "Striatum"	Stonecrop	E	-	GR	-	0.5	yellow	y	June-July		M	
Sedum ochroleucum	Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum reflexum	Stonecrop	E	-	GR	-	0.3	yellow	n	June-July		M	
Sedum rupestre "Sandy's Silver Crest"	Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sedum sarmentosum	Stonecrop	E	-	GR	-	0.5	yellow	n	May-June		M	
Sedum sexangulare	Stonecrop	E	-	GR	-	0.3	yellow	y	June-July		M	
Sedum sichotense	Stonecrop	E	-	GR	-	0.5	yellow	y	July		U	
Sedum spurium "Eco Mt. Emei"	Two Row Stonecrop	E	-	GR	-	0.5	yellow	n	July		M	
Sempervivum montanum "Braunii"	Hens and Chicks	E	-	GR	-	0.5	magenta	y	June-July		M	
Sempervivum tectorum "Hart"	Hens and Chicks	E	-	GR	-	0.5-1	purple	y	June-July		M	
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		N	
Silphium laciniatum	Compass Plant	N	NI	B, U, UR	low	5-8	yellow	n	July-Sept	15	L	
Silphium terebinthinaceum	Prairie Dock	N	UPL	B, U, UR	low	5-10	yellow	n	July-Sept		L	
Silphium trifoliatum	Whorled Rosinweed	N	NI	B, U, UR	medium	4-6	yellow	n	July-Aug		L	
Sisyrinchium angustifolium "Lucerne"	Stout Blue-Eyed Grass	N	FACW-	U, UR	medium	1	blue	n	May-June	0.3	N	
Solidago nemoralis	Gray Goldenrod	N	NI	U, GR, UR	high	2-4	yellow	y	Sept-Oct	1	N	
Solidago caesia	Blue-Stemmed Goldenrod	N	FACU	U, B, UR	medium	1-2	yellow	n	Sept-Oct		M	
Solidago juncea	Early Goldenrod	N	UPL	U, UR	medium	2-4	yellow	y	June-Sept		N	
Solidago speciosa	Showy Goldenrod	N	UPL	UR, U	medium	1-3	yellow	y	Sept-Oct		M	
Solidago ulmifolia	Elm-leaved Goldenrod	N	UPL	UR, U	medium	3	yellow	y	July-Nov		N	
Stachys byzantina "Big Ears"	Lamb's Ears	E	-	GR	-	0.5-1	Purple	n	rarely flowers		M	
Stachys byzantina "Silver Carpet"	Lamb's Ears	E	-	GR	-	0.25-0.5	none	n	rarely flowers		M	
Tephrosia virginiana	Goat's Rue	N	UPL	UR, U	medium	1-3	pink	n	May-June		U	
Teucrium chamaedrys "Summer Sunshine"	Wall Germander	E	-	GR	-	0.75-1	purple	n	May		L	
Sun-Dry Site	**Forbs/Flowers**											
Thymus praecox	Creeping Thyme	E	-	GR	-	0.25-0.5	purple	y	June-Sept		M	
Tradescantia bracteata	Spiderwort	E	-	GR	-	1-1.5	purple	n	May-July		U	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	

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Vernonia gigantea	Ironweed	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		M	
Veronica longifolia "Blue John"	Speedwell	E	-	GR	-	1-1.5	blue	n	June-Sept		U	
Veronicastrum virginicum	Culver's Root	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		N	
Viola pedata	Bird's-foot Violet	N	UPL	GR		0.5	purple	n	April-May		U	
Viola sororia "Freckles"	Sweet Violet	C	-	GR	-	0.6	violet	n	April-May		M	
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		M	
Sun-Dry Site	**Trees, Shrubs, and Vines**											
Acer saccharum	Sugar Maple	N	FACU-	UR	medium	40-80	green	y	April	3.3	N	slow
Aesculus glabra	Ohio Buckeye	N	FACU+	U, UR	high	20-40	green	y	April-May	3	N	
Bignonia capreolata	Crossvine	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		N	
Calycanthus floridus	Sweet Shrub	N	UPL	U, UR	low	6-10	red	n	April-July		L	
Carya cordiformis	Bitternut Hickory	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	L	slow
Celastrus scandens	American Bittersweet	N	FACU-	U, UR	high	15-20	white	y	May-June		N	
Celtis occidentalis	Hackberry	N	FACU	UR	high	40-60	green	y	April-May	3	L	rapid
Cercis canadensis	Redbud	N	FACU-	U, R, B, UR	high	20-30	purple	n	April	2	N	
Cladrastis kentukea	Yellowwood	N	NI	U, UR	low	30-50	white	y	May	2	M	moderate
Cornus kousa	Chinese Dogwood	E	-	U	-	20-30	white	y	May-June		M	slow
Cornus mas	Cornelian Cherry Dogwood	E	-	U	-	15-25	yellow	y	March		N	slow
Cotinus obovatus	American Smoketree	E	-	U	-	20-30	pale gree	y	April-May		L	
Crataegus crus-galli	Cockspur Hawthorn	N	FACU	UR	high	25-35	white	y	May	2	M	moderate
Diospyros virginiana	Persimmon	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	L	slow - fruits may be messy in urban site
Euonymus atropurpureus	Wahoo	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	M	
Fagus grandifolia	American Beech	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	L	slow
Gleditsia triacanthos	Honeylocust	N	FAC-	R, UR	high	100	yellow	y	May-June	4	H	rapid
Gymnocladus dioicus	Kentucky Coffeetree	N	UPL	B, U, UR	medium	75-100	white	n	June	3	M	slow
Hamamelis virginiana	Witch Hazel	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	M	slow
Sun-Dry Site	**Trees, Shrubs, and Vines**											
Hypericum prolificum	Shrubby St. John's Wort	N	FACU	U, B, UR	medium	3	yellow	n	June-Aug	0.8	M	
Juglans nigra	Black Walnut	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	H	rapid
Juniperus virginiana	Eastern Red Cedar	N	FACU	U, UR	high	30-40	n/a	n	n/a		H	slow
Liriodendron tulipifera	Tulip Poplar	N	FACU	U, UR	high	60-90	yellow	y	May-June	3	L	rapid

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Lonicera sempervirens	Trumpet Honeysuckle	N	FACU	U, B, UR	medium	3-20	orange	n	Mar-Aug	0.8	M	
Ostrya virginiana	Eastern Hophornbeam	N	FACU-	U, UR	medium	25-40	yellow	n	April	1.3	M	slow
Prunus americana	Americum Plum	N	FACU-	U, UR	high	15-25	white	n	March	2	H	moderate
Prunus serotina	Black Cherry	N	FACU	U, UR	high	50-80	white	n	April-May	3	M	rapid
Prunus subhirtella	Higan Cherry	E	-	U	-	25-35	pink	n	March-April		L	rapid
Quercus alba	White Oak	N	FACU	B, UR	medium	50-80	yellow	y	May	4	M	slow
Quercus macrocarpa	Bur Oak	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	M	slow
Quercus marilandica	Blackjack Oak	N	UPL	U, UR	medium	20-40	yellow	y	May	2	M	slow
Quercus rubra	Red Oak	N	FACU-	U, UR	medium	50-75	yellow	y	May	3	M	moderate
Quercus prinus	Chestnut Oak	N	UPL	U, UR	medium	50-70	yellow	y	April	3	N	slow
Rhus aromatica	Fragrant Sumac	N	NI	B, U, UR	high	2-6	yellow	y	April		H	spreads to form thickets
Rhus typhina	Staghorn Sumac	N	UPL	UR	high	15-25	red	y	June-July	1.6	H	
Rosa carolina	Pasture Rose	N	UPL	U, UR	high	1-3	white	y	June-Sept	1	H	
Sassafras albidum	Sassafras	N	FACU-	U, UR	high	30-60	yellow	y	April-May	1.5	M	moderate
Viburnum prunifolium	Blackhaw Viburnum	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	M	
Viburnum rufidulum	Southern Blackhaw	N	UPL	U, UR	medium	10-20	white	y	April-May		M	
Shade-Dry Site	**Grasses**											
Bromus pubescens	Woodland Brome	N	NI	UR	medium	2-4	green	n	May-June		N	
Carex cephalophora	Oval-headed Sedge	N	FACU	UR, B	medium	1	green	n	May	0.75	N	
Carex normalis	Spreading Oval Sedge	N	FACU	UR	medium	1-3	green	n	May-June	1	N	
Carex radiata	Lance-fruited Oval Sedge	N	UPL	UR	medium	1	green	n	April-May		M	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Diarrhena americana	Beak Grass	N	NI	U, B, UR	medium	1-2	green	n	August		N	
Elymus villosus	Silky Wild Rye	N	FACU-	UR, B	medium	1-2	yellow	n	June		N	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Asarum canadense	Wild Ginger	N	FACU-	B, UR	medium	1	maroon	n	April-May		M	
Aster cordifolius	Wood Aster	N	UPL	U, UR	medium	1-3	purple	y	Sept-Oct	0.8	**N**	
Aster divaricatus	White Wood Aster	N	UPL	U, UR	low	1-2.5	white	n	Aug-Sept		U	
Shade-Dry Site	**Forbs/Flowers**											
Symphyotrichum shortii (Aster shortii)	Short's Aster	N	UPL	B, UR, U	medium	2-3	blue	n	Sept-Oct		U	
Blephilia ciliata	Downy Wood Mint	N	NI	B, U, UR	medium	1-2.5	blue	n	May-Aug		U	
Blephilia hirsuta	Hairy Wood Mint	N	FACU	U, UR	medium	1-3	blue	n	July-Aug		N	
Campanulastrum americanum	Bellflower	N	FACU	B, UR	high	2-6	blue	n	June-July	0.75	N	
Geranium maculatum	Wild Geranium	N	FACU	R, UR	medium	1	violet	n	April-May		M	

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OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

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Helianthus divaricatus	Woodland Sunflower	N	NI	U, UR	medium	2-5	yellow	n	Sept-Oct		M	
Heuchera americana	Downy Alum Root	N	FACU-	U, UR	medium	1-2	white	n	June-Aug		M	
Heuchera villosa	Hairy Alum Root	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		M	
Monarda clinopodia	Basal Balm	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		M	
Monarda fistulosa	Bee Balm	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	M	
Polemonium reptans	Jacob's Ladder	N	FACU	R, B, UR	medium	1-1.5	blue	n	April-June		U	
Polygonatum biflorum	Solomon's Seal	N	FACU	R, B, UR	medium	1-3	white	n	April-May		M	
Salvia lyrata	Lyre-leaved Sage	N	UPL	B, U, UR	high	1-2	blue	n	April-June		M	
Solidago caesia	Blue-Stemmed Goldenrod	N	FACU	U, B, UR	medium	1-2	yellow	y	Sept-Oct	0.6	M	
Solidago flexicaulis	Zig-Zag Goldenrod	N	FACU	B, R, UR	medium	1-2	yellow	y	Sept-Oct	0.6	M	
Solidago juncea	Early Goldenrod	N	UPL	U, UR	medium	2-4	yellow	n	June-Sept		N	
Stylophorum diphyllum	Celandine Poppy	N	NI	B, UR, U	medium	1-2	yellow	n	April-May		N	
Tephrosia virginiana	Goat's Rue	N	UPL	UR, U	medium	1-3	pink	n	May-June		U	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	
Veronicastrum virginicum	Culver's Root	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		N	
Shade-Dry Site	**Trees, Shrubs, and Vines**											
Acer saccharum	Sugar Maple	N	FACU-	UR	medium	40-80	green	y	April	3.3	N	slow
Aesculus glabra	Ohio Buckeye	N	FACU+	U, UR	high	20-40	green	y	April-May	3	N	
Betula lenta	Sweet Birch	N	FACU	U, UR	medium	72-100	yellow	n	April-May	2.25	M	
Bignonia capreolata	Crossvine	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		N	
Calycanthus floridus	Sweet Shrub	N	UPL	U, UR	low	6-10	red	n	April-July		L	
Carya cordiformis	Bitternut Hickory	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	L	slow
Carya ovata	Shagbark Hickory	N	FACU	U, UR	medium	70-90	yellow	y	April-May	4	H	slow
Celtis occidentalis	Hackberry	N	FACU	UR	high	40-60	green	y	April-May	3	L	rapid
Ceanothus americanus	New Jersey Tea	N	UPL	U, UR	medium	3	blue	n	Mar-Apr	1.2	N	

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Shade-Dry Site	**Trees, Shrubs, and Vines**											
Diospyros virginiana	Persimmon	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	L	slow - fruits may be messy in urban site
Euonymus americanus	Strawberry Bush	N	UPL	U, UR	medium	6-12	green	y	May-June	0.6	M	
Euonymus atropurpureus	Wahoo	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	M	
Fagus grandifolia	American Beech	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	L	slow
Gymnocladus dioicus	Kentucky Coffeetree	N	UPL	B, U, UR	medium	75-100	white	n	June	3	M	slow
Hamamelis virginiana	Witch Hazel	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	M	slow
Hydrangea arborescens	Wild Hydrangea	N	FACU	B, UR, U	medium	3-6	cream	y	June-Sept		M	
Juglans nigra	Black Walnut	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	N	rapid
Lonicera sempervirens	Trumpet Honeysuckle	N	FACU	U, B, UR	medium	3-20	coral	n	Mar-Aug	0.8	M	
Pinus strobus	White Pine	N	FACU	U, UR	medium	75-100	n/a	n	n/a	3.3	L	rapid
Prunus americana	Americum Plum	N	FACU-	U, UR	high	15-25	white	n	March	2	H	moderate
Prunus serotina	Black Cherry	N	FACU	U, UR	high	50-80	white	n	April-May	3	M	rapid
Rhus aromatica	Fragrant Sumac	N	NI	B, U, UR	high	2-6	yellow	y	April		H	will spread to form thickets
Rhus typhina	Staghorn Sumac	N	UPL	UR	high	15-25	red	y	June-July	1.6	H	
Symphoricarpos orbiculatus	Coralberry	N	UPL	B, U, UR	high	2-5	white	y	June-July	1.5	L	
Viburnum prunifolium	Blackhaw Viburnum	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	M	
Viburnum rufidulum	Southern Blackhaw	N	UPL	U, UR	medium	10-20	white	y	April-May		**M**	
Sun--Moist to Wet Site	**Grasses, Sedges and Rushes**											
Andropogon gerardii	Big Bluestem	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	9	M	
Arundinaria gigantea	River Cane	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	L	
Carex annectens	Yellow Fox Sedge	N	FACW	B, W	high	2-3	yellow	n	May-June		U	
Carex bromoides	Brome-like Sedge	N	FACW+	W, R, B	low	1-2	green	n	May		U	
Carex crinita	Fringed Sedge	N	OBL	W	medium	2-4	green	n	May-June	1.5	N	
Carex cristatella	Crested Sedge	N	FACW	W, B	medium	2-3	green	n	May-June	0.75	N	
Carex frankii	Frank's Sedge	N	OBL	W, B, R	high	1-2	green	n	June-July	0.75	N	
Carex granularis	Meadow Sedge	N	FACW+	W, B	medium	1-2	green	n	May-June	0.75	N	
Carex grayi	Gray's Sedge	N	FACW+	W	medium	1-2	green	n	May-June	0.75	N	
Carex lupulina	Hop Sedge	N	OBL	W	medium	1-2	green	n	May-June	1.5	N	
Carex lurida	Lurid Sedge	N	OBL	W	medium	1-2	green	n	May-June	1.3	N	

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Appendix I: Plant List

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Sun--Moist to Wet Site	**Grasses, Sedges and Rushes**											
Carex scoparia	Large-Fruited Oval Sedge	N	FACW	W	medium	2-3	green	n	May	0.75	L	
Carex stipata	Awl-fruited Sedge	N	OBL	W	medium	2-3	green	n	May	0.75	L	
Carex vulpinoidea	Fox Sedge	N	OBL	W, B. R	high	2-3	green	n	May-June	1.3	N	
Elymus riparius	Riverbank Wild Rye	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	N	
Glyceria striata	Fowl Manna Grass	N	OBL	W, B, R	medium	2-4	green	n	May-June	0.3	N	
Juncus effusus	Soft Rush	N	FACW+	W, B, R	medium	2-4	green	n	May-June	1	L	
Leersia oryzoides	Rice Cutgrass	N	OBL	W, B	high	2-4	green	n	Aug-Sept	1.2	M	
Panicum virgatum	Switchgrass	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	11	H	
Scirpus atrovirens	Green Bulrush	N	OBL	W	high	3-5	brown	n	May-June	1	M	
Scirpus cyperinus	Woolgrass	N	FACW+	W	medium	3-5	green	n	July-Aug	1	M	
Scirpus validus	Softstem Bulrush	N	OBL	W	high	4-8	red	n	May-June		L	
Spartina pectinata	Prairie Cordgrass	N	OBL	B, W	medium	4-7	yellow	n	July-Aug	1.5	L	
Tripsacum dactyloides	Eastern Gamma Grass	N	FACW	U, B	medium	4-8	yellow	n	May-Sept	1.6	N	
Sun--Moist to Wet Site	**Forbs/Flowers**											
Acorus calamus	Sweet Flag	N	OBL	W	high	2-2.5	yellow	n	April	1	L	
Agrimonia parviflora	Many-flowered Agrimony	N	FACW	B,W	medium	6	yellow	n	July	0.5	NA	
Alisma subcordatum	Water Plantain	N	OBL	W	high	1-2	white	n	June	0.66	L	
Amsonia tabernaemontana "Short Stack"	Dwarf Bluestar	C	-	R	-	0.75-1	pale blue	y	April-May		M	
Asclepias incarnata	Swamp Milkweed	N	OBL	W, B, R	medium	4-5	pink	n	July-Aug	1.5	M	
Symphyotrichum novae-angliae (Aster novae-angliae)	New England Aster	N	FACW-	W, B, U, R	medium	3-6	purple	n	Aug-Sept		N	
Symphyotrichum puniceum (Aster puniceus)	Purple-stemmed Aster	N	OBL	W	low	6-8	blue	n	Aug-Sept		N	
Doellingeria umbellata (Aster umbellatus)	Flat-topped Aster	N	FACW	B, R	medium	3-5	white	n	Sept-Oct		M	
Bidens aristosa	Tickseed Sunflower	N	FACW	W	0	2-3	yellow	n	Sept-Oct	0.75	N	
Bidens cernua	Nodding Bur Marigold	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	L	
Chelone glabra	White Turtlehead	N	OBL	R, W, B	medium	2-4	white	n	Aug-Sept		N	
Conoclinium coelestinum	Mistflower	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	N	
Coreopsis "Jethro Tull"	Tickseed	E	-	B	-	1-1.5	yellow	n	June-Aug		M	
Echinacea purpurea "Vintage Wine"	Purple Coneflower	C	-	R	-	2-3	white	n	June-Aug	2	L	
Eryngium yuccifolium	Rattlesnake Master	N	FAC	B, U	low	3-4	white	y	July-Sept		L	
Eupatorium fistulosum	Joe-pye Weed	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		M	
Eupatorium maculatum	Spotted Joe-pye Weed	N	FACW	R, W	low	4-6	violet	n	Aug-Sept		M	
Eupatorium perfoliatum	Boneset	N	FACW+	R, U	high	3-5	white	n	Aug-Sept		M	
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Eupatorium purpureum	Purple Joe-pye Weed	N	FAC	W, B	medium	4-6	violet	n	July-Aug		M	
Euthamia graminifolia	Grass-leaved Goldenrod	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		L	
Gaura lindheimeri "Siskiyou Pink"	Gaura	E	-	B	-	2.5-3	yellow	n	May-Aug		U	
Geranium "Gerwat" RIZANNE	Cranesbill	E	-	B	-	1-1.5	yellow	n	May-July		M	
Helenium autumnale	Sneezeweed	N	FACW+	W, B	medium	3-5	pink	n	Sept-Oct	0.5	L	
Helianthus angustifolius	Narrow-leaved Sunflower	N	FACW	B, U	low	4-6	blue	n	Sept-Oct	0.5	N	
Heuchera "Rave On"	Coral Bells	E	-	B	-	1-2	pink/whit	n	July-Aug		M	
Hibiscus "Fantasia"	Hardy Hibiscus	E	-	B	-	2-3	pink/whit	n	July-Sept		M	
Hibiscus laevis	Smooth Rose-mallow	N	OBL	W, B, R	medium	2	pink	y	July-Aug	1	M	
Hibiscus moscheutos	Swamp Hibiscus	N	OBL	W, B, R	high	3-5	pink	n	July	0.8	M	
Iris virginica	Blue Flag Iris	N	-	W, B	medium	2-3	blue	n	May-June	0.5	N	
Liatris spicata	Dense Blazing Star	N	FAC+	W, B	low	3-5	purple	n	July-Aug	1.2	L	
Lycopus americanus	Water Horehound	N	OBL	W, B	medium	1-2	white	n	July-Aug		L	
Mimulus ringens	Monkey Flower	N	OBL	W,B	medium	2-4	blue	n	July-Sept		NA	
Nepeta subsessilis "Candy Cat"	Nepeta	E	-	B	-	2-2.5	pink	n	May-Sept		L	
Peltandra virginica	Arrow Arum	N	OBL	W, R	medium	2-3	white	n	June-July	1.3	M	
Penstemon digitalis	Foxglove Beardtongue	N	FAC	W, R	high	2-3	white	n	June	0.6	M	
Phlox paniculata "Robert Poore"	Phlox	C	-	B	-	3-5	pink	n	July-Sept		M	
Physostegia virginiana "Miss Manners"	Obedient Plant	C	-	R	-	2-2.5	white	n	June-Sept		M	
Pontederia cordata	Pickerelweed	N	OBL	R, W	low	2-3	blue	n	July-Sept	0.8	L	
Potamogeton nodosus	Long-leaved Pondweed	N	OBL	W	medium	1-3	green	n	June-Sept		N	
Pycnanthemum tenuifolium	Slender Mountain Mint	N	FACW	B, U, R	high	1-2	white	n	July-Aug		U	
Pycnanthemum virginianum	Common Mountain Mint	N	FAC	W, B	medium	1-2	white	n	July-Aug		L	
Rudbeckia fulgida	Orange Coneflower	N	FAC	B, U, UR	medium	2-3	yellow	n	Aug-Sept	0.6	M	
Rudbeckia laciniata	Green-headed Coneflower	N	FACW	U, W, B	medium	5-8	yellow	n	July-Aug	1	M	
Sagittaria latifolia	Broad-leaf Arrow-head	N	OBL	R, W	medium	1-3	white	n	July-Sept	1.5	M	
Salvia nemorosa "Sensation Rose"	Sage	E	-	B	-	0.75-1	white	n	June-Sept		U	
Saururus cernuus	Lizard's Tail	N	OBL	W	medium	1-2	yellow	n	June-Sept		M	
Packera aureus	Golden Ragwort	N	FACW	B, R	medium	1	pink	n	May		M	
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		U	
Sparganium eurycarpum	Giant Burreed	N	OBL	W	low	3-6	green	n	June-July	1	M	
Stachys officinalis	Bishop's Wort	E	-	B	-	1.5-2	blue	n	May-June		M	
Teucrium canadense	Germander	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	L	
Sun--Moist to Wet Site	**Forbs/Flowers**											
Tradescantia ohiensis	Spiderwort	N	FAC	B, U	medium	2-3	Purple	n	June-July	0.3	M	

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Verbena hastata	Blue Vervain	N	FACW+	B, W	high	3-5	blue	n	July-Sept		H	
Verbesina alternifolia	Wingstem	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		M	
Vernonia gigantea	Ironweed	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		M	
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		M	
Sun--Moist to Wet Site	**Trees, Shrubs, and Vines**											
Alnus serrulata	Smooth Alder	N	OBL	W, R	medium	15	yellow	n	March-April	2	N	rapid
Amelanchier laevis	Allegheny Serviceberry	N	NI	B, U, R	low	14-40	white	y	April	2.5	L	moderate
Amorpha fruticosa	Leadplant	N	FACW	R, B	medium	1-3	purple	n	June-July	2	H	
Aralia spinosa	Devil's Walkingstick	N	FAC	U	medium	20	white	n	June-Aug	2.5	N	moderate
Aronia arbutifolia	Red Chokeberry	N	NI	R, U	medium	3-6	white	y	May	1.6	L	
Aronia melanocarpa	Black Chokeberry	N	NI	R, U	medium	3-6	white	y	May	2	M	
Betula nigra	River Birch	N	FACW	B, U, R	medium	40-70	brown	n	April-May	1.6	M	rapid
Carpinus betulus "Globosa"	European Hornbeam	E	-	U	-	15-20	green	n	April		N	slow
Carya laciniosa	Shellbark Hickory	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	N	slow
Celtis laevigata	Sugarberry	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	L	moderate
Cephalanthus occidentalis	Buttonbush	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	M	
Chionanthus virginicus	Fringe Tree	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	L	slow
Cornus mas	Cornelian Cherry Dogwood	E	-	U	-	15-25	yellow	y	March		N	slow
Crataegus viridis	Green Hawthorn	N	FACW	U	medium	20-35	white	y	May	1.6	N	moderate
Ilex decidua	Possumhaw Holly	N	FACW	R, B, U	medium	15-30	yellow	n	March-May	1	N	
Ilex verticillata	Winterberry	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	M	
Itea virginica	Virginia Sweetspire	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	N	
Liquidambar styraciflua	Sweetgum	N	FAC	R, U	high	60-80	green	y	April-May	3	H	rapid
Nyssa sylvatica	Black Gum	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	1.5	M	moderate
Physocarpus opulifolius	Common Ninebark	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	L	slow
Platanus occidentalis	Sycamore	N	FACW-	R, U	high	75-100	red	y	April	2.5	L	rapid
Quercus bicolor	Swamp White Oak	N	FACW+	W, U, R	low	50-60	yellow	y	April	3.3	M	rapid
Quercus macrocarpa	Bur Oak	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	M	slow
Quercus palustris	Pin Oak	N	FACW	W, B, U	medium	50-70	yellow	y	April	2.5	L	rapid
Quercus phellos	Willow Oak	N	FAC+	R, W, U	low	40-75	yellow	y	April	1	NH	rapid
Quercus shumardii	Shumard Oak	N	FAC+	U	medium	40-60	yellow	y	April	3.3	M	moderate
Sun--Moist to Wet Site	**Trees, Shrubs, and Vines**											
Rosa palustris	Swamp Rose	N	OBL	B, W, R	medium	2-7	pink	y	June-July	1.5	**N**	
Salix amygdaloides	Peach-leaf Willow	N	FACW	R, W	low	60	white	n	Apr-May	2.5	N	rapid

Project Uses
R =Riparian Restoration
W = Wetland Restoration
B = Bioretention/Rain Garden
GR = Green Roof
U = Urban Green Street/Green Alley
UR = Upland Restoration

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Salinity Tolerance
H = High
M = Moderate
L = Low
U = Unknown

Wetland Indicator

indicato	likelihood of finding plant in a wetland
OBL	99%
FACW	67%
FAC	34-66%
FACU	1-33%
UPL	1%

Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Salix discolor	Pussy-Willow	N	FACW	W	low	25	white	n	Feb-Mar	1.6	H	rapid
Salix exigua	Sandbar Willow	N	OBL	W, R	high	15	white	n	Mar-Apr		L	rapid
Salix nigra	Black Willow	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	M	rapid
Sambucus canadensis	Common Elderberry	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		M	
Spiraea alba	Meadowseet	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	N	
Spiraea tomentosa	Steeplebush	N	FACW-	B, W	medium	2-5	purple	y	July-Sept	1.2	M	
Taxodium distichum	Bald Cypress	N	OBL	W, U, R	medium	50-70	n/a	y	n/a	3.3	H	rapid
Viburnum dentatum	Arrow-wood	N	FAC	R, B	medium	6-10	white	y	May-June		M	
Shade-Moist to Wet Site	**Grasses, Sedges and Rushes**											
Arundinaria gigantea	River Cane	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	L	
Carex bromoides	Brome-like Sedge	N	FACW+	W, R, B	low	1-2	green	n	May		U	
Chasmanthium latifolium	River Oats	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	H	
Elymus riparius	Riverbank Wild Rye	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	N	
Elymus virginicus	Virginia Wild Rye	N	FACW-	UR, B	medium	2-3	yellow	n	June-July		N	
Hystrix patula	Bottlebrush Grass	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		L	
Shade-Moist to Wet Site	**Forbs/Flowers**											
Aquilegia canadensis	Wild Columbine	N	FAC	R, U, B	medium	2-3	red	n	April-May		M	
Arisaema triphyllum	Jack-In-The-Pulpit	N	FACW-	R, B	medium	1-2	maroon	y	April-May		N	
Symphyotrichum lateriflorum (Aster lateriflorus)	Calico Aster	N	FACW-	R, U	high	1-3	purple	y	Sept-Oct	0.8	N	
Athyrium filix-femina	Lady Fern	N	FAC	B, R	medium	1-3	n/a	n	n/a		M	
Bidens cernua	Nodding Bur Marigold	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	L	
Conoclinium coelestinum	Mistflower	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	N	
Eupatorium fistulosum	Joe-pye Weed	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		M	
Eupatorium purpureum	Purple Joe-pye Weed	N	FAC	W, B	medium	4-6	violet	n	July-Aug		M	
Heuchera "Rave On"	Coral Bells	E	-	B	-	1-2	red	n	July-Aug		M	
Lobelia cardinalis	Cardinal Flower	N	FACW+	W, B, R	medium	1-3	blue	n	Aug-Sept	1	M	
Lobelia siphilitica	Blue Lobelia	N	FACW+	W, B, R	medium	1-3	pink	y	Aug-Sept		M	
Nepeta subsessilis "Candy Cat"	Nepeta	E	-	B	-	2-2.5	n/a	n	May-Sept		L	
Onoclea sensibilis	Sensitive Fern	N	FACW	R, B	medium	3-4	n/a	n	n/a		M	
Shade-Moist to Wet Site	**Forbs/Flowers**											
Osmunda cinnamomea	Cinnamon Fern	N	FACW	R, B	low	2-3	pink	n	n/a	1	L	
Osmunda regalis	Royal Fern	N	OBL	R, B	low	2-3	n/a	n	n/a	1.3	N	
Penstemon digitalis	Foxglove Beardtongue	N	FAC	W, B	high	2-3	white	n	June	0.6	M	

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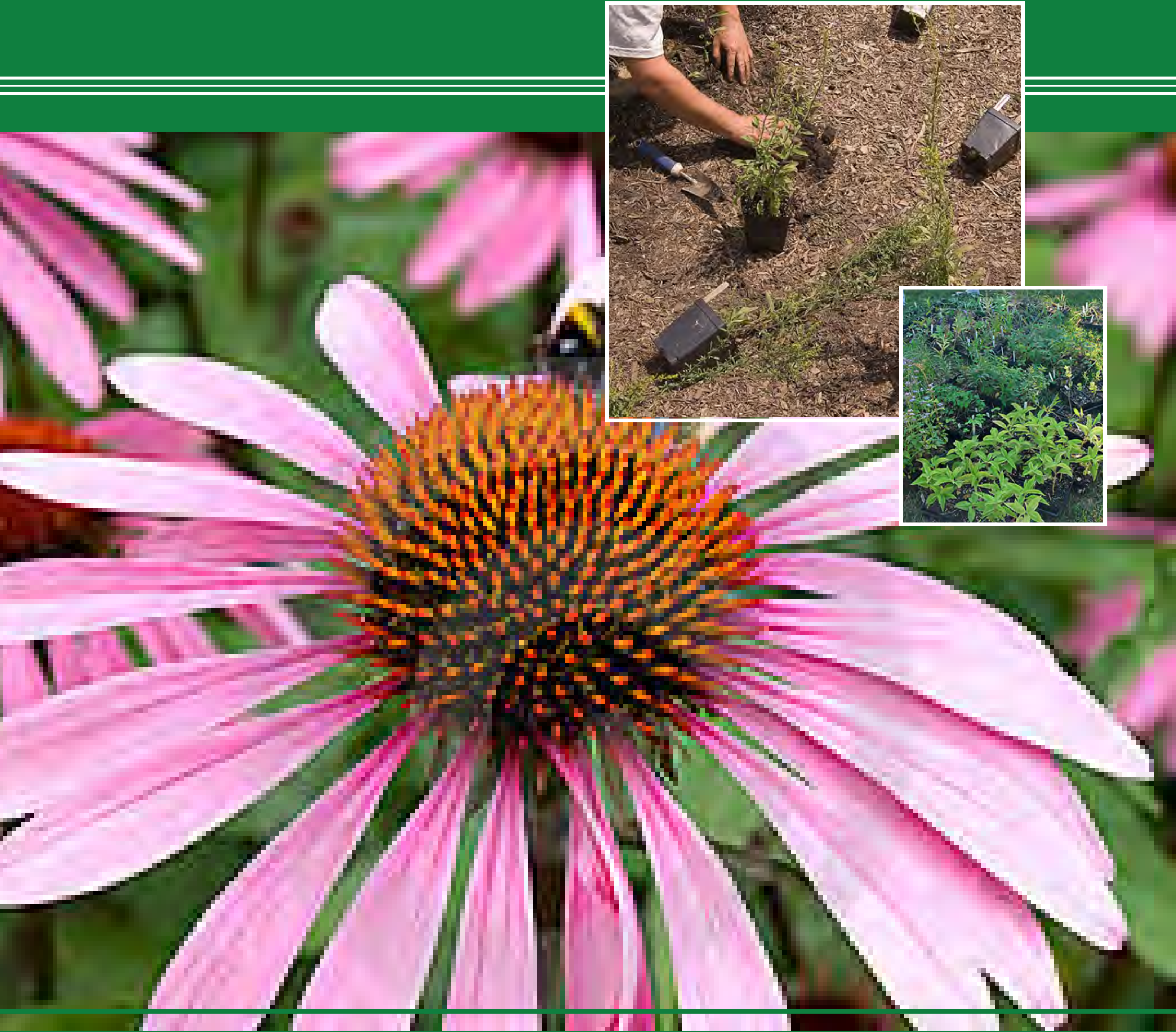
Scientific Name	Comon Name	Nativity	Wetland Indicator	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering time	Root Depth (ft)	Salinity Tolerance	Growth Rate
Senna hebecarpa	Wild Senna	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		U	
Sisyrinchium angustifolium	Stout Blue-Eyed Grass	N	FACW-	U, B	medium	1	blue	n	May-Aug		N	
Symphyotrichum lanceolatum (Aster lanceolatus)	Panicled Aster	N	OBL	R,W	medium	5	white	n	Sept-Oct		NA	
Teucrium canadense	Germander	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	L	
Shade-Moist to Wet Site	**Trees, Shrubs, and Vines**											
Acer japonicum "Taki No Gawa"	Fullmoon Maple	E	-	U	-	10-15	red	y	May		L	slow
Alnus serrulata	Smooth Alder	N	OBL	W, R	medium	15	yellow	n	March-April	2	N	rapid
Amelanchier laevis	Allegheny Serviceberry	N	NI	B, U, R	low	14-40	white	y	April	2.5	L	moderate
Aralia spinosa	Devil's Walkingstick	N	FAC	U	medium	20	white	n	June-Aug	2.5	N	moderate
Aronia arbutifolia	Red Chokeberry	N	NI	R, U	medium	3-6	white	y	May	1.6	L	
Aronia melanocarpa	Black Chokeberry	N	NI	R, U	medium	3-6	white	y	May		M	
Carpinus caroliniana	American Hornbeam	N	FAC	W, B, U, R, UR	medium	20-35	orange	y	Feb	1.6	M	
Carya laciniosa	Shellbark Hickory	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	N	slow
Celtis laevigata	Sugarberry	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	L	moderate
Cephalanthus occidentalis	Buttonbush	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	M	
Chionanthus virginicus	Fringe Tree	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	L	slow
Clematis virginiana	Virgin's Bower	N	FAC	U, R, B	medium	4-8	white	n	Aug-Sept	1.2	N	
Cornus amomum	Silky Dogwood	N	FACW	W, B, U, R	medium	6-10	white	n	April	1.3	N	
Hydrangea quercifolia	Oak-leaf Hydrangea	E	-	B	-	6-8	yellow	n	May-July		M	
Ilex decidua	Possumhaw Holly	N	FACW	R, B, U	medium	15-30	white	y	March-May	1	N	
Ilex verticillata	Winterberry	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	M	
Itea virginica	Virginia Sweetspire	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	N	
Lindera benzoin	Spicebush	N	FACW-	R, W, B	medium	4-8	white	y	April	1.5	M	
Nyssa sylvatica	Black Gum	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	2.5	M	moderate
Physocarpus opulifolius	Common Ninebark	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	L	slow
Salix exigua	Sandbar Willow	N	OBL	W, R	high	15	white	y	Mar-Apr		L	
Salix nigra	Black Willow	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	M	rapid
Sambucus canadensis	Common Elderberry	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		M	
Spiraea alba	Meadowseet	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	N	
Shade-Moist to Wet Site	**Trees, Shrubs, and Vines**											
Spiraea tomentosa	Steeplebush	N	FACW-	B, W	medium	2-5	purple	n	July-Sept	1.2	M	
Viburnum dentatum	Arrow-wood	N	FAC	R, B	medium	6-10	white	y	May-June		M	

Green Infrastructure Plant Guide



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Introduction to Plant Guide

This Plant Guide is designed to be used in conjunction with Louisville Metropolitan Sewer District's Design Manual, Chapter 13 and its appendix of recommended plants. Chapter 13 will provide planning and design information that should be considered before making plant selection for a site. The appendix of recommended plants contains specific information on growing conditions, height, flower color, flowering time, etc. The Plant Guide provides images for the plants as well as additional information on the natural history, management, and growing tips for each species. The table and Plant Guide should be used together to get all the necessary information for each species.

The Plant Guide includes native species, cultivars of native species and non-native plants as choices for landscaping and restoration projects. Native species are species that were present in this region prior to European settlement of this area. Following European settlement of Kentucky, many species were introduced for agriculture and landscaping, and others were introduced accidentally as seed mixed in with other imported materials. This guide attempted to exclude any species considered to be invasive or harmful to nearby natural areas.

Benefits of working with native species are that these species have existed in these growing conditions for thousands of years. Given that you choose the right plant for the right location, native species, once established, will not require additional water or fertilizer inputs. Native species will also provide a source of food for dwindling wildlife species including birds and butterflies. A locally genetic source of native plants will be best adapted to our conditions. A consideration in using native plant materials is that they are a mix of unique individuals. While this makes for a healthy population of plants, it also results in variability in flower color, height, and other physical characteristics of the plants. Utilizing cultivars will provide more consistency in the physical characteristics of plants.

Alpine Thrift

Armeria juniperifolia

This species requires full sun and well drained soil. Drought tolerant. It does not tolerate competition from more aggressive plants. Susceptible to root rot. Good for rock garden, containers or small scale ground cover.

When deadheaded,the plant can give a second bloom. The evergreen leaves provide winter interest in the garden.

Habitat: Sun

Alpine Thrift in bloom in early Summer
© *Henrietta Kress*

Alpine Thrift in bloom
© *Magnus Manske*

Alum Root

Heuchera richardsonii

Drought tolerant. Good edging plant and if planted in mass can form a nice ground cover. Prefers well drained areas. Clumps can be divided every 3 to 4 years in spring. This shallow rooted plant can benefit from additional mulching prior to winter.

The flowers of Alum Root are attractive to native bees.

Alum Root in early Summer
© *J.S. Peterson*

Alum Root in bloom in early Summer
© *Bennie Bengston*

Aromatic Aster
Symphyotrichum oblongifolium

Drought tolerant. Thin regularly to control unwanted spread. Prune in early summer to control growth and height. Some support may be needed for taller plants when in bloom. Cut back dead plant material in late fall or early winter. Leaves are fragrant when crushed. Provides color into the late fall.

Attracts birds, butterflies and bees. Good cut flower.

Aromatic Aster in bloom in late Summer
© *Sally & Andy Wasowski*

Aromatic Aster in bloom
© *Sally & Andy Wasowski*

Arrow Arum
Peltandra virginica

Aquatic plant that requires wet soil. Easily grown in up to 6 inches of water. Plants will clump over time but do not colonize aggressively. Will spread by underground stems as well as by seed.

The flowers are pollinated by flies and wood ducks feed on the black berries.

Habitat: Sun

Arrow Arum colony
© *Dave Stephens bugwood.org*

Arrow Arum in flower
© *Ann Murray*

Arrow Arum at full height
© *Sally & Andy Wasowski*

Ashy Sunflower

Helianthus mollis

This plant is typically found growing in colonies. It can spread aggressively and may need to be weeded back to control. May need to be staked if it grows tall. Plants can be cut back in the early summer to control the height and increase flowering.

Attracts birds, bees and butterflies. Cut back dead plant material in the late winter to allow birds to feed on the seed during the winter months.

Habitat: Sun

Ashy Sunflower in bloom
© *Dropseed Nursery*

Ashy Sunflower in bloom
© *Tom Barnes*

Ashy Sunflower colony in bloom in late Summer
© *Mike Haddock*

Autumn Moor Grass

Sesleria autumnalis

This species spreads well and can be used for erosion control. Can be used as a ground cover under trees and shrubs and should be planted in clumps. Not entirely tolerant of high heat and humidity. Bold gold color display in autumn. Silvery flower stalks are produced in the late summer and are maintained through the winter, creating an attractive accent.

Attracts birds. Cut back the dead plant material in late winter. Plants can be divided in the early spring.

Habitat: Sun

Autumn Moor Grass in winter
© *The Battery Conservancy*

Autumn Moor Grass stand
© *Randy Stewart*

Autumn Moor Grass colony
© *The Battery Conservancy*

Awl-fruited Sedge

Carex stipata

Species tolerates inundation to a depth of up to 6 inches. If planted in the shade, Awl Fruited Sedge will tolerate dry soil. This species spreads quickly and is good for stabilizing disturbed sites. The golden yellow seed heads are attractive in the summer. The narrow leaves create a delicate texture.

The seed provides food for songbirds. The leaves are a food source for caterpillars of several species of butterfly.

Habitat: Sun

Awl Fruited Sedge colony
© *Paul Slichter*

Awl Fruited Sedge seed head
© *Paul Slichter*

Balloon Flower

Playtcodon grandiflorus "Sentimental Blue"

This species emerges late in the spring, so care must be taken not to disturb the soil before the plant emerges. Blooms most of the summer. Division and transplanting are possible but can be difficult because of the stringy root system.

Cut back dead plant material in the early spring.

Habitat: Sun

Balloon Flower in bloom in summer
© *Missouri Botanical Society*

Basal Balm

Monarda clinopodia

This plant forms widely spreading clumps. A member of the mint family, Basal Balm will spread, but not aggressively. The leaves are fragrant when crushed. Cut back dead plant material in the early spring.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun

Basal Balm in winter
© *Dropseed Nursery*

Basal Balm bloom in summer
© *William S. Justice*

Basal Balm at full height
© *Thomas L. Muller*

Beardtongue

Penstemon hirsutus "Pygmaeus"

Dwarf variety, the evergreen leaves will turn a bronze-red in the winter. One of the easiest penstemons to grow. Good for rock gardens. Plants can be divided in the spring.

Attracts butterflies, bees and hummingbirds. Makes a good cut flower. Spent blooms should be cut back in the late winter or early spring.

Habitat: Sun

Beardtongue in winter
© *Rob Broekhuis*

Beardtongue colony in bloom
© *Rob Broekhuis*

Beardtongue blossom
© *Rob Broekhuis*

Beardtongue
Penstemon digitalis "Husker Red"

Needs full sun for best red foliage color. Avoid wet, poorly-drained soil, root rot can occur. May need support during and after blooming. Spent seed heads can be cut back in early summer. The leaves are semi-evergreen and maintain a red color in the winter.

Attracts butterflies and birds. Makes nice cut flowers.

Habitat: Sun

Beardtongue blossom
© Missouri Botanical Garden

Beardtongue in winter
© Dropseed Nursery

Beardtongue at full height in summer
© Missouri Botanical Garden

Bee Balm
Monarda Fistulosa

Dead-head flowers to prolong summer bloom. Plant needs good air circulation and should not be crowded in order to avoid powdery mildew. Leaves are fragrant. This species can spread aggressively and may require weeding back to avoid excessive spread. Cut back dead plant material during the winter months.

Attracts butterflies, bees and hummingbirds.

Habitat: Sun

Bee Balm bloom
© Lynn Crosby Gammill

Bee Balm in winter
© Dropseed Nursery

Bee Balm stand in bloom in summer
© Thomas L. Muller

Bellflower
Campanulastrum americanum

Depending on moisture level and fertility of the soil, this plant can vary in size. Taller plants may need to be staked. During a drought, the plant often drops the lower leaves; however its deep tap root makes this species fairly drought tolerant. Cut back dead plant material during the winter months.

Attracts bees and butterflies. The flowers of this species are a treat for deer.

Habitat: Shade

American Bellflower blossom
© *Stan Gilliam*

American Bellflower stand in bloom
© *Sally & Andy Wasowski*

Bellflower
Campanula trachelium

This clump florming species creates a nice border. Dead-head flowers to prolong summer bloom. Cut back dead plant material during the winter months. Plants can be propagated by division in the spring or fall. This species is native to Denmark and England.

Good for cut flowers.

Habitat: Sun

Bellflower in bloom in summer
© *Rob Broekhuis*

Bellflower blossom
© *Rob Broekhuis*

Big Bluestem

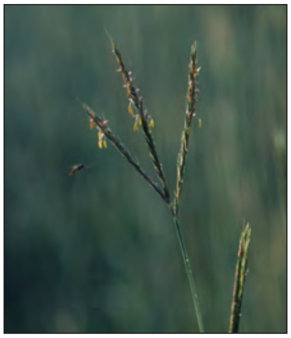
Andropogon gerardii

Strong fall color of reddish gold. Plants can be cut back in the early summer to maintain a shorter height. A dominate grass of the tallgrass prairie. Can be aggressive if left undisturbed. Species tends to flop over in winter months. Cut back dead plant material in the winter.

Prairie chickens and songbirds consume the seeds. One of the highest quality forage grasses on the prairie. Attracts butterflies and grasshoppers.

Habitat: Sun

Big Bluestem in summer



Big Bluestem flower
© *Sally & Andy Wasowski*

Big Bluestem in fall
© *Sally & Andy Wasowski*

Birdfoot Violet

Viola Pedatai

Prefers dry, rocky, sandy soils and full sun. Drought tolerant. Will not tolerant poorly drained soils. Considered one of the most beautiful violets in the world. Plants die back completely in the winter, leaving no visible plant remnants. Reproduction by seed only.

Several color forms of this species exist: pale purple, deep purple, and bicolor.

Attracts bees and butterflies. Adult butterflies use this species as a source of nectar, several caterpillar species feed on the petals and leaves. The seeds are dispersed by ants, which feed on the sugary gel coating the seeds.

Birdfoot Violet blossom
© *Jeff McMillan*

Bishop's Wort

Stachys officinalis

Clumps will spread over time to form a dense ground cover. This species makes a nice border plant. The leaves of Bishop's Wort are evergreen during mild winters. Flower color ranges from white and pink through reddish-purple. Spent flower spikes should be cut back in the fall

Good food source for bee and butterflies. Medicinal plant. This species grows well under Black Walnut Trees and is not attractive to deer.

Habitat: Sun

Bishop's Wort colony in bloom
© *Missouri Botanical Society*

Bishop's Wort bloom in early Summer
© *Missouri Botanical Society*

Bitter Root

Lewisia longipetala "Little Plum"

Blossom is typically bright rose-pink to red but can also open as orange initially making it possible to see three different color blossoms on the same plant. Very drought tolerant, Bitter Root prefers a well-drained rocky soil. Native to the Northwest U.S. The foliage of this species is evergreen. Cut back spent flowers in the late summer.

The flowers attract butterflies. This species is not attractive to deer.

Habitat: Sun

Bitter Root in bloom in Summer
© *Steven Perry*

Bitter Root bloom
© *Moon Rhythm*

Black-eyed Susan

Rudbeckia hirta

This species has a long flowering time from early through mid-summer. Biennial or short lived perennial. Can self-seed freely and may become aggressive. Weeding back may be required to prevent excessive spread. May need to be staked. Cut back dead plant material in the early spring to allow birds to feed on the seed during the winter months.

Attracts birds, bees and butterflies. This species can tolerate soils under Black Walnut trees. Makes good cut flowers.

Habitat: Sun

Black-eyed Susan in winter
© *Dropseed Nursery*

Black-eyed Susan blossom
© *Elaine Haug*

Black-eyed Susan colony in bloom
© *Sally & Andy Wasowski*

Bloody Cranesbill

Geranium sanguineum "Striatum"

Plants prefer full sun and well-drained soil. Drought tolerant. Makes a nice ground cover. Side stems may be removed at any time to control spread. If not deadheaded, some self-seeding may occur in ideal growing conditions. Foliage may decline after flowering in hot summer climates, at which point it may be lightly sheared back and shaped to revitalize. Foliage turns red in autumn. Native to Europe and Asia.

Deer resistant. Can be propagated from divisions in the spring or fall.

Bloody Cranesbill, in flower in spring
© *Missouri Botanical Garden*

Blue Fescue

Festuca glauca "Elijah Blue"

Clump forming. Can be used as a groundcover or edging plant. This drought tolerant species grows well in poor soil; however it can not tolerate poorly drained soil. Cut back in late winter or early spring. Plants are short lived and require frequent divisions. Foliage may decline in particularly hot or humid weather, but it remains evergreen during the winter.

Deer resistant.

Habitat: Sun

Blue Fescue clump in Spring
© *Missouri Botanical Garden*

Blue Fescue with seed heads
© *Missouri Botanical Garden*

Blue Fescue

Festuca ovina "glauca"

Clump forming. Works well as a ground cover or edging plant. Cut back in late winter or early spring. Does not tolerate high summer heat and humidity. Flowers have a red-purple color

Food source for several kinds of caterpillars. Deer resistant.

Habitat: Sun

Blue Fescue with seed heads in summer
© *Rob Broekhuis*

Blue Fescue

Festuca amethystina "Superba"

Clump forming. Cut back in late winter. Should be divided in winter to avoid clumps dying out in the center.

Habitat: Sun

Blue Fescue
© *Conservation Garden Park*

Blue Flag Iris

Iris virginica

Best grown in wet, boggy, acidic soils. In the wild, the roots of this iris are typically underwater for periods of time. Although the flowering period is brief in the spring, the broad, upright leaves are attractive throughout the growing season. A white form of the flower is rarely found.

Cut back dead leaves in the early spring to promote new growth.

Attracts bees and butterflies. Deer are not attracted to this plant since the leaves and roots are somewhat toxic.

Habitat: Sun

Blue Flag Iris blossom
© *Robert H. Mohlenbrock*

Blue Flag Iris in bloom in late Spring
© *Thomas Barnes*

Blue Lobelia

Lobelia siphilitica

Prefers partial sun and moist soil. Can tolerate full sun in moist soils. Divide clumps in spring as needed. May self seed in optimal conditions. Late summer blooms. Cut back dead plant material in the early winter through early spring. This species is longer-lived than its close relative, Cardinal Flower.

Attracts hummingbirds, bees and butterflies.

Habitat: Shade

Blue Lobelia in winter
© *Dropseed Native Plant Nursery*

Blue Lobelia in bloom
© *Dropseed Native Plant Nursery*

Blue Lobelia in bloom in late Summer
© *Dropseed Native Plant Nursery*

Blue Sage

Salvia azurea

This species prefers full sun and well drained soils. Drought tolerant. Has fragrant leaves. Also known as pitcher sage. Plant stems may be cut back to ½ inch in late spring to promote compactness and avoid stem flopping. Cut back again after flowering has concluded.

Attracts bees and butterflies.

Blue Sage in bloom in Spring
© *W.D. and Dolphia Bransford*

Blue Sage bloom
© *Campbell & Lynn Lougmiller*

Blue Vervain
Verbena hastata

Typically forms colonies in the wild by both thick, slowly spreading rhizomes and self-seeding. May self-seed in gardens in optimum growing conditions. Can be short-lived. Flowers on each spike bloom bottom to top, only a few at a time which prolongs the bloom period. Pinching off the tips of the plants several times during the growing season will encourage a bushier shape and increased number of flowers. Dead plant material should be cut back in the late fall through early spring.

Attracts bees, butterflies and birds. Although rabbits sometimes eat the plants, deer avoid it due to its bitter taste.

Habitat: Sun

Blue Vervain dormant in Winter
© *Dropseed Native Plant Nursery*

Blue Vervain in bloom
© *Missouri Botanical Garden*

Blue-Joint Grass
Calamagrostis canadensis

This species establishes easily and spreads quickly. Needs full sun and wet conditions. The flowers are purplish in mid-summer, turning to tan seed heads in the fall. Stands up well in the winter. Cut back in the early spring or later winter.

Attracts waterfowl. Is a forage species for Bison, Deer, and Elk.

Habitat: Sun

Blue-Joint Grass seed head
© *Robert H. Mohlenbrock*

Blue-Joint Grass in summer
© *Sally & Andy Wasowski*

Blunt Broom Sedge
Carex tribuloides

Prefers full sun andmoist conditions. Colonies often form over time. Produces attractive reddish brown seed heads in the summer. Cut back dead plant material during the winter months.

Several bird species feed on the seeds of this plants. The leaves of Blunt Broom Sedge are a food source for many moth and butterfly caterpillars.

Blunt Broom Sedge with seed head
© *Nicky Staunton*

Boneset
Eupatorium perfoliatum

Boneset has a fairly long flowering time from late summer into early fall. There is a faint floral scent. This species can spread by seed and by underground rhizome. May need to be staked depending on plant size. Dead plant material should be cut back during the winter months.

Attracts butterflies and bees. The flowers attract a species of wasp that can help control populations of pest insects. The bitter foliage is not attractive to deer or rabbits. Medicinal qualities.

Habitat: Sun

Boneset in bloom in late Summer
© *W.D. and Dolphia Bransford*

Boneset flower
© *Thomas Barnes*

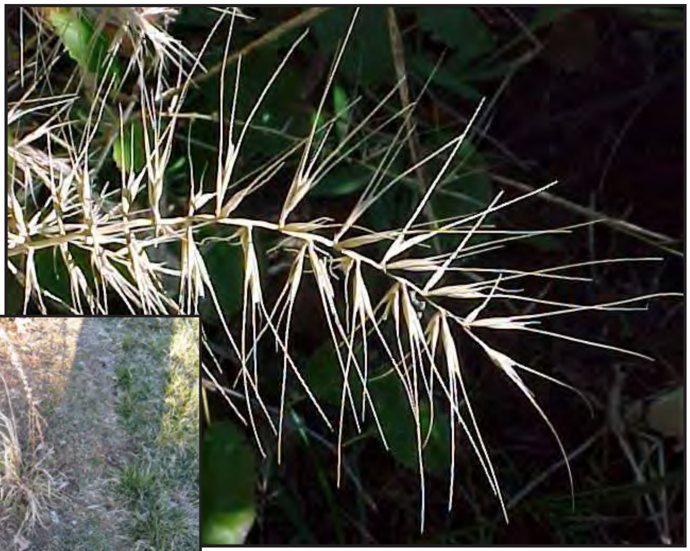
Boneset in winter
© *Dropseed Nursery*

Bottlebrush Grass
Hystrix patula

This very adaptable grass will grow in full sun or full shade and in moist or dry conditions. Bottlebrush Grass spreads primarily by re-seeding itself and may form small colonies of several plants. May become aggressive and require weeding to prevent its spread. Cut back in late winter or early spring. Can be used for erosion control.

Food source for many types of caterpillars. Attracts birds and butterflies.

Habitat: Shade



Bottlebrush Grass in summer
© *Missouri Botanical Garden*

Bottlebrush Grass seed head
© *Sally & Andy Wasowski*

Bottlebrush Grass in winter
© *Dropseed Nursery*

Broad-leaf Arrow-head
Sagittaria latifolia

Vigorous aquatic species. Flowers from July-September. Will self-seed and must dead-head spent flowers to prevent any unwanted self-seeding. Closely related to the Water Plantain. This species is reportedly tolerant of polluted water.

Underground tubers are a source of food for several species of ducks, muskrats and snapping turtles. Another common name for this species, Duck Potato, is related to the underground tuber that ducks enjoy to eat. The flowers attract bird and bees.

Habitat: Sun

Broad-leaf Arrow-head blossom
© *Missouri Botanical Garden*

© *Mike Haddock*

Broad-leaf Arrow-head in Summer
© *Sally & Andy Wasowski*

Cranesbill

Geranium cantabrigiense "Biokovo"

Cranesbill prefers full sun and well drained soil. Best grown as a groundcover. Has a long flowering time from early spring through the summer. This species spreads by underground stems, but is not invasive. Mostly evergreen. Names for its long, narrow seed pod that resemble a crane's bill

Attracts butterflies. Tolerates deer and rabbits. Can be propagated by division in the spring or early fall.

Habitat: Sun

Cranesbill in bloom in Spring
© *Missouri Botanical Garden*

Cranesbill

Geranium "Gerwat" Rizanne

Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun

Cranesbill in bloom in Spring
© *Missouri Botanical Garden*

Cranesbill blossom
© *Missouri Botanical Garden*

Cranesbill

Geranium cantabrigiense "Karmina"

Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun

Cranesbill in bloom in Spring
© *Missouri Botanical Garden*

Cranesbill blossom
© *Missouri Botanical Garden*

Cranesbill

Geranium sanguineum "Max Frei"

Great heat and drought tolerance and will typically bloom through the summer. Plant may be cut back to encourage more blooms. Spreads by underground stems, but is not invasive. A very hardy and easy to grow species. Very long flowering season from May-frost. Mostly evergreen. Named for its narrow seed pod that resembles a crane's bill.

Attracts butterflies. Tolerates deer and rabbits.

Habitat: Sun

Cranesbill in winter
© *Conservation Garden Park*

Cranesbill in bloom in spring
© *Rob Broekhuis*

Brome-like Sedge

Carex bromoides

Forms attractive, dense clumps. Dried remnants of older leaf blades are usually persistent around the base. Cut back late winter or early spring. Prefers wet to consistently wet conditions and full sun to part shade. There is an orange cast to the plants when they are in fruit.

Food source for several species of caterpillars. Attracts birds and ducks. Muskrats will sometimes feed on the roots.

Habitat: Sun

Brome-like Sedge
© *John Hilty*

Broomsedge

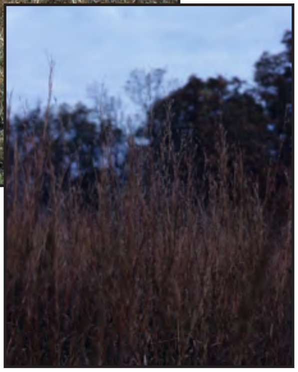
Andropogon virginicus

Very heat and drought tolerant. Adaptable to many soil types - good on dry, rocky soil as well as in bottomlands.The dried out foliage is a golden brown color andremains erect throughout the winter. Cut back in early spring. Most growth occurs in summer and early fall. Fast spreading and good for disturbed sites and erosion control.

Food source for several species of caterpillars and insects. Attracts birds. Provides nesting habitat for various birds and other wildlife.

Habitat: Sun

Broomsedge dormant in winter
© *Sally & Andy Wasowski*



Broomsedge with seed heads
© *Sally and Andy Wasowski*

Bundleflower

Desmanthus illinoensis

Erect plant. Can be weedy. Fern-like foliage can close up at night or in high heat.

Attracts birds, bees and butterflies. This plant fixes high amount of nitrogen into the soil and can help rejuvenate poor soil.

Habitat: Sun

Bundleflower colony in bloom
© *Sally & Andy Wasowski*

Bundleflower seed head
© *Joseph A. Marcus*

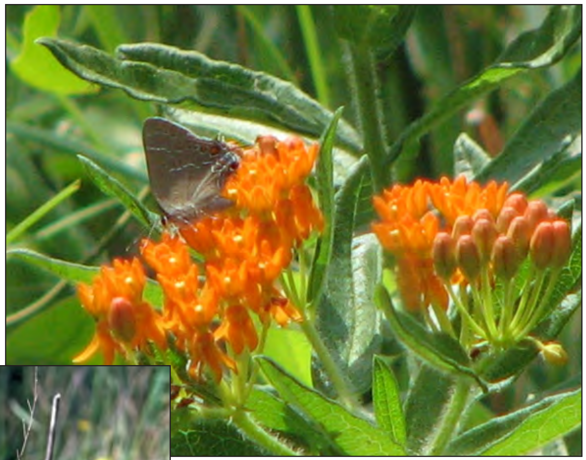
Butterfly Milkweed

Asclepias tuberosa

This species is slow to establish, but very drought tolerant once established. Butterfly Milkweed is susceptible to aphids, which can be taken care of by ladybugs or a soapy water spray. Does well in poor dry soils - is not tolerant of clay or poorly drained soils. Does not transplant well due to its deep taproot and is better left undisturbed. Flowers give way to prominent, spindle-shaped seed pods (3-6" long) which split open when ripe releasing numerous silky-tailed seeds for dispersal by the wind.

Attracts butterflies and hummingbirds. Important food source for adult and caterpillar Monarch butterflies.

Habitat: Sun



Butterfly Milkweed bloom
© *Sandy Smith*

Butterfly Milkweed seed pod
© *M.W. Carlton*

Butterfly Milkweed seed pod
© *Dropseed Nursery*

Calico Aster

Symphyotrichum lateriflorum (Aster lateriflorus)

Easily grown in full sun to partial shade. Taller plants may need to be supported, or plants can be pinched back in the early summer to create shorter, fuller plants. Dead plant material should be cut back in late winter. Has a fairly long flowering season from late summer through the fall.

Attracts butterflies.

Habitat: Shade

Calico Aster in bloom in late Summer
© *W.D. and Dolphia Bransford*

Calico Aster bloom
© *W.D. and Dolphia Bransford*

Cardinal Flower

Lobelia cardinalis

Plant can be propagated by bending a stem down into the mud and fastening it with a rock or stick. Clumps can be divided in the spring. Needs constant moisture. Great for open shady border areas. Can tolerate full sun with moist soil. Tends to be short-lived.

Attracts birds, butterflies and hummingbirds.

Habitat: Shade

Cardinal Flower in winter
© *Dropseed Nursery*

Cardinal Flower blossom
© *Steven Faucette*

Cardinal Flower in bloom in late Summer
©*Tom Barnes*

Catmint

Nepeta faassenii "Blue Wonder"

Drought and heat tolerant. Fragrant foliage. Will. flower for most of the summer. Variable habit ranging from upright to clumping to bushy. Cutting back seed heads after flowering will promote a second bloom. Does not self-seed, seeds are sterile. Propagate with divisions of root ball in the spring. Cut back dead plant material in the winter months. Grows well in urban areas; tolerant of air pollution.

Attracts bees, birds and butterflies. Resistant to deer and rabbits.

Habitat: Sun

Catmint in bloom in Summer
© *Missouri Botanical Garden*

Catmint bloom
© *Missouri Botanical Garden*

Catmint

Nepeta faassenii "Walker's"

Very drought and heat tolerant. Fragrant foliage. Will flower for most of the summer. Variable habit ranging from upright to clumping to bushy. Cutting back seed heads after flowering will promote a second bloom. Does not self-seed, seeds are sterile. Propagate with divisions of root ball in the spring. Cut back dead plant material in the winter months. Grows well in urban areas; tolerant of air pollution.

Attracts bees, birds and butterflies. Resistant to deer and rabbits.

Habitat: Sun

Catmint in bloom in Summer
© *Missouri Botanical Garden*

Catmint in bloom in Summer
© *Missouri Botanical Garden*

Celandine Poppy

Stylophorum diphyllum

Shade loving species with showy flower. Best grown in moist soil and will go dormant in early summer if the soil is too dry. An attractive seed pod forms following the flowers. Once dormant, the dead plant material breaks down quickly, so cutting back is not necessary. Chipmunks feed on the seeds. Ants dispers the seed, feeding on the attached fleshy material.

Habitat: Shade

Celandine Poppy in bloom in Spring
© *Henry Domke*

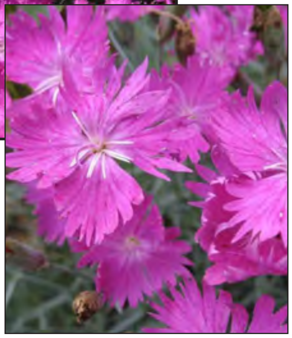
Celandine Poppy bloom
© *Lynn Crosby Gammill*

Cheddar Pinks

Dianthus feuerhexe "Firewitch"

Prefers full sun and well drained soil. Evergreen. Tolerates heat and humidity better than some Dianthus species. Produces clove-scented bright pink flowers. Deadhead flowers to promote new blooms. Mat-forming quality makes it great as a ground cover. Care should be taken when mulching the plants not to allow a build up of mulch around the plants which will cause rotting. Plants can be propagated by division in the spring or fall.

Cheddar Pink in bloom in Spring
© *Missouri Botanical Garden*



Cheddar Pink blossom
© *Missouri Botanical Garden*

Cheddar Pinks

Dianthus subacaulis "Gary Eichhorn"

Prefers full sun and well drained soil. Deadhead flowers to promote new blooms. Care should be taken when mulching the plant not to allow a build up of mulch around the plant which will cause rot. Evergreen mat-forming quality makes it great as a ground cover. Produces fragrant pink flowers.

Habitat: Sun

Cheddar pinks
© *The Trial Gardens at UGA*

Cheddar pinks
© *The Trial Gardens at UGA*

Chives

Allium schoenoprasum

This spring-flowering plant is drought tolerant. Prefers full sun and well drained soil. Forms dense clumps which are easily divided in spring or fall. Easily grown from seed and will self-seed in the garden if spent flower heads are not promptly dead-headed. Native to Asia and Eastern Europe.

Culinary uses. Deer resistant. Can be planted beneath Black Walnut trees. The flowers are pollinated by bees and flies.

Habitat: Sun

Chives dormant in winter
© *Conservation Garden Park*

Chives in bloom in spring
© *Missouri Botanical Garden*

Cinnamon Fern

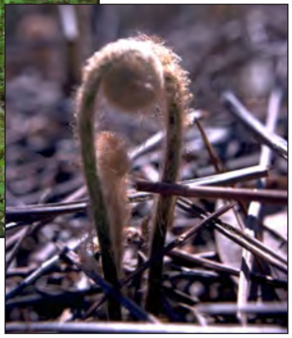
Osmunda cinnamomea

Prefers partial shade. The contrasting stature of fertile and infertile fronds can make for dramatic accents in a landscape. The common name refers to the cinnamon colored fibers near the base of the leaves. Slow growing. Requires moist soil or standing water. Cut back dead plant material in the early spring.

Attracts birds.

Habitat: Shade

Cinnamon Fern with fronds in summer
© *Andy & Sally Wasowski*



Cinnamon Fern fiddleheads
© *Campbell & Lynn Loughmiller*

Cinquefoil

Potentilla neumanniana "Nana"

Grows best in full sun and well drained soil. This species flowers in early summer, but will sometimes have a second bloom in the fall. This mat-forming plant can form a dense ground cover. When grown as a ground cover, it can be mowed occasionally on a high setting to trim up the plants. Leaves are fragrant. The plant is evergreen in mild winters. Easily propagated by division in the spring or fall.

Habitat: Sun

Cinquefoil in bloom in spring
© *Missouri Botanical Garden*

Cleft Phlox
Phlox bifida

Prefers full sun and well drained soil. Mat-forming phlox that grows to only 6" tall, and spreads by trailing or spreading tems and self-seeding to form large colonies over time. Can be used as groundcover or for erosion control. Consider the plant species that are placed near these plants, Cleft Phlox is easily taken over by more aggressive species.

The flowers attract adult butterflies and the leaves are a food source for caterpillars of several moth species.

Cleft Phlox blossom
© *George H. Bruso*

Common Mountain Mint
Pycnanthemum virginianum

This species prefers full sun, but is tolerant of a wide variety of soil types. Makes a nice border planting since the leaves are fragrant when you brush past them. Clusters of flowers open only a few at a time. Can be aggressive in moist soil. Cut back previous years' growth during the winter months.

Attracts butterflies and a wide variety of other beneficial insects.

Deer resistant.

Habitat: Sun

Common Mountain Mint in bloom
© *Sally and Andy Wasowski*

Common Mountain Mint
in bloom
© *Dropseed Nursery*

Common Wood Reed

Cinna arundinacea

Prefers light shade and moist soil. The green flowers are produced in the late summer into early fall and develop into tan seed heads in the later fall and winter. Commonly grows as scattered plants. Cut back in late winter.

Does not seem to attract deer.

Common Wood Reed in the fall
© *Paul Drobot*

Common Wood Reed seed heads
© *Robert Freckman*

Compass Plant

Silphium lacinatum

Grows best in full sun, but is adaptable to many soil conditions. Tall prairie plant with large leaves and very deep tap root. Very drought tolerant. Long-lived blooms. Slow to establish and may not flower until the second or third year. May require staking. Planting this species next to Switchgrass can eliminate the need for staking. Cut back dead plant material in the early spring to allow birds to feed on the seeds over the winter months.

Attracts birds and butterflies.

Habitat: Sun

Compass Plant in winter
© *Dropseed Nursery*

Compass Plant blossom
© *Paul Cox*

Compass Plant in bloom
© *Sally & Andy Wasowski*

Coral Bells

Heuchera "Rave On"

Does best in well-drained soil and partial shade. May require watering during periods of drought. Remove stems of spent flowers to encourage more blooms. This is a heavy flowering cultivar. Mulch applied in winter will help to prevent root heaving. Divide clumps in spring every 3-4 years.

Makes nice cut flowers.

Habitat: Sun

Coral Bells
© *Missouri Botanical Garden*

Creeping Baby's Breath

Gypsophila repens "Alba"

Requires full sun and well drained soil. Easy to grow and drought tolerant. Dwarf hybrid forms a low mass of gray green leaves with an abundance of white flowers in early summer. Cut back dried flower stalks in the late winter. Can be evergreen in mild winters. Propagate by division in the spring or fall.

Attracts butterflies.

Habitat: Sun

Creeping Baby's Breath dormant in winter
© *Conservation Garden Park*

Creeping Baby's Breath
© *Conservation Garden Park*

Creeping Baby's Breath

Gypsophila repens "Rosea"

Requires full sun and well drained soil. Easy to grow and drought tolerant. Dwarf hybrid forms a low mass of gray green leaves with an abundance of white flowers in early summer. Cut back dried flower stalks in the late winter. Can be evergreen in mild winters. Propagate by division in the spring or fall.

Attracts butterflies.

Habitat: Sun

Creeping Baby's Breath dormant in winter
© *Conservation Garden Park*

Creeping Thyme

Thymus praecox

Prefers full sun and well drained soil. This fast growing plant is very drought tolerant. This species forms a ground cover that will tolerate foot traffic.Cut back stems to control growth or appearance. Propagate by division in the spring or fall.

Attracts butterflies and bees. Deer resistant.

Habitat: Sun

Creeping Thyme dormant in winter
© *Conservation Garden Park*

Creeping Thyme in bloom
© *Rob Broekhuis*

Crested Sedge
Carex cristatella

This species requires moist soil with full sun to partial shaes. Forms an attractive brown fruit in the late summer.This sedge spreads by rhizomes and by reseeding itself. Most vegetative growth occurs during the spring and early summer. Cut the dead plant material back in the early spring to allow birds to feed on the seeds over the winter months.

Food source for caterpillars and birds.

Habitat: Sun

Crested Sedge seed head
© *Robert Mohlenbrock*

Culver's Root
Veronicastrum virginicum

Grows best in full sun and moist soil. Very dramatic when in flower. Seldom needs staking except when grown in too much shade. Cut back dead plant material during the winter months. Usually takes several years to establish itself in the garden.

Attracts butterflies and bees. Medicinal plant.

Habitat: Sun

Culver's Root in bloom
© *George H. Bruso*

Culver's Root in winter
© *Dropseed Nursery*

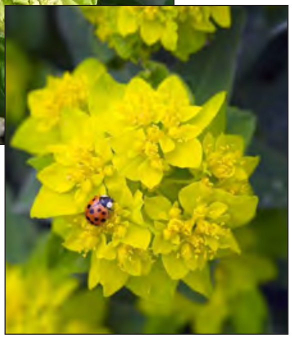
Cushion Spurge
Euphorbia polychroma

Requires well drained soil and full sun to partial shade.Cymes of inconspicuous greenish flowers (lacking both sepals and petals) bloom at the stem ends in spring followed by long-lasting, bright sulphur-yellow bracts which are exceptionally showy and last through summer. Leaves turn red, orange and purple in the fall. Freely self-seeds. Promptly remove spent flowers to prevent any unwanted self-seeding. Trim back plants to 4" in the early summer to keep a compact form.

Attracts butterflies and bees. Deer and rabbit resistant.

Habitat: Sun

Cushion Spurge in spring
© *Missouri Botanical Garden*



Cushion Spurge blossom
© *Missouri Botanical Garden*

Green-headed Coneflower
Rudbeckia laciniata

Grows in full sun and moist soil. Most appropriate for large sites that require quick coverage. Can plant with tall native grasses like Switchgrass and Big Bluestem to support the sometimes floppy stems. Remove spent blooms to encourage a fall rebloom. Divide clumps to control growth. This species spreads rampantly by underground stems. Cut back dead plant material in the early spring to allow birds to feed on the seeds during the winter months.

Attracts butterflies, bees and birds.

Green-headed Coneflower, in flower
in mid summer
© *Sally & Andy Wasowski*

Geenheaded Coneflower,
flower up close
© *Mike Haddock*

Cylindrical Blazing Star

Liatris cylindracea

Very showy and drought tolerant plant. Intolerant of wet soils in winter. Tolerant of summer heat and humidity. Cut back last years growth during the winter months.

Attracts birds, butterflies, hummingbirds and bees.

Habitat: Sun

Cylindrical Blazing Star in bloom
© *Thomas G. Barnes*

Cypress Spurge

Euphorbia cyparissias "Fen's Ruby"

Quite tolerant of poor soils, including rocky, sandy ones. Eight to ten plants per square yard are sufficient to quickly form a dense ground cover. Spreads by rhizomes and can be quite invasive, particularly in rich, moist soils. Also freely reseeds. The evergreen leaves turn orange in the fall. Plants are toxic.

Habitat: Sun

Cypress Spurge in bloom
© *Missouri Botanical Garden*

Cypress Spurge in winter
© *Conservation Garden Park*

Cypress Spurge foliage and bloom
© *Conservation Garden Park*

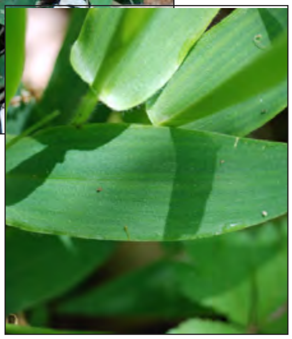
Deertongue Panic Grass
Dichanthelium clandestinum

Prefers partial shade and moist conditions. In some situations, this grass can spread aggressively via its rhizomes.

Food source for caterpillars and grasshoppers. Seed heads are consumed by birds.

Habitat: Shade

Deertongue Panic Grass in summer
© *Mike Haddock*



Deertongue Panic Grass
leaf blade
© *Mike Haddock*

Dense Blazing Star
Liatris spicata

Prefers full sun and moist soil. Taller plants may require staking or other support. Tolerant of summer heat and humidity. Cut back last year's growth during the winter months. Also known as Spiked Gayfeather.

Attracts bees, butterflies and hummingbirds. Makes nice cut flowers.

Habitat: Sun

Dense Blazing Star in bloom
© *Sally & Andy Wasowski*

Dense Blazing Star blossom
© *Julie Makin*

Downy Alumroot

Heuchera Americana "Dale's Strain"

Requires partial shade; drought tolerant. Good ground cover. Leaves are semi-evergreen. Remove stems of faded flower panicles to encourage continued bloom. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Leaves are semi-evergreen. Divide clumps in spring every 3-4 years. Foliage has attractive fall colors.

Seldom browsed by deer. Make nice cut flowers.

Habitat: Sun

Downy Alumroot foliage
© *Missouri Botanical Garden*

Downy Alumroot

Heuchera americana

Requires partial shade; drought tolerant. Good ground cover. Leaves are semi-evergreen. Remove stems of faded flower panicles to encourage continued bloom. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Leaves are semi-evergreen. Divide clumps in spring every 3-4 years. Foliage has attractive fall colors.

Seldom browsed by deer. Make nice cut flowers.

Habitat: Sun

Downy Alumroot foliage
© *Missouri Botanical Garden*

Downy Alumroot colony in bloom
© *Sally & Andy Wasowski*

Downy Skullcap

Scutellaria incana

This easy to grow plant perfers partial shade and moist conditions. Can grow at light levels from deep shade to full sun. Best on dryish, sandy or clay soils. A very attractive plant withh a tidy form. Cut back previous year's growth during the winter months.

Attractive food source for bumblebees. The bitter foliage is not attractive to deer or rabbits.

Downy Skullcap in winter
© *Dropseed Nursery*

Downy Skullcap blossom
© *Sally & Andy Wasowski*

Downy Skullcap in bloom
© *Sally & Andy Wasowski*

Downy Wood Mint

Blephilia ciliata

This drought tolerant species prefers full to partial sun.Similar in appearance to the closely related Bee Balm. Leaves are mildly fragrant when crushed. Leaves are usually considered to be lacking in the pungency and quality needed for use as a culinary herb. Small basal leaves and shoots remain green throughout the winter. Cut back spent flower stalks in the late summer to encourage full growth of the foliage.

The flowers are attractive to bees and butterflies. Foliage is often nibbled on by insects and plants can become rather tattered and unkempt by late summer.

Habitat: Shade

Downy Skullcap blossom
© *Sally & Andy Wasowski*

Dwarf Balloon Flower

Platycodon grandiflorus

These plants emerge late in the spring, so take care not to disturb the soil before they emerge. Grows well in average soil in full sun to part shade. Deadheading spent flowers generally prolongs the bloom period. Taller plants often need to be staked because of floppy stems. Consider cutting back plant stems by 1/2 in May to reduce plant height and possibly avoid staking. Cut back last year's growth in the early spring.

Makes a good cut flower.

Habitat: Sun

Dwarf Balloon Flower in bloom
© *Missouri Botanical Garden*

Dwarf Balloon Flower blossom
© *Missouri Botanical Garden*

Dwarf Bearded Iris

Iris pumila "Baby Blessed-yellow"

Good soil drainage is essential to combat potential soft rot problems. Avoid use of mulch for the same reason. Fertilize lightly in early spring. Fertilize again after bloom and continue to provide uniform moisture throughout the summer to encourage the late summer to fall rebloom. Avoid overhead watering. Deadhead individual spent flowers and remove flowering stems to the ground after bloom. Divide plants when overcrowding occurs (every 3-4 years).

Habitat: Sun

Dwarf Bearded Iris Baby Blessed Yellow
© *Pittsburg Parks Conservancy*

Dwarf Bearded Iris

Iris pumila "Sarah Taylor"

Good soil drainage is essential to combat potential soft rot problems. Avoid use of mulch for the same reason. Fertilize lightly in early spring. Fertilize again after bloom and continue to provide uniform moisture throughout the summer to encourage the late summer to fall rebloom. Avoid overhead watering. Deadhead individual spent flowers and remove flowering stems to the ground after bloom. Divide plants when overcrowding occurs (every 3-4 years).

Habitat: Sun

Dwarf Iris Sarah Taylor
© *www.gardenworldimages.net*

Dwarf Bluestar

Amsonia tabernaemontana "Short Stack"

Requires moist soil. Foliage turns an attractive bright yellow in fall. Best fall foliage color usually occurs in full sun, but flowers generally last longer if given some afternoon shade in hot sun areas. If grown in too much shade, stems may open up and flop. Cut back last year's growth during the winter months. This cultivar is typically less than 1' tall. Best propagated by cuttings.

Habitat: Sun

Dwarf Bluestar in bloom
© *Missouri Botanical Society*

Early Goldenrod

Solidago juncea

Likes full sun. Earliest goldenrod to bloom. Tolerates poor, dry soils. Remove spent flower clusters to encourage additional bloom. May need to be divided every 2 to 3 years to control growth. This species is a good choice for large areas that require fast coverage. Cut back last year's growth during the winter months.

Attracts bees, butterflies and birds.

Habitat: Sun

Early Goldenrod in bloom
@ W.D. and Dolphia Bransford

Eastern Blue-eyed Grass

Sisyrinchium atlanticum

A grass-like, clumped perennial, to 20 in. high, with pale-green foliage and flattened flowering stems terminating in loose clusters of pale-blue, six-petaled, yellow-centered flowers. A member of the iris family. Grows best in moist conditions and full sun. This delicate plant makes a nice border.

Attracts bees.

Eastern Blue-eyes Grass in bloom
© Harry Cliffe

Eastern Bluestar
Amsonia tabernaemontana

When grown in full sun, plants often require no pruning or staking. Can tolerate poorly drained soil and some drought. When grown in some shade and/or in rich soils, however, plants tend to become more open and floppy and often require staking or pruning. For a neater appearance stems may be cut back by 1/2 to 1/3 after flowering to promote bushy growth and, if desired, a more rounded foliage mound. Foliage may turn an attractive yellow in fall. Cut back last season's growth during the winter months. This species is very easy to grow with few disease or pest problems.

Not attractive to deer.

Habitat: Sun

Eastern Bluestar in winter
© *Dropseed Nursery*

Eastern Bluestar blossom
© *Sally & Andy Wasowski*

Eastern Bluestar stand in bloom in spring
© *M.W. Carlton*

Eastern Gamma Grass
Tripsacum dactyloides

This species prefers full sun and moist soil. Typically grows in the wild in pure stands on rairies, limestone slopes, fields, thickets, wood margins and roadsides. Naturalizes by thick, creeping rhizomes and self-seeding. Interesting fall colors. Can become floppy- to avoid this, cut back plants in early summer to keep a shorter, erect form. Cut back to ground after frost kills the foliage.

Food source for caterpillars. Attracts birds and livestock.

Habitat: Sun

Eastern Gama Grass with flower spikes
© *Beth Anderson*

Eastern Gama Grass flower spikes
© *Mike Haddock*

Elm-leaved Goldenrod
Solidago ulmifolia

This species prefers moist to dry shade. Flowers occur on the upper side of hairy stalks which arch out and downward creating a vase-shaped flower cluster. Cut back in late winter. The plants can spread by underground rhizomes; however this is not a particularly aggressively spreading species of goldenrod. Cut back dead plant material in the early spring to allow birds to feed on the seeds over the winter months.

Food source for bees and caterpillars of several moth species. Seeds are a food source for birds.

Habitat: Sun

Goldenrod flowers
© *R.W. Smith*

Elm-leaved Goldenrod
in bloom
© *Mrs. W.D. Bransford*

False Aloe
Manfreda virginica

Drought tolerant, does best in full sun. Long summer bloom occasionally extends into fall. Flowers give way to capsule-like fruit. Fragrant flower. Cut back flowering stalk in the winter months.

Attracts hummingbirds and moths.

Habitat: Sun

False Aloe dormant in winter
© *Dropseed Native Plant Nursery*

False Aloe in Summer
© *Erin Wagoner*

False Blue Indigo
Baptisia australis

Prefers full sun. Over time, plants develop slowly expanding clumps with deep and extensive root systems and should not be disturbed once established. May be grown from seed, but takes several years to establish. Plants take on more of a shrubby appearance and tend to open up after bloom. Trimming or shearing foliage after bloom helps maintain rounded plant appearance and avoids a possible need for staking, but eliminates the developing attractive seed pods. Cut back last year's growth during the winter months.

Attracts butterflies and bees.

Habitat: Sun


False Blue Indigo in winter
© *Dropseed Nursery*


False Blue Indigo blossom
© *Harry Cliffe*


False Blue Indigo in Summer
© *R.W. Smith*

False Sunflower
Heliopsis helianthoides

Tolerates poor soil, grows best in full sun. Quick to establish and easy to grow. Remove spent flowers to extend the blooming season. Some susceptibility to aphids. Taller plants may need staking or other support. Lengthy summer to early fall bloom.

Attracts butterflies, hummingbrds and bees. Works well as a cut flower.

Habitat: Sun

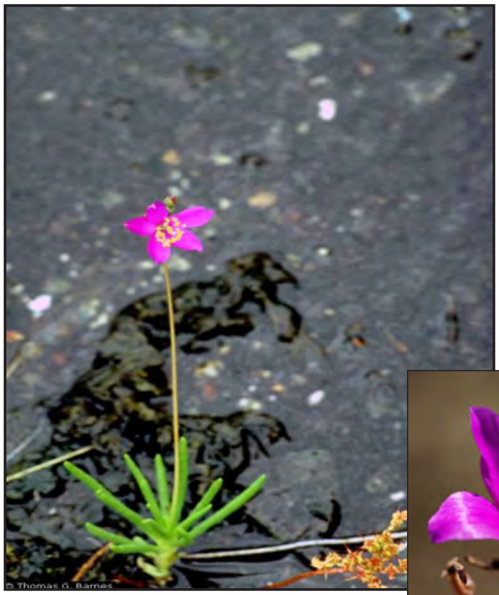

False Sunflower dormant in early Winter
© *Robert L. Stone*

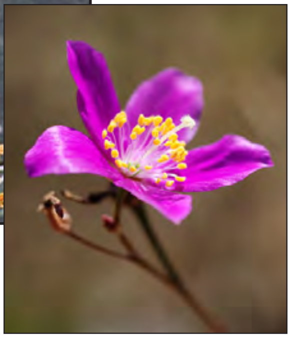

False Sunflower in Summer
© *Sally & Andy Wasowski*

Fame Flower
Talinum calcaricum

Prefers dry or sandy soil. The flowers open in the afternoon or in overcast conditions. This delivate plant is easily out-competed by other vegetation in moist soils. Works well on green roofs or in rock gardens. In good conditions the plants will spread by seed. Dies back completely in the witner - no cutting back needed.

Attracts bees and butterflies.


Fame Flower in bloom
© *Thomas G. Barnes*


Fame Flower blossom
© *Mike Haddock*

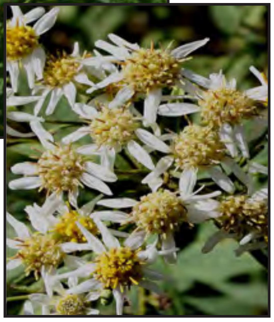
Flat-topped Aster
Doellingeria umbellata (Aster umbellatus)

Prefers full or partial sun and moist conditions. This aster of wet meadows is one of the first asters to bloom - starting in August. Flat-topped Aster can be cut back early in the season to maintain a shorter, fuller form with more flowers. Cut back dead plant material in late fall or early winter.

Attracts bees and butterflies.

Habitat: Sun


Flat-topped Aster
© *Stefan Bloodworth*


Flat-topped Aster blossoms
© *R.W. Smith*

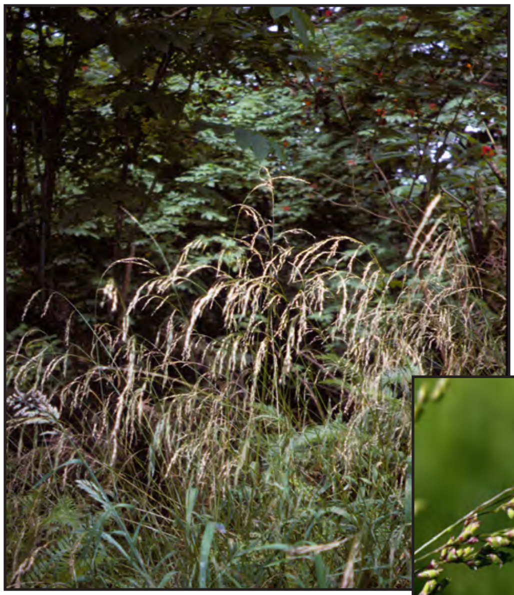
Fowl Manna Grass

Glyceria striata

This grass requires more moisture in sunny areas than when it is growing in the shade. Most vegetative growth occurs during the spring and early summer. This is a good species for wetland restorations. If desired, cut back last season's growth during the winter months. In a wetland setting, leaving the previous year's growth will not inhibit new growth.

Attractive to livestock but not palatable to deer. Provides cover for wildlife.

Habitat: Sun



Fowl Manna Grass
© *Sally & Andy Wasowski*

Fowl Manna Grass flowers
© *R.W. Smith*

Fox Sedge

Carex vulpinoidea

Prefers full sun and moist soil. Good colonizer of disturbed, open, moist ground. This sedge may be weedy and spreads rapidly. Named for the brown cluster of fruit that forms mid-summer and looks like a fox tail. Cut back last year's dead plant material in the early spread to allow birds to feed on the seed during the winter months. This low-growing sedge makes a nice border in a moist area.

Attracts birds.

Habitat: Sun

Fox Sedge dormant in winter
© *Dropseed Native Plant Nursery*

Fox Sedge with seed heads
© *Sally & Andy Wasowski*

Foxglove Beardtongue

Penstemon digitalis

Avoid wet, poorly drained soils. Prefers full sun. Cut back the spent flowering stalks in mid-summer for a tidier look. Leaves remain evergreen during mild winters.

Attracts birds, hummingbirds, bees and butterflies.

Habitat: Sun

Foxglove Beardtongue in winter
© *Dropseed Native Plant Nursery*

Foxglove Beardtongue
© *W. D. and Dolphia Bransford*

Frank's Sedge

Carex frankii

This sedge grow abundantly in wet locations such as swamps, wet meadows, wet prairies and around rivers, lakes, streams and ponds. Prefers full sun. Cut back last year's dead plant material in the early spring to stimulate new growth. Makes a nice border planting in moist sites.

Food source for waterfowl.

Habitat: Sun

Frank's Sedge dormant in winter
© *Dropseed Native Plant Nursery*

Frank's Sedge with seed heads
© *Patrick J. Alexander*

Fringed Sedge
Carex crinita

Grows best in full sun or light shade and moist conditions. The distinctive long, dangling fruig are attractive. This sedge often forms colonies of plants. Some seasonal flooding is tolerated. This is a rather lanky sedge that leans to one side as the spikelets develop. Cut back last year's growth during the winter months.

Food source for caterpillars of moths and butterflies. Food source for wetland birds and ducks.

Habitat: Sun

Fringed Sedge with seed heads
© *Robert Mohlenbrock*

Frost Aster
Symphyotrichum pilosum (Aster pilosus)

Prefers meadows and open woodlands. The disk flowers at the center of the flower heads open yellow, but turn reddish after they are pollinated. The plants can be cut back in June to create a fuller, shorter shaped plant with more flowers. Cut back last year's growth during the winter months.

Attracts birds, bees and butterflies.

Habitat: Sun

Frost Aster in bloom in fall
©*W. D. and Dolphia Bransford*

Frost Aster blossom
© *Julie Makin*

Fumitory

Corydalis lutea

This species prefers full sun to part shade and well drained soil. Wet soils in winter can be fatal. Generally intolerant of hot and humid summer conditions. May aggressively self-seed in the garden in optimum growing conditions. If foliage significantly depreciates in hot summers, plants may be cut back to basal leaves. Long bloom period. Native to southeastern Europe, this species is a weed in the cool climate of Great Britain. Best propagated by seed.

Habitat: Sun

Fumitory in bloom in Summer
© *Missouri Botanical Garden*

Fumitory blossoms
© *Missouri Botanical Garden*

Gaura

Gaura lindheimeri "Siskiyou Pink"

Good drainage is essential. A taprooted plant which tolerates heat, humidity and some drought. Remove spent flower panicles to prolong bloom period. Plants may be cut back in late spring by 1/2 to control size. May self-seed if spent flowers are left in place in autumn. Prefers full sun.

Attracts bees. Deer and rabbit resistant. Good cut flowers.

Habitat: Sun

Gaura dormant in winter
© *Conservation Garden Park*

Gaura in bloom in Summer
© *Missouri Botanical Garden*

Germander

Teucrium canadense

The dense flower spikes can be quite a show, especially when a good sized clump is planted. Plants spread on their own over time by rhizomes and may become aggressive if not kept in check periodically. Prefers moist or shallow, submerged soils and full sun. Cut back last year's growth during the winter months. A member of the mint family, this species has a long flowering period throughout the mid summer.

Attracts butterflies, bees, hummingbirds, and hummingbird moths. Makes a good cut flower.

Habitat: Sun

Germander in bloom in Summer
© *Steven Schwartzman*

Germander blossom
© *Kathleen Graves Cook*

Geum

Geum triflorum

This species prefers well drained soil and full sun. Drought tolerant. Root rot can be a problem in poorly drained soils, particularly in winter. Mature plants frequently form dense mats creating an attractive ground cover. Pink flowers are followed by attractive plume-tailed seeds. Leaves turn deep red in the fall and can be evergreen in mile winters.

Attracts butterflies. Deer resistant. Medicinal plant.

Habitat: Sun

Geum in bloom in Summer
© *John Hixson*

Geum fruiting heads
© *John Hixson*

Giant Bur-reed

Sparganium eurycarpum

Bur reeds are aquatic or marsh herbs with grass-like leaves, and small flowers densely crowded into globose heads in or above the axils of bract-like leaves. Prefers full sun and wet conditions. Good plant for wetland restorations. Last year's growth can be cut back during the winter months; however, plants will thrive in wetland settings without cutting back.

Food source for wetland birds and caterpillars of various moths.

Habitat: Sun

Giant Bur-reed in Summer
© *Mrs. W.D. Bransford*

Giant Bur-reed in flower
© *R.W. Smith*

Goat's Rue

Tephrosia virginiana

Prefers moist conditions and full sun. Good resistance to drought. Once established, plants are best left alone because division and transplanting are difficult. Roots fix nitrogen. A member of the pea family, this species forms long seed pods following flowering. Plant parts are toxic. Cut back last year's growth during the winter months

Attracts butterflies and bees. Wild Turkey feed on the seeds.

Habitat: Sun

Goat's Rue in Summer
© *W.D. and Dolphia Bransford*

Goat's Rue blossom
© *Sally and Andy Wasowski*

Golden Alexanders
Zizia aurea

Often occurs in small colonies. An easy to grow species that is not at all aggressive in the garden. Foliage tends to depreciate as the summer progresses. In ideal conditions can reseed heavily. Dry seedheads turn purple, adding summer interest. Cut back dead plant material in the early spring.

Attracts butterflies and bees. Food source for caterpillars.

Habitat: Sun

Golden Alexanderdormant in winter
© *Sally & Andy Wasowski*

Golden Alexander in Summer
© *Sally & Andy Wasowski*

Golden Ragwort
Packera aureas

Naturalizes into large colonies in optimum growing conditions. Remove flowering stems after bloom/seed dispersal. Basal foliage will serve as an attractive ground cover throughout the growing season as long as consistent moisture is provided. Can be aggressive and may require some weeding out to keep in check. Known for ability to thrive in shady locations. Leaves can be evergreen during mild winters. Plant parts are mildly toxic.

Attracts butterflies and bees.

Habitat: Sun

Golden Ragwort colony in bloom
© *Missouri Botanical Garden*

Golden Ragwort in Summer
© *Missouri Botanical Garden*

Golden Stonecrop
Sedum acre "Aureum"

Tolerates part shade, heat, drought and poor soils. Prefers full sun. Can be used as a groundcover and will withstand some foot traffic. Can be used as a lawn replacement. Fast growing and easy to propagate from cuttings. Leaves develop an attractive red color in the winter.

Attracts butterflies. Deer and rabbit resistant.

Habitat: Sun

Golden Stonecrop dormant in Winter
© *Conservation Garden Park*

Golden Stonecrop in Summer
© *Conservation Garden Park*

Blue-Stemmed Goldenrod
Solidago caesia

Prefers sun to partial shade and dry conditions. Does not spread as aggressively as other goldenrod species. Cut back last year's growth in the late winter so that birds can feed on the seeds during the winter months.

Attracts butterflies, birds, insects and bees. Food source for many species of caterpillars.

Habitat: Shade

Goldenrod
© *Stefan Bloodworth*

Goldenrod
© *Mrs. W.D. Bransford*

Grass-leaved Goldenrod
Euthamia graminifolia

The flat-topped floral arrangement and narrow leaves of this Goldenrod are distinctive. Sometimes it is slender and little branched, while at other times it branches frequently, creating a bushy appearance. Can spread aggressively in moist sunny conditions. Cut back plants in the late winter.

Attracts bees and wasps. Food source for caterpillars. Seeds consumed by a small number of birds.

Habitat: Sun

Grass-leaved Goldenrod flowers
© *Tom Barnes*


Grass-leaved Goldenrod in winter
© *Dropseed Nursery*

Gray Goldenrod
Solidago nemoralis

Prefers full sun, can tolerate both well drained and clay soil. A small goldenrod, this plant seldom reaches 2 ft. in height. Flowers late into the fall. It's a good choice for difficult locations, such as slopes or areas with poor soil, where little else will grow. Not as aggressive as many goldenrod species. Cut back plants in late winter.

Attracts bees and butterflies. Food source for caterpillars. Seeds consumed by a small number of birds. Makes a nice cut flower.

Habitat: Sun


Gray Goldenrod in winter
© *Dropseed Nursery*


Gray Goldenrod in bloom in fall
© *Mrs. W.D. Bransford*

Gray-headed Coneflower

Ratibida pinnata

Yellow Coneflower is an excellent choice for a wildflower garden because of its long blooming period and attractive yellow flowers. Tall stalks may need to be staked; plants can be cut back in spring to create a shorter and fuller plant. This species can also be planted next to Prairie Switchgrass to support its stems from flopping over. Best if massed together when planted. Long summer bloom period. Cut back plants in late fall through late winter

Attracts bees and butterflies. Food source for caterpillars. Seeds consumed by birds.

Habitat: Sun

Gray headed Coneflower in winter
© *Dropseed Nursery*

Gray headed Coneflower
in bloom in mid-summer
© *Sally & Andy Wasowski*

Gray's Sedge

Carex grayi

Prefers moist soil and full sun. The leaves are mostly evergreen. Propagation is through seeding in the fall and division in the spring. Under suitable conditions, this sedge may self-seed. The greenish yellow to brown seed heads of this sedge look like spiked clubs and remain on the plant in winter. The seeds float, allowing them to establish in new areas within a wetland. May not reach full height in hot climates and dry soil. Cut back in late winter or early spring.

Notes: Attracts insects and butterflies. Food source for waterfowl and gamebirds.

Habitat: Sun

Gray's Sedge in spring
©*Bugwood.org*

Gray's Sedge seed head
© *Mike Haddock*

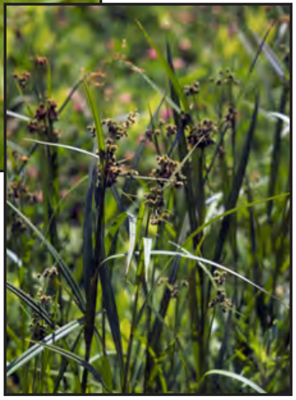
Green Bulrush
Scirpus atrovirens

Prefers full to partial sun and moist conditions. Short-lived. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. Seed heads turn brown and remain on the plant through the growing season. Can be propagated by division in the early spring. Cut back in later winter or early spring.

Provides food and cover for caterpillars, waterfowl, songbirds and shorebirds.

Habitat: Sun

Green Bulrush in early spring
© *Mike Haddock*



Green Bulrush in bloom
© *Sally & Andy Wasowski*

Hairy Alum Root
Heuchera villosa

Requires shade, plants may require watering during periods of drought. Leaves can be evergreen in mild winters.Propagate by divisions in spring. Scorch and general foliage decline often occur if soils are allowed to dry out. Remove stems of faded flowers to encourage additional blooms. In cold winter climates, a winter mulch applied after the ground freezes will help prevent root heaving. Remove dead plant material in the early spring to promote new growth.

Attracts butterflies and huimmingbirds. Makes nice cut flowers.

Habitat: Sun

Hairy Alum Root in bloom in late summer
© *Sally & Andy Wasowski*

Hairy Alum Root in bloom
© *George H. Bruso*

Hairy Beardtongue
Penstemon hirsutus

Prefers full sun. The leaves can be evergreen in mild winters. This is a medium-height penstemon with bushy growth and soft green leaves. Drought tolerant and needs well-drained soil, but it's one of the easiest penstemons to grow. Cut back plants in the late winter. Slow growing, but will form good ground cover over time.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun

Hairy Beardtongue in bloom in spring
© *Rob Broekhuis*

Hairy Beardtongue in winter
© *Dropseed Nursery*

Hairy Beardtongue, blossom
© *Edward M. Martin*

Hairy Wood Mint
Blephilia hirsuta

Prefers full sun to part shade and moist soil. The leaves are fragrant. Foliage is often nibbled on by insects, and plants can become rather tattered and unkempt by late summer. Spent flower stalks can be cut back to create fuller leaves.

Attracts bees and butterflies.

Habitat: Shade

Hairy Wood Mint in bloom in mid-summer
© *Missouri Botanical Society*

Hairy Wood Mint, bloom
© *Thomas Barnes*

Hardy Hibiscus
Hibiscus "Fantasia"

Prefers full sun and moist soil. Japanese beetles can severely damage foliage if left unchecked. Leaf scorch will occur if soils are allowed to dry out. Healthy plants grown in the proper environment usually do not need staking. Cut back stems to 3-4" in late fall. Plants are slow to emerge in the spring. Very easy to grow and not invasive.

Attracts bees and butterflies. Deer tolerant.

Habitat: Sun

Hardy Hibiscus in bloom in late summer
© *Missouri Botanical Garden*

Hardy Ice Plant
Delosperma congestum

Prefers full sun and requires well drained soil. Drought tolerant, succulent that grows very low to the ground with yellow aster-like blooms. For about 4-6 weeks, numerous flowers open in the morning and close in the afternoon, with more blooms appearing the next morning. Evergreen leaves have a red color through the winter. Has a very long flowering season - from late spring through frost. Good for a ground cover.

Deer resistant

Habitat: Sun

Hardy Ice Plant close up of bloom
© *Rob Broekhuis*

Hardy Ice Plant in winter
© *Dropseed Nursery*

Hardy Ice Plant in bloom in summer
© *Philippe.pechoux*

Harebell
Campanula rotundifolia

Prefers full sun to part shade and moist to dry conditions. Easy to grown, but vulnerable to competition from more aggressive species. Deadhead spent flowers to encourage additional bloom. Plants are often short-lived, but will easily remain in the garden in optimum growing conditions by self-seeding. Spread by creeping roots. Long flowering season from June -September. Cut back plants in late winter.

Provides nectar for bees and hummingbirds.

