



CHAPTER 1 DESIGN MANUAL OVERVIEW

1.1 Introduction

The response of an urbanized watershed to precipitation is significantly different from the response of a natural watershed. The relationship between the amount of impervious surfaces in a watershed and the effect on the hydrology and water quality has been well documented. Post-developed peak runoff is expected to exceed pre-developed runoff from a similar storm event. This is most commonly the result of reduced infiltration and decreased travel time, which significantly increases peak discharge rates and runoff volumes. Factors influencing the amount (volume) of runoff include precipitation depth, the infiltrative capacity of soils, soil moisture, vegetative cover type, the amount of impervious surfaces, and surface retention. Travel time is determined primarily by slope, length of flow path, depth of flow, and roughness of flow surfaces.

Land modifications such as grading, paving of streets, driveways, parking lots, and the construction of buildings and other facilities characteristic of urban development reduce both the infiltration rate of the soil and the soil storage capacity by eliminating pervious surfaces and reducing vegetation. As the runoff moves over these impervious surfaces pollutants are picked up and carried to the receiving waterbody. A variety of inorganic, organic, and bacteriological pollutants are transported in surface runoff as it moves across the urban landscape. The majority of the annual pollutant loading is added to local streams from the smaller, high frequency (< 1-year) storms. Increases in the overall volume of runoff can destabilize stream bank material and increase downstream erosion.

To accommodate the higher discharge rates and volumes of stormwater runoff in suburban and higher-density urban development, storm sewer conveyance systems are installed to provide safe and efficient drainage of the landscape. Additional protection is provided through storage facilities which control release rates to downstream systems. Traditional design considerations have focused on the prevention of damage to the development site, drainageways, streets, public and private property from flooding. Recently, focus has been added to the reduction of soil erosion and pollutant discharge. With the implementation of the stormwater NPDES Phase II regulations, the improvement of stormwater runoff quality is now an additional stormwater management goal for Boone County.

1.2 Purpose

The purpose of this manual is to present planning and design guidelines for the management of stormwater quality *and* quantity in the suburban and urban environment. This manual establishes standard methods and principals for the design of stormwater collection systems, stormwater detention and retention facilities, stormwater treatment and construction site best management practices (BMPs).



The design factors, formulas, graphs, and procedures are intended for use as engineering guides for determination of quantity, rate of flow, method of collection, storage, conveyance, and discharge of storm water. The Engineer is encouraged to use cost-effective designs that are hydrologically and hydraulically appropriate through the use of good engineering judgment. The material in this manual includes the hydrologic design and implementation of stormwater quality BMPs and traditional analysis and design of stormwater runoff conveyance for larger storm events to prevent flooding. Additional guidance is provided on improved site planning, construction site runoff control and the protection of environmentally sensitive areas. While this manual includes most of the commonly-used stormwater BMPs, it is not a comprehensive list. Additional design guidance from other technical documents is referenced as applicable.

1.3 Background

A driving factor behind the development of this manual is the need to comply with the National Pollution Discharge Elimination System (NPDES) Phase II requirements. Boone County has developed this manual based on the City of Columbia's Stormwater Management and Water Quality Manual, City of Springfield's Stormwater Design Criteria Manual, Mid-America Regional Council and the Kansas City Chapter of the American Public Works Association's Section 5600 and Best Management Practices for Water Quality Manual. However, an effort has been made to customize the policies and procedures to more closely fit the types of development expected in the unincorporated areas of Boone County.

1.4 Goals

The overall goals of this manual and the related ordinances are to:

- minimize the long term cost of operation and maintenance of stormwater management facilities for both Boone County and private property owners
- provide guidance to local developers, engineers and construction personnel that will assist in complying with the NPDES permit for state and federal regulations
- reduce the environmental impact of increased stormwater runoff due to development both during construction and in the long term
- control flooding to provide protection of both private and public infrastructure
- minimize nonpoint source pollution to streams in Boone County
- protect the public's health, safety and welfare
- provide additional protection for environmentally sensitive areas



1.5 Chapter Summaries

Chapter 1: Design Manual Overview

This chapter serves as an executive summary of the design manual. It summarizes the manual's purpose, background, goals and provides chapter descriptions. It also provides information about additional permitting issues related to the construction of stormwater management facilities beyond the requirements of the County.

Chapter 2: Stormwater Plan and Permit Requirements

This chapter provides an overview of the various development processes and the required information for plan and permit submittals. This includes the expectations for each type of plan sheet or calculation Boone County Public Works requires for the approval of stormwater management facilities and associated pollution prevention in subdivisions, planned developments and commercial site development. Plan review checklists corresponding to these requirements can be found in Appendix B.

Chapter 3: Hydrology and Hydraulics

This chapter provides a brief review of the hydrologic and hydraulic calculations and formulas for determining runoff quantities, velocities and system capacities. This chapter is not intended as a substitute for formal hydrology and hydraulics training and may also be supplemented by extensive information available in industry accepted computer software for hydrologic and hydraulic modeling. Various charts and figures to assist with these calculations are included at the end of the chapter.

Information on determining water quality and channel protection volumes is also included in this chapter. However, specific design guidance for sizing individual post-construction best management practices can be found in the Mid-America Regional Council's (MARC) Manual for Best Management Practices for Stormwater Quality dated March 2008.

Chapter 4: Enclosed Systems

This chapter provides specific design criteria for the locations and sizing of storm sewer systems. This includes protection from flooding for various classifications of streets. Energy dissipation at the outlet of an enclosed system is discussed both here and in Chapter 8 – Erosion and Sediment Control. The chapter also includes guidance for reviewing the overflow from the enclosed system. Various charts and figures to assist with these calculations are included at the end of the chapter.

Chapter 5: Open Channels

This chapter provides guidance in natural stream protection and design criteria for the locations and sizing of engineered open channel stormwater conveyance systems. Natural stream protection is partially addressed in the zoning code



through the stream buffer regulations. However, it is recognized that occasionally it is necessary to enter the streamside zone or the stream for utility and road crossings. This chapter provides guidance for limited stream assessments to minimize the impacts of the construction activities and the location of stormwater outfalls. Various charts and figures to assist with these calculations are included at the end of the chapter.

Chapter 6: Stormwater Management

The traditional stormwater management goals for quantity management have centered on storing peak volumes of runoff from large rainfall events and discharging it at a slower (typically pre-development) rate. While traditional storage practices can reduce the peak runoff flows from urban development and provide some level of flood protection, the increase in runoff volume and frequency of peak flows is not reduced and very little improvement in stormwater quality is accomplished unless the water is retained in the basin for more than six (6) months. This chapter provides design criteria for the design of facilities to address quantity management. Design methodologies for sizing these facilities may be supplemented by Hydrologic and Hydraulic information found in Chapter 3. This chapter also discusses a wider variety of alternatives to traditional pond storage. Discussion of operation and maintenance plans is also presented.

Although management of the quantity of stormwater runoff reduces impacts to natural channel systems, it does not sufficiently address treatment of pollutants introduced in the developed environment. This chapter further discusses typical pollutants generated by different types of land treatments and the BMPs that can address these pollutants. Stormwater management plans, as required by the Stormwater Management Ordinance, will address both the quantity and quality of the stormwater runoff from developments.

Chapter 7: Protection of Environmentally Sensitive Areas

This chapter highlights the additional issues presented by the development of land near environmentally sensitive areas such as Karst sinkholes, caves, springs, losing streams, wetlands, and outstanding state resource waters. Per the Stormwater Management Ordinance, developments near these areas will require additional measures be taken to reduce the risk of any surface or groundwater contamination. Additional information related to the identification of these areas is provided in Appendix C.

Chapter 8: Erosion and Sediment Control

This chapter provides a menu of various construction site related best management practices for erosion control, stormwater runoff management, sediment control, tracking control and general good housekeeping for pollution prevention. Both the erosion and sediment control plan sheets and narrative (Stormwater Pollution Prevention Plan – SWPPP) should utilize options within



this chapter to describe how the contractor will attempt to prevent the discharge of pollutants during construction activities.

As noted in this chapter, this is not intended as an exhaustive list of BMPs and specifically did not attempt to address the growing variety of proprietary products on the market for these purposes. The County encourages the introduction of various alternatives to the plans if the ultimate objective of pollution prevention can be achieved.

This chapter is significantly based on guidance developed by the City of Springfield. We appreciate their sharing of their draft erosion prevention and sediment control guidelines.

Appendix A: Definitions

Occasionally the vernacular used to describe land development planning and zoning issues does not correlate with the combined stormwater quality and quantity goals set forth in this manual. This appendix provides definitions to better serve the user of this manual.

Appendix B: Checklists and Worksheets

This appendix provides the user copies of the plan review checklists that will be utilized in the review and approval of all plans and reports required by the Stormwater Management Ordinance and further detailed within this manual. It is recommended that the developer's engineers utilize these checklists to minimize the comments received from staff and expedite the approval and permitting process. These checklists correspond to plan requirements in Chapter 2. Worksheets have also been designed to aid with understanding and concept clarification. Several of the workshops are mandatory, and will help speed the plan approval process.

Appendix C: Environmentally Sensitive Areas

This appendix provides a list of specific environmentally sensitive areas as identified in the Code of State Regulations. This information may be supplemented by GIS databases.

1.6 Requirements of other agencies

Rules and regulations of other agencies also pertain to stormwater management systems, which may or may not compliment these criteria. When conflicts are encountered, the more stringent criteria shall govern. The following agencies have jurisdiction over streams and/or discharges from stormwater collection systems and may require additional permits. Other regulations, permits and requirements may not be limited to these agencies.

- Federal Emergency Management Agency (FEMA)
- U S. Army Corps of Engineers
- Missouri Department of Natural Resources



- Environmental Protection Agency



CHAPTER 2 STORMWATER PLAN AND PERMIT REQUIREMENTS

2.1 Introduction

This chapter details the requirements for the preparation of stormwater plans and provides information on permit requirements. Also included are the requirements for meetings related to plan and plat review.

2.2 Stormwater and Land Disturbance Permits

The purposes of the stormwater and land disturbance permits are: to protect County assets such as roads, bridges and storm drains; give the County the opportunity to oversee the work for proper installation; insure protection of environmentally sensitive areas; and prevent discharge of pollutants to our waterways. When applying for a permit, please provide completed applications for all applicable permits including the Land Disturbance Permit, Stormwater Discharge Permit, Building Permit and Right-of-Way permit, and/or Driveway Permit when submitting construction plans for approval. Prior to issuance of any County permits, the County must also receive copies of all other jurisdictional approvals (COE, Floodplain, MoDOT, DNR, etc) and copies of executed off-site easements.

1. Stormwater Discharge Permit

Per the Stormwater Management Ordinance, no stormwater facilities or permanent stormwater BMPs shall be constructed or altered without obtaining a Stormwater Discharge Permit. This permit may only be obtained after approval of all grading and stormwater management plans, including an operation and maintenance plan for the development.

2. Land Disturbance Permit

Per the Stormwater Management Ordinance, any development that disturbs greater than one acre will require a County land disturbance permit in addition to the Land Disturbance Permit required by the Missouri Department of Natural Resources. This includes projects that are part of a greater plan or sale that will cumulatively disturb greater than one acre.

- a. **Permit Application:** The permit application should be submitted with the Stormwater Management Construction plans and must include a copy of the Stormwater Pollution Prevention Plan (SWPPP). Any development near an environmentally sensitive area, as defined in the Stormwater Management Ordinance, that disturbs greater than 3000 square feet, must also obtain a land disturbance permit.



Grading only: if the developer would like to begin clearing and rough grading, Boone County Public Works must approve the following plans before a land disturbance permit can be issued:

- Rough Grading Plan
- Erosion and Sediment Control Plan
- Stormwater Pollution Prevention Plan (SWPPP)

- b. **Pre-Construction Meeting:** It is the responsibility of the permittee to schedule a pre-construction conference with Boone County Public Works prior to the start of land disturbance activity. The inspector will verify the installation of the temporary construction entrance(s) and perimeter controls. The inspector will also review the areas where existing vegetation is to be preserved. The permittee will be responsible for notifying all contractors and other entities, including utility crews, that will perform work at the site to be in attendance. Once the Boone County Inspector has reviewed the facility and SWPPP with the contractor(s), the permit will be issued on-site and work may begin.
- c. **Permit Expiration:** The land disturbance permit duration and expiration will be dependant on the proposed construction schedule. Generally the permit will expire if work is not completed within two years and may be renewed through written request. The stormwater discharge permit is considered ongoing and will not include an expiration date. Construction of facilities under a stormwater discharge permit should be completed within two years.

2.3 Development Review Process

The plans submitted to the County should include all information necessary to review the design, build and inspect the construction of the storm drainage systems and related appurtenances. The plans and calculations must be prepared and certified by a Registered Professional Engineer, licensed in the State of Missouri, and submitted to the Director of Planning for review by all County departments.

Figure 2.1 at the end of this chapter, displays the flow chart for the Subdivision Review Process for submittal and review of subdivision plats and development plans. The flow chart for Site Plan Review Process (figure 2.2) displays the process for submittal and review of site plans that do not require rezoning (commercial, industrial, multi-family).

2.4 Concept Review Meeting

Time is available for developers to meet with county staff and other interested agencies to discuss and review multiple layout possibilities for developments. The concept review is



mandatory and allows for open discussion on a wide array of potential issues and challenges to avoid as the layout comes together. Minimal information is required for the concept review, and should be submitted in electronic or faxable form prior to this meeting. Please bring three full size copies to the meeting. These reviews are scheduled for the 2nd and 3rd Mondays of each month. Please call 573-499-4330 one week in advance to schedule your review.

2.5 Pre-Application Meeting

Early planning for new development will include attendance at a Pre-Application Meeting at the Planning and Building Department. This meeting is mandatory and critical for the preparation of an acceptable stormwater management plan.

The Pre-Application Meeting will assist the developer and their engineer in identifying major storm water issues related to maximizing water quality protection, while minimizing flooding, project costs, stormwater facility conflicts and construction difficulties. With early discussions of concerns, the plan is less likely to experience delays in the review process. This is also the time that innovative ideas may be discussed and preliminary approval for design variances can be provided so that the developer and their engineer can proceed with some assurance of approval.

The first major design consideration is the identification of the natural features of the property. Specifically, these include the existing topography, predominate soils and drainage area boundaries, which will dictate the types of BMPs, width of buffers and the location and configuration of stormwater facilities and water quality controls. The existing buffers and natural drainage ways should play a significant role in determining the location and configuration of streets and lots. Consideration of a site's natural topography and the proximity of sensitive features is critical to the design of proper stormwater management. A development that preserves existing drainage patterns and terrain may be able to reduce front end construction costs and long term maintenance.

Additional requirements for land development in environmentally sensitive areas should be identified early in the design process. If there is a watershed plan, those recommendations should be addressed early in the planning stage, to prevent future land-use conflicts.

1. Pre-Application Meeting Requirements

Pre-Application Meetings are scheduled for the 2nd and 3rd Mondays of each month. Please call 573-499-4330 to schedule your review. Eight (8) copies of the plan should be submitted to the Director of Planning one week prior to the meeting date. This plan will be reviewed according to the following criteria and as referenced in the checklist located in at the end of this chapter.



- a. **General Information:** The plan should provide the following general information: legal description of the site, address or Parcel number (available on GIS website), aerial vicinity map showing the surrounding streets and landmarks, photo scale, north arrow, tract boundaries, adjacent municipal boundaries, project narrative describing the purpose of the project, and any expected variances from standards (ie street widths, curb and gutter, sidewalks).
- b. **Design Considerations:** Please provide staff with a map of the area with existing topography, using 2-foot contours or best available data; soil information, including information on the predominate soils, and the current infiltration and/or permeability for those soils (NRCS soil survey for Boone County); the location of natural streams with arrows showing direction of water flow; the delineation of stream buffers and flood plain limits; the location of any sensitive resource areas such as karst features, wetlands, impaired waterbodies or outstanding resource areas (Appendix C); and the existing stormwater outfalls.
- c. **Infrastructure/Facilities:** Provide a sketch depicting the location of existing roads and utilities, proposed lot lines and/or building locations, and the proposed placement of roadways, parking lots, etc.
- d. **Potential Stormwater BMPs:** The engineer may want to be prepared to discuss the types of stormwater quality and quantity BMPs expected on the site. Low impact development concepts that utilize dispersed microdetention are encouraged and often can be more cost-effective in handling runoff. Often these concepts do not “fit” into traditional stormwater management, zoning and subdivision regulations. It is intended for this pre-application meeting to serve as a forum to discuss the potential design and code variances and gain preliminary staff approval.
- e. **Meeting Notes:** Meeting notes will be kept by staff of Boone County so that all discussions and decisions will be documented. All meeting attendees will sign these meeting notes.

2.6 Preliminary Plat/Plan Review

After the Pre-Application Meeting, the developer or their engineer should obtain a copy of the Preliminary Plat Checklist (in Appendix B) to begin preparation of acceptable stormwater plan, calculations and plat layout. This information is available from the Planning and Building Department or the Boone County Public Works website. Preliminary plat/plans are not required for Site Plans that do not involve subdivision or zoning issues.



All requirements listed in the preliminary plat/plan checklist and comments from the Pre-Application Meeting must be addressed prior to requesting a hearing before the Planning and Zoning Commission. After the Preliminary Plat/Plan and the Preliminary Stormwater Management Plan have been approved, the developer must submit final public improvement plans including all stormwater related plans and associated calculations and documentation. Plans must be completed in accordance with this manual following the checklists and formats provided.

2.7 Variance Requests

Whenever possible, variances from requirements should be submitted with the preliminary plat/plan. This may include those variances necessary to provide better stormwater management such as smaller street widths, reduced sidewalks, removal of curb and gutters, reduction in parking spaces, etc.

If the variance is from a regulatory (code) requirement, submit the variance request letter with information as outlined in the Subdivision Regulations to the Planning and Building Department. If the variance is from a design standard or methodology, the Engineer should provide the supporting documentation to justify the requested deviation in a letter to the Director of Planning.

2.8 Preliminary Stormwater Management Plan Review

Provide a conceptual layout of the stormwater management facilities and BMPs. The stream reach should be identified with any proposed channel modifications, including the placement and type of outfall (primary, tributary, edge of buffer). Include existing stormwater system layout, including culverts, drain pipes, stormdrains inlets and water courses. The facilities and BMPs identified should have adequate surface area to convey, capture and treat the stormwater runoff as described in chapter 6. Also include drainage area information, preliminary runoff calculations, maintenance access routes and proposed easement locations. Identify the proposed placement of common land orland for special uses or features including: stated intent for ownership or dedication, responsible party for supervision and maintenance and a preliminary BMP landscaping plan.

Limited Stream Assessment: If the proposed project will be entering the stream or buffer area, a limited stream assessment is required. Additional details can be found in Chapter 5. The following information will be needed for the the review:

- Predeveloped conditions and flow rates
- Photographs
- Stream analysis and inventory
- Longitudinal profile
- Identification of bed and bank materials



Narrative: Please provide a description of the stormwater practices that will be implemented on the site. This description should include an indication of the pollutants of concern during construction and after build out (ie. high rates of fertilizer if building a golf course). The stormwater best management practices should treat those expected pollutants. The narrative should also include the following: non-structural practices such as scheduling or vegetative buffers; structural practices including detention or retention basins; and any individual lot practices such as site fingerprinting and rain gardens.

The narrative should also include a general discussion of the Erosion and Sediment Control plan identifying both temporary and permanent Best Management Practices that may be used for construction site runoff control.

2.9 Construction Stormwater Management Plan Review

Provide a proposed layout of the stormwater management facilities and BMPs. The stream reach should be identified with any proposed channel modifications, including the placement and type of outfall (primary, tributary, edge of buffer). Include existing stormwater system layout, including culverts, drain pipes, stormdrains inlets and water courses. Include existing stormwater system layout including culverts, drain pipes, stormdrains, inlets and watercourses. Demonstrate the facilities and BMPs identified have adequate surface area to convey, capture and treat the stormwater runoff as described in chapter 6. Include drainage area information, hydrologic and hydraulic runoff calculations, maintenance access routes and proposed easement locations. Include stormwater facilities and/or BMP maintenance agreement and plans. Provide citations to supporting references for proposed BMPs.

Limited Stream Assessment: If the proposed project will be entering the stream or buffer area, a limited stream assessment is required. Additional details can be found in Chapter 5. The following information will be needed for the the review:

- Predeveloped conditions and flow rates
- Photographs
- Stream analysis and inventory
- Longitudinal profile
- Identification of bed and bank materials

Narrative: Please provide a description of the stormwater practices that will be implemented on the site. This description should include an indication of the pollutants of concern during construction and after build out (ie. high rates of fertilizer if building a golf course). The stormwater best management practices should treat those expected pollutants. The narrative should also include the following: non-structural practices such as scheduling or vegetative buffers; structural practices including detention or retention basins; and any individual lot practices such as site fingerprinting and rain gardens.



The narrative should also include a general discussion of the Erosion and Sediment Control plan identifying both temporary and permanent Best Management Practices that may be used for construction site runoff control.

2.10 Construction Plan Review

Typically, final construction plans are submitted after the Planning and Zoning and County Commission approves the preliminary plat/plan. Final plans for grading and infrastructure construction must be submitted to the County for review by Boone County Public Works prior to construction. Please provide five (5) copies of the construction plans. The following plans need to be included as applicable: roadway, stormwater management, grading, erosion and sediment control.

1. General Plan Requirements:

When preparing submittals for County review, please follow these guidelines.

a. Plan Sheets

Each set shall have a title sheet, a general layout sheet, plan and profile sheets as applicable, cross section sheets as applicable and details (standard and special)

b. Signature Block

The title sheet for each set of plans shall contain a Standard Approval Signature block similar to the one shown below.

Approved For Construction	
_____	_____
Manager of Boone County Design and Construction	Date

c. Registered Professional Seals

The registered professional (Engineer, Surveyor, Geologist, etc) should seal all plans, reports and calculations per state statute.

d. Scales

Plans shall be drawn at a scale appropriate to clearly present the design and of not more than one (1) inch equals one hundred (100) feet. When necessary to provide adequate information on a general layout sheet, a smaller scale may be used. Bar Scales shall be shown on each sheet.



e. Calculation Summary

The Engineer shall submit a summary of all calculations and investigation analysis: hydraulic, hydrologic, erosion and sediment control, structural, geotechnical and others as necessary to adequately and fully explain the designs being submitted. The calculation summary shall indicate the methods used to perform the calculations and determine the final results. The Director may require additional supporting documentation when the results cannot be verified using the methods indicated in the summary.

f. Electronic Archive

Upon approval, an electronic copy of the final signed and sealed plans will be retained by the County in Adobe Acrobat Reader format (.pdf).

2.11 Modifications to Construction Plans

A field modification of any plan requires the owner, developer or contractor to provide Boone County Public Works with written documentation of the change. These changes may not alter the overall direction of stormwater discharge and must not significantly alter associated calculations for sizing and location of facilities and BMPs.

Major changes will require a resubmittal of affected plan sheets, calculations and reports. At the Director's discretion, a complete resubmittal may be required.

2.12 Final Plat Submittal

The Final Plat shall be submitted to the Planning and Building Department along with all construction plans for the public infrastructure. Boone County Public Works will review the Final Plat for consistency with the approved construction plans. The Final Plat must be recorded before the land-disturbance permit can be closed.



CHAPTER 3 HYDROLOGY AND HYDRAULICS

3.1 Introduction

This chapter sets forth the hydrologic parameters to be used in computations to determine volumes and peak rates of stormwater runoff as well as the hydraulic calculations for sizing stormwater conveyance systems. When analyzing an area for design purposes, urbanization of the full watershed should be considered. Zoning maps, land use plans, and master plans should be used as aids in establishing the anticipated surface character of the ultimate development. The selection of design runoff coefficients and/or percent impervious cover factors are explained in the following discussions.

3.2 Computation Methods for Runoff

Runoff rates for each element of the proposed storm drainage system should be calculated using the criteria of this section for land use runoff factors, rainfall, and system time. Any nationally accepted computer modeling programs using NRCS methodologies are acceptable.

1. Rational Method

The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 100 acres. All modeling requiring a hydrograph should be done using NRCS methodology. The Rational Method is defined as follows:

$$Q = KCiA \quad \text{where:}$$

Q = Peak rate of runoff to system in cfs

K = Dimensionless coefficient to account for antecedent precipitation (shown in Table 3.1 at the end of this chapter), except the product of $C \cdot K$ shall not exceed 1.0.

C = Runoff coefficient as determined in accordance with Table 3.2 at the end of chapter 3.

i = Rainfall intensity in inches per hour as determined in accordance with Figure 3.1 at the end of chapter 3.

The “C” value can be calculated from any type of land use and known percent impervious surface from the following equation:

$$C = 0.3 + 0.6 * I, \text{ where:}$$

I = percent impervious divided by 100



2. Time of Concentration (T_c)

Time of concentration is the longest time required for a rain drop to travel from the watershed divide to the watershed outlet. T_c is a fundamental watershed parameter used to compute the peak discharge for a watershed. The equation uses inputs for the longest watercourse length in the watershed (L), the average slope of that watercourse (S), and a coefficient representing the type of groundcover (C). Usually L and S can be obtained from topographic maps. The coefficient is determined from photographs of the watershed or field reconnaissance in addition to general accepted values for certain types of land use.

This calculation uses the FAA equation. The ASCE (American Society of Civil Engineers) recommends its use. (see figure 3.2)

$$T_c = \frac{1.8 (1.1-C) L^{0.5}}{S^{0.33}}$$

Where:

C = dimensionless runoff coefficient

L = distance traveled (in feet) from the furthest point in the watershed

S = watershed slope (in percent)

3. NRCS Unit Hydrograph Method

NRCS methodologies must be used for areas 100 acres or larger, and for detention basin routing. Areas less than 100 acres may use these methodologies as well. The NRCS unit hydrograph method includes the use of the NRCS unit hydrograph, the Type II rainfall distribution, 24-hour storm duration and NRCS TR-55 or WinTR55 methodologies for calculating time of concentration and runoff coefficients with the following exception: overland sheet flow length in the time of concentration calculation is limited to 100 feet (as established in the most current version of TR-55).

a. Rainfall Depths:

The rainfall depths for Boone County Missouri are provided in Table 3.3 at the end of chapter 3.

b. Runoff Coefficients:

Runoff coefficients for various land use and zoning classifications by soil group may be found in Table 3.4 at the end of chapter 3. This information is also available in TR-55 and WinTR-55, a free program available on the National Resource Conservation Service's website.

For areas not listed in Table 3.4, a composite runoff coefficient based on the actual percentages of pervious and impervious surfaces should be used.



All Curve Numbers for disturbed soils or soils to be distributed shall be one letter greater than the Curve Number in the undisturbed condition. For example, if an area with Type C soils will be graded and seeded with grass, the composite curve number for the post-construction runoff calculations will need to be as if it is in Type D soils (CN = 84 vs. 79).

c. Rainfall Mass

The NRCS Type 2, twenty-four hour rainfall distribution should be used for computations that employ the use of rainfall mass. That rainfall distribution is reproduced in Table 3.5 at the end of this chapter, but is usually included in most hydrologic computer software and may not need to be input into the program. Other methods of computing rainfall mass (Huff Distribution) are acceptable and up to the design engineer.

4. Unit Hydrographs

The NRCS Dimensionless Unit Hydrograph (either curvilinear or triangular) should be the basis for computation of runoff hydrographs.

5. Time of Concentration and Lag Time

Time of Concentration (T_c) for NRCS methods shall be calculated using the method described in TR-55, except that the maximum overland flow length shall be 100 feet.

Lag Time: (T_L) is the calculated time between the maximum rainfall intensity of a storm and the point of maximum discharge on the outlet hydrograph. Lag Time is used instead of time of concentration for unit hydrograph models. It shall be calculated as $3/5^{\text{th}}$ the time of concentration (T_c). The NRCS software, TR-55 and WinTR-55 calculate and apply lag time automatically. In other software the lag time may need to be calculated from T_c as indicated above and input into the program.

6. Hydrograph Routing

Routing of hydrographs through storage elements or reservoirs shall be by modified-Puls level pool routing. Routing through channels shall be by the Muskingum-Cunge method.

7. Calibration and Model Verification

Engineers recognize that significant uncertainty is associated with design discharge estimates and should provide estimates that are reasonably conservative and protective of the public interest. All design discharge estimates should be calibrated to the extent possible using reliable gauge data, high water marks, or historical accounts. Model results should be evaluated to verify that they are reasonably conservative as compared to observed data and standard practice. Model calibration should not be used to justify discharge estimates that are lower than those provided by the baseline unit hydrograph method, unless unusual site specific factors justify. In



these situations the hydrologic impact of such factors must be thoroughly examined and documented.

3.3 Methods for Stormwater Management

This section addresses runoff from projects after the construction phase is complete. Post-construction BMPs must treat runoff from the newly constructed or redeveloped site including runoff from roads, parking lots, yards, rooftops, and other land uses associated with development.

1. Water Quality Volume (WQv)

The stormwater that initially runs off an area may have a higher concentration of pollution than the water that runs off later, after the rainfall has 'cleansed' the newly disturbed or impervious surfaces of the catchment. This high pollutant loaded water is sometimes called the "first flush"

The existence of this first flush of pollutants provides an opportunity for controlling stormwater pollution from a broad range of land uses. First flush collection systems are employed to capture and reduce the water velocity, then isolate the polluted runoff from the cleaner water at the tail end of the storm.

Boone County has set the volume of water for the first flush as the storm event that produces less than or equal to 90% of the volume of all 24-hour storms on an annual basis. The Water Quality Storm rainfall for Boone County is 1.3 inches. The Water Quality Volume is the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is based on the Water Quality Storm and volumetric runoff coefficient and site area.

- a. Structural and non-structural practices shall be designed to capture and treat the Water Quality Volume. Two methods can be used to calculate the WQv for a proposed development—the Standard Method and the Small-Storm Hydrology Method.

1. Short-Cut Method

$WQv = P * Rv$ where:

WQv = Water Quality volume (in watershed inches)

P = Rainfall depth generated by the 90% storm event in inches (water quality storm)

Rv = volumetric runoff coefficient = $0.05 + 0.009(I)$

Where:

I = Percent of site with impervious cover

2. **The Small Storm Hydrology Method** (Claytor and Schueler 1996) is based on the volumetric runoff coefficient (Rv), which



accounts for specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method may be used for all drainage areas. R_v 's used to compute the volume of runoff are identified in Table 3.6 at the end of chapter 3. The Small Storm Hydrology Method is:

$$WQ_v = P * \text{Weighted } R_v$$

Where:

WQ_v = Water Quality volume (in watershed inches)

Weighted $R_v = \sum (R_{v1} * A_{c1}) + (R_{v2} * A_{c2}) + \dots (R_{vi} * A_{ci}) / \text{Total Acreage}$

P = Rainfall generated by 90% storm even in inches (water quality storm)

R_{vi} = Volumetric runoff coefficient for impervious cover type i

A_{ci} = Acreage of impervious cover type i

Total Acreage = Total acreage of the drainage area

If a portion of the site has disconnected impervious surfaces, reduction factors are applied to R_v . The reduction factors (from Table 3.7) are multiplied by the computed R_v for connected impervious areas to obtain the corrected value.

In order to use the reduction factors for disconnected impervious surfaces, as general guidance, the impervious area above the pervious surface area should be less than one-half of the pervious surface and the flowpath through the pervious area should be at least twice the impervious surface flowpath.

The Small Storm Hydrology method has the advantage of evaluating the precise elements of a particular site and should be utilized for most design applications to estimate accurate runoff volumes. The method requires somewhat more effort to identify the specific land surface area ratios and additional effort is needed to assess the disconnections of impervious areas. The method rewards site designs which utilize disconnections of impervious surfaces by lowering the computed R_v and the required WQ_v .

To convert WQ_v from watershed inches to volume in cubic feet:

$$WQ_v \text{ (in cubic feet)} = [WQ_v \text{ (in watershed inches)} / 12] * A$$

Where:

A = Watershed area (in square feet)

- b. To size a conveyance BMP correctly, calculate the peak discharge for the Water Quality Storm. Use the following procedure for estimating the peak discharge for the Water Quality Storm (Claytor and Schueler 1996):



1. **Calculate a Curve Number (CN)**

based on the previously calculated WQv:

$$CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25 QP)^{1/2}]$$

Where:

P = Water Quality Storm rainfall (inches)

Q = Runoff volume (inches) equal to WQv

2. **Determine Time of Concentration (Tc):**

$$T_c = (L^{0.8}[(1000/CN)-9]^{0.7})/(1140 * Y^{0.5})$$

Where:

Tc = Time of concentration (hours)

L = Flow length (feet)

CN = Runoff Curve Number

Y = Average watershed slope (percent)

Use a minimum of 0.1 hours for Tc.

3. **Determine Initial Abstraction (Ia)**

Use Table 3.8 at the end of this chapter, or TR-55.

4. **Compute Ia/P** and use Figure 3.3 at the end of this chapter, or Exhibit 4-II in TR-55 to determine the unit peak discharge (qu) for the appropriate Tc.

If Ia/P is outside of the limiting values of Figure 3.3, the limiting value should be used.

Convert this value from cfs/sm/in to cfs/ac/in, multiplying by (1 square mile/640 acre).

5. **Calculate the peak discharge:**

$Q_p = q_u * A * WQv$ where:

Qp = Peak discharge (cubic feet per second [cfs])

qu = Unit peak discharge (cubic feet per second/acre/inch of runoff)

A = Drainage area (acres)

WQv = Water Quality Volume (watershed inches)

For computing runoff volume and peak flow rate for storms larger than the Water Quality Storm, use the published Curve Number



from TR-55, and follow the prescribed procedures in TR-55 or other approved methods.

Water Quality Hydrology Example Calculations:

Example 1

3-acre office park, 70% Impervious, 30% Lawn and Landscaping

Flow length = 400 feet, average watershed slope = 4%

Calculate WQv in watershed inches:

Because this is a small site with one predominant type of cover, use the Short-Cut Method.

$$\begin{aligned} P &= 1.3 \text{ inches} \\ R_v &= 0.056 + 0.009(70\%) \\ &= 0.68 \\ WQ_v &= (1.3)(0.68) \\ &= 0.88 \text{ watershed inches} \end{aligned}$$

Convert WQv to cubic feet:

$$\begin{aligned} WQ_v &= \frac{0.88 \text{ in}}{12 \text{ in/ft}} * 3 \text{ acres} * 43560 \frac{\text{ft}^2}{\text{acre}} \\ &= 9583.2 \text{ ft}^3 \end{aligned}$$

Calculate peak discharge for the Water Quality Storm:

1. $CN = 1000/[10 + 5 * 1.3 + 10 * 0.88 - 10(0.88^2 + 1.25 * 0.88 * 1.3)^{0.5}] = 95.7$
2. $T_c = (400^{0.8}[(1000/95.7) - 9]^{0.7}) / (1140 * 4^{0.5}) = 0.07 \text{ hours}$

*Use 0.10 hours (minimum Tc)

3. From table 3.8 or Table 4-1 in TR-55
CN = 95, Ia = 0.105
CN = 96, Ia = 0.083

Using linear interpolation, CN = 95.7, Ia = 0.090

4. $I_a/P = 0.090/1.3 = 0.7$
From Figure 3.3 (or TR-55 Exhibit 4-II), the limiting value for $I_a/P = 0.10$.
Therefore, using $I_a/P = 0.10$,

$$\begin{aligned} q_u &= 1000 \text{ cfs/m}^2/\text{in} * \frac{1 \text{ m}^2}{640 \text{ acre}} \\ q_u &= 1.56 \text{ cfs/ac/in} \end{aligned}$$



$$5. Q_p = (1.56 \text{ cfs/ac/in})(3 \text{ ac})(0.88 \text{ in}) \\ = 4.12 \text{ cfs}$$

Example 2

12-acre commercial development and park, 2 acres flat rooftops, 2.3 acres impervious parking, 0.7 acres narrow streets, 7 acres green space (hydrologic soils group C)

Flow length = 1000 feet, average watershed slope = 2%

Calculate WQ_v in watershed inches:

Use the Small Storm Hydrology Method

$$P = 1.3 \text{ inches}$$

$$\text{Weighted } R_v = [(0.86)(2 \text{ ac}) + (0.98)(2.3 \text{ ac}) + (0.75)(0.7 \text{ ac}) + (0.22)(7 \text{ ac})]/12 \text{ ac} \\ = 0.50$$

$$\text{WQ}_v = (1.3)(0.50) \\ = 0.65 \text{ watershed inches}$$

Convert WQ_v to cubic feet:

$$\text{WQ}_v = \frac{0.65 \text{ in}}{12 \text{ in/ft}} * 12 \text{ acres} * 43560 \frac{\text{ft}^2}{\text{acre}} \\ = 28314 \text{ ft}^3$$

Calculate peak discharge for the Water Quality Storm:

$$1. \text{ CN} = 1000/[10 + 5 * 1.3 + 10 * 0.65 - 10(0.65^2 + 1.25 * 0.65 * 1.3)^{0.5}] \\ = 92.3$$

$$2. \text{ T}_c = (1000^{0.8}[(1000/92.3) - 9]^{0.7}) / (1140 * 2^{0.5}) \\ = 0.24 \text{ hours}$$

3. From table 3.8 (or Table 4-1 in TR-55)

$$\text{CN} = 92, \text{ I}_a = 0.174$$

$$\text{CN} = 93, \text{ I}_a = 0.151$$

Using linear interpolation, CN = 92.3, I_a = 0.167

$$4. \text{ I}_a/P = 1.3$$

From Figure 3.3 (or TR-55 Exhibit 4-II), the limiting value for I_a/P = 0.10. Therefore, using I_a/P = 0.10,

$$q_u = 750 \text{ cfs/m}^2/\text{in} * \frac{1 \text{ m}^2}{640 \text{ acre}}$$

$$q_u = 1.17 \text{ cfs/ac/in}$$

$$5. Q_p = (1.17 \text{ cfs/ac/in})(12 \text{ ac})(0.65 \text{ in})$$



= 9.13 cfs

2. Channel Protection Storage Volume (CP_v)

The channel protection volume is the volume of water that generates the bank-full condition. This is defined by the 1.5 to 2 year storm event. These frequent flows provide velocities that are strong enough to modify and govern the channel shape and condition. There are two allowable methods to provide channel protection on newly developed sites.

- a. **Two-year capture, One-year release:** To provide channel protection, detention should be modeled such that the inflow storm equals the post-developed 2-year 24-hour storm event (50% annual chance) storm and the outflow storm equals the pre-developed one-year, 24-hour storm event. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

A detention pond or underground vault is normally needed to meet the CP_v requirement. As a basis for determining Channel Protection Storage Volume, the following assumptions may be made:

- The model TR-55 (or approved equivalent) shall be used for determining peak discharge rates.
- The rainfall depth for the two-year (50% annual chance), 24-hour storm event is 3.5 inches. Use Type II rainfall distribution.
- The length of overland flow used in time of concentration (T_c) calculations is limited to no more than 100 feet for post project conditions.
- CP_v shall be addressed for the entire site. If a site consists of multiple drainage areas, CP_v may be distributed proportionately to each drainage area. Where additional detention/retention is provide in one portion of the site to achieve the overall site's CP_v storage, no one discharge point can release greater than the pre-developed 2-year (50% annual chance) peak discharge from the entire site.
- Extended detention storage provided for the CP_v does not fully meet the WQ_v requirement (that is CP_v and WQ_v should be treated separately).
- The stormwater storage needed for CP_v may be provided above the WQ_v storage in stormwater ponds and wetlands; thereby meeting all storage



criteria in a single facility with appropriate hydraulic control structures for each storage requirement.

- Infiltration is not recommended for CPv control because of large storage requirements. If proven effective, appropriate and desirable however, in some rare situations it may be permissible.

b. **Micro Detention:**

When space is tight, or in residential subdivisions, the design engineer can use multiple small detention basins, instead of one large basin to detain some or all of the stormwater runoff on the development site. Stormwater micro-management works by temporarily storing stormwater in many varied locations near where it falls as precipitation. The idea is to release the volume of stormwater runoff into the storm drain system gradually to reduce the peak flow. Numerous components may comprise a micro detention system, including: downspout disconnection; surface storage of stormwater (conventional detention/retention) with regulated outflow; or even sub-surface storage with regulated outflow achieved by a combination of catch basin flow restrictors. Rarely is the total volume of stormwater generated entirely infiltrated. Therefore, micro-detention is typically only one of a series of BMPs.

To encourage micro-detention and utilize stormwater BMPs to detain stormwater, the difference (increase) in the runoff volume that is predicted due to the development during the 2-year event will be stored and released at no more than 0.1 cfs/acre. The following procedures shall be used:

- Store the **extra volume** of water that is predicted to runoff due to development during the 2-year event.
- Use the TR-55 Method or those based on Rational Method coefficients to calculate the additional runoff volume.
- The storage volume can be spread among multiple small storage areas.
- The rate of release from these storage areas can be no more than 0.1 cfs/acre.
 - 0.1 cfs/acre is the runoff rate that occurs for a basin with CN of 78 and Tc of 15 minutes during a 24-hour water quality storm (1.3" of rainfall using SCS type II rainfall distribution).
- At least 75% of the site area must drain through one of these basins and the volume stored must account for added runoff from entire disturbed site.
- Drainage areas can go through any number of individual storage basins, but credit is only given once for any particular area. Areas in series



should produce better results, but this method does not attempt to account for the added benefit.

- Because this method does not address peak flow rates leaving the site, please verify that there are no flooding problems immediately downstream.
- Easements are required for detention areas that are used to meet this requirement.

Equations

1) $S_r = Q_{2\text{post}} - Q_{2\text{exist}}$ Where

S_r is the Required Storage (ft^3)

$Q_{2\text{post}}$ is the total runoff for the total disturbed area post project in a 2-year storm (ft^3)

$Q_{2\text{exist}}$ is the total runoff for the total disturbed area pre project in a 2-year storm (ft^3)

SCS Method

2) $Q_2 = A * ((P - I_a)^2 / ((P - I_a) + S)) * (43560 / 12)$

3) $I_a = 0.2 * S$

4) $S = (1000 / \text{CN}) - 10$

Where:

Q_2 is the total runoff volume (ft^3)

A is the total site disturbed area (acres)

CN is the NRCS curve number taken from tables in manual based on pre or post project conditions

P is the 2-year, 24 hour rainfall depth (inches)

I_a and S are variables in the NRCS method that are calculated directly from CN as shown in equations 3 and 4.

Rational Coefficient Method

5) $Q_2 = A * P * C * (43560 / 12)$

Where

Q_2 is the total runoff volume (ft^3)

A is the drainage area (acres)

P is the 2 year, 24 hour rainfall depth (inches)

C is the rational method coefficient taken from tables in the manual based on pre or post project conditions.

To make sure that an appropriate amount of storm water makes it to each of the detention areas, each detention area is only given credit for a proportional amount of drainage area as described by the following equations.

6) $AVR = A / S_r$



Where

AVR is the allowed area to volume ratio

A is the total site disturbed area (acres)

S_r is the Required Storage (ft^3)

$$7) A_{cui} = A_{ci} - A_{cuti}$$

Where

A_{cui} is the untreated contributing drainage area (see note) for storage area i.
(acres)

A_{ci} is the total contributing drainage area for storage area i. (acres)

A_{cuti} is the total upstream treated area for all upstream storage areas in a series.
(acres)

NOTE: It does not matter whether the contributing areas are from the project site or not. It is the total volume of water stored, that is important. However, for water quality (WQv) credits, it does matter which water you treat.

$$8) A_{ti} = \text{Minimum of } (A_{cui} \text{ OR } S_i * AVR)$$

Where

A_{ti} = the treated area for storage area i. (acres)

S_i is the total volume of storage in storage area i, below the depth at which the outflow rate equals the allowable outflow rate.

Criteria: The sum of all S_i must equal or exceed S_r AND the sum of all A_{ti} must equal or exceed 75% of the disturbed site area.

3.4 Hydraulic Calculations for Pipes, Culverts, and Open Channels

Gravity versus Pressure Flow for Enclosed Systems - Two design philosophies exist for sizing storm drains under the steady uniform flow assumption. The first is referred to as open channel, or gravity flow design, in which the water surface within the conduit remains open to atmospheric pressure. Pressure flow design, on the other hand, requires that the flow in the conduit be at a pressure greater than atmospheric. For a given flow rate, design based on open channel flow requires larger conduit sizes than those sized based on pressure flow. While it may be more expensive to construct storm drainage systems designed based on open channel flow, this design procedure provides a margin of safety by providing additional headroom in the conduit to accommodate an increase in flow above the design discharge. Under most ordinary conditions, it is recommended that storm drains be sized based on a gravity flow criteria at full flow or near full. However, pressure flow design is allowed. As hydraulic calculations are performed, frequent



verification of the existence of the desired flow condition should be made. Storm drainage systems can often alternate between pressure and open channel flow conditions from one section to another (U.S. Department of Transportation Federal Highway Administration, 1996).

1. Gravity Flow

For gravity flow conditions, Manning's formula shall be used as described below.

$$Q = \frac{1.486}{n} A \cdot R^{2/3} S^{1/2}$$

Where:

Q = Discharge (in cubic feet per second)

A = Cross sectional area of flow (in square feet)

n = Roughness Coefficient (see Table 3.9 at the end of this chapter)

R = Hydraulic radius $R = \frac{A}{P}$ (in feet)

S = Slope (in feet per foot)

P = Wetted perimeter (in feet)

2. Pressure Flow

In closed conduits flowing under pressure flow, the hydraulic grade line (HGL) will be above the crown of the pipe. In this case, the Bernoulli equation shall be used to calculate pipe capacity:

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_f + h_m$$

Where:

$\frac{p_1}{\gamma}$ = upstream system pressure head (feet)

$\frac{v_1^2}{2g}$ = upstream velocity head (feet)

z_1 = elevation of upstream system invert (feet)

$\frac{p_2}{\gamma}$ = downstream pressure head (feet)



$$\frac{v_2^2}{2g} = \text{downstream velocity head (feet)}$$

$$z_2 = \text{downstream invert elevation (feet)}$$

$$h_f = \text{system friction loss (feet)}$$

$$h_m = \text{system junction (so-called minor) losses (feet)}$$

Pipe friction losses, h_f , may be calculated using the friction slope method. This derivation of Manning's equation is from (FHWA, 1996).

$$h_f = S_f \cdot L = \frac{(Q \cdot n)^2}{(1.486A \cdot R^{2/3})^2} \cdot L$$

Where:

$$S_f = \text{friction slope, ft/ft}$$

Note: For normal flow, S_f = HGL slope. However, due to numerous inlets, junctions, changes in direction and slope etc., and due to the nature of rainfall, storm drainage systems are often in unsteady, gradually varied or rapidly varied flow regimes in which this is not true.

Junction (so-called minor) losses, h_m , shall be calculated by:

$$h_m = k \cdot \frac{v^2}{2g}$$

Where:

k = Coefficient as shown in Table 3.10 at the end of chapter 3

$$\frac{v^2}{2g} = \text{downstream velocity head (feet)}$$

A step-by-step procedure for manual calculation of the HGL using the energy loss method is presented in Section 7.5 of FHWA's Urban Drainage Design Manual (FHWA, 1996). For most drainage systems, computer methods such as HYDRA, StormCAD, CulvertMaster, SWMM, or IntelliSOLVE are the most efficient means of evaluating the HGL and designing the system elements.

3. Culverts



Culverts are classified as having either entrance or outlet control. Either the inlet opening (entrance control), or friction loss within the culvert and/or backwater from the downstream system (outlet control) will control the discharge capacity. Culverts must be analyzed for both types of flow. Whichever produces the highest headwater depth must be used.

a. Entrance Control

Entrance control occurs when the culvert is hydraulically short (when the culvert is not flowing full) and steep. The flow regime at the entrance is critical as the water falls over the brink (water passes from subcritical to supercritical flow). If the tailwater covers the culvert completely (i.e., a submerged exit), the culvert will be full at that point, even though the inlet control forces the culvert to be only partially full at the inlet. The transition from partially full to full occurs in a hydraulic jump, the location of which depends on the flow resistance and water levels. If the flow resistance is very high, or if the headwater and tailwater levels are high enough, the jump will occur close to or at the entrance. Design variables for culverts operating under entrance control shall be determined from Figures 3.4 through 3.10.

b. Outlet Control

If the flow in a culvert is full for its entire length, then the flow is said to be under outlet control. The discharge will be a function of the differences in tailwater and headwater levels, as well as the flow resistance along the barrel length. Design variables for culverts operating under outlet control shall be determined from Figures 3.11 through 3.17.

Alternatively, refer to the Federal Highway Administration website for these charts and more (www.fhwa.dot.gov/bridge/hec05.pdf). Download applicable design manuals, reports, and FHWA hydraulics engineering software such as Bridge Waterways Analysis Model (WSPRO), FHWA Culvert Analysis, and HDS 5 Hydraulic Design of Highway Culverts from:

www.fhwa.dot.gov/bridge/hydssoft.htm. HEC-RAS may also be used for culvert analysis.

4. Open Channels/Bridges

Proper evaluation of the velocity, depth, and width of flow requires analyses of the structures and conditions that impact the flow. Boundary flow conditions upstream and downstream from the open channel system must be established. The standard-step backwater method, using the energy equation, can be used to determine the depth, velocity, and width of flow. Major stream obstructions, changes in slope, changes in cross-section, and other flow controls can cause significant energy loss. In these cases, the energy equation does not apply and the momentum equation must be used to determine the depth, velocity, and width of flow.



Hydraulic calculations for open channels may also be made by the U.S. Army Corps of Engineer's 'HEC-RAS River Analysis System' computer programs. The HEC-RAS system is intended for calculating water surface profiles for steady and unsteady, gradually varied flow. The system can handle a full network of channels, a dendritic system, or a single river reach. HEC-RAS is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. (Available from <http://www.hec.usace.army.mil/software/hec-ras/>)

3.5 Hydraulic Analysis of Systems by Computer Models

The following list provides commonly used computer programs for analyzing specific hydraulic systems. This is not an exhaustive list and alternates may be used that are widely accepted throughout the engineering industry.

Enclosed pipe systems in gravity flow

- SWMM Transport (EPA)
- HYDRA (FHWA)
- StormCad (Haested Methods)
- DR3M (USGS)
- InteliSOLVE
- Hydraflow (Autodesk)

Enclosed pipe systems in pressure flow

- SWMM EXTRAN (EPA)
- MOUSE (DHI)
- HYDRA (FHWA)
- StormCad (Haested Methods)
- InteliSOLVE
- Hydraflow (Autodesk)

Culverts

- HY8 (FHWA)
- WSPRO (USGS)
- CulvertMaster (Haested Methods)
- HEC-RAS (USACE)
- Hydraflow (Autodesk)

Open Channels and Culverts/Bridges

- HEC-RAS (USACE)
- WSPRO (USGS)
- HYCHL (FHWA)
- SWMM Transport and EXTRAN (EPA)
- DR3M (USGS)
- Hydraflow (Autodesk)



CHAPTER 3 HYDROLOGY AND HYDRAULICS

Section 2 Tables and Graphs

TABLE 3.1 ANTICEDENT PRECIPITATION COEFFICIENTS

Design Storm	K
10 year (10% annual chance) and more frequent	1.0
25 year (4% annual chance)	1.1
50 year (2% annual chance)	1.2
100 year (1% annual chance)	1.25

TABLE 3.2 RUNOFF COEFFICIENTS BY LAND USE/ZONING

LAND USE/ZONING	AVERAGE PERCENT IMPERVIOUS	AVERAGE PERCENT PERVIOUS	RATIONAL METHOD "C"
1. Business			
Downtown Area	95	5	0.87
Neighborhood Areas	85	15	0.81
2. Residential			
Single-Family Areas	35	65	0.51
Multifamily Areas	60	40	0.66
Churches & Schools	75	25	0.75



3. Industrial			
Light Areas	60	40	0.66
Heavy Areas	80	20	0.78
Parks, Cemeteries	10	90	0.36
Railroad Yard Areas	25	75	0.45
4. Undeveloped Areas	0	100	0.3
5. All Surfaces			
Impervious: asphalt Concrete, roofs, etc.	100	0	0.9
Turf	0	100	0.3
Wet detention basins	100	0	0.9



TABLE 3.3 24-HOUR RAINFALL DEPTHS FOR BOONE COUNTY, MISSOURI

Recurrence Interval	% chance in given year	Depth (in)/24 hour
1-year storm event	100	3
2-year storm event	50	3.5
5-year storm event	20	4.5
10-year storm event	10	5.2
25-year storm event	4	5.9
50-year storm event	2	6.6
100-year storm event	1	7.3



TABLE 3.4
NRCS RUNOFF COEFFICIENTS

Runoff curve numbers for urban areas ¹					
Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area ²	A	B	C	D
<i>Fully developed urban areas (vegetation established)</i>					
Open space (lawns, parks, golf courses, cemeteries etc.) ³					
Poor condition (grass cover < 50%)		68	79	86	89
Fair (grass cover 50%-75%)		49	69	79	84
Good (grass cover > 75%)		30	61	74	80
Impervious areas					
Pavement, roof, etc.		98	98	98	98
Streets and roads					
Paved w/ curb (excluding right-of-way)		98	98	98	98
Paved w/ roadside swale (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
Urban Districts					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by avg. lot size					
1/8 acre or less	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	79	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82
<i>Developing urban areas</i>					
Newly graded areas					
(pervious areas only, no vegetation) ⁴		77	86	91	94

From USDA, TR-55, Urban Hydrology for Small Watersheds, 1986

¹Average runoff condition, and Ia=0.2S.



²The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious are considered equivalent to open space in good hydrologic condition. CN's for other combination of conditions may be computed as shown in TR-55, 1986—Figure 2-3 or 2-4.

³CN's shown are equivalent to those of pasture. Composite DN's may be computed for other combinations of open space cover type.

⁴Composite CN's to use for the design of temporary measures during grading and construction should be computed as shown in TR-55, 1986—Figure 2-3 or 2-4.

Runoff curve numbers for undeveloped areas ¹					
Cover description	Hydrologic Condition	Curve numbers for hydrologic soil group			
		A	B	C	D
Pasture, grassland or range-continuous grazing ²	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow-continuous grass, protected from grazing, generally mowed for hay.		30	58	71	78
Brush-brush/weed/grass mix with brush the major element ³	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 ⁴	48	65	73
Woods-grass combination (orchard or tree farm) ⁵	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods ⁶	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 ⁴	55	70	77
Farmsteads-buildings, lanes, driveways, and surrounding lots		59	74	82	86

¹Average runoff condition, and $I_a=0.2S$.

²Poor: <50% ground cover or heavily grazed with no mulch.

Fair: 50 to 75% ground cover and not heavily grazed.

Good: >75% ground cover and not heavily grazed.

³Poor: <50% ground cover

Fair: 50 to 75% ground cover

Good: >75% ground cover

⁴Actual curve number is less than 30; use CN = 30 for runoff computations.



⁵CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

⁶Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.

Fair: Woods are grazed but not burned, and some forest litter covers the soil.

Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

TABLE 3.5: NRCS (aka SCS) TYPE II RAINFALL DISTRIBUTION

TIME IN HOURS	ACCUMULATED RAINFALL IN PERCENT OF 24-HOUR RAINFALL
0.0	0.0
2.0	2.20
4.0	4.80
6.0	8.00
8.0	12.00
9.0	14.70
9.5	16.30
10.0	18.10
10.5	20.40
11.0	23.50
11.5	28.30
11.75	38.70
12.0	66.30
12.5	73.50
13.0	77.20
13.5	79.90
14.0	82.00
16.0	88.00
20.0	95.20
24.0	100.00



TABLE 3.6 VOLUMETRIC COEFFICIENTS FOR URBAN RUNOFF FOR DIRECTLY CONNECTED IMPERVIOUS AREAS (CLAYTOR AND SCHUELER 1996)

Rainfall (inches)	Flat roofs and large unpaved parking lots	Pitched roofs and large impervious areas (large parking lots)	Small impervious areas and narrow streets	Silty soils HSG-B	Clayey soils HSG-C and D
0.75	0.82	0.97	0.66	0.11	0.20
1.00	0.84	0.97	0.70	0.11	0.21
1.25	0.86	0.98	0.74	0.13	0.22
1.30	0.86	0.98	0.74	0.13	0.22
1.50	0.88	0.99	0.77	0.15	0.24

TABLE 3.7 REDUCTION FACTORS TO VOLUMETRIC RUNOFF COEFFICIENTS FOR DISCONNECTED IMPERVIOUS SURFACES (CLAYTOR AND SCHUELER 1996)

Rainfall (inches)	Strip commercial and shopping center	Medium-to-high-density residential with paved alleys	Medium-to-high-density residential without alleys	Low-density residential
0.75	0.99	0.27	0.21	0.20
1.00	0.99	0.38	0.22	0.21
1.25	0.99	0.48	0.22	0.22
1.30	0.99	0.50	0.22	0.22
1.50	0.99	0.59	0.24	0.24



TABLE 3.8
Initial Abstraction (Ia) VALUES FOR VARIOUS CURVE NUMBERS

Curve Number	Ia (in.)	Curve Number	Ia (in.)
61	1.279	78	0.564
62	1.226	79	0.532
63	1.175	80	0.500
64	1.125	81	0.469
65	1.077	82	0.439
66	1.030	83	0.410
67	0.985	84	0.381
68	0.941	85	0.353
69	0.899	86	0.326
70	0.857	87	0.299
71	0.817	88	0.273
72	0.778	89	0.247
73	0.740	90	0.222
74	0.703	91	0.198
75	0.667	92	0.174
76	0.632	93	0.151
77	0.597	94	0.128



Table 3.9
MANNING’S ROUGHNESS COEFFICIENT

Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe (RCPs).....	0.013
Reinforced Concrete Elliptical Pipe.....	0.013
Corrugated Metal Pipe (CMPs):	
2 $\frac{2}{3}$ x $\frac{1}{2}$ in. Annular or Helical Corrugations unpaved - plain	0.024
2 $\frac{2}{3}$ x $\frac{1}{2}$ in. Annular or Helical Corrugations paved invert	0.021
3x1 in. Annular or Helical Corrugations unpaved - plain	0.027
3x1 in. Annular or Helical Corrugations paved invert	0.023
6x2 in. Corrugations unpaved - plain.....	0.033
6x2 in. Corrugations paved invert.....	0.028
Vitrified Clay Pipe.....	0.013
Asbestos Cement Pipe	0.012
Open Channels (Lined)	
Gabions.....	0.025
Concrete	
Trowel Finish	0.013
Float Finish.....	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble masonry	0.025
Dry Rubble or Riprap	0.030
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.033
Grass (Sod).....	0.030
Riprap	0.035
Grouted Riprap	0.030
Open Channels (Unlined) Excavated or Dredged	
Earth, straight and uniform.....	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds & brush uncut.....	0.090
Natural Stream	
Clean stream, straight.....	0.030
Stream with pools, sluggish reaches, heavy underbrush.....	0.100
Flood Plains	
Grass, no brush.....	0.030
With some brush.....	0.090
Street Curbing.....	0.014



Table 3.10
HEAD LOSS (so-called minor loss) COEFFICIENT k

Condition $\left(Loss = k \frac{v^2}{2g} \right)$	k
Manhole, junction boxes and inlets with shaped inverts*:	
Thru flow.....	0.15
Junction.....	0.4
Contraction transition.....	0.1
Expansion transition.....	0.2
90 degree bend.....	0.4
45 degree and less bends.....	0.3
Culvert inlets:	
Pipe, Concrete	
Projecting from fill, socket end (grove end).....	0.2
Projecting from fill, sq. cut end.....	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove end).....	0.2
Square edge.....	0.5
Round (radius=1/12D).....	0.2
Mitered to conform to fill slope.....	0.7
Standard end section.....	0.5
Beveled edges, 33.7° or 45° bevels.....	0.2
Side or slope-tapered inlet.....	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall).....	0.9
Headwall or headwall and wingwalls square edge.....	0.5
Mitered to conform to fill slope, paved or unpaved slope.....	0.7
Standard end section.....	0.5
Beveled edges, 33.7° or 45° bevels.....	0.2
Side or slope-tapered inlet.....	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square edged on 3 edges.....	0.5
Rounded on 3 edges to radius of 1/12 barrel dim. or beveled edges on 3 sides.....	0.2
Wingwalls at 30° to 75° to barrel	
Square edged at crown.....	0.4
Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge.....	0.2
Wingwalls at 10° to 25° to barrel - square edged at crown.....	0.5
Wingwalls parallel (extension of sides) - square edged at crown.....	0.7
Side or slope-tapered inlet.....	0.2

***Note:** When 50 percent or more of the discharge enters the structure from the surface, “k” shall be 1.0.



**Figure 3.1: RAINFALL/INTENSITY/DURATION
FREQUENCY CURVES**

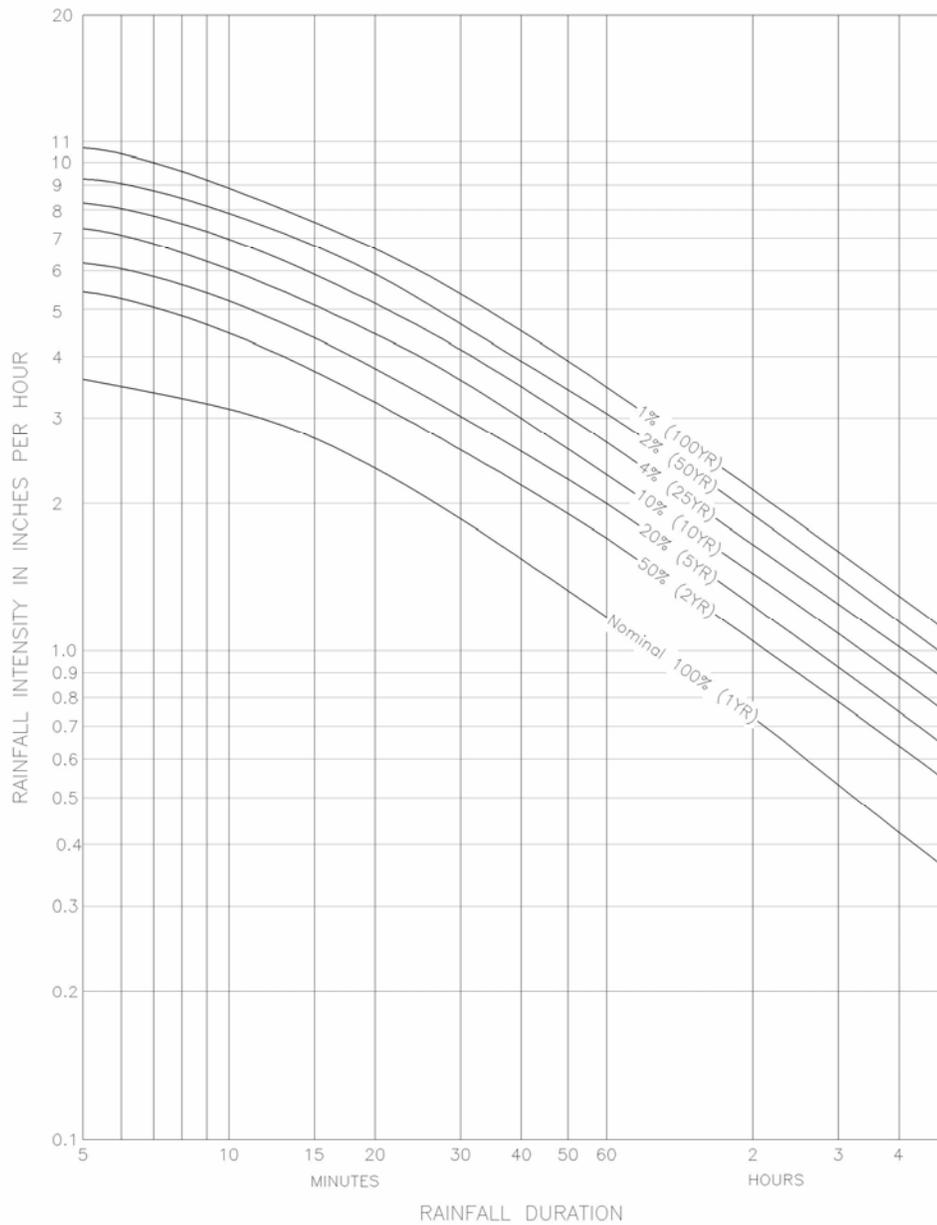




Figure 3.2
OVERLAND FLOW (INLET TIME) NOMOGRAPH

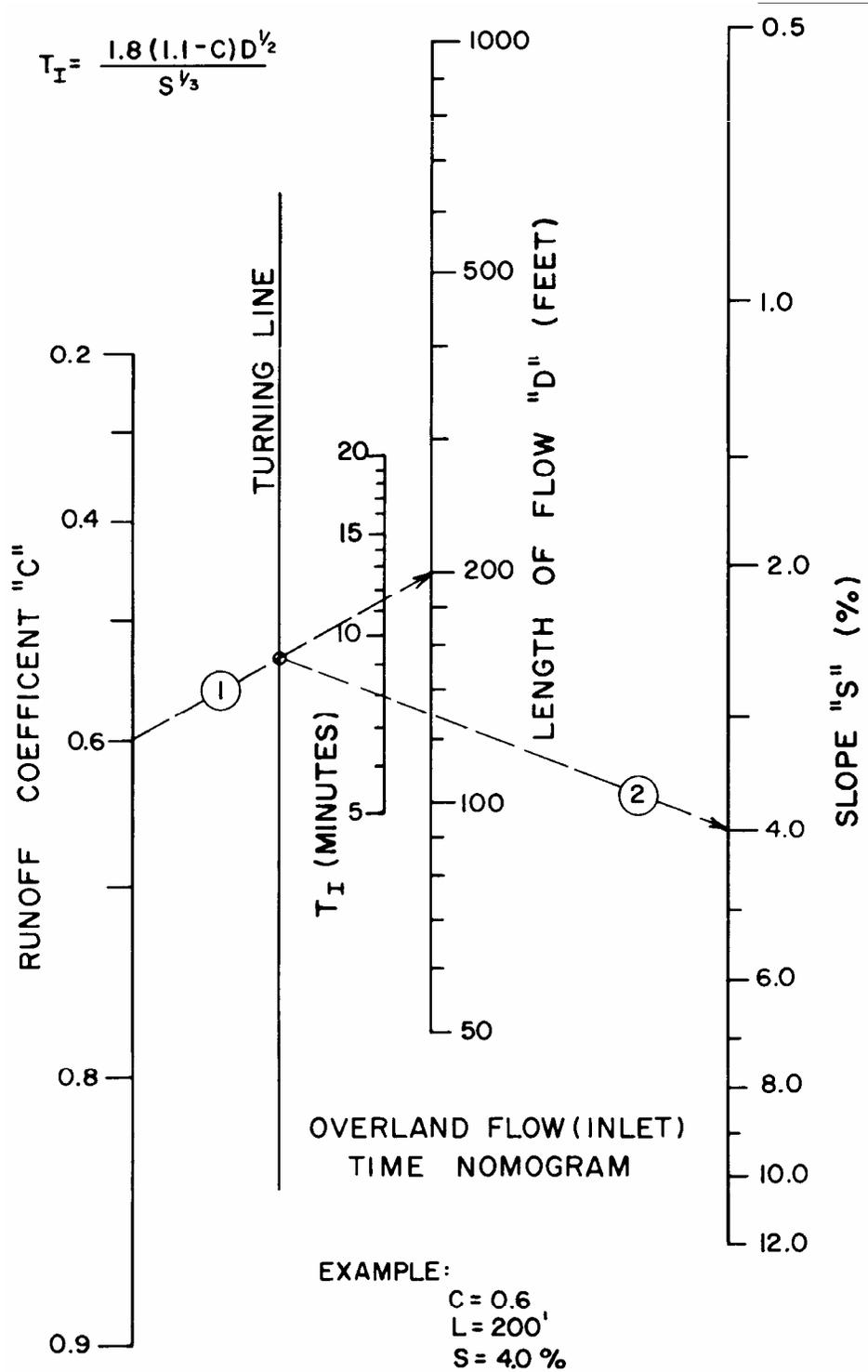




Figure 3.3
UNIT PEAK DISCHARGE IN CFS/SQUARE MILE/INCH OF RUNOFF

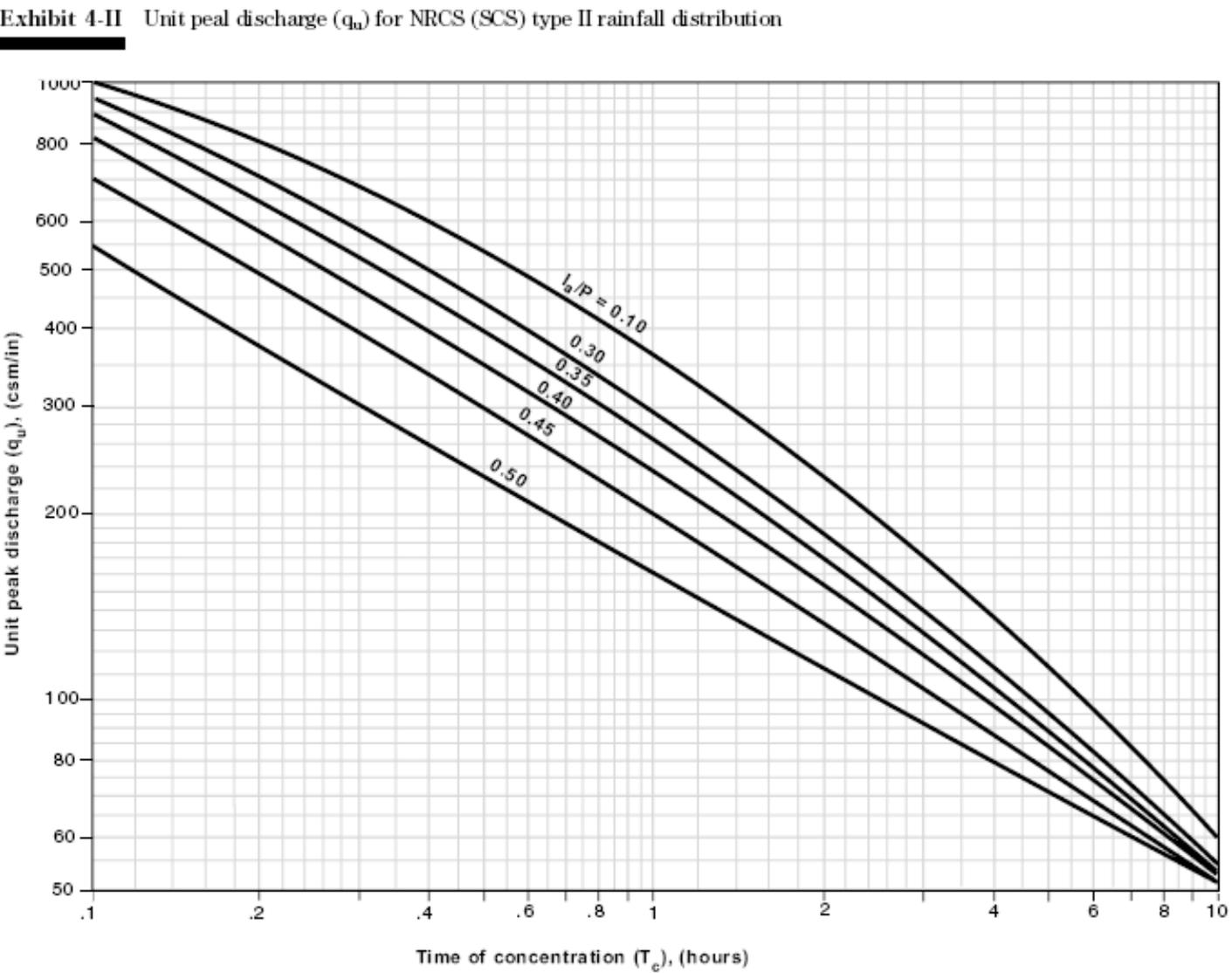




Figure 3.4

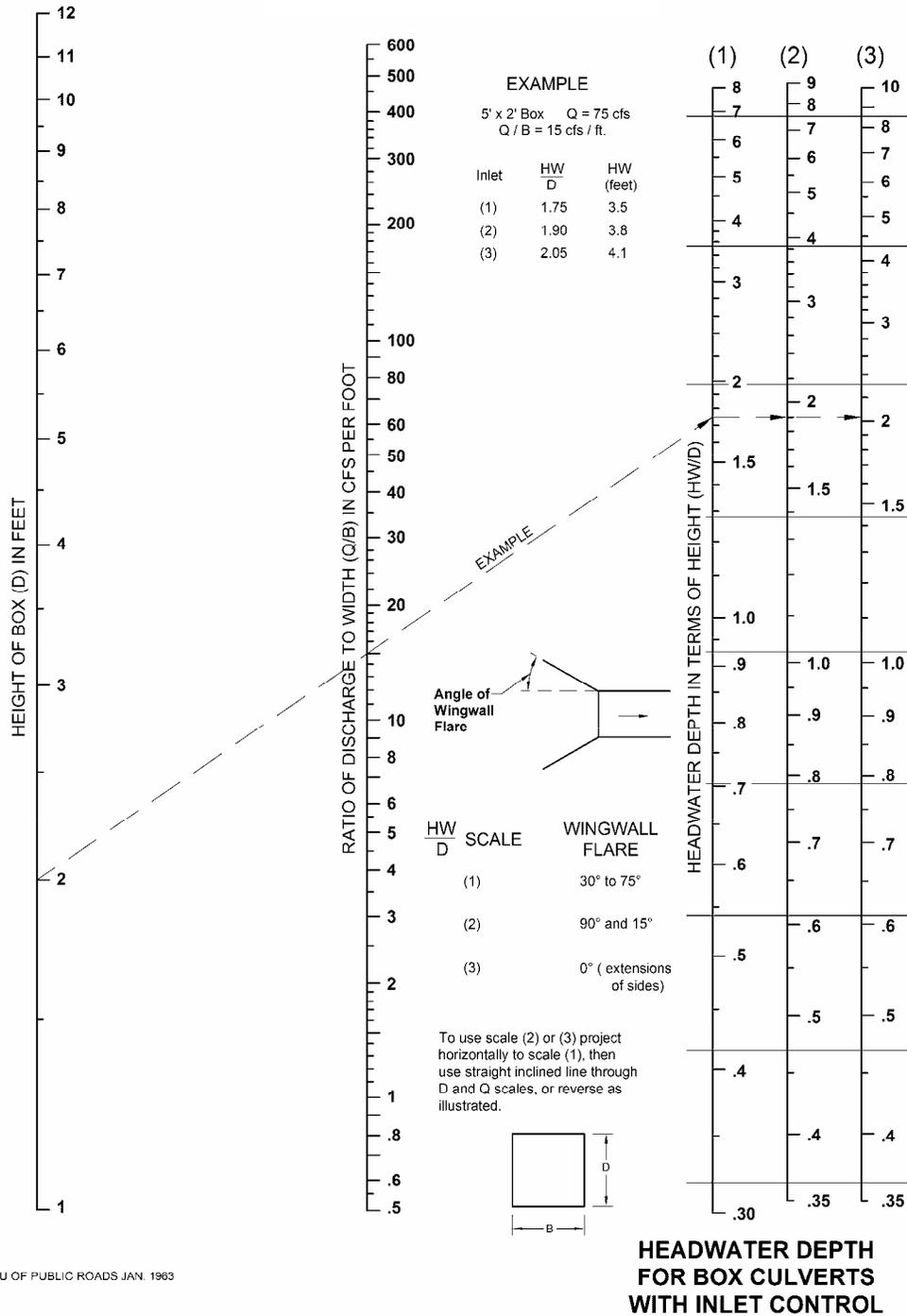
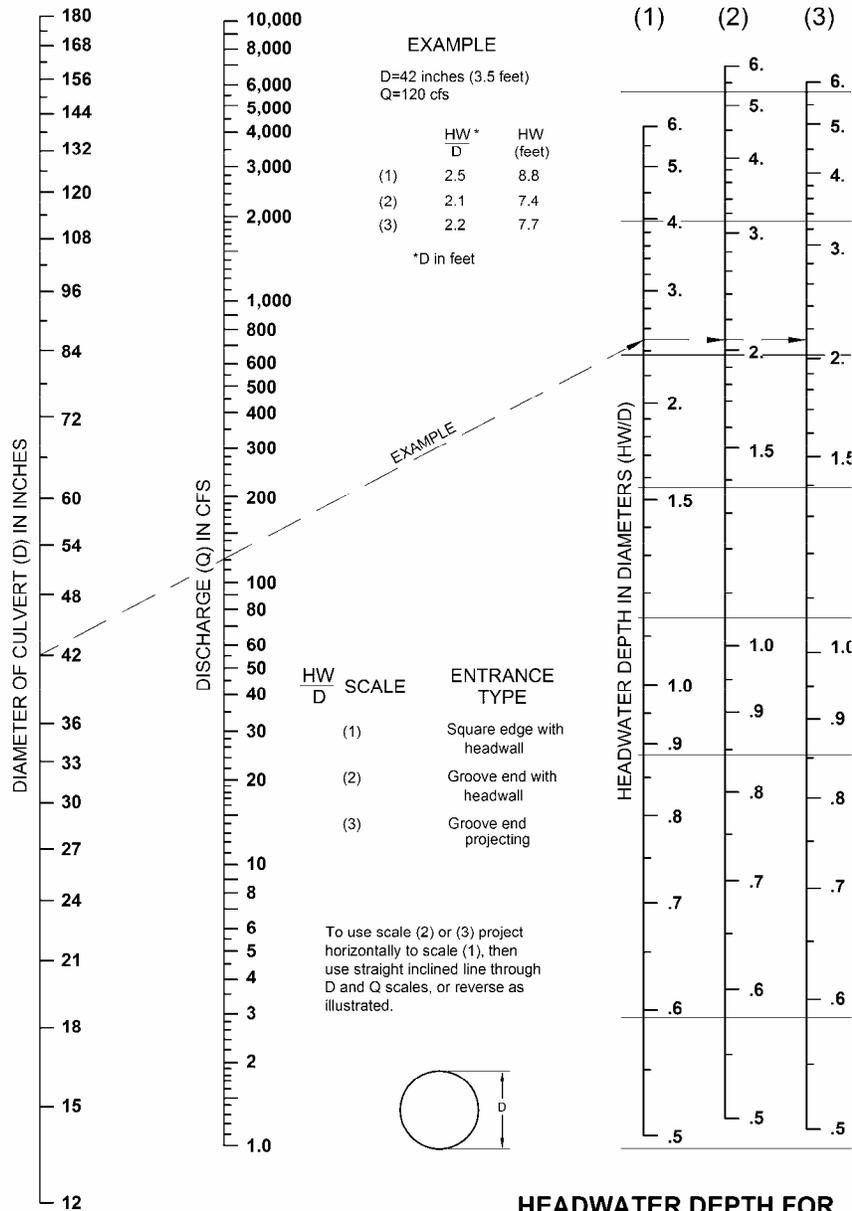




Figure 3.5

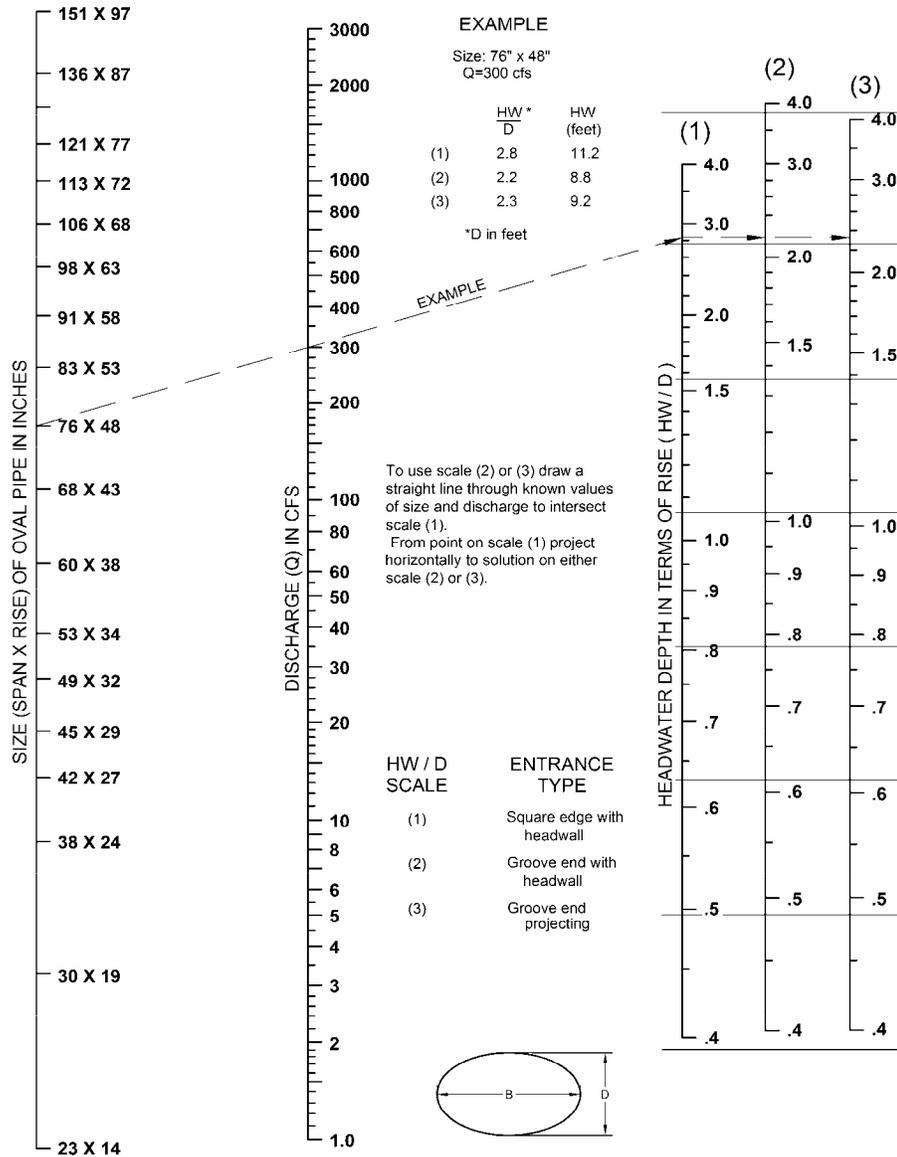


BUREAU OF PUBLIC ROADS JAN. 1963
HEADWATER SCALES 2 & 3 REVISED MAY 1964

**HEADWATER DEPTH FOR
CONCRETE PIPE CULVERTS
WITH INLET CONTROL**



Figure 3.6

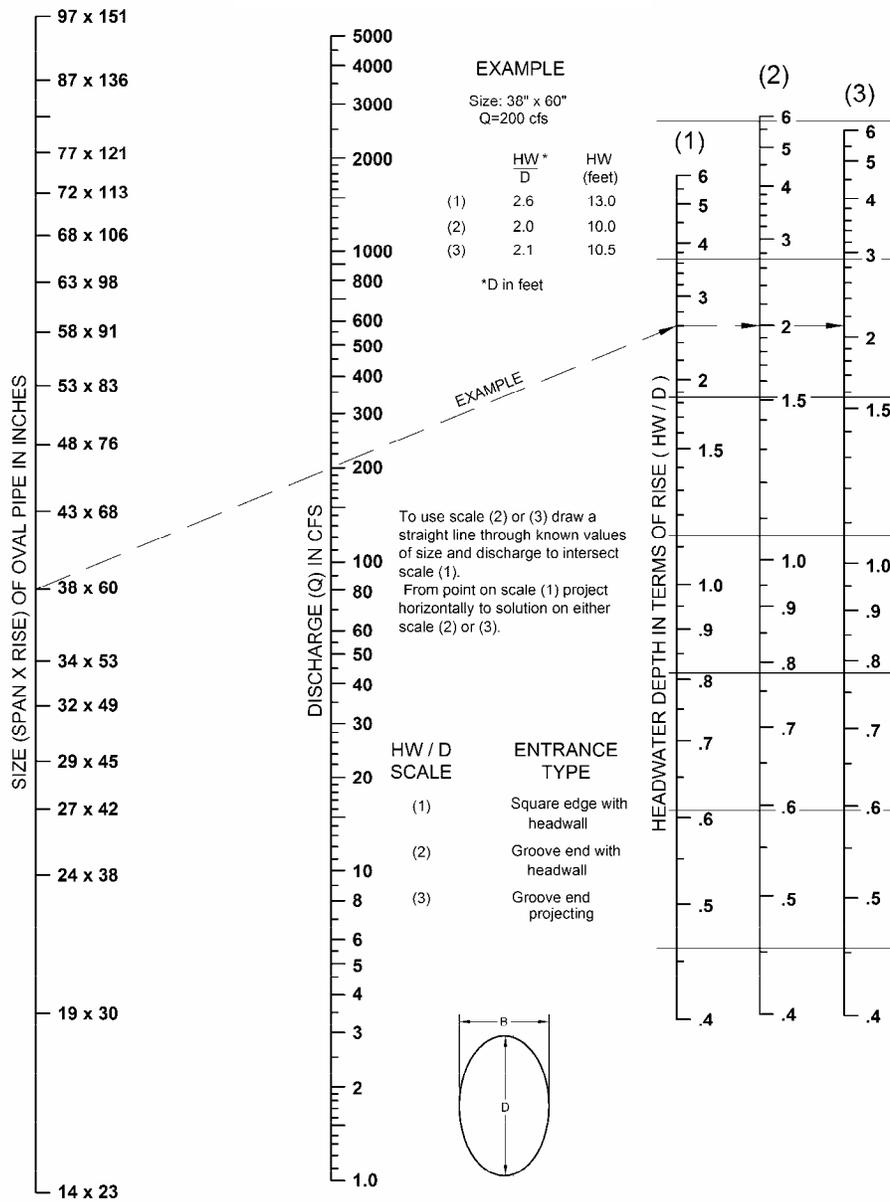


BUREAU OF PUBLIC ROADS, JAN. 1963

**HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL
WITH INLET CONTROL**



Figure 3.7



BUREAU OF PUBLIC ROADS JAN. 1963

**HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS VERTICAL
WITH INLET CONTROL**



Figure 3.8

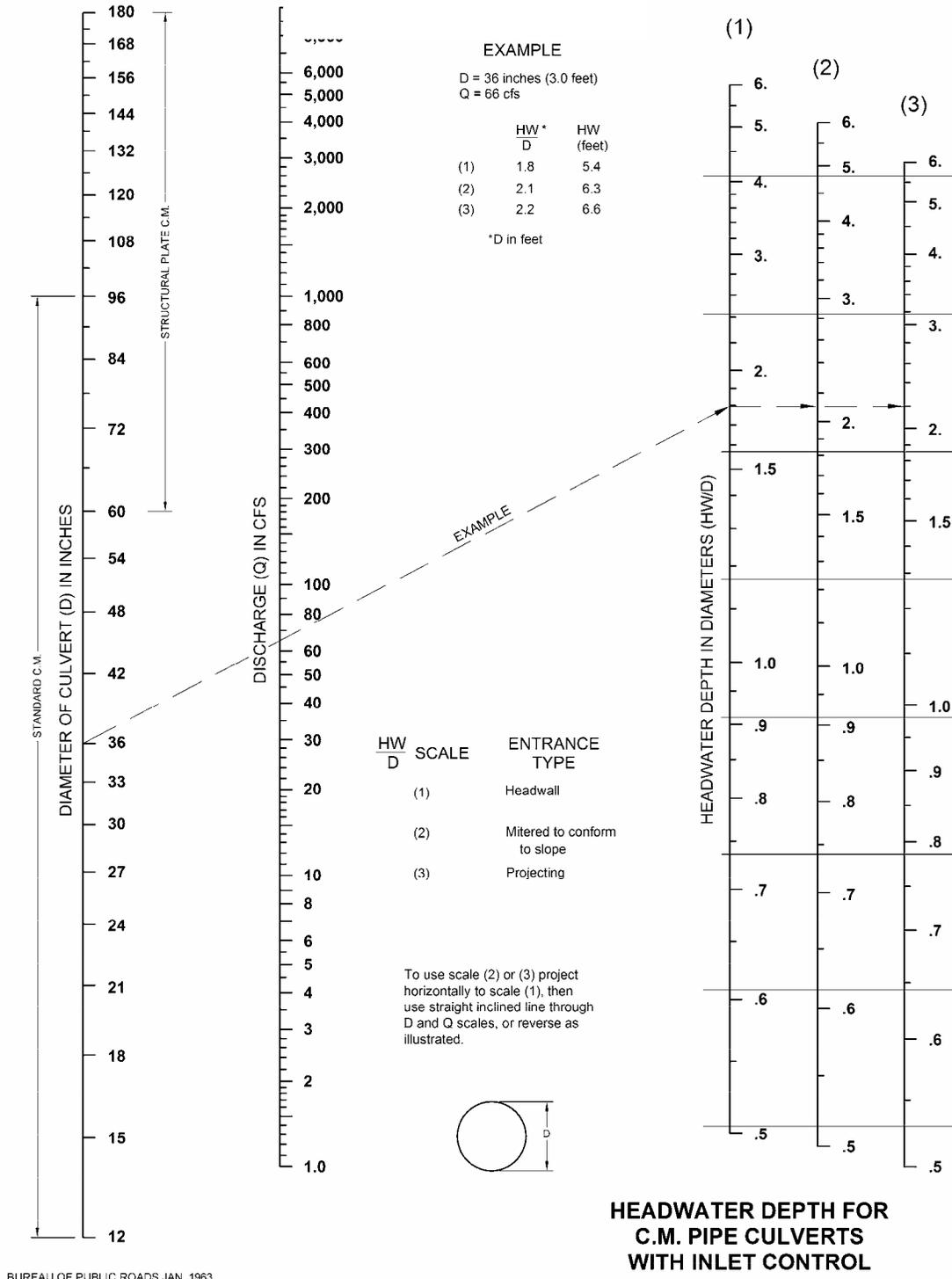




Figure 3.9

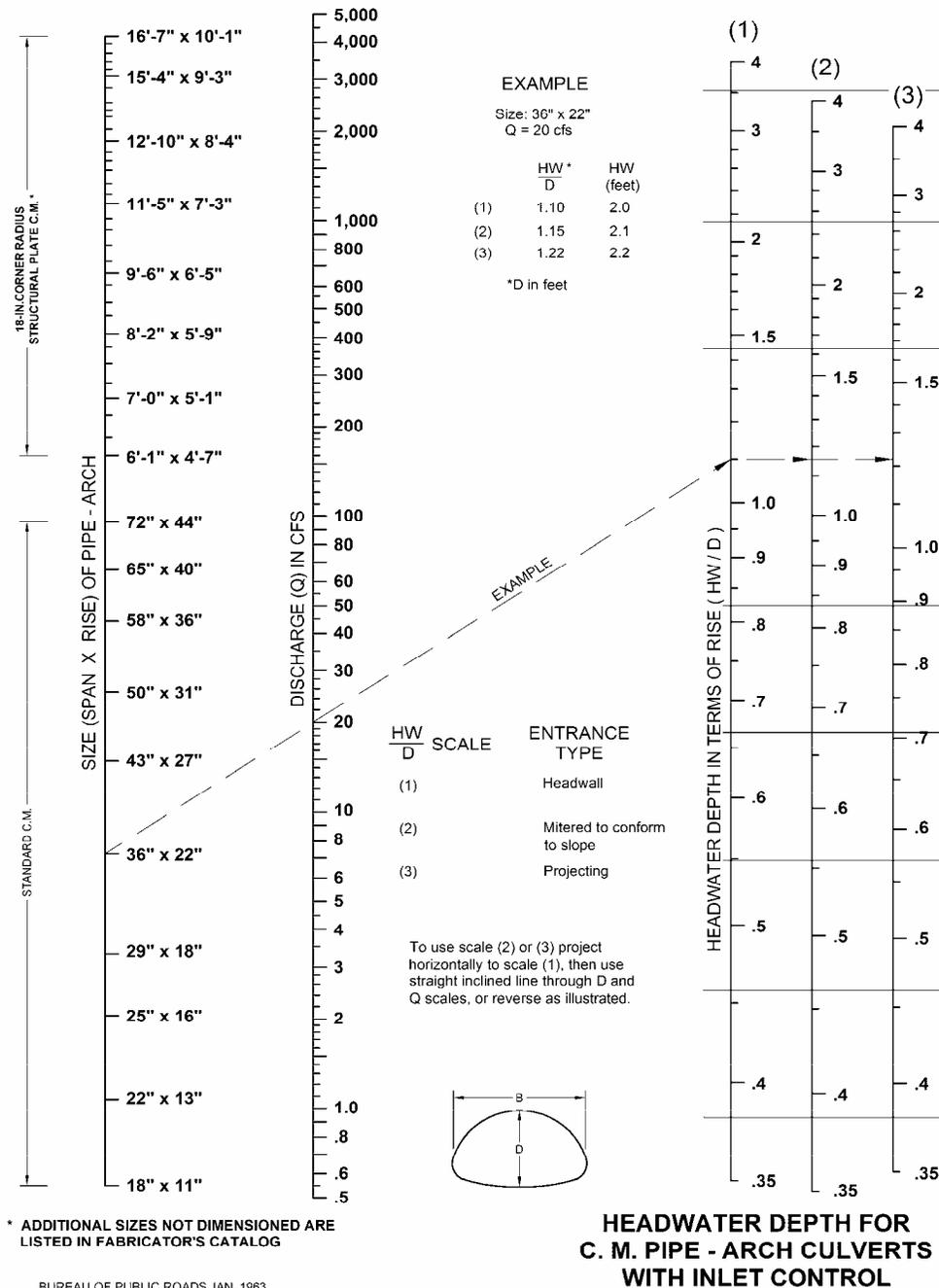




Figure 3.10

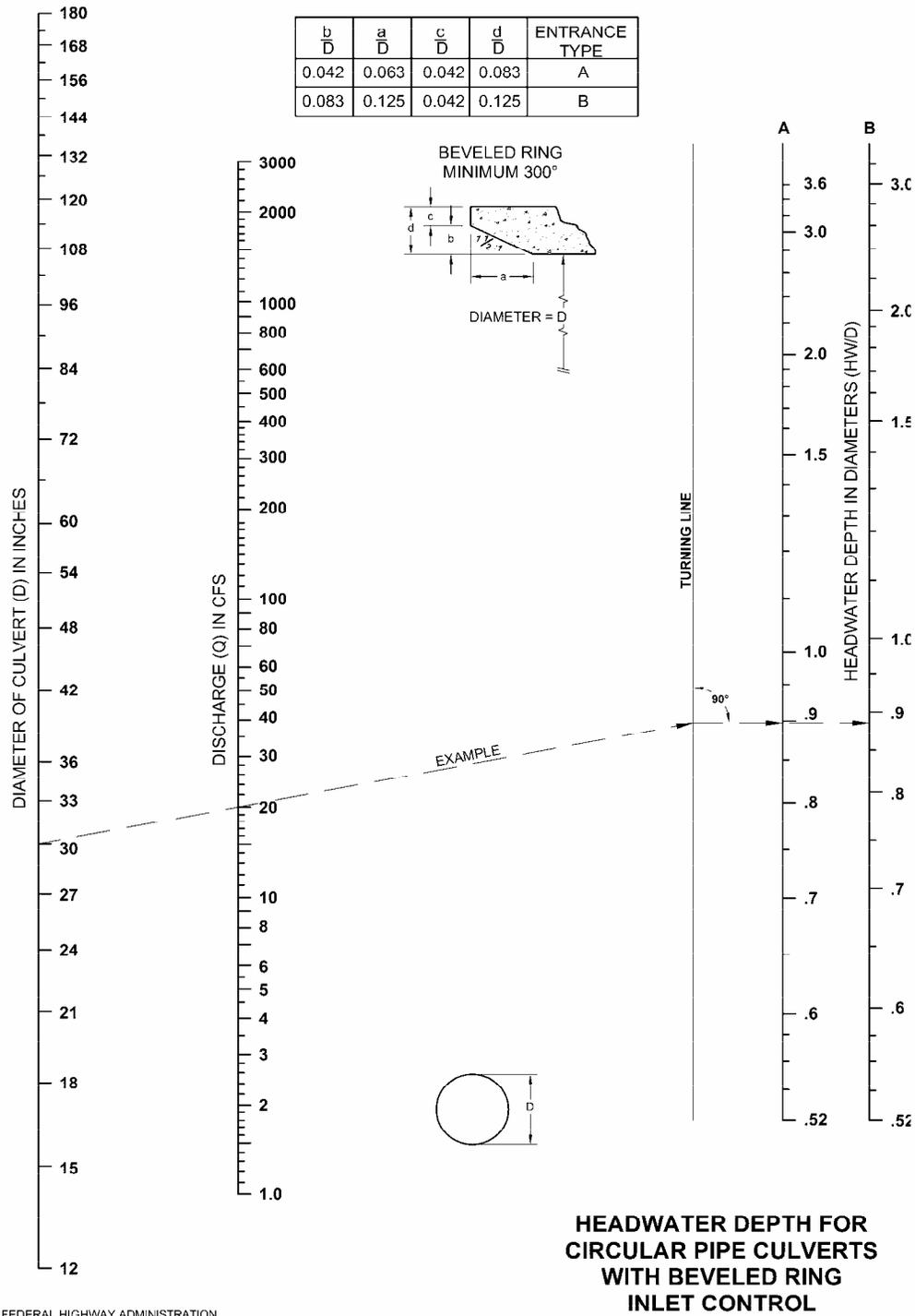




Figure 3.11

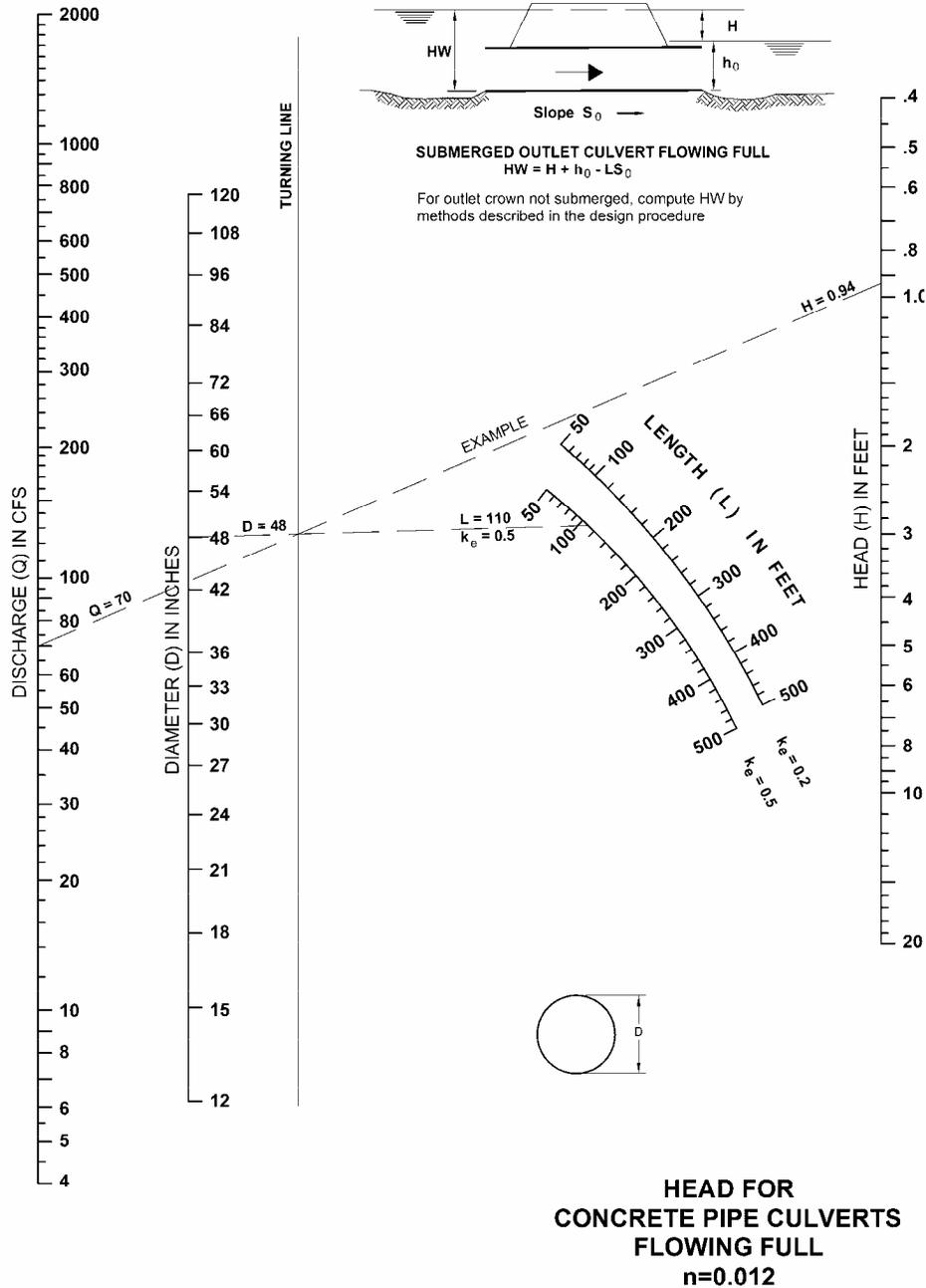
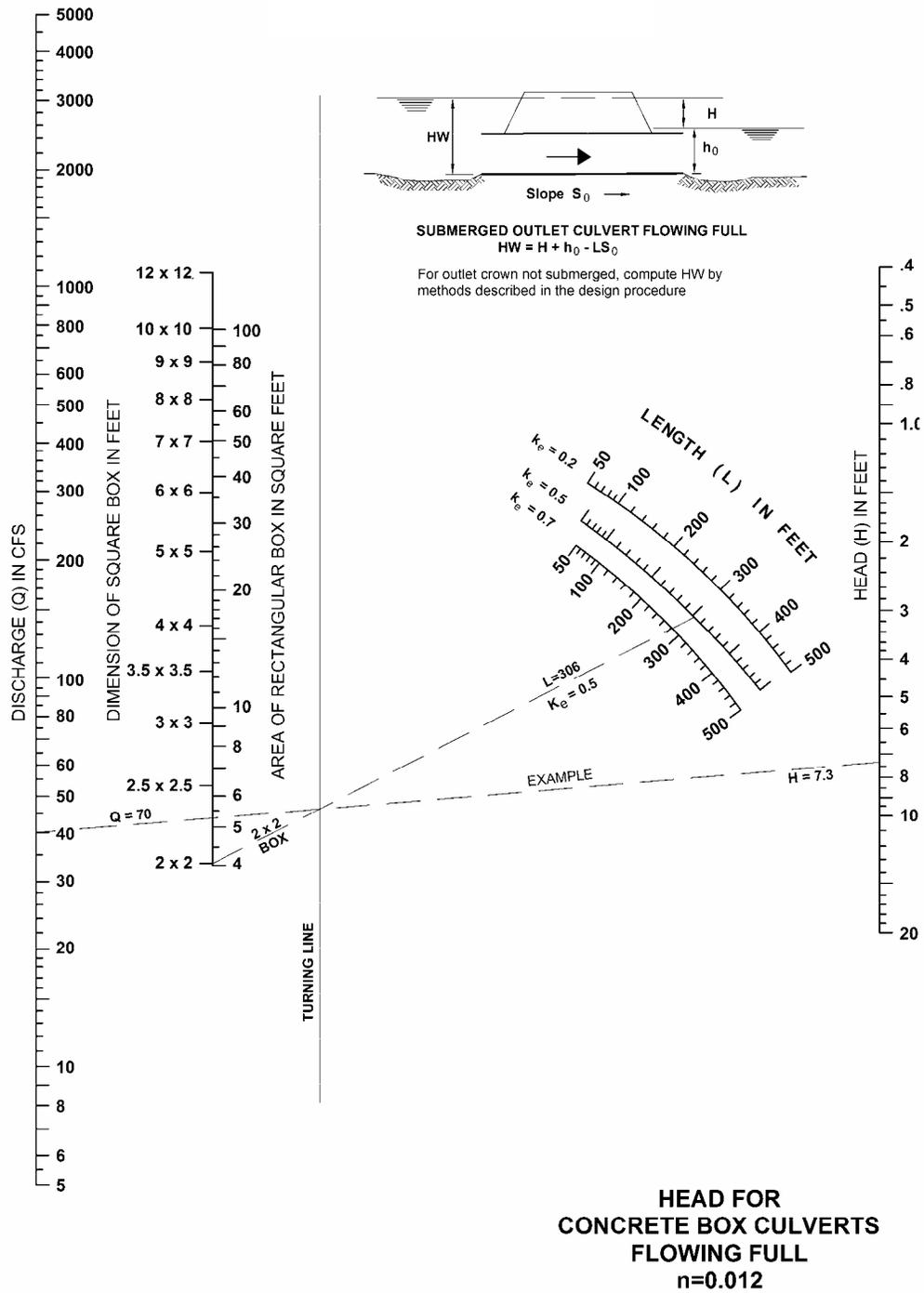




Figure 3.12



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Figure 3.13

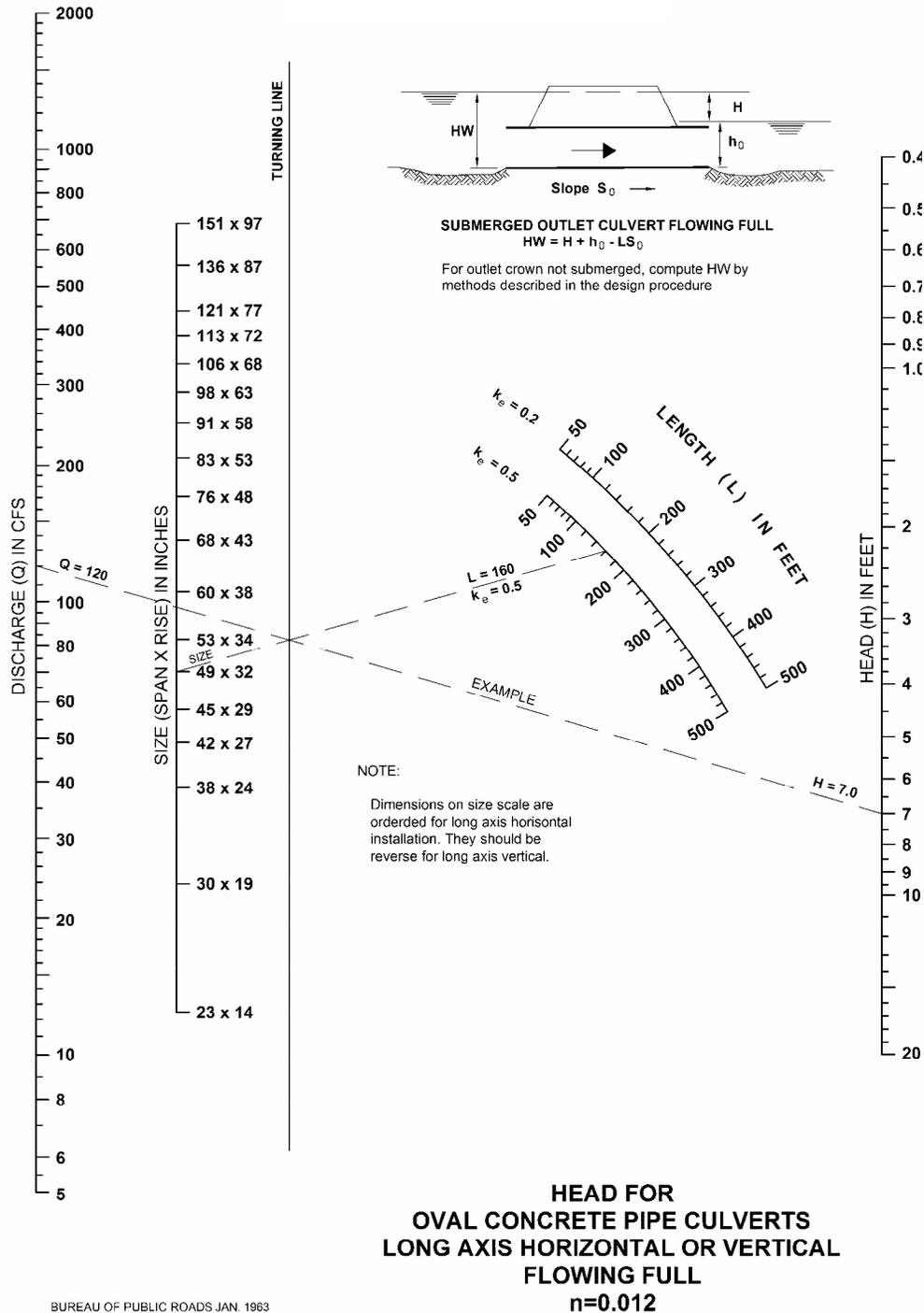
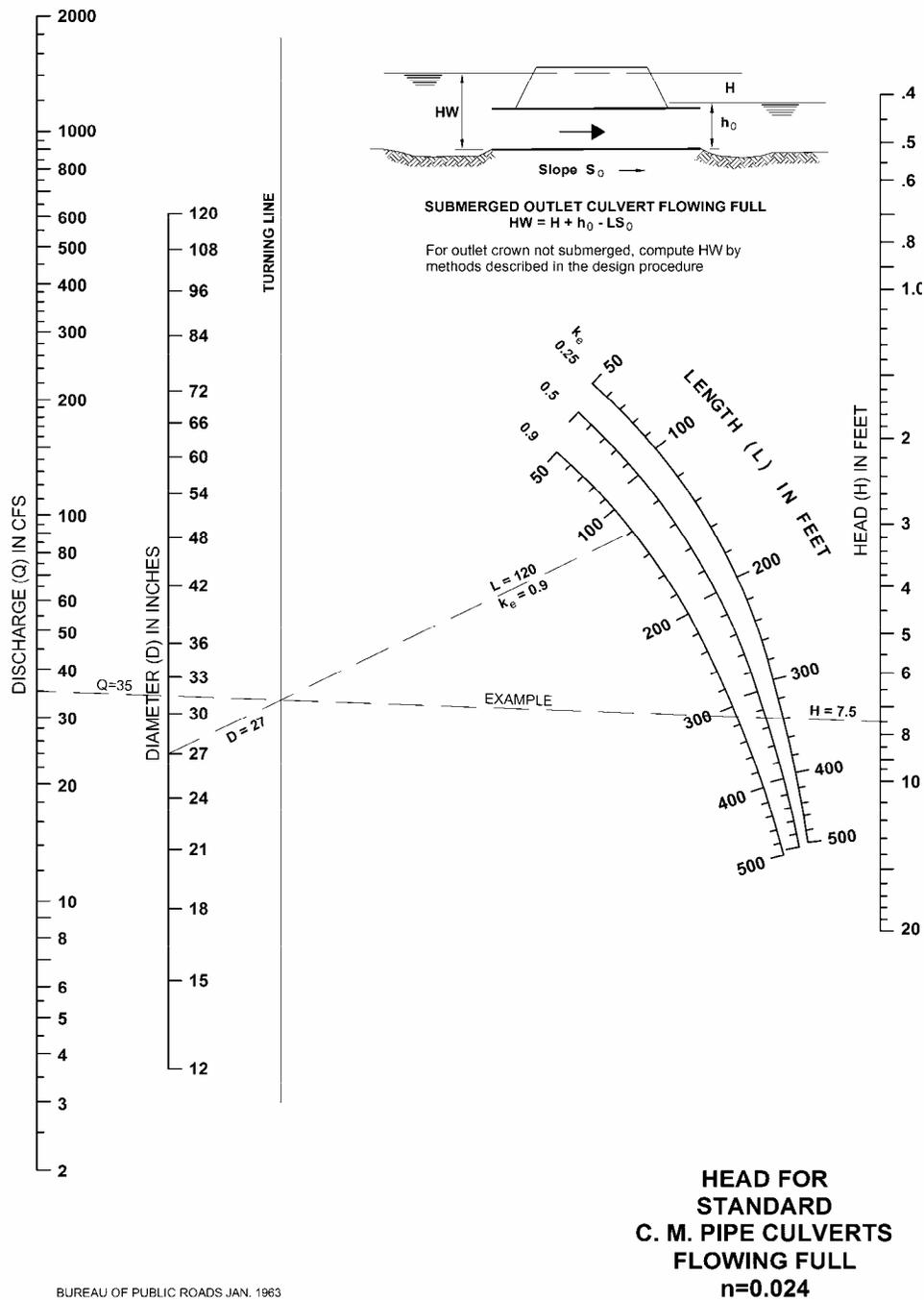




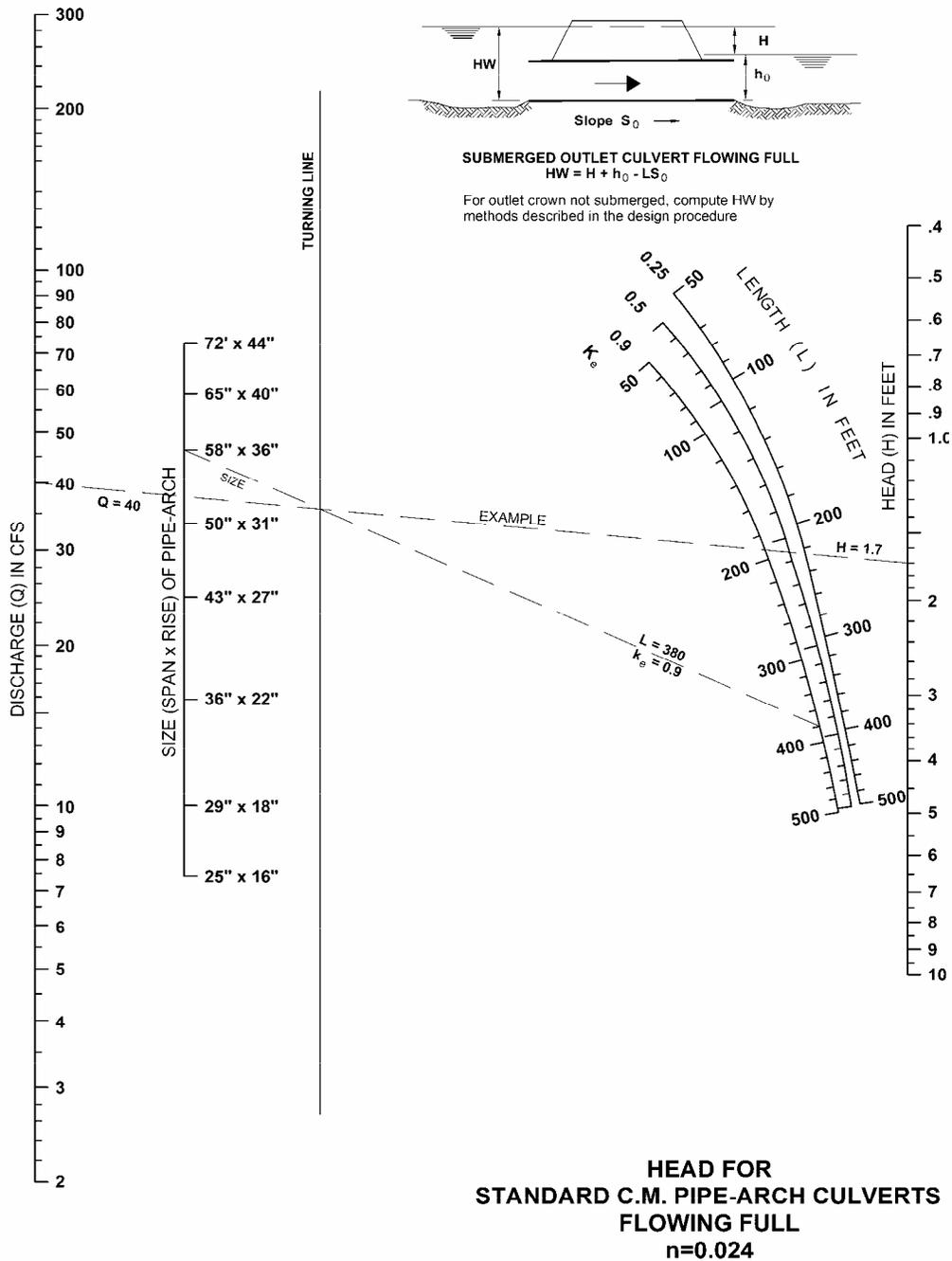
Figure 3.14



BUREAU OF PUBLIC ROADS JAN. 1963



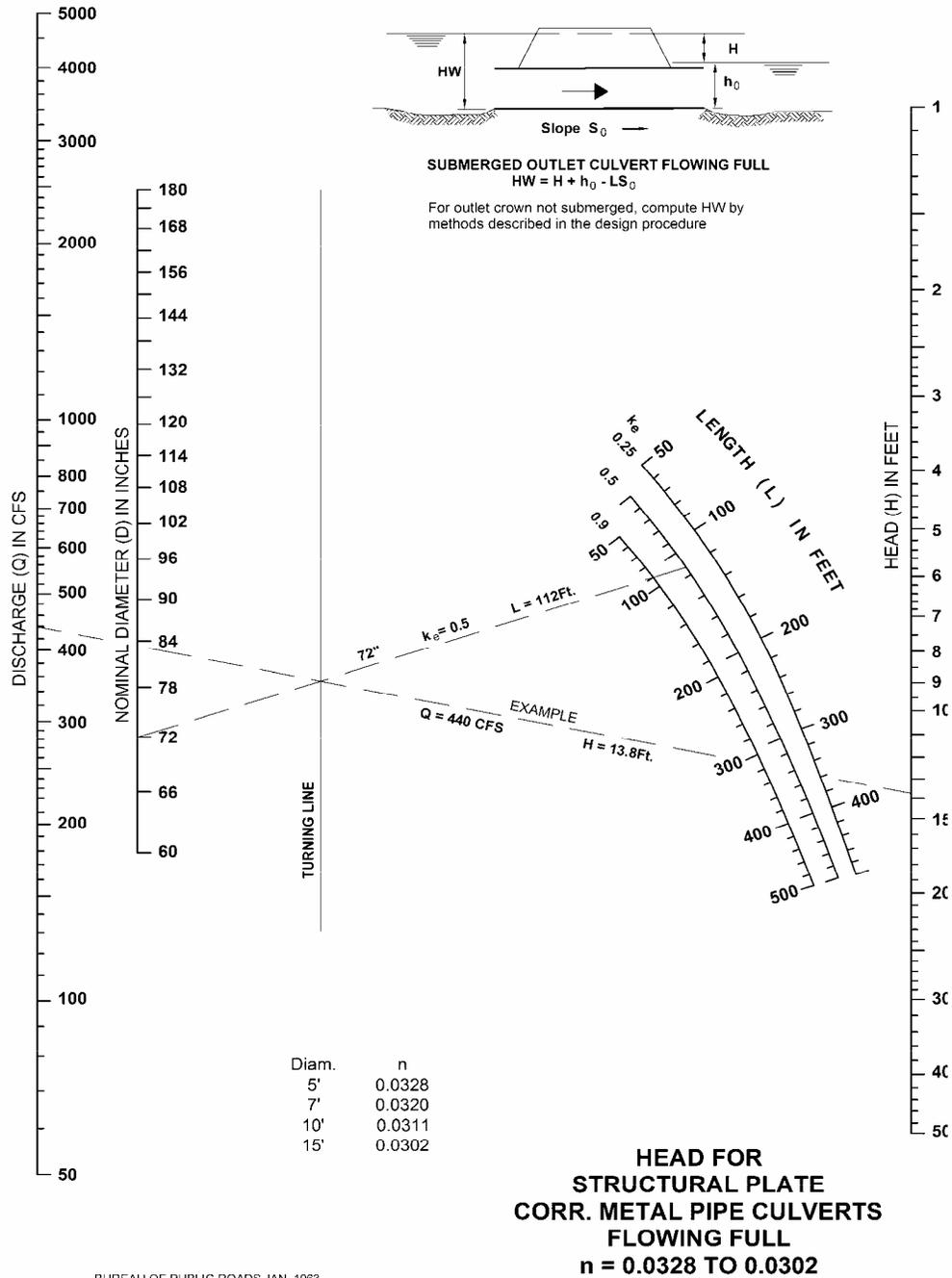
Figure 3.15



BUREAU OF PUBLIC ROADS, JAN. 1963



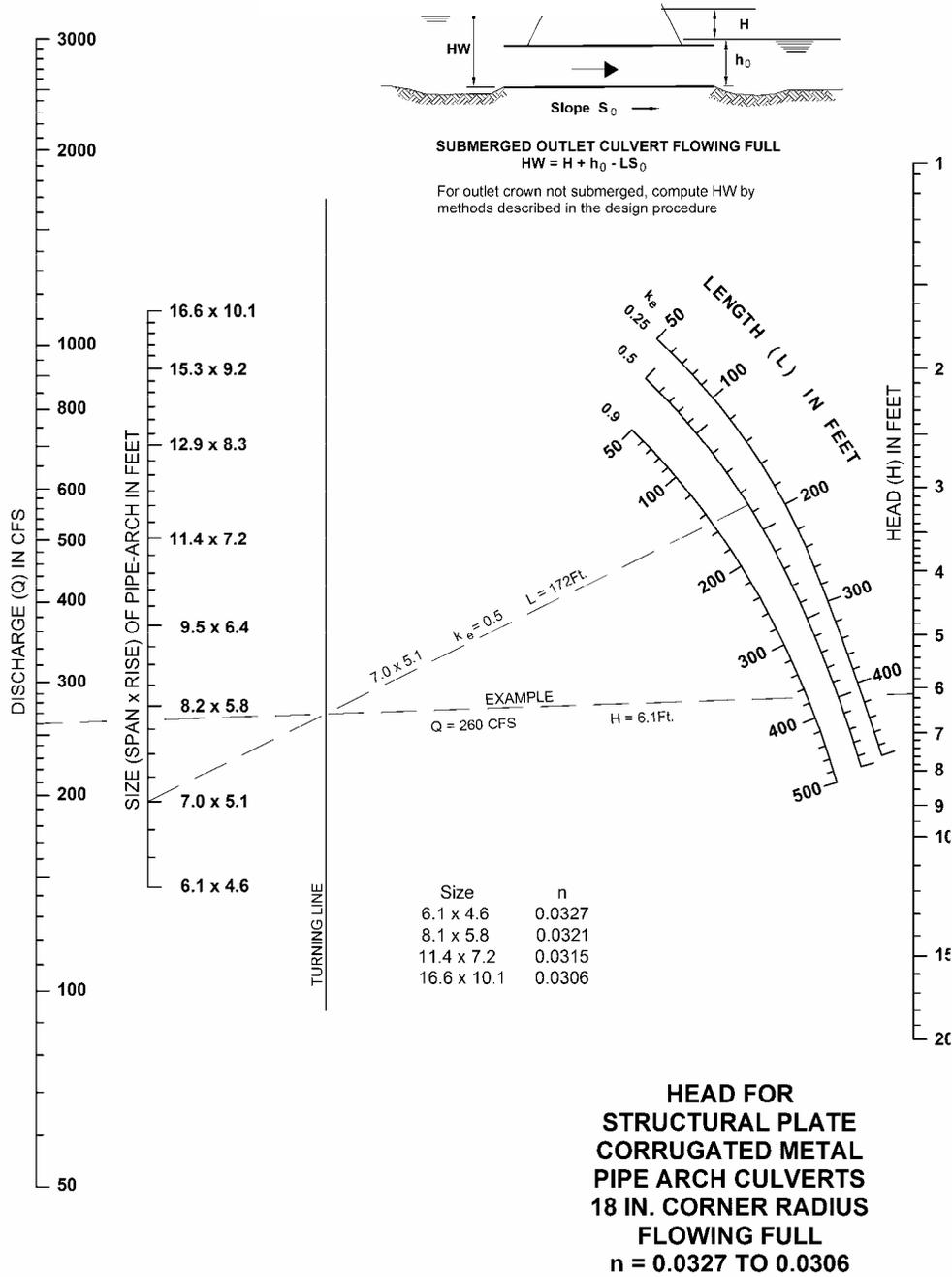
Figure 3.16



BUREAU OF PUBLIC ROADS, JAN. 1963



Figure 3.17



BUREAU OF PUBLIC ROADS, JAN. 1963



CHAPTER 4 ENCLOSED SYSTEMS

4.1 Introduction

Enclosed conveyance systems consisting of inlets, conduits and manholes may be used to convey stormwater runoff where site conditions will not permit the stable and non-erosive use of natural or engineered channels. Where used, such systems must be designed in accordance with design criteria and performance standards given below.

4.2 General Guidance

1. Where storm drainage along the side lot lines of residential property is to be in conduit, the conduit shall extend to a point at least 40 feet to the rear of the front building line or 10 feet beyond the rear line of the structure, whichever is greater.
2. Where culverts are placed under roadways, they shall extend to at least the limits of the right-of-way or the toe of the roadway embankment, whichever is greater.
3. Pipe drains or culverts constructed to intercept the flow of ditches or channels, which may be enclosed in a conduit at a future time, shall be installed at adequate depth to permit their extension at the same required depth.
4. Curb inlets shall be installed at or near intersections where they are deemed necessary for the safety of pedestrian and vehicular traffic. Curb inlets shall be placed to intercept the storm water before it reaches the crosswalks. No curb inlet shall be located within a crosswalk or within curb radius at the intersection.
5. Concentrated discharges in excess of 2 cfs for the 10-year storm should not discharge directly onto or across public sidewalks or to the street gutter. Likewise, sheet flow of large turf areas (greater than 9000 square feet) or paved areas (greater than 3000 square feet) or a proportional combination thereof, should not discharge across public sidewalks or into the street.
6. All plans for drainage systems shall indicate the overflow path for the portion of the 100 year (1% annual chance) storm that the system cannot accommodate.
7. Stormwater collection systems shall be designed to the 10 year (10% annual chance) storm for property in a residential zoning district and the 25 year (4% annual chance) storm for property in all other zoning districts.



8. Downspouts shall not discharge within the building setback unless there is a drainage swale established to carry the water to the front or rear of the property or closest natural drainage course. Downspouts may discharge within the building setback if discharging into a rain garden, rain barrel or other stormwater best management practice.

4.3 Existing Drainage Systems

Existing on-site drainage system pipes, structures, and appurtenances within the project limits may be retained as elements of an improved system providing:

- They are in structurally sound condition.
- Their hydraulic capacity, including surcharge, is equal to or greater than the capacity required by these criteria.
- Easements exist or are dedicated to allow for operation and maintenance.

Discharge from an existing upstream storm drainage system shall be computed assuming its capacity is adequate to meet the performance criteria given below. The computed discharge shall be used to design the new downstream system even if the actual capacity of the existing upstream system is less.

4.4 Inlet Design

Only Type M curb opening inlets shall be used on public streets for design flows. Other inlets or combinations of inlets must be approved by the Director. See detail 505.01 A-F (Boone County Roadway Regulations), for more information.

1. Design Method

Inlets shall be designed using Figures 4.1 and 4.2 at the end of chapter 4 or calculations within appropriate engineering software. Note that the Theoretical Captured Discharge (left side of chart) is the design capacity. A 20% reduction for clogging factor shall be used for all inlets. Deflectors must be used when the street grade is greater than or equal to 4%.

2. Inlet spacing for streets

Inlets shall be located to provide clear driving lanes for various street classifications as specified below.

- a Local residential streets** – inlets shall be spaced at such an interval as to provide one clear lane of traffic having a minimum width of 10 feet during the peak flows of a 10 year (10% annual chance) design storm.
- b Collector streets and commercial streets** – inlets shall be spaced at such an interval as to provide one clear lane of traffic having a minimum width of 12 feet during the peak flows of a 25 year (4%



annual chance) design storm. The clear lane shall be centered on the centerline of the roadway.

- c **Arterial streets** – inlets shall be spaced to provide one clear lane of traffic in each direction during the peak flows of a 25 year (4% annual chance) design storm. Two lanes of traffic being defined as 20 feet in width, being 10 feet on either side of the crown, for undivided roadways, and as one 12 foot wide lane on each side of the median for divided roadways.
- d In addition to the inlet spacing requirements for limiting width of flow, inlets shall be located to limit gutter flow from crossing the street centerline at the time of peak discharge for the design storm to the following limits:

CONDITION CAUSING FLOW TO CROSS STREET CENTERLINE	MAXIMUM DISCHARGE
Transitions to super elevation	1.0 CFS
Sump at midblock	Not Allowed
Overflow of non-gutter flow	See 4.5

Note: For new development, any inlets at intersections shall be positioned outside the curb return and sidewalk ramps.

3. Freeboard Requirements

Any opening through which surface water is intended to enter (or may backflow from) the system shall be at or above the hydraulic grade line in the inlet during the design storm, specified in Table 4.1, where such calculation must include junction (so-called “minor”) losses.

4. Gutter Capacity

Gutter capacity may be determined from Izzard's Formula below (see Figure 4.3 at the end of chapter 4 for graphical solution):

$$Q = \frac{0.56z \cdot S_o^{1/2} \cdot D^{8/3}}{n}$$

Where:

Q = The gutter capacity in cubic feet per second

z = The reciprocal of the average cross-slope, including gutter section, in feet per foot

S_o = The longitudinal street grade in feet per foot

D = The depth of flow at curb face in feet

n = Manning's "n", see Table 3.9 at the end of Chapter 3



4.5 Protection for Streets

Concentrated flow not conveyed in the gutter system, shall be conveyed under streets to prevent vehicles from being swept from the roadway in infrequent storms. These crossings (bridges, culverts or underground systems) must be designed to completely convey flood flows without street overtopping in accordance with:

**TABLE 4.1
DESIGN STORM CAPACITY FOR STREETS**

Street Classification	Min. Design Storm Capacity	Design Storm Return Interval
Arterial	2%	50 year
Collector/Commercial	4%	25 year
Local	10%	10 year

1. Roadway Overtopping

Concentrated flow in excess of the minimum design storm may only overtop the roadway if both of the following conditions are met:

- The span of the structure opening is less than 20 feet.
- The peak stormwater runoff from the 100 year (1% annual chance) storm is 250 cfs or less unless a guard rail is installed on the downstream side of the roadway.

Such overflow depths at low points in roadways during the 100 year (1% annual chance) storm will be limited to 7 inches measured at the high point in the roadway cross section; except that it also shall not exceed 14 inches at the deepest point in the roadway cross section. Depths may be limited where necessary by lengthening the vertical curve of the roadway, by reducing roadway crown, or by other similar means. Roadway overtopping depths shall be determined by integrating the broad crested wier formula across the roadway profile. Each incremental flow can be determined by using the formula:

$$q = Clh^{3/2}$$

Where:

q = the flow for an increment of profile length (width of flow)

l = the incremental width

C = a flow coefficient that shall not exceed 3.0



H = the average depth of flow at each increment

The total flow Q is the sum of the incremental flows. Depth determinations can be made through an iterative process where successive depths are chosen, Q is calculated for each depth and then compared to the known Q at the overtopping point.

Overflow protection criteria provides additional accessibility criteria at major stream crossings for emergency personnel, and provides the public with protection against injury and property damage.

4.6 Enclosed Pipe Systems

1. **General requirements:**
 - a. The crown(s) of pipe(s) entering a drainage structure should be at or above the crown of the pipe exiting from the structure and must provide a minimum fall in the invert of the structure of 0.2 feet. Alternatively, the crowns of the pipes may be at or above the HGL of normal flow at design frequency.
 - b. The maximum spacing between manholes shall be 400 feet for 30-inch diameter or less; 600 feet for pipes more than 30-inch diameter.
 - c. Prefabricated wye and tee connections may be utilized provided at least one of the pipes is greater than 30 inches in diameter.
 - d. Select pipe size and slope so that the velocity of flow will increase progressively, or will not appreciably decrease, at inlets, bends or other changes in geometry or configuration.
 - e. Pipes shall be installed in a straight line at grade.
 - f. Do not discharge the contents of a larger pipe into a smaller one, even though the capacity of the smaller pipe may be greater due to steeper slope.
 - g. Conduits are to be checked at the time of their design with reference to critical slope. If the slope on the line is greater than critical slope, the unit will likely be operating under entrance control instead of the originally assumed normal flow. Conduit slope should be kept below critical slope if at all possible. This also removes the possibility of a hydraulic jump within the line.



- h. Pipes should be parallel or perpendicular with the centerline of streets unless otherwise unavoidable.

2. Capacity

Capacity shall be determined in accordance with Chapter 3. Minimum design for pipe under street pavement shall be in accordance with Chapter II of the Boone County Roadway Regulations. For partially full pipe flow, Figure 4.4 can be used to obtain hydraulic parameters of the flow.

3 Pressure Flow

After considering the discussion presented at the beginning of Chapter 3, an enclosed system may be designed to operate with pressure flow, for the design storms specified in Table 4.1 if all the following conditions are met:

- a. The Hydraulic Grade Line (HGL) must be at or below any openings to the ground or street at all locations.
- b. Appropriate energy losses for bends, transitions, manholes, inlets, and outlets, are used in computing the HGL. This is addressed in the hydraulics section.
- c. Energy methods (Bernoulli's equation) must be used for the computations.

4. Outfalls and Energy Dissipation

The outfall of all enclosed systems shall include energy dissipation sufficient to transition outlet flows to velocities and applied shear stresses consistent with the normal flow conditions in the receiving channel for the range of flows up to and including the 10-year, 25-year storms (10%, 4% annual chance for residential and commercial properties respectfully. Calculations, at a minimum, shall include the 1 year (100% annual chance), the 10 year (10% annual chance) and the 100 year (1% annual chance) storms.

- a. Figure 4.5 provides guidance for riprap aprons for various size pipes and limitations on the use of aprons.
- b. Outfalls shall not be permitted on slopes of greater than 6:1. Flow shall be piped or run in an engineered channel to a point as outlined in Section 5.1.5.
- c. Energy dissipation for lateral outflows to natural streams and edge of buffer outfalls to riparian buffers shall follow the guidance in Section 5.1.5.



- d. Effective energy dissipating structures shall be provided to meet the requirements stated in Table 5.1 (end of Chapter 5) when conditions are beyond the limitations of rock aprons. Examples of energy dissipating structures are:
- Hydraulic Jump Basins
 - Impact Baffle Basins
 - Plunge Pool and Plunge Basin
 - Slotted-Grating or Slotted Bucket Dissipators
 - Stilling Basins
 - Internal Pipe Rings
- e. Grade control shall be provided downstream of the dissipator or shall be constructed integrally with it. In addition, the developing agencies' recommendations for armoured transition to natural channel shall be included as part of the design.
- f. The suitability of each method is site dependent. The FHWA computer program HY8 Energy (downloadable free from the FHWA hydraulics website) lists methods and applicability. Energy dissipaters shall be designed according to the criteria and procedures defined in professionally acceptable references. Several such references include:
- United States. Department of the Interior. Bureau of Reclamation. Design of Small Dams. 1987 ed. Denver: GPO, 1987.
 - United States. Department of the Interior. Bureau of Reclamation. A Water Resource Technical Publication. Engineering Monograph No. 25. Hydraulic Design of Stilling Basins and Energy Dissipaters. 1978 ed. GPO, 1978.
 - Federal Highway Administration (FHWA), 1983. Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular (HEC) No. 14, along with HY8Energy design software
 - US Army Corps of Engineers, 1994. Hydraulic Design of Flood Control Channels, US Army Corps of Engineers Engineer Manual EM 1110-2-1601.



- Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance (Latest Edition), National Highway Institute, HEC No. 23.
- River Engineering for Highway Encroachments, Highways in the River Environment, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA NHI 01-004, December 2001.

5. Minimum Pipe Slope

Unless approved by the director of public works, the minimum allowable pipe slope for any pipe is 0.4 %.

6. Velocity Within the System

The velocity within the system shall be between 2 and 15 feet per second for the design flow.

4.7 OVERFLOW PROVISIONS

Each conveyance element of the stormwater drainage system (whether open, enclosed, or detention) shall include an overflow element if the in-system capacity is less than the 100 year (1% annual chance) storm flows. Overflow systems shall:

1. Be designed to route downstream any amount of the 100 year (1% annual chance) storm exceeding the in-system design capacity specified in Table 4.1 (page 5 of chapter 4), while providing 1 foot of freeboard to low exterior sill or low opening of adjacent structures.
2. Include streets, engineered channels, redundant piping, spillways, parking lots, drives or combinations thereof.
3. Limit the maximum water surface elevation generated by the 100 year (1% annual chance) storm as specified in Section 4.5.1.
4. Be limited to the natural drainage basins. Transfer of overflow out of a natural drainage basin (e.g. a thoroughfare straight-graded through a drainage basin with a sump in another drainage basin) may sometimes be allowed at the discretion of the Director. These overflows must be added to the overflows in the receiving drainage basin and the combined overflow must still meet the criteria within this chapter.

4.8 EASEMENTS

Easements are required per the Stormwater Ordinance. The minimum easement width is 15 feet or the sum of the conduit diameter and twice the cover depth, whichever is greater. However, the easement width shall increase if necessary to



encompass the overflow spread from the 100 year (1% annual chance) rainfall event. Easements should be centered on the pipe or overflow path.

1. Permanent

The Director may require wider easements when other utilities are located within the same easement and/or when the depth of cover is substantial or the conduit is very large.

2. Temporary

Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is located in areas developed prior to construction.



Figure 4.1

THEORETICAL INLET CAPACITY
4'-0" LONG DEPRESSED CURB OPENING INLET

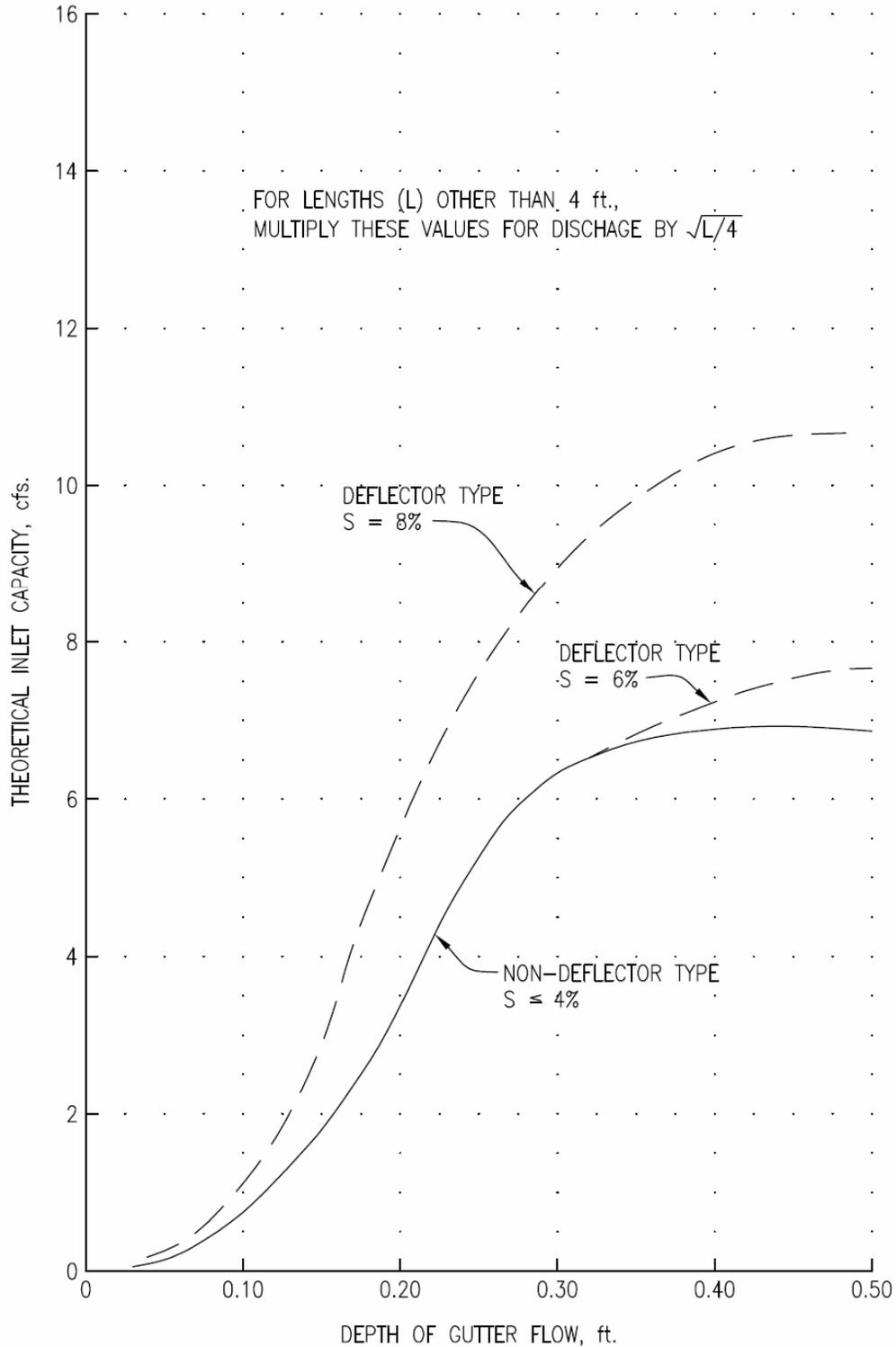
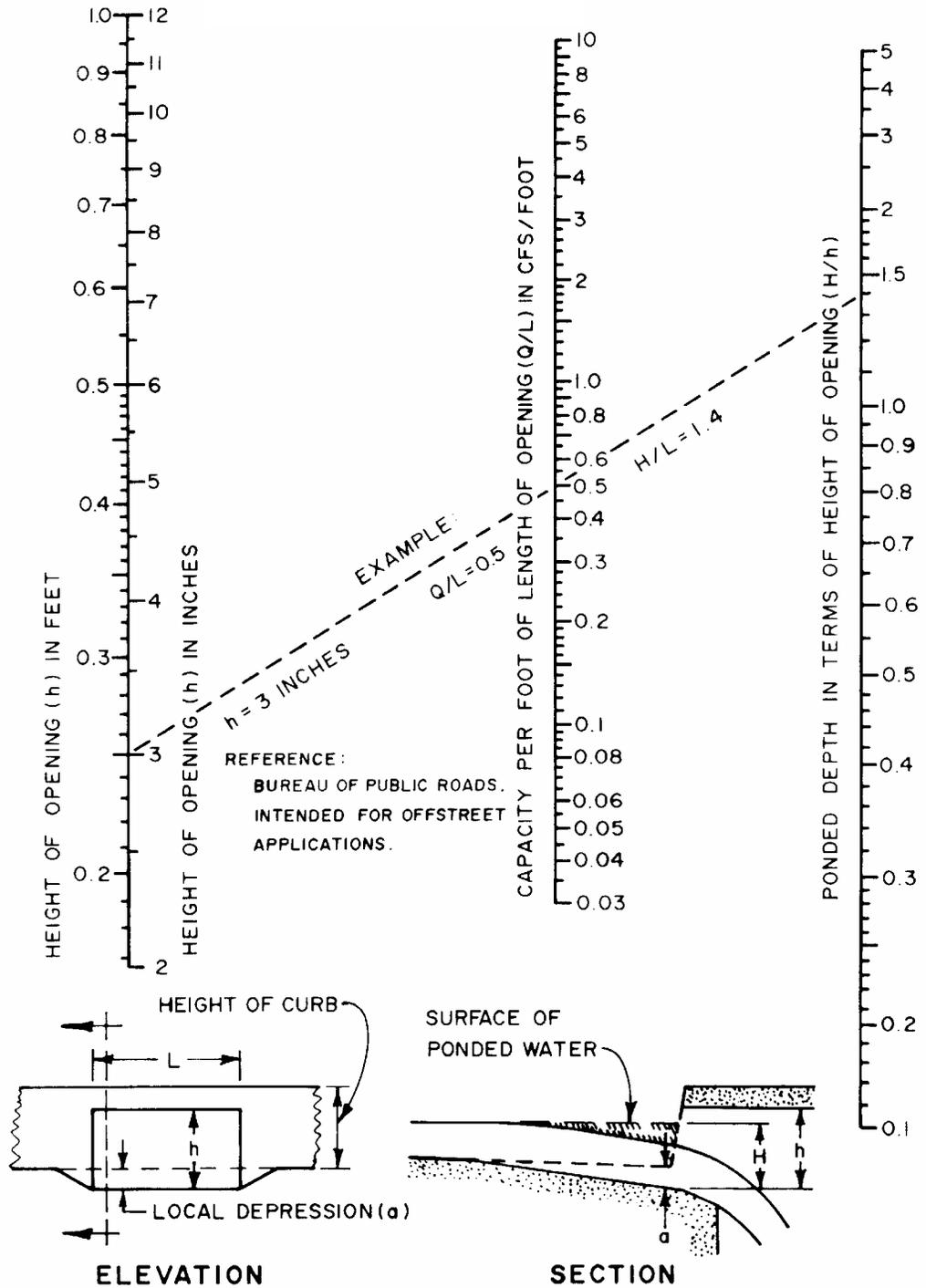




Figure 4.2



CAPACITY OF CURB OPENING INLET
AT LOW POINT IN GRADE.



Figure 4.3

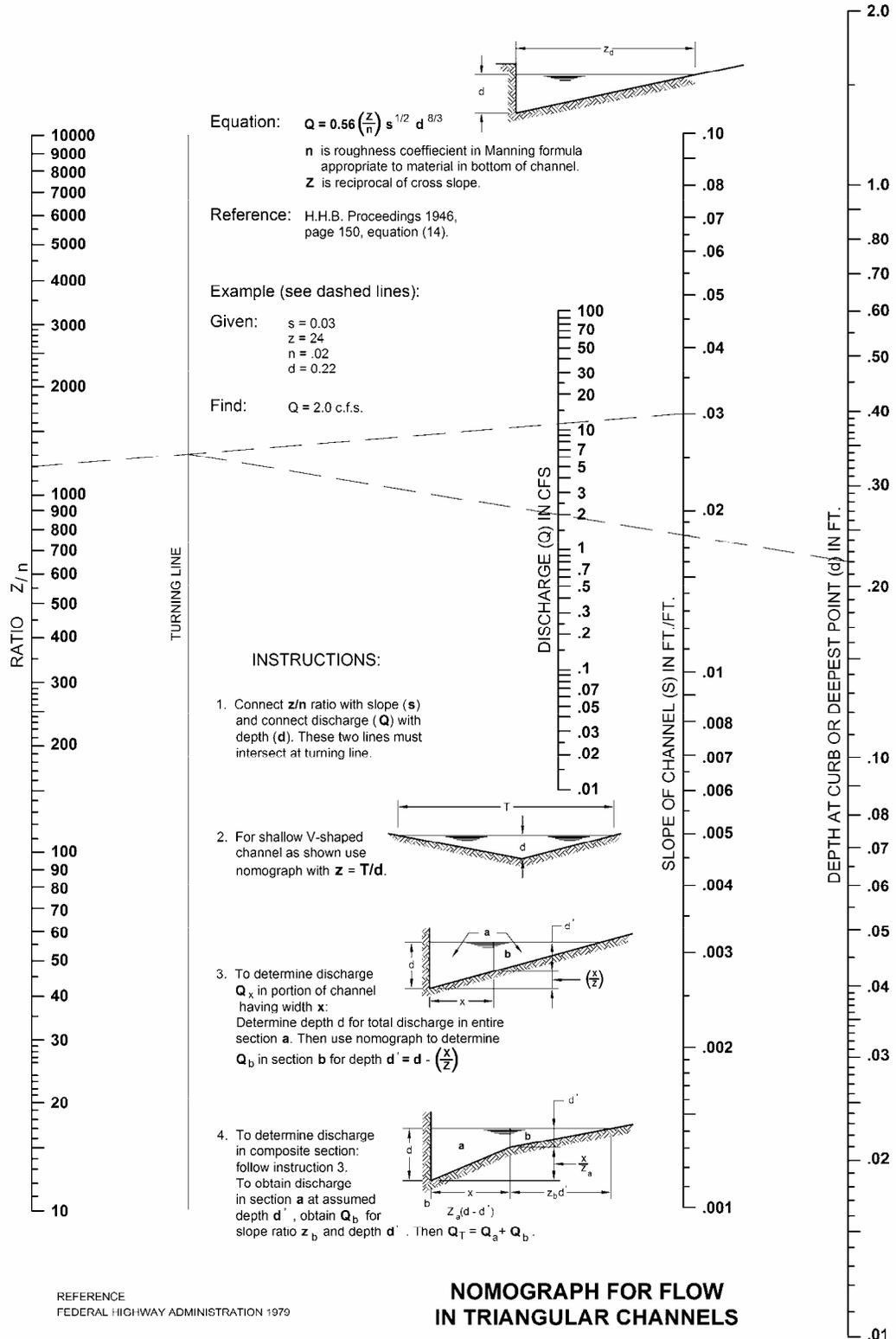
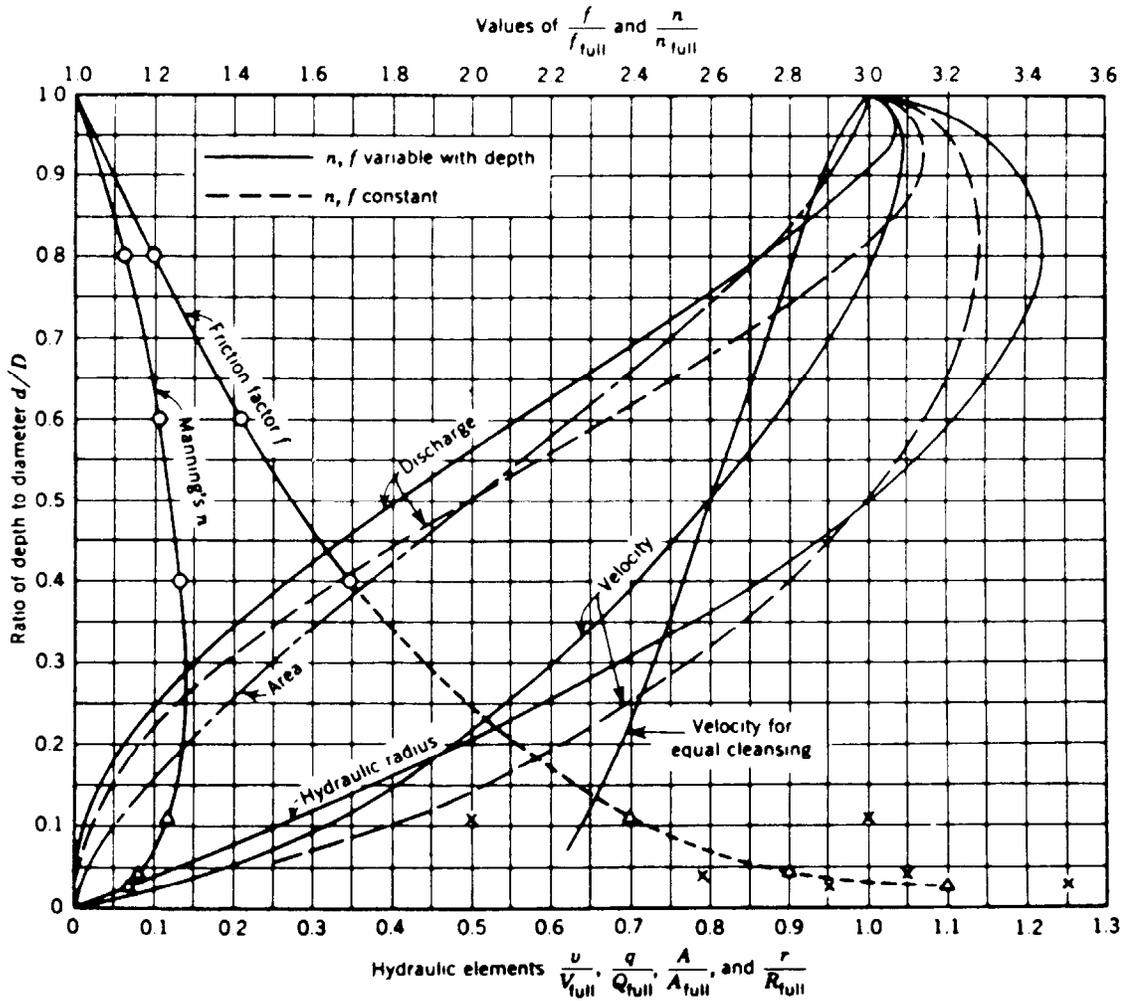




Figure 4.4



- | | | | |
|------------|---------------------------------|------------|--|
| v | = Actual velocity of flow (fps) | A | = Area occupied by flow (ft ²) |
| V_{full} | = Velocity flowing full (fps) | A_{full} | = Area of pipe (ft ²) |
| q | = Actual quantity of flow (cfs) | r | = Actual hydraulic radius (ft.) |
| Q_{full} | = Capacity flowing full (cfs) | R_{full} | = Hydraulic radius of full pipe (ft.) |

HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS (2)



CHAPTER 5 OPEN CHANNELS

5.1 Introduction

This chapter focuses on the conveyance of stormwater in open channels. It is divided into natural stream systems and engineered channels. With primarily earthen bank and bed materials, these systems are particularly sensitive to the sheer stresses created by frequent flow conditions. Each section focuses on energy management in addition to traditional capacity and overflow requirements.

5.2 Natural Streams

This section sets forth the requirements for the protection of natural streams as a conveyance for stormwater. Unless otherwise provided for by County, State, or Federal ordinance, regulation, or standards, existing natural streams shall be preserved and protected to the maximum extent practicable.

1. Stream Preservation and Buffers Zones:

Stream buffers shall be protected per the Stream Buffer Regulations in Chapter 26 of the Boone County Zoning Regulations.

2. In Stream Construction - General Requirements:

All applicable permits shall be obtained by the USCOE and MoDNR (404/401 permits) prior to initiation of construction in streams or the streamside buffer zone. Each project shall conform to the general requirements of this subsection and to the appropriate specific requirements of the subsections following:

a. Transitions

In-stream structures shall be designed to gradually blend into the natural channel and provide a smooth transition of both geometry and roughness.

b. Repair of Disturbed Banks

The side slopes of banks where construction occurs shall be restored with vegetation as quickly as possible. Native species are preferred due to their tolerance of local conditions and their deep root systems.

3. Limited Stream Assessment

A limited stream assessment is required when any construction will enter the stream or streamside buffer zone. It shall include the components

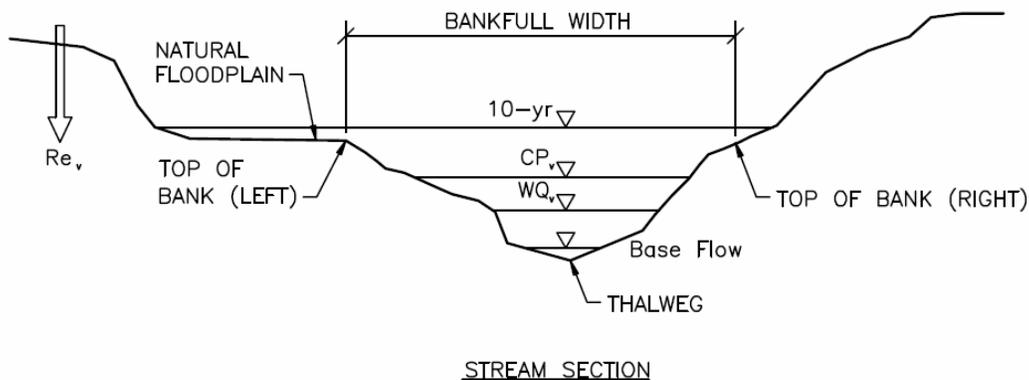


listed below, except as modified by the Director to better fit project needs. This should, at a minimum, include the area on the property where encroachments are made in the stream or buffer zone, plus one wave form upstream and down or 300 feet upstream and down, whichever is less.

a. Plan Form Analyses and Inventory

The plan-view of the natural stream using aerial photographs or planning-level aerial survey shall be plotted to an appropriate scale. For smaller sites, the site topographic survey may be used. The following items shall be shown:

1. Top of bank.
2. Ground contours (if available).
3. Floodplain for the 100-year (1% annual chance storm).
4. Approximate thalweg and locations of riffles, runs and pools.
5. Active scour and depositional areas, point bars, and islands.
6. Photographs of main channel, streamside vegetation, and each riffle, appropriately referenced to plan-view location.



b. Longitudinal Profile and Sections

The elevations of the profile along the thalweg shall be field surveyed to the nearest 0.1 ft. and the following features noted: riffles, pools, exposed bed rock, and advancing headcuts (areas of bed elevation change that appear to be actively migrating upstream). The top of left and right bank shall be plotted at correct elevation along the profile. Frequency of field information shall be sufficient to indicate the general condition of the channel and its overall stream structure. This information is



more critical when disturbing the stream or discharging a concentrated flow in the stream-side zone.

c. Bed and Bank Materials

The Engineer shall provide a narrative discussing the types of materials found in the bed and bank as they relate to the stream's propensity to change.

4. Discharge Outfalls

Energy dissipation shall be provided to reduce shear stress at the outfall. Discharge points for outflows from enclosed systems or constructed channels shall be designed as one of the following:

a. Primary Outfall

Primary outfalls are those where the entire upstream channel is replaced by an enclosed system or constructed channel which discharges flow in line with the direction of the downstream segment. Energy dissipation shall be provided at the outlet to reduce velocities per Section 4.3.(3). Grade control downstream of the outlet and energy dissipater shall be provided to prevent undermining of the outfall by future headcuts. The alignment and location of the outfall and associated energy dissipater and grade control should make a smooth transition into the downstream channel. Primary outfalls shall be used whenever the contributing drainage area of the outfalls is greater than 80% of the downstream channel.

b. Tributary Outfall

Tributary outfalls are primary outfalls located on a tributary to a larger downstream segment. Energy dissipation and transition to the natural stream flow should take place at least ten tributary channel widths upstream of the confluence. Grade control in the tributary upstream of the confluence shall be provided. Tributary outfalls may be used in all situations of tributary flow.

c. Lateral Outfall

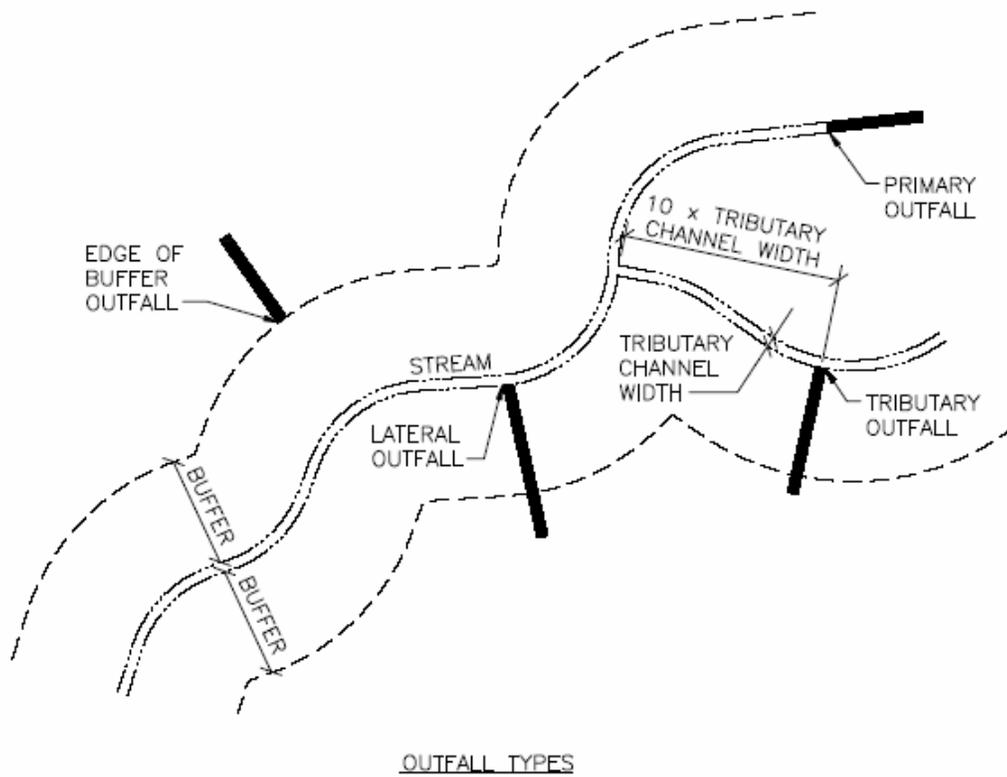
Lateral outfalls are small outfalls that discharge from the banks of a natural stream. Outfalls shall be located to enter on a riffle or from the outside of a bend, but should generally not enter from the inside of a bend. Outfall pipes shall be oriented perpendicular to the flow of the stream with the invert at or slightly below top of the next downstream riffle. Outfalls shall be flush with or setback from the bank. The bank shall be shaped to provide a smooth transition and protected with reinforced vegetation (preferred) or rip-rap. If



the outfall is in a bend, it shall be set back from the existing bank a sufficient distance to account for future meander migration, and the transition shall be graded and reinforced with vegetation. Rip-rap or hard armor protection should not be used in a bend. Perpendicular outfalls may only be used when the contributing drainage area of the outfall is less than 40% of that in the downstream channel.

d. Edge of buffer Outfall

Edge-of-buffer outfalls are discharge points in the outer half of the riparian buffer that return the discharge to diffused overland flow. Outfalls shall be designed to spread flow into a sheet flow condition and allow overland flow and infiltration to occur. Overland flow shall be directed to run in the outer portion of the buffer parallel to the channel direction to increase length of flow and prevent short-circuiting directly into the stream. Low weirs and berms may be graded to direct flow and encourage short-term ponding. The buffer zone utilized for infiltration shall be maintained in dense, erosion-resistant vegetation designed to withstand the shear stresses of a 10-year (10%) storm. Edge-of-buffer outfalls shall only be used if each individual outfall can be designed to operate without scour or the formation of gullies.



OUTFALL TYPES



5. Culverts, Bridges, and Above Grade Crossings

- a. Crossings should generally be located on a riffle or run. If the width of the roadway, pathway or above grade crossing is large relative to the length of the riffle, then grade control structures may be needed at the riffles upstream and downstream to isolate the impact of the crossings. If a crossing cannot be made at a riffle, avoid armoring a pool and place at-grade grade control structures at the riffle immediately upstream and downstream of the crossing.
- b. Realignment of channels to accommodate crossings and their approach should be avoided and minimized as much as possible. Any areas relocated shall have the banks stabilized in accordance with Section 4.3 and shall be included in the reach isolated by upstream and downstream grade control.
- c. For bridges the multi-stage channel shape should be maintained and additional area to convey the design flow shall be above the elevation of the bank-full discharge.
- d. For multi-cell culvert crossings that have a cumulative width larger than the bank-full width, those cells wider than the bank-full width shall have a flowline located at the lowest estimated bank-full depth, or a weir wall or other structure upstream of the culvert opening shall be installed with a height to prevent access to the cell during flows less than bank-full flow. The weir wall shall be designed so that the hydraulic efficiency at the 100-year (1% chance) ultimate conditions storm is not reduced.
- e. Culverts shall be designed so that there is no backwater effect at all flows up to the 2-year (50% annual chance) storm discharge.

6. Below Grade Stream Crossings

- a. Below grade stream crossings primarily include utility pipelines. Crossings should generally be at riffles and grade control structures constructed at the riffle, in addition to or constructed integrally with any encasement of the line the utility may require.
- b. If riffle crossing is not feasible, the crossing should be in a pool that is protected by a downstream grade control structure. The top of crossing elevation should be at least two feet below the top of grade control. Crossings under pools should not be armored directly, but are protected by downstream grade control.



- c. Below grade crossings shall be perpendicular to the stream whenever possible. If a perpendicular crossing is not feasible, the grade control protecting the crossing shall be perpendicular.
- d. Constriction or alteration of the pre-existing channel shape shall be avoided. If alteration occurs, sediment transport continuity and energy management shall be verified. Stream banks shall be repaired using vegetative methods whenever possible and the hydraulic roughness of the repaired stream bank should match that of the undisturbed stream banks.

7. Grade Control

- a. Where grade control structures are needed, they shall be placed in locations where the stream bed profile will support the creation or continuance of a riffle. The flowline of the grade control shall match the existing riffle.
- b. Where stream slope is less than 2%, the Newberry-style grade control structure detailed in Figure 5.1 (at the end of chapter 5) is recommended. Structures shall be constructed from durable stone sized using USACE methodology for steep channels (USACE EM 1110-2-1601, page 3-8, Equation 3-5). Rock shall generally comply with USACE gradations as given in (USACE EM 1110-2-1601, Hydraulic Design of Flood Control Channels, Chapter 3). Shotrock with sufficient fines to fill voids may be used. The use of filter fabric and uniform gradations of stone are discouraged in stream beds.
- c. Where grades are in excess of 2%, low-drop step structures should be used.
- d. Alternate styles of grade control may be approved by the Director. Guidance for grade control design is given in Thomas et.al, 2000. A Design Procedure for Step Pool Structures.
- e. Construction of new grade control structures may be waived by the Director if it is determined through review of the stream assessment that existing riffles are adequate to prevent or retard advancing headcuts. The County may alternatively choose to accept the risk of future headcut instead of disturbing a stable channel.