Habitat: Sun

Harebell colony in bloom
© *Thomas Muller*

Harebell in bloom in summer
© *Rob Broekhuis*

Hens and Chicks
Sempervivum montanum "Braunii"

Prefers full sun and well drained soil. Drought tolerant. Spreads slowly. Evergreen. Hardy small succulent with tight rosettes to 2-3 inches in diameter crowded with mid-green colored fleshy leaves. Plants produce many offsetting rosettes that are held tightly crowded together. Clusters of reddish-purple star-shaped flowers rise up on short stalks in early summer. Remove old foliage in the late winter before the new leaves emerge. Can be propagated by division in the early spring.

Deer tolerant.

Habitat: Sun

Hens and Chicks in bloom in early summer
© *Rob Broekhuis*

Hens and Chicks

Sempervivum arachnoideum "Cobweb"

Prefers full sun and well drained soil. Drought tolerant. Low-growing, evergreen succulent. Spreads slowly. Evergreen. Great for rock gardens. Can be propagated by division in the early spring. Remove old foliate in the late winter before the new leaves emerge.

Deer tolerant.

Habitat: Sun

Hens and Chicks in winter
© *Rob Broekhuis*

Hens and Chicks in bloom
© *Daderot at Wikipedia*

Hens and Chicks

Sempervivum tectorum "Hart"

Prefers fulll sun and well drained soil. Drought tolerant. Spreads slowly. Evergreen. Hardy small succulent with tight rosettes to 2-3 inches in diameter crowded with mid-green colored fleshy leaves. Plants produce many offsetting rosettes that are held tightly crowded together. Clusters of reddish-purple star-shaped flowers rise up on short stalks in early summer. Remove old foliage in the late winter before the new leaves emerge. Can be propagated by division in the early spring.

Deer tolerant.

Habitat: Sun

Hens and Chicks colony before bloom
© *R.A.Howard*

Hop Sedge
Carex lupulina

Prefers full sun to part shade and moist to wet conditions. Useful for wetland restoration; also has a nice form and attractive seed head for wet gardens. This species will tolerate occasional flooding. The leaves become a lighter shade of green in bright sunlight. Cut back in late winter.

Attracts birds and waterfowl. Food source for caterpillars and certain insects.

Habitat: Sun

Hop Sedge seed head
© *Mike Haddock*

Indian Grass
Sorghastrum nutans

Prefers full sun and dry to moist soil. Cut back early in the season to keep plant at a lower height. Cut back last year's growth. in late winter or early spring. Fall color deep orange. Can spread aggressively. This species is tolerant of air pollution and can be grown under Black Walnut trees.

Attracts birds. Food source for caterpillars and grasshoppers. Consumed by livestock.

Habitat: Sun

Indian Grass seed head in winter
© *Dropseed Nursery*

Indian Grass seed head in Fall
© *Mike Haddock*

Indian Grass in prairie
© *Mike Haddock*

Ironweed
Vernonia gigantea

Very adaptable and hardy plant. Prefers full sun and dry to moist soil. May need support depending on height. Overall plant height may be reduced by cutting back plant stems in late spring. Remove flower heads before seed develops to avoid any unwanted self-seeding. Cut back in early to late winter.

Attracts bees and butterflies. This species' name refers to the very strong fibers of its stem.

Habitat: Sun

Ironweed in winter
© *Sally and Andy Wasowski*

Ironweed in bloom in late summer
© *R.W. Smith*

Jack-in-the-Pulpit
Arisaema triphyllum

Prefers partial shade and moist soil. This species can tolerate full sun in rich, moist soil. Slow growing perennial. A heavy, leafy winter cover should be left in place. Plant dies back completely in winter.

Berries attract birds. The swollen root is edible, but it must first be cooked, or it will cause a strong burning reacation.

Habitat: Shade

Jack in the Pulpit seed head while in bloom
© *Sally & Andy Wasowski*

Jack in the Pulpit blossom
© *Stefan Bloodworth*

Jacob's Ladder

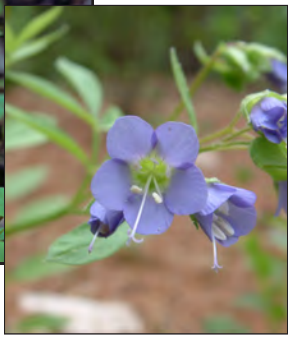
Polemonium reptans

This species prefers shade and moist soil. Plants will go dormant in drought conditions. Divide clumps in early spring or late summer. This species' name alludes to the ladder-like appearance of the pinnate leaves. Plant dies back completely in the winter.

Attracts bees and butterflies.

Habitat: Shade

Jacob's Ladder clump in spring
© *Sally and Andy Wasowski*



Jacob's Ladder blossom in spring
© *Stefan Bloodworth*

Japanese Sedge

Carex morrowii "Ice Dance"

Clump-forming, semi-evergreen perennial similar in appearance to a grass. Prefers shady and moist conditions. Cut back in late winter. May benefit from a winter mulch. Forms an attractive ground cover in shady areas. This species spreads by underground rhizomes, but not aggressively.

Habitat: Sun

Japanese Sedge in winter
© *Conservation Garden Park*

Japanese Sedge seed head
© *Missouri Botanical Gardens*

Japanese Sedge colony in spring
© *Missouri Botanical Gardens*

Joy-Pye Weed

Eupatorium fistulosum

Joe-Pye Weed is a substantial plant which needs space, but when planted in groups or massed can provide spectacular flowering and architectural height. This adaptable plant can grow in full sun or partial shade, and tolerates a variety of soil conditions. Plants can be cut back in the early summer to reduce their height. Cut plants to the ground in winter.

Attracts bees and butterflies.

Habitat: Sun

Joe-Pye Weed bloom in late summer
© *Larry Allain*

Joe-Pye Weed in winter
© *Dropseed Nursery*

Joe-Pye Weed flowers
© *Thomas Barnes*

June Grass

Koeleria macrantha

June Grass is a cool-season grass that will go dormant in late summer in warmer climates. It is shorter in height and turns green earlier in the season than most short grasses. Prefers full sun and well drained soil. This very drought tolerant speceis makes a nice border for a garden. Not an aggressive spreader. Cut back in late winter or early spring.

Attracts birds. Food source for grasshoppers.

Habitat: Sun

June Grass dormant in winter
© *Kathyrn E. Bolin*

June Grass in spring
© *Dave Powell*

Kalimeris

Kalimeris incisa "Blue Star"

This very easy to grow species prefers full sun to part shade and medium moisture. Kalimeris has a long flowering season - from early summer through early fall. It performs well in hot and humid summers - but this species can't tolerate clay or other poorly drained soils. Foliage may be pinched back in early summer to stimulate new growth. Cut back after flowering to encourage a possible fall rebloom.

Attracts butterflies and makes a nice cut flower.

Kalimeris close up of blue blossom
© *Missouri Botanical Garden*

Kalimeris in bloom in summer
© *Missouri Botanical Garden*

Knautia

Knautia macedonica

Upright, clump-forming perennial. Likes full sun and moderately moist soil. Somewhat intolerant of the heat and humidity of the deep South. Remove spent flowers to encourage rebloom in early autumn. This species has a long flowering season - from early summer through early fall. Cut back last year's growth in the later winter.

This species makes a nice cut flower.

Habitat: Sun

Knautia colony in late summer
©*Missouri Botanical Garden*

Knautia close up of bloom
© *Rob Broekhuis*

Lady Fern

Athyrium filix-femina

This species prefers shady, moist conditions; however it tolerates drier soils than many other ferns. Will tolerate full sun if soil is kept constantly moist. Shelter from wind to protect fronds from breaking. Lady fern will spread, but very slowly. Divide clumps in spring every few years to reposition crowns at the soil level. Dies back completely in the winter.

Habitat: Shade

Lady Fern in spring
© *Sally & Andy Wasowski*

Lady Fern in spring
© *Lindsey Koepke*

Ladybells

Adenophora confusa

This species likes sun to part shade and moist conditions. It does have the potential to spread but unwanted growth can be pulled up in the spring. Remove seed pods before they develop to reduce excessive spread. Drought tolerant and very hardy.

Makes a nice cut flower.

Habitat: Sun

Ladybells bloom in summer
© *Rob Broekhuis*

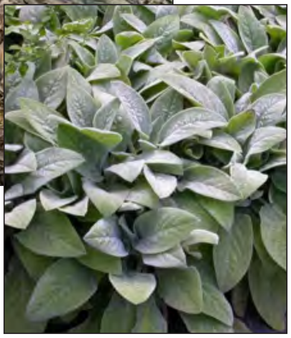
Lamb's Ears
Stachys byzantine "Big Ears"

Prefers full sun and well drained soil. This drought tolerant species can be evergreen during mild winters. Tends to rot and develop leaf diseases in humid summer climates. Well-drained soils are essential in order to combat potential rot problems. Avoid overhead watering. If mid-summer foliage decline occurs, pick off damaged leaves as needed. Spreads by creeping stems that root as they go along the ground and can be mildly aggressive in rich soils. Forms an attractive groundcover. Rarely flowers. Divide in the fall or early spring.

Deer and rabbit resistant. Will grow under Black Walnut trees and is tolerant of air pollution.

Habitat: Sun

Lamb's Ears dormant in winter
© *Conservation Garden Park*



Lamb's Ears "Big Ears"
colony in summer
© *Missouri Botanical Gardens*

Lamb's Ears
Stachys byzantine "Silver Carpet"

Prefers full sun and well drained soil. This drought tolerant species can be evergreen during mild winters. Tends to rot and develop leaf diseases in humid summer climates. Well-drained soils are essential in order to combat potential rot problems. Avoid overhead watering. If mid-summer foliage decline occurs, pick off damaged leaves as needed. Spreads by creeping stems that root as they go along the ground and can be mildly aggressive in rich soils. Forms an attractive groundcover. Rarely flowers. Divide in the fall or early spring.

Deer and rabbit resistant. Will grow under Black Walnut trees and is tolerant of air pollution.

Habitat: Sun

Lamb's Ears dormant in winter
© *Conservation Garden Park*

Lamb's Ears "Silver Carpet"
colony in spring
© *Missouri Botanical Gardens*

Late Boneset

Eupatorium serotinum

Lower leaves sometimes discolor and fall off during a drought. The size of this plant is significantly affected by moisture levels. Cut back plants in the late winter.

Attracts bees, butterflies and birds.

Habitat: Shade

Late Boneset bloom in late summer
© *Mike Haddock*

Late Boneset in summer
© *Robert L. Stone*

Little Bluestem

Schizachyrium scoparium "The Blues"

This cultivar is notable for its very intense blue color during the growing season. Prefers full sun and dry to moist conditions. Does not require staking or cutting back during the growing season or winter months. Takes on an attractive golden brown color during the fall and into the winter. The fluffy white seeds are an attractive accent and are maintained into the winter. Very drought tolerant. Cut back to several inches above ground level in the early spring. Once established, plants can be divided in the early spring

Attracts birds. Food source for many insects.

Habitat: Sun

Little Bluestem "The Blues" in spring
© *Missouri Botanical Gardens*

Little Bluestem

Schizachyrium scoparium

Prefers full sun and dry to moist conditions. Does not require staking or cutting back during the growing season or winter months. Takes on an attractive golden brown color during the fall and into the winter. The fluffy white seeds are an attractive accent and are maintained into the winter. Very drought tolerant. Cut back to several inches above ground level in the early spring. Once established, plants can be divided in the early spring

Attracts birds. Food source for many insects.

Habitat: Sun

Little Bluestem dormant in winter
© *Dropseed Nursery*

Little Bluestem seed head
© *Mike Haddock*

Lizard's Tail

Saururus cernuus

For water gardens, plant in containers in shallow water to 6" deep. For natural ponds, set plants or rhizomes in sandy or muddy pond margins under shallow water or in moist, boggy soils. Does best in full sun. Unrestrained rhizomes will spread to form colonies. Fragrant white flowers - the leaves and roots also have a pleasant citrus aroma. The foliage of this species is toxic.

Habitat: Sun

Lizard's Tail colony in summer
© *Sally & Andy Wasowski*

Lizard's Tail in bloom
© *Harry Cliffe*

Long-leaved Pondweed

Potamogeton nodosus

Use as oxygenator in water gardens. Decorative, trailing habit in ponds. Grow in aquatic containers of sandy loam, root in muddy pool bottoms at depth of 6 - 24. Can spread aggressively in shallow water. Prefers full sun

Attracts insects, wetland birds, ducks, turtles and muskrats. Pondweed provides protective cover for rish.

Habitat: Sun

Long-leaved Pondweed colony in summer
© *Joseph A. Marcus*

Lurid Sedge

Carex lurida

The seedheads resemble small sweetgum balls but do not grow above the foliage. This sedge is less prone to summer dieback and remains attractive during warm weather. Cut back in late winter or early spring. Prefers full sun and moist soil.

Attracts insects, birds, and butterflies.

Habitat: Sun

Lurid Sedge seed head
© *Robert H. Mohlenbrock*

Lurid Sedge in spring
© *Nicky Staunton*

Lyre-leaved Sage

Salvia lyrata

Lyre-leaved sage makes a great evergreen groundcover, with somewhat ajuga-like foliage and showy blue flowers in spring. It will reseed easily in loose, sandy soils and can form a solid cover with regular watering. It tolerates mowing and can be walked on. Best grown in full sun and moist soil

Attracts bees, hummingbirds, and butterflies. Not attractive to deer.

Habitat: Sun

Lyre-leaved Sage
dormant in winter
© *Dropseed Nursery*

Lyre-leaved Sage blue
blossom in spring
© *Harry Cliffe*

Lyre-leaved Sage colony in spring
© *Sally & Andy Wasowski*

Many-Flowered Agrimony

Agrimonia parviflora

Immature fruits are green, while mature fruits are brown. Vegetative colonies of plants are often produced.

Attracts bees.

Habitat: Sun

Many-flowered Agrimony
in bloom in July
© *Larry Allain*

Many-flowered Agrimony
close up of blossom
© *Robert H. Mohlenbrock*

Meadow Blazing Star

Liatris ligulistylis

This species of blazing star is an upright, clump-forming perennial that typically grows to 2' (infrequently to 3') tall in the wild. It may grow taller in cultivation, particularly if planted in rich, fertile garden soils. May need staking. Intolerant of wet soils in winter. Tolerant of summer heat and humidity. Prefers full sun and moist to dry conditions.

Attracts bees, butterflies, hummingbirds and birds. Makes a nice cut flower.

Habitat: Sun

Meadow Blazing Star before bloom
© *Rob Broekhuis*

Meadow Blazing Star
bloom in late Fall
© *Bennie Bengston*

Meadow Sedge

Carex granularis

Cut back in the late winter or early spring. Prefers partial sun and moist soil.

Attracts birds. Food source for caterpillars and other insects. Not attractive to deer or rabbits.

Habitat: Sun

Meadow Sedge seed head
© *Robert H. Mohlenbrock*

Mexican Sedum "Diploid"

Sedum hispanicum "Diploid"

Drought tolerant. Grows best in full sun and well drained soil. Leaves turn purple in the winter.

Habitat: Sun

Mexican Sedum "Diploid" colony in spring
© *Rob Broekhuis*

Mexican Sedum "Diploid" in winter
© *Rob Broekhuis*

Mistflower

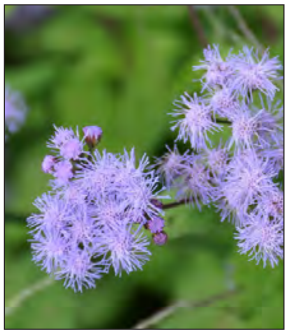
Conoclinium coelestinum

This plant can spread quickly. Divide every three years to control growth. Cut back in summer to promote denser habit. Cut back plant in late winter. Prefers full sun to partial shade and moist soil. When planted in a moss, the pale violet flowers resemble mist over the ground.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Sun

Mistflower dormant in winter
© *Dropseed Nursery*



Mistflower blue blossom in Fall
© *Mrs. W.D. Bransford*

Mistflower colony in bloom
© *Mike Haddock*

Monkey Flower

Mimulus ringens

This plant can spread, but it isn't a strong colonizer. Foliage will turn yellow and shrivel away in response to drought conditions. The size of a plant is strongly influenced by moisture conditions and soil fertility. Cut back in late winter.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Sun

Monkey Flower dormant in winter
© *Dropseed Nursery*

Monkey Flower in bloom
in mid-summer
© *Mrs. W.D. Bransford*

Narrow-leaved Sunflower

Helianthus angustifolius

Prefers full sun and moist to dry conditions. May need to be staked. Pinch plants back in early summer to promote branching. Numerous small plantlets develop around the base and can be divided yearly to produce additional plants. May need to be weeded back - can spread aggressively. Cut back plants in late winter.

Attracts bees, butterflies, and birds.

Habitat: Sun

Narrow-leaved Sunflower
flower dormant in winter
©*Dropseed Nursery*

Narrow-leaved Sunflower
flower in Fall
© *Sally & Andy Wasowski*

Narrow-leaved Sunflower colony in bloom in Fall
© *Sally & Andy Wasowski*

Nepeta

Nepeta subsessilis "Candy Cat"

Prefers full sun to partial shade and moist to dry conditions. Drought tolerant. Plants may be cut back before first flowering to promote more compact size. Shear flower spikes after initial flowering to promote continued bloom. Fragrant flowers and leaves. Cut back last year's growth in the early spring. Good for rain gardens since this species will tolerate some flooding and also periods of drought.

Habitat: Sun

Nepeta "Candy Cat" in bloom in summer
© *Missouri Botanical Gardens*

New England Aster

Symphyotrichum novae-angilae (Aster novae-angliae)

New England Aster flowers until frost. Cut back plants in early summer to maintain a shorter and fuller shape. May require staking. Can be aggressive. The flower color is variable, ranging from lavender to blue to white. Cut back dormant plants in late winter. This species prefers full sun, but is tolerant of many soil types including clay.

Attracts bees and butterflies. Makes nice cut flowers.

Habitat: Sun

New England Aster dormant in winter
© *Dropseed Nursery*

New England Aster in bloom
© *Mariann Watkins*

New England Aster in bloom in Fall
© *Albert F.W.Vick*

Nodding Bur Marigold

Bidens cernua

Numerous yellow flower heads nod increasingly as the flowers mature. This plant often forms colonies and spreads by reseeding itself. The leaves occasionally succumb to powdery mildew during the fall. This plant is less tolerant of dry conditions than other Bidens species. Cut back plants in late winter. This fairly aggressive species is a good choice for wetland restorations.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun

Nodding Bur Marigold colony in bloom
© *W.D. and Dolphia Bransford*

Nodding Bur Marigold bloom
© *Mike Haddock*

Nodding Wild Onion

Allium cernuum

Prefers full sun. This species is very drought tolerant; however, it is not able to withstand competition from more aggressive plant species. Best grown in rocky soils. All parts of the perennial have a mild, oniony scent. Plants benefit from being divided every third year or when 8-10 bulbs appear in the clump. Foliage persists past flowering into late summer before dying back.

Attracts hummingbirds, bees, and butterflies.

Habitat: Sun

Nodding Wild Onion dormant in winter
© *Dropseed Nursery*

Nodding Wild Onion in bloom
© *Rob Broekhuis*

Obedient Plant

Physostegia virginiana "Miss Manners"

"Miss Manners" is a patented cultivar that is distinguished by its non-spreading, clump-forming, compact growth habit and long season of bloom.

Obedient Plant is given its name because each individual flower will, upon being pushed in any one direction, temporarily remain in the new position as if it were hinged. Cut back dormant plant material in the early spring.

Attracts hummingbirds, bees, and butterflies.

Habitat: Sun

Obedient Plant "Miss Manners" in bloom in summer
© *Missouri Botanical Gardens*

Obedient Plant

Physostegia virginiana

May need staking, especially if grown in soils with high fertility. Prune back in early spring to reduce height and minimize tendency toward floppiness (optional). Spreads and can be aggressive in the garden. Divide every 2-3 years to control growth.

Obedient plant is given its name because each individual flower will, upon being pushed in any one direction, temporarily remain in the new position as if it were hinged. Cut back dormant plant material in the early spring.

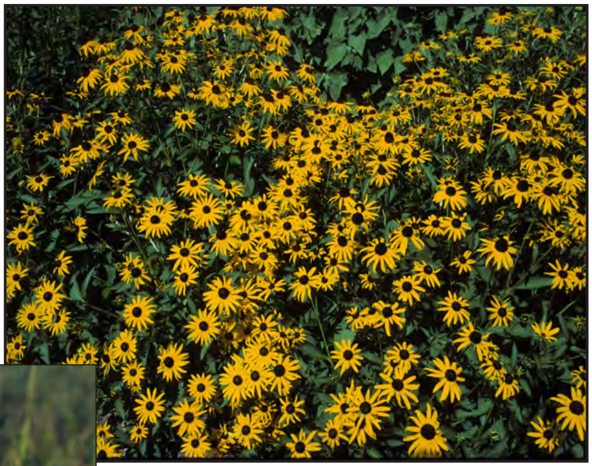
Attracts hummingbirds, bees, and butterflies.

Obedient Plant colony in bloom in summer
© *Sally & Andy Wasowski*

Obedient Plant in bloom in summer
© *Mariann Watkins*

Orange Coneflower

Rudbeckia fulgida



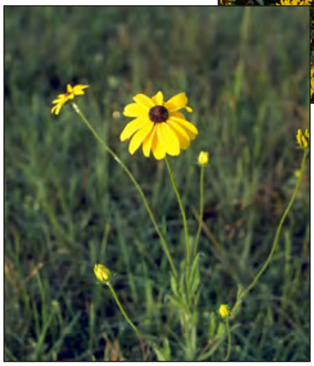
Orange Coneflower colony in bloom in Fall
© *Sally & Andy Wasowski*

Prefers full sun and moist to dry soil. This species flowers for a long period during the mid-summer. Dead heading spent flowers can prolong flowering time. Divide when clumps become overcrowded. Cut back dormant plant material in the early spring to allow birds to feed on the seed heads during the winter months.

Attracts butterflies.

Habitat: Sun

Orange Coneflower dormant in winter
© *Dropseed Nursery*



Orange Coneflower yellow bloom
© *George H. Bruso*

Ornamental Onion "Ozawa"

Allium thunbergii "Ozawa"

Prefers full sun to part shade and moist soil. This species is very drought tolerant. Red-violet florets in 1-2" diameter globular clusters appear atop thin stems in September and October. Leaves turn an attractive tawny orange at frost. Divide clumps to encourage more flowering. Fragrant flowers.

Not attractive to deer.

Habitat: Sun

Ornamental Onion "Ozawa" in bloom in August
© *Missouri Botanical Garden*

Ornamental Onion
Allium thunbergii "Ozawa"

This species prefers full sun to part shade and moist, well drained soil. Drought tolerant. In fall, the foliage turns an attractive yellow, a nice contrast to the reddish-brown flower stems that last well into the winter. Sterile flowers prevent spread by seed. Cut back last year's growth in the early spring.

Habitat: Sun

Ornamental Onion
© *Missouri Botanical Garden*

Ornamental Oregano
Origanum laevigatum

Prefers full sun and moist soil. This species makes a nice ground cover. Fragrant foliage. The species dies to the ground in cold winters. Leaves deepen in color as the summer progresses, with the best purple colors usually occurring in cool climates. Will spread by runners, but not aggressively.

Attracts butterflies and bees. Makes nice cut flowers.

Habitat: Sun

Ornamental Oregano in winter
© *Conservation Garden Park*

Ornamental Oregano in bloom in late summer
© *Missouri Botanical Gardens*

Ornamental Oregano foliage turning purple in Fall
© *Conservation Garden Park*

Oval-headed Sedge
Carex cephalophora

Cut back in late winter. A nice low-growing option for dry shade.

Food source for insects and caterpillars. Attracts birds.

Habitat: Shade

Oval-headed Sedge seed heads
© *Ted Bodner*

Pale Indian Plantain
Arnoglossum atriplicifolium

Pale Indian Plantain may need support – cut back plants early in the season to create a shorter, fuller shape. Cut plants back in the late winter.

Attracts bees and wasps.

Habitat: Sun

Pale Indian Plantain colony in bloom in summer
© *Sally & Andy Wasowski*

Pale Indian Plantain at full height
© *Mike Haddock*

Pale Purple Coneflower
Echinacea pallida

An adaptable plant that is tolerant of drought, heat, humidity and poor soils. Prefers full sun. Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Cut back last year's growth in the early spring to allow birds to feed on the seed head throughout the winter months.

Attracts bees butterflies and birds.


Pale Purple Coneflower in winter
© *Dropseed Nursery*


Pale Purple Coneflower bloom in spring
© *Sally and Andy Wasowski*


Pale Purple Coneflower in bloom in prairie
© *Thomas L. Muller*

Panicled Aster
Symphyotrichum lanceolatum (Aster lanceolatus)

Can tolerate both wet and dry conditions, may lose lower leaves in very dry conditions. Tolerant of disturbance.

Attracts bees and butterflies.

Habitat: Shade


Panicled Aster plant in late Fall
© *Mrs. W.D. Bransford*


Panicled Aster in bloom in Fall
© *George H. Bruso*

Pasque Flower

Pulsatilla vulgaris

Prefers full sun to part shade and moist soil. Flowers vary in color from blue to reddish purple with a bushy center clump of golden yellow stamens and give way to feathery seed heads which are quite showy. This low-growing plant is good for borders.

Habitat: Sun

Pasque Flower seed heads
© *Rob Broekhuis*

Pasque Flower in bloom in Spring
© *Rob Broekhuis*

Pennsylvania Sedge

Carex pennsylvanica

Foliage is pale-green in spring and summer, turning sandy-tan in fall. One of the first sedges to bloom in the spring. Cut back in late winter. Forms nice ground cover or lawn alternative.

Attracts birds. Food source for grasshoppers, caterpillars and other insects.

Pennsylvania Sedge in summer
© *Stefan Bloodworth*

Pennsylvania Sedge seed head
© *Stefan Bloodworth*

Phlox

Phlox paniculata "Robert Poore"

Prefers medium moisture and full sun to part shade. Needs good air circulation (space well and thin out stems as needed) to help combat potential powdery mildew problems. Avoid overhead watering. Appreciates a summer mulch which helps keep the root zone cool.

Attracts bees, hummingbirds, butterflies and birds. The fragrant blossoms make nice cut flowers. Not attractive to deer. Can thrive in clay soil and under Black Walnut trees.

Habitat: Sun

Phlox "Robert Poore" colony in bloom Summer
© *Missouri Botanical Gardens*

Phlox "Robert Poore" bloom in Summer
© *Missouri Botanical Gardens*

Phlox

Phlox paniculata

Prefers medium moisture and full sun to part shade. Needs good air circulation (space well and thin out stems as needed) to help combat potential powdery mildew problems. Avoid overhead watering. Appreciates a summer mulch which helps keep the root zone cool.

Attracts bees, hummingbirds, butterflies and birds. The fragrant blossoms make nice cut flowers. Not attractive to deer. Can thrive in clay soil and under Black Walnut trees.

Habitat: Sun

Phlox colony in late Summer
© *Andy & Sally Wasowski*

Phlox pink bloom in late Summer
© *Steven Faucette*

Pickerelweed
Pontederia cordata

This emergent aquatic, with its leaves and flowers above water and portions of the stem under water, is found typically in shallow, quiet water. Set plant roots in spring into mud at the margins of a pond or in containers (rich organic loams) in a water garden under 3-5" of water. Outside of containers, rhizomes can spread rapidly to form colonies under optimum growing conditions. If spread is a concern, grow plants in containers.

Dragonflies and damselflies commonly lay their eggs on plant stems near the water surface. Attracts bees and butterflies. Food source for ducks.

Habitat: Sun

Pickerelweed colony in bloom
© *Albert F.W.Vick*

Pickerelweed blue blossom in late Summer
© *Albert F.W.Vick*

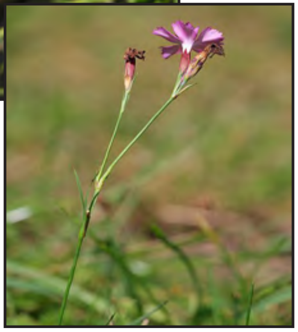
Pinks
Dianthus carthusianorum

Tall growing dianthus topped with clusters of up to 50 deep magenta blooms on each stem. Prefers dry, sunny sites. Deadhead regularly to prolong flowering. This drought tolerant plant is evergreen in mild winters.

Attracts butterflies.

Habitat: Sun

Pinks in bloom in Spring
© *Audrius Meskauskas*



Pinks in Spring
© *Kristian Peters*

Large-Fruited Oval Sedge

Carex scoparia

This sedge adapts to full sun, wet to moist conditions, and various kinds of soil, including those containing mud, sand, or gravel. Cut back in late winter..

The leaves are a source of food for butterflies and moths and the seeds are food for a variety of birds.

Habitat: Sun

Pointed Broom Sedge colony in summer
© *Mike Haddock*

Pointed Broom Sedge seed head
© *Mike Haddock*

Poverty Grass

Danthonia spicata

Poverty grass is a perennial bunchgrass with wiry clumps of naked stems and tufts of curly, basal leaves. This grass does not tolerate competition from taller ground vegetation. Thrives in well-drained, nutrient poor soils.

Attracts butterflies.

Habitat: Sun

Poverty Grass
© *dropseed nursery*

Prairie Cordgrass
Spartina pectinata

Prairie cordgrass is fast-growing and has been used to prevent soil erosion. Stems often remain erect through the winter and provide good cover for wildlife. Fall color is an attractive yellow. Cut back in late winter or early spring.

Attracts ducks. Important source of protective cover and nesting habitat for many wetland birds and other kinds of wildlife.

Habitat: Sun

Prairie Cordgrass prairie in late Summer
© *Sally & Andy Wasowski*

Prairie Cordgrass with seed head
© *Sally & Andy Wasowski*

Prairie Dock
Silphium terebinthinaceum

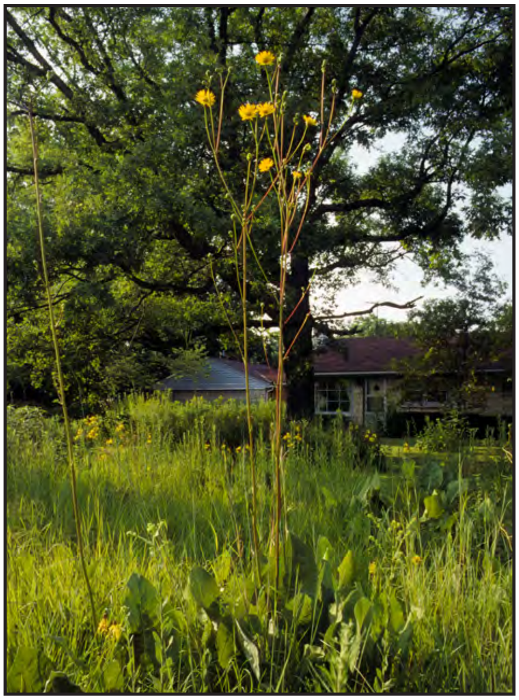
Prefers full sun and can tolerate a wide variety of soil conditions. Very large, wide, spade-shaped basal leaves subtend a 3-8 ft. flowering stalk. Taprooted, slow-to-establish plant which may not flower until the second or third year. Usually does not need support, but often leans. Cut back plant material in the early spring to allow birds to feed on the seedheads during the winter months.

Attracts bees, hummingbirds and birds.

Habitat: Sun

Prairie Dock dormant in winter
© *Dropseed Nursery*

Prairie Dock bloom in late Summer
© *Thomas Barnes*



Prairie Dock at full height
© *Sally & Andy Wasowski*

Prairie Dropseed

Sporobolus heterolepis "Tara"

'Tara' is a dwarf version of the species. It typically grows in the form of a vase (more upright and less arching than the species) to 12" tall, with attractive flowering spikes rising in summer well above the foliage to 24" tall. Orange-red fall color can be spectacular.

Attracts birds.

Habitat: Sun

Prairie Dropseed "Tara" in summer
© *Missouri Botanical Garden*

Prairie Dropseed in winter
© *Dropseed Nursery*

Prairie Dropseed

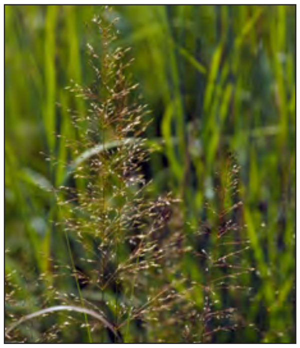
Sporobolus heterolepis

Great accent or ground cover for the landscape. Foliage turns copper-gold in fall, gradually fading to light beige by winter. Late summer flowers bloom in airy panicles above the foliage. Flowers are noted for their coriander-like fragrance. Cut back plants in the late winter.

Attracts birds.

Habitat: Sun

Prairie Dropseed in winter
© *Dropseed Nursery*



Prairie Dropseed seed head
© *Sally & Andy Wasowski*

Prairie Dropseed in bloom in late Summer

© *Bonnie L. Harper*

Prairie Onion
Allium stellatum

Prairie Onion prefers part shade and moist to dry soil. Deadhead flowers before seed set to help control any unwanted spread. Foliage persists to the time of or slightly past flowering in summer before dying back. Plants are easily grown from seed which should be planted in spring or from bulbs/bulb offsets which should be planted in autumn.

Attracts bees and butterflies.

Habitat: Sun

Prairie Onion pink blossom in late Summer
© W.D. and Dolphia Bransford

Prairie Onion bloom in late Summer
© Sally & Andy Wasowski

Prairie Sagewort
Artemisia frigida

This low-spreading, semi-evergreen shrub is very drought tolerant, prefering full sun and dry soils. A good soil stabilizer and ground cover. Prune plants in spring to control growth, but be careful to leave sufficient numbers of live buds on each stem to facilitate bushy growth. Never prune stems to the ground. Foliage may also be lightly sheared in summer to shape, but avoid pruning in fall. Susceptible to root rot in moist soils, particularly poorly drained ones.

Provides nesting material for native bees; attractive food source for deer.

Prairie Sagewort colony in Spring
© Sally & Andy Wasowski

Prairie Sagewort with bloom in mid-Summer
© Phyllis Weyand

Purple Coneflower
Echinacea purpurea "Vintage Wine"

'Vintage Wine' is noted for its upright plant habit and long bloom period. Ray flowers extend horizontally rather than droop. This is a patented plant.

Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Freely self-seeds if at least some of the seed heads are left in place. The dead flower stems will remain erect well into the winter and, if flower heads are not removed, are often visited by goldfinches.

Attracts bees, hummingbirds, birds and butterflies.

Habitat: Sun

Purple Coneflower "Vintage Wine" bloom in Summer
© *Missouri Botanical Garden*

Purple Coneflower dormant in winter with seed head
© *Dropseed Nursery*

Purple Coneflower
Echinacea purpurea

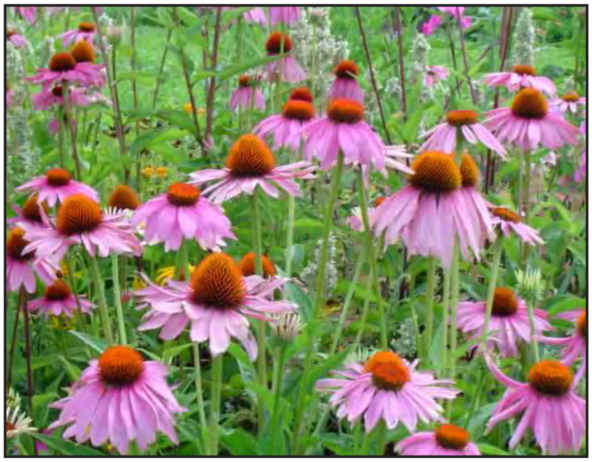
Divide clumps when they become overcrowded (about every 4 years). Plants usually rebloom without deadheading, however prompt removal of spent flowers improves general appearance. Freely self-seeds if at least some of the seed heads are left in place and can spread aggresively. The dead flower stems will remain erect well into the winter and, if flower heads are not removed, are often visited by goldfinches.

Attracts bees, hummingbirds, birds and butterflies.

Habitat: Sun

Purple Coneflower bloom in summer
© *Joseph A. Marcus*

Purple Coneflower in winter
© *Dropseed Nursery*



Purple Coneflower colony in bloom
© *Dropseed Nursery*

Purple Joe-Pye Weed

Eupatorium purpureum

Plants prefer full suny to partial shade and moist conditions. These very tall plants can be cut back in the early summer to keep at a shorter height. Cut dormant plants to the ground in late winter. Fragrant flowers are very attractive to butterflies. Flowers give way to attractive seed heads which persist well into winter.

Attracts bees, birds and butterflies.

Habitat: Sun

Purple Joe-Pye Weed bloom before opening
© *Mike Haddock*

Purple Joe-Pye Weed in winter
© *Dropseed Nursery*

Purple Joe-Pye Weed in bloom in late summer
© *W.D. Bransford*

Purple Prairie Clover

Dalea purpurea

This species prefers full sun and well-drained soil. Does not compete well with more aggressive species. A nitrogen-fixing plant; very drought tolerant. May self-seed in optimum growing conditions.

Attracts bees. Food source for caterpillars and other insects.

Habitat: Sun

Purple Prairie Clover bloom in Summer
© *R.W. Smith*

Purple Prairie Clover in Winter
© *Dropseed Nursery*

Purple Prairie full plant in bloom
© *R.W. Smith*

Purple-Stemmed Aster

Symphyotrichum puniceum (Aster puniceus)

This species prefers full sun and moist to wet soil. To control height, cut plants back in the early summer. Will spread by seed. Cut back dormant plants in the late winter.

Attracts butterflies and makes a good cut flower.

Habitat: Sun

Purple-stemmed Aster in bloom in late Summer
© *Missouri Botanical Gardens*

Pussytoes

Antennaria dioica

This drought tolerant species prefers full sun and dry soil.In optimum growing conditions, plants can spread by stolons to form an attractive ground cover. Plants are dioecious (male and female flowers on separate plants), with male flowers typically appearing on shorter flower stalks.

Habitat: Sun

Pussytoes in bloom in early Summer
© *Rob Broekhuis*

Pussytoe flowers
© *Missouri Botanical Garden*

Rattlebox
Ludwigia alternifolia

This species prefers full sun and can tolerate wet and dry conditions - making it a good candidate for a rain garden. The petals drop easily, often lasting less than a day. When the capsule is shaken, the seeds rattle, which gives rise to the common name "rattle-box". The dried stems and fruit have an attractive reddish-brown color in the winter. Cut back dormant plant material in the late winter.

Rattlebox in winter
© *Dropseed Nursery*

Rattlebox yellow blossom in Summer
© *Mike Haddock*

Rattlebox stand in bloom
© *Edwin M. Martin*

Rattlesnake Master
Eryngium yuccifolium

Prefers full sun and moist to dry soil. Plants tend to open up and sprawl if grown in overly fertile soils or in anything less than full sun. This is a taprooted plant which transplants poorly and is best left undisturbed once established. Taller plants may need support.

Attracts bees. Attracts parasatoid wasps, which can help control pest species in the garden.

Habitat: Sun

Rattlesnake Master in bloom in late Summer
© *Dropseed Nursery*

Rattlesnake Master in Winter
© *Dropseed Nursery*

Rattlesnake Master at full height in Spring
© *Sally & Andy Wasowski*

Rice Cutgrass

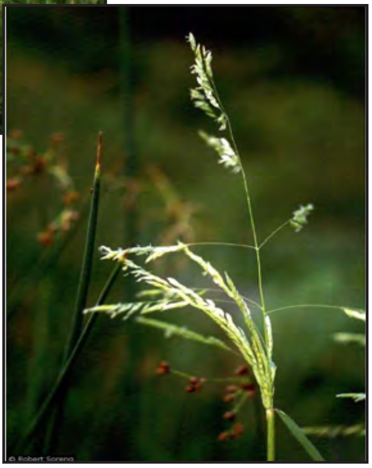
Leersia oryzoides

Prefers full sun and wet conditions. This species is somewhat aggressive in disturbed wetlands. Dense colonies of plants are often produced. Cut back in late winter or early spring. In a wetland restoration, it is not necessary to cut back the dormant plant material to maintain plant vigor

Attracts birds and butterflies.

Habitat: Sun

Rice Cutgrass colony in Spring
© *Patrick J. Alexander*



Rice Cutgrass seed head
© *Robert Soreng*

River Cane

Arundinaria gigantea

Plants prefer moist soil, but do not tolerate flooding. Prefer full sun in optimum growing conditions, it will naturalize to form immense, dense monocultural - commonly called canebrakes. Promising species for use in soil stabilization along streams. If naturalization is not desired, rhizomatous spread may be discouraged via constructing soil barriers or growing plant in a very large plastic pot sunk to the rim. Should not be cut back. This species flowers rarely, and the colony dies following flowering.

Habitat: Sun

River Cane colony at full height in Summer
© *Missouri Botanical Garden*

River Cane in Summer
© *Missouri Botanical Garden*

River Oats

Chasmanthium latifolium

This very adaptable species will grown in full sun as well as full shade, and will tolerate a wide variety of soil conditions. Self-seeds and may spread aggressively. Leaving foliage in place over winter adds interest to the landscape, helps protect crowns from the cold, and provides food for birds. Cut back to the ground in late winter.

Attracts butterflies and birds.

Habitat: Shade

River Oats with seed heads dormant in winter
© *Dropseed Nursery*

River Oats in Spring
© *Dropseed Nursery*

Riverbank Wild Rye

Elymus riparius

Prefers partial shade and moist soil. Used for erosion control and riverbank rehabilitation. Cut back in late winter.

Seeds are a food source for birds.

Habitat: Shade

Riverbank Wild Rye seed head
© *Robert H. Mohlenbrock*

Rose Wine Sage
Salvia nemorosa "Rosenwein"

Likes full sun and dry to medium soil. Plants may repeat bloom throughout the summer, but need regular moisture to encourage this. Remove spent flower spikes to help extend the bloom period. Plants may become somewhat floppy and open up as the summer progresses, particularly in humid climates. Cut back plants after flowering has ended.

Attracts bees and butterflies. Deer resisitant.

Habitat: Sun


Rose Wine Sage colony in bloom in Summer
© *Missouri Botanical Gardens*

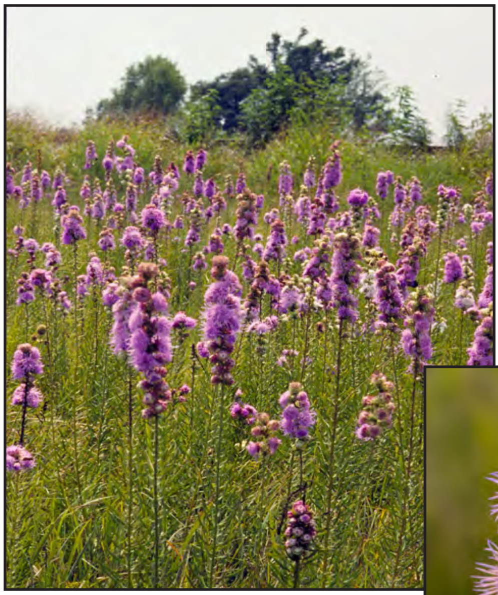

Rose Wine Sage rose blossom
© *Missouri Botanical Gardens*

Rough Blazing Star
Liatris aspera

This drought tolerant species prefers full sun and well drained soil. Blooms later (late summer to fall) than most other Liatris species. May need support at the time of blooming.

Attracts bees, hummingbirds and butterflies. Provides nectar for butterflies such as: tiger swallowtail, clouded sulphur, orange sulphur, gray hairstreak, aphrodite fritillary, painted lady, red admiral, and wood nymph.

Habitat: Sun


Rough Blazing Star in prairie in late Summer
© *Sally & Andy Waswoski*


Rough Blazing Star with purple blossom
© *Henry Domke*

Rough Goldenrod

Solidago rugosa

Prefers full sun and moist soil. Tolerant of clay soil. Plants can be aggressive spreaders in optimum growing conditions, but are generally not considered to be invasive. Cut back plants in late winter.

Attracts bees, birds and butterflies. Not attractive to deer.

Rough Goldenrod in bloom in Fall
© *W.D. and Dolphia Bransford*

Rough Goldenrod flowers
© *R.W. Smith*

Round-headed Lespedeza

Lespedeza capitata

This species likes full sun and moist to dry soil conditions. Drought tolerant. Stems remain erect through the winter when the seedheads have turned dark brown. Adds nitrogen to the soil. Cut back plants in the late winter. Spreads primarily by seed, but does not spread aggressively.

Attracts bees and birds. Food source for caterpillars and other insects.

Habitat: Sun

Round-headed Bush Clover seed heads
© *Sally & Andy Wasowski*

Round-headed Bush Clover in bloom
© *Mike Haddock*

Royal Fern
Osmunda regalis

This fern requires shade and rich, moist soil. Divide in fall or spring.

Habitat: Shade


Royal Fern dormant in winter
© *Stephen Brown*


Royal Fern seed heads
© *Sally & Andy Wasowski*


Royal Fern colony in Summer
© *Sally & Andy Wasowski*

Sage
Salvia nemorosa "Marcus"

'Marcus' is a dwarf clump-forming perennial salvia with deep violet flowers that typically grows to only 8-10" tall. This cultivar does not set viable seeds. Cut back plants after flowering has ended. Prefers full sun and moist to dry soil.

Attracts bees, hummingbirds and butterflies. Not attractive to deer.

Habitat: Sun


Sage in bloom in Spring
© *Missouri Botanical Garden*


Sage flowers in Spring
© *Missouri Botanical Garden*

Sage

Salvia nemorosa "Sensation Rose"

"Sensation Rose" is noted for its compact form, free branching habit, long bloom period and lavender-pink flowers. Salvia nemorosa "Rose Wine" has a similar pink flower color and is shown in the image above. This cultivar does not set viable seeds. Cut back plants after flowering has ended.

Attracts bees, hummingbirds and butterflies. Not attractive to deer.

Habitat: Sun

Sage in bloom in Spring
© *Missouri Botanical Garden*

Sea Thrift

Armeria maritima

Compact and low-growing plant forms a good groundcover. Foliage mounds tend to rot in the center if grown in moist, fertile soils or in heavy clay. Good drainage is essential. Drought tolerant, prefers full sun.

Habitat: Sun

Sea Thrift in bloom in Spring
© *Missouri Botanical Garden*

Sea Thrift in bloom in Spring
© *Rob Broekhuis*

Sea Thrift dormant in winter
© *Conservation Garden Park*

Sedum

Sedum acre "Oktoberfest"

Sedum Acre "Oktoberfest" is a fast-spreading evergreen variety which forms a low carpet of tiny succulent green leaves, smothered by star-shaped creamy-white flowers all summer long. Many people even use this Sedum seed as a lawn substitute as it tolerates moderate foot traffic once it is well-established.

Attracts bees and butterflies.

Habitat: Sun

Sedum before bloom in Spring
© *Conservation Garden Park*

Sedum in winter
© *Conservation Garden Park*

Sensitive Fern

Onoclea sensibilis

Will grow in shade or full sun. Prefers moist soil. Usually grows taller in wet soils which it tolerates well. Spreads by both creeping rhizomes and spores, and can be somewhat aggressive in optimum growing conditions. Commonly called sensitive fern because the green vegetative fronds are sensitive to and suffer almost immediate damage from the first fall frost. Plants die back completely in the winter. Divide in fall or spring.

Attracts birds.

Habitat: Shade

Sensitive Fern colony in Spring
© *Sally & Andy Wasowski*

Sensitive Fern leaf in Spring
© *Jesse Gaudet*

Short's Aster
Symphyotrichum shortii (Aster shortii)

Prefers shade and moist soil. The centers of the flowers start out yellow but turn brick red after pollination. It will self-sow and spread throughout an area, but individual plants are short-lived. May need support. Cut back plants in the late winter.

Attracts bees, butterflies and hummingbirds. Also attracts birds such as cardinals, finches, grosbeaks, sparrows, thrashers, towhees, chickadees, nuthatches, titmice, and turkeys.

Habitat: Shade

Short's Aster colony in bloom in Fall
© *Sally & Andy Waswoski*

Short's Aster blue blossom in Fall
© *Stefan Bloodworth*

Shortbeak Sedge
Carex brevior

Cut back in late winter or early spring.

Attracts birds.

Habitat: Sun

Shortbeak Sedge stand in summer
© *Mike Haddock*

Shortbeak Sedge seed head
© *Mike Haddock*

Showy Goldenrod

Solidago speciosa

This is one of the showiest of about 125 species of goldenrod that occur throughout the United States; they are most common in the East. Prefers full sun and dry to moist soils. Can be aggressive in moist soils - will tolerate clay soil. Mature plants develop a woody stem. Cut back plants in the late winter.

Attracts bees, butterflies and birds. Deer resistant.

Habitat: Sun

Showy Goldenrod in bloom in Fall
© *Mike Haddock*

Showy Goldenrod flowers
© *Mike Haddock*

Side-oats Grama

Bouteloua curtipendula

Foliage turns golden brown in autumn, sometimes also developing interesting hues of orange and red. Cut back in late winter. This is a very drought tolerant medium-tall grass that mixes well in plantings with spring wildflowers because it stays short in the spring.

Attracts butterflies and birds. Food source for grasshoppers and caterpillars. Provides nesting material for birds.

Habitat: Sun

Side-oats Grama dormant in winter
© *Dropseed Nursery*

Side-oats Grama seed head
© *Mike Haddock*

Side-oats Grama in Summer
© *Sam C. Strickland*

Silky Wild Rye

Elymus villosus

Can thrive in sun or shade, prefers moist soil. Cut back in late winter.

Food source for leafhoppers and caterpillars.

Habitat: Sun

Silky Wild Rye stand in Fall
© *Sally & Andy Wasowski*

Silky Wild Rye seed head
© *Sally & Andy Wasowski*

Silver Sedge

Carex morrowii "Silver Sceptre"

'Silver Sceptre' is a Japanese grass sedge cultivar that is ornamentally grown in shade areas for its narrow, variegated foliage. It typically grows in a dense, arching, grass-like clump. Green leaf blades are variegated with white edges. Cut back in late winter.

Habitat: Sun

Silver Sedge "Silver Sceptre" dormant in winter
© *Conservation Garden Park*

Silver Sedge "Silver Sceptre" in Summer
© *Conservation Garden Park*

Slender Mountain Mint
Pycnanthemum tenuifolium

This species will tolerate full sun to partial shade and moist to wet soil. All parts of the plant emit a strong, mint-like aroma when crushed. A vigorous and sometimes aggressive plant. Cut back plants in the late winter.

Attracts bees, butterflies and wasps.

Habitat: Sun

Slender Mountain Mint dormant in winter with seed head
© *Dropseed Nursery*

Slender Mountain Mint white bloom in late Summer
© *Mike Haddock*

Small Yellow Onion
Allium flavum

Prefers full sun and dry soil. The bulbs should be planted fairly deeply. Most members of this genus are intolerant of competition from other plants. Divide bulbs in late summer or fall.

Attracts bees.

Habitat: Sun

Small Yellow Onion in bloom in July
© *Rob Broekhuis*

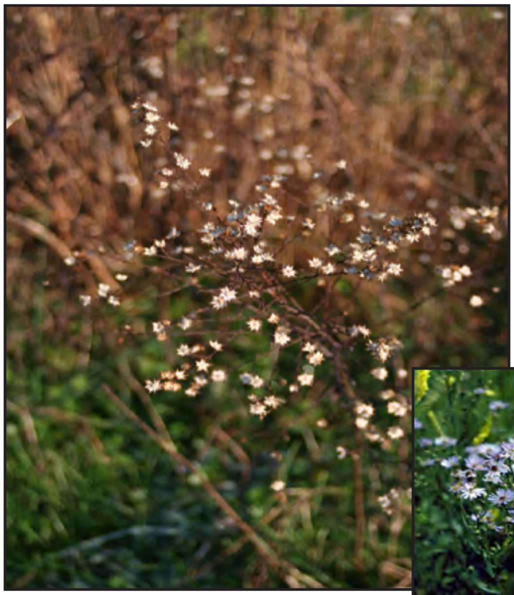
Small Yellow Onion scape
© *Rob Broekhuis*

Smooth Blue Aster
Symphyotrichum laeve (Aster laevis)

Prefers full sun and moist to dry soil. Provides nice color in the late fall. Freely self-seeds. It is vulnerable to powdery mildew and other foliar disease to a moderate extent. Cut back in mid-summer to maintain a shorter form. Cut back dormant plant material in late winter.

Attracts bees and butterflies. Food source to caterpillars and insects.

Habitat: Sun



Smooth Blue Aster dormant in winter
© *Dropseed Nursery*

Smooth Blue Aster in bloom in Fall
© *W.D. and Dolphia Bransford*

Smooth Rose-Mallow
Hibiscus laevis

Prefers full sun and moist soil. Dried pods provide winter interest in the garden. Taller plants may need staking. Cut back dormant plant material in late winter. Flower color varies from white to pink.

Attracts bees and butterflies. Food source for caterpillars and insects. Japanese beetles will eat foliage and flowers and can be a problem.

Habitat: Sun

Smooth Rose-Mallow pink blossom
© *W.D. and Dolphia Bransford*

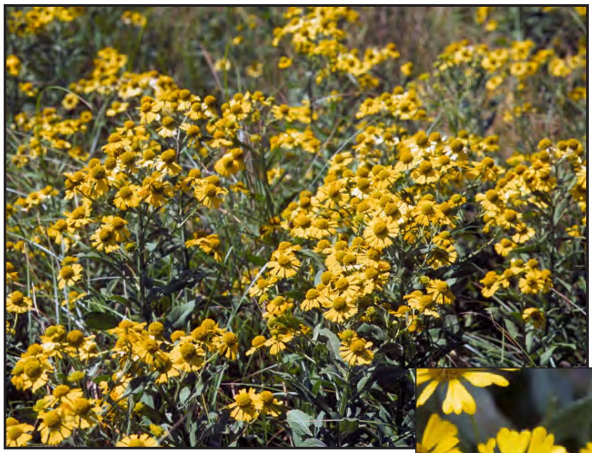
Smooth Rose-Mallow bloom in late Summer
© *Joseph A. Marcus*

Sneezeweed
Helenium autumnale

Prefers full sun and moist soil. Although not required, plants may be cut back in early June (at least six weeks before normal flowering) to reduce plant height and to encourage increased flowering, healthier foliage and less need for support. Remove spent flowers to encourage additional bloom. Can be aggressive. Provides late color in the garden. Cut back plants in late winter.

Attracts bees, wasps and butterflies. Food source for caterpillars and insects.

Habitat: Sun


Sneezeweed colony in bloom in Fall
© *Sally & Andy Wasowski*

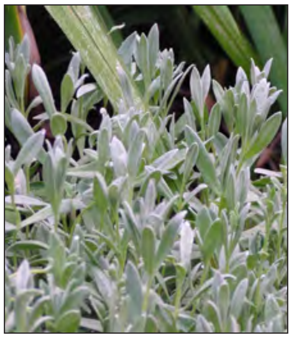

Sneezeweed blossom in Fall
© *Sally & Andy Wasowski*

Snow-In-Summer
Cerastium tomentosum "Silver Carpet"

This species prefers full sun and dry soil. Forms a nice ground cover, spreading over time, but not aggressively. Shear back by one-third after flowering for fresh full foliage. Avoid shearing during hot dry conditions. Can be divided every year if necessary. Cut back in early spring.

Habitat: Sun


Snow-in-Summer flowers
© *Missouri Botanical Garden*


Snow-in-Summer foliage in Spring
© *Garden Soft*


Snow-in-Summer in bloom in Spring
© *Missouri Botanical Garden*

Soft Rush
Juncus effusus

Notwithstanding its preference for abundant moisture, soft rush will perform surprisingly well in average garden soils as long as they receive consistent irrigation. Will tolerate full sun or partial shade. Plants keep nice form and some green color during winter. No need to cut back plants in the fall or early spring. Clumps are often slow to establish, but once established will spread by creeping rhizomes.

Habitat: Sun


Soft Rush in Spring
© *Missouri Botanical Garden*


Soft Rush dormant in winter
© *Dropseed Nursery*

Softstem Bulrush
Scirpus validus

This plant require wet soil and full sun. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. This plant is good for habitat reconstruction and erosion control along areas with occasional flooding. Can spread aggressively.

Provides nesting habitat and food for waterfowl.

Habitat: Sun


Softstem Bulrush colony Spring
© *Sally & Andy Wasowski*


Softstem Bulrush seed head
© *Sally & Andy Wasowski*

Solomon's Seal

Polygonatum biflorum

Solomon's Seal prefers shady conditions and moist soil. Good understory plant. White flowers are followed by blue-black berries in autumn. Foliage turns an attractive yellow in fall. Plant material dies back completely in the winter.

Attracts birds, bees, hummingbirds and butterflies.

Habitat: Shade

Solomon's Seal colony in Spring
© *Sally & Andy Wasowski*

Solomon's Seal bloom in Spring
© *Norman G. Flaigg*

Speedwell

Veronica longifolia "Blue John"

This species thrives in full sun and moist soil. Taller plants may need support. 'Blue John' is a compact long leaf speedwell cultivar that features dense, erect, terminal spikes of tiny pale blue flowers atop upright stems rising to 20" tall. Cut back spent blooms to lengthen flowering period. Cut back dormant plant material during the winter months.

Attracts bees, hummingbirds and butterflies. This species is not attractive to deer or rabbits.

Habitat: Sun

Speedwell blue blossom in Summer
© *Missouri Botanical Gardens*

Spiderwort
Tradescantia bracteata

Good for full sun and moist soil, although this species will tolerate dry soils and can be quite drought resistant. Divide clumps when they become overcrowded. Foliage declines after flowering and should then be cut back almost to the ground to encourage new growth and a possible fall bloom. Young shoots are susceptible to snail damage. Foliage sprawls in an unattractive manner by mid-summer. Cut back dormant plant material during the winter months.

Habitat: Sun

Spiderwort colony in Spring
© *W.D. and Dolphia Bransford*

Spiderwort bloom in Spring
© *W.D. and Dolphia Bransford*

Spiderwort
Tradescantia ohiensis

This very drought tolerant species prefers full sun to part shade and will thrive in a variety of soil types. When touched in the heat of the day, the flowers shrivel to a fluid jelly. Divide clumps when they become overcrowded. Cut back to 6-12” in mid-summer to encourage new growth and a possible fall bloom. Young shoots are susceptible to snail damage. Foliage tends to sprawl in an unattractive manner by mid-summer. Cut back spent plant material during the summer months.

Habitat: Sun

Spiderwort colony in early Summer
© *W.D. and Dolphia Bransford*

Spiderwort bloom in early Summer
© *Mike Haddock*

Spotted Dead Nettle

Lamium maculatum "Aureum"

It is best to cut this plant back after the first bloom to promote compact growth. This plant can be invasive. When grown as a ground cover, starter plants may be spaced 6-10" apart for quick coverage. If mid-summer foliage decline occurs, plants may be cut back or sheared to stimulate new foliage growth.

The leaves of Lamium maculatum "Aureum" have a golden leaf color. Lamium maculatum "Ghost" is a cultivar with silver-white leaves. Lamium maculatum "Chequers" is a cultivar with a green leaf with a white stripe across the center.

Habitat: Sun

Spotted Dead Nettle with purple blossom in Summer
© *Garden Soft*

Spotted Joe-pye Weed

Eupatorium maculatum

This species thrives in part shade and moist soils. Taller plants may need to be staked - or plants can be cut back in the early summer to produce a shorter, fuller growth form. Divide the plants in fall as they go dormant, or in the spring just as shoots first appear. Cut back plants in the late winter.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun

Spotted Joe-pye Weed purple bloom in late Summer
© *W.D. and Dolphia Bransford*

Spotted Joe-pye Weed flowers
© *Stefan Bloodworth*

Spreading Oval Sedge
Carex normalis

Cut back in late winter or early spring.

Attracts birds. Food source for caterpillars.

Habitat: Shade

Spreading Oval Sedge seed head
© *Andrew Hipp*

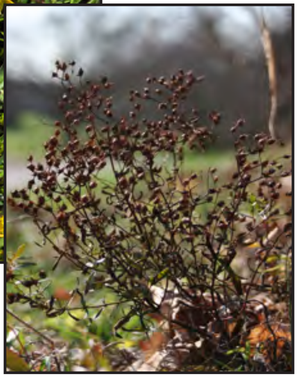
St. John's Wort
Hypericum sphaerocarpum

This species require full sun, but will grow in dry to moist soil. Spreads rapidly by underground runners creating a nice ground cover. The profuse flowers are open on the plant for a long period mid-summer. Requires thinning to prevent spread.

Attracts bees. Food source for caterpillars.

Habitat: Sun

St. John's Wort in bloom in Summer
© *Sally & Andy Wasowski*



St. John's Wort dormant in winter
© *Dropseed Nursery*

Lance-fruited Oval Sedge

Carex radiata

Drought tolerant groundcover for shady sites. Cut back in late winter.

Attracts birds.

Habitat: Shade

Star Sedge in Summer
© *Kansas State University*

Star Sedge in Summer
© *Kansas State University*

Star Sedge dormant in winter
© *Kansas State University*

Stiff Goldenrod

Solidago rigida

Stiff Goldenrod prefers full sun and dry to moist soil. This species has deep roots that allow it to compete well with native grasses. Can be weedy. May need to be divided every 2 to 3 years to control growth. Taller plants may need some support . Plants can be cut back mid-summer to create a shorter, fuller plant. Cut back plants in late winter.

Attracts bees and butterflies.

Habitat: Sun

Stiff Goldenrod in Fall
© *Mike Haddock*

Stiff Goldenrod in Winter
© *Dropseed Nursery*

Stiff Goldenrod bloom in Fall
© *Mike Haddock*

Stonecrop

Sedum ochroleucum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop in Summer
© *Qwertzy2*

Stonecrop

Sedum reflexum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop in Summer
© *Stonecrop in Summer*

Stonecrop in bloom in Summer
© *Stonecrop in bloom in Summer*

Stonecrop

Sedum sarmentosum

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop as groundcover in Summer
© *Garden Soft*

Stonecrop

Sedum sexangulare

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop in Summer
© *Semolo75*

Stonecrop

Sedum sichotense

Mat-forming plant grows quickly and forms a nice groundcover. Leaves turn reddish orange in cooler temperatures.

Attracts butterflies.

Habitat: Sun

Stonecrop in Summer
© *Ghislain Chenais*

Stonecrop

Sedum dasyphyllum "Blue Ridge"

Mat-forming plant grows quickly and forms a nice groundcover. Leaves turn pink and purple in Autumn.

Attracts butterflies.

Habitat: Sun

Stonecrop "Blue Ridge" in Summer
© *Ghislain Chenais*

Stonecrop
Sedum album "Coral Carpet"

This small, spreading stonecrop typically grows 3-6" high and can somewhat quickly form a dense mat of foliage. New growth emerges salmon-orange (coral), matures to bright green and eventually turns reddish-bronze in winter.

Attracts butterflies.

Habitat: Sun

Stonecrop "Coral Carpet" in Spring
© *Missouri Botanical Gardens*

Stonecrop "Coral Carpet" as groundcover
© *Garden Soft*

Russian Stonecrop
Sedum kamtschaticum

Plants can be divided in the early spring. Stem or leaf cuttings can be taken in the early summer.

Attracts bees and butterflies.

Habitat: Sun

Golden Stonecrop
© *Stan Shebs*

Copy
© *Caption*

Russian Stonecrop

Sedum floriferum "Weihenstephaner Gold"

Low-growing stonecrop that forms a nice groundcover - prefers full sun and dry soil. Succulent leaves turn purple in fall and winter. Plants may be sited 12" apart when grown as a ground cover. Tip cuttings from plants may be rooted directly in soil around the plants.

Attracts bees and butterflies. Not attractive to deer and rabbits.

Habitat: Sun

Russian Stonecrop colony
© *Missouri Botanical Garden*

Stonecrop

Sedum rupestre "Sandy's Silver Crest"

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop "Sandy's Silver Crest" in bloom in July
© *Rob Broekhuis*

Stonecrop
Sedum middenorffianum "Striatum"

Mat-forming plant grows quickly and forms a nice groundcover.

Attracts butterflies.

Habitat: Sun

Stonecrop in Summer
© *Qwertzy2*

Stout Blue-Eyed Grass "Lucerne"
Sisyrinchium angustifolium "Lucerne"

This low-growing perennial likes full sun and moist soil. Plants need to be divided at least every other year. "Lucerne" is noted for its profuse bloom of large, one inch diameter, star-like, intense blue flowers with yellow centers over a long May-June bloom period. This cultivar is not known for aggressively self-seeding. Makes a nice border planting.

Attracts bees.

Habitat: Sun

Stout Blue-Eyed Grass "Lucerne" foliage
© *Rob Broekhuis*

Stout Blue-Eyed Grass "Lucerne" in bloom in Spring
© *Missouri Botanical Garden*

Stout Blue-Eyed Grass flowers
© *Missouri Botanical Garden*

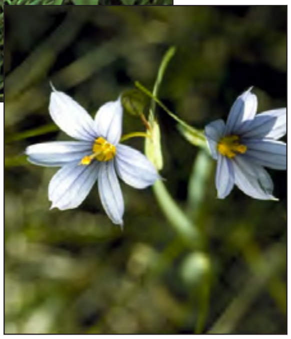
Stout Blue-Eyed Grass
Sisyrinchium angustifolium

This species likes full sun and moist soil and makes a nice border planting. Plants need to be divided at least every other year.

Attracts bees.

Habitat: Sun

Stout Blue-Eyed Grass in bloom in Summer
© *Harry Cliffe*



Stout Blue-Eyed Grass blossom
© *Bennie Bengston*

Swamp Hibiscus
Hibiscus moscheutos

Although native to wetlands, this species grows well in soils that are just moist. Good for rain gardens. The flowers show a variety of colors varying from white with a red center to pale pink. Taller plants may need to be staked. Cut back in late winter. Japanese beetles can be a problem.

Attracts bees and hummingbirds. Food source for caterpillars.

Habitat: Sun

Swamp Hibiscus blossom
© *Sally & Andy Wasowski*

Swamp Hibiscus in winter
© *Dropseed Nursery*

Swamp Hibiscus in bloom in July
© *W.D. and Dolphia Bransford*

Swamp Milkweed
Asclepias incarnata

This plant require consistantly moist soil, and can grow in full sun or partial shade. Plants have deep taproots and are best left undisturbed once established. Foliage is slow to emerge in spring. Swamp milkweed will inevitably have aphids.

Attracts bees, butterflies and hummingbirds.

Habitat: Sun

Swamp Milkweed blossom
© *Sally & Andy Wasowski*

Swamp Milkweed dormant in winter
© *Dropseed Nursery*

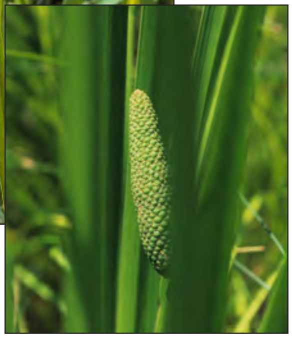
Swamp Milkweed in bloom in Summer
© *Mrs. Albert F.W. Vick*

Sweet Flag
Acorus calamus

This plant requires wet soil and prefers full sun, but will tolerate dense shade. In water gardens, plant rhizomes slightly below the soil surface in moist soils at the water's edge or in containers set in shallow water. Rhizomes or existing clumps may also be planted in containers sunk into wet boggy areas to help prevent any possible invasive spread. Cut back dormant plant material in the winter months. Fragrant.

Habitat: Sun

Sweet Flag in Summer
© *R.A. Howard*



Sweet Flag seed head
© *Sally & Andy Wasowski*

Sweet Violet
Viola sororia "Freckles"

This plant prefers part to full shade and moist soil. Can be invasive in optimum growing conditions. Makes a nice groundcover.

Attracts butterflies and birds.

Habitat: Sun

Sweet Violet in bloom in Spring
© *Meneerke Bloem*

Switchgrass
Panicum virgatum

Bright green leaves occur up and down the stem with purple seed heads. Foliage turns bright yellow in fall. May form sizable colonies. One of the dominant tallgrass prairie species. Cut back dormant plant material in early spring

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun

Switchgrass in winter
© *Dropseed Nursery*

Switchgrass seed heads
© *Sally & Andy Waswoski*

Switchgrass at full height in Summer
© *Sally & Andy Waswoski*

Tall Coreopsis
Coreopsis tripteris

This very drought tolerant species prefers full sun and will thrive in moist to dry soils. Prompt deadheading of spent flowers may encourage additional bloom and prevents any unwanted self-seeding. Freely self-seeds, and in optimum growing conditions will naturalize to form large colonies. If grown in borders, division may be needed every 2-3 years to maintain robustness. Taller plants may need to be staked.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun

Tall Coreopsis in winter
© *Dropseed Nursery*

Tall Coreopsis blossom
© *Mike Haddock*

Tall Coreopsis in bloom in late Summer
© *W. D. and Dolphia Bransford*

Thimbleweed
Anemone virginiana

Spring blooming anemone that is not as aggressive as other varieties. Likes full sun to part shade and moist to dry soil. Flowers give way to thimble-shaped seed heads which remain on the plants well into winter. Three-parted leaves may carry a reddish tinge late into the season.

Attracts bees.

Thimbleweed bloom
© *Mike Haddock*

Thimbleweed in winter
© *Dropseed Nursery*

Thimbleweed in bloom in Spring
© *Thomas L. Muller*

Threadleaf Coreopsis

Coreopsis verticillata "Zagreb"

This drought tolerant species likes full sun and moist to dry soil. Plants may be sheared in mid to late summer to promote a fall rebloom and to remove any sprawling or unkempt foliage. 'Zagreb' can spread in the garden by rhizomes and self-seeding. 'Zagreb' is more compact (to 1.5' tall) and features bright yellow, daisy-like flowers (1-2" diameter).

Attracts bees. Not attractive to deer.

Habitat: Sun

Threadleaf Coreopsis flower
©Missouri Botanical Garden

Threadleaf Coreopsis in bloom in Spring
© Conservation Garden Park

Threadleaf Coreopsis dormant in winter
© Conservation Garden Park

Tickseed Sunflower

Bidens aristosa

This species prefers full sun to partial shade and moist soil. The prickly fruit of Bidens species are known as beggars-ticks, the very common, 2-pronged stickers that cling to clothing. It can be aggressive and is better suited to larger projects where spread is beneficial. Cut back plants in late winter.

Habitat: Sun

Tickseed Sunflower
©Andy and Sally Wasowski

Tickseed Sunflower blossom
© Albert F.W. Vick

Tickseed Sunflower in bloom in Fall
© Lynn & Campbell Loughmiller

Tickseed

Coreopsis "Jethro Tull"

This species prefers full sun and dry to moist soil. Plants may be sheared in mid to late summer (August) to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes, but reseeding will not occur. "Jethro Tull" is a compact golden-yellow coreopsis that grows inan upright, outward-spreading mound to only 18" tall. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Makes a good cut flower. Not attractive to deer. Will work planted in a container.

Habitat: Sun

Tickseed "Jethro Tull" in bloom in Summer

Tickseed "Jethro Tull" blossom
© *Missouri Botanical Garden*

Tickseed

Coreopsis lanceolata

This species will grow in either sun or shade and prefers dry soil. Very drought tolerant. Plants may be sheared in mid to late summer to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes and self-seeding to form large colonies. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Not attractive to deer.

Habitat: Sun

Tickseed seedling
© *Lady Bird Johnson Wildflower Center*

Tickseed blossom
© *Marcus A. Joseph*

Tickseed in bloom in Spring
© *Sally & Andy Wasowski*

Tickseed

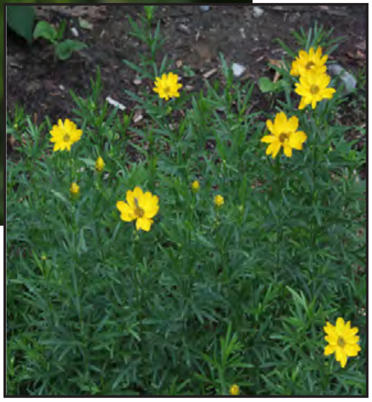
Coreopsis palmata

Grows in full sun to part shade and dry to moist soils. Very drought tolerant. Stiff-stemmed perennial. Plants may be sheared in mid to late summer (August) to promote a fall rebloom and to remove any sprawling or unkempt foliage. Plants will spread by rhizomes and self-seeding. Cut back dormant plant material during the winter months.

Attracts butterflies and bees. Not attractive to deer. Make nice cut flowers.

Habitat: Sun

Tickseed in bloom in Spring
© *Sally & Andy Wasowski*



Tickseed in bloom in Spring
© *R.W. Smith*

Tunic Flower

Petrorhagia saxifraga "Lady Marie"

This very drought tolerant species prefers full sun. May self-seed. Good for borders or rock gardens. Cut back plants in late winter.

Habitat: Sun

Tunic Flower in bloom in Summer
© *Rob Broekhuis*

Tunic Flower blossom
© *Rob Broekhuis*

Tussock Sedge

Carex stricta

Used for erosion control. Forms large colonies. Older leaves turn straw brown as they die, and build up around the base of each clump surrounding the newer yellowish-green leaves. Cut back in late winter or early fall.

Attracts birds and butterflies. Food source for caterpillars. Provides cover for many wetland birds.

Tussock Sedge in Summer
© *Missouri Botanical Garden*

Two Row Stonecrop

Sedum spurium "Eco Mt. Emei"

Spreads quickly to form mats of dense stems and miniature foliage. Dead-head after flowering, to promote vegetative growth. Winter semi-evergreen with bronze foliage.

Attracts butterflies.

Habitat: Sun

Two Row Stonecrop in Summer
© *Conservation Water Park*

Virginia Wild Rye

Elymus virginicus

This plant will thrive in full sun and full shade. Prefers moist soild conditions. Characterized as a prairie grass it is often found in woodlands too. Cut back in late winter or early spring.

Attracts butterflies. Food source for ducks and Canadian geese.

Habitat: Shade

Virginia Wild Rye in Summer
© *Mike Haddock*

Virginia Wild Rye seed head
© *Mike Haddock*

Wall Germander

Teucrium chamaedrys "Summer Sunshine"

This species grows in full sun to part shade and moist soil conditions. Evergreen in mild winter regions. Plants may be pruned to maintain a low height, if desired.

Attracts butterflies and bees.

Habitat: Sun

Wall Germander flowers
© *Missouri Botanical Garden*

Wall Germander in bloom in Spring
© *Rob Broekhuis*

Wall Germander in bloom in Spring
© *Missouri Botanical Garden*

Water Horehound

Lycopus americanus

Prefers full sun and moist to wet soils. Spreads through taproot and abundant production of rhizomes. Good for controlling soil erosion and stabilizing restoration areas. Dormant plant material does not need to be cut back from plants in larger restoration areas to maintain plant vigor.

Attracts butterflies and bees.

Habitat: Sun

Water Horehound in bloom in Summer

Water Horehound blossom
© *Mike Haddock*

Water Plantain

Alisma subcordatum

Prefers full sun and wet soil. The small white flowers resemble baby's breaths. Leaves formed underwater are ribbon-like and soon rot; they are seldom seen on adult plants. Often forms colonies.

Attracts bees.

Habitat: Sun

Water Plantain in Summer
© *Sally & Andy Wasowski*

Water Plantain blossom
© *Harry Cliffe*

White Turtlehead

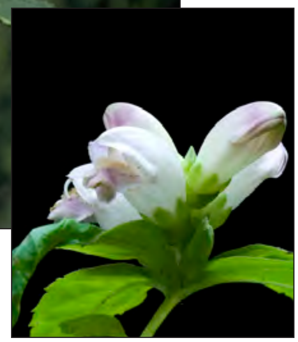
Chelone glabra

This species thrives in part shade and medium to moist soil. Appreciates a layer of composted leaf mulch, particularly in sunny areas. Pinching back the stem ends is encouraged in spring to reduce mature plant height, especially if growing plants in strongly shaded areas where they are more likely to need some support. In optimum environments, however, staking is usually not required. Cut back dead plant material during the winter months.

Attracts hummingbirds, bees and butterflies.

Habitat: Sun

White Turtlehead in bloom in late Summer
©*W.D. and Dolphia Bransford*



White Turtlehead blossom
© *Steven Faucette*

White Wood Aster

Aster divaricatus

A good plant for dry, shady spots. White Wood Aster will flower in full shade and spreads readily.

Attracts bees and butterflies.

Habitat: Shade

White Wood Aster in bloom in late Summer
© *George H. Bruso*

White Wood Aster flower
© *Robert Stone*

Whorled Rosinweed
Silphium trifoliatum

This drought tolerant species prefers full sun and moist to dry soil. Taller stems may need support. Plants can be cut back in the early summer to promote a shorter statured form. Cut back dormant plant material in late fall or early spring.

Attracts birds, bees and butterflies.

Habitat: Sun

Whorled Rosinweed dormant in winter
© *Dropseed Nursery*

Whorled Rosinweed in bloom in late Summer
© *W.D. and Dolphia Bransford*

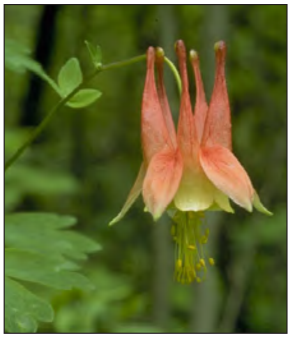
Wild Columbine
Aquilegia canadensis

This species will grow in shade, or in sun with moist soil. Cut back the stems after flowering to promote a second bloom. This plant will self seed and spread. Wild Columbine is evergreen unless the temperature exceeds 110 degrees F or -10 degrees F, which will cause the leaves to go dormant until the temperature returns to a more tolerable level.

Attracts hummingbirds, butterflies and bees.

Habitat: Shade

Wild Columbine leaves in winter
© *Dropseed Nursery*



Wild Columbine blossom
© *Mariann Watkins*

Wild Columbine in bloom in Spring
© *Jerry Garrett*

Wild Geranium
Geranium maculatum

Prefers shade and moist, rich soil; however it will tolerate dry soil in shady conditions and will tolerate some sun if the soil is moist and rich. Plant colonizes by thick rhizomes but is not aggressive. Foliage may yellow in hot summers if soil is allowed to dry out. Leaves die back completely in the winter.

Attracts butterflies and bees.

Habitat: Shade

Wild Geranium in bloom in Spring
© *Sally & Andy Wasowski*

Wild Geranium blossom
© *Thomas L. Muller*

Wild Ginger
Asarum canadense

Prefers shade and moist, rich soil; however it will tolerate dry soil in shady conditions and will tolerate some sun if the soil is moist and rich. The solitary greenish-purple flower is at ground level, hidden below the leaves. Can create a dense groundcover over time. Evergreen in mild winters.

Attracts butterflies. Food source for caterpillars.

Habitat: Shade

Wild Ginger in bloom
© *Mrs. W.D. Bransford*

Wild Ginger flower
© *Stefan Bloodworth*

Wild Ginger colony in Spring
© *Sally & Andy Wasowski*

Wild Quinine

Parthenium integrifolium

Wild Quinine prefers full sun and tolerates a variety of soil conditions. This species spreads by underground rhizomes, but not aggressively. Cut back plants in late winter.

Attracts bees. Makes a nice cut flower.

Habitat: Sun

Wild Quinine blossom
© *Stefan Bloodworth*

Wild Quinine in winter
© *Dropseed Nursery*

Wild Quinine in bloom in late Summer
© *Thomas L. Muller*

Wild Senna

Senna hebecarpa

Prefers sun to part shade and moist soil. After the bloom period, long brown seed pods form and last through the winter. May need to be staked.

Attracts bees, butterflies and hummingbirds. Seed pods attract birds.

Habitat: Sun

Wild Senna blossom
© *Mike Haddock*

Wild Senna seed pods
© *Julie Makin*

Wild Senna in bloom in late Summer
© *Mike Haddock*

Wild Stonecrop
Sedum ternatum

Tolerates part shade and moist soils better than most other sedums. Stems break away and die in winter, leaving newly rooted plants separated from the mother plant. Spread by creeping by creeping stems. Makes a nice ground cover. Drought tolerant.

Attracts butterflies. Not attractive to deer or rabbits.

Wild Stonecrop blossom
© *Missouri Botanical Garden*

Wild Stonecrop blossom
© *W.D. and Dolphia Bransford*

Wild Stonecrop in bloom in Spring
© *W.D. and Dolphia Bransford*

Wingstem
Verbesina alternifolia

Will thrive in full sun or partial shade and moist soil. Weedy clump forming plant. Taller stems may need support. Cut back dormant plant material in the winter. This species provides winter interest in the garden - ice ribbons form along the stem of this species after the first winter's freeze.

Attracts butterflies and birds.

Habitat: Sun

Wingstem blossom
© *Mike Haddock*

Wingstem with ice ribbon in Winter
©*Glen Conner*

Wingstem in bloom in late Summer
©*Mike Haddock*

Wood Aster
Aster cordifolius

A good option for a dry, shady location. Occasionally the foliage is affected by powdery mildew and other kinds of disease during the fall. During hot dry weather, the lower leaves may wilt and fall off. The size of this plant is variable depending on the fertility of the soil and moisture conditions. Cut back dead plant material in the late winter.

Attracts butterflies and bees.

Habitat: Shade

Wood Aster in bloom in Fall
© *W.D. and Dolphia Bransford*

Wood Aster blossom
© *W.D. and Dolphia Bransford*

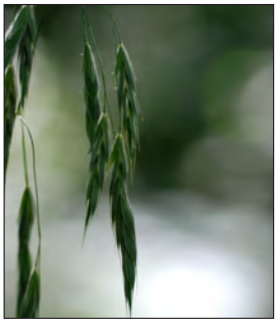
Woodland Brome
Bromus pubescens

One of the taller grasses that will tolerate shade. Cut back in late winter or early spring.

Attracts birds.

Habitat: Shade

Woodland Brome flowers
© *Mike Haddock*



Woodland Brome seed head
© *Mike Haddock*

Woodland Brome in Summer
© *Mike Haddock*

Woodland Sunflower
Helianthus divaricatus

A plant for dry, shady sites. Very drought tolerant. Spreads over time by creeping rhizomes to form colonies. Divide every 3-4 years to control spreadand maintain vigor. Taller plants may need staking. Cut back plants in early spring to allow birds to feed on the seedheads during the winter months.

Attracts birds, bees and butterflies. Make nice cut flowers. Not attractive to deer.

Habitat: Shade

Woodland Sunflower in bloom in Fall
© *Albert F.W.Vick*

Woodland Sunflower blossom
© *Edwin M. Martin*

Woolgrass
Scirpus cyperinus

Good for erosion control when planted en masse. Bulrush forms a buffer against wind and wave action, thus permitting other aquatic plants to grow in an otherwise unfavorable environment. Cut back in late winter or early spring.

Attracts ducks and other wetland birds. Provides nesting habitat for many wetland birds. Food source for caterpillars.

Habitat: Sun

Woolgrass dormant in winter
© *Matthew L.Wagner*

Woolgrass in Summer
© *Elaine Haug*

Yellow Fox Sedge
Carex annectens

Prefers full to part sun and wet to moist conditions. Cut back in late winter or early spring. Good for erosion control.

Attracts birds. Food source for caterpillars. Not attractive to deer.

Habitat: Sun

Yellow Fox Sedge seed head in Spring
© Sally & Andy Wasowski

Yellow Fox Sedge seed head
© R.W. Smith

Zig-Zag Goldenrod
Solidago flexicaulis

This species will grown in full sun to full shade and moist soil. Will also grow in clay soils. Drought tolerant. Plants can be somewhat spreading in optimum growing conditions. Susceptible to powdery mildew and leaf spot.

Attracts birds and butterflies. Not attractive to deer.

Habitat: Shade

Zig-Zag Goldenrod in seed
© Restoring the Landscape.com

Zig-Zag Goldenrod blossom
© Sally & Andy Wasowski

Zig-Zag Goldenrod in bloom in Fall
© Albert F.W.Vick

Trees and Shrubs

Allegheny Serviceberry

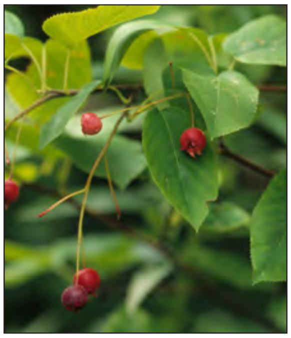
Amelanchier laevis

Serviceberry is a multiple-trunked tree or shrub, 15-25 ft. tall, with dense, fine-textured branching. Serviceberries are subject to many disease and insect problems, but damage from these problems is usually cosmetic rather than life threatening.

Attracts birds. Food source for caterpillars.

Habitat: Sun

Allegheny Serviceberry Flowers



Allegheny Serviceberry, edible berries ripen mid-summer
© *Sally & Andy Wasowski*

Allegheny Serviceberry in the spring
© *Mark Brand 1997-2001*

American Beech

Fagus grandifolia

Leaves turn copper-colored in the fall and hold on most of the winter. Beech develops suckers from its vast system of surface roots. Entire beech groves have often grown from the roots of a single tree. Shade tolerant. Long-lived. Not suitable for small areas. Resistant to many pests and diseases, though a barkfungus disease has proven fatal. Prune in summer or early fall. Root system is shallow, so it is difficult to grow grasses under beech.

Attracts butterflies, birds and other wildlife. Food source for caterpillars. Beechnuts is one of the most important food sources for wildlife.

Habitat: Sun

American Beech in early fall
© *Alfred Vick*

American Beech fruit
© *Benny Simpson*

American Bittersweet
Celastrus scandens

A high-climbing, twining, woody vine that produces small green flowers and distinctive bicolored fruits. Generally one male plant is needed for 6-9 female plants. Female plants may be vegetatively propagated to create more female plants. Prune in late winter to early spring.

Oriental Bittersweet is a very invasive introduced species that spreads easily into natural areas and reduces the diversity of native species. American Bittersweet fruits are arranged in clusters at the ends of the stems. Fruits of Oriental Bittersweet are located in the axils of the leaves along the entire length of the stem.

Attracts birds.

Habitat: Sun

American Bittersweet with early summer blossoms
© *Mike Haddock*

American Bittersweet, colorful fruit ripen in the fall
© *Mike Haddock*

American Hazelnut
Corylus americana

Prompt removal of root suckers will help maintain plant appearance, and, if desired, help prevent thicket formation. In spring before the leaves have emerged, male flowers appear in showy, 2-3" long, yellowish brown catkins and female flowers appear in small, reddish, inconspicuous catkins. Female flowers give way to small, egg-shaped, 1/2" long, edible nuts (maturing July-August) which are encased in leafy, husk-like, ragged-edged bracts. Fall color is quite variable, ranging from attractive combinations of orange, rose, purplish red, yellow and green to undistinguished, dull yellowish green. Plants can be pruned back to 50% of total size every 5 years to promote fruit production.

Attracts birds and other wildlife.

American Hazelnut, early spring with male flowers
© *Missouri Botanical Garden*

American Hazelnut female flower
© *Sally & Andy Wasowski*

American Hornbeam

Carpinus caroliniana

This slow-growing deciduous understory tree is known for its smooth gray trunk with muscle-like fluting, elliptic-oval dark green leaves and distinctive, pendulous seed clusters of winged nutlets, which appear in late spring after the flowering catkins. Leaves turn yellow, orange and red in fall. This species requires little pruning is not susceptible to disease or insect damage.

Habitat: Shade

American Hornbeam - fruit and fall color

American Hornbeam female flowers
© *Sally & Andy Wasowski*

American Hornbeam's sinewy texture
© *Mark Brand 1997-2001*

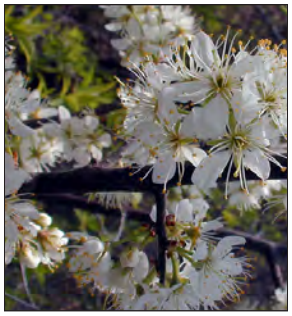
American Plum

Prunus americana

A thicket-forming shrub or small tree with short trunk, many spreading branches, broad crown, showy large white flowers, and red plums. Fall foliage ranges from electric red to pale yellow. American Plum is sometimes grown for erosion control, spreading by root sprouts. This species has fragrant flowers and thorns. Plum curculio and brown rot can affect the fruit. Other potential disease problems include leaf spot, canker and black knot. Potential insect problems include aphids, scale, borers and tent caterpillars.

Attracts bees, birds and butterflies.

Habitat: Sun



American Plum, spring flowers
© *Mike Haddock*

American Plum, fruit
© *Mike Haddock*

American Plum with spring flowers
© *Mike Haddock*

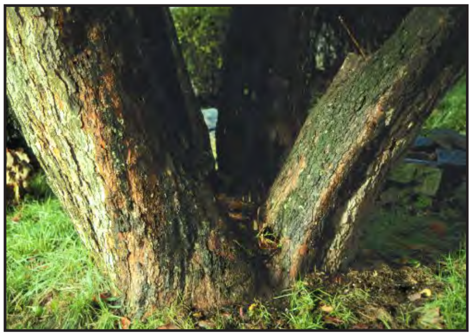
American Smoketree

Cotinus obovatus

Once it is established within its range, this species thrives on tough conditions and neglect and should not be over-watered. Rich soil and too much water may create a weak plant. A small tree valued for its trunk and branches, cloud-like spring blooms, and standout fall foliage.

Attracts birds.

Habitat: Sun



American Smoketree, bark
© *Mark Brand 1997-2001*

American Smoketree, spring flowers
© *Albert F.W. Vick*

American Smoketree in fall color
© *Mark Brand 1997-2001*

Arrow-wood

Viburnum dentatum

Lustrous, dark-green foliage turns yellow to wine-red in fall. Suckers freely from base; suckers require periodic cutting unless a dense, thicket growth is desired. This species is adaptable to many soil types and moisture levels.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun

Arrow-wood, fruit
© *R.W. Smith*

Arrow-wood, spring flowers
© *Lynn & Campbell Loughmiller*

Arrow-wood in bloom, spring
© *Sally & Andy Wasowski*

Bald Cypress

Taxodium distichum

This lofty, deciduous conifer is slender and conical in youth, becoming flat-topped in very old age. Develops a buttressed trunk base. Exfoliating bark is red-brown to silver. Fall foliage is orange and red. Plants can experience damage from some insects and diseases; however are seldom severely damaged.

Attracts birds. Food source for caterpillars.

Habitat: Sun

Bald Cypress, in fall
© *Norman G. Flaigg*

Bald Cypress, in fall with developing cones
© *Marilyn Kircus*

Bald Cypress, mid-summer
© *David K. Northington*

Bitternut Hickory

Carya cordiformis

This is the most rapid growing of all hickory trees. It is difficult to transplant because of a large taproot, but perhaps less so than other hickories. Suffers from soil compaction and is sometimes weakened by its branching structure. In manicured areas, the small nuts can be a nuisance. Unlike other hickories, this species casts an open shade, allowing turf or ornamentals to thrive underneath. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun

Bitternut Hickory, mid-summer
© *Missouri Botanical Garden*

Black Cherry

Prunus serotina

This is a fast-growing, pioneer species. Young trees develop a long tap root which makes transplanting difficult. When open-grown it becomes oval-headed with spreading, pendulous limbs and arching branches. Crowded trees grow tall and slender. Aromatic tree; crushed foliage and bark have distinctive cherry-like odor. Fall foliage is yellow. Potential diseases include leaf spot, die back, leaf curl, powdery mildew, root rot and fireblight. Potential insects include aphids, scale, borers, leafhoppers, caterpillars, tent caterpillars and Japanese beetles. Spider mites may also be troublesome. Attracts bees, birds and butterflies. Food source for other wildlife.

Habitat: Sun

Black Cherry in flower
© *Missouri Botanical Garden*

Black Cherry with spring flowers
© *Mark H. Brand*

Black Cherry in winter
© *Paul Cox*

Black Chokeberry

Aronia melanocarpa

This very adaptable shrub will thrive in shade or sun, moist or dry soil. A native shrub option that stays fairly short - typically 5' tall. Remove root suckers to prevent colonial spread. Lustrous, dark green foliage turns an attractive purplish red in autumn. Deciduous shrub.

Attracts birds.

Habitat: Sun

Black Chokeberry, with fall color
© *Mark H. Brand*

Black Chokeberry, spring flowers
© *Missouri Botanical Garden*

Black Chokeberry, with ripe fruit in late summer
© *Missouri Botanical Garden*

Black Gum

Nyssa sylvatica

Tree with a dense, conical or sometimes flat-topped crown, many slender, nearly horizontal branches, and glossy foliage turning scarlet in autumn. Berries are small and blue. Female trees need a male pollinator to set fruit. This slow growing species transplants poorly due to a fleshy, non-fibrous root system. Black gum does not age gracefully and is occasionally troubled by insect and disease problems.

Attracts bees and birds.

Habitat: Sun

Black Gum in winter
© *Mark H. Brand*

Black Gum fruit forming in fall
© *Sally & Andy Wasowski*

Black Gum with fall color
© *Sally & Andy Wasowski*

Black Walnut

Juglans nigra

Slow-growing if not in its preferred moist, fertile, sunny site. Wide-spreading branches form an upright, umbrella-like crown in the woods or a round-topped crown in the open. The deep tap-root makes transplanting difficult. Nuts may become a nuisance as they litter and stain. Foliage is often attacked by caterpillars, and the species is susceptible to anthracnose which defoliates trees for the season. Certain plants such as azaleas, rhododendrons, blueberries, peonies and solanaceous crops (tomatoes, peppers, potatoes), will not grow under Black Walnut trees because of chemicals that the tree puts in the soil. Yellow fall foliage.

Attracts butterflies, bees, and birds. Food source for caterpillars, squirrels and other wildlife.

Habitat: Sun

Black Walnut mid-summer
© *Norman G. Flaigg*

Black Walnut in winter
© *Albert F. W. Vick*

Black Willow
Salix nigra

A fast-growing tree with an open crown and typically several trunks growing out at angles from one root. Short-lived and fast-growing. Susceptible to insect and wind damage. Used to control soil erosion.

Attracts bees, butterflies, birds and other wildlife. Food source for caterpillars.

Habitat: Sun

Black Willow fruit
© *Harry Cliffe*

Black Willow flowers
© *Joseph A. Marcus*

Black Willow in early spring
© *Joseph A. Marcus*

Blackhaw Viburnum
Viburnum prunifolium

Prune immediately after flowering to promote flowering in the following year. Black haw is usually grown as a large, upright, multi-stemmed, deciduous shrub with an irregular crown, but it also may be grown as a small, single trunk tree. Attractive shades of red and purple in the fall.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun

Blackhaw Viburnum in fall
© *Mark H. Brand*

Blackhaw Viburnum flowers
© *Missouri Botanical Garden*

Blackhaw Viburnum, spring flowering
© *Missouri Botanical Garden*

Blackjack Oak

Quercus marilandica

Slow-growing, long-lived, and able to survive on very poor soils. Susceptible to oak wilt. This tree can often have an irregular form in poor soil but develops a symmetrical attractive form in good soil with room to grow.

Attracts birds, butterflies and other wildlife. Food source for caterpillars.

Habitat: Sun

Blackjack Oak in fall
© *Missouri Botanical Garden*

Blackjack Oak leaves mid-summer
© *Missouri Botanical Garden*

Bur Oak

Quercus macrocarpa

Bur oak typically has a very wide, open crown. Usually wider than tall, the tree can exceed 100 ft. in height and width. The acorns of this species are the largest of all native oaks. Bur oak is drought resistant, long-lived and reasonably fast-growing for an oak. Tolerates limey soils better than other oaks. Resistant to oak wilt and a number of other problems. Sensitive to root zone disturbance caused by construction. Fall foliage is yellow.

Attracts birds, butterflies and other wildlife.

Habitat: Sun

Bur Oak in winter
© *Mark H. Brand*

Bur Oak leaves mid-summer
© *Sally & Andy Wasowski*

Bur Oak, mid-summer
© *Sally & Andy Wasowski*

Buttonbush
Cephalanthus occidentalis

Pruning is usually not necessary, but may be done in early spring to shape. If plants become unmanageable, however, they may be cut back near to the ground in early spring to revitalize. Trunks are often twisted. Fragrant flowers.

Attracts bees, birds and butterflies.

Habitat: Sun

Buttonbush fruit
© Sandy Smith

Buttonbush, late spring flowers
© Norman G. Flaigg

Buttonbush, mid-summer
© Sally & Andy Wasowski

Willow Oak
Quercus phellos

Willow Oak is a large sized deciduous oak with narrow, willow-like leaves. Fall foliage is yellow-brown. Grows best in moist soil.

Attracts birds and other wildlife.

Habitat: Sun

Chestnut Oak leaves in the fall
© Missouri Botanical Garden

Chestnut Oak in winter
© Alfred F.W. Vick

Chestnut Oak mid-summer
© Missouri Botanical Garden

Chinese Dogwood

Cornus kousa

Chinese Dogwood is a small, deciduous flowering tree or large multi-stemmed shrub with a vase-shaped habit in the early years, eventually maturing to a more rounded habit. Crimson and scarlet fall colors. This plant has better disease resistance and better cold hardiness than the native flowering dogwood, and is an excellent alternative to flowering dogwood in areas where dogwood anthracnose is a problem.

Attracts birds and butterflies.

Habitat: Sun

Chinese Dogwood, winter
© *Mark H. Brand*

Chinese Dogwood, spring blooms
© *Mark H. Brand*

Chinese Dogwood, spring
© *Mark H. Brand*

Cockspur Hawthorn

Crataegus crus-galli

Cock-spur hawthorn is a small, globular, deciduous tree with a short trunk; exfoliating bark; horizontal, thorny branches which sweep the ground; and thick, glossy foliage which turns bright orange or red in fall. The low, densely set branches make it difficult to grow grasses under this tree. The tree is susceptible to fire blight, several species of rust, and insect damage, but is tolerant of city pollution. Prune in winter or early spring.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun

Cockspur Hawthorn, winter
© *Mark H. Brand*

Cockspur Hawthorn, fall
© *Mark H. Brand*

Cockspur Hawthorn, mid-summer
© *Mark H. Brand*

Common Elderberry
Sambucus canadensis

This is a loose, graceful, deciduous shrub grows to 12 ft. in height. Prune heavily in winter to maintain shape. Elderberry is a fast grower and aggressive competitor with weeds and herbaceous species. Individual plants are very short-lived; however, root masses produce new shoots. Cutting the whole bush to the ground every other year may be necessary to keep the bushes in check.

Attracts bees, butterflies and birds.

Habitat: Sun

Common Elderberry, early summer flower
© *Mark H. Brand*

Common Elderberry, in winter
© *Mark H. Brand*

Common Elderberry, in flower
© *Mark H. Brand*

Common Ninebark
Physocarpus opulifolius

A mound-shaped, thicket-forming deciduous shrub, Common Ninebark offers spiraea-like flowers, attractive and persistent fruit pods, arching branches, yellow fall color, and exfoliating bark. It is a fast-growing shrub, insect and disease resistant, and drought-tolerant. Prune as needed immediately after bloom. Plants may be cut to the ground in winter to rejuvenate.

Attracts birds.

Habitat: Shade

Common Ninebark, in winter
© *Mark H. Brand*

Common Ninebark, spring flowers
© *Stefan Bloodworth*

Common Ninebark leaves
© *Mark H. Brand*

Coralberry

Symphoricarpos orbiculatus

The greenish-white flower clusters are not as showy as the clusters of coral-pink to purple berries up to 1/4 inch in diameter which remain on the plant through winter. Coralberry forms extensive colonies and spreads by rooting at the nodes where it touches the ground. Can be pruned to limit spread and maintain shape. Not susceptible to diseases or insect damage.

Attracts birds and small mammals.

Habitat: Shade

Coralberry in the winter
© *Dropseed Nursery*

Coralberry in the fall with fruit
© *Sally & Andy Wasowski*

Coralberry, mid-summer
© *Sally & Andy Wasowski*

Crossvine

Bignonia carpreolata

Crossvine is sometimes seen high in a tree, as the vine climbs by means of tendrils, allowing it to cling to stone, bricks and fences without support. Persistent, glossy, semi-evergreen leaves change from dark green in summer to reddish-purple in winter. Above ground stems are not reliably winter hardy throughout USDA Zone 5 where they may die to the ground in severe winters (roots are usually hardy therein and will sprout new growth the following spring).

Attracts bees, hummingbirds and butterflies.

Habitat: Sun

Crossvine
© *Ray Matthews*

Crossvine flowers
© *Campbell & Lynn Loughmiller*

Devil's Walking Stick

Aralia spinosa

Will grow in partial shade to full sun and in moist to dry soils. Colonizes freely by rhizomes and suckers. These can be dug out, however it is still too aggressive for small spaces. Has thorns.

Attracts bees, butterflies and birds.

Habitat: Sun

Devil's Walking Stick with flowers in the spring
© *Paul Cox*

Devil's Walking Stick with ripe fruit in the fall
© *Sally and Andy Wasowski*

Devil's Walking Stick, summer
© *Mark H. Brand*

Cornelian Cherry Dogwood

Cornus mas

This dogwood is a multi-stemmed, low-branching, round to oval, deciduous shrub or tree. Can be trained as a small tree by removal of suckers and lower branches. Fall foliage has a purple tinge. Very early spring bloom.

Attracts birds.

Habitat: Sun

Cornelian Cherry Dogwood, bark
© *Mark H. Brand*

Cornelian Cherry Dogwood, spring bloom
© *Mark H. Brand*

Cornelian Cherry Dogwood, summer
© *Mark H. Brand*

Eastern Hophornbeam

Ostrya virginiana

A tree with a trunk that looks like sinewy muscles and a rounded crown of slender, spreading branches. Fruits are borne in a hanging, hop-like structure. Resistantto insects (except the gypsy moth), disease, wind, ce, and most stresses of urban living. Notoriously sensitive to salt. Slow-growing. Yellow fall foliage.

Attracts birds and other wildlife.