Scour from high flow events has undercut the retaining wall, exposing the toe slope. If not reinforced, this stabilization project will fail.

8. Bank Stabilization Projects

Bank stabilization projects should generally be limited to cases where existing buildings or infrastructure face significant property damage or safety issues. Projects to stabilize banks to facilitate reductions in buffer widths for new construction shall be avoided.

- a. Prior to stabilization, the causes of the instability should be considered, including the stream's current phase of channel evolution (Interagency, 2001, Chapter 7) and direction of meander migration. Stabilization may be unnecessary if a channel has ceased incision and widening and is in the process of deposition and restoration. If stability issues appear widespread or complex, a systematic evaluation of the stream system by professionals with expertise in river engineering and fluvial geomorphology may be required by the Director.
- b. Instability caused by geotechnical failure (slumping of banks due to weak soils in the adjacent slopes) shall be distinguished from fluvial failure (erosion of banks caused by stream flows). For geotechnical issues, a geotechnical engineer shall evaluate the slope stability. Geotechnical designs shall provide for a 1.5 factor of safety (ratio of theoretical resisting forces to driving forces) against slope failure where it would endanger buildings, roadways, or other infrastructure, unless a lower factor of safety is approved by the Director. Fluvial failure may require analysis by an expert in bank stability.



- d. Bank stability projects shall have a design life greater than the useful life of the facility being protected, or a life cycle cost analysis shall be performed that considers replacement and repair over the entire protection period. Responsible parties for future maintenance shall be identified in a recorded maintenance agreement.
- e. Stabilization should begin and end at stable locations along the bank. Bank stabilization should be limited to areas of potential erosion and is rarely required on the inside of bends. For long projects, stabilization may alternate from side to side and is rarely necessary across an entire cross section. The existing cross section should be mimicked to the extent practical and need not be planar or uniform over the entire length. Grade control shall be provided at the riffle both upstream and downstream of the stabilization to isolate it from the surrounding stream and protect the foundation from undercutting. Control at intermediate points for longer projects may also be required. Energy management and sediment transport continuity shall be checked, and energy dissipation provided if necessary.
- f. "Hard-Armor" projects are those projects that use rip-rap, placed stone, gabions, retaining walls, or other rigid structures to provide geotechnical and fluvial stability. Such projects shall be designed in accordance with EM 1110-2-1205 (USACE, 1989), EM1110-2-1601 (USACE, 1994), or HEC-11 (FHWA 1989). Materials shall be sized to prevent dislodgement in the 1% storm. Gradation should comply with USACE or FHWA recommendations. Stones should be placed to maintain roughness and variations. All material shall be well placed to ensure interlock and stability. Materials shall be keyed into the bed and banks with adequate allowance for scour along the toe and the
- g. structure should have adequate foundation. Vertical walls should be avoided when possible as they tend to concentrate scour at their toe and are typically smoother than the natural channel.
- h. Soil bioengineering involves the use of living vegetation in combination with soil reinforcing agents such as geogrids to provide bank stabilization by increasing soil shear resistance, dewatering saturated soils, and by reducing local shear stresses through increased hydraulic roughness.



- i. Bio-engineering projects shall be designed in accordance with the principals of NRCS (1996) and Gray and Sotir (1996). Designs will be tailored to the urban environment by consideration of the requirement for immediate functionality upon construction, the extreme variability and high shear stress of urban flows and the availability of mechanized equipment and skilled operators.
- j. Selection of plants and specifications for planting methods and soil amendments shall be prepared by a professional competent in the biological and stabilization properties of plants.
- f. Plants selected shall be appropriate to local conditions and shall be native varieties to the greatest extent practical. Evaluation of local conditions includes assessment of site microclimate, bank slope, soil composition, strength and fertility, type and condition of existing vegetation, proximity to existing infrastructure, soil moisture conditions and likelihood of wildlife predation. Engineering factors influencing plant selection include frequency, height and duration of inundation, near-bank shear stress, size and volume of bed load as well as depth and frequency of scour.
- g. Plants may be either locally harvested or purchased from commercial nurseries. When harvesting trees or forbes for transplantation, no more than 10% of a given stand may be removed and no plant on the state rare or endangered species list may be harvested or damaged in harvesting operations. Plant material grown near Boone County is adapted to local climatic conditions and is preferred over more remote sources. Seed, plant plugs, rhizomes, whips, live stakes, bare root and container stock may be used. Turf grasses, noxious or invasive species shall not be used for bank stabilization projects. A variety of plant species should be used to provide greater reliability to a design. For critical functions such as protection from toe scour a minimum of three species should generally be employed.
- h. Soil bioengineering methods are properly applied in the context of a relatively stable stream system, and relevant general requirements for all stream bank stabilization projects given in this section apply to bio-engineered projects. Soil bioengineering alone is not appropriate when the zone of weakness lies below the root zone of the plantings, or when rapid draw down can occur, such as in a spillway or dam embankment.
- i. Composite methods are those which employ both hard armor and soil bio-engineering. Typically, armor for toe protection in critical



locations is provided, with soil-bioengineering for the remainder. Design principals for both hard armor and soil-bioengineering shall be observed as appropriate.

- k. **In-stream Stability Structures:** In-stream structures are used to focus flow, control grade, dissipate energy and selectively lower near-bank stress. Stream barbs, weirs, guide vanes, vegetative sills, longitudinal peak stone, and grade controls are among the more commonly used in-stream structures. When constructed of natural material such as rock, such structures also create aquatic habitat. They may be used alone or in combination with hard armor, bio-engineering or composite methods. In-stream structure design is a river engineering practice and is beyond the scope of this standard. Preliminary guidance and references for the design of some common structures is given in Castro (1999) and Interagency (2001).



Increased urban stream flows have undercut the stream bank, causing willows to fall into the stream in the picture above.



5.3 Engineered Channels

The criteria in this section apply to created open channels or modified existing open channels where a stream buffer does not exist.

1. Design Storm

Engineered channels shall be designed to completely contain the design storm for the site and shall provide for the overflow of the 100 year (1% annual chance) storm.

2. Velocity

Flow velocity in open channels (with the exception of roadway gutters) shall be controlled to prevent erosion in the channel and at the outlet during the design storm. A minimum flushing velocity must also be maintained.

3. Freeboard

Freeboard shall not be required above the design headwater pool elevation at the culvert entrance. However, the low exterior sill or low opening of adjacent structures shall be a minimum of one foot above the 100-year (1%) return frequency stormwater surface elevation.

4. Channel Linings

- a. Minimum lining height shall be the selected design storm water profile plus at least a 0.5-foot freeboard.
- b. All channel linings, except turf, shall contain provision for relieving back pressures and water entrapment at regular intervals and shall be provided with a filter underlayment to prevent soil piping.
- c. Lining height on the outside bend of curves shall be increased by:

$$y = \frac{D}{4}$$

Where:

y = Increased vertical height of lining in feet

D = Depth of design flow in feet

- d. Increased lining height shall be transitioned from y to zero feet over a minimum of:
 - $30 \times y$ feet downstream from the point of tangency (P.T.).
 - $10 \times y$ feet upstream from the point of curvature (P.C.).



5. Lining Material

The types of lining material listed in Table 5.1 at the end of this chapter shall be used to control damage and erosion. All riprap and gabion linings shall be designed with a filter fabric. The design of the lining material shall protect the channel for conditions up to the 100-year (1% annual chance) storm. This criterion may be reduced to the 10-year (10% annual chance) storm if the Director approves and if responsibility for repair of channel linings in storms greater than the 10-year is clearly established.

Other types of lining materials not specifically listed in Table 5.1 at the end of this chapter may be used when approved by the Director.

The use of concrete lined open channels requires pre-approval from the Director. The Director would consider use of concrete-lined channels in certain redevelopment projects where site conditions did not allow for adjustments to grade or channel location and where structures may be threatened by potential erosion.

6. Side Slopes

Side slopes shall not be steeper than:

- 3 horizontal to 1 vertical for turf lining.
- 2 horizontal to 1 vertical for all other lining materials, unless a geotechnical analysis indicates a steeper slope can be used.
- Side slopes may need to be flatter than 3 horizontal to 1 vertical, if necessary to stabilize slopes.

7. Alignment Changes

Alignment changes shall be achieved by curves having a minimum radius of:

$$R = \frac{V^2 \cdot W}{8D}$$

Where:

R = Minimum radius on centerline in feet

V = Design velocity of flow in feet per second

W = Width of channel at water surface in feet

D = Depth of flow in feet



8. Vertical Wall Channels

Vertical walls may be used for structural lining of improved channels when site conditions warrant; subject to the following special requirements:

- Walls shall be designed and constructed to act as retaining walls.
- Adequate provisions shall be made for pedestrian entry/exit from the channel.

5.4 EASEMENTS

Per the Stormwater Ordinance, permanent easements shall be dedicated to the County for all open channels.

1. Engineered/Natural Channels

Easements shall be 15 feet wide or wide enough to contain the water surface from the 100-year (1% annual chance) return frequency storm, whichever is greater. Easements shall be continuous between street rights-of-way. When an improved channel begins or ends at a point other than the right-of-way of a dedicated street, a 15-foot or wider easement graded to provide maintenance equipment access shall be dedicated from the end of the channel to a street right-of-way. These are minimum requirements.

2. Roadside Channels

Roadside ditches are engineered channels that are located wholly or partly within the street right-of-way. Roadside ditches in the street right-of-way do not require an easement. Otherwise, roadside ditches shall have a dedicated easement from the street right-of-way extending to five feet outside of the top of the outside bank of the channel.



Table 5.1
Permissible Shear Stresses for Lining Material

Lining Category	Lining Type	lb/ft ²	
General	Erosion Control Blankets	1.55-2.35	
	Turf-Reinforced Matrix (TRMs):	Unvegetated:	-----
		Vegetated:	3.0
			8.0
	Geosynthetic Materials	3.01	
	Cellular Containment	8.1	
	Woven Paper Net	0.15	
	Jut Net	0.45	
	Fiberglass Roving:	Single	-----
		Double	0.60
			0.85
	Straw With Net	1.45	
	Curled Wood Mat	1.55	
Synthetic Mat	2.00		
Vegetative	Class A (see Table 5606-2)	3.70	
	Class B (see Table 5606-2)	2.10	
	Class C (see Table 5606-2)	1.00	
	Class D (see Table 5606-2)	0.60	
	Class E (see Table 5606-2)	0.35	
Gravel Riprap	25 mm	0.33	
	50 mm	0.67	
Rock Riprap	150 mm	2.00	
	300 mm	4.00	

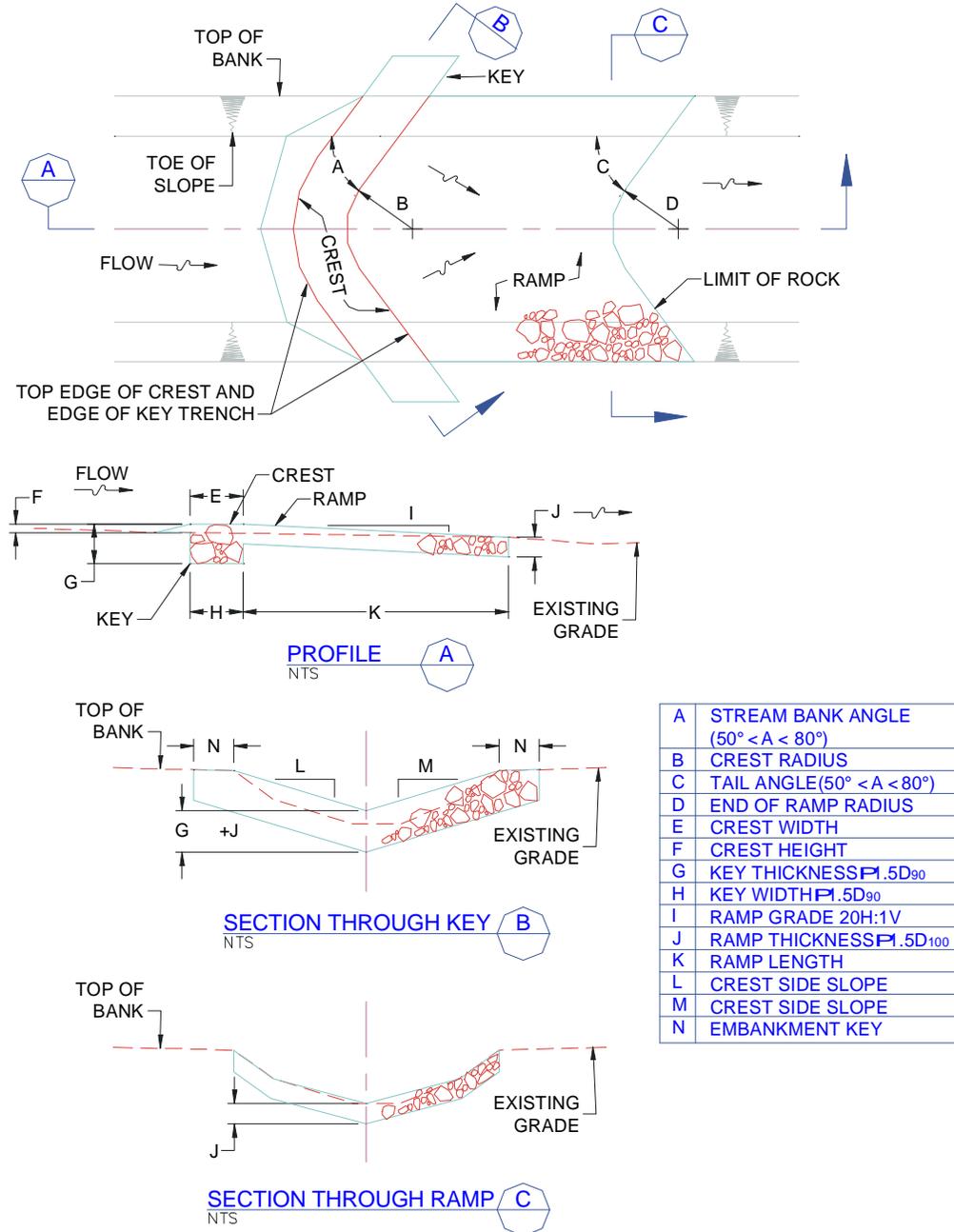
Note: Table 5606-2 from the Kansas City APWA Section 5600 is included for ease of reference on the next page.



Retardance Class	Cover	Condition
A	Weeping Love Grass	Excellent stand, tall (average 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 910 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall (average 300 mm)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short Midwest grasses)	(Good stand, unmowed)
	Weeping lovegrass	Good stand, tall (average 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 480 mm)
	Alfalfa	Good stand, uncut (average 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 330 mm)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut (average 280 mm)
C	Crabgrass	Fair stand, uncut 250 to 1200 mm
	Bermuda grass	Good stand, mowed (average 150 mm)
	Common Lespedeza	Good stand, uncut (average 280 mm)
	Grass-Legume mixture – summer (orchard grass, redtop, Italian ryerass, and common lespedeza)	(Good stand, uncut (150 to 200 mm)
	Centipedegrass	Very dense cover (average 150 mm)
	Kentucky Bluegrass	Good stand, headed (150 to 300 mm)
D	Bermuda grass	Good stand, cut to 60-mm height
	Common Lespedeza	Excellent stand, uncut (average 110 mm)
	Buffalo grass	Good stand, uncut (80 to 150 mm)
	Grass-legume mixture—fall, spring (orchard grass, redtop, Italian, ryegrass, and common lespedeza)	(Good stand, uncut (100 to 130 mm)
	Lespedeza sericea	After cutting to 50-mm height. Very good stand before cutting
E	Bermuda grass	Good stand, cut to height 40-mm
	Bermuda grass	Burned stubble
Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform.		



Figure 5.1: Newberry Style Grade Control Structure



Notes

The depth of key trench shall be a minimum of $1.5 D_{90}$. The crest shall slope downward from the stream bank to the center of the structure to focus the flow to the channel center. The tail ramp is generally sloped at 20 horizontal to 1 vertical and dissipates energy gradually over its length. The upstream face is not perpendicular to the flow but has an upstream oriented "V" or arch shape in plan form.



REFERENCES FOR CHAPTER 5

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CHAPTER 6 STORMWATER MANAGEMENT

6.1 Introduction

Urban and suburban development typically increases impervious surfaces (i.e. pavement and rooftops) which in turn increases the volume and velocity of stormwater discharges. These changes can influence the integrity of the natural stream corridor, which can degrade water quality through the discharge of eroded bank material. Additionally, stormwater runoff from development typically carries a higher load of nutrients and pollutants that can degrade the water quality of receiving lakes and streams.

A nested approach to capturing and treating stormwater runoff will alleviate many of the impacts of development on downstream water quality in addition to providing flood protection. This approach includes; runoff reduction, the treatment of the water quality volume, channel protection, reduction in downstream flooding by detention/retention, and routing of the overflow condition for extreme flood events. Each step in this nested stormwater management strategy provides varying levels of runoff quality and quantity control.

6.2 Runoff Reduction

The idea behind runoff reduction is the removal of a portion of the runoff volume as opposed to capturing that runoff and delaying its release. Runoff reduction can be accomplished through any one or a combination of the following: infiltration, interception and evapotranspiration or capture/reuse. These alternatives allow the post-developed hydrograph to mimic the pre-developed condition and increases groundwater recharge. Per the Stormwater Ordinance, at least 10% of the water quality volume must be addressed through runoff reduction.

To reduce runoff on new development sites the following options are available:

- a. Retain 10% of the total site in trees, grassland or deep-rooted vegetation (shallow-rooted turf grass is not allowed). This 10% of the site must be outside of the Streamside buffer, if applicable.
- b. Re-establish 12% of the total site in trees or deep-rooted vegetation.
 - 1) If planting trees, the density requirement is 6 trees per acre, with a minimum size of 1.5 caliper.
 - 2) If re-establishing native vegetation, the requirement is 80% coverage after two years.
- c. Capture and reuse 10% of the water quality volume
- d. Engineered infiltration
- e. Any combination of the above.



1. Runoff Reduction with deep-rooted vegetation to aid in infiltration.

Historic prairies, wetlands and savannas once occupied millions of acres in North America. Annual plants like corn, or shallow rooted species like bluegrass, have primarily replaced historic communities of deep-rooted, long-lived species (Apfelbaum, 1993). These changes to plant ecosystems have compacted and modified the soil capability to hold water and absorb nutrients.

The native prairie vegetation once contained up to 70% of its biomass below ground. This extensive root system was efficient at carbon fixation, increasing soil organic matter content and infiltration. The soils under the deep roots are able to absorb and hold water in pore spaces throughout the entire rooting depth. Bharati et al., 2002, found that the re-establishment of deep-rooted vegetation improved soil quality and water infiltration after only six years.

Trees also provide numerous water quality benefits, including reductions in stormwater runoff. The tree canopy can capture rainfall, and during hot summer months, much of that water evaporates before it reaches the ground. The duff or leaf layer also stores water like a sponge and works to decompose the vegetation. The root system uses the remaining rainwater that enters the soil, which is then transpired back to the atmosphere.

2. Runoff Reduction with Interception/Evapotranspiration

Although smaller landscaping plants and bushes can provide some interception and evapotranspiration, substantial runoff reduction will come from retaining existing trees and planting new ones. Trees provide runoff reduction via interception, transpiration, and increased infiltration. Additional environmental benefits include improved air quality, reduced heat island effects, pollutant removal and habitat preservation or formation. The degree of runoff reduction provided by trees depends mainly on the tree type (i.e., evergreen or deciduous), canopy area, and the maturity/size of the tree. For an estimate of the amount of interception per tree species, see <http://www.treebenefits.com/calculator/>

3. Runoff Reduction with Capture/Reuse

As many sites look for additional ways to address sustainability, capture and reuse of stormwater – also known as stormwater harvesting – has become an increasingly popular method of runoff reduction. Storage and reuse techniques range from small-scale systems such as rain barrels to cisterns (underground or otherwise) that may hold large volumes of water.

The water captured from a roof tends to be relatively clean (depending on atmospheric conditions, roof material and condition) and often can be used to reduce the potable water used for fire suppression, toilet/urinal flushing or custodial uses with minimal treatment (some facilities rely on a simple swimming pool filter and



chlorine injector). This does require a parallel water system (gray water lines) as this water should not be combined with the potable water source.

Captured rainwater can also be used for landscape irrigation during dry periods. This water would not need to be treated to the same degree as that used for the toilet flushing, but care may need to be taken to remove any solids of a size that could clog the irrigation system. This is especially important if parking lot runoff is used.

Some of these systems can rely on gravity to convey the water while others require some kind of pressurization. This issue should be considered in the design. Cost and frequency of maintenance should also be considered.

The County will allow the designer to assume that the facility will be completely drained between storms. However, an overflow system should be provided when the capacity of the facility is exceeded.

4. Engineered Infiltration

Engineered infiltration is the use of a highly pervious media underlain by an aggregate bed for temporary storage and infiltration of stormwater runoff. Subsurface infiltration is well suited for expansive, generally flat open spaces, such as lawns, meadows, and ball fields, which are located downhill from nearby impervious areas. Stormwater runoff from impervious areas (including rooftops, parking lots, roads, walkways, etc.) is conveyed to the subsurface storage media, and distributed via a network of perforated piping. The storage media typically consists of clean washed, uniformly graded aggregate. However, other proprietary alternatives are available. These alternatives are generally variations on plastic cells that more than double the storage capacity of aggregate beds. Storage media alternatives are suited for sites where potential infiltration area is limited. If designed, constructed, and maintained these features can stand-alone as stormwater runoff volume, rate and quality control practices. If connected to shallow groundwater, then these systems can also maintain aquifer recharge, while preserving valuable open space.

6.3 Treatment of the Water Quality Volume

In order to reduce nonpoint source pollution from a development, the engineer should review the types of pollutants expected from the various surfaces and work to address the pollutant load in the “first flush”, typically defined as the water quality volume (defined in Chapter 3) less any volume subtracted through runoff reduction. In order to do this, the engineer should look for ways to reduce runoff (system disconnection and infiltration, evapotranspiration and/or capture-reuse) to the maximum extent practicable. Then, the remainder of the water quality volume should be treated in BMPs appropriate to the types of pollutants expected. At this time, specific numeric discharge limits and/or pollutant removal rates are not being prescribed. However, as state and federal laws change, the County may re-evaluate the need to set pollutant limits.



1. Design Guidance for Water Quality BMPs

Design criteria for the sizing of the more common stormwater quality BMPs appear in the Mid-America Regional Council (MARC) Manual of Best Management Practices for Stormwater Quality dated March 2008. BMP design criteria are rapidly developing and regularly being refined. If the Engineer prefers to use another source for design guidance, the source should be cited within the design calculations. Sizing information for proprietary BMPs is usually available from the manufacturer and should also be cited as such.

Various land uses and cover types produce different types of pollutants and impact stormwater volumes and velocities in different, but predictable, ways. This section provides general information related to stormwater quality BMPs in addition to a discussion of how each land use type can be addressed.

a. Treatment of Discharge from Buffer Areas and Forests

Natural vegetation provides filtration, infiltration and evapotranspiration of most of the rainfall in these areas and therefore no specific treatment is required for runoff from these areas. Protection of these areas and guidelines for maintenance should be included in the overall post-construction stormwater management operation and maintenance plan. These areas should still be included in the overall runoff calculations for stormwater quantity management.

b. Treatment of Discharge from Rooftops

The runoff discharged from rooftops is relatively clean. The biggest concerns are the temperature of the runoff, any pollutants picked up from the atmosphere and the overall quantity of the water. This water can be reused as a no potable source which is addressed above in Runoff Reduction. When rooftop water is captured and reused, this can serve as both the water quantity and quality BMP. The only additional treatment necessary will be dictated on the type of reuse. For instance, if roof runoff is used for toilet flushing, the water may need additional treatment (filter, chlorination, uv, etc) to be suitable for this purpose. Likewise, if the runoff is used for irrigation, treatment may be needed to prevent clogging of the irrigation system.

If rooftop water is not going to be captured and reused, measures must be taken to address the impacts of the runoff. However, if this water is allowed to discharge across a driving surface, it could pick up significantly more contaminants. Therefore, this should be avoided whenever possible. Additionally, remove direct connection of rooftop water from the storm sewer system whenever feasible.



- c. Treatment of Discharge from Managed Lawns/Landscaped Areas**
The runoff discharged from managed lawn and landscaped areas can contain a variety of pollutants from pesticides, herbicides, fertilizers and animal sources. Poorly maintained areas that are actively eroding can also be a source of sediment discharge. Where these areas are near pedestrian or vehicle traffic, litter may be an additional issue. Runoff resulting from the water quality volume that has not been removed through runoff reduction will need to address these issues. Additionally, non-structural measures should be included in the overall post-construction stormwater management operation and maintenance plan. This may include standard operating procedures for care of these areas related to agrochemical application, mowing height, litter removal, etc.
- d. Treatment of Discharge from Parking Lots/Driveways/Roads**
The runoff discharged from parking lots, driveways and roads can contain a wide variety of pollutants including particulates, nitrogen, phosphorus, lead, zinc, iron, copper, cadmium, chromium, nickel, manganese, cyanide, sodium chloride, calcium chloride and sulphates, and phenols. Additionally, litter from these areas is a primary source of floatables in the receiving water bodies. Water temperature from parking lots can reach levels that are toxic to fish in the receiving waterbody. Runoff resulting from the water quality volume that has not been removed through runoff reduction will need to address these issues. Up to 25% of a site's total impervious surfaces may discharge in a sheet flow condition through existing established vegetation such as may exist in a stream buffer without otherwise being treated. However, this quantity should still be considered in the overall stormwater quantity management.
- e. Treatment of Off-Site Stormwater:** Off-site stormwater conveyed through a land development shall be placed within an easement and conveyed in a manner that does not increase upstream or downstream flooding. Off-site stormwater shall be conveyed around on-site stormwater BMPs, unless the facilities are designed to manage the off-site stormwater. The Director may allow the treatment of off-site stormwater in lieu of the treatment of the entire site's water quality volume.
- f. Additional Criteria for Stormwater Hotspots:** In addition, stormwater discharges from stormwater hotspots may require the use of specific structural, non-structural, and/or pollution prevention practices, including enhanced pre-treatment. Discharges from a stormwater hotspot shall not be infiltrated without enhanced pre-treatment, as approved by the Director.



- g. **Landscape Plan:** The design of vegetative stormwater BMPs shall include a landscape plan detailing both the vegetation in the BMP and the maintenance requirements, and who will manage and maintain the vegetation.

2. Pre-treatment for Water Quality BMPs

Even after site stabilization, BMPs may need adequate pre-treatment to filter coarse pollutants such as sediment and grit to promote long-term functionality. Some fine media filter systems such as sand filters and some proprietary products may also need pre-treatment in order to minimize operation and maintenance costs and activity intervals. A coarse stone diaphragm, settling forebay, vegetative swale/buffer or hydrodynamic separator could serve this purpose.

Pre-treatment may also be needed for BMPs that detain/retain runoff to reduce the operation and maintenance requirements. Detention/retention ponds do very little to address water quality, therefore a forebay or similar pre-treatment method should be used to reduce sediment, trash and nutrients from entering downstream water and reduce the need for expensive dredging or cleaning of the basin.

3. Protection of Water Quality BMPs from Construction Site Runoff

BMPs that rely on infiltration such as bioretention, rain gardens and infiltration basins or trenches, will clog if exposed to excessive sediment. Most permanent stormwater treatment BMPs will need to be installed only after the construction site has been stabilized. BMPs that rely on settling and filtration could likewise require extensive maintenance to preserve functionality.

6.4 Channel Protection

As urbanizing areas are converted from fields to impervious surfaces, the volume of runoff and the frequency of "channel-forming" events increases substantially. Research suggests that this change in hydrology can cause channels to expand to two to five times their original size (Hammer, 1972, Moriwasa and LaFlure, 1979, Allen and Narramore, 1985 and Booth, 1990). Channel erosion, on average, is estimated to account for 66% to 75% of the sediment load in urban watersheds (Trimble, 1997 and Dartinguenave *et al.*, 1997).

To reduce channel erosion on downstream properties and protect in-stream habitats, the stormwater system shall be designed so that post-development discharges will not erode natural channels or steep slopes. The following Tier 1 and/or Tier 2 Performance Criteria are required for all developed sites.

1. **Tier 1 Performance Criteria:** sites having less than 5 acres of land disturbance and less than 20% imperviousness on the entire tract shall apply the following performance standards:



- a. Wherever practical, maintain sheet flow to riparian buffers or vegetated filter strips. Vegetation in buffers or filter strips must be preserved or restored where existing conditions do not include dense vegetation.
- b. Energy dissipaters and/or level spreaders must be used to spread flow at outfalls.
- c. On-site conveyances must be designed to reduce velocity through a combination of sizing, vegetation, check dams, and filtering media (e.g., sand) in the channel bottom and sides.
- d. If flows cannot be converted to sheet flow, they must be discharged at an elevation that will not cause erosion or require discharge across any constructed slope or natural steep slopes.
- e. Outfall velocities must be non-erosive from the point of discharge to the receiving channel or waterbody where the discharge point is calculated.

2. **Additional Performance Criteria for Tier 2 sites:** Sites greater than 5 acres of land disturbance OR greater than 20% imperviousness on the entire tract shall apply the performance standards in subsection (1), in addition to the following performance standards:

- a. Site design techniques that decrease runoff volumes and peak flows. This shall be accomplished by controlling the post-development peak discharge rate to the pre-development rate.

This criterion shall be met for the 2-year, 24-hour storm event, (or equivalent storm runoff volume using other methodologies). The release rate shall be equal to or less than the 1-year, 24-hour storm event. Boone County will give credit for the application Runoff Reduction and WQv measures towards meeting the storage requirements.

OR

- b. In an effort to encourage micro-detention and utilize stormwater BMPs to detain stormwater, the difference (increase) in the runoff volume that is predicted due to the development during the 2-year event will be stored and released at no more than 0.1 cfs/acre; providing that 75% of the water leaving the site drains through at least one of storage basin, and that the volume stored accounts for the added runoff from the entire disturbed site. See Chapter 3 for calculation procedures.

6.5 Flood Control

Stormwater detention facilities are designed specifically to receive and temporarily hold stormwater runoff to provide channel protection and prevent downstream flooding. Detention facilities can delay the discharge of peak flows and reduce velocities to minimize stream bank erosion in downstream waterbodies. Retention facilities are



established for permanent storage of water; only releasing water during the design storm or through evaporation and groundwater recharge. Stormwater storage BMPs that rely primarily on infiltration and evapotranspiration can more closely mimic the pre-development hydrology of the site.

Extensive consideration should be given to Low Impact Development techniques that allow dispersed micro detention to better mimic the site's original hydrology. Swales, rain gardens, Bioretention and constructed wetlands, infiltration basins/trenches, etc can achieve both water quantity and water quality control goals. Many of these systems may not be sufficient to control peak flood control volumes. Overflow systems and additional storage may be necessary to fully control peak discharges.

Flood Control Criteria: Downstream overbank flood and property protection shall be provided by controlling the post-development peak discharge rate to the pre-development rate. This criterion shall be met for the 25-year, 24 hour storm event on property zoned REC, REC-P, C-O, C-N, C-G, C-GP, M-L, M-LP, M-G, M-GP.

Stormwater BMPs that impound water shall demonstrate that the 100-year storm can safely pass through the structure without overtopping or creating damaging conditions downstream.

1. **Discharge to Large Waterbody:** The land development discharges directly to a flood plain, major river or waterbody and the Director determines that waiving the flooding criteria will not harm public health and safety. The applicant shall secure drainage easements from any downstream property owners across whose property the runoff must flow to reach the flood plain, major river or waterbody. The applicant shall also demonstrate that any piped or open-channel system in which the runoff will flow has adequate capacity and stability to receive the project's runoff plus any off-site runoff also passing through the system.
2. **Insignificant Increases in Peak Flow:** The land development results in insignificant increases in peak flow rates, as determined by the Director.
3. **Alternative Criteria Provided:** The land development is subject to a floodplain study that recommends alternative criteria for flood control.
4. **Increases in Downstream Peak Flows or Flood Elevations:** The Director determines that complying with the requirements of this section will result increases in peak flows or downstream flooding conditions due to coincident peaks from the site and the contributing watershed or another factor.
5. **Documentation for Waiver:** When seeking a waiver in accordance with either (1), (2), (3) or (4) above, the applicant shall demonstrate that stormwater discharges will not unreasonably increase the extent, frequency, or duration of flooding at downstream properties and structures or have an unreasonable adverse effect on



streams, aquatic habitats, and channel stability. In making its determination to allow full or partial waivers, the Director shall consider cumulative impacts and the land development's adherence to the land use plans and policies of Boone County, including the promotion of infill and redevelopment in particular areas.

6.6 Redevelopment Criteria

Redevelopment is any development that creates or adds three thousand (3,000) square feet or more of impervious cover by modifying a previously existing improved property. This includes the building of structures, filling, grading, paving; (including the conversion of gravel areas to pavement), or excavating.

Redevelopment excludes ordinary maintenance activities such as remodeling of buildings on the existing footprint, resurfacing and/or repaving of existing paved areas, and exterior changes or improvements that do not materially increase or concentrate stormwater runoff or cause additional nonpoint source pollution.

Land development that qualifies as redevelopment shall meet one of the following criteria:

1. **Reduce Impervious Cover:** Reduce existing site impervious cover by at least 20%.
2. **Provide Treatment:** Provide water quality treatment for at least 20% of the site's pre-development impervious cover and 100% of any new impervious cover, not to exceed 150% of the total new impervious.
 - a. This can be accomplished through stormwater BMPs designed in accordance with the criteria in Ordinance Sections 4.2 through 4.3 and the Boone County Stormwater Design Manual.
 - b. Runoff reduction may be used instead of water quality treatment on land zoned Residential, Transition or Agriculture where the lot size is at least 2.5 acres and impervious cover is less than 10%.
3. **Apply Innovative Approaches:** Utilize innovative approaches to reduce stormwater impacts across the site. Examples include green roofs and pervious parking materials.
4. **Provide Off-Site Treatment:** Provide equivalent stormwater treatment at an off-site facility within the same watershed and as immediately downstream of the site as feasible.
5. **Address Downstream Issues:** Address downstream channel and flooding issues through channel restoration, increase in existing system capacity and/or other off-site remedies.



6. Combination of Measures: Any combination of (1) through (5) above that is acceptable to Boone County Public Works.

6.7 Detention and Infiltration Basin Requirements

Stormwater detention facilities are designed to receive and temporarily hold stormwater runoff to protect downstream areas from flooding. Detention facilities can delay the discharge of peak flows and reduce velocities to minimize streambank erosion in downstream waterbodies. On the other hand, *retention* facilities are for the permanent storage of water; only releasing water during the design storm or through evaporation and groundwater recharge.

1. General Provisions:

- a. Dams which are greater than 10 feet in height but do not fall into State or Federal requirement categories shall be designed in accordance with the latest edition of NRCS (SCS) Technical Release No. 60, "Earth Dams and Reservoirs", as highest hazard rated structures.
- b. All lake and pond development must conform to local, state, and federal regulations. Legal definitions and regulations for dams and reservoirs can be found in the Missouri Code of State Regulations, Division 22.
- c. The water surface of the design storage pool shall be a minimum of 20 feet from building structures. A greater distance may be necessary when the detention facility might compromise foundations or if slope stability is a consideration. The vertical separation between the maximum ponding elevation and the lowest floor of applicable surrounding structures shall be a minimum of 2.0 feet.
- d. In developments where a public street is proposed across the dam of a permanent lake, a right-of-use agreement shall be executed between Boone County and the developer/owner. This right-of-use agreement shall specify that Boone County will maintain the street pavement, sidewalk, street curb inlets and the accompanying piping. The ownership, maintenance of the dam, outlet structures and overflow spillway shall be the responsibility of the developer/owner, homeowners association or other identified responsible party.



2. Primary Outlet Works

The primary outlet shall be designed to meet the following requirements:

- a. The outlet shall be designed to function without requiring attendance or operation of any kind or requiring use of equipment or tools, or any mechanical devices.
- b. All discharge from the detention facility when inflow is equal to or less than the 25-year inflow shall be via the Primary outlet.
- c. The design discharge rate via the outlet shall continuously increase with increasing head and shall have hydraulic characteristics similar to weirs, orifices or pipes.
- d. For dry detention basins, the design shall allow for discharge of at least 80 percent of the detention storage volume within 24 hours after the peak or center of mass of the inflow has entered the detention basin.
- e. Retention basins (Ponds) shall be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.
- f. The Director may require openings be protected by trash racks, grates, stone filters, or other approved devices to insure that the outlet works will remain functional.

3. Emergency Spillways and Draw Down

The emergency spillway may either be combined with the outlet works or be a separate structure or channel meeting the following criteria:

In cases where the impoundment/emergency spillway is not regulated by either State or Federal agencies, the emergency spillway shall be designed to pass the 100 year (1% annual chance) storm with 1 foot of freeboard from the design stage to the top of dam, assuming zero available storage in the basin and zero flow through the primary outlet. This design provides an added level of protection in the event of a clogged primary outlet or a subsequent 100 year (1% annual chance) storm event that occurs before the flood pool from the initial storm event recedes to the principal outlet elevation.

Drain works consisting of valves, grates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less when required for maintenance or inspection shall be provided. Pumping will be considered an alternative if the design engineer can show this is a readily available, viable solution.



4. Erosion Control

Primary outlet works, emergency spillways, and dams, as well as conveyance system entrances to detention basins, shall be equipped with energy dissipating devices as necessary to limit shear stresses on receiving channels.

5. Retention Facility or Wet Pond

For basins designed with permanent pools a sediment forebay shall be provided to trap coarse particles. The minimum normal depth of water before the introduction of excess stormwater shall be four feet. If the pond is to contain fish, at least one-quarter of the area of the permanent pool must have a minimum depth of 10 feet. The side slopes shall conform as closely as possible to regraded or natural land contours, and should not exceed three horizontal to one vertical. Slopes exceeding this limit require erosion control, reasonable safety measures and a geotechnical analysis.

6. Detention Facility or Dry Pond

For facilities designed to be normally dry, a sediment forebay shall be provided to trap coarse particles. Provisions must be incorporated to facilitate interior drainage to outlet structures. Grades for drainage facilities shall not be less than 1½ percent. Paved trickle channels are prohibited. Earth bottoms shall be sodded or vegetated with appropriate native, non-invasive vegetation. A turf-type tall fescue blend is an acceptable alternative. The side slopes of dry ponds should be relatively flat to reduce safety risks and help to lengthen the effective flow path. Slopes shall not be steeper than three horizontal to one vertical.

7. Multipurpose Feature

When possible, dry detention facilities can be designed to serve secondary purposes for recreation, open space, or other types of use which will not be adversely affected by occasional or intermittent flooding.

8. Rooftop Storage

Detention storage may be met in total or in part by detention on roofs. Details of such designs shall include the depth and volume of storage, details of outlet devices and downdrains, elevations and details of overflow scuppers, and emergency overflow provisions. Consideration shall also be given to wave action on structural loading conditions. Connections of roof drains to sanitary sewers are prohibited. Design loadings and special building and structural details shall be subject to approval by the **Director of Planning and Building Inspection**.

Additionally, “green” roof technology that utilizes plant material to provide storage, treatment and evapotranspiration of the stormwater can be utilized to achieve quantity control requirements as well as water quality objectives. The green roof industry has a resource portal at www.greenroofs.com

9. Parking Lot Storage

Parking lots paved with traditional impervious pavements may be designed to provide temporary detention storage of stormwater on a portion of their surfaces. Generally,



such detention areas shall be in the more remote portions of such parking lots. Depths of storage shall be limited to a maximum depth of six inches, and such areas shall be located so that access to and from parking areas is not impaired.

Parking lots paved with pervious pavements or that are designed with innovative turf reinforcement techniques may be designed to provide temporary detention storage of stormwater below their surface in the pore spaces of granular media. The designer should consider the infiltration rate of the soil beneath the media and provide underdrains as necessary to allow for discharge of at least 80 percent of the detention storage volume within 24 hours after the peak or center of mass of the inflow has entered the detention system through either infiltration to the soil or through the underdrains or a combination thereof.

10. Underground Storage

All or a portion of the detention storage may also be provided in underground detention areas, including, but not limited to, oversized storm sewers, vaults, tanks, etc.

Design underground detention facilities with adequate access for maintenance (cleaning and sediment removal). Provide such facilities with positive gravity outlets. Venting shall be sufficient to prevent accumulation of toxic or explosive gases.

11. Other Storage

Extensive consideration should be given to Low Impact Development techniques that allow for dispersed microdetention to better mimic the site's original hydrology. Swales, rain gardens, bioretention and constructed wetlands infiltration basins/trenches, etc can achieve both water quantity and water quality control goals. Additionally, storage and reuse of stormwater for irrigation or toilet flushing is highly encouraged. Many of these systems may not be sufficient to control peak flood control volumes. Overflow systems and additional storage may be necessary to fully control these peak discharges.

6.8 Required Submittals for Detention and Infiltration Basins

The Owner shall submit the following information and data to the Director.

1. Elevation-area-volume curves for the storage facility including notation of the storage volumes allocated to runoff, sediment, and permanent residual water storage for other uses (wet basins only).
2. Inflow hydrographs for all design storms.
3. Stage-discharge rating curves for the emergency spillway, primary outlet works and combined outlets and overflows.
4. Routing curves for all design storms with time plotted as the abscissa and the following plotted as ordinates:
 - a. Cumulative inflow volume.
 - b. Cumulative discharge volume.
 - c. Cumulative storage.
 - d. Stage elevation



5. Operation and maintenance plan

6.9 Ongoing Maintenance for Stormwater BMPs

All stormwater facilities and BMPs shall be maintained in accordance with the approved and recorded stormwater maintenance agreement and stormwater maintenance plan. If no maintenance agreement or plan is in place, the owner shall maintain the facility as designed in order to continue the mitigation of stormwater quantity and quality impacts. This maintenance shall include removal of overgrown vegetation, repair of erosion, repairs to any inlet/outlet structures, and removal of excess silt or any other maintenance deemed necessary to provide said mitigation. The design of stormwater facilities shall incorporate maintenance accommodation and long-term maintenance reduction features.

1. Maintenance Responsibility

The responsible party named in the recorded stormwater maintenance agreement (Section 3.7) shall maintain in good condition and promptly repair and restore all structural and non-structural stormwater facilities and BMPs. The responsible party shall maintain all necessary access routes and appurtenances (grade surfaces, walls, drains, dams and structures, vegetation, erosion and sedimentation controls, and other protective devices) in order to maintain the mitigation of stormwater quantity and quality impacts. Such repairs or restoration and maintenance shall be in accordance with the approved stormwater management construction plan, the stormwater maintenance agreement and the stormwater maintenance plan.

2. Inspection by Boone County Public Works

The County may enter and inspect facilities subject to regulation often as necessary to determine compliance with the stormwater ordinance. If the site has security measures in force that require proper identification and clearance before entry, the responsible party shall make the necessary arrangements to allow access to representatives of the County.

3. Records of Maintenance Activities

The responsible party shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least five (5) years. These records shall be made available to the Director during inspection of the facility and at other reasonable times upon request.

4. Failure to Provide Adequate Maintenance

In the event that the stormwater BMP has not been maintained and/or becomes a danger to public safety or public health, the Director shall notify the responsible party by registered or certified mail. The notice shall specify the measures needed to comply with the maintenance agreement and the maintenance plan and shall specify that the responsible party has thirty (30) days or other time frame mutually agreed to between the Director and the responsible party, within which such measures shall be completed. If such measures are not completed, then the Director shall pursue enforcement procedures pursuant to Section 9 of this Ordinance.



If a responsible person fails or refuses to meet the requirements of an inspection report, maintenance agreement, or maintenance plan; the Director, may correct a violation of the design standards or maintenance requirements by performing the necessary work to place the practice in proper working condition. The Director may assess the responsible party of the practice for the cost of repair.

5. Required Easements

Easements for the stormwater management facilities including structural facilities, engineered channels and overflow paths, are required. Drainage easements shall include access from a convenient public street or parking lot. Minimum dimensions are as follows:

- a. Where a storm drain consists of a closed conduit, the width shall be the greater of fifteen (15) feet or the sum of the conduit diameter and twice the cover depth over the conduit.
- b. The stormwater drainage system easements shall contain the overflow from the 100-year (1% annual chance) storm event and shall indicate the highest expected water surface elevation of said event.
- c. Access easements to and around detention/retention facilities shall be a minimum of fifteen (15) feet wide with cross slopes to be safely accessible by a vehicle unless otherwise approved by the Director.



Figure 6.1

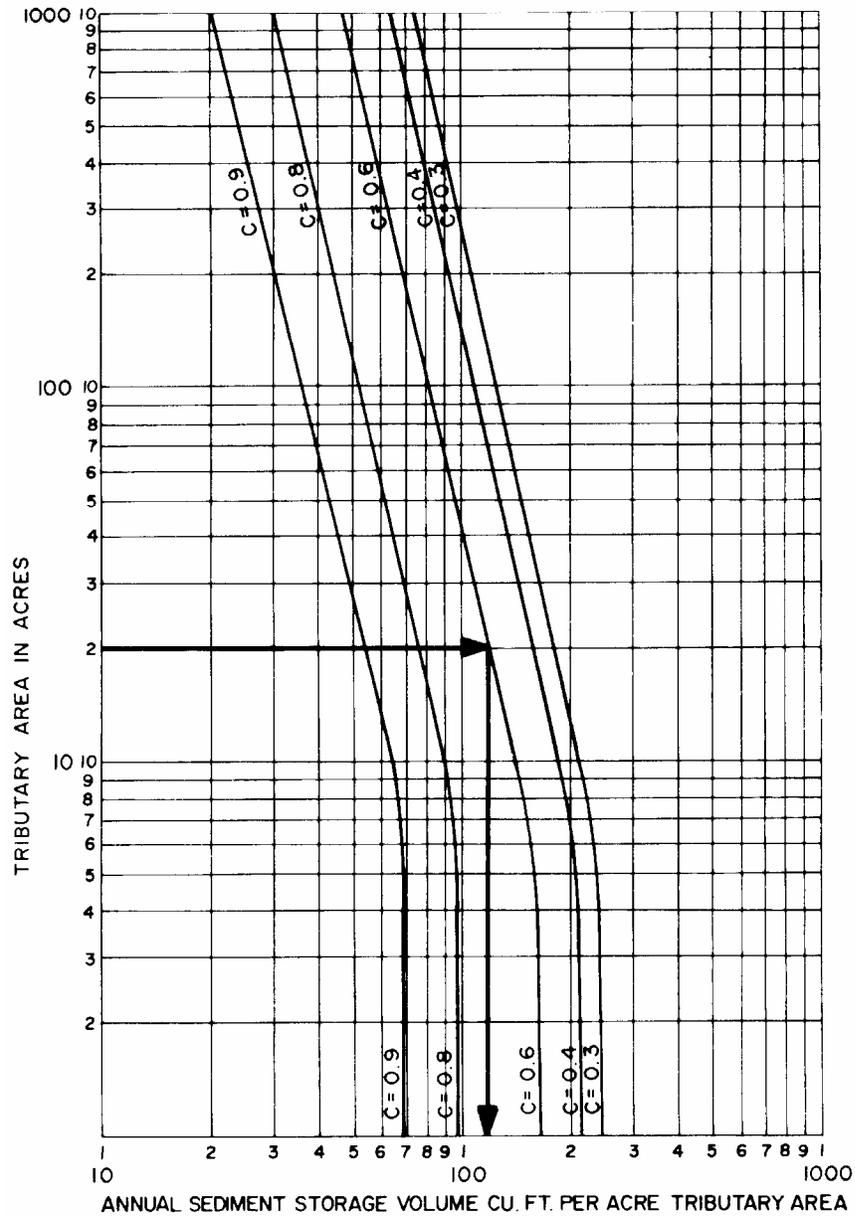
EXAMPLE:

TRIBUTARY AREA = 20 ACRES

RATIONAL METHOD RUNOFF COEFFICIENT "C" = 0.6

SEDIMENT STORAGE = 120 CU. FT. PER ACRE PER YEAR

TOTAL SEDIMENT STORAGE = 120 X 20 = 2400 CU. FT. PER YEAR.



ANNUAL SEDIMENT STORAGE



CHAPTER 7 PROTECTION OF ENVIRONMENTALLY SENSITIVE AREAS

7.1 Introduction

Boone County is located in the Ozark Highlands physiographic region. The bedrock for this region is Mississippian Age limestone, which is highly susceptible to solution weathering. This geology is commonly referred to as “Karst” and is characterized by numerous sinkholes, losing streams, springs, caves, and other related features. As a result, a complex and often fragile interaction exists between surface and groundwater, requiring special consideration and protection. Development on Karst geology can present certain hazards such as unstable soil foundation for structures, flooding, groundwater contamination, and public safety hazards related to sinkhole collapses. In Missouri, fifty-nine percent of the state is underlain by thick, carbonate rock units that host a wide variety of Karst features. This geology is in part, the reason Missouri has large rivers and beautiful streams, as well as plentiful underground water resources.

Additionally, Boone County’s extensive stream network lends itself to the development of wetland areas along the stream corridors and lowland floodplain areas. Wetlands provide a wide range of water quality and quantity control in addition to many ecological, recreational and aesthetic benefits.

Various other environmentally sensitive areas have been identified by state and federal agencies for additional pollution and flooding protection. Lists of these areas are provided in Appendix C.

7.2 Protection and Hazard Minimization Approach

Cleaning up groundwater contamination is time-consuming, expensive and seldom entirely successful. Removing contamination from Karst ecosystems adds additional layers of complexity. Due to the difficulty in tracking underground flow pathways, it is extremely easy to cause accidental damage by the release of pollutants or changes in flow regime. Therefore, prevention by buffering and avoidance is best.

Design standards and methodologies to avoid stormwater releases in areas with Karst topography and minimize potential environmental impacts from development near environmentally sensitive areas are contained in this chapter. The general policy in addressing sensitive area protection is based on the following stepped approach to minimize impacts:

- 1. Avoidance** – Avoid disturbance and impacts in and around environmentally sensitive areas to the Maximum Extent Practicable.



2. **Minimization** – If disturbance or impacts are necessary, they must be minimized to protect against harm to others or the environment.

7.3 Buffer Requirements for Environmentally Sensitive Areas.

1. Per the Stormwater Ordinance, these provisions apply to any stormwater discharge or drainage on new development or redevelopment sites within Boone County that meets one or more of the following criteria:
 - a. Within 1000 feet of and draining to a losing stream*, Outstanding National or State Resource Water*
 - b. Within 100 feet of a Class P Stream*, or Type 1 stream per the Stream Buffer Regulations
 - c. Within 1000 feet of and draining to, or changes the site hydrology of, a jurisdictional wetland as defined by the U.S. Army Corps of Engineers; or
 - d. Runoff that discharges to a groundwater point recharge feature such as a sinkhole or other direct conduit to groundwater such as a cave.

*See listings in Missouri Water Quality Standards 10 CSR 20-7.031. This information is also provided in Appendix C.

2. **Land Disturbance Permit Threshold Lowered:** When any of the above conditions exist, permitting related to land disturbance, stormwater management and water quality control will be required for any land disturbance greater than 3000 square feet.
3. **General Stormwater Management:** Drainage patterns for proposed development must be designed to protect sensitive areas from the effects of runoff from developed areas, and to maintain the drainage areas of groundwater recharge features in a natural state. Special controls must be used where necessary to avoid the effects of erosion, sedimentation, and/or high rates of flow.
4. **Buffer zone limitations and prohibitions:** The natural vegetative cover must be retained within a buffer zone described in this section. All construction activities including grading and filling are prohibited. Additionally, wastewater disposal or irrigation is prohibited.
5. **Buffer zone widths:** The following buffer widths are required to reduce construction activities and retain the natural vegetative cover in unique and environmentally sensitive areas throughout the County.
 - a. Point Recharge Feature (Sinkholes): For a point recharge feature, the buffer zone coincides with the topographically defined drainage area, except that the width of the buffer zone from the edge of the sensitive area shall not be less than 150 feet, or greater than 300 feet from the sinkhole eye.



- b. Wetlands: For a wetland, the buffer zone shall be at least 50 feet.
- c. Outstanding Resource Waters/Losing Streams: For national or state outstanding resource waters, the buffer zone shall be twice that of the stream buffer requirement. (Chapter 26 Boone County Zoning Regulations)
- d. Other Features: For other environmentally sensitive areas, the buffer zone shall be at least 50 feet.

7.4 Wetland Protection

Wetlands are defined as transitional land between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands reduce flooding by absorbing water during rain storms. Wetlands slowly release their water into streams, keeping the stream flows continuous and providing habitat for fish and the invertebrates that serve as food for the fish. Some water percolates from the wetland into the ground and eventually recharges the groundwater. Wetlands can filter out pollutants and trap silt and sediment. Wetlands also provide extensive animal and plant habitat in addition to offering both aesthetic and recreational value.

An area shall be classified as a wetland if it meets the Army Corps of Engineers three (3) parameter technical criteria as outlined in the Corps of Engineers 1987 Wetlands Delineation Manual (Section D. Routine Determinations) under normal conditions:

1. three parameters for wetland determination include prevalence hydrophilic vegetation, hydric soil formation, and presence of adequate hydrology
2. recommended routine method: wetland hydrology and hydric soils can be assumed if an area under examination is dominated (over 50% vegetative cover) by Facultative-wet and/or Obligate plant species as listed in the National List of Plant Species That Occur in Wetlands, Region 3 U.S. Department of the Interior, Washington D.C.; and an abrupt boundary is evident between Facultative-wet and/or Obligate plant communities and Upland plant communities
3. if the area is dominated by Facultative plant species, the hydric soil and hydrology parameters cannot be assumed; therefore, are also required for determination as a wetland
4. exceptions include permitted water quality wet ponds, and ponds fed by wells or other artificial sources of hydrology

Wetlands meeting the Army Corps of Engineers definition of a jurisdictional wetland must be protected in all watersheds. Protection methods for wetlands include:

- a. Appropriate setbacks that preserve the wetlands or wetland functions;
- b. Wetland mitigation, including wetland replacement;
- c. Wetland restoration or enhancement.



The Director may approve the removal and replacement of a wetland if approved by the U.S. Army Corps of Engineers or the elimination of setbacks from a constructed wetland that is primarily used for water quality control.

Questions regarding wetland delineation, or permit and mitigation requirements should be directed to the U.S. Army Corps of Engineers, Kansas City District.

U.S. Army Corps of Engineers, Northwestern Division
Kansas City District
601 E 12th Street
Kansas City, Mo 64106

Phone: 816-389-3486
<http://www.nwk.usace.army.mil/index.cfm>

7.5 Karst Identification and Protection

A unique characteristic of Karst systems is the speed with which groundwater can move. Karst groundwater travel rates are often in the range of a mile per day, as opposed to a few feet per year in non-Karst areas. As a result, a contaminant may reach some springs or wells within a few hours after entering the groundwater system. Travel time is also dependant on the characteristics of the contaminants, such as viscosity. Another consideration of Karst systems is that water entering the subsurface at a single point may discharge from multiple springs and wells. The discharge points can be in different stream or river basins and may be separated from one another by a number of miles.

1. Sinkholes

Per the Stormwater Management Ordinance, any land disturbance activity within a sinkhole including the stabilization of collapse sinkholes requires a land disturbance permit from Boone County Planning. For the purpose of establishing standards for addressing sinkholes, they will be referred to in this chapter as being in one of two broad categories: depression sinkholes or collapse sinkholes.

- a. Depression sinkholes have a defined drainage area and will generally be shown on topographic maps as a closed contour. Development concerns related to depression sinkholes that must be addressed include flood hazards and soil stability within the geologic rim. When runoff from a development is draining to a depression sinkhole, impacts to groundwater quality must be addressed through on-site Best Management Practices (BMPs).
- b. Collapse sinkholes are areas of karst-related subsidence with no defined drainage area when occurring outside of a depression sinkhole. Collapse sinkholes can occur in the bottom of a depression sinkhole and are commonly referred to as the “eye” of the sinkhole.



c. Sinkhole Evaluation

A sinkhole evaluation **must** be completed by a professional engineer or geologist. Sinkholes receiving an increase in runoff volume from a proposed development require an evaluation with the following components:

1. Drainage area map
2. Details of the drainage path of the discharge from the development to the sinkhole (including offsite sinkholes)
3. Sinkhole boundary map based on topography
4. Geological Evaluation

d. Geological Evaluation

A professional geologist or a professional engineer with a demonstrated expertise in geotechnical applications is required if it is determined that the sinkhole will have a geological or hydrological effect off-site, or to determine the structural integrity of the geology, and the stability of the formation. The geological evaluation shall provide the following information:

1. Identification of all sinkholes as depression or collapse sinkholes.
2. A map of the topographic rim (highest closed contour) of all depression sinkholes.
3. A map of the geologic rim based on geologic evaluation of all depression and collapse sinkholes.
4. A map showing non-buildable areas for buildings and other structures on the tract, based on topographic and geologic rims of depression and collapse sinkholes.
5. Detail of proposed stabilization of collapse sinkholes, if applicable.

The topographic rim shall be based on a 2-foot contour interval or less. If the topographic rim is designated a no-build zone, determination of the geologic rim may not be necessary. The no-build zone, at a minimum, shall cover the geologic rim. The flooding evaluation must also be considered when determining the no-build zone.

e. Water Quality Protection

Sinkholes conduits can provide direct recharge routes to groundwater. As a result, these conduits can provide a route for polluted runoff to enter drinking water supplies that are otherwise protected and often being consumed with no treatment. Protection of water quality entering sinkholes helps to insure the quality of area wells, caves, springs and streams. Because the nature of groundwater movement is complex and not fully known, it is assumed that any conduit could potentially be a source of any of the features mentioned above. Therefore, it is critical to



implement water quality protection practices within all developments that drain to sinkholes. Special restrictions may apply to developments within close proximity to private or public wells or in the Devil's Icebox or Hunter's Cave recharge areas as delineated in the Bonne Femme Watershed Plan and in areas that may have an effect on endangered or endemic species.

- f. **Sinkhole or cave-related non-buildable areas:** In areas of extreme risk of flooding, water quality impairment impacts, or potential for sinkhole collapse, the Director of Public works may establish some areas as non-buildable. Discussion during the preliminary plan/plat review phase should address these concerns and establish the required setbacks prior to developing the engineered set of construction plans. No grading or installation of parking areas, streets or other infrastructure shall be permitted within the non-buildable area unless otherwise authorized by the Director.

This non-buildable area shall follow the limits of the sinkhole in most cases. However, the non-buildable area may be expanded or contracted by action of the Director where warranted, due to the nature of the specific sinkhole or cave, the underlying geology, soils, drainage, and any related information, such as depth to bedrock.

In sinkhole cluster areas, the Director may require the developer to provide recommendations from a consulting engineer and a consulting hydrogeologist, based upon substantial and state-of-the-art field studies and evaluation of the specific sinkhole or cave system. These studies shall be submitted to the Director

- g. **Development in Sinkhole Drainage Areas without Discharge to Sinkhole:** Development may occur in the immediate sinkhole drainage area if the developer provides alternative surface drainage away from the sinkhole, while keeping the water in the same surface drainage basin, and providing that the water shall not go into another sinkhole drainage area off the applicant's property. The immediate sinkhole drainage area (or portion thereof) which cannot be provided with an alternative drainage system can be deleted from the development area for calculations utilizing this information to meet regulatory requirements.
- h. **Development in Sinkhole Drainage Areas with Discharge to Sinkhole:** For portions of the sinkhole drainage area where alternative surface drainage methods cannot be provided, the sinkhole can be used for limited surface runoff drainage of a proposed development if the following conditions are met:



- i. That the runoff from the development area is either completely retained in a retention basin or detained in a detention basin. The flow rate out of the above basins shall be regulated so that it is no greater than the flow rate into the sinkhole of the development area prior to development.
 - ii. Enough runoff is diverted from the sinkhole drainage area so that the development of the remaining area does not increase the total quantity or deteriorate the water quality of runoff into the sinkhole. Where additional runoff is anticipated, a consulting engineer and hydrogeologist shall evaluate and show the effect of any additional quantity of runoff to the sinkhole and sinkhole system. The Director shall review the study findings and make a determination that the plan is acceptable.
 - iii. Where the sinkhole outlet is off site, either the runoff leaving the subject property must be shown to be no greater in flow or in quantity than that which existed before development, or easements must be obtained from owners of property where any increase in flow or quantity of water must go to reach the sinkhole outlet. Easement areas shall be approved by the Director based upon the developer's engineer's calculations of the proposed ponding elevation.
- i. Filling in sinkholes and sinkhole drainage areas:**
- i. No street shall be placed below an elevation of at least one (1) foot above the sinkhole ponding elevation and only when collapse of the sinkhole will not adversely affect the road.
 - ii. No increase in the ponding elevation will be allowed by grading or filling without a storm water analysis approved by the Director.
 - iii. It shall be unlawful for any person to place, dump or deposit trash, debris, rubbish, brush, leaves, grass clippings, yard waste, hazardous waste or similar materials within a sinkhole.
- j. Grading or alteration of land near or over Sinkhole:** The alteration of land in a sinkhole by means of grading or the use of motorized equipment without a permit is a violation of this ordinance.
- k. Construction Requirements near Sinkholes:** Generally, the most effective BMPs are separation from known sinkhole eyes and distribution of runoff into sheet flow as it nears the sinkhole. The use of curbs and gutters to channelize flow towards the sinkhole and a hard-lined drainage system are discouraged. The use of a curbless edge, sheet flow, buffer



strips and grass swales are preferred. Where it is necessary to discharge to a sinkhole through a hard-lined drainage system, a higher level of water quality treatment is required such as an extended detention basin or other structural BMP. Construction requirements and BMPs for post-construction are listed below.

1. During Construction:
 - a. Maintain the required buffer from the topographic rim where no vegetative disturbance can occur.
 - b. Maintain a silt barrier around the undisturbed area until all disturbed areas are re-vegetated.
 - c. Provide a ditch check or other sediment control at all point discharges. Provide a sedimentation basin at all point discharges with more than 3000 square feet of drainage area.
 - d. Erosion and sediment control provisions shall be provided in the Storm Water Pollution Prevention Plan (SWPPP) and shall adhere to the Boone County ESC guidelines for all developments and land disturbance activities near any sinkhole

2. Post Construction:
 - a. Sheet flow discharges must maintain a grass buffer strip and properly designed grass swales and ditch checks for point discharges.
 - b. Developments involving the outdoor handling of toxic materials must provide a containment plan to show what measures will be taken to assure that discharges of toxic materials will be contained and prevented from entering a sinkhole.
 - c. A National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit may be required from the Missouri Department of Natural Resources for industrial facilities or other developments handling toxic materials.

2. Caves

Like sinkholes, cave entrances can provide a direct conduit to groundwater and require greater protection from pollutants and flooding per the Stormwater Ordinance. Additionally, because many caves in Boone County are recreational areas, increased flooding (especially flash flooding related to the urbanization of the watershed discharging to the cave) can pose a risk to human life.

3. Losing Streams

Losing streams are discrete recharge zones. A losing stream is a surface stream that contributes water to the Karst groundwater system in a localized area. In Karst areas, almost every stream that lacks year-round flow has losing stream segments. Protection of water quality in and near losing streams is critical for protection of



groundwater quality in wells and springs. A list of identified losing streams in Boone County is located in Appendix C.

The typical losing stream is a dry gravel stream bed, except for a few days or weeks after major rainfall. Many of the losing stream segments were once sinkholes that were filled with coarse stream gravel washed in during storm flows. Losing stream segments can move a few gallons to hundreds of gallons per minute of water from the surface stream into the groundwater system.

By providing treatment of stormwater through structural best management practices and stream buffers, the runoff discharged to receiving streams should not present a pollution hazard to groundwater systems.

4. Springs

Springs are defined as points or zones of natural groundwater discharge in upland and/or riparian zones which produce measurable flow down gradient of the source, or a pool, or both, or (during drought conditions) an area often characterized by the presence of a mesic (constantly moist) plant community. New development should consider the groundwater hydrology to minimize the impact on the quality and quantity of the spring flow.

7.6 Outstanding State Resource Water

The Missouri Clean Water Commission has designated certain water bodies as Outstanding State Resource Waters based on unique habitat and recreational value. In Boone County, portions of five creeks are considered Outstanding State Resource Waters. To sustain these waterways in their current condition, the stream buffer width on land development occurring in these areas, shall be twice the width required in the Stream Buffer Ordinance (cite), See Appendix C for a detailed list of these stream segments. The Boone County GIS may also have these stream segments identified graphically and available per request.

7.7 Critical Habitat for Endangered Species

The Missouri Department of Conservation assists the U.S. Fish and Wildlife Service in identifying endangered species in Missouri and the habitats critical to their survival. Five endangered species have been identified as having habitat in Boone County. See Appendix C for the list of these species and their habitats. Further information about these species and their habitats can be found on the U.S. Fish and Wildlife's and Missouri Department of Conservation's web sites.

7.8 Class P Stream

The U.S. Geologic Survey shows streams with a permanent base flow on their quadrangle maps as solid blue lines. The Missouri Code of State Regulations identifies portions of



six streams in Boone County as permanent flowing streams. See Appendix C for a detailed list of these stream segments. The Boone County GIS may also have these stream segments identified graphically.



CHAPTER 8 EROSION AND SEDIMENT CONTROL

8.1 Introduction

These guidelines are intended to provide the designer, contractor and builder with design criteria and minimum standards for the installation of erosion and sediment controls to comply with the Erosion and Sediment Control Regulations. The regulations were enacted to protect the health, safety, and property of the citizens and to help protect area water resources from pollution due to erosion and transportation of sediment. The regulations are applicable to all land development and land disturbance activity within the regulated MS4 area where the area of disturbance is more than one acre. The regulations require that no person cause or allow sediment to be deposited in any public street, public land, or on any property not under their control as a result of land disturbance from construction activities.

You can comply with the regulations by meeting the following objectives:

- a. Minimize the area disturbed by construction and development;
- b. Provide for containment of sediment until areas are stabilized;
- c. Stabilize disturbed areas as soon as practical after project completion; and
- d. Provide permanent erosion, drainage, and detention controls.

8.2 General Design Guidelines

Erosion is a natural process where soil and rock are loosened and removed. Natural erosion normally occurs at a very slow pace, but when land is disturbed by vegetation removal, grading and other construction activities, the erosion rate often increases dramatically. When erosion occurs on a construction site the sediment is available for transport by either wind or stormwater runoff. The discharge of sediment and other construction site pollutants can negatively impact downstream water quality.

The purposes of erosion and sediment controls are to minimize the amount of erosion that occurs as a result of construction activities and to prevent the sediment from leaving the property. Effective erosion and sediment control requires that the soil surface be protected from the erosive forces of wind, rain, and runoff and that the eroded soil be captured and retained onsite.

When designing sediment and erosion controls, it is necessary to determine whether there is **sheet flow** or **concentrated flow** of stormwater on the property. Sheet flow occurs on gently sloping land without defined drainage ways. The stormwater tends to disperse evenly across the property, although the drainage may be in one direction due to the overall slope. Concentrated flow occurs where there are defined drainage ways that may range from gentle swales to clearly defined waterways. It is possible to have a combination of sheet flow and concentrated flow on the same property.



1. Erosion Protection

Proper planning will help identify potential erosion problems, particularly highly susceptible areas, such as areas of concentrated flow. Removing the vegetative cover and altering the soil structure by clearing, grading and compacting the surface increases an area's susceptibility to erosion. Scheduling can be a very effective means of reducing erosion by minimizing both the exposed area and the duration of exposure. Apply stabilizing measures as soon as possible after the land is disturbed. Plan and implement temporary or permanent vegetation, mulches, or other protective practices to correspond with construction activities. Protect channels from erosion forces by using protective linings and the appropriate channel design. Consider possible future repairs and maintenance of these practices in the design. In scheduling, take into account the season and the weather forecast.

Clearing existing vegetation reduces the surface roughness and infiltration rate and increases runoff velocities and volumes. This is particularly a concern in areas of concentrated flow. Use measures that break the slopes to reduce the problems associated with concentrated flow volumes and runoff velocities. Practical ways to reduce velocities include conveying stormwater runoff away from steep slopes to stabilized outlets, preserving natural vegetation where possible, and mulching and vegetating exposed areas immediately after construction.

2. Sediment Containment

Even with careful planning some erosion is unavoidable, and the resulting sediment must be trapped on the site. In areas where runoff occurs primarily as sheet flow, containment of sediment is relatively simple. In these areas, temporary containment devices may be sufficient. Where concentrations of flow occur, containment of sediment becomes more difficult as the rate and volume of flow increase. In these areas, more extensive or permanent control devices need to be provided. Areas of steep topography and cut or fill slopes need to be given special consideration. Due to the environmental sensitivity of streams, rivers, losing streams, sinkholes, and other Karst topographic features, special consideration also needs to be given to these areas. Plan the location where sediment deposition will occur and maintain access for periodic removal of accumulated sediment. Protect low points below disturbed areas by building barriers to reduce sediment loss. Sediment traps and basins should be constructed before other land-disturbing activities occur.

3. Temporary versus Permanent Controls

Temporary controls, such as straw bale dikes, silt fences, erosion control blankets, etc., are provided for the purpose of controlling erosion and containing sediment until construction is complete. Temporary controls are not needed after the area is stabilized.

Permanent controls consist of riprap, detention basins, etc., which will remain in place through the life of the development. It is possible for the same facility to serve both a temporary and permanent purpose.



4. Maintenance

Regular inspection and maintenance of Best Management Practices (BMPs) are vital to the performance of erosion and sedimentation control measures. If not properly maintained, some practices may cause more damage than they prevent. Always evaluate the consequences of a measure failing when considering which control measure to use, since failure of a practice may be hazardous or damaging to both people and property. For example, a failure of a large sediment basin can have disastrous results, and low points in dikes can cause major gullies to form on a fill slope. It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop.

8.3 BMP Descriptions and Design Guidance

The following principles are effective when they are integrated into a system of control practices and management techniques to control erosion and prevent sedimentation offsite. As a matter of practicality, proprietary erosion and sediment control products are not specifically identified herein. However, the County encourages the use of these products when designed, specified and installed in accordance with manufacturer's recommendations. Sufficient details related to these products should be supplied to facilitate the review of the plans to ensure the suitability of the practice. The following is not meant to provide an exhaustive list of all acceptable erosion and sediment control practices accepted by the county, only as a general guidance document.

There may be instances where certain erosion control designs are beyond the scope of general civil engineering knowledge. Specifically, natural stream stabilization and/or restoration should only be done with specific expertise and experience with these systems. This manual is not intended to convey such a level of knowledge and therefore will not address this level of complexity.



Figure 1. Silt Fences are placed at the perimeter of the job site to capture and prevent sediment from leaving the site.

Figure 2. Rock Check dams can reduce water velocities in areas of channelized flow.



EC-1 SCHEDULING

This BMP involves developing a schedule that includes sequencing of construction activities with the implementation of construction site BMPs such as temporary soil stabilization (erosion control) and temporary sediment control measures for every project. The purpose is to reduce the amount and duration of soil exposed to erosion by wind, rain, runoff and vehicle tracking, and to perform the construction activities and control practices in accordance with the planned schedule.

APPROPRIATE APPLICATIONS:

Construction sequencing shall be scheduled to minimize land disturbance for all projects at all times.

CONDITIONS FOR EFFECTIVE USE:

All land disturbing activities.

WHEN BMP IS TO BE INSTALLED:

Scheduling should take place during the planning stages and be modified throughout the duration of the project.

STANDARDS AND SPECIFICATIONS:

Developing a schedule and planning the project are the very first steps in an effective storm water program. The construction schedule shall be incorporated into the SWPPP. Develop the sequencing and timetable for the start and completion of each item such as site clearing and grubbing, grading, excavation, paving, pouring foundations, installing utilities, etc., to minimize the active construction area during the rainy season. Schedule major grading operations for the non-rainy season when practical. Incorporate staged seeding and re-vegetation of graded slopes as work progresses. Consider the appropriate planting time for specified vegetation when establishing permanent vegetation.

OPERATION AND MAINTENANCE PROCEDURES:

Verify that work is progressing in accordance with the schedule. If progress deviates, take corrective actions. Amend the schedule when changes are warranted.

EC-2 PRESERVATION OF EXISTING VEGETATION

Preservation of existing vegetation is the identification and protection of desirable vegetation that provides erosion and sediment control benefits and includes establishing setbacks to protect stream banks according to the County stream buffer regulations.

APPROPRIATE APPLICATIONS:

Preserve existing vegetation at areas on a site where no construction activity is planned or will occur at a later date.



CONDITIONS FOR EFFECTIVE USE:

Protection of existing vegetation requires planning, and may limit the area available for construction activities.

WHEN BMP IS TO BE INSTALLED:

Existing vegetation to be preserved shall be identified on the plans. Measures to protect said vegetation (such as construction fencing and signage) should be installed prior to the commencement of clearing and grubbing operations or other soil-disturbing activities.

STANDARDS AND SPECIFICATIONS:

Minimize the disturbed areas by locating temporary roadways to avoid stands of trees and shrubs and to follow existing contours to reduce cutting and filling. Mark areas to be preserved with temporary fencing at least 3.2 ft. tall. The fence post spacing and depth shall be adequate to completely support the fence in an upright position. Construction materials, equipment storage, and parking areas shall be located where they will not cause root compaction. Keep equipment away from trees to prevent trunk and root damage. Employees and subcontractors shall be instructed to honor protective devices. No heavy equipment, vehicular traffic, or storage piles of any construction materials shall be permitted within the drip line of any tree to be retained. Trenching shall be as far away from tree trunks as possible, usually outside of the tree drip line or canopy. The ends of damaged or cut roots shall be cut off smoothly.

OPERATION AND MAINTENANCE PROCEDURES:

During the construction phase(s), limits of disturbance shall remain clearly marked at all times. If damage to protected trees occurs, the injured tree shall be attended to by an arborist.

SITE CONDITIONS FOR REMOVAL:

Temporary fencing shall be removed after final stabilization of the site has occurred.

EC-3 DUST (WIND EROSION) CONTROL

Wind erosion control consists of applying water and/or other dust palliatives as necessary to prevent or alleviate erosion by the forces of wind. Alternatives to applying water or other dust palliatives include mulch or vegetative cover, wind barriers, and minimization of soil disturbance.

APPROPRIATE APPLICATIONS:

This practice is implemented on all exposed soils subject to wind erosion.

CONDITIONS FOR EFFECTIVE USE:

Effectiveness depends on soil, temperature, slope, aspect, humidity and wind velocity.

WHEN BMP IS TO BE INSTALLED:



Dust control should be performed routinely, especially in advance of and during periods of dry weather.

STANDARDS AND SPECIFICATIONS:

Water shall be applied by means of pressure-type distributors or pipelines equipped with a spray system or hoses and nozzles that will ensure even distribution. Phase work to the extent practical to minimize concurrent areas of soil disturbance. For areas not subjected to traffic, vegetation provides the most practical method of dust control and should be established as early as possible. Wind barriers such as solid board fences, snow fences, burlap fences, crate walls, and similar materials can be used to control air currents and blowing soil. Barriers placed at right angles to prevailing wind currents at intervals of about 10 times their height are effective in controlling soil blowing. Paved areas that have soil on them from construction sites should be cleaned regularly. Mulching offers a fast and effective means of controlling dust when properly applied. Binders and tackifiers may need to be used on organic mulches. NOTE: If calcium chloride or spray-on adhesives are used for dust control, a permit may be required from MoDNR.

OPERATION AND MAINTENANCE PROCEDURES:

Check areas that have been protected to ensure coverage.

SITE CONDITIONS FOR REMOVAL:

Dust control should be implemented when soils are exposed until cover is established.

EC-4 HYDRAULIC MULCH-BONDED FIBER MATRIX

Hydraulic mulch consists of applying a mixture of shredded wood fiber or a hydraulic bonded fiber matrix (BFM) and a stabilizing emulsion or tackifier with hydroseeding equipment, which temporarily protects exposed soil from erosion by raindrop impact or wind. BFMs adhere directly to the soil, eliminating gaps between the product and the soil. A water-insensitive crust does not form; therefore plant growth is not inhibited. Mulch and BFMs will biodegrade completely into material beneficial to plant growth. Seed may be applied simultaneously with mulching.

APPROPRIATE APPLICATIONS:

Hydraulic mulch and BFMs are applied to disturbed areas requiring temporary protection until permanent vegetation is established or disturbed areas that must be re-disturbed following an extended period of inactivity.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow only.

Wood fiber hydraulic mulches and BFMs are generally short-lived (only last part of a growing season) and need 24 hours to dry before rainfall occurs to be effective.



WHEN BMP IS TO BE INSTALLED:

Hydraulic mulch or bonded fiber matrix should be applied immediately after completion of a phase of grading.

STANDARDS AND SPECIFICATIONS:

Follow manufacturer's recommendations to maximize usefulness. Avoid mulch over-spray onto the traveled way, sidewalks, and lined drainage channels. Materials for wood fiber-based hydraulic mulches and bonded fiber matrices shall meet environmental quality standards and not be a detriment to stormwater discharges from the site.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm until vegetation is fully established. Repair eroded areas and reapply product and vegetation.

SITE CONDITIONS FOR REMOVAL:

Typically these materials are left in place to degrade naturally.

EC-5 MULCHING

A layer of organic material designed to protect exposed soil or freshly seeded areas from erosion by eliminating direct impact of precipitation and slowing overland flows. Mulch materials may include, but are not limited to, grass, hay, straw, wood chips, wood fibers, and shredded bark.

APPROPRIATE APPLICATIONS:

Typically used for soil stabilization as a temporary surface cover on disturbed areas until soils can be prepared for revegetation and permanent vegetation is established. Mulch can also be installed in land--scape areas for permanent use.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow only

The use of appropriate mulch will help ensure the vegetation is established under normal conditions and is essential to seeding success under harsh site conditions. General mulch recommendations to protect from raindrop splash and sheet flow include: straw applied at 2-2.5 tons/acre, wood fiber or wood cellulose applied at 0.5-1 ton/acre, wood chips applied at 5-6 tons/acre, and bark applied at 35 yd³/acre. Where slopes are 25 percent (4:1) or greater, hydromulch, bonded fiber matrix, or erosion control blankets are required.

WHEN BMP IS TO BE INSTALLED:

Mulch should be applied immediately after grading landscaped areas or seeding other areas.

STANDARDS AND SPECIFICATIONS:



Install upstream BMPs to protect area to be mulched. Rough grade area and remove all debris larger than 1 inch if area is to be vegetated and mowed in the future, larger than 2 inches if area is to be permanently mulched. If area is to be seeded, follow requirements of Seeding BMP. Spread mulch evenly.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm until adequate vegetation is established; annually for permanent mulch. Protect from vehicular and foot traffic. Repair damaged, degraded or eroded areas-reseed as needed and replace mulch.

EC-6 SEEDING/MULCHING

Establishment of vegetation by spreading grass seed designed to protect exposed soil from erosion by eliminating direct impact of precipitation and slowing overland flow rates. Once established, the vegetative cover will also filter pollutants from the runoff.

APPROPRIATE APPLICATIONS:

Exposed soil after a phase of rough or finish grading has been completed, or areas where no activity will occur for 14 days.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow (additional stabilization is necessary).

Minimum Rates: Permanent seeding should consist of 90% tall fescue and 10% annual ryegrass. Seed mixture should be applied at 400 pounds/acre. Temporary seeding shall consist of any combination of tall fescue, annual ryegrass, millet, wheat or oats. Seed mixture should be applied at 200 pounds/acre. Dormant season seeding, seed mix should consist of 80% tall fescue, 10% annual ryegrass and 10% spring oats. Seed mixture is to be applied at 600 pounds/acre.

Acceptable Dates: Permanent seeding may be done March 1 to June 1 and August 15 to November 1. Temporary seeding can occur during any season, however winter is the least tolerant. Dormant season seeding includes December 15 to February 29.

WHEN BMP IS TO BE INSTALLED:

Seed and mulch should be applied immediately after rough or finished grading is completed.

STANDARDS AND SPECIFICATIONS:

Install upstream BMPs to prevent erosion and protect the area to be seeded. Complete grading and remove all debris larger than 1 inch. Loosen compacted soils to a depth of 4 inches. Groove or furrow on the contour if necessary. Spread loose topsoil at a depth of 4 inches.

Soil amendments should be applied per soil tests. When these are not available, lime shall be applied at the rate of 1500 pounds effective neutralizing material per acre. Soils with a pH of six



or higher need not be limed. When soil tests are not available, a 13-13-13 grade fertilizer shall be applied at a rate of 500 pounds/acre for permanent seeding and a 10-10-10 grade fertilizer shall be applied at the rate of 200 pounds/acre. Mix soil amendments (lime, fertilizer, etc.) into the top 4 inches of soil.

Plant seed $\frac{1}{4}$ to $\frac{1}{2}$ inches deep using a cyclone seeder, drill, cultipacker seeder, or hydro-seeder. Roll lightly to firm surface. Cover seeded area with mulch. Install additional stabilization (erosion control blankets, netting, bonded fiber matrix, etc.) on slopes steeper than 3:1 and in areas of concentrated flow. Water seeded area immediately. Provide enough water to soak 4 inches into the soil without causing runoff.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least weekly and after every storm. Protect seeded areas from vehicular and foot traffic. Reseed and mulch areas that have not sprouted within 21 days of planting. Repair damaged or eroded areas and reseed/mulch and stabilize as needed. Do not mow until 4 inches of growth occurs. During the first 4 months, mow no more than $\frac{1}{3}$ the grass height.

EC-7 SODDING

Sod consists of a $\frac{3}{4}$ inch to 1 inch mat of vigorous turf, free from disease, insects and weeds. Sod prevents raindrops from disrupting the soil structure and causing erosion. Sod slows water runoff and acts as a filter when sediment laden runoff crosses over the sodded area.

APPROPRIATE APPLICATIONS:

Typically installed in areas requiring immediate erosion protection, such as swales or detention ponds and as filter strips, around inlets, and adjacent to curbs. Also installed in areas requiring immediate aesthetic appearance or function such as entrances to new subdivisions and off site construction areas.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and low concentrated flows with velocities less than 5 fps.

WHEN BMP IS TO BE INSTALLED:

Sod should be installed immediately after finish grading, installation of area inlets, and installation of underground services and foundations of new homes.

STANDARDS AND SPECIFICATIONS:

Rough grade area and remove all debris larger than $\frac{1}{2}$ inch in diameter and concentrated areas of smaller debris. Soil preparation of area to be sodded shall be determined by tests to determine lime and fertilizer requirements. Scarify soil and level to provide an even grade. Soil should not be excessively wet or dry. Lay first row of sod perpendicular to the slope or direction of flow. Butt subsequent rows tight against previous rows with strips staggered in brick-like pattern. Fill minor gaps with good soil and roll entire surface to ensure contact. Stake, staple and/or net



corners and centers of sod strips as required, especially areas of concentrated flow. Water should be applied immediately after installation of sod. Provide enough to soak 4 inches into the soil without causing runoff.

OPERATION AND MAINTENANCE PROCEDURES:

Water sod daily for 3 weeks, enough to soak 4 inches into the soil without causing runoff. Reposition areas of sod that have moved along the slope. Remove sediment accumulations, replace sod if necessary. Repair any eroded areas, replace sod, and stabilize as needed. Do not mow until 3 inches of new growth occurs. During the first 4 months, mow no more than 1/3 the grass height.

EC-8 ROLLED EROSION CONTROL PRODUCTS

Rolled erosion control products include erosion control blankets and turf reinforcement mats. Erosion control blankets are pre-formed protective blanket of plastic fibers, wood fibers, straw or other plant residue designed to protect soil from the impact of precipitation and overland flow, and retain moisture to facilitate establishment of vegetation. Turf reinforcement mats include netting designed to anchor the root system of the vegetation growing through it.

APPROPRIATE APPLICATIONS:

These products may be installed on seeded areas for temporary or permanent use.

CONDITIONS FOR EFFECTIVE USE:

Several factors, such as soil conditions, steepness and length of slope, depth of flow, runoff velocities, and time required to establish desired vegetation, influence the choice of product. Manufacturer's recommendations should be followed. Products are available for a variety of uses: Netting-synthetic or natural fiber mesh installed over disturbed areas to hold organic mulch and/or seed in place, Biodegradable Erosion Control Blanket-natural fiber blanket held together by netting to provide temporary erosion protection on slopes and channels, and Permanent Erosion Control Blanket-synthetic blanket material which provides permanent erosion control on slopes and channels with increased water flow velocities.

WHEN BMP IS TO BE INSTALLED:

Rolled erosion control products should be installed immediately after completion of a phase of grading or installation of vegetation.

STANDARDS AND SPECIFICATIONS:

Follow manufacturer's recommendations and specifications, particularly noting requirements for check slots, fastening devices and need for firm contact with soil.

OPERATION AND MAINTENANCE PROCEDURES:

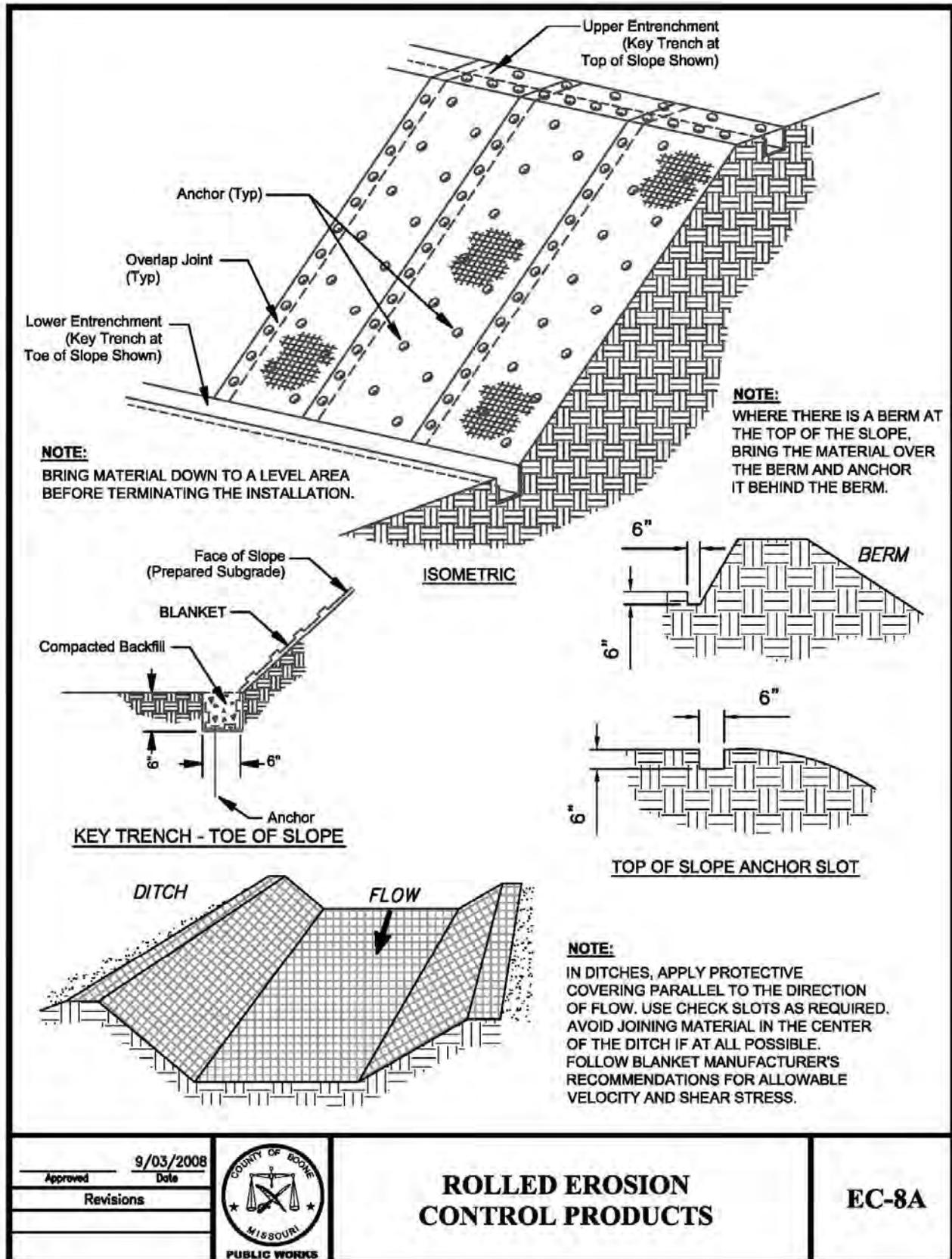


Inspect at least every week and after every storm until adequate vegetation is established. Repair erosion and/or undermining at top of slope. Repair undermining beneath blankets-pull back the blanket(s), fill compact eroded area, re-vegetate and then firmly secure the blanket(s). Reposition or replace blanket(s) that have moved along the slope or have been damaged.

SITE CONDITIONS FOR REMOVAL:

Temporary blankets will generally degrade naturally; permanent blankets remain in place.

STANDARD DRAWING: EC-8a and EC-8b





EROSION CONTROL BLANKET NOTES:

A) SITE PREPARATION:

AFTER SITE HAS BEEN SHAPED AND GRADED, PREPARE A FRIABLE SEEDBED RELATIVELY FREE FROM CLODS AND ROCKS MORE THAN 1 1/2 INCHES IN DIAMETER AND ANY FOREIGN MATERIAL THAT WILL PREVENT UNIFORM CONTACT OF THE BLANKET WITH THE SOIL SURFACE.

B) PLANTING:

LIME, FERTILIZE, AND SEED IN ACCORDANCE WITH SEEDING OR PLANTING PLAN. WHERE GROUND COVERS ARE TO BE PLANTED, LAY THE PROTECTIVE COVERING FIRST AND THEN PLANT THROUGH THE MATERIAL AS PER PLANTING PLAN.

C) LAYING AND STAPLING:

1. START LAYING THE BLANKET FROM THE TOP OF THE CHANNEL OR SLOPE AND UNROLL DOWN-GRADE. ALLOW TO LAY LOOSELY ON SOIL; DO NOT STRETCH.
2. UPSLOPE ENDS OF THE BLANKET SHOULD BE BURIED IN AN ANCHOR SLOT NO LESS THAN 6-INCHES DEEP. TAMP EARTH FIRMLY OVER THE MATERIAL.
3. WHERE MULTIPLE WIDTHS ARE LAID SIDE BY SIDE, THE ADJACENT EDGES SHALL BE OVERLAPPED A MINIMUM OF 6 INCHES AND STAPLED TOGETHER.
4. STAPLES SHALL BE PLACED PER MANUFACTURER'S RECOMMENDATIONS.

D) TROUBLESHOOTING:

CONSULT WITH THE ENGINEER, IF ANY OF THE FOLLOWING OCCUR:

1. MOVEMENT OF THE BLANKET OR EROSION UNDER THE BLANKET IS OBSERVED.
2. VARIATIONS IN TOPOGRAPHY ON SITE INDICATE EROSION CONTROL MAT WILL NOT FUNCTION AS INTENDED; CHANGES IN PLAN MAY BE NEEDED, OR A BLANKET WITH A SHORTER OR LONGER LIFE MAY BE NEEDED.
3. DESIGN SPECIFICATIONS FOR SEED VARIETY, SEEDING DATES, OR EROSION CONTROL MATERIALS CANNOT BE MET; SUBSTITUTION MAY BE REQUIRED. UNAPPROVED SUBSTITUTIONS COULD RESULT IN FAILURE TO ESTABLISH VEGETATION.

E) MAINTENANCE & INSPECTION:

INSPECT CONTROLS AFTER EACH RAIN EVENT OF 1/2 INCH OR GREATER, AND EVERY 7 DAYS UNTIL VEGETATION IS ESTABLISHED. LOOK FOR EROSION OR UNDERMINING BENEATH THE NETTING, BLANKETS, OR MATS. IF ANY AREA SHOWS EROSION, PULL BACK THAT PORTION OF THE MATERIAL, ADD SOIL, AND RESEED; RESECURE THE MATERIAL IN PLACE. IF NETTING, BLANKETS OR MATS BECOME DISLOCATED OR DAMAGED, REPAIR OR REPLACE AND RESECURE IMMEDIATELY.

F) JOINING BLANKETS:

OVERLAP THE END OF THE PREVIOUS ROLL A MINIMUM OF 6 INCHES AND STAPLE. STAPLE ACROSS THE END OF THE ROLL JUST BELOW THE ANCHOR SLOT AND ACROSS THE MATERIAL EVERY 6 INCHES.

G) TERMINAL END:

AT THE POINT AT WHICH THE MATERIAL IS DISCONTINUED, OR WHERE THE BLANKET MEETS A STRUCTURE OF SOME TYPE, STAPLE A MINIMUM OF EVERY 12 INCHES.

H) FINAL CHECK:

THESE INSTALLATION CRITERIA MUST BE ADHERED TO:

1. ALL DISTURBED AREAS ARE SEEDED.
2. PROTECTIVE BLANKET IS IN UNIFORM CONTACT WITH THE SOIL.
3. ALL LAP JOINTS ARE SECURE.
4. ALL STAPLES ARE DRIVEN FLUSH WITH THE GROUND.

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EC-9 GEOTEXTILES AND PLASTIC COVERS

This Best Management Practice (BMP) involves the placement of geotextiles or plastic covers to stabilize disturbed soil areas and protect soils from erosion by wind or water.

APPROPRIATE APPLICATIONS:

Limited applications include very small graded areas and stockpiles.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet and concentrated flows.

Geotextiles and plastic covers have maximum flow rate limitations; consult the manufacturer for proper selection. The use of plastic shall be limited to very short periods of time. The use of plastics and impermeable geotextiles results in 100% runoff, which may cause serious erosion problems in the areas receiving the increased velocities and flow. Use these products with caution. Plastic sheeting is easily vandalized, easily torn, and photodegradable.

WHEN BMP IS TO BE INSTALLED:

Geotextiles and plastic covers should be installed immediately after completion of a phase of grading or while the stockpile is in place.

STANDARDS AND SPECIFICATIONS:

Geotextile blankets shall be secured in place with wire staples or sandbags and by keying into tops of slopes and edges to prevent infiltration of surface water under the geotextile. Plastic sheeting shall be keyed in at the top of the slope and firmly held in place with sandbags or other weights placed no more than 10 feet apart. Seams are typically taped or weighted down their entire length. Anchoring the sheeting is crucial to keeping it in place during windy weather.

OPERATION AND MAINTENANCE PROCEDURES:

All geotextile and plastic sheeting shall be inspected on a weekly basis and after storms to check for erosion, undermining, and anchorage failure. Any failures shall be repaired immediately. If washout or breakages occur, the material shall be re-installed after repairing the damage to the slope.

SITE CONDITIONS FOR REMOVAL:

Upon establishment of other temporary stabilizations or after permanent stabilization has occurred.

EC-10 OUTLETS/VELOCITY DISSIPATION DEVICES

These devices are placed at pipe outlets to prevent scour and reduce the velocity and/or energy of storm water flows. These devices protect the receiving area from erosion.



APPROPRIATE APPLICATIONS:

These devices may be used at the following locations: outlets of pipes, drains, culverts, slope drains, diversion ditches, swales, conduits or channels, outlets located at the bottom of mild to steep slopes, discharge outlets that carry continuous flows of water, outlets subject to short, intense flows of water, such as flash floods, points where lined conveyances to unlined conveyances, and at emergency overflows or outlet pipes of a sediment basin.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Concentrated flow

WHEN BMP IS TO BE INSTALLED:

Energy dissipation devices should be installed with the construction of the upstream BMP or pipe that creates a concentrated discharge.

STANDARDS AND SPECIFICATIONS:

Install riprap, concrete apron, etc. at selected outlet. Riprap aprons are best suited for temporary use during construction. Carefully place riprap to avoid damaging the filter fabric. Align the apron with the receiving stream and keep straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron. If the size of the apron riprap is comprised of large rocks, protect the underlying filter fabric with a gravel blanket. Outlets on slopes steeper than 10% need additional protection.

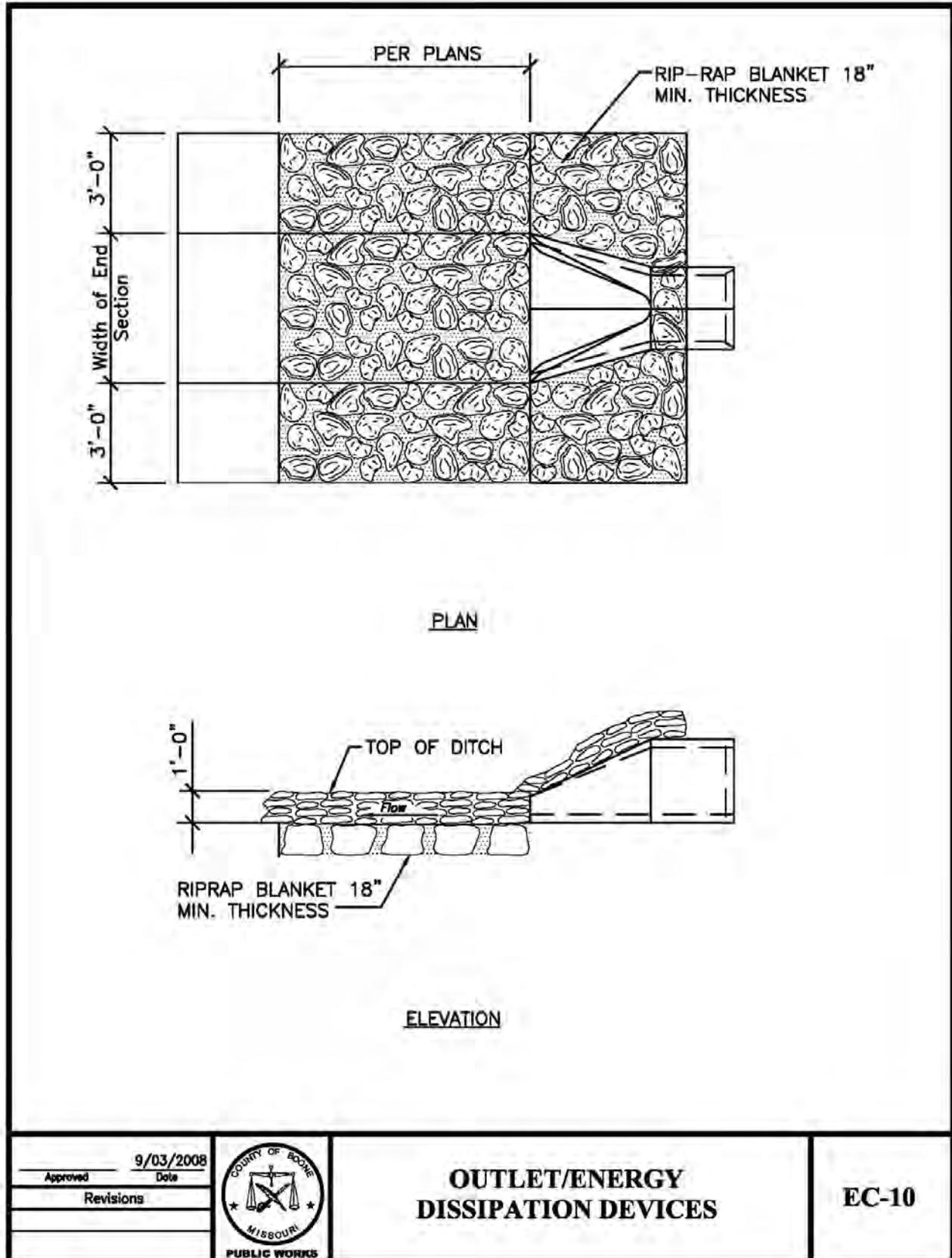
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm during construction. Remove sediment and trash accumulation. Inspect apron for displacement of the riprap and/or damage to the underlying fabric. Repair fabric and replace riprap that has washed away. Inspect for scour beneath the riprap and around the outlet. Repair damage to slopes immediately, extend the pad or place larger rock, as needed.

SITE CONDITIONS FOR REMOVAL:

Temporary devices need to be completely removed as soon as the surrounding drainage area has been stabilized, or at the completion of construction.

STANDARD DRAWING: EC-10





EC-11 TEMPORARY STREAM CROSSING

A temporary stream crossing is a structure placed across a waterway that allows vehicles to cross the waterway during construction, minimizing, reducing, or managing erosion and downstream sedimentation caused by the vehicles. Use of temporary stream crossings is discouraged. Crossings are a direct source of pollution and should be avoided if alternatives are feasible.

APPROPRIATE APPLICATIONS:

Temporary stream crossings are installed at sites: where appropriate permits have been secured (404, 401, etc.), where construction equipment or vehicles need to frequently cross a waterway, when alternate access routes impose significant constraints, and where construction activities will be less than 1 year.

CONDITIONS FOR EFFECTIVE USE:

Design considerations include: current and proposed watershed conditions, average and peak discharge (2 year, 24 hour storm), effect on water surface elevation off-site, velocity, sediment removal, and protection of fish and trees. Criteria for a Low Water Crossing includes: any constant flow less than 3" deep, light traffic, bank height less than 5 feet, and perpendicular to flow or with a slight upstream arc. Criteria for a culvert crossing includes: sized for 2 year, 24 hour storm with 1 foot freeboard and no flooding of offsite areas, pipe parallel to flow, embankment perpendicular to channel or with a slight upstream arc, riprap on exposed faces sized for overtopping during a peak storm period.

WHEN BMP IS TO BE INSTALLED:

The temporary stream crossing should be constructed during dry periods and may require dewatering or temporary diversion of the stream.

STANDARDS AND SPECIFICATIONS:

Procedures are specific to the type of crossing used. Generally, provide a stable means to bypass normal channel flow prior to disturbing channel, stabilize channel bottom, install culvert (if used), grade and compact access ramps and soil embankment, install fabric, stone, and riprap according to design.

OPERATION AND MAINTENANCE PROCEDURES:

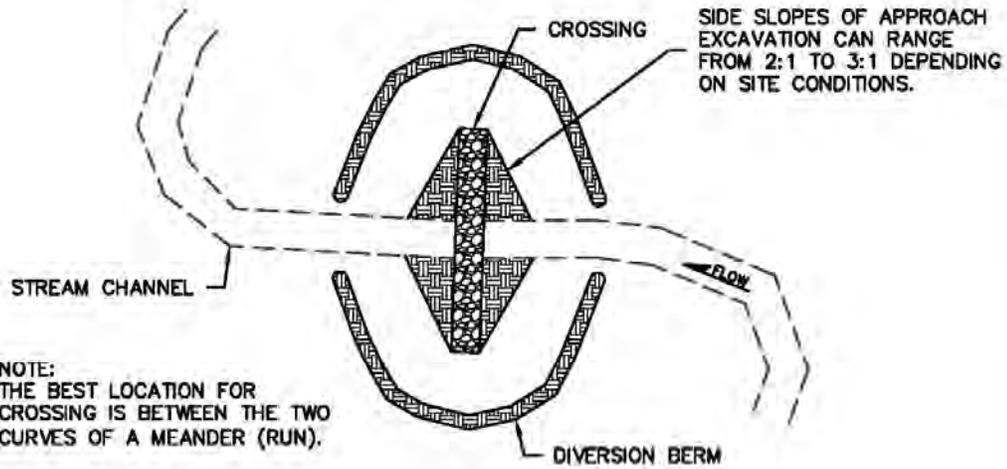
Inspect every week and after every storm-checking for: blockage in the channel, debris buildup, erosion of abutments, channel scour, riprap displacement, piping of soil, and structural weakening. Remove sediment and trash accumulation. Repair and stabilize eroded areas-extend riprap if necessary.

SITE CONDITIONS FOR REMOVAL:

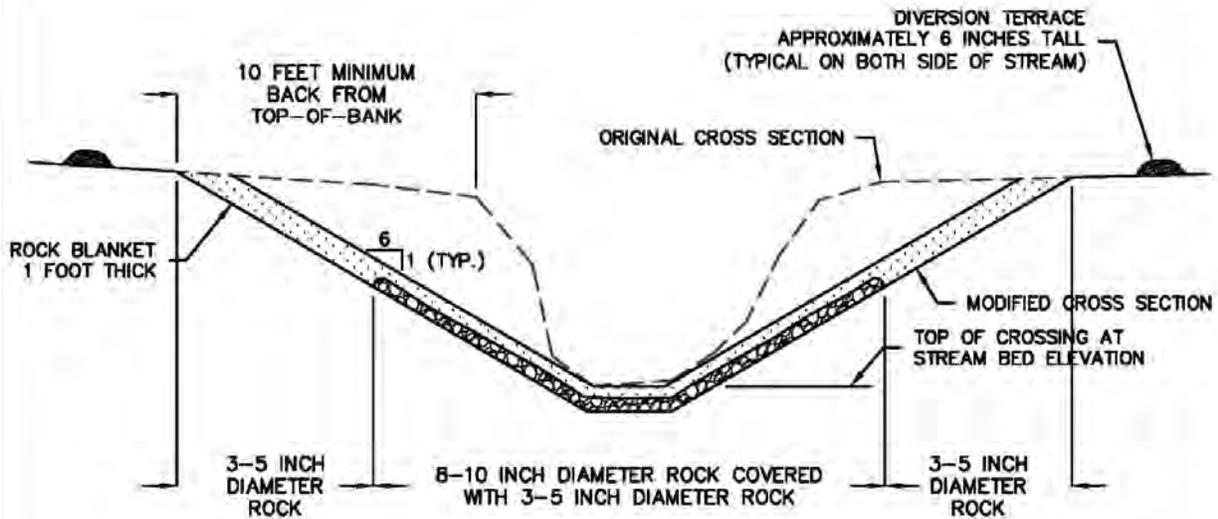


Remove as soon as alternative access is available. All foreign materials should be removed from creek. The streambed/banks should be returned to the original contour and stabilized if necessary.

STANDARD DRAWING: EC-11a and EC-11b



REINFORCED STREAM CROSSING LAYOUT
NOT TO SCALE



REINFORCED STREAM CROSSING PROFILE
NOT TO SCALE

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Approved	9/03/2008										
Revisions	Date										



GENERAL NOTES AND SPECIFICATIONS FOR TEMPORARY (REINFORCED) STREAM CROSSINGS:

1. THE STREAM BED FOR 0.5 MILE BELOW THE PROPOSED CROSSING MUST BE VERTICALLY STABLE. THE CHANNEL SHOULD NOT BE DOWNCUTTING (NO HEADCUTS DOWNSTREAM) OR RAPIDLY FILLING WITH SEDIMENT.
2. LOW FLOW WATER DEPTH SHALL BE LESS THAN SIX INCHES.
3. STREAM BANKS IN THE VICINITY (0.25 MILES UPSTREAM AND DOWNSTREAM) MUST BE STABLE.
4. THE CROSSING SHOULD BE LOCATED IN THE STRAIGHT REACH BETWEEN TWO BENDS.
5. APPROACHES SHOULD BE NO STEEPER THAN 6:1.
6. THE APPROACHES AND CROSSING SHOULD BE OVER EXCAVATED ONE FOOT THAN THE DESIRED SURFACE.
7. THE CROSSING AND THE APPROACHES FOR 10 FEET ON EITHER SIDE OF THE CROSSING SHOULD BE BACKFILLED WITH 8-10 INCH DIAMETER ROCK OR QUARRY RUN SHOT-ROCK TO WITHIN THREE TO FIVE INCHES OF THE DESIRED SURFACE. THE LARGE ROCK SHOULD BE COMPACTED INTO THE STREAM BED AND THE APPROACHES.
8. AFTER THE LARGE ROCK IS COMPACTED, THREE TO FIVE INCH DIAMETER ROCK SHOULD BE PLACED IN THE REMAINDER OF THE APPROACHES AND OVER THE LARGE ROCK TO PROVIDE A RELATIVELY SMOOTH SURFACE.
9. FINAL ELEVATION OF THE PORTION OF THE CROSSING SUBMERGED AT LOW FLOW SHALL NOT BE MORE THAN THREE INCHES ABOVE STREAM BED ELEVATION.
10. SIDE SLOPES OF THE APPROACH CAN RANGE FROM 2:1 TO 3:1 DEPENDING ON CONDITIONS AT THE SITE.
11. SIX INCH TALL DIVERSION BERM SHOULD BE BUILT AROUND THE CROSSING TO PREVENT OVERLAND FLOW FROM ERODING THE APPROACHES. THE DIVERSIONS SHOULD OUTLET AT STABLE LOCATIONS.
12. GROUTING (POURING CONCRETE OVER ROCK) IS PROHIBITED.
13. THE CROSSING SHOULD BE INSPECTED AFTER EACH FLOOD. BE ALERT FOR SIGNIFICANT SCOUR DOWNSTREAM OF THE CROSSING. THE SMALL DIAMETER ROCK MAY HAVE TO BE REPLACED OVER TIME. FREQUENT CLEARING OF SEDIMENT AND DEBRIS FROM THE APPROACHES WILL BE NECESSARY.

	9/03/2008		REINFORCED STREAM CROSSING	EC-11B
Approved	Date			
Revisions				



RM-1 CHECK DAMS

Check dams reduce scour and channel erosion by reducing flow velocity and encouraging sediment settlement. A check dam is a small device constructed of rock, gravel bags, sandbags, fiber rolls, or other proprietary product placed across a natural or man-made channel or drainage ditch.

APPROPRIATE APPLICATIONS:

Check dams can be placed at intervals along drainage swales or channels. The top of the downstream check dam should be level with the base of the upstream check dam. Check dams can also be used during the establishment of grass linings in drainage ditches or channels or in temporary ditches where the short length of service does not warrant establishment of erosion-resistant linings. Not to be used in streams.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Moderate concentrated flow.