Habitat: Sun

Eastern Hophornbeam in winter
© *Mark H. Brand*

Eastern Hophornbeam, emale flowers
© *Mike Haddock*

Eastern Hophornbeam in summer
© *Sally & Andy Wasowski*

Eastern Red Cedar

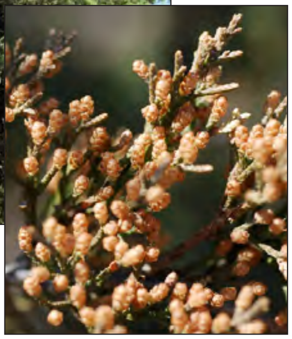
Juniperis virginiana

Evergreen, aromatic tree with trunk often angled and buttressed at base and narrow, compact, columnar crown; sometimes becoming broad and irregular. Pale blue fruits occur on female plants. Foliage may turn brown-green in winter. Root rot and cedar rusts are the most common diseases to harm this species; overall, fairly disease resistant.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun

Eastern Red Cedar- an evergreen
© *Sally & Andy Wasowski*



Eastern Red Cedar male flowers
© *Mike Haddock*

European Hornbeam

Carpinus betulus "Globosa"

Needs little pruning when grown as a tree, but respondswell to hard pruning if grown as a hedge. Best pruned during the period of late summer to mid-winter to avoid significant bleeding. Yellow and orange fall colors.

Attracts birds.

Habitat: Sun

European Hornbeam flowers in winter
© *Gary J. King*

European Hornbeam fruit and leaves
© *Bernheim Forest*

European Hornbeam in summer
© *Bernheim Forest*

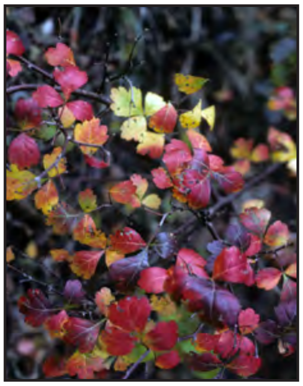
Fragrant Sumac

Rhus aromatica

This shrub turns fall colors of red, yellow and orange. Fragrant sumac colonizes to form thickets and looks best when planted en mass or in drift-like plantings as it occurs in nature. Leaves and twigs are aromatic when bruised. Separate male and female plants – only the female plants produce red berries.

Attracts bees, butterflies, and birds. Food source for a large variety of caterpillars.

Habitat: Sun



Fragrant Sumac, fall color
© *Sally & Andy Wasowski*

Fragrant Sumac berries

Fragrant Sumac in summer
© *Norman G. Flaigg*

Fringe Tree

Chionanthus virginicus

Shrub or small tree with short trunk, narrow, oblong crown, and showy masses of fragrant, lacy, white flowers. Seldom needs pruning. Fall foliage is yellow.

Attracts birds. Food source for caterpillars.

Habitat: Sun

Fringe Tree in winter
© *Mark H. Brand*

Fringe Tree flower
© *Sally & Andy Wasowski*

Fringe Tree in summer

Fullmoon Maple

Acer japonicum "Taki No Gawa"

Leaves emerge with bronze tones, mature to green and develop excellent deep purple, orange and red fall colors. Site in locations protected from strong winds. Stake trunk for more erect growth or leave alone for spreading effect.

Habitat: Shade

Fullmoon Maple in summer
© *Bernheim Forest*

Fullmoon Maple flowers in the spring
© *Bernheim Forest*

Green Hawthorn
Crataegus viridis

Thicket-forming tree with straight, often fluted, trunk and rounded, dense crown of spreading branches, shiny foliage, showy flowers, and small red to yellow fruit. Prune in winter or early spring. Purple and red fall color.

Attracts bees, birds and butterflies. Food source for caterpillars.

Habitat: Sun

Green Hawthorn flowers
© *Stefan Bloodworth*

Green Hawthorn in fruit
© *Sally & Andy Wasowski*

Green Hawthorn in flower
© *Sally & Andy Wasowski*

Hackberry
Celtis occidentalis

Branches of this and other hackberries may become deformed bushy growths called witches-brooms produced by mites and fungi. The leaves often bear rounded galls caused by tiny jumping plant lice. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun

Hackberry in winter
© *Mark H. Brand*

Hackberry in fall
© *Mark H. Brand*

Hackberry in summer
© *Mark H. Brand*

Higan Cherry
Prunus subhirtella

Potential diseases include leaf spot, die back, leaf curl, powdery mildew, root rot and fireblight. Potential insects include aphids, scale, borers, leafhoppers, caterpillars, tent caterpillars and Japanese beetles. Spider mites may also be troublesome.

Attracts bees, birds and butterflies.

Habitat: Sun

Higan Cherry with spring flowers
© Missouri Botanical Garden

Higan Cherry flowers
© Missouri Botanical Garden

Honey Locust
Gleditsia triacanthos

Fall color is yellow. Seed pods change from red-green to maroon-brown as they mature and persist into winter. Most wild trees are not thornless; the long, needle-sharp thorns are extremely vicious and are not desirable in urban areas. Gleditsia triacanthus "Inermims" Thornless Honey Locust is an ideal choice for domestic applications. Honey locust is fast-growing and long-lived. It suffers from mites, Mimosa webworm invaders, a number of cankers, and other pests. Exhibits drought-, heat-, high pH-, and salt-tolerance. Its filtered shade makes underplanting easy.

Attracts butterflies, bees, birds and other wildlife. Food source for caterpillars.

Habitat: Sun

Honey Locust in winter
© Missouri Botanical Garden

Honey Locust in summer
© Missouri Botanical Garden

Honey Locust in fall
© Missouri Botanical Garden

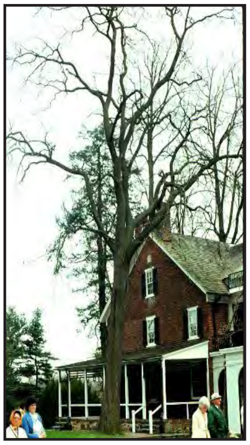
Kentucky Coffeetree
Gymnocladus dioicus

Kentucky coffeetree is resistant to disease and insect problems and adaptable to drought, heat, cold, salt and city conditions. The tree is slow-growing. Occasional root suckers should be pulled. Prune in winter or early spring. Large pods can be messy in manicured settings. When crowded by other trees, this species grows tall and slender. If more open-grown, it becomes a round-topped tree. Fall foliage is yellow-green.

Attracts butterflies, bees, and birds.
Food source for caterpillars.

Habitat: Sun

Kentucky Coffeetree with fruit on female tree
© *Mark H. Brand*



Kentucky Coffeetree in fall
© *Mark H. Brand*

Kentucky Coffeetree in summer
© *Mark H. Brand*

Leadplant
Amorpha fruticosa

Plants develop a leggy character with the majority of their pinnately compound, fine-textured foliage on the upper third of the plant. Can be weedy and invasive. Useful as a shrub to colonize erosion prone areas.

Attracts butterflies and bees. Food source for many species of caterpillars.

Habitat: Sun

Leadplant with mid-summer flowers
© *R.W. Smith*

Leadplant, mid-summer
© *R.W. Smith*

Leadplant in summer
© *Paul Cox*

Meadowsweet

Spiraea alba

Meadowsweet likes wet soil and full sun. Remove spent flower clusters to promote additional bloom.

Attracts bees, butterflies and birds. Food source for caterpillars. Not attractive to deer. Makes nice cut flowers.

Habitat: Sun

Meadowsweet flowers with butterfly
© *Missouri Botanical Garden*

Meadowsweet flowers
© *W.D. and Dolphia Bransford*

Meadowsweet in flower mid-summer
© *Sally & Andy Wasowski*

New Jersey Tea

Ceanothus americanus

Thick, woody, red roots go deep and help plant withstand droughty conditions, but make established shrubs difficult to transplant. Fragrant flowers.

Attracts bees, butterflies and hummingbirds.

Habitat: Shade

New Jersey Tea fruit
© *Julie Makin*

New Jersey Tea flowers
© *Missouri Botanical Garden*

New Jersey Tea flowering in spring
© *Sally & Andy Wasowski*

Oak-leaf Hydrangea
Hydrangea quercifolia

Susceptible to sunscald, chlorosis in alkaline soils, and winter dieback. Many weak, brittle canes are easily broken in wind and ice. Forms colonies from a shallow root system. Canes can be cut to the ground every two or three years to keep the shrub smaller, but if the canes are allowed to grow, the naturally peeling bark is attractive. Pest free. Prune immediately after flowering. Foliage turns bronze and crimson in the fall.

Habitat: Shade

Oak-leaf Hydrangea flowers
© W.D. and Dolphia Bransford

Oak-leaf Hydrangea in winter
© Dropseed Nursery

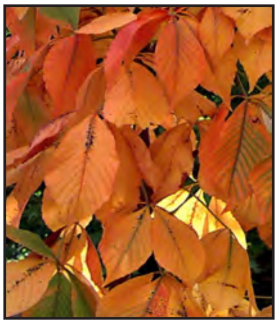
Oak-leaf Hydrangea flowering in July
© W.D. and Dolphia Bransford

Ohio Buckeye
Aesculus glabra

Branches bend toward the ground then arch back up, creating a rounded outline. Fall color is usually yellow, although foliage may develop interesting and attractive shades of orange and red in some years. It can be difficult to grow grass under Ohio buckeye because of the dense foliage. It is one of the first trees to leaf out in the spring and lose its foliage in fall. In hot, droughty situations, leaf blotch, leaf scorch and a variety of other physiological and pest problems can be serious.

Attracts hummingbirds, birds and squirrels.

Habitat: Sun



Ohio Buckeye leaves, fall color
© Mark H. Brand

Ohio Buckeye flowers
© Julie Makin

Ohio Buckeye in early spring
© Julie Makin

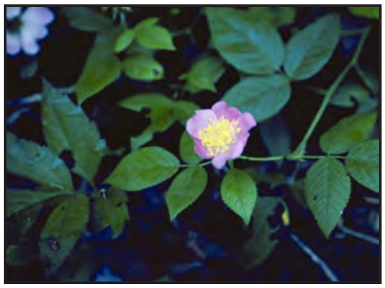
Pasture Rose
Rosa carolina

Remove and destroy diseased leaves from plants, and clean up and destroy dead leaves from the ground around the plants both during the growing season and as part of a thorough clean-up during winter. Crowns appreciate protection in cold winter climates. Prune in late winter to early spring. Fragrant flowers.

Attracts bees, butterflies and birds.

Habitat: Sun

Pasture Rose fruit
© *Missouri Botanical Garden*



Pasture Rose flowering in early summer
© *Mrs. W.D. Bransford*

Pasture Rose flowers
© *Sally & Andy Wasowski*

Peach-leaf Willow
Salix amygdaloides

Medium-sized tree with one or sometimes several straight trunks, upright branches, and spreading crown. Short-lived and fast-growing. Susceptible to insect, disease, and wind damage. Used for erosion control.

Attracts butterflies and birds. Food source for caterpillars.

Habitat: Sun

Peach-leaf Willow flowers
© *Robert L. Carr*

Peach-leaf Willow leaves
© *Robert L. Carr*

Peach-leaf Willow in spring
© *Robert L. Carr*

Persimmon

Diospyros virginiana

This tree is valued for its fruit and attraction to wildlife. Two trees are necessary for the production of fruit. Fruit is not edible until exposed to frost or consistent low temperatures. Promptly remove root suckers unless naturalized effect is desired. Because of a deep root system, successful underplanting is possible. Size of tree can vary greatly depending on soil.

Attracts birds. Food source for caterpillars.

Habitat: Sun

Persimmon bark
© *Mark H. Brand*

Persimmon fruit in fall
© *Mark H. Brand*

Persimmon, summer
© *Mark H. Brand*

Pin Oak

Quercus palustris

Pin oak is a strongly pyramidal tree with a straight-trunk, spreading horizontal branches, very slender pinlike twigs, and a broadly conical crown. Susceptible to iron chlorosis which causes yellow coloration in the leaves through the summer months and can eventually kill the tree. Pin oak is shallow-rooted and easily transplanted, and it will tolerate urban conditions. Fall foliage is red.

Attracts birds, butterflies, hummingbirds and other wildlife. Food source for caterpillars.

Habitat: Sun

Pin Oak leaves in fall

© *Mark H. Brand*

Pin Oak in winter
© *Mark H. Brand*

Pin Oak, mid-summer
© *Mark H. Brand*

Possumhaw Holly

Ilex decidua

Plants of this species are mostly separate male and female, although some plants have perfect flowers (complete flowers with functioning stamens and pistils). For best show of berries, plant female plants, with at least one male plant to insure that pollination will take place. Prune to shape in early spring just before new growth begins. Berries persist through the winter and into the early spring when new growth begins.

Attracts bees, birds and other mammals.

Habitat: Sun

Possumhaw Holly in winter
© *W.D and Dolphia Bransford*

Possumhaw Holly flowers
© *Harry Cliffe*

Possumhaw Holly mid-summer
© *Sally & Andy Wasowski*

Pussy-Willow

Salix discolor

Pussy willow is a narrow shrub or small tree to 20 ft. with multiple trunks and dark-gray, scaly bark. Short-lived and fast-growing, pussy willows should be cut back heavily every few years to encourage new growth. This plant is susceptible to insect, disease, and wind damage and tends to sucker to the point of being invasive if given continuously moist soil.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun

Pussy-Willow flower buds
© *Missouri Botanical Garden*

Pussy-Willow male flowers
© *Missouri Botanical Garden*

Pussy-Willow in winter
© *Missouri Botanical Garden*

Red Chokeberry
Aronia arbutifolia

A very adaptable shrub that will thrive in sun or shade and in moist or dry soil. Remove root suckers to prevent colonial spread. This species typically grows in a vase-shaped form to 6-10' tall and to 3-6' wide, but tends to sucker and form colonies. Foliage turns bright red in autumn.

Attracts birds.

Habitat: Shade

Red Chokeberry fruit
© *Mark H. Brand*

Red Chokeberry with spring flowers
© *Mark H. Brand*

Red Chokeberry, mid-summer
© *Mark H. Brand*

Red Oak
Quercus rubra

Its straight trunk is clear of branches for some distance above the ground and supports a wide canopy, commonly 3/4 that of height. Fall foliage can be crimson, golden-orange, or russet. One of the most rapid-growing oaks, it transplants easily, is hardy in city conditions, and endures cold.

Attracts butterflies, hummingbirds, birds and other wildlife. Food source for caterpillars.

Habitat: Sun

Red Oak in falls
© *Mark H. Brand*

Red Oak in winter
© *Mark H. Brand*

Red Oak, mid-summer
© *Mark H. Brand*

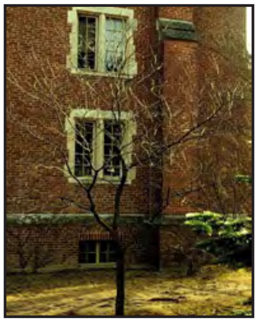
Redbud

Cercis canadensis

Single or multi-stemmed trunk with a wide umbrella-like crown. Showy pink flowers hug the branches and trunk in the spring. Since this tree does not transplant easily, it should be planted when young. Fall foliage may turn yellow. Redbuds are subject to damage by insect pests such as tree hoppers, caterpillars, scale, and leafhoppers. Diseases include Verticillium wilt, leaf spots, and the worst disease, canker. Spreads easily by seed.

Attracts butterflies and birds.

Habitat: Sun



Redbud in winter
© Mark H. Brand

Redbud flowers
© Julie Makin

Redbud in flower, spring
© Albert F.W. Vick

River Birch

Betula nigra

River birch is fast growing and long-lived and is probably our the most trouble-free birch. Do not prune until summer when the sap has stopped flowing. The tree's selling point is its satiny, silver bark that peels to reveala cinnamon-brown trunk beneath. Fall foliage is yellow but seldom effective.

Attracts birds.

Habitat: Sun

River Birch in winter ©
Mark H. Brand

River Birch bark
© Mark H. Brand

River Birch, mid-summer
© Mark H. Brand

Sassafras
Sassafras albidum

The aromatic sassafras is a deciduous tree with horizontal branching in cloud-like tiers. Sassafras can sucker into a small grove, but is easily controlled as a single tree. Large taproot makes transplanting of established trees difficult. If root suckers are not removed, tree will spread and begin to take on the appearance of a large multi-stemmed shrub. It is an appropriate tree to introduce into disturbed sites with infertile soil. Fall foliage is yellow, purple and red.

Attracts bees, butterflies and birds. Food source for caterpillars.

Habitat: Sun

Sassafras fruit
© *Missouri Botanical Garden*

Sassafras in winter
© *Missouri Botanical Garden*

Sassafras with fall color
© *Missouri Botanical Garden*

Shagbark Hickory
Carya ovata

This is the hickory with bark that peels in longcurls off the straight trunk. Tough to transplant, because of a large taproot, and slow to grow. Sensitive to disturbance once established. Undisturbed trees are fairly disease resistant. Leaves turn yellow to golden brown in fall.

Attracts birds. Squirrels harvest nuts.

Habitat: Shade

Shagbark Hickory leaves
© *Missouri Botanical Garden*

Shagbark Hickory bark
© *Albert F.W. Vick*

Shagbark Hickory, mid-summer
© *Mark H. Brand*

Shellbark Hickory
Carya laciniosa

Can be difficult to transplant because of its deep taproot. Cross-pollination generally produces a more abundant crop of better quality nuts. Shellbark nuts are the largest in size of the hickories.

Attracts birds and butterflies. Squirrels harvest nuts.

Habitat: Sun

Shellbark Hickory, leaves
© *Vern Wilkens*

Shellbark Hickory, mid-summer
© *Vern Wilkens*

Shellbark Hickory, bark
© *Vern Wilkens*

Shrubby St. John's Wort
Hypericum prolificum

Blooms on new growth. Prune in early spring. Bark of older branches exfoliates and reveals an orange inner bark in fall. A dry, dehiscent, three-valved capsule persists all winter. Very drought tolerant and disease resistant.

Attracts bees and other insects. Food source for caterpillars.

Habitat: Sun

Shrubby St. John's Wort in winter
© *Dropseed Nursery*

Shrubby St. John's Wort flower
© *Stefan Bloodworth*

Shrubby St. John's Wort in flower, summer
© *George H. Bruso*

Shumard Oak
Quercus shumardii

Shumard Oak is a fast-growing, pyramidal tree, growing 50-90 ft. and becoming more open at maturity. This species is quite drought resistant and also withstands short-term flooding. Can be difficult to transplant and establish. Fall foliage is scarlet.

Attracts butterflies, birds and other wildlife. Food source for caterpillars.

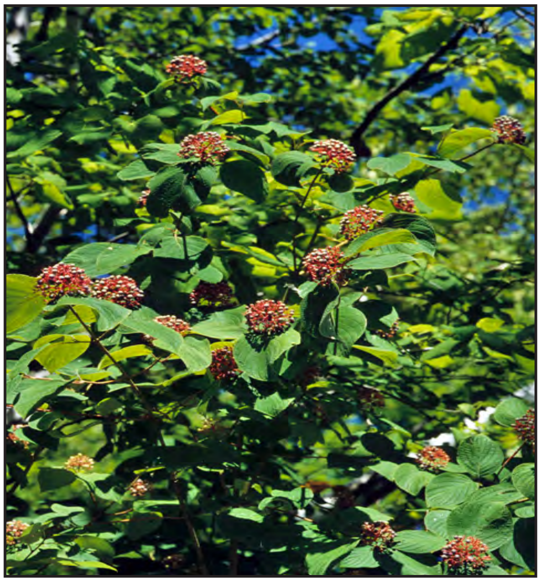
Habitat: Sun

Shumard Oak leaves
© *Chris Evans*

Shumard Oak and acorns
© *Sally & Andy Wasowski*

Shumard Oak with fall color
© *Sally & Andy Wasowski*

Silky Dogwood
Cornus amomum



Branches that touch the ground may root at the nodes. When left alone, this shrub may spread to form thickets. Good plant for colonizing and stabilizing stream banks. Twigs are purplish brown in spring.

Attracts birds.

Habitat: Shade

Silky Dogwood flower
© *Missouri Botanical Garden*

Silky Dogwood fruit
© *Mark H. Brand*

Silky Dogwood with fruit
© *Sally & Andy Wasowski*

Smooth Alder
Alnus serrulata

A multiple-trunked, suckering shrub or small tree, 12-20 ft. tall, with a picturesque habit and shiny gray-brown bark. Yellow and red fall colors. The wood is weak and breakage is common. Very flood tolerant. Alders fix nitrogen and thus serve as nutrient-giving pioneers in reclamation projects.

Attracts birds.

Habitat: Sun

Smooth Alder in summer
© *Karen A. Rawlins*

Smooth Alder male flowers
© *Sally & Andy Wasowski*

Smooth Alder in winter
© *John Ruter*

Sourwood
Oxydendrum arboreum

Tree with conical or rounded crown of spreading branches, clusters of flowers recalling Lily-of-the-valley. Open-grown sourwood is pyramidal and branched to the ground. If grown in shadier situations, the deciduous tree develops a taller, more columnar crown on a limbless trunk. Sourwood leaves turn a brilliant, deep-red in early fall. This species is not typically susceptible to insects or diseases.

Attracts bees and birds.

Sourwood flowers
© *Sally & Andy Wasowski*

Sourwood with fall color
© *Sally & Andy Wasowski*

Sourwood in flower, mid-July
© *Sally & Andy Wasowski*

Southern Blackhaw

Viburnum rufidulum

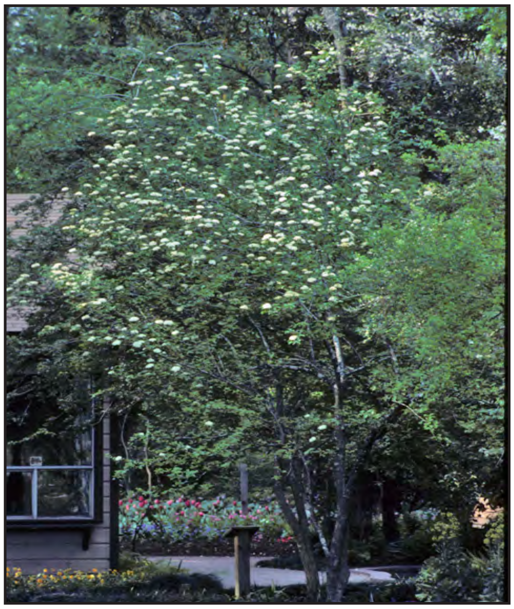
Slow-growing. With its waxy leaves, Southern Blackhaw presents excellent fall hues of red, lavender, pink, and orange. More than one plant should be used in order to facilitate proper pollination necessary for abundant fruit production. Promptly remove root suckers to prevent colonial spread unless naturalization is desired.

Attracts butterflies and birds.

Habitat: Sun

Southern Blackhaw with fall color
© *Stefan Bloodworth*

Southern Blackhaw flowers
© *Lee Page*



Southern Blackhaw in flower, spring
© *Sally & Andy Wasowski*

Spicebush

Lindera benzoin

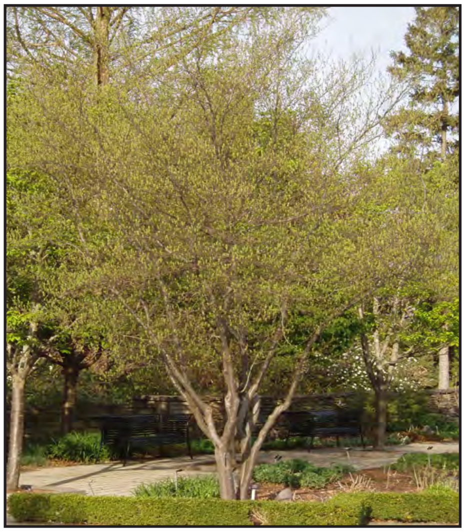
In fall, foliage turns yellow with female plants developing attractive but sometimes hidden red berry-like drupes. Hardy, fast-growing bush. Yellow leaf color in the fallLeaves are aromatic when crushed.

Attracts bees, butterflies, and birds. Food source for a large variety of caterpillars. Will tolerate clay soil. Not attractive to deer.

Habitat: Shade

Spicebush with fall color
© *Mark H. Brand*

Spicebush berries
© *Mark H. Brand*



Spicebush in early spring
© *Julie Makin*

Staghorn Sumac
Rhus typhina

Staghorn Sumac reaches tree size more often than related species and commonly forms thickets. This shrub is most effective when drifts or colonies, typical of natural settings, are allowed to establish. Can be used for erosion control. Colonies can be rejuvenated every few years by cutting them to the ground in mid-winter. Only female plants produce flowers and berries. Berries persist through winter. Attractive fall colors of red, orange and yellow.

Attracts bees and birds. Berries are a food source for a large variety of birds.

Habitat: Sun

Staghorn Sumac with fall color
© *Mark H. Brand*

Staghorn Sumac with fruit
© *John Hixson*

Staghorn Sumac, mid-summer
© *Albert F.W. Vick*

Steeplebush
Spiraea tomentosa

Dense, erect, plumes of pink to rose-purple flowers occur at the tips of the stems. The orange to reddish-brown bark has a peeling texture; the fall foliage is yellow. This species forms flowers on new wood, so prune in late winter to early spring if needed. Spreads by suckers to form colonies. Keep suckers cut back if single-stemmed form is desired. Susceptible to many of the diseases that attack other rose family members, including leaf spot, fire blight and powdery mildew.

Attracts bees, butterflies and birds. Food source for caterpillars.

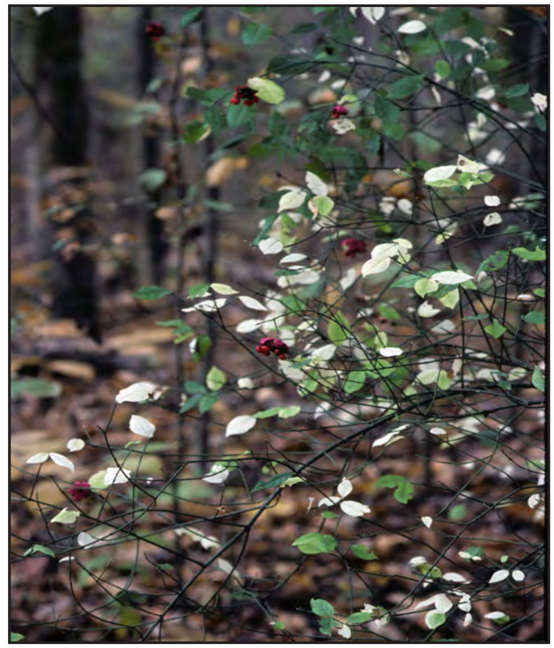
Habitat: Sun

Steeplebush in flower, summer
© *George H. Bruso*

Steeplebush in flower, summer
© *Stefan Bloodworth*

Strawberry Bush

Euonymus americanus

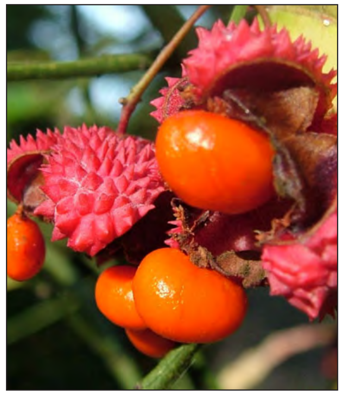


Its ridged twigs become purplish when exposed to the sun. Bright green, oval leaves become dark red in fall when bright red fruits open to reveal orange seeds. Strawberry Bush will spread by underground runners forming small thickets. The stems are relatively weak and taller plants often lean against other shrubs or trees for support.

Attracts birds and other wildlife.

Habitat: Shade

Strawberry Bush flower
© *Chris Evans*



Strawberry Bush fruit
© *Stefan Bloodworth*

Strawberry Bush in fruit
© *Sally & Andy Wasowski*

Sugar Maple

Acer saccharum

Large tree with rounded, dense crown and striking, multicolored foliage in autumn. The dense shade and shallow roots of sugar maple may preclude growing lush grass under its canopy. Has been frequently used as a street tree, but is generally intolerant of road salt, soil compaction and pollution.

Attracts birds.

Habitat: Shade

Sugar Maple, winter
© *Mark H. Brand*

Sugar Maple, mid-summer
© *Mark H. Brand*

Sugar Maple, fall
© *Mark H. Brand*

Sugarberry

Celtis laevigata

This tree tolerates wind, many urban pollutants and a wide range of soil conditions, including poor soils and is often planted along sidewalks and parking lots. Yellow fall color.

Attracts birds and butterflies. Food source for caterpillars.

Habitat: Sun

Sugarberry fruit
© *Franklin Bonner*

Sugarberry leaves
© *Melody Lytle*

Sugarberry mid-summer
© *Sally & Andy Wasowski*

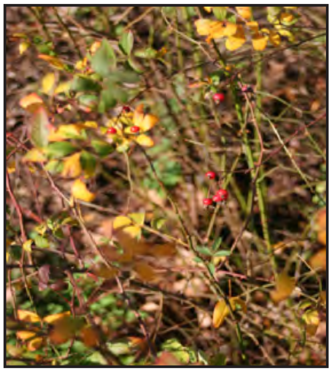
Swamp Rose

Rosa palustris

Swamp rose is an upright deciduous shrub with arching branches. Prune as needed in late winter. Plants slowly spread by suckers. Leaves often turn attractive shades red in fall. Forms attractive red fruits in the fall

Attracts bees, butterflies and birds.

Habitat: Sun



Swamp Rose in winter
© *Dropseed Nursery*

Swamp Rose with fall fruits
© *Missouri Botanical Garden*

Swamp Rose, summer flowers
© *Sally and Andy Wasowski*

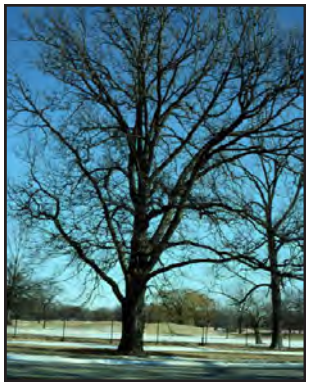
Swamp White Oak

Quercus bicolor

This is one of the faster growing oaks and appears to be more tolerant than similar oaks to landscape use. Swamp white is susceptible to iron chlorosis and prefers somewhat acidic soils. Leaves turn yellow to reddish purple in fall. Mature trees have distinctive, scaly-ridged, gray-brown bark.

Attracts birds and butterflies.

Habitat: Sun



Swamp White Oak in winter
© *Mark H. Brand*

Swamp White Oak male flowers
© *Mark H. Brand*

Swamp White Oak, mid-summer
© *Mark H. Brand*

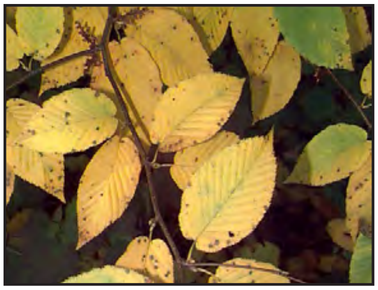
Sweet Birch

Betula lenta

Conical in youth, the deciduous tree becomes ovoid to globular in maturity. Aromatic tree with rounded crown of spreading branches and odor of wintergreen in crushed twigs and foliage. Fall color is golden-yellow and the flower is a catkin that appears before leaf emergence. Do not prune until summer when the sap has stopped flowing.

Attracts birds.

Habitat: Shade



Sweet Birch, leaves with fall color
© *Mark H. Brand*

Sweet Birch in winter
© *Mark H. Brand*

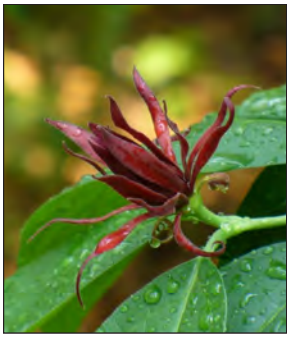
Sweet Birch mid-summer
© *Mark H. Brand*

Sweet Shrub

Calycanthus floridus

Prune immediately after flowering to shape or maintain compactness. Tends to sucker and often forms colonies in the wild. Remove root suckers promptly if naturalization is not desired. Fragrant flowers and aromatic leaves when crushed. Golden yellow fall color.

Habitat: Shade



Sweet Shrub flower
© *Jeff McMillian*

Sweet Shrub in summer
© *Mark H. Brand*

Sweet Shrub fall color
© *Mark H. Brand*

Sweetgum

Liquidambar styraciflua

Can become aggressive in moist, sandy soils. It is not drought-tolerant and does not do well in polluted areas or small areas which limit root development. It grows rapidly and is long-lived, adapting to a variety of sites. It is susceptible to iron chlorosis in soil which is too basic. Plant only in spring as roots, they take 3-4 months to recover from the shock of transplanting. Fall foliage is yellow, orange, purple and red, and will become colorful even without cold temperatures. Gum balls mature to dark brown and usually remain on the tree through the winter, but can create clean-up problems during the general period of December through April as the clusters fall to the ground and do not decompose. Because of this, “Fruitless” cultivars such as Liquidamber styracifula “Rotundiloba” are recommended for urban applications.

Attracts birds.

Habitat: Sun

Sweetgum, mid-summer
© *Sally & Andy Wasowski*

Sweetgum, fall color
© *Benny Simpson*

Sycamore

Platanus occidentalis

The bark of large, old trunks sloughs off in scales or plates leaving a smooth, whitish inner bark. Globular fruits often persist through December. Large, medium- to dark-green, maple-shaped leaves turn brown in fall. Sycamore anthracnose is a significant disease that can severely damage the foliage and twigs, often precipitating premature leaf drop. Canker, leaf spot and powdery mildew may also occur.

Attracts birds and other wildlife.

Habitat: Sun

Sycamore fruit
© Steven Schwartzman

Sycamore bark
© Mark H. Brand

Sycamore, mid-summer
© Mark H. Brand

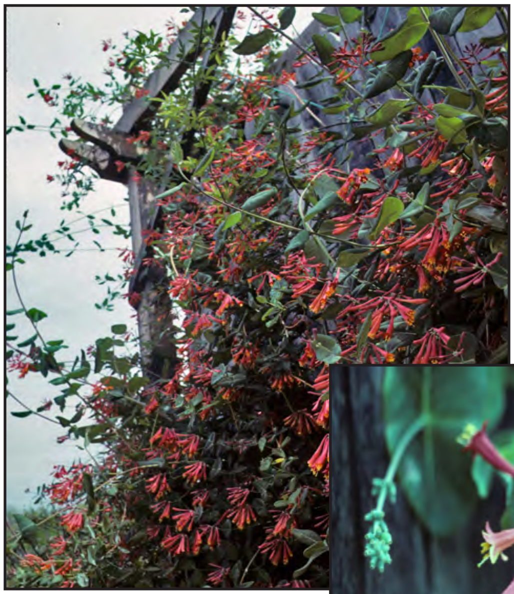
Trumpet Honeysuckle

Lonicera sempervirens

This vine can be a good climber or ground cover. Blooms are followed by bright red berries. Blooms primarily on previous year's stems, so prune to shape after flowering. Trumpet honeysuckle requires light, good air circulation, and adequate drainage to prevent powdery mildew. Some structural assistance may be necessary to help it begin climbing

Attracts bees, birds, hummingbirds and butterflies.

Habitat: Shade



Trumpet Honeysuckle in flower
© Sally & Andy Wasowski

Trumpet Honeysuckle flowers
© Sally & Andy Wasowski

Tulip Poplar

Liriodendron tulipifera

Tulip Poplar has a medium to narrow crown. Showy, yellow-orange, tulip-like flowers are often missed because they are found 50 ft. or higher in the tops of trees. Cone-shaped seed heads remain after leaves have fallen. Golden fall foliage. Tulip Poplar is insect and disease free. It is intolerant of compacted soil and should not be placed in confined beds or planters near pavement.

Attracts bees, butterflies, hummingbirds and birds. Food source for caterpillars.

Habitat: Sun

Tulip Poplar in winter
© Mark H. Brand

Tulip Poplar flower
© Mark H. Brand

Tulip Poplar, mid-summer
© Mark H. Brand

Virgin's Bower

Clematis virginiana

Virgin's Bower is a vigorous, deciduous, twining vine with a rampant growth habit. Lacking tendrils, the vine supports itself by means of twisted stems, or petioles, that wrap around other plants. Branches may be pruned at any time during the growing season. To encourage bushiness, prune stems in the spring to within a few feet off the ground. Climbs well on narrow supports such as twigs or wire fences. Can spread aggressively by self-seeding and suckering.

Attracts bees, hummingbirds and butterflies.

Habitat: Shade

Virgin's Bower in flower
© W.D. and Dolphia Bradsford

Virgin's Bower with open seed pods
© Albert F.W. Vick

Virginia Sweetspire
Itea virginica

Can form dense colonies by root suckering. Fragrant tiny white flowers and strong red and purple fall colors that persist into winter make this plant a desirable ornamental.

Attracts bees, butterflies, hummingbirds and birds.

Habitat: Shade

Virginia Sweetspire, fall color
© *Mark H. Brand*

Virginia Sweetspire flowers
© *Mark H. Brand*

Virginia Sweetspire in flower
© *Mark H. Brand*

Wahoo
Euonymus atropurpureus

Wahoo is a deciduous, shrub or small tree which is most often grown for its attractive red berries and fall color. Susceptible to scale.

Attracts bees, birds and other wildlife. Food source for caterpillars.

Habitat: Sun

Wahoo in winter
© *Julie Makin*

Wahoo fall color
© *Missouri Botanical Garden*

Wahoo fruit
© *Missouri Botanical Garden*

White Oak

Quercus alba

White Oak has wide spreading branches and a rounded crown, the trunk irregularly divided into spreading, often horizontal, stout branches. The round-lobed leaves turn burgundy in fall. Dried leaves remain into winter. Old trees are sensitive to construction disturbance in their root zone and to planting turf around the tree

Attracts birds and butterflies.

Habitat: Sun

White Oak in winter
© *Mark H. Brand*

White Oak leaves, fall color
© *Mark H. Brand*

White Oak, mid-summer
© *Mark H. Brand*

White Pine

Pinus strobus

The largest northeastern conifer, a magnificent evergreen tree with straight trunk and crown of horizontal branches, becoming broad and irregular. Rapid-growing and long lived. Landscape size and shape can be controlled through pruning to the extent that white pine may be sheared and grown as a hedge.

Attracts birds and other wildlife.

Habitat: Shade

White Pine, an evergreen
© *Albert F.W. Vick*

White Pine cones
© *Albert F.W. Vick*

Wild Hydrangea
Hydrangea arborescens

Wild hydrangea suckers freely, creeping over large areas. It is susceptible to sunscald, chlorosis in alkaline soils, and winter dieback. Many weak, brittle canes are easily broken in wind and ice. Fast-growing and short-lived, this hydrangea is often treated as an herbaceous perennial and cut to the ground every winter. If the canes are allowed to grow, the naturally peeling bark is attractive. Blooms on new season growth. Fall foliage is insignificant.

Attracts bees and butterflies. Food source for caterpillars.

Habitat: Shade

Wild Hydrangea leaves
© *Mark H. Brand*

Wild Hydrangea flowers
© *Mark H. Brand*

Wild Hydrangea in flower
© *Mark H. Brand*

Willow Oak
Quercus phellos

Readily transplanted because of shallow roots. A popular street and shade tree with fine-textured foliage that turns yellow to red in the fall.

Attracts birds, butterflies, and other wildlife. Food source for caterpillars.

Habitat: Sun

Willow Oak, mid-summer
© *Mark H. Brand*

Willow Oak leaves
© *Sally & Andy Wasowski*

Winterberry

Ilex verticillata

The leaves of Common winterberry are not shaped with sharp teeth like other hollies and are not evergreen. The purplish green foliage turns black, in fact, with the first frost. Winterberry has separate male and female plants; only females will produce the attractive red berries that persist through the winter. Generally one male winterberry will be sufficient for pollinating 9-10 female plants. Prune to shape in early spring just before new growth appears.

Attracts bees, birds and other mammals. Food source for caterpillars.

Habitat: Shade

Winterberry in winter
© Mark H. Brand

Winterberry fruits
© Stefan Bloodworth

Winterberry, mid-summer
© Mark H. Brand

Witch Hazel

Hamamelis virginiana

This small tree or tall shrub is often multi-trunked and usually grows 10-15 ft. tall but can reach 35 ft. in height. The large, crooked, spreading branches form an irregular, open crown. Promptly remove suckers to prevent colonial spread. Little pruning is required. Prune in early spring if necessary. Fragrant yellow flowers appear in the fall and persist after leaf drop. Fall foliage is gold.

Attracts birds.

Habitat: Sun

Witch Hazel with winter flowers
© Mark H. Brand

Witch Hazel with fall color
© Mark H. Brand

Witch Hazel in summer
© Mark H. Brand

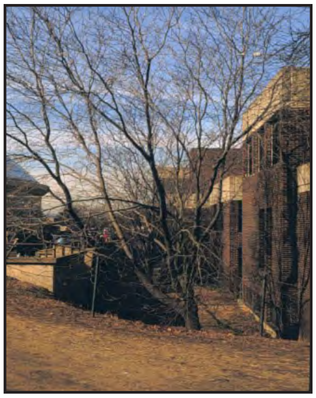
Yellowwood
Cladrastis kentukea

Showy, pendent, foot-long spikes of cream-colored flowers appear in quantity only two or three times a decade. Fall color is a delicate orange or yellow. Yellowwood has deep roots which make transplanting difficult but allows for other species to thrive underneath. Corrective pruning is often necessary to eliminate weak branch forks. Do not prune in the spring or immediately after transplanting. Summer is best for pruning.

Attracts birds and butterflies.

Habitat: Sun

Yellowwood, fall color
© Mark H. Brand



Yellowwood in winter
© Mark H. Brand

Yellowwood in spring with flowers
© Mark H. Brand

Japanese Sedge colony in spring

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Grasses											
Autumn Moor Grass	Sesleria autumnalis	E	-	GR	-	0.75-1	green	y	Sept-Oct		
Big Bluestem	Andropogon gerardii	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	1.6	
Blue Fescue	Festuca amethys-tina "Superba"	E	-	GR	-	0.5	white	y	May-June		
Blue Fescue	Festuca glauca "Elijah Blue"	E	-	GR	-	.75-1	green	n	June-July		
Blue Fescue	Festuca ovina "glauca"	E	-	GR	-	1	green	y	June-July		
Blue-joint Grass	Calamagrostis canadensis	N	UPL	UR, B	low	2-4	green	n	June-July	1.25	
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Broomsedge	Andropogon virginicus	N	FACU	UR, U, B	high	2-3	yellow	y	Aug-Sept	1.2	
Indian Grass	Sorghastrum nutans	N	UPL	UR, B, U, R	medium	1-3	yellow	y	Aug-Sept	2	
Japanese Sedge	Carex morrowii "Ice Dance"	E	-	GR	-	.5-1	green	n	June-July		
June Grass	Koeleria macrantha	N	UPL	UR, U, GR	low	1-2	yellow	n	May-June	1.6	
Lilttle Bluestem	Schizachyrium scoparium "The Blues"	C	FACU-	B, U, GR	medium	2-4	purple	y	Aug-Oct	1	
Little Bluestem	Schizachyrium scoparium	N	FACU-	UR, B, U, GR	medium	2-3	yellow	y	Aug-Sept	1	
Oval-headed Sedge	Carex cephalophora	N	FACU	UR, B	medium	1	green	n	May	0.75	
Poverty Grass	Danthonia spicata	N	UPL	UR, GR	high	1	green	n	June		
Prairie Dropseed	Sporobolus heterolepis	N	UPL	GR, U, B, UR	low	1-3	green	y	July-Sept	1	
Prairie Dropseed	Sporobolus heterolepis "Tara	C		GR, U		1-3	brown	y	July-Sept	1	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Shortbeak Sedge	Carex brevior	N	UPL	UR, U	medium	1-2	yellow	n	May-June		

Ladybells bloom in Summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

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Sun — Dry Site — Grasses *(continued)*											
Side-oats Grama	Bouteloua curtipendula	N	UPL	UR, GR, U	low	1.5-2.5	yellow	y	July-Aug	0.66	
Silky Wild Rye	Elymus villosus	N	FACU-	UR, B	medium	1-2	yellow	n	June		
Silver Sedge	Carex morrowii "Silver Sceptre"	E	-	GR	-	1	green	n	June-July		
Switchgrass	Panicum virgatum	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	1	
Sun — Dry Site — Forbs/Flowers											
Alpine Thrift	Armeria juniperifolia	E	-	GR	-	.5-1	pink	y	May-July		
Ashy Sunflower	Helianthus mollis	N	NI	B, U, UR	low	2-4	yellow	n	Aug-Sept		
Balloon Flower	Playtcodon grandiflorus "Sentimental Blue"	E	-	GR	-	0.5-1	blue	n	July-Aug		
Basal Balm	Monarda clinopodia	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		
Beardtongue	Penstemon digitalis "Husker Red"	C	-	GR	-	2-3	white	n	April-June		
Beardtongue	Penstemon hirsu-tus "pygmaeus"	C	-	GR	-	.5	violet	n	June-July		
Bee Balm	Monarda fistulosa	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	
Bellflower	Campanula trachelium	E	-	GR	-	1.5	blue	n	June-Aug		
Bitter Root	Lewisia longipetala "Little Plum"	E	-	GR	-	0.5	pink	n	May-Sept		
Black-eyed Susan	Rudbeckia hirta	N	FACU-	B, U, UR	medium	2-3	yellow	n	June-Sept	0.8	
Blue-Stemmed Goldenrod	Solidago caesia	N	FACU	U, B, UR	medium	1-2	yellow	n	Sept-Oct		
Bundleflower	Desmanthus illinoensis	N	FAC	R, B	high	2-3	white	n	July	1	
Butterfly Milk-weed	Asclepias tuberosa	N	NI	U, B, UR	medium	1-2.5	orange	n	June-Aug		
Catmint	Nepeta faassenii "Blue Wonder"	E	-	GR	-	.5-1	blue	n	May-Sept		

Purple Coneflower colony in bloom

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Sun — Dry Site — Forbs/Flowers *(continued)*											
Catmint	Nepeta faassenii "Walker's"	E	-	GR	-	1-3	blue	n	May-Sept		
Cheddar Pinks	Dianthus subacaulis "Gary Eichhorn"	E	-	GR	-	1	pink	n	May-July		
Chives	Allium schoenoprasum	E	-	GR	-	1-1.5	purple	n	April-May		
Cinquefoil	Potentilla neumanniana "Nana"	E	-	GR	-	0.25-0.5	yellow	n	April-June		
Compass Plant	Silphium laciniatum	N	NI	B, U, UR	low	5-8	yellow	n	July-Sept	15	
Cranesbill	Geranium cantabrigiense "Biokovo"	E	-	GR	-	.5-1	pink	n	May-June		
Cranesbill	Geranium cantabrigiense "Karmina"	E	-	GR	-	.5-1	red	n	May-June		
Cranesbill grandiflorus	Geranium sanguineum "Max Frei"	E	-	GR	-	.5-.75	purple	n	May-June		
Creeping Baby's Breath	Gypsophila repens "Alba"	E	-	GR	-	0.5	white	n	June-July		
Creeping Baby's Breath	Gypsophila repens "Rosea"	E	-	GR	-	0.5	pink	n	June-July		
Creeping Thyme	Thymus praecox	E	-	GR	-	0.25-0.5	purple	y	June-Sept		
Culver's Root	Veronicastrum virginicum	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		
Cushion Spurge	Euphorbia polychroma	E	-	GR	-	1.5	yellow	y	May		
Cylindrical Blazing Star	Liatris cylindracea	N	UPL	U, UR	low	1-2	purple	n	July-Oct		
Cypress Spurge	Euphorbia cyparissias "Fen's Ruby"	E	-	GR	-	1-1.5	yellow	n	April-June		
Downy Alum Root	Heuchera americana	N	FACU-	UR, U	medium	1-2	white	n	June-Aug		
Downy Alum Root	Heuchera americana "Dale's Strain"	C	-	GR	-	1-2	pink	n	June-Aug		
Dwarf Balloon Flower	Platycodon	E	-	GR	-	1-2.5	blue	n	June-Aug		
Dwarf Bearded Iris	Iris pumila "Baby Blessed-yellow"	E	-	GR	-	1	yellow	n	June		

Geum in bloom in Summer

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Sun — Dry Site — Forbs/Flowers *(continued)*											
Dwarf Bearded Iris	Iris pumila "Sarah Taylor"	E	-	GR	-	1	blue and	n	June		
Early Goldenrod	Solidago juncea	N	UPL	U, UR	medium	2-4	yellow	y	June-Sept		
Elm-leaved Goldenrod	Solidago ulmifolia	N	UPL	UR, U	medium	3	yellow	y	July-Nov		
False Aloe	Manfreda virginica	N	UPL	UR, GR	medium	4	yellow	n	July		
False Blue Indigo	Baptisia australis	N	NI	B, U, UR	low	3-4	blue	n	May-June		
False Sunflower	Heliopsis helianthoides	N	NI	B, U, UR	medium	4-6	yellow	n	June-Oct		
Frost Aster	Symphyotrichum pilosum (Aster pilosus)	N	UPL	U, B, UR	0	2-5	white	n	Sept-Oct	0.8	
Fumitory	Corydalis lutea	E	-	GR	-	1-1,5	yellow	n	May-Sept		
Geum	Geum triflorum	E	-	GR	-	.5-1.5	pink	n	May-July		
Goat's Rue	Tephrosia virginiana	N	UPL	UR, U	medium	1-3	pink	n	May-June		
Golden Alexanders	Zizia aurea	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Golden Stonecrop	Sedum acre "Aureum"	E	-	GR	-	.25-.5	yellow	y	June-July		
Grass-leaved Goldenrod	Euthamia graminifolia	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		
Gray Goldenrod	Solidago nemoralis	N	NI	U, GR, UR	high	2-4	yellow	y	Sept-Oct	1	
Gray-headed Coneflower	Ratibida pinnata	N	NI	B, U, UR	medium	3-5	yellow	n	July-Aug	1.2	
Hairy Alum Root	Heuchera villosa	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		
Hairy Beardtongue	Penstemon hirsutus	N	NI	B, U, UR	medium	1-2	pink	n	May-June		
Hardy Ice Plant	Delosperma congestum	E	-	GR	-	0.1-0.2	yellow	n	June-Sept		
Harebell	Campanula rotundifolia	E	-	GR	-	.5-1.5	blue	n	June-Sept		

Dwarf Balloon Flower in bloom

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Hens and Chicks	Sempervivum montanum "Braunii"	E	-	GR	-	0.5	ma-genta	y	June-July		
Hens and Chicks	Sempervivum tectorum "Hart"	E	-	GR	-	0.5-1	purple	y	June-July		
Ironweed	Vernonia gigantea	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		
Knautia	Knautia macedonica	E	-	GR	-	1.5-2	bur-gandy	n	July-Sept		
Ladybells	Adenophora confusa	E	-	GR	-	2-3	blue	n	May-July		
Lamb's Ears	Stachys byzantina "Big Ears"	E	-	GR	-	0.5-1	Purple	n	rarely flow-ers		
Lamb's Ears	Stachys byzantina "Silver Carpet"	E	-	GR	-	0.25-0.5	none	n	rarely flow-ers		
Late Boneset	Eupatorium serotinum	N	FAC-	UR, U	high	2-4	white	n	July-Oct		
Lyre-leaved Sage	Salvia lyrata	N	UPL	B, U, UR	high	1-2	blue	n	April-June		
Meadow Blazing Star	Liatris ligulistylis	E	-	GR	-	1-3	purple	n	July-Sept		
Mexican Sedum	Sedum hispanicum "Diploid"	E	-	GR	-	0.3'	white	n	July-Aug		
Nodding Wild Onion	Allium cernuum	N	NI	UR, U, GR	low	1-2	white	n	July		
Ornamental Onion	Allium tanguticum "Summer Beauty"	E	-	GR	-	1-1.5	purple	n	July		
Ornamental Onion	Allium thunbergii "Ozawa"	E	-	GR	-	.5-1	purple	n	August		
Ornamental Oregano	Origanum laevigatum	E	-	GR	-	1-2	purple	n	July-Sept		
Pale Indian Plantain	Arnoglossum atriplicifolium	N	NI	UR	medium	3-6	white	n	July-Aug		
Pasque Flower	Pulsatilla vulgaris	E	-	GR	-	0.75-1	violet	n	April-May		
Phlox	Phlox paniculata	N	FACU	UR, B	medium	3-5	pink	n	July-Sept		
Pinks	Dianthus carthusianorum	E	-	GR	-	1.5	pink	n	May-June		

Black-eyed Susan colony in bloom

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Prairie Dock	Silphium terebinthinaceum	N	UPL	B, U, UR	low	5-10	yellow	n	July-Sept		
Prairie Onion	Allium stellatum	E	-	GR	-	1-1.5	pink	n	July-Sept		
Purple Coneflower	Echinacea purpurea	N	NI	GR, U, B, UR	low	3-5	purple	n	June-Aug	2	
Purple Prairie Clover	Dalea purpurea	N	UPL	GR, U, UR	low	1	purple	n	June-Sept	1.25	
Pussytoes	Antennaria dioica	E	-	GR	-	.1-.2	white	n	May-July		
Rattlesnake Master	Eryngium yuccifolium	N	FAC	B, U	low	3-4	white	y	July-Sept		
Rose Wine Sage	Salvia nemorosa "Rosenwein"	E	-	GR	-	1-1.5	rose	n	June-Sept		
Rough Blazing Star	Liatris aspera	N	NI	U, UR	low	1-3	purple	n	Aug-Sept		
Round-headed Lespedeza	Lespedeza capitata	N	FACU-	U, B, UR	low	1-2	purple	n	Aug-Sept	1.5	
Russian Stonecrop	Sedum kamtschaticum "Akibono"	E	-	GR	-	0.5	yellow	n	July		
Salvia	Salvia nemorosa "Marcus"	E	-	GR	-	0.5-1	violet	n	June-Sept		
Sea Thrift	Armeria maritima	E	-	GR	-	.5-1	pink	n	April-May		
Sedum	Sedum acre Oktoberfest	E	-	GR	-	.25-.5	white	y	July-Aug		
Showy Goldenrod	Solidago speciosa	N	UPL	UR, U	medium	1-3	yellow	y	Sept-Oct		
Small Yellow Onion	Allium flavum	E	-	GR	-	1	yellow	n	July		
Smooth Blue Aster	Symphyotrichum laeve (Aster laevis)	N	UPL	U, B, UR	medium	2-4	blue	y	Sept-Oct	0.8	
Snow-In-Summer	Cerastium tomentosum "Silver Carpet"	E	-	GR	-	.5-1	white	n	May-June		
Soapwort	Saponaria lempergii "Max Frei"	E	-	GR	-	0.75-1.5	pink	n	March-April		


Hens and Chicks in bloom in early Summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Spiderwort	Tradescantia bracteata	E	-	GR	-	1-1.5	purple	n	May-July		
Spotted Dead Nettle	Lamium maculatum "Aureum"	E	-	GR	-	1	purple	y	May-Sept		
Spotted Dead Nettle	Lamium maculatum "Chequers"	E	-	GR	-	1	purple	y	May-Sept		
St. John's Wort	Hypericum sphaerocarpum	N	FAC	U, UR, B	medium	1-2	yellow	n	June-Sept		
Stonecrop	Sedum album "Coral Carpet"	E	-	GR	-	0.25-0.5	pink	y	May-June		
Stonecrop	Sedum dasyphyl-lum "Blue Ridge"	E	-	GR	-	0.5-1	white	n	June-July		
Stonecrop	Sedum hybridum "Immergrunchen"	E	-	GR	-	0.3'	yellow	y	July-Aug		
Stonecrop	Sedum middendorf-fianum "Striatum"	E	-	GR	-	0.5	yellow	y	June-July		
Stonecrop	Sedum ochroleucum	E	-	GR	-	0.5	yellow	n	July		
Stonecrop	Sedum reflexum	E	-	GR	-	0.5	yellow	n	June-July		
Stonecrop	Sedum rupestre "Sandy's Silver Crest"	E	-	GR	-	0.5	yellow	n	July		
Stonecrop	Sedum sarmentosum	E	-	GR	-	0.5	yellow	n	May-June		
Stonecrop	Sedum sexangulare	E	-	GR	-	0.3	yellow	y	June-July		
Stonecrop	Sedum sichotense	E	-	GR	-	0.5	yellow	y	July		
Stout Blue-Eyed Grass	Sisyrinchium angustifolium "Lucerne"	N	FACW-	U, UR	medium	1	blue	n	May-June	0.3	
Sweet Violet	Viola sororia "Freckles"	C	-	GR	-	0.6	violet	n	April-May		
Tall Coreopsis	Coreopsis tripteris	N	FAC	U	medium	6-8	yellow	n	Aug-Sept		
Threadleaf Core-opsis	Coreopsis verticillata "Zagreb"	E	-	GR	-	1-1.5	yellow	n	May-June		

Ironweed in bloom in late summer

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Forbs/Flowers *(continued)*											
Tickseed	Coreopsis lanceolata	E	-	GR	-	1-2	yellow	n	May-July		
Tunic Flower	Petrorhagia saxi-fraga "Lady Marie"	E	-	GR	-	0.5	pink	n	June-Oct		
Two Row Stonecrop	Sedum spurium "Eco Mt. Emei"	E	-	GR	-	0.5	yellow	n	July		
Wall Germander	Teucrium chamaedrys "Summer Sunshine"	E	-	GR	-	0.75-1	purple	n	May		
Whorled Rosinweed	Silphium trifoliatum	N	NI	B, U, UR	medium	4-6	yellow	n	July-Aug		
Wild Geranium	Geranium maculatum	N	FACU	UR, R	medium	1	violet	n	April-May		
Wild Quinine	Parthenium integrifolium	N	UPL	U, UR	medium	2-3	white	n	July-Aug		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Zizia aurea	Golden Alexanders	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Sun — Dry Site — Trees, Shrubs, and Vines											
American Beech	Fagus grandifolia	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	slow
American Bittersweet	Celastrus scandens	N	FACU-	U, UR	high	15-20	white	y	May-June		
American Smoketree	Cotinus obovatus	E	-	U	-	20-30	pale green	y	April-May		
American Plum	Prunus americana	N	FACU-	U, UR	high	15-25	white	n	March	2	moderate
Bitternut Hickory	Carya cordiformis	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	slow
Black Cherry	Prunus serotina	N	FACU	U, UR	high	50-80	white	n	April-May	3	rapid
Black Walnut	Juglans nigra	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	rapid
Blackhaw Viburnum	Viburnum prunifolium	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	

Persimmon, early fall

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Trees, Shrubs, and Vines *(continued)*											
Blackjack Oak	Quercus marilandica	N	UPL	U, UR	medium	20-40	yellow	y	May	2	slow
Bur Oak	Quercus macrocarpa	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	slow
Chestnut Oak	Quercus prinus	N	UPL	U, UR	medium	50-70	yellow	y	April	3	slow
Chinese Dogwood	Cornus kousa	E	-	U	-	20-30	white	y	May-June		slow
Cockspur Hawthorn	Crataegus crus-galli	N	FACU	UR	high	25-35	white	y	May	2	moderate
Cornelian Cherry Dogwood	Cornus mas	E	-	U	-	15-25	yellow	y	March		slow
Crossvine	Bignonia capreolata	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		
Eastern Hophornbeam	Ostrya virginiana	N	FACU-	U, UR	medium	25-40	yellow	n	April	1.3	slow
Eastern Red Cedar	Juniperus virginiana	N	FACU	U, UR	high	30-40	n/a	n	n/a		slow
Fragrant Sumac	Rhus aromatica	N	NI	B, U, UR	high	2-6	yellow	y	April		forms thickets
Hackberry	Celtis occidentalis	N	FACU	UR	high	40-60	green	y	April-May	3	rapid
Higan Cherry	Prunus subhirtella	E	-	U	-	25-35	pink	n	March-April		rapid
Honey Locust	Gleditsia triacanthos	N	FAC-	R, UR	high	100	yellow	y	May-June	4	rapid
Kentucky Coffeetree	Gymnocladus dioicus	N	UPL	B, U, UR	medium	75-100	white	n	June	3	slow
Ohio Buckeye	Aesculus glabra	N	FACU+	U, UR	high	20-40	green	y	April-May	3	
Pasture Rose	Rosa carolina	N	UPL	U, UR	high	1-3	white	y	June-Sept	1	
Persimmon	Diospyros virginiana	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	slow - messy
Red Oak	Quercus rubra	N	FACU-	U, UR	medium	50-75	yellow	y	May	3	moderate
Redbud	Cercis canadensis	N	FACU-	U, R, B, UR	high	20-30	purple	n	April	2	

Sassafras with fall color

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Dry Site — Trees, Shrubs, and Vines ***(continued)***											
Sassafras	Sassafras albidum	N	FACU-	U, UR	high	30-60	yellow	y	April-May	1.5	moderate
Shrubby St. John's Wort	Hypericum prolificum	N	FACU	U, B, UR	medium	3	yellow	n	June-Aug	0.8	
Southern Blackhaw	Viburnum rufidulum	N	UPL	U, UR	medium	10-20	white	y	April-May		
Staghorn Sumac	Rhus typhina	N	UPL	UR	high	15-25	red	y	June-July	1.6	
Sugar Maple	Acer saccharum	N	FACU-	UR	medium	40-80	green	y	April	3.3	slow
Sweet Shrub	Calycanthus floridus	N	UPL	U, UR	low	6-10	red	n	April-July		
Trumpet Honeysuckle	Lonicera sempervirens	N	FACU	U, B, UR	medium	3-20	orange	n	Mar-Aug	0.8	
Tulip Poplar	Liriodendron tulipifera	N	FACU	U, UR	high	60-90	yellow	y	May-June	3	rapid
Wahoo	Euonymus atropurpureus	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	
White Oak	Quercus alba	N	FACU	B, UR	medium	50-80	yellow	y	May	4	slow
Witch Hazel	Hamamelis virginiana	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	slow
Yellowwood	Cladrastis kentukea	N	NI	U, UR	low	30-50	white	y	May	2	moderate

Pale Indian Plantain colony in bloom in summer

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Wetland Indicator					
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Shade — Dry Site — Grasses											
Beak Grass	Diarrhena americana	N	NI	U, B, UR	medium	1-2	green	n	August		
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Lance-fruited Oval Sedge	Carex radiata	N	UPL	UR	medium	1	green	n	April-May		
Oval-headed Sedge	Carex cephalophora	N	FACU	UR, B	medium	1	green	n	May	0.75	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Silky Wild Rye	Elymus villosus	N	FACU-	UR, B	medium	1-2	yellow	n	June		
Spreading Oval Sedge	Carex normalis	N	FACU	UR	medium	1-3	green	n	May-June	1	
Woodland Brome	Bromus pubescens	N	NI	UR	medium	2-4	green	n	May-June		
Shade — Dry Site — Forbs/Flowers											
Basal Balm	Monarda clinopodia	N	UPL	U, B, UR	medium	3-4	violet	n	July-Sept		
Bee Balm	Monarda fistulosa	N	UPL	U, B, UR	medium	2-4	violet	n	July-Aug	0.3	
Bellflower	Campanulastrum americanum	N	FACU	B, UR	high	2-6	blue	n	June-July	0.75	
Blue-Stemmed Goldenrod	Solidago caesia	N	FACU	U, B, UR	medium	1-2	yellow	y	Sept-Oct	0.6	
Celandine Poppy	Stylophorum diphyllum	N	NI	B, UR, U	medium	1-2	yellow	n	April-May		
Culver's Root	Veronicastrum virginicum	N	FACU	B, U, UR	low	3-6	white	n	July-Aug		
Downy Alum Root	Heuchera americana	N	FACU-	U, UR	medium	1-2	white	n	June-Aug		
Downy Wood Mint	Blephilia ciliata	N	NI	B, U, UR	medium	1-2.5	blue	n	May-Aug		
Early Goldenrod	Solidago juncea	N	UPL	U, UR	medium	2-4	yellow	n	June-Sept		
Goat's Rue	Tephrosia virginiana	N	UPL	UR, U	medium	1-3	pink	n	May-June		

Lyre-leaved Sage colony in spring

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Forbs/Flowers *(continued)*											
Hairy Alum Root	Heuchera villosa	N	NI	U, UR	medium	1-2	white	n	Aug-Sept		
Hairy Wood Mint	Blephilia hirsuta	N	FACU	U, UR	medium	1-3	blue	n	July-Aug		
Jacob's Ladder	Polemonium reptans	N	FACU	R, B, UR	medium	1-1.5	blue	n	April-June		
Late Boneset	Eupatorium serotinum	N	FAC-	U, UR	high	2-4	white	n	July-Oct		
Lyre-leaved Sage	Salvia lyrata	N	UPL	B, U, UR	high	1-2	blue	n	April-June		
Pale Indian Plantain	Arnoglossum atriplicifolium	N	NI	UR	medium	3-6	white	n	July-Aug		
Short's Aster	Symphyotrichum shortii (Aster shortii)	N	UPL	B, UR, U	medium	2-3	blue	n	Sept-Oct		
Solomon's Seal	Polygonatum biflorum	N	FACU	R, B, UR	medium	1-3	white	n	April-May		
White Wood Aster	Aster divaricatus	N	UPL	U, UR	low	1-2.5	white	n	Aug-Sept		
Wild Geranium	Geranium maculatum	N	FACU	R, UR	medium	1	violet	n	April-May		
Wild Ginger	Asarum canadense	N	FACU-	B, UR	medium	1	ma-roon	n	April-May		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Wood Aster	Aster cordifolius	N	UPL	U, UR	medium	1-3	purple	y	Sept-Oct	0.8	
Woodland Sunflower	Helianthus divaricatus	N	NI	U, UR	medium	2-5	yellow	n	Sept-Oct		
Zig-Zag Goldenrod	Solidago flexicaulis	N	FACU	B, R, UR	medium	1-2	yellow	y	Sept-Oct	0.6	

Crossvine

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Trees, Shrubs, and Vines											
American Beech	Fagus grandifolia	N	FACU	UR	medium	50-70	yellow	y	April-May	2.6	slow
Americum Plum	Prunus americana	N	FACU-	U, UR	high	15-25	white	n	March	2	moderate
Bitternut Hickory	Carya cordiformis	N	FACU+	U, UR	medium	50-80	green	y	April-May	4.2	slow
Black Cherry	Prunus serotina	N	FACU	U, UR	high	50-80	white	n	April-May	3	rapid
Black Walnut	Juglans nigra	N	FACU	R, UR	medium	50-75	yellow	n	April-May	3.3	rapid
Blackhaw Viburnum	Viburnum prunifolium	N	FACU	U, UR	medium	12-15	white	y	May-June	1.5	
Coralberry	Symphoricarpos orbiculatus	N	UPL	B, U, UR	high	2-5	white	y	June-July	1.5	
Crossvine	Bignonia capreolata	N	FAC+	GR, U, UR	medium	50	orange	n	March-May		
Fragrant Sumac	Rhus aromatica	N	NI	B, U, UR	high	2-6	yellow	y	April		forms thickets
Hackberry	Celtis occidentalis	N	FACU	UR	high	40-60	green	y	April-May	3	rapid
Kentucky Coffeetree	Gymnocladus dioicus	N	UPL	B, U, UR	medium	75-100	white	n	June	3	slow
New Jersey Tea	Ceanothus americanus	N	UPL	U, UR	medium	3	blue	n	Mar-Apr	1.2	
Ohio Buckeye	Aesculus glabra	N	FACU+	U, UR	high	20-40	green	y	April-May	3	
Persimmon	Diospyros virginiana	N	FAC-	R, U, UR	high	35-60	yellow	y	May-June	3	slow - messy
Shagbark Hickory	Carya ovata	N	FACU	U, UR	medium	70-90	yellow	y	April-May	4	slow
Southern Blackhaw	Viburnum rufidulum	N	UPL	U, UR	medium	10-20	white	y	April-May		
Staghorn Sumac	Rhus typhina	N	UPL	UR	high	15-25	red	y	June-July	1.6	
Strawberry Bush	Euonymus americanus	N	UPL	U, UR	medium	6-12	green	y	May-June	0.6	
Sugar Maple	Acer saccharum	N	FACU-	UR	medium	40-80	green	y	April	3.3	slow

Fragrant Sumac in the fall.

Project Uses		
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GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Dry Site — Trees, Shrubs, and Vines *(continued)*											
Sweet Birch	Betula lenta	N	FACU	U, UR	medium	72-100	yellow	n	April-May	2.25	
Sweet Shrub	Calycanthus floridus	N	UPL	U, UR	low	6-10	red	n	April-July		
Trumpet Honeysuckle	Lonicera sempervirens	N	FACU	U, B, UR	medium	3-20	coral	n	Mar-Aug	0.8	
Wahoo	Euonymus atropurpureus	N	UPL	U, UR	medium	20-25	purple	y	Apr-Jun	1	
White Pine	Pinus strobus	N	FACU	U, UR	medium	75-100	n/a	n	n/a	3.3	rapid
Wild Hydrangea	Hydrangea arborescens	N	FACU	B, UR, U	medium	3-6	cream	y	June-Sept		
Witch Hazel	Hamamelis virginiana	N	FACU+	U, UR	medium	15-20	yellow	n	Oct-Dec	1.6	slow
Sun — Moist to Wet Site — Grasses, Sedges and Rushes											
Awl-fruited Sedge	Carex stipata	N	OBL	W	medium	2-3	green	n	May	0.75	
Big Bluestem	Andropogon gerardii	N	FAC-	R, W, U, B	medium	4-6	yellow	y	September	9	
Brome-like Sedge	Carex bromoides	N	FACW+	W, R, B	low	1-2	green	n	May		
Crested Sedge	Carex cristatella	N	FACW	W, B	medium	2-3	green	n	May-June	0.75	
Eastern Gamma Grass	Tripsacum dactyloides	N	FACW	U, B	medium	4-8	yellow	n	May-Sept	1.6	
Fowl Manna Grass	Glyceria striata	N	OBL	W, B, R	medium	2-4	green	n	May-June	0.3	
Fox Sedge	Carex vulpinoidea	N	OBL	W, B. R	high	2-3	green	n	May-June	1.3	
Frank's Sedge	Carex frankii	N	OBL	W, B, R	high	1-2	green	n	June-July	0.75	
Fringed Sedge	Carex crinita	N	OBL	W	medium	2-4	green	n	May-June	1.5	
Gray's Sedge	Carex grayi	N	FACW+	W	medium	1-2	green	n	May-June	0.75	
Green Bulrush	Scirpus atrovirens	N	OBL	W	high	3-5	brown	n	May-June	1	

Dwarf Bluestar in bloom

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Grasses, Sedges and Rushes *(continued)*											
Hop Sedge	Carex lupulina	N	OBL	W	medium	1-2	green	n	May-June	1.5	
Large-Fruited Oval Sedge	Carex scoparia	N	FACW	W	medium	2-3	green	n	May	0.75	
Lurid Sedge	Carex lurida	N	OBL	W	medium	1-2	green	n	May-June	1.3	
Meadow Sedge	Carex granularis	N	FACW+	W, B	medium	1-2	green	n	May-June	0.75	
Prairie Cordgrass	Spartina pectinata	N	OBL	B, W	medium	4-7	yellow	n	July-Aug	1.5	
Rice Cutgrass	Leersia oryzoides	N	OBL	W, B	high	2-4	green	n	Aug-Sept	1.2	
River Cane	Arundinaria gigantea	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	
Riverbank Wild Rye	Elymus riparius	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	
Soft Rush	Juncus effusus	N	FACW+	W, B, R	medium	2-4	green	n	May-June	1	
Softstem Bulrush	Scirpus validus	N	OBL	W	high	4-8	red	n	May-June		
Switchgrass	Panicum virgatum	N	FAC	U, B, R	medium	4-5	yellow	n	July-Aug	11	
Woolgrass	Scirpus cyperinus	N	FACW+	W	medium	3-5	green	n	July-Aug	1	
Yellow Fox Sedge	Carex annectens	N	FACW	B, W	high	2-3	yellow	n	May-June		
Sun — Moist to Wet Site — Forbs/Flowers											
Arrow Arum	Peltandra virginica	N	OBL	W, R	medium	2-3	white	n	June-July	1.3	
Bishop's Wort	Stachys officinalis	E	-	B	-	1.5-2	blue	n	May-June		
Blue Flag Iris	Iris virginica	N	-	W, B	medium	2-3	blue	n	May-June	0.5	
Blue Vervain	Verbena hastata	N	FACW+	B, W	high	3-5	blue	n	July-Sept		
Boneset	Eupatorium perfoliatum	N	FACW+	R, U	high	3-5	white	n	Aug-Sept		

Tickseed Sunflower in bloom in Fall

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Broad-leaf Arrow-head	Sagittaria latifolia	N	OBL	R, W	medium	1-3	white	n	July-Sept	1.5	
Common Mountain Mint	Pycnanthemum virginianum	N	FAC	W, B	medium	1-2	white	n	July-Aug		
Coral Bells	Heuchera "Rave On"	E	-	B	-	1-2	pink/ white	n	July-Aug		
Cranesbill	Geranium Gerwat Rizanne	E	-	B	-	1-1.5	yellow	n	May-July		
Dense Blazing Star	Liatris spicata	N	FAC+	W, B	low	3-5	purple	n	July-Aug	1.2	
Dwarf Bluestar	Amsonia tabernaemontana "Short Stack"	C	-	R	-	0.75-1	pale blue	y	April-May		
Flat-topped Aster	Doellingeria umbellata (Aster umbellatus)	N	FACW	B, R	medium	3-5	white	n	Sept-Oct		
Foxglove Beardtongue	Penstemon digitalis	N	FAC	W, R	high	2-3	white	n	June	0.6	
Gaura	Gaura lindheimeri "Siskiyou Pink"	E	-	B	-	2.5-3	yellow	n	May-Aug		
Germander	Teucrium canadense	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	
Giant Bur-reed	Sparganium eurycarpum	N	OBL	W	low	3-6	green	n	June-July	1	
Golden Alexanders	Zizia aurea	N	FAC	W, B, U, UR	medium	2-3	yellow	n	May		
Golden Ragwort	Packera aureus	N	FACW	B, R	medium	1	pink	n	May		
Grass-leaved Goldenrod	Euthamia graminifolia	N	FAC	B, U, UR	high	4-5	yellow	n	Sept-Oct		
Green-headed Coneflower	Rudbeckia laciniata	N	FACW	U, W, B	medium	5-8	yellow	n	July-Aug	1	
Hardy Hibiscus	Hibiscus "Fantasia"	E	-	B	-	2-3	pink/ white	n	July-Sept		
Ironweed	Vernonia gigantea	N	FAC	B, U, UR	high	5-10	purple	n	Aug-Sept		
Joe-Pye Weed	Eupatorium fistulosum	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		
Lizard's Tail	Saururus cernuus	N	OBL	W	medium	1-2	yellow	n	June-Sept		

Hardy Hibiscus in bloom in late summer

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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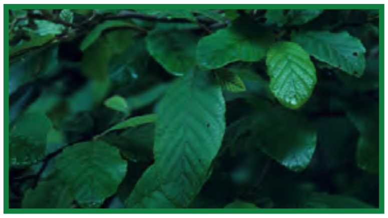
Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Long-leaved Pondweed	Potamogeton nodosus	N	OBL	W	medium	1-3	green	n	June-Sept		
Many-flowered Agrimony	Agrimonia parviflora	N	FACW	B, W	medium	6	yellow	n	July	0.5	
Mistflower	Conoclinium coelestinum	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	
Monkey Flower	Mimulus ringens	N	OBL	W, B	medium	2-4	blue	n	July-Sept		
Narrow-leaved Sunflower	Helianthus angustifolius	N	FACW	B, U	low	4-6	blue	n	Sept-Oct	0.5	
Nepeta	Nepeta subsessilis "Candy Cat"	E	-	B	-	2-2.5	pink	n	May-Sept		
New England Aster	Symphyotrichum novae-angliae (Aster novae-angliae)	N	FACW-	W, B, U, R	medium	3-6	purple	n	Aug-Sept		
Nodding Bur Marigold	Bidens cernua	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	
Obedient Plant	Physostegia virginiana "Miss Manners"	C	-	R	-	2-2.5	white	n	June-Sept		
Orange Coneflower	Rudbeckia fulgida	N	FAC	B, U, UR	medium	2-3	yellow	n	Aug-Sept	0.6	
Phlox	Phlox paniculata "Robert Poore"	C	-	B	-	3-5	pink	n	July-Sept		
Pickerelweed	Pontederia cordata	N	OBL	R, W	low	2-3	blue	n	July-Sept	0.8	
Purple Coneflower	Echinacea purpurea "Vintage Wine"	C	-	R	-	2-3	white	n	June-Aug	2	
Purple Joe-Pye Weed	Eupatorium purpureum	N	FAC	W, B	medium	4-6	violet	n	July-Aug		
Purple-stemmed Aster	Symphyotrichum puniceum (Aster puniceus)	N	OBL	W	low	6-8	blue	n	Aug-Sept		
Rattlesnake Master	Eryngium yuccifolium	N	FAC	B, U	low	3-4	white	y	July-Sept		
Sage	Salvia nemorosa "Sensation Rose"	E	-	B	-	0.75-1	white	n	June-Sept		
Slender Mountain Mint	Pycnanthemum tenuifolium	N	FACW	B, U, R	high	1-2	white	n	July-Aug		
Smooth Rose-mallow	Hibiscus laevis	N	OBL	W, B, R	medium	2	pink	y	July-Aug	1	



Smooth Alder leaves

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Sun — Moist to Wet Site — Forbs/Flowers *(continued)*											
Sneezeweed	Helenium autumnale	N	FACW+	W, B	medium	3-5	pink	n	Sept-Oct	0.5	
Spiderwort	Tradescantia ohiensis	N	FAC	B, U	medium	2-3	Purple	n	June-July	0.3	
Spotted Joe-Pye Weed	Eupatorium maculatum	N	FACW	R, W	low	4-6	violet	n	Aug-Sept		
Swamp Hibiscus	Hibiscus moscheutos	N	OBL	W, B, R	high	3-5	pink	n	July	0.8	
Swamp Milkweed	Asclepias incarnata	N	OBL	W, B, R	medium	4-5	pink	n	July-Aug	1.5	
Sweet Flag	Acorus calamus	N	OBL	W	high	2-2.5	yellow	n	April	1	
Tickseed	Coreopsis "Jethro Tull"	E	-	B	-	1-1.5	yellow	n	June-Aug		
Tickseed Sunflower	Bidens aristosa	N	FACW	W	o	2-3	yellow	n	Sept-Oct	0.75	
Water Horehound	Lycopus americanus	N	OBL	W, B	medium	1-2	white	n	July-Aug		
Water Plantain	Alisma subcordatum	N	OBL	W	high	1-2	white	n	June	0.66	
White Turtlehead	Chelone glabra	N	OBL	R, W, B	medium	2-4	white	n	Aug-Sept		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Wingstem	Verbesina alternifolia	N	FAC	UR, R, W, B	high	4-8	yellow	n	Aug-Oct		
Sun — Moist to Wet Site — Trees, Shrubs, and Vines											
Allegheny Serviceberry	Amelanchier laevis	N	NI	B, U, R	low	14-40	white	y	April	2.5	moderate
Arrow-wood	Viburnum dentatum	N	FAC	R, B	medium	6-10	white	y	May-June		
Bald Cypress	Taxodium distichum	N	OBL	W, U, R	medium	50-70	n/a	y	n/a	3.3	rapid
Black Chokeberry	Aronia melanocarpa	N	NI	R, U	medium	3-6	white	y	May	2	
Black Gum	Nyssa sylvatica	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	1.5	moderate

Possumhaw Holly berries

Project Uses		
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
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Sun — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Black Willow	Salix nigra	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	rapid
Bur Oak	Quercus macrocarpa	N	FAC-	U, UR	medium	60-80	yellow	y	April	2.3	slow
Buttonbush	Cephalanthus occidentalis	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	
Common Elderberry	Sambucus canadensis	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		
Common Ninebark	Physocarpus opulifolius	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	slow
Cornelian Cherry Dogwood	Cornus mas	E	-	U	-	15-25	yellow	y	March		slow
Devil's Walkingstick	Aralia spinosa	N	FAC	U	medium	20	white	n	June-Aug	2.5	moderate
European Hornbeam	Carpinus betulus "Globosa"	E	-	U	-	15-20	green	n	April		slow
Fringe Tree	Chionanthus virginicus	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	slow
Green Hawthorn	Crataegus viridis	N	FACW	U	medium	20-35	white	y	May	1.6	moderate
Leadplant	Amorpha fruticosa	N	FACW	R, B	medium	1-3	purple	n	June-July	2	
Meadowsweet	Spiraea alba	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	
Peach-leaf Willow	Salix amygdaloides	N	FACW	R, W	low	60	white	n	Apr-May	2.5	rapid
Pin Oak	Quercus palustris	N	FACW	W, B, U	medium	50-70	yellow	y	April	2.5	rapid
Possumhaw Holly	Ilex decidua	N	FACW	R, B, U	medium	15-30	yellow	n	March-May	1	
Pussy-Willow	Salix discolor	N	FACW	W	low	25	white	n	Feb-Mar	1.6	rapid
Red Chokeberry	Aronia arbutifolia	N	NI	R, U	medium	3-6	white	y	May	1.6	
River Birch	Betula nigra	N	FACW	B, U, R	medium	40-70	brown	n	April-May	1.6	rapid
Sandbar Willow	Salix exigua	N	OBL	W, R	high	15	white	n	Mar-Apr		rapid


Meadowsweet in flower mid-summer

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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

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Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Sun — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Shellbark Hickory	Carya laciniosa	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	slow
Shumard Oak	Quercus shumardii	N	FAC+	U	medium	40-60	yellow	y	April	3.3	moderate
Smooth Alder	Alnus serrulata	N	OBL	W, R	medium	15	yellow	n	March-April	2	rapid
Steeplebush	Spiraea tomentosa	N	FACW-	B, W	medium	2-5	purple	y	July-Sept	1.2	
Sugarberry	Celtis laevigata	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	moderate
Swamp Rose	Rosa palustris	N	OBL	B, W, R	medium	2-7	pink	y	June-July	1.5	
Swamp White Oak	Quercus bicolor	N	FACW+	W, U, R	low	50-60	yellow	y	April	3.3	rapid
Sweetgum	Liquidambar styraciflua	N	FAC	R, U	high	60-80	green	y	April-May	3	rapid
Sycamore	Platanus occidentalis	N	FACW-	R, U	high	75-100	red	y	April	2.5	rapid
Virginia Sweetspire	Itea virginica	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	
Willow Oak	Quercus phellos	N	FAC+	R, W, U	low	40-75	yellow	y	April	1	rapid
Winterberry	Ilex verticillata	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	

Virginia Wild Rye in Summer

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
GR = Green Roof	**U** = Urban Green Street/Alley	**UR** = Upland Restoration

Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
E = Exotic, not native to Kentucky
C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Grasses, Sedges and Rushes											
Bottlebrush Grass	Hystrix patula	N	FACU	UR, R, B, U	medium	3-5	green	y	June-Aug		
Brome-like Sedge	Carex bromoides	N	FACW+	W, R, B	low	1-2	green	n	May		
Deertongue Panic Grass	Dichanthelium clandestinum	N	FAC+	R, B	high	2	green	n	June-July		
River Cane	Arundinaria gigantea	N	FACW-	R	medium	3-25	n/a	n	Feb-May	1.5	
River Oats	Chasmanthium latifolium	N	FACU	UR, R, B, U	medium	2-3	green	n	July-Aug	0.8	
Riverbank Wild Rye	Elymus riparius	N	FACW	R	medium	3-5	yellow	n	July-Aug	0.8	
Virginia Wild Rye	Elymus virginicus	N	FACW-	UR, B	medium	2-3	yellow	n	June-July		
Shade — Moist to Wet Site — Forbs/Flowers											
Blue Lobelia	Lobelia siphilitica	N	FACW+	W, B, R	medium	1-3	pink	y	Aug-Sept		
Calico Aster	Symphyotrichum lateriflorum (Aster lateriflorus)	N	FACW-	R, U	high	1-3	purple	y	Sept-Oct	0.8	
Cardinal Flower	Lobelia cardinalis	N	FACW+	W, B, R	medium	1-3	blue	n	Aug-Sept	1	
Cinnamon Fern	Osmunda cinnamomea	N	FACW	R, B	low	2-3	pink	n	n/a	1	
Coral Bells	Heuchera "Rave On"	E	-	B	-	1-2	red	n	July-Aug		
Foxglove Beardtongue	Penstemon digitalis	N	FAC	W, B	high	2-3	white	n	June	0.6	
Germander	Teucrium canadense	N	FACW-	B, U	high	1-3	blue	n	June-Sept	0.3	
Jack-In-The-Pulpit	Arisaema triphyllum	N	FACW-	R, B	medium	1-2	ma-roon	y	April-May		
Joe-Pye Weed	Eupatorium fistulosum	N	FACW	W, B	medium	7-10	violet	n	Aug-Sept		
Lady Fern	Athyrium filix-femina	N	FAC	B, R	medium	1-3	n/a	n	n/a		
Many-flowered Agrimony	Agrimonia parviflora	N	FACW	B, W	medium	6	yellow	n	July	0.5	

Allegheny Serviceberry, fall color

Project Uses		
R = Riparian Restoration	**W** = Wetland Restoration	**B** = Bioretention Cell/Rain Garden
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Wetland Indicator					
Indicator	**OBL**	**FACW**	**FAC**	**FACU**	**UPL**
Likelihood of finding plant in Wetland	99%	67%	34-66%	1-33%	1%

Nativity
N = Native to Kentucky
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Forbs/Flowers *(continued)*											
Mistflower	Conoclinium coelestinum	N	FAC	W, B	high	1-2	violet	n	Sept-Oct	1.2	
Nepeta	Nepeta subsessilis "Candy Cat"	E	-	B	-	2-2.5	n/a	n	May-Sept		
Nodding Bur Marigold	Bidens cernua	N	OBL	W, R	high	1-4	yellow	n	June-Sept	0.75	
Panicled Aster	Symphyotrichum lanceolatum (Aster lanceolatus)	N	OBL	R, W	medium	5	white	n	Sept-Oct		
Purple Joe-Pye Weed	Eupatorium purpureum	N	FAC	W, B	medium	4-6	violet	n	July-Aug		
Royal Fern	Osmunda regalis	N	OBL	R, B	low	2-3	n/a	n	n/a	1.3	
Sensitive Fern	Onoclea sensibilis	N	FACW	R, B	medium	3-4	n/a	n	n/a		
Stout Blue-Eyed Grass	Sisyrinchium angustifolium	N	FACW-	U, B	medium	1	blue	n	May-Aug		
Wild Columbine	Aquilegia canadensis	N	FAC	R, U, B	medium	2-3	red	n	April-May		
Wild Senna	Senna hebecarpa	N	FAC	B, UR	medium	3-5	yellow	n	July-Aug		
Shade — Moist to Wet Site — Trees, Shrubs, and Vines											
Allegheny Serviceberry	Amelanchier laevis	N	NI	B, U, R	low	14-40	white	y	April	2.5	moderate
American Hornbeam	Carpinus caroliniana	N	FAC	W, B, U, R, UR	medium	20-35	orange	y	Feb	1.6	
Arrow-wood	Viburnum dentatum	N	FAC	R, B	medium	6-10	white	y	May-June		
Black Chokeberry	Aronia melanocarpa	N	NI	R, U	medium	3-6	white	y	May		
Black Gum	Nyssa sylvatica	N	FAC	B, U, W, R	medium	30-50	green	y	May-June	2.5	moderate
Black Willow	Salix nigra	N	FACW+	W, R	high	50	green	n	Apr-May	2.6	rapid
Buttonbush	Cephalanthus occidentalis	N	OBL	B, R, W	high	5-12	white	n	June-July	1.2	
Common Elderberry	Sambucus canadensis	N	FACW-	W, B, U, R	high	5-12	white	y	June-July		

Virginia Sweetspire fall color

Project Uses		
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Wetland Indicator					
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Nativity
N = Native to Kentucky
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C = Cultivar of a Kentucky Native Species

Common Name	Scientific Name	Nativity	Wetland Indicator[1]	Project Uses	Spread	Height (ft)	Flower Color	Fall Showy	Flowering Time	Root Depth (ft)	Growth Rate
Shade — Moist to Wet Site — Trees, Shrubs, and Vines *(continued)*											
Common Ninebark	Physocarpus opulifolius	N	FACW-	B, U, R	medium	5-8	purple	y	May-June	1	slow
Devil's Walkingstick	Aralia spinosa	N	FAC	U	medium	20	white	n	June-Aug	2.5	moderate
Fringe Tree	Chionanthus virginicus	N	FAC+	R, U	medium	12-20	white	n	May-June	1.7	slow
Fullmoon Maple	Acer japonicum "Taki No Gawa"	E	-	U	-	10-15	red	y	May		slow
Meadowsweet	Spiraea alba	N	FACW+	B, W	low	3-6	white	n	June-Sept	1	
Oak-leaf Hydrangea	Hydrangea quercifolia	E	-	B	-	6-8	yellow	n	May-July		
Possumhaw Holly	Ilex decidua	N	FACW	R, B, U	medium	15-30	white	y	March-May	1	
Red Chokeberry	Aronia arbutifolia	N	NI	R, U	medium	3-6	white	y	May	1.6	
Sandbar Willow	Salix exigua	N	OBL	W, R	high	15	white	y	Mar-Apr		
Shellbark Hickory	Carya laciniosa	N	FAC	W. R	medium	60-80	yellow	n	April-May	5	slow
Silky Dogwood	Cornus amomum	N	FACW	W, B, U, R	medium	6-10	white	n	April	1.3	
Smooth Alder	Alnus serrulata	N	OBL	W, R	medium	15	yellow	n	March-April	2	rapid
Spicebush	Lindera benzoin	N	FACW-	R, W, B	medium	4-8	white	y	April	1.5	
Steeplebush	Spiraea tomentosa	N	FACW-	B, W	medium	2-5	purple	n	July-Sept	1.2	
Sugarberry	Celtis laevigata	N	FACW	R, B, U	high	60-8-	green	y	April-May	2	moderate
Virginia Sweetspire	Itea virginica	N	OBL	W, R, B	low	3-5	white	n	June-July	1.2	
Virgin's Bower	Clematis virginiana	N	FAC	U, R, B	medium	4-8	white	n	Aug-Sept	1.2	
Winterberry	Ilex verticillata	N	FACW+	R, B, U	medium	6-10	white	y	May	1.3	

Louisville and Jefferson County
Metropolitan Sewer District

700 West Liberty Street
Louisville, KY 40203

Appendix II: Invasive Species

Kudzu infestation (Photo: Kentucky Energy and Environment Cabinet, Division of Forestry).

Introduction

This appendix contains non-native plants that have been identified by the *Kentucky Exotic Pest Plant Council* as having the ability to spread aggressively into native plant communities. Many of these plants are still available for purchase at some nurseries or over the internet and their use in gardens over time has caused them to spread and infest natural areas and parks. Outside of their indigenous habitat, these plants can easily overtake ecosystems and threaten biodiversity. **All of these plants should be avoided when making your planting list.** If any of these plants become established in your revegetated areas, remove them immediately using one of the recommended control methods.

Note: Herbicides in this appendix are listed by their chemical, not commercial, names. Read labels carefully for the active chemical, its strength, precautionary statements, recommended personal protective equipment, environmental hazards and directions. When applying herbicide near or around water, be sure to use a product that is advertised as water-safe. Always keep the label available when using the herbicide and heed all safety warnings. If you are applying herbicide for commercial purposes, please refer to the *University of Kentucky Pesticide Safety Education Program* at http://pest.ca.uky.edu/PSEP/welcome.html. This website contains information about categories of various commercial pesticide applicator licenses and will help you determine if you need a license, which one and how to apply.

For additional information about invasive plant species, please refer to the *Kentucky Exotic Pest Plant Council* website at http://www.se-eppc.org/ky. In addition to reference information about invasive plants, there is information about how to support KY-EPPC's efforts in combating invasive exotic species.

Do NOT Use
Invasive Species List

- **Akebia** *(Akebia quinata)*
- **Autumn Olive** *(Elaeagnus umbellata)*
- **Bicolor Lespedeza** (*Lespedeza bicolor)*
- **Burning Bush** (*Euonymus alatus)*
- **Bush Honeysuckles** (*Lonicera maackii , L. morrowii , L. tatarica , L. x bella)*
- **Canada Thistle** (*Cirsium arvense)*
- **Chinese Silver Grass** *(Miscanthus sinensis)*
- **Chinese Yam** (*Dioscorea batatas, D. oppositifolia, D. bulbifera)*
- **Common Burdock** *(Arctium minus)*
- **Common Chickweed** (*Stellaria media)*
- **Common Reed** *(Phragmites australis)*
- **Common Teasel** *(Dipsacus sylvestris)*
- **Crown Vetch** (*Coronilla varia)*
- **English Ivy** (*Hedera helix)*
- **Fescue** (*Festuca arundinacea)*
- **Garlic Mustard** *(Alliaria petiolata)*
- **Goose Grass** *(Eleusine indica)*
- **Ground Ivy** *(Glechoma hederacea)*
- **Ivy-leafed/ Purple Morning Glory** *(Ipomoea hederacea, I. purpurea)*
- **Japanese Honeysuckle** *(Lonicera japonica)*
- **Japanese Barberry** *(Berberis thunbergii)*
- **Japanese Knotweed** *(Polygonum cuspidatum)*
- **Japanese Spiraea** *(Spiraea japonica)*
- **Japanese Stilt Grass** *(Microstegium vimineum)*
- **Johnson Grass** *(Sorghum halepense)*
- **Jointhead Grass** *(Arthraxon hispidus)*
- **Kentucky Bluegrass** *(Poa pratensis)*
- **Korean Lespedeza, Kobe Lespedeza** *(Lespedeza stipulacea, L. striata)*
- **Kudzu** *(Pueraria lobata)*
- **Lesser Periwinkle** *(Vinca minor)*
- **Mimosa** *(Albizia julibrissin)*
- **Multiflora Rose** *(Rosa multiflora)*
- **Musk Thistle** *(Carduus nutans)*
- **Oriental Bittersweet** *(Celastrus orbiculata)*
- **Ox-Eye Daisy** *(Chrysanthemum leucanthemum)*
- **Poison Hemlock** *(Conium maculatum)*
- **Princess Tree** *(Paulownia tomentosa)*
- **Privet** *(Ligustrum sinense, L. vulgare)*
- **Purple Loosestrife** *(Lythrum salicaria)*
- **Queen Anne's Lace** *(Daucus carota)*
- **Sericea Lespedeza** *(Lespedeza cuneata)*
- **Smooth Brome Grass** *(Bromus inermis)*
- **Spotted Knapweed** *(Centaurea biebersteinii)*
- **Star of Bethlehem** *(Ornithogalum umbellatum)*
- **Tree of Heaven** *(Ailanthus altissima)*
- **White Mulberry** *(Morus alba)*
- **White Poplar** *(Populus alba)*
- **White Watercress** *Rorippa nasturtium-aquaticum*
- **Winter Creeper** *Euonymus fortunei*
- **Yellow and White Sweet Clover** *Melilotus officinalis, M. alba*

Akebia, Chocolate Vine

Akebia quinata

James H. Miller, USDA Forest Service, Bugwood.org

Nancy Fraley, USDI National Park Service, Bugwood.org

Description

- Twining vine or vigorous ground cover, typically deciduous in Kentucky.
- Slender rounded stems are green when young and brown when mature.
- Leaflets are green, oval and slightly purple when they emerge.
- Leaflets are 1½ to 3 inches long and arranged in groups of five whose stems meet from a center point.
- Flowers are chocolate-colored and have flattened sausage-like pods that appear in late March or early April.

Distribution

Found in five mid-Atlantic and southeastern states, including Kentucky.

Establishment method

Spreads primarily through vegetative growth. Is capable of growing twenty to forty feet in a season.

Threat

Grows quickly and produces a dense mat that can overpower understory trees, shrubs and even canopy trees by overtopping and smothering them.

Control

Vines that are growing as ground cover may be pulled and removed with follow-up pulling to exhaust the plants. Climbing vines should be cut low to the ground and the stump treated with a 25% glyphosate application. Repeated treatment will most likely be necessary.

Origin

Central China, Japan, Korea. Was introduced to the U.S. in 1845 as an ornamental

Resources

The Pennsylvania DCNR, the Plant Conservation Alliance's Alien Plant Working Group and www.invasive.org.

Autumn Olive

Elaeagnus umbellata

James H. Miller, USDA Forest Service, Bugwood.org

Pennsylvania Dept. of Conservation and Natural Resources - Forestry Archive,, Bugwood.org

Description

- Shrub that grows to 20 feet with a bushy and spreading crown.
- Leaves grow alternately on the stem, are short-stemmed, hairless, dark green above and silvery underneath.
- Twigs are silvery or golden brown, often with prominent spines.
- Abundant berries turn red as they mature in the fall and are speckled with brown to silvery scales.
- Small clusters of fragrant tube-shaped yellowish flowers bloom May-June.

Distribution

Autumn Olive was actively promoted for wildlife habitat, hedge rows, strip mine reclamation and ornamental uses. Found throughout the eastern and midwestern U.S.

Establishment method

An individual plant can produce up to 8 pounds of fruit that is eaten and spread by birds and small mammals. Plants develop fruits annually after 3 years of age.

Threat

Rapid growth enables this shrub to out-compete native species. Prolific fruit production ensures ready distribution. Fire stimulates re-sprouts, making grassland management in infested areas more difficult.

Control

For large thickets where the threat to non-target species is minimal, apply a foliar spray of 2-4% triclopyr or glyphosate. For individual trees, cut the trunk close to the ground and apply a 25-40% concentration of triclopyr or glyphosate.

Origin

Native to China, Korea and Japan.

Resources

Kentucky Exotic Pest Plant Council

Bicolor Lespedeza

Lespedeza bicolor

James H. Miller, USDA Forest Service, Bugwood.org

Description

- Upright, semi-woody, perennial forb, 3 to 10 feet tall with many grey-to-green slender stems and arching branches.
- Leaves are oval, 3-part, numerous and alternate along the stems.
- Flowers are less than ½ inches long, purple and pea-like, grow in clusters and appear in the summer.

Distribution

Found throughout the eastern half of the U.S.

Establishment method

Spreads through its seeds.

Threat

An aggressive invader of open areas forming dense thickets that can displace native plants.

Control

Dig individual plants before they develop seed heads or apply a foliar application of 5% glyphosate with a surfactant in late summer. For larger infestations, mow or weed-eat the plants 1 to 3 months before applying the foliar herbicide application. If glyphosate is not effective, try similar rates of triclopyr.

Origin

Native to Asia, introduced to the U.S. in the late 1800s for wildlife food and habitat.

Resources

NC State University, www.invasive.org, USDA Plant Database, Indiana Cooperative Agricultural Pest Survey Program.

Burning Bush

(Winged Euonymus, Winged Wahoo)
Euonymus alatus

© 2009 Barry Rice

Invasive.org

Description

- Deciduous shrub with gray stems and corky wing-like ridges.
- Opposite leaves, elliptic with a tapered tip, have fine serrations on the margins.
- Leaves turn bright red color in fall.
- Flowers are small, yellowish green in color and inconspicuous in pairs at the tips of y-shaped stems.
- Smooth, purplish fruit are a half-inch long and are present from September through October. Each fruit contains approximately four red-to-orange seeds.

Distribution

Found in most states in the eastern U.S. and the upper midwest.

Establishment method

Spreads quickly by root suckers and from birds dispersing seeds.

Threat

Can form dense thickets in natural woods and shade out native plants. It is also an adaptive plant, growing well in a wide range of soil types and pH levels.

Control

Hand-pull small plants. Larger plants can be cut and the stump surface painted with 25% glyphosate. Foliar spray is also an option but most effective during early summer months.

Origin

Introduced from northeast Asia and promoted as an ornamental.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA .

Bush Honeysuckles

Lonicera maackii , L. morrowii , L. tatarica , L. x bella

Lonicera mackii

© 1999 Nick Kurzenko

Lonicera morrowii

© 2003 Joseph Dougherty/ecology.org

Lonicera tatarica

Chris Evans, River to River CWMA, Bugwood.org

Description

- Shrubs, ranging from 6 to 15 feet in height.
- Egg-shaped to oblong opposite leaves are 1 to 2 ½ inches long with pointed tips, leafing out first in spring and persisting into late fall.
- Pairs of fragrant, tubular white-to-pink flowers appear in late spring.
- Fruits are red or orange berries containing many seeds.

Distribution

Introduced for use as ornamentals and for wildlife food and cover. Bush Honeysuckles are found in a wide variety of habitats from the Central Great Plains to southern New England and south to Tennessee and North Carolina.

Establishment method

Plants fruit prolifically and are highly attractive to birds who distribute the fruits and seed. In established populations, vegetative sprouting also aids in their reproduction.

Threat

Aggressively forms dense shrub layer that crowds out native plant species. Can reduce tree regeneration and eliminate understory species due to deep shade cast by dense thickets. Fruits are rich in carbohydrates but do not offer migrating birds the high-fat, nutrient-rich food sources needed for long flights. Increased predation of nests built in Honeysuckle Bushes has been attributed to its branching structure and lack of thorns which enable predators easy access.

Control

Hand removal of seedlings or small plants may be useful for small populations; however any portion of root remaining can resprout. Apply 2% glyphosate or triclopyr foliar spray where risk to non-target species is minimal. Air temperature should be above 65 degrees F. As an alternative, cut stems low to ground and immediately treat cut stump surface with a 25% solution of glyphosate or triclopyr.

Origin

China, Asia and Russia. *L. x bella* is a hybrid of *L. morrowii* and *L. tatarica*. These shrubs were introduced to the U.S. as ornamental plants and for wildlife cover.

Resources

Kentucky Exotic Pest Plant Council

Canada Thistle

Cirsium arvense

www.missouriplants.com

Description

- Perennial herbaceous plant, grows up to 4 feet tall.
- Leaves are lance-shaped with irregular lobes and prickly spines. Leaves alternate along the stem.
- Stems are ridged and hairy.
- Flowers are purple to white, ½ inches in diameter and typically flower late June to August.

Distribution

Found throughout the continental U.S. except in the deep south.

Establishment methods

Plants spread through sprouting from an extensive root system and from the distribution of numerous seeds per plant.

Threat

Dense thistle patches may form from a single plant. Seeds can be blown up to ½ mile. Once established it spreads rapidly and is difficult to remove.

Control

Hand-pulling can stimulate the plants to send up more sprouts from the roots. However, repeated pulling will eventually starve underground stems in areas where other dense vegetation compete. Mowing can be effective if plants are cut in the early bud stage. Repeated mowing over successive years will be necessary. Foliar application of 2% glyphosate or glufosinate-ammonium can be effective when sprayed early in the season before the plants have flowered.

Origin

Brought to the U.S., most likely accidentally, from Europe in the 1600s.

Resources

Wildflowers and Weeds Info, Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org, USDA Plant National Database.

Chinese Silver Grass

Miscanthus sinensis

James H. Miller, USDA Forest Service, Bugwood.org

© 2001 CDFA

Description

- Loose plume-like heads of pale pink-to-red flowers that turn silver in fall.
- Produces tall stalks that persist through winter.
- Leaves grow from the base and arise from a large central clump.
- Individual leaves taper to a point and are 3 to 4 feet long.
- Margins are sharp and slightly serrated.
- Seeds are rough with a twisted bristle tip.
- Spreads primarily by underground roots or rhizomes.

Distribution

Can invade roadsides, old fields, shores of reservoirs and forest openings following fires. Has spread throughout the eastern U.S. to Colorado and California.

Establishment method

Spreads through airborne seed as well as through its roots, forming colonies. May also resprout from a piece of underground sprouting stem.

Threat

Aggressive. Highly flammable and poses a fire hazard as burning plants can have flame lengths of 30 feet.

Control

Small patches may be grubbed, but all roots must be removed. Plant must be actively growing for herbicidal control. Use a 2% glyphosate foliar spray in fall or late spring. Cover the leaves to the point of runoff, but be careful not to spray desirable vegetation.

Origin

Originated in Asia. Introduced to the U.S. as an ornamental.

Resources

Kentucky Exotic Pest Plant Council

Chinese Yam

(Cinnamon Vine, Air Potato)
Dioscorea batatas, D. oppositifolia, D. bulbifera

Dioscorea opppsitifolia

Troy Evans, Great Smoky Mountains National Park, Bugwood.org

Description

- Chinese Yam is a long-climbing vine with 2- to 3-inch wide shiny heart-shaped leaves having arc-shaped veins.
- Leaves may vary in shape to arrowhead-like with lobes at the leaf base.
- Pea- to marble-sized bulbils that look like small potatoes occur at leaf nodes in late summer. These may become potato-sized in other regions.
- Ripe bulbils drop readily at slightest touch. New plants sprout from bulbils.

Distribution

Found increasingly along stream corridors, forest openings, roadsides and around old home sites.

Establishment method

Reproduces prolifically starting in late June and can spread rapidly along forest edges and openings.

Threat

The vine is fast-growing (up to 1 inch per day at peak). It covers trees, shrubs, ground vegetation and structures.

Control

Shading not recommended for long-term control. Mechanical control includes clipping, pulling or burning plants before bulbils form in mid-June. Follow with foliar herbicide control of sprouts with 25% glyphosate in June to August as bulbils are just forming.

Origin

Native to China; it was introduced to the United States as a food crop in the early 1800s.

Resources

The Nature Conservancy, the National Park Service and the Universities of Tennessee, Florida and Connecticut.

Common Burdock

Arctium minus

Richard Old, XID Services, Inc.

Description

- Biennial in the Aster family; forms a rosette in the first year and grows to 6 feet tall in the second year.
- The large, heart-shaped leaves are smooth above and wooly-hairy beneath.
- The flowers range from white to purple and somewhat resemble a thistle, flowering from July to October.
- Flowers dry to a bur with hooked bract.

Distribution

Grows in full or partial shade along roadsides, on stream banks and in old fields. It is found throughout North America.

Establishment method

Spreads by seed, one plant typically produces 15,000 seeds.

Threat

Crowds out native vegetation in natural areas. Host for powdery mildew and root rot. Can taint milk products if grazed in large quantities.

Control

Mowing or cutting the plant when in flower is an effective control. Application of a 2% solution of glyphosate herbicide to the leaves is also an effective control method.

Origin

Europe. Burdock was brought to the U.S. by early settlers for its medicinal properties.

Resources - USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants; Virginia Tech Weed Identification Guide http://www.ppws.vt.edu/scott/weed_id/arfmi.htm.

Common Chickweed

Stellaria media

John D. Byrd, Mississippi State University, Bugwood.org

Description

- Winter annual that often forms dense mats 2 to 6 inches high.
- Leaves are opposite and oval with pointed tips and there is a characteristic line of hairs along one side of the stem.
- Flowers have 5 deeply cut white petals, giving the appearance of 10 petals.

Distribution

This species is found on disturbed sites, in cultivated fields, along roadsides, in forest communities and in gardens throughout the U.S.

Establishment method

Spreads by seeds (each plant produces between 600-15,000 seeds) and reproduces vegetatively through a fibrous root system.

Threat

Crowds out native vegetation and forms a monoculture.

Control

Spray leaves with a 2% glyphosate solution. Application of herbicide in the very early spring can catch this species in growth but before many other native species are active.

Origin

The Common Chickweed is originally from Europe.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants, www.invasive.org.

Common Reed

Phragmites australis

© 2005 Luigi Rignanese

© 2009 Steve Matson

Description

- Perennial grass with hollow stout stems that can grow up to 15 feet tall.
- Leaves are narrow, long and tapered at the ends; they can grow up to 2 feet long.
- Large feathery plumes of flowers develop by mid-summer.
- Purple/brown flowers turn tan or gray and seeds set through fall and winter.

Distribution

Thrives in sunny wetland habitats. Occurs throughout the U.S.

Establishment method

Spreads rapidly by underground sprouting stems, which may extend 30 feet in one year. Produces large quantities of wind-borne seeds.

Threat

Crowds out native vegetation and forms a monoculture. Monocultures as large as 7000 acres have been documented.

Control

Apply a 2% solution of water-safe glyphosate herbicide to the leaves when plants are tasseling. Re-treatments are often needed due to denseness of foliage and inability of spray to reach all plants at one time. Cutting with hedge trimmers just before seeds set can reduce vigor. Treatment will be needed for several years.

Origin

The origin is uncertain. *Phragmites australis* is found on every continent except Antarctica.

Resources

Kentucky Exotic Pest Plant Council

Common Teasel

Dipsacus sylvestris

R.A. Howard. ©Smithsonian Institution. Courtesy of Smithsonian Institution, Richard A. Howard Photograph Collection.

Description

- Herbaceous plant up to 6 feet tall with stout straight stems that branch at the top.
- Leaves are paired along the stem, are long and narrow and have prickles on the underside midrib.
- Flowers are tiny, pink and clustered on a head with straight prickles sticking out like a pin cushion.

Distribution

Found throughout the continental U.S.

Establishment method

Propagated by seeds. A single teasel plant can produce over 2,000 seeds; 30-80% of these seeds may germinate.

Threat

The plant is easily spread and difficult to exterminate.

Control

Stems of teasel can be cut just below the ground surface just before flowering. (The stems will resprout if they are cut prior to flowering). If the flowers have opened, the plant material should be removed from the site to prevent formation of additional seed. Glyposate can be applied to the leaves at a 2% concentration before the plant starts to bolt.

Origin

Europe. This species is thought to have been introduced accidentally to the U.S. with other seed.

Resources

www.invasive.org, www.missouriplants.com, USDA Plant National Database, http://dnr.wi.gov/invasives.

Crown Vetch

Coronilla varia

© 2005 Louis-M. Landry

© 2008 Louis-M. Landry

Description

- Creeping stem reaches 1 ½ feet in length
- Compound leaves (multiple tiny "leaflets" on each leaf stem) range from 2 to 4 inches in length and have nine to twenty-five oblong leaflets.
- Five to twenty pea-like flowers that vary from pink, rose or lilac appear in late May-August

Distribution

Widely distributed as an ornamental ground cover and for erosion control on banks and mine reclamation throughout the continental U.S.

Establishment method

Spreads vegetatively by underground roots or rhizomes and by seed. Seeds remain viable in the soil for several years requiring consistent post-treatment monitoring.

Threat

Crown Vetch's rapid growth allows it to cover and out-compete native vegetation. May form single-species stands that can dominate treeless natural areas that receive full sun, such as grasslands.

Control

Hand-pulling of mature plants may be effective for small initial infestations. Mowing in the flower bud stage for two to three consecutive years may reduce vigor and control further spread. Cut plants as low to the ground as possible before they seed. Mowing or burning and then applying an herbicide such as 2% triclopyr or 2% glyphosate to the leaves while the plants are actively growing has been effective for control. Repeated treatments are often needed due to the dense growth of plants and the inability to adequately cover all stem surfaces with herbicide in one application.

Origin

Native to Europe, southwest Asia and northern Africa.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's-Alien Plant Working Group, The Nature Conservancy and the USDA .

English Ivy

Hedera helix

Chris Evans, River to River CWMA, Bugwood.org

Description

- Evergreen vine that can grow up to 100 feet.
- Leaves are dark green and waxy; leaf shape is variable but typically has three lobes with a heart-shaped base.
- Flowers are triggered by sunlight and are yellowish-green, occurring at the ends of the stems.
- Fruits are black and round.

Distribution

Found throughout the eastern U.S. and along the west coast.

Establishment method

Spreads primarily along the ground by runners. Fruit can be eaten by birds, spreading seed. Broken pieces of stem are able to root in the soil.

Threat

Forms a thick ground cover that displaces native understory species. English ivy can climb into trees, covering branches and slowly killing trees.

Control

Hand-pulling can be an effective control method if all of the above-ground stems are pulled. Foliar application of 2 to 4% glyphosate solution with 0.5-1% non-ionic surfactant can be effective, but repeated treatments will be necessary. Herbicide will be most effective in the summer and fall; however, in order to avoid native annuals, treatment could be applied in the winter.

Origin

Europe, introduced to the U.S. as an ornamental plant

Resources

www.invasive.org, USDA Plant Database, Plant Conservation Alliance's Alien Plant Working Group.

Fescue, Kentucky 31 Fescue

Festuca arundinacea

Ted Bodner, Southern Weed Science Society, Bugwood.org

Description

- Cool season perennial grass, grows up to six feet tall and remains green in the winter and spring.
- Moderately stout stems are unbranched with 1 to 3 swollen, light green nodes at the base.
- Leaves grow mostly from the base, are flat, 4 to 18 inches long with whitish to yellow-green flared collars.
- Flowers grow in loose, diversely branching clusters that are 4 to 12 inches tall and have a slightly purplish cast.

Distribution

Found in almost every state in the U.S.

Establishment method

It spreads mainly through sprouting underground stems and can form extensive colonies.

Threat

Extensive colonies compete with and displace native plants. It is frequently infected with a fungus that can cause illness in livestock and some wild animals.

Control

Growth can be reduced by competition from other species, especially legumes. A controlled burn in the spring before native warm season grasses have germinated can also be effective. A better option may be a spring burn followed by a foliar application of 2.5% glyphosate, chlorsulfuron or metsulfuron to new sprouts before warm season grasses appear.

Origin

Native to Europe; planted as livestock forage in the mid-1800s.

Resources

The Nature Conservancy, www.invasive.org and the USDA .

Garlic Mustard

Alliaria petiolata

Tom Heutte, USDA Forest Service, Bugwood.org

Description

- Biennial herb, over winters as a rosette, 2 to 3 feet tall at maturity.
- Leaves are broadly heart-shaped with scalloped edges; new leaves have a garlic odor when crushed.
- Flowers are small and white and produced in April-May; seed pods are long and narrow.

Distribution

Thrives in forested communities and edge habitats. Garlic Mustard is most widespread in the midwestern and northeastern U.S. and in southern Ontario.

Establishment method

Spreads only by seeds, which are transported by wind, water and animals. Seeds may remain viable in the soil for up to seven years.

Threat

Crowds out native vegetation and forms a monoculture in the understory of forest communities. Studies indicate that Garlic Mustard can harm certain butterfly species and alter the composition of soil fungi at a site, reducing regeneration of tree species.

Control

The most effective method of control is to cut and remove Garlic Mustard plants when they are in flower and before they set seed. Seeds can continue to mature when the Garlic Mustard is cut; therefore, it is essential to remove the cut plant material from the site.

Late fall or early spring application of a 2% solution of glyphosate herbicide to the leaves is also effective. Management must be repeated annually until the seed bank has become depleted

Origin

Originally from Europe, Garlic Mustard was introduced to the United States as a garden herb.

Resources - http://wiki.bugwood.org/Invasipedia

Goose Grass

Eleusine indica

Hitchcock, A.S. (rev. A. Chase). 1950. Manual of the grasses of the United States. USDA Miscellaneous Publication No. 200. Washington, DC. 1950.

John D. Byrd, Mississippi State University, Bugwood.org.

Description

- Summer annual with stems radiating outward from a distinctive white center.
- Forms a green mat-like clump with flattened stems that grow in a low rosette.
- Leaves are 2 to 14 inches long and folded along the midvein.
- Flowers cluster along stiff spikes; usually two to six spikes radiate out from a single stem.

Distribution

Found throughout most of the continental U.S., with the exception of the Pacific Northwest.

Establishment methods

Reproduces by seed.

Threat

Each plant can radiate out 2 ½ feet and tolerates a wide range of conditions.

Control

Hand-pull individual plants or mow plants before they go to seed. Repeat this treatment until initial seed source has been exhausted.

Origin

Goose Grass originated in Africa.

Resources - University of California Agriculture and Natural Resources, Virginia Tech Weed Identification Guide, USDA Plants National Database.

Ground Ivy

Glechoma hederacea

Leslie J. Mehrhoff, University of Connecticut

Description

- Perennial herb in the Mint family.
- The stems lie along the ground and the plants form a dense mat.
- The leaves are kidney-shaped with scalloped edges and have a minty odor when crushed.
- The pale violet flowers are tubular and open from March-May.

Distribution

This species is found on disturbed sites, open woods, forest edges, lawns, gardens and pastures throughout most of the U.S.

Establishment method

Spreads by seeds and by creeping stems.

Threat

Ground Ivy can form dense mats that displace native plant species. The plant is toxic to many vertebrates.

Control

Spray leaves with a 2% glyphosate herbicide solution.

Origin

Originally from Eurasia; introduced into North America in the 1800s as an ornamental and medicinal plant.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants, www.invasive.org

Ivy-leafed Morning Glory, Purple Morning Glory

Ipomoea hederacea, Ipomoea purpurea

Ivy-leafed Morning Glory

Purple Morning Glory

Description

- Annual vines, can grow up to six feet long, branching occasionally.
- Round stems are light green to dull red and mostly covered in hairs.
- Leaves of Ivy-leafed Morning Glory are deeply 3-lobed and indented at the base; up to 4 inches wide in the middle.
- Leaves of Purple Morning Glory are heart-shaped and have hairs that lie flat against the leaf.
- Flowers of Ivy-leafed Morning Glory are blue to purplish-pink, up to 2 inches wide, in the form of a funnel and bloom primarily in the morning on sunny days.
- Flowers of Purple Morning Glory occur in clusters of three or more and range in color from purple to white.

Distribution

Ivy-leafed Morning Glory is found throughout the eastern and midwestern U.S.; Purple Morning Glory is found in all U.S. states except Idaho and Wyoming.

Establishment method

The vines grow vegetatively. Birds sometimes eat the plants' large seeds, dispersing them elsewhere. Rain, wind and gravity may also disperse the seeds.

Threat

Plants are especially aggressive in disturbed areas. They are capable of climbing native vegetation and easily out-compete native plants for resources.

Control

Small infestations can be hand-pulled, being sure to get the entire root. For more mature plants, a cut-stem treatment can be successful. After cutting the stem low to the ground, apply a 30% solution of glyphosate to the cut stem within 15 to 20 seconds. Successful control has also been achieved with repeated foliar applications of 2-4% glyphosate.

Origin

Central and South America; was introduced to the United States by early settlers in 1700 and sold as an ornamental.

Resources - WCRC-4 research, USDA Agricultural Research Service, www.illinoiswildflowers.info/weeds/, www.missouriplants.com, USGS Weeds in the West Project.

Japanese Honeysuckle

Lonicera japonica

Chuck Bargeron, University of Georgia, Bugwood.org

Description

- Evergreen to semi-evergreen vine that can grow to over 80 feet in length.
- Leaves grow in opposite pairs on the stem, are oval-shaped, 1 to 2 ½ inches long and cling to the vine without a leaf stem.
- Flowers are white-pink to yellow and look like those of the bush honeysuckles.
- Fruits develop in the fall and are shiny, small and black.

Distribution

Found throughout the northeast, southeast, midwest and southwestern U.S.

Establishment method

Spreads by seeds, underground rhizomes and above-ground runners.

Threat

The vine can girdle young saplings and form dense vegetative mats, shading everything underneath. The vine may also engulf small trees, pulling them down under their weight.

Control

Control of this plant is very difficult, so vigilance to identify and eliminate the plant before it establishes is crucial. Pull out any young stems, attempting to remove the entire root. Late fall burns when native plants are dormant followed by a foliar herbicide application of 2% glyphosate to resprouts can be effective. Foliar herbicide applications, whether following a burn or not, are best applied within two days of the first killing frost.

Origin

Eastern Asia, originally planted in the 1800s for erosion control, landscaping and wildlife habitat.

Resources

The Nature Conservancy, www.invasive.org and the USDA .

Japanese Barberry

Berberis thunbergii

Plant Conservation Alliance's Alien Plant Working Group

Description

- Dense deciduous shiny shrub that grows two to eight feet tall.
- Branches are brown, deeply grooved and grow in a zig-zag form.
- Leaves are ½ inch to 1 ½ inches long, oval to spatula-shaped and green or bluish green.

Distribution

Found throughout the southeast, southwest and parts of the midwest. Scattered across Kentucky. Grows in native grasslands, fields, road cuts and in forest edges.

Establishment method

Spreads into new area via seed and resprouts vigorously from cut stumps.

Threat

Strong competitor in open areas, disturbed forests and forest edges. Crowds out native trees and shrubs. Can grow in a variety of soils. Can be a problem along streams.

Control

Hand-pulling of young seedlings is recommended where feasible. Treat trees by girdling, basal trunk spraying or cutting to eliminate seed production. Freshly cut stumps should be treated with 25% solution of glyphosate or triclopyr with water or Garlon 4 with an oil-based surfactant. Root or stump sprouting is likely as well as seedlings, so follow-up foliar spraying with 2% glyphosate or triclopyr is recommended.

Origin

Originated in Japan. Was introduced to the U.S. in 1875 as an ornamental shrub.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

Japanese Knotweed

Polygonum cuspidatum

©Elaine Haug. Provided by Smithsonian Institution, Department of Systematic Biology-Botany. United States, VA, Woodbridge, Occoquan National Wildlife Refuge.

Description

- Forms dense stands that reach 10 feet tall.
- Leaves are 2 to 6 inches long and heart-shaped.
- Stems are bamboo-like (hollow), light green to purplish-red, smooth and swollen at joints where leaves are attached.
- Small flowers are white to greenish white in small sprays along smallest branches.

Distribution

Found throughout much of the U.S. and scattered across KY. Grows along streams, home sites, low-lying areas and rights of way.

Establishment method

Spreads primarily vegetatively through its long, stout underground stems that will root and send up shoots. Stems are sometimes transported through fill dirt or, occasionally, carried by water.

Threat

Dense thickets crowd native vegetation. Tolerates adverse growing conditions. Quickly expands in natural areas from cultivated sources. Threatens riparian areas where it is rapidly colonizing scoured shorelines.

Control

Hand-pull small plants. Grub larger plants removing roots (rhizomes) and other plant parts. Foliar spray with glyphosate or triclopyr (2%) during growing season. Treat cut plants with 25% solution to knock down plants for easier foliar spraying when new sprouts and leaves emerge.

Origin

Originated in Japan. This species was introduced to the U.S. as an ornamental landscape plant.

Resources

Southeast Exotic Pest Plant Council

Japanese Spiraea

Spiraea japonica

Great Smoky Mountains National Park Resource Management Archive, USDI National Park Service, Bugwood.org

Description

- Deciduous shrub four to six feet tall with slender, brownish, erect stems.
- Leaves alternate along the stem, are 1 to 3 inches long, oval to lance-shaped and have toothed edges.
- Rosy-pink flowers grow in a cluster at the tips of the branches.
- Lustrous seed pods contain seeds $^{1}/_{10}$ inch long.

Distribution

Found throughout the eastern part of the U.S.

Establishment methods

Spreads via seed carried by water and soil that may be transported from one site to another.

Threat

Each plant produces hundreds of seeds. Once established, plants can form dense stands which displace natives and close open areas. The plant vigorously resprouts from cuts, so repeated control treatments are necessary.

Control

For small infestations, hand-pulling seedlings or cutting larger plants may be effective with repeated treatment. For larger infestations or dense stands, apply a foliar application of 2% glyphosate before the plant has gone to seed. If the infestation is intermingled with native understory plants, employ a cut-stem treatment with an application of 25 to 40% glyphosate immediately after cutting.

Origin

Eastern Asia. Japanese Spiraea was introduced into the United States as an ornamental landscape plant around 1870.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org, USDA Plant National Database.

Japanese Stilt Grass

(Asian Stilt Grass, Nepal Grass)
Microstegium vimineum

© 2009 Barry Rice

Description

- Pale green lance-like thin leaves up to 3 inches long on thin stems. Silvery strip of reflective hairs at center of upper side of leaf is a distinctive mark.
- Size varies: can be up to 3 feet tall, but often ½ to 2 feet. Sometimes seen as a nearly mat-like cover where mowed.
- Plants are shallow-rooted and are easily pulled up.

Distribution

Observed along road sides, stream banks, gravel beds and trails, but also found deep in forests. Found throughout Kentucky.

Establishment method

Seeds remain viable for up to seven years and are easily spread by hay, soil on shoes, tires and water.

Threat

Adapted to shade, invades forests and forms dense patches that crowd out native plants in open and shaded sites. Spreads easily and can take over fields and forests quickly, especially moist, rich soils and wetlands.

Control

Repeated hand-pulling, especially when plants are in full bloom (late summer). Larger populations may be weed-whacked in late summer just before plants produce seeds. Important to control small populations quickly. Chemical controls include foliar application of 2% glyphosate. In wet areas, wetland herbicide formulations are needed.

Origin

Japan, Korea, China, Malaysia, India. Japanese Stilt Grass was introduced accidentally to the U.S. – the seeds were carried in with packing material.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Southern Appalachian Man and the Biosphere Program (samab.org), TVA, the University of Tennessee, U.S. Fish & Wildlife Service, the Nature Conservancy, Plant Conservation Alliance and others.

Johnson Grass

Sorghum halepense

©James H. Miller. James H. Miller and Karl V. Miller. 2005. Forest plants of the southeast and their wildlife uses. University of Georgia Press., Athens. Courtesy of University of Georgia Press.

Description

- Perennial grass, grows in large clumps that can grow 7 to 8 feet tall.
- Flowers are in a purple-colored branched cluster at the end of the stem.
- Leaves are 6 to 20 inches long with a white mid vein.
- Stems are pink to red near the base.

Distribution

Found throughout the continental U.S.

Establishment methods

Propagates through large underground stems and massive seed production.

Threat

By the 20th century, Johnson Grass was recognized as one of the six most damaging weeds in the U.S. Forms dense stands and has the capability of producing large numbers of seeds that remain viable in the soil for 25 years. Nutritional value as fodder is very low as compared to native species. Out-competes native plants for water.

Control

Hand-pulling is usually not effective because underground stems are left behind; however this method, when repeated, may reduce vigor. If implemented, hand-pulling is best done in early spring. Mechanical cutting and use of 2% glyphosate as a foliar spray are acceptable when used repetitively.

Origin- Introduced from the Mediterranean region as a forage crop.

Resources- Kentucky Exotic Pest Plant Council

Jointhead Grass

Arthraxon hispidus

Leslie J. Mehrhoff, University of Connecticut

Description

- Creeping annual grass that grows to a height of 1 ½ feet.
- Leaves are short and wide and have an oval shape with a pointed tip; the edges of the leaves are hairy.
- Flowers are composed of many spikelets that resemble fingers and open from September to October.

Distribution

This species prefers sunny moist sites and is found primarily in the eastern half of the U.S.

Establishment method

Spreads by water-dispersed seeds.

Threat

Jointhead Grass can form dense stands that displace native plant species, particularly along shorelines.

Control

The species can be controlled by hand-pulling or mowing prior to seed production. May also be treated with a foliar application of 2-4% glyphosate solution.

Origin

Eastern Asia: China, Japan and Korea.

Resources

USDA Forest Service Invasive Plants Website http://www.na.fs.fed.us/fhp/invasive_plants; Virginia Tech Weed Identification Guide http://www.ppws.vt.edu/scott/weed_id/arahi.htm.

Kentucky Bluegrass

Poa pratensis

Robert H. Mohlenbrock. USDA SCS. 1989. Midwest wetland flora: Field office illustrated guide to plant species. Midwest National Technical Center, Lincoln. Courtesy of USDA

Description

- Shallow-rooted perennial grass.
- Distinguished by its flat leaf blade and boat-shaped leaf tip.
- Flowers are in clusters of two to six on a loosely branched form at the end of the stem that can grow as tall as 4 ½ feet.

Distribution

Found in all of continental U.S., although more common in the north than in the south.

Establishment method

Spreads via sprouts from its roots, aerial sprouts from leaves that form their own roots, as well as by seed.

Threat

Kentucky Bluegrass is especially a problem in tallgrass and mixed grass prairies. It can penetrate between native plants, competing for resources.

Control

In small stands where Kentucky Bluegrass has intermingled with other native species, herbicide treatment is not recommended and hand-pulling may be effective. However, in areas where Bluegrass dominates or is a monoculture, a foliar application of 2% glyphosate in the early spring when native warm season plants are dormant can be effective.

Origin

There is some debate as to whether Kentucky Bluegrass is native to the northern U.S. and Canada or whether it was introduced here and has naturalized. It is thought that Kentucky Bluegrass is native to Europe and Eurasia and was spread extensively throughout North American for use as a pasture and turf grass starting in the early 1600s.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.missouriplants.com.

Korean Lespedeza, Kobe Lespedeza

Lespedeza stipulacea, Lespedeza striata

www.missouriplants.com

www.weedalert.com

Description

- Summer annual that grows primarily along the ground forming mats 15 to 18 inches in diameter.
- Leaves consist of three leaflets $^1/_2$ inch to $^3/_4$ inch long and with obvious venation.
- Flowers are pinkish purple and are found on the leaf axils.

Distribution

Found throughout the eastern and midwestern U.S.

Establishment method

Spreads via seed.

Threat

Spreads rapidly in open areas, road sides and disturbed areas; can outcompete native vegetation.

Control

Foliar application of herbicide containing 5% fluroxypyr, metsulfuron or triclopyr when the plant is actively growing and in the seedling or flowering stage.

Origin

Native to Asia. Both plants were brought to the U.S. as cover crops and fodder for cattle and horses.

Resources

www.missouriplants.com, Virginia Tech Weed Identification Guide, www.weedalert.com.

Kudzu

Pueraria lobata

James H. Miller, USDA Forest Service, Bugwood.org

Forest & Kim Starr, U.S. Geological Survey, Bugwood.org

Description

- Fast-growing perennial, semi-woody vine, usually with three leaflets resembling pea leaves.
- Leaflets 2 to 4 inches wide and hairy on edges.
- Light purple/pink flowers with a fragrant, sweet grape smell in late summer.
- Roots are fleshy with massive tap roots.

Distribution

Major infestations in eastern and western Kentucky with scattered populations statewide.

Establishment method

Spreads primarily vegetatively through runners and rooting underground stems. Vine nodes may also root to form new plants.

Threat

Kudzu kills or degrades other plants by shading them under a blanket of leaves, by girdling stems and tree trunks and by breaking branches or uprooting trees by its weight.

Control

Seedlings can be sprayed with herbicide or pulled. The root system must be killed. Mow or cut monthly over two or more growing seasons. Sever vines and treat roots to get foliar levels manageable for more direct treatments. Late season cutting of vines at root tops followed by immediate stump treatment with 25% glyphosate works best. Foliar application of 2% glyphosate to small plants repeatedly in a season may keep plants in check. No biological controls are available.

Origin

Asia (China, Japan). Was introduced as a ground cover for erosion-prone sites.

Resources

Plant Conservation Alliance's Alien Plant Working Group

Lesser Periwinkle

Vinca minor

Dan Tenaglia, Missouriplants.com, Bugwood.org

Description

- Evergreen to semi-evergreen trailing vine and groundcover that reaches almost seven feet long.
- Stems are slender, somewhat woody and green in color.
- Leaves are glossy, 1 inch long and grow in pairs along the stem.
- Flowers are periwinkle in color, 1 inch wide, five-petaled and flower in the spring.

Distribution

Found throughout most of the U.S.

Establishment method

Spreads vegetatively.

Threat

Periwinkle forms dense and extensive mats along open areas and forest floors that exclude native vegetation.

Control

Can be removed by digging, raising the runners from the soil with a rake and mowing the plants. For most effective removal and in dense stands, spray the cut area with a 3% solution of glyphosate immediately after cutting the stems. Follow-up spot treatment will be necessary. Mix glyphosate and water with a surfactant for plants with waxy cuticles. Apply in early spring when the plant is vigorously growing and the cuticle is not yet thick.

Origin

Introduced from Europe as a horticultural plant.

Resources

DCNR Invasive Exotic Plant Tutorial for Natural Land Managers, Plant Invaders of Mid-Atlantic Natural Areas, www.invasive.org.

Mimosa, Silk Tree

Albizia julibrissin

James H. Miller, USDA Forest Service, Bugwood.org

Description

- Small to medium-sized tree with multiple trunks and spreading crown.
- Leaves finely divided and fern-like, bark light brown.
- Flowers a delicate white and pink in clusters like pom-poms in mid-summer.
- Bean pods six inches long and conspicuous through early winter.

Distribution

Found throughout the southeast, southwest and parts of the midwest. Scattered across Kentucky. Grows in native grasslands, fields, road cuts and in forest edges.

Establishment method

Spreads into new area via seed and resprouts vigorously from cut stumps.

Threat

Strong competitor in open areas, disturbed forests and forest edges. Crowds out native trees and shrubs. Can grow in a variety of soils. Can be a problem along streams.

Control

Hand-pulling of young seedlings is recommended where feasible. Treat trees by girdling, basal trunk spraying or cutting to eliminate seed production. Freshly cut stumps should be treated with 25% solution of glyphosate or triclopyr with water or Garlon 4 with horticultural oil. Root or stump sprouting is likely as well as seedlings, so follow-up foliar spray with 2% glyphosate or triclopyr is recommended.

Origin - Iran to Japan. Was introduced to the U.S. as an ornamental in 1745.

Resources

Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

Multiflora Rose

Rosa multiflora

Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

James H. Miller, USDA Forest Service, Bugwood.org

Description

- Thorny, round-shaped, medium to large shrub.
- Leaves have 7 to 9 leaflets arranged in pairs and with one at the end of the stem.
- Leaves have a characteristic fringe along the base of the leaf stem.
- Flowers are small and white to pinkish white, appearing in May or June.
- Fruit turn from green to red to brown through winter.

Distribution

Widely distributed in Kentucky along roadsides, fence rows, stream sides, forest edges and into the interior of forests and unmaintained fields.

Establishment method

Reproduces by seeds that are spread by birds and other animals and vegetatively when arching canes touch the ground and root from the tip

Threat

Forms single-species thickets crowding out native plants, especially at stream sides.

Control

Mowing can keep invasions in check. Pulling up small plants can be effective if repeated to control root sprouts and seedling germination. Chemical control involves foliar sprays of glyphosate or triclopyr at 2% to 3% or cut-stump treatment of the same chemicals at 25% concentrations.

Origin

Japan, Korea, eastern China. Multiflora Rose was originally introduced to the U.S. as a rootstock for ornamental Roses. In the 1930s, it was promoted by the U.S. Soil Conservation Service for erosion control and as a "living fence" to contain livestock.

Resources

Southeast Exotic Pest Plant Council, Plant Conservation Alliance's Alien Plant Working Group and www.invasive.org.

Musk Thistle, Nodding Thistle

Carduus nutans

James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Usually a biennial, a seedling emerges in mid- to late July and develops into a rosette the first year; the second year it bolts in mid-March.
- Mature plants range from 1½ to 6 feet tall with multi-branched spiny stems.
- Spiny leaves are dark green and coarsely lobed with a smooth waxy surface.
- Large, showy, pink-purple disk-shaped flower heads contain hundreds of tiny individual flowers which emerge in May to August and occur at the tips of stems. The flower heads will droop at a 90- degree angle from the stem when mature.

Distribution

Found throughout the continental U.S. except for Maine, Vermont and Florida.

Establishment method

Spreads via seed. Each plant can produce thousands of straw-colored seeds with plume-like hairs.

Threat

Invades native grasslands and pastures. Can out-compete natives as grazing animals will not eat it.

Control

Hand-pulling or cutting of small populations can be done after the stems have bolted but should be done before seed production. Flowers and seed heads should be bagged and taken to landfill to minimize seed dispersal. Foliar spraying of 3% glyphosate or triclopyr applied during rosette stage prior to stem development is also effective.

Origin

Nodding Thistle was accidentally introduced to the U.S. from Europe and Asia.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.invasive.org.

Oriental Bittersweet

Celastrus orbiculata

James H. Miller, USDA Forest Service, Bugwood.org

James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Twining vine with round, glossy to semi-glossy, finely toothed leaves the size of a quarter to half-dollar.
- Flowers and fruit occur at base of leaf stems.
- Greenish-yellow flowers bloom in May with 5 petals.
- Greenish-yellow fruits split open to reveal three red-orange fleshy seeds.

Distribution

Scattered in Kentucky with populations spreading. Alluvial woods, road sides, thickets and old home sites.

Establishment method

Seeds spread by birds and small mammals.

Threat

Aggressively covers, shades and chokes native vegetation including ground layer, shrubs and canopy trees. Believed to readily hybridize with native bittersweet. Tolerates shade.

Control

Hand-pull small infestations, but requires 100% removal, which is difficult. For dense infestations, cut vines and paint cut stems with 25% glyphosate herbicide. Apply herbicides before spring wildflowers emerge or after killing frost. Follow-up and late season treatments necessary.

Origin

Eastern Asia - introduced to the U.S. in the 1860s as an ornamental plant.

Resources

TN Exotic Plant Management Manual; Plant Conservation Alliance's Alien Plant Working Group; Exotic Pest Plants of Southeastern Forests.

Ox-Eye Daisy

Chrysanthemum leucanthemum

Description

- Perennial plant with flower stems 1 to 3 feet tall.
- Small tuft of leaves develop at base with other leaves alternating up the stem.
- Flowers grow one per stem and have a typical daisy-like appearance.

Distribution

Found throughout the U.S.

Establishment method

Livestock and animals feed on the plants and pass the still-viable seeds through their systems to other areas.

Threat

Has the potential to form dense colonies, replacing up to 50% of the native grass species in pastures. Heavy infestations increase the potential for soil erosion because its shallow roots displace deeper-rooted native grasses. Typical plants can produce up to 500 seeds.

Control

Hand-pull all plants before the flowers form seed heads. Seeds remain viable for two to three years, so repeated monitoring and pulling is necessary.

Origin

Introduced from Eurasia as an ornamental plant.

Resources

www.invasive.org, www.illinoiswildflowers.info/weeds/, USFS Weed of the Week.

Poison Hemlock

Conium maculatum

William & Wilma Follette. USDA NRCS. 1992. Western wetland flora: Field office guide to plant species. West Region,Sacramento.

Description

- Annual plant whose hollow stems are purple mottled, erect, smooth and from 2 to 10 feet tall.
- Small white flowers grouped in large clusters that are 1 ½ to 2 ½ inches wide.
- Fern-like leaves are alternate and basal, upper leaves progressively smaller.
- Leaves are sub-divided 3 to 4 times; the enlarged leaf base sheaths the stem.

Distribution

Invades riparian areas, ditches, old fields, roadsides throughout most of North America.

Establishment method

Plant spreads by seed alone, which can be carried by water, somewhat by wind or through mud on vehicles or gardening equipment.

Threat

All parts of the plant are toxic to humans and animals when eaten. Prolific seed production, aggressive growth habits and tolerance of shade allow rapid spread which overwhelms native vegetative cover. Not valuable to wildlife as food or shelter.

Control

The suggested method for small infestations is to dig up the plants or cut them back before flowering. It is not necessary to remove the entire root since the plant is an annual. Do not compost flowers as they can go to seed.

Origin

Eurasia. Introduced to the U.S. as a garden plant.

Resources

The Nature Conservancy's Element Stewardship Abstract, U.S. Forest Service Weed of the Week.

Princess Tree

Paulownia tomentosa

James R. Allison, Georgia Department of Natural Resources, Bugwood.org

Description

- Deciduous tree that grows up to 60 feet tall.
- Leaves are arranged in pairs along the stem, 6 to 12 inches long and heart-shaped and hairy on the underside.
- Stems are markedly flattened at the "nodes" where stems and branches meet.
- Flowers are showy, appearing in clusters in the spring. Long, tubular, pale-violet flowers develop in upright clusters.
- Fruit resemble pecan nuts and split to release thousands of seeds.

Distribution

Found throughout the eastern U.S. and Texas

Establishment method

Reproduces via seed and root sprouts, the latter growing up to 15 feet in a season.

Threat

This tree is a prolific reproducer. Individual trees are capable of producing up to twenty million seeds, each easily transportable via water and wind. Trees vigorously resprout from either stem or root after being cut, burned or even bulldozed. Its aggressive growth allows it to out-compete native plants for resources.

Control

Young sprouts may be hand-pulled. It is best to pull them after a rain in order to get the entire root since broken root fragments may resprout. For more mature trees, cut the stump close to the ground after the tree has flowered but before it has gone to seed and immediately apply a mixture of 50% glyphosate or triclopyr to the outer 20% of the stump. The stump should be monitored for resprouts which should be cut and painted with herbicide.

Origin

East Asia, China. Princess Tree was introduced to the U.S. as an ornamental around 1840.

Resources

U.S. Forest Service Weed of the Week, Plant Conservation Alliance's Weed Working Group, www.invasives.org.

Privet

Ligustrum sinense, L. vulgare

Description

- Semi-evergreen shrub that grows to 20 feet tall.
- Trunks usually occur as multiple stems with many long, leafy branches.
- Leaves grow in pairs on the stem, are oval, with hair on the underside midvein and are less than 2 inches long.
- Flowering occurs in late spring, when small, white flowers develop at the ends of branches in 2 to 3 inch-long clusters.
- Fruit are oval, fleshy, less than ½ inch long, ripen to a dark purple to black color and persist into winter.

Distribution

Found in cultivated landscapes, wildlands and disturbed areas throughout the southeastern U.S., particularly in wet to moist habitats and along fence rows.

Establishment method

Grows readily from seed or resprouting stumps. Seeds may be spread by wildlife, particularly birds.

Threat

Can form dense thickets that out-compete native vegetation.

Control

Young seedlings may be pulled when they are tall enough to grasp but have not yet produced seed. They are best pulled after a rain when the ground is moist. For large homogenous stands, a foliar herbicide spray may be used; suggested is 2% glyphosate, metsulfuron or triclopyr mixed with a 0.5% ionic surfactant to ensure that the herbicide will cling to the leaves. For individual plants, cut the stem and paint the stump with a 25% glyphosate mixture.

Origin

It originated in China and was introduced to the U.S. as an ornamental shrub.

Resources

The Nature Conservancy, the Missouri Dept. of Conservation, www.invasive.org and the USDA.

Purple Loosestrife

Lythrum salicaria

© 2005 Louis-M. Landry

Description

- Erect perennial herb with leaves growing in opposite pairs or in a circular arrangement around the stem, with heart-shaped bases.
- Showy spikes of purple-magenta flowers during the summer months.
- Grows four to eight feet tall and can have 30 to 50 stalks per root mass.
- Strong tap root, stems become woody, persisting for up to two years.

Distribution

Found in every state except Florida.

Establishment method

A prolific seed producer; seeds that germinate in the spring will produce a flowering stem that year. Seeds remain viable for several years.

Threat

Quickly adapts to natural and disturbed wetlands; overtakes native aquatic plants and forms large dense stands. Displacement of native aquatic species impacts waterfowl dependent upon them for food and cover. Research suggests that Loosestrife plants can alter the pH of wetlands, inhibiting success of amphibian populations.

Control

Small infestations and young plants can be pulled by hand, preferably before seed sets in late summer, early fall. Plant parts should be bagged and removed from the site as any plant fragment that remains could resprout. Cutting and mowing increase vegetative spreading. Older plants can be treated by a foliar application with a 2-4% glyphosate formulation for use over water.

Origin

Introduced from Eurasia as an ornamental.

Resources

Kentucky Exotic Pest Plant Council

Queen Anne's Lace, Wild Carrot

Daucus carota

Chris Evans, River to River CWMA, Bugwood.org

Description

- Biennial plant that may grow 3 feet tall.
- Leaves are deeply divided and look similar to carrot leaves.
- Stems are coarse and hairy.
- Flowers are white and grow in a flat-topped round cluster.

Distribution

Found throughout the U.S.

Establishment method

Seeds have barbs that allow dispersal by animals and wind.

Threat

One plant can produce 1,000 to 40,000 seeds. Queen Anne's Lace invades disturbed open areas and, because of a deep taproot and rapid maturation, may out-compete native plants for water.

Control

Hand-pull individual plants from low on the stem before plants set seed.

Origin

Native to Europe and southwest Asia and introduced to the U.S. as an ornamental.

Resources

The Nature Conservancy's Element Stewardship Abstract, www.invasive.org, USFS Weed of the Week .

Sericea Lespedeza, Chinese Lespedeza

Lespedeza cuneata

James H. Miller, USDA Forest Service, Bugwood.org

Description

- Perennial herb in the Pea family.
- Grows erect from 3 to 5 ½ feet in height with leaves that grow alternately on the stem.
- Each leaf is divided into three smaller leaflets about ½ to 1 inch long with awl-shaped spines.
- Leaflets are covered with densely flattened hairs making them appear grayish green or silver.
- Flowers are pea-like, white with purple markings and emerge singly or in clusters of 2 to 4 in the upper axils.
- Older stems are woody and fibrous.

Distribution

Found in open areas throughout the eastern United States.

Establishment method

Mature seeds may remain viable for up to 20 years. Seedlings may represent only 1% of the seeds actually available in the soil. Fruits are eaten and dispersed by animals. Haying of infested fields can also disperse seed.

Threat

Invades bottomlands and burned grasslands, crowding out native plants and forming pure stands. High tannin content makes it undesirable to wildlife.

Control

Hand-pulling is impractical, but mowing plants in the flower bud state for two or three consecutive years may reduce vigor and control further spread. Cut as low to the ground as possible. Foliar herbicide treatment in early to mid-summer with a 2% solution of triclopyr is effective. On wet sites, a 2% solution of glyphosate is effective from late June until seed set.

Origin

Introduced from eastern Asia for erosion control, wildlife food and as a forage crop.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA .

Smooth Brome Grass

Bromus inermis

Ohio State Weed Lab Archive, Ohio State University, Bugwood.org

Description

- Perennial grass 1 to 3 ½ feet tall.
- Leaves are narrow and 6 to 15 inches long, hairless and flat.
- Flower heads bloom at top of plant and are purplish, growing in drooping branching clusters of 7 to 10 flowers.
- Characteristic "W" shape wrinkle near the leaf tip.

Distribution

Found throughout the U.S.

Establishment method

Spreads via seed and from spreading roots that sprout new plants.

Threat

Roots form a thick sod that can out-compete native grasses and wildflowers. Seeds are tenacious, staying viable in the soil for up to ten years.

Control

Cut or hand-pull the plants when the seed head is just beginning to form but is not yet hard. Monitoring and repeated pulling will be necessary.

Origin

Introduced from Europe for use as forage and pasture grass.

Resources

Plant National Database, www.invasive.org, www.illinoiswildflowers.info/weeds/, The Nature Conservancy's Element Stewardship Abstract.

Spotted Knapweed

Centaurea biebersteinii

USDA Plant National Database

Description

- Biennial or short-lived perennial herbaceous plant, 2 to 3 feet tall.
- First year's leaves grow from the base and form a rosette from which grow 1 to 20 wiry, white-haired, branched stems during the second year.
- Leaves are alternate, grayish and divided into lance-shaped lobes decreasing in size at the top.
- Flowers are purple to pink in color, appear in early summer and have black tips on the petal-like underside fringe.

Distribution

Found throughout most of the continental U.S.

Establishment methods

Spreads through seed distribution and new plants sprouting from lateral roots

Threat

Especially threatening to dry prairies, oak and pine barrens and sandy ridges. Spotted Knapweed thrives especially well in these conditions and out-competes native vegetation.

Control

Hand-pull first-year rosettes and second year plants before they go to seed. Repeated mowing may be effective to prevent second-year plants from flowering. Foliar application of 0.5% clopyralid during bud growth can be effective.

Origin

Europe and western Asia. It was accidentally introduced in contaminated alfalfa and clover seed in the late 1800s.

Resources

Minnesota Department of Natural Resources, www.invasive.org, USDA Plant National Database.

Star of Bethlehem

Ornithogalum umbellatum

R.A. Howard. ©Smithsonian Institution. Courtesy of Smithsonian Institution, Richard A. Howard Photograph Collection. United States, MA, Weston.

Description

- Perennial plant with 6 inch to 12 inch-long leaves sprouting from base and spanning one-foot across.
- There is often a white stripe down the center of leaves.
- Flowers are white and six-petaled, resembling a star and sprout from individual stems from the base of the plant.
- Blooms occur in late spring and last about two weeks.

Distribution

Throughout eastern, midwestern U.S. and along the west coast.

Establishment method

Most plants develop from bulbs. Smaller "bulblets" form around the parent bulb and these are what form new plants each year.

Threat

Aggressive in full sun to light-shade. Because it germinates and flowers in the spring, it has the potential to displace some native spring wildflowers.

Control

Herbicide has limited effect on this plant due to the energy reserves in the bulbs. The most effective, although time-consuming, method is to sift through the soil and remove every bulb and bulblet. Annual monitoring may be necessary to ensure all bulbs are removed.

Origin

Eastern Europe and parts of the Middle East; it was introduced to the U.S. as an ornamental plant.

Resources

Virginia Tech Weed Identification Guide, www.illinoiswildflowers.info.

Tree of Heaven

Ailanthus altissima

James H. Miller, USDA Forest Service, Bugwood.org

Jan Samanek, State Phytosanitary Administration, Bugwood.org

Description

- Rapidly growing deciduous tree; grows up to 80 feet tall.
- Leaves are 1 to 4 feet long, each having 10 to 41 spear-shaped and smooth-edged leaflets.
- Small lobes at leaflet base are a key identifier, each lobe having a small hard bump (gland).
- Crushed leaves, broken twigs and cut bark have acrid burnt peanut butter odor.
- Yellow-green flowers cluster at end of limbs in July, turn to gray seed clusters in winter.

Distribution

Widespread in the U.S.; scattered throughout Kentucky.

Establishment method

Reproduces by seed and by sprouting from its roots.

Threat

Grows thickly, excluding native species. Roots exude chemicals that push out native plants. Infests closed woodlands but is most common along open areas and forest edges. Each female tree can produce as many as 325,000 seeds per year.

Control

Hand-pull young seedlings, removing entire root. For more mature trees, cut down before they go to seed and immediately spray stump with 25% glyphosate solution.

Origin

Central China. Introduced to the U.S. as an ornamental tree around 1840.

References

TN Exotic Plant Management Manual, Plant Conservation Alliance's Alien Plant Working Group, www.invasive.org.

White Mulberry

Morus alba

Ohio State Weed Lab Archive, The Ohio State University, Bugwood.org

Description

- Deciduous shrub or tree, can grow up to 30 to 50 feet tall.
- Young bark, bark along the roots and inner bark have an orange color.
- Glossy green leaves are 3 to 6 inches long, grow alternately along the stem, have blunt teeth, heart-shaped bases and are variable in shape.
- Fruits resemble long blackberries, growing 1 to 1 ¼ inches long and ripening in July.

Distribution

Found throughout the U.S. except Nevada, Alaska and Arizona.

Establishment method

Seeds are spread by wildlife that feed on the tasty fruits. Locally, new trees can sprout from existing tree roots.

Threat

Capable of hybridizing with and replacing native mulberry. It can transfer a harmful root disease to native mulberry.

Control

Trees should be cut close to the ground and the outer rim of the stump treated with 25-40% glyphosate or triclopyr. Stump should be monitored for resprouts which should be cut and treated with herbicide.

Origin

Asia; this species was introduced to the U.S. during colonial times in an effort to promote a silkworm industry in the US.

Resources

California Rare Fruit Growers, U.S. Forest Service Weed of the Week, www.invasive.org.

White Poplar

Populus alba

Herman, D.E., et al. 1996. North Dakota tree handbook. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck. Courtesy of ND State Soil Conservation Committee.

Description

- Deciduous tree, can grow to be 40 to 80 feet tall.
- The bark on young trees is smooth and greenish white becoming gray and wrinkled as trees mature.
- Leaves resemble those of maples except the top is shiny and dark green and the underside is bright white and hairy.
- Young green or brown twigs are covered with dense woolly hair.
- Fruits are small hairy seed pods that are wind-dispersed.

Distribution

Found throughout the continental U.S. except Arizona.

Establishment method

Seeds are spread by the wind; this species also spreads by sprouting from the roots.

Threat

This tree produces large seed crops and is a vigorous resprouter. Will escape original planting site and out-compete native trees and shrubs for resources.

Control

Hand-pull seedlings and young plants, making sure to remove the entire root system to prevent resprouts. Manual removal is best after a rain or when the soil has been loosened. Mature trees may be cut and the stumps treated with a 25-40% glyphosate or triclopyr solution painted on the outer 20% of the stump rim.

Origin

Eurasia; White Poplar was introduced to the U.S. in 1748 as an ornamental tree.

Resources

U.S. Forest Service Weed of the Week, www.invasive.org, Univ. of Wisconsin Green Bay Herbarium, USDA Plant National Database.

White Watercress

Rorippa nasturtium-aquaticum

Robert H. Mohlenbrock. USDA NRCS. 1995. Northeast wetland flora: Field office guide to plant species. Northeast National Technical Center, Chester. Courtesy of USDA NRCS Wetland Science Institute.

Description

- Leafy green perennial that grows in water or on wet soil.
- Leaves alternate along hollow stems; each leaf contains three to nine oval-shaped "leaflets"; the terminal leaflet is larger than the side ones.
- Flowers are less than 1/4 inch wide, white and four-petaled, blooming from April through September on relatively long stems.
- Seed pods are slender and no more than 1/2 inch long.

Distribution

Found throughout the continental U.S. but is native in some of those states.

Establishment method

Nodes on the stems can send forth roots and spread the plant vegetatively.

Threat

Watercress rapidly forms dense stands that exclude native plants.

Control

Hand-pulling is recommended.

Origin

Europe. Introduced in 1831.

Resources

Central Jersey Invasive Species Strike Team, USDA Plant Database.

Winter Creeper

Euonymus fortunei

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Description

- Evergreen vine that forms a dense ground cover. Can also grow as a shrub up to 3 feet in height or climb 40- to 70-foot vertical surfaces with the aid of aerial roots.
- 1 to 2 ½ inch-long paired leaves are dark green, shiny and egg-shaped with finely-toothed margins and whitish veins.
- Inconspicuous green-white 5-petaled flowers bloom June to July.
- Fruits are pinkish to red capsules that split open to expose seeds adorned with a fleshy orange seed coat in fall.

Distribution

Scattered throughout the eastern United States.

Establishment method

Spreads vegetatively from lateral shoots off its branches and by new plants produced from shoots at the stem. Stems that break off may be carried via water and establish elsewhere. Vines produce fruits that are eaten by birds and wildlife that disperse the seed and establish new plants.

Threat

Forms dense ground cover that eliminates native species from the understory and inhibits establishment of tree seedlings. Impedes recruitment of canopy species. Can overtop trees and cause decreased vigor.

Control

Hand-pull young infestations and sensitive areas where herbicide is not suitable; however, any plant stem left can resprout. For larger vines, immediately apply a 25% solution of glyphosate or triclopyr to cut stems. Foliar spray with a surfactant can be effective on large populations.

Origin

Introduced from China as an ornamental ground cover.

Resources

TN & SE Exotic Pest Plant Councils (tneppc.org and se-eppc.org), Plant Conservation Alliance's Alien Plant Working Group, The Nature Conservancy and the USDA.

Yellow and White Sweet Clover

Melilotus officinalis and Melilotus alba

Melilotus alba

© 2005 Louis-M. Landry

Melilotus officionalis

© 2005 Louis-M. Landry

Description

- Primarily a biennial, first year's growth is vegetative. Second year plants have a taproot that may exceed 50 inches and flowering stems that ascend 1-10 feet upward.
- Fruit is a small one- to two-seeded pod.
- Flowers are pea-like, either yellow or white.
- Both species flower in June and July, yellow usually a few weeks earlier than white.
- Leaves are alternate and divided into three serrated leaflets; the middle leaflet is on a distinct stalk.

Distribution

Its use in agriculture and for soil stabilization has helped it to spread across N. America. It is now found in every state.

Establishment method

A plant can produce 14,000 to 350,000 seeds. Seeds may remain viable in the soil for more than 20 years.

Threat

Invades grasslands and out-competes native plants for space and resources. Infested areas managed with prescribed fire can actually enhance germination rates and seedling establishment.

Control

For small infestations, hand-pulling of first year stems in late summer/early fall may be effective. Mowing in late spring/early summer may reduce but not prevent seed set as flowering shoots can re-sprout. Foliar application of 2,4-D on young seedlings at two to three tablespoons per gallon with a surfactant has been effective.

Origin

Europe and Western Asia. Introduced as a forage crop and for nitrogen fixing to rebuild depleted soils.

Resources

Kentucky Exotic Pest Plant Council

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TREE PRESERVATION

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TREE PRESERVATION
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CHAPTER 14
TREE PRESERVATION

14.1 PURPOSE

MSD's objective is to preserve as many trees as possible during design and construction of facilities. Trees are beneficial to a community and provide an aesthetically pleasing environment. Trees reduce noise, purify the air, modify the climate, in most cases increase property values and provide wildlife habitats.

To meet these objectives, during the planning and design stages, the proposed routing of the facility must be carefully reviewed. The routing should avoid trees when possible and stay outside of the tree's dripline.

The Louisville and Jefferson County Planning Commission is further developing the following guidelines. The contents of this chapter are intended to be interim guidelines pending completion of the final document.

14.2 GUIDELINES AND GENERAL INFORMATION

14.2.1 General

Generally, cutting the root of a tree within the dripline will reduce the tree's life support system by as much as 25%, outside the dripline only 5%. These percentages can vary with different species of trees.

Exhibit 14-1 shows the common root structure of trees. Exhibit 14-2 shows the dripline and root zones for trees.

14.2.2 Survey Information Needed

a. Species of Tree (Use the Audubon Society Field Guide to North American Trees, Eastern Region).

b. Size (DBH - Diameter at Breast Height). **DBH is measured at approximately 4.5 feet above ground.**

c. Value of the Tree ("Valuation of Trees in Kentucky" - **Kentucky** Arborist **Association**, Inc.).

d. Dripline (Diameter).

e. Encroachment Allowed within the Dripline.

f. Location

1. All trees, **4**-inches in diameter or greater, shall be located and the species given within 30-feet of the centerline of the pipe or 14-feet outside the top of slope of ditches.
2. All trees less than **4**-inches in diameter shall be located and species given, when within an existing or proposed sewer and drainage easement.
3. When trees are grouped together, at a very close interval, locate the approximate center of the grouping and list the most dominant species of the group.

g. Condition (healthy, dead or dying).

14.2.3 Alignment

Pipelines and ditches shall be designed to meander around trees when possible, but necessary measures shall be taken to reinforce ditches in these meandering bends to prevent erosion. The use of the "Green Approach" to reinforce these bends is preferred. The "Green Approach" refers to the use of vegetative solutions to erosion rather than hard liners such as concrete, riprap or gabion, and **revetment** mattresses.

14.2.4 Tunneling or Boring

a. When within a dripline of a tree, consider boring or tunneling. A minimum of 2 feet to the top of the bore or tunnel is recommended. A distance of 3 feet to the top of the tunnel or bore for trees under 12 inches in diameter and 4 feet to the top of the tunnel or bore for trees 12 inches in diameter or more is preferred.

b. For trees 6 inches in diameter and smaller at the DBH, the work pits wall for tunneling or boring should come no closer than the dripline of the tree or as shown on Exhibit 14-3.

c. The side of the tunnel or bore shall be at least 2 feet from the outside of the tree.

d. Most roots live in the top 18 inches of soil. However, root patterns vary depending on the species, size of the tree and the kind of soil. A test pit should be dug to determine if the tunnel or bore should be lowered or could be raised.

14.2.5 Selection & Location

For the answer to "What tree to plant and where to plant it?" contact the City of Louisville's Arborist or Forester or another qualified Arborist.

14.2.6 Arborist

A qualified Arborist shall review all plans, where construction is to take place in a treed area. This plan review and a site visit should determine the effect of the project on the trees that are present. The Arborist should make recommendations on how to prevent or minimize tree damage.

14.2.7 Utility Easements

Do not replant trees within the utility or sewer and drainage easement without written permission from the utility for which the easement was granted.

14.2.8 Root Barrier

Use a root barrier device where necessary to prevent roots from causing damage to pavement or structures.

14.2.9 Replacement

Where removing a tree of significant size and if the property owner agrees, a note shall be placed on the plans stating that a replacement tree, 3-inch caliper, will be planted within the same property and outside the permanent easement. **The replacement tree will be selected from the general guidelines of Chapter 13 of this manual.**

14.2.10 Relocation

Where it is not possible to leave a tree in a permanent easement undisturbed, investigate the possibility of moving the tree outside the permanent easement upon agreement of the property owner.

14.2.11 Construction

a. Protection of the bark of trees shall be prescribed by specifying a method of protection in the specifications or the special provisions.

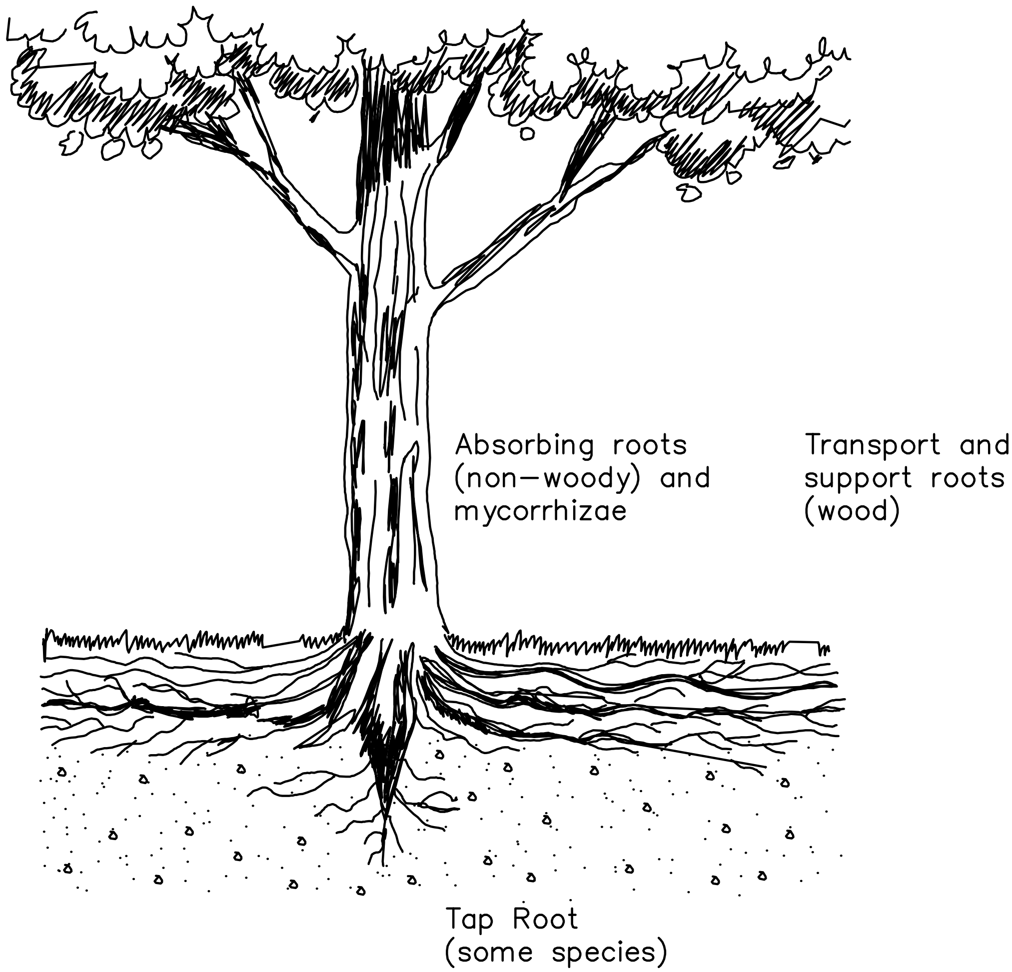
b. Protection of the tree's root system from compaction by construction equipment, vehicular parking, or excessive foot traffic shall be specified in the specifications or the special provisions.

c. Design facilities to reduce the operating of vehicles, equipment, or parking within the dripline of all trees.

MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

EXHIBIT 14-1
COMMON ROOT STRUCTURE

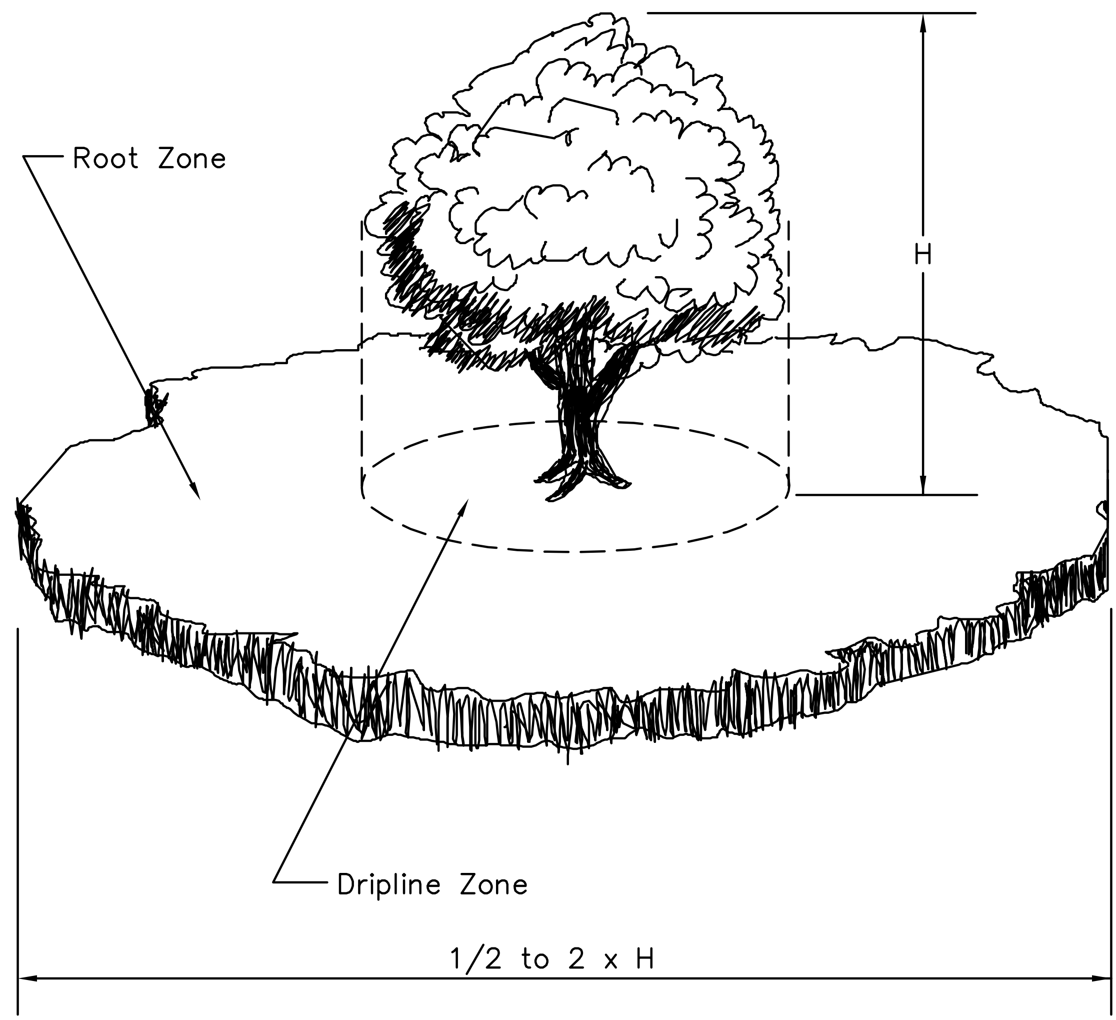
EFFECTIVE DATE: JUNE 30, 2009



MSD
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky
40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

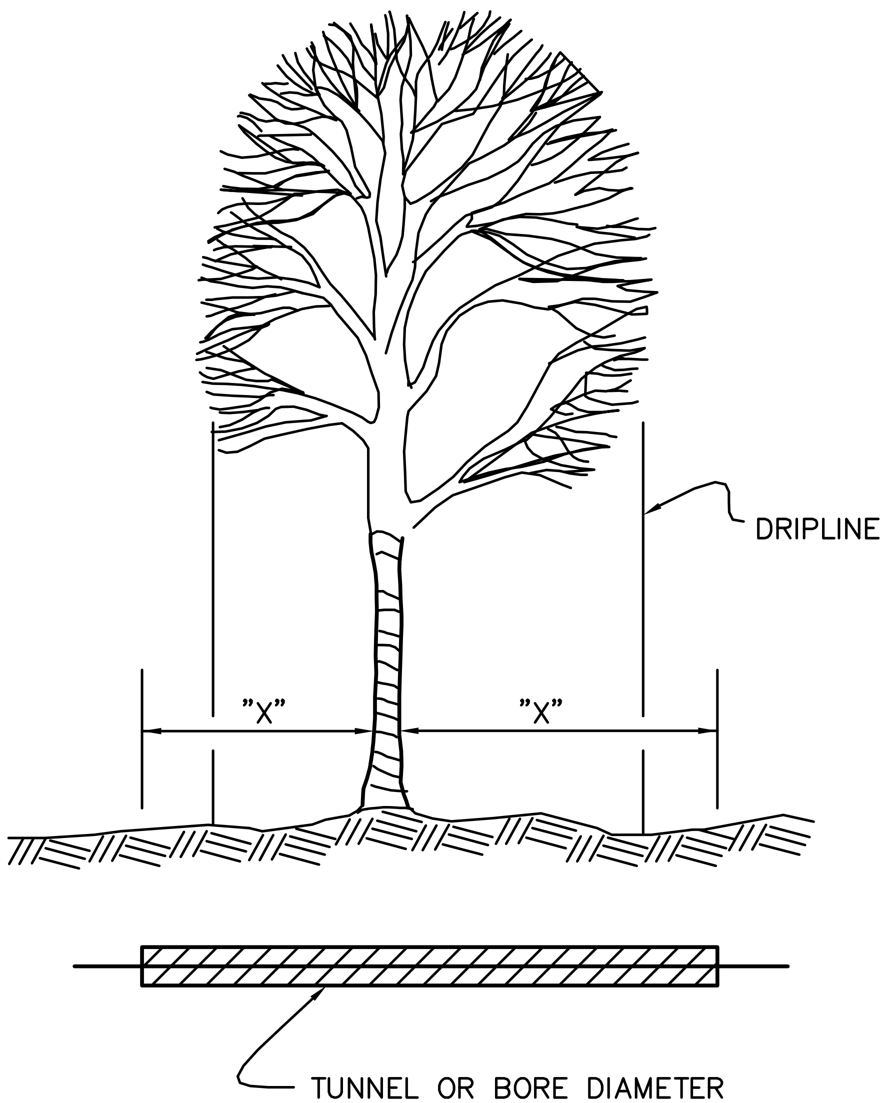
EXHIBIT 14-2
DRIPLINE

EFFECTIVE DATE: JUNE 30, 2009



MSD Louisville and Jefferson County Metropolitan Sewer District 700 W. Liberty Street Louisville, Kentucky 40203-1913 502-587-0603 – WWW.MSDLOUKY.ORG	EXHIBIT 14-3 TUNNEL OR BORE LENGTHS FOR TREE PROTECTION EFFECTIVE DATE: JUNE 30, 2009

Diameter	Distance "X"
6"–9"	5–Feet
10"–14"	10–Feet
15"–19"	12–Feet
over 19"	15–Feet



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CHAPTER 15
SMALL PUMP STATIONS

15.1 PURPOSE

This chapter:

a. Identifies the planning and design approach to be used for small pump stations.

b. Defines specific criteria for the design of small, sanitary pump stations **and their associated force mains**.

c. Delineates submittal requirements required by MSD for review and approval of small pump stations.

d. Delineates requirements for opinions of construction and operating costs.

e. Pump stations must satisfy the regulations of agencies having jurisdiction. Pump stations, at a minimum, shall conform to this document, MSD's Miscellaneous Electrical, Instrumentation & Control Design Standards, and to the Recommended Standards for Wastewater Facilities, 2004 Edition (Ten State Standards).

15.2 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit the Concept Plan and Final Design submittals to MSD for review and approval. Approval by MSD will be required prior to authorization of any succeeding design phase.

15.2.1 Concept Plan Submittals

The purpose of a Concept Plan is to provide MSD with preliminary design data for proposed facilities (sanitary sewers, pump stations, force main sewers). The Concept Plan is used to determine the compatibility of proposed facilities with the approved countywide 201 Plan and Area Action Plans and to justify alternatives recommended for providing sanitary sewer service.

Developers and engineers submitting Concept Plans should reference previous Area Action Plans and the countywide 201 Plan for information on the existing environment and collection system and on estimated future conditions. Concept Plan submittals relating to pump stations shall include the following elements.

a. Project Background

1. Narrative description of the proposed service and drainage areas that can be served by the proposed facility.
2. Description and reference to any Action Plan requirements that relate to the proposed service area (on-site area to which service will be provided) and drainage areas (off-site areas that can be served with the proposed facilities).
3. Topographic map showing the boundaries of the proposed service and drainage areas.

b. Existing Environment

1. Existing land use for the proposed service area, adjacent areas, and drainage areas, delineating project area or development site.
2. Existing hydrology, land features, floodplains, geological characteristics, surface conditions, subsoil conditions, and water table details.

c. Existing Collection System

1. Current sanitary sewer and stormwater collection system maps for the proposed service area, drainage area, and surrounding area.
2. Details of existing system to which a proposed sewer or force main may connect. Capacity of existing sewer system to receive flow from force main or future gravity sewer if temporary pump station is installed.
3. Locations of streets, alleys, unusual obstructions, required rights-of-ways, and all similar data that may help to define the physical features of a proposed sewer project.

d. Future Conditions

1. Designated land use for the proposed service area, drainage area, and surrounding area.
2. Population and flow projections for the proposed service area and drainage areas as called out in the Area Action Plans.
3. Types of development, i.e., residential, commercial, or industrial.
4. Area Action Plan forecasts for the proposed service area, drainage area, and surrounding area.
5. Location of future roads, parks, industrial areas, etc., which may affect the routing and location of sewers and force mains.
6. Construction phasing to accommodate proposed development.

e. Pump Station Justification

In many cases, pump stations are unavoidable and necessary to provide service to a new area. The need for a sanitary pump station must be justified according to one or more of the following criteria. Compliance with one or more of the following criteria does not relieve the designer from the requirement to evaluate alternatives if portions of the service area do not satisfy these conditions:

1. The pump station is recommended in an approved Area Action Plan; or
2. The elevation of a proposed service area is too low to be served by existing or future on-site or off-site gravity sewers; or
3. Interceptor sewers, planned by MSD, are not in place; or
4. The proposed sanitary pump station has been determined to be a cost-effective alternative to an on-site or off-site gravity sewer. To justify a pump station using these criteria, alternatives must be developed and evaluated as described in the following two sections.

f. Development of Alternatives

The following are minimum alternatives to be considered when a cost-effectiveness study is required as part of the pump station justification.

1. Gravity Sewer to Existing Collection System:
   Provide description and preliminary drawings to illustrate existing facilities, proposed facilities, and connection.
2. Interim Solutions:
   Temporary pump stations that provide service until permanent interceptors or other facilities are constructed.
3. Other Possible Solutions:
   a. Consolidation with other pump stations.
   b. Address sewer connections that are not cost-effective due to site conditions or not possible due to elevation differences, individually.
   c. Grinder pumps for individual homes or small clusters of homes.
4. Pump Station Construction:
   Provide description and preliminary drawings to illustrate existing facilities, proposed facilities, and connection.

g. Evaluation of Alternatives

The alternatives shall be evaluated based on a cost-effectiveness analysis outlined in Section 15.3.4. The analysis shall be performed on each alternative and include both economic and non-economic factors.

15.2.2 Final Design Submittals

Design submittals relating to pump stations shall include the following elements:

a. MSD plans and standard specifications modified to specific project needs with additional diagrams and technical data as necessary to construct the proposed installation.

b. Population and flow projections and calculations.

c. Wetwell calculations.

d. Force main calculations.

e. Pump curve/system curves in feet of total dynamic head versus flow in gallons per minute with the following labels: Pump Curve; Single Pump Operation Curve; Two-Pump Operation Curve; Three-Pump Operation Curve (if applicable); Design Point(s); and Operating Point(s) and Operating Envelope. Shut-off head should be included where it will be a controlling point.

f. Total hydraulic efficiency at operating point(s).

g. Pump cycle time.

h. Valve configuration.

i. Float setting calculations.

j. Buoyancy calculations.

k. Force main pressure and water hammer calculations.

l. Determinations for air release, air/vacuum, and/or sewage combination air valves.

m. Odor control calculations and/or assumptions.

n. Electrical calculations and/or power requirements (refer to Section 15.5.5.1 for specific requirements).

o. Opinions of capital and operation and maintenance costs. **Energy efficiency is to be considered in the design.**

p. Site plans showing details of site access, landscaping (if applicable), and electrical utility pole or service rack location.

15.3 DESIGN APPROACH

15.3.1 Compliance with Area Sanitary Plans

Proposed construction or expansion of small sanitary pump stations shall be in compliance with the approved countywide wastewater 201 Plan and approved Area Action Plans.

15.3.2 Approvals

Prior to construction or expansion of a small sanitary pump station, the design documents must receive the approval of the following agencies and be signed and sealed by a Professional Engineer currently registered in the Commonwealth of Kentucky:

a. MSD

b. Kentucky Division of Water

c. Jefferson County Health Department

15.3.3 Service Level

Guidelines presented in this Design Manual govern the planning and design of small pump stations defined as follows:

a. Range in size up to 700 gallons per minute (peak flow) and/or up to 80 feet of total dynamic head.

b. Proposed construction or expansion of sanitary pump stations exceeding the stated ranges will be considered by MSD on an individual basis.

15.3.4 Cost-Effectiveness Analysis

The cost-effectiveness comparison analysis between a pump station and gravity sewer shall include both economic and non-economic factors.

a. Economic Factors

The economic portion of the cost-effectiveness analysis shall use a present worth calculation that considers capital costs, operation and maintenance costs, and salvage values.

Capital costs shall include opinions of construction cost as outlined in Section 15.6, engineering costs based on recognized fee curves and costs for acquisition of properties, easements and rights-of-way, including legal costs. Operation and maintenance costs shall include opinions of cost for labor, utilities, maintenance and repair of facilities. Salvage values shall be developed on straight-line depreciation.

Life cycle costs should be considered over a 20-year period. Unless otherwise directed by MSD, a discount rate equal to that required by the Division of Water should be used to calculate the present worth value of each alternative.

b. Non-Economic Factors

Non-economic factors to be addressed in narrative form, as a part of the cost-effectiveness analysis, should include:

1. Environmental Impact: The short-term and long-term impacts of the alternative on the environment.
2. Reliability: A measure of how dependable the alternative performs over time.
3. Operability: The ease with which the alternative operates over time.
4. Constructability: The ease with which an alternative can be constructed and phased into operation.
5. Resistance to vandalism.
6. Aesthetics and comments on neighborhood/property owner acceptance.

15.4 DESIGN CRITERIA

15.4.1 Definitions

a. Residential Equivalent Population: Refer to Exhibits 8-2 and 8-3.

b. **Design** Average Daily Flow: Residential equivalent population x 100 gallons per capita per day (gpcd). **This term is also referred to as Average Flow.**

c. Peak Flow: **Design** Average **Daily** Flow x peaking factor.

Peaking factor = $\frac{18 + (P)^{1/2}}{4 + (P)^{1/2}}$; Where P = population in thousands

d. Initial Average Flow: Initial residential equivalent population x 100 gpcd.

e. Initial Peak Flow: Initial average flow x peaking factor.

f. 20-Yr. Average Flow: 20-yr. residential equivalent population x 100 gpcd.

g. 20-Yr. Peak Flow: 20-yr. average flow x peaking factor.

h. Ultimate Average Flow: Ultimate residential equivalent population x 100 gpcd.

Ultimate residential equivalent population is defined as the population halfway between 20-year population and watershed saturation population.

i. Ultimate Peak Flow: Ultimate average flow x peaking factor.

j. Watershed Saturation Population: The maximum projected population for the watershed based on present zoning that is equated to equivalent residential units.

k. Emergency Response Storage Volume: Ultimate average flow x 120 min.

15.4.2 General

Population and flow projections for developed and undeveloped areas that are used to design pump stations shall be as defined in Chapter 8. Saturation and 20-year population projections shall be those as used in approved Area Action Plans.

For instances where an Action Plan is unavailable, population projections should be prepared by the Design Engineer and be submitted to MSD for approval.

When designing a new pump station to serve an existing collection system, an infiltration and inflow (I&I) study which considers the effects of wet weather flow shall be performed. The I&I study shall be based on peak flow data

provided by MSD based upon available computer model simulations for the area.

Pump station peaking factors should be the same as sanitary sewer peaking factor, which includes anticipated wet-weather flows.

Pump stations shall be of the wetwell type utilizing submersible pumps. They shall operate automatically under normal conditions but be capable of manual control. Pump stations shall be planned and designed to include provisions for ease of future elimination. Precast concrete or cast-in place concrete wetwells are acceptable.

The pump station top shall be designed to an elevation at least 2 feet above the 100-year flood elevation or the pump station shall be flood proofed to provide maximum protection against flooding while still permitting operation.

Pumps shall be sized such that the pumping capacity, with the largest pump out of service, will handle the peak design flow condition.

All gate and check valves shall be installed horizontally in shallow concrete valve vaults next to the wetwells. The arrangement shall provide for easy access to the equipment to facilitate maintenance. Valve vaults are confined spaces; therefore, they require adequate means for ingress and egress, including OSHA approved ladders and access hatches of sufficient size.

If the pump station is provided with potable water service, the service line shall have a backflow preventer and/or a pressure vacuum breaker ASSE #1020 or a reduced pressure zone ASSE #1013 installed to prevent possible cross connections to the potable water supply. The service line shall be installed in compliance with Louisville Water Company regulations.

Each pump station shall be accessible via an access road with a minimum width of 12 feet and a turn-around to accommodate an AASHTO SU design vehicle at the pump station site. The access road shall be paved with bituminous concrete with a pavement design appropriate to the vehicle and shall be designed to an elevation at least 2 feet above the 100-year flood elevation and maximum grade of 7 percent.

Fencing of the pump station site shall be reviewed on a case-by-case basis by MSD. Landscaping shall comply with buffer requirements of the Louisville and Jefferson County Planning Commission. Any deviations from the above criteria shall be submitted to MSD for review and approval.

To ensure uniformity and MSD system compatibility, MSD has prepared Standard Drawings and Specifications for a typical duplex pump station and its electrical system (see Exhibits 15-1 **through 15-4**). **The DWG files can be found on MSD's web site.** The Design Engineer should use the information that is provided herein to customize these documents in order for the installation to meet the specific project needs. The Design Engineer shall be responsible for the design of the system.

15.4.3 Process

15.4.3.1 Wetwell

Wetwells shall be designed for the ultimate peak flow. The cycle of operation for each pump shall not be less than 15 minutes and the maximum detention time in the wetwell shall average no more than 30 minutes.

The wetwell volume for optimum operation shall be computed as follows:

$$V = (\phi q)/4 \; ;$$

Where:

V = Required operating capacity in gallons

ϕ = Minimum time of one pumping cycle in minutes, from start to start. Ideally ϕ = 15 minutes (maximum 30 minutes; minimum 12 minutes)

q = Pump capacity in gallons per minute (use ultimate peak flow)

Detention times for both initial average flow and ultimate average flow conditions shall be computed.

Wetwell volume shall be based on a maximum draw down depth of 4 feet between the lead pump on elevation and the pumps off elevation.

The design of the pump station shall incorporate a minimum two-hour emergency response storage volume based on ultimate average flow conditions as stipulated under Section 15.4.1. The required volume must be provided in the wetwell and/or a separate, self-draining surge tank between the high wetwell alarm elevation and the invert elevation of the lowest influent gravity sewer. The two-hour emergency response storage volume may be waived by MSD if two sources of electric service are provided or there is an emergency generator permanently installed at the pump station. Unless specifically prevented by site conditions, the Design Engineer shall layout the collection system and pump station such that the top of the wetwell or nearest upstream manhole is at least two feet below the lowest building floor elevation receiving sewer service. In the event that emergency response measures are overburdened, this will provide a point of relief to prevent backups into homes and the adverse impacts on public health and property damage. The Design Engineer shall identify the location and characteristics of the overflow relief point on the Drawings.

Avoid dropping influent flows into wetwells **by installing a drop pipe connection on the wetwell interior or exterior** to eliminate air entrainment. **The wetwell shall be considered as a Class 1, Division 1 hazardous location. Rail packages shall be non-sparking.** Further wetwell sizing constraints are detailed in Section 15.5.3, Pump Control.

15.4.3.2 Force Main

Force mains shall be designed for ultimate peak flow conditions and checked for initial and ultimate peak flow conditions to insure the velocity ranges.

Sewage combination air valves shall be provided at all high points in the force main. Long horizontal runs and increases in slope may require air/vacuum and/or air release valves, realizing that air release valves are for pockets of air accumulated during operation and air/vacuum valves are to exhaust or admit air during filling or draining the force main. Cleanouts shall be provided at all low points and at additional critical locations. The Design Engineer shall consider and review with MSD the location of all air release valves, air/vacuum valves, sewage combination air valves and cleanouts.

The Engineer shall provide an economic analysis comparing the installation of air release and air/vacuum release valves against the installation of deeper force main piping. The economic analysis shall take into account the installation and maintenance costs associate with the air release and air/vacuum release valves. Air release and air/vacuum release valves shall be specifically designed for wastewater service and be sized per the manufacturer's recommendations.

The air and vacuum release valves will be contained in a vault and vented above ground. A manually controlled isolation valve shall be installed between the force main and the air release or air/vacuum release valves.

Joint restraints **or concrete thrust** blocks shall be **installed** at bends**. An analysis must be made to determine if a joint restraint is required either upstream or downstream of the bend.**. For slopes of 20 percent and greater, anchors shall be provided at each joint (at a minimum). A flexible through-wall connector shall be used at pipe penetrations through structures to allow for differential settlement.

Force main design criteria shall be as follows:

a. Minimum Pipe Size

1. 4-inch I.D. for wastewater pumps
2. 2-inch I.D. for grinder pumps

b. Design Pipe Roughness Coefficient (C)

1.	PVC	C = 120 **and 150**
2.	Polyethylene	C = 120
3.	Lined Ductile Iron	C = 120
4.	Steel or Unlined Iron	C = 100

c. Velocity (V) Range

1. V = 2.0 to 5.0 feet per second (fps) for wastewater pumps
2. V = 3.0 to 5.0 fps for grinder pumps

Note: A maximum velocity of 6.0 fps is allowable with a present worth economic calculation that considers capital and operating costs in order to justify any increase above 5.0 fps.

15.4.3.3 System Head Curve

The pump/system curve calculation may be performed utilizing any acceptable hydraulic equation.

The system head curve is a plot of the discharge through a pipe system given the size against the head losses as a result of friction in that pipe system. Selection of pump size shall be based on static head and total dynamic head. The design operating point is at the intersection of the pump curve and the system curve. Also, the pump should have an impeller size such that the shut-off head exceeds the pumping head at peak Q.

Static head or static pressure (h_s) shall be based on the average elevation of lead pump on/off:

h_s = (Elevation of highest point in force main) - (Average elevation of lead pump on/off)

Fittings and valves **can** be converted to an equivalent length of force main to compute station losses.

Friction losses (h_f) in the force main **can** be computed according to the Hazen-Williams formula as follows:

$$H_f = (10.44)\,(L)\,\frac{(q)^{1.85}}{(C)^{1.85}\,(d)^{4.8655}}\,;$$

Where:

L = Length of pipe (feet)
q = Flow rate (gallons per minute)
C = Hazen-Williams friction loss coefficient
d = Pipe diameter (inches)

Compute total dynamic head as follows:

TDH = Static Lift + Friction Loss
= $h_s + h_f$

The TDH shall be calculated for the design roughness coefficient as stated in Section 15.4.3.2 and per the pipe manufacturer's **and pump supplier** recommended roughness coefficient. **All applicable** system curves shall be plotted on the pump curve submitted.

The operating point for the selected pump shall be in the range of initial peak flow to ultimate peak flow as determined by MSD. The pump efficiency at the operating point should be within the acceptable operating range of 60 to 120% of the capacity at the best efficiency point. The selected pump must be approved by MSD.

The pump efficiency shall be included in the final design submittal. Grinder pump efficiencies may be obtained from the manufacturer. Following pump selection, the system should be checked for low static head conditions (i.e., full wetwell condition). The minimum head curve shall be plotted on the pump curve. This check is performed to insure that in no case will the pump be required to operate outside its normal operating range. Such an occurrence could result in overloading of the motor and eventual pump failure. **The motors shall be sized to be non-overloading over the entire pump curve.**

When pump stations are proposed to discharge into gravity sewers, the capacity of the gravity sewer receiving the discharge shall be checked to determine the impact on the sewer capacity.

When pump stations are proposed to discharge into force main sewers, an analysis of the existing pump station shall be performed to evaluate the impact of the additional flow in the existing force main and its effect on the existing pump(s) performance. The Design Engineer should check initial and ultimate flow conditions to see if the existing pump capacity is compromised. Conditions should be verified when the existing pump station is pumping and when it is not pumping (on and off). An analysis of the potential for reverse flow through the existing pumps shall be included. If the capacity is reduced, a recommended upgrade to this station should also be presented in conjunction with the proposed pump station design. Approval of systems that discharge into force mains will be evaluated on a case-by-case basis.

15.4.3.4 Buoyancy

Buoyancy shall be analyzed on the wetwell to determine whether additional methods of restraint are necessary. Mechanical equipment, water weight, and other temporary loads shall not be included in the analysis. A safety factor of 1.5 (minimum) is required.

Buoyancy Force shall be computed as follows:

Buoyancy Force = (Displaced Volume) x (Unit Weight of Water)

Opposing Force shall be computed as follows:

Opposing Force = Weight of Barrel + Weight of Bottom Slab + Weight of Top Slab + Net Weight of Saturated Soil over Bottom Slab Extension + Any Additional Restraints (Do not include electrical/mechanical components).

Factor of Safety is computed as follows:

$$\text{Factor of Safety} = \frac{\text{Opposing Force}}{\text{Buoyant Force}} \geq 1.5$$

15.4.3.5 Force Main Pressure and Water Hammer Calculations

From the Uni-Bell Handbook of PVC Pipe, Design and Construction, 1986, water hammer is an increase in pressure in a pipe caused by a sudden change in velocity. The velocity change usually results from the closing of a valve. The maximum surge pressure encountered is a function of wave velocity (a) as follows:

$$a = 4660/(1 + (kd/Et))^{1/2};$$

Where:

- a = Wave velocity
- k = Fluid bulk modulus, 300,000 pounds per square inch (psi) for water
- d = Pipe ID, (inches)
- E = Modulus of elasticity of pipe
  400,000 psi for PVC pipe
  24,000,000 psi for ductile iron pipe
  110,000 psi for polyethylene
- t = Wall thickness (inches)

OR

$$a = 4660/((1 + (k/E)(DR\text{-}2))^{1/2};$$

Where:

- DR = (O.D. (inches)) ÷ (wall thickness (inches))
- DR = Dimension Ratio

The maximum surge pressure (P) is computed as follows:

$$P = \frac{aV}{2.31\ g};$$

Where:

- V = Maximum change in velocity (velocity goes to 0 feet per second)

g = Acceleration due to gravity (32.2 feet per second-squared)
P = Pressure surge (pounds per square inch)

Total pressure is computed as:

Total Pressure = Maximum Surge Pressure + Static Pressure = $P + h_S$

Total pressure must be less than the rated pressure of the pipe (rated pressure including surge allowance).

Cyclic Surge (Fatigue) Analysis is determined (for PVC force mains only) as follows:

a. Estimate the number of pump cycles for the proposed system using a design life of 80 years (use 4 cycles per hour and a safety factor of 2.5).

b. Calculate the peak hoop stress (S) using Vinson's formula.

$$C = (5.05 \times 10^{21})\, S^{-4.906};$$

Where:

C = Average number of cycles to failure
S = Peak hoop stress (pounds per square inch)

c. Determine Total System Pressure (P_T)

$$P_T = \text{Maximum Surge Pressure} + \text{Static Pressure}$$

d. Use International Standards Organization (ISO) formula to determine minimum dimension ratio.

$$DR_{required} = (2S/P_T) + 1 \;;$$

Where:

DR = Dimension Ratio
S = Peak Hoop Stress
P_T = Total System Pressure

The calculated DR value must be greater than the DR of the selected pipe.

Force main pressure and water hammer calculations for ductile iron pipe shall be based upon AWWA Standards

C150/A21.15-91, "American National Standard for the Thickness Design of Ductile Iron Pipe." Calculations for polyethylene pipe shall be based upon AWWA Standards C906-90 "Standard for Polyethylene (PE) Pressure Pipe and Fittings."

15.4.3.6 Odor Control

The Design Engineer shall consider the need for odor control if detention time in either the wetwell or the force main, based on the average flow, exceeds 30 minutes.

Refer to Chapter 17, Odor Control, for specific requirements.

15.5 ELECTRICAL

15.5.1 General

This section provides guidelines for the design and preparation of plans and specifications as related to small sanitary pump station power, control, and telemetry. All electrical documents must be signed and sealed by a Professional Electrical Engineer currently registered in the Commonwealth of Kentucky.

All concepts and designs are to strike a balance between function, initial cost, operational cost, and ease of maintenance. Generally accepted designs, materials, and methods are to be used throughout the project. **MSD provides sample design documents that balance these issues. Drawings and specifications for full-voltage started 3-phase and single-phase, and soft started 3-phase, duplex pump stations are available for downloading from MSD's website. The Design Engineer shall utilize these as a template for completing design.** If, however, the Design Engineer identifies an opportunity to take advantage of an innovative design approach, the Design Engineer is to present the proposal in writing to MSD for evaluation.

15.5.2 Applicable Standards or Codes

All systems, designs and procedures are to meet or exceed the requirements of the latest issue of the following codes or standards:

- Kentucky Building Code: KBC
- National Electrical Code: NEC
- Underwriters Laboratories, Inc.: UL
- Factory Mutual: FM
- National Fire Protection Association: NFPA

- National Electrical Manufacturers Association: NEMA
- Occupational Safety and Health Administration: OSHA
- Kentucky Occupational Safety and Health Administration: KYOSHA

Designs should relate to the following specific requirements:

- NFPA 37 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
- NFPA 110 Standard for Emergency and Standby Power Systems
  NFPA 820 Recommended Practice for Fire Protection in Wastewater Treatment and Collection Facilities

15.5.3 Pump Control

15.5.3.1 Automatic Operational Sequence

Programmable logic controller (PLC) based primary controls shall operate the pumps and shall perform automatic alternation and duplexing for two pumps or triplexing for three pumps. The **PLC** shall alternate the lead pump once the wetwell level has been pumped down to the stop elevation. The **PLC** shall also provide for energizing the other pump as a backup or lag pump if needed. Provisions shall also be made for overriding the alternator by manually selecting the pump sequence.

A float switch-based back up control system shall be included that will sequentially start and stop all pumps via time delay relay(s). The back up control system shall function independently of the PLC controls. Upon actuation of a backup float switch, both pumps will be started sequentially with the use of time delay relays. As the level in the pump station falls below the backup stop float switch, the pumps will be stopped in sequential fashion with time delay relays.

A step control or variable level scheme shall be used for the pump control. These schemes shall establish the following sequence of operations:

a. Constant Speed Pumps - The lead pump shall start when the wetwell volume from the pumps "off elevation" to the lead pump "start elevation" is equal to the volume derived in Section 15.4.3.1. The minimum separation between these elevations shall be 12 inches.

If the influent sewage flow into the wetwell is greater than the capacity of one pump, the second and, if applicable, third pumps shall start at ascending, separate levels (start elevations). They then continue to run until the liquid level in the wetwell is pumped down to a predetermined level (stop elevation) for all pumps.

b. Variable speed pumps will be considered on a case-by-case basis.

A PLC program shall be provided and downloaded by MSD based on the sample pump station designs identified earlier. Elevations (in feet above the wet well floor) shall be provided by the Design Engineer to MSD for pump controls. Deviation from the sample pump station designs may render incompatible the associated PLC program developed by MSD for the Developer's use. At MSD's discretion, responsibility for PLC program development for non-standard pump stations may be transferred to the Developer.

15.5.3.2 Control Settings

PLC-based primary controls shall stop all pumps at the wetwell level equal to the minimum level recommended by the manufacturer of the proposed pumps **plus 24 inches and a minimum of 12 inches below the PLC controls lead start elevation**. The increment in levels between the **PLC control** multi-pump start points shall be a minimum of 12 inches.

The elevation for actuation of the back up stop float switch shall be 12 inches below the PLC controls stop elevation. The back up start float switch shall be 12 inches above the last lag pump PLC controls start elevation.

The **SCADA** high water alarm level shall be at or lower than the invert of the influent pipe and at least 12 inches above the **back up start float switch** elevation. **The local high water alarm level shall be a minimum of 12 inches above the high water SCADA alarm.**

15.5.3.3 Level Detection

A hydrostatic level transmitter shall be the preferred method of level detection and shall be incorporated into the pumping station operation. **Float switches shall provide back up pump control and high level alarm signaling. The level transmitter shall be installed in a stainless steel stilling well**. The float switches shall be **free hanging and** suspended by weighted cables, which contain the wiring. The cables shall be of sufficient length to be installed without splicing. Level detection systems that require maintenance personnel to enter the wetwell to repair or replace components are unacceptable. Intrinsically safe relays must be used in conjunction with float switches**, and intrinsically-safe signal repeater used with the level transmitter,** in order to meet the requirements of Class 1, Division I, Group D hazardous locations.

15.5.3.4 Operator Interface

A graphic touch screen "human-machine interface" terminal (HMI) shall be provided for indicating status and alarms, and for input from the operator for various control functions. Two exceptions are the inclusion of a hardwired Hand-Off-Auto switch and a reset pushbutton for each pump to allow manual operation of pumps and resetting of motor starter faults without the HMI or PLC. MSD shall provide and download graphics programming for the operator interface for the sample duplex pump stations designs identified earlier. Deviation from the sample pump station designs may render incompatible the associated HMI graphics developed by MSD for the Developer's use. At MSD's discretion, responsibility for HMI program development for non-standard pump stations may be transferred to the Developer.

15.5.3.5 Pump Interlock

Sensors and control hardware shall be provided to monitor the following conditions:

a. Motor stator over-temperature.
b. Seal leakage.
c. Loss-of-phase, phase reversal, or under voltage.
d. Electrical overload (solid-state, temperature compensated **overload relay for full-voltage started pumps**).
e. **Starter fault (from reduced voltage solid-state starter on soft started pumps).**
f. Short circuit.

All of these conditions shall de-energize the appropriate pump(s). Seal leakage **and over-temperature** shall be **latched in the PLC program until** manually reset **via either "soft buttons" on the** the **HMI on the** control panel inner door **or remotely via the MSD SCADA system**. **When the back up level control mode is engaged,** motor stator over-temperature **and seal failure** shall de-energize the pump**, however, the pump will be re-enabled upon if either interlock self-resets e.g. the motor cools down**. **Electrical overload relays and soft starters shall be provided with a reset pushbutton on the inner door of the control panel, independent of PLC or HMI controls.**

Loss-of-phase, phase reversal or under voltage condition shall de-energize all pumps **in any mode of control**. The monitor for these conditions shall reset automatically once the problem parameter falls within its appropriate range. If, **upon** reset **of the monitor**, the control system calls for more than one pump, the additional pump(s) shall be energized after a time delay(s) **in both the PLC logic or the backup control system to reduce motor inrush current on the electrical service or the generator.**

15.5.4 Alarm System

15.5.4.1 Station Local Alarms

The station shall be provided with a local alarm system **powered from the main control panel and powered via an uninterruptible power supply (UPS). The following shall initiate the local alarm.**

a. High wetwell level.
b. Power failure.

These alarms should annunciate locally via a red flashing light and a horn. The horn shall have a silence button accessible to the general public. The light shall remain on during alarm condition. The horn and light will de-energize automatically **once** the listed alarm conditions **have reset**.

15.5.4.2 Telemetry

The following alarm signals shall be provided **as inputs to the PLC for transmission via MSDs county-wide SCADA system:**

a. Power failure.
b. High wetwell level.
c. Pump on (1 per pump).
d. Pump overload **or starter fault** (1 per pump).
e. Pump seal leak **(1 per pump)**
f. **Pump high** temperature **(1 per pump)**
g. Pump circuit **breaker tripped** (1 per pump).
h. Pump **circuit breaker off** (1 per pump).
i. Pump in Hand (1 per pump)
j. Pump in Auto (1 per pump)
k. Pump in Off (1 per pump)
l. Failure of UPS or DC power supply
m. Main circuit breaker tripped.
n. Transfer switch in normal position.
o. Transfer switch in emergency position.
p. Normal source available.
q. Emergency source available.
r. Generator failure.
s. Generator running.
t. **Generator control in Auto.**

All alarms shall be implemented via 120 VAC dry contacts.

The control panel shall include a blank space on the subpanel for mounting of a modem. MSD shall provide and field install the modem upon notification of control panel installation. MSD shall also provide cabling and antenna as necessary to deliver the SCADA signal from the PLC modem port to its host SCADA site.

15.5.5 Pump Station Electrical Criteria

15.5.5.1 General

All pumping stations shall be wired in strict accordance with the latest edition of the National Electric Code. Pumps and equipment shall normally be designed to operate from a 230/460 volt, three-phase power source. No single-phase to three-phase converters will be allowed. Single-phase service will be considered by MSD on a case-by-case basis. Single-phase pump stations shall have capacitor start motors. A control power transformer will not be required to facilitate auxiliary equipment when **240/**120 volts are available from the utility. All motor starters and controls shall be located in a shop-assembled control cabinet, located above ground level.

All conductors shall be insulated, stranded, copper wire, rated at 600 volts.

An enclosed circuit breaker shall be provided and rated for use as service entrance equipment and shall be housed in a stainless steel, NEMA 4X enclosure. **It shall include an auxiliary contact for indicating a tripped condition to the PLC.**

Pump control cabinets shall be stainless steel, NEMA 3R enclosures suitable for outdoor installation. Each cabinet shall be equipped with a hasp, staple, and three-point latching handle to provide watertight and tamper-proof service and shall be mounted on **a wet well electrical rack.** Each cabinet shall have a hinged inner door, containing all operator control devices, and must be appropriately sized for the application.

Motor starters shall be enclosed in separate enclosures with interface wiring to pumps and control panel as indicated on the sample duplex pump station drawings. Reduced-voltage starting, if required, shall utilize solid-state motor starters with bypass contactors. The solid-state starters shall be used to start and stop the pumps with the bypass contactor utilized for full speed operation. Consult with LG&E for motor starting requirements.

Separate pedestal mounted stainless steel enclosures shall be provided to facilitate the junction of cords from Class I, Division 1 wet well components with permanent wiring to non-hazardous starters and control panel. Cable hangers shall be used to suspend wet well component cables and facilitate easy access for component removal from the wet well top slab. Conduit seal-offs shall be provided between the cord junction box and the respective starter or control panel to isolate them from hazardous and corrosive wet well gases.

At a minimum, the following key issues must be addressed in the design with calculations and/or NEC references to verify such:

a. Service size
b. Feeder/service conductor size
c. Ground conductor size
d. Feeder/service disconnect size

e. Branch circuit conductor size
f. Branch circuit type of protection
g. Branch circuit over-current protection rating
h. Motor controllers size and overload protection rating
i. Pump control system transformer over-current protection
j. Available fault current
k. Feeder/service over-current protection
l. Ground fault protection if required

The sample electrical design drawings available on MSD's website identify conduit and conductor connections with "fill-in-the-blank" provisions for number and size of wires, and conduit sizes.

The **service conductors,** main **circuit breaker, transfer switch, and starter** branch **circuit conductors**, must be sized so that the full capacity of the motor starters may be utilized in the future.

15.5.5.2 Emergency Power

An on-site internal combustion engine-powered generator shall be provided. MSD prefers the use of natural gas. However, MSD will consider economic factors presented by the Engineer regarding generator and gas service costs vs. the use of diesel generators. These stations shall be totally automatic and shall include all necessary transfer switches and other components. The electrical generators shall be housed in weatherproof enclosures. A critical silencer must be provided to minimize noise from the engine-powered generator.

For those generators with a control panel higher than 6 feet above finished grade, an aluminum or stainless steel platform shall be provided around the perimeter of the generator to facilitate access to the control panel as well as routine maintenance points on the generator.

Generator output circuit breakers shall be equipped with an auxiliary contact to indicate the breaker is tripped. This signal contact shall be combined with other signals in the generation of a common failure alarm SCADA signal. Other SCADA signals as identified above shall be provided.

Transfer switches shall be provided with a time-delayed neutral position and shall be mounted in a stainless steel, NEMA 3R enclosure with three-point latching handle **on an deadfront outer**

door. An inner door shall be provided behind the deadfront door for the mounting of operator interface devices. Accessories shall be provided to meet the SCADA requirements mentioned above.

When two independent public electrical utility sources are available, the requirements for in-place generators may be waived by MSD in favor of the dual utility feed.

15.6 OPINIONS OF COST

Opinions of probable cost shall be based on the best professional opinions of the Design Engineer. The Design Engineer should use recent bid tabulations, and information from suppliers and contractors in formulating the opinions of cost.

15.6.1 Opinions of Capital Cost

Opinions of capital cost shall be in Construction Specification Institute (CSI) formatting and shall be grouped by category.