WHEN BMP IS TO BE INSTALLED:

Check dams can be installed prior to disturbance of natural vegetation in the contributing drainage area or immediately after construction of a drainage way.

STANDARDS AND SPECIFICATIONS:

Check dams should be placed at a distance and height to allow small pools to form behind them. Install the first check dam approximately 16 feet from the outfall device and at regular intervals based on slope gradient and soil type. For multiple check dam installation, backwater from the downstream check dam should reach the toe of the upstream dam. High flows (typically a 2-year storm or larger) should safely flow over the check dam without an increase in upstream flooding.

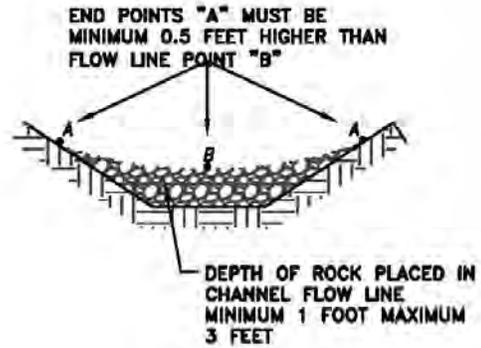
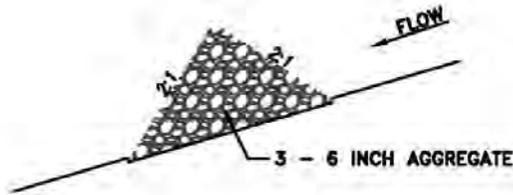
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove trash and leaf accumulation. Remove sediment when depth reaches one-half of the check dam height. Repair/restore dam structure, if necessary, to original configuration to protect the banks.

SITE CONDITIONS FOR REMOVAL:

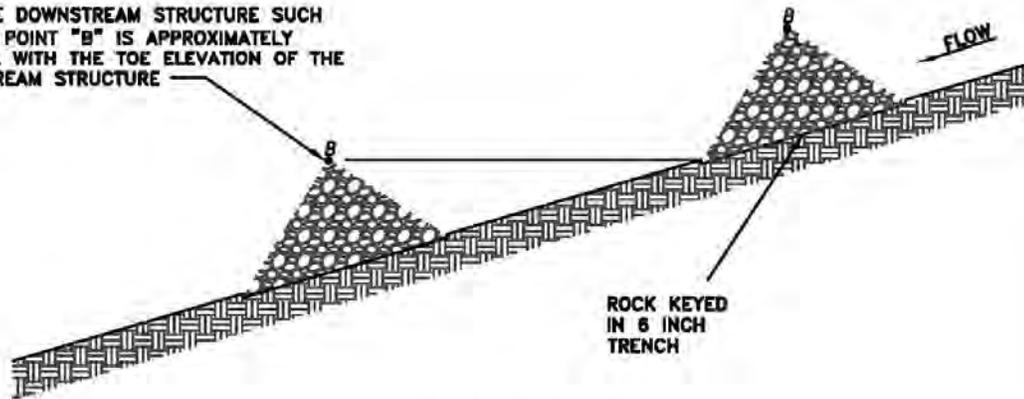
Remove after contributing areas have been adequately stabilized and vegetation is adequately established in drainage way. Regrade and vegetate the area.

STANDARD DRAWING: RM-1



FRONT VIEW

PLACE DOWNSTREAM STRUCTURE SUCH THAT POINT "B" IS APPROXIMATELY LEVEL WITH THE TOE ELEVATION OF THE UPSTREAM STRUCTURE



SIDE VIEW

NOTE:

ROCK CHECK DAMS SHALL BE USED ONLY FOR DRAINAGE AREAS LESS THAT 10 ACRES UNLESS APPROVED BY THE ENGINEER.

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Date	
Revisions	



CHECK DAMS

RM-1



RM-2 EARTH BERMS AND DRAINAGE SWALES

A compacted earth, compost or gravel ridge, excavated channel or a combination of ridge and channel designed to direct runoff away from or around disturbed areas. Diversions built on a level contour are used in combination with temporary slope drains to provide adequate conveyance. Diversions built with positive drainage slopes release runoff into additional BMPs, such as sediment traps or level spreaders.

APPROPRIATE APPLICATIONS:

These features may be used to: convey surface runoff down sloping land, intercept and divert runoff to avoid sheet flow over sloped surfaces, divert and direct runoff towards a stabilized watercourse, drainage pipe or channel, intercept runoff from paved surfaces. Berms, swales, and lined ditches also may be used: below steep grades where runoff begins to concentrate, along roadways and facility improvements subject to flood drainage, at the top of slopes to divert runoff from adjacent or undisturbed slopes and at bottom and mid-slope locations to intercept sheet flow or to convey concentrated flows.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and low-volume concentrated flows.

Contributing Area: Contributing slope length-300 feet maximum; 100 feet for slopes greater than 5%.

WHEN BMP IS TO BE INSTALLED:

Berms and/or swales should be installed prior to disturbance of natural vegetation on slopes and at intervals during construction of fill slopes.

STANDARDS AND SPECIFICATIONS:

Care must be applied to correctly size and locate berms, swales, and ditches. Excessively steep, unlined berms and swales are subject to gully erosion. Grade and compact the channel and/or ridge. Provide stabilized outfall areas. Conveyances should be stabilized with vegetation or a protective lining. Other BMPs, such as check dams and erosion control blankets, may be necessary to prevent scour and erosion.

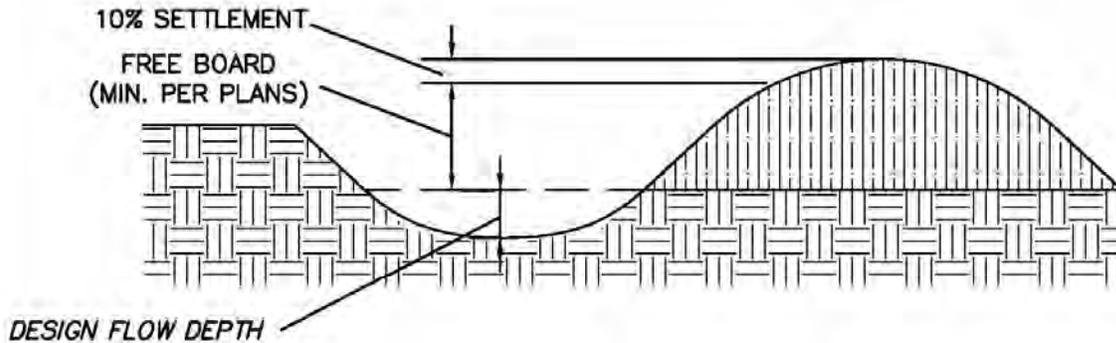
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Inspect channel linings, embankments, and beds of ditches and berms for erosion and accumulation of debris and sediment. Remove debris and sediment, repair linings and embankments as needed-replace riprap, linings or soil stabilizers as needed.

SITE CONDITIONS FOR REMOVAL:

Temporary diversions should be removed as soon as the surrounding drainage area has been stabilized.

STANDARD DRAWING: RM - 2



NOTES:

1. TEMPORARY DIVERSION BERMS MUST BE INSTALLED AS A FIRST STEP IN THE LAND-DISTURBING ACTIVITY AND MUST BE FUNCTIONAL PRIOR TO LAND DISTURBANCE.
2. THE OUTLET OF THE DIVERSION SHALL BE LOCATED IN AN UNDISTURBED OR STABILIZED AREA.
3. TEMPORARY OR PERMANENT SEEDING AND MULCH SHALL BE APPLIED TO THE BERM IMMEDIATELY FOLLOWING ITS CONSTRUCTION.
4. ALL TREES, BRUSH, STUMPS, OBSTRUCTIONS, AND OTHER OBJECTIONABLE MATERIAL SHALL BE REMOVED AND DISPOSED OF SO AS NOT TO INTERFERE WITH THE PROPER FUNCTIONING OF THE DIVERSION.
5. THE DIVERSION SHALL BE EXCAVATED OR SHAPED TO LINE, GRADE, AND CROSS-SECTION AS REQUIRED AND FREE OF IRREGULARITIES WHICH WILL IMPEDE FLOW.
6. FILLS SHALL BE COMPACTED AS NEEDED TO PREVENT UNEQUAL SETTLEMENT THAT WOULD CAUSE DAMAGE IN THE COMPLETED DIVERSION. FILL SHALL BE COMPOSED OF SOIL WHICH IS FREE FROM EXCESSIVE ORGANIC DEBRIS, ROCKS, OR OTHER OBJECTIONABLE MATERIALS.
7. ALL EARTH REMOVED AND NOT NEEDED IN CONSTRUCTION SHALL BE SPREAD OR DISPOSED OF SO THAT IT WILL NOT INTERFERE WITH THE FUNCTIONING OF THE DIVERSION.
8. THE BERM SHOULD BE ADEQUATELY COMPACTED TO PREVENT FAILURE.
9. THE BERM SHOULD BE LOCATED TO MINIMIZE DAMAGES BY CONSTRUCTION OPERATIONS AND TRAFFIC.

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RM-3 TERRACING

Terracing involves defined swales constructed at regular intervals along the face of a slope designed to reduce erosion by capturing surface runoff and directing it to an adequate, stable outlet.

APPROPRIATE APPLICATIONS:

Typically installed on long steep slopes on which erosion is a concern. Terraces should not be constructed in sandy or rocky soil.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow.

Slope Characteristics: Maximum of 3:1 slope.

Contributing Slope Length: Maximum of 30 feet for slopes steeper than 4:1; maximum for 50 feet for 4:1 and flatter.

WHEN BMP IS TO BE INSTALLED:

Terracing should be installed as fill is constructed. On existing slopes, terraces should be graded prior to removal of vegetation.

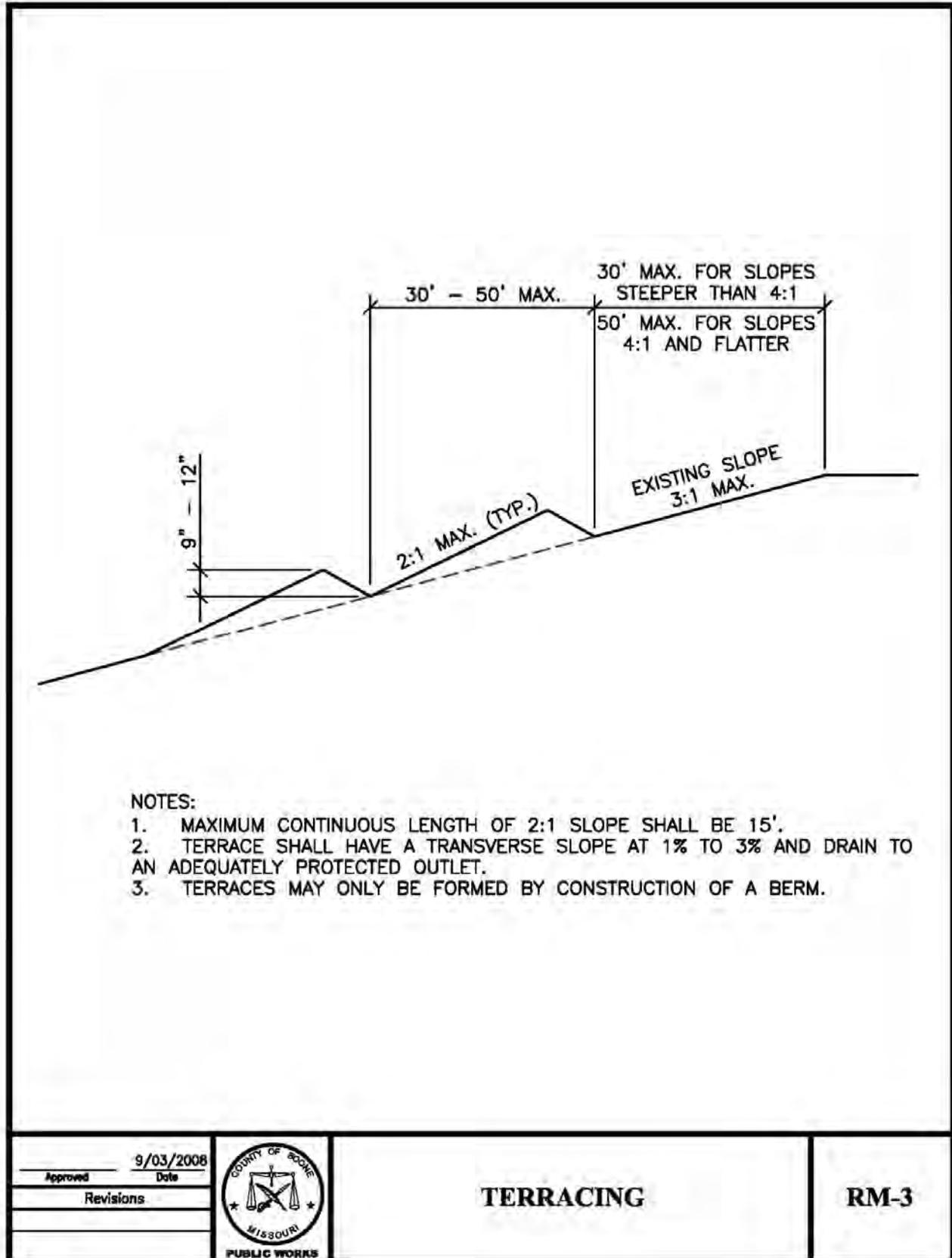
STANDARDS AND SPECIFICATIONS:

Grade terraces as required by the design. Construct the stable outfall as designed. Vegetate the slope and terraces immediately after BMP installation.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm during construction. Remove sediment accumulations along terraces. Repair settled and eroded areas. Remove sediment and stabilize eroded areas at outlet. Revegetate as needed

STANDARD DRAWING: RM - 3





RM-4 SLOPE DRAINS

A slope drain is a flexible or rigid pipe which extends from the top to the bottom of a cut or fill slope. These structures are designed to protect exposed slopes from upstream runoff and can be used with other BMPs to intercept and direct surface flow away from disturbed slope areas. Slope drains typically extend beyond the toe of the slope to a stable area or outlet.

APPROPRIATE APPLICATIONS:

Slope drains may be used on construction sites where slopes may be eroded by surface runoff.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow. Contributing Area: Maximum of 5 acres per slope drain; pipe sized for 15 year, 20 minute storm.

WHEN BMP IS TO BE INSTALLED:

Slope drains should be installed concurrently with diversion devices as soon as cut and fill operations have occurred.

STANDARDS AND SPECIFICATIONS:

Slope drains must be installed and maintained properly because failure will usually result in severe erosion of the slope. Other points of concern are failure from overtopping due to inadequate pipe inlet capacity or blockage, and lack of maintenance of the upstream diversion device capacity. Generally install slope drain down the slope-perpendicular to slope contours, extending beyond toe of slope. Install flared end or t-section at pipe inlet. Section should be well entrenched and stable so water can enter freely. Place compacted fill over and around pipe in the area of diversion device. Ensure that all pipe connections are secure. Securely anchor the exposed section of the drain with stakes. Install flared end section at pipe outlet-discharge into a sediment trap or other stabilized outlet. Protect area around inlet with filter fabric. Protect outlet with riprap or other energy dissipation device.

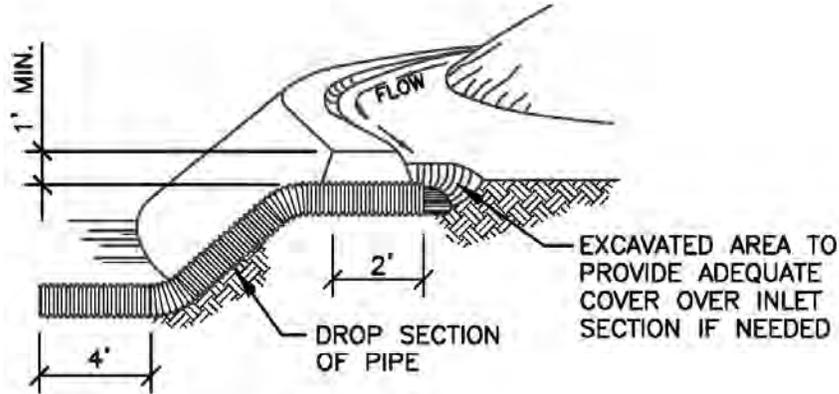
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm during construction. Remove sediment and trash accumulation at inlet. Repair settlement, cracking, or piping holes. Repair leaks or inadequate anchoring along pipe. Remove sediment and stabilize eroded areas at outlet-extend if necessary.

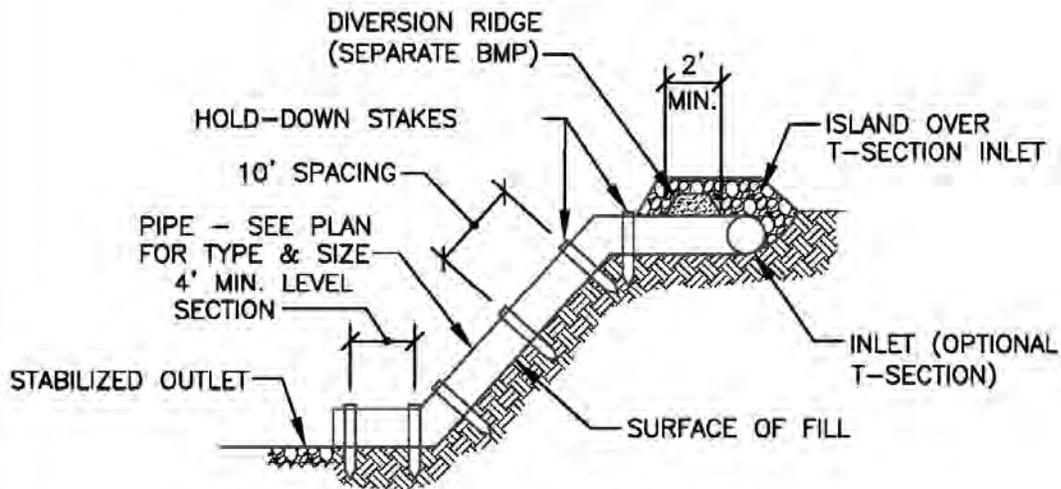
SITE CONDITIONS FOR REMOVAL:

Remove concurrently with upstream diversion device after slope has been stabilized. Stabilize the exposed areas where the slope drain and diversion device were removed.

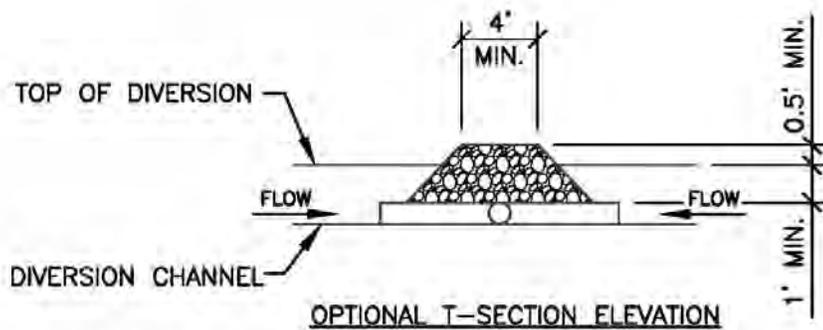
STANDARD DRAWING: RM - 4



PERSPECTIVE



PROFILE



OPTIONAL T-SECTION ELEVATION

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Date	
Revisions	



SLOPE DRAINS

RM-4



RM-5 SOIL ROUGHENING

Soil roughening is a temporary erosion control practice often used in conjunction with grading. Soil roughening involves increasing the relief of a bare soil surface with horizontal grooves by either stair-stepping (running parallel to the contour of the land) or using construction equipment to track the surface. Slopes that are not fine graded and left in a roughened condition can reduce erosion by reducing runoff velocity, increasing infiltration, trapping sediment and preparing the soil for seeding and planting by giving seed an opportunity to take root and grow.

APPROPRIATE APPLICATIONS:

Soil roughening is appropriate for all slopes, but works especially well on slopes greater than 3:1, on piles of excavated soil, and in areas with highly erodible soils. This technique is especially appropriate for soils that are frequently disturbed, because roughening is relatively easy.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow.

Contributing Area: Unlimited on slopes <10%, slopes >10% require additional BMPs

WHEN BMP IS TO BE INSTALLED:

Soil roughening should be done immediately after rough grading; prior to seeding or mulching.

STANDARDS AND SPECIFICATIONS:

Methods for roughening soil differ depending on the type of slope and the available equipment. These methods include stair-step grading, grooving, and tracking. When choosing a method, consider factors such as slope steepness, mowing requirements, whether the slope is formed by cutting or filling, and available equipment. Soil roughening is not appropriate for rocky slopes. Tracked machinery can excessively compact the soil, therefore lightweight machinery should be used.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and immediately after every storm. Rework the slope and regroove after sediment buildup is deeper than ½ the groove depth, or if rills have formed across the roughened surface.

SITE CONDITIONS FOR REMOVAL:

The slope should be reworked to the design grades prior to final stabilization.



RM-6 FIBER ROLLS/WATTLES

Fiber rolls (also called fiber logs or straw wattles) are tube-shaped erosion-control devices filled with straw, flax, rice, coconut fiber material, or composted material. Each roll is wrapped with UV-degradable polypropylene netting for longevity or with 100 percent biodegradable materials like burlap, jute, or coir. These devices reduce erosion on long or steep slopes by breaking up the slope length.

APPROPRIATE APPLICATIONS:

Fiber rolls can be used in areas of low shear stress such as; along the toe, top, face, and at-grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow, at the end of a downward slope where it transitions to a steeper slope, along the perimeter of a project or stockpile, as check dams in unlined ditches, and downslope of exposed soil areas.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow.

WHEN BMP IS TO BE INSTALLED:

Wattles should be installed immediately after rough grading; prior to seeding or mulching.

STANDARDS AND SPECIFICATIONS:

On slopes, install fiber rolls along the contour with a slight downward angle at the end of each row to prevent ponding at the midsection. Turn the ends of each fiber roll upslope to prevent runoff from flowing around the roll. Determine the vertical spacing for slope installations on the basis of the slope gradient and soil type. A good rule of thumb is: 1:1 slopes=10 feet apart, 2:1 slopes=20 feet apart, 3:1 slopes=30 feet apart, and 4:1 slopes=40 feet apart. Stake fiber rolls securely into the ground and orient them perpendicular to the slope. Fiber rolls can also be used at projects with minimal slopes. Typically, the rolls are installed along sidewalks, on the bare lot side, to keep sediment from washing onto sidewalks and streets and into gutters and storm drains.

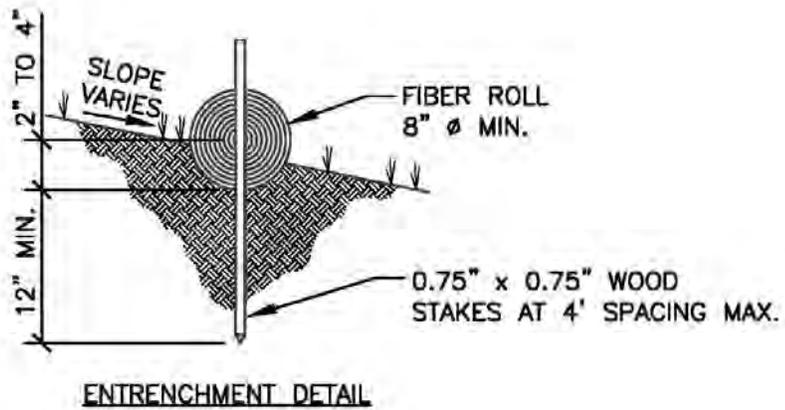
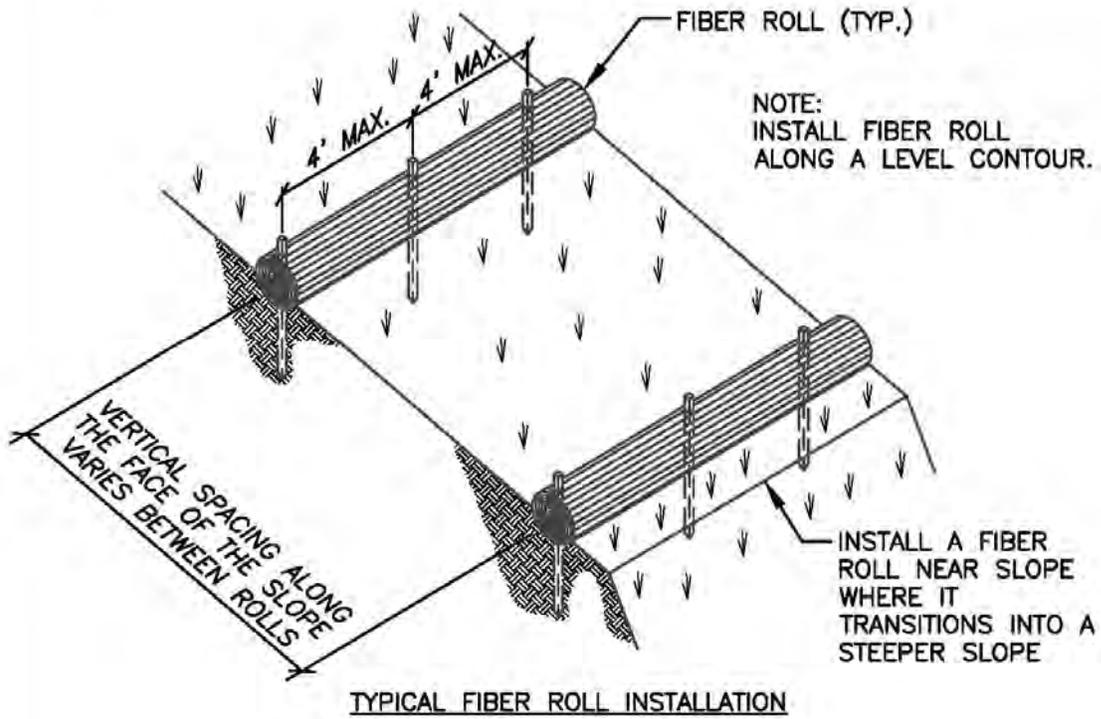
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove sediment accumulation when it reaches $\frac{1}{2}$ the height of the roll/wattle. Repair or replace split, torn, unraveled, or slumping fiber rolls.

SITE CONDITIONS FOR REMOVAL:

Fiber rolls are typically left in place on slopes. If they are removed after stabilization has been achieved, collect and dispose of the accumulated sediment.

STANDARD DRAWING: RM-6



<table border="1"> <tr> <td>Approved</td> <td>9/03/2008</td> </tr> <tr> <td>Date</td> <td></td> </tr> <tr> <td>Revisions</td> <td></td> </tr> <tr> <td></td> <td></td> </tr> </table>	Approved	9/03/2008	Date		Revisions					<p>FIBER ROLLS/WATTLES</p>	<p>RM-6</p>
Approved	9/03/2008										
Date											
Revisions											



SC-1 VEGETATED FILTER STRIP

Vegetated filter strips or buffers are areas of natural or established vegetation maintained to protect the water quality of neighboring areas. Buffer zones slow stormwater runoff, provide an area where runoff can permeate the soil, contribute to ground water recharge, and filter sediment. Slowing runoff also helps to prevent soil erosion and streambank collapse.

APPROPRIATE APPLICATIONS:

Vegetated buffers can be used in any area able to support vegetation. They are most effective and beneficial on floodplains, near wetlands, along streambanks, and on unstable slopes. Filter strips can be used adjacent to low or medium density residential areas on gently sloping ground.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Overland sheet flow only-cannot treat high velocity flows.

WHEN BMP IS TO BE INSTALLED:

Filter strips can be established immediately after rough grading to trap sediment during construction and/or immediately after final grading as a permanent measure to control surface runoff.

STANDARDS AND SPECIFICATIONS:

Determine buffer widths after carefully considering slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and amount of pollutants, and annual rainfall. Make sure buffer widths increase as slope increases. In areas where flows are more concentrated and fast, combine buffer zones with other practices such as level spreaders, infiltration areas, or diversions to prevent erosion and rilling. Fence off any undisturbed vegetated strips to be preserved. No activity, including parking/storing vehicles or equipment, shall be permitted in the vegetated/woody strip. If a grass filter strip is constructed, it must be completed and vegetated before construction in a contributing area is started.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove sediment accumulation once it reaches 6" in depth. Fill and compact eroded areas and reseed, mulch and fertilize or establish other vegetation in the affected areas. After improvements are complete, regrade and reseed the top edge of the filter strip to remove sediment trapped during construction and prolong the effective use of the filter strip.



SC-2 SILT FENCE

A silt fence is a length of filter fabric stretched between anchoring posts spaced at regular intervals along the site at low/downslope areas. The filter fabric should be entrenched in the ground at least 6". When installed correctly and inspected frequently, silt fences encourages the ponding of runoff and can be an effective barrier to sediment leaving the site.

APPROPRIATE APPLICATIONS:

Installed along slopes, at base of slopes, and around the perimeter of a site as a final barrier to sediment being carried off site. Silt fence should not be used in areas of concentrated flow or as check dams.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow only

Contributing Area: Drainage area should not exceed 0.25 acres per 100-foot fence length.

Slope Length: The slope length above the fence should not exceed 100 feet.

WHEN BMP IS TO BE INSTALLED:

Silt fence should be installed prior to disturbance of natural vegetation and at intervals during construction of fill slopes.

STANDARDS AND SPECIFICATIONS:

If a standard-strength fabric is used, it can be reinforced with wire mesh behind the filter fabric. This increases the effective life of the fence. The maximum life expectancy for synthetic fabric silt fences is about 6 months, depending on the amount of rainfall and runoff. The fence should be designed to withstand the runoff from a 10-year peak storm event. Generally, drive posts for fence line, dig trench to required dimensions in front of posts for fabric burial, attach wire mesh to posts (if necessary), attach fabric to posts-allowing required length below ground level to run fabric along bottom of trench, and backfill and compact soil in trench to protect and anchor fabric. Alternate (and actually preferred) construction procedures include installing the fence by slicing it into the ground with specialized equipment.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Monitor and remove sediment buildup that is deeper than ½ the fence height. Replace torn/clogged fabric; repair loose fabric. Repair unstable or broken posts. Stabilize any areas susceptible to undermining. Add additional fencing if necessary to provide adequate protection.

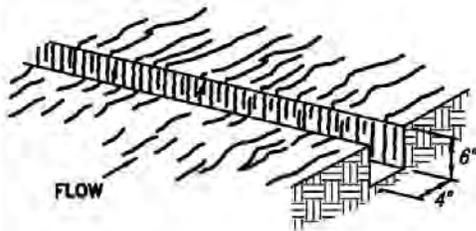
SITE CONDITIONS FOR REMOVAL:

After permanent vegetation of slope is established, remove fence, regrade trench area and vegetate.

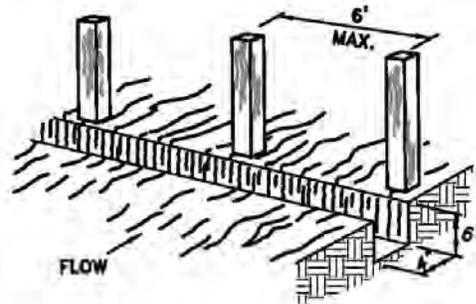


STANDARD DRAWING: SC-2a and SC-2b

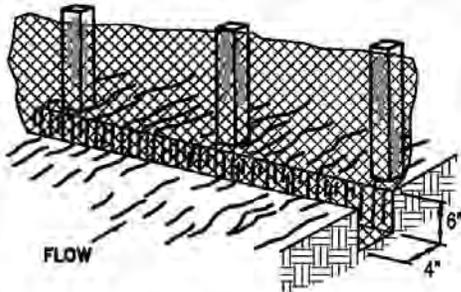
1. EXCAVATE A 6"x4" TRENCH



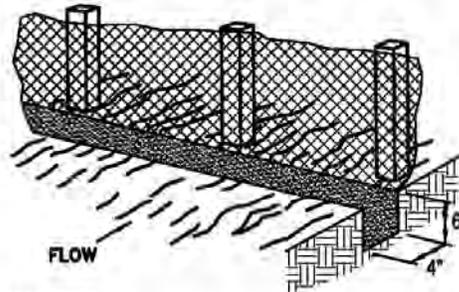
2. SET THE STAKES ALONG THE DOWN SLOPE SIDE OF THE TRENCH.



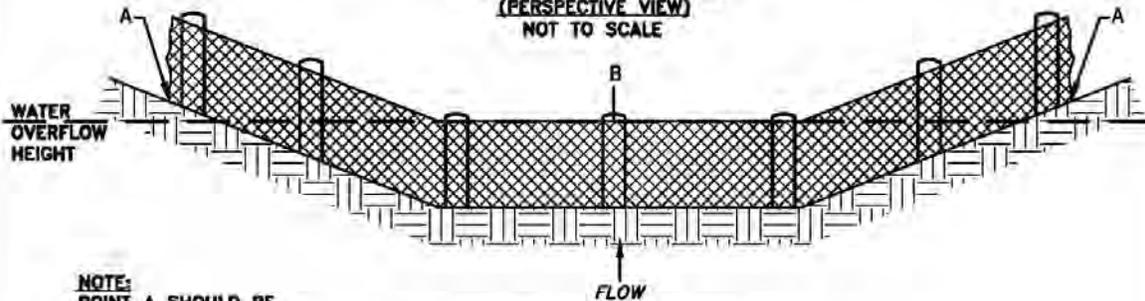
3. STAPLE GEOTEXTILE MATERIAL TO STAKES AND EXTEND IT INTO AND AROUND THE BOTTOM OF THE TRENCH.



4. BACK FILL AND COMPACT THE EXCAVATED SOIL OVER THE GEOTEXTILE IN THE TRENCH.



**SHEET FLOW INSTALLATION
(PERSPECTIVE VIEW)
NOT TO SCALE**



NOTE:
POINT A SHOULD BE
HIGHER THAN POINT B.

**DRAINAGE WAY INSTALLATION
(FRONT ELEVATION)
NOT TO SCALE**

Approved	9/03/2008
Date	
Revisions	



SILT FENCE

SC-2A



SILT FENCE NOTES:

A) INSTALLATION

1. THE HEIGHT OF SILT FENCE SHALL BE A MINIMUM OF 18 INCHES ABOVE THE ORIGINAL GROUND SURFACE AND SHALL NOT EXCEED 34 INCHES ABOVE THE GROUND SURFACE.
2. THE FABRIC SHALL BE PURCHASED IN A CONTINUOUS ROLL CUT TO LENGTH OF THE BARRIER TO AVOID THE USE OF JOINTS. WHEN JOINTS ARE UNAVOIDABLE, FILTER CLOTH SHALL BE SECURELY SPLICED TOGETHER ONLY AT SUPPORT POSTS, WITH A MAX 6 INCH OVERLAP.
3. DIG A TRENCH AT LEAST 6 INCHES DEEP AND 4 INCHES WIDE ALONG THE TRENCH ALIGNMENT.
4. DRIVE POSTS AT LEAST 24 INCHES INTO THE GROUND ON THE DOWNSLOPE SIDE OF THE TRENCH. SPACE POSTS A MAXIMUM OF 6 FEET APART.
5. THE SEDIMENT FABRIC SHALL BE FASTENED SECURELY TO THE UPSLOPE SIDE OF THE POSTS USING A MINIMUM OF ONE INCH LONG, HEAVY-DUTY WIRE STAPLES OR TIE-WIRES, AND EIGHT INCHES OF THE FABRIC SHALL BE EXTENDED INTO THE TRENCH. THE FABRIC SHALL NOT BE STAPLED TO EXISTING TREES.
6. PLACE THE BOTTOM 1 FOOT OF FABRIC IN THE MINIMUM-OF-6-INCH DEEP TRENCH, LAPPING TOWARD THE UPSLOPE SIDE. BACK FILL WITH COMPACTED EARTH OR GRAVEL.
7. IF A SILT FENCE IS TO BE CONSTRUCTED ACROSS A DITCH LINE OR SWALE, IT MUST BE OF SUFFICIENT LENGTH TO ELIMINATE ENDFLOW, AND THE PLAN CONFIGURATION SHALL RESEMBLE AN ARC OR HORSESHOE, PLACED ON A CONTOUR, WITH THE ENDS ORIENTED UPSLOPE. EXTRA-STRENGTH SEDIMENT FABRIC SHALL BE USED WITH A MAXIMUM 3-FOOT SPACING OF POSTS.
8. TO REDUCE MAINTENANCE, EXCAVATE A SHALLOW SEDIMENT STORAGE AREA IN THE UPSLOPE SIDE OF THE FENCE. PROVIDE GOOD ACCESS IN AREA OF HEAVY SEDIMENTATION FOR CLEAN OUT AND MAINTENANCE.
9. SILT FENCES SHALL BE REMOVED WHEN THEY HAVE SERVED THEIR USEFUL PURPOSE, BUT NOT BEFORE THE UPSLOPE AREA HAS BEEN PERMANENTLY STABILIZED.
10. INSTALLATION WITH SLICING METHOD IS PREFERRED.

B) TROUBLESHOOTING:

1. DETERMINE THE EXACT LOCATION OF UNDERGROUND UTILITIES, BEFORE FENCE INSTALLATION SO UTILITIES ARE NOT DISTURBED.
2. GRADE ALIGNMENT OF FENCE NEEDED TO PROVIDE A BROAD, NEARLY LEVEL AREA UPSTREAM OF FENCE TO ALLOW SEDIMENT COLLECTION AREA.

C) INSPECTION MAINTENANCE:

1. INSPECT SILT FENCES AT LEAST ONCE A WEEK AND AFTER EACH 1/2" OF RAINFALL. MAKE ANY REQUIRED REPAIRS IMMEDIATELY.
2. SHOULD THE FABRIC OF A SEDIMENT FENCE COLLAPSE, TEAR, DECOMPOSE, OR BECOME INEFFECTIVE, REPLACE IT PROMPTLY.
3. REMOVE SEDIMENT DEPOSITS AS NECESSARY TO PROVIDE ADEQUATE STORAGE VOLUME FOR THE NEXT RAIN AND TO REDUCE PRESSURE ON THE FENCE. AVOID DAMAGING OR UNDERMINING THE FENCE DURING CLEANOUT. SEDIMENT ACCUMULATION SHOULD NOT EXCEED 1/2 THE HEIGHT OF THE FENCE.
4. REMOVE ALL FENCING MATERIALS AND UNSTABLE SEDIMENT DEPOSITS, AND BRING THE AREA TO GRADE AND STABILIZE IT AFTER THE CONTRIBUTING DRAINAGE AREA HAS BEEN PROPERLY AND COMPLETELY STABILIZED.

<p>9/03/2008 Approved Date</p> <p>Revisions</p>		<h2>SILT FENCE NOTES</h2>	<h2>SC-2B</h2>
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SC-3 STRAW BALE DIKE

A straw bale dike consists of a series of straw (or hay) bales butted firmly end to end and anchored in place with stakes placed along the low/downslope areas of a site. The straw bales should be entrenched in the ground. When installed correctly and inspected frequently, straw bale dikes encourage the ponding of runoff and can be an effective barrier to prevent sediment from leaving the site in stormwater runoff.

APPROPRIATE APPLICATIONS:

Installed along slopes, at base of slopes, and around the perimeter of a site as a final barrier to sediment being carried off site. Straw bale dikes should not be used in areas of significant concentrated flow as check dams.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and minimal concentrated flow.

Contributing Area: Drainage area should not exceed 0.25 acres per 100-foot fence length. For minor swales where the dike will serve as a ditch check, the drainage area shall not exceed 2 acres.

Slope Length: The slope length above the fence should not exceed 100 feet. Reduce this as the area above the dike steepens.

WHEN BMP IS TO BE INSTALLED:

Straw bale dikes should be installed prior to disturbance of natural vegetation and at intervals during construction of fill slopes.

STANDARDS AND SPECIFICATIONS:

The maximum life expectancy for straw bale dikes is about 3 months, depending on the amount of rainfall and runoff. The dike should be designed to withstand the runoff from a 10-year peak storm event. The dike should be installed on level ground at least 10 feet from the toe of the slope. Excavate a trench at least 4" deep and a bale width wide and long enough that the end bales are upslope of the sediment pool. Anchor bales by driving two 36" long 2"x2" hardwood stakes through each bale until nearly flush with the top. Drive the first stake toward the previously laid bale to force the bales together. Wedge loose straw into any gaps between the bales. Backfill and compact the excavated soil against the bales to ground level on the downslope side and to 4" above ground level on the upslope side.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove sediment buildup that is deeper than ½ the dike height. Replace deteriorated or damaged bales. Repair unstable or broken stakes.

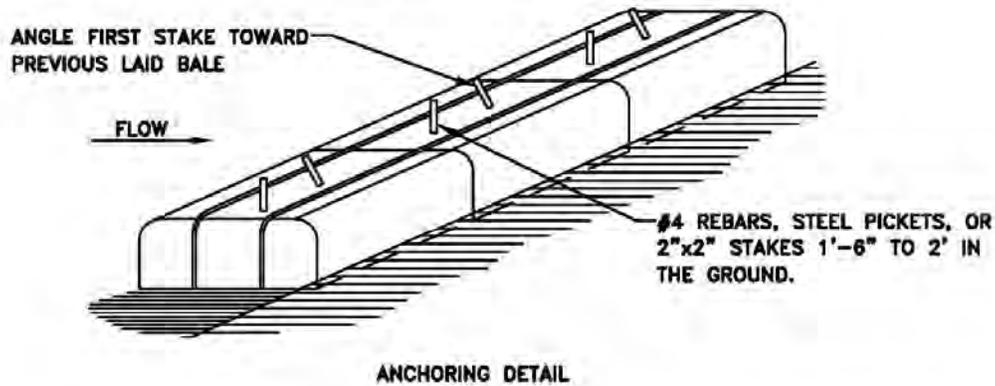
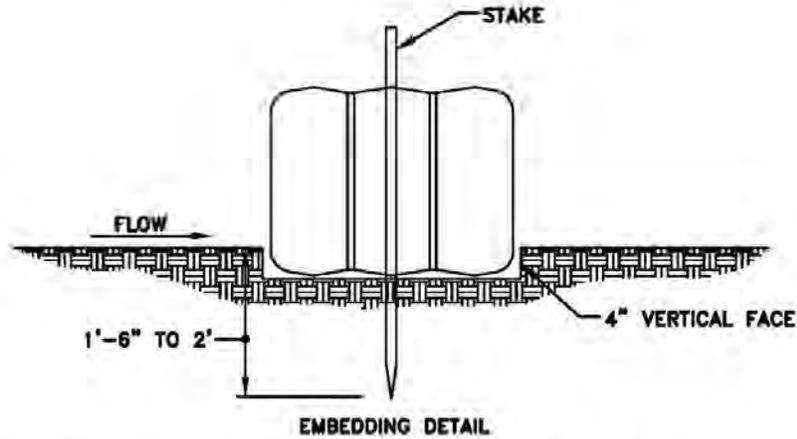


Stabilize any areas susceptible to undermining. Add additional bales if necessary to provide adequate protection.

SITE CONDITIONS FOR REMOVAL:

After permanent vegetation of slope is established, remove the dike, regrade trench area and vegetate.

STANDARD DRAWING: SC-3



1. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY ABUTTING THE ADJACENT BALES.
2. EACH BALE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 4".
3. BALES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE-BARS DRIVEN THROUGH THE BALES. THE FIRST STAKE IN EACH BALE SHALL BE ANGLED TOWARD PREVIOUSLY LAID BALE TO FORCE BALES TOGETHER.
4. INSPECTION SHALL BE AT LEAST ONCE A WEEK AND AFTER EACH 1/2" RAIN. REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY.
5. BALES SHALL BE REMOVED BY THE OWNER WHEN THEY HAVE SERVED THEIR USEFULNESS SO AS NOT TO BLOCK OR IMPEDE STORM FLOW OR DRAINAGE.

	9/03/2008		STRAW BALE DIKE	SC-3
Approved	Date			
Revisions				



SC-4 COMPOST FILTER SOCKS

A compost filter sock is a type of contained compost filter berm. It is a mesh tube filled with composted material that is placed perpendicular to sheet-flow runoff to control erosion and retain sediment in disturbed areas.

APPROPRIATE APPLICATIONS:

Compost filter socks are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat stormwater that runs off as sheet flow. Filter socks can also be used on pavement as inlet protection for storm drains and as small check dams to slow water flow in small ditches. Filter socks used for erosion control are usually 12 inches in diameter, although 8 inch, 18 inch, and 24 inch– diameter socks are used in some applications.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and small concentrated flow

Contributing Area: Drainage area should not exceed 0.25 acres per 100-foot fence length.

Slope Length: The slope length above the fence should not exceed 100 feet.

WHEN BMP IS TO BE INSTALLED:

Filter socks can be used prior to disturbance of natural vegetation and at intervals during construction of fill slopes.

STANDARDS AND SPECIFICATIONS:

The diameter of the filter sock will vary depending upon the steepness and length of the slope. In areas of concentrated flow, filter socks are sometimes placed in an inverted V going up the slope, to reduce the velocity of water running down the slope. The project engineer may also consider placing filter socks at the top and base of the slope or placing a series of filter socks every 15 to 25 feet along the vertical profile of the slope. Generally, the filter sock is filled, put in place, and anchored using stakes, so no trenching is required. During installation, the ends of the sock should be directed upslope

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove sediment buildup that is deeper than $\frac{1}{2}$ the filter sock height. Repair unstable or broken posts. Stabilize any areas susceptible to undermining. Add additional socks if necessary to provide adequate protection.

SITE CONDITIONS FOR REMOVAL:

Remove the sock after permanent vegetation of slope is established. Regrade trench area and vegetate.



SC-5 COMPOST FILTER BERMS

A compost filter berm is a dike of compost or a compost product that is placed perpendicular to sheet flow runoff to control erosion in disturbed areas and retain sediment. It can be used in place of a traditional control tool such as a silt fence or compost filter socks.

APPROPRIATE APPLICATIONS:

Vegetated compost filter berms are generally placed along the perimeter of a site, or at intervals along a slope. A filter berm also can be used as a check dam in small drainage ditches.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and small concentrated flow.

Contributing Area: Drainage area should not exceed 0.25 acres per 100-foot fence length.

WHEN BMP IS TO BE INSTALLED:

Install the compost berm prior to disturbance of natural vegetation and at intervals during construction of fill slopes.

STANDARDS AND SPECIFICATIONS:

The compost filter berm dimensions should be modified based on site-specific conditions, such as soil characteristics, existing vegetation, site slope, and climate, as well as project-specific requirements. Generally the berms are trapezoidal in cross section with the base twice the height of the berm. The compost should be uniformly applied to the soil surface, compacted, and shaped to into a trapezoid. Compost filter berms can be installed on frozen or rocky ground. The filter berm may be vegetated by hand, by incorporating seed into the compost prior to installation, or by hydraulic seeding following berm construction.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every storm. Remove sediment buildup deeper than ½ the filter berm. Any areas that have been washed away should be replaced. If the berm has experienced significant washout, the filter berm alone may not be the appropriate BMP for the area or the size of the berm may need to be increased.

SITE CONDITIONS FOR REMOVAL:

Vegetated filter berms are normally left in place and provide long-term filtration of stormwater as a post-construction best management practice (BMP). If temporary, break down the berm once construction is complete and spread the compost around the site as a soil amendment or mulch.



SC-6 SEDIMENT BASIN

A temporary settling basin designed to slowly release runoff, detaining it long enough to allow most of the sediment to settle out. Basins should be used in conjunction with additional BMPs, such as temporary seeding, to reduce the total amount of sediment washing into the structure. Sediment basins may also be designed to be converted from a temporary basin to a permanent storm water detention basin after construction has ended.

APPROPRIATE APPLICATIONS:

Should be located as close to the sediment source as possible. A sediment basin should not be used in areas of continuously running water (live streams) nor areas where failure of the embankment will result in loss of life, damage to homes or structures, or prevent the use of roadways or utilities.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow.

Basin Volume: Volume of 10 year, 20 minute storm plus silt load of 1800 cf/acre below riser top.

WHEN BMP IS TO BE INSTALLED:

Sediment basins should be placed prior to the disturbance of natural vegetation.

STANDARDS AND SPECIFICATIONS:

For permanent structures, a qualified professional engineer experienced in designing dams should complete the basin design. Excavate basin to length, width, depth and slopes specified on plans. Place and compact fill to construct dam to elevation at least 1 foot above crown of outlet pipe. Install outlet pipe and compact clay soil around pipe. Install the perforated riser pipe, wrap with fabric, and surround with uniformly graded gravel. Install energy dissipation at downstream end of outlet pipe. Complete installation of dam to an elevation 10% above design height to allow for settling. Grade and stabilize spillway. Install monitoring post near outlet of basin. Mark maximum allowable sediment depth.

OPERATION AND MAINTENANCE PROCEDURES:

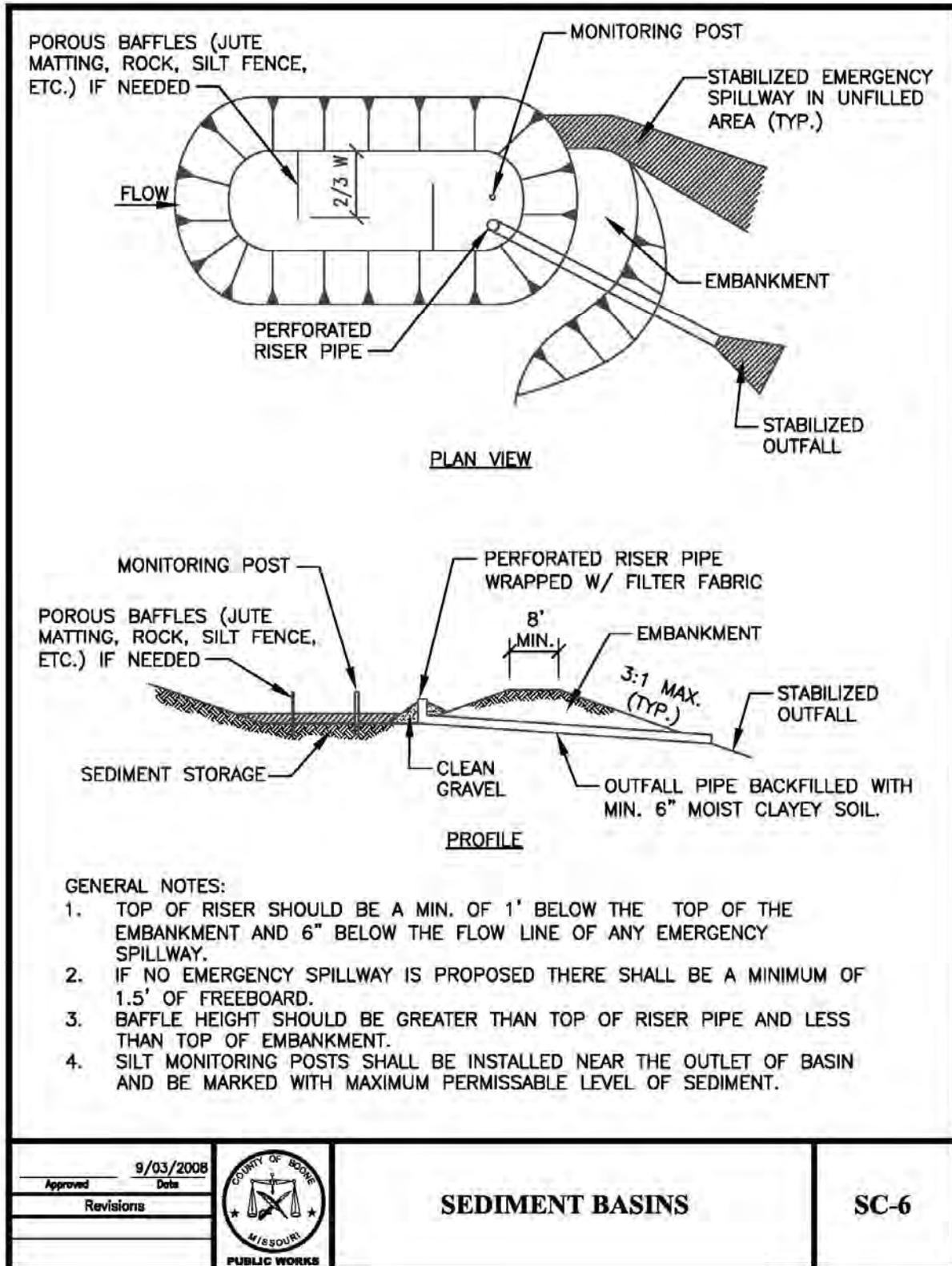
Inspect at least every week and after every ½” storm. Remove trash accumulation at outlet. Remove sediment accumulations once sediment reaches design depth, as indicated on monitoring posts. Repair and re-vegetate any erosion damage on spillway. Repair settlement, cracking, piping holes, or seepage at embankment. Replace gravel around riser if basin does not drain properly.

SITE CONDITIONS FOR REMOVAL:

Remove after upstream areas are stabilized. Regrade as appropriate and vegetate immediately.



STANDARD DRAWING: SC-6





SC-7 SEDIMENT TRAP

A sediment trap is a temporary containment area that allows sediment in collected storm water to settle out during infiltration or before the runoff is discharged.

APPROPRIATE APPLICATIONS:

Sediment traps are commonly used at the outlets of stormwater diversion structures, channels, slope drains, construction site entrances, vehicle wash areas, or other runoff conveyances.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow.

Contributing Area: Maximum of 5 acres.

Trap Volume: Silt load of 1800 cf/acre.

WHEN BMP IS TO BE INSTALLED:

Install sediment traps prior to disturbance of natural vegetation.

STANDARDS AND SPECIFICATIONS:

Take care to situate sediment traps for easy access by maintenance crews. Excavate an area for the sediment trap, making sure the side slopes are no steeper than 2:1 and the embankment height no more than 5 feet from the original ground surface. Install dewatering pipe, if necessary. Place and compact fill to construct embankments and the spillway. To reduce flow rate from the trap, line the outlet with rip rap and gravel over the dewatering pipe, if necessary. The spillway weir for each temporary sediment trap should be at least 4 feet long for a 1-acre drainage area and increase by 2 feet for each additional drainage acre added, up to a maximum drainage area of 5 acres. Install monitoring posts in the trap which mark $\frac{1}{2}$ the design depth for sediment accumulation.