Opinions of capital cost shall include a construction contingency of 3% and should include a cost for necessary land, easement, or right-of-way acquisition.

15.6.2 Opinions of Operation and Maintenance Cost

Opinions of operation and maintenance cost shall include costs for labor, utilities, maintenance and repair. **Energy efficiency is to be considered in the design.**

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Louisville, Kentucky
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STANDARD DUPLEX PUMP STATION DETAILS

EFFECTIVE DATE: JUNE 30, 2009

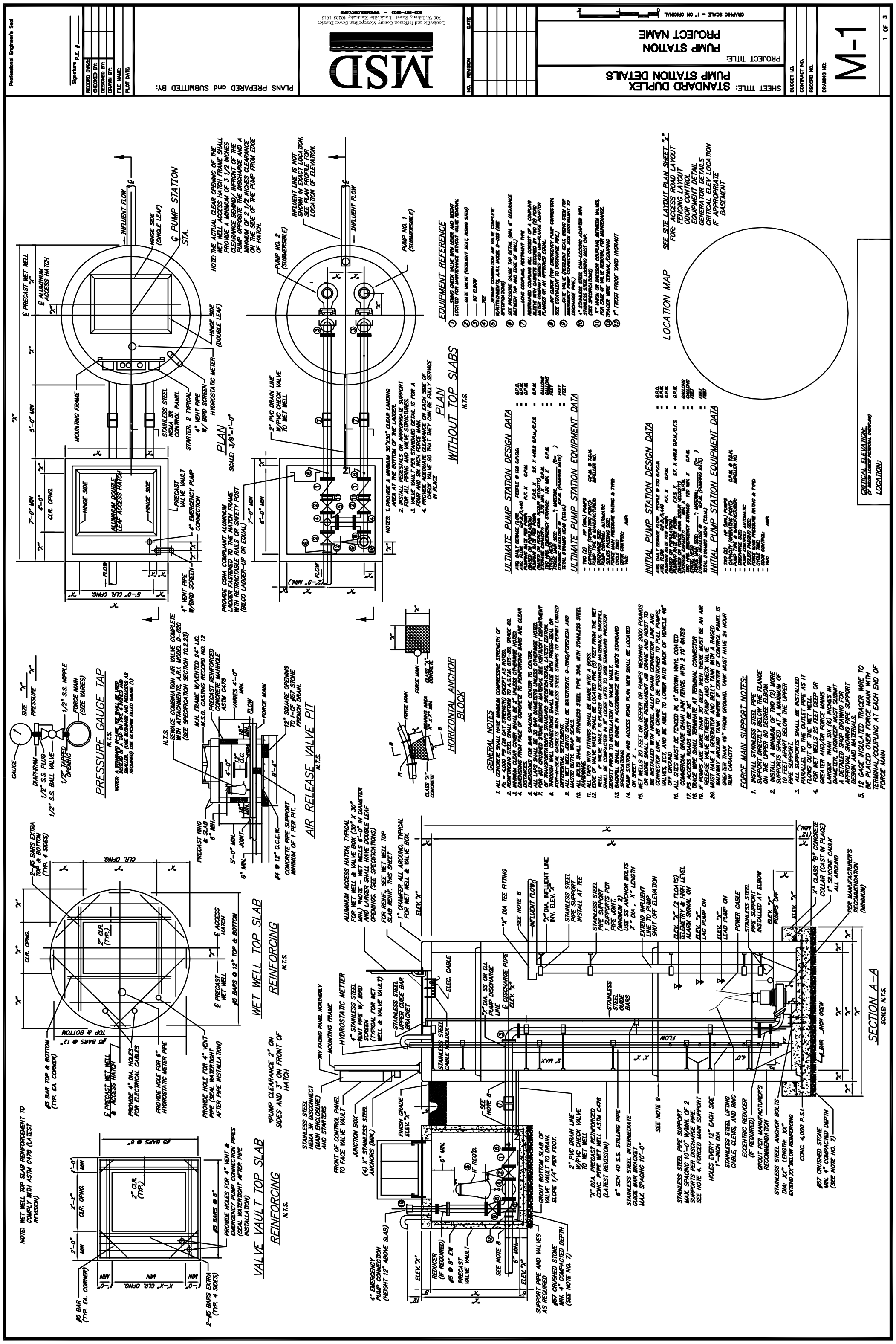

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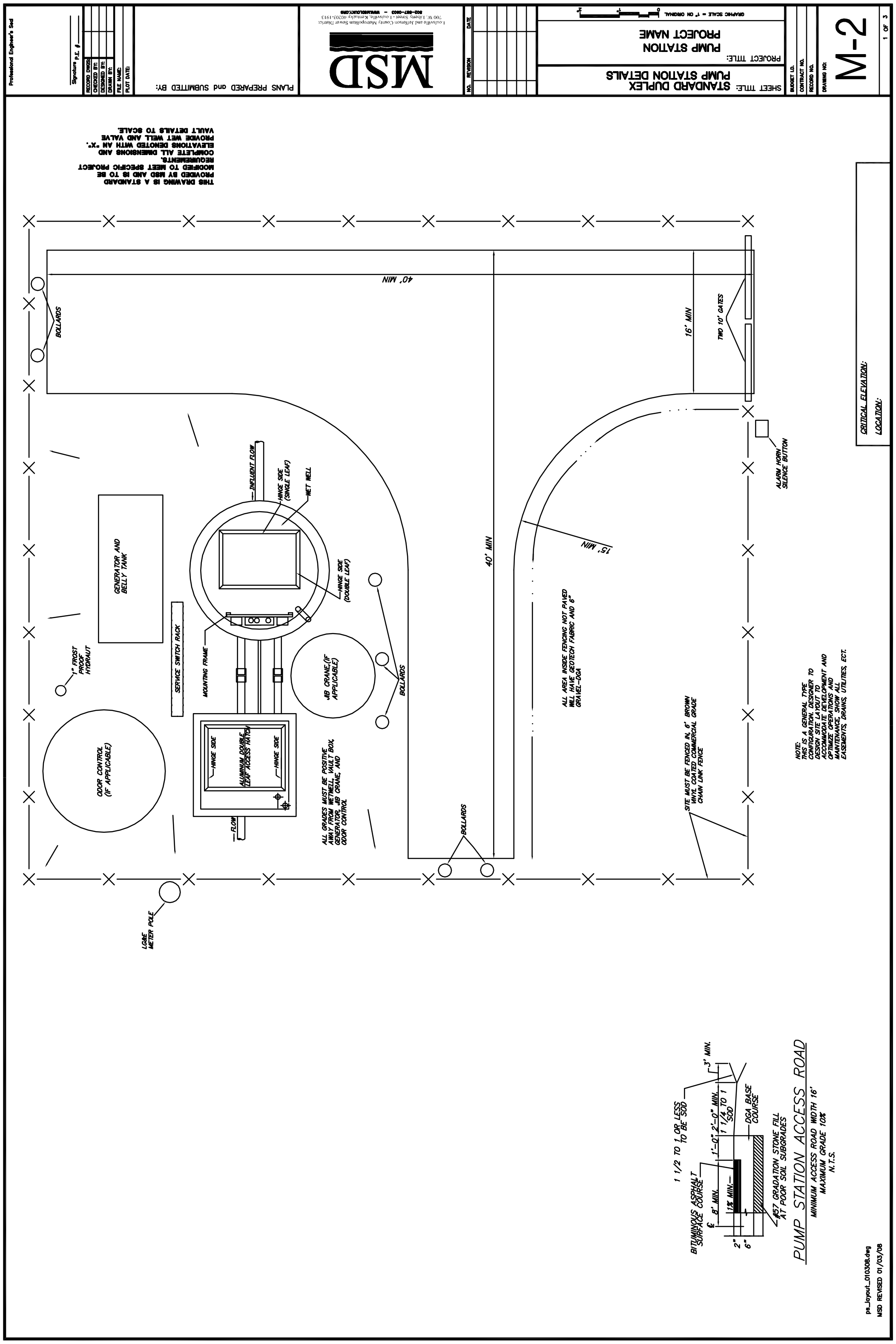
EXHIBIT 15-1 PAGE 2

STANDARD DUPLEX PUMP STATION DETAILS

EFFECTIVE DATE: JUNE 30, 2009



MSD Louisville and Jefferson County Metropolitan Sewer District 700 W. Liberty Street Louisville, Kentucky 40203-1913 502–587–0603 – WWW.MSDLOUKY.ORG	EXHIBIT 15-2 PAGE 1 STANDARD DUPLEX PUMP STATION (THREE PHASE) EFFECTIVE DATE: JUNE 30, 2009

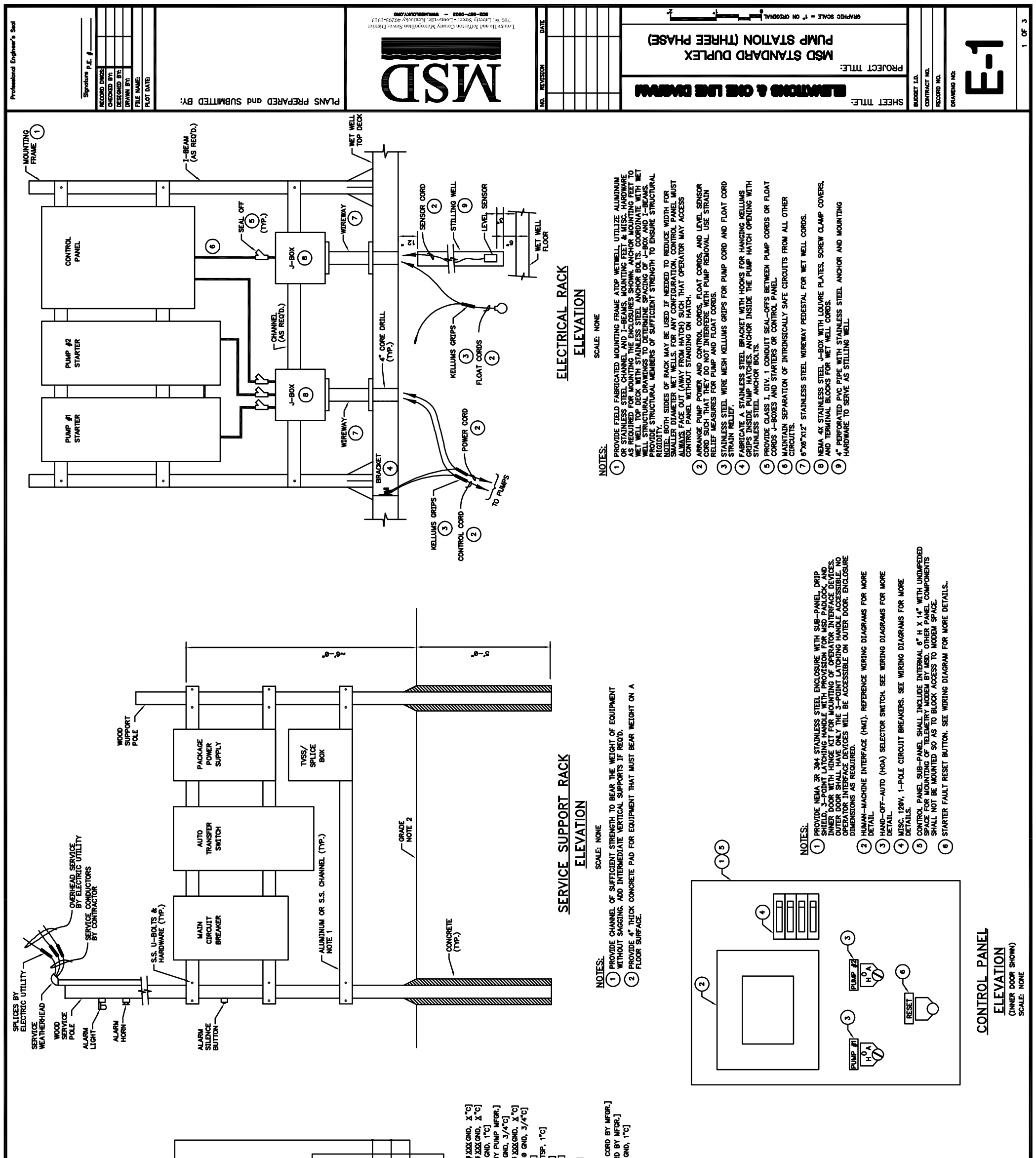


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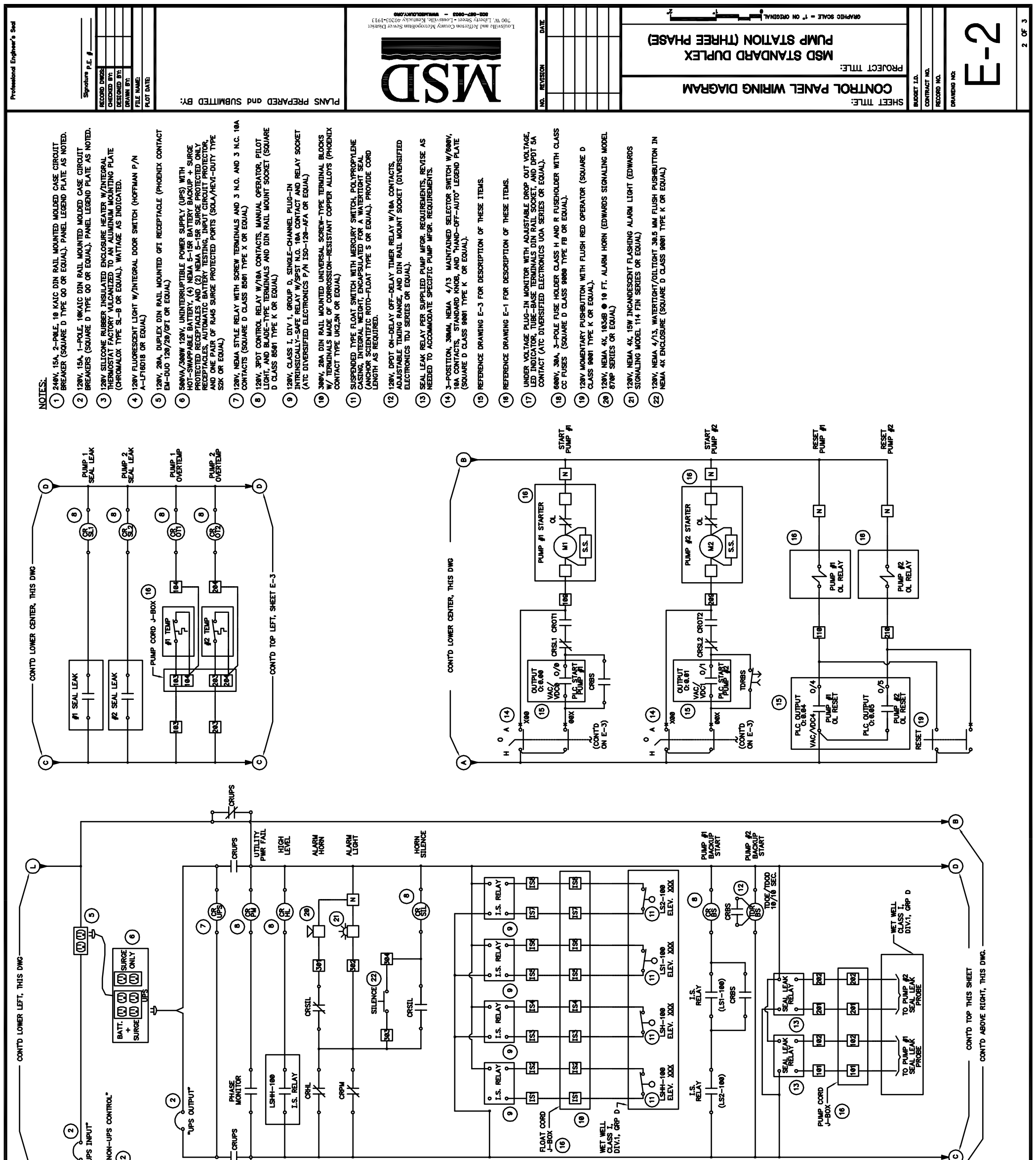
EXHIBIT 15-2 PAGE 2
STANDARD DUPLEX PUMP STATION
(THREE PHASE)

EFFECTIVE DATE: JUNE 30, 2009



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STANDARD DUPLEX PUMP STATION
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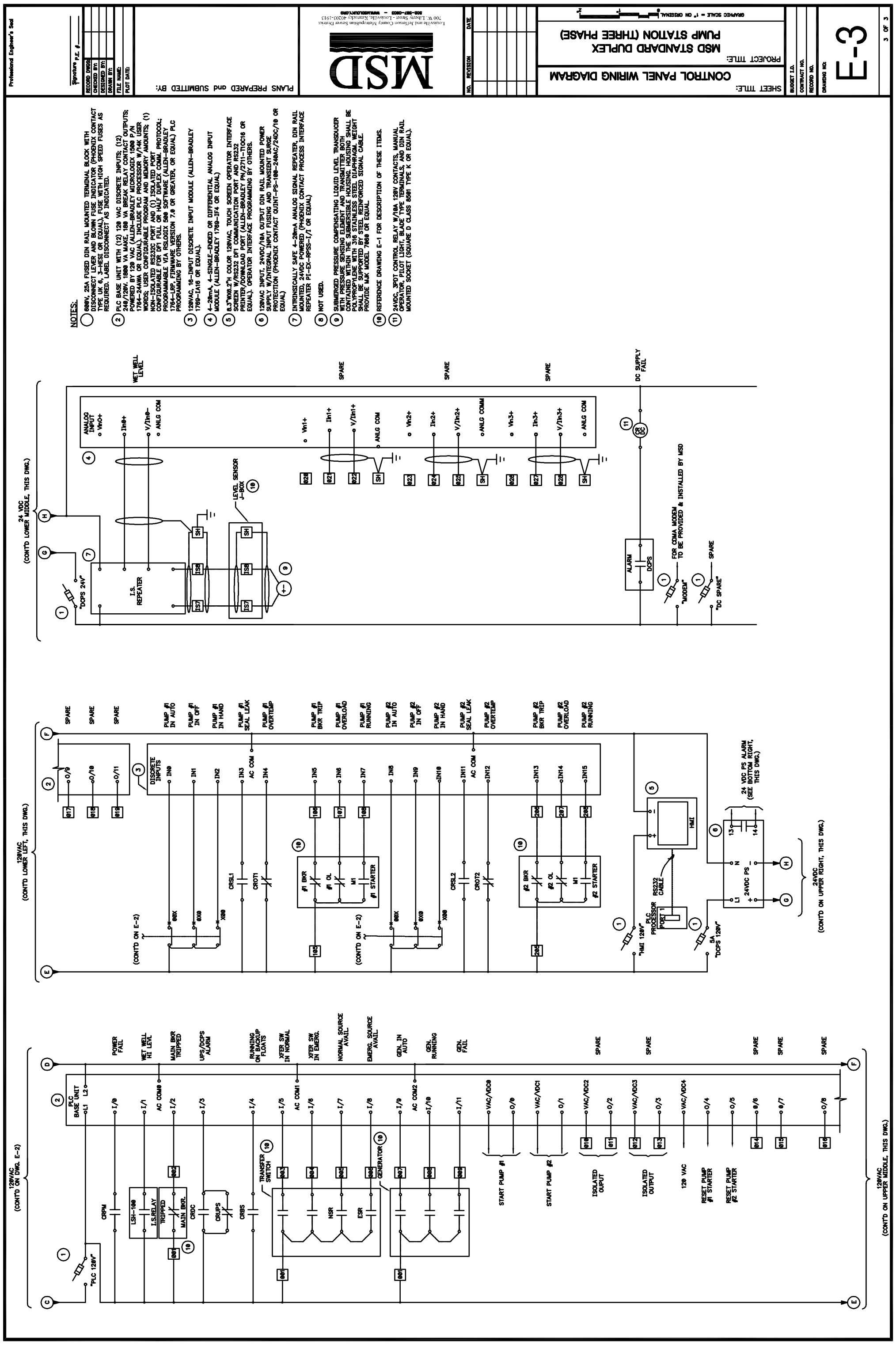

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EXHIBIT 15-3 STANDARD DUPLEX PUMP STATION (SINGLE PHASE)

EFFECTIVE DATE: JUNE 30, 2009

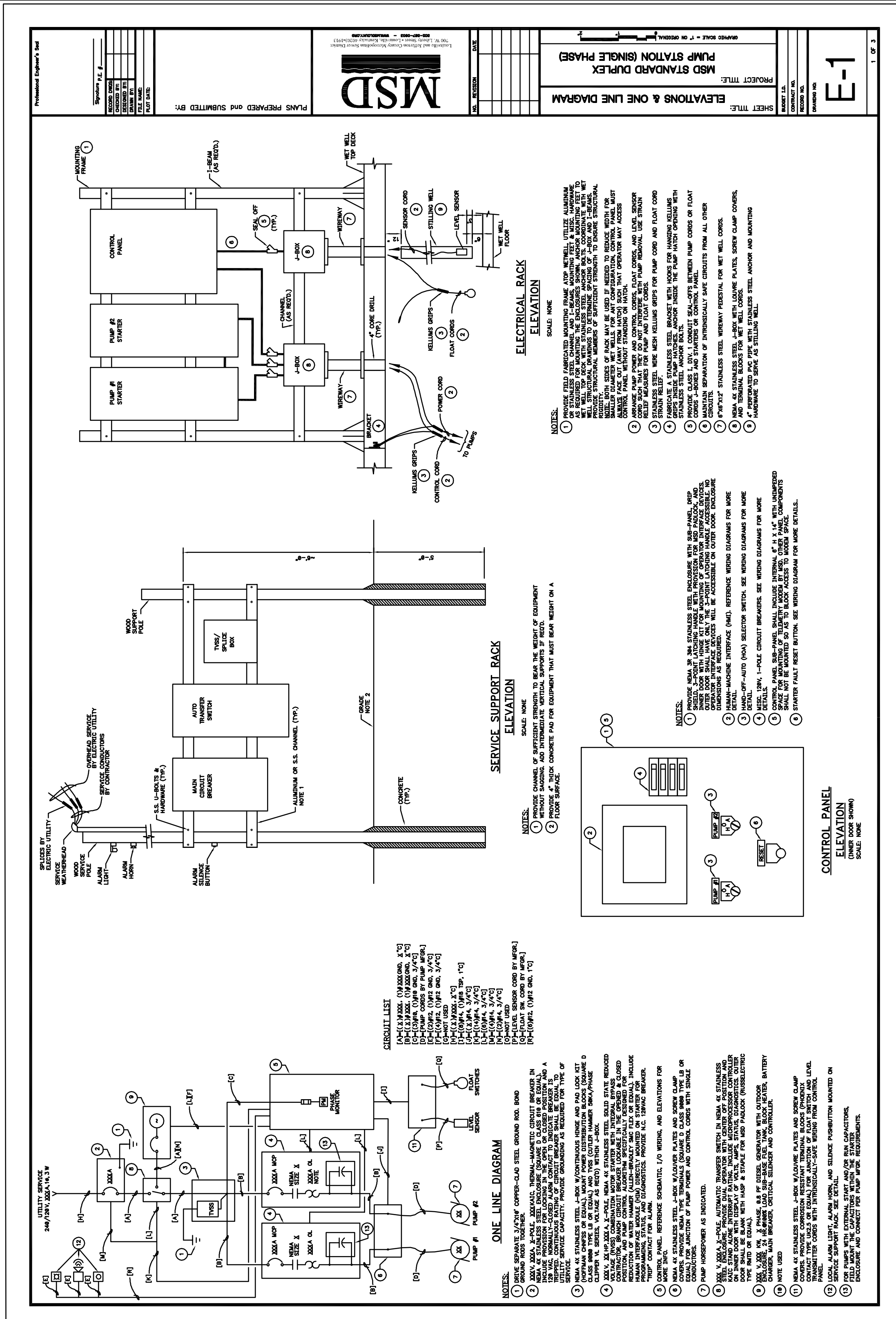

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EXHIBIT 15-3

STANDARD DUPLEX PUMP STATION (SINGLE PHASE)

EFFECTIVE DATE: JUNE 30, 2009

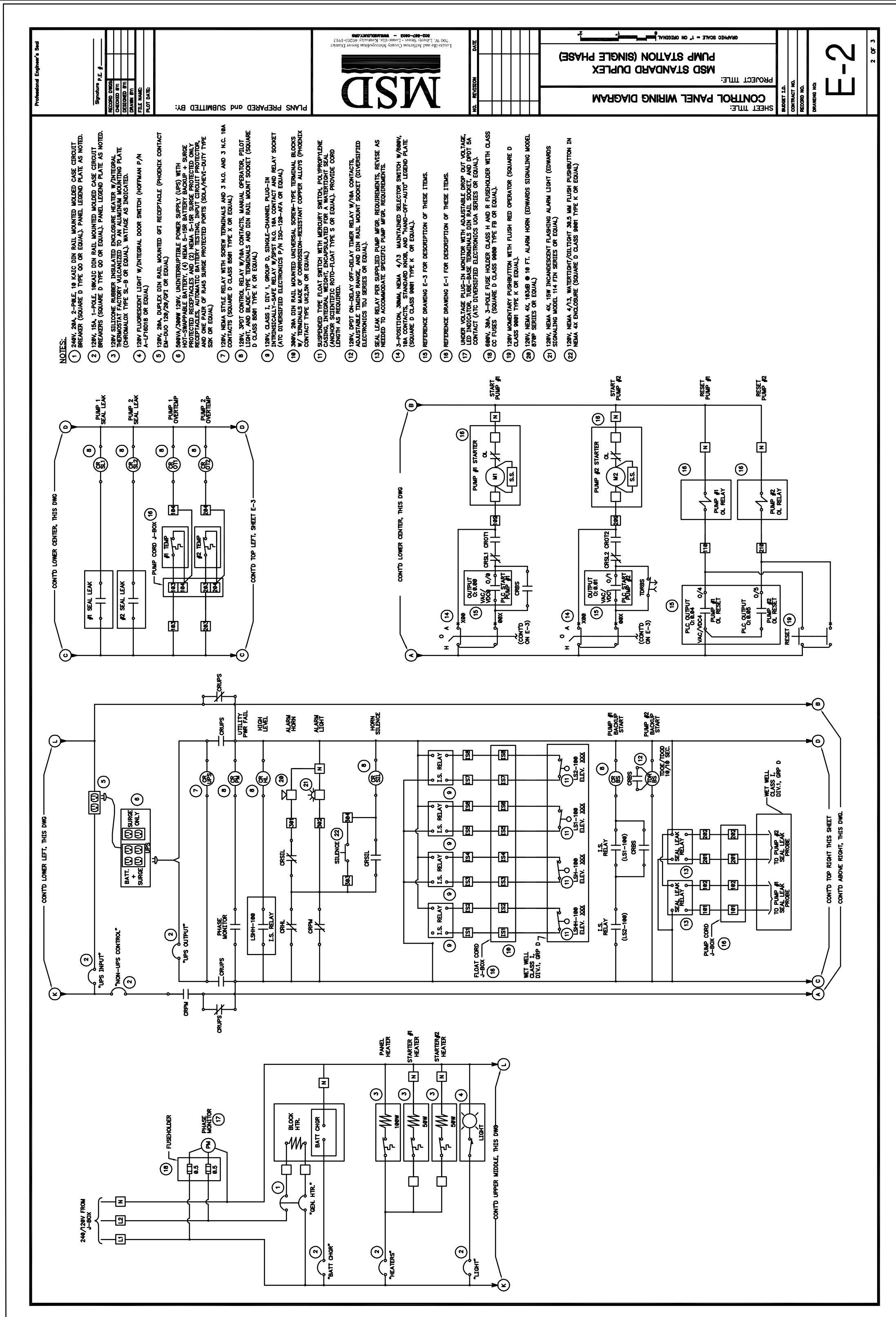

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EXHIBIT 15-3

STANDARD DUPLEX PUMP STATION (SINGLE PHASE)

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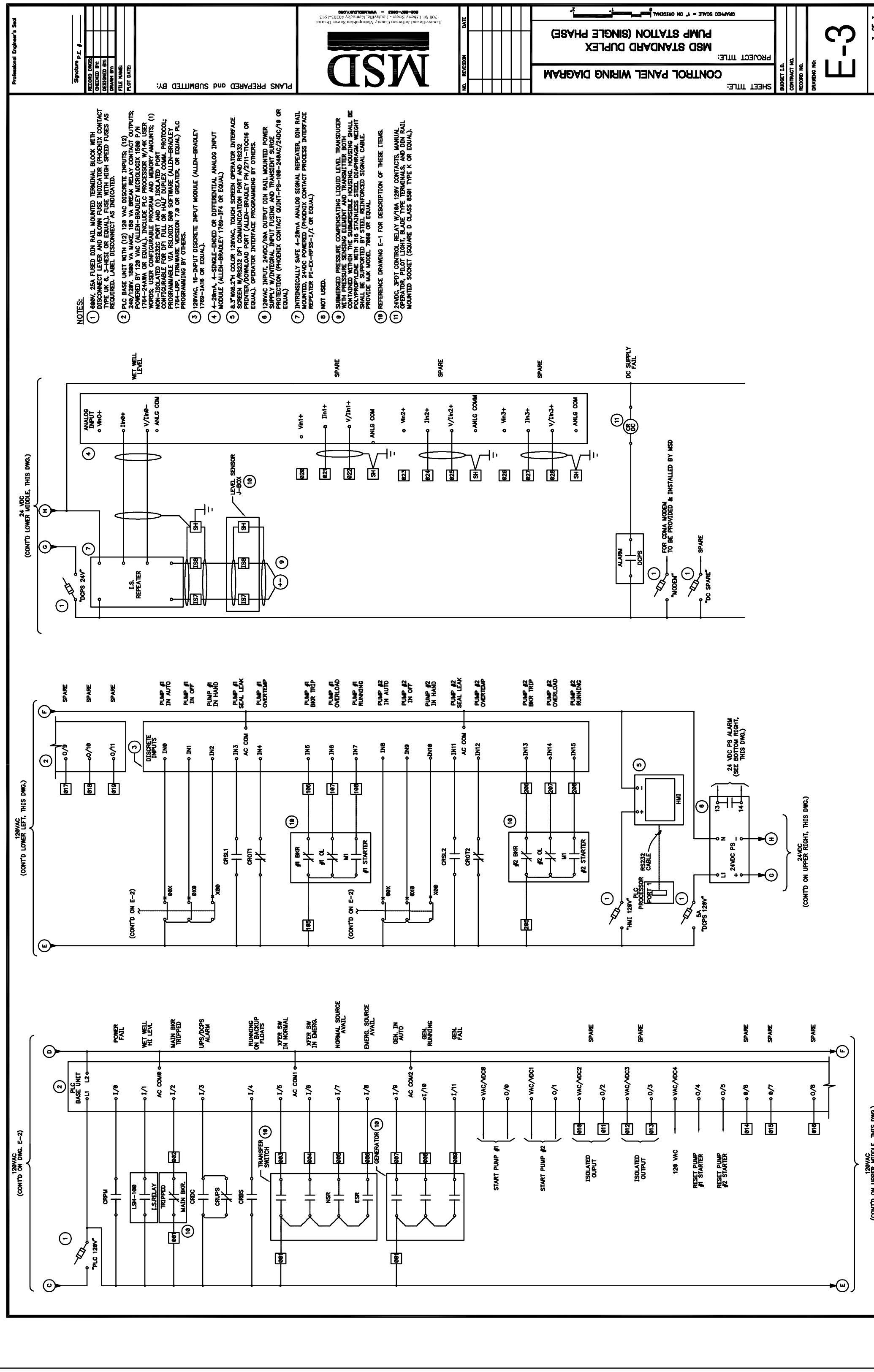

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EXHIBIT 15-4
STANDARD DUPLEX PUMP STATION
(SOFT STARTERS)

EFFECTIVE DATE: JUNE 30, 2009

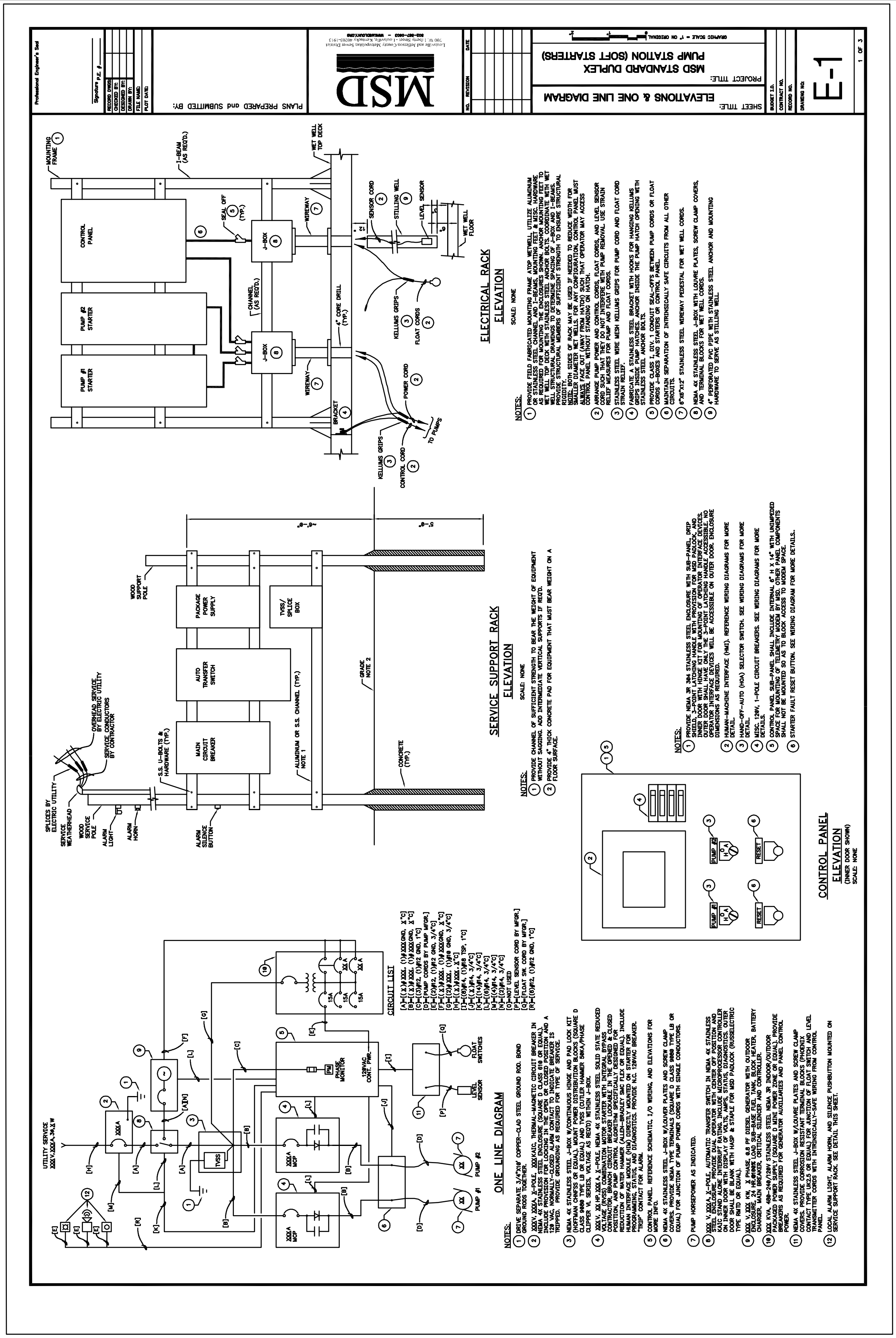

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EXHIBIT 15-4

STANDARD DUPLEX PUMP STATION (SOFT STARTERS)

EFFECTIVE DATE: JUNE 30, 2009

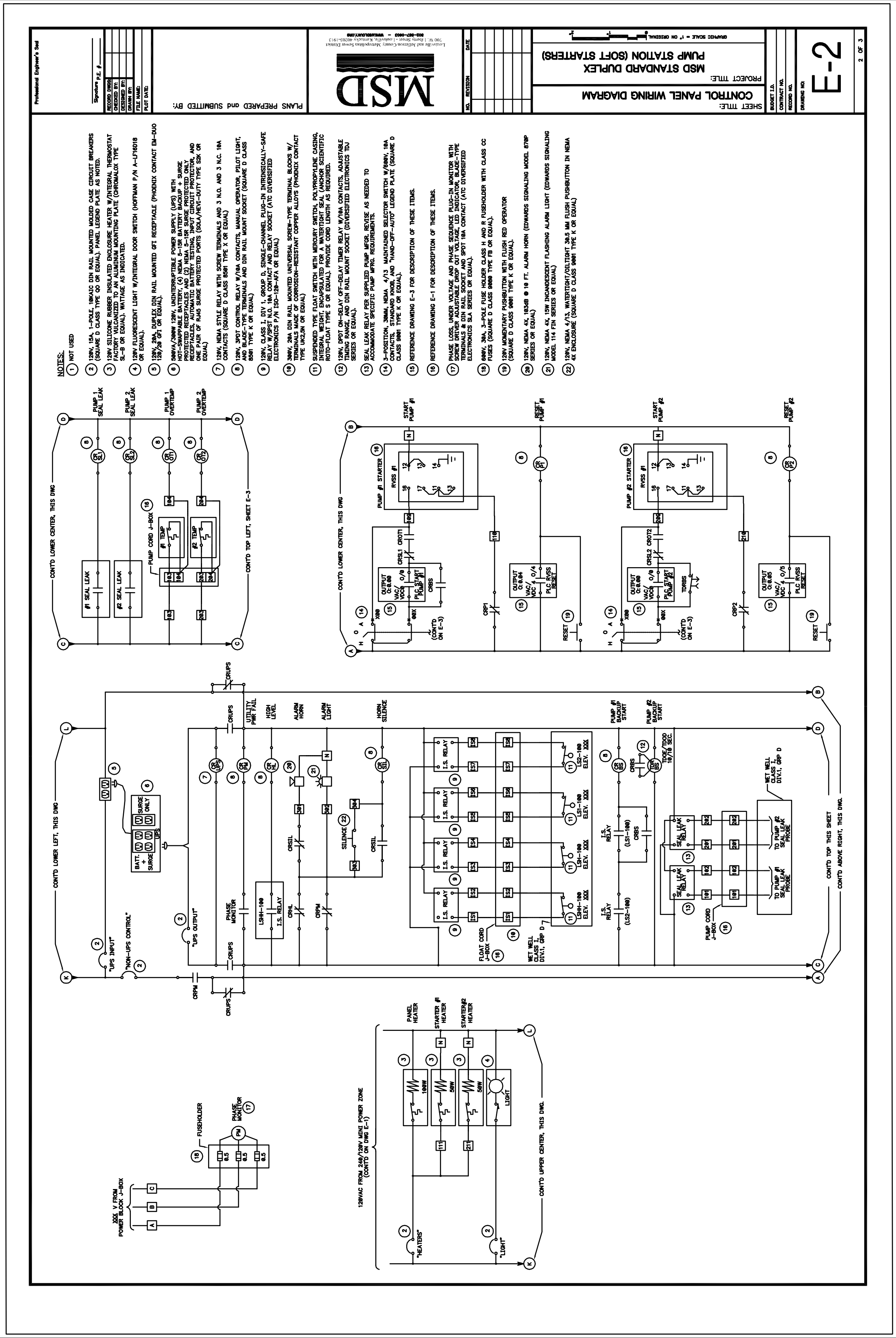

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EXHIBIT 15-4 PAGE 3
STANDARD DUPLEX PUMP STATION
(SOFT STARTERS)

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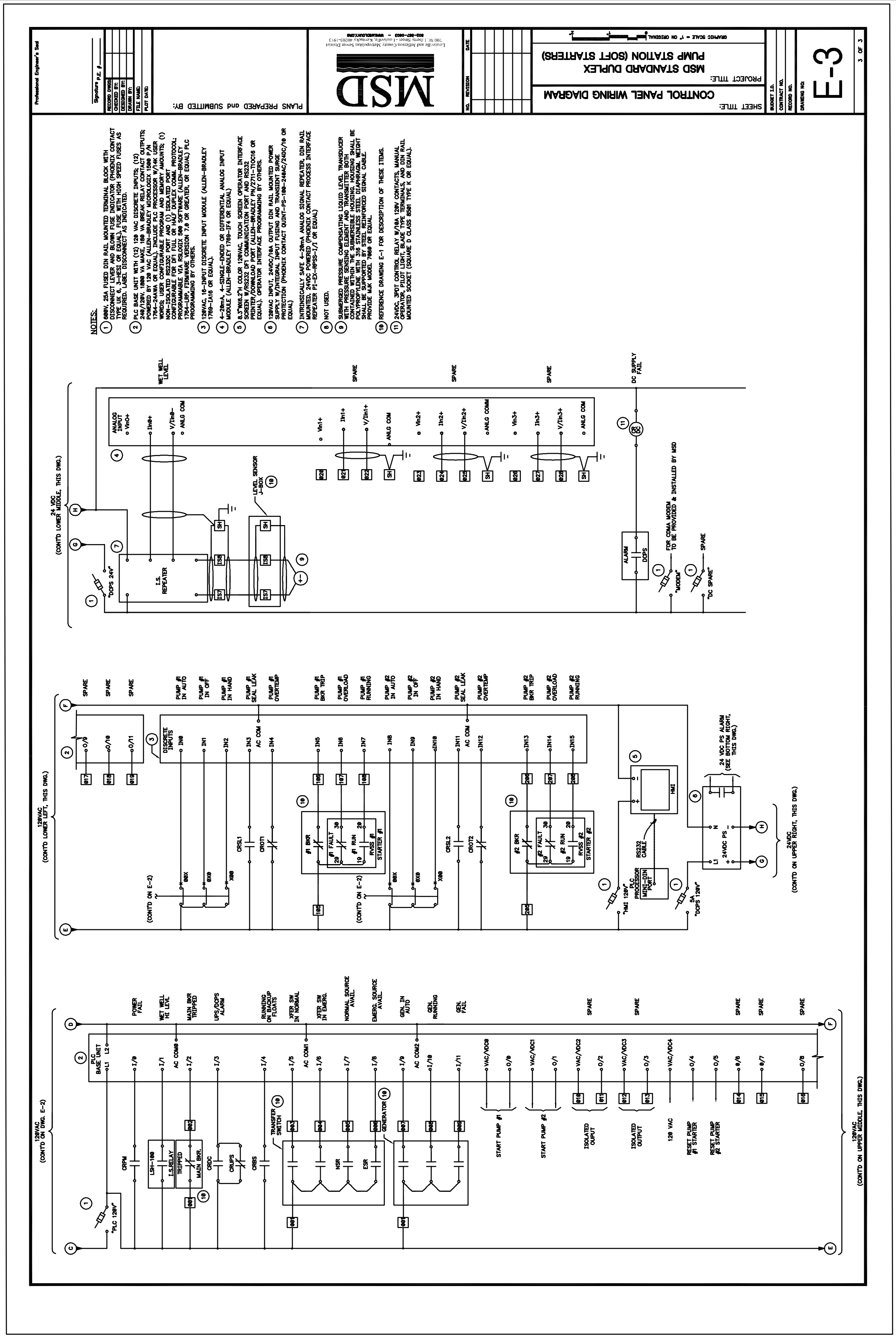

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CHAPTER 16
ODOR CONTROL

16.1 PURPOSE

The purpose of this chapter is to:

a. Identify the planning and design approach to be used for controlling odors from pumping stations, force mains, sanitary sewers and small wastewater treatment plants.

b. Define specific criteria by which odor control systems will be designed.

c. Identify submittal requirements required by MSD for review and approval of odor control systems.

d. Outline the requirements for opinions of construction and operating costs.

16.2 SUBMITTAL REQUIREMENTS

The Design Engineer shall submit to MSD for review and approval, the Concept Plan, Preliminary Design and Final Design. If the odor control systems are being designed as part of a larger project then the odor control submittals shall be made a part of the submittals for the larger project. Approval by MSD will be required prior to authorization of any succeeding design phase.

Submittals shall be prepared in report format (8.5-inch x 11-inch) and shall be spiral bound, three-ring bound or bound in some other permanent manner. Appended to or included in the bound submittal shall be maps, figures, and drawings as necessary. Sections are to be organized and tabbed according to the requirements of this section.

16.2.1 Concept Plan Submittal

The purpose of a Concept Plan is to provide MSD with preliminary design data for proposed odor control facilities to determine the compatibility of proposed facilities with the design manual and to justify recommended alternatives.

Concept Plan submittals relating to odor control shall be submitted in accordance with Chapter 2, Section 2.3 and include the following elements:

a. A narrative description of the proposed system.

b. Justification of the need for the system and of the type of system proposed. Identification of potential odor producing conditions.

c. Odor control system design criteria form. (Exhibit 16-1).

d. Location of the facility for which odor control is being provided and proximity to potentially sensitive odor receptors.

e. Description of the potential odor control alternatives and rationale used to select the proposed system.

f. Discussion on availability of utilities required to service system.

g. Identification of duties required of operating and maintaining personnel and listing of potential hazards of handling proposed chemicals (if applicable).

h. Cost effective analysis as described in Section 16.3.4.

16.2.2 Preliminary Design and Final Design Submittals

Preliminary Design and Final Design submittals relating to odor control facilities shall be prepared in accordance with Chapter 4 – Drafting Standards and include the following elements:

a. Design Documentation - Preliminary and Final Design submittal shall include all design requirements, assumptions, background data, design calculations and references. Submittals shall include, but not be limited to, those elements outlined in Section 16.4.1.

b. Plans - Show the project name, sheet title and submittal date on all sheets. Plans must be legible and uncluttered. Final documents shall include Professional Engineer stamp and signature on each sheet.

c. Specifications - Prepare specifications consistent with the MSD Contract Documents Manual.

16.3 DESIGN APPROACH

16.3.1 Approvals

Prior to construction or enhancement of odor control facilities, the design documents must receive the written approval of MSD. The Design Engineer shall consult the **Louisville Metro** Air Pollution Control District (**LM**APCD) to determine if a permit to construct and/or operate an air treatment system is required for the project.

16.3.2 Service Level

Guidelines presented in this Design Manual govern the planning and design of odor control systems defined as follows:

a. Chemical feed systems designed to control the formation and release of odorous compounds from wastewater pumping stations, force mains, sanitary sewers and small treatment plants.

b. Air treatment systems for pump stations, force mains and small treatment plants, which capture the odorous air and treat it by means of absorption, adsorption, oxidation or chemical biological stabilization.

16.3.3 Justification

MSD will determine the need for odor control system(s), based on information provided by the design engineer, on a case-by-case basis according to the following criteria:

a. The history of odor complaints in the vicinity. If the MSD has received odor complaints from residents within 100 yards of the proposed facility within the previous year, odor control will be required.

b. The potential that the facility has to create an off-site odor nuisance. If the facility is fed by upstream pumping stations, if it has collection sewers that have low velocities (<2 ft/sec) and/or long detention times (>6 hours) or if it is expected to receive heavy industrial flow, odor control will be required. On-site odor control will also be required if the wetwell has an average detention time in excess of 45 minutes and may be required with lesser detention times if other conditions warrant it.

c. The proximity of proposed facilities to existing and future homes, businesses and roads. If a home or business is located within 150 feet of the facility, or is expected to be within this distance, odor control facilities will be required.

d. Design calculations provided by the design engineer. Refer to Exhibit 16.1.

16.3.4 Cost Effective Analysis

The cost effective comparison analysis between odor control alternatives shall include both economic and non-economic factors.

The economic portion of the cost-effectiveness analysis shall use a present worth calculation that considers capital costs, operation and maintenance costs, and salvage values.

Capital costs shall include opinions of construction cost as outlined in Section 16.5, engineering costs based on recognized fee curves and costs for acquisition of properties, easements and rights-of-way, including legal costs. Operation and maintenance costs shall include opinions of cost for labor, utilities, maintenance and repair of facilities. Salvage values shall be developed on straight-line depreciation.

Life cycle costs should be considered over a 20-year period. Unless otherwise directed by MSD, a discount rate equal to that required by the Division of Water should be used to calculate the present worth value of each alternative.

Non-economic factors to be addressed in narrative form, as a part of the cost-effectiveness analysis, should include:

1.	**Environmental Impact:**	**The short-term and long-term impacts of the alternative on the environment.**
2.	**Reliability:**	**A measure of how dependable the alternative performs over time.**
3.	**Operability:**	**The ease with which the alternative operates over time.**

16.4 DESIGN CRITERIA

16.4.1 General

Design requirements, assumptions, background data, design calculations and references must be documented and submitted to MSD. If it is determined that an odor control system is required based on the preliminary information and the design calculations submitted on Exhibit 16-1, the following information shall be submitted to MSD for review, as a minimum:

a. Air Treatment Systems

1. Description of source
2. Air flow rate
3. Actual or anticipated odorous compounds and projected concentrations. Include mass loadings data and calculations to support projections.
4. Number of air changes per hour

5. Headloss calculations and duct sizes
6. Exhaust fan sizing
7. Treatment system description, size, dimensions and space requirements
8. Media replacement projections

b. Chemical Addition Systems
   1. Pump cycle times
   2. Force main velocities and flow rates
   3. Chemical feed dosages
   4. Bench scale and/or demonstration test results
   5. Air relief valve and force main discharge locations and their relationship to nearby homes and businesses.
   6. Chemical storage tank sizing and safety requirements
   7. Actual or anticipated sulfide levels in wastewater
   8. Chemical feed equipment

16.4.2 Odor Production

Odor complaints from collection systems, pump stations, force mains and small wastewater treatment plants are generally caused by the release of hydrogen sulfide (H_2S) gas. Therefore, the chemical feed and air treatment systems described herein are primarily designed to control H_2S. The following is a description of the sulfide generation process in wastewater systems:

- A slime layer will develop on the submerged walls of gravity sewers and force mains if the velocity of the wastewater through the pipe is too low to scour the sides.

- In aquatic environments lacking dissolved oxygen only anaerobic bacteria attach to the slime layer. These bacteria reduce sulfate (SO_4^{2-}), one of the most common anions in water and wastewater to sulfide (S^{2-}).

- The sulfide ions combine with hydrogen ions in the wastewater to form hydrogen sulfide. Depending on pH, the hydrogen sulfide dissociates to dissolved hydrogen sulfide gas (H_2S), hydrosulfide ion (HS^{1-}), and sulfide ion (S^{2-}). At neutral pH of 7, the distribution is approximately 50% H_2S and 50% HS^{1-}. At pH 6, the distribution is approximately 90% dissolved hydrogen sulfide gas and 10% hydrosulfide ion.

- Dissolved hydrogen sulfide gas is the only form of dissolved sulfide which can be released from wastewater to the atmosphere. H_2S produces the "rotten egg" odor characteristic of septic sewage. The release of H_2S from solution is accelerated under turbulent conditions.

Gravity sewers are generally designed to accommodate population growth well into the future. Often, designers will utilize larger pipe at shallower slopes to allow for future flows, minimize the sewer depth, and reduce construction cost. This practice often results in lower wastewater velocities during the initial years when the sewer carries substantially lesser volumes.

Wastewater velocity directly impacts wastewater detention time within the sewer, the amount of grit and organic solids deposition (both of which tend to further reduce wastewater velocity and increase depth of flow), and the extent of slime layer buildup within the submerged portion of the sewer. Velocity thus affects formation of dissolved sulfide and also the release of hydrogen sulfide gas into the sewer atmosphere.

As with sewers, pump station wet wells are normally designed for future flows. While this practice makes economic sense, it does allow for excessive detention times during the initial years of operation. The longer the detention time, the greater the likelihood that the wastewater will become septic. Unless the pump suction pipes and wetwell geometry are appropriately designed, the accumulation of organic matter will promote the generation of dissolved sulfide and hydrogen sulfide gas.

Force mains, inverted siphons and other surcharged pipes are normally completely full of wastewater, and because this condition does not allow reaeration from the sewer atmosphere, dissolved oxygen levels in the wastewater become depleted, and significant quantities of dissolved sulfide can be generated. These conditions should be avoided when possible.

16.4.3 Odor Control Design Guidelines

16.4.3.1 Pipeline Design

Good design and maintenance practices will reduce sulfide problems in collection systems without the use of chemical addition or air treatment. In general, pipeline design should adhere to the following;

a. Limit the use of closed conduit systems (force mains, siphons, and surcharged sewers). If a closed conduit system must be used, limit its length and provide adequate velocity to scour the pipe. Limiting the use and length of force mains in raw wastewater conveyance systems is probably the single most important factor in minimizing sulfide release from collection systems.

b. Wastewater velocities in both gravity and pressure pipes must be adequate to prevent deposition and accumulation of solids, especially during periods of low flow.

c. Maintain gravity trunk sewer and interceptor velocities to the point where wastewater surface reaeration is adequate to prevent sulfide build-up. Maintain dissolved oxygen levels above 0.5 mg/L.

The minimum acceptable velocity for small sewers (less than 18 in. diameter) is two (2.0) feet per second (fps) at initial peak flow conditions as defined in Chapter 8 Section 8.9**.3 and 8.9.4**. Velocities as low as 1.0 fps may be acceptable during low-flow periods and during the early years of development of an area if it is adequately justified. Otherwise, the minimum design velocity shall never be less than 2.0 fps and may need to be higher if a significant sediment load is anticipated. Further information on the design of large diameter systems with regard to sulfide control can be found in ASCE-Manuals and Reports on Engineering Practice-No. 69- "Sulfide in Wastewater Collection and Treatment Systems."

The minimum allowable slopes for sanitary sewer systems are shown on Exhibit 8-5 Chapter 8 – Sanitary Sewer Systems.

The oxygen content of the sewer atmosphere should be maintained close to the 21% found in clean air. Suppression of oxygen content occurs where there are few, if any, connections to an interceptor and/or there is a siphon, pumping station or surcharged section which is blocking the movement of air through the interceptor.

16.4.3.2 Pump Station and Force Main Design

The primary means of minimizing sulfide formation in force mains is maintenance of scouring velocities. It is recommended in Chapter 15 that force mains be designed with a velocity between 2 and 5 fps. A velocity of 2 fps is acceptable with regard to odor control on short force mains (less than 1,000 ft.), but on longer force mains the minimum velocity should be as follows:

MINIMUM SCOUR VELOCITY FOR FORCE MAINS		
Force Main Size (in.)	Minimum Velocity (fps)	
	Typical (1)	Heavy Grit Load (2)
$\leq$10	3.2	3.9
12-30	3.5	4.3
32-60	4.1	5.0
(1) Average or typical wastewater where scour velocity is achieved frequently. (2) Heavy grit load or substantial time between scouring velocity events.		

The wastewater discharged from the force main should enter the receiving manhole at the invert or below the water level to reduce turbulence. Interior drop pipes shall be used to lower forcemain discharge elevation to manhole invert.
Pump station wet wells should be designed to limit detention time and prevent the deposition of solids in order to minimize sulfide production. New pump station and force main designs shall be modeled to predict H_2S production and release. If the station and force main has the potential to be an odor source, then the designer should take the appropriate actions which may include reducing the pump cycle times using dual force mains, using variable speed pumps or decreasing detention time by adjusting the pump level switches.

The bottom of the wet well shall be sloped to match the requirements of the pumps being installed based on pump/wet well modeling. Pump suction should generate enough velocity at its floor to move solids and eliminate dead spots. Influent drop pipes should be used to bring wastewater in below the wet well water level to reduce turbulence.

All wetwells shall have a 6-inch diameter corrosion resistant fiberglass, aluminum or stainless steel vent pipe with two flanged 90º elbows, which will allow connection to odor control device.

16.4.3.3 Chemical Feed Systems

Chemicals may be added to the wastewater to prevent the formation of sulfides through oxidation or precipitation of sulfides that are already in solution. Certain chemicals, such as calcium nitrate (Bioxide) prevent the formation of sulfides because bacteria use nitrates, if no dissolved oxygen (DO) is present, preferentially over sulfates, which prevents the sulfates from being reduced to sulfides. Hydrogen peroxide, potassium permanganate, hypochlorite and chlorine will oxidize sulfides after their formation in the wastewater. Iron salts, such as ferrous chloride, react with the sulfides to produce an insoluble precipitate and prevent the release of H_2S. In addition, caustic (sodium hydroxide) has been used in slug doses to inactivate slime layers in pipes.

MSD currently uses calcium nitrate for purposes of odor control through chemical addition. Hydrogen peroxide, ferrous chloride, potassium permanganate, hypochlorite and chlorine are not used at pumping stations due to poor performance, excessive cost and/or safety concerns.

MSD has found calcium nitrate and ferrous chloride to be effective in controlling H_2S. Calcium nitrate is also easy to handle by operating personnel. An important difference between these two chemicals is that nitrate solutions are less effective at preventing the release of H_2S if sulfides are already in solution. $FeCl_2$, on the other hand, will precipitate the sulfides after they are formed and prevent further formation. This means nitrates should be added upstream of sulfide formation where possible.

Another product used by MSD is a mixture of calcium nitrate and anthraquinone (marketed as Bioxide AQ). This product is often used in situations where existing sulfides have to be removed and where the formation of dissolved sulfides (DS) need to be prevented. This product is non-hazardous and is handled like calcium nitrate except a mixer is required in the storage tank to prevent settling.

The first step in designing a chemical feed system is to conduct laboratory tests on the wastewater to determine sulfide levels under various conditions. For existing pump stations, these tests should be performed on the wastewater as it exits the force main because the sulfide levels will be highest at this point.

The following design criteria shall be used as a guide in designing systems to feed nitrates at pump stations.

CHEMICAL FEED SYSTEM DESIGN CRITERIA	
Criterium	Nitrates
Method of Delivery	Bulk Liquid
Design Dosage Range (1)	1.5 gallons/lb DS
Minimum Reaction Time (mins.)	30
Maximum Allowable DS at Discharge (mg/l)	0.3-0.5
Storage Tank Capacity (days)	90
Storage Tank Material	See Note (2)
Secondary Containment	Secondary containment berm may be required depending on threat to nearby water supplies
Number of Chemical Feed Pumps	2
Chemical Feed Point (Discharge point must be visible from above)	Entrance to P.S. Wetwell above High Water Level

Notes:

1. Design dosages shall be used to size equipment on systems where field tests cannot be performed. Actual dosages will be determined via field tests when system is on-line.
2. Cross-linked High Density Polyethylene or Fiberglass Reinforced Plastic (FRP).

The liquid chemical feed system equipment shall consist of a chemical storage tank (or drums), chemical metering pump(s), pump calibration tube and control panel. Nitrate storage tanks shall be enclosed unless a variance is allowed by MSD and the tank shall include flanges for a fill pipe, pump suction line and vent.

If the chemical is being stored in drums as shown on Exhibit 16-2 the pumping system shall consist of a single diaphragm-type electronic metering pump with spare parts, a calibration cylinder and a pump stand. Pump materials shall be compatible with the chemical being pumped.

The pump and control unit that shall be used with the tank shown in Exhibit 16-3 shall include two metering pumps (with spare parts), pump calibration tube, pump timer, heaters, thermostat, on/off/auto switches, GFI outlet, in a stainless steel NEMA 3R enclosure suitable for outdoor installation. Refer to Exhibit 16-4.

16.4.3.4 Air Treatment Systems

Unlike chemical feed systems, which are designed to prevent the formation of odorous compounds, air treatment systems are designed to capture and treat the odors after they are produced.

Air treatment systems may include the air collection ductwork, an exhaust fan and a means of removing the odorous compounds from the air. System components shall be designed using the following criteria:

a. Ductwork

- Ductwork shall be designed based on the following criteria:

  Materials of Construction — Below Grade:

  - SCH40 or SDR35 PVC Pipe
  - DR 32.5 high density polyethylene

  Above Grade:

  - Fiberglass reinforced plastic coated for UV protection
  - 304 stainless steel

- Air Velocity in Duct — 1500 - 2500 ft/min

- Duct size shall be computed using the following equations:

  $Q = (V)(AC/hr)(1\ hr/60\ min)$
  $A = Q/v$
  $D = (4A/\pi)^{0.5}$

  Where:

  A = Duct cross-sectional area (ft^2)
  D = Duct diameter (ft)
  V = Volume of structure from which air is to be drawn (ft^3)
  v = Velocity of air through duct (ft/min) - (2500 ft/min)
  AC/hr = Air changes per hour from area being ventilated
  Q = Air flow rate (ft^3/min)

The ventilation rate (air changes per hour) shall be based on NFPA 820-Fire Protection in Wastewater Treatment Plants (latest edition) issued by the National Fire Protection Association.

b. Exhaust Fan

Exhaust fans shall be corrosion resistant and constructed of fiberglass reinforced plastic or 304L stainless steel materials with sliding motor mounts to allow sheave replacement.

Fans shall be located indoors if possible and if not then noise suppression devices may be required. Constant speed motors will be acceptable in most applications and timers should be considered if intermittent operation may be required. Flexible connectors shall be mounted on the inlet and outlet flanges of the fan and the volute of the fan shall be equipped with a drain to remove condensate.

c. Air Treatment

1. Modular Biofilters

Biofiltration uses naturally occurring microbes to biologically break down odors in waste air streams into carbon dioxide and water. Typically, air is drawn through a humidification chamber through a media bed, which provides a surface on which the microbes can flourish and then discharged through a stack after treatment. The biofilters shall be a modular design which are essentially fully assembled in the factory and delivered to the site ready for connection of ducts and utilities.

Use the following criteria when designing biofilters. Note these design criteria are applicable for installations with H_2S concentrations of 50 parts per million (ppm) or less. Installations with higher expected H_2S concentrations will require lower loading rates and special design considerations.

TYPICAL BIOFILTER DESIGN CRITERIA	
Media Type	Inorganic Media
Air Plenum Depth (inches)	12-18
Media Depth (feet)	4-6
Loading Rate (cfm/ft^2)	12-18
Empty Bed Residence Time (EBRT) (seconds)	20-30
Maximum H_2S concentration (ppm)	50
Maximum Pressure Drop through Media (inches w.c./ft media depth)	0.25-0.33
Initial Media pH Range	7-8.5
Media Moisture Content (% by weight)	40-60
Media Porosity %	40-50

Water Usage (gallons/ 100,000 ft^3 of air)	10
Maximum Air Temperature (°F)	105
Anticipated Media Life (years)	10-12

There are two primary types of biofilter media. Organic media consists of wood chips, bark nuggets, compost and other organic materials or a combination of these locally available materials. It typically has a lower initial cost than inorganic media but it has to be replaced every 2-3 years and has a higher pressure drop resulting in higher power costs.

Inorganic media is typically a nutrient rich mixture of organic and inorganic material that has an expected life of 10 years or more, has lower pressure drop and power costs and is less susceptible to compaction and drying out. Inorganic media shall be used in MSD biofilters.

2. Carbon Canisters

Activated carbon is an effective method of treating a variety of organic contaminants and odor causing compounds. Carbon canisters are vessels, which allow the odorous air to pass through a bed of odor adsorbing carbon-based media. Carbon canisters are available in many shapes and sizes including preassembled, skid-mounted units. Integrally mounted fans are also available. Refer to Exhibit 16-5 for a detail of a typical skid-mounted carbon canister. The size of the canister will be based on the air flow rate, the estimated contaminant loadings and the type of carbon used. The typical velocity through the bed is 50 - 75 feet per minute.

Small carbon canisters are also available for installation on the vent pipes of wetwells. These vent canisters are passive (no fan) and are bolted to a standard 6" diameter vent flange as shown on Exhibit 16-6.

Carbon adsorbs and captures volatile organics and will adsorb hydrogen sulfide if the carbon is impregnated with caustic or if specifically formulated for H_2S removal. MSD will not regenerate carbon on-site therefore the carbon must be replaced as its adsorption capacity is reached. Carbon is not suitable for high concentrations of H_2S (i.e. greater then 5 ppm) due to its limited adsorption capacity. Carbon must be periodically replaced. Most adsorbers located at pumping stations and wastewater treatment plants should use caustic impregnated carbon.

3. Packed Bed Scrubbers

Scrubbers are used to absorb and oxidize H_2S and other organic compounds in a packed bed of randomly dumped media. Water is recirculated to the top of the media from a collection sump. Caustic chemicals are added to adjust the pH to about 9.5-10, and hypochlorite or potassium hydroxide is dosed to oxidize the absorbed odorants. Typical design criteria are as follows:

Media height -	6 - 10 ft.
Velocity -	350 - 450 ft/min
Recirculation flow rates -	12 - 14 gpm/1,000 cfm
Water blowdown rate -	1 – 3 gpm
Headloss -	2 - 4 inches w.c.

Other requirements for a scrubber installation shall include a demister, automatic control of pH and oxidation reduction potential (ORP), freeze protection and sump high and low level switches. Scrubbers are well suited for high H_2S loadings, and should be installed where close monitoring and control is available from operating personnel. Scrubbers typically are not used at MSD pumping stations and other small facilities due to the chemical storage and handling requirements and their need for operator attention.

4. Odor Counteractants

Odor counteractants, or odor neutralizers, can reduce odor intensity by interacting two specific compounds in certain proportions. In most cases, the odor counteractant is sprayed into the foul air stream using an atomizer. The atomizer divides the counteractant into tiny particles, which improves surface contact between the odorous compounds and the counteractant.

MSD will not accept odor counteractants as a permanent odor control system but may consider it as a temporary solution while a permanent system is installed.

16.4.4 Applications

Selecting the best means of controlling odors requires an understanding of the cause of the odors, the compounds present, the duration and frequency of the odor, site conditions, utilities available and ultimately the overall cost effectiveness. MSD will evaluate each situation and determine the level of odor control required at each site on a case-by-case basis but the following guidelines may be used to predict odor control requirements.

Summary of MSD Collection System Odor Control Guidelines

1. Pipeline Design

   a. Minimize use of force mains and siphons

   b. Maintain dissolved oxygen levels above 0.5 mg/L

   c. Minimum allowable velocity for gravity sewers 2 feet per second unless waiver is received

   d. Minimum allowable velocity for force mains is 2 feet per second for force mains less than 1000 feet long. Refer to 16.4.3.2 for minimum velocities on longer mains.

   e. Minimize use of air release valves on force mains

   f. Air release valves shall be PVC coated for corrosion protection

   g. Force mains shall discharge to receiving manhole at manhole invert via internal drop pipes if necessary. Internal drop pipes shall have open tee connection for clean out purposes.

   h. Chemical feed system shall be designed in basic conformance with Exhibit 16-2.

   i. Calcium nitrate shall be used in the chemical feed systems unless conditions favor using a different chemical.

   j. The need for a chemical feed system at the pump station will be based on:

      - Predicted total sulfide production in the force main (Exhibit 16-1)
      - History of odor complaints in area
      - Density of population along force main route
      - Number of air release valves

- Potential for downstream corrosion

2. Pump Station Wetwell Design

   a. Gravity sewers discharging to a wetwell shall discharge below low water level to minimize turbulence. Interior drop pipes shall be used.

   b. The wetwell bottom shall be designed to prevent the deposition of solids.

   c. Wetwell detention times shall be less than 45 minutes whenever possible.

   d. All wetwells shall be equipped with a 6-inch diameter flanged corrosion-resistant vent pipe and a carbon canister (Exhibit 16-5) shall be attached to the vent to treat the air prior to exhausting. A larger carbon canister with exhaust fan (Exhibit 16-4) may be required if deemed necessary by MSD.

   e. Access hatches to wetwells shall be sealed with weather stripping to prevent fugitive emissions.

   f. Drain lines from valve vaults to the wetwell shall be trapped to prevent odor emissions from valve vault vent.

   g. Packed bed scrubbers, biofilters and other air treatment systems will only be used at pump station sites when abnormal situations exist and when specifically requested by MSD.

Design engineer shall review potential need for odor control, evaluate odor control options and make recommendations in the Concept Plan submittal. Submittal shall include the information outlined in Section 16.2.1. MSD will review the information and determine need for odor control.

16.5 OPINIONS OF COST

Opinions of probable cost shall be prepared in accordance with Chapter 2, Section 2.6.

16.6 REFERENCES

(1) Bowker, R.P.G., J.M. Smith, N.A. Webster, Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants, Design Manual, U.S. Environmental Protection Agency, Center for Environmental Research, Cincinnati, Ohio, 1985.

(2) Sulfide in Wastewater Collection and Treatment Systems, American Society of Civil Engineers, New York, NY, 1982.

(3) Bowker, R.P.G., N.A. Webster, Detection, Control, and Correction of Hydrogen Sulfide Corrosion in Existing Wastewater Systems, U.S. EPA, Office of Wastewater Enforcement and Compliance, Washington, D.C., 1992.

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LOUISVILLE AND JEFFERSON COUNTY
METROPOLITAN SEWER DISTRICT
RESIDENTIAL AND LIGHT COMMERCIAL DEVELOPMENT PUMP STATIONS
WETWELL DETENTION TIMES AND PROJECTED SULFIDES

Development: ______________________________

Developer: ______________________________

Engineer: ______________________________

Pump Station:			
(a)	Initial Average Daily Flow Rate (gpm)		Data Input
(b)	Wetwell Diameter (ft):		Data Input
(c)	Depth from All Pumps Off to Lead Pump On (ft):		Data Input
(d)	Will Pumps Have VFDs:	Yes/No	Data Input
(e)	One Pump Flow Rate (gpm):		Data Input
(f)	Number of Pumps:		Data Input
(g)	Distance from Wetwell to Nearest Current or Future Residence (ft):		Data Input
(h)	Distance from Wetwell to Nearest Body of Water (ft):		Data Input
(i)	Does Station Receive Flow from Any Other Pump Station?	Yes/No	Data Input
(j)	Name of Upstream Station:		Data Input
(k)	Volume in Wetwell with Pumps Off (gallons): $V = [3.14*(b)^2/4]*(c)*7.48\ gal/ft^3$	0	Formula
(l)	Wetwell Detention Time(DT) (min): DT = (k)/(a)	#DIV/0!	Formula
Force Main:			
(m)	Force Main Length (ft):		Data Input
(n)	Force Main Inside Diameter (ft):		Data Input
(o)	Number of Air Release Valves (ARV):		Data Input
(p)	Closest Distance from ARV to Residence (ft):		Data Input
(q)	Distance from Discharge Manhole to Nearest Residence (ft):		Data Input
(r)	Force Main Cross Sectional Area (ft^2): $A = 3.14*(n)^2/4$	0.00	Formula
(s)	Force Main Velocity With One Pump Running (ft/s): V = (e)/(r)/7.48/60	#DIV/0!	Formula
(t)	Force Main Volume (Ft^3): V = (m)*(r)	0.00	Formula
(u)	Force Main Detention Time at Avg.Daily Flow (min): DT = (t)*7.48/(a)	#DIV/0!	Formula
(v)	Sulfide Flux Coefficient (ft/hr):	0.001	Given
(w)	Effective Biological Oxygen Demand of Wastewater (mg/L):	280	Given
(x)	Hydraulic Radius of Full Pipe (ft): HR = (n)/4	0	Formula
(y)	**Predicted Total Sulfide Production (mg/L):** $S_c = [3.28*(v)*(w)*[(1+0.48*(x)](x)^{-1}]*(u)/60$	**#DIV/0!**	Formula
(z)	Predicted Total Sulfide Mass (lbs/day): S_m =(y)*(a)*60*24/1000000*8.34	#DIV/0!	Formula
	Predicted Bioxide Usage (gals/day): B = (z)*1.0	**#DIV/0!**	Formula

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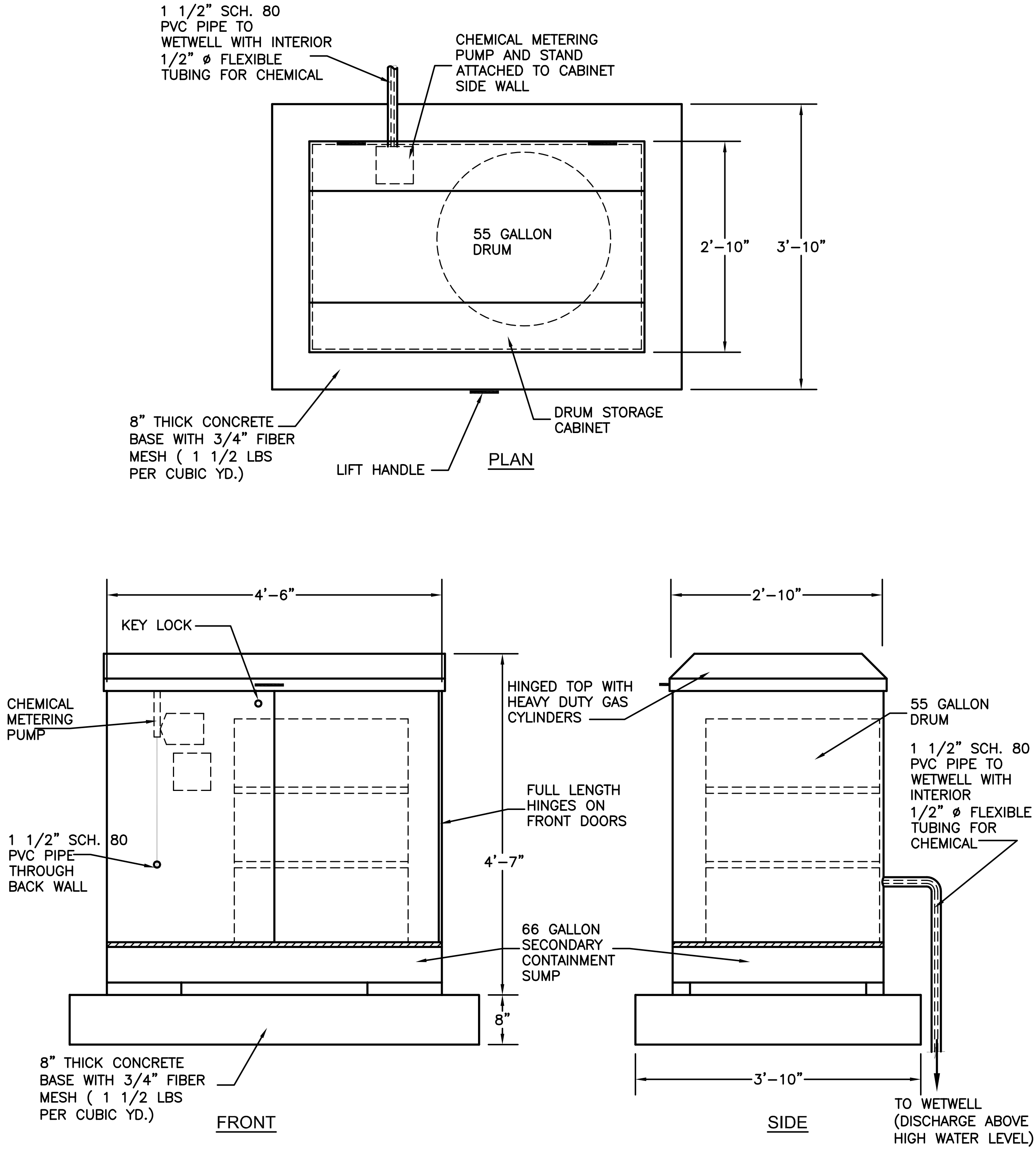
EXHIBIT 16-2
ODOR CONTROL CHEMICAL DRUM STORAGE CABINET DETAIL

EFFECTIVE DATE: JUNE 30, 2009



NOTE:
DRUM STORAGE CABINET SHALL BE DENIOS ENCLOSED 2-DRUM HAZMAT STATION OR EQUAL. CABINET SHALL BE CONSTRUCTED OF WELDED STEEL WITH CORROSION AND WEATHER RESISTANT FINISH.

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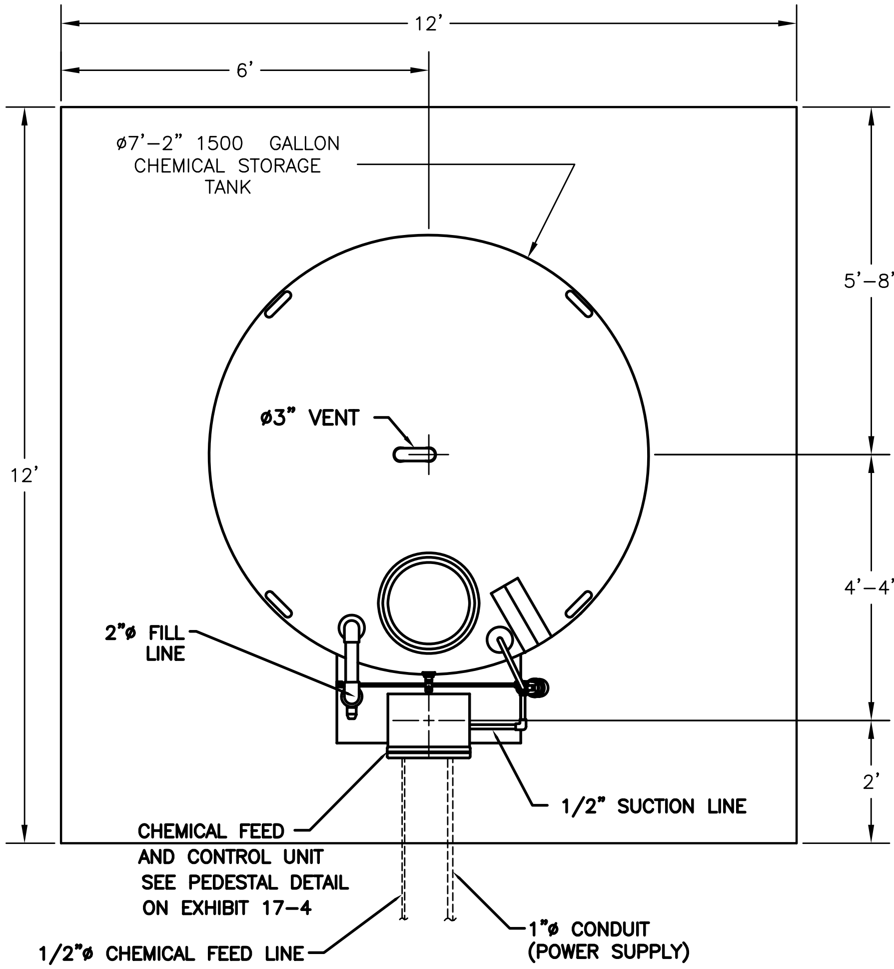
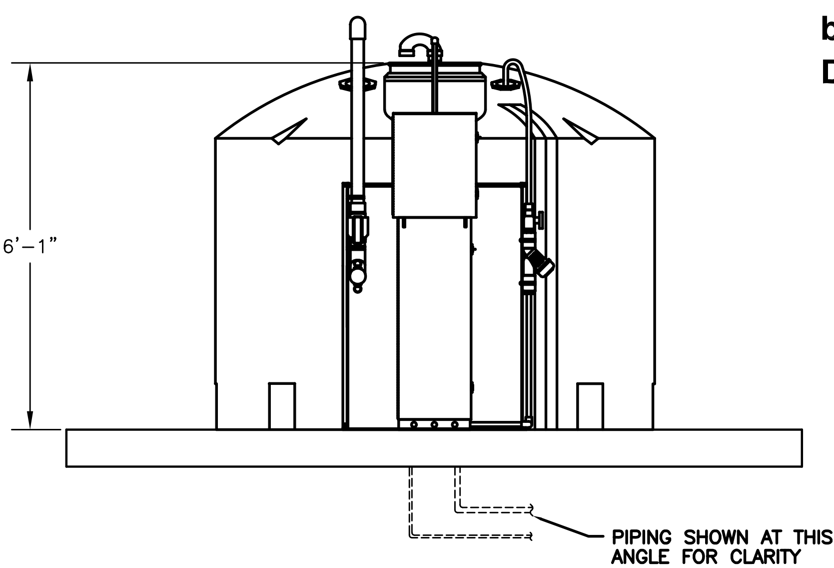
EXHIBIT 16-3
CHEMICAL FEED SYSTEM WITH
1500 GALLON ICT TANK

EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

Drawing prepared by US Filter / Davis Process.



ELEVATION VIEW

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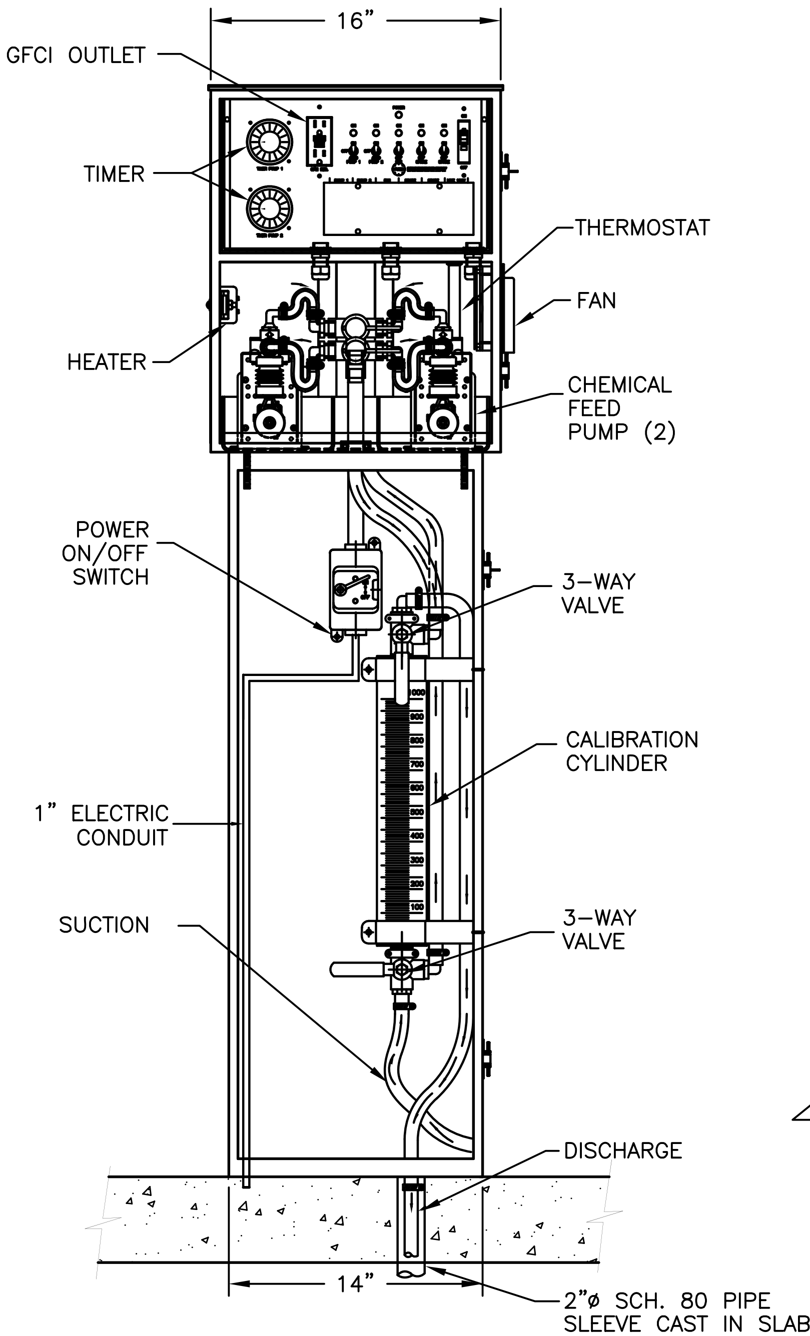
EXHIBIT 16-4
CHEMICAL FEED SYSTEM
CONTROL PANEL DETAIL

EFFECTIVE DATE: JUNE 30, 2009

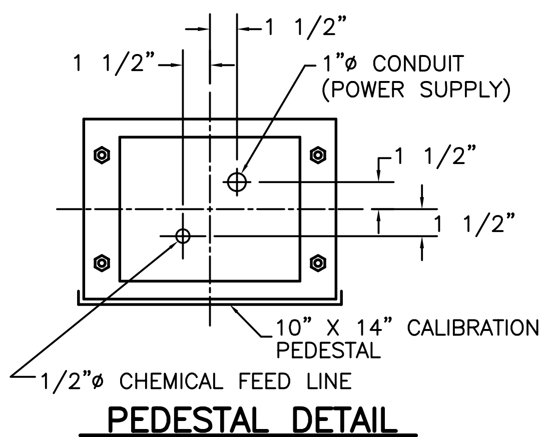
NOTES

1. ALL PIPING AND APPURTENANCES , SCH 80 PVC
2. ALL HARDWARE REQUIRED FOR INSTALLATION SHALL BE STAINLESS STEEL.



CHEMICAL FEED AND CONTROL UNIT

Drawing prepared by US Filter / Davis Process.



PEDESTAL DETAIL

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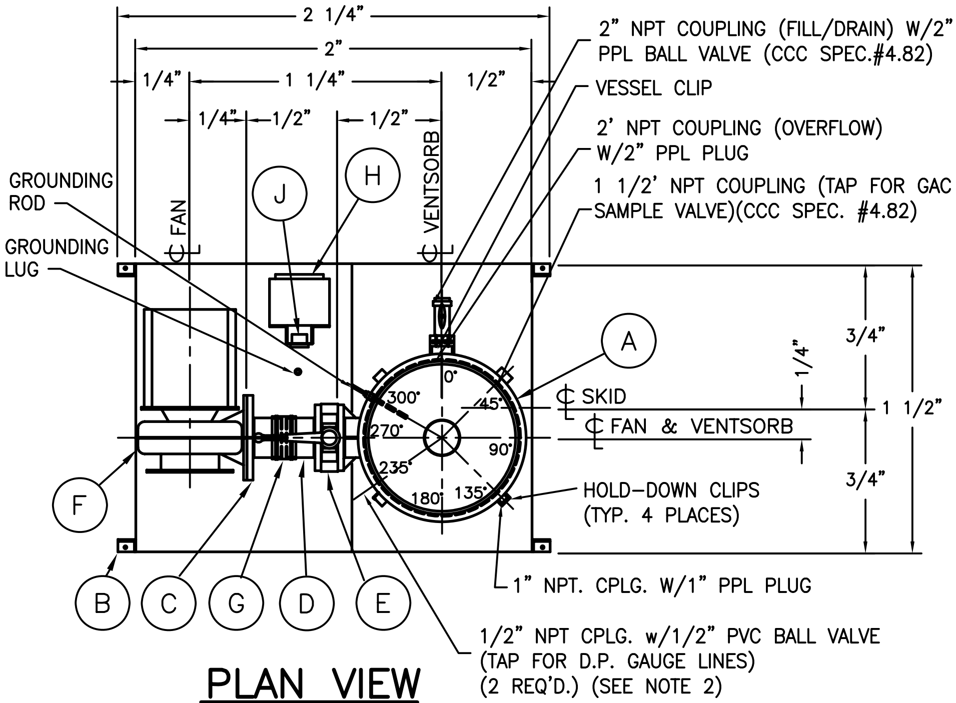
EXHIBIT 16-5
TYPICAL SKID MOUNTED CARBON ADSORBER DETAIL

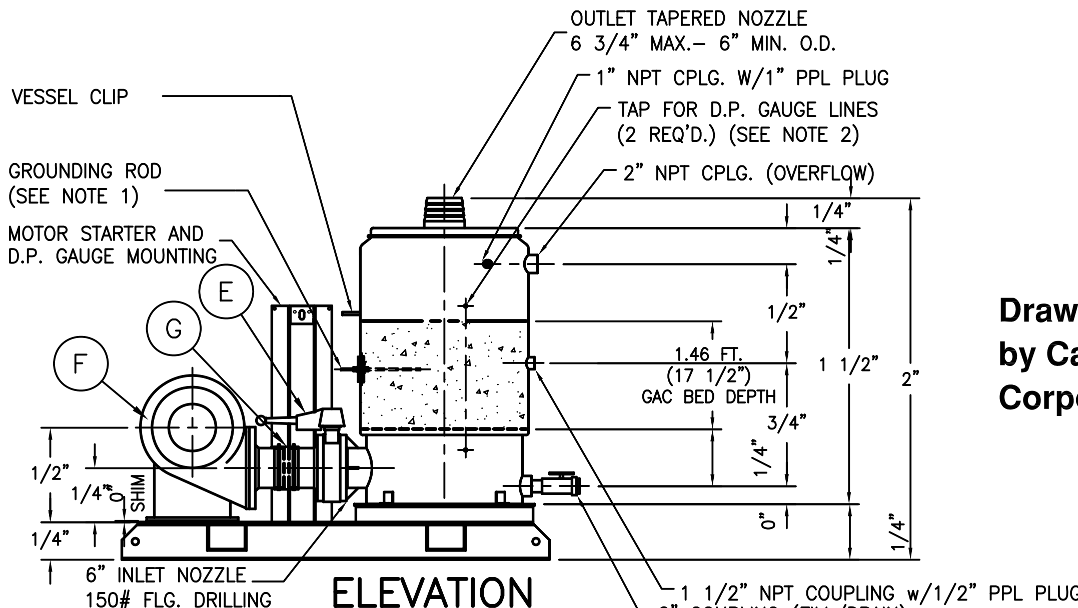
EFFECTIVE DATE: JUNE 30, 2009



PLAN VIEW

1. 3/8" THK. x 4 1/4" O.D. WALL REINFORCEMENT BOSS (1) INSIDE & (1) OUTSIDE. HOLE THRU VESSEL TO BE DRILLED CLOSE TO THE MIDDLE OF THE GAC BED. ROD TO EXTEND APPROX. 10" INTO GAC BED. GROUNDING ROD (316 STN STL.)

2. INSTALL 1/2" HALF-COUPLING OUTSIDE. THREAD 1/2" NPT PIPE NIPPLE INTO COUPLING. ATTACH 1/2" PVC ISOLATION VALVE. (CCC SPEC. #4.50) ATTACH 1/2" NPT X 1/4" TUBE SWAGELOCK S.S. MALE ELBOW. ATTACH LINES FROM DP GAUGE. (2 REQD-(1)ABOVE THE GAC BED AND (1)BELOW GAC BED)



ELEVATION

(APPURTENANCES ROTATED FOR CLARITY)
(SEE PLAN VIEW FOR PROPER ORIENTATION)

Drawing prepared by Calgon Carbon Corporation

BILL OF MATERIAL

MK#	REQD.	MAT'L.	DESCRIPTION
A	1	PE.	CANNISTER, 28" DIA. x 51" HIGH W/ 6" NOZZLES
B	1	C. STL.	MOUNTING SKID, 48" x 71 1/4" x 6 1/4" THK.
C	1	PPL.	FLANGED SPOOL (BLOWER SIDE)
D	1	PPL.	FLANGED SPOOL (VESSEL SIDE)
E	1	PVC	6" BUTTERFLY VALVE W/LEVER OPERATOR (3.16)
F	1	FRP	FRP FAN (SEE FAN DATA)(RFE-200)
G	1	SILICONE	6" FLEX BOOT W/2- STN. STL. CLAMPS
H	1	FRP	COMBINATION MOTOR STARTER
J	1	–	D.P. GAUGE (DWYER MINIHELIC – MODEL #5020)

ESTIMATED ASSEMBLED WEIGHTS:
EMPTY: 1,163#
OPERATING: 1,388#
FLOODED: 2,303#
CARBON CAPACITY: 225#

FAN DATA

CAPACITY:400 CFM@4553 RPM	RPM: 3600
PRESSURE: 10" SP	TYPE: TEXP
ARRG'T: 10	
ROTATION: CW-BH	S.F.: 1.15
ISOLATORS: YES	REMARKS: GRAPHITE
WEATHER GUARD: YES	IMPREGNATED

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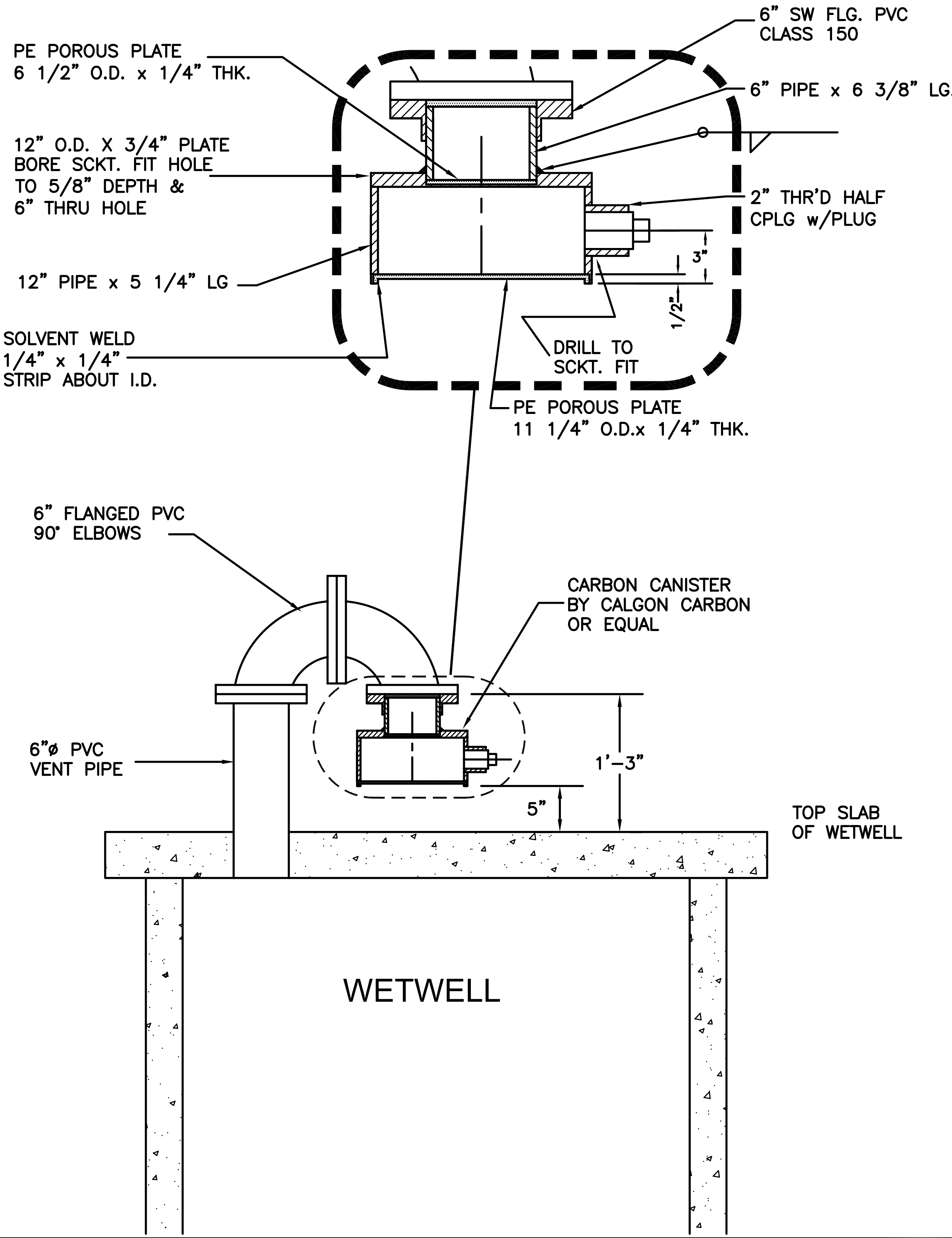
EXHIBIT 16-6
WETWELL VENT CARBON
CANISTER DETAIL

EFFECTIVE DATE: JUNE 30, 2009



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GEOTECHNICAL

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GEOTECHNICAL
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CHAPTER 17
GEOTECHNICAL

17.1 PURPOSE

This section establishes the minimum standards for performing geotechnical explorations on MSD projects. Geotechnical explorations are required on all MSD projects, unless otherwise directed by MSD. Reasons for performing geotechnical explorations include, but are not limited to, the following:

a. To establish the bedrock depth along the alignment of proposed sewers or at the location of proposed structures.

b. To determine the subsurface profile and properties (texture, moisture content, density, shear strength, compressibility, etc.) of soil and bedrock materials. This information is needed for the design of below grade structures, (wetwells, junction structures, tanks, etc.) building foundations, sheeting and bracing systems, retaining walls, stable channel slopes, pavements, and embankments. Additionally, this information is necessary when unsuitable foundation conditions are at the trench subgrade level or when unstable trench wall conditions are anticipated.

c. To investigate the subsurface conditions at tunnel or boring and jacking sites. The composition and nature of materials at underground crossings is needed to establish the conditions to be encountered (soft ground, hard ground, or mixed face tunneling) and the appropriate construction method.

d. To provide information regarding groundwater so that the contractor can plan for an adequate dewatering system.

e. To determine pavement section makeup, layer thickness and condition.

17.2 GENERAL

17.2.1 Right of Entry

When the geotechnical exploration work will require entry onto private property, the property owner shall be contacted, the work described, and permission to enter obtained. Efforts to contact property owners shall include telephone calls and the leaving of letters for those who are not at home. In some instances, MSD may deem it necessary to issue a letter of introduction and identification (on MSD's letterhead), which the geotechnical field party will provide to the owner. In the event that the owner does not grant permission, and it is evident that the geotechnical work will be delayed, MSD should be notified, in writing, immediately. It is the responsibility of MSD to take whatever course of action is deemed necessary to obtain the legal right of entry in accordance with state statutes.

17.2.2 Protection of Underground Structures and Utilities

Prior to drilling and sampling in public rights-of-way and easements, the Kentucky Underground Utility Protection Center (BUD) shall be called at 1-800-752-6007 and requested to mark the locations of existing underground facilities. At least 2-business days notice is required for service. BUD confirmation numbers should be documented so that a record for the request is available. Drilling should not begin until clearance has been provided or notification that all underground utility lines are marked has been received.

On private property, the BUD does not normally maintain records. It then becomes necessary to employ the property owner's assistance and knowledge of service lines, underground storage tanks, septic tank facilities and/or use visible surface features, such as meter vaults, shut-off valves, etc., to estimate the locations of underground facilities. Borings should be offset accordingly, if necessary, to avoid any conflicting utilities.

If there is any reason to believe that an underground facility exists in an area to be drilled, and its location cannot be determined with reasonable accuracy, then that boring should not be advanced.

17.2.3 Erosion Prevention and Sediment Control/Ground Restoration

All efforts should be extended to avoid rutting, especially in residential areas. Ruts should be repaired with leveling the area with topsoil and seeding or sodding as required by MSD or as agreed upon with the property owner.

When using a truck-mounted drill rig, efforts should be made to access boring locations without crossing streams. In the event that crossing a stream is necessary to access a critical boring location, a ford in the stream, which is regularly used by the property owner, should be used after receiving approval from the property owner and MSD. Any rutting should be repaired with seeding and sodding as described above.

Dozer roads cut to permit access to boring and sounding locations should be leveled and seeded and strawed immediately following completion of the work.

Upon completion, borings should be completely backfilled from the bottom to the ground surface, using excavated cuttings. Reversed auger rotation or down pressure on the drill tools should be used to achieve compaction. In sodded areas, the sod should first be carefully cut, lifted from the boring site, and set aside. After backfilling, the sod should be replaced over the boring and tamped. Asphalt cold patch or concrete should be used to repair borings in pavements.

When drilling around sinkholes or at a site with the potential to drain storm water directly into a water feature (including streams, lakes or impoundments, or along steep slopes), special care should be taken to place all auger cuttings back into the hole. If excess cuttings remain, they should be removed from the site.

17.3 DRILLING AND SAMPLING

17.3.1 Methods and Equipment

Unless otherwise authorized by MSD, power equipment shall be utilized to obtain geotechnical data. In most cases, this will involve a truck or skid-mounted soils drilling rig equipped with continuous flight mechanical augers. In some instances it may be advantageous to use an air track rock drill if only rock soundings are being performed. In areas where drilling rig access is restricted with steep slopes, heavy woods, soft ground, or where the rock surface is known to be shallow with reasonable assurance (for example, next to a rock bottom stream), MSD may permit the use of manually driven sounding rods or hand augers.

In general, all soil test borings shall be performed in accordance with ASTM D 1586 "Standard Method for Penetration Test and Split Barrel Sampling of Soils". Split-barrel samples shall be taken at five-foot depth intervals and at changes in strata. When undisturbed samples in clay soils are required (for example, when shear strength determinations are needed), samples should be obtained in accordance with ASTM D 1587 "Standard Practice for Thin-Walled Tube Sampling of Soils".

Observation wells should be installed in completed soil borings whenever groundwater is encountered during the drilling process. Casing should be of 1-inch diameter field slotted PVC pipe. Water table readings should be obtained from observation wells no sooner than seven days from completion of the boring.

Rock core drilling shall be performed in accordance with ASTM D 2113 "Standard Practice for Diamond Core Drilling for Site Investigation", except when wire line drilling is permitted. The diameter of the rock core shall not be less than 2-1/8 inches.

Limestone formations are prevalent across much of Jefferson County. Rock remnants and hard clay soils are sometimes encountered above the top of rock in these formations. Accordingly, when performing rock line soundings with mechanical augers, the field crew should note the depth intervals of any rock remnants or hard clay soils encountered above the top of rock.

17.3.2 Location, Frequency and Depth Requirements for Soundings and Borings

When required, rock soundings should be performed at intervals of 50 feet where rock is encountered and 100 feet where rock is not encountered along the proposed alignment of collector and interceptor sewers, manholes, pump stations, and underground structures. The soundings should be advanced to a maximum depth, which corresponds to one foot below the invert elevation or to auger refusal, whichever occurs first. The requirements for rock soundings may be waived by MSD in areas of the Jefferson County where the bedrock surface is known to be deeper than excavation depths.

The requirements for soil test borings will be evaluated by MSD on a project-by-project basis. In general, soil test borings will be required for sewers located in areas with deep, potentially unstable soils or where high groundwater may be expected. When required, soil test borings should be drilled at approximate intervals of 500 feet and should be terminated 4 feet below the invert elevation or at auger refusal, whichever occurs first. If bedrock occurs higher than the invert elevation, then rock core drilling should extend the boring to 2 feet below the invert elevation.

Whenever possible, the boring plan should be developed to position test borings at locations of special interest. For example, test borings should be sited at the deepest excavation or where the open trench may affect existing buildings or major utilities. Borings should be drilled at the access pits or shafts of tunnels. If access is available, intermediate borings along the tunnel alignment should be advanced at 100-foot intervals. For large pump station and wastewater treatment plants, the number of borings needed may vary based on the number and layout of the individual facilities.

17.4 LABORATORY ANALYSES

Representative split-barrel samples should be analyzed for Atterberg limits, (ASTM D 4318) particle size distribution (ASTM D 422), specific gravity (ASTM D 854) and moisture content (ASTM D 2216). The samples should then be classified in accordance with ASTM D 2487 "Test Method for Classification of Soils for Engineering Purposes". Representative samples of soil materials, which are to be placed and compacted to controlled moisture-density conditions, should be subjected to Standard Proctor moisture-density tests (ASTM D 698) to determine the maximum dry density and optimum moisture content. Additionally, for any projects requiring pavement design, representative samples of proposed subgrade soils should be subjected to laboratory California Bearing Ratio tests (ASTM D 1883) to provide design CBR values.

When shear strength parameters are required for geotechnical analyses, these parameters should be determined as follows. The shear strength for non-cohesive materials (sand and sand-gravel mixtures) should be measured in accordance with ASTM D 3080 "Standard Test Method for Direct Shear Test of Soils under Consolidated-Drained Conditions". The undrained shear strength for cohesive soils (clays) should be measured in accordance with ASTM D 2166 "Standard Test Method for Unconfined Compressive Strength of Cohesive Soil". The drained shear strength for cohesive soils should be measured in accordance with ASTM D 4767 "Standard Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils."

17.5 REPORT DEVELOPMENT AND DRAFTING

Reports of geotechnical explorations should include discussions on the project, general site conditions, site geology, scope of work, results of the exploration, and conclusions and recommendations relative to the proposed design and construction. More specifically, the site description should include discussions of the site topography, site drainage characteristics, any existing improvements, etc. Descriptions of the site geology should include underlying soil types and rock formations. Other geologic features such as faults or susceptibility to sinkholes should also be included. A description of the scope of work should also be provided and should include a complete description of the drilling, sampling, and laboratory analysis programs. The results of the exploration should include descriptions of soil types, depths, the presence of any groundwater, etc. Descriptions of rock cores should note the presence of joints, voids, mudseams, recovery ratios and rock quality designation values. References to site locations should also be included. In addition, any engineering analysis performed (slope stability, settlement, etc.) should be discussed. Finally, the conclusions and recommendations relative to design and construction from a geotechnical standpoint should be included.

When submitting the results of rock line soundings, the depth intervals of any rock remnants or hard clay soils encountered above the top of rock should be reported.

Geotechnical exploration data, including boring locations, graphical boring logs, sounding symbols, penetration test blowcounts, unconfined compressive strengths, natural moisture contents, groundwater elevations, top of rock elevations, etc., should be placed on the plan and profile drawings by the Design Engineer. The drawings should reflect the difference between soundings performed with mechanical augers and soundings performed with manually driven sounding rods. For intervals that have been sounded by mechanical augers and by manually driven soundings rods, report both sets of data. The elevations of any rock remnants or hard clay soils encountered above the top of rock should also be noted on the drawings. Refer to the MSD Geotechnical Legend Sheet, Exhibit 17-1, for the appropriate symbols. MSD's drafting standards as outlined before should be followed.

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EXHIBIT 17-1
GEOTECHNICAL LEGEND SHEET

EFFECTIVE DATE: JUNE 30, 2009

RQD (%)	Rock Quality
90–100	Excellent
75–90	Good
50–75	Fair
25–50	Poor
0–25	Very Poor

LIMESTONE

SANDSTONE

NONDURABLE SHALE (SDI≤89)

DURABLE SHALE (SDI≥90)

Description of Soil Relative Density or Consistency

SOIL TYPE	RELATIVE DENSITY OR CONSISTENCY	RANGE OF PENETRATION RESISTANCE	RANGE OF UNCONFINED COMPRESSIVE STRENGTH
Fine grained soils (More than half of material is smaller than No. 200 sieve size)	Very Soft Soft Medium Stiff Very Stiff Hard	Less than 2 blows per foot 2 – 4 4 – 8 8 – 15 15 – 30 >30	Less than 0.25 tsf 0.25 – 0.50 0.5 – 1.0 1.0 – 2.0 2.0 – 4.0 >4.0 tsf
Coarse grained soils (More than half of material is larger than No. 200 sieve size)	Very loose Loose Medium Dense Very Dense	Less than 4 blows per foot 4 – 10 10 – 30 30 – 50 >50	Not Applicable

Unified Soil Classifications

MAJOR DIVISIONS		SYMBOL	NAME
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sands, little or no fines
		SM	Silty Sands, sand-silt mixture
		SC	Clayey sands, sand-clay mixture
FINE GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	SILTS AND CLAYS LL IS GREATER THAN 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
UNCLASSIFIED MATERIAL		NONE	Non-classified material (i.e. concrete, asphalt, crushed stone, cinders, slag, rubble, talus, etc.) Include visual description

AI	Activity Index
LI	Liquidity Index
N	Penetration Resistance
S+C(%)	Material finer than No. 200 sieve
•S	Location of Sounding
•SB	Location of Soil Boring
◉	Location of Soil Boring and Rock Core
▽	Water Elevation
▮	Thin-walled Tube Sample
<	Standard Penetration Test Sample
Qu	Unconfined Compressive Strength
w(%)	Moisture Content
RQD(%)	Rock Quality Designation
SDI(%)	Slake Durability Index
Rec.(%)	Core Recovery
ϕ	Angle of Internal Friction
$\bar{\phi}$	Effective Angle of Internal Friction
c	Cohesion
$\bar{c}$	Effective Cohesion
γ	Total Unit Weight
⊻ M	Manual Rod Sounding – No Rock Encountered
M	Manual Rod Sounding to Rock
⊻ A	Auger Sounding – No Rock Encountered
A	Auger Sounding to Rock

PLANS PREPARED AND SUBMITTED BY:

CONSTRUCTED BY:

FINAL RECORD DRAWING BY:

MSD GEOTECHNICAL LEGEND
PROJECT NAME
PROJECT DESCRIPTION

CHAPTER 18
POST-CONSTRUCTION WATER QUALITY BEST MANAGEMENT PRACTICES

Table of Contents

18.1 INTRODUCTION AND PURPOSE

The Post-Construction Water Quality Best Management Practices chapter of the Design Manual was originally published in 2013 pursuant to Louisville Metro's Municipal Separate Storm Sewer System permit requirements and Article 6 of the MSD Wastewater/Stormwater Discharge Regulations to establish and enforce a water quality treatment standard and to promote clean, safe waterways in our community. Post-construction water quality best management practices (BMPs) improve water quality by treating stormwater that flows through drainage conveyances and storm sewers into streams by capturing, filtering and/or infiltrating stormwater.

Rain Garden at the Northeast Library

Planning strategies must meet the minimum requirements identified in this section to comply with MSD's post-construction water quality requirements. However, as part of the planning process, additional benefits should be considered such as over-sizing BMPs for flood reduction benefits and ancillary benefits of BMPs, such as reduction in heat island effects.

Federal and local regulatory programs can impact water quality and quantity. This section provides an overview of the basic regulatory programs. The regulatory programs outlined should not be considered static, as requirements of regulatory programs frequently change over time. Therefore, the designer should always consult pertinent statutes and ordinances when developing a project. Where regulations are in conflict, the more restrictive requirements shall be applied.

18.1.1 Acronyms

ASTM American Society of Testing and Materials

BMP Best Management Practice

CFR Code of Federal Regulations

CFS Cubic Feet per Second

CSO Combined Sewer Overflow

CSS Combined Sewer System

EPA Environmental Protection Agency

EPSC Erosion Prevention & Sediment Control

ESAL Equivalent Single Axle Load

FPS Feet per second

H:V Horizontal: Vertical

IOAP Integrated Overflow Abatement Plan

KDOW Kentucky Division of Water

KPDES Kentucky Pollutant Discharge Elimination System

KRS Kentucky Revised Statutes

KYTC Kentucky Transportation Cabinet

MS4 Municipal Separate Storm Sewer System

O&M Operation & Maintenance

PVC Polyvinyl Chloride

RE Required Water Quality Volume Rain Event

SSO Sanitary Sewer Overflow

TSS Total Suspended Solids

USACE United States Army Corps of Engineers

VP Water Quality Volume Provided

VR Water Quality Volume Required

WQV Water Quality Volume

18.1.2 Definitions

Aquatic Bench Shallow areas around the edge of a wet basin that sustains vegetation and that provide water quality benefits.

Best Management Practice Schedules of activities, prohibitions of practices, treatment requirements, operating (BMP) procedures, and other various protocols used to prevent or reduce the discharge of pollutants to the Waters of the United States.

Bioswale Stormwater conveyance features that mimic ecological function of a landscape, often serving as replacements to open ditches or underground pipes.

Catch Basin Insert Device added to catch basins for the purpose of capturing or retaining stormwater pollutants including sediment, debris, oils or metal.

Check Dam Small stone dam built across minor channels, swales, bioswales, or drainage ditches; used to reduce erosion and allow pollutants/sediments to settle.

Choker Course a finer aggregate layer placed above more course the base aggregate layer in permeable pavement design for leveling of the surface material.

Class V Injection Well Defined by EPA as a bored, drilled or driven shaft or a dug hole that is deeper than it is wide, an improved sinkhole or a subsurface fluid distribution system.

Clean Water Act An act by which congress mandated that the EPA address non-point source pollution in stormwater runoff.

Combined Sewer Overflow An outfall, which MSD is authorized to discharge during wet weather, as defined by MSD's KPDES permit for the Morris Forman WWTP.

Combined Sewer System (CSS) The portion of MSD’s Sewer System designed to convey municipal sewage (domestic, commercial, and industrial wastewaters) and stormwater runoff through a single-pipe system to MSD’s Morris Forman WWTP or CSOs.

Compost Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Constructed Wetland Stormwater management practices that are generally shallow, except for pool areas and contain dense native aquatic vegetation. Constructed wetlands temporarily store stormwater runoff, treat pollutants and create habitat.

Cultivar A plant cultivated for its desirable characteristics and often used in ornamental or landscaped gardens.

Detention Managing stormwater runoff or sewer flows through a temporary holding and controlled release.

Dry Well See Class V Injection Well.

Emergency Spillway Gates or structures that regulate the passage of flood flows around the dam or containment structure.

Energy Dissipater A mechanism to break up and slow the flow of water.

Erosion Detachment and movement of soil or rock fragments by water, wind, ice or gravity.

Evapotranspiration The combined loss of water from a given area and during a specific period of time, by evaporation from the soil and by transpiration from plants.

Exfiltration A method for managing stormwater runoff whereby stormwater enters and travels through green infrastructure from the surface and drains into subsurface soils.

Extensive Green Roof A stormwater management practice comprised of a roofing system consisting of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive roofs have soil depths of six inches or less that is designed to support dense, low growing, drought tolerant vegetation.

Filter Fabric A woven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.

First flush The first portion of runoff generated by rainfall event and containing the main portion of the pollutant load resulting from the rainfall.

Floatable A type of litter pollution that floats on the surface of stormwater, typically bottles, cans, styrofoam containers or other trash.

Forebay A manmade pool of water in front of a larger body of water, often used for energy dissipation and debris collection.

Freeboard A vertical distance between the elevation of the design high water and the top of a dam, levee or diversion ridge.

Frost Heave Uplift of soil or pavement surface due to expansion of groundwater upon freezing.

Geogrid Manufactured soil reinforcement products that stabilize subsurface conditions through a multi-directional load distribution grid.

Gray Infrastructure Constructed structures such as treatment facilities, sewer systems, stormwater systems, or storage basins. The term “gray” refers to the fact that such structures are typically made of, or involve the use of concrete.

Green Dry Basin Stormwater management practices that are similar to standard dry basins, except that they contain a forebay for capturing the heavier sediment and floatables, non-turf grass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm events and no low flow channel so sheet flow can be promoted. Water quality benefits include uptake and filtering through deep rooted, native plants; extended detention time to encourage increased particle settling; temporary stormwater detention; and a slower rate of release that reduces downstream bank erosion.

Green Infrastructure An adaptable term used to describe various materials, technologies, and practices that use natural systems—or engineered systems that mimic natural processes— to enhance overall environmental quality and provide utility services. As a general principal, greeninfrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. Examples of green infrastructure include green roofs, porous pavement, rain gardens, and tree boxes.

Green Wet Basins Stormwater management practices that are similar to standard wet basins, except that they contain an aquatic bench along the perimeter of the pond just below the normal pool level and possibly other plantings above the normal pool elevation in the extended portion of the basin. Water quality benefits include uptake and filtering through deep rooted, native plants; extended detention time to encourage increased particle settling; temporary stormwater detention; and a slower rate of release that reduces downstream bank erosion.

Heat Island Effect Causes an area to be consistently warmer than its surrounding rural area, often due to urban development. Affects communities by increasing energy demand, air pollution, and water quality.

Impaired Waters Surface water that is negatively impacted by pollution, resulting in decreased water quality. Kentucky Division of Water publishes impaired waters in its 303(d) list.

Impervious surface Surfaces that do not allow water to permeate or infiltrate through the material, such as paved roadways, sidewalks, rooftops, etc.

Infiltration The process through which stormwater runoff penetrates into the soil from the ground surface.

Infiltration Rate A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions including the presence of an excess of water.

Infiltration Trench Shallow, excavated areas that receive stormwater that are typically filled with aggregate and contain no outlet structure.

Inlet A place or means of entry into the stormwater system.

Intensive Green Roof A stormwater management practice comprised of a waterproof layer, drainage system, engineered soils and vegetation. Intensive green roofs have soil depths greater that six inches to support the root growth of larger vegetation, including: plants, shrubs and trees.

Invasive Species A non-native species that adversely affect the habitats that they invade by disrupting the natural balance of the habitat either by dominating resources, habitat or native species.

MS4 Permit Program Municipal Separate Storm Sewer System; Permitted by the Kentucky Division of Water, operated by MSD with its co-permittees including Louisville Metro and the Cities of Anchorage, Jeffersontown, St. Matthews and Shively.

Mulch A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover and minimizes temperature fluctuations.

Nonpoint Source Pollution The EPA defines this term as any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground and carrying with it pollutants that are eventually deposited in lakes, rivers, wetlands, coastal waters and ground water.

Nutrients A type of water pollution that degrades waterways. Nutrients including excess nitrogen and phosphorous lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat.

Outlet The point at which water discharges through a pipe or drain.

Overland Flow Surface runoff that occurs when soil is saturated and excess water from rain or snowmelt flows over the land.

Pathogen An organism capable of causing disease, including disease-causing bacteria, protozoa, and viruses.

Peak Flow The maximum flow of water during a storm event, usually expressed in CFS (cubic feet. per second).

Permeable Pavers Pavement surfaces that promote infiltration of stormwater that consist of individual concrete or stone shapes that are placed adjacent to one another over a sub-base.

Permeable/Pervious/Porous Allows water to pass through.

Pervious Concrete A permeable pavement that allows the water to infiltrate into the subsoil through the pavement surface and base layers.

Phosphorus A type of nutrient pollution that causes degradation of waterways. See Nutrients.

Planters Are similar to rain gardens and bioretention basins in that they detain, filter and infiltrate stormwater; and are suitable for plants ranging from native flowers to shrubs or small trees. They are most commonly used as infiltration of stormwater runoff from rooftop downspouts.

Pretreatment The process removing pollutants from stormwater before entering green infrastructure and either infiltrating into subsurface soil or exiting into waterways or water bodies.

Proprietary Water Quality Units A manufactured structure connected to a storm sewer system that removes debris and pollutants from stormwater runoff through mechanical or hydrodynamic means.

Rain Garden A stormwater management practice, sometimes referred to as bioretention cells, bioinfiltration cells, or biofiltration cells which are shallow stormwater basins that mimic the ecological functions of a natural landscape. Rain gardens contain deep rooted vegetation or cultivar species to filter and infiltrate stormwater.

Recharge Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Retrofit Refers to the addition of new technology or features to older systems.

Riparian Area Ecosystems that occur along waterways or bodies of water.

Sanitary Sewer A pipe or conduit (sewer) intended to carry wastewater or water-borne wastes from homes, businesses, and industries to the publicly owned treatment works.

Sanitary Sewer Overflow (SSO) Any discharge of wastewater to Waters of the United States from MSD's Sewer System through a point source not authorized by a KPDES permit, as well as any release of wastewater from MSD's Sewer System to public or private property that does not reach Waters of the United States, such as a release to a land surface or structure that does not reach Waters of the United States; provided, however, that releases or wastewater backups into buildings that are caused by blockages, flow conditions, or malfunctions in a building lateral, or in other piping or conveyance system that is not owned or operationally controlled by MSD are not SSOs.

Sensitive Areas Areas of particular environmental significance or sensitivity as determined by the Kentucky Pollutant Discharge Elimination System (KPDES) permitting authority in coordination with State and Federal agencies, that include Outstanding National Resources Waters, waters with threatened or endangered species and their habitats, waters with primary contract recreation, public drinking water intakes or their designated protection areas.

Spillway See Emergency Spillway.

Stipend A stipend is a short-term financial incentive for green infrastructure construction cost recovery.

Stormwater Water runoff that is a result of natural precipitation.

Stream Defined by the Clean Water Act, see Waters of the US.

Treatment Train The use of multiple BMPs in series on a site to meet the water quality volume requirement for stormwater management.

Tree Box provides similar benefits as a rain garden/bioretention basin in its design purpose and stormwater benefits by infiltrating, treatment, temporary detention, and biological uptake using trees and tall bushes.

Turbidity The cloudiness of a fluid caused by microscopic particles suspended in the fluid.

Underdrain A pipe or series of pipes that run longitudinal with the ground surface and capture excess stormwater to allow the green infrastructure practice to drain.

Underground Storage The practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures with the intent of releasing the stormwater runoff to the surface drainage system at a reduced rate and completely drained prior to the next rain event, similar to a green dry detention pond.

United States Environmental Protection Agency The federal agency responsible for enforcing the Clean Water Act, Safe Drinking Water Act and other federal environmental regulations.

Urbanization The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.

Vegetated Buffer Uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff, generally consisting of native, deep rooted grasses, shrubs and trees.

Water Quality A term used to describe the chemical, physical and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Quality Standards Standards that set the goals, pollution limits, and protection requirements for each waterbody. These standards are composed of designated (beneficial) uses, numeric and narrative criteria, and antidegradation policies and procedures.

Water Table The upper surface of the free groundwater in a zone of saturation; locus of points in subsurface water at which hydraulic pressure is equal to atmospheric pressure.

Waters of the United States As defined in 40 CFR I22.2: and the Clean Water Act.

Watershed Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.

Wetlands A region of land whose soil is saturated with moisture permanently or seasonally.

18.1.3 Kentucky Pollutant Discharge Elimination System Permit for Stormwater Quality

Louisville Metro's Municipal Separate Storm Sewer System (MS4) is regulated by the Kentucky Pollutant Discharge Elimination System (KPDES) Permit, as required by the Clean Water Act, which is administered by Kentucky Division of Water. MSD, the City of Anchorage, the City of St. Matthews, the City of Jeffersontown, the City of Shively and Louisville Metro are MS4 co-permittees and collaborate to meet permit requirements. As a result of this co-permittee relationship, Louisville MSD leads, implements and enforces designated permit activities, including post-construction stormwater management. Post-construction stormwater management is regulated through MSD's Wastewater/Stormwater Discharge Regulations (WDRs).

18.1.4 MSD Wastewater/Stormwater Discharge Regulations (WDRs)

Effective August 1, 2013, MSD amended the WDRs to include post-construction minimum control measures and green infrastructure. The post-construction requirements apply to all new development and redevelopment with a disturbed area equal to or greater than one (1) acre, including projects less than one acre that are part of a larger common plan of development or a common scheme of development equal to or greater than one acre, located in the City of Louisville, Jefferson County, and the incorporated cities of Jefferson County. Water quality best management practices (BMPs) must treat at least 90% of the impervious area on the site. Pursuant to the WDRs, MSD has the authority to:

- Review and approve post-construction plans
- Perform pre-construction site meetings, inspections and negotiated compliance efforts in the enforcement of these regulations
- Provide education and training program for contractors
- Develop, implement, and administer a post-construction Best Management Practice Long-Term Maintenance Program
- Administer and manage a fee in lieu program

18.1.5 Impacts of Stormwater Management

With urbanization, naturally occurring pervious areas are reduced and replaced with impervious surfaces. Urbanization also increases the types and amounts of pollutants that enter local streams and drainage ways. Some of the increased pollutant runoff is due to the increased stormwater runoff volume. Research indicates that small frequently occurring rain events account for a significant amount of the pollutants generated from stormwater runoff. Pollutants typically found in stormwater runoff include the following:

- Nutrients
- Bacteria and pathogens
- Petrochemical products
- Heavy metals
- Pesticides and herbicides
- Thermal pollution
- Sediments
- Deicers
- Floatables

Floatables in Middle Fork Beargrass Creek at Cherokee Park

A summary of the potential pollutants including pollutant sources and pollutant impacts is provided in the following paragraphs.

Nutrients Naturally occurring nutrients, such as phosphorous and nitrogen, are commonly found in manmade fertilizers which are typically used on lawns, golf courses, parks, and construction sites to promote vegetative growth. These chemicals can disrupt the aquatic ecosystem through increased vegetative and algae growth, which can result in lower dissolved oxygen (DO) levels, as well as taste and odor problems. Lower DO levels are caused by the decomposition of organic materials in waterways and algae respiration. The resulting lower DO levels can lead to fish kills and the loss of sensitive aquatic species.

Bacteria and Pathogens
Bacteria and pathogens can impact human health when they enter the body through ingestion or open wounds. Coliform bacteria originate from human and animal waste, including wildlife and domestic animals. Leaking sewer systems, failing septic systems, sanitary sewer overflows (SSOs) and combined sewer overflow (CSOs) are also potential sources of these pollutants.

Petrochemical Products
Petrochemical products such as plastics and cosmetics enter the waterways through litter, garbage can overflows, and mishaps in the waste collection process. These products travel and gather in our streams. Accumulated plastics modify the structures of aquatic habitat, reduce light levels to deeper waters, and often deplete oxygen levels. Furthermore, aquatic life ingests these toxic products, which alter the biological processes within aquatic organisms.

Heavy Metals
Heavy metals originate from such sources as preserved wood, paint, and metals from automobile tires and brake liners. These enter the waterways through corrosion, flaking, dissolving, decaying or leaching. Heavy metals are toxic to aquatic organisms, terrestrial wildlife, and humans, can be bioaccumulative, and can contaminate drinking water supplies.

Pesticides and Herbicides
Pesticides and herbicides, used to control vegetation, , have the potential to enter water sources through storwater runoff. Both can be toxic to aquatic life and terrestrial wildlife, as well as the general public.

Thermal Pollution
The change of ambient water temperature can affect the level of DO in the water and the life cycle of some aquatic species. Water temperature can be increased by cooling waters used by power plants, as well as urban runoff and loss of tree canopy. As water temperature increases, DO levels decrease, which is harmful to aquatic animals and can promote algae growth.

Sediments
The amount of particulate matter in water is usually measured by total suspended solids (TSS), which is the amount of solids suspended in a water column. Fine sediments can become suspended in water affecting the clarity of water, or turbidity. Sediment typically comes from soil/streambank erosion, construction activities, or roadways. The impacts from excessive sediment include: stream warming, transportation of pollutants during rain events, destruction of stream habitats, declines in certain sensitive mussel, fish and macroinvertebrate populations, and decreased flow capacity of pipes and channels, which can lead to localized flooding. Water that is too turbid does not allow sunlight to penetrate the water and grow phytoplankton, which are the foundation for the aquatic food chain.

Deicers
Deicers are used to melt snow and ice from roadways and walkways. Deicers can harm aquatic life by increasing salt levels and conductivity within stormwater runoff that enters streams and rivers.

Floatables
Floatables include trash and organic materials such as leaves, grass, and other yard waste that float on the surface of the water. Floatables are unsightly and can damage aquatic habitats. As organic floatables decompose, they deplete the level of DO needed by fish and other aquatic organisms.

18.1.6 BMP Benefits to Water Quantity and Quality

Pollutant loadings to local waterways can be decreased by treating and reducing stormwater runoff. Table 18.1 contains a summary of the relative pollutant treatment and stormwater management benefits that can be provided by well-maintained BMPs. The intent of this table is to provide a brief summary of the potential benefits of the recommended BMPs including: pollutant reduction, hydrologic characteristics, and a reduction in potential runoff volumes.

18.1.7 Resources

Plan review requirements, checklists, calculation sheets, stormwater quality long-term maintenance agreements, and other resources are available on MSD's website, www.louisvillemsd.org.

Table 18.1 Water Quality BMP Summary								
● Significant Benefit ◐ Partial Benefit ○ Low or Unknown Benefit	**Pollution Reduction**							
	Sediment	Phosphorus	Nitrogen	Metals	Pathogens	Floatables	Oil and Grease	Dissolved Pollutants
Rain Gardens	●	◐	◐	◐	◐	◐	◐	◐
Bioswales	●	◐	◐	◐	◐	◐	◐	◐
Constructed Wetlands	●	◐	◐	◐	◐	◐	◐	◐
Green Wet Basins	●	◐	◐	◐	◐	◐	◐	◐
Green Dry Basins	●	◐	◐	◐	○	◐	◐	○
Green Roofs	○	○	○	○	○	○	○	○
Permeable Pavers	◐	○	◐	◐	○	○	○	○
Tree Boxes	●	◐	◐	◐	○	◐	◐	◐
Vegetated Buffers	◐	◐	◐	◐	○	◐	○	○
Underground Storage	◐	○	○	○	○	◐	○	○
Catch Basin Inserts	◐	○	○	◐	○	◐	◐	○
Proprietary Water Quality Units	Varies by Technology							
Infiltration Trenches	●	●	●	●	◐	◐	◐	◐

Table 18.1 Water Quality BMP Summary (continued)

● Significant Benefit ◐ Partial Benefit ○ Low or Unknown Benefit	Hydrologic Characteristics				Runoff Volume Reduction
	Surface Flow Reduction	Infiltration	Stormwater Conveyance	Peak Flow Control	Runoff Capture
Rain Gardens	◐	●	○	◐	●
Bioswales	◐	◐	●	◐	◐
Constructed Wetlands	◐	○	◐	◐	○
Green Wet Basins	◐	○	◐	◐	○
Green Dry Basins	◐	◐	◐	◐	◐
Green Roofs	●	○	○	◐	◐
Permeable Pavers	●	●	○	○	●
Tree Boxes	◐	◐	○	○	◐
Vegetated Buffers	◐	◐	◐	○	◐
Underground Storage	◐	●	○	●	●
Catch Basin Inserts	○	○	○	○	○
Proprietary Water Quality Units	Varies by Technology				
Infiltration Trenches	●	●	○	◐	●

18.2 SELECTION PROCESS

18.2.1 Introduction

The purpose of this section is to provide guidance for managing the water quality requirements on a project site. The primary goal of a BMP is to provide water quality improvements before runoff leaves a site. Although the process for selecting BMPs is the same for all sites, the BMP selections will vary from site to site. It is important for a design professional to consider and assess numerous factors, including but not limited to: site characteristics, the Water Quality Volume (VR) required to be managed on a site, site design, constructability of BMPs, and long-term operation and maintenance of BMPs. This section provides the process for selecting post-construction water quality design components for a site, but is not intended to address every site planning or design variable that a designer may encounter. The application of sound engineering, planning, surveying principles and judgment apply. Approval of plans pursuant to this process does not relieve the designer from required compliance with the other sections of the MSD Design Manual and other applicable standards.

The BMPs in the MSD Design Manual should be considered as a list of tools and implemented based on the site conditions, and stormwater management needs to comply with the Clean Water Act and post-construction stormwater water quality requirements.

18.2.2 Water Quality BMP Practice Selection Steps

Developing a post-construction water quality project involves considering long-term BMPs throughout the life of the project, from the concept stage through the final design and subsequent operation and maintenance.

STEP 1: Determine Required Water Quality Rain Event (RE)*

RE = 0.60 inch (80th percentile storm)*

* RE requirements may be greater than 0.60 inch for projects applying for MSD financial incentives

STEP 2: Calculate Water Quality Volume Required (VR)

$$VR \text{ (cubic feet)} = (1/12)(RE)(A)(0.05+(0.009)(I))$$

where I = Percentage of impervious cover and
A = Disturbed drainage area in square feet

STEP 3: Select the appropriate BMP(s) and determine water quality volume provided (VP) for each selected BMP**

Consideration should be given to selecting BMPs with runoff reduction abilities. The water quality volume calculation for each BMP type can be found in Section 18.4 for each BMP type.

**See Section 18.4.10 for design criteria related to water quality units

STEP 4: Verify total Volume Provided (VP) for all BMPs is greater than VR determined in Step 2

The designer should experiment with various BMPs or a combination of BMPs until VR is managed and/or treated. If the total VP is greater than or equal to VR, then the designer can move to Step 5. BMPs must be oversized (up to 10%) to account for areas that bypass the BMP. The VP of the BMP or the sum of the BMPs must always be equal to or greater than VR.

$$\sum VP = \sum VP_1 + VP_2 + \ldots \text{ for each BMP}$$

STEP 5: Provide Operation and Maintenance (O&M) Documentation, including an operation and maintenance plan and signed Long Term Operation and Maintenance Agreement

During Step 5 of the selection process for BMPs, consideration should be given to operation and maintenance of BMPs, including documentation requirements (see 18.7 for details on operation and maintenance needs).

18.2.3 Minimum Design Requirements

18.2.3.1 Runoff Capture

Runoff from at least 90% of the site's disturbed impervious area is required to be managed or treated by a BMP. This allows for flow from discharges at property lines or locations with little to no setback to be accommodated. In these instances other site BMPs must be oversized to capture additional VR to make up the difference for the total site water quality volume. The maximum oversizing of BMPs to account for bypassing site area shall be 10%.

18.2.3.2 Pretreatment

Pretreatment practices are required for underground infiltration basins, wet and dry basins, and constructed wetlands and are recommended for other practices to facilitate long-term maintenance and extend the life of the practice. Protection of BMPs from erosive velocities and clogging from sediment is critical to sustain designed soil infiltration rates. Once this material becomes clogged, the practice must be excavated and reinstalled.

The following pretreatment measures may be used:

- Forebay
- Vegetated strip
- Proprietary water quality unit
- Catch basin inserts

Proprietary water quality units and vegetated strips can be used as pretreatment or as stand-alone BMPs. Design criteria for proprietary water quality units and vegetated strips are located in 18.4. Forebays are typically used for rain gardens, constructed wetlands, and wet and dry basins. Design criteria for forebays for each BMP are located within each section in 18.4. Design criteria for catch basin inserts is discussed in more detail in the following subsection.

18.2.3.2.1 Catch Basin Inserts

Catch Basin Inserts are devices added to catch basins for the purpose of capturing or retaining stormwater pollutants including sediment, debris, oils or metal. They may only be used as pretreatment for other BMPs, and cannot receive credit toward a site's required water quality volume.

They are are installed underneath the grate of an inlet to remove sediment, debris, oils or metals from stormwater inflow by filtering, settling or absorbing pollutants. Catch basin inserts are beneficial because they install easily in retrofit systems and work well in a treatment train as they minimize clogging in downstream water quality features.

Because of their minimal storage capacity for captured sediment, catch basin inserts should only be used where appropriate. They are suitable for use in unpaved areas with minimal erosion or in parking lots with a small drainage area but are not suitable for receiving runoff from areas with heavy sediment flow.

Performance ability and size vary based on the manufacturer and/or project need. Inserts should be designed and installed based on the manufacturer's recommendations. Recycled and reusable products are available for some types of insert media. The following types of material are generally used in combination with the catch basin inserts:

- Metal/Plastic Screens—typically effective in the removal of sediment and other debris
- Fabric—typically effective in the removal of oil and grease
- Filter Inserts—designed to remove metals or other types of pollutants

Catch basin inserts should be designed to bypass stormwater flow in excess of the water quality design volume into another system or inlet. This prevents overflow of the catch basin if it becomes clogged or when there is excessive rainfall. The bottom of the filter media should be located above the crown of the outlet pipe. This will ensure that the water quality design volume is filtered through the media.

The catch basin should be located in an area that is accessible for maintenance at any time. Special consideration should be given during the design phase to ensure that the basin will not be blocked for maintenance by vehicles or other obstructions.

Catch basin insert removes debris underneath an inlet grate on Trade Port Drive.

18.2.3.3 Hotspots

Hotspots are a land use or activity that generate higher concentrations of pollutants, including but not limited to; hydrocarbons, sediments and trace metals that are found in stormwater near the land use. Due to the potential for groundwater contamination, BMPs that utilize infiltration are prohibited to treat stormwater runoff from hotspots as defined below. Separation from the groundwater table or an impermeable liner for impoundment structures should be considered for hotspots.

Hotspot locations include:

- Gas/fueling stations
- Vehicle washing/steam cleaning
- Auto salvage yards/auto recycling facilities
- Outdoor material storage areas
- Landfills
- Facilities that store or generate hazardous materials
- Industrial sites

18.2.3.4 Infiltration Rates

The minimum average infiltration rate for all infiltrating practices shall be 0.5 inches/hour. Where the minimum infiltration rate is not achieved, design cannot account for infiltration and an underdrain is required. Perched or elbowed underdrains, a minimum of 4 inches in diameter with minimum 0.5% slope, are required to increase exfiltration through increased contact time with native soils. All underdrain systems require a 4 inch minimum cleanout. Underdrains shall be surrounded by a minimum 24" wide and 15" deep area of double washed #57 stone.

Infiltration rates may decrease over time due to settlement of filter media, compaction, or accumulation of sediment in the practice. To sustain infiltration rates long-term, it is important that a maintenance plan is in place. Regular maintenance should be conducted to optimize operating infiltration rates.

18.2.3.5 High Water Tables

High water tables can impact the efficiency of a BMP. High infiltration BMPs are prohibited in these areas since high water tables can prevent the percolation of stormwater into the subsoil. In addition, special geotechnical considerations may be necessary in these areas, especially for embankment or impoundment facilities.

Where a high water table occurs (vertically) within two feet of the plane of infiltration (bottom of BMP), infiltration shall not be considered as part of the water quality volume. High water table data must be acquired by geotechnical exploration.

18.2.3.6 Shallow Soils/Depth to Bedrock

Thin soil zones and shallow bedrock limit the capacity of BMPs to exfiltrate into native soils. Where shallow soils and depth to bedrock occurs (vertically) within three feet of the plane of infiltration, infiltration shall not be considered as part of the water quality volume. Depth to bedrock data must be acquired by geotechnical exploration.

18.2.3.7 Karst Areas

Sinkholes and karst topography limit options for BMPs, and additional infiltration may cause sinkholes to develop. Where sinkholes or karst features are present onsite, infiltration shall not be considered as part of the water quality volume.

18.2.3.8 Engineered Soils

The soil composition for engineered soils may vary based on site conditions, project objectives, and proposed plantings. The clay content for the composite mix must not exceed 10% of the overall mix, by volume. The following soil mix is recommended, but other soil mixtures may be used based on site characteristics and proposed plantings. To enhance infiltration rates and prevent soil consolidation over time, a soil mix with a high sand content is recommended. The typical soil mix to enhance infiltration rates and prevent soil consolidation over time consists of the following materials, by volume:

- 70%-85% sand
- 10% to 20% silt + clay, with no more than 5% to 10% clay;
- 5% to 10% organic matter

18.2.3.9 Mosquito Control

For mosquito control, BMPs must be designed to have no ponding or standing water within 36 hours of a rainfall event.

18.2.4 Construction

For BMPs designed to infiltrate stormwater runoff, it is essential that soils are not compromised by compaction from construction equipment. Care should be taken to minimize soil compaction throughout the BMP and especially at the plane of infiltration so that infiltration rates of native soils are not impacted. Acceptable excavation methods at infiltration practices include hand labor with shovels or the use of an excavator such as a backhoe or track hoe (located outside the perimeter or footprint of the practice). Heavy equipment should never be used over existing or the footprint of planned infiltration practices. Prior to site disturbance, the perimeter of the practice should be partitioned off with temporary fencing/tape to keep heavy equipment from crossing the perimeter throughout time of active construction. In cases where the BMP is sufficiently large that equipment must enter it, methods proposed to limit and restore compacted soil must be approved in advance.

Designers should also consider construction access and staging during the design process. BMPs should be constructed last whenever possible and remain offline until at least 80%, preferably 100%, of the contributing area is stabilized. Activities that could compact soils where BMPs are sited should be avoided. Where site constraints make this unavoidable, the designer shall compensate accordingly in the design of the BMP.

18.2.5 As-built Drawings

MSD requires that as-built drawings be submitted for all BMPs used to meet the water quality volume. The as-built drawings must contain at a minimum the following information for each BMP as applicable:

- Location and dimensions of BMP, including pretreatment, diversion structures, underdrain systems, inlets, outlets, and overflows
- Depth and area of engineered soil and aggregate layers
- Manufacturer model and size (water quality unit only)
- Post-Construction infiltration rates (infiltration practices only)

The site disturbance permit will not be released until the as-built drawings are approved.

18.2.6 Alternative Practices for Post-Construction Water Quality BMPs

To encourage innovation, alternative management practices that are not included in the MSD Design Manual, Standard Specifications, and Standard Drawings may be allowed upon review and approval by MSD. The alternative management practice must be supported by evidence that it will perform at least equivalently to a currently approved control contained in the MSD Design Manual, Standard Specifications, or Standard Drawings and conforms to current American Society for Testing and Materials (ASTM) Standards. However, if the control or practice fails, or is inadequate to contain the target pollutants (i.e. TSS) onsite or meet long-term post-construction stormwater management objectives, the permittee will be required to remove and replace it with a control approved by MSD and in accordance with the MSD Design Manual Standard Specifications and Standard Drawings.

18.2.7 Fee in Lieu Program

MSD has the authority per the Wastewater/Stormwater Discharge Regulations to establish a fee in lieu program to mitigate stormwater runoff off-site. This program would allow developments where green infrastructure is not feasible on-site to mitigate for water quality off-site or pay a fee that would fund stormwater quality mitigation projects.

18.2.8 Design Considerations

Consideration should be given to preserving the natural features of a project site. Post-construction water quality BMPs can range from natural features on a property that treat runoff, to manmade structures that treat stormwater before it enters the drainage system. Research indicates that it is more effective to treat stormwater at its source; therefore, preserving the natural features on a site can be a cost effective means for stormwater management.

When determining the best BMP(s) for the project, consider the following:

Development Features
Development features include both the natural and manmade features of the site, including utilities, park areas, waterfront areas, landscaping, conservation areas, roads, and sidewalks. Development features should be considered during the site assessment and planning phase.

Watershed Factors
Watershed factors to consider include pollutants, water quality, sources of water pollution and location of the property within the watershed. The applicability of some BMPs will be limited due to the size of the contributing drainage area and the functionality of BMPs. Where applicable, the maximum and minimum contributing drainage area sizes are shown on the BMP fact sheet guidelines.

Aesthetic and Habitat Related Issues
Aesthetic and habitat related issues can include a site’s proximity to impaired waters or sensitive areas, and if there are threatened and/or endangered species or their suitable habitat identified on the site.

Topography
A site’s topography will impact the location and types of BMPs that can be used. It is important to try to utilize the natural topography to the best extent possible.

Proximity to Sensitive Features or Obstructions
Proximity to wells, wellhead protection areas, septic systems, buried utilities, overhead utilities and other obstructions can limit which BMPs are applicable to a specific site.

Vegetation
Vegetation on a site can both enhance and impede the effectiveness of a BMP. For example, deciduous trees near pervious pavement can clog the BMP with leaves, but reduce stormwater runoff by rainfall interception and evapotranspiration. In spite of these challenges, appropriately selected vegetation in BMPs can improve performance.

Existing Development and Steep Slopes
One goal of stormwater management is to allow for the natural recharge of groundwater. This process also has the potential to impact adjacent ground during and after storm events.

Saturating the soils on steep slopes (6 percent or greater) can cause the failure of the slope and adjacent structures.

Local Planning and Regulatory Requirements
Federal, state and/or local regulatory requirements may prohibit or require certain BMPs to meet specific standards. The designer should consult all applicable ordinances and regulatory requirements, as they may impact the design process, selection criteria, operation and maintenance and the cost of the BMPs. Some of the planning and regulatory aspects to consider when planning BMPs for a site are: CSO mitigation, TMDL requirements, 401/404 permitting, floodplain permitting, and MSD credits/incentives. Review local ordinances and zoning codes to verify that potential BMPs comply with these requirements and that there are not any regulatory impediments to the BMPs proposed for the site.

Operation and Maintenance
The operation and maintenance schedule and costs may impact the decision to use a BMP. Some BMPs require more long-term maintenance than others, resulting in increased cost of the BMPs.

Treatment Trains
A treatment train is the use of multiple BMPs in series on a site to meet the VR for stormwater management. Treatment trains can include structural and non-structural BMPs. When assessed and planned, a treatment train consists of all of the design concepts and BMPs that work to accomplish the desired water quality volume volume. The general approach for treatment trains should consider:

1. Avoiding additional stormwater runoff volume.
2. Managing stormwater runoff as close to the source as possible.
3. As appropriate, infiltrating as much of the stormwater runoff as possible.

18.3 Infiltration Testing Specifications

Single-ring infiltrometer infiltration test (Photo: URS)

The purpose of many BMPs is to store, treat and infiltrate stormwater into the soil, mimicking natural systems. Subsurface conditions are key in assessing the feasibility of infiltration in the design of BMPs. Infiltration capacity testing and design of BMPs that rely on infiltration to treat the stormwater quality volume shall follow the specifications summarized in this chapter. Where the infiltration rate cannot be demonstrated to be equal to or exceed 0.5 inches per hour, either an underdrain will be required or a non-infiltration BMP selected.

While National Resources Conservation Service (NRCS) soil classification of the site is encouraged as part of a desktop analysis to gain familiarity with potential native soil conditions, it is not adequate justification for infiltration testing results and cannot be substituted for infiltration testing using infiltrometers or test pits. The following infiltration testing options are addressed:

- Single-Ring Infiltrometer
- Test Pit
- Other Infiltration Testing and Verification Methods

18.3.1 Infiltration Testing Requirements

Infiltration testing is required for BMPs requesting infiltration credit and which do not include an underdrain. All infiltration practices used to meet the water quality volume standard are subject to the following testing requirements:

- Infiltration tests shall not be conducted in the rain or within 24 hours of significant rainfall events (greater than 0.5 inches), or when the temperature is below freezing.

- Infiltration testing performed, including testing procedures followed, shall be documented and submitted as part of the plan approval process to MSD.

Portions of this Section present testing methods at the bottom of an excavation. It is the testing personnel's responsibility to be aware of and take proper health and safety precautions for activities in an excavation. See the U.S. Occupational Health and Safety Administration (OSHA) for guidelines and requirements (www.osha.gov).

Minimum testing requirements are summarized in Table 18.2.

Table 18.2 Infiltration Testing Requirements	
BMP Type	**Conceptual Design Testing**
Linear practices (i.e. bioswales, interconnected tree boxes, infiltration trenches, etc.)	All of the following are required: • 1 single-ring infiltrometer test • 1 test pit per 400 linear feet • Minimum 1 infiltration test per test pit of BMP practice
Non-linear practices (rain gardens, basins, etc.)	All of the following are required: • 1 single-ring infiltrometer test • 1 test pit per 2500 square feet of practice area for 10,000 square feet or less of practice area • Minimum 1 infiltration test per test pit per BMP More tests are acceptable as long as additional tests are spaced evenly. An effective infiltration rate should be determined by averaging infiltration tests.

18.3.2 Qualified Professionals

Infiltration testing shall be conducted by a qualified professional and plans including infiltration testing results must be certified by a professional engineer or professional geologist.

18.3.3 Background and Desktop Analysis

A desktop analysis of soils data, topography, location of streams, waterbodies, existing/previous land uses, and structures is encouraged to identify potential BMP locations and types. Existing, previous soil investigation or lab data may also be used to support preliminary siting of BMPs and infiltration testing. While NRCS soil classification desktop analysis is encouraged to gain familiarity with potential native soil conditions, it cannot be substituted for infiltration testing using infiltrometers or test pits.

18.3.4 Test Pits

Where the feasibility analysis meets minimum infiltration criteria, the test pits are necessary for conducting infiltration testing per Table 18.2 to further verify site information characteristics.

This test method consists of a trench or pit that allows visual observation of the soil horizons and overall soil conditions at a particular location on the site. Multiple test pit observations can be made for a relatively low cost and in a short time period. The use of soil borings shall not be substituted for test pits. Test pits allows in-situ visual observation of soil conditions, where soil borings do not. Soil borings are encouraged to supplement data collection, but cannot be substituted for infiltrometer or test pits.

1. Dig a backhoe-excavated trench/pit, 2-1/2 to 3 feet wide, to the proposed depth of the infiltration plane of the practice at the location of the proposed BMP.
2. Safe test pit entry should always be observed. A test pit should never be accessed if it is not safe to do so. OSHA regulations should always be followed.

3. Document the soil profile (soil horizons, soil texture and color and depth below ground surface, depth to water table, and depth to bedrock, etc).
4. Based on observed field conditions, the qualified professional should consider modifying the proposed infiltration plane of the practice and adjust infiltration testing locations as necessary.
5. Perform Single-Ring Infiltrometer test (below) at depth of infiltration plane of the proposed practice.
6. Soil samples may be collected at various horizons for additional analysis at the designer's discretion.
7. After testing is complete, re-fill the test pit with original native soils and stake the location of the test pit.

18.3.5 Single-Ring Infiltrometer Infiltration Test

This test method utilizes perforated 200 millimeter (mm) to 250 mm (8- inch to 10-inch) plastic or metal canisters with bottom set in coarse drainage sand to minimize disturbance to in-place soils and to prevent siltation of the test hole during testing.

1. Holes in the test canister should be 3 mm (1/8 inch) diameter and spaced on 25 mm (1 inch) centers.
2. Excavate a test hole to the depth of the infiltration plane, or the bottom of the BMP, and approximately 25 mm (1 inch) larger diameter and approximately 25 mm (1 inch) deeper than the dimensions of a test canister. If the depth of testing is greater than 18 inches, it may be necessary to excavate a shallow test pit to conduct testing.
3. Check that the sides of the test hole are not smooth, but scarified.
4. Place coarse drainage sand in the bottom of the hole and place the canister firmly into the hole. The bottom of the hole should be uncompacted.
5. Backfill the space around the canister with soil and tamp the soil into place.
6. Fill canister with water and allow to drain completely or to soak the surrounding soils for a minimum of one hour, whichever occurs first.
7. Refill the canister and measure the rate at which the water level drops.
8. Record the infiltration rate as the decrease in depth of water per hour (inches/hour).

Where the feasibility analysis does not meet minimum infiltration criteria, the designer may prefer the use of an underdrain rather than continue with further testing.

18.3.6 Other Infiltration Testing and Verification Methods

Other infiltration testing standards that are acceptable include ASTM D3385-09 Standard Test Method for Infiltration Rate of Soils in Field Using Double Ring Infiltrometer.

Verification methods such as soil borings may be used to verify site conditions where final locations of BMPs are adjusted and do not fall within the original testing location. Test results must verify that the soil conditions are the same as those from the original test results.

18.4 BMP Fact Sheets

This section provides design standards and requirements for the following BMPs:

- Rain Gardens/Bioswales
- Constructed Wetlands
- Green Wet Basins
- Green Dry Basins
- Green Roofs
- Permeable Pavers
- Tree Boxes
- Vegetated Buffers
- Underground Infiltration Basins
- Proprietary Water Quality Units
- Open Infiltration Trenches

Information on each BMP is provided in the fact sheets, as well as:

- Benefits and limitations
- Application and site feasibility
- Design criteria
- Step by step design procedures

MSD has developed companion documents to support the design and plan submittal process. Plan review checklists and design calculation sheets are available at www.louisvillemsd.org.

18.4.1 Rain Gardens/Bioswales

Rain garden at Louisville & Jefferson County MSD main office with naturalized native plantings.

Rain gardens, also referred to as bioretention/biofiltration cells, are shallow stormwater basins (minimum ponding depth 4 to maximum 12 inches typical) that mimic the ecological functions of a natural landscape. Rain gardens contain deep rooted native vegetation or cultivar species to filter stormwater, promote infiltration and provide wildlife habitat. They can also take form in a raised landscape bed, or stormwater planter box. Similar to rain gardens, bioswales (or linear rain gardens) are vegetated channels that provide treatment and retention; however bioswales also convey stormwater flows.

Rain gardens and bioswales improve water quality through:

- Treatment of stormwater percolating through soil and filter media
- Groundwater recharge and detention of stormwater
- Natural evapotranspiration
- Biological uptake

Advantages/Benefits	Disadvantages/Limitations
• Provides infiltration and groundwater recharge, filtering pollutants and reduces stormwater runoff volume • Suitable for runoff from highly impervious areas • Increases biodiversity by providing urban habitats for wildlife • Good retrofit capability	• Location constraints (utilities, shallow groundwater, shallow bedrock, sinkholes, down gradient from buildings/basements, overflow pathway, etc.) • Maintenance commitment (basic gardening/landscape maintenance) • Available space for capture of target volume • Not for slopes > 4%

18.4.1.1 Application and Site Feasibility

Rain gardens and bioswales can be flexible in design to accommodate landscape requirements. Rain gardens are infiltration practices and bioswales are filtration/conveyance practices that are appropriate in a wide variety of land use applications such as commercial, industrial, or residential areas and they are often located adjacent to parking lots or roof downspouts. Where a raised bed or box is desired, a planter box type of rain garden may be suitable for the site. Infiltration planters are designed to capture and infiltrate stormwater runoff through an open box design.

A bioswale treats stormwater runoff from paved surfaces.

This section includes guidance for rain gardens and bioswales on a larger scale. MSD's *A How-To Guide for Building Your Own Rain Garden* was developed specifically for homeowners. A copy can be downloaded from the MSD website at www.louisvillemsd.org.

18.4.1.2 Physical Requirements

Key physical considerations are:

- Soil type and infiltration—Rain gardens should drain within 36 hours. Infiltration rates for native soils with clay content may improve over time with installation of deep rooted plants as they have the potential to penetrate and loosen the soils. Soils shall have an infiltration rate of 0.5 inches per hour or greater. Sandy, permeable soils promote infiltration but are also susceptible to erosion, and should be protected in applications receiving or directing stormwater conveyance.
- Deep rooted plants—Native plants are preferred, but non-invasive cultivars/hardy plants can also be used to landscape the rain garden. Native, hardy plants with deeper root systems and tolerance for drought to wet conditions are suitable for the varying wet and dry conditions of rain gardens. See Chapter 13 of the MSD Design Manual for a list of approved plants.
- Slopes—Slopes affect flow rates, bioswale/linear rain garden capacities, infiltration rates, and erosion.
- Building foundations—Sufficient space is required from building foundations. Where a gravel infiltration trench is used in a rain garden, the gravel infiltration trench of the rain garden must be set back from building foundations a minimum of 10 feet. For all applications, buildings and building foundations must be waterproofed with foundation drains to limit seepage into basements or lower levels.
- Space available—Sufficient space is required to plant herbaceous plants, shrubs or trees and allow space for foliage growth above ground and root growth below ground. Plant type and species vary by preferred landscape, tolerance for inundation, and aesthetic qualities.
- Groundwater table – The groundwater table shall be at least 2 feet, preferably 4 feet, below the bottom of the rain garden or bioswale.

18.4.1.3 Design Criteria

The design of a rain garden or bioswale includes several elements to manage stormwater ponding and infiltration as well as to facilitate water quality improvement. For a summary of design parameters, see Table 18.3.

18.4.1.3.1 Types

Based on site characteristics and desired aesthetics, select the type of rain garden, i.e. traditional rain garden, planter box or linear rain garden/bioswale.

Traditional Rain Garden: Where conveyance is not required and mild slopes exist, traditional rain gardens may be suitable. Rain gardens are generally shallow, relatively flat, depressed areas that contain deep rooted native vegetation to help slow and filter stormwater.

Linear Rain Gardens or Bioswales: Where conveyance is required and mild slopes exist on site, linear rain gardens or bioswale type of rain gardens may be suitable. Bioswales are generally shallow, wide, and gently sloped, and contain deep rooted native vegetation that helps slow and filter stormwater.

Planters: Where a raised bed or box is desired, a planter box type of rain garden may be suitable for the site. Infiltration planters are designed to capture and infiltrate stormwater runoff through an open box design. If infiltration into native soils is not desired, planters may be designed to capture and retain stormwater runoff with a flow-through closed box design, also called flow-through planters. Flow-through planters include an overflow pipe and underdrain system. If the in-situ soil infiltration rate is less than 0.5 inches per hour, then an underdrain is required. Underdrains should be designed to be a minimum of 4 inches in diameter, minimum 0.5% slope and include a 4 inch minimum cleanout. The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil composition in the box and surrounding soils. If an underdrain is needed, storage space can be provided beneath an underdrain system to allow more time for infiltration to occur. A planter should not accept drainage from more than 0.25 acres of impervious area; a smaller drainage area is encouraged for better performance. Planters have specific design criteria and will be considered on a case by case basis.

18.4.1.3.2 Location

Since rain gardens are retention structures, they are designed to effectively capture stormwater runoff. When finding the most appropriate location for the rain garden, it is best to find a site with a small drainage area. For larger drainage areas, it is recommended that multiple rain gardens or larger vegetated infiltration BMPs be established.

Bioswale at Kentucky Gymnastics Academy

Rain gardens should be built where the groundwater table is at least 2 feet, preferably 4 feet, below the lowest point of the rain garden to promote effective infiltration. Areas with erosion or sediment flow are not suitable locations for rain gardens because the structures and soil may become clogged. In addition, rain gardens and bioswales should be placed at least 10 feet from building foundations and underground utilities, with the exception of closed or flow-through planter boxes. See Exhibit 18-1, 18-2 and 18-3 for a rain garden and bioswale typical cross-sections.

18.4.1.3.3 Flow Capacity, Velocity and Freeboard

Since bioswales are conveyance features, they are designed to slow and detain small storm events while also safely bypassing large storms to protect the bioswale from erosion. Bioswales along a roadway should have adequate flow conveyance and maintain adequate freeboard to avoid flooding or overtopping the pavement. When rain gardens or bioswales are in close proximity to the pavement structure, they should have enough flow capacity to provide positive subgrade drainage. See Chapter 10 for drainage design requirements.

18.4.1.3.4 Erosion Prevention

Linear rain gardens, or bioswales, conveying stormwater should be lined with biodegradable erosion control matting for erosion prevention and sediment control during the plant establishment period. Turf reinforcement mats, or other enhanced erosion protection may be necessary in locations of concentrated flow or to protect against high stormwater velocities produced by large storm events. Mat selection should be based upon anticipated flow velocities, vegetation planting requirements, and longevity needs.

18.4.1.3.5 Slopes

Site topography should be considered in bioswale design, including slope and cross-sectional area to maintain nonerosive velocities. Typically, slopes should be less than 2%. In areas with slopes between 2% and 4%, check dams or weirs must be placed perpendicular to the flow to increase detention and extend time for infiltration. Rain gardens or bioswales are not suitable for slopes greater than 4%. Placement of check dams or weirs should include scour protection to limit erosion. Bioswales require a minimum slope of 1%, unless an underdrain is installed. See Exhibit 18-4 for a typical check dam detail.

18.4.1.3.6 Inlet and Pretreatment

Pretreatment eases maintenance, especially in land use areas with high sediment loads. The use of a forebay, or other energy dissipating device, such as a strip of vegetation or gravel filter, to spread the flow at the inlet is recommended to facilitate maintenance and removal of accumulated sediment and to prevent erosion. See Exhibit 18-5 for typical forebay plan and profile.

18.4.1.3.7 Sizing and Ponding Area

The surface storage parameter should be designed to retain/capture the volume produce by the rainfall events specified in Table 18.3. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. Typical ponding depth should be 4 inches minimum to 12 inches. Certain situations may allow deeper ponding depths. An overflow drain also must be installed to move excess water during a large storm event or due to clogging. The maximum drainage area to rain garden area ratio is 10:1. Ratios greater than 10:1 will be reviewed on a case-by-case basis.

Sizing of a rain garden is determined by the storage capacity, or water quality volume, provided by the porosity of any amended soils and in the ponding above any amended or in situ soils. This volume must be equal to or greater than the Water Quality Volume Required (VR).

See Table 18.3 for the calculation used to determine the storage capacity of the rain garden or bioswale.

18.4.1.3.8 Check Dams

Check dams should be used to pond water within bioswales to slow flows, prevent erosion and promote infiltration. Typical check dam construction materials are earth, stone, river rock, and rot resistant timbers. See Exhibit 18-4 for a typical check dam detail.

18.4.1.3.9 Engineered Soils

Engineered soils (as identified in Table 18.3) must be used unless native soils have a minimum infiltration rate of 0.5 inches per hour. Minimum engineered soil depth is 36 inches. Maximum recommended engineered soil depth is 6 feet. Erosion control should be incorporated into the design when engineered soils are used, particularly when vegetation is being established.

18.4.1.3.10 Underdrains

If the infiltration rate of in situ soil is less than 0.5 inches per hour, an underdrain is required. For Engineered Soils with an Underdrain, underdrains should be constructed with perforated pipe or slotted corrugated pipe with a minimum 4-inch diameter with a mimimum 0.5% slope and bedded in double washed KY #57 stone. Underdrains shall be surrounded by a minimum 24” wide and 15” deep area of double washed #57 stone. Filter fabric should be avoided in this situation due to its propensity for clogging. To minimize the migration of soil particles into the stone layer and underdrain, layer double washed KY #8 stone over the double washed KY #57 stone layer. Where filter fabric is necessitated, choose non-woven filter fabric. Underdrain pipes should be designed to include a 4 inch minimum cleanout. See Exhibit 18-6 for a typical underdrain with clean out detail.

18.4.1.3.11 Plant Selection

Rain gardens and bioswales are typically planted with deep rooted native grasses, sedges, and forbs. In selecting plants, consider the favorable conditions where plants can thrive. The conditions for plants used should be able to survive both droughts and inundated scenarios. Note that plants located on bermed areas on the perimeter of the rain garden or bioswale should never be underwater and should tolerate dry conditions. At inflow and outflow areas of the rain garden, the use of an herbaceous layer of ground cover is recommended over mulching to prevent erosion of mulch and soil layers.

Bioswale at Unipak, LLC in Jeffersontown.

Ground covers also act as a weed control by providing a thick cover that inhibits the growth of unwanted plants. Mulch options include shredded bark mulch, which is preferred to maximize moisture and nitrogen retention, and stone mulch, which is preferred in areas where steeper slopes and higher velocities are present. The slope of the rain garden should be designed to minimize erosion. Mulch should be applied as an even 2 to 3-inch layer avoiding mounding around trees, shrubbery and plants. Whether to plant with seed, plugs or container plants is often an economic and maintenance decision. Seeding is less expensive initially, but requires a longer establishment period, and makes maintenance and weeding more intense. Plugs and container plants are more expensive than seed, but plants will grow and establish quicker and less weeding will be required.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. Native species and non-invasive cultivar/hardy species are provided in Chapter 13 of the MSD Design Manual.

18.4.1.3.12 Outlet Design

A high flow bypass or diversion structure must be included to safely convey high flows from large storm events. If an underdrain is used, this may also help expedite the infiltration process when there is an excess amount of water retained within the structure after ground saturation has occurred.

Table 18.3 Rain Garden/Bioswale Application and Site Feasibility Criteria

Design Parameter	**Criteria**
Drainage Area	Dependent on application.
Soils	Minimum infiltration rate for in situ soils is 0.5 inches per hour. Recommended soil mix (by volume) for engineered soils: • 70%-85% sand • 10% to 20% silt + clay, with no more than 5% to 10% clay; • 5% to 10% organic matter Underdrains are required for in situ soils with an infiltration rate less than 0.5 inches per hour. Underdrains to utilize minimum 4-inch diameter perforated pipe.
Sizing	Dependent on application and drainage area. For rain gardens, size so that typical ponding depth is 4 inches minimum to 12 inches. Certain situations may allow deeper ponding depths. No standing water should be present 36 hours following a storm event.
Longitudinal Slope	No greater than 4%, 1%-2% preferred. Where greater than 4%, use terracing techniques to achieve slopes as needed. For bioswales, minimum slope of 1% unless an underdrain is installed. For slopes between 2% and 4%, use check dams or weirs to increase detention, extend time for infiltration, and prevent erosion.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.

Design Flows and Conveyance Capacity	Pass the 2- and 10-year, 24-hour storms. Bypass or design overflow of the 100-year, 24-hour storm with 6 inches of freeboard.
Pretreatment	Forebay—Size pretreatment forebay to hold 10% to 15% of the VR with a depth of 2 to 4 feet.
Inlet/Outlet Protection	Overflow outlet or spillway required. Scour protection required at inlet and discharge point for rain gardens. Bioswales, should be lined with biodegradable erosion control matting during the plant establishment period and turf reinforcement mats in locations of concentrated flow as needed.
Volume Provided (VP)	The water quality design volume provided (VP) by a rain garden or bioswale is: $VP\ (ft^3) = (A)(M)(p) + (A)(P)$, where • A = area of the bioswale (ft^2) • M = depth of the media (ft) • p = media porosity (% void), typically 40% • P = average height of water above the media during the RE rain event in feet Design calculation sheets are available at www.louisvillemsd.org
Landscape Plan	Landscape plan required showing native plants and/or non-invasive cultivars, plant size, spacing, installation and maintenance notes. Obtaining a one- or two-year maintenance agreement and warranty from the nursery or landscaper is recommended.

18.4.2 Constructed Wetlands

Constructed wetlands incorporate marsh and pool areas to temporarily store stormwater runoff, treat pollutants and create aesthetic value and wildlife habitat. Constructed wetlands are generally shallow and contain dense native aquatic vegetation, typically covering 60% to 80% of the surface area that uptake pollutants from stormwater runoff. Constructed wetlands improve water quality through:

- Control of runoff volumes
- Biological uptake of pollutants through native plants and biodegradation by microorganisms
- Sediment settling and filtering
- Adsorption and other chemical/physical processes

Native plants in a constructed wetland improve water quality.

Advantages/Benefits	Disadvantages/Limitations
• Reduces runoff rates • Increases biodiversity by providing habitat for aquatic and wildlife species • Opportunity for multiple uses, including passive recreation and outdoor recreation • Can be used as a BMP in small areas (pocket wetlands) or on larger tracts of land	• Needs regular flow of water, so stormwater runoff may need to be supplemented during dry conditions • Needs to be properly designed and managed to reduce potential to breed mosquitoes • Water quality of discharge can change with seasonal growth of plantings • Does not provide groundwater recharge • May need maintenance for invasive species

18.4.2.1 Application and Site Feasibility

Constructed wetlands are a depressional feature that are used to treat and temporarily store stormwater runoff. Constructed wetlands can be used in small areas as pocket wetlands, or can be larger shallow emergent marsh systems. Generally, to help sustain wetlands during dry periods, design should incorporate a contributing watershed area of 5 to 10 acres for pocket wetlands, and greater than 10 acres for shallow wetlands. The permeability of the soils around the constructed wetlands should be less than 0.14 inches per hour to prevent drainage. In addition, wetlands should have an aerial extent of 2% to 5% of the watershed they drain. Constructed wetlands are appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional, or residential areas.

Two basic designs of constructed wetlands are addressed: pocket wetlands and shallow wetlands. Pocket wetlands are intended for smaller drainage areas of 5 to 10 acres, consist of a forebay and a shallow marsh area and may be constructed near the groundwater level for a reliable source of water.

Shallow wetlands consist of a combination of a forebay, shallow emergent marsh areas, 0 to 6 inches deep, deep emergent marsh areas, 6 to 12 inches deep, in combination with a deeper micropool.

18.4.2.2 Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space is required to treat and temporarily store the stormwater runoff
- Drainage area—Utilize a large drainage area to provide base flow during drier weather
- Soil conditions—Soils need to have a low permeability to allow ponding of the water; constructed wetlands typically do not infiltrate stormwater runoff

18.4.2.3 Design Criteria

The design of constructed wetlands includes several elements to facilitate water quality improvement and routing and detention of stormwater runoff. For a summary of design parameters,
see Exhibit 18-7 for a typical pocket wetland plan view and profile and Exhibit 18-8 for a typical shallow wetland plan view and profile.

18.4.2.3.1 Configuration, Layout and Slope

Common constructed wetlands components include the following:

- Access
- Inlet(s)
- Sediment forebay
- Shallow water zones (0 to 6 inches) and deeper water zones (6 to 12 inches)
- Outlet and overflow structures
- Deeper pool zones, including a micropool near the outlet to allow for final settling and prevent and resuspension of settled matter prior to discharge
- Hydraulic connectivity

The configuration and layout of these components will be dictated by the size available for the constructed wetland, site topography, flow paths and access. Constructed wetlands should not be constructed within 10 feet of a property line or within 50 feet of a private well or septic system.

18.4.2.3.2 Soils

Constructed wetlands are intended to stay wet, so the soils need to be relatively impermeable and limit infiltration; however, they should be above the local high water table. Underlying soils should consist of 20% to 40% clay or greater and less than 50% sand and have a slow to very slow infiltration rate. If the underlying soils have a permeability of 0.14 inches per hour or less, then they will not typically require the use of an impermeable or low permeability liner. Soils with permeability rates greater than 0.14 inches per hour will require the use of an impermeable or low permeability liner.

18.4.2.3.3 Conveyance

Though the constructed wetlands primary function is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because the pooled water in the wetlands allows opportunity for solid particles in the stormwater to settle, the flow path should be diffuse and as long as possible.

Pocket wetlands do not provide a long flow path and are only used in smaller areas. To provide a long flow path in the shallow wetland design, the constructed wetland needs to have a length to width ratio of at least 2:1, with 3:1 preferred, or internal dikes that provide a winding path for the stormwater runoff.

Constructed wetlands need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the wetlands will help to reduce velocities during larger flows, reducing the potential for erosion. An emergency spillway is also needed to safely convey high flow out of the wetlands. The area downstream of the emergency spillway needs to be protected to prevent scour.

18.4.2.3.4 Pretreatment—Forebay

Excessive sediment accumulation in a wetland can reduce hydraulic capacity, block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into either the pocket wetland or shallow wetland. Forebay are designed to remove sediment from the stormwater flow prior to dispersal into the wetland. Having a typical depth of 2 to 4 feet, they must be sized to provide approximately 10% of the VR and prevent the resuspension of settled solids into the stormwater flow. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the wetlands system and reduce velocities to prevent erosion. Location and design should allow for ready access to perform maintenance, including removal of accumulated sediment.

18.4.2.3.5 Treatment

The primary pollutant removal mechanism in wetlands is sedimentation, since many pollutants are affiliated with sediment particles in stormwater. Consequently, proper design, construction and maintenance of the sediment forebays are critical to the wetlands' performance.

The shallow (0 to 6 inches) and deeper (6 to 12 inches) water zones in the wetlands promote numerous treatment processes. Slowing flows over these zones promotes additional particle settling and biological uptake of organic pollutants by wetland vegetation while exposure to sun and air promotes other degradation processes.

Constructed wetland cell in Buechel

A micropool near the outlet helps keep vegetation from encroaching on and clogging the outlet and helps prevent resuspension of sediment into the discharge.

The pocket and shallow wetlands should be sized to have a minimum pool volume equal to the required VR. The distribution of the volume amongst the forebay, shallow water zone, deep water zone and micropool should be as follows:

- 10% to 15% for forebay
- 10% to 15% for micropool
- 30% to 35% for shallow water zones (0 to 6 inches)
- 35% to 40% for deeper water zones (6 to 12 inches)

Constructed wetlands need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments.

Because keeping the wetlands wet is critical for their viability, a water balance should be performed. Estimate the seasonal inflows, such as rainfall, stormwater runoff and groundwater contribution, and outflows. Evaporation, transpiration and any infiltration should be included in the estimate. Size the wetlands to be able to sustain the wetland vegetation should there be minimal rainfall and runoff in a thirty day time period. If seasonal drying is anticipated, compensate in the plant selection process, but the effectiveness of the wetlands may be reduced.

18.4.2.3.6 Outlet

The design and configuration of the outlet structure will depend on whether storage is provided over and above the VR. The outlet structure should be designed to provide at least 24 hours of detention and return to normal pool elevation within 36 hours with a typical increased water depth of no greater than 2 - 3' unless otherwise approved. Depth of water coverage and ponding times should be considered when selecting plant species

Typical outlet structures include reverse-sloped pipes, weirs or risers connected to a discharge pipe that discharges to the downgradient receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars for around discharge pipe to prevent seepage.

An emergency spillway, either separate from, or in conjunction with, the outlet structure should be included to safely convey high flows from storm events greater than the RE rain event. A minimum of one foot of freeboard should be provided during the 100-year, 24-hour rain event. The discharge from the outlet structure should be equipped with armoring, plunge pools, energy dissipaters or similar best management practices to prevent scour. The outlet should be designed such that the water surface elevation returns to the VR elevation between 24 and 36 hours after a rainfall.

18.4.2.3.7 Landscaping/Plant Selection

A landscaping plan is required for planting constructed wetlands. The plan should include bed preparation and identification of the various planting zones and plants for each planting zone, depending on type of constructed wetland. Planting zones can include:

- Shallow marsh zone – will include plants appropriate to an average depth of 6 inches and will have a greater diversity of plants than the deep marsh zone
- Deep marsh zone – will include plants appropriate for water depths of 6 to 12 inches
- Ephemeral zone – will include plants that will be subject to wet and dry periods
- Dry zone – will include upland plants suitable for dry conditions
- Temporary cover seed

For a summary of planting zones for the pocket and shallow constructed wetlands, see Exhibit 18-9.

Choices available for planting the wetlands include seed, rhizomes, bare root stock, potted plants, plugs and transplanting vegetation from an established site. Planting rhizomes and seed is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and have an increased survival rate. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Constructed wetland with native plantings

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

18.4.2.3.8 Safety

Like any BMP that holds water, safety is a significant consideration. The side slopes should be 4:1 (H:V) or flatter. In addition, a vegetated buffer around the wetlands can be provided to minimize undesired access or direct desired access and enhance wildlife habitat.

Maintenance equipment access should be considered while in the configuration/layout phase of design.

Table 18.4 Constructed Wetlands Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	5 to 10 acres of upstream drainage for pocket wetlands and a minimum of 10 acres for shallow wetlands to maintain adequately wet conditions during dry weather.
Soils	Low permeability soils that typically consist of 20% to 40% clay or greater and less than 50% sand with slow or very slow infiltration rates Soils with permeability rates greater than 0.14 inches per hour will require the use of an impermeable or low permeability liner.
Sizing	Footprint of constructed wetland should be 2% to 5% of the watershed drainage area.
Side Slopes	No greater than 4:1 (H:V), flatter is recommended.
Design Flows and Conveyance Capacity	Pass the 100-year, 24-hour storms with 1 foot of freeboard. Return to VR elevation between 24 and 36 hours. Minimum length to width ratio of 2:1 with 3:1 or more preferred.
Pretreatment	Forebay—Size pretreatment forebay to hold 10% to 15% of the VR with a depth of 2 to 4 feet.
Outlet Protection	Scour protection required at discharge point
Volume Provided (VP)	The water quality design volume provided (VP) by a constructed wetland is: VP (ft3) = (A)[(p)(M) + P] + PD, where • A = area of the constructed wetland (ft^2) • p = media porosity (% void), typically 40% • M = depth of the media (ft) • P = ponding depth of water (ft) • PD = Volume of Pretreament Device Design calculation sheets are available at www.louisvillemsd.org.
Landscape Plan	Landscape plan required showing native plants and/or non-invasive cultivars, plant size, spacing, installation and maintenance notes. Obtaining a one- or two-year maintenance agreement and warranty from the nursery or landscaper is recommended.

18.4.3 Green Wet Basins

Green wet basins are similar to standard wet basins, except for the addition of vegetation along an aquatic bench around the perimeter of the basin to provide water quality benefits and they retain the stormwater runoff for at least 24 hours. The vegetation helps provide water quality benefits. Green wet basins improve water quality by:

- Biological uptake and filtering of native plants
- Sediment settling, including attached pollutants
- Temporary retention of stormwater

Wet basin with native vegetation along the perimeter

Advantages/Benefits	Disadvantages/Limitations
• Relatively high removal rate for many pollutants • Increases biodiversity by providing habitats for wildlife and aquatic life • Reduces channel/stream bank erosion by reducing number of bankfull events • Opportunity for multiple use, including active and passive recreation	• Projects may require complying with KDOW dam regulations • Large space requirement • Possible safety concerns with a pool of water, fence may be required • Not to be used in high groundwater areas

18.4.3.1 Application and Site Feasibility

Green wet basins are similar to a standard wet basin; however, they contain an aquatic bench around the perimeter of the basin. Native vegetation can be planted from the normal pool level to a depth of no greater than 18 inches for water quality benefits. Native vegetation can also be planted above the normal pool elevation in the safety bench zone around the perimeter of the green wet basin. In addition, features may need to be included in the basin to minimize short circuiting between the inlet and outlet. Green wet basins can be constructed new or can be the result of retrofitted standard wet basins.

Green wet basins are appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or residential areas.

18.4.3.2 Physical Requirements

Key physical considerations are:

- Space availability - Sufficient space is required to treat and temporarily store stormwater runoff
- Drainage area - Have adequately large drainage area to provide hydrologic inputs during drier weather

- Plantings - Robust aquatic planting around the perimeter of the green wet basin to provide water quality treatment
- Outlet Structure - Outlet structure designed to provide retention for the 2, 10, 25, and 100-yr, 24-hour storms.
- Minimum permanent pool depth of 5 feet.

18.4.3.3 Design Criteria

Generally, green wet basins need to have a drainage area of 25 acres to help sustain water levels during dry periods providing wet conditions for the aquatic bench. The permanent pool should be a minimum of 5 feet and no deeper than 12 feet to prevent thermal stratification. The following criteria should be included in the design of green wet basins. For a summary of design parameters and site feasibility criteria, see Table 18.5. See Exhibit 18-10 for a typical green wet basin profile.

18.4.3.3.1 Conveyance

Although primary function of green wet basins is not conveyance, they do have to convey stormwater runoff from the inlet to the outlet. Because the pooled water in the basins allow opportunity for solid particles in the stormwater runoff to settle, the flow path needs to be diffused and as long as possible. To provide a long flow path, basins need to have a length to width ratio of at least 2:1, with 3:1 preferred.

Green wet basins need to be capable of passing the 100-year, 24-hour storm without damaging the vegetation or the surrounding embankments. The basin should have a normal pool depth of a minimum 5 feet deep and a maximum of 12 feet. A wide flow path through green wet basins will help to spread out and slow down larger flows, reducing the potential for erosion. An outlet structure including an emergency spillway to safely convey the flow out of the green wet basin is also needed. The area downstream of the outlet structure and emergency spillway should be protected to prevent any scour.

18.4.3.3.2 Soils

Green wet basins are intended to hold water; therefore the underlying soils need to be relatively impermeable. Soils should have a permeability ≤ 0.14 inches/hour. Soils with permeability rates greater than 0.14 inches per hour will require the use of an impermeable or low permeability liner.

18.4.3.3.3 Landscaping/Plant Selection/Side Slopes

An aquatic bench around the perimeter of green wet basins is required. This bench must be a minimum of 5 feet wide with a slope of 10% or flatter and a depth of no more than 18 inches below normal pool.

In addition, a safety bench with a 10-foot buffer above the normal pool elevation with native plantings and non-invasive cultivars is required around the basin. These plantings need to be located such that they do not impact access for maintenance activities. A landscaping plan is required for planting green wet basins. The plan should include bedding preparation, identification of the various planting zones and required plants for each planting zone. In addition, the plan should identify wet zones, ephemeral zones that will be subject to wet and dry periods as well as dry zones in order to select plants appropriate for each zone. Plants should be placed so that their roots do not impact any piping or other structures.

Choices available for planting the green wet basins include seed, rhizomes, bare root stock and potted plants. Planting rhizomes and seeds is less expensive initially, but requires a longer establishment period.

Mature plants are more expensive, but they grow and provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Green Wet Basin in Buechel has a naturalized buffer

18.4.3.3.4 Forebay

Excessive sediment accumulation in a green wet basin can reduce hydraulic capacity, block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the basin. The forebay must be sized to provide approximately 10% of the VR and prevent the resuspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 2 to 4 feet, which will also prevent the growth of unwanted vegetation and allow for the survival of mosquito eating fish and/or natural colonizing amphibians/insects. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the basin and reduce velocities to prevent erosion. The forebay should also be designed and located to allow for ready access to perform maintenance, including removal of accumulated sediment.

18.4.3.3.5 Outlet Structure

The outlet structure should include orifices or weirs (or a combination there of) to provide at least 24 hours of detention. The outlet must also detain the 2-, 10-, 25-, and 100-year, 24-hour storms. Considerations should be given to protecting the orifices from getting clogged with debris. Basins must be designed to return to normal pool elevation within 36 hours.
Low flow orifices shall be designed using the following equation:

$$a = \frac{2A\,(H - H_o)^{0.5}}{3600CT(2g)^{0.5}}$$

Where:
a = Area of orifice (ft^2)
A = Average surface area of the pond (ft^2)
C = Orifice coefficient, 0.66 for thin, 0.80 for materials thicker than orifice diameter
T = Drawdown time of pond (hrs), must be greater than 24 hours
g = Gravity (32.2 ft/sec^2)
H = Elevation when pond is full to storage height (ft)
H_o = Final elevation when pond is empty (ft)

18.4.3.3.6 Safety

Like any BMP that holds water, safety is a significant consideration. The side slopes within the basin shall be 3:1 or flatter. A safety bench with a maximum slope of 15:1 and minimum width of 10 feet must be provided just above the permanent pool level around the perimeter of the green wet basin. This safety bench shall be planted with native plants or non-invasive cultivars as a buffer to deter public access and enhance wildlife habitat. An aquatic bench functions as a safety feature and should be relatively flat with a maximum slope of 10% and a minimum width of 5'.

Table 18.5 Green Wet Basins Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	At least 25 acres of upstream drainage area to maintain water levels during dry weather.
Soils	Soil permeability should be ≤ 0.14 inches/hour.
Sizing	Depth 5 feet to 12 feet deep. Length to width ratio of at least 2:1, with 3:1 preferred.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended. Aquatic bench shall be a minimum 5-foot wide with a slope should be no greater than 10% and safety bench shall be a minimum of 10 feet wide with a maximum slope of 15:1.
Conveyance	Outlet structure and emergency spillway required.
Design Flows and Conveyance Capacity	Detain for at least 24 hours and pass the 2-, 10- and 100-year, 24-hour storms with at least one foot of freeboard. Green Wet Basins shall drain back to normal pool within 36 hours after the storm event.
Pretreatment	Forebay - Size pretreatment forebay to hold 10% to 15% of the VR with a depth of 2 to 4 feet
Outlet Protection	The area downstream of the outlet structure and emergency spillway should be protected to prevent any scour.
Volume Provided (VP)	The water quality design volume provided (VP) by a green wet basin is equal to VR.
Landscape Plan	Must provide a landscape plan showing native plants and/or non-invasive cultivars within the 10-foot buffer area and the minimum 5-foot aquatic bench.

18.4.4 Green Dry Basins

Green dry basins are similar to standard dry basins. The differences are that a green dry basin contains a forebay for capturing the heavier sediment and floatables, native or non-turf grass vegetation along the bottom of the basin, a multi-stage outlet that detains the runoff from the more frequent storm events, and no low flow channel to promote sheet flow. By design, green dry basins allow for extended detention, about 36 hours. Green dry basins improve water quality through:

- Biological uptake and filtering through deep rooted, native plants
- Sediment settling, including attached pollutants
- Temporary detention of stormwater
- A slower rate of release that reduces downstream bank erosion

Green dry basin concept rendering

Advantages/Benefits	Disadvantages/Limitations
• Effective at removing sediment • Increases biodiversity by providing urban habitats for wildlife • Well accepted by community	• Relatively large space requirement • Tends not to drain well, leading to maintenance challenges • Can pose a safety hazard due to water pooling during rain events • Not to be used in high groundwater areas

18.4.4.1 Application and Site Feasibility

Green dry basins are similar to standard dry basins, except for the addition of native vegetation, a forebay and a multistage outlet. Features may need to be included in basins to minimize short circuiting between the inlet and outlet.

Generally, green dry basins need to have a drainage area of at least 10 acres to keep the vegetation watered during the dry periods and a low flow orifice sized to not likely become plugged with debris. Green dry basins can be constructed new or can be the result of retrofitting standard dry basins. Green dry basins are appropriate for use in a wide variety of land use applications such as commercial, industrial or multi-family residential areas.

18.4.4.2 Physical Requirements

Key physical considerations are:

- Space available - Sufficient space is required to temporarily store the stormwater runoff.
- Drainage area - Have adequately large drainage area to provide some flow during drier weather and maintain larger low flow orifices.

- Plantings - Robust plantings along the bottom of green dry basins provide water quality treatment; plantings need to be able to survive the dry to submerged conditions that they will experience.
- Groundwater table - The groundwater table shall be at least 2 feet, preferably 4 feet, below the bottom of the basin.

18.4.4.3 Design Criteria

The following criteria should be included in the design of green dry basins. For a summary of design parameters, see Table 18.6. See Exhibit 18-11 for typical green dry basin profile.

18.4.4.3.1 Pretreatment—Forebay

Excessive sediment accumulation in green dry basins can block flow paths and smother vegetation. To remove the solids from the stormwater runoff, a forebay is essential for each inlet into the basin. The forebay should be sized to provide approximately 10% of VR and to prevent the re-suspension of settled solids into the stormwater flow. Typically the forebay depth will need to be about 2 to 4 feet deep. The forebay outlet should contain a dike, weir or bench to spread flows evenly across the green dry basin and reduce velocities to prevent erosion. The forebay should also be designed to allow for ready access to perform maintenance, including removal of accumulated sediment and floatables.

18.4.4.3.2 Conveyance

Though the primary function of green dry basins is not conveyance, they do have to convey the stormwater runoff from the inlet to the outlet. Because pooled water in the basins allows opportunities for the solid particles in the stormwater to settle, the flow path needs to be diffuse and as long as possible. To provide a long flow path, basins must have a length to width ratio of at least 2:1, with 3:1 preferred. The minimum slope of the flow path is 2%.

Green dry basins need to be capable of passing the larger storms without damaging the vegetation or the surrounding embankments. A wide flow path through the green dry basins will help to spread out and slow down larger flows, reducing the potential for erosion. An outlet structure and emergency spillway is also needed to safely convey the flow out of the green dry basins. The area downstream of the outlet structure and emergency spillway must be protected to prevent scour.

18.4.4.3.3 Outlet

The design and configuration of the outlet structure should allow for extended detention of the stormwater runoff from the required RE and the 2-year, 10-year, 25-year, and 100-year, 24-hour rain events. The outlet structure will likely consist of a riser connected to a discharge pipe that discharges to the downstream receiving channel. The outlet structure should be constructed in the embankment to allow for easy access to perform maintenance. Consideration should be given to providing trash racks to prevent outlet clogging and anti-seep collars around the discharge pipe to prevent seepage.

Low flow orifices shall be designed using the following equation:

$$a = \frac{2A\,(H - H_o)^{0.5}}{3600CT(2g)^{0.5}}$$

Where:
a = Area of orifice (ft^2)
A = Average surface area of the pond (ft^2)
C = Orifice coefficient, 0.66 for thin, 0.80 for materials thicker than orifice diameter
T = Drawdown time of pond (hrs), must be greater than 24 hours
g = Gravity (32.2 ft/sec^2)
H = Elevation when pond is full to storage height (ft)
H_o = Final elevation when pond is empty (ft)

A high flow bypass either separate from or in conjunction with the outlet structure should be included to safely convey high flows from large storm events. A minimum of one foot of freeboard should be provided during the 100-year, 24-hour rain event. The discharge from the outlet structure should be equipped with armoring, plunge pool, energy dissipater or similar best management practices to prevent scour.

18.4.4.3.4 Landscaping/Plant Selection

A landscaping plan is required for planting green dry basins. The plan shall include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Identify ephemeral zones that will be subject to wet and dry periods and dry zones and select plants appropriate for each zone. Choices available for planting the green dry basins include seed, rhizomes, bare root stock and potted plants. Planting rhizomes and seed is less expensive initially, but requires a longer establishment period. Mature plants are more expensive, but provide aerial coverage quicker and survive better. Often a combination of materials is used to balance costs with promoting rapid plant establishment.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native and cultivar species are provided in Chapter 13 of the MSD Design Manual.

18.4.4.3.5 Safety

Like any BMP that holds water, safety is a significant consideration. The side slopes should be 3:1 or flatter, 4:1 are preferred.

Table 18.6 Green Dry Basins Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	At least 10 acres of upstream drainage area.
Soils	Minimum infiltration rate for in situ soils is 0.5 inches per hour Recommended soil mix (by volume) for engineered soils: • 70%-85% sand • 10% to 20% silt + clay, with no more than • 5% to 10% clay; • 5% to 10% organic matter
Sizing	Minimum length to width ratio of 2:1 with 3:1 or more preferred.
Longitudinal Slope	Minimum slope of the flow path is 2%.
Side Slopes	No greater than 3:1 (H:V), 4:1 or flatter recommended.
Conveyance	Outlet structure and emergency spillway required.
Design Flows and Conveyance Capacity	Detain for at least 24 hours and pass the 2-, 10-, 25- and 100-year, 24-year storms with at least one foot of freeboard. Green dry basins shall be fully discharged within 36 hours after the storm event.
Pretreatment	Forebay—Size pretreatment forebay to hold 10% to 15% of the VR with a depth of 2 to 4 feet.
Outlet Protection	The area downstream of the outlet structure and emergency spillway should be protected to prevent any scour.
Volume Provided (VP)	The water quality design volume provided (VP) by a green dry basin is equal to VR.
Landscape Plan	Must provide a landscape plan showing native plants and/or non-invasive cultivars for green dry basin. Turf grass is not permitted in bottom of the green dry basin.

18.4.5 Green Roofs

A green roof is a roofing system made up of the following layers: a waterproof layer, drainage system, engineered soils and vegetation. Extensive green roofs are classified as green roofs with a soil depth of six inches or less. This shallow soil/growing medium layer is designed to support dense, low growing, and drought tolerant vegetation. Intensive green roofs have soil/growing medium depths greater than six inches to support the root growth of larger plants, shrubs, trees or elaborate rooftop gardens. Green roofs may also be called vegetated roofs or eco-roofs. Green roofs improve water quality through:

Green Roof at the Metro Archives

- Significant reduction of roof runoff volume
- Reduction of runoff pollutant loads compared to traditional roof applications
- Reduction of impervious area
- Biological uptake through drought tolerant plants

Advantages/Benefits	Disadvantages/Limitations
• Reduces energy costs • Provides additional roof insulation • Reduces urban heat island effect • Improves air quality • Extends life of roof • Adds landscaping value to outdoor rooftop gathering spaces • Provides wildlife habitat • Allows for retrofit opportunities	• Roof strength/structure may limit retrofit application • Extreme sun and wind conditions can challenge plant survival • Potential for roof leaks if not properly installed and maintained • Irrigation often necessary to establish plants • Planting on a sloped roof requires erosion control structures and is not recommended for intensive green roofs

18.4.5.1 Application and Site Feasibility

A green roof can be placed on high density residential, commercial, or industrial buildings that have the structural stability to support the increased loads of the green roof system. Fully saturated, extensive green roofs weigh approximately 15 to 25 pounds per square foot. Intensive green roofs weigh approximately 25 to 80 pounds per square foot. Passive outdoor amenity/recreational spaces may benefit or compliment a green roof with paths and patio areas adjacent to planting beds. Rooftops may be flat or sloped as steep as 25% for extensive roofs, given consideration for structural stability and erosion control of the system. Intensive green roofs must be flat or slightly sloped. An extensive green roof may be constructed on a new roof, or a remodeled roof that has the waterproofing and structural stability to hold the system in saturated, wet weather conditions. Especially in ultra-urban areas, green roofs can be used as passive recreational spaces including roof garden patios or functioning vegetable and herb gardens, given that structural considerations are met. Intensive green roof beds can be combined with shallower, extensive beds to supplement the roof with larger shrubs or trees at less cost than designing the entire roof as an intensive green roof.

18.4.5.2 Physical Requirements

Key physical considerations are:

- Roof stability—The roof must be structurally capable of supporting saturated soil/growing medium, vegetation and other structural loads. Shallower planting depths can reduce costs and structural loads.
- Roof waterproofing and drainage—The drainage layer is a key component to convey excess moisture through saturated soils/growing medium and off the roof deck. The roof must be waterproofed to prevent leaking and damage of the structure below. The waterproofing layer should be protected to prevent roots from damaging it. Leak detection systems may be installed to identify and locate leaks.
- Plant selection—Plant selection is limited due to extreme rooftop weather conditions including wind, sun, drought and cold winter temperatures. Plants selected should be able to withstand these extreme conditions. Green roofs require increased maintenance or irrigation during extreme conditions.
- Slope of rooftop—Extensive green roofs are suitable for both flat or sloped rooftops, but are much easier to design and install for flat rooftops (with a pitch of up to 1.5%). Rooftops with steep slopes require additional structural components to hold the soil/growing medium and drainage layers in place and prevent erosion. Rooftops with slopes greater than 25% are not suitable for extensive green roofs. Intensive green roofs are suitable for both flat and slightly sloped rooftops, up to 10%.

18.4.5.3 Design Criteria

Green roofs have several elements to manage stormwater including eliminating impervious area, plant absorption, and reduction of stormwater runoff volumes. The area of the green roof shall be considered pervious area and will not require additional water quality treatment. If a green roof covers at least 90% of a roof, the green roof shall be considered to treat 100% of the roof surface.

Proprietary green roof designs and materials available on the market may have requirements in addition to those in the guidance provided here. For a summary of design parameters, see Table 18.7.

Extensive Green Roof at Healthy House in Louisville, KY

18.4.5.3.1 Location of Green Roof Bed

Consider the purpose of the green roof. If the roof is intended for access by building occupants or patrons, beds must be separated by walking paths and patio areas. Beds should be clearly delineated and separated to minimize damage to plants and compression of soils due to walking or standing.

Wind and uplift pressures tend to be higher around the roof perimeter, and therefore should have a vegetation-free buffer between the green roof bed and the edge of the roof. Any rooftop openings should also have a vegetation-free buffer.

18.4.5.3.2 Structural Integrity of Roof

The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating a green roof. The dead load, including the total weight of green roof materials; saturated soil and snow loads; and other live loads must be considered. The placement of large trees or shrubs should be located over columns or main beams to support the heavy weight of the soil and plants.

18.4.5.3.3 Waterproofing

Since water is being retained on the rooftop, it is essential to have adequate waterproofing to minimize leaks that can damage the building interior. Waterproofing may be accomplished through the use of a waterproofing membrane or other waterproofing roofing systems. Coordinate with the roofing system manufacturer for application and comply with their specifications for installation.

A protective layer or root barrier should be used to prevent roots from damaging the waterproof membrane. The root balls of large trees and shrubs should also be anchored to avoid piercing the waterproof membrane. Electronic leak detection systems may also be considered to notify and locate leaks when they occur.

18.4.5.3.4 Drainage

The drainage layer often consists of a manufactured material or a shallow gravel layer to store stormwater for plant uptake and routing of stormwater. The design should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.

18.4.5.3.5 Soil and Plants

Soils for extensive green roofs should be between 3 and 6 inches thick. Soils for intensive green roofs should be greater than 6 inches thick. The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical extensive green roof soil mix may consist of the following materials, by volume:

- 50% pumice perlite
- 25% organic compost
- 25% topsoil

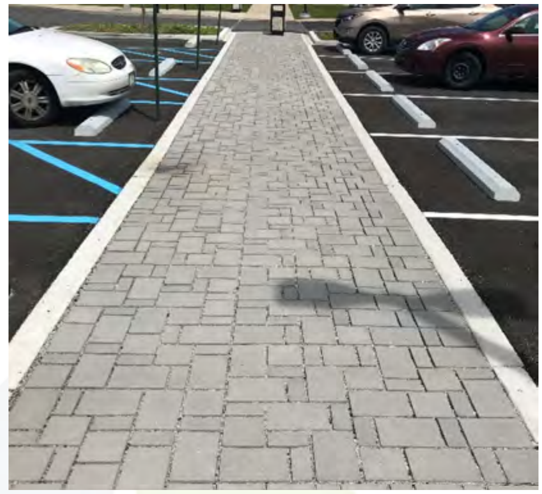
Some growing media contain no soil. The manufacturer will recommend plant types suitable for use with their product.

Plant species should be selected based on drought resistance and tolerance of extreme conditions including high winds, heat and cold. Intensive green roof plants require more maintenance such as irrigation and pruning compared to extensive green roof plants. To reduce maintenance, plants should be selected with the goal of reducing the need for irrigation, fertilizer and pesticides after establishment. A list of plant species is provided in Chapter 13 of the MSD Design Manual. Although perennial, self-sustaining, native plant varieties are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities or function.

Table 18.7 Extensive/Intensive Green Roof Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	The area of the green roof shall be considered pervious area and will not require additional water quality treatment. If a green roof covers at least 90% of a roof, the green roof shall be considered to treat 100% of the roof surface. Area of the green roof is considered pervious area and treatment area is only the area of the green roof.
Soil Mix/Media	The soil mix may be determined by the product manufacturer and can vary based on selected plant species. A typical green roof soil mix may consist of the following materials, by volume: • 50% pumice perlite • 25% organic compost • 25% topsoil
Sizing	The structural integrity of the roof should be evaluated by a licensed professional engineer to determine the loading limits of the existing or proposed roofing system and feasibility of incorporating a green roof. Extensive Green Roof – Soil depth of 3 to 6 inches. Intensive Green Roof – Soil depth greater than 6 inches.
Slopes	Extensive Green Roof – Flat slope (up to 1.5% pitch) to less than 25% slope. Intensive Green Slope – Flat rooftop (up to 1.5% pitch) to 10% slope.
Conveyance	The drainage layer must be present to convey excess moisture through saturated soils and off the roof deck.
Design Flows and Conveyance Capacity	Design should allow runoff to flow from saturated soils, through the drainage layer and to downspouts during rain events.
Outlet Protection	Roof must contain a waterproofing membrane or other waterproofing roofing system. Follow waterproofing manufacturer's recommendations. Additionally, a protective layer should be installed to prevent damage to the waterproof membrane.
Volume Provided (VP)	The water quality design volume provided (VP) by a green roof is: $VP\ (ft3) = (A)[(p)(M)] + (A)S$, where • A = area of the roof (ft^2) • p = media porosity (% void), typically 40% • M = depth of the media (ft) • S = storage depth of the drainage layer (ft) Design calculation sheets are available at www.louisvillemsd.org.

Landscape Plan	Plants should be selected based on drought resistance and tolerance of extreme conditions. For the intensive green roof, plants should be selected that will reduce the need for irrigation, fertilization and pesticide application. Trees and shrubs should be removed and replaced with smaller specimens every 10 to 25 years.

18.4.6 Permeable Pavers



Permeable pavers at YMCA East

Permeable pavers are pavement surfaces that promote infiltration of stormwater through gaps in the paver system. Pavers can be used in block or grid-systems, are aesthetically pleasing, and are Americans with Disabilities Act (ADA) compliant. Permeable pavers consist of individual concrete or stone shapes that are placed adjacent to one another over a specially designed sub-base. Permeable Pavers improve water quality through:

- Effective removal of light sediment and pollutants
- Reduction of stormwater runoff through infiltration to surrounding soils
- Surface flow reduction of peak flows

Advantages/Benefits	Disadvantages/Limitations
• Reduces volume of stormwater runoff • Reduces impermeable areas • Reduces need for drain pipe • Longer life than traditional pavement • Reusable product • Reduces need for detention space • Attractive/aesthetic pavement options	• Higher cost of pavers versus traditional concrete or asphalt pavement • Geotechnical exploration required • Significant maintenance requirements • Specialized knowledge required for proper installation • Not recommended for use in roadway • Not recommended under tree canopy

18.4.6.1 Application and Site Feasibility

Permeable pavers are an alternative to traditional asphalt and concrete paving methods and allow stormwater to infiltrate into the soil below. A professional (geologist or engineer) with geotechnical experience shall evaluate the soil to determine the proper design for the site being considered for permeable pavers. To minimize the frequency and amount of needed maintenance, it is recommended that strict silt control measures be used. Keeping the site clean during construction and maintaining vegetation along edges of the application will reduce clogging of the practice. Permeable paver design shall consider vehicular loads. Most current permeable pavers are not designed for high traffic areas or for areas used by heavy vehicles. For this reason, it should not be used in driving lanes and is best applied for parking areas or areas of pedestrian traffic only.

18.4.6.2 Physical Site Considerations

Minimum site requirements:

- The ratio of Drainage Area to Paver Footprint Area should not exceed 5:1. Ratios greater than 5:1 will be reviewed on a case-by-case basis
- The groundwater table should be a minimum of 2 feet below the base of the paver system
- Surrounding topography should have a maximum slope of 20%
- There should be a minimum separation of 10 feet from buildings
- Permeable pavers shall only be used in parking stalls and walkways

18.4.6.3 Design Criteria

The base layer under the permeable pavers is key to their performance. The design of this layer is based on vehicle equivalent single axle loads (ESALS), soil subgrade (geotechnical review), frost heave, design vehicle, pedestrian usage and the paver manufacturer's instructions. While the actual paver is designed to last much longer, most pavement/base designs are based upon a 20 year pavement life. The design and installation of permeable pavers shall be performed by qualified professionals. For a summary of design parameters, see Table 18.8. See Exhibit 18-12 for typical permeable pavement section.

Permeable Pavers at Brown Foreman

18.4.6.3.1 Intended Use

Intended use is a key consideration when selecting the type of permeable paver. This fact sheet addresses brick, concrete, and articulated concrete block/paver types. Permeable pavers shall only be used in parking stalls and walkways. Pavers shall not be used in drive lanes.

18.4.6.3.2 Storage Capacity

The base layers of the permeable paver system are designed to store stormwater until it can infiltrate into the subsoil or drainage system. The engineer will design the base layers, or the appropriate outlet system, to provide a depth that will accommodate the required VR. The VP provided by the designed permeable paver system can be calculated using the equation in Table 18.8.

18.4.6.3.3 Slopes (Subsoil and Pavement)

If a large slope is applied to either the pavement surface or subsoil, the depth of the base and/or the effective subsoil must be increased to account for the loss of capacity. If the base depth cannot be increased, trenching or piping may have to be used to transfer water from the system and avoid overflows. Because of this concern, it is recommended that the subsoil have a 0% slope and the surface have a 0.5% slope if it is at all possible. For subsurface slopes greater than 2%, benching is required.

18.4.6.3.4 Soil Stabilization

Soil stabilization is a concern with any type of pavement, but it is especially concerning with permeable pavers as a result of water being introduced into the pavement system and the lack of soil compaction to allow for proper drainage of the system. To address stabilization concerns, geogrid shall be placed on the subsoil surface before any of the aggregate layers are placed. If the aggregate layer is greater than 12 inches it is recommended to place a second layer of geogrid on the aggregate at this depth. The remaining aggregate will be placed on the second layer of geogrid. The selection of geogrid will be based on the size of aggregate used in the pavement system. The geogrid will convert the point loads created by vehicle tires into a uniform load distributed over the entire pavement area. By having a uniform load as opposed to point loads, the deformation/failure of the soil and pavement are greatly decreased, resulting in less failure in the pavement system over time. Any geogrid used in conjunction with the permeable pavers shall include the following geogrid specifications, at a minimum:

- Manufactured from a punched polypropylene sheet
- Triangular geogrid shall be used
- Resistant to weathering and chemical degradation

Geotextile fabric shall not be used as a soil stabilization device; however, it may be used in conjunction with geogrid if the Engineer has concerns with soil separation between the aggregate and subsoil.

18.4.6.3.5 Edge Restraint

An edge restraint is a barrier around the perimeter of the permeable pavers. It must be made of concrete and be adjacent to asphalt and other paved surfaces. This feature can be placed flush with the top of the pavers so that it can be driven over if overflow is desired, but must adhere to Louisville Metro/ADA requirements. The concrete edge restraint should extend to the lesser of: the bottom of the base layer or 18 inches below the surface of the permeable pavers. The edge restraint is used to keep the pavers from shifting after a load is placed on them. Edge restraints are required for brick, concrete, and articulated concrete block/paver types.

18.4.6.3.6 Base Design

The base of the permeable paver system will act as the storage layer for stormwater until the water infiltrates into the subsoil or is removed from the system through an underdrain system. The base should be made up of 2 layers of double washed aggregate. The first layer is placed directly on the geogrid and consists of double washed No. 3 stone. This first layer should be a minimum thickness of 18.5 inches. Due to the thickness of the first layer, a second layer of geogrid is recommended to be placed between the two layers of stone in the base layer. The second layer of stone consists of double washed (with quarry certification letter confirming the stone was double washed) No. 57 stone and should be placed directly upon the geogrid covering the No. 3 stone. This second layer of base should be a minimum of 4 inches

Mechanical installation of permeable interlocking concrete pavers thick. The entire base layer, including both the No. 3 and No. 57 layers, should be a minimum of 22.5 inches thick. See Section 18.6, Aggregate Specifications, for additional guidelines on the aggregate used for this practice. This minimum thickness will be structurally sufficient for the design ESAL of permeable pavers. The base thickness may be increased based on storage capacity. The base layer should completely drain after a design storm event if properly maintained.

18.4.6.3.7 Choker Course

The choker course is placed on top of the base layer and should be comprised of double washed No. 8 aggregate. The minimum thickness of the choker course is 1.5 inches. This course serves as a leveling surface for the pavers. The aggregate in the base is too large to produce an even surface suitable for the pavers to achieve a smooth surface. Choker course should be used for brick, concrete, and articulated concrete block pavers. Choker course may be omitted provided manufacturer specifications state that pavers can produce a level surface without a choker course.

18.4.6.3.8 Frost Heave Considerations

As with any type of pavement surface, frost heave is a concern where freezing temperatures are prevalent in the winter months. To reduce the possibility of frost heave, the base layer should be placed at 65% of the frost line (approximately 24 inches below the surface in the Louisville area for an average of a 3 feet frost depth).

18.4.6.3.9 Underdrain System

Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour. Underdrain systems are a series of pipes that run longitudinal with the pavers. The pipes used in an underdrain system are perforated pipes that tie into a non-perforated outlet. The size of the pipe is determined by the calculated stormwater capacity drained onto the permeable pavers. Underdrains should be designed to utilize slotted pipe with a minimum of 4 inches in diameter, minimum 0.5% slope and include a 4 inch minimum cleanout. Underdrains shall be surrounded by a minimum 24" wide and 15" deep area of double washed #57 stone. The underdrain should be elevated above the base of the excavation to encourage infiltration. Perched or elbowed underdrains are encouraged to allow for temporary storage and groundwater infiltration.

18.4.6.3.10 Overflow Design

An overflow must be designed for all paver designs to allow for larger storm events to drain to a suitable outlet and limit ponding over the pavers to no more than 6 inches.

18.4.6.3.11 Joint Aggregate Material

Chip stone or aggregate shall be installed between all paver joints to be even with paver surface. Chip stone or aggregate must be double washed.

Table 18.8 Permeable Paver Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	Drainage Area to Paver Footprint Area should not exceed 5:1. Permeable pavers shall not be used in high traffic areas or for areas used by heavy vehicles.
Soils	Underdrains are required when the in-situ soil infiltration rate is less than 0.5 inches/hour. Geogrid will be placed on the subsoil for stabilization. Underdrains shall utilize slotted pipes with a minimum diameter for four inches.
Sizing	The area and depth of the paver system shall be determined based on the design storage capacity.
Profile Grade	The subsoil is recommended to have a 0% slope and the surface is recommended to have a 0.5% slope. For subsurface slopes greater than 2%, benching is required. Maximum surface slope is 3%.
Slopes	Surrounding topography shall have a maximum slope of 20%. Recommended subsoil slope is 0% and the surface slope is 0.5%. For subsurface slopes greater than 2%, benching is required.
Outlet	An overflow must be designed for all paver designs to allow for larger storm events to drain to a suitable outlet as the maximum allowed ponding on pavers is 6 inches.
Volume Provided (VP)	The water quality design volume provided (VP) by a permeable pavers is: $VP\ (ft^3) = (A)(p1)(d1)$ • A = area of permeable pavers (ft^2) • $p1$ = porosity of base layer (% void), typically 40% • $d1$ =depth of base layer (ft) *Note: this formula only applies if the paver surface and sub soil have a 0% slope Design calculation sheets are available at www.louisvillemsd.org.

18.4.7 Tree Boxes

A tree box is very similar to a rain garden/bioretention cell in its design purpose and stormwater management benefits, except it exclusively uses trees and tall shrubs. At a minimum, a tree box temporarily detains the stormwater runoff as it flows through the box prior to discharge into the storm sewer system, drainage trench, overflow pipe or surface overflow through inlets and outlets. If surrounding soils have adequate permeability, a tree box can also be designed to promote infiltration of the stormwater runoff. A tree box can be used as a single BMP or connected in series through trenches. A tree box improves water quality through:

- Reduction of runoff volume through infiltration
- Treatment of stormwater percolating through soil and filter media
- Temporary detention of stormwater runoff
- Biological uptake through deep rooted, native plants

Advantages/Benefits	Disadvantages/Limitations
• Visually appealing • Can be used to address landscaping requirements • Provides infiltration, reducing runoff volume • Increases biodiversity by providing urban habitats for wildlife • Reduces heat island effects	• Increased maintenance over traditional curb and gutter drainage systems • Soil conditions may limit application • Limited to small drainage areas • Not recommended for high groundwater level areas • May not comply with KYTC requirements for state roads

18.4.7.1 Application and Site Feasibility

A tree box is a local feature that is used to treat and detain, and possibly infiltrate stormwater runoff. It may be connected in a series to provide opportunities for enhanced treatment of the stormwater and promote better tree viability. A tree box is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas. Tree boxes will need Metro/KYTC approval during the design phase, depending on where the tree boxes are installed and which entity holds jurisdiction.

Tree boxes along Story Avenue

18.4.7.2 Physical Requirements

Key physical considerations are:

- Space availability - Sufficient space is required to plant the tree or shrub and allow space for its growth both above ground and below ground.
- Soil types - Soil types affect infiltration and the ability for the tree roots to grow and spread. In addition, soils under existing infrastructure around the tree box need to be evaluated to determine their ability to allow the tree roots to spread.
- Tree box media - The infiltration rate of the media in the tree box will dictate how large a box area will be required for the VR.
- Location - Construction in a Louisville Metro right-of -way (ROW) or KYTC ROW will require conformance to applicable standards
- Footprint - A grate covering the tree box footprint is preferred to a fence around the perimeter of the box.
- Curb Cuts - Curb cuts must be rounded or covered with a plate.

18.4.7.3 Design Criteria

The design of a tree box includes several elements to manage stormwater: detention and conveyance to facilitate water quality improvement and infiltration to reduce stormwater runoff volumes into the sewer system. Generally, a tree box follows the same design approach as a rain garden/bioretention cell. There are proprietary tree boxes with standard sizes from manufacturers. If a proprietary tree box is not chosen, the following guidance can be used to size a tree box. For a summary of design parameters, see Table 18.9. See Exhibit 18-13 for typical tree box section.

18.4.7.3.1 Selection of Tree Box Type and Size

A tree box can be designed to capture and infiltrate the stormwater runoff through an open box design. If infiltration is not desired, temporary detention of the stormwater runoff can be accomplished using a flow-through sealed box design. The sealed box design will include an underdrain system connected to the storm sewer system, while the need for an underdrain system in the open box design will depend on the infiltration rate of the surrounding soil. The amount of infiltration that can be accomplished in the open box design will depend on the infiltration rate of the soil composition in the box and surrounding soils. Storage space can be provided under an underdrain system to allow more time for infiltration to occur. The tree box should not accept drainage from more than 0.25 acres of impervious area, but a smaller drainage area is encouraged for better performance.

Sizing of a tree box is based on the volume provided by the porosity of the tree box media and in the ponding above the tree box media. The volume should at least be equal to the Required VR.

Evaluate in situ soil conditions to determine if they have the needed infiltration for the tree box. If in situ soil have an infiltration rate less than 0.5 inches per hour, engineered soils and an underdrain are required.

18.4.7.3.2 Soil Composition

The soils around the tree box are extremely important, especially in an open box design where the tree roots are allowed to expand out past the tree box. If tree roots are allowed to spread, they will typically extend at least as far as the branches. However, if the surrounding soils are too compacted, the tree roots may not be able to penetrate the soil, thus limiting its viability.

The infiltration rate of the surrounding soil type is an important consideration for the open box design. Heavier clay or compacted soils have lower infiltration rates, while sandy, permeable, uncompacted soils promote infiltration.

If the primary purpose of the tree box is temporary detention with subsequent drainage to the storm sewer system (sealed box design), then an underdrain system is required. An underdrain system is required for open box designs that do not have the needed infiltration rates in the surrounding soils. Underdrains should be constructed with perforated pipe or slotted corrugated pipe (minimum 4 inches in diameter, minimum 0.5% slope and include a 4 inch minimum cleanout) and bedded in double washed No. 57 stone measuring a minimum 24” wide and 15” deep. Topsoil should be stripped and stockpiled for reuse. When grading and soil mix is placed, care should be taken that the soil is not compacted, resulting in a diminished infiltration capacity.

18.4.7.3.3 Plant Selection

A tree box is typically planted with a deep rooted, native tree or shrub. In selecting a tree or shrub, consider the box and soil depth, space for roots to grow, if the box will retain water for extended periods of time and select species accordingly.

Although native species are preferred, non-invasive cultivars may be used or combined with native species to achieve desired landscape aesthetic qualities. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual.

Table 18.9 Tree Box Application and Site Feasibility Criteria Chart	
Design Parameter	**Criteria**
Drainage Area	Tree boxes should not accept drainage from more than 0.25 acres of impervious area. Smaller drainage areas are encouraged for better performance.
Soils/Media	Ideal soils are sandy loam, loamy sand, or loam texture. Soil infiltration should be > 0.5 inches per hour or an underdrain must be used. Ideal media will contain adequate content for plant growth while maintaining infiltration rates greater than 1 inch per hour. A tree box should dewater within 36 hours. If necessary, an underdrain system can be added.
Sizing	Sizing of a tree box is based on the volume provided by the porosity of the tree box media and in the ponding above the tree box media.
Outlet	Overflow outlet or spillway required.
Volume Provided (VP)	The water quality design volume provided (VP) by a tree box is: $VP\ (ft^3) = (A)[(p)(M)+h]$ • A = area of tree box (ft^2) • p = media porosity (% void), typically 40% • M = depth of the media (ft) • h = average height of water above the media during the RE rain event in feet Design calculation sheets are available at www.louisvillemsd.org.
Landscaping	A deep rooted, native tree or shrub planting is preferred. When selecting a species, consideration should be given to box size, soil depth, and typical water retention times. A list of native species and cultivar species are provided in Chapter 13 of the MSD Design Manual. Low railing or a grate may be necessary as a protective barrier if there is a drop-off from the adjacent pavement. The maximum distance from the plating media to pavement is 12 inches.

18.4.8 Vegetated Buffers

A vegetated buffer, or filter strip, is a uniformly graded and densely vegetated area that treats and infiltrates stormwater runoff. The vegetation in the buffer works to slow down the stormwater runoff, settling and filtering some pollutants and uptaking others. The stormwater runoff volume can also be reduced by infiltration into the pervious soil, if available, and by absorption and evapotranspiration of the vegetation. For a vegetated buffer to be effective, the stormwater has to enter and flow through the buffer in sheet flow. The slope shall be a minimum of 2% and a maximum of 6%. The vegetation shall consist of native, deep rooted grasses, shrubs and trees. A vegetated buffer can be managed or unmanaged depending on the desired aesthetics. A vegetated buffer improves water quality through:

Vegetated buffer strip along a bike path

- Settling and filtering pollutants
- Reducing stormwater peak flows due to infiltration of stormwater runoff

Advantages/Benefits	Disadvantages/Limitations
• Reduces stormwater runoff volume through infiltration and groundwater recharge • Can be used as part of conveyance system and provides pretreatment for other BMPs	• Need to provide sheet flow to and throughout the buffer • Limited applications (i.e. adjacent to trails and sidewalks) • Not recommended for steep slopes or “hot spot” areas

18.4.8.1 Application and Site Feasibility

A vegetated buffer usually receives stormwater runoff from an upgradient impervious area and through sheet flow, is able to treat the runoff and if the soils allow, infiltrate some of the stormwater runoff volume. For the buffer to be effective, the runoff needs to enter and flow through the entire buffer length in sheet flow. Often a vegetated buffer is used as preliminary treatment of the stormwater prior to entering another BMP. A vegetated buffer is appropriate for use in a wide variety of land use applications including commercial, industrial, institutional or multi-family/high density residential areas.

18.4.8.2 Physical Requirements

Key physical considerations are:

- Space availability—Sufficient space to provide the buffer width and length is required
- Slope—The slope of the vegetated buffer shall be a minimum of 2% and a maximum of 6%
- Soil types—Soil types affect the amount of infiltration and the ability for the vegetation to thrive
- Sheet flow—Sheet flow needs to be provided throughout the vegetated buffer

18.4.8.3 Design Criteria

The design of a vegetated buffer includes several elements to manage stormwater treatment and infiltration. For a summary of design parameters, see Table 18.10. See Exhibit 18-14 for typical vegetated buffer plan and profile.

Existing natural areas including reserved open space and woodland protection areas may be considered as vegetated buffer on a case-by-case basis. At a minimum, these areas must be deed restricted, have substantial vegetation cover with limited invasive species or provide a planting plan for infill and remediation. Calculations may be required to show adequate slopes and/or velocities though the area.

18.4.8.3.1 Buffer Slope and Length

Uniform grading within the buffer is required to maintain the sheet flow throughout the buffer. The vegetated buffer slope in the direction of flow shall be a minimum of 2% and a maximum of 6%, which prevents ponding of the runoff, but does not promote the formation of concentrated flow. The length of the buffer (parallel to flow) shall be a minimum of 25 feet and shall be determined using the formula given in Table 18.10.

18.4.8.3.2 Buffer Width and Drainage Area

Stormwater runoff must enter the vegetated buffer as sheet flow across its entire width (perpendicular to flow) at a depth no greater than 1 inch for the required RE rain event. The buffer width shall be greater than or equal to the width of the contributing drainage area, with a minimum of 25 feet. Minimum travel time is 10 minutes.

The vegetated buffer is intended to treat runoff from a small contributing drainage area, typically not to exceed 3 acres. The flow length of the contributing drainage area shall be less than 300 feet. This will maintain sheet flow of stormwater into the vegetated buffer and reduce the risk of shallow concentrated flow forming.

18.4.8.3.3 Soil Composition

Soils with minimal clays are recommended for a vegetated buffer. The objective is to use soils that are able to sustain a dense vegetative growth.

18.4.8.3.4 Location

Vegetated buffers must be located in an open space. Area must be labeled as a “no mow” area and have signage showing area is a “no mow” area.

18.4.8.3.5 Naturalized Planting Plan

A naturalized planting plan is required for vegetated buffers. The plan shall include bedding preparation, identification of the various planting zones and recommended plants for each planting zone. Native species or native, non-invasive cultivars are required for use in vegetated buffers. Plants shall consist of native or native cultivars of deep rooted herbaceous plants (grasses, forbs, wildflowers), shrubs and trees. Native plants require minimal watering (once established), weeding, pest control fertilization and pruning; they are ideal for naturalized vegetated buffers. For this reason, exotic, non-native species are not suitable for vegetated buffers due to watering and other maintenance requirements. Include an inventory of all plants present in the vegetated buffer in the planting plan.

Remove invasive plant species if they are present in the vegetated buffer and replace with approved native plants. A list of native and native cultivar species (nativity categories N and C) are provided in Chapter 13 of the MSD Design Manual.

Plants should be selected based site conditions (i.e. sun/shade and wetland indicator status) suitable for each zone (see Chapter 13 of the MSD Design Manual). The planting plan and established plant density shall be consistent with the Manning's "n" value specified in design for buffer length and travel time. See Chapter 13 of the MSD Design Manual for plant spacing requirements.

Table 18.10 Vegetated Buffers Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	The area draining to the vegetated buffer shall be less than 3 acres. The flow length of the contributing drainage area shall be less than 300 feet.
Soils	Soils with minimal clays are recommended for a vegetated buffer.
Sizing	The width of the vegetated buffer (perpendicular to the flow) shall be greater than or equal to the width of the contributing drainage area, with a minimum of 25 feet. The length of the buffer (parallel to flow) shall be a minimum of 25 feet.
Slopes	The slope shall be uniformly graded with a minimum of 2% and a maximum of 6%.
Conveyance	Stormwater runoff must enter the vegetated buffer in sheet flow across its entire width.
Design Flows and Conveyance Capacity	Minimum travel time through the vegetated buffer is 10 minutes. Use the following equation to calculate travel time, T (in minutes): $T=[0.42*(n*L)^{0.8}]/(P^{0.5}*S^{0.4})$ or $L = ((T_c\text{^}1.25)*(P\text{^}0.625)*(S\text{^}0.5))/(338*n)$ • L = length of the buffer parallel to the flow path (ft) • T = travel time through the vegetated buffer (minutes) • P = RE (typically 0.6") • S = slope of the filter strip along the flow path (ft/ft) • n = Manning's "n" roughness coefficient, typical values (per USDA Urban Hydrology for Small Watersheds, TR-55) • T_c = time of concentration (hours)
Velocity (V)	Calculate the velocity of the stormwater runoff across the buffer to be sure that it is less than 2.0 feet per second (fps) using the following equation: V=Q/(d*W), where • d = the depth of flow (ft) • Q = peak discharge to the buffer from the required RE rain event (cfs) • W = minimum width (perpendicular to flow) of the filter strip (perpendicular to the flow (ft) Design calculation sheets are available at www.louisvillemsd.org.
Landscaping	The vegetation shall consist of dense, native, deep rooted grasses, shrubs and trees. Planting Plan required with native plants and/or non-invasive cultivars and their locations.

18.4.9 Underground Infiltration Basins

Underground infiltration basins include the practice of collecting and detaining stormwater runoff underground in pipes, vaults, chambers or modular structures. The collected stormwater runoff is intended to be infiltrated, with overflows being released back to the surface drainage system or storm sewer system at a reduced rate. The basin must be completely drained prior to the next rain event, similar to a green dry detention basin. An underground storage system may be constructed of a variety of materials, including concrete, steel or plastic. There are many proprietary products on the market. Underground storage improves stormwater management through:

- Detention of stormwater runoff, reducing peak flows
- Reduction of stormwater runoff volume through infiltration to surrounding soils

Underground Infiltration Basin at Churchill Downs

Advantages/Benefits	Disadvantages/Limitations
• Reduces channel/stream bank erosion by reducing the number of bankfull events • Increased public safety compared to surface detention BMPs • Can be used where available surface space is limited	• Requires pretreatment to reduce maintenance efforts • Not to be used in areas with high groundwater table

18.4.9.1 Application and Site Feasibility

Underground infiltration basins are applicable in areas where water quantity control is desired and land is not available or is too expensive for above ground BMPs. Underground infiltration basins need to be located such that the stormwater runoff gravity feeds into and out of the storage system. Underground infiltration basins should be located in areas that can be excavated in the future, should the need arise. Underground infiltration basins are appropriate for use in a wide variety of land use applications such as commercial, industrial, institutional or multi-family/high density residential areas, typically in ultra-urban areas.

18.4.9.2 Physical Requirements

Key physical considerations are:

- Space availability - Sufficient space is required to locate the required storage volume and provide access for maintenance vehicles.
- Material selection - Select the material of construction for the underground infiltration basin based on desired useful life, earthwork requirements, overburden support and potential for the system to float.

- Access – Multiple, appropriately spaced manholes/access ports need to be provided to allow for maintenance and inspection of the system.
- Slopes - The bottom of the underground infiltration basin should be sloped between 0.5% and 4% to allow for complete draining.
- Groundwater table - The groundwater table shall be at least 2 feet, preferably 4 feet, below the bottom of the infiltration basin.

18.4.9.3 Design Criteria

The design of underground infiltration basins includes several elements to properly reduce stormwater runoff volumes and reduce peak flow rates into the sewer system. For a summary of design parameters, see Table 18.11. Refer to Chapter 10 of the MSD Design Manual for detention requirements. See Exhibit 18-15 for typical plan and profiles for underground infiltration basin.

18.4.9.3.1 EPA Regulations for Class V Injection Well (Underground Injection Control, UIC)

Infiltration basins can be classified as a Class V Injection well by the EPA if it meets the following criteria (see the Class V wells page at www.epa.gov):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system."

If the infiltration basin designed meets any of the criteria listed above, the EPA form 7520-16 should be filled out and all other additional EPA regulations should be followed. Other terms including well, injection well, improved sinkhole or drywell will trigger requirements by the EPA.

18.4.9.3.2 Inlet and Pretreatment

Inlets need to be provided in the quantity, size and configuration needed for the desired stormwater runoff to enter the underground infiltration basin. Pretreatment, focused on the removal of floatables and sediment, must be provided at each inlet to the basin to reduce maintenance efforts and prevent any groundwater contamination. Pretreatment may include catch basin inserts or proprietary water quality units.

18.4.9.3.3 Outlet

The outlet orifices need to be sized to prevent clogging, typically no smaller than 6 inches, but provide the required retention of the stormwater runoff.

18.4.9.3.4 Overflow and Bypass

The underground infiltration basin must have an emergency overflow to allow for safe passage of the larger storm events. In addition, a bypass system or overflow path should be provided to allow the underground infiltration basin to be taken out of service should it become inoperable.

18.4.9.3.5 Infiltration

Soils must have a permeability rate of at least 0.5 inches/hour to promote infiltration.

18.4.9.3.6 Overburden Support

When selecting the underground infiltration basin material, consider the loading coming from above. The loading will include backfill, pavement, and possibly vehicular traffic.

18.4.9.3.7 Drawdown Time

The stormwater runoff VP collected in underground storage should drain out to a surface drainage or sewer system or infiltrate into the surrounding soils within 36 hours or as approved by MSD.

Table 18.11 Underground Infiltration Basins Application and Site Feasibility Criteria	
Design Parameter	**Criteria**
Drainage Area	Underground infiltration basins need to be located such that the stormwater runoff gravity feeds into and out of the storage system.
Soils	Minimum soil permeability of at least 0.5 inches/hour is required.
Sizing	Sufficient space is required to locate the required storage volume and provide access for maintenance vehicles.
Slopes	Slopes between 0.5% minimum and 4% maximum.
Design Flows and Conveyance Capacity	Detain for at least 24 hours and pass the 2-, 10-, 25- and 100-year, 24-year storms. Shall be fully discharged within 36 hours after the storm event. Must have an emergency overflow to allow for safe passage of the larger storm events and a bypass system allowing basin to be taken out of service should it become inoperable.
Pretreatment	Pretreatment is required at each inlet to the basin to reduce maintenance efforts and prevent any groundwater contamination. Pretreatment may include catch basin inserts or proprietary water quality units.
Outlets and Access	The outlet orifices need to be sized to prevent clogging, typically no smaller than 8 inches, but provide the required retention of the stormwater runoff. Multiple, appropriately spaced manholes/access ports to be provided to allow for maintenance and inspection of the system.
Volume Provided (VP)	The water quality design volume provided (VP) by a underground infiltration basin is: VP (ft^3) = (A)(M)(p),where • A = area of the infiltration basin (ft^2) • M = depth of the media (ft) • p = media porosity (% void), typically 40% Design calculation sheets are available at www.louisvillemsd.org.

18.4.10 Proprietary Water Quality Units

Proprietary water quality units (WQUs) vary based on manufacturer, but are typically underground treatment systems installed at the downgradient end of an on-site stormwater system. These systems are space-efficient and use a swirling vortex or multiple chambers to separate sediments and floatables, such as oil/grease, from stormwater inflow. Proprietary water quality units improve water quality through:

- Effective removal of total suspended solids
- Effective removal of oil/grease
- Pretreatment and use in series with other BMPs

Water quality unit

Advantages/Benefits	Disadvantages/Limitations
• Ease of installation • Optimal for sites less than 5 acres, with space limitations or where infiltration capacity is limited • Appropriate for retrofit applications • Good for impervious area runoff that may clog other types of BMPs • Can be designed to be suitable for hazardous substance runoff	• Not effective for volume reduction or infiltration of stormwater • Maintenance frequency varies depending on size of structure and quantity of flow and pollutants • Not effective for removal of dissolved pollutants and fine particles • Potential source of pollutants if maintenance is neglected • Low community amenity value (habitat, flood control, landscaping)

18.4.10.1 Application and Site Feasibility

Proprietary water quality units can provide water quality benefits for sites with limited area for infiltration opportunities. Some systems are suitable for areas with impervious runoff or hazardous materials because they provide treatment of water before it is infiltrated into the soil.

18.4.10.2 Physical Requirements

Proprietary water quality units vary based on the manufacturer; the approved types of units are outlined below.

18.4.10.2.1 Chambered Devices

Chambered devices allow water to flow into a sump-like structure separated by vertical baffle plate walls, dividing the structure into chambers. Typically, sediment and debris settle and oil and grease collect at the surface in the first two chambers, and flow exits the unit in a third chamber. As with hydrodynamic units, these structures must be designed to bypass larger storms. Regular inspection and maintenance frequency must be considered as part of the design process.

18.4.10.2.2 Hydrodynamic Devices

Hydrodynamic units route flow through the system using a swirling motion. Particles of sediment and debris separate and fall to the bottom, while floating materials are retained by a baffle wall. Hydrodynamic devices must be designed to bypass flow from larger storm events to prevent re-suspension of captured sediment and debris. Regular inspection and maintenance frequency should be considered as part of the design process.

18.4.10.3 Design Criteria

Design for water quality units shall be based on MSD minimum design requirements as well as the manufacturer's recommendations.

18.4.10.3.1 Location

Water quality units can be installed upstream of BMPs in series for pretreatment. Pretreatment is required for BMPs where maintenance access is limited such as infiltration trenches and underground detention and infiltration systems. Refer to manufacturer's recommendations for maximum drainage area. Water quality units must be located in an easily accessible area, not in a public roadway, for maintenance and inspection. The maximum depth of the water quality unit is 25 feet to allow for inspection of the unit. See Exhibit 18-16 for typical diversion structure arrangements.

18.4.10.3.2 Inflow Regulation

All proprietary water quality units shall be configured as offline systems, diverting the water quality volume into the unit for treatment and returning flow to the conveyance system or downstream BMP. Inflow regulation protects the unit from peak flows while treating the first flush and designed water quality volume. A bypass structure should direct the water quality flow rate into the water quality unit and allow larger storm events to bypass the unit. Bypass can be accomplished through a weir or offset pipes.

Weir

A junction box with an internal weir structure directs the required water quality peak flow rate (Q_p) though the WQU while higher flows bypass the WQU over the weir. Weirs are typically 6 inches to 24 inches tall but must be designed based upon the characteristics of the upstream pipe system, with a minimum weir height of 6 inches. A critical factor when designing the weir height is the hydraulic jump that is created when the Q_p hits the weir. A weir that is set too low will allow the hydraulic jump to overtop the weir and thus allow some Q_p to bypass the WQU. Conversely, a weir set too high will send flows beyond Q_p through the WQU possibly causing the re-suspension of previously captured solids and debris. The most important variable in the hydraulic jump is the slope of the pipe immediately upstream of the diversion structure. The higher the slope, the larger the energy head and thus, the higher the hydraulic jump. The slope of the upstream pipe should be kept as low as possible to lower the hydraulic jump. As a general rule, the weir height should be no more than ½ of the diameter of the pipe immediately downgradient of the junction box. If more than one pipe converges in the junction box, design the weir height assuming all of the Q_p enters the junction box through the larger pipe.

Offset pipes

Another method to direct Q_p to the WQU while bypassing high flows is to use offsite pipes with a "low flow" pipe to the WQU at the invert of the junction box while a larger pipe is located at a higher elevation in the junction box structure. In an offset pipe configuration, the low flow pipe is typically in a submerged condition with flow to the WQU calculated through the appropriate orifice equation with the bypass pipe invert set at the top of the required height "h" to force the Q_p through the orifice. A hydraulic jump is still a key design consideration and must be accounted for when setting the bypass pipe elevation. The minimum offset shall be 6 inches.

18.4.10.3.3 Pretreatment

Proprietary water quality units containing a filter media require a pretreatment/settling chamber to remove coarse sediment, solids, and debris that could clog the filter media.

18.4.10.3.4 Sizing

The Required Water Quality Peak Flow Rate (Q_p) to be treated by a WQU shall be calculated using the Rational Method (see Sections 10.2.3 and 10.3.1 of the MSD Design Manual). The area and composite c-factor should match the pipe chart on the Composite Drainage Plan sheet except that the rainfall intensity value (i) shall be 0.5 inches per hour (the 80th percentile storm intensity for an average year), regardless of the Time of Concentration (Tc).

18.4.10.3.5 Installation

Installation should always occur per manufacturer's recommendations. A manufacturer's representative should be present on-site during the installation of the water quality unit to ensure proper installation. Based on the water quality unit chosen, screens may also need to be installed to prevent mosquitos and rodents from entering the unit. Water quality units are not designed for use in areas under construction and should remain offline or plugged until at least 80%, preferably 100% of the site is stabilized.

18.4.10.3.6 Pollutant Removal

Pollutant removal varies based on the individual design of the water quality unit and can be customized per manufacturers' recommendations. At a minimum, units must achieve a Total Suspended Solids (TSS) removal efficiency of 80% based on OK-110 (D50=110µm) particle size distribution for the peak flow rate and be on the currently approved list for the City of Indianapolis (see Section 18.4.10.3.7). If the water quality unit is to be used as pretreatment for another BMP, a minimum of 50% TSS removal is required.

18.4.10.3.7 Proprietary Water Quality Unit Approval

MSD formally allows reciprocity with the City of Indianapolis for approving proprietary water quality units using the currently approved version of the "City of Indianapolis Stormwater Quality Unit (SQU) Selection Guide". Units approved by the City of Indianapolis using the TSS specification above may be considered "approved" for use in Jefferson County for the required flow rate.

If a unit is not on the list, the design engineer must submit third party verification of performance (such as New Jersey Department of Environmental Protection, New Jersey Corporation of Advanced Technology, Maine Department of Environmental Protection, etc.) to show that the proposed unit meets MSD's specifications, for MSD review and approval for use.

18.4.11 Open Infiltration Trenches

Open infiltration trench in the Parklands at Floyds Fork.

Open infiltration trenches are shallow, excavated areas that receive stormwater. Overland flow or a perforated inlet pipe allows stormwater to infiltrate through an aggregate bed and into the underlying soil, filtering stormwater pollutants. Design requirements for infiltration trenches include: pretreatment, drainage area size, storage capacity, and the exfiltration of the water to subsurface soil. Infiltration trenches improve water quality through:

- Treatment of stormwater percolating through soil
- Removal of light sediment/pollutants (pretreatment required to prevent clogging)

Advantages/Benefits	Disadvantages/Limitations
• Suitable for sites with limited space • Reduces volume of stormwater runoff and provides peak flow control • Appropriate for small sites (< 5 acres) unless large infiltration area is available • Provides infiltration and pollutant filtration	• May not be suitable for locations impacting utilities, shallow groundwater, bedrock, sinkholes and buildings/basements • Not suitable for slopes >3% • Access to infiltration interface is limited

18.4.11.1 Application and Site Feasibility

Infiltration trenches are filled with aggregate and have a designed overflow or bypass during high flow events. Infiltration trenches are applicable for a wide variety of uses such as the perimeter of parking areas or medians between drive lanes; however, they are not applicable for conveyance areas. Bottom slope shall not exceed 3%.

18.4.11.2 Physical Requirements

Key physical constraints:

- Surface dimension vs. depth - if an infiltration trench is designed so that it is deeper than it is wide, then it meets the EPA definition of a Class V Injection Well. See the Design Criteria section for more information.
- Infiltration - Trenches should drain in 24 to 36 hours. Native soils shall have an infiltration rate of 0.5 inches per hour or greater. For infiltration rate less than 0.5 inches per hour, an underdrain is required.
- Groundwater table - The groundwater table shall be at least 2 feet, preferably 4 feet, below the bottom of the infiltration trench.

18.4.11.3 Design Criteria

The design of an infiltration trench includes several elements to manage stormwater infiltration to facilitate water quality improvement. For a summary of design parameters, see Table 18.12. See Exhibit 18-17 for typical open infiltration trench plan and profile.

18.4.11.3.1 EPA Regulations for Class V Injection Wells and Underground Injection Control (UIC)

Infiltration trenches are generally long, narrow stormwater quality features that capture stormwater; however, an infiltration trench can be classified as a Class V Injection well by the EPA if it meets certain criteria (see the Class V wells page at www.epa.gov):

- "Any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or"
- "An improved sinkhole, or"
- "A subsurface fluid distribution system." (epa.gov)

If the infiltration trench designed meets any of the criteria listed above, the EPA form 7520-16 must be filled out and all other additional EPA regulations shall be followed. Wells, injection wells, improved sinkholes or dry wells will trigger EPA permitting requirements. MSD cannot approve injection wells without EPA approval.

18.4.11.3.2 Location

Infiltration trenches are retention structures when they are designed to effectively capture and infiltrate stormwater runoff. When finding the most appropriate location for the trench, it is best to find a location with a small drainage area that receives overland flow with no concentrated flows. The flow length of the contributing drainage area shall be less than 300 feet. This will maintain sheet flow of stormwater into the infiltration trench and reduce the risk of shallow concentrated flow forming.

Areas with heavy sediment flow or a significant pollutant load are not suitable locations because the pretreatment device and subsurface aggregate may become clogged or the groundwater contaminated. Infiltration trenches should be located at least 10 feet from building foundations and underground utilities.

18.4.11.3.3 Sizing

The surface storage parameter should be designed to retain/capture the volume produced by the rainfall events specified in Table 18.12. The depth of ponding within these structures should be kept relatively low to prevent hydraulic overloading of the in situ media. An overflow feature shall be installed to move excess water during a large storm event or in case of clogging. Sizing of infiltration trenches is based on the volume provided by the porosity of the media in the trench and in the ponding area above the trench media. The volume should at least be equal to the VR. See Table 18.12 for the VP formulas.

18.4.11.3.4 Storage Capacity

Infiltration trenches are designed to detain small storm events while also safely passing large storms with adequate freeboard. Infiltration trenches should have an adequate overflow system and maintain adequate freeboard to avoid flooding or overtopping of the area surrounding the BMP.

Open Infiltration Trench at Misa Metal Fabricating, Inc.

18.4.11.3.5 Slopes

Site topography should be considered in an infiltration trench design. Typically, the slopes of the contributing drainage area should be less than 10%. This prevents excessive scouring of the vegetated area due to high velocities from stormwater inflow. Additionally, the contributing area should be stabilized to reduce unnecessary silting of the practice.

18.4.11.3.6 Pretreatment

Pretreatment must be used for all applications to prevent clogging and ease maintenance, especially in land use areas with high sediment loads. Examples of pretreatment are pea gravel and vegetated buffers.

18.4.11.3.7 Infiltration Testing and Native Soils

Infiltration testing is required to be performed per Section 18.3. Infiltration trenches typically contain no outlet structure; however, an overflow structure is required. The native soils beneath the trench should have an infiltration rate of 0.5 inches per hour or greater and should be designed to drain in 24 to 36 hours. For infiltration rate less than 0.5 inches per hour, an underdrain is required.

The slope of subsurface native soils shall not exceed 3% and shall be sloped away from building foundations.

18.4.11.3.8 Storage Media

Infiltration trenches shall be installed using double washed aggregate (with a certification letter from the quarry), pea gravel, sand, and filter fabric. All storage media shall be clean and free of fines. For more information on aggregate requirements, see Section 18.6. River rock maybe used in trenches with non-load-bearing applications. A 6-inch to 12-inch layer of sand should be installed on the bottom of the trench to promote infiltration and to prevent compaction of the native soils. Filter fabric shall also be installed on the sides only of the trench to prevent migration of the native soils into the storage media. A 6-inch to 12-inch layer of double washed pea gravel is required for the top layer of the trench to facilitate capture of sediment before it enters the storage layer and to facilitate maintenance for removal of sediment that passes through pretreatment structures.

18.4.11.3.9 Underdrains

If the infiltration rate of in situ soil is less than 0.5 inches per hour, an underdrain is required. Underdrains should be constructed with perforated pipe or slotted corrugated pipe with a minimum 4-inch diameter and bedded in double washed KY #57 stone. Filter fabric should be avoided in this situation due to its propensity for clogging. Where filter fabric is necessitated, choose non-woven filter fabric. Underdrain pipes should be designed to be a minimum of 4 inches in diameter, minimum 0.5% slope and include a 4 inch minimum cleanout. Underdrains shall be surrounded by a minimum 24" wide and 15" deep area of double washed #57 stone. See Exhibit 18-6 for a typical underdrain.

18.4.11.3.10 Overflow

An overflow must be included to safely convey high flows from large storm events. The planning and installation of the high flow bypass or diversion structure will be largely based on each site design. For overflows tied into the combined sewer system, backflow prevention is required. Use splash blocks or other BMPs at overflow outlets to prevent scour.

18.4.11.3.11 Observation and Cleanout Wells

Observation and clean-out wells must be installed near the inlet and the center of the trench to monitor the water level of the trench and check for clogging. The observation well shall be a 6-inch perforated PVC pipe with a removable and lockable cap. See Exhibit 18-18 for typical observation well section.

Table 18.12 Open Infiltration Trench Application and Site Feasibility Criteria Chart

Design Parameter	Criteria
Drainage Area	Small contributing drainage areas receiving overland sheet flow with no concentrated flows are best suited. The flow length of the contributing drainage area shall be less than 300 feet.
Soils	Native soils shall have an infiltration rate of 0.5 inches per hour or greater. For infiltration rate less than 0.5 inches per hour, an underdrain is required.
Sizing	Sizing of infiltration trenches is based on the volume provided by the porosity of the media in the trench and in the ponding area above the trench media.
Slopes	Bottom slope shall not exceed 3%. Slopes of the contributing drainage area should be less than 10%.
Design Flows and Conveyance Capacity	Pass the 2-,10-, and 100-year, 24-hour storms with 6 inches of freeboard.
Pretreatment	Pretreatment must be used to prevent clogging. Examples of pretreatment include pea gravel and vegetated buffers.
Observation and clean-out Wells	Observation and clean-out wells must be installed near the inlet and the center of the trench to monitor the water level of the trench and check for clogging.
Outlet Protection	An overflow feature shall be installed to convey excess water during a large storm event or in case of clogging and maintain adequate freeboard to avoid flooding or overtopping of the surrounding area. Use splash blocks or other BMPs at overflow outlets to prevent scour.
Volume Provided (VP)	The water quality design volume provided (VP) by an open infiltration trench is: $VP\ (ft^3) = (A)(p1)(d1)$ • A = area of trench (ft^2) • p1 = porosity of base layer (% void), typically 40% • d1 =depth of base layer (ft) Design calculation sheets are available at www.louisvillemsd.org.

18.5 CONSTRUCTION

This section addresses construction practices unique to construction of post-construction water quality BMPs as a supplement to MSD's erosion prevention and sediment control requirements. Proper construction practices are critical to the initial and long-term functionality of the BMPs. Because most post-construction water quality BMPs rely on infiltration to maximize treatment volumes, it is important to protect the location of the BMPs on construction sites from compaction and sedimentation.

Construction of permeable paver parking lane and tree boxes

18.5.1 Construction Sequencing

Erosion and sedimentation carried from other areas of the construction site can clog and compromise the permeability of filter media and native soils. BMPs should be constructed in the final phases of construction. Once constructed, BMPs must be kept offline until at least 80% of the contributing area of the site is stabilized. All BMPs must be free of sediment and trash prior to site disturbance permit release. BMPs shall not be used as an erosion control device.

18.5.2 Good Housekeeping and Pollution Prevention

Good housekeeping practices, or pollution prevention practices, protect BMPs as well as keep harmful pollutants and construction waste out of our waterways. Spills and excess materials should be promptly cleaned up so that they do not wash into downstream drainages.

18.5.3 Compaction

Compaction must be minimized in locations for green infrastructure construction. These areas should be identified and marked by stakes or construction fencing to create a barrier so that heavy equipment does not compact native soils. Excavation should be performed by hand or performed from outside of the footprint of the practice when heavy equipment is necessary.

18.5.4 Infiltration Test

An infiltration test must be performed for all infiltrating practices after construction is complete to show minimum infiltration rate is met.

18.6 AGGREGATE SPECIFICATIONS

18.6.1 Clean Aggregate Specification

There are fundamentally different aggregate specifications for green infrastructure and traditional gray infrastructure practices. Green infrastructure requires water flow, storage, and infiltration through media and aggregate, whereas traditional projects combine aggregate with binding agents, creating impermeable surfaces. For aggregate used in green infrastructure projects, it is especially important to minimize fines coating the surface of the aggregate stone by double washing. Aggregate that is not double washed and clean is not suitable for post-construction water quality practices. Aggregates used in post-construction water quality practices must be accompanied with a certification letter from the quarry indicating that the stone was double washed.

18.6.2 Compaction and Settlement

The aggregate components of post-construction water quality practices should be compacted to minimize post-construction settlement while allowing exfiltration into in situ soils. Compact the aggregate utilized for storage volume or load-bearing structures to minimize settlement at the surface. Compaction of the aggregate needs to be determined by the designer based on the anticipated loads at the surface. Typically, vibratory plate compactors are used to obtain about 95% compaction of the aggregate.

At the aggregate/in-situ soil interface, the intermixing of these two materials should be minimized. Two typical approaches for minimizing this intermixing is the use of geotextile fabric (non-woven, sides only) and geogrids. Geogrids provide structural stability and keep the different layers of aggregate separated (i.e. the No. 3 aggregate layer should be kept separate from the No. 57 aggregate layer). This separation will help reduce settling due to the smaller particles filling in the void space provided by the larger aggregate. The aperture size of the geogrids is important in keeping the aggregate layers separated. See specifications for BMP for use of geogrid and geotextile fabric in combination with manufacturer specifications. Typically, geogrid is applied at each layer of aggregate size, and geotextile fabric is placed on the sides only, not on the bottom of the practice.

18.6.3 Prohibited Materials

Post-construction water quality practices rely on the void space and connection with in situ soils to store and exfiltrate stormwater. Dense Grade Aggregate (DGA) is aggregate that includes a wide variety of stone sizes. Stormwater cannot pass through DGA as readily as coarse grades and is not acceptable for use in post-construction water quality practices. For this reason, the use of DGA, construction waste, waste concrete, recycled materials, and similar materials is prohibited in the construction of post-construction water quality practices.

Stone used as base layer for green infrastructure

18.6.4 Non-Structural Applications

For non-structural applications (i.e. rain gardens, bioswales, etc), river rock may be used instead of a crushed limestone as the coarse aggregate. Additional caution shall be used in the vicinity of roads, parking lots and sidewalks when using river rock. Double washed crushed No. 3 Stone, No. 57 Stone, and No. 8 Stone is also acceptable. River rock is considered an acceptable substitute because there are less fines and grit on the rock. However, river rock is not recommended for practices with a loading (i.e. roads, parking lots pavers and sidewalks); due to reconsolidating and shifting. River rock is typically available in the following sizes: 1/2 inch and down, 3/8 inch to 5/8 inch, and 3/4 inch to 2 inches.

18.6.5 Structural Applications

For structural applications where post-construction water quality practices are to be used to support applications carrying load (i.e. permeable pavers), conform to KYTC gradations.

Furnish crushed aggregate meeting the quality of section 805 of the KYTC Construction Standards with the following exception: a shale content of 2% will be allowed, providing the combined shale, friable particles, and minus No. 200 content does not exceed 2%.

18.6.6 Required Documentation

A specification sheet showing the aggregate has been double-washed, certified by the quarry, is required for all structural applications or otherwise where coarse aggregate stone is used for post-construction water quality practices. Certifications for double washed coarse aggregate specifications shall be supplied to MSD inspectors and the property owner on site for each load of aggregate.

18.6.7 Number 3 Stone

Number 3 Stone (No. 3) is placed at the very bottom of the infiltration BMP and is used as a storage area. The stones must be double washed to keep as much fine material out of the storage area as possible.

Table 18.13 Gradation Sizes of No. 3 Stone Sieve Size-Percent Passing*				
2 ½ inch	2 inch	1 ½ inch	1 inch	½ inch
100	90-100	35-70	0-15	0-2
*No greater than 2% passing No. 200				

Number 3 Stone

Number 3 Stone

18.6.8 Number 57 Stone

No. 57 stone should be used as a base for a structure with loadings. An example of this would be sidewalks and roadways. In addition, it is generally placed on top of No. 3 stone. For practices that include pervious pavers, the No. 57 rock should be placed directly below the bricks. Most practices require double washed No. 57 stone. This 'washing' allows for fine material to be removed from the rocks, reducing the amount of clogging in the structure.

Table 18.14 Gradation Sizes of No. 57 Stone Sieve Size-Percent Passing*				
1 ½ inch	1 inch	½ inch	No. 4	No. 8
100	90-100	25-60	0-10	0-2
*No greater than 2% passing No. 200				

Number 57 Stone

Number 57 Stone

18.6.9 Number 8 Stone

No. 8 stone should be placed between the brick, concrete, or articulate concrete pavers. The stone should be washed, to keep fine material out of the storage areas and reduce clogging.

Table 18.15 Gradation Sizes of No. 8 Stone Sieve Size-Percent Passing*				
½ inch	3/8 inch	No. 4	No. 8	No. 16
100	85-100	10-30	0-10	0-5
*No greater than 2% passing No. 200				

Number 8 Stone

Number 8 Stone

18.7 OPERATION & MAINTENANCE GUIDANCE

Maintenance is a critical aspect of a properly functioning BMP. Pursuant to the Wastewater/Stormwater Discharge Regulations, sites with BMPs are required to enter into long-term Operations & Maintenance (O&M) agreements with MSD regarding the inspection and maintenance requirements for the BMPs. Annual reports are required for all BMPs. These records must be made available to MSD or Louisville Metro government upon request.

18.7.1 Overview of Maintenance Procedures

Routine inspections will help to maintain function of the BMP systems and prevent problems from arising. As most BMP systems are largely affected by the seasonal changes and storms, inspections should typically be conducted at the beginning of each season as well as after large rain events.

In general, the inspection and maintenance of BMP systems includes:

- Removal of sediment buildup
- Removal of debris from any inflow and outflow points
- Local erosion prevention and sediment control
- Routine inspection of the structural integrity of the BMP to ensure function
- Replacement of filter media (if needed)

In general vegetation maintenance includes:

- Irrigation and weeding during the first few months of planting to ensure species establishment
- Maintenance of the health and abundance of native species and plantings
- Annual trimming or pruning to prevent woody species growth
- Removal of any invasive species

This section provides detailed O&M procedures for each BMP.

18.7.2 Bioretention (Rain Garden, Bioswale, Tree Box or Planter Box)

Maintenance should be periodically conducted to ensure that the bioretention area is functioning properly. Initially (for the first year), the plantings will require more intensive maintenance to ensure proper species establishment and function. This initial maintenance of the system will primarily consist of:

- Monthly inspections of the soil
- Removal of accumulated debris or sediment buildup
- Erosion repair
- Watering during periods with no rain
- Replacement of dead or diseased vegetation
- Weeding of non-native invasive species.

Vegetation should be cut back and removed from the garden during the winter months when plants are dormant. Mulch should be added every 1-2 years; 2-3 inches of shredded hardwood mulch is preferred. Care should be given when mulching not to allow mulch to pile up on the stems of plants (woody or herbaceous).

After major rain events, it is important to inspect bioretention cell and make sure drainage paths are clear and any pooling water dissipates within 36 hours; note that water may pool for longer times during the winter and early spring.

If the bioretention BMP is not functioning properly, repairs to the under-drain as well as inflow and outflow structures may be needed.

By their design, bioretention cells are not in danger of becoming a breeding ground for mosquitoes. It takes 24 to 36 hours for a mosquito egg to hatch, after which it takes 10 to 14 days for the mosquito to complete its larval development to become an adult. By having a properly functioning and draining bioretention cell, the chances of providing mosquito habitat are virtually eliminated. If the bioretention cell holds enough water for mosquitoes to successfully breed, there is a problem with the soil, underdrain or outflow structure that should be addressed.

Table 18.16 Bioretention (Rain Garden, Bioswale, Tree Box or Planter Box) Maintenance Schedule	
Schedule	**Activity**
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
At least 3 times per year	• Prune and control weeds • Remove and replace dead or damaged vegetation • Mow perimeter areas as needed
Semi-annually in spring and fall	• Remove sediment, trash and debris from inlets/forebays • Inspect inflow points for clogging and remove any sediment • Inspect for erosion, rills or gullies and repair • Herbaceous trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from rain garden to prevent clogging and replace dead plants • Develop/adjust vegetation maintenance plan for trimming and dividing perennials (if applicable) to prevent overcrowding and stress and to achieve desired aesthetic qualities; remove any non-native, invasive species • Inspect vegetation for health and signs of stress; if vegetation begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe infiltration rates after rain events; bioretention BMPs should drain within 36 hours of a storm event • A mulching depth of about 2-3 inches should be inspected and obtained, and additional mulch should be added if necessary • Evaluate areas containing low flow stone or gravel; replace if necessary
Upon failure	• Replace/repair inlets, outlets, scour protection or other structures as needed • Replace vegetation as needed to align with original planting plan • If the rain garden is not meeting desired infiltration rates or over time soil has compacted, check soil infiltration rates by performing a percolation test • Re-aerate or replace soil and mulch layers as needed to achieve infiltration rate of 0.5 inches per hour • When removing soil for replacement, take to landfill or soil recycling center

18.7.3 Constructed Wetland

Constructed wetlands should be visited every quarter and following major rain events during the first year after construction. Inspections should evaluate:

- The success of the native plantings
- Establishment of invasive non-native plants
- Inlet/outlet conditions
- Sediment/debris accumulation

Repairs, replacements, and maintenance should be conducted as problems arise to maintain the functionality of the wetland. Maintenance will consist of:

- Repairs to the structural integrity of the outlet and containment edges
- Erosion and burrow repair
- Monitoring and removal of debris and sediment buildup with special care not to impact water storage capacity
- Invasive non-native species control
- Replacement of native plant material as needed to a minimum coverage of 50% of the wetland

Visits to the site can be reduced to 2 times per year in the second and third years after establishment.

A high level of qualitative monitoring should occur during the first three years after the wetland is installed to insure proper function and establishment of the constructed wetland. Monitoring should focus on successful establishment of native wetland plants, water storage capacity, and pollutant removal. Visual observations of the wetland can be recorded to determine how frequently sediment/debris should be removed. Over time, large wetlands that are heavily loaded will require more frequent monitoring than smaller less loaded wetlands.

Visual observations should be recorded for the establishment and density of native wetland vegetation and the presence of non-native and invasive species. Changes of concern include an increase in the numbers of aggressive non-native species, a decrease in the density of the vegetative cover to less than 50% of the wetland, and signs of disease. An invasive species management plan may need to be implemented if invasive species are present within the constructed wetland.

If near a populated area, monitor the wetland regularly for mosquito populations and develop and implement a control plan as needed.

Table 18.17 Constructed Wetland Maintenance Schedule	
Schedule	**Activity**
Quarterly during the first growing season	• Remove and replace dead, severely diseased vegetation, or damaged plants • Remove or control weeds and invasive species • Monitor wetland after major storm events to ensure structures are functioning properly and inspect for erosion
Semi-annually in spring and fall	• Inspect inflow points for clogging • Inspect for erosion, rills or gullies along the embankments and repair • Remove fallen, clipped, or trimmed plant material from wetland to prevent outlet clogging • Harvesting of seasonally dead plant material in the fall may be needed if high nutrient level treatment is desired • Inspect vegetation for health and signs of stress; if plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Observe water levels to confirm that they are as designed • Mow maintenance access areas around wetland • Maintain signs in "no mow" areas
Annually or as needed	• Remove sediment, trash and debris from inlets/forebays when one-quarter of the forebay volume has been lost
5 plus years or upon failure	• Monitor sediment accumulation and remove when one-quarter of the constructed wetland's design volume has been lost • Dredge sediment to meet original design volume and replace vegetation as needed to align with original planting plan

18.7.4 Green Wet Basin

A wet basin should be inspected semi-annually in the Spring and Fall as well as after major rain events. The basin should be maintained for structural stability and proper inflow and outflow discharge. Accumulated sediment and debris should be removed from the basin as well as the inflow area to prevent future clogging during rain events. Overall health and abundance of the native vegetation should be maintained, replacing dead or diseased plants as necessary. In addition, seasonal or yearly management should be conducted to remove or control invasive non-native vegetation from the site as well as to remove woody vegetation from all embankment areas.

Inspection of the buffer zone, downstream of the outflow point, should be conducted regularly to make sure that the wet basin is functioning properly and the outflow is not negatively impacting downstream habitats. This includes inspection for any erosion along the embankment of the basin.

Table 18.18 Green Wet Basin Maintenance Schedule	
Schedule	**Activity**
Monthly during the first growing season	• Remove and replace dead or damaged plants • Remove or control weeds and invasive species • Inspect and repair erosion • Water as needed to keep plants alive
Semi-annually in Spring and Fall	• Inspect inflow/outflow points for clogging • Remove any trash and debris • Inspect for erosion, rills or gullies along the embankments and repair • Vegetation should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from basin to prevent outlet clogging • If plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Inspect for plant root damage due to piping and mammal burrows; remove/repair when discovered • Mow maintenance access areas around green wet basins; do not mow buffer area around basin • Clean pond and forebay of debris and trash
Annually	• Remove sediment from inlets/forebays when one-quarter of the forebay volume has been lost
5 plus years or upon failure	• Monitor sediment accumulation and remove when one-quarter of the green wet basin's design volume has been lost • Dredge sediment to meet original design volume and replace vegetation as needed to align with original planting plan

18.7.5 Green Dry Basin

The seasonal maintenance of a dry basin consists primarily of the inspection of the inlet and outlet pipes for structural integrity; the clearing of sediment and debris from the inlet and outlet pipes as well as the basin; and the removal of debris from upstream areas to prevent it from washing into the basin. It is important to note that improperly maintained basins can reduce the storage volume of the pond as well as create breeding areas for mosquitoes.

Native vegetation should be maintained seasonally and after major rain events. Maintenance consists of replacement of dead or diseased plants, replanting of eroded areas, and invasive species control. The basin should also be trimmed annually to prevent the growth of woody species.

Table 18.19 Green Dry Basin Maintenance Schedule	
Schedule	**Activity**
Monthly during the first growing season	• Remove and replace dead or damaged plants • Remove or control weeds and invasive species • Inspect for erosion • Water as needed to keep plants alive
Semi-annually in spring and fall	• Inspect inflow/outflow points for clogging • Remove any trash and debris from forebay • Inspect for erosion, rills or gullies along the embankments and repair • Vegetation should be inspected to evaluate their health and remove any dead or severely diseased vegetation • Remove fallen, clipped or trimmed plant material from basin to prevent outlet clogging • If plants begin showing signs of stress, including drought, flooding, disease, nutrient deficiency, insect attack or improper mowing, treat the problem or replace the plants • Inspect for plant root damage due to piping and mammal burrows; remove/repair when discovered • Mow maintenance access areas around green dry basins • Green dry basins should drain within 36 hours of a storm event • Clean pond of debris and trash • Remove any sediment accumulation
Annually	• Remove sediment from inlets/forebays when one-quarter of the forebay volume has been lost
5 plus years or upon failure	• Monitor sediment accumulation and remove when one-quarter of the green dry basin's design volume has been lost • Remove sediment to meet original design volume and replace vegetation as needed to align with original planting plan

18.7.6 Green Roof

Green roofs will require irrigation or natural precipitation at least once a week until the plants have fully established. Once the plants have matured, extensive green roofs no longer need to be irrigated except in cases of extreme drought. The roof will require regular weeding during the establishment phase and only seasonal weeding thereafter. Vegetation should be monitored seasonally to maintain overall health and plants should be replaced or resown as needed. Plants should be fertilized annually or as recommended by the source nursery.

The increased weight and the addition of more intensive plantings tend to increase the maintenance requirements of those green roofs. The same overall maintenance noted for an intensive green roof should be followed, but on a more frequent basis. Plantings will need additional care and maintenance due the increased soil depth and the likelihood of additional invasive exotic plants becoming established.

The severe consequences of drainage backups, root punctures, and leaks in the waterproofing membrane system make seasonal inspections crucial. Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil. Debris and dead vegetation should be removed along with any woody vegetation. See minimum maintenance schedule in Table 18.17 below.

Table 18.20 Green Roof Maintenance Schedule (Extensive and Intensive Green Roofs)	
Schedule	**Activity**
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
Minimum 3 times during growing season	• Remove sediment, trash, weeds and debris • Implement landscaping maintenance plan for trimming to achieve desired aesthetic qualities • Mulch as needed • Inspect landscaping for health and signs of stress • If vegetation begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect underneath roof system • Drainage routes should be kept clear so that leakage is avoided and plants are not susceptible to increased moisture in the soil • Observe infiltration rates after rain events; green roof should drain within 24 hours of a storm event
Upon failure	• Replace green roof system

18.7.7 Permeable Pavement

Permeable pavers, require that the surface be kept clean of organic materials and debris through periodic vacuuming and low-pressure washing. Cleaning should be conducted seasonally with certain sites requiring additional maintenance due to the local conditions, and the frequency of storm events. Such cleaning will help to maintain the pavement's flow capacity and restore permeability. Areas should be routinely inspected for settling and loss of water flow through the system and maintenance should be conducted as problems arise. Regular maintenance should help prevent these issues.

For permeable pavers, after cleaning additional aggregate fill may need to be added and the pavers should be inspected for damages and repaired as needed. Research has shown that the use of a street sweeper or air jet to maintain pavers is relatively ineffective, that a vacuum/water jet combination attachment is most effective for surface maintenance, and that the rate of surface clogging can be slowed by adding a chip stone to the gaps between blocks.

Table 18.21 Permeable Pavement Maintenance Schedule	
Schedule	**Activity**
At least once per year	• Vacuum/water jet combination attachment • Replace aggregate between pavers as necessary (if applicable)
Monthly during the growing season	• Inspect the pavement for trash, debris and dirt • Keep weeds and grass out of the paved area (unless concrete grid pavers are being used) • Mow/trim adjacent vegetation and remove clippings and other debris from the area using a leaf blower • Visually inspect the pavement after large storms to ensure the overflow drainage system is working After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damage and repaired as needed
Semi-annually in spring and fall or as needed	• Sweep or vacuum the pavement with a street sweeper or street vacuum • If the pavement are installed in an area that is subject to higher than normal amounts of sediment (i.e. an area with large trucks traveling on it daily) it may need to be cleaned more often • Replace any joint material that may have eroded • Observe the system during a rain event • Areas should be routinely inspected for settling and loss of water flow through the system
As needed in winter	• Organic deicers may be used to melt ice and snow • Snow plows may be used when necessary under the following conditions: o The edges of the plow are beveled o The blade of the snow plow is raised 1 to 2 inches o The snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces
Upon failure	• When the base layer becomes clogged, remove pavers or pavement and replace/repair base layer to achieve design infiltration volume/rate. Note: Chip stone aggregate may be used between paver joints to prevent complete failure

18.7.8 Tree Boxes

Tree boxes should be kept free of debris and trash, and periodic cleaning should be conducted to clear the inflow and outflow mechanisms. The vegetation in the boxes will require more intensive maintenance over the first several months after installation, but this demand will decrease as the plants become established. Boxes should be kept free of invasive species and the overall health of the plants should be maintained. The soil and mulch in the boxes should be tested periodically to avoid the build-up of pollutants that may harm the vegetation. Any mulch used should be replaced biannually.

Tree boxes require regular irrigation during dry periods. If an under-drain system is used, maintenance of inflow and outflow structures will require periodic inspection and removal of sediment and debris, if necessary. In addition to general maintenance procedures, the tree/shrub should be trimmed or pruned according to an established maintenance plan.

18.22 Tree Box Maintenance Schedule

Schedule	Activity
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions
Semi-annually in spring and fall	• Remove sediment, trash, weeds and debris • Implement vegetation maintenance plan for trimming to achieve desired aesthetic qualities • Inspect vegetation for health and signs of stress • If tree/shrub begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Observe infiltration rates after rain events. The tree box should drain within 24 hours of a storm event • Replace mulching as needed, maintain at least 2-3 inches of mulch
10-25 years	• Remove tree/shrub and replace with smaller specimen

18.7.9 Vegetated Buffer

Initially, vegetated buffers should be inspected after major rain events to ensure proper draining. The vegetated buffer should maintain desired slope, length and width. Bare spots or eroded areas should be repaired to ensure they are functioning according to design specifications. Vegetation should only be mowed according to maintenance plans and “No Mow” areas should be clearly defined. Inspections should consist of replacement and care of plant materials and irrigation during dry periods. Accumulated sediment or other trash and debris should be removed and the buffer should be checked for erosion.

Table 18.23 Vegetated Buffer Maintenance Schedule	
Schedule	**Activity**
As needed	• Water as recommended by the nursery during establishment and then as needed during dry conditions • Trim vegetation in accordance with nursery recommendations
Semi-annually in spring and fall during first year and annually thereafter	• Inspect grading of vegetated buffer to ensure sheet flow across the entire buffer length and width • Inspect vegetation for health and signs of stress; if tree/shrub/grass begins showing signs of stress, including drought, flooding, disease, nutrient deficiency or insect attack, treat the problem or replace the vegetation • Inspect buffer for erosion and bare spots and repair
Following significant rain events (>10 yrs)	• Inspect and repair eroded or damaged areas to maintain sheet flow to and across the vegetated buffer

18.7.10 Catch Basin Inserts

Catch basin inserts will require very frequent sediment removal as their volume is very limited in comparison to the volume of the catch basin sump. It is necessary to routinely remove sediment, trash and debris and to replace the inserts if they are damaged. Inspections of catch basin inserts should be scheduled, at a minimum, prior to the first seasonal rains as well as during and after each major rain event.

The site should also be checked for excessive erosion or sediment flow upstream of the catch basin. It may also be necessary to periodically check the catch basin to ensure stormwater is flowing through the filter system. In addition to general maintenance procedures, the catch basin inserts should be replaced annually.

Table 18.24 Catch Basin Inserts Maintenance Schedule	
Schedule	**Activity**
Preventative measures	Inflow should flow through the filter system
Regularly and after Major Storm Events	Inspect catch basin inserts for clogging and remove sediment, trash or debris
Semi-annually in spring and fall	Visit site to ensure there is not excessive erosion or sediment flow upstream of the catch basin insert
As Needed	Replace catch basin inserts

18.7.11 Proprietary Water Quality Units

Proprietary water quality units should be inspected seasonally and after major rain events or per manufacturer's recommendations to ensure proper function. Manufacturer's guidelines should be followed and an individual maintenance plan should be developed for all systems based on routine inspections. In general, maintenance will include pumping and pressure washing the unit and cleaning blockage or sediment buildup with use of vacuum trucks or boom trucks. Drainage areas should be regularly maintained to prevent the flow of trash, sediment and debris into the system. Note that the system may need additional cleaning in the event that a spill of a foreign substance enters the unit.

Inspections should be conducted after the first rain event and also after major storms. Repairs to inlets, outlets, control valves or other structures should be performed periodically. Safety and maintenance practices for confined spaces should be followed when appropriate.

Table 18.25 Proprietary Water Quality Units Maintenance Schedule

Schedule	Activity
As needed	• Inspect drainage areas to proprietary WQUs for trash, erosion and debris • Perform cleanout if hazardous or foreign substances are spilled in the drainage areas • Repair inlets, outlets, control valves or other structural features as needed • Inspect system after major rain events to ensure it is draining properly
Quarterly	• Inspect system for blockage or sediment buildup and perform cleanout if necessary • Follow manufacturer's guidelines and develop/adjust maintenance plan for the system
Annually	• Perform cleanout of the system with vacuum or boom trucks • Clean any sediment or oil chambers • Inspect inlets, outlets and other structural features; repair as needed

18.7.12 Infiltration Trench or Basin (Open and Underground Storage)

Infiltration trenches and basins (Open or Underground Storage) will require maintenance inspections at least annually but more frequent inspections are recommended. It is necessary to check the observation well for clogging annually or as-needed basis (if applicable). All pretreatment systems and other structures connected to the infiltration BMP should be routinely checked for clogging. If the aggregate layer becomes clogged with sediment and debris, it may be necessary to remove the layer and replace it with new aggregate. It may also be necessary to check the observation well after major rain events to ensure the trench is draining properly. The top of the trench and all pretreatment devices should be cleared of leaves and other debris routinely. It is necessary to mow the area around the pretreatment devices, as well as the perimeter of the trench to clear access for maintenance. If the entire system appears to be clogged with sediment and is no longer functioning properly, this may trigger the removal of the sediment accumulation and replacement aggregate.

Table 18.26 Infiltration Trench Maintenance Schedule (Open and Underground Storage)

Schedule	Activity
Open Storage	
Schedule	**Activity**
2-3 times per year as needed	• Monitor the drain observation well after large rain events and check for any ponding water • Mow or trim the perimeter of the practice and any pretreatment devices; grass clippings should be removed to prevent clogging • Check observation well for clogging
Semi-annually	• Check pretreatment systems and other structures for clogging; remove sediment and debris as necessary • Inspect the top layer of the trench for ponding water, leaves, grass clippings or other debris • Inspect any piping or other structural devices for damage and replace as necessary
Upon failure	• If the entire system becomes clogged, remove and install clean, double washed trench aggregate • It may also be necessary to replace piping, filter fabric, etc.
Underground Storage	
As needed	• Inspect drainage areas to BMP for trash, erosion and debris • Perform cleanout if hazardous or foreign substances are spilled in the drainage areas • Repair inlets, outlets, control valves or other structural features as needed • Inspect system after major rain events to ensure it is draining properly
Quarterly	• Inspect system for blockage or sediment buildup and perform cleanout if necessary
Annually or as needed	• Perform cleanout of the system with vacuum or boom trucks • Clean pretreatment device • Clean any trapped or sump manhole structures connected to system (if applicable) • Inspect inlets, outlets and other structural features; repair as needed
Upon failure	• When the base layer becomes clogged and no longer infiltrates at the design rate/volume, the subsurface will need to be removed and replace to achieve the design infiltration rate/volume Note: Pretreatment is required for the system to prevent complete failure

18.8 REFERENCES

Associates, S., Consultants, G., Sustainable Streams, L., & Kentucky, S. D. (2012). *Storm Water Best Management Practices Manual.* Florence. Retrieved from http://www.sd1.org/Resources/NKYStormWaterBMPManualFeb2012.pdf

Center, T. W., & Control, T. D. (2003). *Tennessee Guide to the Selection & Design of Stormwater Best Management Practices (BMPs).* Nashville. Retrieved from https://www.mtas.tennessee.edu/sites/default/files/phaseIIguide.pdf

City of Columbus Department of Public Utlities. (2017). *Stormwater Strategic Plan Green Infrastructure Design & Implementation Guidelines.* Columbus. Retrieved from https://www.columbus.gov/utilities/projects/blueprint/Green-Infrastructure-Design-Guidelines-and-Supplemental-Specifications/

Metro Water Services. (2016). *Low Impact Development Stormwater Management Manual.* Nashville. Retrieved from https://www.nashville.gov/Portals/0/SiteContent/WaterServices/Stormwater/docs/SWMM/2016/Vol5LID/2016_FullVol5LIDManual.pdf

Resources, M. D. (2012). *Missouri Guide to Green Infrastructure.* Retrieved from https://dnr.mo.gov/pubs/pub2446.pdf

USACE, & Services, M. W. (2009). *Green Infrastructure Design Using Low Impact Development.* Nashville. Retrieved from https://www.nashville.gov/Portals/0/SiteContent/GeneralServices/docs/Landscape-Manual/Green_Infrastructure_Design.pdf

USACE, & Services, M. W. (n.d.). *Rain Gardens for Nashville.* Nashville. Retrieved from https://ag.tennessee.edu/tnyards/Documents/Rain%20Garden%20Brochure%20Metro%20Nashville.pdf

Works, I. D. (2016). *City of Indianapolis Department of Public Works Green Infrastructure Supplemental Document 2016.* Indianapolis. Retrieved from https://citybase-cms-prod.s3.amazonaws.com/bba092d3974b4bb195c23acd2ba2c18e.pdf

(2010). *Storm Water Design and Specification Manual.* Fort Wayne. Retrieved from https://www.cityoffortwayne.org/resources-for-you/developers-engineers-contractors/3242-green-design-standards.html

18.9 EXHIBITS

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky 40203
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www.louisvillemsd.org

EXHIBIT 18-1
RAIN GARDEN & OVERFLOW STRUCTURE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

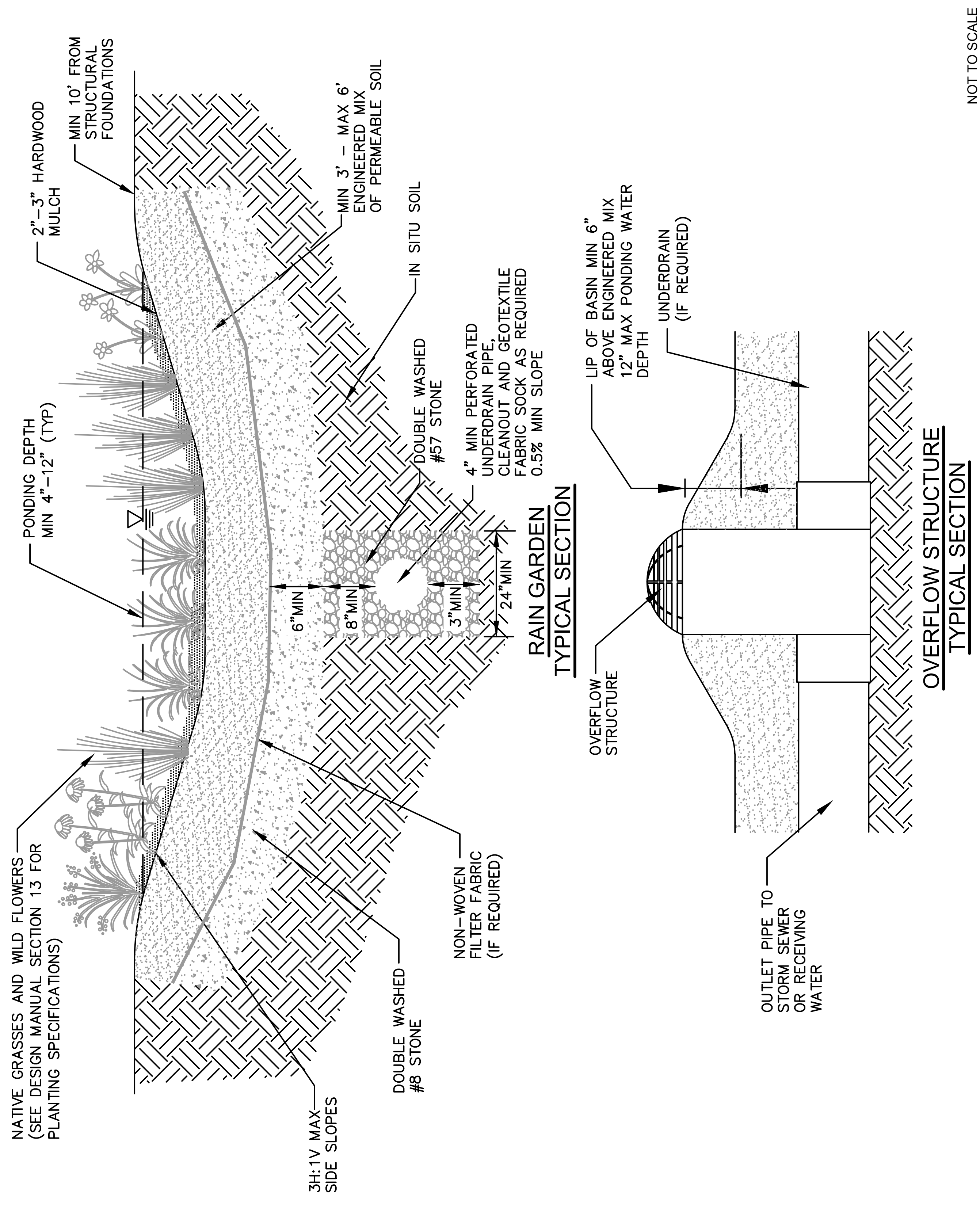

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EXHIBIT 18-2
RAIN GARDEN INLET & OUTLET SPLASH BLOCKS

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE

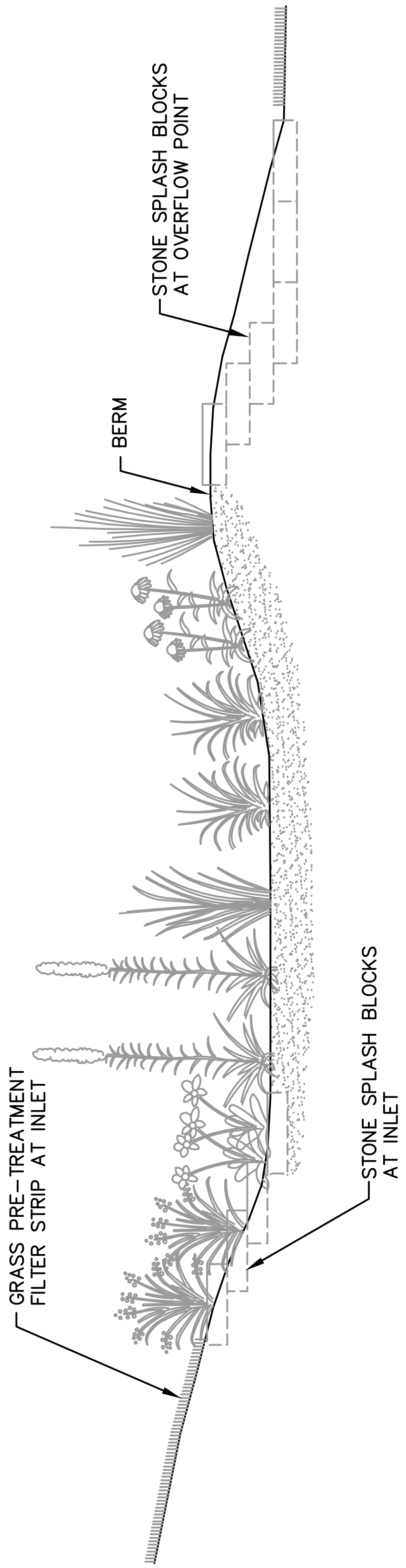

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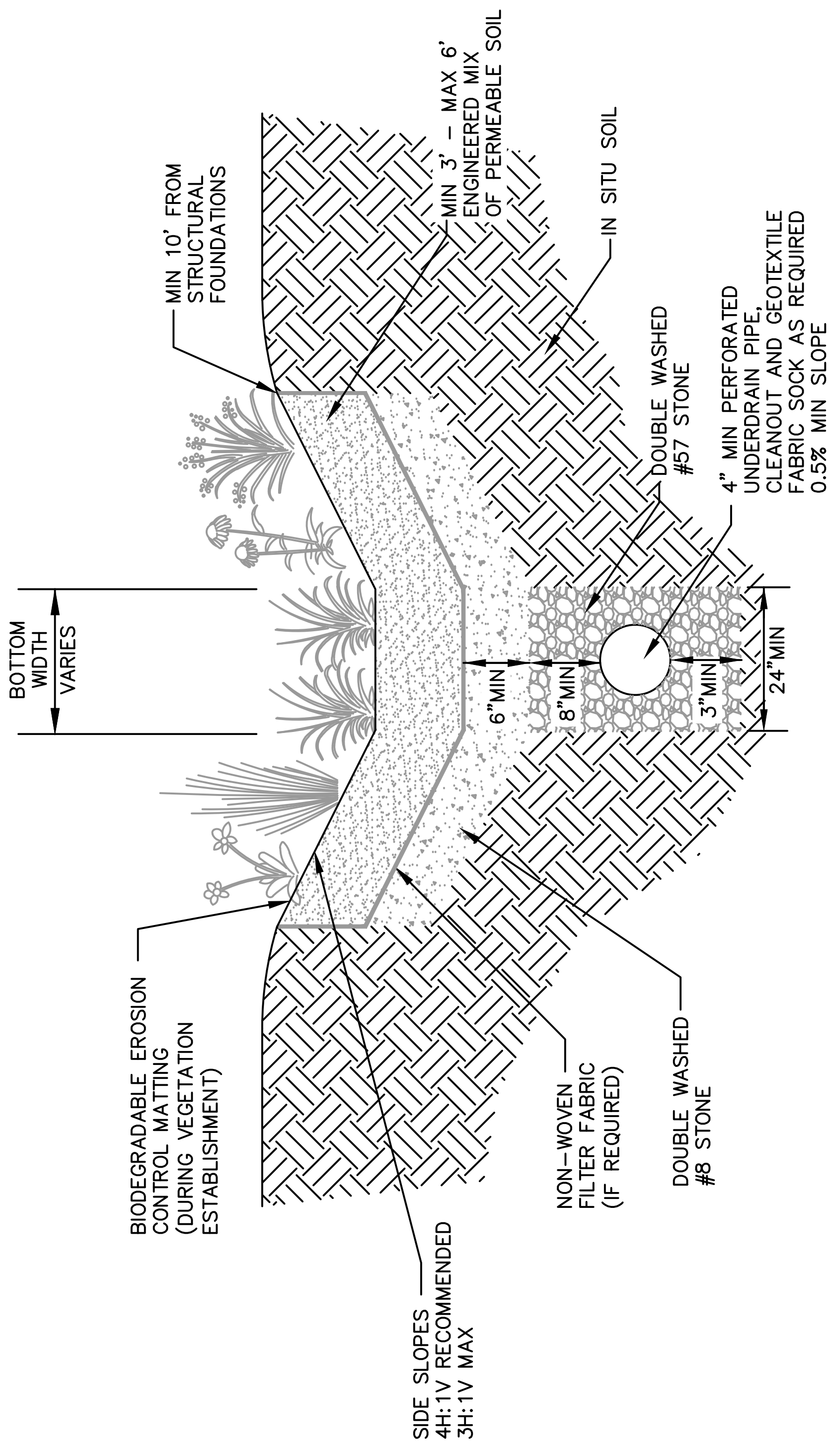
EXHIBIT 18-3
BIOSWALE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



BIOSWALE
TYPICAL SECTION

NOTES:
1. LONGITUDINAL CHANNEL SLOPE 1% - 4%
2. CHECK DAMS OR WEIRS REQUIRED FOR SLOPES 2% - 4%

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EXHIBIT 18-4
CHECK DAM WITHIN BIOSWALE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

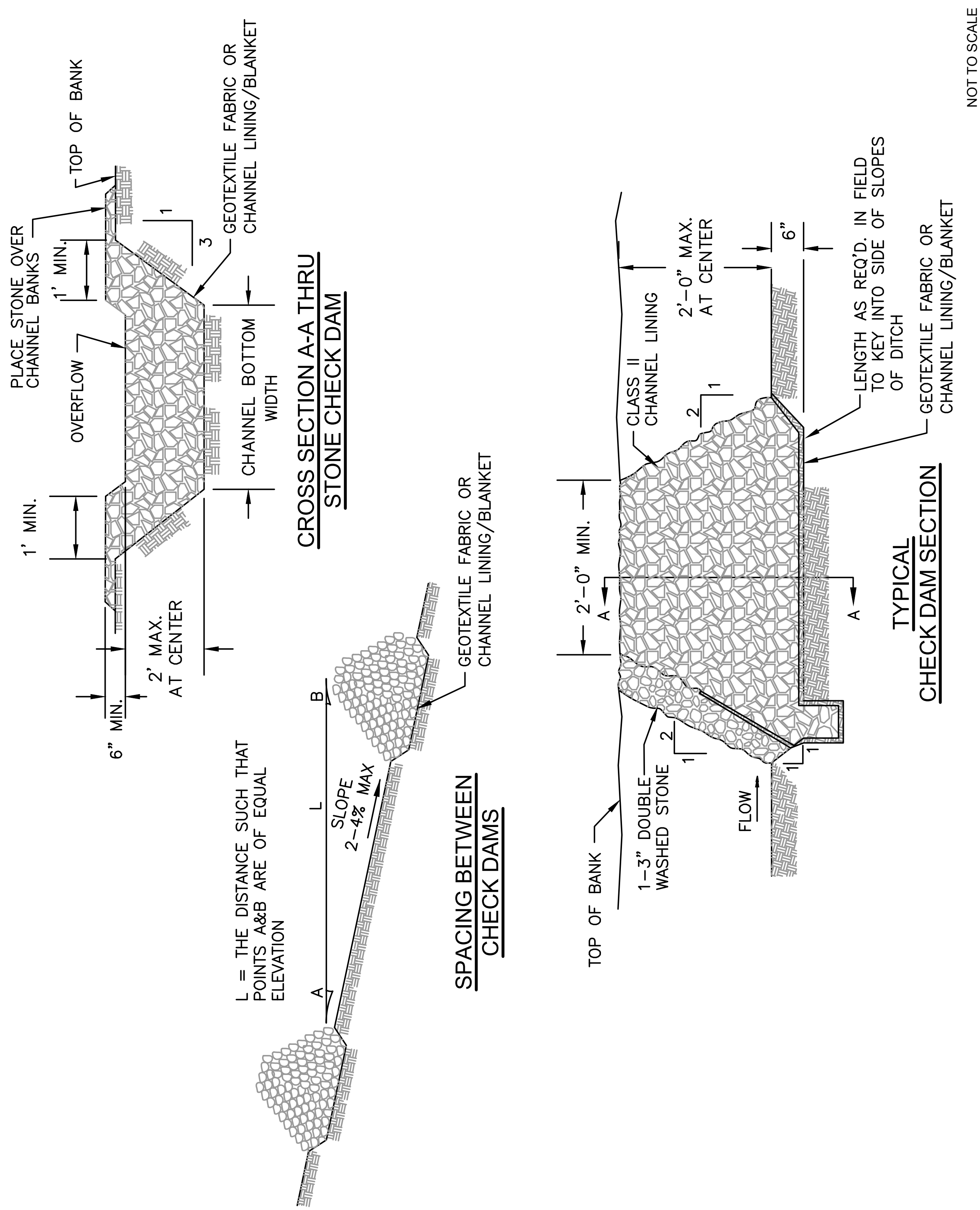

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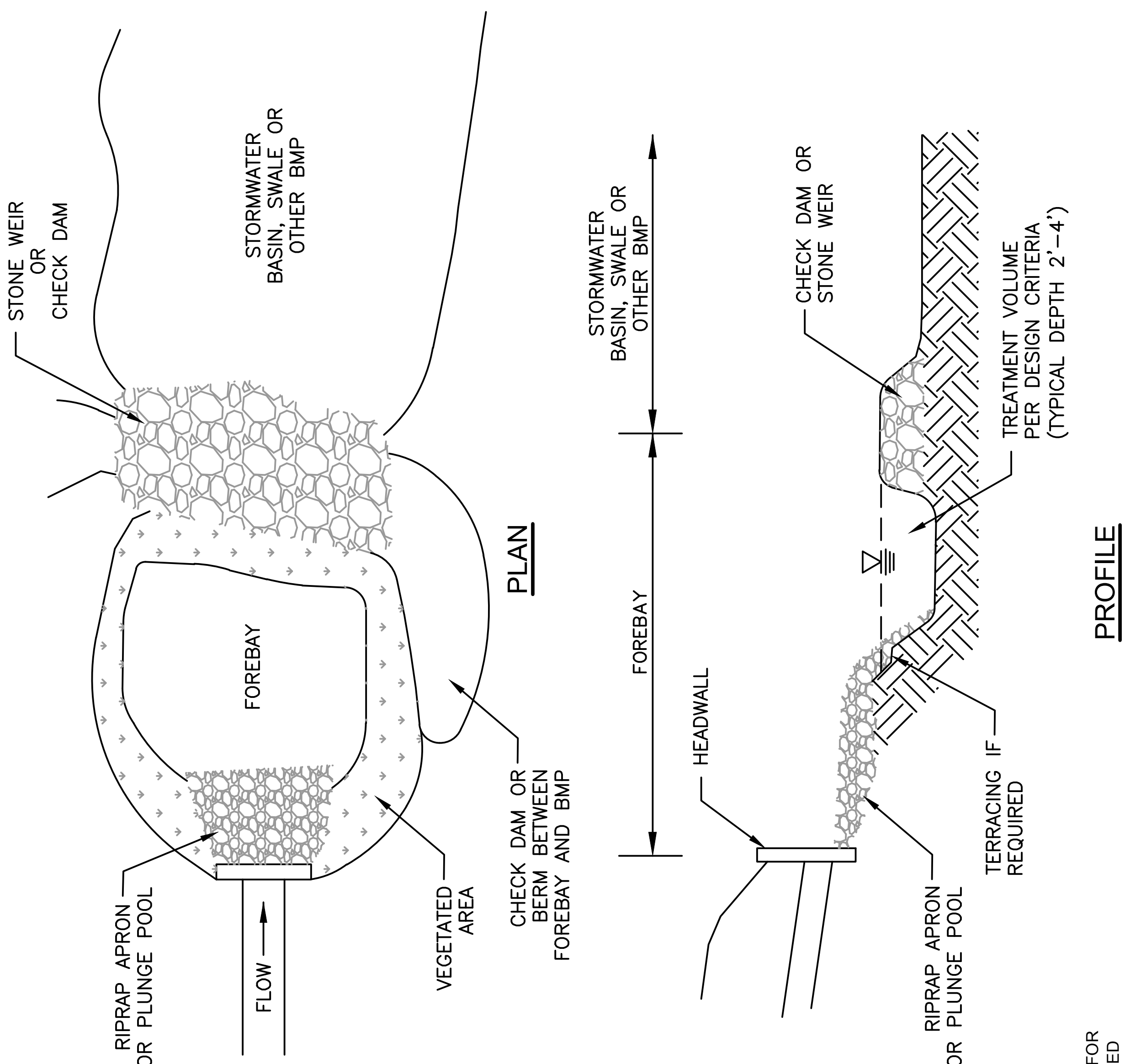
EXHIBIT 18-5
FOREBAY

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTE:
FOREBAYS ARE RECOMMENDED FOR RAIN GARDENS AND ARE REQUIRED FOR CONSTRUCTED WETLANDS, AND WET AND DRY BASINS

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EXHIBIT 18-6
UNDERDRAIN WITH CLEANOUT

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE

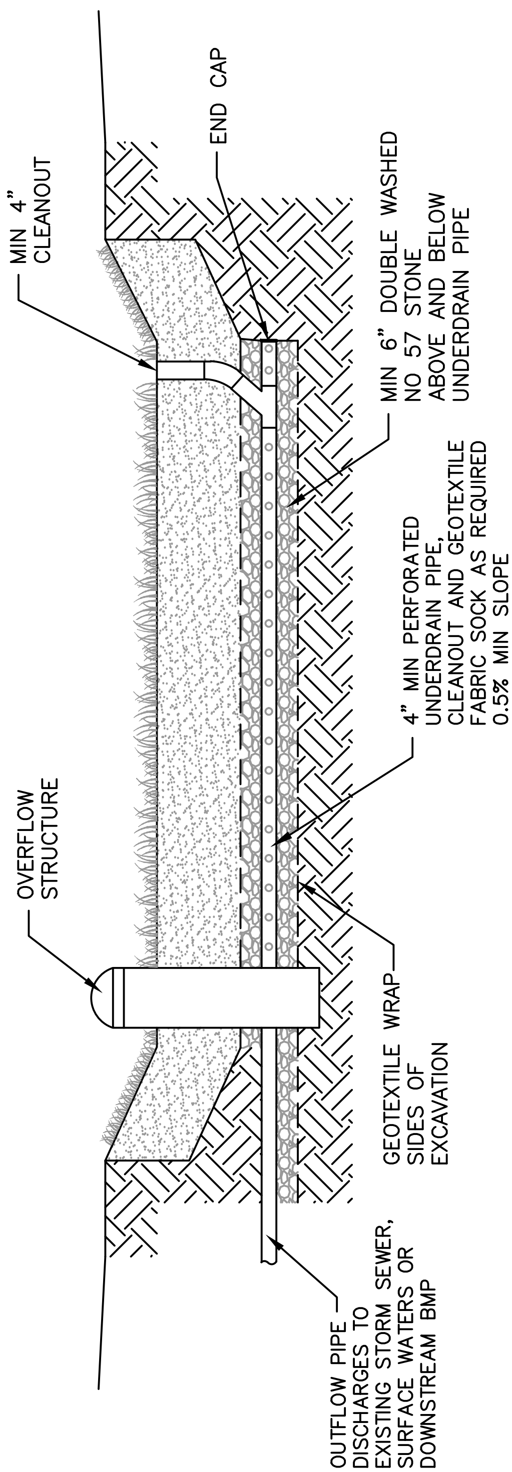

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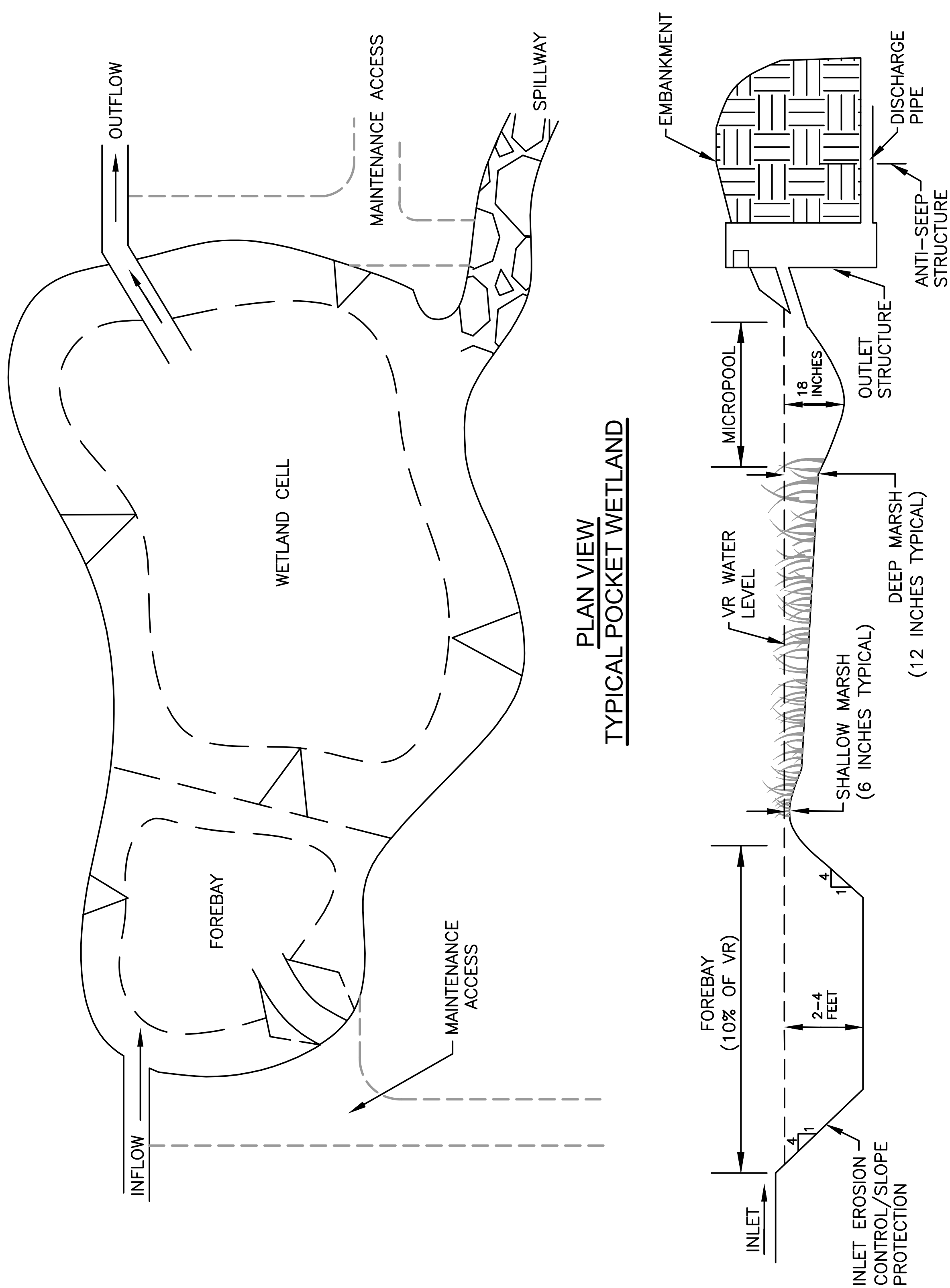
EXHIBIT 18-7
CONSTRUCTED POCKET WETLAND TYPICAL PLAN VIEW AND PROFILE

EFFECTIVE DATE: JUNE 30, 2021



PLAN VIEW
TYPICAL POCKET WETLAND

PROFILE
TYPICAL POCKET WETLAND

NOT TO SCALE

NOTES:
1. MUST BE MODIFIED PER SITE SPECIFIC DESIGN.
2. SEE MSD GREEN INFRASTRUCTURE DESIGN MANUAL CHAPTER 18.4.2 FOR MORE INFORMATION ON CONSTRUCTED WETLAND DESIGN.

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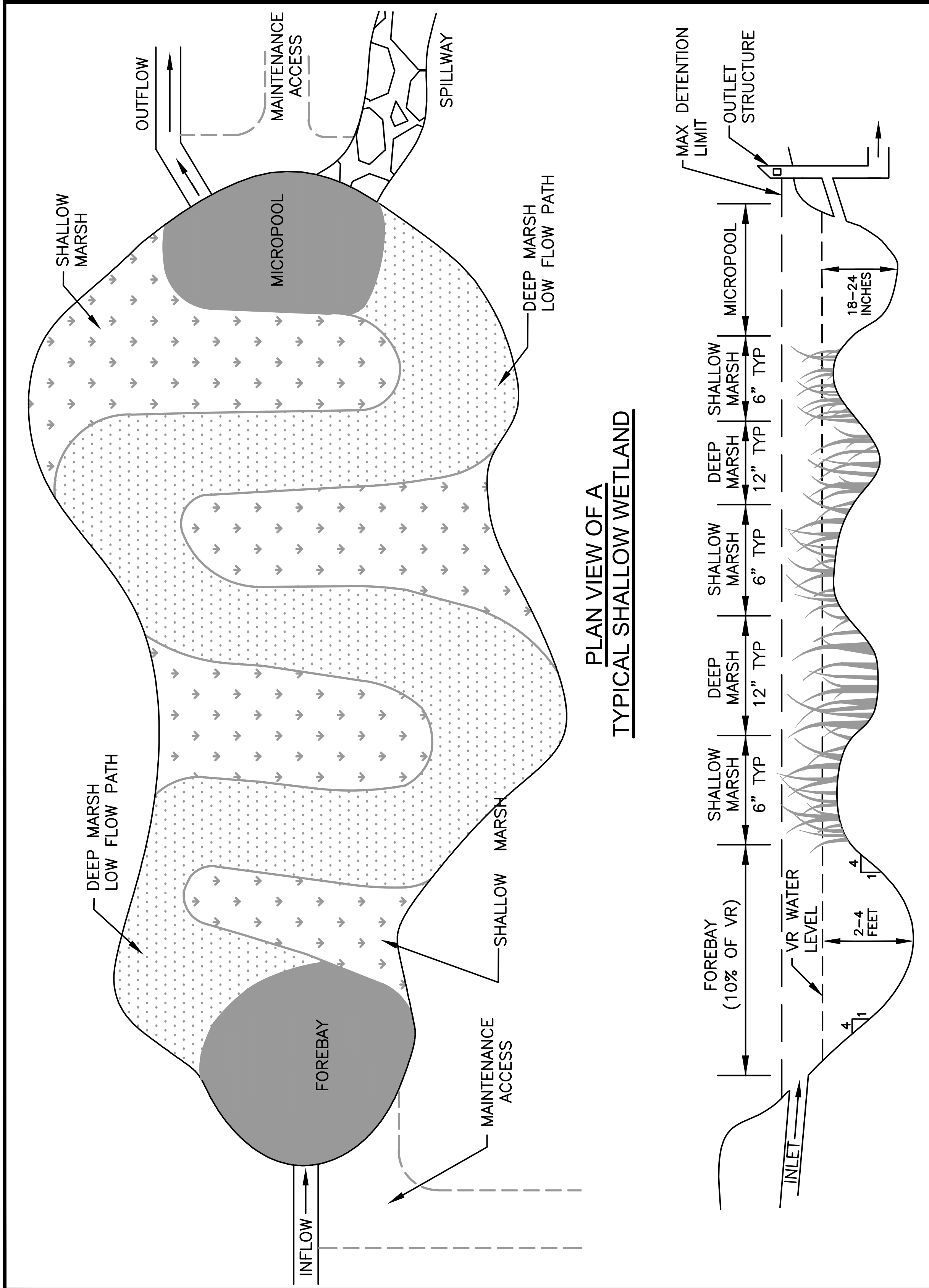
EXHIBIT 18-8
CONSTRUCTED SHALLOW WETLAND
TYPICAL PLAN VIEW AND PROFILE

EFFECTIVE DATE: JUNE 30, 2021



PROFILE OF A TYPICAL SHALLOW WETLAND

NOT TO SCALE

NOTES:
1. MUST BE MODIFIED PER SITE SPECIFIC DESIGN.
2. SEE MSD GREEN INFRASTRUCTURE DESIGN MANUAL CHAPTER 18.4.2 FOR MORE INFORMATION ON CONSTRUCTED WETLAND DESIGN.

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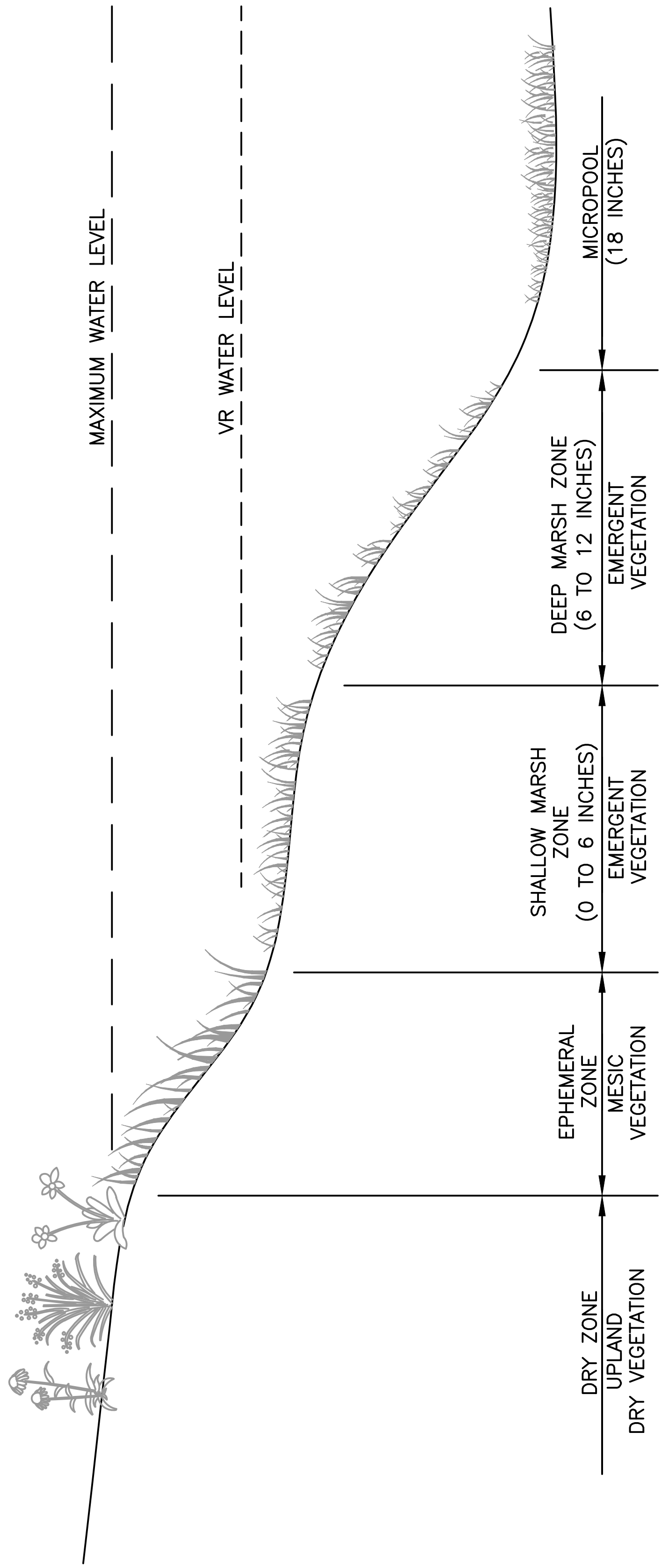
EXHIBIT 18-9
CONSTRUCTED WETLAND PLANT SELECTION ZONES

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTES:
1. MUST BE MODIFIED PER SITE SPECIFIC DESIGN.
2. SEE MSD GREEN INFRASTRUCTURE DESIGN MANUAL CHAPTER 18.4.2 FOR MORE INFORMATION ON CONSTRUCTED WETLAND DESIGN.
3. MICRO (DEEP) POOLS, DEEP AND SHALLOW MARSH (WATER) ZONES, EPHEMERAL ZONES AND DRY ZONES SHOULD BE IDENTIFIED WITH APPROPRIATE VEGETATION TYPES FOR CONSTRUCTED WETLANDS.

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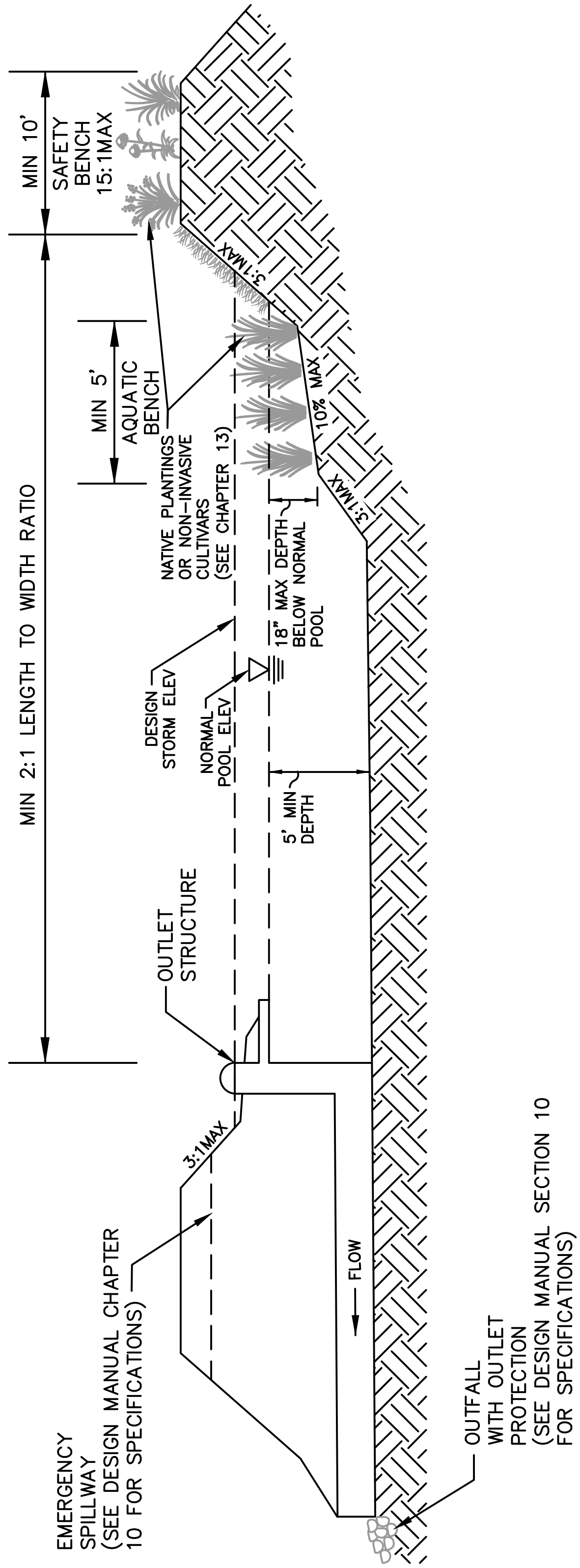
EXHIBIT 18-10
GREEN WET BASIN TYPICAL PROFILE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTE:
FOREBAY REQUIRED AT BASIN INLET.
REFER TO EXHIBIT 18-5 FOR TYPICAL FOREBAY PLAN AND PROFILE.

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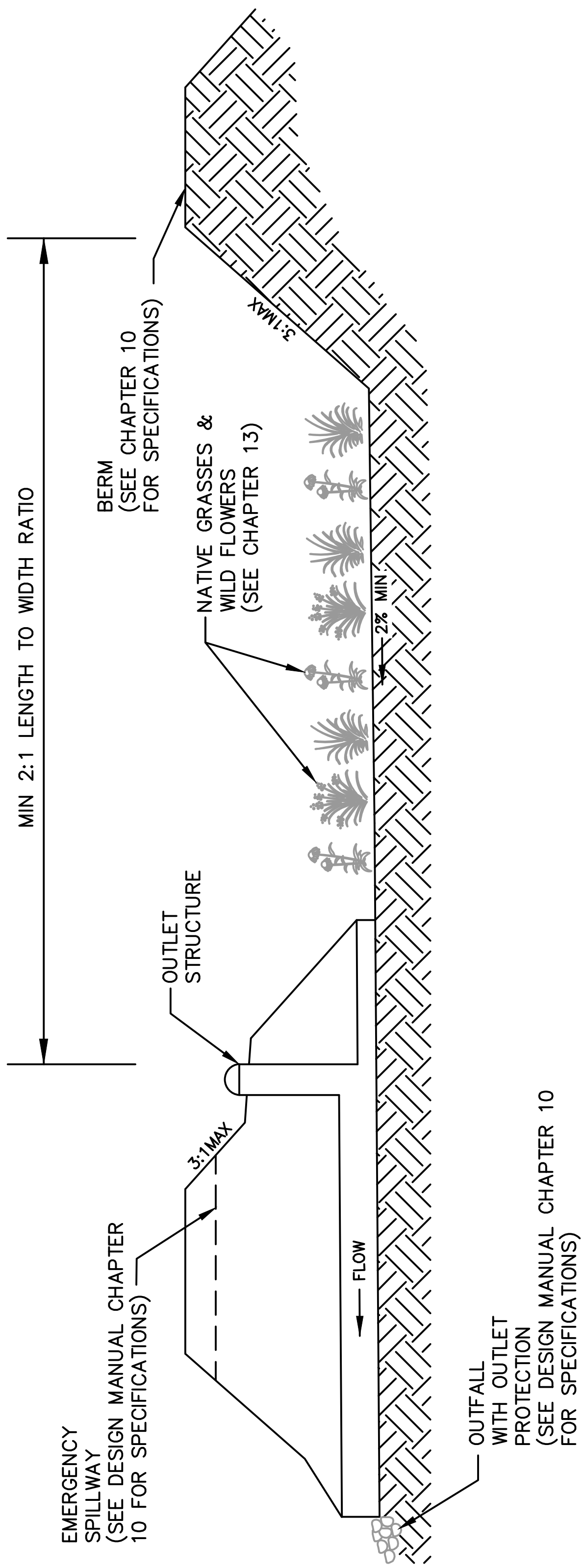
EXHIBIT 18-11
GREEN DRY BASIN TYPICAL PROFILE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTE:
FOREBAY REQUIRED AT BASIN INLET.
REFER TO EXHIBIT 18-5 FOR TYPICAL FOREBAY PLAN AND PROFILE.

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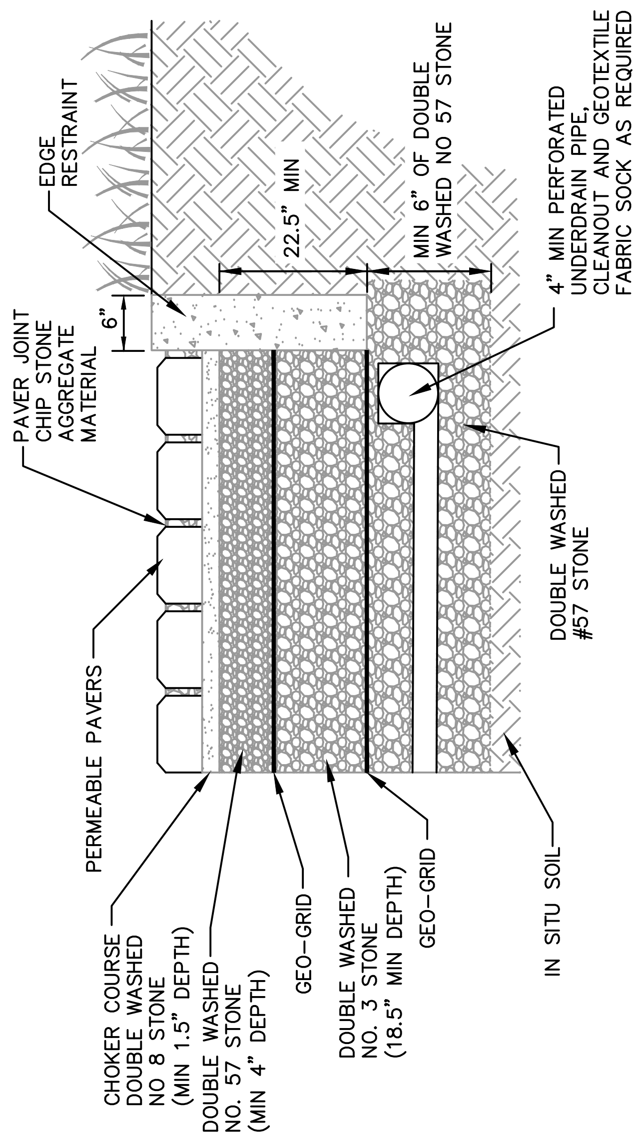
EXHIBIT 18-12
PERMEABLE PAVER TYPICAL SECTION

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTE:
MINIMUM SEPARATION OF 10 FEET FROM BUILDING FOUNDATIONS

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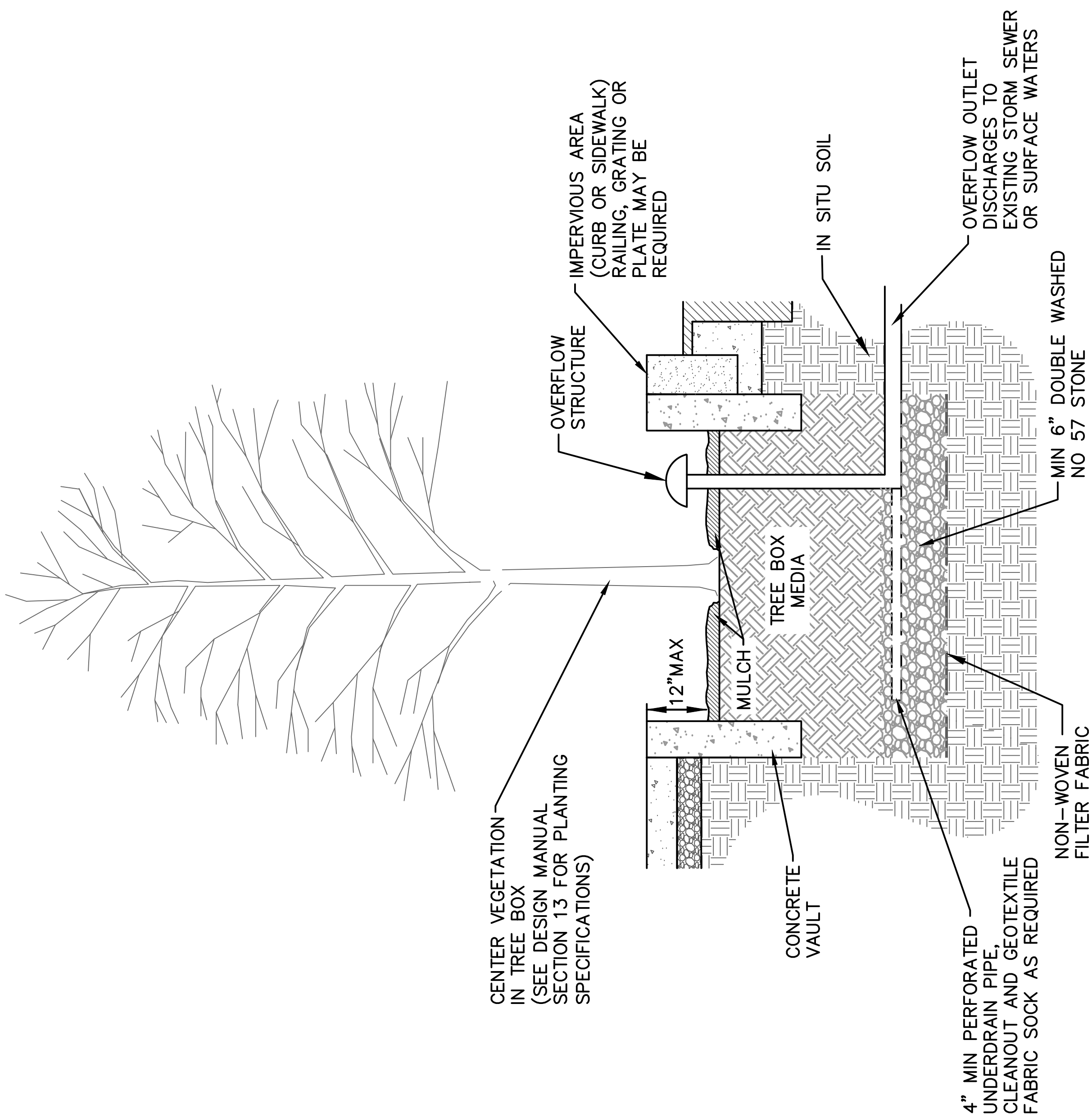
EXHIBIT 18-13
TREE BOX TYPICAL SECTION

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



TREE BOX
TYPICAL SECTION

NOTE:
MINIMUM SEPARATION OF 10 FEET FROM BUILDING FOUNDATIONS

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EXHIBIT 18-14
VEGETATED BUFFER PLAN & PROFILE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

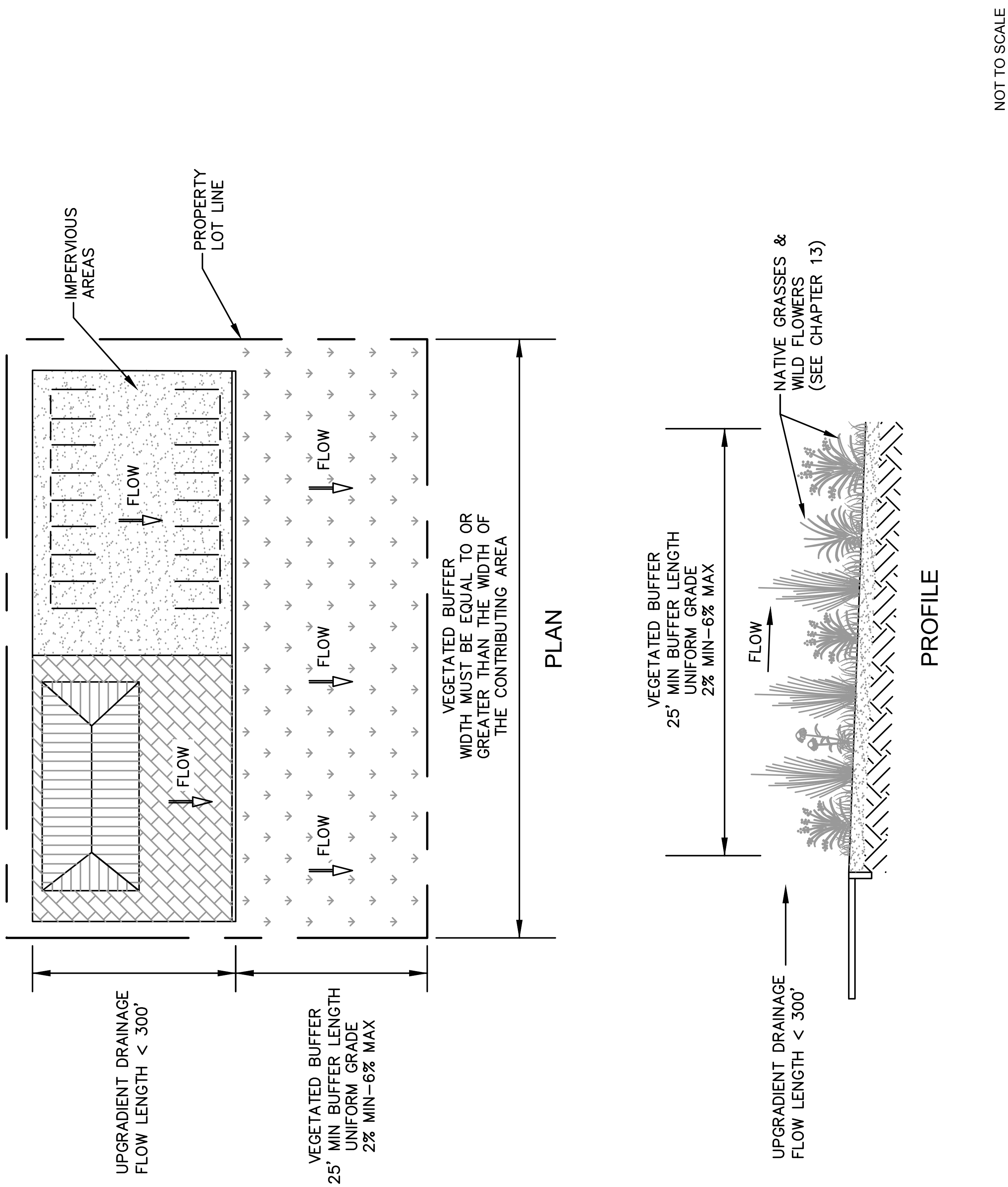

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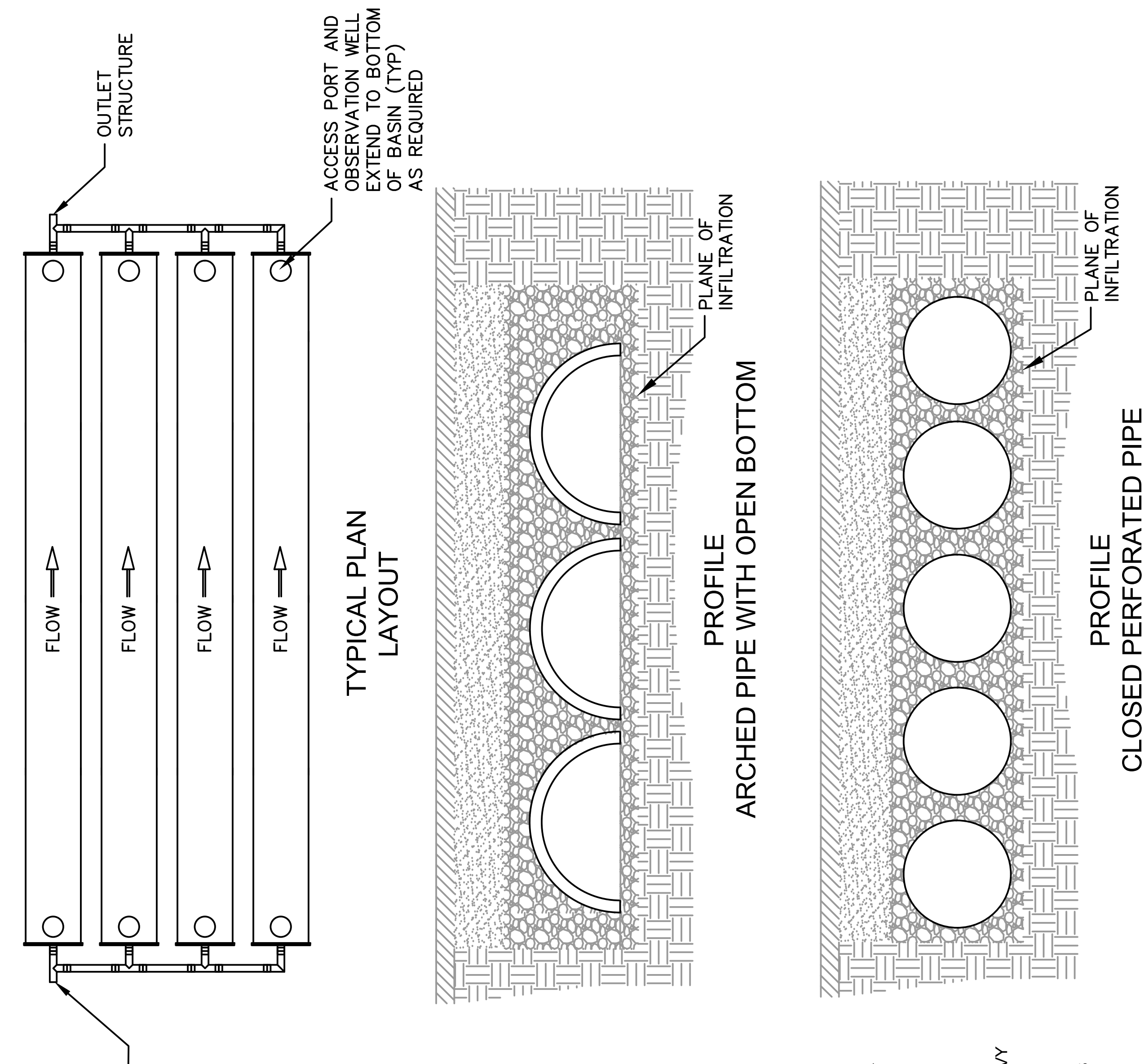
EXHIBIT 18-15
UNDERGROUND INFILTRATION BASIN

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021



NOTE:

1. PRETREATMENT REQUIRED FOR SYSTEM.
2. STONE AND FILTER FABRIC PER DESIGN REQUIREMENTS.
3. STONE TO BE DOUBLE WASHED.
4. ACCESS PORTS AND EMERGENCY OVERFLOW REQUIRED.
5. PIPE SLOPE BETWEEN 0.5% - 4%
6. CONTRACTOR TO MINIMIZE COMPACTION AND THE USE OF HEAVY MACHINERY IN THE BASIN AREA.
7. MULTIPLE, APPROPRIATELY SPACED MANHOLES/ACCESS PORTS TO BE PROVIDED TO ALLOW FOR MAINTENANCE AND INSPECTION OF THE SYSTEM.

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EXHIBIT 18-16
WATER QUALITY UNIT GENERAL ARRANGEMENT

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

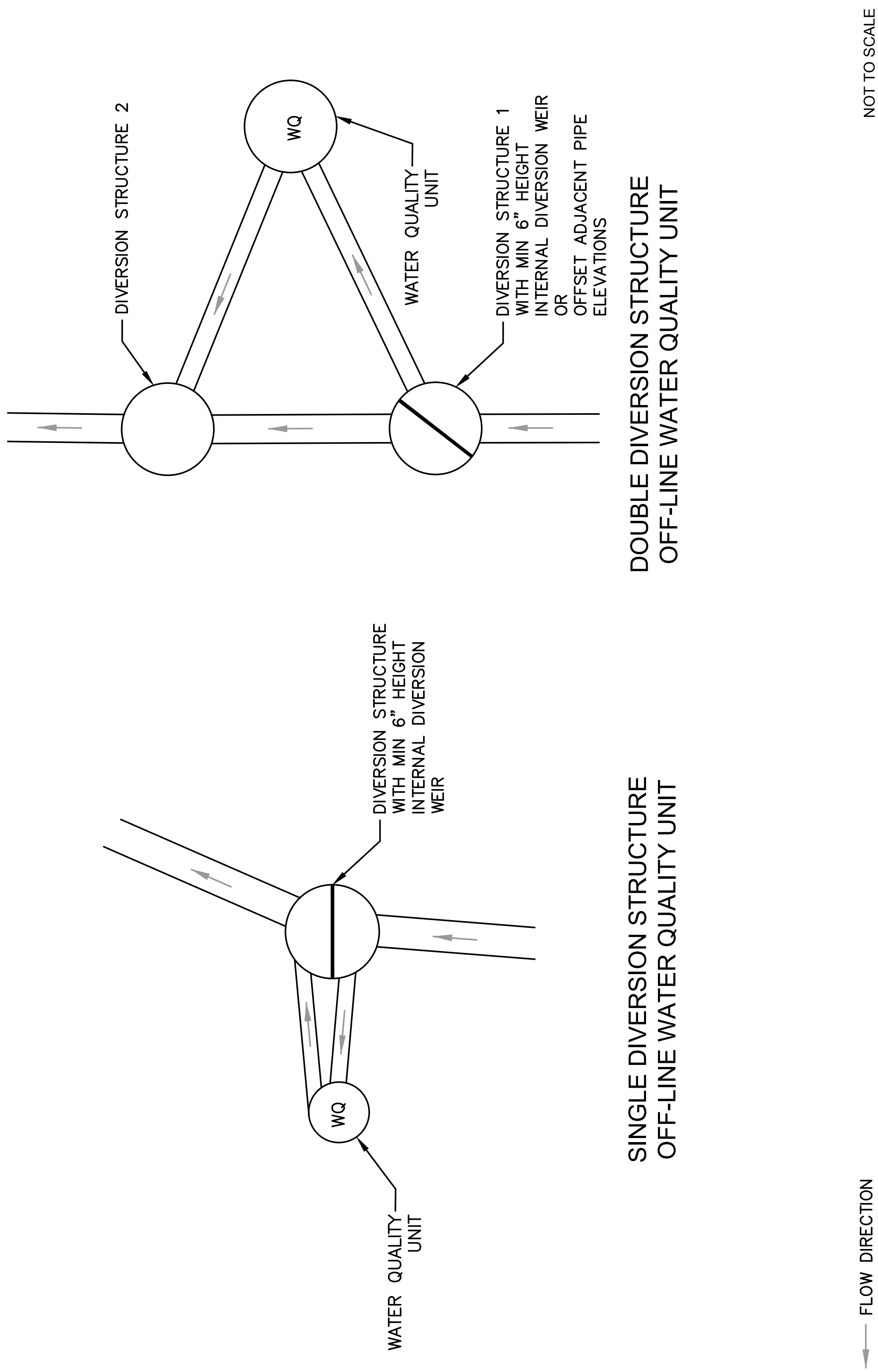

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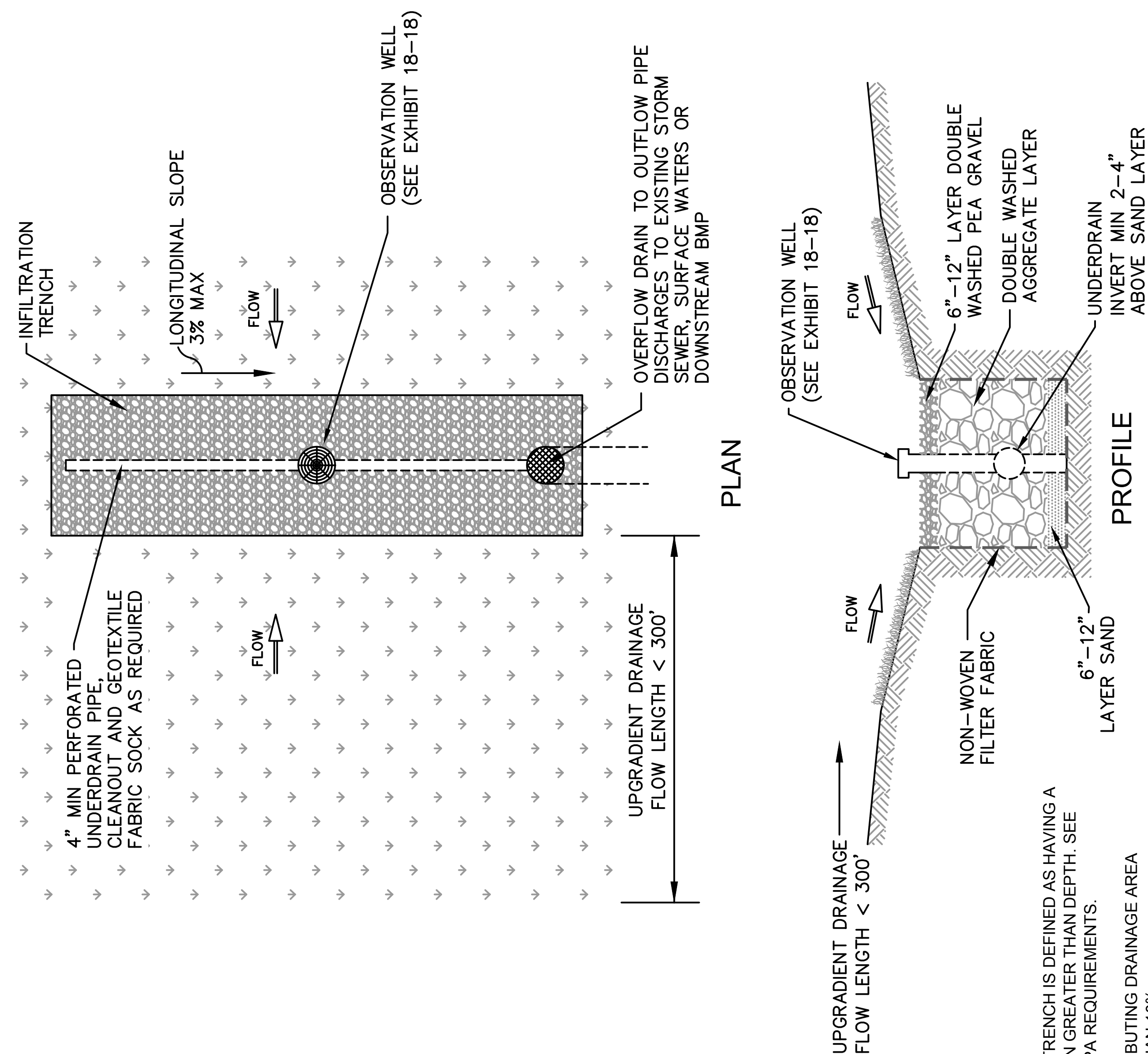
EXHIBIT 18-17
INFILTRATION TRENCH PLAN & PROFILE

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



NOTE:
1. AN INFILTRATION TRENCH IS DEFINED AS HAVING A SURFACE DIMENSION GREATER THAN DEPTH. SEE CHAPTER 18 FOR EPA REQUIREMENTS.

2. SLOPE OF CONTRIBUTING DRAINAGE AREA SHOULD BE LESS THAN 10%.

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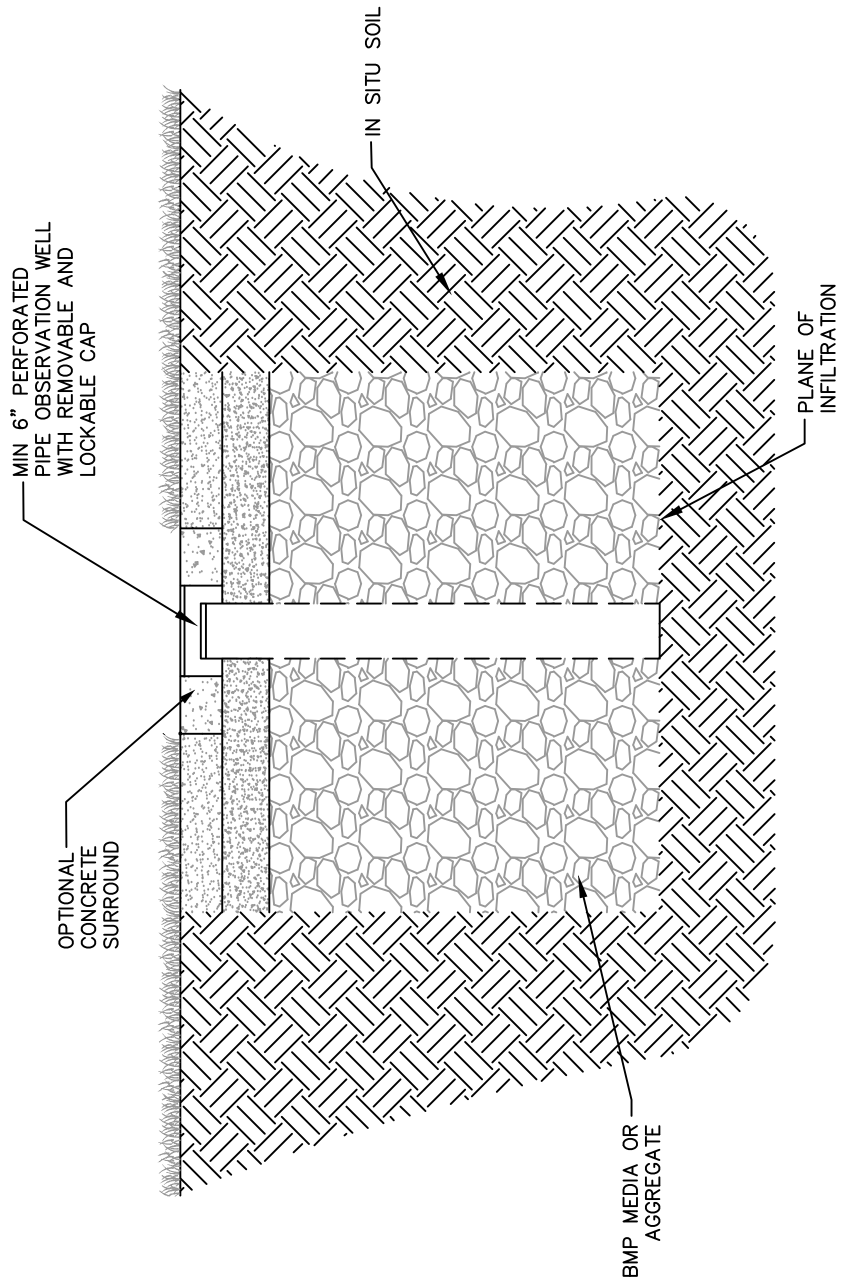
EXHIBIT 18-18
OBSERVATION WELL

REFER TO MSD DESIGN MANUAL CHAPTER 18 FOR DESIGN CRITERIA

EFFECTIVE DATE: JUNE 30, 2021

NOT TO SCALE



APPENDIX A
SELECTED DEFINITIONS

AASHTO - American Association of State Highway Transportation Officials.

ASTM - An abbreviation for American Society for Testing and Materials.

Abandoned - To remove from service for all functional use.

Activated Sludge Process - The process of using biologically active sewage sludge to hasten breakdown of organic matter in sewage during secondary waste treatment.

Acute Toxicity - Any poisonous effect produced within a short period of time, usually within 24-96 hours, resulting in severe biological harm and often death of test organisms.

Aeration - The process of being supplied or impregnated with air. Aeration is used in wastewater treatment to foster biological and chemical oxidation.

Aerobic - This refers to life or processes that can occur only in the presence of oxygen.

Ammonia - One of the seven forms that nitrogen can exist in nature (NH_3-N). It is used as an indicator of water quality because nitrogen is one of the fertilizing elements necessary for algal growth.

Anaerobic - Refers to life or processes that occur in the absence of oxygen.

Arch - The curved top of a structure, usually referred to as being from the springline to the top.

Assimilation - Conversion or incorporation of absorbed nutrients into protoplasm. Also refers to the ability of a body of water to purify itself of organic pollution.

Auger - A boring instrument used for subsurface exploration.

Available Chlorine - A measure of total oxidizing power.

Available Oxygen - The quantity of dissolved oxygen available for oxidation of organic matter in a body of water.

Average Daily Flow - That flow occurring in the sewers as a 24-hour dry weather average, including a nominal amount of infiltration, otherwise described as the total quantity of flow tributary to a point divided by the number of days of flow measurement.

Backfill -
(a) The refilling of an excavation after a structure has been placed therein.

(b) The material placed in an excavation in process of backfilling.

Bacteria - Single-celled microorganisms that lack chlorophyll. Some bacteria are capable of causing human, animal, or plant diseases; others are essential in pollution control because they break down organic matter in the air and in the water.

Baffle - Any deflecting device used to change the direction of flow or the velocity of water.

Bar Screen - A preliminary treatment process that removes oversize solids in order to protect downstream treatment processes. Bar screens normally consist of vertical or inclined steel bars spaced at equal intervals across a channel of wastewater.

Barrel, Manhole - The vertical portion of a manhole used to gain access to a sewer or sewer structure.

Base, Manhole - The bottom or supporting structure on which the manhole barrel rests.

Bedding - The earth or other materials on which a sewer or other structure is supported.

Bell - The recessed, over enlarged, female end of a pipe into which the male or spigot end fits.

Biodegradable - The process of decomposing quickly as a result of the action of microorganisms.

Biological Oxidation - The process by which bacterial and other microorganisms feed on complex organic materials and decompose them. Self-purifications of waterways and activated sludge wastewater treatment processes depend on this process. The process is also called biochemical oxidation.

Biosolids - Settleable solids separated from the water during processing of wastewater.

Blazed - The act of removing a portion of bark from a tree for surveying purposes.

Blow Off - A waste gate or device for discharging accumulated solids or for emptying a depressed sewer.

Blueline Stream - Natural surface drainage structure shown on USGS topographic maps as a solid blueline. Also, classified by Kentucky Division of Water as a natural drainage structure having continuous flow during normal weather conditions.

Borings - Subsurface investigations performed to classify the types of soils.

Branch, Y (Wye) - A pipe joined to another pipe (usually at 60 degrees with alignment of the other) molded together and manufactured as a whole unit.

Bulkhead - A partition closing off an opening, usually constructed of timber, brick, or concrete.

Five-Day Carbonaceous Biochemical Oxygen Demand (CBOD5) - A measure of the amount of oxygen consumed in five days by the biological processes that break down organic carbonaceous matter in water. Large amounts of organic waste use up large amounts of dissolved oxygen; thus the greater the degree of pollution, the greater the BOD.

Capacity - The amount of flow in terms of cubic feet per second that a conduit can or will discharge. Capacity depends on factors such as velocity, coefficient of roughness, size, shape, and slope of conduit.

Carbon Dioxide - A colorless gas heavier than air, which is poisonous if inhaled. Its presence can be detected with proper equipment. Common in sewers that are not properly ventilated.

Castings - Metallic objects (normally cast iron) formed in a mold. Examples are: manhole lids; manhole rims; catch basin grates; and frames; etc.

cfs - Cubic feet per second - A unit of measure of the volume of liquid flow past a given point in one second.

Chamber, Chlorine Contract - A structure in which water and chlorine is mixed and then detained in order to achieve disinfection.

Chamber, Diversion - A chamber which contains a device for drawing off all or part of the flow.

Chamber, Junction - A converging section of a conduit used to facilitate the flow from one or more conduits into the main conduit.

Chamber - A general term applied to a space enclosed by walls or to a compartment often prefixed by a descriptive word, such as "junction chamber", "grit chamber", etc.

Chamfer - A flat surface created by slicing off a square edge or corner.

Chemical Oxygen Demand (COD) - A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the biochemical oxygen demand test, is used to determine the degree of pollution in an effluent.

Chlorination - The application of chlorine to drinking water or sewage for disinfection or the oxidation of undesirable compounds or micro-organisms.

Chlorinator - A device for adding a chlorine in the form of a gas or liquid to water.

Chlorine - An element ordinarily existing as a greenish-yellow gas about 2.5 times as heavy as air. At atmospheric pressure and a temperature of -30.1 degrees Fahrenheit, the gas becomes an amber liquid about 1.5 times as heavy as water. The chemical symbol of chlorine is Cl, its atomic weight is 35.457, and its molecular weight is 70.914.

Clarification - The removal of suspended solids by means of gravity settling, which can be aided by chemically-induced coagulation.

Clarifier - A settling tank which allows solids to separate out by gravity and contains a method to mechanically remove solids from the bottom of the tank.

Coagulant Agent - Chemical(s) that cause very fine particles to clump together into larger particles.

Coagulation - The clumping of very fine particles into larger particles induced by chemicals such as lime or alum. The larger particles allow separation of the solids from the water by settling, skimming, draining or filtering.

Coefficient - A numerical quantity interposed in a formula which expresses the relationship between two or more variables, which may be derived by theoretical or experimental methods.

Coefficient, Roughness - A factor, "n", in the Kutter, Manning, Hazen-Williams, and other formulae, which represents the effect of roughness of the confining channel or conduit material upon the energy losses in the flowing water.

Collar - (a) A cylindrical ring of either brick or precast concrete, secured upon the cone or barrel of a manhole upon which the frame will rest.

(b) A cylindrical monolithic concrete encasement for securing a joint and preventing shear by movement.

Collector System - A network of lateral and branch sewers in a defined area, which collects and transports sewage to a larger sewer.

Comminutor - A device that shreds solids in the wastewater in order to make them easier to treat and transport.

Composite Sample - A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of individual samples. Periodic samples may have equal volume or may be roughly proportioned to the flow at the time each sample is taken.

Conduit - A continuous piping or passage system for transporting water or sewage underground. Also, used for containing wires and cables of other utilities.

Connection, House - See Property Service Connection.

Contract Documents - The Agreement, Addenda (which pertain to the Contract Documents), Bid Proposal (including documentation accompanying the bid and any post-bid documentation submitted prior to the Notice of Award) when attached as an exhibit the Agreement, the Bonds, the General Conditions, the Special Provisions, the Specifications and the Drawings as the same or more specifically identified in the Agreement, together with all amendments, modifications and supplements issued on or after the effective date of the Agreement.

Cradle - Type of bedding, usually of gravel or concrete, being laid upwards from the trench bottom to the springline of the pipe.

Crown - The highest inside part of a conduit; the inner top of a conduit.

Cubic Feet per Second - (Abbreviated c.f.s.) A unit of measure of the volume of liquid flow past a given point in one second.

Cul-de-sac - An alley or street having no outlet at one end, usually having an area at its dead end for turning around.

Culvert - A closed conduit typically of precast or monolithic structure of sufficient length for the passage of water.

Datum - An agreed standard point or plane of stated elevation. Any position or element in relation to which others are determined, for example, the horizontal control system used in map making.

Dead Man - A post put in solid ground for furnishing and fastening or anchoring guy wires.

Dechlorination - Removal of residual chlorine in water by a chemical or physical processes.

Delta - Used as a symbol, this indicates the angle of deflection from the forward tangent either left or right to the centerline of the sewer.

Detention Tank - A tank used to provide adequate storage time for chemical or physical reactions to occur.

Digestion - The biochemical decomposition of organic matter. Digestion of biosolids takes place in tanks where the biosolids decompose, resulting in partial gasification, liquefaction, and mineralization of pollutants.

Discharge -

(a) As applied to a sewer or stream; the rate of flow, or volume of water flowing therein at a given place and within a given period of time.

(b) The act, in water or other liquid, of passing through an opening or along a conduit or channel.

(c) The water or other liquid which emerges from an opening or passes along a conduit or channel.

Disinfection - Effective killing by chemical or physical processes of organisms capable of causing infectious disease. Chlorination is currently the most common method in wastewater treatment processes.

Diversion - An arrangement of pipes, conduits, gates and/or valves that allows flow to be passed around a hydraulic structure or appurtenance.

Double System - Usually two conduits laid in parallel -- one conduit laid in the trench being used for a drain, and the other as a sewer or sewers laid on either side of a street.

Drainage Area - A tributary area which is generally limited by a topographic area, but may be also limited by political boundary or economic factors.

Drop Inlet - A contrivance of pipe fittings which is utilized when an incoming sewer is considerably higher than the outgoing sewer.

Dynamic Head - In pumping water, a head usually expressed in pounds per square inch (p.s.i.) representing both the pressure due to the elevation to which the water is pumped and that due to friction of the water in the pipe; the head against which a pump works.

Effluent - The water or wastewater that flows from a basin, treatment process or treatment plant.

Encasement - Usually monolithic concrete that is used to enclose the periphery of a conduit.

Engineer - A consultant or in-house designer who is in responsible design and who is a registered Professional Engineer in the Commonwealth of Kentucky.

Equivalent - Being equal in measure.

Extended Aeration - Treatment process similar to conventional activated sludge with the exception that the wastewater is retained in the aeration tank longer (18-24 hours).

Fascines - A long bundle of sticks of wood bound together and used for such purposes as filling ditches and making revetments for riverbanks.

Fecal Coliform Bacteria - A group of organisms indigenous to the intestinal tracts of humans and other mammals. The presence of fecal coliform in water is an indicator of pollution and of potentially dangerous bacterial contamination.

Filtration - The process of passing water through material such as a bed of sand, coal or other granular substance to remove impurities such as suspended particles and bacteria.

Final Effluent - The effluent from the final treatment unit of a wastewater treatment plant.

Flap Gate - A gate that opens and closes by rotation around a hinge or hinges at the top of the gate, permitting the fluid to pass only in one direction.

Floc - A clump of solids formed in sewage by biological or chemical action.

Flocculation - The process of gathering fine particles to form larger particles after coagulation by the use of gentle mixing.

Flood Level - The stage of a stream at the time of a flood.

Flood Plain - The land contained within the perimeter of the probable limiting flood.

Flood Frequency - The frequency with which the maximum flood may be expected to occur at a site in any average interval of years. Frequency analysis defines the "N-year flood" as being the flood which will, over a long period of time, be equaled or exceeded on the average once every N years.

Flow, Dry-Weather (Sanitary) - The flow of wastewater in a sewer during dry weather. Such flow consists mainly of sewage and wastes with no stormwater or groundwater included.

Flow Meter - A device that measures the rate at which water is flowing through the conduit or channel.

Force Main - A pipe under internal pressure created by being on the discharge side of a pump station.

fps - Feet per second.

Gate, Sluice - A gate constructed to slide vertically, or nearly so, and fasten into or against a permanent structure.

Grade -

(a) The inclination or slope of a stream channel, conduit or natural ground surface, usually expressed in terms of the ratio or percentage of vertical rise or fall per 100 feet of horizontal distance. See Slope.

(b) The elevation of the invert of the bottom of a pipe line, canal, culvert, sewer, etc.

Grade, Hydraulic - In a closed conduit under pressure, a line joining the elevations to which water would rise in pipes freely vented and under atmospheric pressure. See Gradient, Hydraulic; also, Line, Hydraulic Grade.

Gradient - The rate of change of any characteristic per unit of length, or slope. The term is usually applied to such things as elevation, velocity, pressure, etc. See Slope.

Gradient, Hydraulic - The slope of the hydraulic grade line, the rate of change of pressure head, the ratio of the loss in the sum of the pressure head, and positive head to the flow distance.

Grit - The heavy material present in wastewater, such as sand, gravel, and cinders.

Groundwater - Subsurface water occupying the zone of saturation. In a strict sense, the term applies only to water below the water table.

Head - The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid.

Head, Friction - The head lost by water flowing in a conduit as the result of intermolecular friction or disturbances setup by the contract between the moving water and its containing conduit.

Head, Loss of - The vertical distance or height through which a body must fall freely under the force of gravity to acquire the velocity which it possesses. It is equal to the square of the velocity divided by twice the acceleration of gravity.

Heavy Metals - Metallic elements with high molecular weights, generally toxic in low concentrations to plant and animal life. Such metals often reside in the environment and accumulate biologically. Examples include mercury, chromium, cadmium, arsenic, and lead.

Hydraulic Grade Line - A hydraulic profile of the piezometric level of water at all points along the line. The term is usually applied to water moving in a conduit, open channel, stream, etc. In an open channel it is the free water surface.

Hydrogen Sulfide (H_2S) - A malodorous gas made up of hydrogen and sulfur with the characteristic odor of rotten eggs. It can be emitted in the natural decomposition of organic matter if it becomes anaerobic. In heavy concentrations, it can cause illness or death.

I/I - Refers to infiltration and/or inflow.

Increment, Area - A precise part of an area or one of a series of areas.

Industrial Waste - That waste from the processes of manufacturing discharge in water, as distinguished from the normal sanitary waste contributed by employees.

Infiltration - Refers to groundwater that enters a sewer system through such sources as defective pipes, pipe joints, connections, or manholes.

Infiltration, Groundwater - That part of sanitary sewage flow derived from groundwater sources and passing into public sewers through defects or faulty construction.

Inflow - Refers to water discharged into service connections and sewer pipes from foundations and roof drains, paved surfaces and sump pumps.

Inorganic Matter - Chemical substances of mineral origin, or more correctly not of basic carbon structure.

Interceptor - See Sewer Interceptor.

Interceptor Sewer - A sewer which receives flow from a number of collector sewers or outlets and, frequently, additional predetermined quantities of stormwater (if from a combined system), and transports such water to a point for treatment or disposal.

Invert - The floor, bottom or lowest portion of the internal cross-section of a sewer or other conduit.

Joint, Bell-and-Spigot - A form of joint used on pipes which have an enlarged diameter or bell at one end, and a spigot at the other which fits into and is laid in the bell. The joint is then made tight by cement, lead, a rubber "O" ring, or other jointing compounds or materials.

Lamp Hole - 8" diameter cleanout on the end of a long 8" sanitary stub.

Lathes - Wooden 1" x 2" survey stakes.

Local Drainage System - A drainage system that does not receive or transport runoff from an adjoining property.

Manhole - An opening by which a man may enter or leave a sewer, conduit, or other closed structure for inspection, cleaning, and other maintenance operations, closed by a removable cover.

MGD - Millions of gallons per day.

Microbes - Minute life form or micro-organisms, especially one that causes disease.

Milligrams per liter (mg/L) - A measure of the concentration by weight of a substance per unit volume. One mg/L is equivalent to one part per million (ppm).

Monolithic - Cast-in-place, rather than precast.

MSD - Louisville and Jefferson County Metropolitan Sewer District.

Neutralization - Addition of an acid or alkali to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

Nutrients - Elements or compounds essential as raw materials for organism growth and development. Common nutrients are carbon, oxygen, hydrogen, nitrogen, sulfur and phosphorus.

Organism - Living organisms common to the intestinal tract of man and other mammals whose presence in wastewater is an indicator of pollution and of potentially dangerous bacterial contamination.

Outcrop, Rock - The appearance at the earth surface of a rock strata.

Outfall - The conduit leading to the discharge stream through which the effluent flows.

Oxygen Demand - The quantity of oxygen utilized in the biochemical oxidation of organic matter.

Package Wastewater Treatment Plant - A prefabricated wastewater treatment plant that is hauled to the plant site and installed as the only facility.

Peak - A maximum quantity which occurs over a relatively short period of time, such as an hour or day.

Peak Demand - The maximum, momentary load placed on a wastewater plant or pumping station.

Peak, Instantaneous - The maximum rate which ever occurs, possibly for only a moment.

pH - A measure of the acidity or alkalinity of a material, liquid, or solid. pH is represented on a scale of 0 to 14, with 7 representing a neutral state, 0 representing the most acid, and 14 representing the most alkaline.

Pipe, Vitrified Clay - A pipe made of clay burned in a kiln with surfaces glazed for water tightness. It is used for carrying sewage and sometimes for carrying water. It is seldom used under pressure.

Pollutant - Any gas, liquid, or solid that makes a resource unfit for a specific purpose.

Population, Equivalent - A hypothetical number of persons representing flow. The equivalent population of an existing industry or a school, for example, is determined from the normal flow of sewage divided by the average contribution of wastewater per person.

Population, Saturation - The actual or equivalent population of a given area that exists or would occur when the area is completely developed according to its present use for developed areas, and its present zoning for undeveloped areas.

Population, Total Equivalent - The sum of the residential population in a given area, and its equivalent population.

Potable Water - Water suitable for drinking or cooking purposes from health and aesthetic considerations.

ppm - Part per million. A measure of the concentration by weight of a substance per unit volume. One ppm is equal to one mg/L.

Precast - That which is formed in a mold or form and distributed by the manufacturer as a complete unit.

Precipitate –

(a) Noun: An insoluble, finely-divided substance which is a product of a chemical reaction within a liquid.

(b) Verb: Separation from solution of an insoluble substance.

Pretreatment - Any process used to reduce pollution before the wastewater is introduced into a sewer system for further treatment.

Primary Treatment - An early stage process in wastewater treatment in which floating and settleable solids are mechanically separated from the water being treated.

Private Drainage System - See Local Drainage System

Property Service Connection - That portion of a sewer system located within an easement or right-of-way which transports sewage from private property to the main sewer.

Proposed - That which is to have immediate consideration for construction.

Pump Station - A station at which sewage is pumped to a higher elevation.

Receiving Waters - A stream, river, lake, ocean, or other surface or groundwaters into which treated or untreated wastewater is discharged.

Sanitary Sewers - Sewers intended to carry wastewater from residences, businesses and industries. Stormwater runoff is carried in a separate system.

Screen - A device with openings used to retain or remove suspended or floating solids in flowing water or sewage.

Secondary Treatment - Wastewater treatment process used to convert dissolved or suspended materials into a form more easily separated from the water being treated. The most common form of secondary treatment is a biological treatment process that is followed by secondary clarifiers.

Sedimentation Tanks - Tanks where the solids are allowed to settle or to float. Settled solids are pumped to thickeners or digesters. Scum that floats in a sedimentation tank is either skimmed off or recycled through the wastewater treatment plant.

Sedimentation - The separation of solids by means of gravity.

Service Area - A geographic area serviced by a public utility or served by a sewage collection system.

Settleable Solids - Bits of debris and fine matter heavy enough to settle out of wastewater.

Sewage - Largely, the water supply of a community after it has been fouled by various uses. From the standpoint of source, it may be a combination of the liquid or water carried wastes from residences, businesses and institutions, together with those from industrial establishments, and with such groundwater, surface water, and stormwater as may be present.

Sewage, Combined - Sewage containing both sanitary sewage and surface or stormwater.

Sewage, Domestic - Sewage derived principally from dwellings, businesses, institutions, and the like. It may or may not contain groundwater, surface water, or stormwater.

Sewage, Industrial - Sewage in which industrial wastes pre-dominates.

Sewage, Sanitary -

(a) Domestic sewage with storm and surface water excluded.

(b) Sewage discharging from the sanitary conveniences of dwellings (including apartment complexes and hotels), office buildings, factories, or institutions.

(c) The water supply of a community after it has been used and discharged into a sewer.

Sewer - A pipe or conduit that carries waste, storm or surface water.

Sewer, Branch - A sewer which receives sewage from lateral sewers and discharges into a larger sewer.

Sewer, Collector - A sewer which receives flow directly from property service connections. Collector sewers are tributaries to interceptor sewers.

Sewer, Combined - A sewer intended to receive both wastewater and storm or surface water.

Sewer, Interceptor - A sewer which receives flow from a number of collector sewers or outlets and, frequently, additional predetermined quantities of stormwater (if from a combined system), and transports such water to a point for treatment or disposal.

Sewer, Inverted Siphon - A section of sewer constructed lower than adjacent sections to pass beneath a watercourse or other obstruction. It runs full or at greater than atmospheric pressure because its crown is depressed below the hydraulic grade line.

Sewer, Lateral - A sewer which receives sewage from a relatively small area which discharges into a branch or other sewer and has few others sewers tributary to it.

Sewer, Main - The principal sewer to which branch sewers and submains are tributary, also called trunk sewer.

Sewer, Outfall - A sewer that receives wastewater and/or stormwater and carries it to a point of final discharge.

Sewer, Relief - A sewer built to carry the flows in excess of the capacity of an existing sewer.

Sewer, Sanitary - A sewer which primarily carries sewage, and to which storm surface, and ground waters are not intentionally admitted.

Sewer, Submain - An arbitrary term used for relatively large branch sewers.

Slope - The inclination of the invert of a conduit expressed as a decimal or as feet per stated length measured horizontally in feet.

Soundings - Method used to ascertain the depth of rock strata.

Springline - The inner edge of the inclined or horizontal base where the arch begins.

Stabilization - The process of converting active organic matter into inert, harmless material.

Stacks – A vertical connection to a collector sewer. Used when more economical than a typical property service connection.

Storm Sewer - A separate sewer that carries runoff from storms, surface drainage and street, and does not include domestic or industrial wastes.

Subgrade - The bottom of a trench or other excavation that is somewhat below the predetermined elevation of the bottom of the final excavation or structure, the intervening space being backfilled with some special material such as sand, gravel, broken stone, or tamped earth, or impervious lining. The term is also applied to the elevation of such bottom.

Submain - See Sewer, Submain.

Sump - A depression that serves as a receptacle for liquids to be pumped.

Surcharge - A condition where a sewer is inadequate to discharge the total amount of flow when it is just filled or flowing at the planned depth or head. The amount of surcharge is measured by the volume or rate of excess flow or by the excess height of the hydraulic grade line.

Surface Water - Water on the earth's surface open to the atmosphere, such as rivers, streams, and oceans.

Swale - A shallow ditch which does not exceed 6" in depth from the top of bank.

"Ten-States Standards" - "Recommended Standards for Wastewater Facilities of the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers." 1990 Edition.

Through Drainage System – A drainage system that collects or transports runoff from more than one property.

Topography - The configuration of a surface area including its relief, or relative elevations, and the location of its natural and constructed features.

Total Dissolved Solids (TDS) - The total amount of dissolved materials, organic and inorganic, contained in water and wastes. Excessive dissolved solids make water unpalatable for drinking water and unsuitable for some industrial uses.

Transition - A short section of a conduit used as a conversion section to unite two conduits having different hydraulic elements.

Trunk - See Trunk Sewer.

Trunk Sewer - A sewer which receives many tributary branches and which serves a large area.

USGS - Abbreviation for United States Geological Survey.

Velocity, Self-Cleaning - The minimum velocity in sewers necessary to keep solids in suspension and prevent their deposition and the subsequent nuisances from stoppages and odors on decomposition.

Wastewater - See Sewage.

Water Quality Criteria - The maximum levels of pollutants that can be reached prior to impacting the suitability of water for a given water use classification. Generally, water use classification includes: public water supply; recreation; propagation of fish and other aquatic life; agricultural use and industrial use.

Water Quality Standard - A plan for water quality management containing four major elements: the use (recreation, drinking water, fish and wildlife propagation, industrial or agricultural) to be made of the water; criteria to protect those uses; implementation plans (for needed industrial municipal waste treatment improvements) and enforcement plans; and an anti-degradation station to protect existing high quality waters.

Watershed - The area drained by a given stream or segment of a stream.

APPENDIX B
SYSTEMS INTERNATIONAL CONVERSIONS

Alphabetical List of Units

To Convert From	To	Multiply By
acre-foot	meter^3 (m^3)	1.233 482 E+03
acre	meter^2 (m^2)	4.046 856 E+03
astronomical unit	meter (m)	1.495 98 E+11
atmosphere (normal)	pascal (Pa)	1.013.25 E+05
bar	pascal (Pa)	1.000 000 E-05
barrel (for petroleum, 42 gal)	meter^3 (m^3)	1.589 873 E-01
British thermal unit (International Table)	joule (J)	1.055 056 E+03
bushel (U.S.)	meter (m^3)	3.523 907 E-02
caliber (inch)	meter (m)	2.540 000 E-02
calorie (International Table)	joule (J)	4.186 800 E+00
cal/g	joule/kilogram (J/kg)	4.186 800 E+03
calorie (thermochemical)/minute	watt (W)	6.973 333 E-02
carat (metric)	kilogram (kg)	2.000 000 E-04
centimeter of mercury (0°)	pascal (Pa)	1.333 22 E+03
centimeter of water (4°C)	pascal (Pa)	9.806 38 E+01
circular mil	meter^2 (m^2)	5.067 075 E-10
cup	meter^3 (m^3)	2.365 882 E-04
day (mean solar)	second (s)	8.640 000 E+04
degree (angle)	radian (rad)	1.745 329 E-02
degree Celsius	Kelvin (K)	$t_K = t_{°C}+273.15$
degree Fahrenheit	degree Celsius	$t_{°C} = (t_{°F}-32)/1.8$
degree Fahrenheit	Kelvin (K)	$t_K = (t_{°F}+459.67)/1.8$
degree Rankine	Kelvin (K)	$t_K = t_{°R}/1.8$
dyne	newton (N)	1.000 000 E-05
dyne-centimeter	newton-meter (Nm)	1.000 000 E-07
dyne/centimeter	pascal (Pa)	1.000 000 E-01
electron volt	joule (J)	1.602 19 E-19
erg	joule (J)	1.000 000 E-07
faraday (chemical)	coulomb ©	9.649 57 E+04
fluid ounce (U.S.)	meter^3 (m^3)	2.957 353 E-05
foot	meter (m)	3.048 000 E-01
foot^3/minute	meter^3/second)m^3/s)	4.719 474 E-04
foot/second	meter^3/second (m^3/s)	2.831 685 E-02
foot^3	meter^3 (m^3)	2.831 685 E-02
foot^3	gallons (gal)	7.48052 E+00
foot^2	meter^2 (m^2)	9.290 304 E-02
foot/hour	meter/second (m/s)	8.466 667 E-05
foot/minute	meter/second (m/s)	5.080 000 E-03
foot/second	meter/second (m/s)	3.048 000 E-01
foot^2/second	meter^2/second (m^2/s)	9.290 304 E-02
foot of water (39.2°F)	pascal (Pa)	2.988 98 E+03
footcandle	lumen/meter^2 (lm/m^2)	1.076 391 E+01
footcandle	lux (lx)	1.076 391 E+01
foot-pound-force	joule (J)	1.355 818 E+00

To Convert From	To	Multiply By
foot-pound-force/hour	watt (W)	3.766 161 E-04
foot-pound-force/minute	watt (W)	2.259 697 E-02
foot-pound-force/second	watt (W)	1.355 818 E+00
foot-second^2	meter/second^2 (m/s^2)	3.048 000 E-01
gallon (U.S. dry)	meter^3 (m^3)	4.404 884 E-03
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 E-03
gallon (U.S. liquid)/day	meter^3/second (m^3/s)	4.381 264 E-08
gallon (U.S. liquid)/minute	meter^3/second (m^3/s)	6.309 020 E-05
gallon/minute	foot^3/hr	8.020800 E+00
gamma	tesla (T)	1.000 000 E-09
gill (U.S.)	meter^3 (m^3)	1.182 941 E-04
grad	degree (angular)	9.000 000 E-01
grad	radian (rad)	1.570 796 E-02
gram	kilogram (kg)	1.000 000 E-03
gram/centimeter^3	kilogram/meter^3 (kg/m^3)	1.000 000 E+03
gram-force/centimeter^2	pascal (Pa)	9.806 650 E+01
horsepower (electric)	watt (W)	7.460 000 E+01
horsepower (metric)	watt (W)	7.354 99 E+02
inch	meter (m)	2.540 000 E-02
inch^2	meter^2 (m^2)	6.451 600 E-04
inch^3	meter^3 (m^3)	1.638 706 E-05
inch^3/minute	meter^3/second (m^3/s)	2.731 177 E-07
inch of mercury (32°F)	pascal (Pa)	3.386 389 E+03
inch of water (39.2° F)	pascal (Pa)	2.490 82 E+02
kilocalorie (International Table)	joule (J)	4.186 800 E+03
kilocalorie (thermochemical)	joule (J)	4.184 000 E+03
kilocalorie (thermochemical)/minute	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/second	watt (W)	4.184 000 E+03
kilogram-force (kgf)	newton (N)	9.806 650 E+00
kilogram-force-meter	Newton-meter (N m)	9.806 650 E+00
kilogram-force-second^2/meter (mass)	kilogram (kg)	9.806 650 E+00
kilogram-force/centimeter^2	pascal (Pa)	9.806 650 E+04
kilogram-force/meter^2	pascal (Pa)	9.806 650 E+00
kilogram-force/millimeter^2	pascal (Pa)	9.806 650 E+06
kilogram-mass	kilogram (kg)	1.000 000 E+00
kilometer/hour	meter/second (m/s)	2.777 778 E_01
kilowatt-hour	joule (J)	3.600 000 E+06
kip (1000 lbf)	newton	4.448 222 E+03
kip/inch^2 (ksi)	pascal (Pa)	6.894 757 E+06
knot (International)	meter/second (m/s)	5.144 444 E-01
liter (L)	feet^3 (ft^3)	3.53000 E+02
liter (L)	gallons(gal)	0.264000 E+00
liter (L)	meter^3 (m^3)	1.000 000 E-03
lux	lumen/meter^2 (lm/m^2)	1.000 000 E+00
maxwell	weber (Wb)	1.000 000 E-08
mil	meter (m)	2.540 000 E-08
mile (International Nautical)	meter (m)	1.852 000 E+03
mile (U.S. nautical)	meter (m)	1.852 000 E+03
mile (U.S. statue)	meter (m)	1.609 344 E+03

To Convert From	To	Multiply By
$mile^2$ (U.S. statue)	$meter^2$ (m^2)	2.589 988 E+06
mile/hour (U.S. statue)	meter/second (m/s)	4.470 400 E-01
mile/hour (U.S. statue)	kilometer/hour	1.609 344 E+00
minute (angle)	radian (rad)	2.908 882 E-04
moment of inertia ($lbm·ft^2$)	$kilogram\text{-}meter^2$ ($kg·m^2$)	4.214 011 E-02
moment of inertia ($lbm·in^2$)	$kilogram\text{-}meter^2$ ($kg\ m^2$)	2.926 397 E-04
ounce (U.S. fluid)	$meter^3$ (m^3)	2.957 353 E-05
peck (U.S)	$meter^3$ (m^3)	8.809 768 E-03
pennyweight	kilogram (kg)	1.555 174 E-03
pint (U.S. dry)	$meter^3$ (m^3)	5.506 105 E-04
pint (U.S. liquid)	$meter^3$ (m^3)	4.731 765 E-04
poise (absolute viscosity)	pascal-second (Pa·s)	1.000 000 E-01
pound-force-foot/inch	newton-meter/meter (N·m/m)	5.337 866 E+01
pound-force-foot/inch	newton-meter/meter (N·m/m)	4.448 222 E+00
pound-force/inch	newton/meter (N/m)	1.751 268 E+02
pound-force/foot	newton/meter (N/m)	1.459 390 E+01
$pound\text{-}force/foot^2$	pascal (Pa)	4.788 026 E+01
$pound\text{-}force/inch^2$ (psi)	pascal (Pa)	6.894 757 E+03
$pound\text{-}force\text{-}second/foot^2$	pascal-second (Pa·s)	4.788 026 E+01
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 E-01
pound-mass (troy or apothecary)	kilogram (kg)	3.732 417 E-01
$pound\text{-}mass/foot^2$	$kilogram/meter^2$ (kg/m^2)	4.882 428 E+00
pound-mass/second	kilogram/second (kg/s)	4.535 924 E-01
$pound\text{-}mass/foot^3$	$kilogram/meter^3$ (kg/m^3)	1.601 846 E+01
$pound\text{-}mass/inch^3$	$kilogram/meter^3$ (kg/m^3)	2.767 990 E+04
pound-mass/gallon (U.S. liquid)	$kilogram/meter^3$ (kg/m^3)	1.198 264 E+02
pound-mass/foot – second	pascal – second (Pa·s)	1.488 164 E+00
quart (U.S. dry)	$meter^3$ $(m)^3$	1.101 221 E-03
quart (U.S. liquid)	$kilogram/meter^3$ (kg/m^3)	9.463 529 E-04
rod	meter (m)	1.101 221 E-03
roentgen	coulomb/kilogram (C/kg)	2.579 760 E-04
second (angle)	radian (rad)	4.848 137 E-06
slug	kilogram (kg)	1.459 390 E+01
$slug/foot^2$	$kilogram/meter^3$ (kg/m^3)	5.153 788 E+02
slug/foot-second	pascal-second (Pa·s)	4.788 026 E+01
statute mile (U.S.)	meter (m)	1.609 344 E+03
stere	$meter^3$ (m^3)	1.000 000 E+00
tablespoon	$meter^3$ (m^3)	1.478 676 E-05
teaspoon	$meter^3$ (m^3)	4.928 922 E-06
tex	kilogram/meter (kg/m)	1.000 000 E-06
ton (assay)	kilogram (kg)	2.916 667 E-02
ton (long, 2240 ibm)	kilogram (kg)	1.016 047 E+03
ton (metric)	kilogram (kg)	1.000 000 E+03
ton (nuclear equivalent of TNT)	joule (J)	4.200000 E+09
ton (register)	$meter^3$ (m^3)	2.831 685 E+00
ton (short, 2000 ibm)	kilogram (kg)	9.071 847 E+02
ton (short, mass)/hour	kilogram (kg)	2.519 958 E-01
ton (long, mass)/$yard^3$	$kilogram/meter^3$ (kg/m^3)	1.328 939 E+03
watt-hour	joule (J)	3.600 000 E+03

To Convert From	To	Multiply By
watt-second	joule (J)	1.000 000 E+00
yard	meter (m)	9.144 000 E-01
$yard^2$	$meter^2$ (m^2)	8.361 274 E-01
$yard^3$	$meter^3$ (m^3)	7.645 549 E-01
$yard^3$/minute	$meter^3$/second (m^3/s)	1.274 258 E-02
year (calendar)	second (s)	3.153 600 E+07

APPENDIX C
FLEXIBLE PIPE
UTILIZATION IN MSD SYSTEM

For many years pipe materials installed into MSD's gravity sewer system were rigid pipe products comprised predominantly of two types. These were vitrified clay pipe (VCP), which was installed for small and intermediate size sewers, and reinforced concrete pipe (RCP) which was typically laid for larger diameter sewers. While each of these traditional products has some limitations, in general they have proven to b very durable and strong and they have served well in the MSD system.

In the early 1980's, solid wall polyvinyl chloride pipe (PVC) was introduced into MSD's sanitary system. PVC pipe has now replaced clay pipe as the preferred product for small to intermediate size sanitary sewers. Since PVC pipe diameters were limited to 18 inches and below, and these pipe materials exhibit relatively high stiffness values, MSD's standard crushed stone encasement (based on the industry standard ASTM D2321) has proven to be adequate for the necessary structural support.

In recent years, manufacturers have developed a number of new flexible pipe products with increasing diameters and some with lower stiffness values. These have included corrugated polyethylene (PE) pipe, high-density polyethylene (HDPE) profile-wall pipe, corrugated PVC pipe, PVC profile wall pipe, and steel spiral rib pipe. Many of these products have been reviewed and approved for use, because MSD recognizes that in certain situations the benefits of lighter weights and fewer joints may be greater than the structural disadvantages associated with flexible pipe.

However, MSD also recognizes that the use of flexible pipe products may not be appropriate in every situation. Accordingly, MSD's Director of Engineering has issued Guidelines for Use of Flexible Pipe for Drainage Facilities. These guidelines were developed after evaluating flexible pipe materials and seeking input from local engineers, developers and contractors. A copy of the guidelines, which have been in effect since February, 1991, is attached.

MSD considers the use of flexible pipe in drainage applications more critical than in sanitary facilities for several reasons. First, drainage facilities often include pipes installed at shallow depths. This makes the pipe more susceptible to damage caused by construction equipment, traffic loads, utility cuts, etc. Second, the flexible pipes products that are approved for sanitary applications tend to exhibit high stiffness values compared with flexible pipe products approved for drainage applications. Last, drainage pipes are typically of larger diameter. This means that larger loads must be supported by the pipe/soil structure. Consequently, more care must be exercised during installation to ensure that the crushed stone is properly worked into the haunching and initial backfill zones to provide the required lateral support.

It is for these reasons that rigid pipes are the preferred product in MSD's drainage system. MSD's policy requires that the Engineer justify the use of flexible pipe on drainage projects. The following is an application form and checklist which should be completed when an Engineer decides to use flexible pipe in the MSD drainage system.

APPLICATION FOR USE OF FLEXIBLE PIPE IN DRAINAGE FACILITIES WITHIN MSD DRAINAGE SERVICE AREA

General Data

Date:____________________

Project Name:____

Owner/Developer:____

Engineer:____

MSD Reviewer:____

Decision: ____________ Accepted ____________ Rejected

____________ Revise and Resubmit

Flexible Pipe Data

Type of Pipe Proposed:____

Manufacturer/Trade Name:____

Diameter:______________________ in. Min./Max. Cover:_________ ft./ _________ ft.

Justification Data

It is the responsibility of the Engineer submitting plans for approval to request and justify the use of flexible pipe materials. As a minimum, the Engineer must address the following items. Attach written responses to this application and reference MSD's Design Manual whenever applicable. Include responses as notes on plans when response requires Contractor's attention.

Item 1. Outline procedures to protect flexible pipe from excessive construction loadings (both equipment and backfill material). If conditions are outside of those used in the Min./Max. Burial Depths Chart for Flexible Pipe, (for example, if backfill weights or construction loads are greater) provide design calculations in accordance with 1) AASHTO Design Procedures Section 12 or Section 18 (as appropriate) and 2) the Modified Iowa Equations to demonstrate a maximum deflection of 5 percent. Design calculations must also show maximum allowable loads, maximum construction loads and maximum in-service loads.

Item 2. Provide information which demonstrates the proposed flexible pipe has adequate hydraulic capacity (If “n” value is higher than a previously approved product).

Item 3. Provide geotechnical data to support design assumptions concerning soil stiffness in haunching and initial backfill zones. Refer to MSD’s trench Details for trench widths and crushed stone encasement dimensions, and reference the required trench width and encasement information on plans.

Item 4. Does the groundwater condition or provisions where long runs of concrete encasement indicate that the pipe will be subjected floatation? If yes, discuss measures to prevent occurrence and reference on plans.

Item 5. Discuss the potential for post-installation damage by subsequent construction of other utilities, service connections, fence posts, structure excavation, etc. Flexible pipe shall not be allowed within road right of ways and other locations where potential for damage exists.

Item 6. If steep slopes exist, discuss methods to be employed that will prevent creep or downslope slippage.

Item 7. Discuss the need to provide end treatments to protect inlet/outlet end of flexible pipes from damage.

Item 8. Flexible pipe generally requires more inspection to ensure proper bedding, haunching, backfilling, etc. Outline a plan for the owner/developer to provide the construction inspection of flexible pipe, if MSD inspection forces are not available for full-time inspection during pipe installation. The plan should include the inspector’s qualifications and procedures that will be followed to provide complete inspection of installation procedures. Note that supervision must be provided by a registered professional engineer.

MSD Review Comments: ____

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APPENDIX D
MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

The attached table outlines minimum and maximum burial depths for the flexible pipe products that are currently approved for use on MSD projects. It was developed using the design procedures contained in the AASHTO Standard Specifications – Division I, Section 12 for aluminized steel pipe and Section 18 for thermoplastic pipe. It also considers a limiting deflection of 5 percent, using the Modified Iowa Method. This table should be used as a reference when standard conditions apply.

Standard conditions assume that the pipe is installed in a trench conforming with the details shown in Appendix F. Backfill is assumed to be 120 pounds per cubic foot. This corresponds to normal soil receiving moderate compaction, or sand which has been flushed and jetted. If the backfill is expected to contain significant quantities of rock fragments, then a higher unit weight should be used and project specific calculations should be performed when unusual (greater than AASHTO H-20) live loadings are expected or the loading does not represent a true negative projecting installation. This could occur in situations containing fill embankments.

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Louisville and Jefferson County
Metropolitan Sewer District

EXHIBIT D-1
MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

EFFECTIVE DATE: APRIL 1, 1995

MINIMUM AND MAXIMUM BURIAL DEPTHS FOR FLEXIBLE PIPE

Pipe Type	Applicable Standard	Diameter (inches)	Stiffness (psi)	Minimum / Maximum Burial Depth (feet)
ETI Ultra-Rib Pipe Ribbed PVC Sewer Pipe	ASTM D-794	8" through18"	60 PSI	1.0 / 25.0'
		21" through 30"	46 PSI	1.0 / 25.0'
Perma-Loc Corrugated PVC Sewer Pipe	ASTM F-794	18" - 36"	46 PSI	1.0 / 25.0'
Contech A 2000 PVC Sewer Pipe	ASTM F-949	4" - 18"	55 PSI	1.0 / 25.0'
Carlon Vylon H. C. Profile PVC Sewer Pipe	ASTM F-794	21" - 48"	46 PSI	1.0 / 25.0'
ADS - N12 HDPE Corrugated Pipe	AASHTO M252	4" - 8"	50 PSI	1.0 / 20.0'
	AASHTO M252	10"	50 PSI	1.0 / 17.0'
	AASHTO M294	12"	50 PSI	1.0 / 17.0'
	AASHTO M294	15"	42 PSI	1.0 / 17.0'
	AASHTO M294	18"	40 PSI	1.0 / 17.0'
	AASHTO M294	24"	34 PSI	1.0 / 17.0'
	AASHTO M294	30"	28 PSI	1.0 / 14.0'
	AASHTO M294	36"	22 PSI	1.0 / 12.0'
Hancor Hi-Q HDPE Corrugated Pipe	AASHTO M252	4" - 6"	50 PSI	1.0 / 23.0'
	AASHTO M252	8"	50 PSI	1.0 / 20.0'
	AASHTO M252	10" - 12"	50 PSI	1.0 / 16.0'
	AASHTO M294	15"	42 PSI	1.0 / 16.0'
	AASHTO M294	18"	40 PSI	1.0 / 16.0'
	AASHTO M294	24"	34 PSI	1.0 / 16.0'
	AASHTO M294	30"	28 PSI	1.0 / 15.0'
	AASHTO M294	36"	22 PSI	1.0 / 12.0'
Driscopipe Permacore HDPE Profile Pipe	ASTM F-894	18" through 48"	RSC 160	1.0 / 25.0'
Solid Wall PVC Pipe				
SDR 35	ASTM D-3034	4" through 27"	46 PSI	1.0 / 25.0'
SDR 26	ASTM D-2241	1-1/2" through 12"	115 PSI	1.0 / 25.0'
SDR 21	ASTM D-2241	1-1/2" through 12"	234 PSI	1.0 / 25.0'
CONTECH Aluminized Steel ULTRA-FLO	AASHTO M36	18" through 48"	16 gauge	1.0 / 25.0'
	AASHTO M36	54"	16 gauge	1.25 / 22.0'
	AASHTO M36	60"	16 gauge	1.25 / 20.0'
	AASHTO M36	18" through 48"	14 gauge	1.0 / 25.0'
	AASHTO M36	54" through 60"	14 gauge	1.25 / 25.0'
	AASHTO M36	66"	14 gauge	1.5 / 25.0'
	AASHTO M36	72"	14 gauge	1.5 / 24.0'
	AASHTO M36	78"	14 gauge	1.75 / 22.0'
	AASHTO M36	18" through 60"	12 gauge	1.0 / 25.0'
	AASHTO M36	66" through 72"	12 gauge	1.25 / 25.0'
	AASHTO M36	78"	12 gauge	1.5 / 25.0'
	AASHTO M36	84"	12 gauge	1.75 / 25.0'
	AASHTO M36	90" through 96"	12 gauge	2.0 / 25.0'
	AASHTO M36	102"	12 gauge	2.5/ 25.0'

NOTE: Based on H-20 loading, 100% pavement transference, AASHTO impact factors, prism load with soil unit weight of 120 pcf, and soil modulus of 1000 psi. Refer to installation details for trench width and installation specifications.

APPENDIX E
REQUIRED PIPE CLASS FOR
REINFORCED CONCRETE PIPE

The attached chart contains the required pipe class for reinforced concrete pipe. It was developed using the revised bedding factors outlined in ACPA publication Design Data 40. This chart should be used as a reference when standard conditions apply.

Standard conditions assume that the pipe is installed in a trench conforming with the details shown in Appendix F. Backfill is assumed to be 120 pounds per cubic foot. This corresponds to normal soil receiving moderate compaction, or sand which has been flushed and jetted. If the backfill is expected to contain significant quantities of rock fragments, then a higher unit weight should be used and project specific calculations should be performed. Furthermore, project specific calculations should be preformed when unusual (greater than AASHTO H-20) live loadings are expected or the loading does not represent a true negative projecting installation. This could occur in situations containing fill embankments.

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MSD

Louisville and Jefferson County Metropolitan Sewer District

EXHIBIT E-1
CIRCULAR RCP CLASS AND DEPTH CHART

EFFECTIVE DATE: JANUARY 1, 2001

REQUIRED PIPE CLASS FOR CIRCULAR REINFORCED CONCRETE PIPE IN TRENCH INSTALLATION WITH #57 CRUSHED STONE PIPE CRADLE

Height of Cover (feet)

Pipe Inner Diameter (in)	0.5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
12	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
15	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
18	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4
21	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
24	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
27	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
30	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
33	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
36	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
39	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
42	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
48	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
54	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
60	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
66	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
72	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
78	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
84	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
90	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
96	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4
102	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
108	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
114	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
120	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
126	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
132	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
138	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
144	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4

Notes: (1) Based on H - 20 loading, 100% pavement transference, AASHTO impact factors, soil unit weight of 120 pcf with Marston Equation, maximum allowable MSD trench widths, and bedding factor = 2.4. Refer to installation details for trench width and installation specifications.
(2) For pipe sizes 12-inch through 24-inch diameter, non-reinforced concrete pipe meeting ASTM C14 Class III, can be used where reinforced concrete pipe Class III is allowed.

APPENDIX F
TRENCH DETAILS

An evaluation of standard installation procedures and specifications which are referenced by pipe product manufacturers has resulted in revisions to MSD's trench details. Installation specifications which were reviewed in developing the revised details include manufacturer's specific recommended trench width and the following ASTM specifications.

1.) ASTM D 2321: Standard Practice for Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.

2.) ASTM A 798: Standard Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications.

The revised details are illustrated in the following exhibits. In certain installations conformance with manufacturers recommended procedures will result in wider trench widths and more crushed stone encasement than MSD has previously required. This is especially the case for large diameter flexible pipes, and in situations where flexible pipe is used and poor soil conditions exist.

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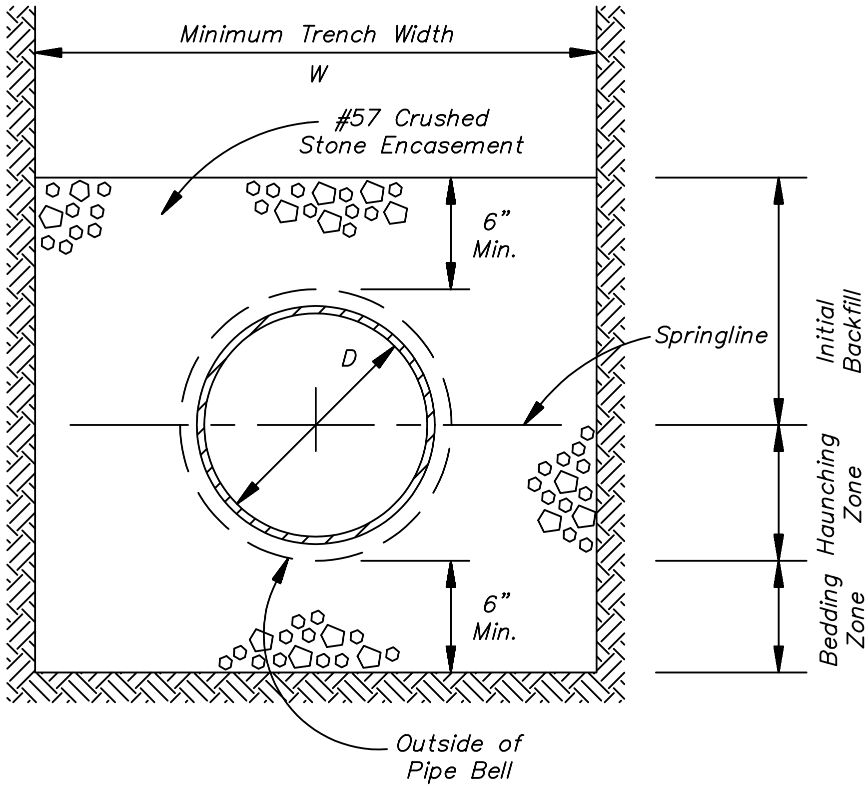
MSD
Louisville and Jefferson County
Metropolitan Sewer District

EXHIBIT F-1
CRUSHED STONE ENCASEMENT FOR THERMOPLASTIC PIPE 4” - 12” DIA.

EFFECTIVE DATE: JANUARY 1, 2001



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
4”	1’–9”	2’–0”
6”	1’–11”	3’–0”
8”	2’–1”	4’–0”
10”	2’–3”	5’–0”
12”	2’–6”	6’–0”

*See Note 6

NOTES

1. Place #57 crushed stone in 6” maximum layers and work in around pipe by hand within the haunching zone.

2. Provide bell holes in pipe bedding, no larger than necessary, to ensure uniform pipe support. Fill all voids under bell by hand with bedding material.

3. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.

4. Any trench bracing used below the top of pipe shall be left in place.

5. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.

6. For installations in poor native soils where in–situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N–values less than 10, the minimum trench width shall be expanded by increasing the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 2.5 pipe diameters (2.5 x D).

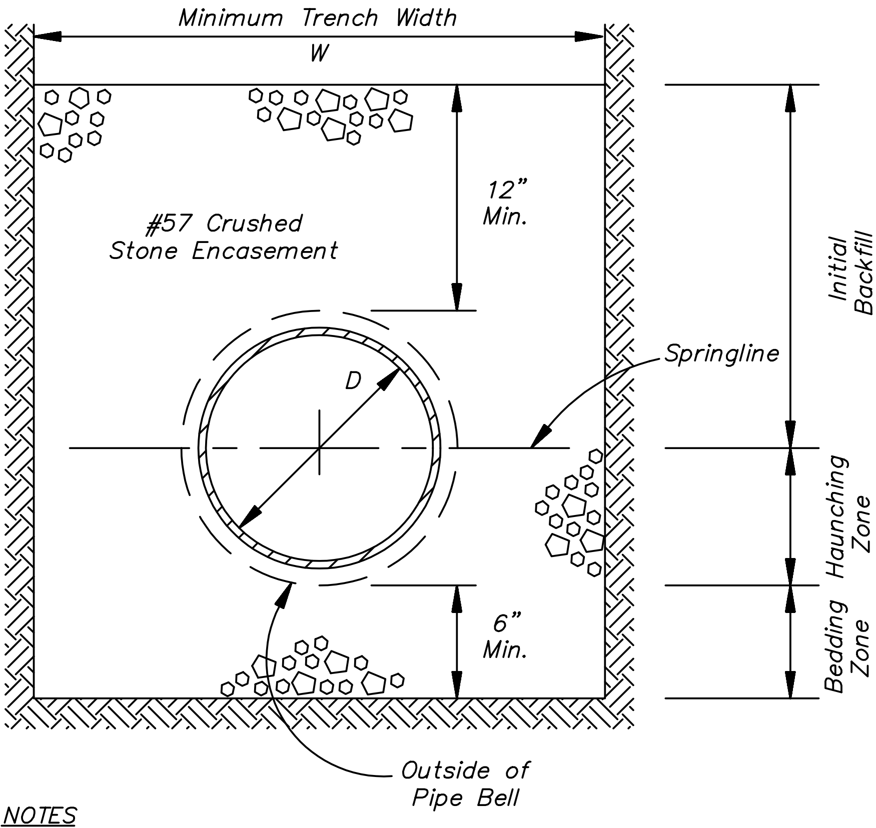
7. Deflection tests shall be performed as per MSD specifications.

8. For installations where the trench bottom consists of soft clay or very loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.

9. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24” above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

EXHIBIT F-2
CRUSHED STONE ENCASEMENT FOR
THERMOPLASTIC PIPE 15" - 48" DIA.

EFFECTIVE DATE JANUARY 1, 2001



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
15"	2'–10"	6'–3"
18"	3'–3"	6'–6"
24"	4'–4"	7'–0"
30"	5'–6"	7'–6"
36"	6'–6"	9'–0"
42"	7'–11"	10'–6"
48"	8'–4"	12'–0"

*See Note 6

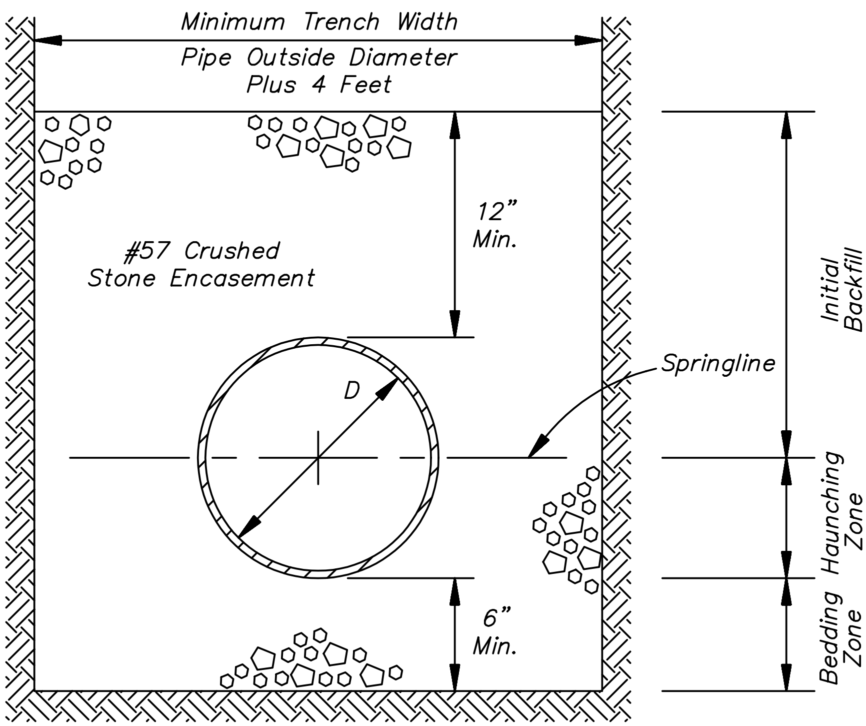
NOTES

1. Place #57 crushed stone in 6" maximum layers and work in around pipe by hand within the haunching zone.
2. Provide bell holes in pipe bedding, no larger than necessary to ensure uniform pipe support. Fill all voids under bell by hand with bedding material.
3. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.
4. Any trench bracing used below the top of pipe shall be left in place.
5. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.
6. For installations in poor native soils where in–situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N–values less than 10, the minimum trench width shall be expanded by increasing the the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 30" or one pipe diameter (D) whichever is greater.
7. Deflection tests shall be performed as per MSD specifications.
8. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.
9. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

EXHIBIT F-3
CRUSHED STONE ENCASEMENT FOR
CORRUGATED/SPIRAL RIB METAL PIPE

EFFECTIVE DATE: JANUARY 1, 2001

MSD
Louisville and Jefferson County
Metropolitan Sewer District



Nominal Pipe Dia. (D)	W	
	Good Soil or Rock	Poor Soil*
18"	3'–3"	6'–6"
21"	3'–10"	6'–9"
24"	4'–4"	7'–0"
30"	5'–6"	7'–6"
36"	6'–6"	9'–0"
Larger Than 42"	Pipe O.D. Plus 48"	

*See Note 6

NOTES

1. Place #57 crushed stone in 6" maximum layers and work in around pipe by hand within the haunching zone.

2. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.

3. Any trench bracing used below the top of pipe shall be left in place.

4. For installations where significant groundwater flow is anticipated, such as if pumping methods are required to dewater, the trench excavation below the water table, or if after construction, the permeable encasement will act as a "french drain" under high ground water levels, the entire perimeter of the crushed stone encasement shall be wrapped with an approved geotextile fabric to prevent the migration of fines and loss of pipe support.

5. For installations in poor native soils where in–situ lateral soil resistance is negligible, such as soft clay with unconfined compressive strengths less than 0.5 tsf or loose sands with standard penetration test N–values less than 10, the minimum trench width shall be expanded by increasing the distance between the side of the pipe and the line of actual excavation or trench bracing to a minimum of 30" or one pipe diameter (D) whichever is greater.

6. Deflection tests shall be performed as per MSD specifications.

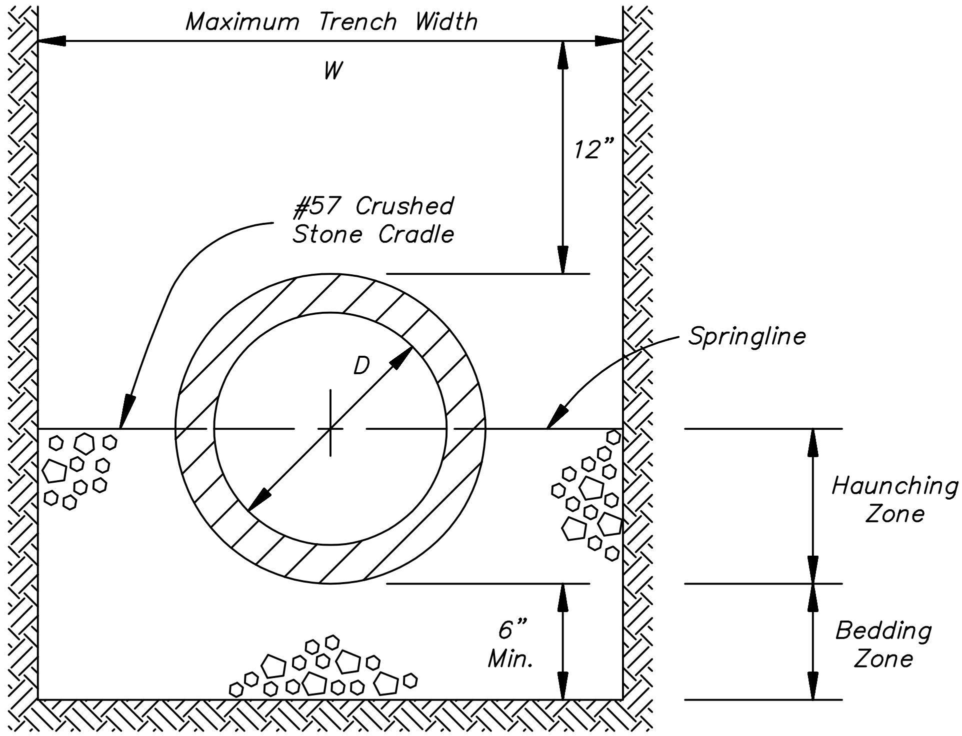
7. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.

8. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

EXHIBIT F-4
CRUSHED STONE CRADLE FOR REINFORCED CONCRETE PIPE

EFFECTIVE DATE: JANUARY 1, 2001

MSD
Louisville and Jefferson County Metropolitan Sewer District



NOTES

1. Place #57 crushed stone in 6" maximum layers and work under pipe by hand within the haunching zone.

2. Check grade of the pipe after placement of crushed stone up to springline to insure the desired flow line alignment has not changed.

3. Any trench bracing used below the top of pipe shall be left in place.

4. For installations where the trench bottom consists of soft clay or loose sands, undercut to a depth as required by the Engineer, and replace with a foundation of #57 crushed stone compacted in maximum six inch layers. Class "B" concrete shall be used to backfill the undercut zones in ditches and streams.

5. To prevent damage to the pipe and disturbance of the pipe encasement, provide a minimum depth of cover of 24" above the top of pipe before allowing vehicles or construction equipment to traffic the trench surface. Where construction loads may be excessive, the minimum cover shall be increased.

6. The maximum allowable trench width shall apply to a height of 12" above the outside top of the pipe.

Nominal Pipe Dia. (D)	W
12"	3'–5"
15"	3'–9"
18"	4'–1"
21"	4'–4"
24"	4'–8"
27"	5'–1"
30"	5'–5"
33"	5'–10"
36"	6'–2"
39"	6'–8"
42"	6'–11"
48"	7'–6"
Larger Than 48"	Pipe O.D. Plus 2'–8"

APPENDIX G

MSD CRITERIA FOR PRECAST STRUCTURES

Effective October 1, 1990

1. Any use of precast structures must be so noted on the plans, including a typical detail for each type of structure for the project.

2. Structures which require specially designed footings, cut-off walls, etc., will not be allowed as precast.

3. Openings in precast structures for pipes shall be the outside diameter of the pipe plus maximum of 6 inches. In order to use non-shrink grout, the opening shall be the outside diameter of pipe plus 3 inches. (Outside diameter of pipe plus 4 ½ inches is permissible when tapered hole forms are utilized.)

4. For precast structures (other than those with knockout panels), the opening around the pipe shall either be filled with non-shrink grout for the wall thickness of the structure or the pipe shall be encased with a minimum 6-inch collar of concrete from the inside face of the wall to 1'-0" outside the outer face of the wall. The pipe shall be adequately supported to prevent settling while the grout or the concrete encasement is setting up. The inside face of the structure walls shall be finished with a trowel and wet brush finish.

5. For circular structures, the following applies as to the maximum inside diameter (or horizontal dimension) of pipe to be used with a given size of manhole.

Diameter of Structure	Maximum Size of Pipe*
4'-0"	24 inches
5'-0"	36 inches
6'-0"	48 inches

*Outside diameter may be considered on a case-by-case basis for flexible pipe.

6. For circular structures, the minimum distance allowed between precast holes for the pipes shall be 12 inches.

7. For circular structures and rectangular structures (other than those with knockout panels), the minimum vertical distance from the holes for the pipes to the top of the structure wall shall be 4 inches. If this vertical distance is less than 12 inches, then additional reinforcing steel shall be furnished for this section. The top slab must be designed for HS-20 loading.

8. For precast structures with knockout panels, holes for the pipe shall not be cut into the structural members (i.e., top beams and corner columns) and non-shrink grout shall not be allowed to be placed around the pipes. The pipes shall be encased with concrete a minimum 6-inch collar around the outside of pipe or a minimum of 3 inches beyond the hole knocked in the wall, whichever is greater. Also, the concrete encasement shall extend from the inside face of the wall to 1'-0" outside the outer face of the wall.

9. Precast structures with knockout panels shall not be used with more than 2 feet of earth cover unless load calculations are supplied.

10. For rectangular structures where pipe will be installed in adjacent walls (other than those with knockout panels), at least 6 inches of wall (measured from the interior corner)is required on each side of the pipe beyond the precast opening for the pipe. This rule is not applicable for structures which have pipe installed in opposite walls or where one outlet pipe is utilized.

11. A wash is required in the bottom of catch basins to provide positive drainage (sloped toward outlet).

APPENDIX H

POLICY ON DESIGN OF STORMWATER CAPITAL PROJECTS
ADOPTED BY MSD BOARD JULY 11, 1994

Policy Statements

a. General

Flood reduction solution alternatives shall be evaluated primarily based upon relative cost. MSD shall implement the most cost-effective solution whenever feasible. In addition to standard and traditional alternatives, such as modifying or replacing downstream structures and improving stream conveyance, floodproofing of affected structures shall be routinely considered in evaluating solution alternatives. If acquisition and relocation of demolition of affected structures is identified as the most cost-effective solution alternative for a drainage problem, then the Board shall consider the specific situation and decide on the alternative to be used.

Solution alternatives should be evaluated secondarily on the opportunity to use Best Management Practice (BMPs) to improve water quality and maintain natural habitat. Of alternatives with similar estimated costs, the alternative with the highest potential to improve water quality and maintain habitat shall be chosen.

b. Priorities for Project Evaluation

Projects should address drainage requests in the following order of priority:

1. Eliminate or reduce flowing with risk of personal injury.
2. Eliminate first floor flooding.
3. Eliminate or reduce basement flooding.
4. Provide an outlet for drainage from a critical upstream project or area.
5. Eliminate or reduce flooding which interferes with transportation of priority access roads to neighborhoods.
6. Control erosion in situations where structures or property are being damaged or erosion is occurring outside of defined easements.
7. Eliminate long-term standing water of "yard flooding" which occurs outside a defined easement.
8. Control erosion within a defined easement.
9. Eliminate long-term standing water due to the lack of an outlet within an easement.

The final solution to the problems within a project area should address as many as possible of the above-listed items that exist, while remaining cost-effective.

c. Definition of Project Scope

Improvement projects fall into the three categories, depending upon the numbers and locations of affected buildings and residents and the scope of construction effort required: mini-project, neighborhood project, and regional project.

Mini-projects shall meet the following criteria. If one or more of the listed criteria are not met, the project is beyond the scope of a mini-project and is either a neighborhood or regional project.

1. Project addresses a problem located within a single defined subdivision or group of structures.

2. Project does not involve construction of, or improvement to, a regional detention facility.

3. Project does not involve improvement of conveyance within a defined blueline stream.

Neighborhood projects shall meet the following criteria. If one or both of the listed criteria are not met, the project is beyond the scope of a neighborhood project and is a regional project.

1. Project addresses a problem located in one or more subdivisions or groups of structures in a centralized area.

2. Project does not involve construction of a regional detention facility.

Regional projects shall meet the following criteria:

1. Project addresses problems of multiple subdivision, developments, or groups of structures; at least some of the problems are independent and could be solved by separate neighborhood projects.

2. Project influences extend downstream and upstream in the watershed, beyond the typical reach of a neighborhood project.

3. Project involves construction or modification of a regional detention facility or improvement to conveyance of a blueline stream.

d. Design Criteria and Guidelines

Specific design criteria for drainage projects are found in this Design Manual. General guidance for all drainage design and particular guidance of various project categories follows.

For all projects, the guidelines of the Stream Corridors/Greenways Multi-Objective Plan shall be followed. The disturbance of natural stream corridors should be minimized, the preservation of natural streams and habitat should be emphasized, and the use of the piped systems and lined channels should be discouraged. In addition, designs should incorporate BMP's for water quality control.

Structural improvements, such as downstream culvert replacements or upstream detention ponds, shall be designed to mitigate existing flooding problems and provide one foot of freeboard for the 100-year event. If improvements require phasing of funding and/or construction, phasing should be done beginning from the downstream improvements and proceeding upstream. An exception to this general phasing rule is a detention facility, which should be constructed in the early phases of overall project construction. All projects shall be constructed in conformance with the Soil Erosion and Sediment Control Ordinance.

Mini-projects will be designed to establish adequate conveyance capacity of improve the conveyance capacity of the existing drainage system to control frequent storm events. Drainage systems shall be designed so that no flooding of habitable structures occurs during a 100-year event. Neighborhood projects shall be designed similarly so that drainage systems do not allow flooding of habitable structures for the 100-year event. Regional projects shall be designed to reduce or eliminate flooding of habitable structures and property. Regional facilities should also be evaluated for their impacts on base flow, since maintenance of adequate base flow in receiving waters is essential to watershed-wide water quantity and quality management.

e. Non-structural Solution Alternative Design Criteria

e.1. Floodproofing

Floodproofing is the term for procedure which eliminate or reduce flood damage by protecting or modifying buildings instead of preventing flood waters from reaching them. Dry floodproofing seals the exterior of the home and protects the interior. Wet floodproofing involves designing or retrofitting a building's electrical systems, utilities, and valuable items so that they are located above the predicted flood stage and allowing flood water to pass into or through the structure. Both types of floodproofing shall be routinely considered among possible alternatives for solving drainage and flooding problems. If floodproofing alone, or in combination with other measures, provides the lease expensive solution to a problem, it should be utilized.

Floodproofing has limitations; it protects to a specific elevation and does not guarantee a structure will not be damaged by flood waters. Floods exceeding the design event could still damage the structure. Also, some means of floodproofing requires human intervention (e.g., blocking openings and entryways). Education of the owners or residents of floodproofed structures, in terms of their responsibilities and expectations, is essential to the success of floodproofing operations.

Floodproofing designs shall be based upon the 100-year storm event and provide one foot of freeboard. Designs should conform to the guidelines listed in the Kentucky Flood Protection Manual and/or the appropriate Federal Emergency Management Agency (FEMA) Publication.

FEMA 15 – Design Guidelines for Flood Damage Reduction
FEMA 54 – Elevated Residential Structures
FEMA 85 – Manufactured Home Installation in Flood Hazard Areas
FEMA 102 – Floodproofing Non-residential Structures
FEMA 114 – Retrofitting Flood-prone Residential Structures

e.2 Acquisition and Relocation

The cost of acquiring flood-prone properties for relocation or demolition as a solution alternative for flooding problems shall be determined routinely and compared to the costs of other alternatives. For such a property, the total acquisition cost will include the following component costs: for demolition candidates, buying the property, razing the building, disposing of waste materials, and restoring the site; for relocation candidates, buying the old property, buying and preparing the new site, moving and installing the building on the new site, and restoring the old site.

In a case where acquisition appears to be the lowest cost alternative, the MSD Board will receive a summary of alternatives, costs, and supporting arguments. The Board will then decide whether to select acquisition of another alternative to address the specific case. For any property from which a flood-prone building is moved or demolished, redevelopment shall meet the criteria of the floodplain management ordinance.

f. Conformance with Watershed Master Plans

Projects shall be designed and constructed in a manner consistent with the Watershed Master Plan for the area. If a project is proposed that does not conform to the Watershed Master Plan, the impact of the project on the entire drainage basin shall be evaluated prior to final design and construction. The completed project shall be represented in future updates of the Watershed Master Plan model.

g. Public Involvement

g.1. Public Meetings

Public involvement shall be mandatory for all drainage projects. Complaint files and resident interviews shall be the basis for assessing the need for a project and developing its scope. Public meetings will be held for at least three stages of each project: pre-design, presentation of alternatives, and pre-construction. Additional public meetings may be scheduled as needed to inform residents further and to build support for a project.

g.2. Consensus Building

Through the public involvement process, MSD will describe the goals, approach, and anticipated benefits of a proposed project to the affected parties and will evaluate their level of support. A strong majority of affected individuals must support a project for it to proceed. If support is weak, there will be not project. If support is moderate, MSD will approach the local elected official to explain the need for strong support and to enlist the official's help in increasing the local approval. If a strong majority support the project, it will go forward, utilizing condemnation if necessary to assure the project's progress.

h. Easements

Residents who will benefit from a project are expected to provide easements needed for the project at no cost to the project. Residents whose property is affected but not benefited by a project may be asked to donate easements. Easement acquisition must be timely; attempts to obtain easements at no cost must not slow a project's schedule. If a project has strong consensus support and benefits but necessary easements cannot be obtained rapidly, MSD will pursue condemnation after obtaining specific Board approval.

i. Project Funding

In general, MSD will fund the assessment of problems related to public drainage facilities and the design and construction of projects to solve the problems. Projects which provide greater benefits should receive higher priority in the process of scheduling work. During project planning, issues outside MSD's responsibility may be added into a project if the requesting owner or owners are willing to fund the difference in project costs.

Flooding due to existing, approved development shall be addressed by MSD. Alternative solutions shall be evaluated and presented to the affected parties. MSD will fund the most cost-effective feasible solution. If the parties involved prefer an alternative solution and are willing to fund the difference in cost, MSD may consider implementing the alternative.

Flooding resulting from the unapproved actions or development by a citizen, group or company shall be mitigated by that individual. Solution alternatives developed by the responsible party will be subject to review and comment by MSD and the public.

Inter-agency projects for infrastructure improvement are encouraged. MSD will coordinate with other government agencies to review planned projects in areas for which mini-projects are planned. Lead agency approaches, with a single contractor performing all proposed improvements, are encouraged. Costs of the drainage improvements will be prorated to the costs of the other improvements.