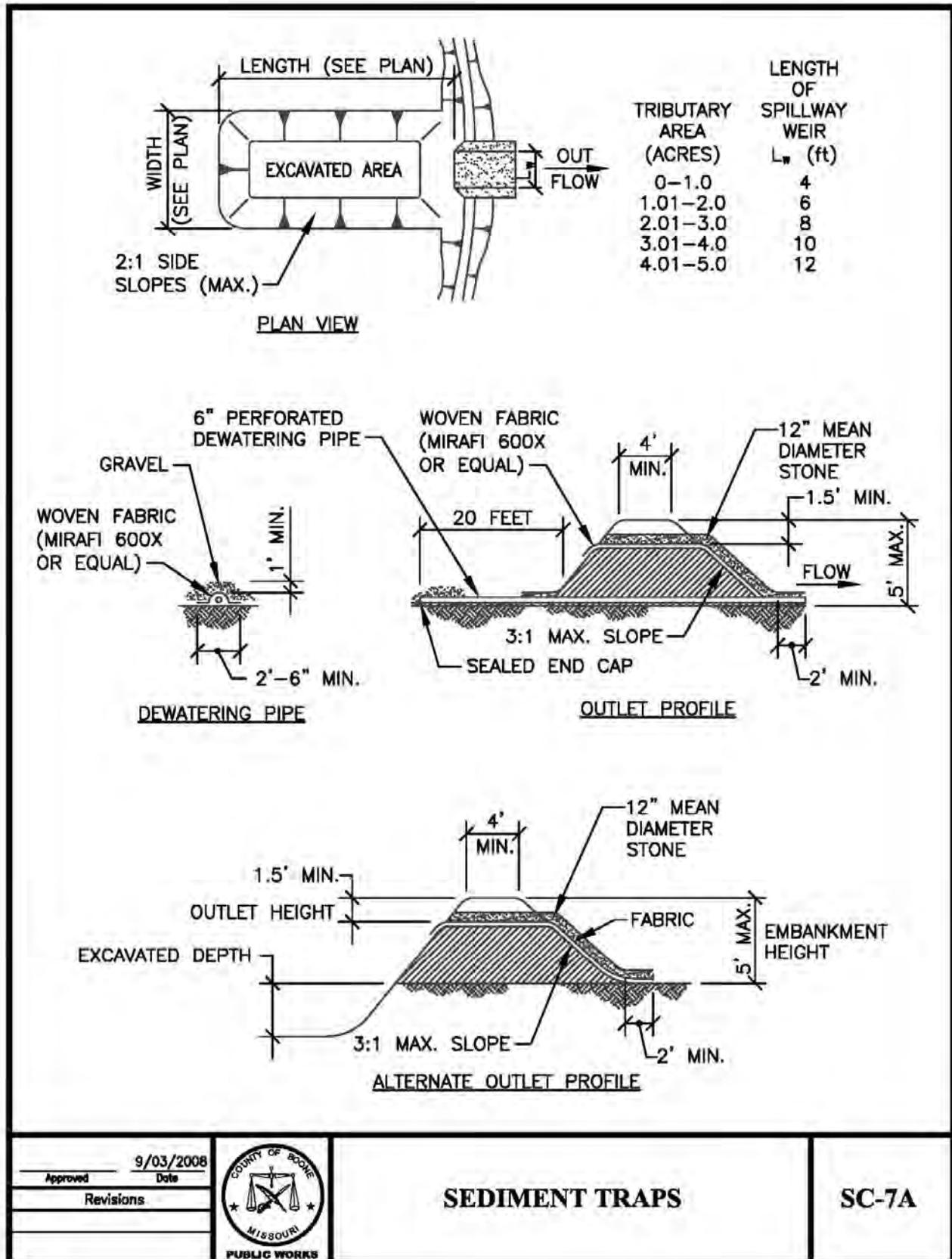
OPERATION AND MAINTENANCE PROCEDURES:

Inspect at least every week and after every $\frac{1}{2}$ " storm. Remove trash accumulation. Remove sediment accumulations once sediment reaches design depth, as indicated on monitoring posts. Repair and revegetate any erosion damage. Repair settlement, cracking, piping holes, or seepage at embankment.

SITE CONDITIONS FOR REMOVAL:

Remove after upstream areas are stabilized. Regrade as appropriate and vegetate immediately.

STANDARD DRAWING: SC-7a and SC-7b



Approved	9/03/2008
Date	
Revisions	



SEDIMENT TRAPS

SC-7A



TEMPORARY SEDIMENT TRAP NOTES:

A) CONSTRUCTION SPECIFICATIONS:

1. THE AREA UNDER THE EMBANKMENT SHALL BE CLEARED, GRUBBED, AND STRIPPED OF ANY VEGETATION AND ROOT MAT.
2. FILL MATERIAL FOR THE EMBANKMENT SHALL BE FREE OF ROOTS OR OTHER WOODY VEGETATION, ORGANIC MATERIAL, LARGE STONES, AND OTHER OBJECTIONABLE MATERIAL. THE EMBANKMENT SHOULD BE COMPACTED IN 6-INCH LAYERS BY TRAVERSING WITH CONSTRUCTION EQUIPMENT.
3. THE EARTHEN EMBANKMENT SHALL BE SEEDED WITH TEMPORARY OR PERMANENT VEGETATION IMMEDIATELY AFTER INSTALLATION
4. CONSTRUCTION OPERATION SHALL BE CARRIED OUT TO MINIMIZE EROSION AND WATER POLLUTION.
5. ALL CUT AND FILL SLOPES SHALL BE 2H:1V OR FLATTER EXCEPT FOR EXCAVATED, WET STORAGE AREAS WHICH MAY BE AT A MAXIMUM 1H:1V GRADE.

B) INSPECTION AND MAINTENANCE

1. INSPECT THE TEMPORARY SEDIMENT TRAP WEEKLY AND AFTER EACH STORM EVENT OF 1/2-INCH OR GREATER.
2. REMOVE AND PROPERLY DISPOSE OF SEDIMENT WHEN IT ACCUMULATES TO ONE-HALF THE DESIGN VOLUME.
3. PERIODICALLY CHECK THE EMBANKMENT, SPILLWAY, AND OUTLET APRON FOR EROSION DAMAGE, SETTLING SEEPAGE, OR SLUMPING ALONG THE TOE AND REPAIR IMMEDIATELY.
4. REPLACE THE SPILLWAY GRAVEL FACING IF IT BECOMES CLOGGED.
5. INSPECT VEGETATION AND RESEED IF NECESSARY.
6. REPLACE ANY DISPLACED RIPRAP SO THAT NO REPLACEMENT ROCK IS ABOVE THE DESIGN GRADE.
7. REMOVE THE TEMPORARY SEDIMENT TRAP AFTER THE DRAINAGE AREA HAS BEEN PERMANENTLY STABILIZED, INSPECTED, AND APPROVED. DO SO BY DRAINING ANY WATER, REMOVING THE SEDIMENT TO A DESIGNATED DISPOSAL AREA, AND GRADING THE SITE TO BLEND WITH THE SURROUNDING AREA; THEN STABILIZE.

<u>Approved</u>	9/03/2008 <small>Date</small>		SEDIMENT TRAPS	SC-7B
<u>Revisions</u>				



SC-8 CURB AND GUTTER INLET PROTECTION

A temporary sediment control barrier consisting of a filter media, such as compost filter socks, gravel and mesh, sandbags, gravel bags, etc., around a curb and gutter inlet designed to prevent sediment from entering the storm sewer. Shallow temporary ponding may occur during and after rainfall events.

APPROPRIATE APPLICATIONS:

Place protection at inlets where runoff may contain sediment-laden water.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow.

Contributing Area: Maximum of 1 acre.

WHEN BMP IS TO BE INSTALLED:

Install inlet protection immediately after installation of the inlet, or prior to land disturbing activities beginning on the contributing upstream area to the inlet.

STANDARDS AND SPECIFICATIONS:

Typical types of curb and gutter inlet protection include: fabricated inlet filters (follow manufacturer's instructions), compost filter sock (make sure that both ends of the sock are anchored accordingly), gravel and wire mesh (construct and anchor wood frame, fasten wire mesh and fabric to frame and place the gravel on top of the entire structure), sandbags and gravel bags (may be placed either as a j-hook on the upstream end of the inlet or as a full barrier, sometimes stacked 2 bags high, across the entire opening of the inlet). Incorporate an overflow bypass into the inlet protection structure in areas, such as heavy traffic streets, where excessive ponding of water around the inlet may become a safety issue. Sediment controls behind the curb will be necessary to prevent the discharge of sediment in these bypasses.

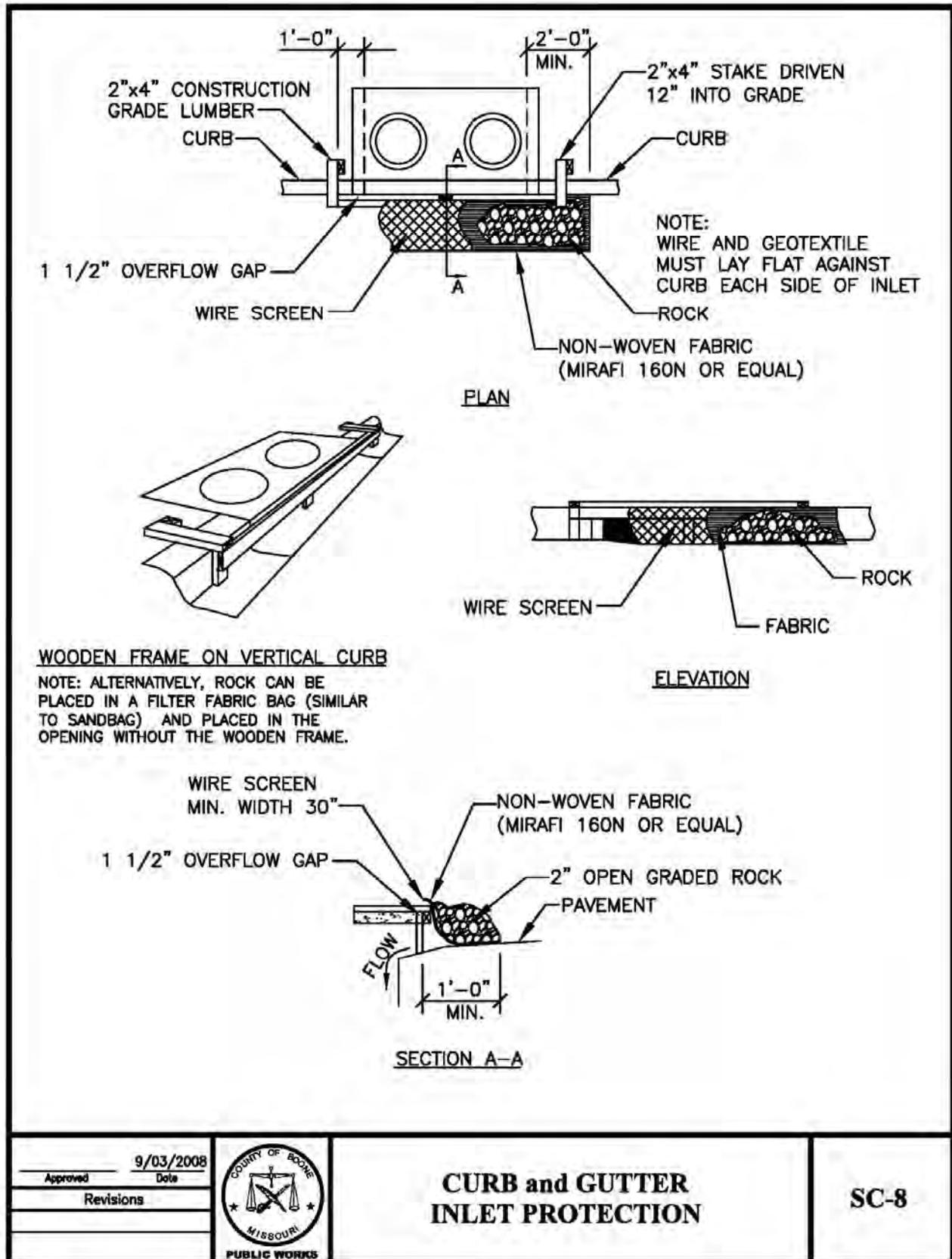
OPERATION AND MAINTENANCE PROCEDURES:

Inspect inlet protection of all media types weekly and after each ½" rainfall event to make sure they are functioning properly. Remove trash and debris. Remove sediment from the inlet protection when half of the protection structure height has been filled. Repair elements to original configuration as needed.

SITE CONDITIONS FOR REMOVAL:

Remove after contributing drainage areas have been adequately stabilized.

STANDARD DRAWING: SC-8





SC-9 DROP INLET PROTECTION

A temporary sediment control barrier consisting of a filter fabric around a recessed area inlet designed to prevent sediment from entering the storm sewer. Shallow temporary ponding may occur during and after rainfall events.

APPROPRIATE APPLICATIONS:

At recessed area or yard inlets where runoff may contain sediment-laden water.

CONDITIONS FOR EFFECTIVE USE:

Type of Flow: Sheet flow and concentrated flow.

Contributing Area: Maximum of 1 acre.

WHEN BMP IS TO BE INSTALLED:

Place inlet protection immediately after installation of the inlet, or prior to land disturbing activities beginning on the contributing upstream area to the inlet.

STANDARDS AND SPECIFICATIONS:

Typical types of drop inlet protection include: manufactured filtering product or silt fence frames. Follow the manufacture's instruction for placement of proprietary products. For the silt fence protection, install a wood frame, dig a trench around the inlet for fabric to be buried, fasten fabric tightly to frame, backfill and compact trench. Alternatively, a sod filter can be installed by preparing and fertilizing the soil around the inlet and installing sod for a distance of at least 4 feet in each direction. The sod should be staked, stapled and/or netted at the corners and center of sod strips as required and then watered immediately. For safety, inlet protection structures which pond water onto streets, parking lots or driveways should be designed to have some method for allowing excess water from large storms to bypass or overflow.

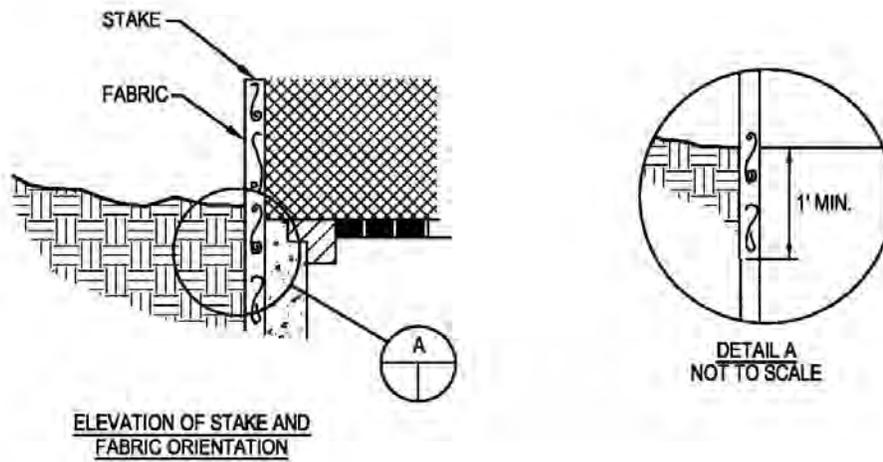
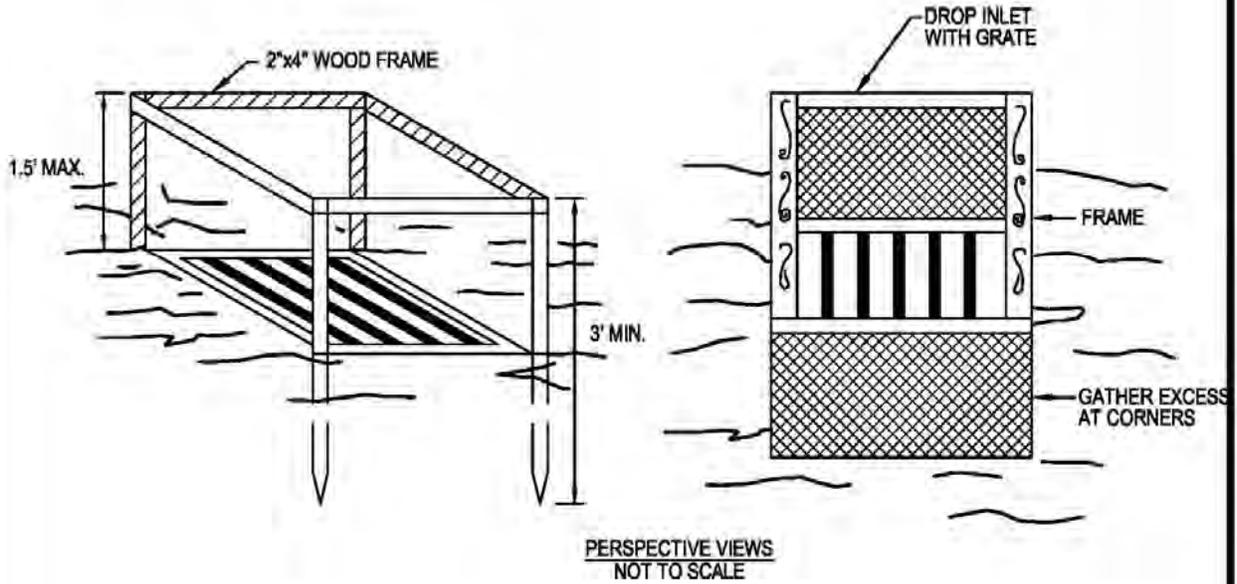
OPERATION AND MAINTENANCE PROCEDURES:

Inspect inlet protection of all media types weekly and after each significant rainfall event to make sure they are functioning properly. Remove trash and debris. Remove sediment from the inlet protection when half of the protection structure height has been filled. Repair elements to original configuration as needed.

SITE CONDITIONS FOR REMOVAL:

Remove after contributing drainage areas have been adequately stabilized.

STANDARD DRAWING: SC-9a and SC-9b



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Date	
Revisions	



**DROP INLET PROTECTION
(SILT FENCE)**

SC-9A



SEDIMENT FENCE DROP INLET PROTECTION NOTES:

A) CONSTRUCTION SPECIFICATIONS:

1. SEDIMENT FENCE SHALL BE CUT FROM A CONTINUOUS ROLL TO AVOID JOINTS.
2. FOR STAKES, USE 2X4 WOOD OR EQUIVALENT METAL WITH A MINIMUM LENGTH OF 3 FEET.
3. SPACE STAKES EVENLY AROUND THE PERIMETER OF THE INLET A MAXIMUM OF 3 FEET APART, AND SECURELY DRIVE THEM INTO THE GROUND, APPROXIMATELY 18 INCHES DEEP.
4. TO PROVIDE NEEDED STABILITY TO THE INSTALLATION, FRAME WITH 2X4 WOOD STRIPS AROUND THE CREST OF THE OVERFLOW AREA AT A MAXIMUM OF 1.5 FEET ABOVE THE DROP INLET CREST.
5. PLACE THE BOTTOM 12 INCHES OF THE FABRIC IN A TRENCH AND BACK FILL THE TRENCH WITH 12-INCHES OF COMPACTED SOIL.
6. FASTEN FABRIC SECURELY BY STAPLES, OR WIRE IT TO THE STAKES AND FRAME. JOINTS MUST BE OVERLAPPED TO THE NEXT STAKE.

B) INSPECTION AND MAINTENANCE:

1. THE STRUCTURE SHALL BE INSPECTED WEEKLY AND AFTER EACH RAIN EVENT OF 1/2 INCH OR GREATER AND REPAIRS MADE AS NEEDED.
2. SEDIMENT SHALL BE REMOVED AND THE TRAP RESTORED TO ITS ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO ONE HALF THE DESIGN DEPTH OF THE TRAP. REMOVED SEDIMENT SHALL BE DEPOSITED IN A SUITABLE AREA AND IN SUCH A MANNER THAT IT WILL NOT ERODE.
3. STRUCTURES SHALL BE REMOVED AND THE AREA STABILIZED WHEN THE REMAINING DRAINAGE AREA HAS BEEN PROPERLY STABILIZED.

Approved _____ Date 9/03/2008		DROP INLET PROTECTION (SILT FENCE) NOTES	SC-9B
Revisions _____ _____ _____			



TC-1 CONSTRUCTION ENTRANCE/EXIT

A stabilized entrance to a construction site which is designed to minimize the amount of sediment tracked from the site on vehicles and equipment. Mud and sediment fall off of tires as they travel along the stabilized entrance.

APPROPRIATE APPLICATIONS:

At locations where it is safe for construction vehicles and equipment to access existing streets, preferably at the location of future streets or drives.

CONDITIONS FOR EFFECTIVE USE:

Site conditions will dictate design and need. Ditches or pipes, if needed, sized for 15 year, 20 minute storm; HGL 6" below surface of entrance.

WHEN BMP IS TO BE INSTALLED:

Install stabilized construction entrance/exit prior to vehicles or equipment accessing unpaved areas. This will most likely be the first BMP to be installed on the site.

STANDARDS AND SPECIFICATIONS:

Limit the points of entrance/exit to the construction site. Properly grade and compact each construction entrance/exit to prevent runoff from leaving the site. Install culvert under entrance if needed to maintain positive drainage. Place fabric and cover with aggregate, forming a diversion across the entrance, if needed, to direct runoff away from the roadway. Require all employees, subcontractors, and suppliers to utilize the stabilized construction access.

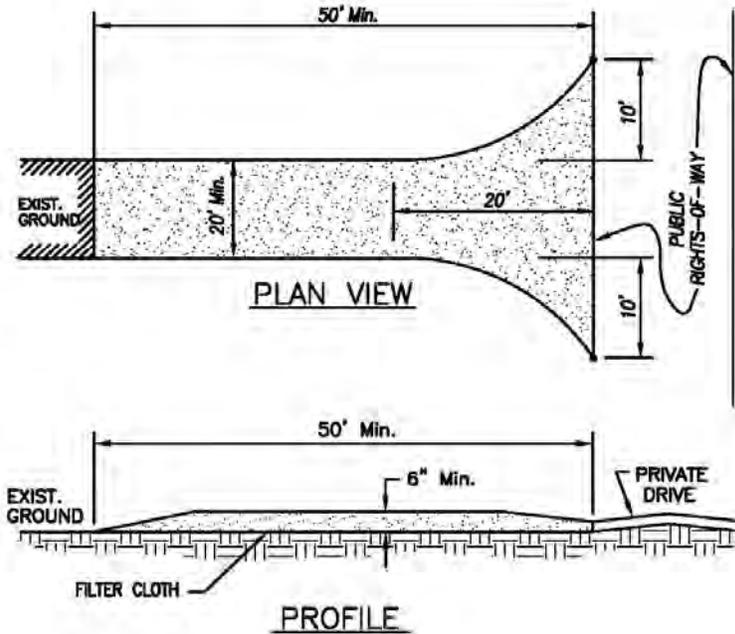
OPERATION AND MAINTENANCE PROCEDURES:

Inspect routinely for damage and assess effectiveness of the BMP. Remove sediment and clods of dirt from construction entrance continuously. Replace rock, as necessary, to maintain a clean surface for traffic. Repair any areas that have settled. Keep all temporary roadway ditches clear. Immediately remove any mud or debris tracked onto paved surfaces.

SITE CONDITIONS FOR REMOVAL:

Remove when vehicles and equipment will no longer require access to unpaved areas.

STANDARD DRAWING: TC-1



CONSTRUCTION SPECIFICATIONS

1. STONE SIZE – USE 2" STONE.
2. LENGTH – AS REQUIRED, BUT NOT LESS THAN 50 FEET.
3. THICKNESS – NOT LESS THAN SIX (6) INCHES.
4. WIDTH – TWENTY (20) FOOT MINIMUM, BUT NOT LESS THAN THE FULL WIDTH AT POINTS WHERE INGRESS OR EGRESS OCCURS.
5. FILTER CLOTH – WILL BE PLACED OVER THE ENTIRE AREA PRIOR TO PLACING OF STONE.
6. SURFACE WATER – ALL SURFACE WATER FLOWING OR DIVERTED TOWARD CONSTRUCTION ENTRANCES SHALL BE PIPED ACROSS THE ENTRANCE. IF PIPING IS IMPRACTICAL, A MOUNTABLE BERM WITH 3:1 SLOPES WILL BE PERMITTED.
7. MAINTENANCE – THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION WHICH WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHTS-OF-WAY. THIS MAY REQUIRE PERIODIC TOP DRESSING WITH ADDITIONAL STONE AS CONDITIONS DEMAND AND REPAIR AND/OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT. ALL SEDIMENT SPILLED, DROPPED, WASHED OR TRACKED ONTO PUBLIC RIGHTS-OF-WAY MUST BE REMOVED IMMEDIATELY.
8. PERIODIC INSPECTION AS NEEDED MAINTENANCE SHALL BE PROVIDED WEEKLY AND AFTER EACH RAIN EVENT GREATER THAN 1/2".

<table border="1"> <tr> <td style="width: 50%; text-align: center;">Approved</td> <td style="width: 50%; text-align: center;">9/03/2008 Date</td> </tr> <tr> <td colspan="2" style="text-align: center;">Revisions</td> </tr> <tr> <td colspan="2" style="height: 20px;"> </td> </tr> <tr> <td colspan="2" style="height: 20px;"> </td> </tr> </table>	Approved	9/03/2008 Date	Revisions							<p>CONSTRUCTION ENTRANCE/EXIT</p>	<p>TC-1</p>
Approved	9/03/2008 Date										
Revisions											



TC-2 WASHDOWN STATION

An area located at stabilized construction access points to remove sediment from tires and undercarriages, and to prevent sediment from being transported onto public roadways.

APPROPRIATE APPLICATIONS:

Tire washes may be used on construction sites where dirt and mud tracking onto public roads by construction vehicles may occur.

CONDITIONS FOR EFFECTIVE USE:

A downstream sediment trapping BMP is needed to treat dirty runoff from the washdown station. These stations require a supply of wash water and a turnout or doublewide exit to avoid having entering vehicles drive through the wash area.

WHEN BMP IS TO BE INSTALLED:

Washdown stations should be installed along with the stabilized construction entrance/exit, prior to vehicles or equipment accessing unpaved areas.

STANDARDS AND SPECIFICATIONS:

Grade and compact area for drainage under washdown pad. Install wash rack, which should be designed and constructed/manufactured for anticipated traffic loads. Provide a drainage ditch, grade that will convey the runoff from the wash area to a sediment trapping device. The drainage ditch should be of sufficient grade, width, and depth to carry the wash runoff. Install water supply and hose. Post signs in advance of the station indicating that all muddy vehicles and equipment must use the station prior to exiting the site.

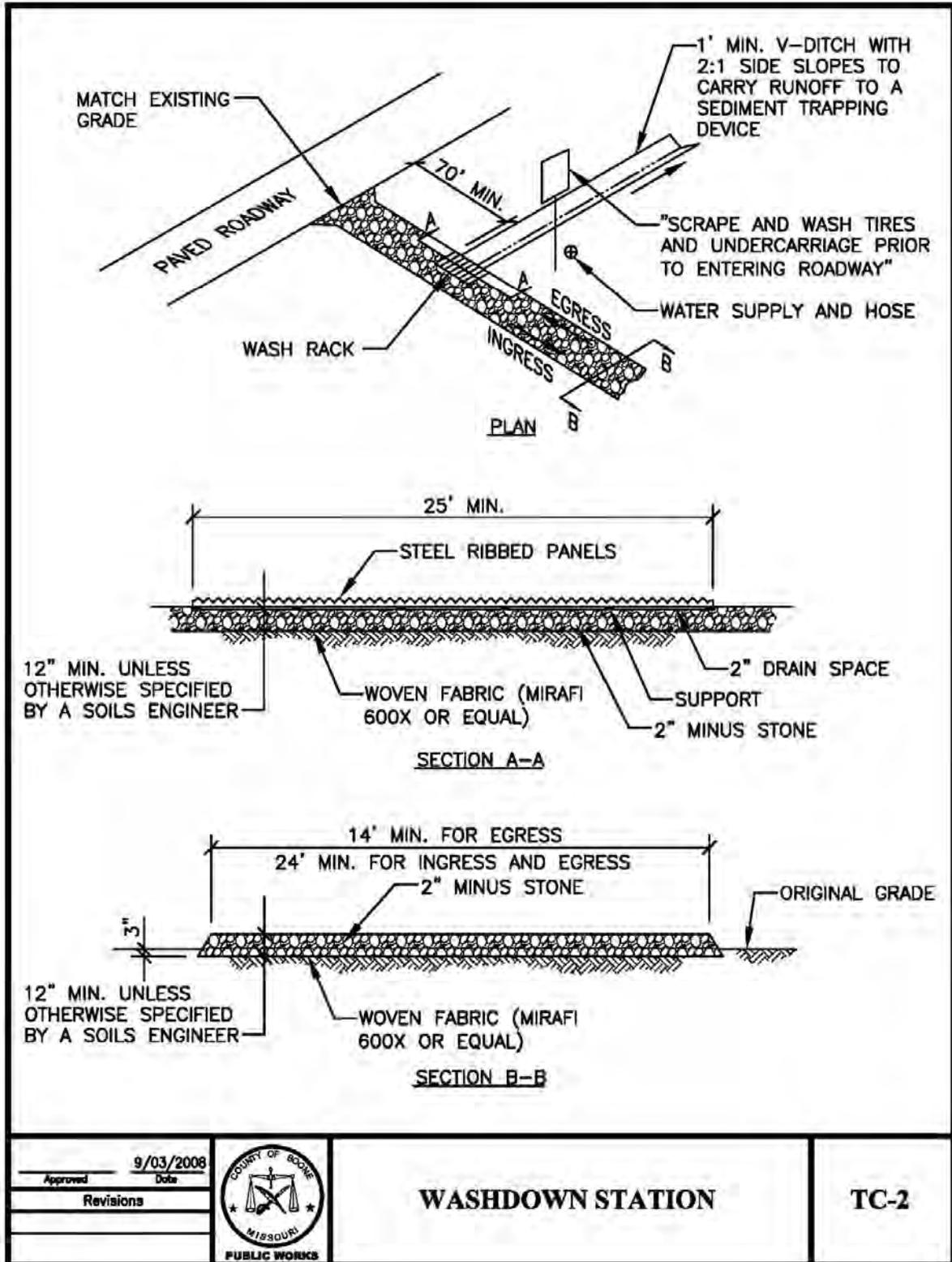
OPERATION AND MAINTENANCE PROCEDURES:

Remove accumulated sediment in wash rack and/or sediment trap on a daily basis or as needed to maintain system performance. Repair any areas that have settled. Replace rock if necessary to maintain a clean surface.

SITE CONDITIONS FOR REMOVAL:

Remove when vehicles and equipment will no longer access unpaved areas.

STANDARD DRAWING: TC-2





PP-1 NON-SEDIMENT POLLUTION CONTROL

These control measures are designed to prohibit chemicals, hazardous materials, solid waste, human waste and construction debris from polluting stormwater. Pollutants carried in solution or as surface films on runoff will be carried through most erosion control and sediment capture BMPs. Keeping substances like fuel, oil, asphalt, paint, solvents, fertilizer, soil additives, concrete wash water, solid waste, human waste and construction debris from polluting runoff can be accomplished to a large extent through good housekeeping on the site and following the manufacturer's recommendations for disposal.

APPROPRIATE APPLICATIONS:

Temporary sanitary facilities, collection, storage and fueling areas should be located onsite in an area that does not receive a substantial amount of runoff from upland areas and does not drain directly to lakes, creeks, streams, rivers, sewers, groundwater, wetlands, or road ditches.

CONDITIONS FOR EFFECTIVE USE:

An effective management system requires training and signage to promote proper storage, handling and disposal of materials, and follow up observations of actions and inspection of storage areas by management. Plans should contain notes clearly stating requirements for addressing potential pollutants.

WHEN BMP IS TO BE INSTALLED:

Pollution control practices should begin immediately and continue throughout the project.

STANDARDS AND SPECIFICATIONS:

Place waste receptacles near area of work. All fueling facilities present on the site shall adhere to applicable federal and state regulations concerning underground storage, above ground storage, and dispensers. Hazardous wastes shall be managed according to Missouri Hazardous Waste Laws and Regulations. Install appropriate signage. Post guidelines for proper handling, storage and disposal of materials, and emergency spill cleanup on site. Provide sufficient temporary toilet facilities to serve the number of workers on the site.

OPERATION AND MAINTENANCE PROCEDURES:

Inspect activities on a regular basis. Inspect storage areas and control devices at least every week and after every storm. Maintenance of temporary toilet facilities should be frequent and thorough. Make necessary corrections and repairs.

SITE CONDITIONS FOR REMOVAL:

Remove after contributing drainage areas have been adequately stabilized.

STANDARD NOTES:

General pollution notes:



1. Handling and disposal of hazardous materials:

DO: Prevent spills

Use up products completely

Follow label directions for disposal

Remove lids from empty bottles and cans when disposing in trash

Recycle wastes whenever possible

DON'T: Don't pour waste into sewers or waterways on the ground

Don't pour waste down the sink, floor drain or septic tanks

Don't bury chemicals or containers, or dispose of them with other waste

Don't burn chemicals or containers

Don't mix chemicals together

2. Containers shall be provided for collection of all waste material including construction debris, trash, petroleum products and any hazardous materials to be used onsite. All waste material shall be disposed of at facilities approved for that material.

3. No waste materials shall be buried on-site.

4. Mixing, pumping, transferring or otherwise handling construction chemicals such as fertilizer, lime, asphalt, concrete drying compounds, and all other potentially hazardous materials shall be performed in an area away from any watercourse, ditch or storm drain.

5. Equipment fueling and maintenance, oil changing, etc., shall be performed only in an area designated for that purpose. The designated area is equipped for recycling oil and catching spills.

6. Concrete wash water shall not be allowed to flow directly to storm sewers, streams, ditches, lakes, etc without being treated. A sump or pit shall be constructed to contain concrete wash water.

7. All paint, solvents, petroleum products and petroleum waste products, and storage containers (such as drums, cans, or cartons) shall be stored according to BMPs. The materials exposed to precipitation shall be stored in watertight, structurally sound, closed containers. All containers shall be inspected for leaks or spillage during the once per week inspection of BMPs. If substances such as oil, diesel fuel, hydraulic fluid, antifreeze, etc. are spilled, leaked, or released onto soil, the soil shall be dug up and properly disposed of. Spills on pavement shall be absorbed with sawdust, kitty litter or product designed for that purpose and disposed of at a licensed sanitary landfill. Hazardous or industrial wastes such as most solvents, gasoline, oil-based paints, and cement curing compounds require special handling. These materials will be removed from the site and recycled or disposed of in accordance with MoDNR requirements.

8. State law requires the party responsible for a petroleum product spill in excess of 50 gallons to report the spill to MoDNR (537-634-2436) as soon as practical after discovery.



Federal law requires the responsible party to report any release of oil if it reaches or threatens a sewer, lake, creek, stream, river, groundwater, wetland, or area, like a road ditch, that drains into one of the above.

9. Sufficient temporary toilet facilities to serve the number of workers on the site shall be provided. The facilities shall be serviced frequently to maintain a sanitary condition.



Appendix A – Definitions

Bankfull: An established river stage/elevation at a given location along a river which is intended to represent the maximum safe water level that will not overflow the river banks or cause any significant damage within the river reach.

Best Management Practices (BMP): Activities, practices and procedures which control soil loss and reduce or prevent water quality degradation caused by nutrients, animal wastes, toxins, organics and sediment in the runoff. BMPs may either be structural (grass swales, terraces, retention and detention ponds, and others); or non-structural (disconnection of impervious surfaces, directing downspouts onto grass surfaces, ordinances and educational activities).

Bioengineered Channel: A channel, which embodies biological, ecological, and engineering concepts to convey stormwater runoff, prevent soil erosion, control sedimentation, and provide wildlife habitat. The channel may be stabilized entirely with native materials or may selectively incorporate man-made structural materials.

Bioretention: Soil and plant-based stormwater management practices designed to filter runoff from developed communities by mimicking vegetated systems that naturally control hydrology through detention, filtration, infiltration, and evapotranspiration.

Bottomlands: Low-lying areas, adjacent to rivers and creeks subject to frequent flooding.

Channel Lining: Includes any type of material used to stabilize the banks or bed of an engineered channel including, but not limited to, vegetation, rock or manufactured liners.

Contractor: The individual, firm, partnership, joint venture, or corporation contracting with the Owner for performance of the work described in the specifications and plans.

County: Boone County, Missouri

Curve Number (CN): A runoff coefficient developed in the U.S. Natural Resource Conservation Service (NRCS) family of hydrologic models by combining land use and one of four hydrologic soil types on a parcel of land.

Design Storm: The combination of rainfall depth, duration, and distribution of a hypothetical rainfall event with a given likelihood of occurring in any year. For example, the 100 year storm event has a 1% chance of occurrence during any year, whereas a 2 year storm event has a 50% chance of occurrence in any year.



Detention Facility: A storm water management facility controlling peak discharges of storm water runoff from a site. This may be an open air basin (wet or dry pond), but could also be an underground system (pipes or vault).

Detention Storage: The volume of water a stormwater detention facility or basin can store to attenuate the peak flow rate of a design storm event.

Developer: is a person directing or participating in the direction of improvements on and/or to land, including, but not limited to, the owner of the land, a general contractor or a commercial agent engaged for such activity.

Development: is a change in the zoning, intensity of use or allowed use of any land, building, structure or premises for any purpose. The subdivision or severance of land. The construction, erection or placing of one or more buildings or structures on land or use of land or premises for storage of equipment or materials. Making of an addition, enlargement or alteration to a building or structure, in, on, over or under land, which has the effect of increasing the size or usability thereof. Land disturbance activities such as but not limited to site-grading, excavation, drilling, removal of topsoil or the placing or dumping of fill and installation of drainage works. The use of the term shall include redevelopment in all cases unless otherwise specified in these regulations.

Director: The Director of Public Works

Dry Detention Facility: Any detention facility designed to permit no permanent impoundment of water.

Easement: means a legal right granted by a landowner to a grantee allowing the use of private land for conveyance or treatment of stormwater runoff and access to stormwater practices.

Edge of Buffer Outfall: An outfall with a discharge point in the outer half of the riparian buffer in order to return the discharge to a diffused overland flow.

Emergency Spillway: A device or devices used to discharge water under conditions of inflow that exceed the design outflow from the primary spillway of a detention facility. The emergency spillway functions primarily to prevent damage to the detention facility that would permit the sudden release of impounded water.

Enclosed System: A network of underground storm sewer pipes and associated appurtenances that conveys stormwater.

Engineer: See 'Registered Professional Engineer.'



Engineered Channel: An open drainage channel, explicitly designed to convey stormwater runoff. Unlike natural channels, engineered channels are usually designed not adjust to changing flow conditions.

Extended Detention Wetland: A land area that is permanently wet or periodically flooded by surface or groundwater, and has developed hydric soil properties that support vegetation growth under saturated soil conditions. It may have been engineered with adequate capacity to detain large storm flows.

FHWA: Federal Highway Administration.

Floodplain: A relatively level surface of stratified alluvial soils on either side of a watercourse, which is inundated during flood events. May or may not be identified on FEMA Flood Insurance Rate Maps.

Filter Strip: A grassed area that accepts sheet flow runoff from adjacent surfaces. It slows runoff velocities and filters out sediment and other pollutants. Filter strips may be used to treat shallow, concentrated, and evenly distributed storm flows.

First Flush: The quantity of initial runoff from a storm or snowmelt event that commonly contains elevated pollutant concentrations. Often the first flush contains most of the pollutants in drainage waters produced by the water quality storm event.

Freeboard: The difference in elevation between the top of a structure such as a dam or open channel and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.

Hydrologic Soil Group (HSG): NRCS soil grouping according to runoff producing characteristics. The chief criterion is capacity of soil (absent of vegetation) to permit infiltration. Soils are grouped from HSG A (greatest infiltration and least runoff) to D (least infiltration and greatest runoff).

Impact Stilling Basin: A pool placed below an outlet spillway and designed for reducing discharge energies in order to minimize downstream erosive effects.

Impervious Surface: A surface that prevents the infiltration of stormwater, such as a parking lot, street, or rooftop.

Improved Channel: Any channel altered by the installation of lining materials.

Incision: Adjustment of the channel bed elevation downwards, typically in response to some type of disturbance, such as increased water velocity.

Increased Runoff: Increase in volume or peak flow of stormwater runoff.

Infiltration: the process of percolating stormwater into the subsoil.



Infiltration System: a system or facility that allows water to percolate into the subsurface of the soil. This may recharge shallow or deep groundwater.

Lateral Outfall: A small outfall that discharges from the banks of a natural stream.

Limited Stream Assessment: A review of stream data necessary to determine the optimum placement of disturbances to the stream and the streamside buffer zone in order to best avoid future issues related to the coexistence of the infrastructure and the natural stream.

Low-drop Structures: A step pool energy dissipation structure typically constructed out of rock or concrete with a design vertical drop of 2 feet or less per step.

National Pollutant Discharge Elimination System (NPDES): Defined in Section 402 of the Clean Water Act, a permit system regulating the discharge of pollutants to the waters of the United States including those from nonpoint sources such as stormwater.

Native Species: Plant and animal species that exist in the region where they have evolved.

Natural Stream: Any river, creek, channel, or drainageway that has an alignment, bed and bank materials, profile, bed configuration, and channel shape predominately formed by the action of moving water, sediment migration, and biological activity. The natural channel's form results from regional geology, geography, ecology, and climate. Natural streams are capable of adjusting bank width and bedload in response to increases in flow volume and velocities.

Open Channel: A drainageway with an open water surface.

Ordinary High Water Mark: A line on the bank established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Outfall: The location of a discharge of a concentrated flow of stormwater either from an engineering channel or pipe.

Owner: the owner or owners of the freehold of the premises or lesser estate therein, a mortgagee or vendee in possession, assignee of rents, receiver, executor, trustee, lessee or other person, firm or corporation in control of a piece of land. As used herein, owner also refers to, in the appropriate context: (i) any other person authorized to act as the agent for the owner; (ii) any person who submits a stormwater management concept or design plan for approval or requests issuance of a permit,



when required, authorizing land development to commence; and (iii) any person responsible for complying with an approved stormwater management design plan.

Pervious Pavement: A special type of pavement that allows water to infiltrate the surface layer and enter into a high-void, aggregate, sub-base layer. The captured water is stored in the reservoir layer until it either infiltrates the underlying soil strata or is routed through a drainage system to a conventional stormwater conveyance system.

Plans: The approved plan drawings, profiles, typical cross-sections, working drawings, etc., and exact reproductions thereof, which show the location, character, dimensions, and details of the work to be done.

Point bars: Depositional features generally occurring on the inside of stream bends and opposite cut banks.

Pollutant: Anything, which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes, yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, articles, and accumulations, which may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; including but not limited to sediments, slurries and concrete rinsate and noxious or offensive matter of any kind.

Pools: A deep reach of a stream. Often, pools are located between two riffles or behind an obstruction such as a fallen tree. Pools are a small and relatively deep body of quiet water in a stream or river. These areas are depositional during low flow, but may scour during a high flow event.

Predevelopment: The time period prior to a proposed or actual development activity at a site. Predevelopment may refer an undeveloped site or a developed site that will be redeveloped or expanded.

Primary Outfall: An outfall where the entire upstream channel is replaced by an enclosed system (pipes) or constructed channel(s) which discharges flow in line with the direction of the downstream segment.

Primary Outlet Works: A device such as an inlet, pipe, weir, etc., used to discharge water during operation of a storage facility.

Principal Spillway: A device such as an inlet, pipe, or weir used to discharge water during operation of a detention facility under conditions of the design storm.



Rain Garden: A small depression planted with native wetland and prairie vegetation where runoff is collected and allowed additional time to infiltrate.

Redevelopment: means a change to previously existing, improved property. This includes but is not limited to the demolition or building of structures, filling, grading, paving, or excavating. Redevelopment excludes ordinary maintenance activities such as remodeling of buildings on the existing footprint, resurfacing and/or repaving of existing paved areas, and exterior changes or improvements that do not materially increase or concentrate stormwater runoff or cause additional nonpoint source pollution.

Registered Professional Engineer: A licensed engineer who is registered with, and authorized to practice engineering in, Missouri.

Riffles: Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as natural channel armoring or bedrock outcrop wholly or partly submerged beneath the water surface.

Riparian Buffers: Areas of native herbaceous and woody vegetation adjacent to and along ephemeral, perennial and intermittent streams and open bodies of water.

Riparian Zone: The vegetated area along the fringe of a stream or other water body.

Sand Filter: A self-contained bed of sand used to treat wastewater or stormwater runoff; the water subsequently is collected in underground pipes for additional treatment or discharge.

Sediment Storage: The volume allocated to contain accumulated sediments within a detention facility.

Site: A tract or contiguous tracts of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office commercial parks, and other planned unit developments shall be considered a single site. This shall include phased development where construction at a tract or contiguous tracts of land may occur in increments.

Storm Event: A rainfall event used for design, which is defined by the probability such an event, will be equaled or exceeded in any one year.

Storm Drainage System: All of the natural and man-made facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, swales, street gutters, inlets, and detention facilities, which serve to convey, store and treat surface drainage.

Stormwater Detention Facility: Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.



Streams: See "Natural Streams"

Swale: A relatively wide, shallow ditch used to convey stormwater.

Thalweg: The deepest part of a channel cross-section. The dominant thread of stream flow creates the thalweg.

Topsoil: Fertile, friable soil of uniform quality and consisting of the soil series A horizon, without a mixture of subsoil materials or B horizon, and shall be reasonably free from materials such as hard clods, stiff clay, hardpan, partially disintegrated stone, large stone or any other impurities. Topsoil shall be reasonably free from grass, roots, or debris, which are considered to be harmful to plant establishment and growth.

Total Suspended Solids (TSS): Organic and inorganic matter such as clay and plant materials suspended in stormwater. This excludes litter, debris, and other gross solids exceeding 1 millimeter in diameter.

Tree Preservation: A Site design that maintains existing trees and shrubs in a healthy and undamaged condition.

Tributary Area: All land draining to the point of consideration, regardless of ownership.

Tributary Outfall: An outfall primarily located on a tributary to a larger downstream segment of a natural stream.

Underdrain: A small diameter perforated pipe that allows the bottom of a detention basin, bioretention cell, channel or swale to drain.

Uplands: Lands elevated above the floodplain that are seldom or never inundated.

Water Quality: The chemical, physical, and biological characteristics of water. This term also can refer to regulatory concerns about water's suitability for swimming, fishing, drinking, agriculture, industrial activity, and healthy aquatic ecosystems.

Water Quality Storm: The storm event that produces less than or equal to 90 percent stormwater runoff volume of all 24-hour storms on an annual basis.

Water Quality Volume (WQv): The storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. It is calculated by multiplying the Water Quality Storm times the volumetric runoff coefficient and site area.



Watershed: or “Catchment” is the entire geographical area drained by a river and its tributaries; an area characterized by the conveyance of all runoff to the same outlet.

Wet Detention Facility: A detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility. Most often, this is in the form of a wet pond.

Wet Pond: A constructed system with sufficient capacity to detain flood volumes and to store the WQv above a permanent pool.

Wetland Treatment System: A stormwater or wastewater treatment system consisting of shallow ponds and channels vegetated with aquatic or emergent plants. This system relies on natural microbial, biological, physical, and chemical processes to treat stormwater or wastewater.

Work: Work shall mean the furnishing of all labor, materials, equipment, and other incidentals necessary or convenient to the successful completion of the project.

Boone County Public Works

Design & Construction Division

5551 Highway 63 South Columbia, Missouri 65201

Phone (573) 449-8515 Fax (573) 875-1602



CONSTRUCTION DOCUMENT REVIEW TRANSMITTAL

PROJECT NAME: _____

SITE LOCATION: _____

_____ 1/4 OF THE _____ 1/4 OF SECTION _____, TOWNSHIP _____, RANGE _____

NEW DEVELOPMENT

RE-DEVELOPMENT

PURPOSE OF SUBMITTAL:

FIRST TIME REVIEW

RE-REVIEW PER COMMENTS

RE-SUBMITTAL FOR MAJOR AMENDMENT

OTHER: _____

LAND DISTURBANCE RELATED:

# OF COPIES SUBMITTED	<input type="checkbox"/>	COUNTY LAND DISTURBANCE PERMIT APPLICATION	⇒	APPLICATION FEE:	<input type="checkbox"/> NEW- \$150	<input type="checkbox"/> RENEWAL-\$50
	<input type="checkbox"/>	PRELIMINARY STORMWATER MANAGEMENT PLAN(S)				
	<input type="checkbox"/>	EROSION AND SEDIMENT CONTROL PLAN(S)				
	<input type="checkbox"/>	STORMWATER POLLUTION PREVENTION PLAN (SPWPPP)	⇒	<input type="checkbox"/>	SWPPP PERFORMANCE BOND OR GUARANTEE	
	<input type="checkbox"/>	SEDIMENT TRAP/BASIN DESIGN CALCULATIONS				
	<input type="checkbox"/>	ROUGH GRADING PLAN(S)				
	<input type="checkbox"/>	COPY OF MISSOURI DNR FORMS 'E' & 'G'				
	<input type="checkbox"/>	COPY OF US ARMY COE J.D. OR PERMIT APPROVAL LETTER				
	<input type="checkbox"/>	LIMITED STREAM ASSESSMENT (IF DISTURBANCE IN CHANNEL OR BUFFER)				
	<input type="checkbox"/>	SINKHOLE EVALUATION (IF DISCHARGE TO ON-SITE SINKHOLE)				
	<input type="checkbox"/>	GEOLOGICAL EVALUATION (IF OFF-SITE SINKHOLES)				
	<input type="checkbox"/>	OTHER: _____				

STORMWATER RELATED:

# OF COPIES SUBMITTED	<input type="checkbox"/>	COUNTY STORMWATER DISCHARGE PERMIT APPLICATION	⇒	APPLICATION FEE:	<input type="checkbox"/> \$50
	<input type="checkbox"/>	COPY OF APPROVED PRELIM. STORMWATER MANAGEMENT PLAN(S)			
	<input type="checkbox"/>	STORMWATER MANAGEMENT CONSTRUCTION PLAN(S)	⇒	MAJOR AMENDMENT FEE:	<input type="checkbox"/> \$25
	<input type="checkbox"/>	STORMWATER FACILITIES AND/OR BMP MAINTENANCE AGREEMENT AND PLAN	⇒	RECORDING FEE:	<input type="checkbox"/> \$ _____
	<input type="checkbox"/>	EASEMENT LEGAL DESCRIPTIONS FOR REVIEW			
	<input type="checkbox"/>	SIGNED EASEMENT DOCUMENTS	⇒	RECORDING FEE:	<input type="checkbox"/> \$ _____
	<input type="checkbox"/>	DRAINAGE AREA MAP(S)			
	<input type="checkbox"/>	COUNTY STORMWATER FORMS 1A, 2, 3 & 4A FOR NEW DEVELOPMENTS OR FORMS 1B, 2 & 4B FOR REDEVELOPMENTS			
	<input type="checkbox"/>	WATER QUALITY HYDROLOGY CALCULATIONS			
	<input type="checkbox"/>	WATER QUALITY BMP DESIGN CALCULATIONS			
	<input type="checkbox"/>	STORMWATER DETENTION HYDROLOGY & HYDRAULIC DESIGN CALCULATIONS			
	<input type="checkbox"/>	STORMWATER CONVEYANCE SYSTEM HYDROLOGY & HYDRAULIC DESIGN CALCULATIONS			
	<input type="checkbox"/>	OTHER: _____			
<input type="checkbox"/>	OTHER: _____				
<input type="checkbox"/>	OTHER: _____				

OTHER PLANS:

# OF COPIES	<input type="checkbox"/>	FINAL GRADING PLAN(S)
	<input type="checkbox"/>	ROADWAY PLAN(S)
	<input type="checkbox"/>	SITE DEVELOPMENT PLAN(S)
	<input type="checkbox"/>	OTHER: _____

NOTES: _____

SUBMITTED BY: _____ DATE: _____

COMPANY: _____

ADDRESS: _____

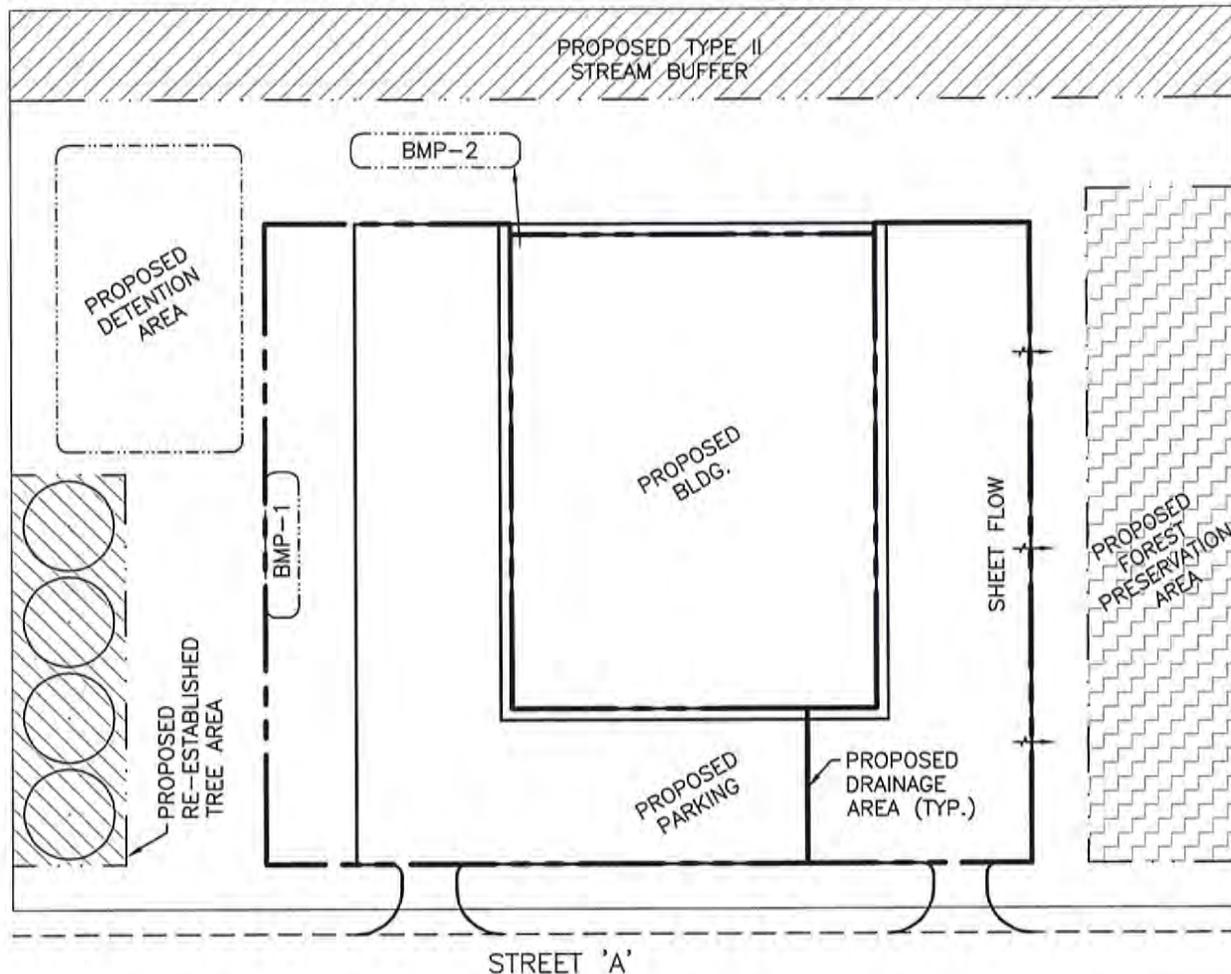
CITY: _____ STATE: _____ ZIP: _____

EMAIL: _____ PHONE: _____ FAX: _____

STORMWATER CALCULATIONS

[PROJECT NAME]
Boone County, Missouri
[PROJECT NUMBER]

Prepared By:
[CONSULTING FIRM NAME]
[STREET ADDRESS]
[CITY, STATE ZIP]
Ph: [PHONE NUMBER]
Fax: [FAX NUMBER]



DESIGN APPROACH:

RUNOFF REDUCTION, WATER QUALITY VOLUME TREATMENT, TIER 2 CHANNEL PROTECTION DETENTION AND FLOOD CONTROL DETENTION ARE REQUIRED FOR THIS SITE.

GRADE 0.50 ACRES OF PROPOSED IMPERVIOUS AREA TO DISCHARGE AS SHEET FLOW THRU ESTABLISHED VEGETATION AND FOREST.

CALCULATE THE THEORETICAL SITE WATER QUALITY TREATMENT VOLUME (BEFORE RUNOFF REDUCTION) USING THE SHORT CUT METHOD.

DETERMINE WHICH RUNOFF REDUCTION METHOD(S) WILL BE UTILIZED AND CALCULATE THE PROPOSED RUNOFF REDUCTION VOLUME. USE A COMBINATION OF FOREST PRESERVATION AND TREE RE-ESTABLISHMENT.

CALCULATE THE ADJUSTED SITE WATER QUALITY TREATMENT VOLUME.

CALCULATE THE WATER QUALITY VOLUME FOR EACH PROPOSED BMP DRAINAGE AREA.

SIZE THE FILTER BED SURFACE AREAS OF THE PROPOSED BIORETENTION CELLS TO TREAT CALCULATED WATER QUALITY VOLUME FOR EACH RESPECTIVE BMP DRAINAGE AREA.

THE TOTAL WATER QUALITY VOLUME FOR ALL PROPOSED BMP'S MUST BE GREATER THAN OR EQUAL TO THE ADJUSTED SITE WATER QUALITY TREATMENT VOLUME.

KNOWN INFORMATION:

EXISTING AND PROPOSED ZONING IS CG-P
 NO FLOODPLAIN
 STREAM BUFFER AS SHOWN
 NO ENVIRONMENTALLY SENSITIVE AREAS
 NO HOTSPOTS

TOTAL SITE AREA IS 5.00 ACRES
 PROPOSED STREAM BUFFER AREA IS 0.50 ACRES
 PROPOSED FOREST PRESERVATION AREA IS 0.40 ACRES
 PROPOSED TREE RE-ESTABLISHMENT AREA IS 0.20 ACRES
 PROPOSED TOTAL SITE IMPERVIOUS AREA IS 2.00 ACRES
 PROPOSED LANDSCAPE/TURF AREA IS 1.90 ACRES
 PROPOSED TOTAL DISTURBANCE AREA IS 3.00 ACRES

PROPOSED IMPERVIOUS AREAS ARE CONNECTED

STORMWATER EXAMPLE:

NEW COMMERCIAL DEVELOPMENT

03/15/2010



FORM 1A

STORMWATER MANAGEMENT SUMMARY - NEW DEVELOPMENT

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT)

PROJECT NAME: EXAMPLE - NEW DEVELOPMENT - COMMERCIAL

PROJECT LOCATION: BOONE COUNTY, MISSOURI

EXISTING ZONING: CG-P PROPOSED ZONING: CG-P

100-YR FLOODPLAIN ON SITE? NO YES

STREAM BUFFER ON SITE? NO TYPE I TYPE II TYPE III EXTRA WIDTH FOR STEEP SLOPES

LAND DISTURBANCE IN STREAM BUFFER? N/A NO YES (LIMITED STREAM ASSESSMENT REQUIRED)

ENVIRONMENTALLY SENSITIVE AREAS? NO YES (SEE ADDITIONAL REQUIREMENTS)

STORMWATER HOTSPOTS ON SITE? NO YES (SEE ADDITIONAL REQUIREMENTS)

TOTAL SITE AREA (A_T): 5.00 ACRES

TOTAL DISTURBED AREA (A_D): 3.00 ACRES

TOTAL AREA OF STREAM BUFFER (A_B): 0.50 ACRES

TOTAL AREA OF PRESERVED FOREST (A_F): 0.40 ACRES

TOTAL SITE IMPERVIOUS AREA (A_{IT}): 2.00 ACRES 40.0 % OF TOTAL SITE AREA ($I = A_{IT}/A_T$)

TOTAL SITE IMPERVIOUS AREA DISCHARGING AS SHEET FLOW THRU ESTABLISHED VETEMENTATION (A_{IS}): 0.50 ACRES 25.0 % OF A_{IT} (NOT TO EXCEED 25%)

THEORETICAL SITE WQ TREATMENT AREA (A_{TR}): 3.60 ACRES ($A_{TR} = A_T - A_B - A_F - A_{IS}$) [BEFORE RUNOFF REDUCTION IS APPLIED]

SITE R_v COEFF. CALCULATION METHOD: SHORTCUT SMALL STORMS $R_v =$ 0.4100 (FROM FORM 3)

THEORETICAL SITE WQ TREATMENT VOLUME: (BEFORE RUNOFF REDUCTION IS APPLIED) 6,965 FT³ $P \times R_v \times [A_{TR} \times (43560/12)]$ WHERE: $P = 1.3$ INCHES

TYPE OF RUNOFF REDUCTION PROVIDED? N/A PRES. VEG. RE-EST. VEG. CAPTURE & REUSE ENGINEERED

AMOUNT OF RUNOFF REDUCTION PROVIDED: 836 FT³ 12.0 % OF THEO. WQ_v (FROM FORM 4A)

ADJUSTED SITE WQ TREATMENT VOLUME: (THEORETICAL WQ_v - RUNOFF REDUCTION VOLUME) 6,129 FT³ REQD. \leq 6,517 FT³ PROVIDED (FROM FORM 2)

TYPE OF CHANNEL PROTECTION PROVIDED? N/A TIER 1 TIER 2 CONV. DETENTION MICRO-DETENTION

CP CONV. DETENTION SITE PEAK DISCHARGE: N/A $Q_{1(PRE)} =$ 5.4 CFS \geq $Q_{2(POST)} =$ 5.0 CFS

FLOOD CONTROL - SITE PEAK DISCHARGE: N/A $Q_{25(PRE)} =$ 13.9 CFS \geq $Q_{25(POST)} =$ 13.0 CFS



FORM 2 WATER QUALITY BMP SUMMARY

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT AND REDEVELOPMENT IF REQUIRED)

PROJECT NAME: EXAMPLE - NEW DEVELOPMENT - COMMERCIAL

PROJECT LOCATION: BOONE COUNTY, MISSOURI

BMP DESCRIPTION	DATA SPECIFIC TO EACH BMP DRAINAGE AREA			
	WQ BMP #	TREATMENT AREA (A _{TR}) (AC)	WQ VOLUME CALCULATED (WQ _v) (FT ³)	WQ PEAK ⁽¹⁾ DISCHARGE (Q _p) (CFS)
BIORETENTION CELL (15' x 65' FILTER BED AREA)	BMP-1	0.92	3,020	N/A
BIORETENTION CELL (15' x 75' FILTER BED AREA)	BMP-2	0.78	3,497	N/A
TOTALS		1.70	6,517	X

NOTES:
1. IF REQUIRED.



FORM 3

SITE VOLUMETRIC RUNOFF COEFFICIENT (R_v) WORKSHEET

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT)

PROJECT NAME: EXAMPLE - NEW DEVELOPMENT - COMMERCIAL

PROJECT LOCATION: BOONE COUNTY, MISSOURI

SITE VOLUMETRIC RUNOFF COEFFICIENT (R_v) CALCULATION METHODS:

1. SHORT CUT METHOD: USE

$$R_v = 0.05 + (0.009 \times I) \quad \text{WHERE: } I = \% \text{ OF SITE IMPERVIOUSNESS (FROM FORM 1A)}$$

$$I = \underline{40.0} \%$$

$$R_v = \underline{0.4100}$$

2. SMALL STORMS METHOD: USE

URBAN SURFACE CONDITIONS	R _{vi}	A _i (AC)	DRF (NOTE 1)	R _{vi} x A _i x DRF (AC)
FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			0.00
PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98	2.00	1.00	1.96
SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			0.00
PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	0.00
PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24	3.00	X	0.72
TOTALS	X	5.00	X	2.68
WEIGHTED R _v = TOTAL (R _{vi} x A _i x DRF)/TOTAL A _i	0.5360			

NOTE 1: R_v REDUCTION FACTORS FOR DISCONNECTED IMPERVIOUS SURFACES

- 1.00 CONNECTED IMPERVIOUS SURFACE
- 0.99 STRIP COMMERCIAL & SHOPPING CENTER
- 0.50 MEDIUM TO HIGH DENSITY RESIDENTIAL WITH PAVED ALLEYS
- 0.22 MEDIUM TO HIGH DENSITY RESIDENTIAL WITHOUT PAVED ALLEYS
- 0.22 LOW DENSITY RESIDENTIAL



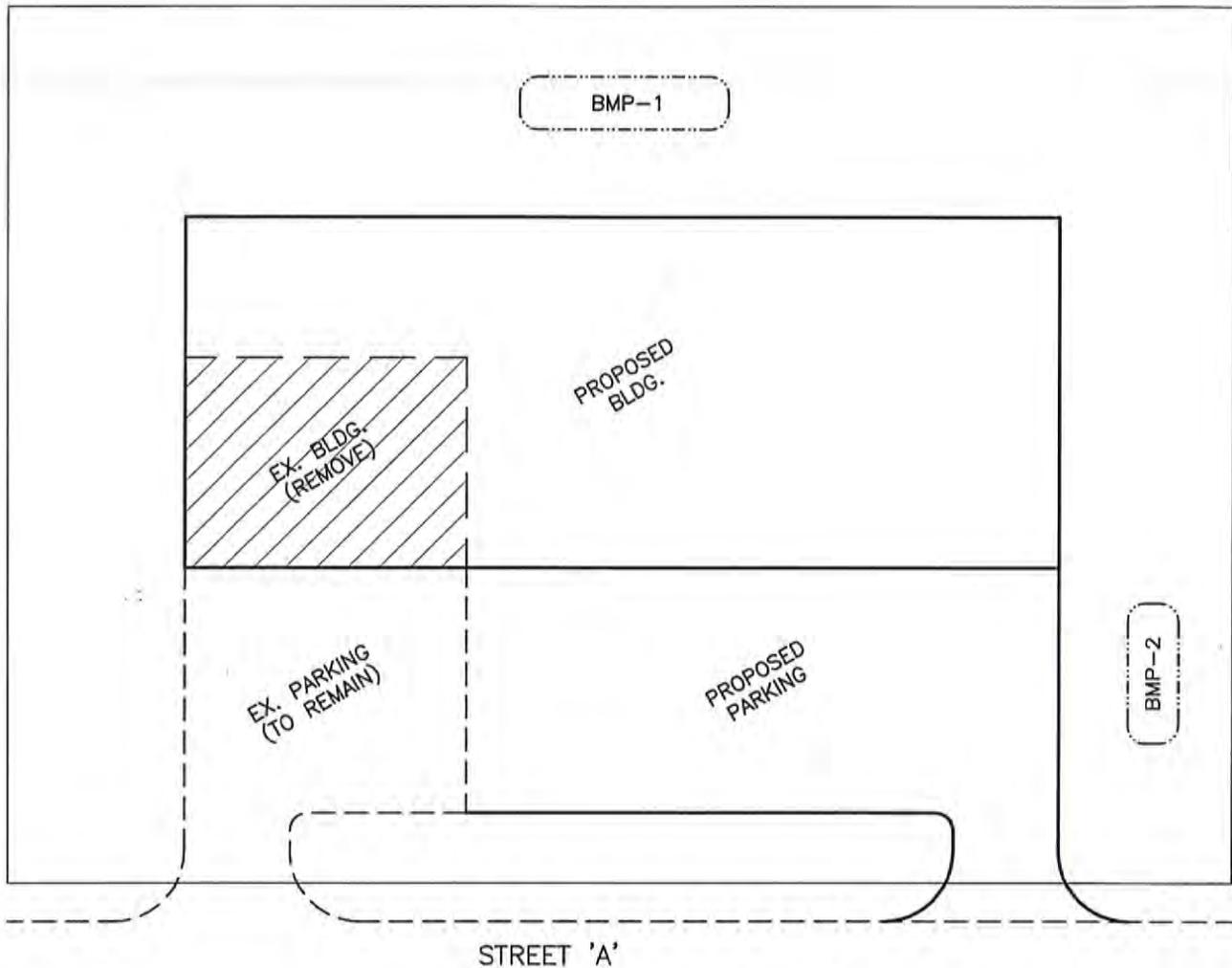
**BIORETENTION CELL DESIGN CALCULATIONS
EXAMPLE - NEW DEVELOPMENT - COMMERCIAL
BOONE COUNTY, MISSOURI**

BIORETENTION FILTER AREA DESIGN											
BMP NO.	BMP WQ VOLUME WQ _v (FT. ³)	FILTER ⁽¹⁾ MEDIA DEPTH d _f (FT.)	MEDIA COEFF. OF PERM. OF PERM. k (FT./DAY)	PONDING ⁽²⁾ DESIGN DEPTH h _{max} (FT.)	PONDING AVG. DEPTH h _{avg} (FT.)	FILTER ⁽⁴⁾ TIME t _f (DAYS)	MIN. FILTER BED ⁽⁵⁾ SURFACE AREA A _f (FT. ²)	DESIGN FILTER ⁽⁶⁾ BED WIDTH W _f (FT.)	MIN. FILTER BED LENGTH MIN. L _f (FT.)	PROP. FILTER ⁽⁷⁾ BED LENGTH L _f (FT.)	PROP. FILTER ⁽⁸⁾ SURFACE AREA A _f (FT. ²)
BMP-1	3,020	2.50	1.00	0.50	0.25	3.0	915	15	61	65	975
BMP-2	3,497	2.50	1.00	0.50	0.25	3.0	1060	15	71	75	1125

NOTES:

1. FILTER MEDIA DEPTH SHOULD BE BETWEEN 2.5' AND 4'
2. FILTER MEDIA COEFFICIENT OF PERMEABILITY SHOULD BE AT LEAST 1.0 FT/DAY
3. MAXIMUM PONDING DEPTH SHOULD BE BETWEEN 3" AND 6"
4. FILTER TIME OF 1 TO 3 DAYS IS RECOMMENDED
5. MINIMUM FILTER BED SURFACE AREA IN SQUARE FEET: $A_f = [WQ_v \cdot d_f] / [k \cdot t_f \cdot (h_{avg} + d_f)]$
6. THE MINIMUM DESIRED FILTER BED WIDTH IS 15' AND OPTIMALLY HALF OF L_f
7. THE MINIMUM DESIRED FILTER BED LENGTH IS 40' AND OPTIMALLY TWO TIMES W_f
8. THE PROPOSED FILTER BED SURFACE AREA MUST BE GREATER THAN OR EQUAL TO THE MINIMUM FILTER BED SURFACE AREA CALCULATED





DESIGN APPROACH:

THERE IS NOT A 20% OR GREATER REDUCTION IN IMPERVIOUS AREA AND THE SITE IS NOT ZONED RESIDENTIAL OR AGRICULTURE SO THE ENTIRE WATER QUALITY VOLUME MUST BE TREATED WITHOUT REDUCTION CREDIT FOR RUNOFF REDUCTION METHODS.

CALCULATE THE MINIMUM REQUIRED SITE WATER QUALITY TREATMENT VOLUME.

CALCULATE THE WATER QUALITY VOLUME FOR EACH PROPOSED BMP DRAINAGE AREA USING THE SHORT CUT METHOD.

SIZE THE FILTER BED SURFACE AREAS OF THE PROPOSED BIORETENTION CELLS TO TREAT CALCULATED WATER QUALITY VOLUME FOR EACH RESPECTIVE BMP DRAINAGE AREA.

THE TOTAL WATER QUALITY VOLUME FOR ALL PROPOSED BMP'S MUST BE GREATER THAN OR EQUAL TO THE MINIMUM REQUIRED SITE WATER QUALITY TREATMENT VOLUME.

KNOWN INFORMATION:

EXISTING AND PROPOSED ZONING IS CG-P
 NO FLOODPLAIN
 NO STREAM BUFFER
 NO ENVIRONMENTALLY SENSITIVE AREAS
 NO HOTSPOTS

TOTAL SITE AREA IS 2 ACRES
 EXISTING TOTAL SITE IMPERVIOUS AREA IS 0.25 ACRES
 EXISTING IMPERVIOUS AREA TO BE REMOVED IS 0.10 ACRES
 PROPOSED NEW IMPERVIOUS AREA IS 0.85 ACRES
 PROPOSED TOTAL SITE IMPERVIOUS AREA IS 1.00 ACRES
 PROPOSED TOTAL DISTURBANCE AREA IS 1.00 ACRES

STORMWATER EXAMPLE:

COMMERCIAL REDEVELOPMENT

03/15/2010



FORM 1B

STORMWATER MANAGEMENT SUMMARY - REDEVELOPMENT

(MANDATORY SUBMITTAL ITEM FOR REDEVELOPMENT)

PROJECT NAME: EXAMPLE - COMMERCIAL REDEVELOPMENT

PROJECT LOCATION: BOONE COUNTY, MISSOURI

EXISTING ZONING: CG-P PROPOSED ZONING: CG-P

100-YR FLOODPLAIN ON SITE? NO YES

STREAM BUFFER ON SITE? NO TYPE I TYPE II TYPE III EXTRA WIDTH FOR STEEP SLOPES

LAND DISTURBANCE IN STREAM BUFFER? N/A NO YES (LIMITED STREAM ASSESSMENT REQUIRED)

ENVIRONMENTALLY SENSITIVE AREAS? NO YES (SEE ADDITIONAL REQUIREMENTS)

STORMWATER HOTSPOTS ON SITE? NO YES (SEE ADDITIONAL REQUIREMENTS)

TOTAL SITE AREA (A_T): 2.00 ACRES

TOTAL DISTURBED AREA (A_D): 1.00 ACRES

EXIST. IMPERVIOUS AREA REMOVED (A_{IR}): 0.10 ACRES

NEW IMPERVIOUS AREA (A_{ITN}): 0.85 ACRES

EXIST. TOTAL SITE IMPERVIOUS AREA (A_{ITE}): 0.25 ACRES 12.5 % OF TOTAL SITE AREA (A_{ITE}/A_T)

PROP. TOTAL SITE IMPERVIOUS AREA (A_{ITP}): 1.00 ACRES 50.0 % OF TOTAL SITE AREA (A_{ITP}/A_T)

NET CHANGE IN TOTAL SITE IMPERVIOUS AREA ($A_{NET} = A_{ITP} - A_{ITE}$): 0.75 ACRES 300.0 % INCREASE REDUCTION

WQ TREATMENT OPTIONS:

1. IS $A_{NET} \geq 20\%$ REDUCTION? YES (NO FURTHER TREATMENT REQUIRED) NO (PROCEED TO OPTION 2)

2. REQD. IMPERV. TREATMENT AREA (A_{TR}): (USE SMALLER CALCULATED AREA)

$(A_{ITE} \times 20\%) + (A_{NET} \times 100\%) = \frac{0.80}{1.13}$ ACRES USE 0.80

NOT TO EXCEED ($A_{NET} \times 150\%$) = 1.13 ACRES

SITE WQ_v CALCULATION METHOD: $P \times R_v \times [A_{TR} \times (43560/12)]$ WHERE: $P = 1.3$ & $R_v = 0.05 + (0.009 \times 100\%) = 0.95$

REQD. SITE WQ TREATMENT VOLUME (WQ_v): 3,586 FT³

2A. IS SITE ZONED RES., TRANSITIONAL OR AGRICULTURE & $A_T \geq 2.5$ AC & $A_{ITP} < 10\%$ OF A_T ? YES (RUNOFF REDUCTION METHODS MAY BE USED TO TREAT 10% OF SITE WQ_v) NO (PROCEED TO OPTION 2B IF TREATMENT IS NOT SATISFIED BY OPTION 1)

TYPE OF RUNOFF REDUCTION PROVIDED? N/A PRES. VEG. RE-EST. VEG. CAPTURE & REUSE ENGINEERED

AMOUNT OF RUNOFF REDUCTION PROVIDED: 0 FT³ 0.0 % OF SITE WQ_v (FROM FORM 4B IF USED)

2B. PROVIDE WQ TREATMENT FOR SITE IMPERVIOUS AREA WITH WQ BMPS: N/A (IF TREATMENT IS PROVIDED BY 1 OR 2A ABOVE) YES (TREAT 100% OF SITE WQ VOLUME WITHOUT RUNOFF REDUCTION)

WQ TREATMENT VOL. PROVIDED BY BMPS: 4,507 FT³ (FROM FORM 2 IF USED)



FORM 2

WATER QUALITY BMP SUMMARY

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT AND REDEVELOPMENT IF REQUIRED)

PROJECT NAME: EXAMPLE - COMMERCIAL REDEVELOPMENT

PROJECT LOCATION: BOONE COUNTY, MISSOURI

BMP DESCRIPTION	DATA SPECIFIC TO EACH BMP DRAINAGE AREA			
	WQ BMP #	TREATMENT AREA (A _{TR}) (AC)	WQ VOLUME CALCULATED (WQ _v) (FT ³)	WQ PEAK ⁽¹⁾ DISCHARGE (Q _p) (CFS)
BIORETENTION CELL (15' x 60')	BMP-1	0.40	2,702	N/A
BIORETENTION CELL (15' x 40')	BMP-2	0.60	1,805	N/A
TOTALS		1.00	4,507	X

NOTES:

- 1. IF REQUIRED.



**BMP WATER QUALITY VOLUME AND PEAK DISCHARGE CALCULATIONS
SHORT CUT METHOD
EXAMPLE - COMMERCIAL REDEVELOPMENT
BOONE COUNTY, MISSOURI**

BMP DRAINAGE AREA NO.	WATER QUALITY VOLUME							WATER QUALITY PEAK DISCHARGE							
	TOTAL AREA A (AC.)	IMPERV. AREA (AC.)	IMPERV. AREA I (%)	VOLUMETRIC ⁽¹⁾ RUNOFF COEFF. R _v	WQ STORM EVENT P (IN.)	WQ ⁽²⁾ VOLUME WQ _v (IN.)	WQ ⁽³⁾ VOLUME WQ _v (FT ³)	WQ ⁽⁴⁾ CURVE NO. CN _{WQ}	FLOW LENGTH L (FT.)	AVG. SLOPE Y (%)	TIME OF ⁽⁵⁾ CONC. T _c (HRS.)	INITIAL ⁽⁶⁾ ABS. I _a (IN.)	I _a /P	UNIT PEAK ⁽⁷⁾ DISCHARGE q _u (CFS/SM/IN)	WQ PEAK ⁽⁸⁾ DISCHARGE Q _p (CFS)
BMP-1	0.65	0.60	92.31	0.8808	1.3	1,1450	2,702	99			N/A	0.020	0.016		N/A
BMP-2	0.45	0.40	88.89	0.8500	1.3	1,1050	1,805	98			N/A	0.041	0.031		N/A
TOTALS	1.10	1.00				2.2500	4,507								

NOTES:

1. SHORT CUT METHOD: $R_v = 0.05 + 0.009(i)$ WHERE: i = % IMPERVIOUSNESS IN DRAINAGE AREA
2. WATER QUALITY VOLUME IN WATERSHED INCHES: $WQ_v = P \cdot R_v$ WHERE: P = 1.3 INCHES
3. WATER QUALITY VOLUME IN CUBIC FEET: $WQ_v = [(P \cdot R_v) / 12] \cdot (\text{TOTAL AREA} \cdot 43,560)$
4. $CN = 1000 / [10 + 5P + 10Q - 10(Q^2 + 1.25QP)^{0.5}]$; WHERE $Q = WQ_v$ IN INCHES
5. $T_c = (L^{0.2} [(1000/CN) - 9]^{0.7}) / (1140 \cdot Y^{0.5})$
6. $I_a = 0.2 [(1000/CN) - 10]$
7. USE I_a/P , T_c AND TR-55 EXHIBIT 4-II TO DETERMINE THE UNIT PEAK DISCHARGE (q_u)
8. $Q_p = (q_u / 640) \cdot A \cdot WQ_v$ (IN INCHES)

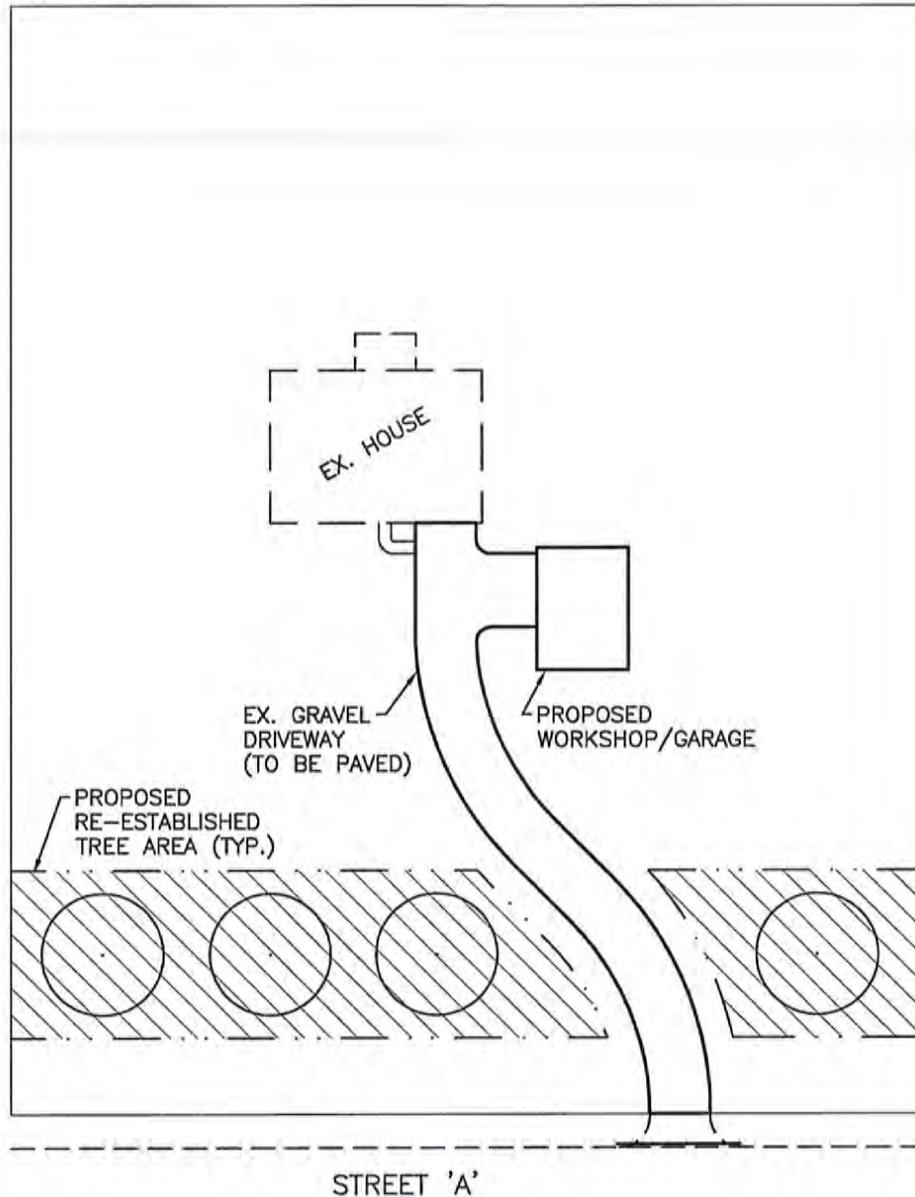
**BIORETENTION CELL DESIGN CALCULATIONS
EXAMPLE - COMMERCIAL REDEVELOPMENT
BOONE COUNTY, MISSOURI**

BIORETENTION FILTER AREA DESIGN											
BMP NO.	BMP WQ VOLUME WQ _v (FT. ³)	FILTER ⁽¹⁾ MEDIA DEPTH d _f (FT.)	MEDIA COEFF. OF PERM. k (FT./DAY)	PONDING ⁽²⁾ DESIGN DEPTH h _{max} (FT.)	PONDING AVG. DEPTH h _{avg} (FT.)	FILTER ⁽⁴⁾ TIME t _f (DAYS)	MIN. FILTER BED ⁽⁵⁾ SURFACE AREA A _f (FT. ²)	DESIGN FILTER ⁽⁶⁾ BED WIDTH W _f (FT.)	MIN. FILTER BED LENGTH MIN. L _f (FT.)	PROP. FILTER ⁽⁷⁾ BED LENGTH L _f (FT.)	PROP. FILTER ⁽⁸⁾ SURFACE AREA A _f (FT. ²)
BMP-1	2,702	2.50	1.00	0.50	0.25	3.0	819	15	55	60	900
BMP-2	1,805	2.50	1.00	0.50	0.25	3.0	547	15	36	40	600

NOTES:

1. FILTER MEDIA DEPTH SHOULD BE BETWEEN 2.5' AND 4'
2. FILTER MEDIA COEFFICIENT OF PERMEABILITY SHOULD BE AT LEAST 1.0 FT/DAY
3. MAXIMUM PONDING DEPTH SHOULD BE BETWEEN 3" AND 6"
4. FILTER TIME OF 1 TO 3 DAYS IS RECOMMENDED
5. MINIMUM FILTER BED SURFACE AREA IN SQUARE FEET: $A_f = [WQ_v \cdot d_f] / [k \cdot t_f \cdot (h_{avg} + d_f)]$
6. THE MINIMUM DESIRED FILTER BED WIDTH IS 15' AND OPTIMALLY HALF OF L_f
7. THE MINIMUM DESIRED FILTER BED LENGTH IS 40' AND OPTIMALLY TWO TIMES W_f
8. THE PROPOSED FILTER BED SURFACE AREA MUST BE GREATER THAN OR EQUAL TO THE MINIMUM FILTER BED SURFACE AREA CALCULATED





DESIGN APPROACH:

THERE IS NOT A 20% OR GREATER REDUCTION IN IMPERVIOUS AREA BUT THE SITE IS AGRICULTURE ZONED, AT LEAST 2.5 ACRES AND LESS THAN 10% IMPERVIOUS COVER SO RUNOFF REDUCTION METHODS ALONE MAY BE USED INSTEAD OF WATER QUALITY TREATMENT.

CALCULATE THE MINIMUM REQUIRED SITE WATER QUALITY TREATMENT VOLUME.

DETERMINE WHICH RUNOFF REDUCTION METHOD(S) WILL BE UTILIZED TO TREAT A MINIMUM OF 10% OF THE SITE WATER QUALITY TREATMENT VOLUME. USE TREE RE-ESTABLISHMENT.

KNOWN INFORMATION:

EXISTING AND PROPOSED ZONING IS A-2
 NO FLOODPLAIN
 NO STREAM BUFFER
 NO ENVIRONMENTALLY SENSITIVE AREAS
 NO HOTSPOTS

TOTAL SITE AREA IS 2.50 ACRES
 EXISTING TOTAL SITE IMPERVIOUS AREA IS 0.09 ACRES
 EXISTING IMPERVIOUS AREA TO BE REMOVED IS 0.00 ACRES
 PROPOSED NEW IMPERVIOUS AREA IS 0.14 ACRES
 PROPOSED TOTAL SITE IMPERVIOUS AREA IS 0.23 ACRES
 PROPOSED TOTAL DISTURBANCE AREA IS 0.30 ACRES

PROPOSED TREE RE-ESTABLISHMENT AREA IS 0.33 ACRES

STORMWATER EXAMPLE:

LARGE LOT RESIDENTIAL OR
 AGRICULTURAL REDEVELOPMENT
 03/15/2010



FORM 1B

STORMWATER MANAGEMENT SUMMARY - REDEVELOPMENT

(MANDATORY SUBMITTAL ITEM FOR REDEVELOPMENT)

PROJECT NAME: EXAMPLE - REDEVELOPMENT - LARGE RESIDENTIAL/AGRICULTURAL LOT

PROJECT LOCATION: BOONE COUNTY, MISSOURI

EXISTING ZONING: A-2 PROPOSED ZONING: A-2

- 100-YR FLOODPLAIN ON SITE? NO YES
- STREAM BUFFER ON SITE? NO TYPE I TYPE II TYPE III EXTRA WIDTH FOR STEEP SLOPES
- LAND DISTURBANCE IN STREAM BUFFER? N/A NO YES (LIMITED STREAM ASSESSMENT REQUIRED)
- ENVIRONMENTALLY SENSITIVE AREAS? NO YES (SEE ADDITIONAL REQUIREMENTS)
- STORMWATER HOTSPOTS ON SITE? NO YES (SEE ADDITIONAL REQUIREMENTS)

TOTAL SITE AREA (A_T): 2.50 ACRES

TOTAL DISTURBED AREA (A_D): 0.30 ACRES *-grading & all disturbance.*

EXIST. IMPERVIOUS AREA REMOVED (A_{IR}): 0.00 ACRES

NEW IMPERVIOUS AREA (A_{ITN}): 0.14 ACRES

EXIST. TOTAL SITE IMPERVIOUS AREA (A_{ITE}): 0.09 ACRES 3.6 % OF TOTAL SITE AREA (A_{ITE}/A_T)

PROP. TOTAL SITE IMPERVIOUS AREA (A_{ITP}): 0.23 ACRES 9.2 % OF TOTAL SITE AREA (A_{ITP}/A_T)

NET CHANGE IN TOTAL SITE IMPERVIOUS AREA ($A_{NET} = A_{ITP} - A_{ITE}$): 0.14 ACRES 155.6 % INCREASE REDUCTION

WQ TREATMENT OPTIONS:

1. IS $A_{NET} \geq 20\%$ REDUCTION? YES (NO FURTHER TREATMENT REQUIRED) NO (PROCEED TO OPTION 2)
2. REQD. IMPERV. TREATMENT AREA (A_{TR}): $(A_{ITE} \times 20\%) + (A_{NET} \times 100\%) =$ 0.16 ACRES USE 0.16
 (USE SMALLER CALCULATED AREA) NOT TO EXCEED ($A_{NET} \times 150\%$) = 0.21 ACRES

SITE WQ_v CALCULATION METHOD: $P \times R_v \times [A_{TR} \times (43560/12)]$ WHERE: $P = 1.3$ & $R_v = 0.05 + (0.009 \times 100\%) = 0.95$

REQD. SITE WQ TREATMENT VOLUME (WQ_v): 708 FT³

- 2A. IS SITE ZONED RES., TRANSITIONAL OR AGRICULTURE & $A_T \geq 2.5$ AC & $A_{ITP} < 10\%$ OF A_T ? YES (RUNOFF REDUCTION METHODS MAY BE USED TO TREAT 10% OF SITE WQ_v)
 NO (PROCEED TO OPTION 2B IF TREATMENT IS NOT SATISFIED BY OPTION 1)

TYPE OF RUNOFF REDUCTION PROVIDED? N/A PRES. VEG. RE-EST. VEG. CAPTURE & REUSE ENGINEERED

AMOUNT OF RUNOFF REDUCTION PROVIDED: 93 FT³ 13.2 % OF SITE WQ_v (FROM FORM 4B IF USED)

- 2B. PROVIDE WQ TREATMENT FOR SITE IMPERVIOUS AREA WITH WQ BMPS: N/A (IF TREATMENT IS PROVIDED BY 1 OR 2A ABOVE)
 YES (TREAT 100% OF SITE WQ VOLUME WITHOUT RUNOFF REDUCTION)

WQ TREATMENT VOL. PROVIDED BY BMPS: 0 FT³ (FROM FORM 2 IF USED)



FORM 1A

STORMWATER MANAGEMENT SUMMARY - NEW DEVELOPMENT

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT)

PROJECT NAME: _____

PROJECT LOCATION: _____

EXISTING ZONING: _____ PROPOSED ZONING: _____

100-YR FLOODPLAIN ON SITE? NO YES

STREAM BUFFER ON SITE? NO TYPE I TYPE II TYPE III EXTRA WIDTH FOR STEEP SLOPES

LAND DISTURBANCE IN STREAM BUFFER? N/A NO YES (LIMITED STREAM ASSESSMENT REQUIRED)

ENVIRONMENTALLY SENSITIVE AREAS? NO YES (SEE ADDITIONAL REQUIREMENTS)

STORMWATER HOTSPOTS ON SITE? NO YES (SEE ADDITIONAL REQUIREMENTS)

TOTAL SITE AREA (A_T): _____ ACRES

TOTAL DISTURBED AREA (A_D): _____ ACRES

TOTAL AREA OF STREAM BUFFER (A_B): _____ ACRES

TOTAL AREA OF PRESERVED FOREST (A_F): _____ ACRES

TOTAL SITE IMPERVIOUS AREA (A_{IT}): _____ ACRES _____ % OF TOTAL SITE AREA ($I = A_{IT}/A_T$)

TOTAL SITE IMPERVIOUS AREA DISCHARGING AS SHEET FLOW THRU ESTABLISHED VETETATION (A_{IS}): _____ ACRES _____ % OF A_{IT} (NOT TO EXCEED 25%)

THEORETICAL SITE WQ TREATMENT AREA (A_{TR}): _____ ACRES ($A_{TR} = A_T - A_B - A_F - A_{IS}$) [BEFORE RUNOFF REDUCTION IS APPLIED]

SITE R_v COEFF. CALCULATION METHOD: SHORTCUT SMALL STORMS $R_v =$ _____ (FROM FORM 3)

THEORETICAL SITE WQ TREATMENT VOLUME: _____ FT^3 $P \times R_v \times [A_{TR} \times (43560/12)]$ WHERE: $P = 1.3$ INCHES
(BEFORE RUNOFF REDUCTION IS APPLIED)

TYPE OF RUNOFF REDUCTION PROVIDED? N/A PRES. VEG. RE-EST. VEG. CAPTURE & REUSE ENGINEERED

AMOUNT OF RUNOFF REDUCTION PROVIDED: _____ FT^3 _____ % OF THEO. WQ_v (FROM FORM 4A)

ADJUSTED SITE WQ TREATMENT VOLUME: _____ FT^3 REQD. \leq _____ FT^3 PROVIDED (FROM FORM 2)
(THEORETICAL WQ_v - RUNOFF REDUCTION VOLUME)

TYPE OF CHANNEL PROTECTION PROVIDED? N/A TIER 1 TIER 2 CONV. DETENTION MICRO-DETENTION

CP CONV. DETENTION SITE PEAK DISCHARGE: N/A $Q_{1(PRE)} =$ _____ CFS \geq $Q_{2(POST)} =$ _____ CFS

FLOOD CONTROL - SITE PEAK DISCHARGE: N/A $Q_{25(PRE)} =$ _____ CFS \geq $Q_{25(POST)} =$ _____ CFS



FORM 1B

STORMWATER MANAGEMENT SUMMARY - REDEVELOPMENT

(MANDATORY SUBMITTAL ITEM FOR REDEVELOPMENT)

PROJECT NAME: _____

PROJECT LOCATION: _____

EXISTING ZONING: _____ PROPOSED ZONING: _____

- 100-YR FLOODPLAIN ON SITE? NO YES
- STREAM BUFFER ON SITE? NO TYPE I TYPE II TYPE III EXTRA WIDTH FOR STEEP SLOPES
- LAND DISTURBANCE IN STREAM BUFFER? N/A NO YES (LIMITED STREAM ASSESSMENT REQUIRED)
- ENVIRONMENTALLY SENSITIVE AREAS? NO YES (SEE ADDITIONAL REQUIREMENTS)
- STORMWATER HOTSPOTS ON SITE? NO YES (SEE ADDITIONAL REQUIREMENTS)
- TOTAL SITE AREA (A_T): _____ ACRES
- TOTAL DISTURBED AREA (A_D): _____ ACRES
- EXIST. IMPERVIOUS AREA REMOVED (A_{IR}): _____ ACRES
- NEW IMPERVIOUS AREA (A_{ITN}): _____ ACRES
- EXIST. TOTAL SITE IMPERVIOUS AREA (A_{ITE}): _____ ACRES _____ % OF TOTAL SITE AREA (A_{ITE}/A_T)
- PROP. TOTAL SITE IMPERVIOUS AREA (A_{ITP}): _____ ACRES _____ % OF TOTAL SITE AREA (A_{ITP}/A_T)
- NET CHANGE IN TOTAL SITE IMPERVIOUS AREA ($A_{NET} = A_{ITP} - A_{ITE}$): _____ ACRES _____ % INCREASE REDUCTION

WQ TREATMENT OPTIONS:

1. IS $A_{NET} \geq 20\%$ REDUCTION? YES (NO FURTHER TREATMENT REQUIRED) NO (PROCEED TO OPTION 2)
2. REQD. IMPERV. TREATMENT AREA (A_{TR}): $(A_{ITE} \times 20\%) + (A_{NET} \times 100\%) =$ _____ ACRES USE _____
 (USE SMALLER CALCULATED AREA) NOT TO EXCEED ($A_{NET} \times 150\%$) = _____ ACRES

SITE WQ_v CALCULATION METHOD: $P \times R_v \times [A_{TR} \times (43560/12)]$ WHERE: $P = 1.3$ & $R_v = 0.05 + (0.009 \times 100\%) = 0.95$

REQD. SITE WQ TREATMENT VOLUME (WQ_v): FT³

- 2A. IS SITE ZONED RES., TRANSITIONAL OR AGRICULTURE & $A_T \geq 2.5$ AC & $A_{ITP} < 10\%$ OF A_T ? YES (RUNOFF REDUCTION METHODS MAY BE USED TO TREAT 10% OF SITE WQ_v)
 NO (PROCEED TO OPTION 2B IF TREATMENT IS NOT SATISFIED BY OPTION 1)

TYPE OF RUNOFF REDUCTION PROVIDED? N/A PRES. VEG. RE-EST. VEG. CAPTURE & REUSE ENGINEERED

AMOUNT OF RUNOFF REDUCTION PROVIDED: FT³ _____ % OF SITE WQ_v (FROM FORM 4B IF USED)

- 2B. PROVIDE WQ TREATMENT FOR SITE IMPERVIOUS AREA WITH WQ BMPS: N/A (IF TREATMENT IS PROVIDED BY 1 OR 2A ABOVE)
 YES (TREAT 100% OF SITE WQ VOLUME WITHOUT RUNOFF REDUCTION)

WQ TREATMENT VOL. PROVIDED BY BMPS: FT³ (FROM FORM 2 IF USED)



FORM 3

SITE VOLUMETRIC RUNOFF COEFFICIENT (R_v) WORKSHEET

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT)

PROJECT NAME: _____

PROJECT LOCATION: _____

SITE VOLUMETRIC RUNOFF COEFFICIENT (R_v) CALCULATION METHODS:

1. SHORT CUT METHOD: USE

$R_v = 0.05 + (0.009 \times I)$ WHERE: $I =$ % OF SITE IMPERVIOUSNESS (FROM FORM 1A)

$I =$ _____ %

$R_v =$ _____

2. SMALL STORMS METHOD: USE

URBAN SURFACE CONDITIONS	R_{vi}	A_i (AC)	DRF (NOTE 1)	$R_{vi} \times A_i$ \times DRF (AC)
FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
TOTALS	X		X	
WEIGHTED $R_v =$ TOTAL ($R_{vi} \times A_i \times$ DRF)/TOTAL A_i				

NOTE 1: R_v REDUCTION FACTORS FOR DISCONNECTED IMPERVIOUS SURFACES

- 1.00 CONNECTED IMPERVIOUS SURFACE
- 0.99 STRIP COMMERCIAL & SHOPPING CENTER
- 0.50 MEDIUM TO HIGH DENSITY RESIDENTIAL WITH PAVED ALLEYS
- 0.22 MEDIUM TO HIGH DENSITY RESIDENTIAL WITHOUT PAVED ALLEYS
- 0.22 LOW DENSITY RESIDENTIAL



FORM 4A

RUNOFF REDUCTION WORKSHEET

(MANDATORY SUBMITTAL ITEM FOR NEW DEVELOPMENT)

PROJECT NAME: _____

PROJECT LOCATION: _____

RUNOFF REDUCTION GOAL: PERMANENTLY REDUCE 10% OF THE WATER QUALITY VOLUME.

TOTAL SITE AREA (A_T): _____ ACRES (FROM FORM 1A)

THEORETICAL SITE WQ TREATMENT VOLUME:
(BEFORE RUNOFF REDUCTION IS APPLIED) _____ FT³ (FROM FORM 1A)

MIN. REQD. RUNOFF REDUCTION VOLUME: _____ FT³ (THEORETICAL WQ_v x 10%)

PROP. RUNOFF REDUCTION VOLUME: _____ FT³ _____ % OF WQ_v

RUNOFF REDUCTION METHODS:

1. PRESERVE	PROPOSED AREA		MIN. GOAL % OF A _T	% OF GOAL PROVIDED	RR EQUIV. (FT ³)
	ACRES	% OF A _T			
AREA OF SITE PRESERVED IN TREES, GRASSLAND OR DEEP-ROOTED VEGETATION. SHALLOW-ROOTED TURF GRASS DOES NOT COUNT. (PRESERVED AREA CAN NOT INCLUDE STREAM BUFFER AREA).			10%		

2A. RE-ESTABLISH TREES	PROPOSED AREA		MIN. GOAL % OF A _T	% OF GOAL PROVIDED	RR EQUIV. (FT ³)
	ACRES	% OF A _T			
AREA OF SITE RE-ESTABLISHED WITH TREES: PLANT 6 TREES MIN./ACRE _____ AC x 6 = _____ TREES ROUND UP TO _____ TREES MIN. PROPOSED = _____ TREES			12%		

DESCRIPTION: _____

2B. RE-ESTABLISH DEEP-ROOTED VEGETATION	PROPOSED AREA		MIN. GOAL % OF A _T	% OF GOAL PROVIDED	RR EQUIV. (FT ³)
	ACRES	% OF A _T			
AREA OF SITE RE-ESTABLISHED WITH DEEP-ROOTED VEGETATION:			12%		

DESCRIPTION: _____

3. CAPTURE & REUSE	RR EQUIV. (FT ³)
WATER QUALITY VOLUME CAPTURED & REUSED:	
DESCRIPTION:	

4. ENGINEERED INFILTRATION	RR EQUIV. (FT ³)
WATER QUALITY VOLUME INFILTRATED THRU AN ENGINEERED SYSTEM:	
DESCRIPTION:	

TOTAL RR EQUIV. = _____



BMP VOLUMETRIC RUNOFF COEFFICIENT (R_v) CALCULATOR SMALL STORMS METHOD

PROJECT NAME: _____
BOONE COUNTY, MISSOURI

BMP DRAINAGE AREA NO.	VOLUMETRIC ⁽¹⁾ RUNOFF COEFF. R _v	URBAN SURFACE CONDITIONS	R _{vi}	A _i (AC)	DRF ⁽²⁾	R _{vi} x A _i x DRF (AC)
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	
		FLAT ROOFS & LARGE UNPAVED PARKING LOTS	0.86			
		PITCHED ROOFS & LARGE IMPERVIOUS AREAS	0.98			
		SMALL IMPERVIOUS AREAS & NARROW STREETS	0.74			
		PERVIOUS AREAS - SILTY SOILS (HSG-B)	0.13		X	
		PERVIOUS AREAS - CLAYEY SOILS (HSG-C&D)	0.24		X	
		TOTALS	X		X	

NOTES:

1. WEIGHTED R_v = [TOTAL (R_{vi} x A_i x DRF)]/[TOTAL A_i]
2. R_v REDUCTION FACTORS FOR DISCONNECTED IMPERVIOUS SURFACES
 - 1.00 CONNECTED IMPERVIOUS SURFACE
 - 0.99 STRIP COMMERCIAL & SHOPPING CENTER
 - 0.50 MEDIUM TO HIGH DENSITY RESIDENTIAL WITH PAVED ALLEYS
 - 0.22 MEDIUM TO HIGH DENSITY RESIDENTIAL WITHOUT PAVED ALLEYS
 - 0.22 LOW DENSITY RESIDENTIAL



BIORETENTION CELL DESIGN CALCULATIONS

PROJECT NAME: _____
BOONE COUNTY, MISSOURI

BIORETENTION FILTER AREA DESIGN											
BMP NO.	BMP WQ VOLUME WQ _v (FT. ³)	FILTER ⁽¹⁾ MEDIA DEPTH d _f (FT.)	MEDIA COEFF. OF PERM. OF PERM. k (FT./DAY)	PONDING ⁽²⁾ DESIGN DEPTH h _{max} (FT.)	PONDING AVG. DEPTH h _{avg} (FT.)	FILTER ⁽⁴⁾ TIME t _f (DAYS)	MIN. FILTER BED ⁽⁵⁾ SURFACE AREA A _f (FT. ²)	DESIGN FILTER ⁽⁶⁾ BED WIDTH W _f (FT.)	MIN. FILTER BED LENGTH MIN. L _f (FT.)	PROP. FILTER ⁽⁷⁾ BED LENGTH L _f (FT.)	PROP. FILTER ⁽⁸⁾ SURFACE AREA A _f (FT. ²)

NOTES:

1. FILTER MEDIA DEPTH SHOULD BE BETWEEN 2.5' AND 4'
2. FILTER MEDIA COEFFICIENT OF PERMEABILITY SHOULD BE AT LEAST 1.0 FT/DAY
3. MAXIMUM PONDING DEPTH SHOULD BE BETWEEN 3" AND 6"
4. FILTER TIME OF 1 TO 3 DAYS IS RECOMMENDED
5. MINIMUM FILTER BED SURFACE AREA IN SQUARE FEET: $A_f = [WQ_v \cdot d_f] / [k \cdot t_f \cdot (h_{avg} + d_f)]$
6. THE MINIMUM DESIRED FILTER BED WIDTH IS 15' AND OPTIMALLY HALF OF L_f
7. THE MINIMUM DESIRED FILTER BED LENGTH IS 40' AND OPTIMALLY TWO TIMES W_f
8. THE PROPOSED FILTER BED SURFACE AREA MUST BE GREATER THAN OR EQUAL TO THE MINIMUM FILTER BED SURFACE AREA CALCULATED





Appendix C – Environmentally Sensitive Areas

Buffer Requirements:

<i>Sensitive Area</i>		<i>Drainage or Runoff Within</i>	<i>Buffer</i>
1	Losing Stream	1,000 ft	Type I Stream – 200 ft Type III Stream – 60 ft Type II Stream – 100 ft
2	Outstanding National or State Resource Water	1,000 ft	Type I Stream – 200 ft Type III Stream – 60 ft Type II Stream – 100 ft
3	Class P Stream	100 ft	At least 50 ft
4	Jurisdictional Wetland	1,000 ft	At least 50 ft
5	Sinkhole	Any Distance	Not less than 150 ft from the edge, or greater than 300 ft from the sinkhole eye
6	Cave	Any Distance	At least 50 ft
7	Other		At least 50 ft

Losing Streams in Boone County:

	<i>Waterbody name</i>	<i>Miles</i>	<i>Coordinates</i>
1	Trib. to L. Bonne Femme Cr.	1	SE SE NW 01 47N 13W SE NE NW 12 47N 13W
2	Trib. to Clear Cr.	1	SE SW SW 31 48N 12W SW SE SW 30 48N 12W
3	Trib. to Gans Cr	1	SE SW NE 06 47N 12W NE NE NW 07 47N 12W
4	Slate Cr	1.5	SE SW SE 34 46N 12W NW NE SE 09 45N 12W
5	Trib. to Jemerson Cr.	2	NE SE SE 21 46N 12W SW NE SW 29 46N 12W
6	Bonne Femme Cr.	4	NW NE NW 10 47N 12W NE NE SW 20 47N 12W
7	Trib. to Bonne Femme Cr.	1.5	SW NE SE 29 47N 12W SE SE NW 30 47N 12W
8	Trib. to Fowler Cr.	1.5	SW SW NW 13 46N 12W SE NE SW 24 46N 12W
9	Bass Cr.	0.5	SW NW NE 28 47N 12W SE NW NW 28 47N 12W



Outstanding State Resource Waters in Boone County

	<i>Waterbody name</i>	<i>Miles</i>	<i>Location</i>
1	Bass Creek	1	Three Creeks CA
2	Bonne Femme Creek	2	Three Creeks CA
3	Devils Ice Box Cave Branch	1.5	Rock Bridge SP
4	Gans Creek	3	Rock Bridge SP
5	Turkey Creek	4.6	Three Creeks CA

US Fish & Wildlife Endangered Species List for Boone County

<i>Species</i>	<i>Status</i>	<i>Habitat</i>
Gray bat (<i>Myotis grisescens</i>)	Endangered	Caves
Indiana bat (<i>Myotis sodalis</i>)	Endangered	Caves and mines; Maternity and foraging habitat: small stream corridors with well developed riparian woods; upland forests
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Threatened	Statewide in Winter
Pallid sturgeon (<i>Scaphirhynchus albus</i>)	Endangered	Mississippi and Missouri Rivers; Sturgeon will travel upstream into Perche Creek during flood events.
Running buffalo clover (<i>Trifolium stoloniferum</i>)	Endangered	Disturbed bottomland meadows
Topeka shiner (<i>Notropis topeka</i>)	Endangered	Small prairie (or former prairie) streams in pools containing clear, clean water. Most Topeka shiners are found in perennial streams (flow year-round), or streams maintained by groundwater seepage. Topeka shiners need streams with clean gravel, rock, or sand bottoms.



Class P Streams in Boone County

	<i>Waterbody Name</i>	<i>Miles</i>
1	Bonne Femme	7.8
2	Hinkson Creek	7.6
3	Little Bonne Femme	9
4	Perche Creek	11
5	Perche Creek	17.5
6	Sugar Branch	2.3

Designated Sinkhole Areas (designated by MoDNR, other properties with sinkholes not in these areas will comply with Chapter 7 of the Stormwater Design Manual):

<i>Area</i>	<i>Coordinates</i>
1 Pierpont	S1/2 03 47N 12W S1/2 08 47N 12W NW1/4 and N1/2 NE1/4 17 47N 12W N1/2 NW1/4 and NE1/4 18 47N 12W E1/2 21 47N 12W W1/2 SW1/4 28 48N 12W SW1/4 and S1/2 NE1/4 and E1/2 SW1/4 29 48N 12W E1/2 SW1/4 12 14N 13W
2 Rocheport and Huntsdale	NE1/4 and NW1/4 07 48N 14W SW1/4 and SE1/4 08 48N 14W S1/2 09 48N 14W W1/2 15 48N 14W 16 48N 14W E1/2 and E1/2 NW1/4 17 48N 14W N1/2 21 48N 14W NW1/4 22 48N 14W
3 Midway	W1/2 NE1/4 and E1/2 NW1/2 02 48N 14W SE1/4 19 49N 13W S1/2 20 49N 13 W N1/2 29 49N13W NE1/4 30 49T 13W 26 49N 14W E1/2 35 49N 14W

References:

Code of State Regulations, Rules of Department of Natural Resources, Division 20 Clean Water Commission, Chapter 7 Water Quality.

<http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf>