STORMWATER MANAGEMENT & EROSION CONTROL DESIGN MANUAL

City of Rock Hill
Planning & Development Department
Infrastructure Division
PO Box 11706
Rock Hill, SC 29731-1706

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CHAPTER 1 - INTRODUCTION

1.1 Introduction

1.1.1 Purpose

The purpose of this Stormwater Management Design Manual is to assist in the design and evaluation of stormwater management facilities within the City of Rock Hill. It provides engineering guidance to:

- Local agencies responsible for implementing the City of Rock Hill Stormwater Management Program;
- Engineers responsible for the design of stormwater management structures;
- Developers involved in site planning and design; and
- Others involved in stormwater management at various levels who may find the manual useful as a technical reference to define and illustrate engineering techniques.

This Stormwater Management Design Manual has been prepared in accordance with the requirements of the Zoning Ordinance of Rock Hill, South Carolina and the South Carolina Stormwater Management and Sediment Reduction Act to accomplish the following objectives:

- Reduce stormwater impacts on water quality;
- Reduce stormwater impacts on water quantity;
- Protect downstream areas from adverse stormwater impacts resulting from development;
- Identification of what is required for stormwater plan submittal and plan reviews; and,
- Submittal of high quality stormwater design plans from the design community.

1.1.2 Contents

The Manual presents technical and engineering procedures and criteria needed to comply with the City of Rock Hill stormwater regulations. The Manual provides the following information:

- Stormwater management requirements;
- Summarization of the permit application process;
- Submittal requirements and the plan review process;
- Technical guidance to meet stormwater management design requirements; and,
- Guidelines for designing, implementing, and maintaining stormwater best management practices (BMPs) to be used in the City of Rock Hill to improve water quality, minimize stormwater runoff impacts due to increased flow volumes, and maintain peak discharge rates from developed areas to predevelopment levels.
- Reduce stormwater impacts on water quality;
- Reduce stormwater impacts on water quantity;

1.1.3 Limitations

The Design Manual was developed under the assumption the user possesses a basic understanding of stormwater control design, construction, or land development depending on the user's particular area of expertise. Users of this Manual who are not justly qualified by education or experience in the fields of stormwater control design, construction, or land development should consult with a qualified professional in one or more of these areas prior to adhering to the requirements contained within the Manual.

This Manual is not intended to be a systematic design methodology addressing every land development situation which may occur in the City. The application of engineering principles and judgment combined with the information contained within this Manual are required to successfully complete the planning, design, and preparation of documents for stormwater management plan submittal.

This Manual is not intended to restrain or inhibit engineering creativity, freedom of design, or the need for engineering judgment. When shown to be applicable, new procedures, techniques, and innovative stormwater BMPs can be submitted with supporting documentation. The documentation submitted by design professionals should show these procedures are equal to, or exceed the procedures and/or controls contained in this Design Manual.

1.1.4 Updating

This manual will be updated and revised, as necessary, to reflect up-to-date engineering practices and information applicable to the City of Rock Hill area. Manual users can find updated information on the City of Rock Hill webpage at www.cityofrockhill.com.

1.2 Abbreviations

A	Drainage area or area draining into the facility (acres, square
A	miles)
AMC	Cross sectional flow area (ft^2)
b or b_o	Antecedent moisture condition
b_s	Channel bottom width (feet)
C	Top width for rip-rap at water surface (feet)
C_d	Runoff coefficient
D	Weir coefficient
D	Pipe diameter (inches)
d	Depth of rip-rap (feet)
d_n	Channel depth (feet)
E_o	Normal depth (feet)
HW	Ratio of frontal flow to total gutter flow (Q_w/Q)
i	Headwater (feet)
I	Runoff intensity (in/hr)
I_a	Percent of impervious cover (%)
K	Initial abstraction (inches)
K_e	Hydraulic conductivity
L	Inlet loss coefficient, for measuring efficiency
L_a	Flow length; culvert length (feet)
n	Apron length (feet)
P	Manning's roughness coefficient
Q	Rainfall depth (inches); Wetted perimeter (feet)
$Q_{x\text{-}yr,}$	Peak discharge rate (cfs or inches); Gutter flow rate (cfs)
Rural	Peak discharge for the X-yr event in a rural/undeveloped basin
Q_s	Flow rate outside gutter for composite gutter systems (cfs)
Q_w	Flow rate within gutter for composite gutter systems (cfs)
R	Hydraulic radius (feet)
R_o	Radius of curve section in a stream (feet)
S	Soil potential maximum retention (inches); Longitudinal slope (ft/ft) Culvert slope (ft/ft)
S_w	Gutter slope in composite gutter systems (ft/ft)
S_x	Pavement cross slope (ft/ft)
T	Spread of water in gutter (feet)
T	Channel top width (feet)
t_c	Time of concentration (minutes)
Ts	Spread of water outside of depressed gutter sections (feet)
T_t	Travel time (minutes)
TW	Tail water (feet)
V, v	average velocity (ft/sec)
WQCV	water quality capture volume (inches or ft^3)
Z	Channel side slope (ZH:1V)

1.3 References

City of Charlotte Storm Water Services-Mecklenburg County Storm Water Services, July 8, 1993 or most recent edition, Charlotte-Mecklenburg Storm Water Design Manual.

Greenville, South Carolina Storm Water Management Design Manual, January 1992

CHAPTER 2 – DEVELOPMENT PROCESS

2.1 Development Process

2.1.1 Permit Application Center

The Permit Application Center (PAC) was established in 1987 to assist developers with the plan review and permitting process. Its primary goal is to ensure timely review of plans and to serve as a clearinghouse for all construction and property development within the City.

The PAC will act as a liaison between City departments, contractors, architects, engineers and property owners. The PAC will route and track all plans to City departments and compile all comments and recommendations and submit them to the developer or the company's representative for revision. At times, you may need to talk to specific departments, so the PAC staff can refer you to the appropriate person.

This process is intended to avoid duplication and conflicting comments. If you need further assistance (forms, fees, approvals, codes, or additional information), the PAC has copies of all documents including codes, regulations, and standards and handbooks.

In serving as a centralized contact for all construction and property development, the PAC will be updating and streamlining the review process annually.

Contact the PAC at (803) 329-5590.

2.1.2 Land Development Permit Process

The Rock Hill City Council has passed an ordinance to require a land development permit prior to any development or construction activity including grading. This permit is required on preliminary plats, group developments, and non-residential developments submitted on or after January 1, 2002.

Obtaining a land development permit requires written approval from SCDOT (South Carolina Department of Transportation) for right-of-way encroachment, SCDHEC (South Carolina Department of Health and Environmental Control) for stormwater management, and site plan approval from the City of Rock Hill, which includes compliance with city codes and regulations. A breakdown of the land development permit requirements is shown in Table 2-1. It must be noted that the Stormwater Management and Sediment Control plan will not be implemented by the contractor until all Federal and State permits regarding wetlands management have been obtained.

Table 2.1.2.1 Land Development Permit Requirements

Required Approvals	Subdivisions	Group Developments	Non-Residential Development Sites
SCDOT			
Encroachment Permit	Yes	Yes	Yes
SCDHEC			
Stormwater Management Permit	Yes	Yes	Yes
City of Rock Hill			
Preliminary Plat	Yes	No	No
Group Development Plan	No	Yes	No
Site Plan	Yes	Yes	Yes
Landscape Plan	Yes	Yes	Yes
Tree Removal Permit	Yes	Yes	Yes
Encroachment Permit	Yes	Yes	Yes

2.2 Fee Schedule

2.2.1 Fee Schedule Summary

Table 2.2.1.1: Zoning Code Services & Fees
See City of Rock Hill website for current fee schedule—www.cityofrockhill.com

2.3 Data Availability

2.3.1 Introduction

Identification of drainage needs should be a part of the early planning phase of a project, when appropriate procedures for performing hydraulic calculations are selected. Several categories of data may be relevant to a particular drainage project, including published data on precipitation, soils, land use, topography, stream flow, and flood history.

The collection of data can be very time consuming and expensive; therefore, it is important to identify existing data to keep the collection of field data to a minimum. The following sections present some of the data sources that can be used for drainage and flood studies in the City of Rock Hill.

2.3.2 Previous Studies

Comprehensive Plan

The Comprehensive Plan for the City of Rock Hill promotes the best use of limited resources and determines what the most important needs are so the City can prioritize them as they make decisions on how to use their resources. It enables the City to provide efficient services and encourages development where services are already available or easily accessible which saves tax money on extending services elsewhere. The City of Rock Hill has also completed various Stormwater Master Plans in the City and should be consulted at the beginning of a drainage study.

The Comprehensive Plan is available on the City of Rock Hill's website at **http://www.cityofrockhill.com**.

US Geological Survey

The US Geological Survey has published several papers and studies on the hydrologic aspects of South Carolina. Information on USGS activities can be obtained by contacting the Columbia District Office at the following address:

U.S. Geological Survey
Water Science Center
720 Gracern Road
Suite 129
Columbia, SC 29210
(803)750-6100 or (888)275-8747

More information can be found on the USGS website at **http://www.usgs.gov/**.

Federal Emergency Management Agency (FEMA)

FEMA Flood Insurance Maps can be purchased from FEMA's flood mapping website at **http://www.floodmaps.fema.gov/**.

US Army Corps of Engineers

The Corps of Engineers may be a source for the following information:

Data related to record high water marks,
Local flood control studies, and
Floodplain information.

2.3.3 Natural Resources Data

The major categories of pertinent natural resources data include precipitation, soils, topography, streamflow and flood history, and groundwater.

Precipitation

Precipitation data for most drainage studies can be obtained from the Intensity-Duration-Frequency (IDF) curve for Rock Hill, found in Table 4.3.5.1 or the precipitation depths found in Table 4.2.3.1.

Soils

Information from the SCS soils report entitled Soil Survey of York County, South Carolina, completed in 1965 is suitable for use in hydrologic modeling, but additional site-specific data from more detailed or later surveys may be appropriate as a supplement to the published data. Other data related to soils and quantifying erosion and specific erosion control practices can be obtained from the Erosion And Sediment Control Practices For Developing Areas, South Carolina Land Resources Conservation Commission, Erosion and Sediment Control Division, June 1985.

More information about Soil Survey of York County, South Carolina can be obtained from:

NRCS Field Office
1460 E. Alexander Love Hwy.
York, SC 29745
Tel: (803) 684-3137 Fax: (803) 628-0069

Topography

USGS 7.5-minute topographic quadrant maps are offered by the City Information System (CIS) Division (**http://www.rhmaps.ci.rock-hill.sc.us/products.asp**). The CIS Division offers various mapping and digital products.

Streamflow

Local streamflow data can be obtained from the Real-Time Gaging Station webpage hosted by the South Carolina Department of Natural Resources (DNR) at
http://www.dnr.state.sc.us/water/hydro/usgs/usgsrt.html.

Groundwater

Data on groundwater levels and movements can be obtained from:

- information on existing detention ponds and other ponds in the area;
- existing non-pumping wells or wells temporarily shut off to determine the static groundwater level;
- observations made by inspectors and others during construction of sanitary sewers, storm sewers, and major buildings; and
- regional or area-wide reports prepared by the USGS or state agencies.

If existing data sources are not sufficient to define the position of the groundwater table, it may be necessary to construct special observation wells, particularly at potential sites of detention facilities.

2.3.4 Manmade Features

Land Use

If historical information such as flood records or high water marks are being considered in an analysis, older land use maps or aerial photos should be sought identifying early conditions possibly having undergone change. The City of Rock Hill Infrastructure Division should be contacted about the availability of such data.

- Digital coverages of the existing land uses can be requested from the Infrastructure Division.
- Future land use projections can be obtained from the Rock Hill Comprehensive Plan.

2.4 Field Investigations

2.4.1 Introduction

Field investigations are generally necessary to determine drainage areas, identify pertinent features, obtain high water information, survey channel sections, bridge, and culvert crossings. Field investigations are recommended at each site to verify site-specific conditions and obtain survey data when published data are inadequate. Factors most often needing to be confirmed by field inspection are:

- selection of roughness coefficients,
- evaluation of apparent flow direction and diversions,
- observation of land use and related flood hazards,
- geomorphic relationships, and
- high-water marks or profiles and related frequencies.

2.5 Contact Information

2.5.1 Other Contacts

SCDHEC (South Carolina Department of Health/Environmental Control)

Water	803-734-5310
Sewer	803-734-5300 (domestic)
	803-734-5625 (industrial)
Stormwater	803-285-7461

York County Natural Gas Authority

803-329-5255

Comporium

Kelly Brazil 803-326-6160

SCDOT (South Carolina Department of Transportation)

Brad Trout 803-327-6186
**All encroachment permits must be submitted to the City of Rock Hill for approval prior to sending to SCDOT.

2.6 References

City of Rock Hill webpage. www.cityofrockhill.com

Greenville, South Carolina Storm Water Management Design Manual, January 1992.

CHAPTER 3 - CITY ORDINANCES AND PLAN REQUIREMENTS FOR STORMWATER MANAGEMENT AND SEDIMENT CONTROL PLANS

3.1 Stormwater Management Regulations and Policies

3.1.1 Overview

To address the adverse impacts of urbanization and land development, Federal, State and Local regulations have been adopted to protect the quantity and quality of the runoff received by natural receiving water bodies.

With the mandate of the Clean Water Act, the Environmental Protection Agency (EPA) stated it is illegal to discharge any pollutant to the "Waters of the United States" without a NPDES Permit. The various types of NPDES stormwater permits are described below.

3.1.2 Clean Water Act

The federal Clean Water Act (CWA) requires discharge permits, called National Pollutant Discharge Elimination System (NPDES) permits, be obtained for every point source discharge of wastewater. The 1987 amendments to the CWA also required NPDES permits for industrial discharges, including stormwater runoff associated with land disturbing activity (typically land development and construction) of 5 acres or greater. The threshold five-acre area was challenged and the federal NPDES regulations were amended in accordance with a court order for stormwater discharges in December 1999. These amendments lower the acreage for when an NPDES permit is required for construction or land clearing to one acre while allowing a case-by-case determination for sites less than 1 acre.

The 1987 CWA Amendments also require NPDES permitting for stormwater runoff from urbanized areas. A municipal separate storm sewer system (MS4) NPDES permit is required based on population. MS4s are divided into three categories: large (250,000 or greater); medium (less than 250,000 but equal to or greater than 100,000); and small (greater than 50,000). The implementation schedule for these MS4 permits has been repeatedly delayed, but large and medium permits are being implemented.

For both the land disturbing and MS4 nonpoint source permits, preventing pollution at the source through the use of Best Management Practices (BMPs) is the preferred and most practical method. Additional BMPs can be used as needed to address capture, control, and treatment of pollutants after they have been generated or released from a source area. Authority to administer the NPDES permit program was delegated to SCDHEC in accordance with the CWA by the United States Environmental Protection Agency (EPA).

3.1.3 South Carolina Pollution Control Act

The South Carolina Pollution Control Act (PCA) S.C. was originally enacted in 1950 and was last amended in 1970 during the initial stages of the environmental movement. It was written very broadly and is applicable to essentially any activity.

The most important provision of the statute is Section 48-1-90, states it is "unlawful for any person, directly or indirectly, to throw, drain, run, allow to seep or otherwise discharge into the environment…[any] wastes, except as in compliance with a permit" issued by SCDHEC.

3.1.4 South Carolina Sediment Reduction Act

The South Carolina Stormwater Management and Sediment Reduction Act of 1991 (SMSRA) S.C. Code Ann. §§ 48-14-10 et seq. was enacted to address the increase in stormwater runoff rate and quantity, the decrease of rainwater infiltration, and the increase in erosion associated with the extensive urban development has been occurring throughout the state. The City of Rock Hill has the authority to implement the requirements of this Act and its associated regulations.

3.1.5 NPDES Permit for Stormwater Discharges Associated with Industrial Activity

All stormwater runoff from "industrial activities" is considered an illegal discharge without an NPDES Stormwater Permit (SCR100000). These permits require certain industries to develop and implement a Stormwater Pollution Prevention Plan (SWPPP), which must include appropriate BMPs to minimize pollution to the receiving natural water bodies. There are two general types of industrial activity permits: "construction related" and "other". A NPDES stormwater permit for stormwater discharges from construction sites is required for all construction sites disturbing one or more acres of land. The requirements for obtaining and complying with this type of permit are covered within this Design Manual.

3.1.6 NPDES Municipal Separate Stormwater System Water (MS4) Permit

The City of Rock Hill has obtained a NPDES MS4 Permit from the South Carolina Department of Health and Environmental Control (DHEC) for stormwater discharges. The permit requires the City to develop and implement a Stormwater Management Program (SWMP) to control the discharge of pollutants from its MS4 to the maximum extent practicable (MEP).

The City of Rock Hill has been granted the authority by the South Carolina Constitution and the South Carolina General Assembly to handle the following responsibilities:

- Comply with all Federal and State regulatory requirements imposed by the NPDES Permit in accordance with the Clean Water Act to manage stormwater discharges from the City of Rock Hill MS4.
- Conduct all activities necessary to carry out the stormwater management programs and other requirements included in the City of Rock Hill NPDES Permit, the SWMP, and the Zoning Ordinance of Rock Hill, and pursue the necessary means and resources required to properly fulfill this responsibility.
- Enter into contractual agreements with other governmental entities, private persons, or entities to provide or procure services to conduct and carry out stormwater management activities.
- Maintain the stormwater system consistent with provisions of the City of Rock Hill NPDES Permit, the SWMP, the Zoning Ordinance of Rock Hill, and pursue the necessary means and resources required to properly fulfill this responsibility.
- Direct and oversee the continuous implementation of the City of Rock Hill SWMP and the Zoning Ordinance of Rock Hill and direct and ensure compliance with the City of Rock Hill NPDES permit.
- Direct, review, and recommend for approval by City Council, the Stormwater Management Program Operating Budget; and,

Direct, review, and recommend for approval by City Council, the necessary changes to the existing Stormwater Management Funding.

3.2 Local Ordinances

3.2.1 Stormwater Related Ordinances

The following Rock Hill Ordinances affect stormwater management within the City. These are:

- The City of Rock Hill Zoning Ordinance (latest revision) Article 2-300(J) & Article 6-500(D),
- The Code of Ordinances, City of Rock Hill, South Carolina, Chapter 10, Article VII Flood Prevention, and
- The Code of Ordinances, City of Rock Hill, South Carolina, Chapter 29, Article V Stormwater Management Utility.

3.3 Plan Requirements for Stormwater Management and Sediment Control Plans

3.3.1 Introduction

Stormwater Management and Sediment Control Plans shall include appropriate measures and practices for Stormwater Management and Sediment Control, installed in a timely sequence during the land disturbing activity process, and maintained to insure their proper functioning. Plans shall be prepared according to this manual, the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina, and the erosion control checklist, which both can be found on the city's website (www.cityofrockhill.com).

3.3.2 Mandatory Standards and Plan Requirements

Mandatory Standards for All Stormwater Management and Sediment Control Plans

Stormwater management and sediment control for all projects shall meet design requirements as specified in Article 2-300(J), Stormwater Management and Sediment Control Plans, in the Zoning Ordinance of Rock Hill, South Carolina. The following sections outline the basic design standards for each type of development category.

All references in the following sections cite the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina.

Stormwater Management and Sediment Control Plans shall include appropriate measures and practices for Stormwater Management and Sediment Control, installed in a timely sequence during the land disturbing activity process, and maintained to insure their proper functioning. Plans shall be prepared according to the following which can be found in Article 2-300(J) of the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina:

1. Determine the general soil suitability of the proposed land use. Identify areas which are subject to severe erosion and off-site areas which are especially vulnerable to damage from erosion and/or sedimentation. Identify and evaluate potential erosion, sediment and stormwater problems, and select appropriate control measures;
2. Expose the smallest practical area of land for the least possible time during land disturbing activity. When feasible, retain and protect natural vegetation. Place emphasis on conservation of existing on-site soil. Save topsoil, where practical, for replacing on graded areas. Use temporary vegetation cover, geotextiles, mulching, grassed or surfaced waterways and outlets, straw and silt traps, to control runoff, protect areas subject to erosion and remove heavy sediment loads from runoff. A twenty (20') feet wide vegetated water quality buffer is required downstream of all outfalls while construction activities are being conducted,
3. Provide for the management of increased runoff caused by changed soil conditions and surface conditions. Effective means include the use of diversion ditches, detention and retention basins, enlarged and protected drainage channels, grade control structures, and effective use of street gutters and storm sewers;
4. Install permanent vegetative cover and other long-term measures as soon as practical in the construction process;
5. When the person conducting land-disturbing activity is also conducting the borrow or waste disposal activity, areas from which borrow is obtained and which are not regulated by the provisions of City of Rock Hill Zoning Ordinance, and waste areas for surplus materials other than landfills regulated by the South Carolina Department of Health and Environmental Control, shall be considered as part of the land-disturbing activity even when they are not located on the project site.
6. Land-disturbing activity in connection with construction adjacent to, over, or under a lake or natural watercourse shall be planned and conducted in such a manner so as to minimize the extent and duration of disturbance of the stream channel. The relocation of a stream, where relocation is an essential part of the proposed activity, shall be planned and executed so as to minimize changes in the

stream flow characteristics, except when justification for significant alteration to flow characteristic is provided;

7. When channel velocity is calculated to exceed sufficient stability for the channel cross section and grade, riprap, bituminous or other lined open channels shall be substituted for grassed channels;
8. In addition to functional purposes; utilize natural streams or improved open channels for landscaping, environmental, architectural, or aesthetic purposes;
9. A Stormwater Management and Sediment Control Plan shall be filed for a residential development and the buildings constructed within, regardless of the phasing of construction.
   a. In applying the Stormwater Management and Sediment Control criteria, individual lots in a residential subdivision development shall not be considered to be separate land disturbing activity projects and shall not require individual permits unless the overall erosion development erosion control permits have expired. Instead, the residential subdivision development, as a whole, shall be considered to be a single land disturbing activity project. Hydrologic parameters reflecting the ultimate subdivision development shall be used in all engineering calculations.
   b. If individual lots or sections in a residential subdivision are being developed by different property owners, all land-disturbing activities related to the residential subdivision shall be covered by an approved Stormwater Management and Sediment Control Plan and NPDES permit. Individual lot owners or developers may sign a copermittee agreement indicating all activities on the lot will be carried out in accordance with the approved Stormwater Management and Sediment Control Plan for the overall residential subdivision. Failure to provide this certification will result in owners or developers of individual lots developing a Stormwater Management and Sediment Control Plan meeting the requirements of SCDHEC and this ordinance.
10. Any site with ten (10) acres or more of disturbance requires the sediment basin outlet structure to be designed so the outlet discharge is extracted, as the water surface fluctuates, from the top of the water surface.
11. The twenty-five (25) year flow to the nearest receiving system shall not exceed the system's capacity. If the system's capacity is exceeded, the site flow must be restricted or the capacity of the receiving system must be increased at the developer's expense.

3.3.3 Grading Permits including land disturbing activities of less than one (1) acre, which are not part of a larger common plan of development or sale

Stormwater Management and Sediment Control for all projects shall meet the design requirements as specified in this section and the erosion control checklist found on the city's website (www.cityofrockhill.com) and include as a basis the following data to the extent required by this ordinance.

1. Name and address and phone number of the owner of the property where the project is proposed; the developer; the applicant and whoever is responsible for compliance with the plan; a completed and notarized financial responsibility form, and the following certification:

   Applicants Certification
   "I (We) hereby certify that all land disturbing activities including clearing, grading, construction and/or development will be done pursuant to this plan and agree to indemnify any person damaged by failure to comply with the approved plan. City, County and State authorities will be allowed to enter upon the project site provided they present appropriate credentials."

2. Title, scale, north arrow, date, name of individual or organization preparing the plan, the boundary lines of the site, the tax map number, the parcel number(s), and approximate acreage on which the land disturbing activity is to take place and the approximate area to be disturbed.
3. A vicinity map sufficient to locate the site and to show the relationship of the site to its general surroundings at a scale of not less than one (1) inch equals one (1) mile.
4. A general description of the subject property and adjacent property and a description of the subject property and adjacent property and a description of existing structures, buildings, and other fixed improvements located on the subject and adjacent properties.
5. General description of the topographic and predominant soil conditions of the tract from the York County Soil Survey.
6. A narrative description of the Stormwater Management and Sediment Control Plan to be used during land-disturbing activities.
7. The existing and proposed topography, at a contour interval suitable for the design.

8. The proposed grading and earth disturbing activities, including:
   a. surface area involved; and
   b. limits of grading including limitation of mass clearing and grading whenever possible;
   c. proposed improvements on the site;
   d. a complete and adequate grading plan for borrow pits and material processing facilities where applicable, showing the storm drainage ways serving such area.
9. The name and number of the Federal Emergency Management Agency flood maps and Federal and State wetland maps, where appropriate. Use of the current FIRM maps is required.
10. Erosion and sediment control provision, including:
   a. provisions to preserve top soil and limit disturbance;
   b. details of site grading;
   c. design details for structural controls which include diversions and swales,
   d. a description of their proposed operation.
11. A time schedule and sequence of operations indicating the anticipated starting and completion dates of each land disturbing activity operation, as well as the date by which final stabilization will occur.
12. Specifications for seeding mixes and rates, type of sod, seedbed preparation, lime, and fertilizer applications, and mulching and related data.
13. A description of the maintenance program for erosion and sediment control and stormwater management facilities including inspection programs, vegetative establishment on exposed soils, methods and frequency of removal and disposal of spoil or waste material, and disposition of temporary and permanent structural measures.
14. Location of buffer yards and required vegetation and screening as required by the City of Rock Hill Zoning Ordinance.
15. A digital copy, five (5) copies of the erosion control/grading plan, and two (2) copies of the calculations must be submitted for approval.

3.3.4 Grading Permits including land disturbing activities of less than one (1) acre, which are part of a larger common plan of development or sale

Stormwater Management and Sediment Control Plans for land disturbing activities shall provide the information required in City of Rock Hill Zoning Ordinance and the erosion control checklist found on the city's website (www.cityofrockhill.com) as well as meet the design requirements as specified in this section and include as a basis the following data to the extent required by this ordinance.

1. All the information required by the City of Rock Hill Zoning Ordinance.
2. All plans will require all sediment and erosion controls be inspected by the contractor at least once every seven calendar days and after any storm event of greater than 0.5 inches of precipitation during any 24-hour period.
3. A sequence of construction operation shall be contained in all plans describing the relationship between implementation and maintenance of sediment controls, including permanent and temporary stabilization and the various stages or phases of earth disturbance and construction. The sequence of construction shall, at a minimum, include the following activities:
   a. Clearing and grubbing for those areas necessary for installation of perimeter controls;
   b. Installation of construction drive, sediment basins, and traps;
   c. Construction of perimeter controls;
   d. Remaining clearing and grubbing;
   e. Road grading;
   f. Grading for the remainder of the site;
   g. Utility installation and whether storm drains will be used or blocked until after completion of construction;
   h. Final grading, landscaping, and/or stabilization; and
   i. Removal of sediment controls.

* Changes to the sequence of construction operations may be modified by the person conducting the land disturbing activity or their representative and do not constitute a violation unless stormwater runoff and sediment control measures are not utilized.

4. The following notes shall be on the plan, and the person responsible for the land disturbing activity is required to do the following. Failure to follow these notes shall constitute a violation of the City of Rock Hill Zoning Ordinance;
   a. Contact the Infrastructure Division not less than forty-eight (48) hours before commencement of the land disturbing activity to set up a pre-construction meeting. The developer shall also contact the City of Rock Hill before and after the removal of the temporary sediment control measures.
   b. Begin installation of interim erosion and sediment control and stormwater management measures within forty-eight (48) hours of the commencement of land disturbing activities.
   c. The developer engaged in or conducting the land disturbing activity shall be responsible for installing and maintaining all temporary and permanent erosion and sediment control measures and facilities during the development of a site as required by the approved plan or any provision of this ordinance. Operations and maintenance conditions shall be included in the plan outlining how the developer intends to provide for operations and maintenance during construction.
   d. Before beginning soil disturbance or redisturbance, all perimeter sediment controls shall be installed and temporary stabilization measures shall be completed on topsoil stockpiles.
   e. Areas at final grade shall receive permanent stabilization measures within seven calendar days of reaching final grade.
   f. The responsibility for maintaining all permanent erosion and sediment control measures and facilities after site land disturbing activity is completed shall lie with the landowner or person in possession or control, except facilities and measures installed within road or street right-of-ways or easements accepted for maintenance by the City of Rock Hill.
5. The following certifications shall be on the plan; however, no design shall be certified to by a professional who is not qualified to practice in accordance with the laws of the state of South Carolina and the rules of the Board or Commission with governing authority for his particular profession:

   <u>Professionals Certification</u>
   I hereby certify that this plan is designed to contain sediment on the property concerned and to provide for the control of stormwater runoff from the property and that to the best of by knowledge and belief all the provisions are in accordance with the Zoning Ordinance of the City of Rock Hill, South Carolina.

   ____________________________ ____________________________

Date	Registered Landscape Architect
	Registered Tier B Surveyor
(SEAL)	Registered Professional Engineer

6. Plans may also be prepared by employees of the federal government in accordance with Title 40, Chapter 22, Section 460 of the South Carolina Code of Law and submitted by the person responsible for the land disturbing activity. The employee should place proper Federal identification on the plan.
7. A clear statement of defined maintenance responsibility shall be established during the plan review and approval process and placed on the plan.
8. The developer shall install on-site facilities for the detention-storage and controlled release of stormwater runoff in accordance with the City of Rock Hill Zoning Ordinance.
9. The following support documentation must be submitted with the plans:
   Stormwater management and stormwater drainage computations, including:
   a. Pre- and post-development velocities, peak rates of discharge, and inflow and outflow hydrographs of stormwater runoff at all existing and proposed points of discharge from the site.
   b. Site conditions around points of all surface water discharge including vegetation and method of flow conveyance from the land disturbing activity.
   c. Design details for structural controls.
   d. A USGS 7.5 map or copy with the subject area highlighted.
   e. All hydrologic computations shall be accomplished using a volume based hydrograph method acceptable to the city. The storm duration for computation purposes for this method shall be the 24-hour rainfall event, SCS distribution with a 0.1 hour burst duration time increment; however, the SCS 6-hr. rainfall event is recommended for drainage areas less than 50 acres. The rational or modified rational methods are acceptable for sizing individual culverts or storm drains that are not part of a pipe network or system and do not have a contributing drainage area greater than 20 acres. The storm duration for computational purposes for this method shall be equal to the time of concentration of the contributing drainage area or a minimum of 0.1 hours.

***Additional information necessary for a complete project review may be required by the City Manager, or his designee, as deemed appropriate. This additional information may include items such as the location and size of sewers, water lines, septic fields, well, etc.

10. Provisions for stormwater runoff control during the land disturbing activity and during the life of the facility shall meet the following minimum design requirements:
    a. Post development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10 year frequency, 24-hour duration storm event. The City Manager, or his designee, may require a less frequent storm event if circumstances warrant.
    b. Off-site discharges of closed storm sewers or improved open channels will be permitted only at natural streams or man-made drainage channels. Discharge velocities shall be reduced to provide a nonerosive velocity flow from a structure, channel, or other control measure or the velocity of the 10 year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.
    c. Design criteria for channel modification will be as follows:

       Open Channels - Open channels shall be provided with an improved cross section that will carry the runoff from the appropriate design rainfall and preclude the creation of backwater inundation of any area outside dedicated drainage easements. In addition, a no-rise or no-impact certificate is required for any channel modification, and culvert/bridge design within the FEMA detailed studied streams.

       Closed Storm Sewer and Culverts - Closed storm sewers and culverts shall be constructed of precast reinforced concrete pipe or box culvert design, in conformance with standards adopted by the City of Rock Hill. They shall be sized to carry the runoff from the appropriate design rainfall and to preclude the creation of backwater inundation of any area outside dedicated drainage easements.

       Bridges – Any bridge design shall be in accordance with South Carolina Department of Transportation standards and specifications; however, a bridge will only be considered as a last resort if a box or arch culvert cannot be designed to accommodate the crossing.

11. Sediment basins and traps shall be designed to achieve an eighty (80) percent efficiency in removing total suspended solids (TSS) from the discharge effluent from a site. Note, sediment traps can only be designed for drainage areas less than five (5) acres; otherwise, basins are to be designed.
12. All stormwater management and sediment control practices shall be designed, constructed, and maintained with consideration for the proper control of mosquitoes and other vectors. These requirements must be part of the inspection and maintenance agreement as specified in the City of Rock Hill Zoning Ordinance. These requirements must be reviewed during any inspection. Practices may include, but are not limited to:
    a. The bottom of retention and detention ponds should be graded and have a slope not less than 1.0 percent. There should be no depressions in a normally dry detention facility where water might pocket when the water level is receding.
    b. Normally dry swales and detention pond bottoms should be utilized in permanently wet structures to prevent an overgrowth of vegetation in the pond. Manual harvesting is preferred.
    c. Fish may be stocked in permanently wet retention and detention ponds.
    d. Normally dry swales and detention pond bottoms should be constructed to minimize the creation of tire ruts during maintenance activities.
13. Drainage easements shall be provided as follows:
    a. Underground Stormwater Easement - Where development is traversed by a stormwater management system, adequate areas for storm drainage shall be allocated. The easement shall conform substantially to the lines of such system and be sufficient width to convey stormwater. Adequate access for maintenance and equipment shall be required. Generally, for underground stormwater drainage the minimum width of the easement shall not be less than twenty (20) feet.
    b. Open Channel Easement - A drainage easement of not less than twenty (20) feet shall be provided for all open swale channels. For channels which drain into a collector, or a main channel, or into a piped drainage system, the width of the drainage easement shall be equal to the maximum top channel width plus an additional twenty (20) feet, with at least fifteen (15) feet on one side of the previously measured top channel width. In all cases, except natural drainage, channels should have the sides sloped and protected to minimize erosion.
    c. Drainage easements shall be kept cleared as necessary to provide for proper drainage and anticipated maintenance.

   d. Access easements shall be a minimum of twenty (20) feet in width.
   e. All easements required under this section shall be submitted as part of the Stormwater Management and Sediment Control Plan and subsequently recorded at the York County Court House.
   f. A deed of property referencing the easement shall be returned to the City of Rock Hill Planning & Development Department after recordation. It shall be a violation of this ordinance not to record or return the necessary documentation related to the easement.
14. Measures, other than ponds, to achieve water quality improvement are recommended on sites containing less than ten acres.
15. When work in a live waterway is performed, precautions shall be taken to minimize encroachment, to control sediment transport, and to stabilize the work area to the greatest extent possible during construction.
16. Vehicle tracking of sediments from land disturbing activities onto paved roads shall be minimized.
17. The Stormwater Management and Sediment Control plan shall not be implemented until all Federal and State permits regarding wetlands management have been obtained.
18. Stormwater management requirements for a specific project shall be based on the entire area to be developed, or if phased, the initial submittal shall control all areas proposed in the initial phase and shall establish a procedure and obligation for total site control.
19. Where ponds are the proposed method of control, the person responsible for the land disturbing activity shall submit to the approving agency, when required, an analysis of the impacts of stormwater flows downstream in the watershed for the 2, 10, 25, 50, and 100 year frequency storm event. The analysis shall include hydrologic and hydraulic timing modifications of the proposed land disturbing activity, with and without the pond. The results of the analysis will determine the need to modify the pond design or to eliminate the pond requirement. If a clearly defined downstream point of restriction is not indentified, the downstream impacts shall be established with the concurrence of the City Manager, or his designee.
20. Designs shall be in accordance with standards developed or approved by the City.
21. Ease of maintenance must be considered as a site design component and access to the stormwater management structure must be provided.
22. Infiltration practices have certain limitations on their use on certain sites. These limitations include the following items:
    a. Areas draining to these practices must be stabilized and vegetative filters established prior to runoff entering system. Infiltration practices shall not be used if a suspended solids filter system does not accompany the practice. If vegetation is the intended filter, there shall be, at least a twenty (20) foot length of vegetative filter prior to stormwater runoff entering the infiltration practice;
    b. The bottom of the infiltration practice shall be at least 0.5 feet above the seasonal high water table, whether perched or regional, determined by direct piezometer measurements which can be demonstrated to be representative of the maximum height of the water table on an annual basis during years of normal precipitation, or by the depth in the soil at which mottling first occurs;
    c. The infiltration practice shall be designed to completely drain of water within seventy-two (72) hours;
    d. Soils must have adequate permeability to allow water to infiltrate. Infiltration practices are limited to soils having an infiltration rate of at least 0.5 inches per hour. Initial consideration will be based on a review of the appropriate soil survey, and the survey may serve as a basis for rejection. On-site soil borings and textural classifications must be accomplished to verify the actual site and seasonal high water table conditions when infiltration is to be utilized. The soil hydraulic conductivity rate, K must be specified on design calculations for effectiveness of the infiltration practice;
    e. Infiltration practices greater than three (3) feet deep shall be located at least ten (10) feet from building and basement walls;
    f. Infiltration practices designed to handle runoff from impervious parking areas shall be a minimum of one hundred fifty (150) feet from any public or private water supply well;
    g. The design of an infiltration practice shall provide an overflow system with measures to provide a non-erosive velocity of flow along its length and at the outfall;
    h. The slope of the bottom of the infiltration practice shall not exceed five percent. Also, the practice shall not be installed in fill material as piping along the fill/natural ground interface may cause slope failure;
    i. An infiltration practice shall not be installed on or atop a slope whose natural angle of incline exceeds 20 percent.

   j. When using perforated pipe, cleanouts must be provided at a minimum of every seventy-five (75) feet along the pipe to allow for access and maintenance.

23. A regional approach to stormwater management is an acceptable alternative to site specific requirements and is encouraged.
24. A maintenance schedule is required to be included for all permanent best management practices.
25. Five (5) copies of submittals must be approved before a pre-construction meeting is conducted.

3.3.5 Grading Permits and Water Quality

Stormwater Management and Sediment Control Plans for land disturbing activities shall meet the design requirements as specified in the two preceding sections and as specified in this section, and include as a basis the following data to the extent required by the Zoning Ordinance. General submission requirements for projects with land disturbing activities shall follow the erosion control checklist found on the city's website (www.cityofrockhill.com) and include the following information:

1. Water quality control is an integral component of overall stormwater management. The following design criteria for flow control are established for water quality control purposes, unless a waiver is granted based on a case-by-case basis:
   a. Post-development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10 year frequency, 24-hour duration storm event.
   b. Discharge velocities shall be reduced to provide a nonerosive velocity flow from a structure, channel, or other control measure of the velocity of the ten (10) year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.
2. The following design criteria are established for water quality protection unless a waiver or variance is granted on a case-by-case basis.
   a. When ponds are used for water quality protection, the ponds shall be designed as both quantity and quality control structures. Sediment storage volume shall be calculated considering the clean out and maintenance schedules specified by the designer during the land disturbing activity. Sediment storage volumes may be predicted by the Universal Soil Loss equation.
   b. Stormwater runoff and drainage to a single outlet from land disturbing activities which disturb ten (10) acres or more shall be controlled during the land disturbing activity by a sediment basin where sufficient space and other factors allow these controls to be used until the final inspection. The sediment basin shall be designed and constructed to accommodate the anticipated sediment loading from the land disturbing activity and meet a removal efficiency of eighty (80) percent total suspended solids (TSS) or 0.5 ML/L peak settable solids concentration. The outfall device or system design shall take into account the total drainage area flowing through the disturbed area to be served by the basin.
   c. Other practices may be acceptable to the appropriate plan approval agency if they achieve an equivalent removal efficiency of eighty (80) percent for suspended solids or 0.5 ML/L peak settable solids concentration, which ever is less, the efficiency shall be calculated for disturbed conditions for the ten (10) year and 24 hour design storm.
   d. Permanent water quality ponds having a permanent pool shall be designed to store and release the first 0.5 inch of runoff from the site and any contributing offsite areas over a minimum 24-hour period. The storage volume shall be designed to accommodate, at least, 0.5 inch of runoff from the entire site. The facility must provide provisions for mosquito control.
   e. Permanent water quality ponds, not having a permanent pool, shall be designed to release the first 1.0 inch of runoff depth from the site and any contributing offsite areas over a 24-hour period.
   f. Permanent infiltration practices, when used, shall be designed to accept, at a minimum, the first 1.0 inch of runoff depth from the site and any contributing offsite areas over a minimum 24-hour period.

3.3.6 Residential Grading Permits

1. In developing plans for residential subdivisions, individual lots in a residential subdivision development shall be required to obtain and comply with a general permit and the residential subdivision development, as a whole, shall be considered to be a single land disturbing activity requiring a permit

(all lots shall be included in the total disturbed acreage for permitting purposes). Hydrologic parameters reflecting the ultimate subdivision development shall be used in all engineering calculations.

If individual lots or sections in a residential subdivision are being developed by different property owners, all land disturbing activities related to the residential subdivision shall be covered by the approved drainage plan for the residential subdivision. Individual lot owners and/or builders shall sign a copermittee agreement certifying all activities on that lot will be carried out in accordance with the approved drainage plan for the residential subdivision or a separate plan and permit will be required.

2. Residential subdivisions which were approved prior to the effective date of these regulations are not exempt from these requirements. Development of new phases of existing subdivisions, which were not previously approved, shall comply with the provisions of these regulations. In-fill lots in existing subdivisions/neighborhoods shall comply with the provisions of these regulations.
   a. A narrative description of the stormwater management facilities to be used.
   b. A general description of topographic and soil conditions of the development site.
   c. A general description of adjacent property and a description of existing structures, buildings, and other fixed improvements located on surrounding properties.
   d. A plan to accompany the narrative which shall contain:
      - Site location drawing of the proposed project, indicating the location of the proposed project in relation to roadways, jurisdictional boundaries, streams and rivers; the boundary lines of the site on which the work is to be performed;
      - All areas within the site which will be included in the land disturbing activities shall be identified and the total disturbed area calculated;
      - A topographic map of the site;
      - Anticipated starting and completion dates of the various stages of land disturbing activities and the expected date of the final stabilization will be completed.
      - The location of temporary and permanent vegetative and structural stormwater management control measures with associated notes and details as required per the erosion control checklist.
   e. Stormwater management plans shall contain certification by the persons responsible for land disturbing activities stating the land disturbing activities will be accomplished pursuant to the plan.
   f. Stormwater management plans shall contain a certification by the person responsible for the land disturbing activities the City of Rock Hill Infrastructure Division has the right to conduct on-site inspections at any time.

Submittals for subdivision development are to include an engineered grading plan providing grading requirements for the individual lots as well as the overall subdivision (all final lot grading is required to be included on the plans and in the disturbed acreage for permitting). The grading plan will establish a grade elevation at each corner of the lot and at the mid-points of side lot lines. Any swales necessary to provide proper sheet flow are to be shown on the plan.

Prior to receiving a Certificate of Occupancy for the structure, the building contractor is to finish grade the lot to the prescribed elevations of the grading plan, install final stabilization to the city's satisfaction, and provide the City Infrastructure Division an as-built site plan of all storm drainage and detention/water quality systems. The as built site plan is to be prepared by and signed /sealed by a registered surveyor, landscape architect, or engineer.

The Infrastructure Division will review and approve the final stabilization and as-built plan before notifying the Inspections Division the structure may be released for a Certificate of Occupancy.

Structures built in subdivisions where engineered grading plans have been prepared will not receive a Certificate of Occupancy until the Inspection Division receives confirmation of grading compliance from the Infrastructure Division.

3.3.7 Waiver from Stormwater Management and Sediment Control Plan Requirement

The Planning & Development Director may grant waivers from the requirements of this section for individual land disturbing activities in accordance with the following standards:

(a) ***Written Request Required***

1. Any requests for waivers from the standards in this section shall be made in writing, and shall contain descriptions, drawings, and any other information necessary to evaluate the proposed land disturbing activity.

2. A separate written waiver request shall be required if there are subsequent additions, extensions, or modifications which would alter the approved stormwater runoff characteristics to a land disturbing activity receiving a waiver.

(b) ***Types of Waivers***

1. A project may be eligible for a waiver of stormwater management for both quantitative and qualitative controls if the applicant can demonstrate the proposed project will return the disturbed area to a pre-development runoff condition and the pre-development land use is unchanged at the conclusion of the project.

2. A project may be eligible for a waiver of stormwater management for water quantity control if the applicant can demonstrate:

   a. The proposed project will have no significant adverse impact on the receiving natural waterway or downstream properties; or

   b. The imposition of peak control requirements for rates of stormwater runoff would aggravate downstream flooding.

(c) ***Procedure***

1. The Planning & Development Director will review the request for waiver within ten (10) business days. Failure of the Planning & Development Director to act by the tenth (10^{th}) day will result in the automatic approval of the waiver.

2. Risk analysis may be used to justify a design storm event other than prescribed or to show that rate and volume control is detrimental to the hydrologic response of the basin, and therefore, should not be required for a particular site.

3. A complete watershed hydrologic and hydraulic analysis must be performed using an engineering model or procedure acceptable to the Planning & Development Director. The information and data required to be submitted is as follows:

   a. Watershed designation on the 7.5 minute topographic map exploded to a minimum of one (1) inch equals for hundred (400) feet.

   b. Inclusion of design and performance data to evaluate the effects of any structures which affect discharge. Examples may be ponds or lakes, road crossings acting as attenuation structures and there may be others, which must be taken into account.

   c. Land use data shall be obtained from the most recent aerial photograph and field verified and updated.

d. The water surface profile shall be plotted for the conditions of pre- and post-development for the two (2), ten (10), twenty-five (25), and one hundred (100) year, twenty-four (24) hour storm.

e. Elevations of any structure potentially damaged by the resultant flow shall also be shown.

f. Elevations of any roadway crossings with the potential of being overtopped by the resultant flow shall be shown.

4. Based on the results of this type of evaluation, the Planning & Development Director shall review and evaluate the proposed regulation waiver or change.

3.4 References

The City of Rock Hill Zoning Ordinance, Rock Hill, South Carolina.

Greenville County Stormwater Management Design Manual. Greenville County, South Carolina. First Edition. January 2003.

CHAPTER 4 - HYDROLOGY

4.1 Stormwater Ordinance Review

4.1.1 Hydrologic Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following hydrology information was taken from the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

Mandatory Standards and Plan Requirements
Determine the general soil suitability of the proposed land use. Identify areas subject to severe erosion, and off-site areas that are especially vulnerable to damage from erosion and/or sedimentation. Identify and evaluate potential erosion, sediment and stormwater problems, and select appropriate control measures;

Grading Permits
All hydrologic computations shall be accomplished using a volume based hydrograph method acceptable to the city. The storm duration for computation purposes for this method shall be the 24-hour rainfall event, SCS distribution with a 0.1 hour burst duration time increment. The rational or modified rational methods are acceptable for sizing individual culverts or storm drains that are not part of a pipe network or system and do not have a contributing drainage area greater than 20 acres. The storm duration for computational purposes for this method shall be equal to the time of concentration of the contributing drainage area or a minimum of 0.1 hours.

Post development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10-year frequency, 24-hour duration storm event. The City Manager, or his designee, may require a less frequent storm event.

Off-site discharges of closed storm sewers or improved open channels shall be permitted only at natural streams or man-made drainage channels. Discharge velocities shall be reduced to provide a non-erosive velocity flow from structures, channels, or other control measures or to the velocity of the 10-year 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.

A regional approach to stormwater management is an acceptable alternative to site specific requirements and is encouraged.

Water quality control is an integral component of overall stormwater management. The following design criteria for flow control are established for water quality control purposes, unless a waiver is granted based on a case-by-case basis:

- Post-development peak discharge rates shall not exceed pre-development discharge rates for the 2- and 10-year frequency 24-hour duration storm event.

- Discharge velocities shall be reduced to provide a non-erosive velocity flow from structures, channels, or other control measures of to the velocity of the 10-year 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, which ever is greater.

4.2 Hydrologic Design Policies

4.2.1 Hydrologic Methods

Many hydrologic methods are available. Recommended methods and the circumstances for their use are listed in Table 4.2.1.1 below. If other methods are used, they must first be calibrated to local conditions, tested for accuracy and reliability, and then submitted to the Rock Hill Infrastructure Division for approval. In addition, complete source documentation must be submitted for approval.

Table 4.2.1.1: Recommended Hydrologic Methods

Method	Size Limitations*	Comments
Rational Formula	0 – 10 Acres	Acceptable for sizing individual culverts or storm drains only and are not part of a pipe network or system. Not to be used for storage design.
SCS Method (TR-55)	0 – 2000 Acres	Used for estimating peak flows from urban areas.
United States Corp of Engineer's: HEC-1 HEC-HMS	No size limitations	This methodology can be used for larger areas (> 2000 acres). However, designers are requested to consult with the City prior to using this or any other methodology for such larger developments.

*Size limitation refers to the subwatershed size to the point where stormwater management facility (i.e., culvert, inlet) is located.

4.2.1.2: Applications of the Recommended Hydrologic Methods

Method	Rational Method	SCS Method	USGS Equations
Extreme Flood Protection		+	+
Storage Facilities		+	+
Outlet Structures		+	+
Gutter Flow and Inlets	+		
Storm Drain Pipes	+	+	+
Culverts	+	+	+
Small Ditches	+	+	+
Open Channels		+	+
Energy Dissipation		+	+

4.2.2 Design Frequency Policy

The various portions of the stormwater collection systems must be designed with respect to certain sized storm events. These requirements are listed in Table 4.2.2.1. Per Rock Hill Zoning Ordinance Regulations.

SCDOT design standards shall be met when designing storm sewer systems located within SCDOT right-of-ways.

Table 4.2.2.1: Design Frequencies

Description and Chapter Reference	Manual Chapter	Design Storm Event
Ditch and Channel Systems	Chapter 5	10-yr. 24 hour
Storm System Pipes	Chapter 6	10-yr. 24 hour
Culverts	Chapter 7	10-yr. 24 hour
Detention Facilities	Chapter 8	2, 10, 25, 50, and 100-yr. 24 hour
Emergency Spillway Facilities	Chapter 8	100-yr. 24 hour

Note: Any of the design storm frequencies listed above may be changed to include the 2, 10, 25, 50, and 100-year return periods.

Table 4.2.2.2: Design Frequencies for Roadways

Roadway Level of Service	Design Storm Event
Residential Road	25-yr. 24 hour
Collector	25-yr. 24 hour
Thorough Fare	50-yr. 24 hour
Highway	100-yr. 24 hour

The minimum design storm frequencies listed in the table above are required for each roadway level of service.

4.2.3 Design Rainfall Depths

The design rainfall depths shall follow a Type II rainfall distribution and shall be used in conjunction with the 24-hour rainfall depth. Table 4.2.3.1 presents rainfall depths as displayed in Appendix F in South Carolina DHEC Storm Water Management BMP Handbook by County published by the South Carolina Department of Health and Environmental Control and also NOAA using the Winthrop College, SC station.

Table 4.2.3.1: Depth-Duration-Frequency Values for York County, SC

Time	Return Period						
	1-yr.	2-yr.	5-yr.	10-yr.	25-yr.	50-yr.	100-yr.
6-hour	2.1	2.5	3.2	3.7	4.4	4.9	5.5
24-hour	2.8	3.6	4.5	5.3	6.3	7.1	7.9

4.3 Rational Method

4.3.1 Introduction

An important formula for determining the peak runoff rate is the Rational Formula. It is characterized by:

- Consideration of the entire drainage area as a single unit,
- Estimation of flow at the most downstream point only, and
- The assumption rainfall is uniformly distributed over the drainage area and is constant over time.

The Rational Formula follows the assumption:

- The predicted peak discharge has the same probability of occurrence (return period) as the used rainfall intensity (i), and
- The runoff coefficient (C) is constant during the storm event.

When using the Rational Method some precautions should be considered:

- In determining the C value (runoff coefficient based on land use) for the drainage area, hydrologic analysis should take into account any future changes in land use that might occur during the service life of the proposed facility.
- The Rational Method uses a composite C and a single t_c value for the entire drainage area. Therefore, if the distribution of land uses within the drainage basin affect the results of hydrologic analysis (e.g., if the impervious areas are segregated from the pervious areas), then the basin should be divided into sub-drainage basins.

The charts, graphs, and tables included in this section are given to assist the engineer in applying the Rational Method. The engineer should use sound engineering judgment in applying these design aids and should make appropriate adjustments when specific site characteristics dictate these adjustments are appropriate.

4.3.2 Application

The Rational Method can be used to estimate stormwater runoff peak flows for the design of gutter flows, drainage inlets, storm drainpipe, culverts and small ditches. It is most applicable to small, highly impervious areas. Twenty (20) acres is the recommended maximum drainage when using the Rational Method.

The Rational Method should not be used for storage design or any other application where a more detailed routing procedure is required.

The Rational Method should also not be used for calculating peak flows downstream of bridges, culverts or storm sewers acting as restrictions and impact the peak rate of discharge.

4.3.3 Equations

The Rational Formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration, t_c (the time required for water to flow from the most remote point of the basin to the location being analyzed).

The Rational Formula is shown as **Equation 4.3.3.1**.

$$Q = C * i * A \qquad \textbf{Equation 4.3.3.1}$$

where: Q = maximum rate of runoff (ft^3/s),
C = runoff coefficient representing a ratio of runoff to rainfall,
i = average rainfall intensity for a duration equal to the t_c (in/hr), and
A = drainage area contributing to the design location (acres).

Once each of these variables has been determined, the peak discharge can be calculated. Each of these variables is discussed in detail in the following sections.

Higher frequency storms require modifying the runoff coefficient because infiltration and other abstractions have a proportionally smaller effect on runoff. Adjust the runoff coefficient by the factor C_f as indicated in the table titled Runoff Coefficient Adjustment Factors for Rational Method. The product of C and C_f should not exceed 1.0. **Table 4.3.3.1** presents frequency adjustment factors.

Table 4.3.3.1: Frequency Adjustment Factors (C_f)

Design Storm Event	Frequency Adjustment Factor (Cf)
25-Yr	1.1
50-Yr	1.2
100-Yr	1.25

The Rational Formula for the 25, 50, and 100-yr. design storms becomes:

$$Q = C * C_f * I * A \qquad \textbf{Equation 4.3.3.2}$$

4.3.4 Time of Concentration

Use of the Rational Formula requires the time of concentration (t_c) for each design point within the drainage basin. The duration of rainfall using this method is assumed to equal the time of concentration. From this assumption, the average rainfall intensity (i) is estimated. The time of concentration is the total time it takes runoff to flow to the outlet from the most hydraulically distance point of the watershed or subbasin. Time of concentration is determined for each subbasin over the drainage path. The travel time is considered the sum of the overland flow time, shallow concentrated flow, and channel flow.

Overland flow time includes flow over grassed or undisturbed areas and can be estimated using Figure 4.3.4.1. After a distance of 300 feet, runoff begins to concentrate, transforming into shallow concentrated flow through the formation of gullies or small rills. Shallow concentrated flow can occur on grassed or undisturbed land uses, in small, manmade ditches that are paved or unpaved, or in curb and gutters. The designer as necessary should modify the maximum length of 100 feet of overland flow in the post construction condition. Some land uses will facilitate shorter distances of overland flow before the concentration of flows begins. The travel time for the distances where shallow concentrated flow is occurring, Figure 4.3.4.4, can be used as well. Figure 4.3.4.4 can be use to determine the velocity of the flow. Travel time in engineered structures, such as gutters, closed, and open conduits gutters, can be determined using Figure 4.3.4.1, 4.3.4.2, or 4.3.4.3. In most cases shallow concentrated flow should be limited to 1,000 feet. This distance should be reduced due to site layout, slopes, and soil types.

Another method that can be used to determine the overland flow portion of the time of concentration is the "Kinematic Wave Nomograph" (Figure 4.3.4.3). This method can also be used for watersheds with overland flow distances above 300 feet. The kinematic wave method incorporates several variables including rainfall intensity and Manning's "n". In using the nomograph, the engineer has two unknowns starting the computations: the time of concentration and the rainfall intensity. A value for the rainfall intensity "I" must be assumed. The travel time is determined iteratively.

If one has determined the length, slope and roughness coefficient, and selected a rainfall intensity table, the steps to use Figure 4.3.4.3 are as follows:

(Step 1) Assume the rainfall intensity.

(Step 2) Use Figure 4.3.4.3 (or the equation given in the figure) to obtain the first estimate of time of concentration.

(Step 3) From the time of concentration obtained from Step 2, the corresponding rainfall intensity is determined using Table 4.3.5.1. If this rainfall intensity corresponds with the assumed intensity, the problem is solved. If not, proceed to Step 4.

(Step 4) Assume a rainfall intensity between the assumed one in Step 1 and the one determined in Step 3.

(Step 5) Repeat Steps 1 through 3 until there is good agreement between the assumed rainfall intensity and the one obtained from the rainfall intensity tables

For a distance greater than 1,000 feet or when a stormwater inlet is encountered and flows enter a formal channel or closed conduit, flows are considered channel flows. To obtain the travel time in these situations, Figure 4.3.4.2, which is a graphical representation of Manning's equation, is used. This figure estimates velocity and is then converted into a time over the distance of channel flow. As with the overland and shallow concentrated flows, there are numerous other methods for determining the travel time in various structures, such as street gutters, roadside swales, closed conduits, or drainage channels. However, in all cases, the time of concentration will not be less than 5 minutes due to the limitation of the IDF (Intensity Duration Frequency) curve, discussed in section 4.3.5.

Generally, the time of concentration for overland flow is only a part of the overall design problem. Often one encounters swale flow, confined channel flow, and closed conduit flow-times must be added as part of the overall time of concentration. When this situation is encountered, it is best to compute the confined flow-times as the first step in the overall determination of the time of concentration. This method gives the designer a rough estimate of the time involved for the overland flow, which will give a better first start on the rainfall intensity assumption. For example, if the flow time in a channel is 15 minutes and the overland flow time from the most distant point to the channel is 10 minutes, then the total time of concentration is 25 minutes.

Other methods and charts may be used to calculate overland flow time if approved by the City of Rock Hill. One other possibility is the Graphical Peak Discharge section found in SCS TR-55.

For locations where runoff from two distinct areas is converging, the time of concentration to this confluence is determined for both and the larger one is used as the time of concentration for the entire contributing area.

Two common errors should be avoided when calculating time of concentration. First, when designing a drainage system, the overland flow path is not necessarily the same before and after development and grading operations have been completed. Selecting overland flow paths in excess of 50 feet for impervious areas, especially directly connected impervious areas (DCIA) (See Section 4.4.7), should be done only after careful consideration. Second, in some cases, runoff from a portion of the drainage area which is mostly impervious or contains a high degree of DCIA may result in a greater peak discharge than would occur if the entire area were considered. In these subbasins, the Rational Formula should be used to determine the peak discharge from the DCIA only, a runoff coefficient of 98 and a time of concentration of 5 minutes, even though this time maybe considerably less, on the order of a minute or less. Using these "DCIA" variables, a peak discharge rate is computed and compared to the computed value to that from the Rational method based on the entire contributing area. This method is commonly referred to as the Lloyd-Davies Method. The larger of the peak discharges calculated should be used for that particular watershed.

Figure 4.3.4.1: Rational Formula - Overland Time of Flow Nomograph (Source: Airport Drainage, Federal Aviation Administration, 1965)

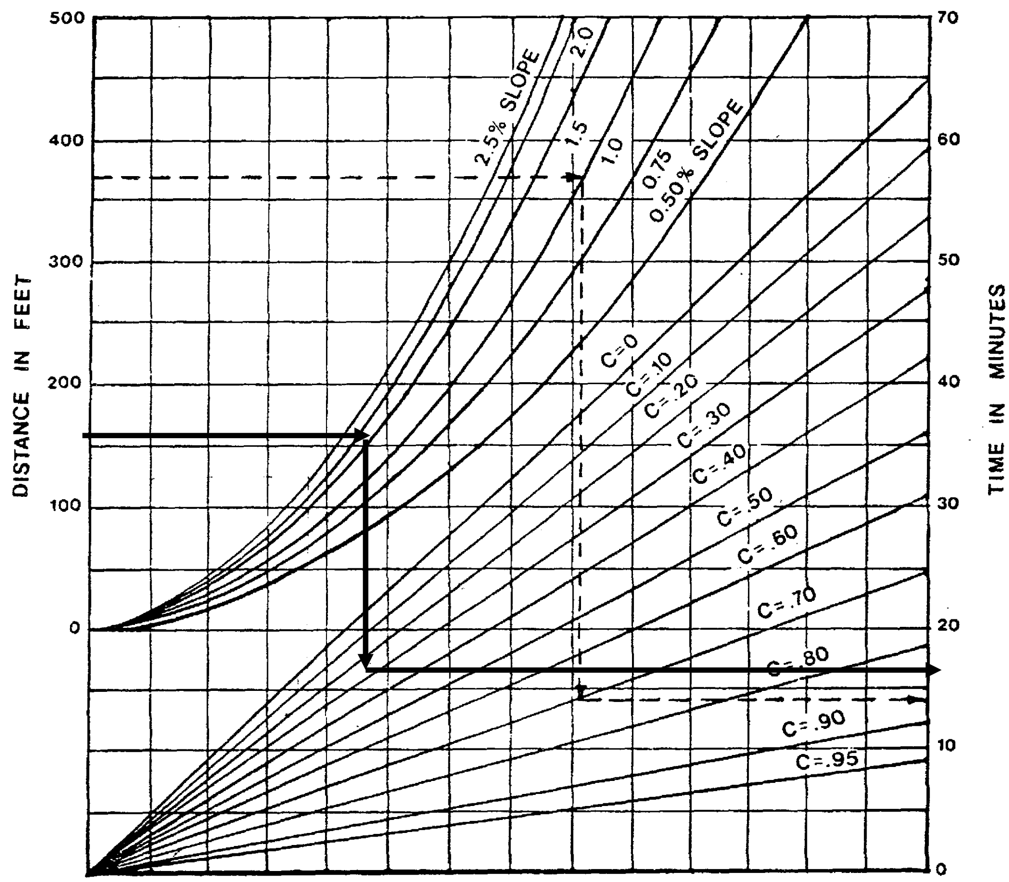
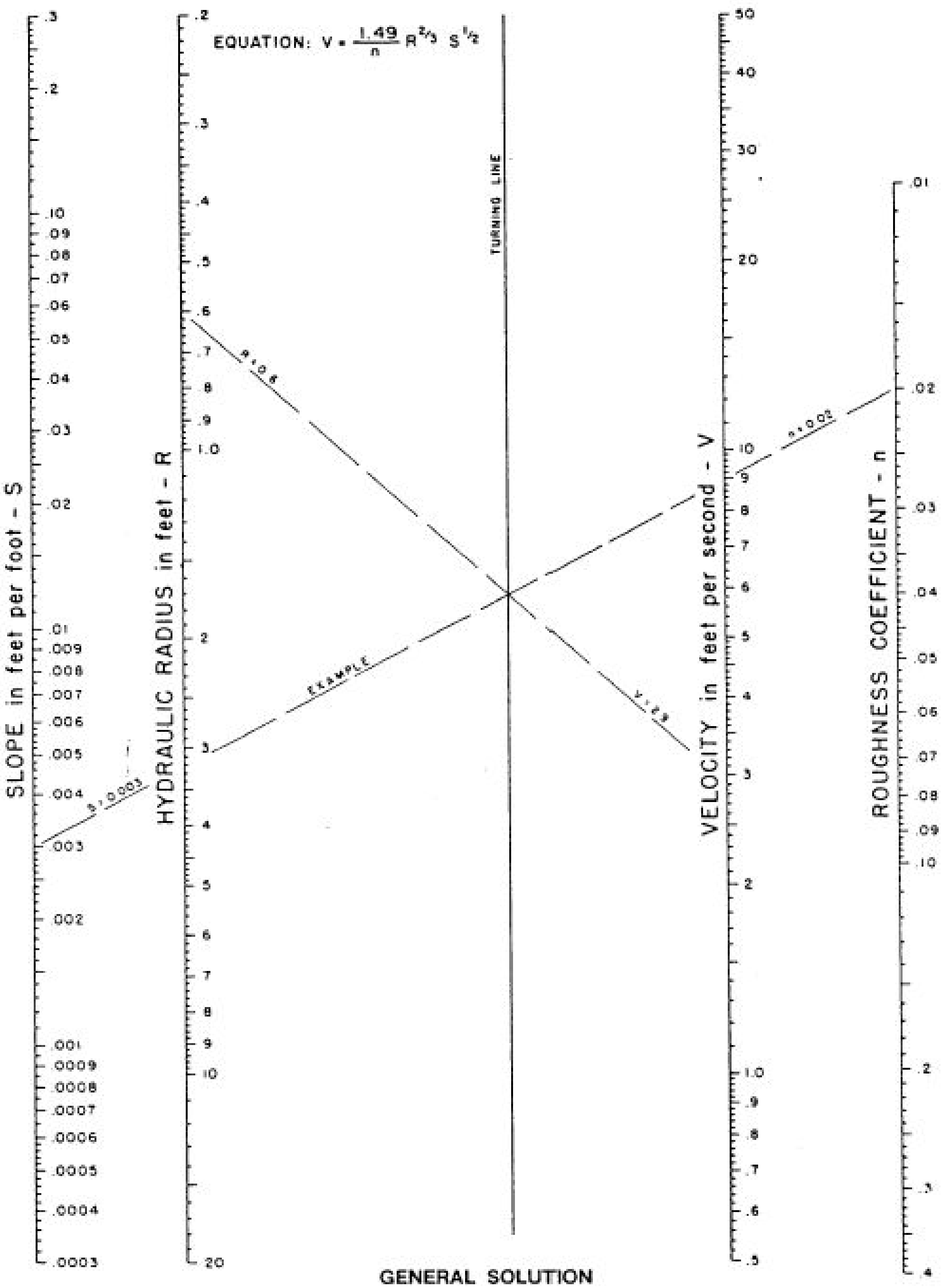


Figure 4.3.4.2: Manning's Equation Nomograph (Source: USDOT, FHWA, HDS-3 (1961))



Reference: USDOT, FHWA, HDS-3 (1961).

Figure 4.3.4.3: Kinematic Wave Nomograph (Source: Manual For Erosion And Sediment Control In Georgia, 1996)

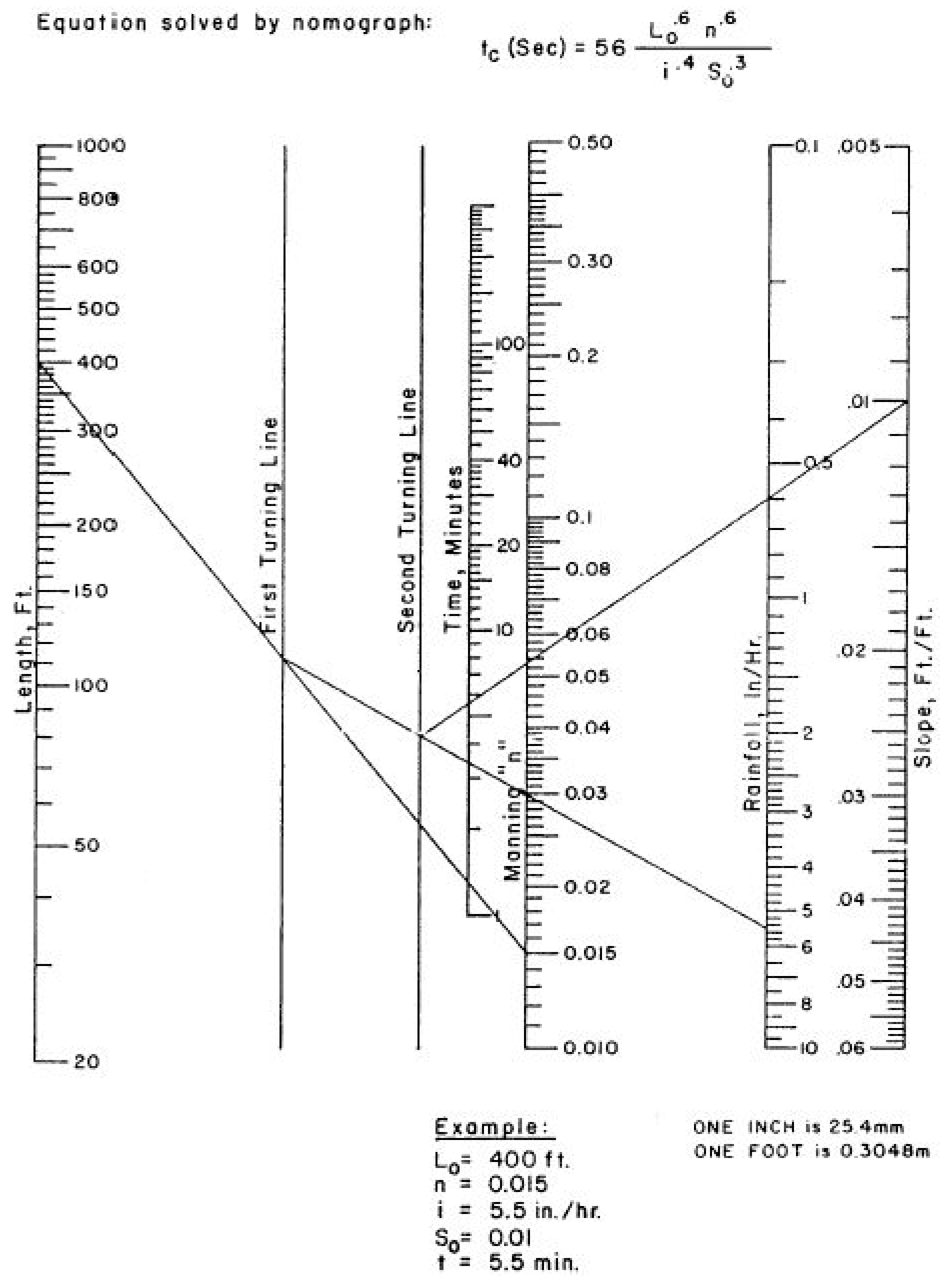
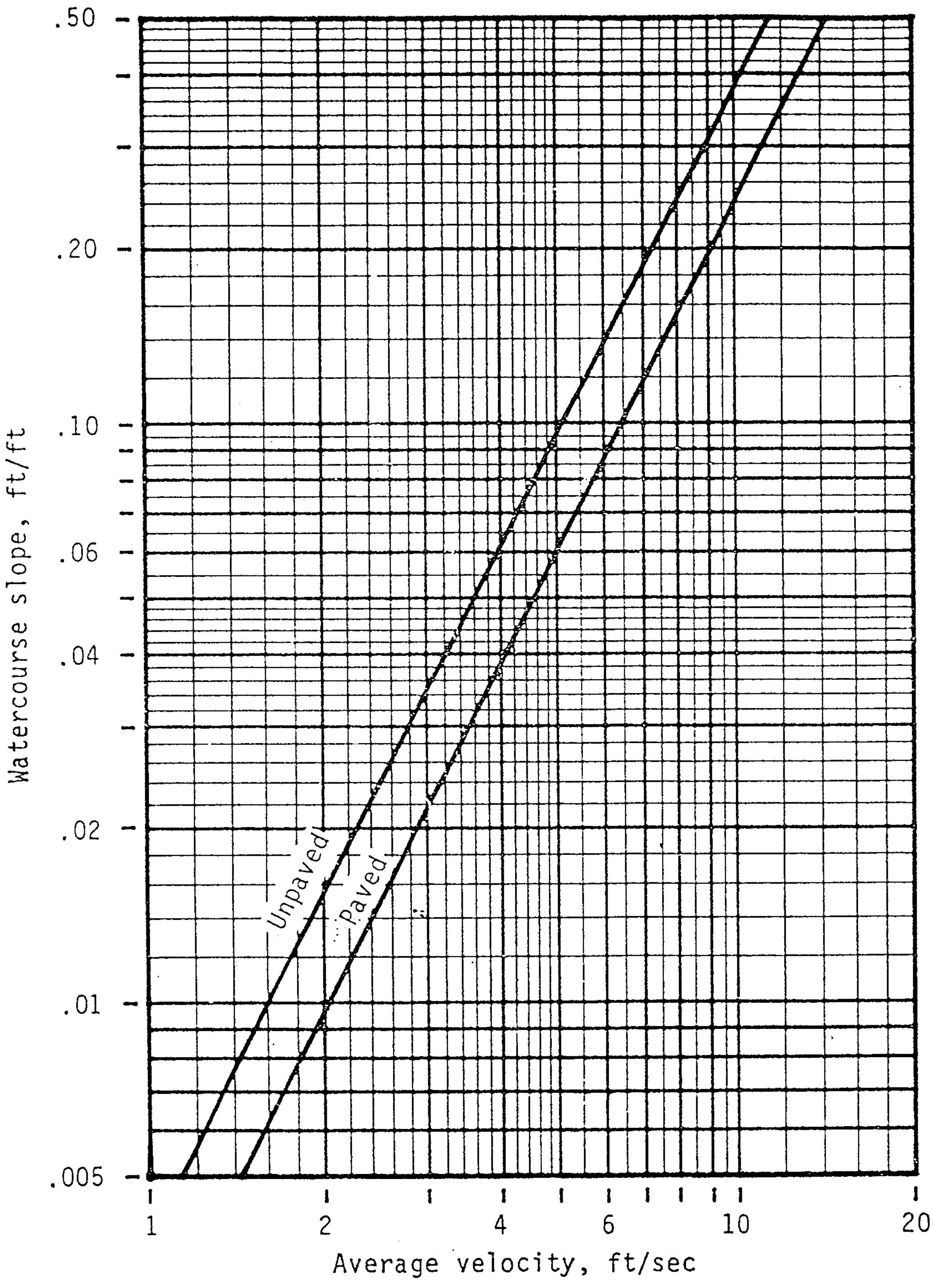


Figure 4.3.4.4: Average Velocities for Estimating Travel Time for Shallow Concentrated Flow (Source: SCS, TR-55, Second Edition, June 1986)



4.3.5 Rainfall Intensity

The rainfall intensity (i) is the average rainfall rate in in/hr for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the drainage area, the rainfall intensity is determined. The rainfall intensity for the City of Rock Hill shall be used for all hydrologic analysis using the Rational Formula. Rainfall intensity values can be calculated by using the following formula and proceeding table:

$$i = \frac{a}{(b + t_c)^c} \qquad \textbf{Equation 4.3.5.1}$$

where:

i = rainfall intensity (in/hr),
t_c = time of concentration (minutes), and
a, b, c = coefficients.

The coefficients for the 2, 5, 10, 25, 50, and 100-year rainfalls are given for the City of Rock Hill. The intensity values for time of concentration of 5, 10, and 15 minutes are also listed in the table for the same frequencies. To use these values, compute the time of concentration using the velocity method in the NRCS TR-55 manual. Then, apply the above equation to obtain the appropriate intensity value. The Rainfall Intensity Equation allows for automated calculation of rainfall values for the Rational Method. The coefficients are determined using Table 4.3.5.1, as presented by the South Carolina Department of Transportation's in "Rainfall Intensity Values Utilized by South Carolina Department of Transportation".

Table 4.3.5.1: Rainfall Intensity Values Utilized by South Carolina DOT

Frequency (Years)	a	b	c	i (t_c=5)	i (t_c=10)	i (t_c=15)
2	240.26568	35.61513	1.03559	5.19	4.60	4.13
5	254.71848	33.33552	1.02140	6.15	5.42	4.85
10	264.71357	31.82192	1.01175	6.89	6.06	5.40
25	276.98802	30.00177	1.00001	7.91	6.92	6.15
50	286.34575	28.61559	0.99107	8.80	7.66	6.79
100	294.57238	27.37215	0.98314	9.65	8.38	7.41

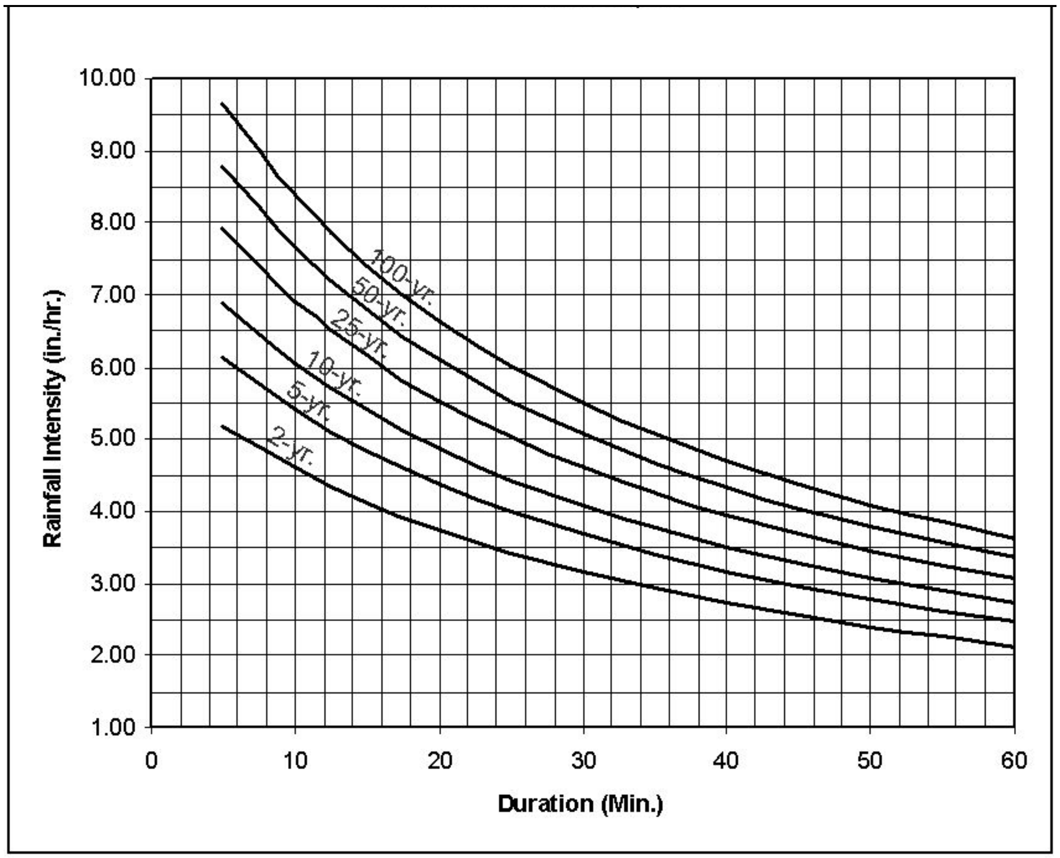
Table 4.3.5.2: City of Rock Hill Rainfall Intensity Values

Time(hr.)	2-YR	10-YR	25-YR	50-YR	100-YR
0.0333	5.19	6.89	7.91	8.8	9.65
0.0833	5.19	6.89	7.91	8.8	9.65
0.1667	4.6	6.06	6.92	7.66	8.38
0.25	4.13	5.4	6.15	6.79	7.41
0.3333	3.74	4.88	5.54	6.1	6.64
0.4167	3.42	4.44	5.04	5.53	6.01
0.5	3.16	4.08	4.62	5.07	5.5
0.667	2.72	3.5	3.96	4.33	4.69
0.8333	2.4	3.07	3.46	3.79	4.1
1	2.14	2.73	3.08	3.36	3.64

Time(hr.)	2-YR	10-YR	25-YR	50-YR	100-YR
1.25	1.84	2.34	2.64	2.88	3.11
1.5	1.61	2.05	2.31	2.52	2.72
1.75	1.43	1.83	2.05	2.24	2.42
2	1.29	1.64	1.85	2.01	2.17
3	0.92	1.17	1.32	1.44	1.55
6	0.49	0.63	0.71	0.78	0.84
12	0.25	0.32	0.37	0.4	0.44
24	0.12	0.16	0.19	0.21	0.23

The Intensity-Duration-Frequency (IDF) Curve for the Rock Hill, SC for the six storms (2-year - 100-year) is shown in Figure 4.3.5.1. These curves are plots of the tabular values and no values are given for times less than 5 minutes.

Figure 4.3.5.1: IDF Curve for Rock Hill, SC.



4.3.6 Runoff Coefficient (C)

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the design engineer. While engineering judgment will always be required in the selection of runoff coefficients, typical coefficients represent the integrated effects of many drainage basin parameters. Some recommended runoff coefficients for the Rational Method are given in Table 4.3.6.1.

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas. Composites can be made with the values from Table 4.3.6.1 by using percentages of different land uses. In addition, more detailed composites can be made with coefficients for different surface types such as rooftops, asphalt, and concrete streets and sidewalks. The composite procedure can be applied to the entire drainage area or to typical "sample" blocks as a guide to selecting reasonable coefficient for each of the blocks.

It should be remembered the Rational Method assumes all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area then another hydrologic method should be used where hydrographs can be generated and routed through the drainage system.

Using only the impervious area from a highly impervious site (and the corresponding high C factor and shorter time of concentration) usually will yield a higher peak runoff value than by using the whole site. This should be checked particularly in areas where the overland portion is grassy (yielding a long tc) to avoid underestimating peak runoff. See Section 4.3.4 for more information on the Lloyd-Davies Method.

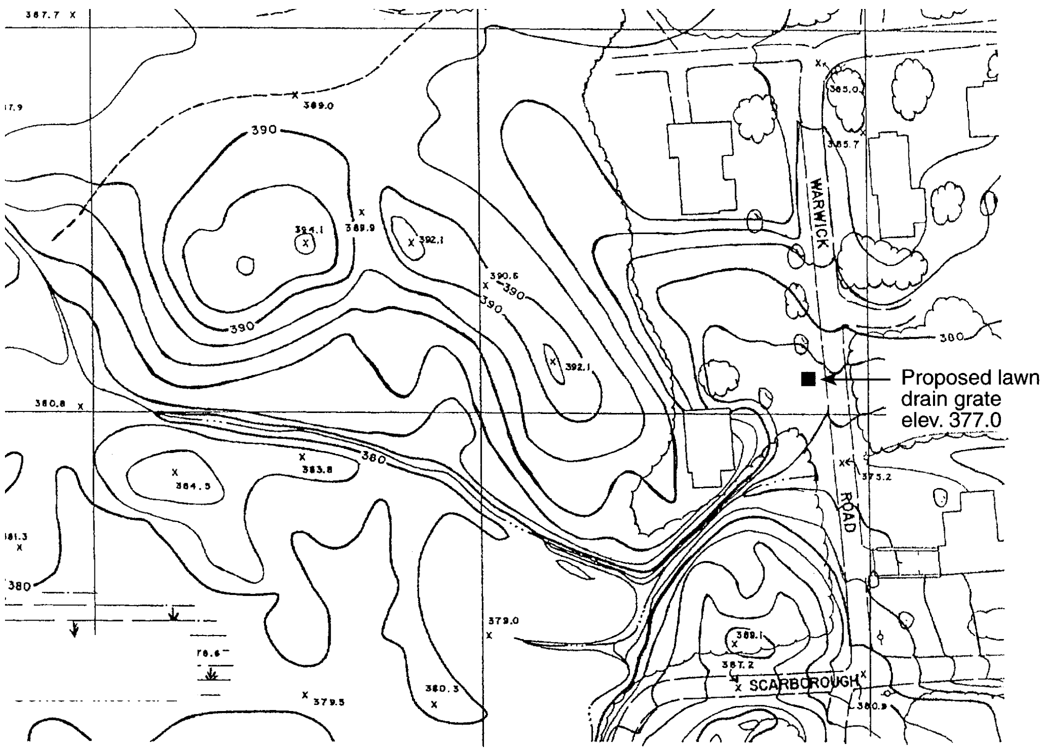
Table 4.3.6.1: Runoff Coefficients

Land Use	(C) Value	Land Use	(C) Value
Business		**Parks, Cemeteries**	0.10-0.25
Downtown Areas	0.70-0.95	**Playgrounds**	0.30-0.40
Neighborhood Areas	0.30-0.70	**Railroad Yards**	0.30-0.40
Residential		**Lawns**	
Single Family Areas	0.30-0.50	Sandy Soil, Flat 2%	0.05-0.10
Multi-units, detached	0.40-0.60	Sandy Soil, Average 2-7%	0.10-0.15
Multi-units, attached	0.60-0.75	Sandy Soil, Steep 7%	0.15-0.20
Suburban	0.35-0.40	Heavy Soil, Flat 2%	0.13-0.17
Apartment dwelling areas	0.30-0.70	Heavy Soil, Average 2-7%	0.18-0.22
Industrial		Heavy Soil, Steep 7%	0.25-0.35
Light Areas	0.30-0.80	**Streets**	
Heavy Areas	0.60-0.90	Asphaltic	0.85-0.95
Unimproved Areas		Concrete	0.90-0.95
Sand or Sandy Loam Soil, 0-3%	0.15-0.20	Brick	0.70-0.85
Sand or Sandy Loam soil, 3-5%	0.20-0.25	**Drives and Walks**	0.75-0.95
Black or Loessial Soil, 0-3%	0.18-0.25	**Roofs**	0.75-0.95
Black or Loessial Soil, 3-5%	0.25-0.30		
Black or Loessial Soil, >5%	0.70-0.80		
Deep Sand Area	0.05-0.15		
Steep Grassed Slope	0.70		

4.3.7 Example Problem #1

Following is an example problem illustrating the application of the Rational Method to estimate peak discharges. The objective is to determine the peak discharge rate at the lawn drain grate as shown on the topographic map in Figure 4.3.7.1. The scale is approximately 1in. = 100 ft. The property is located in Rock Hill and the design for the grate is to be based on the 100-year event. Use a velocity method for the time of concentration.

Figure 4.3.7.1: Example Problem #1 - Site Layout.



Topographic map of residential area

The first step is to determine the drainage area served by the grate. The drainage area is outlined as shown in Figure 4.3.7.2 and is determined to be 2.1 acres. Note: the area has various land uses (impervious, grass, woods) so an average, area-weighted C value is used.

Table 4.3.7.1: Example problem #1 Areas and Corresponding Runoff Coefficients

Land Use	Land Area (Acres)	Runoff Coefficient (C)
Impervious	0.20	0.95
Grass	0.74	0.25
Woods	1.22	0.15

$$C = \frac{\sum CA}{\sum A} = \frac{0.95(0.2) + 0.25(0.74) + 0.15(1.22)}{0.2 + 0.74 + 1.22} = 0.26$$

The next step is to determine the time of concentration using the most hydraulically distant point. A site visit would normally be required to establish the characteristics of the flow path. For the purposes of this example, the following flow path is used:

Table 4.3.7.2: Example Problem #1 – Worksheet

Path	Note	Length (ft)	Slope (ft/ft)
Point A to B (390 ft contour)	Overland Flow	160	(392.5-390)/160 = 0.016 or 1.6%
Point B to Grate Inlet	Shallow Concentrated Flow	350	(390-377)/350 = 0.37 or 3.7%

Note: See Figure 4.3.7.2 for points A and B and their flow paths.

The travel time for the overland flow is computed using Figure 4.3.7.2 with slope = 1.6% and C = 0.26. The travel time in overland flow is then about 22 minutes. Note: if a curb and gutter system is encountered, a separate drainage time for that section, in addition to the overland flow over the grassed/undisturbed area, would be required.

The velocity for the shallow concentrated flow, using the unpaved curve, is 3.1 ft/sec and the travel time is 350/(3.1*60) = 1.9 minutes.

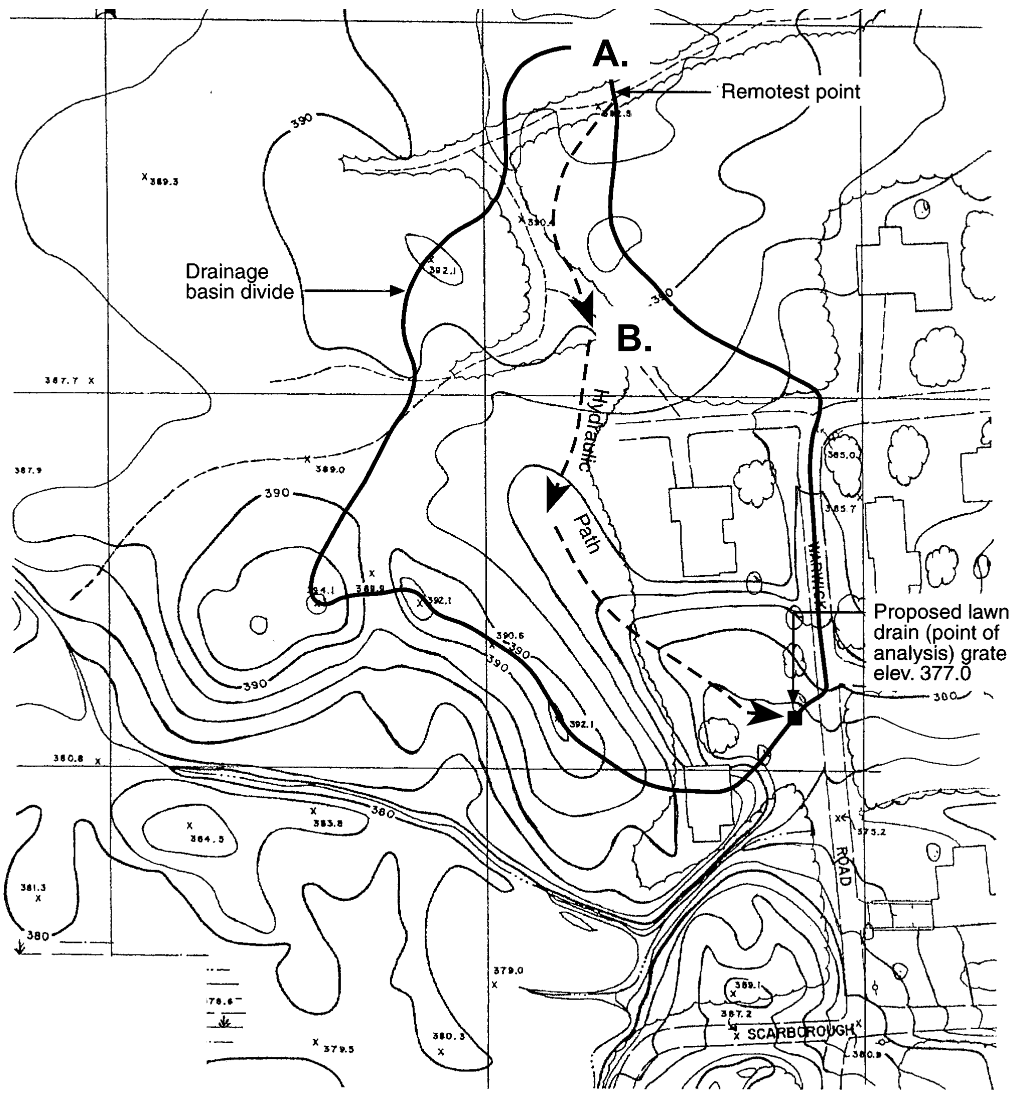
The total time of concentration is then 22 + 1.9 = 23.9 minutes so use 24 minutes.

The intensity, taken from the IDF curve (Figure 4.3.5.1) with a t_c=24 min for a 100-yr. storm is 6.2 in/hr.

Substituting these variables into the Rational Formula, the peak discharge rate, assuming a frequency adjustment factor of 1.25 per Table 4.3.3.1 for the 100-yr. design storm is:

$$Q = CC_f iA$$
$$Q = 0.26(1.25)(6.2\,\text{in/hr})(2.16\,\text{acres})$$
$$Q = 4.35\,\text{cfs}$$

Figure 4.3.7.2: Drainage Area Contributing to Proposed Lawn Drain.



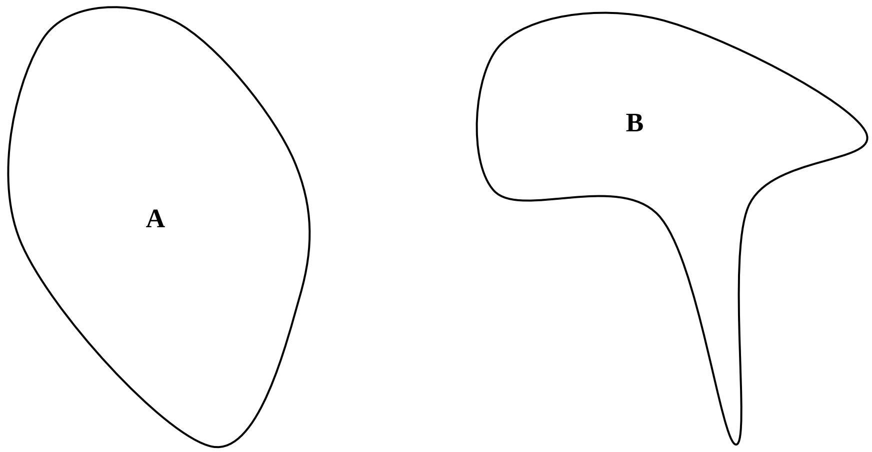
4.3.8 Example Problem #2

Rational Method on basins with widely varying hydrologic properties

When a storm event occurs, it takes some time before the entire basin contributes to the discharge. Specifically, the storm must equal or exceed the time of concentration of the basin for the entire area to contribute. For storms of shorter duration, it may be reasonable to assume the contributing area is proportional to the lapsed tc. Thus storm durations equal to 10% of tc, the bottom 10% of the basin is contributing to flow at the outlet. The rest of the water has not had time to travel to the outlet.

The rational method is best suited to basins where the drainage area increases more or less uniformly with basin length. Basin A is an example of this sort, whereas, basin B is an example of the drainage area is not proportional to length over the whole basin.

Figure 4.3.8.1: Example Problem #2 - Watersheds



In the "real" world, this linearity assumption is usually sound. Now consider a basin with t_c equal to 60 min. and a total area of 40 ac. Applying the linearity assumption, we can determine the contributing area as a function of elapsed storm duration.

Table 4.3.8.1: Example Problem #2 - Worksheet

Elapsed Time- T- min	T/t_c	Contributing area- ac (T/t_c) x area (ac)
15	15 min. / 60 min. = 0.25	0.25 x 40 acres = 10 acres
30	30 min. / 60 min. = 0.50	0.50 x 40 acres = 20 acres
45	45 min. / 60 min. = 0.75	0.75 x 40 acres = 30 acres
60	60 min. / 60 min. = 1.00	1.00 x 40 acres = 40 acres

When two basins of widely varying tc discharge to the same point, various storm durations may be considered to determine the peak discharge. The rational method is applied to the total contributing areas of the two basins with an average runoff coefficient.

4.3.9 Example Problem #3

Determine the peak flow for the Rock Hill, 100-year event for the system below. An IDF curve generated for the Rock Hill area has been used for the precipitation data.

Figure 4.3.9.1: Example Problem #3 - Watershed

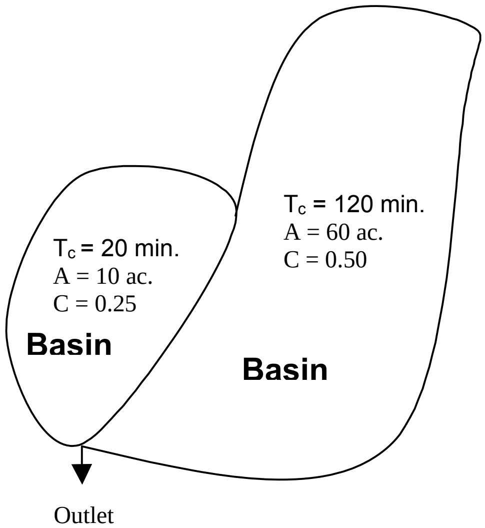


Table 4.3.9.1: Example problem #3 - Worksheet

[1]Storm Duration (minutes)	[2]Contributing Area Basin A (C = 0.25)	[2]Contributing Area Basin B (C = 0.50)	Total Area (acres)	Average C $\frac{\sum CA}{\sum A}$	[3]Intensity 100-yr (in/hr)	[4]$Q=CC_f iA$ (cfs)
20	10	10	20	0.375	6.64	62.3
40	10	20	30	0.417	4.69	73.4
60	10	30	40	0.437	3.64	79.5
80	10	40	50	0.450	2.97	83.5
100	10	50	60	0.458	2.51	86.3
120	10	60	70	0.464	2.17	88.1

1 Also known as 'elapsed time' in Example Problem #2
2 Contributing area calculated per Table 4.3.8.1 Example Problem #2
3 Intensity calculated per Equation 4.3.5.1 and using Table 4.3.5.1
4 Since the 100-yr. design storm is being considered Equation 4.3.3.2 must be used

The peak flow is 88.1 cfs. It is possible for the peak to occur before the longest duration of the storm.

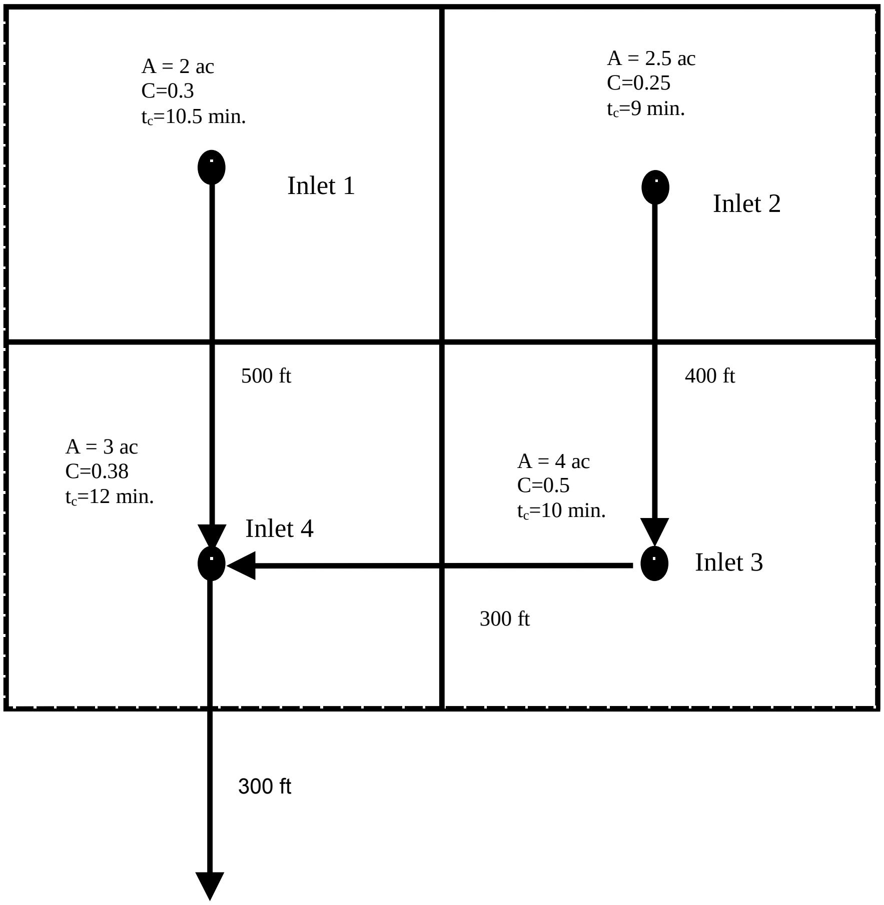
4.3.10 Example Problem #4

Determine the design flow rates (Rock Hill 25-year event) for each of the stormwater pipes (1-4, 2-3, 3-4, 4-outlet) in the subdivided watershed below. The area (ac), runoff coefficient (C), and the time of concentration (min) are given for each inlet area. The velocity within each pipe is 2.5 ft/s.

Assume, the IDF data for Rock Hill is given by the following equation, which is Equation 4.3.5.1 and using Table 4.3.5.1, with a = 276.71357, b = 30.00177, c = 1.00001:

$$i = \frac{a}{(b + t_c)^c} = \frac{276.71357}{(30.00177 + t_c)^{1.00001}}$$

Figure 4.3.10.1: Stormwater Pipes System



Inlet 1 to Inlet 4

t_c=10.5 min

$$i = \frac{276.98802}{(30.00177 + 10.5)^{1.00001}} = 6.84 \quad in/hr$$

Q = (0.30)(6.84in/hr)(2 ac) = 4.10 cfs

Travel time (T_t) 1 to 2

$$T_t = \frac{500}{2.5(60)} = 3.3 \text{ min}$$

Inlet 2 to Inlet 3

t_c = 9 min

$$i = \frac{276.98802}{(30.00177 + 9)^{1.00001}} = 7.10 \quad in/hr$$

Q = 0.25(7.10)(2.5) = 4.44 cfs

Travel time (T_t) 2 to 3

$$T_t = \frac{400}{2.5(60)} = 2.67 \text{ min}$$

Inlet 3 to Inlet 4

A = 2.5 + 4.0 = 6.5 ac

t_c is the larger of

$t_{c\ 2\text{-}3} + T_{t\ 2\text{-}3}$ = 9 + 2.67 = 11.67 min
t_{c3} inlet = 10 min

$$i = \frac{276.98802}{(30.00177 + 11.67)^{1.00001}} = 6.64\ in/hr$$

$$C = \frac{\sum CA}{\sum A} = \frac{C_1A_1 + C_2A_2 + ...C_nA_n}{A_1 + A_2 + ...A_n} = \frac{0.25(2.5) + 0.5(4)}{6.5} = 0.40$$

Q = (0.40)(6.64 in/hr)(6.5 ac) = 17.26 cfs

Inlet 4 – Outlet

A = 2.0 + 2.5 + 4.0 + 3.0 = 11.5 ac

$$T_t = \frac{300}{2.5(60)} = 2.0 \text{ min}$$

Tc is the larger of:

t_c inlet = 12 min
10.5 min + $T_{t\ 1\text{-}4}$ = 10.5 + 3.33 = 10.83 min.
11.67 + $T_{t\ 3\text{-}4}$ = 11.67 + 2.0 = 13.67 min.

$$i = \frac{276.98802}{(30.00117 + 13.67)^{1.00001}} = 6.34\ in/hr$$

Using equation 4.3.3.2, the average C, and assuming the frequency adjustment factor equals 1.25 gives:

$$Q = C_f\left(\sum CA\right)(i) = (1.25)(4.365)(6.34) = 34.59\ cfs\ .$$

4.4 NRCS Hydrologic Method

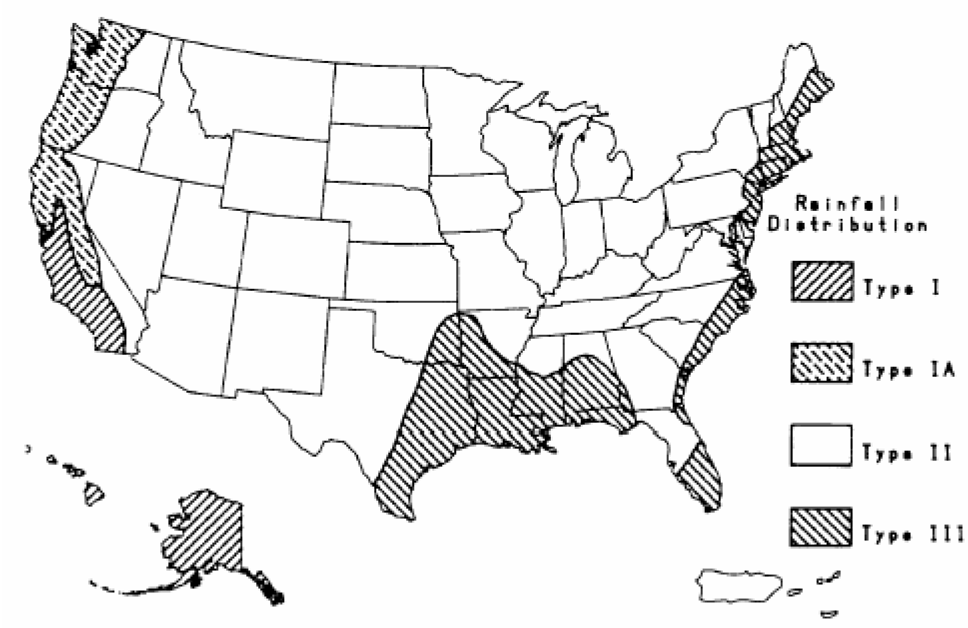
4.4.1 Introduction

The National Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) hydrologic method utilizes basic data similar to the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. The NRCS approach, however, is more sophisticated in that it also considers the time distribution of the rainfall, the initial rainfall losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm. Details of the methodology can be found in the NRCS publication Urban Hydrology for Small Watersheds, 2nd Edition, Technical Release Number 55, 1986.

A typical application of the NRCS method includes the following basic steps:

1. Determination of curve numbers that represent different soil types and land uses within the drainage area.
2. Calculation of time of concentration to the study point.
3. Using the Type II rainfall distribution, total and excess rainfall amounts are determined. Note: See Figure 4.4.1.1 for the geographic boundaries for the different NRCS rainfall distributions.
4. Using the unit hydrograph approach, the hydrograph of direct runoff from the drainage basin can be developed.

Figure 4.4.1.1: Rainfall Distributions



4.4.2 Application

The NRCS method can be used for both the estimation of stormwater runoff peak rates and the generation of hydrographs for the routing of stormwater flows. The NRCS method can be used for most design applications, including storage facilities and outlet structures, storm drain systems, culverts, small drainage ditches and open channels, and energy dissipators.

Technical Release 55 (TR-55) incorporates NRCS procedures and presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable in small watersheds, especially urbanizing watersheds, in the United States.

Limits to TR-55

- NRCS type distributions
- 24-hour duration rainfall
- 10 subwatersheds
- minimum 0.1 hour and maximum 10-hour time of concentration

4.4.3 Equations and Concepts

The hydrograph of outflow from a drainage basin is the sum of the elemental hydrographs from all the sub-areas of the basin, modified by the effects of transit time through the basin and storage in the stream channels. Since the physical characteristics of the basin including shape, size and slope are constant, the unit hydrograph approach assumes that there is considerable similarity in the shape of hydrographs from storms of similar rainfall characteristics. Thus, the unit hydrograph is a typical hydrograph for the basin with a runoff volume under the hydrograph equal to one (1.0) inch from a storm of specified duration. For a storm of the same duration but with a different amount of runoff, the hydrograph of direct runoff can be expected to have the same time base as the unit hydrograph and ordinates of flow proportional to the runoff volume. Therefore, a storm that produces 2 inches of runoff would have a hydrograph with a flow equal to twice the flow of the unit hydrograph. With 0.5 inches of runoff, the flow of the hydrograph would be one-half of the flow of the unit hydrograph.

The following discussion outlines the equations and basin concepts used in the NRCS method.

Drainage Area - The drainage area of a watershed is determined from topographic maps and field surveys. For large drainage areas it might be necessary to divide the area into sub-drainage areas to account for major land use changes, obtain analysis results at different points within the drainage area, combine hydrographs from different sub-basins as applicable, and/or route flows to points of interest.

Rainfall - The NRCS method applicable to the City of Rock Hill is based on a storm event that has a Type II distribution. These distributions are used to distribute the 24-hour volume of rainfall for the different storm frequencies (Figure 4.4.1.1). A typical Peaking Factor of 484 shall be utilized for all hydrology models.

Rainfall-Runoff Equation - A relationship between accumulated rainfall and accumulated runoff was derived by NRCS from experimental plots for numerous soils and vegetative cover conditions. The following NRCS runoff equation, Equation 4.4.3.1, is used to estimate direct runoff from 24-hour or 1-day storm rainfall.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$ **Equation 4.4.3.1**

where: Q = accumulated direct runoff (in),
P = accumulated rainfall (potential maximum runoff) (in),
I_a = initial abstraction including surface storage, interception, evaporation, and infiltration prior to runoff (in), and
S = potential maximum soil retention (in).

The empirical relationship shown in Equation 4.4.3.2 is used to determine the initial abstractions, I_a.

$$I_a = 0.2 * S$$ **Equation 4.4.3.2**

This is an average value that could be adjusted for flatter areas with more depressions if there are calibration data to substantiate the adjustment.

Substituting 0.2S for I_a, Equation 4.4.3.1 becomes:

$$Q = \frac{(P - 0.2 * S)^2}{P + 0.8 * S}$$ **Equation 4.4.3.3**

where: S = 1000/CN - 10, and
CN = NRCS curve number.

4.4.4 Curve Number (CN)

The major factors required to determine the curve number (CN) are cover type, treatment, hydrologic condition, hydrologic soil group (HSG) of the watershed soils, and antecedent moisture condition (AMC). Another factor of consideration is whether impervious areas are directly connected to the system or if the system is unconnected and flows from impervious areas spread over pervious areas before reaching the outlet point. The curve number is similar to the Rational Method C-Factor as it is based on the surface condition of the project site. Table 4.4.4.1 provides a description of the various soil types that should be expected to be encountered in Rock Hill. Soils types are distinguished based in infiltration rates and subsurface permeability. Soil types in a particular area are most often determined using NRCS Soil Survey maps. Where these resources are unavailable designers should determine soils types based on personal knowledge through experience or have soil samples taken. Curve numbers for various soils type and landuses are given in Table 4.4.4.2. Particle size distributions and the corresponding HSG for soils in South Carolina are located in Appendix A at the end of this manual.

Table 4.4.4.1: HSG Descriptions

Soil Group	Description
HSG A:	Soils with a low runoff potential due to high infiltration rates, primarily deep well-drained sands.
HSG B:	Soils with a moderate runoff potential due to moderate infiltration rates, primarily moderately deep to deep with coarse to moderately fine textures.
HSG C:	Soils having a moderately high runoff potential due to low infiltration rates, primarily moderately fine to fine textures.
HSG D:	Soils having a high runoff potential due to very low infiltration rates, predominantly clay soils or soils with high water tables.

Table 4.4.4.2: Curve Numbers

Land uses	Hydrologic Soil			
	A	B	C	D
Cultivated Land				
Without conservation treatment	72	81	88	91
With conservation treatment	62	71	78	81
Pasture or Range Land				
Poor condition: < 50% ground cover	68	79	86	89
Good condition: > 75% ground cover	39	61	74	80
Meadow of Continuous Grass Protected from Grazing	30	58	71	78
Wood or Forest Land				
Poor: forest litter, small trees, and brush are regularly cleared	45	66	77	83
Fair: grazed with some forest litter covering the soil	36	60	73	79
Good: no grazing, litter and brush adequately cover the soil	30	55	70	77
Open Spaces (lawns, parks, golf courses, and cemeteries)				
Poor: grass cover > 50%	68	79	86	89
Fair: grass cover from 50% to 75%	49	69	79	84
Good: grass cover > 75%	39	61	74	80
Impervious Areas				
Paved parking lots, roofs, and driveways	98	98	98	98
Streets and Roads				
Paved curb and storm sewers excluding right-of-way	98	98	98	98
Paved open ditches including right-of-way	83	89	92	93
Gravel including right-of-way	76	85	89	91
Dirt including right-of-way	72	82	87	89

Urban Districts					
Commercial and business	(85% average impervious area)	89	92	94	95
Industrial	(72% average impervious area)	81	88	91	93
Residential Districts by Lot Size					
1/8 acre or less, townhomes	(65% average impervious area)	77	85	90	92
¼ acre	(38% average impervious area)	61	75	83	87
1/3 acre	(30% average impervious area)	57	72	81	86
½ acre	(25% average impervious area)	54	70	80	85
1 acre	(20% average impervious area)	51	68	79	84
2 acres	(12% average impervious area)	46	65	77	82
Developing Urban Areas, Newly Graded Areas with no Vegetation		77	86	91	94

*The average percent impervious areas shown were used to develop the composite CNs for the described land use. The impervious areas are assumed to be directly connected to the drainage system, with the impervious areas having a CN of 98 and the pervious areas being equivalent to open space in good hydrologic condition. If the impervious area is not connected, the NRCS method has an adjustment to reduce the effect.

- The Soil Conservation Service is now the National Resource Conservation Service (NRCS).

When a drainage area has more than one land use, a composite curve number can be calculated and used in the analysis. It should be noted when composite curve numbers are used, the analysis does not take into account the location of the specific land uses but sees the drainage area as a uniform land use represented by the composite curve number.

4.4.5 Antecedent Moisture Conditions

The index of runoff potential before a storm event is termed the Antecedent Moisture Condition (AMC). The AMC is an attempt to account for the variation in CN at a particular site for various storm conditions. The CNs listed in Table 4.4.3.1 are for average AMC, or AMC II, and are used primarily for design applications. AMC II are recommended for most hydrologic analysis, except in the design of state-regulated Category I dams, where AMC III may be required, or in areas with high water table conditions, where AMC III should be considered. AMC I should be considered in low flow analysis in semi-arid to arid regions. The AMC is a calibration parameter for modeling against real calibration data. The AMC I and III can be determined using the following equation:

AMC I Little rain or drought conditions preceding rainfall event. The curve numbers for AMC I can be calculated using the following equation:

$$\mathrm{CN}\,(\mathrm{AMC\,I}) = \frac{4.2\mathrm{CN}(\mathrm{AMC\ II})}{10 - 0.058\mathrm{CN}(\mathrm{AMC\,II})}$$

AMC II Standard CNs developed from rainfall and runoff data.

AMC III Considerable rainfall prior to rain event in question. The curve numbers for AMC III can be calculated using the following equation:

$$\mathrm{CN}\,(\mathrm{AMC\,III}) = \frac{23\mathrm{CN}(\mathrm{AMC\ II})}{10 - 0.13\mathrm{CN}(\mathrm{AMC\,II})}$$

4.4.6 Urban Modification of the NRCS Method

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered when computing the CN for urban areas. Modifications to the NRCS methods should be considered to prevent underestimated effects of urbanization. The NRCS method is based on relationships developed for mostly agricultural watersheds and for urban applications, the effects of imperviousness, as well as those due to changes to the pervious areas, on curve numbers and moisture condition need to be considered.

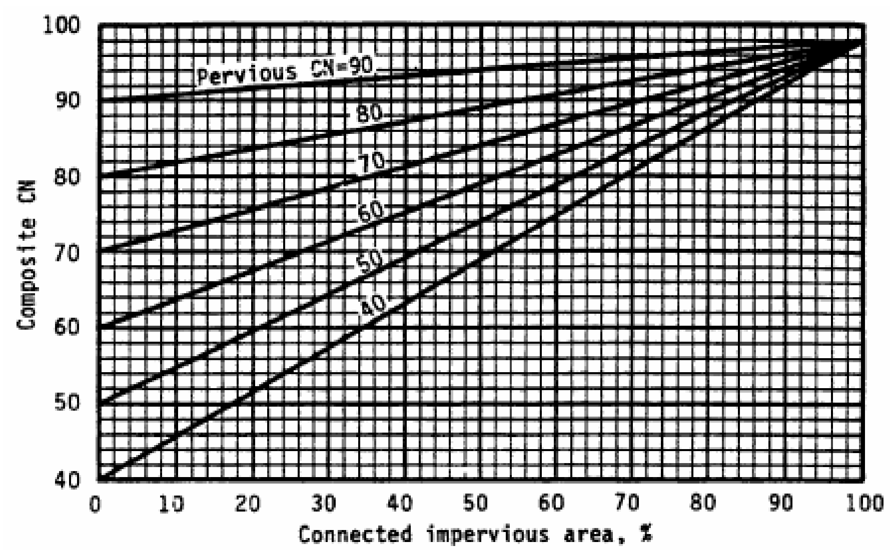
Consideration should be given to the effects of heavy equipment, which is expected to compact the soil during construction or if grading will mix the surface and subsurface soils, thereby changing soils composition and the resulting runoff potential from those disturbed areas.

Connected Impervious Areas--An impervious area is considered connected if runoff from it flows directly into the storm drainage system without encountering any pervious areas along its path. Indirectly connected areas are those where runoff from the area occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system. Directly connected impervious areas (DCIA) can produce runoff from even the smallest storm events and produce fast rainfall/runoff responses that can come and go before other portions of the watershed begin producing runoff. Therefore, these areas should be treated with care when designing highly impervious developments. When using the NRCS method, DCIA and indirectly connected impervious areas (ICIA) are classified together.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table 4.4.4.2 are not applicable, use Figure 4.4.6.1 to compute a composite CN.

For example, Table 4.4.4.1 gives a CN of 70 for a ½-acre lot with HSG B soils, with an assumed impervious area of 25 percent. If the lot actually has 20 percent impervious area and a pervious area CN of 61, the composite CN obtained from Figure 4.4.6.1 is 68. The decrease in the CN from 70 to 68 reflects the decrease in the percent impervious area.

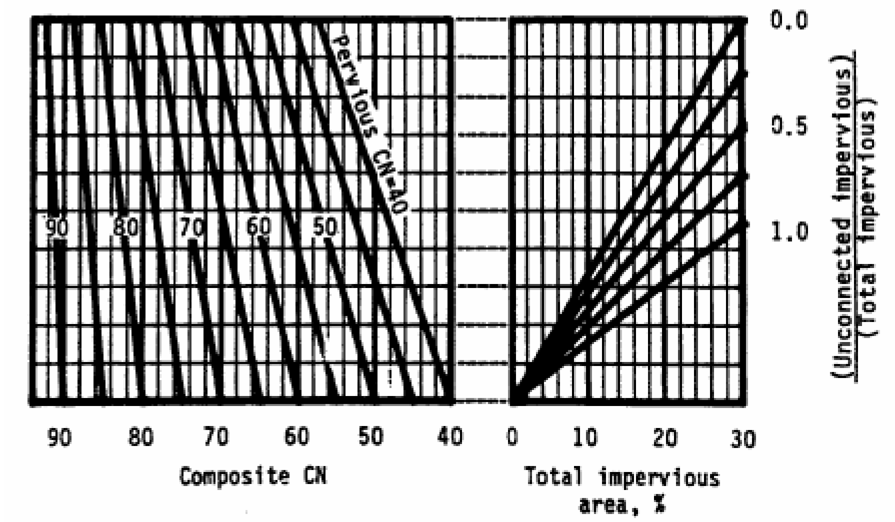
Figure 4.4.6.1: Curve Number Adjustment Based on DCIA



<u>Unconnected Impervious Areas:</u> Runoff from these areas is spread over a pervious area as sheet flow. To determine the CN when all or part of the impervious area is not directly connected to the drainage system, there are two options. Use Figure 4.4.6.2 if the total impervious area is less than 30%. Use Figure 4.4.6.1 if the total unconnected impervious area is equal to or greater than 30 percent, because the absorptive capacity of the remaining pervious area will not significantly affect the runoff.

When the impervious area is less than 30%, obtain the composite CN by entering the right half of Figure 4.4.6.2 with the percentage of total impervious area and the ratio of total unconnected impervious are to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN. For example, a ½-acre lot with 25 percent total impervious area (75 percent of that is unconnected) and a pervious CN of 61, the composite CN from Figure 4.4.6.2 is 66.

Figure 4.4.6.2: Composite CN with Unconnected Impervious Areas (Source: NRCS, TR-55, Second Edition, June 1986)



4.4.7 Travel Time Estimation

Travel time (T_t) is the time it takes water to travel from one location to another within a watershed, through the various components of the drainage system. Time of concentration (t_c) is computed by summing all the travel times for consecutive components of the drainage conveyance system from the hydraulically most distant point of the watershed to the point of interest within the watershed. Following is a discussion of related procedures and equations.

Travel Time

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time is the ratio of flow length to flow velocity, calculated using Equation 4.4.7.1.

$$T_t = \frac{L}{3600V} \qquad \textbf{Equation 4.4.7.1}$$

Where: T_t = travel time (hr),
L = flow length (ft),
V = average velocity (ft/s), and
3600 = conversion factor from seconds to hours.

Sheet Flow

Sheet flow can be calculated using Equation 4.4.7.2.

$$T_t = \frac{0.42\,(nL)^{0.8}}{60(P_2)^{0.5}(S)^{0.4}} \qquad \textbf{Equation 4.4.7.2}$$

Where: T_t = travel time (hr),
n = Manning roughness coefficient (see Table 4.4.7.1),
L = flow length (ft),

P_2 = 2-year, 24-hour rainfall depth (in), and
S = land slope (ft/ft).

Table 4.4.7.1: Manning's Roughness Coefficients (Source: Soil conservation Service, (1986))

Surface Description		Manning's Sheet Flow n
Smooth Surfaces (concrete, asphalt, gravel, bare soil)		0.011
Fallow (no residue)		0.05
Cultivated Soils	Residue cover > 20%	0.06
	Residue cover < 20%	0.17
Grass	Short grass prairie	0.15
	Dense grasses*	0.24
	Bermuda Grass	0.41
Range (natural)		0.13
Woods	Light underbrush	0.40
	Medium underbrush	0.60
	Dense underbrush	0.80

*Includes species such as weeping lovegrass, bluegrass, buffalo grass, and native grass mixtures.

Shallow Concentrated Flow

After a maximum of 300 feet in the pre-developed and 100 feet in the post-developed condition, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure 4.3.4.4 in which average velocity is a function of watercourse slope and type of channel.

Average velocities for estimating travel time for shallow concentrated flow can be computed from using Figure 4.3.4.4, or the following equations. These equations can also be used for slopes less than 0.005 ft/ft.

Unpaved $\mathbf{V = 16.13(S)^{0.5}}$ **Equation 4.4.7.3**

Paved $\mathbf{V = 20.33(S)^{0.5}}$ **Equation 4.4.7.4**

where: V = average velocity (ft/s), and
S = slope of hydraulic grade line (watercourse slope, ft/ft).

These two equations are based on the solution of Manning's equation with different assumptions for n (Manning's roughness coefficient) and r (hydraulic radius, feet). For unpaved areas, n is 0.05 and r is 0.4 ft; for paved areas, n is 0.025 and r is 0.2 ft.

After determining average velocity using Figure 4.3.4.4 or either of the previous two equations, use equation 4.4.7.1 to estimate travel time for the shallow concentrated flow segment.

Open Channels

Velocity in channels should be calculated from the Manning equation. Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, where channels have been identified by the local municipality, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity for travel time calculations is usually determined for bank-full elevation assuming low vegetation winter conditions. Manning's equation is:

$$V = \frac{1.49(R)^{2/3}(S)^{1/2}}{n} \qquad \textbf{Equation 4.4.7.5}$$

Where: V = average velocity (ft/s),
R = hydraulic radius = A/P_w (ft),
A = cross sectional flow area (ft^2),
P_w = wetted perimeter (ft),
S = slope of the hydraulic grade line (ft/ft), and
n = Manning's roughness coefficient for open channel flow.

After average velocity is computed using this equation, Tt for the channel segment can be estimated using equation 4.4.7.1.

Limitations

- Equations in this section should not be used for sheet flow longer than 300 feet for impervious land uses.
- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate tc.
- A culvert or bridge can act as detention structure if there is significant storage behind it. Detailed storage routing procedures should be used to determine the outflow through the culvert or bridge.

4.4.8 Example Problem #1

The following example problems can be found in the U.S. Soil Conservation Service publication Technical Release 55: Urban Hydrology for Small Watersheds.

The Watershed covers 250 acres in the City of Rock Hill. Seventy percent (175 acres) is a Mecklenburg Soil, which is in hydrologic soil group C. Thirty percent (75 acres) is a Cecil soil, which is in HSG B. The event is a 25-year frequency, 24-hour storm with total rainfall of 6 inches.

Seventy percent (175 acres) of the watershed, consisting of all the Cecil soil and 100 acres of the Mecklenburg soil, is ½ acre residential lots with lawns in good hydrologic condition. The rest of the watershed is scattered open space in good hydrologic condition.

Figure 4.4.8.1: Worksheet #2 - Runoff Curve Number and Runoff (Source: NRCS, TR-55, Second Edition, June 1986)

Project	Heavenly Acres	By	RHS	Date	5/10/2003
Location	York County, SC	Checked	RHR	Date	5/11/2003
Check one:	☐ Present	☒ Developed	175 Acres Residential		

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover Description (cover type, treatment, and hydrologic condition; percent impervious, unconnected/connected impervious area ratio)	CN[*1] Table 4.4.4.2	CN[*1] Fig. 4.4.6.1	CN[*1] Fig. 4.4.6.2	Area ☒ acres ☐ mi² ☐ %	Product of CN x Area
Cecil, B	25% impervious, 1/2 acre lots, good condition	70			75	5250
Mecklenburg, C	25% impervious, 1/2 acre lots, good condition	80			100	8000
Mecklenburg, C	Open space, good condition	74			75	5550
				Totals ➡	250	18,800

*1 Use only one CN source per line.

$$CN(weighted) = \frac{total\,product}{total\,area} = \frac{18{,}800}{250} = 75.2$$

Use CN ➡ 75

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency……………………………………..	yr.	25		
Rainfall, P (24-hour)………………………..	in.	6.0		
Runoff, Q…………………………………….	in.	3.28		

(Use P and CN with Table 4.2.3.1, Fig. 4.4.6.1, or Eqs. 4.4.3.2 and 4.4.3.3.)

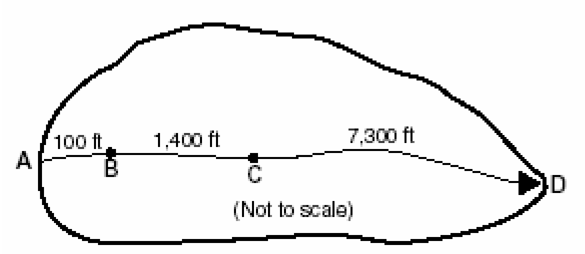
4.4.9 Example Problem #2

The sketch below shows a watershed in the City of Rock Hill. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

<u>Segment AB</u>
Sheet flow;
dense grass;
slope (s) = 0.01 ft/ft; and
length (L) = 100 ft.

<u>Segment BC</u>
Shallow concentrated flow;
unpaved;
s = 0.01 ft/ft; and
L = 1,400 ft.

<u>Segment CD</u>
Channel flow;
Manning's n = .05;
flow area (a) = 27 ft^2;
wetted perimeter (p_w) = 28.2 ft;
s = 0.005 ft/ft; and
L = 7,300 ft.



See Figure 4.4.9.1 for the computations made of this example.

Figure 4.4.9.1: Worksheet #3 - Time of Concentration or Travel Time (Source: SC3, TR-55, Second Edition, June 1986)

Project	Heavenly Acres	By	RHS	Date	5/10/2003
Location	York County, SC	Checked	RHR	Date	5/11/2003

Check one: ☐ Present ☒ Developed

Check one: ☒ Tc ☐ Tt through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to Tc only)

	AB			
1. Surface description (table 2-1)…………	Dense Grass			
2. Manning's roughness coefficient, n (table 3-1)…………	0.24			
3. Flow length, L (total L <= 300 ft.)…………ft	100			
4. Two-year 24-hour rainfall, P_2…………in	3.5			
5. Land slope, s…………ft/ft	0.01			
6. $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}s^{0.4}}$ Compute T_t……hr	0.3	+		= 0.30

Shallow concentrated flow

	BC			
7. Surface description (paved or unpaved)…………	Unpaved			
8. Flow length, L …………ft	1400			
9. Watercourse slope, s…………ft/ft	0.01			
10. Average velocity, V (figure 3-1)…………ft/s	1.6			
11. $T_t = \frac{L}{3600V}$ Compute T_t……hr	0.24	+		= 0.24

Channel flow

	CD			
12. Cross sectional flow area, a…………ft^2	27			
13. Wetted perimeter, P_w…………ft	28.2			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r…………ft	0.957			
15. Channel slope, s………… ft/ft	0.005			
16. Manning's roughness coeff., n …………	0.05			
17. $V = \frac{1.49r^{2/3}s^{1/2}}{n}$ Compute V…………ft/s	2.05			
18. Flow length, L…………ft	7300			
19. $T_t = \frac{L}{3600V}$ Compute T_t……hr	0.99	+		= 0.99
20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)…………Hr				1.53

4.5 References

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WEF and ASCE, Design and Construction of Urban Stormwater Management Systems, ASCE Manual of Practice 77, WEF Manual of practice FD-20, 1992.

CHAPTER 5 – OPEN CHANNEL HYDRAULICS

5.1 Stormwater Ordinance Review

5.1.1 Open Channel Hydraulic Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following open channel hydraulic information was taken from the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

Grading Permits

- Off-site discharges of closed storm sewers or improve open channels will be permitted only at natural streams or man-made drainage channels. Discharge velocities shall be reduced to a non-erosive velocity from structures, channels, or other control measures or to the velocity of the runoff from a 10-year, 24-hour storm in the receiving waterway prior to the land disturbing activity, whichever is greater.

Design criteria for channel modification will be as follows:

- Open Channels - Open channels shall be provided with an improved cross section that will carry the runoff from the appropriate design rainfall and preclude the creation of backwater inundation of any area outside dedicated drainage easements.

5.2 Design Criteria

5.2.1 General Criteria

The following criteria shall be used for open channel design:

1. Channels with bottom widths greater than 10 feet shall be designed with a minimum bottom cross slope of 12 to 1.
2. Channel side slopes shall be stable throughout the entire length and slope shall be a maximum of 2:1.
3. Super-elevation of the water surface at horizontal curves shall be accounted for by increased freeboard.
4. Transition to channel sections shall be smooth and gradual, with a minimum of 5:1 taper.
5. Open channel drainage systems shall be designed to handle the 10-year 24-hour storm event.
6. Open channel drainage systems traversing between residential lot rear property lines shall be limited to draining a maximum of six (6) total residential lots before an enclosed drainage system is required to pick up the flow. These drainage systems shall not transport any street or offsite drainage through the lot rears and a twenty (20') foot wide private drainage easement will be required to be dedicated with the final plat.

5.2.2 Velocity Limitations

Discharge velocities shall be reduced to a non-erosive velocity flow from structures, channels or other control measures or to the velocity of runoff from a 10-year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.

The final design of artificial open channels should be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 5.2.2.1. Seeding and mulch should only be used when the design value does not exceed the allowable value for bare soil. Velocity limitations for vegetative linings are reported in Table 5.2.2.2.

Table 5.2.2.1 Maximum Velocities for Several Lining Materials

Material	Maximum Velocity (ft/s)
Sand	2.0
Silt	3.5
Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay	5.0
Graded Loam or Silt to Cobbles	5.0
Coarse Gravel	6.0
Shales and Hard Pans	6.0

Table 5.2.2.2 Maximum Velocities for Vegetative Type Linings

Vegetative Type	Slope Range (%)[1]	Maximum Velocity[2] (ft/s)
Bermuda grass	0->10	5
Bahia		4
Tall fescue grass mixtures[3]	0-10	4
Kentucky bluegrass	0-5	6
Buffalo grass	5-10	5
Grass mixture	0-5[1]	4
Sericea lespedeza, Weeping lovegrass Alfalfa	0-5[4]	3
Annuals[5]	0-5	3
Sod		4
Lapped sod		5

1 Do not use on slopes steeper than 10% except for side-slope in combination channel.
2 Use velocities exceeding 5 ft/s only where good stands can be maintained.
3 Mixtures of Tall Fescue, Bahia, and/or Bermuda
4 Do not use on slopes steeper than 5% except for side-slope in combination channel.
5 Annuals - used on mild slopes or as temporary protection until permanent covers are established.

Source: Manual for Erosion and Sediment Control in Georgia, 1996

5.3 Open Channel Flow Calculations

5.3.1 Manning's Equation

Manning's Equation, presented in three forms below, is recommended for evaluating uniform flow conditions in open channels:

$$v = \left(\frac{1.49}{n}\right) R^{2/3} S^{1/2}$$ **Equation 5.3.1.1**

$$Q = \left(\frac{1.49}{n}\right) A R^{2/3} S^{1/2}$$ **Equation 5.3.1.2**

$$S = \left(\frac{Qn}{1.49 R^{2/3} S^{1/2}}\right)^2$$ **Equation 5.3.1.3**

where:
V = average channel velocity (ft/s),
Q = discharge rate for design conditions (cfs),
n = Manning's roughness coefficient,
A = cross-sectional area (ft^2),
R = hydraulic radius (ft),
P = wetted perimeter (ft), and
S = slope of the energy grade line (ft/ft).

5.3.2 Manning's n Values for Open Channel Flow

The Manning's n value is an important variable in open channel flow computations. Variation in this variable can significantly affect discharge, depth, and velocity estimates. Since Manning's n values depend on many different physical characteristics of natural and man-made channels, care and good engineering judgment must be exercised in the selection process. Manning's Roughness Coefficient (n) is influenced by many factors including:

- Physical roughness of the channel surface,
- The irregularity of the channel cross section,
- Channel alignment and bends,
- Vegetation,
- Silting and scouring, and
- Obstructions within the channel.

Recommended Manning's n values for artificial channels with rigid, unlined, temporary, and rip-rap linings are given in Table 5.3.2.1. For natural channels, Manning's n values should be estimated using experienced judgement and information presented in publications such as the Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains, FHWA-TS-84-204, 1984.

5.3.3 Direct Solutions

When the hydraulic radius, cross-sectional area, and roughness coefficient and slope are known, discharge can be calculated directly from equation 5.3.1.2. The slope can be calculated using equation 5.3.1.3 when the discharge, roughness coefficient, area, and hydraulic radius are known.

Nomographs for obtaining direct solutions to Manning's Equation are presented in Figures 4.3.4.2 (Chapter 4) and 5.3.3.1. Figure 4.3.4.2 provides a general solution for the velocity form of Manning's Equation, while Figure 5.3.3.1 provides a solution of Manning's Equation for trapezoidal channels.

<u>General Solution Nomograph</u>

The following steps are used for the general solution nomograph in Figure 4.3.4.2 found in Chapter 4:
1. Determine open channel data, including slope in ft/ft, hydraulic radius in ft, and Manning's n value.
2. Connect a line between the Manning's n scale and slope scale and note the point of intersection on the turning line.
3. Connect a line from the hydraulic radius to the point of intersection obtained in Step 2.
4. Extend the line from Step 3 to the velocity scale to obtain the velocity in ft/s.

<u>Trapezoidal Solution Nomograph</u>

The trapezoidal channel nomograph solution to Manning's Equation in Figure 5.3.3.1 can be used to find the depth of flow if the design discharge is known or the design discharge if the depth of flow is known.
1. Determine input data, including slope in ft/ft, Manning's n value, bottom width in ft, and side slope in ft/ft
2. a. Given the design discharge, find the product of Q times n, connect a line from the slope scale to the Qn scale, and find the point of intersection on the turning line.
   b. Connect a line from the turning point from Step 2a to the b scale and find the intersection with the z = 0 scale.

c. Project horizontally from the point located in Step 2b to the appropriate z value and find the value of d/b.
d. Multiply the value of d/b obtained in Step 2c by the bottom width b to find the depth of uniform flow, d.

3. a. Given the depth of flow, find the ratio d divided by b and project a horizontal line from the d/b ratio at the appropriate side slope, z, to the z = 0 scale.
b. Connect a line from the point located in Step 3a to the b scale and find the intersection with the turning line.
c. Connect a line from the point located in step 3b to the slope scale and find the intersection with the Qn scale.
d. Divide the value of Qn obtained in Step 3c by the n value to find the design discharge, Q.

The Federal Highway Administration has prepared numerous design charts to aid in the design of rectangular, triangular, and trapezoidal open channel cross sections. In addition, design charts for grass lined channels have been developed. For a complete discussion of these charts and their use in open channel design refer to the publication Design Charts For Open Channel Flow, Federal Highway Administration, Hydraulic Design Series No. 3, 1973.

Table 5.3.2.1 Manning's Roughness Coefficients

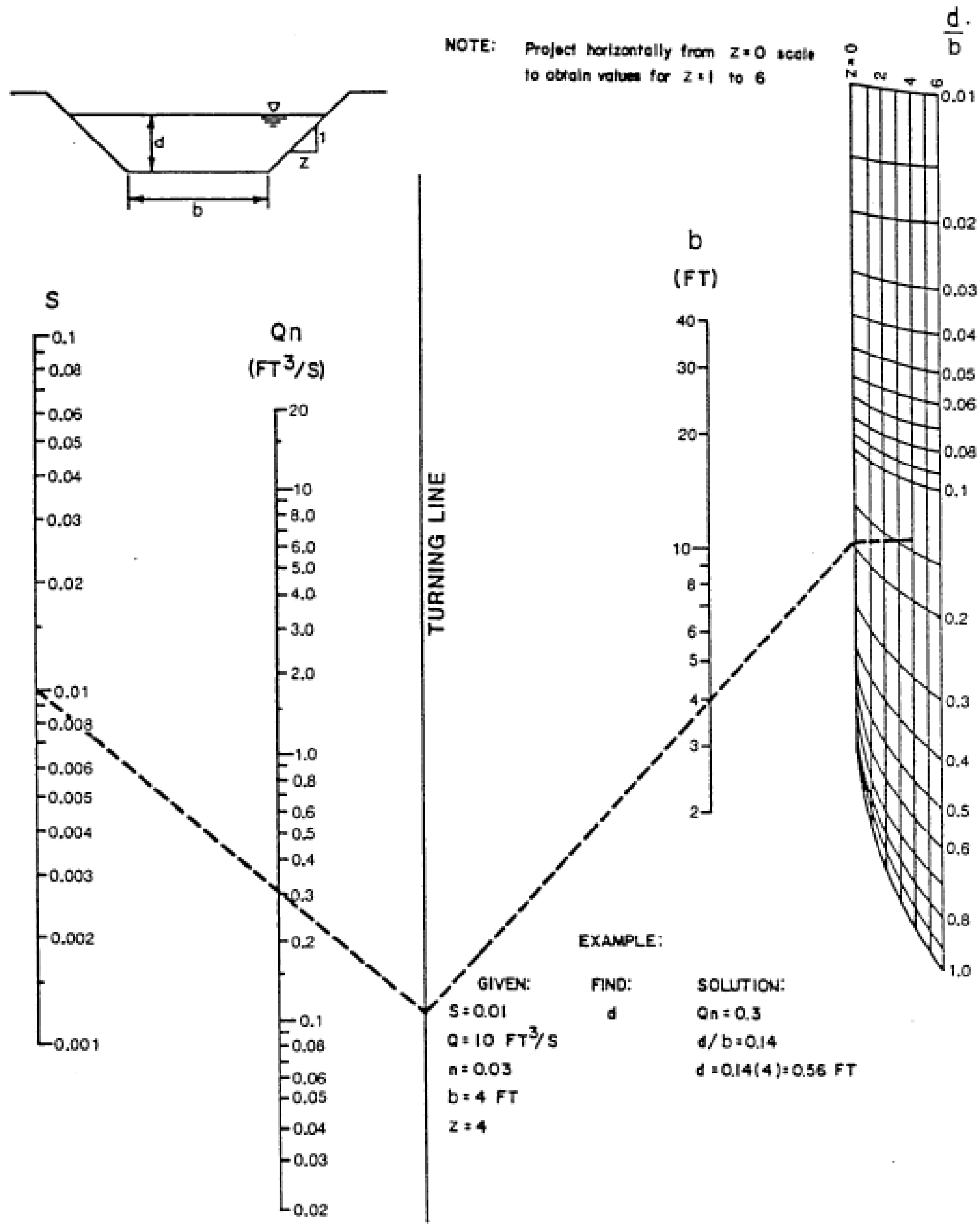
Type of Flow Media	Min	Normal	Max
Pipes			
Plastic (PVC and ABS)		0.009	
Cast iron, coated	0.011	0.013	0.014
Cast iron, uncoated	0.012		0.015
Clay or concrete drain tile	0.010	0.011	0.020
Concrete		0.013	
Corrugated metal	0.021	0.025	0.027
Steel, riveted and spiral	0.013	0.016	0.017
Brick		0.016	
Vitrified sewer pipe	0.010	0.014	0.017
Wrought iron, black	0.012		0.015
Wrought iron, galvanized	0.013	0.016	0.017
Excavated or Dredged Ditches and Channels			
Earth Straight and Uniform			
Clean recently completed	0.016	0.018	0.020
Clean after weathering	0.022	0.025	0.030
Gravel, uniform section, clean	0.022	0.027	0.033
Earth Winding and Sluggish			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds, plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.025	0.030	0.035
Stony bottom and weed sides	0.025	0.035	0.045
Cobble bottom and clean sides	0.030	0.040	0.050
Dragline Excavated or Dredged			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
Rock Cuts			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050

Type of Flow Media	Min	Normal	Max
Channels Not Maintained, Vegetation and Brush Uncut			
Dense vegetation in channel as high as flow depth	0.050	0.080	0.120
Clean bottom, vegetation and brush on sides	0.040	0.050	0.080
Clean bottom, brush and vegetation up to high stage	0.045	0.070	0.110
Clean bottom, dense brush and vegetation on over-banks	0.080	0.100	0.140
Natural Streams on Plain			
Clean straight, full stage, no rifts or pools	0.025	0.030	0.033
Stones, vegetation, straight, full stage	0.030	0.035	0.040
Clean, winding, some pools and shoals	0.033	0.040	0.045
Vegetation, stones, winding, some pools and shoals	0.035	0.045	0.050
Sluggish reaches, vegetation, deep pools	0.050	0.070	0.080
Much vegetation, deep pools, or floodways with timber and underbrush	0.075	0.100	0.150
Natural Mountain Streams with no Vegetation in Channel, Trees and Brush Along Banks are only Submerged at High Stages			
Bottom consists of gravel cobbles and few boulders	0.030	0.040	0.050
Bottom consists of cobbles with large boulders	0.040	0.050	0.070
Floodplains			
Pasture, no Brush			
Short grass	0.025	0.030	0.035
High grass	0.030	0.035	0.050
Cultivated Areas			
No crop	0.020	0.030	0.040
Mature row crop	0.025	0.035	0.045
Mature field crop	0.030	0.040	0.050
Brush			
Scattered brush, heavy weeds	0.035	0.050	0.070
Light brush and trees in winter	0.035	0.050	0.060
Light brush and trees in summer	0.040	0.060	0.080
Medium to dense brush in winter	0.045	0.070	0.110
Medium to dense brush in summer	0.070	0.100	0.160
Trees			
Dense willows, summer, straight	0.110	0.150	0.200
Cleared land, tree stumps, no sprouts	0.030	0.040	0.050
Cleared land, tree stumps, with heavy sprouts	0.050	0.060	0.080
Heavy stand of timber, floodstage below branches	0.080	0.100	0.120
Heavy stand of timber, floodstage above branches	0.100	0.120	0.160

Type of Flow Media	Min	Normal	Max
<u>Lined Channels</u>			
Asphaltic concrete machine placed		0.014	
Asphaltic exposed, prefabricated	0.015	0.016	0.018
Concrete		0.013	0.015
Concrete Rubble	0.016		0.029
Shotcrete	0.016		0.017
Grouted Rip-rap	0.028	0.030	0.040
Stone Masonry	0.030	0.032	0.040
Jute Net	0.019	0.022	0.028
Straw with net	0.025	0.033	0.065
Curled wood mat	0.028	0.035	0.066
Synthetic geotextile mat	0.021	0.025	0.036
Gravel Rip-rap			
1-inch D50	0.030	0.033	0.044
2-inch D50	0.034	0.041	0.066
Rock Rip-rap			
6-inch D50	0.035	0.069	0.104
12-inch D50	0.040	0.078	0.120

Sources: Design Hydrology and Sedimentology for Small Catchments, Hann et. al., 1995 HEC-15

Figure 5.3.3.1: Solution of Manning's Equation for Trapezoidal Channels



Reference: USDOT, FHWA, HEC-15 (1986).

5.3.4 Trapezoidal Channels

The hydraulic radius (R) is defined as being:

$$\mathbf{R} = \frac{\mathbf{A}}{\mathbf{P}} \qquad \textbf{Equation 5.3.4.1}$$

where:

A = Cross sectional flow area(ft^2) and
P = Wetted perimeter (ft).

The wetted perimeter is defined as being the length of the boundary between water and the channel sides and bottom at any cross section. The wetted perimeter is the distance around the flow cross section starting at one edge of the channel and traveling along the sides and bottom to the other channel edge.

The cross sectional area (A) for a trapezoidal channel can be determined from:

$$A = bd + Zd^2 \qquad \text{Equation 5.3.4.2}$$

where:

A = Cross sectional flow area (ft^2),
b = Bottom width of channel (ft),
d = Flow depth of channel (ft), and
Z = Channel side slopes (ZH:1V).

The hydraulic radius (R) for a trapezoidal channel can be calculated from:

$$R = \frac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}} \qquad \text{Equation 5.3.4.3}$$

The expression for the hydraulic radius for wide, shallow channels can be simplified for calculations. Consider a trapezoidal channel that is wide and shallow. The trapezoid can then be approximated by a rectangle.

$$R = \frac{A}{P} = \frac{bd}{b + 2d} \qquad \text{Equation 5.3.4.4}$$

If b is much larger than d (b >> d), then 2*d is ignored leaving,

$$R = \frac{A}{P} = \frac{bd}{b} = d \qquad \text{Equation 5.3.4.5}$$

5.3.5 Circular Channels

The maximum flow capacity of a circular pipe occurs at a depth equal to 0.938*D.

The hydraulic radius of a pipe is defined by the flow depth and an angle (θ) that is measured in radians.

$$A = \frac{D^2}{8}(\theta - \sin\theta) \qquad \text{Equation 5.3.5.1}$$

$$R = \frac{D}{4}\left(1 - \frac{\sin\theta}{\theta}\right) \qquad \text{Equation 5.3.5.2}$$

Flow Depth 0 < y < D/2

For the flow depth (y) in a pipe and pipe diameter (D) where: **0 < y < D/2**

$$\theta = 2\tan^{-1}\left[\frac{\sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - Y\right)^2}}{\frac{D}{2} - Y}\right] \qquad \text{Equation 5.3.5.3}$$

<u>Flow Depth y = D/2</u>
For the flow depth (y) in the pipe and pipe diameter (D) where: **y = D/2**

$$\theta = \pi \qquad \textbf{Equation 5.3.5.4}$$

<u>Flow Depth D/2 < y < D</u>
For the flow depth (y) in the pipe and pipe diameter (D) where: **D/2 < y < D**

$$\theta = 2\pi + 2\tan^{-1}\left[\frac{\sqrt{\left(\frac{D}{2}\right)^2 - \left(Y - \frac{D}{2}\right)^2}}{\frac{D}{2} - Y}\right] \qquad \textbf{Equation 5.3.5.5}$$

5.3.6 Normal Depth Calculation

Normal depth calculations can be found by using the following methods:

- Trial and Error
- Graphical Procedures
- Computer Models

<u>Trial and Error</u>
A trial and error procedure for solving Manning's equation can be used to calculate the normal depth of flow in a uniform channel when the channel shape, slope, roughness and design discharge known.

The flow rate, Q, is generally expressed in cubic feet per second (cfs), and may be written as

$$Q = VA \qquad \textbf{Equation 5.3.6.1}$$

Where:
V = average flow velocity over a cross section (ft/sec), calculated using Manning's Equation, and
A = area of cross section (ft^2)

Using Manning's Equation, the continuity equation can be solved as:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2} \qquad \textbf{Equation 5.3.6.2}$$

Rearrangement of the continuity equation results in the following ratio:

$$AR^{2/3} = \frac{nQ}{1.49(S)^{1/2}} \qquad \textbf{Equation 5.3.6.3}$$

To calculate the normal depth of flow (d_n) by the trial and error process, trial values of depth (d_n) are selected to calculate a corresponding flow area (A), wetted perimeter (P), and hydraulic radius (R). For each trial depth selected, a corresponding $(AR)^{2/3}$ value is calculated. Trial values of the depth are selected until the $(AR)^{2/3}$ value equals the known ratio calculated by using the known roughness, design discharge, and channel slope.

Graphical Procedure

Graphical methods for simplifying the trial and error procedure have been created for trapezoidal channels to calculate the normal depth of flow. This method utilizes a known ratio based on the channel side slopes, channel bottom width, channel slope, Manning's roughness coefficient n, and design discharge.

The design ratio is expressed as:

$$d_n ratio = \frac{Qn}{b_o^{8/3} S^{1/2}} \qquad \textbf{Equation 5.3.6.4}$$

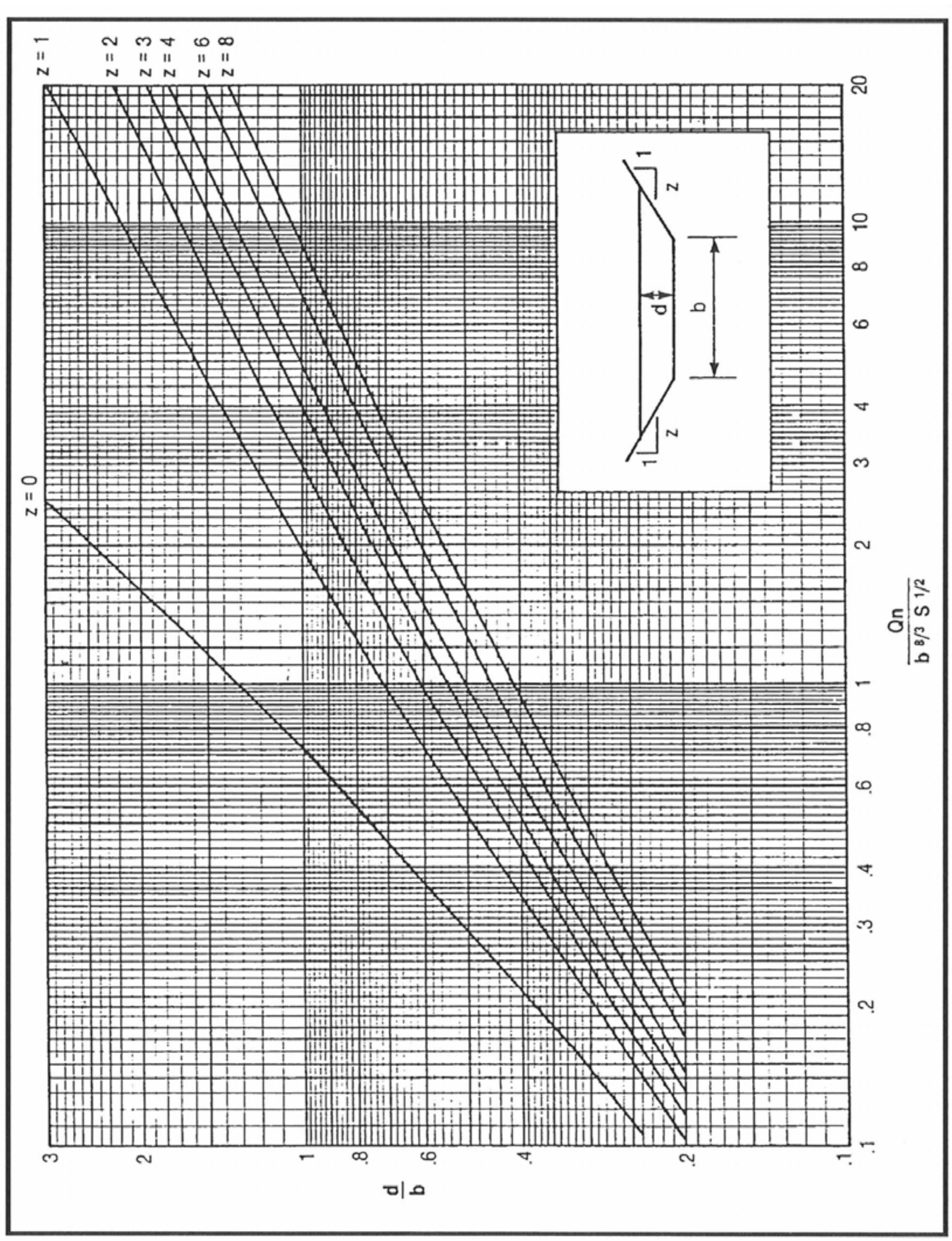
Where:

Q = Peak flow rate (ft^3/sec),
n = Manning roughness coefficient,
b_o = Channel bottom width (ft), and
S = Channel slope (ft/ft).

Once the normal depth ratio is calculated, and the side slopes (ZH:1V) are determined, Figure 5.3.7.1 may be used to determine the normal depth of flow.

- Locate the value for the normal depth ratio on the x-axis of Figure 5.3.7.1, and extend this value up to the appropriate side slope curve.
- From this intersection point, extend back to the y-axis to obtain the d_n/b ratio.
- Once the d_n/b_o ratio has been obtained, multiply the d_n/b_o ratio value by the channel bottom width (b_o) to calculate the normal depth of flow in the channel.

Figure 5.3.6.1: Normal Depth for Trapezoidal Channels (Source: Greenville County Storm Water Management Design Manual, 2003)



5.3.7 Example Problem

Graphical Procedure Example

Given: A channel is to be designed with the following parameters:

Peak flow rate Q	=	50 cfs
Manning's n	=	0.045
Channel bottom width	=	5 ft
Channel side slopes	=	3H:1V
Channel bed slope	=	0.01 ft/ft

Find: The normal depth (dn) of flow in the channel.

Solution:

1. Calculate the normal depth ratio (dn ratio).

$$\mathbf{d_n ratio} = \frac{\mathbf{(50)(0.045)}}{\mathbf{5^{8/3}(0.01)^{1/2}}}$$

$$\mathbf{d_n ratio} = \mathbf{0.31}$$

2. Locate the value for the normal depth ratio on the x-axis of Figure 6.1, and extend this value up to the appropriate side slope curve.

   - Locate 0.31 on the x-axis and extend this value up to the side slope curve Z=3.

3. From this intersection point read back to y-axis to obtain the dn/bo ratio.

   - The ratio intersection reads to be 0.31

4. Multiply the dn/bo ratio by the bottom width (bo) to obtain the normal depth.

   - 0.31 * 5.0 ft = 1.55 ft
   - The normal depth (dn) of the channel is calculated to be **1.55-feet**.

5.3.8 Computer Models

There are various computer models available that are capable of calculating the flow depth in a given channel reach. Many of these models are capable of handling a full network of channels, or just the computations for a single channel reach. These models are also capable of calculating water surface elevations for subcritical, supercritical, and mixed flow regimes. The effects of various obstructions such as bridges, culverts, weirs, and structures in the over-bank areas may also be considered in the calculations. The actual models used for these calculations shall be at the discretion of the design professional with approval from the City of Rock Hill Infrastructure Division. When using a computer model, the design professional takes full responsibility of any accepted output data.

5.4 Channel Stabilization

5.4.1 Assumptions

Rip-rap placement in both natural and prismatic channels has the following limitations:

1. Maximum side slope is 2:1
2. Maximum allowable velocity is 14 feet per second

Rip-rap design procedures can be based on the results and analysis performed by Maynord, 1987; Reese, 1984; Reese, 1988.

5.4.2 Design of Rip-rap Lined Channels

Design of erosion protection within the channel should be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

Straight Channel Sections:

1. Enter the graph of Figure 5.4.2.1 with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line above the point of intersection)

2. If the channel side slopes are steeper than 3H:1V, continue with Step 3; if not, the procedure is complete.

3. Enter the graph in Figure 5.4.2.2 with the side slope and the base width to maximum depth ratio (b/d). Where the two lines intersect, move horizontally left to read K_1.

4. Determine from the graph in Figure 5.4.2.3 the angle of repose for the d_{50} stone size and the channel side slope. (Use an angle of 42^o for d_{50} >10-inches. Do not use rip-rap on slopes steeper than the angle of repose for the stone size.)

5. Enter graph in Figure 5.4.2.4 with the side slope of the channel and the angle of repose for the d_{50} stone size. Where the two lines intersect, move vertically down to read K_2.

6. Compute $d_{50} * K_1/K_2 = d_{50}$ to determine the correct size stone for the bottom and side slopes of straight sections of channel.

Figure 5.4.2.1: Maximum Depth of Flow for Rip-Rap Lined Channels

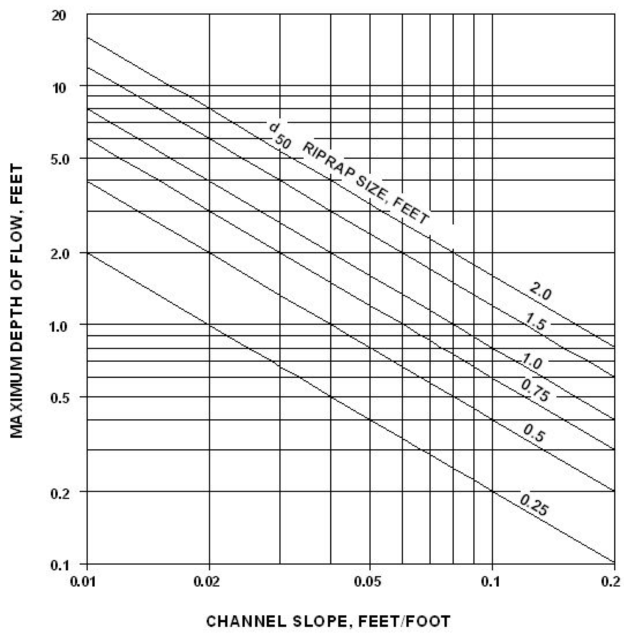


Figure 5.4.2.2: Distribution of Boundary Shear Around Wetted Perimeter of Trapezoidal Channel

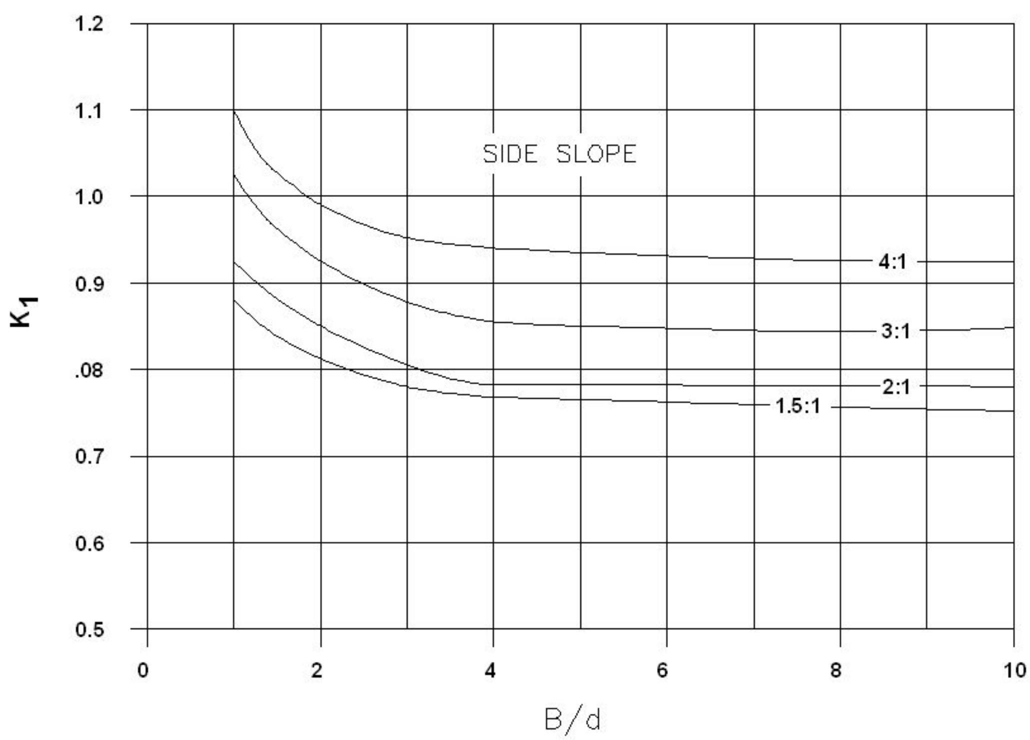


Figure 5.4.2.3: Angle of Repose for Rip-Rap Stones

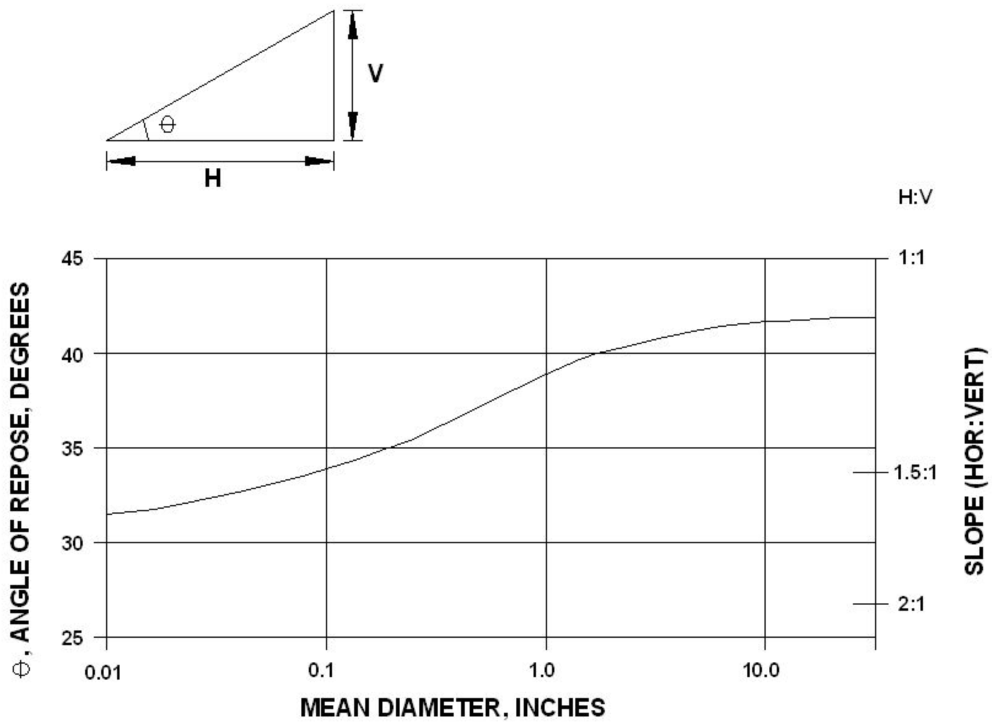
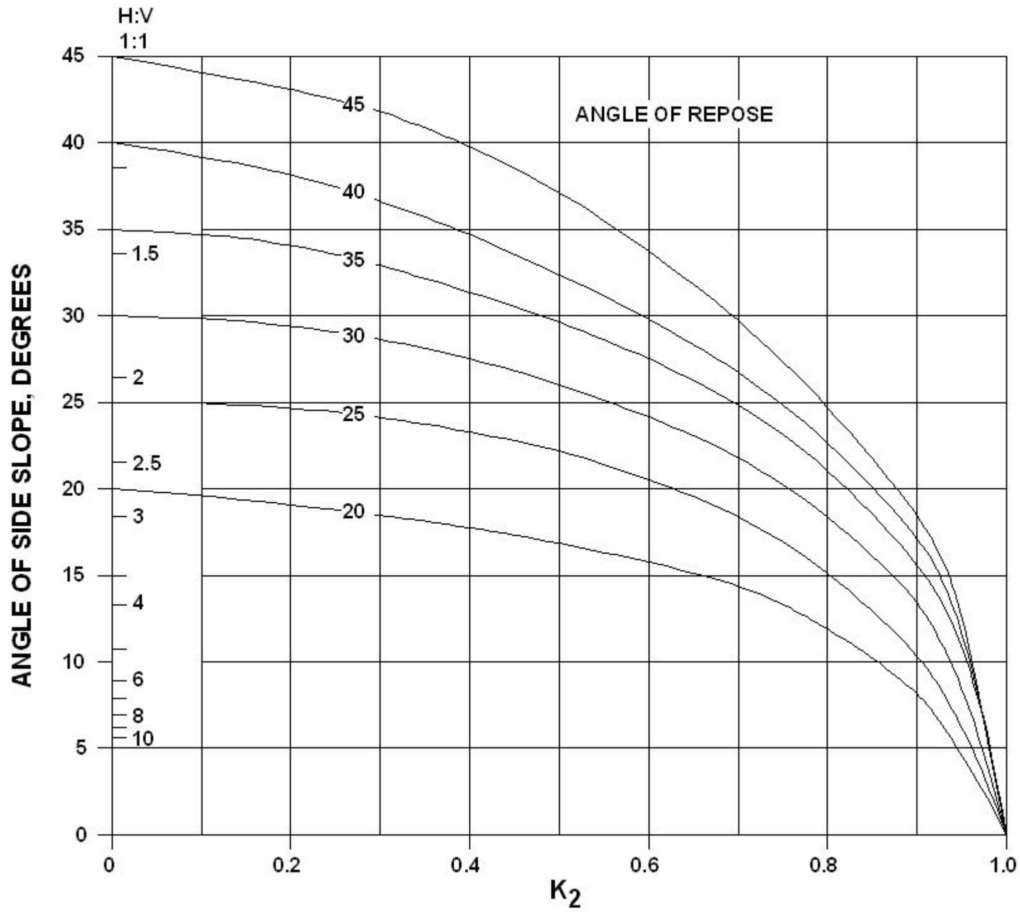


Figure 5.4.2.4: Ratio of Critical Shear Stress on Sides to Critical Shear Stress on Bottom



Curved Channel Sections:

1. 1. Enter the graph of Figure 5.4.2.2 with the maximum flow depth (feet) and channel slope (ft/ft). Where the two lines intersect, choose the d_{50} stone size. (Select d_{50} for diagonal line <u>above</u> the point of intersection)

2. Determine the radius of the curved section (R_O) in feet.

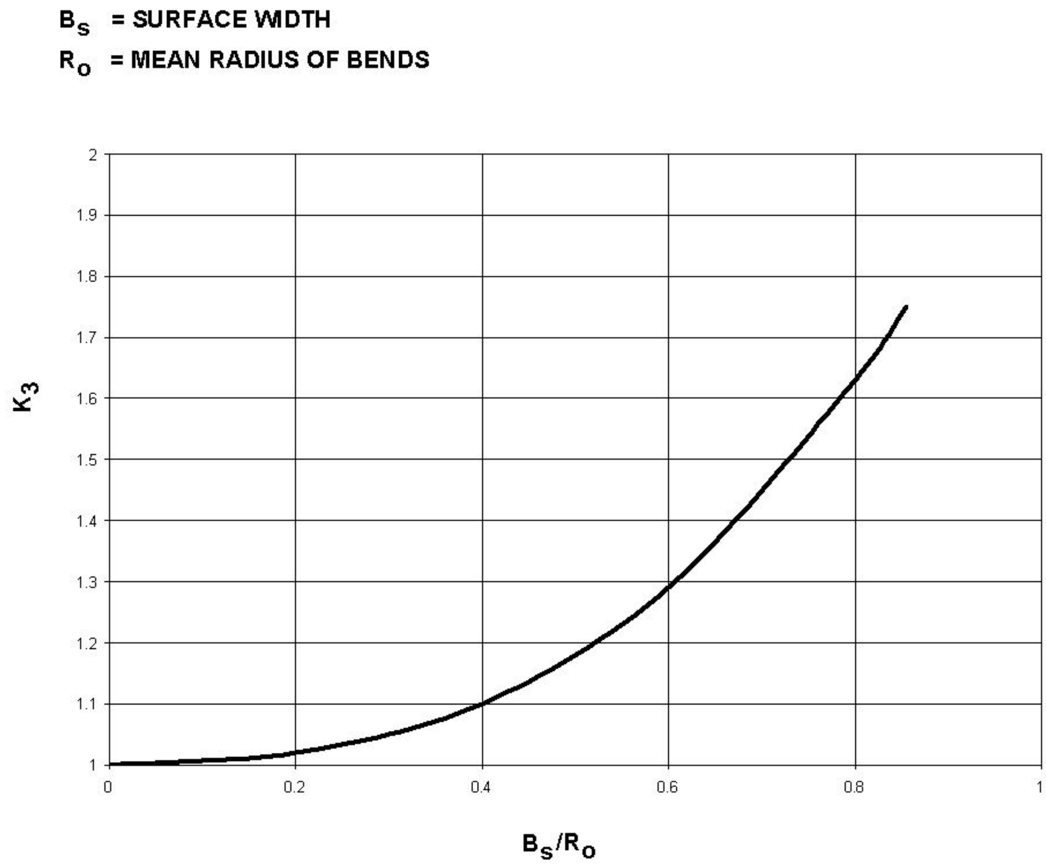
3. Calculate the top width of the rip-rap at the design water surface (B_S) in feet.
   B_S = $B_O + 2(Z*D)$
   B_O = Bottom width of channel (feet)
   Z = Channel sides slopes defined as ZH:1V
   D = Depth of rip-rap (feet)

4. Calculate the Ratio B_S / R_O.

5. Knowing the value of the B_S/R_O ratio from step 4., use the graph in Figure 5.4.2.5 and read the corresponding value of K_3 .

6. Compute (d_{50} x K_3) = d_{50} to determine the correct size stone for the bottom and side slopes of curved channel sections.

Figure 5.4.2.5: Ratio of Maximum Boundary Shear in Bends to Maximum Bottom Shear in Straight Reaches



5.4.3 Straight Channel Section Example Problem

Given: A trapezoidal channel has a depth (D) of 3-feet, a bottom width (B_o) of 8-feet, side slopes (Z) 2:1, and a 2 percent slope.

Find: A stable rip-rap size for the bottom and side slopes of the channel.

Solution:

1. From Figure 5.4.2.1, for a 3-foot-deep channel over a 2 percent grade,
   Read d_{50} = 0.75-feet or 9-inches.

2. Since the side slopes are steeper than 3:1, continue with step 3

   **If side slopes were less than 3:1, the process would be complete.

3. From Figure 5.4.2.2, B_O/d = 8/3 = 2.67, Side slopes Z = 2,
   Read K_1 = 0.82.

4. From Figure 5.4.2.3, for d_{50} = 9-inches,
   Read Angle of Repose = 41

5. From Figure 5.4.2.4, side slopes Z = 2, and Angle of Repose = 41 ,
   Read K_2 = 0.73.

6. Stable Rip-rap = d_{50} x (K_1/K_2) = 0.75 x (0.82/0.73) = 0.84-feet or 10-inches

5.4.4 Curved Channel Section Example Problem

Given: The preceding straight channel example has a curved section with a radius of 50-feet.

Find: A stable rip-rap size for the bottom and side slopes of the curved channel section.

Solution:

1. R_O = 50-feet.

2. Calculate Channel Top Width of Water Surface
   $B_S = B_O + 2(Z*D) = 8 + 2(2*3) = 20$-feet.

3. Calculate the Ratio B_S / R_O
   $= 20/50 = 0.40$

4. From Figure 5.4.2.5, for $B_S / R_O = 0.40$
   Read $K_3 = 1.1$

5. $d_{50} \times K_3 = (0.84\text{-ft.} \times 1.1) = 0.92$-feet or 11-inches.

5.5 References

American Association of State Highway and Transportation Officials, 1982. Highway Drainage Guidelines.
Federal Highway Administration, 1978. Hydraulics of Bridge Waterways. Hydraulic Design Series No. 1.
Federal Highway Administration, 1985. Hydraulic Design of Highway Culverts. Hydraulic Design Series No. 5.
Federal Highway Administration, 1971. Debris-Control Structures. Hydraulic Engineering Circular No. 9.
Federal Highway Administration, 1987. HY8 Culvert Analysis Microcomputer Program Applications Guide. Hydraulic Microcomputer Program HY8.
HYDRAIN Culvert Computer Program (HY8). Available from McTrans Software, University of Florida, 512 Weil Hall, Gainesville, Florida 32611.
U. S. Department of Interior, 1983. Design of Small Canal Structures.
Greenville, South Carolina Storm Water Management Design Manual, January 1992

Chapter 6 – Storm Drainage Systems

6.1 Stormwater Ordinance Review

6.1.1 Storm Drainage System Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following storm drainage system information was taken from the City of Rock Hill Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

Grading Permits

Stormwater management and stormwater drainage computations, including:

- Pre- and post-development velocities, peak rates of discharge, and inflow and outflow hydrographs of stormwater runoff at all existing and proposed points of discharge from the site.
- Post development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10 year frequency 24-hour duration storm event. The City Manager, or his designee, may require a less frequent storm event.
- Off-site discharges of closed storm sewers or improve open channels will be permitted only at natural streams or man-made drainage channels. Discharge velocities shall be reduced to provide a non-erosive velocity flow from structures, channels, or other control measures or to the velocity of the 10 year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.
- Closed Storm Sewer and Culverts - Closed storm sewers and culverts shall be constructed of precast reinforced concrete pipe or box culvert design, in conformance with standards adopted by the City of Rock Hill. They shall be sized to carry the runoff from the appropriate design rainfall and to preclude the creation of backwater inundation of any area outside dedicated drainage easements.
- The rational or modified rational methods are acceptable for sizing individual culverts or storm drains that are not part of a pipe network or system and do not have a contributing drainage area greater than 20 acres. The storm duration for computational purposes for this method shall be equal to the time of concentration of the contributing drainage area or a minimum of 0.1 hours.

6.2 Design Criteria

6.2.1 Introduction

Storm drains shall include necessary open ditches, pipes, culverts, storm sewers, intersectional drains, drop inlets, and other necessary appurtenances, and shall be installed by a sub-divider according to the approved plans and specifications submitted to the Permit Application Center. The Storm Water Checklist should be referenced for additional requirements that should be reflected on all appropriate construction plans (See webpage at www.cityofrockhill.com).

Design factors to be considered during gutter, inlet, and pavement drainage calculations include:

- Return period
- Spread
- Storm drain location

- Inlet types and spacing
- Longitudinal slope
- Cross slope
- Curb and gutter sections
- Roadside and median channels
- Bridge decks
- Shoulder gutter
- Median barriers

6.2.2 Design Storm Requirements

Calculations should include the pre- and post- construction flows for the 2, 10, 25, 50, and 100 year, 24-hr. storm events; however all storm sewer pipes located within right-of-way or easements shall be 18 inches in diameter or greater to accommodate maintenance. (Per the City of Rock Hill Regulations)

Calculations should include the following:

- Methods
- Area
- Coefficient of Runoff
- Intensity
- Flow
- Velocity
- Size
- Grades of pipes and ditches

6.2.3 Flow Velocity and Pipe Requirements

- Discharge velocities shall be reduced to provide a non-erosive velocity flow from structures, channels, or other control measures or to the velocity of the 10 year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater. (Per the City of Rock Hill Zoning Ordinance)

- The minimum desirable physical slope should be 0.5 percent or the slope which will produce a velocity of 2.5 feet per second when the storm sewer is flowing full, whichever is greater.

- Storm drainage systems shall be designed to convey stormwater runoff by gravity flow unless otherwise approved.

- The minimum pipe size to be used in private storm drainage systems shall be 15-inches. Any storm drainage pipe in a right-of-way or drainage easement shall be 18-inches in diameter (See Section 6.2.2).

- Whenever possible, all storm sewer drop inlets, catch basins, and manholes will be installed with the crown of the inlet pipe matching the crown of the outlet pipe, unless the inlet and outlet pipes are the same size. In this case, the total drop across the structure between the inlet and outlet will be no less than 0.1 foot, whenever possible. Variances to this may be addressed by the reviewing engineer, based on the acceptability of the hydraulic grade line calculations.

- Headwalls or flared end sections are required at all inlet and outlet of all pipe systems.

- Minimum cover for Class III RCP is 2 feet and the minimum cover for Class IV RCP is 1 foot. Pipe cover is measured from the top of pipe to the subgrade of the pavement section.

- Maximum pipe length between drainage structures is 500 feet for maintenance purposes.

- All drainage structures shall have manhole access.

6.3 Gutter Flow Calculations

6.3.1 Introduction

This section presents design guidance for gutter flow hydraulics originally published in HEC-12, Drainage of Highway Pavements and AASHTO's Model Drainage Manual. The following in depth design procedures for inlet design may be referenced in the American Association of State Highway and Transportation Officials (AASHTO) Model Drainage Manual, 1991. The following requirements must be met:

6.3.2 Requirements

- Maximum spread of 6-feet in the travel lane based upon the Rational Method using the 10-yr. storm event with a 5 minute intensity.
- Valley gutter shall have a maximum allowable spread of 7-feet.
- Standard 2-feet 6-inch curb and gutter is allowed a total maximum spread of 8-feet from the face of the curb.

6.3.3 Equations

The following form of Manning's Equation should be used to evaluate gutter flow hydraulics for triangular (uniform) gutter cross-sections:

$$\mathbf{Q = [0.56/n]\, S_x^{5/3}\, S^{1/2}\, T^{8/3}} \qquad \textbf{Equation 6.3.3.1}$$

where:

Q = gutter flow rate (cfs), {10-yr. with a 5 minute intensity}
n = Manning's roughness coefficient,
S_x = pavement cross slope (ft/ft),
S = longitudinal slope (ft/ft), and
T = width of flow or spread (ft).

6.3.4 Nomograph

A nomograph for solving Equation 6.3.3.1 is presented in Figure 6.3.4.1. Manning's n values for various pavement surfaces are presented in the table below.

6.3.5 Manning's n Table

Table 6.3.5.1: Manning's n Values for Street and Pavement Gutters

Type of Gutter or Pavement	Range of Manning's n
Concrete gutter, roweled finish	0.012
Asphalt pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter with asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016
For gutters with small slopes, where sediment may accumulate, increase above values of n by	0.002

Note: Estimates are by the Federal Highway Administration

Reference: USDOT, FHWA, HDS-3 (1961)

6.3.6 Uniform Cross Slope

The nomograph in Figure 6.3.4.1 is used with the following procedures to find gutter capacity for uniform cross slopes:

Condition 1: Find spread, given gutter flow.

1. Determine input parameters, including longitudinal slope (S), cross slope (S_x), gutter flow (Q), and Manning's n.
2. Draw a line between the S and S_x scales and note where it intersects the turning line.
3. Draw a line between the intersection point from Step 2 and the appropriate gutter flow value on the capacity scale. If Manning's n = 0.016, use Q from Step 1; if not, use the product of Q and n.
4. Read the value of the spread (T) at the intersection of the line from Step 3 and the spread scale.

Condition 2: Find gutter flow, given spread.

1. Determine input parameters, including longitudinal slope (S), cross slope (S_x), spread (T), and Manning's n.
2. Draw a line between the S and S_x scales and note where it intersects the turning line.
3. Draw a line between the intersection point from Step 2 and the appropriate value on the T scale. Read the value of Q or Q*n from the intersection of that line on the capacity scale.
4. For Manning's n values of 0.016, the gutter capacity (Q) from Step 3 is selected. For other Manning's n values, the gutter capacity times n (Q*n) is selected from Step 3 and divided by the appropriate n value to give the gutter capacity.

6.3.7 Composite Gutter Sections

To find the flow in a gutter with width (W) less than the total spread (T), Figure 6.3.7.1, in combination with Figure 6.3.4.1, is used. Such calculations are generally used for evaluating composite gutter sections or frontal flow for grate inlets.

A direct solution of gutter flow in a composite gutter section is provided in Figure 6.3.7.2. The flow rate at a given spread or the spread at a known flow rate can be found from this figure. Figure 6.3.7.2 involves a complex graphical solution of the equation for flow in a composite gutter section. Typical of graphical solutions, extreme care in using the figure is necessary to obtain accurate results.

Condition 1: Find spread, given gutter flow.

1. Determine input parameters, including longitudinal slope (S), cross slope (S_x), depressed section, or gutter, slope (S_w), depressed section, or gutter, width (W), Manning's n, total gutter flow (Q), and a trial value of gutter capacity above the depressed section (Q_s).
2. Calculate the gutter flow (Q_w) in width W using Equation 6.3.7.1.

$$Q_w = Q - Q_s \qquad \textbf{Equation 6.3.7.1}$$

3. Calculate two ratios: Q_w/Q, which is commonly viewed as the portion of the total gutter flow that can be captured by a grate inlet and known as the efficiency, E_o , and S_w/S_x. Then use Figure 6.3.7.1 to find an appropriate value of W/T.
4. Calculate the spread (T) by dividing the depressed section width (W) by the value of W/T from Step 3.
5. Find the spread above the depressed section (T_s) by subtracting W from the value of T obtained in Step 4.
6. Use the value of T_s from Step 5 along with Manning's n, S, and S_x to find the actual value of Q_s from Figure 6.3.4.1.
7. Compare the value of Q_s from Step 6 to the trial value from Step 1. If values are not comparable, select a new value of Q_s and return to Step 1.

Condition 2: Find gutter flow, given spread.

1. Determine input parameters, including spread (T), spread above the depressed section (T_s), cross slope (S_x), longitudinal slope (S), depressed section slope (S_w), depressed section width (W), Manning's n, and depth of gutter flow (d).

2. Use Figure 6.3.4.1 to determine the capacity of the gutter section above the depressed section (Q_s). Use the procedure for uniform cross slopes, substituting T_s for T.
3. Calculate the ratios W/T and S_w/S_x, and, from Figure 6.3.7.1, find the appropriate value of E_o (the ratio of Q_w/Q).
4. Calculate the total gutter flow using Equation 6.3.7.2.

$$Q = Q_s / (1 - E_o) \qquad \textbf{Equation 6.3.7.2}$$

where:
Q = gutter flow rate (cfs),
Q_s = flow capacity of the gutter section above the depressed section (cfs), and
E_o = ratio of frontal flow to total gutter flow (Q_w/Q).

5. Calculate the gutter flow (Q_w) in width, W, using Equation 6.3.7.1.

Figure 6.3.7.1: Flow in Triangular Gutter Sections (Source: AASHTO Model Drainage Manual, 1991).

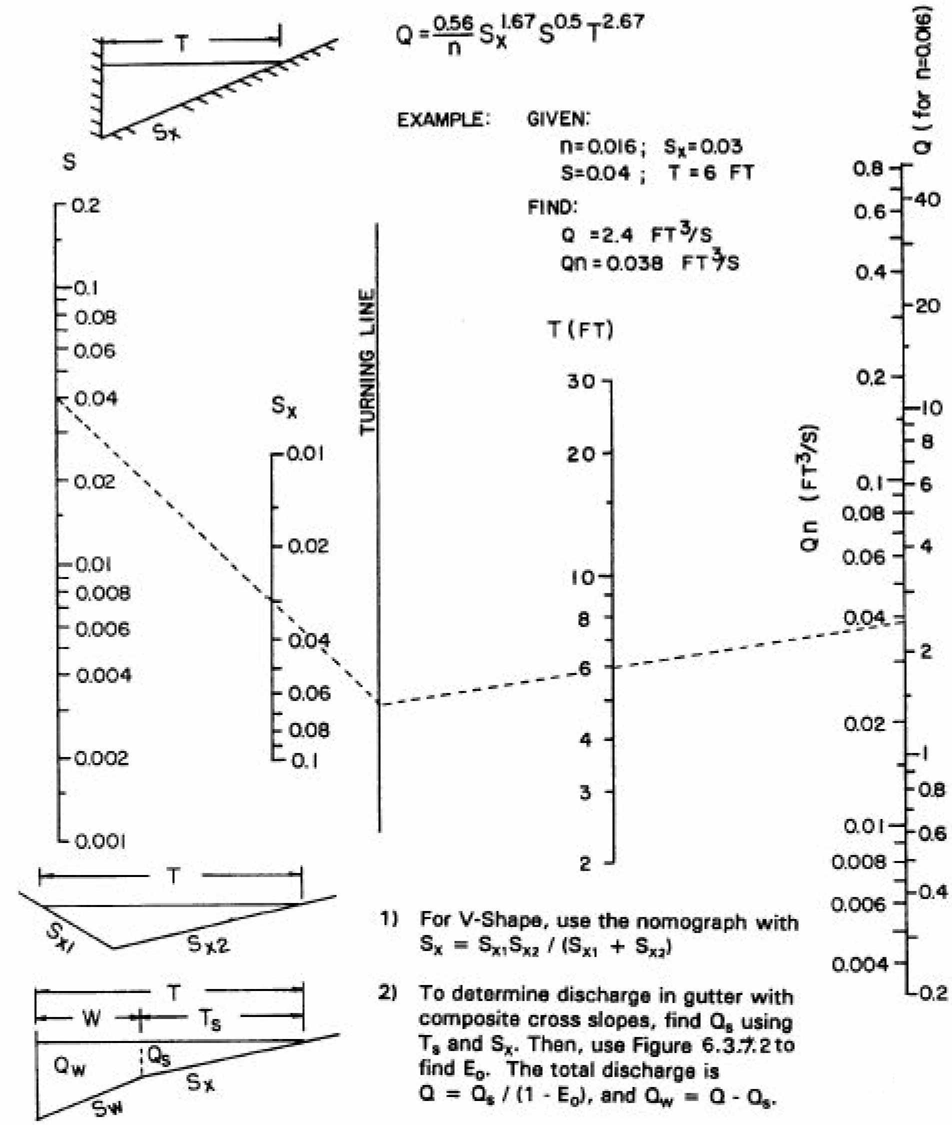


Figure 6.3.7.2: Ratio of Frontal Flow to Total Gutter Flow (Source: AASHTO Model Drainage Manual, 1991).

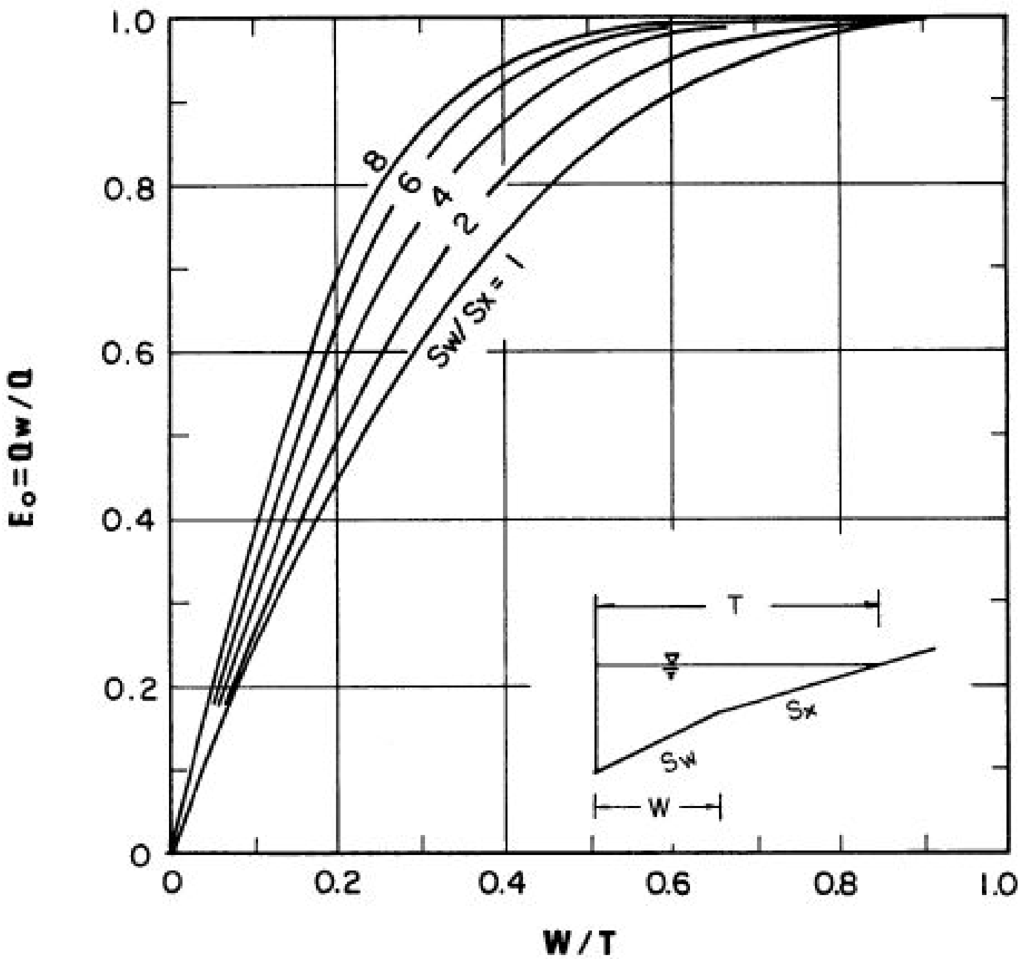
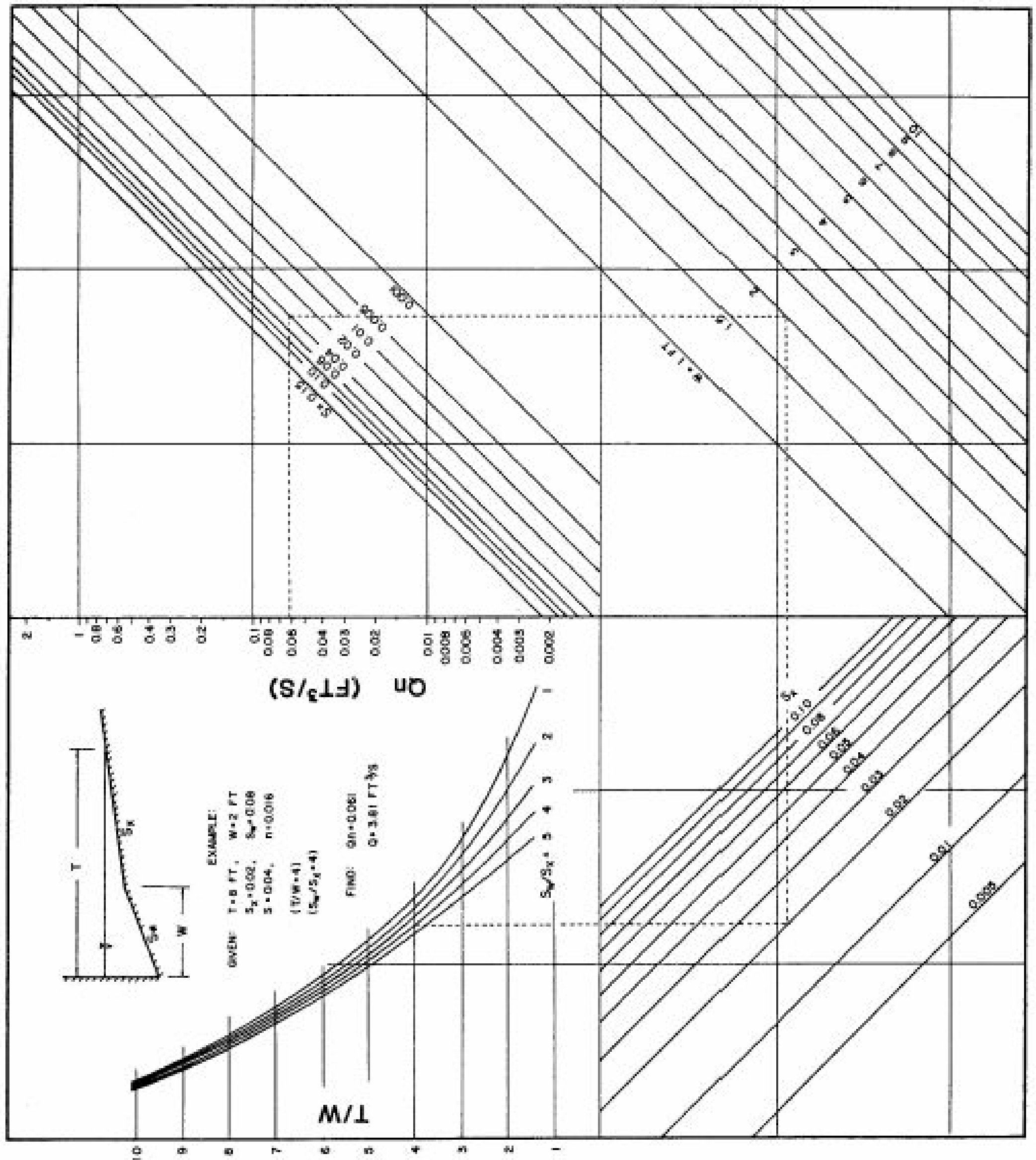


Figure 6.3.7.3: Flow in Composite Gutter Sections (Source: AASHTO Model Drainage Manual, 1991).



6.3.8 Example Problem #1

Given:

T = 8 ft.
n = 0.015
S_x = 0.025 ft/ft
S = 0.01 ft/ft

Find:

(a) Flow in gutter at design spread
(b) Flow in width (W = 2 ft) adjacent to the curb

Solution:

(a) From Figure 6.3.4.1, Q*n = 0.03

Q = Q*n/n = 0.03/0.015 = 2.0 cfs

(b) T = 8 - 2 = 6 ft
(Q*n) = 0.014 (from Figure 6.3.7.1) (flow in 6-foot width outside of width (W))
Q = 0.014/0.015 = 0.9 cfs
Q_w = 2.0 - 0.9 = 1.1 cfs

Flow in the first 2 ft adjacent to the curb is 1.1 cfs and 0.9 cfs in the remainder of the gutter.

6.3.9 Example Problem #2

<u>Given:</u>

T = 6 ft.
T_s = 6 - 1.5 = 4.5 ft.
S_x = 0.03 ft/ft
S = 0.04 ft/ft
S_w = 0.833 ft/ft
n = 0.014
W = 1.5 ft.

<u>Find:</u>

Flow in the composite gutter

<u>Solution:</u>

1) Use Figure 6.3.4.1 to find the gutter section capacity above the depressed section.
   Q_s*n = 0.038
   Q_s = 0.038/0.014 = 2.7 cfs

2) Calculate W/T = 1.5/6 = 0.25 and
   S_w/S_x = 0.0833/0.03 = 2.78
   Use Figure 6.3.7.1 to find E_o = 0.64

3) Calculate the gutter flow using Equation 6.3.7.2.
   Q = 2.7/(1 - 0.64) = 7.5 cfs

4) Calculate the gutter flow in width, W, using Equation 6.3.7.1
   Q_w = 7.5 - 2.7 = **4.8 cfs**

6.4 Storm Drains

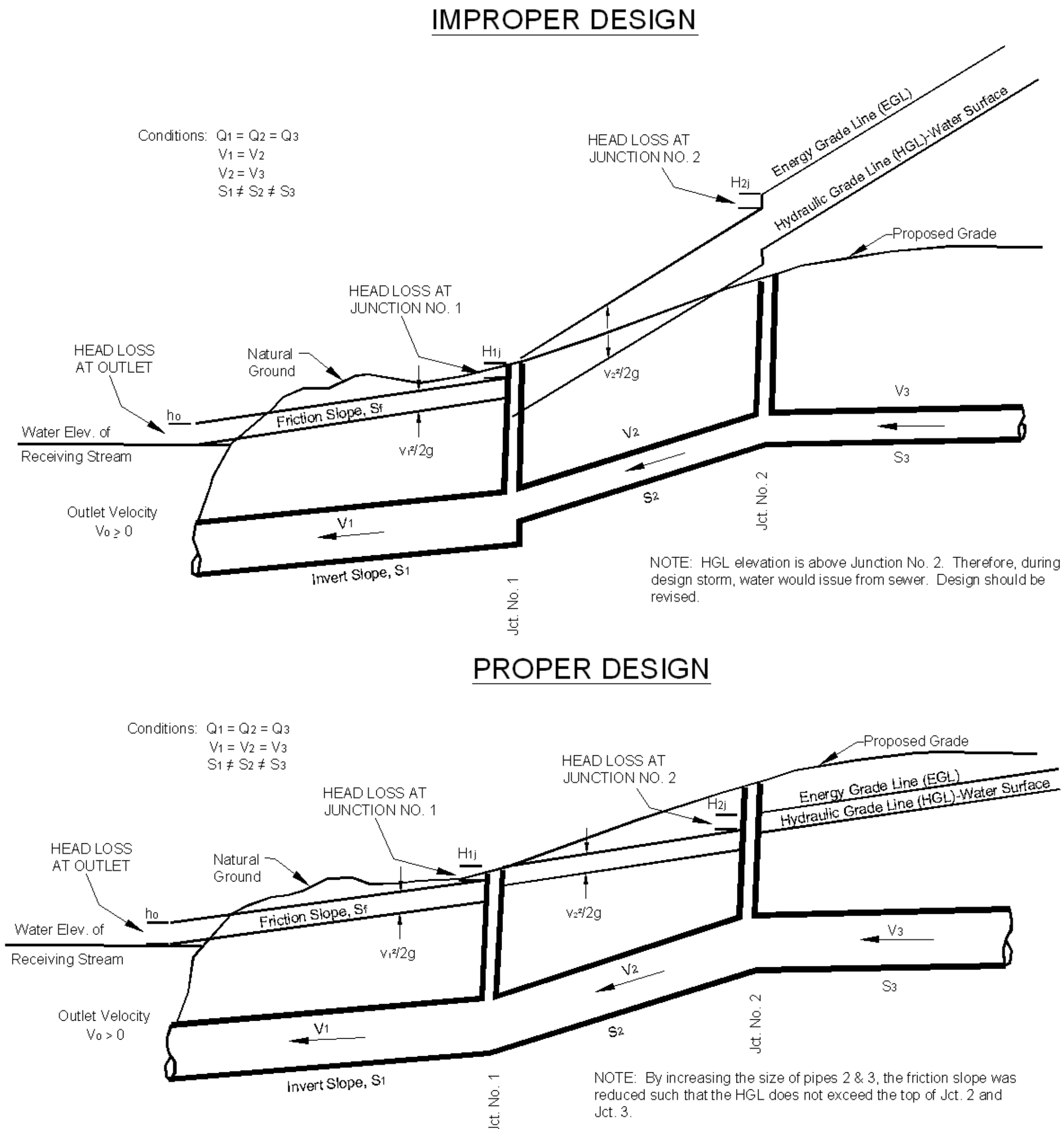
6.4.1 Energy and Hydraulic Grade Lines

All head losses in a storm sewer system are considered in computing the hydraulic grade line. The hydraulic grade line is used to determine the water surface elevations, under design conditions in the various inlets, catch basins, manholes, junction boxes, etc.

A Hydraulic control is a set water surface elevation from which the hydraulic calculations are begun. All hydraulic controls along the alignment are established. If the control is at a main line upstream inlet (inlet control), the hydraulic grade line is equivalent to the water surface elevation minus the entrance loss minus the difference in velocity head. If the control is at the outlet (outlet control), the water surface is the outlet pipe is equivalent to the hydraulic grade line.

The improper and proper design of the energy and hydraulic grade lines for a storm sewer under constant discharge is shown in Figure 6.4.1.1. When the storm sewer system is designed correctly the energy and hydraulic computations will yield representations such as the "proper" drawing in Figure 6.4.1.1.

Figure 6.4.1.1: Energy and Hydraulic Grade Lines for Storm Sewer Under Constant Discharge (Source: Greenville, South Carolina Stormwater Management Design Manual, January 1992)



6.4.2 Nomographs for Flow in Storm Sewers

The nomograph solution of Manning's formula for full flow in circular storm drain pipes is shown in Figures 6.4.2.1 through 6.4.2.5, has been provided to solve the Manning's equation for part full flow in storm drains.

Figure 6.4.2.1: Nomograph for Solution of Manning's Formula for Flow in Storm Sewers (Source: AASHTO Model Drainage Manual, 1991)

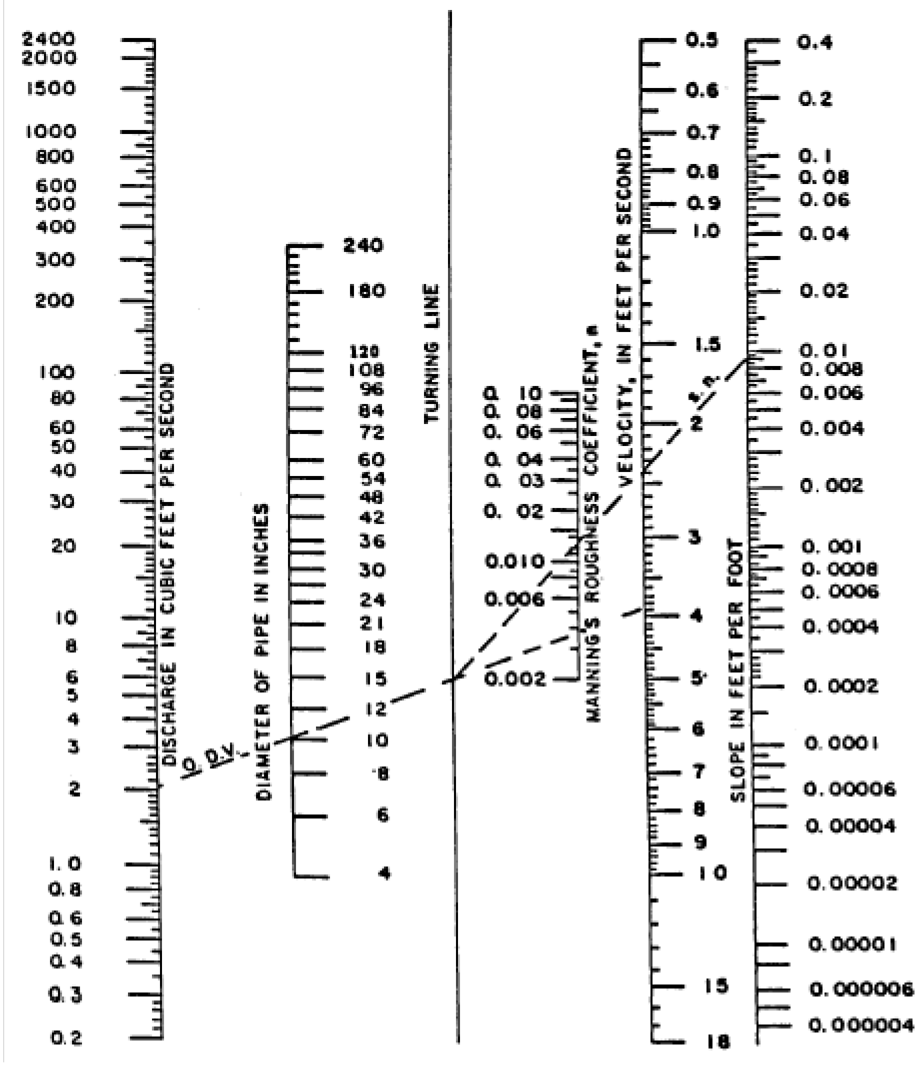


Figure 6.4.2.2: Nomograph for Computing Required Size of Circular Drain, Flowing Full, n=0.013 or 0.015 (Source: AASHTO Model Drainage Manual, 1991)

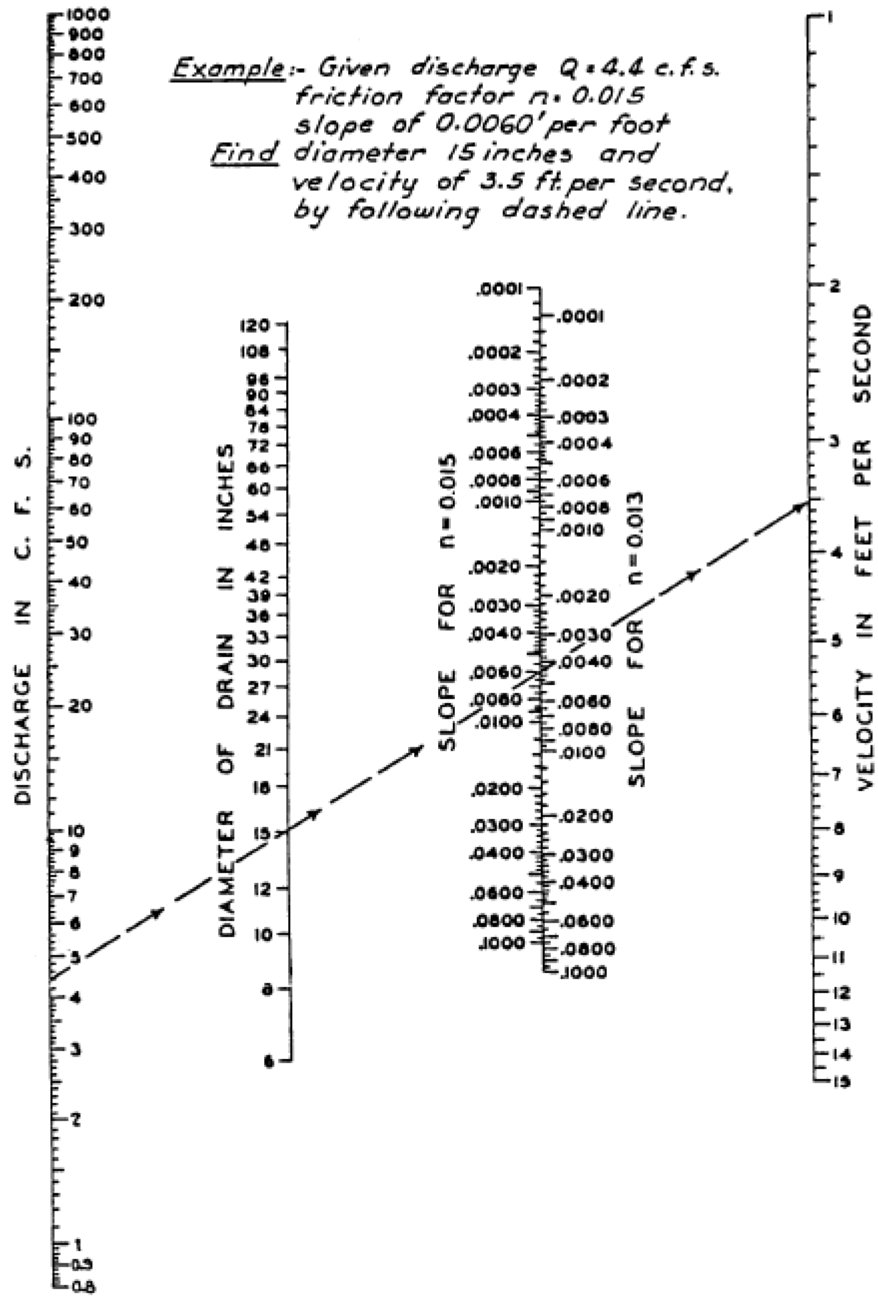


Figure 6.4.2.3: Concrete Pipe Flow Nomograph (Source: AASHTO Model Drainage Manual, 1991)

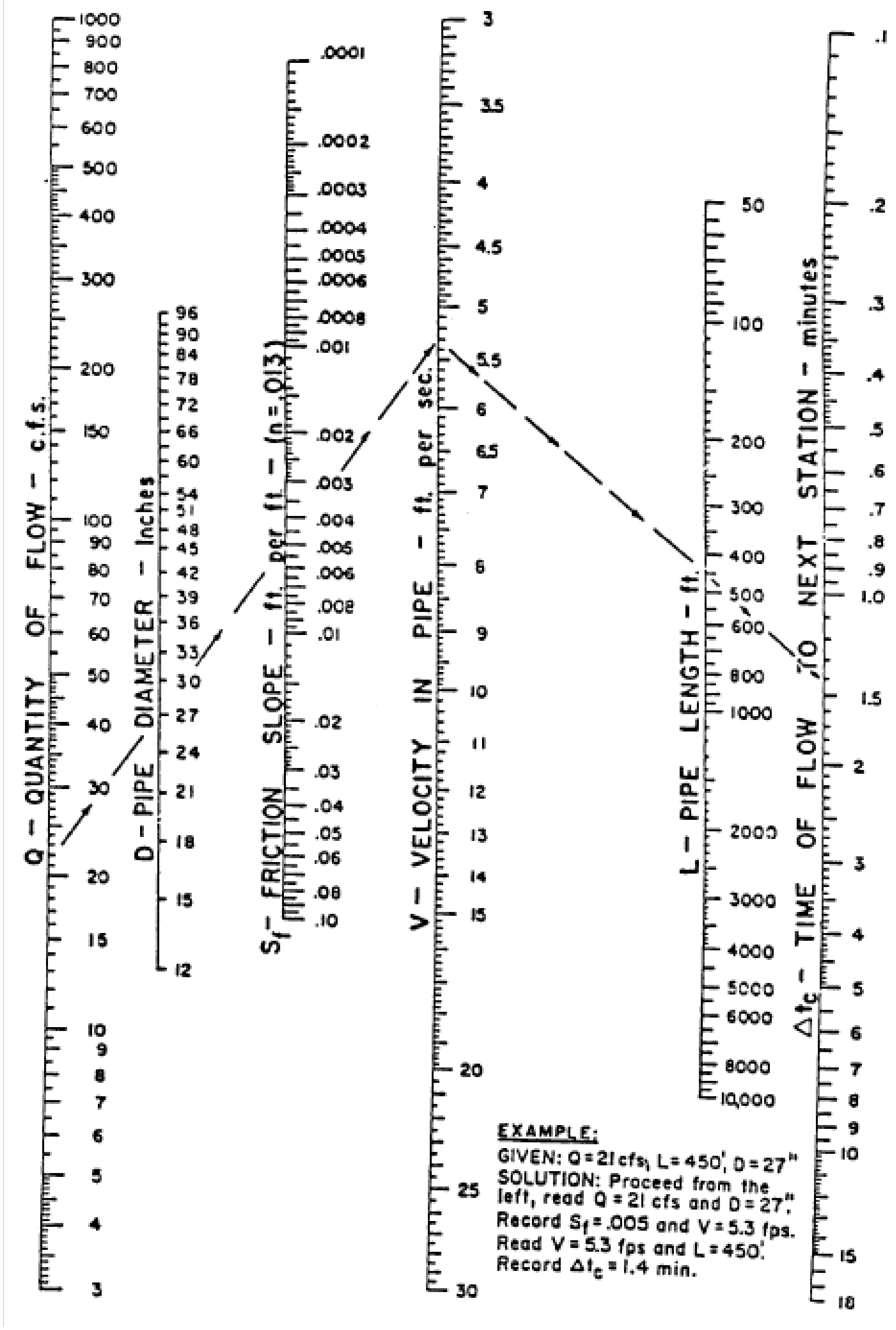
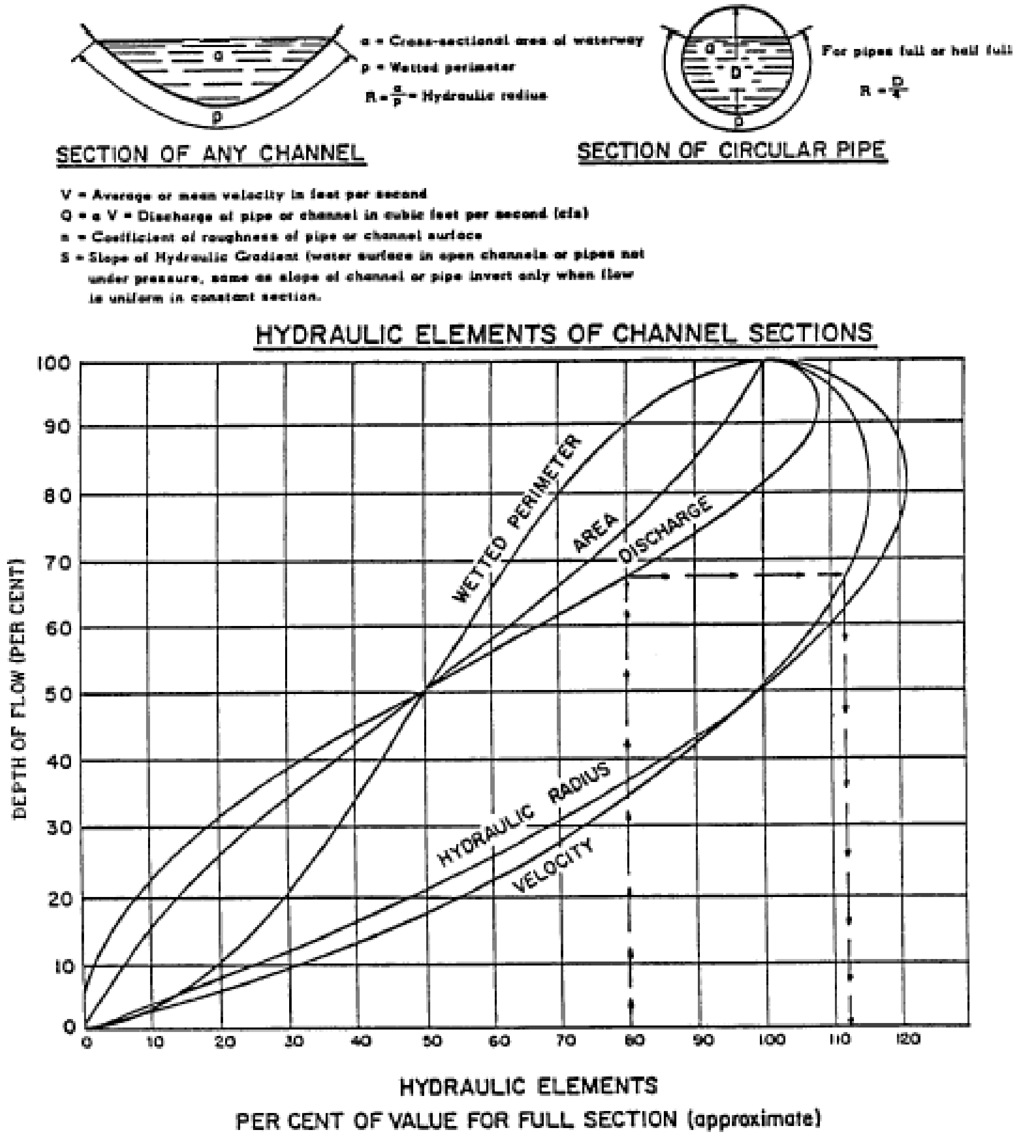


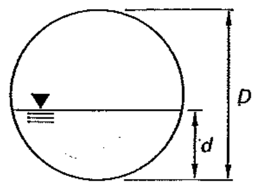
Figure 6.4.2.4: Values of Various Elements of Circular Section for Various Depths of Flow (Source: AASHTO Model Drainage Manual, 1991)



V = Average of mean velocity in feet per second
Q = Discharge of pipe or channel in cubic feet per second
S = Slope of hydraulic grade line

Figure 6.4.2.5: Area, Wetted Perimeter, and Hydraulic Radius of Partially Filled Circular Pipes (Source: Civil Engineering Reference Manual for the PE Exam)

Area, Wetted Perimeter, and Hydraulic Radius
of Partially Filled Circular Pipes



$\frac{d}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wetted perimeter}}{D}$	$\frac{r_h}{D}$	$\frac{d}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wetted perimeter}}{D}$	$\frac{r_h}{D}$
0.01	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
0.02	0.0037	0.2838	0.0132	0.52	0.4127	1.6108	0.2561
0.03	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
0.04	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
0.05	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
0.06	0.0192	0.4949	0.0389	0.56	0.4526	1.6911	0.2676
0.07	0.0242	0.5355	0.0451	0.57	0.4625	1.7113	0.2703
0.08	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
0.09	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
0.10	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
0.11	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2797
0.12	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2818
0.13	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2839
0.14	0.0688	0.7670	0.0871	0.64	0.5308	1.8546	0.2860
0.15	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
0.16	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
0.17	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
0.18	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2935
0.19	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2950
0.20	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
0.21	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2973
0.22	0.1281	0.9764	0.1312	0.72	0.6054	2.0264	0.2984
0.23	0.1365	1.0003	0.1364	0.73	0.6143	2.0488	0.2995
0.24	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3006
0.25	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
0.26	0.1623	1.0701	0.1516	0.76	0.6404	2.1176	0.3025
0.27	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
0.28	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
0.29	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
0.30	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
0.31	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
0.32	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
0.33	0.2260	1.2239	0.1848	0.83	0.6969	2.2916	0.3041
0.34	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
0.35	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
0.36	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
0.37	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
0.38	0.2739	1.3284	0.2061	0.88	0.7320	2.4341	0.3008
0.39	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2995
0.40	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
0.41	0.3032	1.3898	0.2181	0.91	0.7504	2.5322	0.2963
0.42	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
0.43	0.3229	1.4303	0.2257	0.93	0.7612	2.6061	0.2922
0.44	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
0.45	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
0.46	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
0.47	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
0.48	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2735
0.49	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
0.50	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

6.4.3 Storm Drainage Standard Drawings

A variety of storm drainage standard drawings can be found on the City of Rock Hill's website—www.cityofrockhill.com. Included are various SCDOT catch basins, junction boxes, manhole rim and cover, drainage steps, drop inlets, pipe collar, pipe plug, flared end section, and curb transition drawings.

6.5 References

American Association of State Highway and Transportation Officials, 1982. Highway Drainage Guidelines.

Civil Engineering Reference Manual for the PE Exam, 9th Edition
Michael R. Lindeburg, PE.

Federal Highway Administration, 1978. Hydraulics of Bridge Waterways. Hydraulic Design Series No. 1.

Federal Highway Administration, 1985. Hydraulic Design of Highway Culverts. Hydraulic Design Series No. 5.

Federal Highway Administration, 1971. Debris-Control Structures. Hydraulic Engineering Circular No. 9.

Federal Highway Administration, 1987. HY8 Culvert Analysis Microcomputer Program Applications Guide. Hydraulic Microcomputer Program HY8.

HYDRAIN Culvert Computer Program (HY8). Available from McTrans Software, University of Florida, 512 Weil Hall, Gainesville, Florida 32611.

U. S. Department of Interior, 1983. Design of Small Canal Structures.

Greenville, South Carolina Storm Water Management Design Manual, January 1992

CHAPTER 7 – DESIGN OF CULVERTS

7.1 Stormwater Ordinance Review

7.1.1 Culvert Design Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following culvert design information was taken from the Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

Grading Permits

Stormwater management and stormwater drainage computations, including:

- Pre- and post-development velocities, peak rates of discharge, and inflow and outflow hydrographs of stormwater runoff at all existing and proposed points of discharge from the site.
- Post development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10-year frequency 24-hour duration storm event. The City Manager, or his designee, may require a less frequent storm event.
- Off-site discharges of closed storm sewers or improve open channels will be permitted only at natural streams or man-made drainage channels. Discharge velocities shall be reduced to provide a non-erosive velocity flow from a structure, channel, or other control measure or the velocity of the 10-year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.
- The rational or modified rational methods are acceptable for sizing individual culverts or storm drains that are not part of a pipe network or system and do not have a contributing drainage area greater than 20 acres. The storm duration for computational purposes for this method shall be equal to the time of concentration of the contributing drainage area or a minimum of 0.1 hours.
- Closed Storm Sewer and Culverts - Closed storm sewers and culverts shall be constructed of precast or prefabricated pipe or box design, in conformance with standards adopted by the City of Rock Hill. They shall be sized to carry the runoff from the appropriate design rainfall and to preclude the creation of backwater inundation of any area outside dedicated drainage easements.

7.2 Design Criteria

7.2.1 Return Period

Roadway culvert design shall include all cross drainage facilities that transport stormwater runoff under roadways. These systems shall be designed based upon SCDOT requirements where applicable. For non-SCDOT roads, the following criteria shall be followed:

- All cross-drain culverts shall be designed to pass, at a minimum, the 50-year, 24-hour storm event without overtopping the road. The design shall assume a future built-out condition of the drainage basin using the current zoning.
- Additional hydraulic capacity shall be required as necessary to prevent backwater effects that may adversely impact upstream property or structures.

7.2.2 Velocity Limitations

Both minimum and maximum velocities should be considered when designing a culvert. The maximum velocity should be consistent with channel stability requirements at the culvert outlet. As outlet velocities increase, the need for channel stabilization at the culvert outlet increases. If velocities exceed permissible velocities for the various types of nonstructural outlet lining material available, the installation of structural energy dissipators is appropriate.

The maximum allowable velocity for outlet pipes is 10 feet per second, but outlet protection shall be provided where discharge velocities will cause erosion problems.

A minimum velocity of 2.5 feet per second when the culvert is flowing partially full is recommended to ensure a self-cleaning condition during partial depth flow. When velocities below this minimum are anticipated to cause unacceptable sedimentation, the installation of a sediment trap upstream of the culvert should be considered.

7.2.3 Buoyancy Protection

To protect HDPE and metal culverts against buoyancy failures, a standard concrete headwall, flared end, or endwall shall be used to counteract the hydrostatic uplift force.

7.2.4 Length and Slope

Since the capacity of culverts on outlet control will be affected by the length of the culvert, their length should be kept to a minimum and existing facilities shall not be extended without determining the decrease in capacity that will occur.

In general, the culvert slope should be chosen to approximate existing topography.

7.2.5 Debris Control

In designing debris control structures it is recommended the Hydraulic Engineering Circular No. 9 entitled "Debris -Control Structures" is consulted.

7.2.6 Headwater Limitations

The allowable headwater elevation is determined from an evaluation of land use upstream of the culvert and the proposed or existing roadway elevation. Headwater is the depth of water above the culvert invert at the entrance end of the culvert using a 25-year design storm event.

The following criteria related to headwater should be considered:

- Minimize upstream property damage.
- Elevations established to delineate flood plain zoning.
- Low point in the road grade that is not at the culvert location.
- Ditch elevation of the terrain that will permit flow to divert around culvert.
    - Following HW/ D criteria:

      (1) For drainage facilities with cross-section area equal to or less than 30 sq. ft
      -HW/ D = to or < 1. 5.

      (2) For drainage facilities with cross-section area greater than 30 sq. ft -HW/D = to or < 1. 2.

- The headwater should be checked for the 100-year flood to ensure compliance with flood plain management criteria and for most facilities the culvert should be sized to maintain flood-free conditions on major thoroughfares with 18 inches freeboard at the low-point of the road.

- The maximum acceptable outlet velocity should be identified (see Section 5.2.2 in Chapter 5 Open Channel Hydraulics). Either the headwater should be set to produce acceptable velocities or stabilization or energy dissipation should be provided where these velocities are exceeded.

- Other site-specific design considerations should be addressed as required.

- In general the constraint which gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.

7.2.7 Tailwater Considerations

The hydraulic conditions downstream of the culvert site must be evaluated to determine a tailwater depth for a range of discharge. At times there may be a need for calculating backwater curves to establish the tailwater conditions. The following conditions must be considered:

- If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line should be determined.

- For culverts, which discharge to an open channel, the stage-discharge curve for the channel must be determined.

- If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert may establish the design tailwater depth for the upstream culvert.

If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body may establish the culvert tailwater.

7.2.8 Culvert Inlets

Selection of the type of inlet is an important part of culvert design - particularly with inlet control. Hydraulic efficiency and cost can be significantly affected by inlet conditions.

The inlet loss coefficient K_e, is a measure of the hydraulic efficiency of the inlet, with lower values indicating greater efficiency. All methods described in this chapter, directly or indirectly, use inlet coefficients. Recommended inlet coefficients are given in Table 7.2.8.1.

Type of Structure and Design of Entrance	Coefficient K_e
<u>Pipe, Concrete</u>	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls:	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded [radius = 1/12(D)]	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Pipe, or Pipe-Arch, Corrugated Metal</u>	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Box, Reinforced Concrete</u>	
Headwall parallel to embankment (no wingwalls):	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of [1/12(D)] 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(D)] or Beveled top edge	0.2
Wingwalls at 10° or 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: End sections conforming to fill slope, made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance.

7.2.9 Inlets with Headwalls

Headwalls may be used for a variety of reasons:

(1) Increasing the efficiency of the inlet
(2) Providing embankment stability
(3) Providing embankment protection against erosion
(4) Providing protection from buoyancy
(5) Shorten the length of the required structure

The relative efficiency of the inlet depends on the pipe material. Concrete headwalls are required for all metal and HDPE culverts and where buoyancy protection is necessary. Corrugated pipe in a headwall is essentially a square-edged with an inlet coefficient of about 0.5.

For tongue and groove, or bell and concrete pipe, little increase in hydraulic efficiency is realized by adding a headwall. The primary reasons for using headwalls are for embankment protection, buoyancy control, and ease of maintenance.

7.2.10 Wingwalls and Aprons

Wingwalls are used where the side slopes of the channel adjacent to the entrance are unstable or where the culvert is skewed to the normal channel flow.

Little increase in hydraulic efficiency is realized with the use of wingwalls, regardless of the pipe material used and, therefore, the use should be justified for other reasons. Wingwalls can be used to increase hydraulic efficiency if designed as a side-tapered inlet. The figure below illustrates several cases where wingwalls are justified.

If high headwater depths are encountered or the approach velocity in the channel produces scour, a short channel apron should be provided at the toe of the headwall. This apron should extend at least one pipe diameter upstream from the entrance, and the top of the apron should not protrude above the normal streambed elevation.

7.2.11 Improved Inlets

Where inlet conditions control the amount of flow that can pass through the culvert, improved inlets can greatly increase the hydraulic performance at the culvert.

7.2.12 Material Selection

For culvert selection, only reinforced concrete pipe (RCP), high density polyethylene (HDPE), and corrugated aluminum alloy (CAAP) is allowed within City street right-of-way installed per SCDOT Specifications, current edition. Recommended Manning's n values are given in Table 7.2.12.1.

Table 7.2.12.1 Manning's n Values

Type of Conduit	Wall & Joint Description	Manning's n
Concrete Pipe	Good joints, smooth walls	0.011-0.013
	Good joints, rough walls	0.014-0.016
	Poor joints, rough walls	0.016-0.017
Concrete Box	Good joints, smooth finished walls	0.014-0.018
	Poor joints, rough, unfinished walls	0.014-0.018
Corrugated Metal Pipes and Boxes Angular Corrugations	2 2/3 by 1/2 inch corrugations	0.022-0.027
	6 by 1 inch corrugations	0.022-0.025
	5 by 1 inch corrugations	0.025-0.026
	3 by 1 inch corrugations	0.027-0.028
	6 by 2 inch structural plate	0.033-0.035
	9 by 2 1/2 inch structural plate	0.033-0.037
Corrugated Metal Pipes, Helical Corrugations, Full Circular Flow	2 2/3 by 1/2 inch corrugated 24 inch plate width	0.012-0.024
Spiral Rib Aluminum Pipe	3/4 by 3.4 in recess at 12 inch spacing, good joints	0.012-0.013

7.2.13 Culvert Sizes

The minimum private culvert diameter shall be 15 inches. Culverts 18-inches in diameter or larger must be used in all right-of-ways and public easements.

7.2.14 Weep Holes

Weep holes are sometimes used to relieve uplift pressure. Filter materials should be used in conjunction with the weep holes in order to interpret the flow and prevent the formation of piping channels. The filter materials should be designed as underdrain filter so that it will not become clogged and so that piping cannot occur through the pervious material and the weep hole. Plastic woven filter cloth would be placed over the weep hole in order to keep the pervious material from being carried into the culvert.

7.2.15 Outlet Protection

See Chapter 9 Energy Dissipation chapter for information on the design of outlet protection.

7.2.16 Erosion and Sediment Control

For erosion and sediment control, the use of one or a combination of the following control measures may be appropriate:

- Silt boxes
- Brush silt barriers
- Temporary silt fence and filter cloth
- Check dams

See Chapter 10 Best Management Practices, Chapter 11 The Erosion and Sediment Control Plan, or the South Carolina State Erosion and Sediment Control Manual for design standards and details.

These measures will be utilized as necessary during construction to minimize pollution of streams and damages to wetlands.

7.2.17 Environmental Considerations

In addition to controlling erosion, siltation and debris at the culvert site, care must be exercised in selecting the location of the culvert site. Environmental considerations are a very important aspect of culvert design.

Where compatible with good hydraulic engineering, a site should be selected that will permit the culvert to be constructed to cause the least impact on the stream or wetlands. This selection must consider the entire site, including any necessary lead channels.

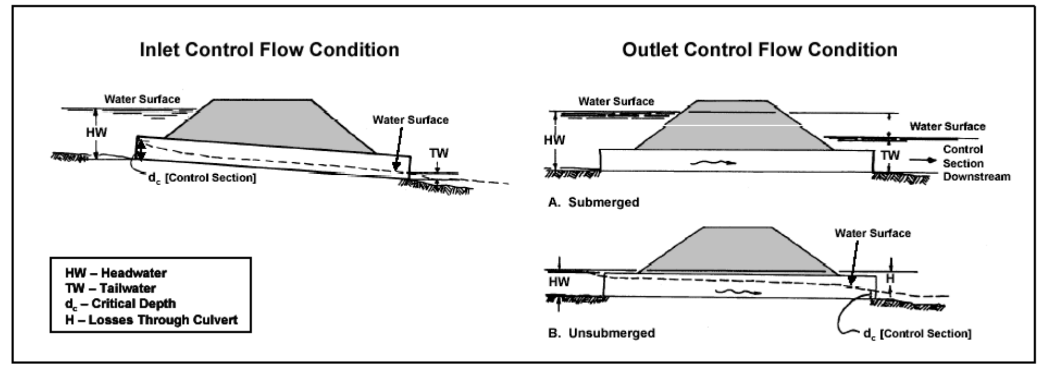
7.2.18 Types of Flow Control

There are two types of flow conditions for culverts that are based upon the location of the control section and the critical flow depth:

Inlet Control – Inlet control occurs when the culvert barrel is capable of conveying more flow than the inlet will accept. This typically happens when a culvert is operating on a steep slope. The control section of a culvert is located just inside the entrance. Critical depth occurs at or near this location, and the flow regime immediately downstream is supercritical.

Outlet Control – Outlet control flow occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. The control section for outlet control flow in a culvert is located at the barrel exit or further downstream. Either subcritical or pressure flow exists in the culvert barrel under these conditions.

Figure 7.2.18.1: Culvert Flow Conditions (Adapted from: HDS-5, 1985).



Proper culvert design and analysis requires checking for both inlet and outlet control to determine which will govern particular culvert designs. For more information on inlet and outlet control, see the FHWA Hydraulic Design of Highway Culverts, HDS-5, 1985.

7.2.19 Nomographs

The use of culvert design nomographs requires a trial and error solution. Nomograph solutions provide reliable designs for many applications. It should be remembered that velocity, hydrograph routing, roadway overtopping, and outlet scour require additional, separate computations beyond what can be obtained from the nomographs. Figures 7.2.19.1 and 7.2.19.2 show examples of an inlet control and outlet control nomograph for the design of concrete pipe culverts. For other culvert designs, refer to the complete set of nomographs in Appendix C at the end of this manual.

The nomographs referenced in the Federal Highway Administration (FHWA) Hydraulic Design Series Number 5 (HDS 5) may be used in the design of culverts. Similar nomographs from other sources may be used if they are used in a similar manner as the techniques described for the FHWA nomographs.

Figure 7.2.19.1: Headwater Depth for Concrete Pipe Culvert with Inlet Control (Adapted from: HDS-5, 1985)

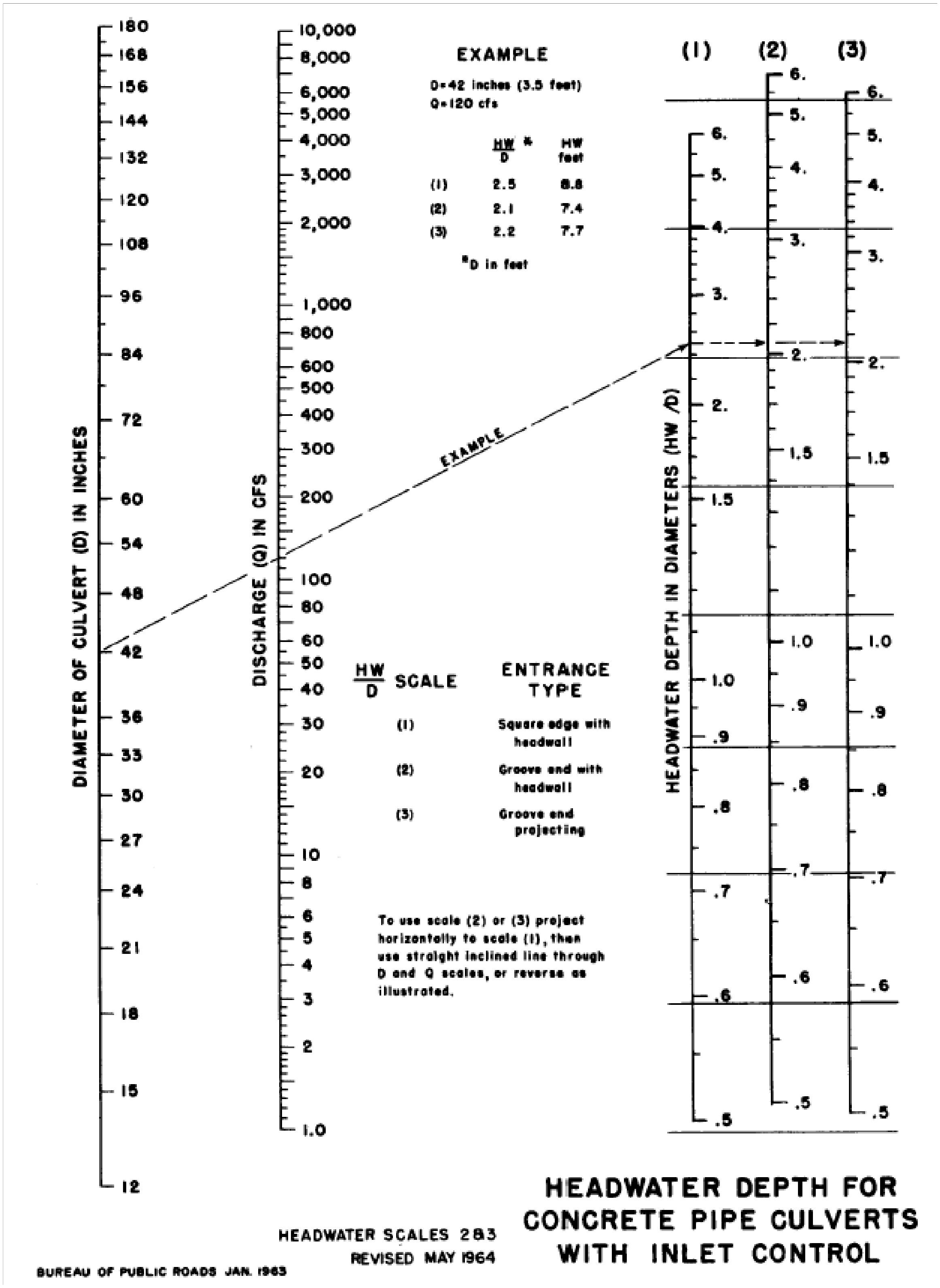
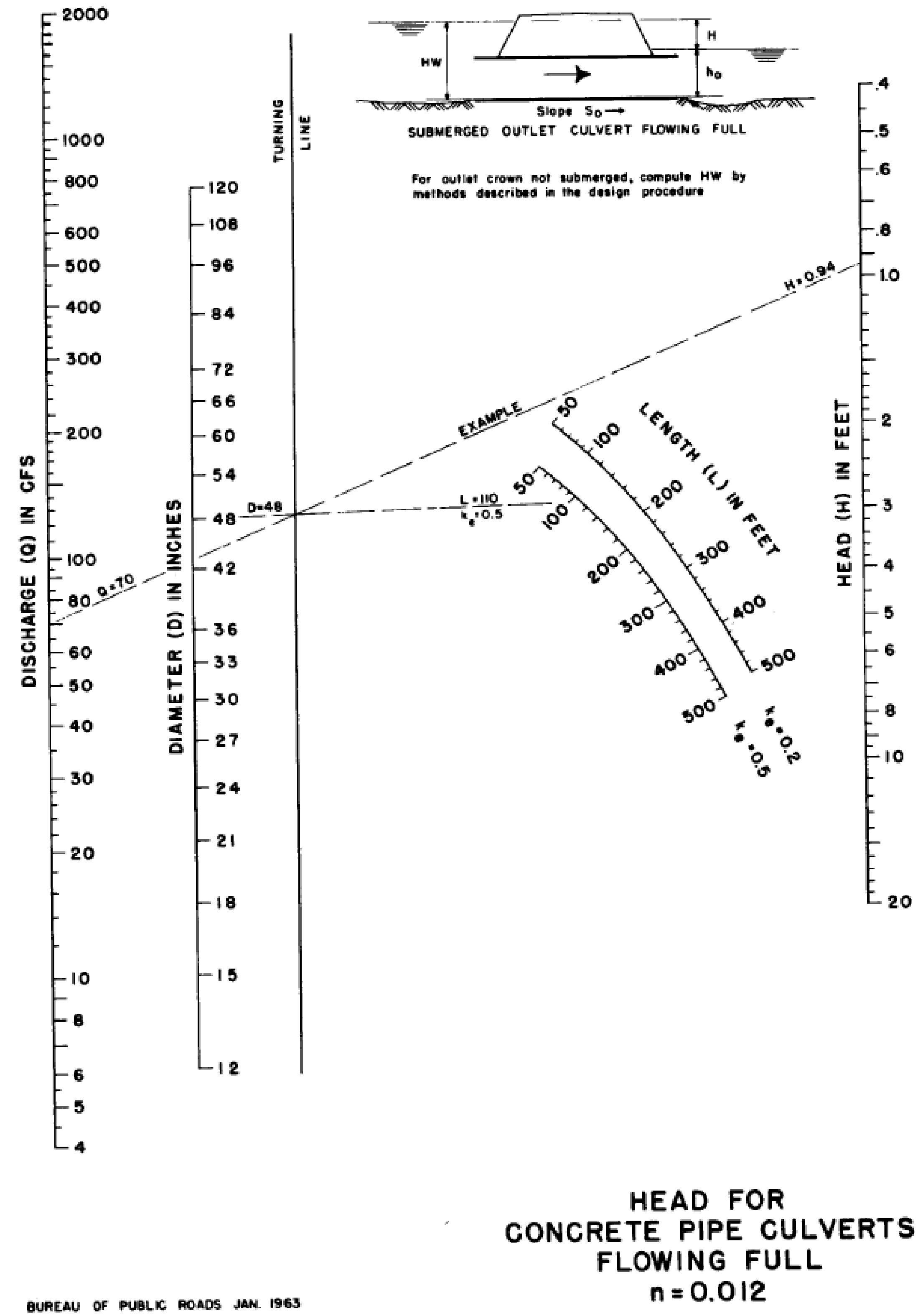


Figure 7.2.19.2: Head for Concrete Pipe Culverts Flowing Full (Adapted from: HDS-5, 1985)



7.2.20 Design Procedure

The following design procedure requires the use of inlet and outlet nomographs.

(Step 1) List design data:

Q = discharge (cfs)
L = culvert length (ft)
S = culvert slope (ft/ft)
TW= tailwater depth (ft)
V = velocity for trial diameter (ft/s)
K_e= inlet loss coefficient
HW= allowable headwater depth for the design storm (ft)

(Step 2) Determine trail culvert size by assuming a trial velocity 3 to 5 ft/s and computing the culvert area, A = Q/V. Determine the culvert diameter (inches).

(Step 3) Find the actual HW for the trial size culvert for both inlet and outlet control.

- For inlet control, enter inlet control nomograph with D and Q and find HW/D for the proper entrance type.
- Compute HW and, if too large or too small, try another culvert size before computing HW for outlet control.
- For outlet control enter the outlet control nomograph with the culvert length, entrance loss coefficient, and trial culvert diameter.
- To compute HW, connect the length scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. Compute the headwater elevation HW from the equation:

$$HW = H + h_o - L*S \qquad \textbf{Equation 7.2.20.1}$$

Where:
h_o = ½ (critical depth + D), or tailwater depth, whichever is greater
L = culvert length
S = culvert slope

(Step 4) Compare the computed headwaters and use the higher HW nomograph to determine if the culvert is under inlet or outlet control.

- If inlet control governs, then the design is complete and no further analysis is required.
- If outlet control governs and the HW is unacceptable, select a larger trial size and find another HW with the outlet control nomographs. Since the smaller size of culvert had been selected for allowable HW by the inlet control nomographs, the inlet control for the larger pipe need not be checked.

(Step 5) Calculate exit velocity and if erosion problems might be expected, refer to Chapter 9 for appropriate energy dissipation designs.

7.2.21 Performance Curves - Roadway Overtopping

A performance curve for any culvert can be obtained from the nomographs by repeating the steps outlined above for a range of discharges that are of interest for that particular culvert design. A graph is then plotted of headwater versus discharge with sufficient points so that a curve can be drawn through the range of interest. These curves are applicable through a range of headwater, velocities, and scour depths versus discharges for a length and type of culvert. Usually charts with length intervals of 25 to 50 feet are satisfactory for design purposes. Such computations are made much easier by the use of computer programs.

To complete the culvert design, roadway overtopping should be analyzed. A performance curve showing the culvert flow as well as the flow across the roadway is a useful analysis tool. Rather than using a trial and error procedure to determine the flow division between the overtopping flow and the culvert flow, an overall performance curve can be developed.

The overall performance curve can be determined as follows:

(Step 1) Select a range of flow rates and determine the corresponding headwater elevations for the culvert flow alone. The flow rates should fall above and below the design discharge and cover the entire flow range of interest. Both inlet and outlet control headwaters should be calculated.

(Step 2) Combine the inlet and outlet control performance curves to define a single performance curve for the culvert.

(Step 3) When the culvert headwater elevations exceed the roadway crest elevation, overtopping will begin. Calculate the equivalent upstream water surface depth above the roadway (crest of weir) for each selected flow rate. Use these water surface depths and equation 4.3.2 to calculate flow rates across the roadway.

$$\mathbf{Q = C_d * L_r * (HW)^{1.5}} \qquad \textbf{Equation 7.2.21.1}$$

Where:
Q = overtopping flow rate (ft^3/s),
C_d = overtopping discharge coefficient,
L_r = length of roadway (ft), and
HW = upstream depth, measured from the roadway crest to the water surface upstream of the weir drawdown (ft).

Note: See Figure 7.2.21.1 on the next page for guidance in determining a value for Cd. For more information on calculating overtopping flow rates see pages 39 - 42 in HDS No. 5.

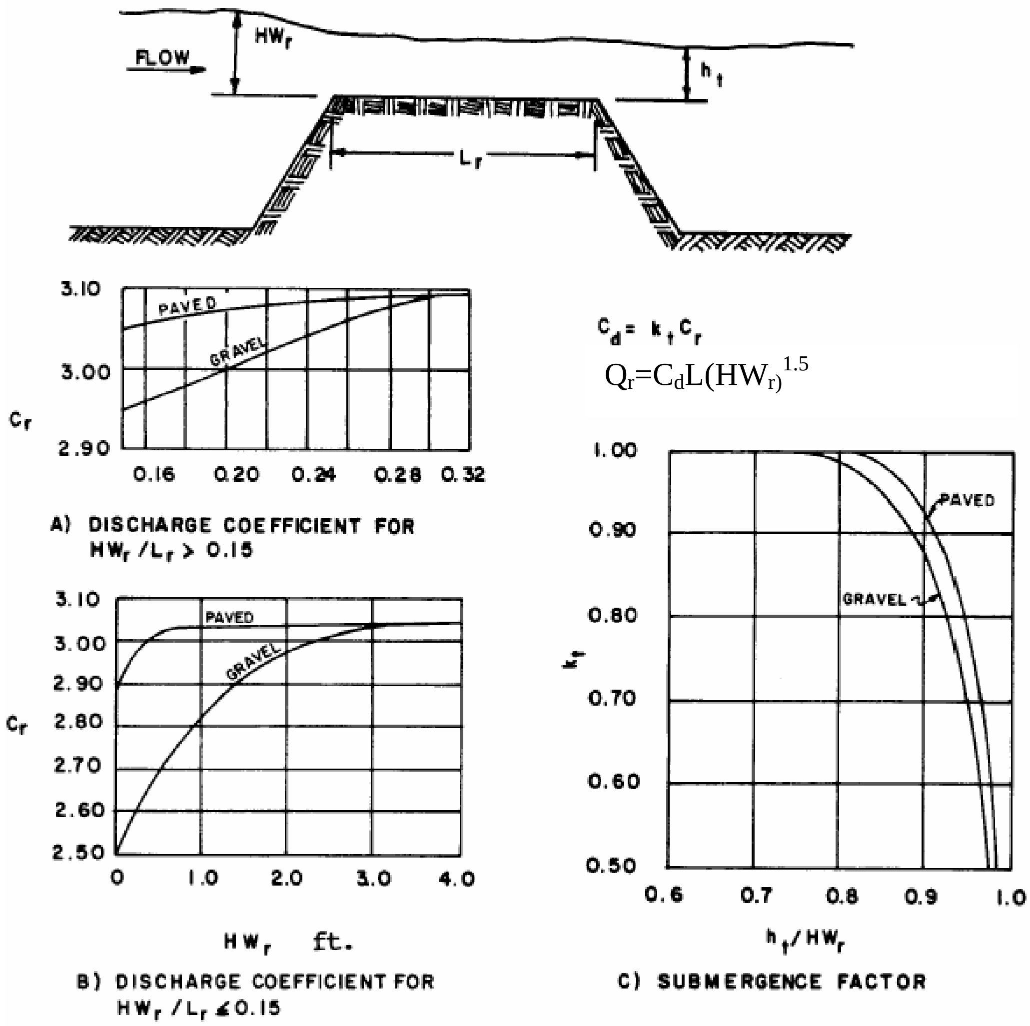
(Step 4) Add the culvert flow and the roadway overtopping flow at the corresponding headwater elevations to obtain the overall culvert performance curve.

7.2.22 Storage Routing

A significant storage capacity behind a highway embankment attenuates a flood hydrograph. Because of the reduction of the peak discharge associated with this attenuation, the required capacity of the culvert, and its size, may be reduced considerably. If significant storage is anticipated behind a culvert, the design should be checked by routing the design hydrographs through the culvert to determine the discharge and stage behind the culvert. Additional routing procedures are outlined in Hydraulic Design of Highway Culverts, Section V - Storage Routing, HDS No. 5, Federal Highway Administration.

Note: Storage should be taken into consideration only if the storage area will remain available for the life of the culvert as a result of purchase of ownership or right-of-way or an easement has been acquired.

Figure 7.2.21.1: Discharge Coefficients for Roadway Overtopping (Source: HDS No. 5, 1985)



7.2.23 Culvert Design Example

The following example problem illustrates the procedures to be used in designing culverts using the nomographs.

Problem

Size a culvert given the following example data, which were determined by physical limitations at the culvert site and hydraulic procedures described elsewhere in this manual.

Input Data

Discharge for 2-yr flood = 35 cfs,
Discharge for 25-yr flood = 70 cfs,
Allowable HW for 25-yr discharge = 5.25 ft,
Length of culvert = 100 ft,
Natural channel invert elevations - inlet = 15.50 ft, outlet = 14.30 ft,
Culvert slope = 0.012 ft/ft,
Tailwater depth for 25-yr discharge = 3.5 ft,
Tailwater depth is the normal depth in downstream channel, and
Entrance type = Groove end with headwall.

Computations

(1) Assume a culvert velocity of 5 ft/s. Required flow area = 70 cfs/5 ft/s = 14 ft2 (for the 25-yr recurrence flood).

(2) The corresponding culvert diameter is about 48 in. This can be calculated by using the formula for area of a circle: Area = (3.14D2)/4 or D = (Area times 4/3.14)0.5. Therefore: D = ((14 sq ft x 4)/3.14)0.5 x 12 in/ft) = 50.6 in

(3) A grooved end culvert with a headwall is selected for the design. Using the inlet control nomograph (Figure 7.2.19.1), with a pipe diameter of 48 inches and a discharge of 70 cfs; read a HW/D value of 0.93.

(4) The depth of headwater (HW) is (0.93) x (4) = 3.72 ft, which is less than the allowable headwater of 5.25 ft. Since 3.72 ft is considerably less than 5.25 try a small culvert.

(5) Using the same procedures outlined in steps 4 and 5 the following results were obtained.

42-inch culvert – HW = 4.13 ft
36-inch culvert – HW = 4.98 ft

Select a 36-inch culvert to check for outlet control.

(6) The culvert is checked for outlet control by using Figure 7.2.19.2.

With an entrance loss coefficient K_e of 0.20, a culvert length of 100 ft, and a pipe diameter of 36 in., an H value of 2.8 ft is determined from the figure. The headwater for outlet control is computed by the equation: HW = H + h_o - LS

Compute h_o
h_o = TW or ½ (critical depth in culvert + D), whichever is greater.
h_o = 3.5 ft or ho = ½ (2.7 + 3.0) = 2.85 ft
Note: critical depth is obtained from Chart 4 in Appendix C.

Therefore: h_o = 3.5 ft
The headwater depth for outlet control is:
HW = H + h_o - LS = 2.8 + 3.5 - (100) x (0.012) = 5.10 ft

(7) Since HW for outlet control (5.10 ft) is greater than the HW for inlet control (4.98 ft), outlet control governs the culvert design. Thus, the maximum headwater expected for a 25-year recurrence flood is 5.10 ft, which is less than the allowable headwater of 5.25 ft.

(8) Estimate outlet exit velocity. Since this culvert is on outlet control and discharges into an open channel downstream with tailwater above culvert, the culvert will be flowing full at the flow depth in the channel. Using the design peak discharge of 70 cfs and the area of a 36-inch or 3.0-foot diameter culvert the exit velocity will be:

Q = VA
Therefore: $V = 70 / (3.14(3.0)^2)/4 = 9.9$ ft/s

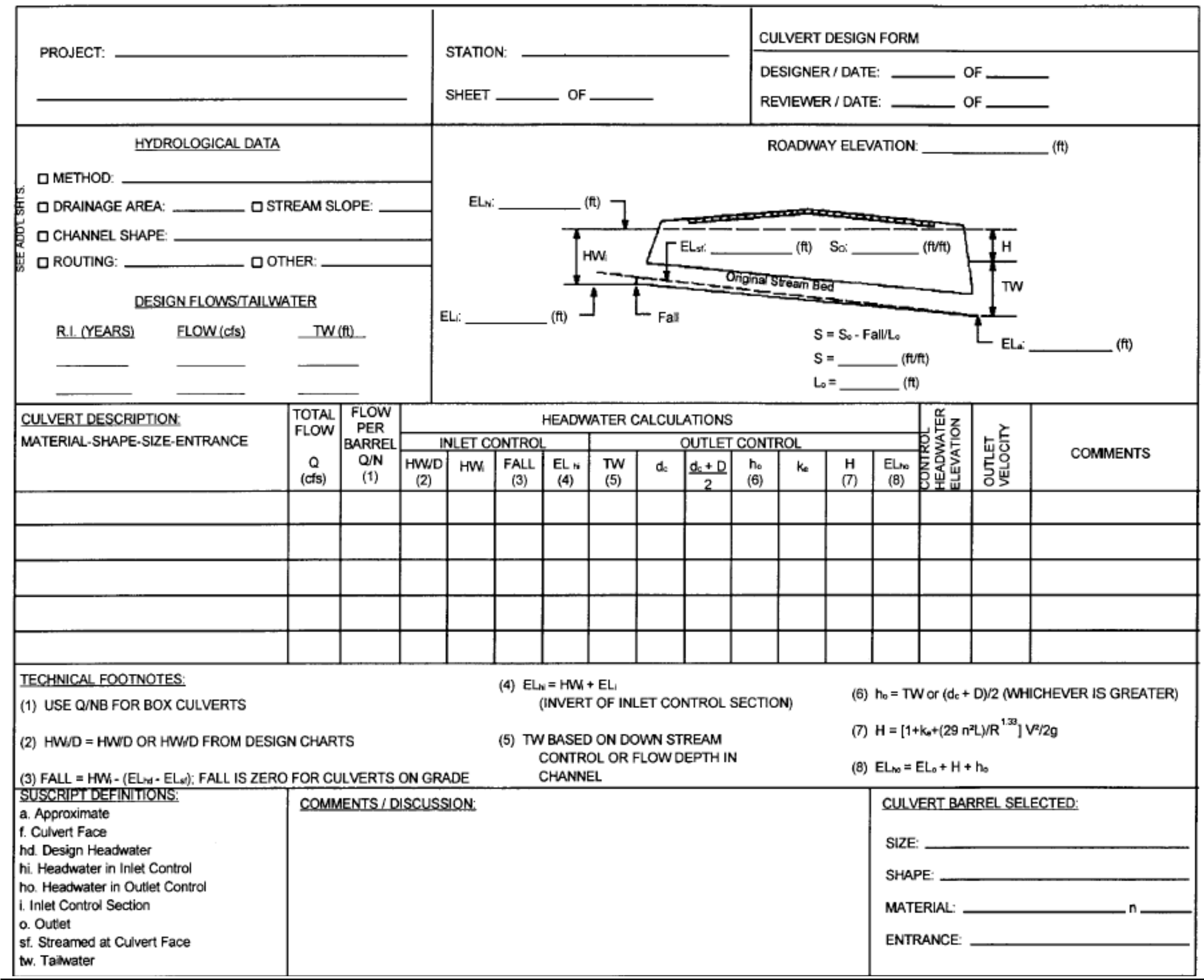
With this high velocity, consideration should be given to provide an energy dissipator at the culvert outlet. See Chapter 9 (Energy Dissipation).

(9) Check for minimum velocity using the 2-year flow of 35 cfs.
Therefore: V = 35 / (3.14(3.0)2/4 = 5.0 ft/s > minimum of 2.5 - OK

(10) The 100-year flow should be routed through the culvert to determine if any flooding problems will be associated with this flood.

Figure 7.2.23.1 provides a convenient form to organize culvert design calculations.

Figure 7.2.23.1: Culvert design calculation form (Source: HDS No. 5, 1985)


PROJECT: ______

STATION: ______

SHEET ______ OF ______

CULVERT DESIGN FORM

DESIGNER / DATE: ______ OF ______

REVIEWER / DATE: ______ OF ______

HYDROLOGICAL DATA

- ☐ METHOD: ______
- ☐ DRAINAGE AREA: ______ ☐ STREAM SLOPE: ______
- ☐ CHANNEL SHAPE: ______
- ☐ ROUTING: ______ ☐ OTHER: ______

SEE ADD'L SHTS.

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)

ROADWAY ELEVATION: ______ (ft)

CULVERT DESCRIPTION: MATERIAL-SHAPE-SIZE-ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL				OUTLET CONTROL							CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
			HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	TW (5)	d_c	$\frac{d_c + D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)			

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HW_i/D = HW/D OR HW_i/D FROM DESIGN CHARTS

(3) FALL = $HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL

(6) h_o = TW or $(d_c + D)/2$ (WHICHEVER IS GREATER)

(7) $H = [1+k_e+(29\ n^2L)/R^{1.33}]\ V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUSCRIPT DEFINITIONS:

a. Approximate
f. Culvert Face
hd. Design Headwater
hi. Headwater in Inlet Control
ho. Headwater in Outlet Control
i. Inlet Control Section
o. Outlet
sf. Streamed at Culvert Face
tw. Tailwater

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED:

SIZE: ______

SHAPE: ______

MATERIAL: ______ n ______

ENTRANCE: ______

7.3 Flood Routing and Culvert Design

7.3.1 Introduction

Flood routing through a culvert is a practice that evaluates the effect of temporary upstream ponding caused by the culvert's backwater. By not considering flood routing it is possible that the findings from culvert analyses will be conservative. If the selected allowable headwater is accepted without flood routing, then costly over designs of both the culvert and outlet protection may result, depending on the amount of temporary storage involved. However, if storage is used in the design of culverts, consideration should be given to:

- The total area of flooding,
- The average time that bankfull stage is exceeded for the design flood up to 48 hours in rural areas or 6 hours in urban areas, and
- Ensuring that the storage area will remain available for the life of the culvert through the purchase of right-of-way or easement.

7.3.2 Design Procedure

The design procedure for flood routing through a culvert is the same as for reservoir routing. The site data and roadway geometry are obtained and the hydrology analysis completed to include estimating a hydrograph. Once this essential information is available, the culvert can be designed. Flood routing through a culvert can be time consuming. It is recommended that a computer program be used to perform routing calculations; however, an engineer should be familiar with the culvert flood routing design process.

A multiple trial and error procedure is required for culvert flood routing. In general:

1. A trial culvert(s) is selected.
2. A trial discharge for a particular hydrograph time increment (selected time increment to estimate discharge from the design hydrograph) is selected.
3. Flood routing computations are made with successive trial discharges until the flood routing equation is satisfied.
4. The hydraulic findings are compared to the selected site criteria.
5. If the selected site criteria are satisfied, then a trial discharge for the next time increment is selected and this procedure is repeated; if not, a new trial culvert is selected and the entire procedure is repeated.

7.4 References

American Association of State Highway and Transportation Officials, 1982. Highway Drainage Guidelines.

Federal Highway Administration, 1978. Hydraulics of Bridge Waterways. Hydraulic Design Series No. 1.

Federal Highway Administration, 1985. Hydraulic Design of Highway Culverts. Hydraulic Design Series No. 5.

Federal Highway Administration, 1971. Debris-Control Structures. Hydraulic Engineering Circular No. 9.

Federal Highway Administration, 1987. HY8 Culvert Analysis Microcomputer Program Applications Guide. Hydraulic Microcomputer Program HY8.

HYDRAIN Culvert Computer Program (HY8). Available from McTrans Software, University of Florida, 512 Weil Hall, Gainesville, Florida 32611.

U. S. Department of Interior, 1983. Design of Small Canal Structures.

Greenville, South Carolina Storm Water Management Design Manual, January 1992

CHAPTER 8 – STORAGE AND DETENTION

8.1 Zoning Ordinance Review

8.1.1 Storage and Detention Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following storage and detention information was taken from the Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

<u>Stormwater</u>

- The developer shall install on-site facilities for the detention-storage and controlled release of stormwater runoff in accordance with this manual, the Zoning Ordinance, and the approved plans.

- Stormwater management and stormwater drainage computations should include:

  - Pre- and post-development velocities, peak rates of discharge, and inflow and outflow hydrographs of stormwater runoff at all existing and proposed points of discharge from the site

- All stormwater management and sediment control practices shall be designed, constructed and maintained with consideration for the proper control of mosquitoes and other vectors. These requirements must be part of the inspection and maintenance agreement as specified by the City of Rock Hill. These requirements must be reviewed during any inspection. Practices may include, but are not limited to:

  - The bottom of retention and detention ponds should be graded and have a slope not less than 0.5 percent. There should be no depressions in a normally dry detention facility where water might pocket when the water level is receding.

  - Normally dry swales and detention pond bottoms should be utilized in permanently wet structures to prevent an overgrowth of vegetation in the pond. Manual harvesting is preferred.

  - Fish may be stocked in permanently wet retention and detention ponds with a minimum pool depth of 6-8'.

  - Normally dry swales and detention pond bottoms should be constructed to minimize the creation of tire ruts during maintenance activities.

- Where ponds are the proposed method of control, the person responsible for the land disturbing activity shall submit to the approving agency, when required, an analysis of the impacts of stormwater flows downstream in the watershed for the 2, 10, 25, 50, and 100 year frequency storm event. The analysis shall include hydrologic and hydraulic timing modifications of the proposed land disturbing activity, with and without the pond. The results of the analysis will determine the need to modify the pond design or to eliminate the pond requirement as allowed by the Zoning Ordinance. If a clearly defined downstream point of constriction is not available, the downstream impacts shall be established with the concurrence of the City Manager, or his designee.

<u>Water Quality</u>

- Water quality control is also an integral component of stormwater management. The following design criteria are established for water quality protection unless a waiver or variance is granted on a case-by-case basis.

- When ponds are used for water quality protection, the ponds shall be designed as both quantity and quality control structures. Sediment storage volume shall be calculated considering the clean out and maintenance schedules specified by the designer during the land disturbing activity. Sediment storage volumes may be predicted by the Universal Soil Loss equation.

- Stormwater runoff and drainage to a single outlet from land disturbing activities which disturb ten (10) acres or more shall be controlled during the land disturbing activity by a sediment basin where sufficient space and other factors allow these controls to be used until the final inspection. The sediment basin shall be designed and constructed to accommodate the anticipated sediment loading from the land disturbing activity and meet a removal efficiency of eighty (80) percent suspended solids or 0.5 ML/L peak settable solids concentration. The outfall device or system design shall take into account the total drainage area flowing through the disturbed area to be served by the basin.

- Other practices may be acceptable to the appropriate plan approval agency if they achieve an equivalent removal efficiency of eighty (80) percent for suspended solids or 0.5 ML/L peak settable solids concentration, whichever is less, the efficiency shall be calculated for disturbed conditions for the ten (10) year, 24 hour design storm (the 6 hour storm may be used when approved by the city).

- Permanent water quality ponds having a permanent pool shall be designed to store and release the first 0.5 inch depth of runoff from the site and associated contributing offsite drainage basin over a 24-72 hour period. The storage volume shall be designed to accommodate, at least, 0.5 inch of runoff from the entire site and any contributing offsite areas.

- Permanent water quality ponds, not having a permanent pool, shall be designed to store and release the first 1.0 inch depth of runoff from the site and associated contributing offsite drainage basin over a 24-72 hour period.

- Permanent infiltration practices, when approved, shall be designed to accept, at a minimum, the first 1.0 inch volume of runoff from all impervious surfaces draining into the practice, which may include offsite areas and shall have an infiltration rate of 0.5 in/hr at a minimum.

8.2 Design Criteria

8.2.1 Introduction

This section provides general guidance on stormwater runoff storage for meeting stormwater management control requirements (i.e., water quality treatment, downstream channel protection, overbank flood protection, and extreme flood protection). The use of detention facilities within a stormwater management system is essential for peak flow attenuation of larger flows for overbank and extreme flood protection as well as providing the extended detention of flows for water quality treatment and downstream channel protection. Detention can be provided within an on-site system through the use of structural stormwater controls and/or nonstructural features and landscaped areas. Detention can also be distributed throughout a development.

Storage can also be categorized as on-line or off-line. On-line storage uses a structural control facility that intercepts flows directly within a conveyance system or stream. Off-line storage is a separate storage facility to which flow is diverted from the conveyance system. No on-line facilities will be allowed to be installed in street rights-of-ways drainage systems.

Low impact development methods, such as bio-retention, rain gardens, bio-swales, vegetated buffers, etc. are strongly recommended for WQ treatment, and may be utilized to reduce detention pond WQCV requirements. See the US EPA sponsored "Low Impact Development Urban Design Tools Website" (http://www.lid-stormwater.net/index.html) for WQ BMP techniques, specifications and design tools.

8.2.2 Release Rates and Flow Velocities

Post-development discharge rates from the entire development area shall not exceed pre-development discharge rates for the 2 and 10-year frequency, 24-hour duration storm events.

- Outlet control structures are required to control the 2, 10, 25, and 100-year storm events.

- Outlet control structures should release the water quality capture volume over a time period at or above the drain time, as discussed below.

- Emergency spillways shall be designed to safely pass the post-development 100-year, 24-hour storm event without overtopping any dam structures and include one (1') foot of freeboard above the 100-year elevation. Emergency spillways shall be separate from the outlet structure to prevent blockages.

- The same hydrologic procedures shall be used in determining both the pre-development and post-development peak flow rates.

Discharge velocities shall be reduced to provide a non-erosive velocity flow from a structure, channel, or other control measure or the velocity of the 10 year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is less. (Per Zoning Ordinance of Rock Hill)

8.2.3 Design Procedure

This section discusses the general design procedures for designing storage to provide standard detention of stormwater runoff for overbank and extreme flood protection. The design procedures for all structural control storage facilities are the same whether or not they include a permanent pool of water. In the latter case, the permanent pool elevation is taken as the "bottom" of storage and is treated as if it were a solid basin bottom for routing purposes. It should be noted that the location of structural stormwater controls is very important as it relates to the effectiveness of these facilities to control downstream impacts. In addition, multiple storage facilities located in the same drainage basin will affect the timing of the runoff through the conveyance system, which could decrease or increase flood peaks in different downstream locations. Therefore, a downstream peak flow analysis should be performed as part of the storage facility design process. The storage volume is defined as the volume of runoff that can be captured by the structure. Storage volume shall be adequate to attenuate the post-development peak discharge rates to pre-developed discharge rates for the 2 and 10-year storms. All dry detention basin volumes shall be drained from the structure within 72 hours.

The following steps can be used in the design of detention facilities. Prior to beginning the design process, several data requirements must be completed, including the development of an inflow hydrograph for all necessary storms (2, 10, 25, and 100-year storm events), stage-storage relationships of the storage facility, and a stage-discharge rating curve for all outlets.

1. Compute inflow hydrograph for runoff from the 2, 10, 25, and 100-year design storms using the hydrologic methods.
2. Perform preliminary calculations to evaluate detention storage requirements for the hydrographs from Step 1. Preliminary calculations involve determining a storage volume from which the stage-volume relationship and rating curve are developed using the SCS/TR-55 Method.
3. Determine the physical dimensions necessary to hold the estimated volume from step 2, including freeboard. The maximum storage requirement calculated from Step 2 should be used. From the selected shape determine the maximum depth in the pond.
4. Select the type of outlet and size the outlet structure. The estimated peak stage will occur for the estimated volume from Step 2. The outlet structure should be sized to convey the allowable discharge at this stage.
5. Perform routing calculations using inflow hydrographs from Step 1 to check the preliminary design using a storage routing computer model. If the routed post development peak discharges from a design storm exceeds the existing development peak discharges, then revise the available storage volume, outlet device, etc., and return to Step 3.

6. Perform routing calculations using the 25 & 100-year hydrograph to determine if any increases in downstream flows from this hydrograph will cause damages and/or drainage and flooding problems. If problems will be created then the storage facility must be designed to control the increased flows from the 25 and/or 100-year storm. If not then consider emergency overflow from runoff due to the 25 and/or 100-year (or larger) design storm and established freeboard requirements.
7. Evaluate the downstream effects of detention outflows for the 25 and 100-year storms to ensure that the routed hydrograph does not cause downstream flooding problems. The exit hydrograph from the storage facility should be routed though the downstream channel system until a confluence point is reached where the drainage area being analyzed represents 10% of the total drainage area.
8. Evaluate the control structure outlet velocity and provide channel and bank stabilization if the velocity will cause erosion problems downstream.

Routing of hydrographs through storage facilities is critical to the proper design of these facilities. Although storage design procedures using inflow/outflow analysis without routing have been developed, their use in designing detention facilities has not produced acceptable results in many areas of the country. Although hand calculation procedures are available for routing hydrographs through storage facilities, they are very time consuming, especially when several different designs are evaluated. Many standard hydrology and hydraulics textbooks give examples of hand-routing techniques. For this Manual, it assumed that designers will be using one of the many computer programs available for storage routing and thus other procedures and example applications will not be given here.

8.2.4 Outlet Works

Outlet works selected for storage facilities typically include a principal spillway and an emergency overflow, and must be able to accomplish the design functions of the facility. Outlet works can take the form of combinations of drop inlets, pipes, weirs, and orifices. Slotted riser pipes are discouraged because of clogging problems, but curb openings may be used for parking lot storage up to 6” deep (parking lot storage deeper than 6” will not be allowed). The principal spillway is intended to convey the design storm without allowing flow to enter an emergency outlet. For large storage facilities, selecting a flood magnitude for sizing the emergency outlet should be consistent with the potential threat to downstream life and property if the basin embankment were to fail. The minimum flood to be used to size the emergency outlet is the 100-year flood. The sizing of a particular outlet works shall be based on results of hydrologic routing calculations.

Outlet structures shall be made of strong, durable and non-corroding materials, components, and fasteners such as reinforced concrete pipe. Anti-flotation blocks shall be adequately designed to eliminate flotation of the outlet structure. Anti-seep collars shall be installed on all barrel pipes (outlet pipes) leaving an outlet structure. Trash racks shall be installed over all outlets on the structure.

8.2.5 Side Slope

Vegetated embankments shall be less than 15-feet in height and shall have side slopes no steeper than 3H:1V. Embankments protected with Erosion Control Blankets or Turf Reinforcement Matting shall be no steeper than 2H:1V. Geotechnical slope stability analysis is required for slopes greater than 10-feet in height and embankments that have steeper slope than those indicated above.

8.2.6 Freeboard

A minimum freeboard of 1.0 feet above the 100-year, 24-hour design storm high water elevation shall be provided for impoundment depth less than 15-feet. Impoundment depths greater than 15-feet are subject to the requirements of the Safe Dams Act unless the facility is excavated.

8.2.7 Safety Fence

A minimum four (4’) feet high safety fence, meeting current Zoning Code requirements, shall be implemented around all stormwater basins that are greater than 2-feet in depth and with side slopes steeper than 4:1.

8.2.8 Underground Storage

A preliminary meeting must be scheduled with the City Engineer in the Rock Hill Infrastructure Division before any underground storage facility will be accepted and permitted. All design procedures regarding underground storage facilities should be deferred until a conceptual design plan is approved by the City Engineer.

8.2.9 Special Conditions

Watersheds having well documented water quantity and/or quality problems may have more stringent or modified design criteria, as determined from master plan studies by the City of Rock Hill, including but not limited to:

- Reduction of peak flow rates from pre-development to post-development,
- Reduction of total volume released from pre-development to post-development, and
- Downstream channel, culvert or property improvements.

8.2.10 Design Approval and Detention Waivers

All designs of detention systems utilized for stormwater quantity control shall be submitted with a design summary report when applying for a Stormwater Management Permit.

A project may be eligible for a waiver from the stormwater management requirements for water quantity control if the applicant can justly verify that:

- The proposed project will not create any significant adverse effects on the receiving natural waterway downstream of the property.
- The imposition of peak flow rate control for stormwater management would create, aggravate, or accelerate downstream flooding.
- All requirements for a detention waiver in Article 2-300(J) of the Zoning Ordinance are met

8.3 Water Quality Requirements

8.3.1 Water Quality Plan

Stormwater releases from any part of a development or redevelopment, no area restrictions, shall meet the following criteria:

1. All construction activities must be designed and planned to not impact the chemical, biological and physical integrity of the waters of the US within the city limits of Rock Hill.
2. The Water Quality Plan must contain a description of the post-construction BMPs for the site and rationale for choosing them. The rationale must address the anticipated impacts on the hydrology, water quality and riparian habitat. Sediment basins should provide a minimum trapping efficiency of 80 percent or 0.5 ML/L peak settable solids concentration. Detail drawings and long-term maintenance plans must be provided for all post-construction BMPs. Maintenance plans must assure that pollutants, which collect within structural post-construction practices, be disposed of in accordance with local, state and federal regulations.
3. Post construction BMPs must achieve the following goals:

(a) For all development on previously undeveloped property, structural (designed) post-construction stormwater treatment practices shall be incorporated into the permanent drainage system for the site. Redevelopment of a site draining to an impaired waterbody requires implementation of water quality practices to mitigate the impairment.

(b) Permanent water quality ponds having a permanent pool shall be designed to store and release the first 0.5 inch depth of runoff from the site and associated offsite areas over a minimum 24-72 hour period. The storage volume shall be designed to accommodate, at least, 0.5 inch depth of runoff from the entire site and offsite areas. The calculation shall be a straight volume calculation and shall not be routed.

(c) Permanent water quality ponds, not having a permanent pool, shall be designed to store and release the first (1") inch depth of runoff from the site and associated offsite areas over a minimum 24-72 hour period. The storage volume shall be designed to accommodate, at least, 1.0 inch depth of runoff from the entire site and offsite areas. The calculation shall be a straight volume calculation and shall not be routed.

(d) Permanent infiltration practices, when allowed, shall be designed to accept, at a minimum, the first (1") inch depth of runoff from all impervious areas at a minimum infiltration rate of 0.5 in/hr. A minimum of two (2) soil tests shall be performed and certified by a PE in the location of the infiltration practice to a minimum of 4' below the practice bottom.

(e) The use of pre-fabricated water quality devices will be reviewed and approved on a case by case basis by the city. Third party lab and field test results must be provided showing the removal efficiency of the device. All devices are required to provide a minimum 80% removal of 100 micron particles. The device and/or design must include provisions for by-passing the device during flows greater than the capacity of the device in order to avoid resuspension or pollutants.

(f) All fuel dispensing, vehicle repair and similar facilities require practices to be installed, in addition to the required water quality measures as listed above, to mitigate petroleum based product runoff.

(g) Low impact development methods, such as bio-retention, rain gardens, bio-swales, vegetated buffers, etc. are strongly recommended for WQ treatment, and may be utilized to reduce detention pond WQCV requirements. See the US EPA sponsored "Low Impact Development Urban Design Tools Website" (http://www.lid-stormwater.net/index.html) for WQ BMP techniques, specifications and design tools.

8.3.2 Facility Maintenance

Facilities shall be cleaned and maintained so the full water quality volume is available and the facility functions as designed at all times. A post-construction "Stormwater Mitigation Maintenance Plan" must be submitted for review and approval. The plan shall provide a comprehensive schedule and maintenance procedure to address the site and any future operations. The plan shall describe appropriate Best Management Practices to manage detention basins, water quality facilities, sensitive natural areas, private stormwater systems, dumpster/compactor areas, cleaning and washing activities, material and equipment storage areas, etc. An approved plan shall be posted at the site management facility or place of business and be readily accessible by employees, including City Stormwater Utility personnel upon request.

8.3.3 Exemptions

Development and redevelopment activities can be exempted from this section if it can be demonstrated this requirement, for the particular site in question, was incorporated within another larger common plan of development or regional stormwater management plan.

8.4 Construction and Maintenance Considerations

8.4.1 Proper Design

An important step in the design process is identifying whether special provisions are warranted to properly construct or maintain proposed storage facilities. To assure acceptable performance and function, storage facilities that require extensive maintenance are discouraged. The following maintenance problems are typical of urban detention facilities and facilities shall be designed to minimize problems:

- grass and vegetation maintenance,
- sedimentation control,
- standing water or soggy surfaces,
- blockage of outlet structures,
- maintenance of fences,
- perimeter plantings
- weed growth,
- bank deterioration,
- mosquito control, and
- litter accumulation.

Proper design should focus on the elimination or reduction of maintenance requirements by addressing the potential for problems to develop.

- Both weed growth and grass maintenance may be addressed by constructing side slopes that can be maintained using available power driven equipment, such as tractor mowers.

- Sedimentation may be controlled by constructing traps to contain sediment for easy removal or low-flow channels to reduce erosion and sediment transport.

- Bank deterioration can be controlled with protective lining or by limiting back slopes.

- Standing water or soggy surfaces may be eliminated by sloping basin bottoms toward the outlet, constructing low-flow pilot channels across basin bottoms from the inlet to the outlet, or by constructing underdrain facilities to lower water tables.

- In general, when the above problems are addressed, mosquito control will not be a major problem.

- Outlet structures should be selected to minimize the possibility of blockage (i.e., installation of trash racks, adequate protection of small outlets, etc.).

- One way to deal with the maintenance associated with litter and damage to fences and perimeter plantings is to locate the facility for easy access where regular maintenance can be conducted.

- All reports and construction plans should document who will be assuming ownership and long-term maintenance responsibilities associated with storage and detention facilities, to ensure that the drainage works will remain in good working order and function properly according to its original design. Long-term operation and maintenance responsibilities include costs.

- All storage and detention facilities will meet any pertinent requirements outlined by NPDES regulations.

8.5 References

American Association of State Highway and Transportation Officials, 1982. Highway Drainage Guidelines.

Atlanta Regional Commission, Georgia Stormwater Management Manual, Volume 2: Technical Manual, 2001.

Federal Highway Administration, 1978. Hydraulics of Bridge Waterways. Hydraulic Design Series No. 1.

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Federal Highway Administration, 1987. HY8 Culvert Analysis Microcomputer Program Applications Guide. Hydraulic Microcomputer Program HY8.

HYDRAIN Culvert Computer Program (HY8). Available from McTrans Software, University of Florida, 512 Weil Hall, Gainesville, Florida 32611.

U. S. Department of Interior, 1983. Design of Small Canal Structures.

Greenville, South Carolina Storm Water Management Design Manual, January 1992.

CHAPTER 9 – ENERGY DISSIPATION

9.1 Overview

9.1.1 Introduction

Energy dissipators shall be employed whenever the velocity of flows leaving a stormwater management facility exceeds the erosive velocity of the downstream channel system. The purpose of this section is to aid in selecting and designing an energy dissipator which should be used to control erosive velocities that could damage channels and stream banks.

9.1.2 General Criteria

Erosion problems at culvert, pipe and engineered channel outlets are common. Determination of the flow conditions, scour potential, and channel erosion resistance shall be standard procedure for all designs.

- Energy dissipators shall be employed whenever the velocity of flows leaving a stormwater management facility exceeds the erosion velocity of the downstream area channel system.

- Energy dissipator designs will vary based on discharge specifics and tailwater conditions.

- Outlet structures should provide uniform redistribution or spreading of the flow without excessive separation and turbulence.

9.1.3 Recommended Dissipators

For many designs, the following outlet protection and energy dissipators provide sufficient protection at a reasonable cost.

- Rip-rap apron
- Geotextile matting per the manufacturer's specifications
- Rip-rap outlet basins

The Federal Highway Administration Hydraulic Engineering Circular No. 14 entitled Hydraulic Design of Energy Dissipators For Culverts And Channels, includes design procedures of energy dissipators.

Furthermore, several standard energy dissipator designs have been documented by the U.S. Department of Transportation including hydraulic jump, forced hydraulic jump, impact basins, drop structures, stilling wells, and rip-rap.

9.2 Design Guidelines

9.2.1 Introduction

(1) If outlet protection is required, choose an appropriate type. Suggested outlet protection facilities and applicable flow conditions (based on Froude number and dissipation velocity) are described below:
   (a) Rip-rap aprons may be used when the outlet Froude number (Fr) is less than or equal to 2.5. In general, rip-rap aprons prove economical for transitions from culverts to overland sheet flow at terminal outlets, but may also be used for transitions from culvert sections to stable channel sections. Stability of the surface at the termination of the apron should be considered.
   (b) Rip-rap outlet basins may also be used when the outlet Fr is less than or equal to 2.5. They are generally used for transitions from culverts to stable channels. Since rip-rap outlet basins function by creating a hydraulic jump to dissipate energy, performance is impacted by tailwater conditions.

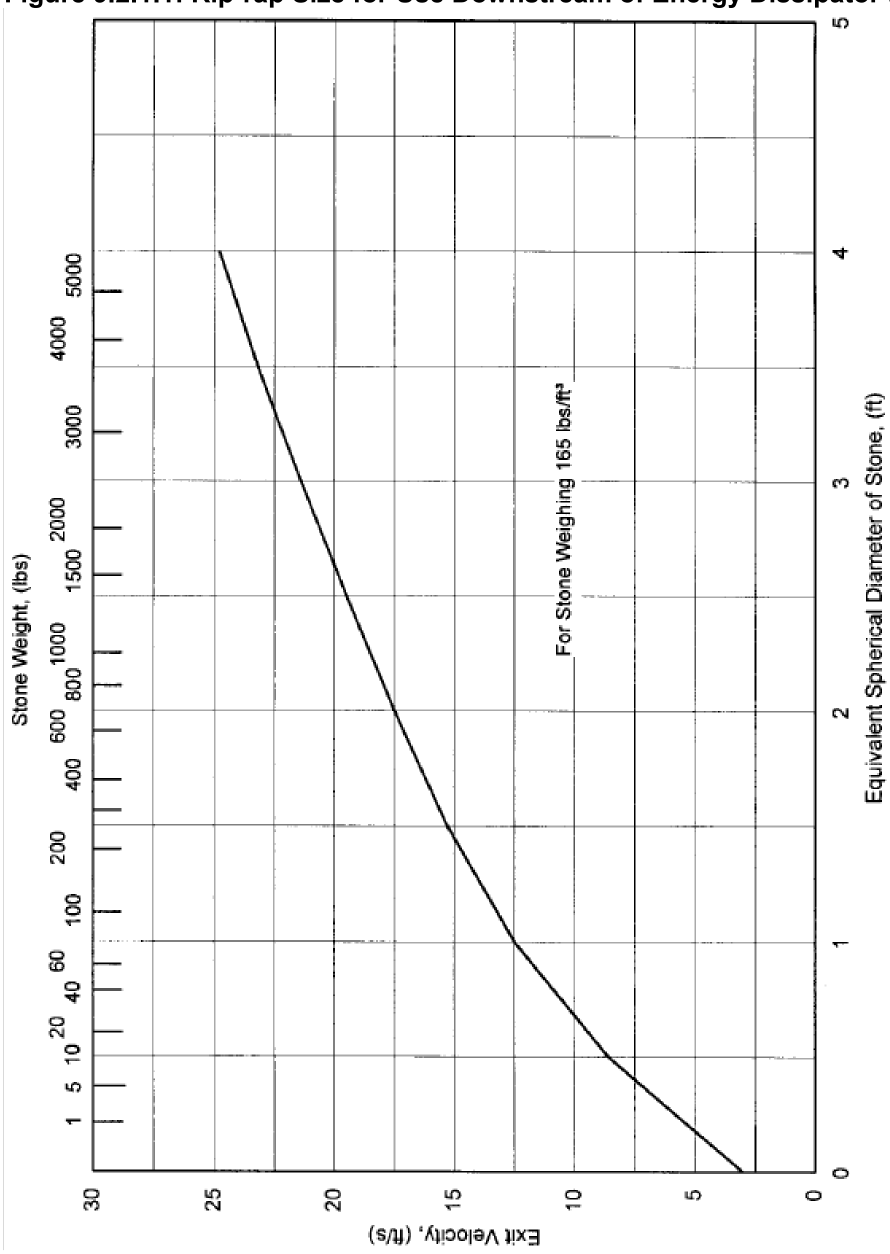
(c) Baffled outlets have been used with outlet velocities up to 50 feet per second. Practical application typically requires an outlet Fr between 1 and 9. Baffled outlets may be used at both terminal outlet and channel outlet transitions. They function by dissipating energy through impact and turbulence and are not significantly affected by tailwater conditions.

(2) When outlet protection facilities are selected, appropriate design flow conditions and site specific factors affecting erosion and scour potential, construction cost, and long-term durability should be considered.

(3) If outlet protection is not provided, energy dissipation will occur through formation of a local scour hole. A cutoff wall will be needed at the discharge outlet to prevent structural undermining. The wall depth should be slightly greater than the computed scour hole depth, hs. The scour hole should then be stabilized. If the scour hole is of such size that it will present maintenance, safety, or aesthetic problems, other outlet protection will be needed.

(4) Evaluate the downstream channel stability and provide appropriate erosion protection if channel degradation is expected to occur. Figure 9.2.1.1 provides the rip-rap size recommended for use downstream of energy dissipators.

Figure 9.2.1.1: Rip-rap Size for Use Downstream of Energy Dissipator (Source: Searcy, 1967)



9.3 Rip Rap Aprons

9.3.1 Description

A rip-rap-lined apron is a commonly used practice for energy dissipation because of its relatively low cost and ease of installation. A flat rip-rap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Protection is provided primarily by having sufficient length and flare to dissipate energy by expanding the flow. Rip-rap aprons are appropriate when the culvert outlet Fr is less than or equal to 2.5.

9.3.2 Design Procedure

The procedure presented in this section is taken from USDA, SCS (1975). Two sets of curves, one for minimum and one for maximum tailwater conditions, are used to determine the apron size and the median rip-rap diameter, d50. If tailwater conditions are unknown, or if both minimum and maximum conditions may occur, the apron should be designed to meet criteria for both. Although the design curves are based on round pipes flowing full, they can be used for partially full pipes and box culverts. The design procedure consists of the following steps:

1. If possible, determine tailwater conditions for the channel. If tailwater is less than ½ the discharge flow depth (pipe diameter if flowing full), minimum tailwater conditions exist and the curves in Figure 9.3.2.1 apply. Otherwise, maximum tailwater conditions exist and the curves in Figure 9.3.2.2 should be used.
2. Determine the correct apron length and median rip-rap diameter, d50, using the appropriate curves from Figures 9.3.2.1 and 9.3.2.2. If tailwater conditions are uncertain, find the values for both minimum and maximum conditions and size the apron as shown in Figure 9.3.2.3.
   (a) *For pipes flowing full:*
   Use the depth of flow, d, which equals the pipe diameter, in feet, and design discharge, in cfs, to obtain the apron length, L_a, and median rip-rap diameter, d_{50}, from the appropriate curves.
   (b) *For pipes flowing partially full:*
   Use the depth of flow, d, in feet, and velocity, v, in ft/s. On the lower portion of the appropriate figure, find the intersection of the d and v curves, then find the rip-rap median diameter, d_{50}, from the scale on the right. From the lower d and v intersection point, move vertically to the upper curves until intersecting the curve for the correct flow depth, d. Find the minimum apron length, L_a, from the scale on the left.
   (c) *For box culverts:*
   Use the depth of flow, d, in feet, and velocity, v, in feet/second. On the lower portion of the appropriate figure, find the intersection of the d and v curves, then find the rip-rap median diameter, d_{50}, from the scale on the right. From the lower d and v intersection point, move vertically to the upper curve until intersecting the curve equal to the flow depth, d. Find the minimum apron length, L_a, using the scale on the left.

3. If tailwater conditions are uncertain, the median rip-rap diameter should be the larger of the values for minimum and maximum conditions. The dimensions of the apron will be as shown in Figure 9.3.2.3. This will provide protection under either of the tailwater conditions.

Figure 9.3.2.1: Design of Rip-Rap Apron Under Minimum Tailwater Conditions (Source: SCDHEC Manual)

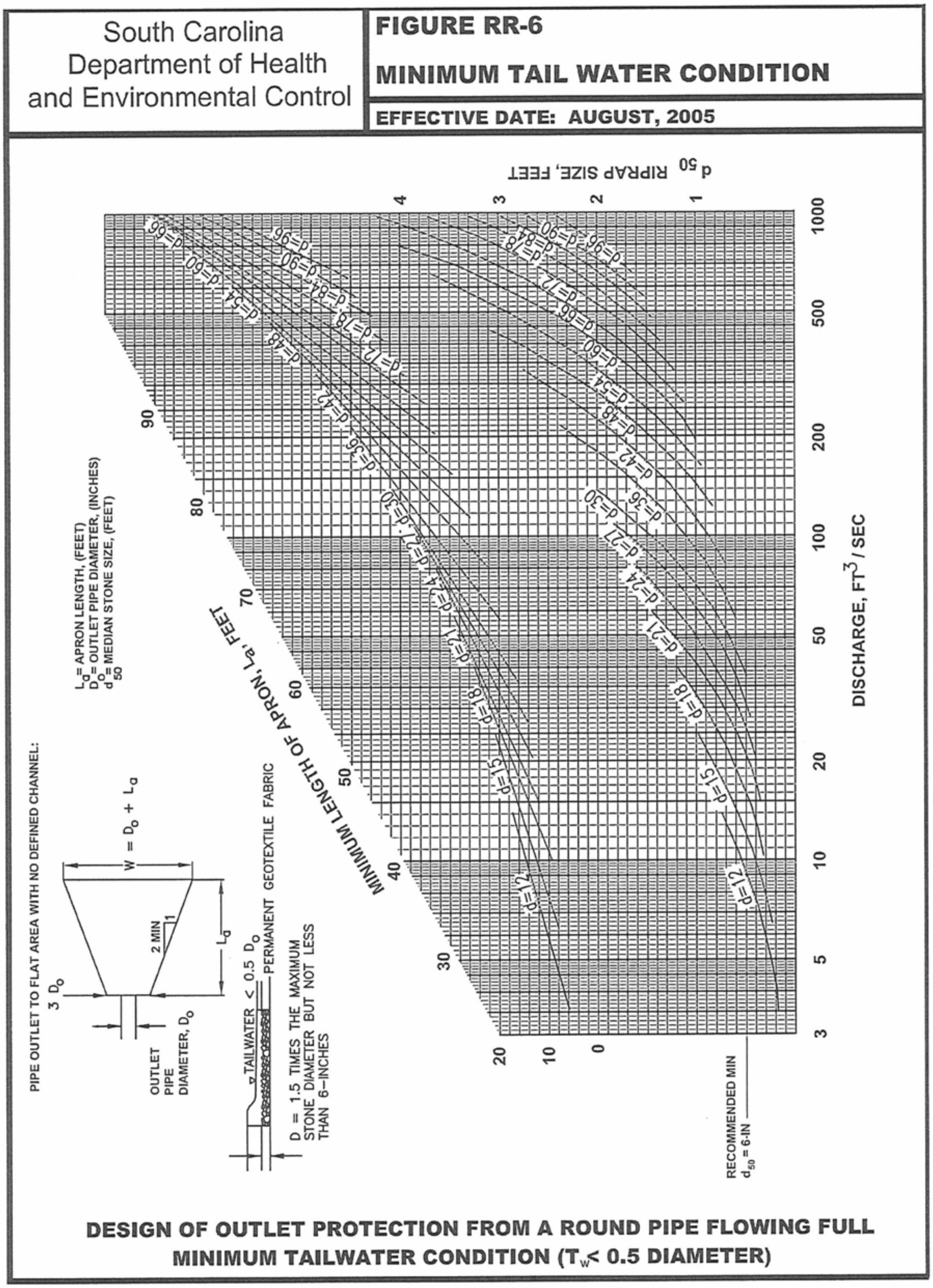


Figure 9.3.2.2: Design of Rip-Rap Apron Under Maximum Tailwater Conditions (Source: SCDHEC Manual)

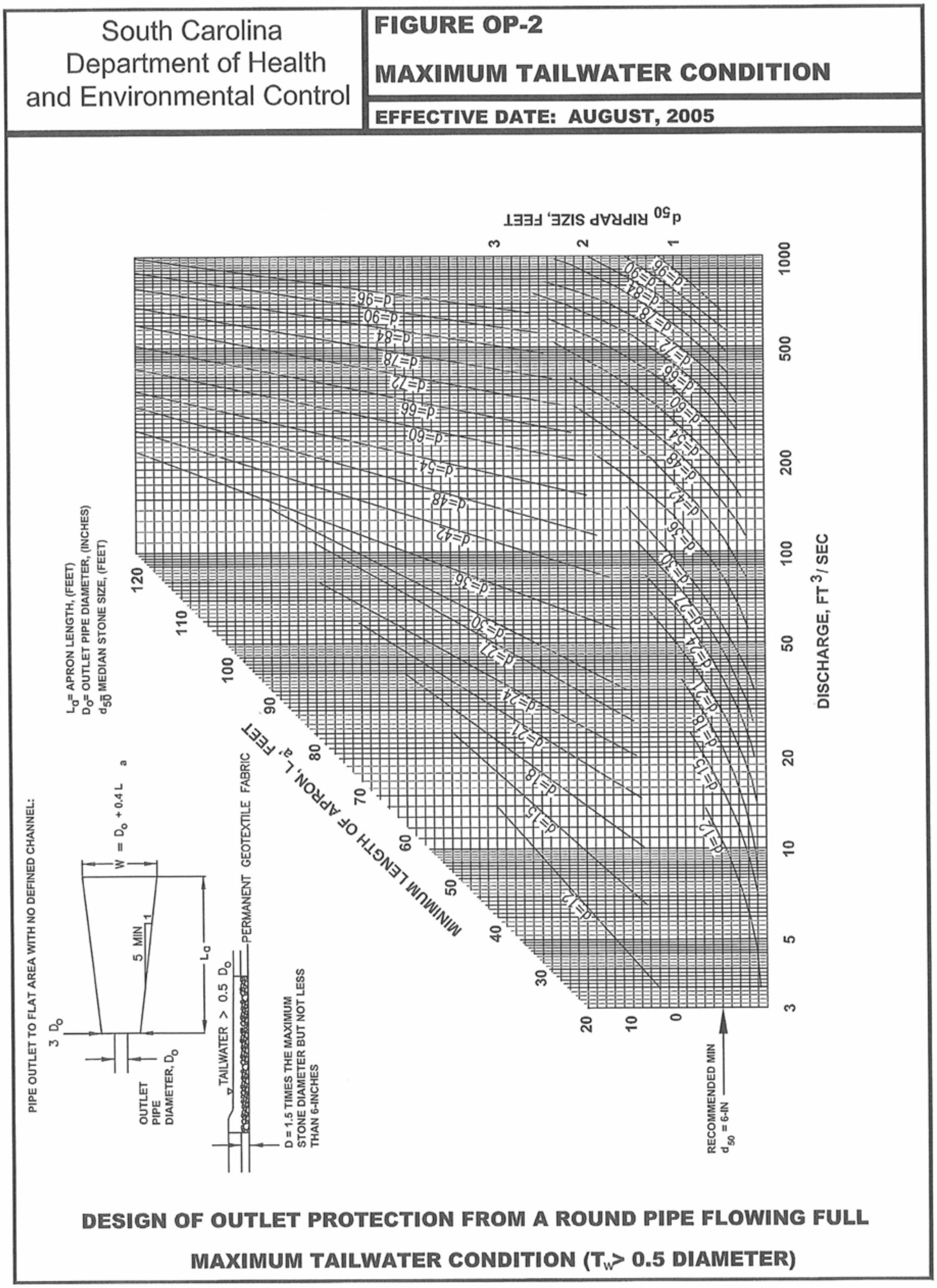
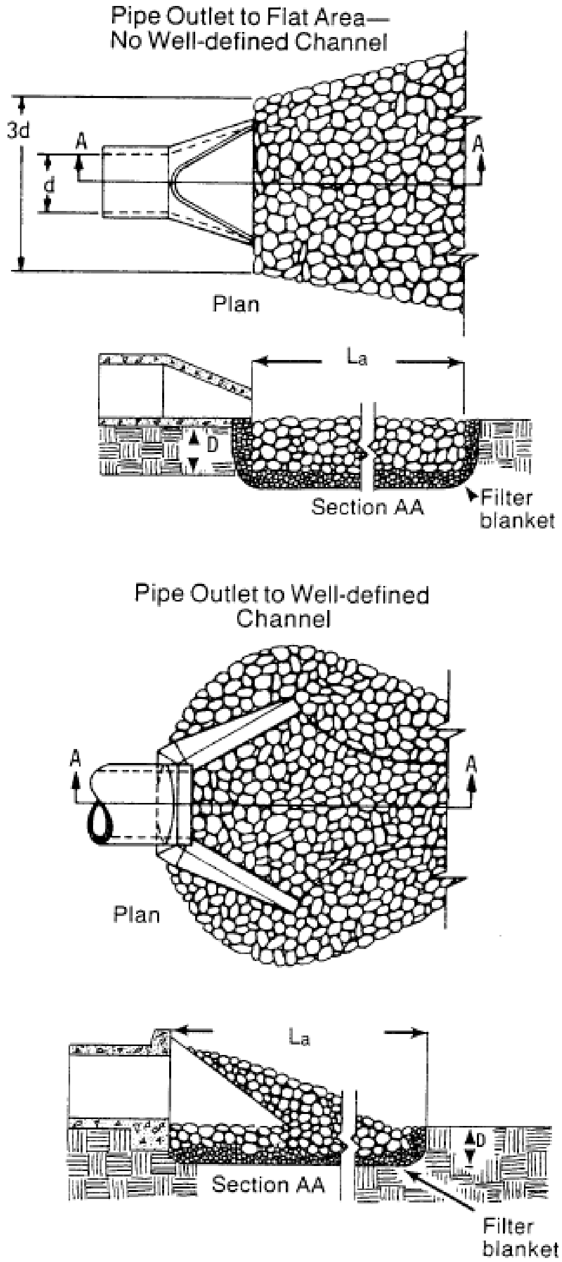


Figure 9.3.2.3: Rip-Rap Apron (Source: Manual for Erosion and Sediment Control in Georgia, 1996)



Notes

1. L_a is the length of the riprap apron.
2. D = 1.5 times the maximum stone diameter but not less than 6".
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6" above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.

9.3.3 Design Considerations

The following items should be considered during rip-rap apron design:

- The maximum stone diameter should be 1.5 times the median rip-rap diameter.
  d_{max} = 1.5 x d_{50} , d_{50} = the median stone size in a well-graded rip-rap apron.
- The rip-rap thickness should be 1.5 times the maximum stone diameter or 6 inches, whichever is greater. Apron thickness = 1.5 x d_{max} (Apron thickness may be reduced to 1.5 x d_{50} when an appropriate filter fabric is used under the apron.)

- The apron width at the discharge outlet should be at least equal to the pipe diameter or culvert width, d_w. Rip-rap should extend up both sides of the apron and around the end of the pipe or culvert at the discharge outlet at a maximum slope of 2:1 and a height not less than the pipe diameter or culvert height, and should taper to the flat surface at the end of the apron.

- If there is a well-defined channel, the apron length should be extended as necessary so that the downstream apron width is equal to the channel width. The sidewalls of the channel should not be steeper than 2:1.

- If the ground slope downstream of the apron is steep, channel erosion may occur. The apron should be extended as necessary until the slope is gentle enough to prevent further erosion.

- The potential for vandalism should be considered if the rock is easy to carry. If vandalism is a possibility, the rock size must be increased or the rocks held in place using concrete or grout.

9.3.4 Example Designs

Example #1: Rip-rap Apron Design for Minimum Tailwater Conditions

A flow of 280 cfs discharges from a 66-in pipe with a tailwater of 2 ft above the pipe invert. Find the required design dimensions for a rip-rap apron.
(1) Minimum tailwater conditions = 0.5 d_o, d_o = 66 in = 5.5 ft; therefore, 0.5 d_o = 2.75 ft.
(2) Since TW = 2 ft, use Figure 9.3.2.1 for minimum tailwater conditions.
(3) By Figure 9.3.2.1, the apron length, L_a, and median stone size, d_{50}, are 38 ft and 1.2 ft, respectively.
(4) The downstream apron width equals the apron length plus the pipe diameter:
$W = d + L_a = 5.5 + 38 = 43.5$ ft
(5) Maximum rip-rap diameter is 1.5 times the median stone size:
$1.5 (d_{50}) = 1.5 (1.2) = 1.8$ ft
(6) Rip-rap depth = $1.5 (d_{max}) = 1.5 (1.8) = 2.7$ ft.

Example #2: Rip-rap Apron Design for Maximum Tailwater Conditions

A concrete box culvert 5.5 ft high and 10 ft wide conveys a flow of 600 cfs at a depth of 5.0 ft. Tailwater depth is 5.0 ft above the culvert outlet invert. Find the design dimensions for a rip-rap apron.
(1) Compute 0.5 d_o = 0.5 (5.0) = 2.5 ft.
(2) Since TW = 5.0 ft is greater than 2.5 ft, use Figure 9.3.2.2 for maximum tailwater conditions.
$v = Q/A = [600/(5) (10)] = 12$ ft/s
(3) On Figure 9.3.2.2, at the intersection of the curve, d_o = 60 in and v = 12 ft/s, d_{50} = 0.4 ft. Reading up to the intersection with d = 60 in, find La = 40 ft.
(4) Apron width downstream = $d_w + 0.4 L_a = 10 + 0.4 (40) = 26$ ft.
(5) Maximum stone diameter = $1.5 d_{50} = 1.5 (0.4) = 0.6$ ft.
(6) Rip-rap depth = $1.5 d_{max} = 1.5 (0.6) = 0.9$ ft.

9.4 Rip Rap Basins

9.4.1 Description

Another method to reduce the exit velocities from stormwater outlets is through the use of a rip-rap basin. A rip-rap outlet basin is a preshaped scour hole lined with rip-rap that functions as an energy dissipator by forming a hydraulic jump.

9.4.2 Basin Features

General details of the basin recommended in this section are shown in Figure 9.4.2.1. Principal features of the basin are:

- The basin is preshaped and lined with rip-rap of median size (d_{50}).

- The floor of the rip-rap basin is constructed at an elevation of h_s below the culvert invert. The dimension h_s is the approximate depth of scour that would occur in a thick pad of rip-rap of size d_{50} if subjected to design discharge. The ratio of h_s to d_{50} of the material should be between 2 and 4.
- The length of the energy dissipating pool is 10 x h_s or 3 x W_o, whichever is larger. The overall length of the basin is 15 x h_s or 4 x W_o, whichever is larger.

9.4.3 Design Procedure

The following procedure should be used for the design of rip-rap basins.

1. Estimate the flow properties at the brink (outlet) of the culvert. Establish the outlet invert elevation such that $TW/y_o < 0.75$ for the design discharge.
2. For subcritical flow conditions (culvert set on mild or horizontal slope) use Figure 9.4.2.2 or Figure 9.4.2.3 to obtain y_o/D, then obtain V_o by dividing Q by the wetted area associated with y_o. D is the height of a box culvert. If the culvert is on a steep slope, V_o will be the normal velocity obtained by using the Manning equation for appropriate slope, section, and discharge.
3. For channel protection, compute the Froude number for brink conditions with $y_e = (A/2)^{0.5}$. Select d_{50}/y_e appropriate for locally available rip-rap (usually the most satisfactory results will be obtained if $0.25 < d_{50}/y_e < 0.45$). Obtain h_s/y_e from Figure 9.4.2.4, and check to see that $2 < h_s/d_{50} < 4$. Recycle computations if h_s/d_{50} falls out of this range.
4. Size basin as shown in Figure 9.4.2.1.
5. Where allowable dissipator exit velocity is specified:
   (a) Determine the average normal flow depth in the natural channel for the design discharge.
   (b) Extend the length of the energy basin (if necessary) so that the width of the energy basin at section A-A, Figure 9.4.2.1, times the average normal flow depth in the natural channel is approximately equal to the design discharge divided by the specified exit velocity.
6. In the exit region of the basin, the walls and apron of the basin should be warped (or transitioned) so that the cross section of the basin at the exit conforms to the cross section of the natural channel. Abrupt transition of surfaces should be avoided to minimize separation zones and resultant eddies.
7. If high tailwater is a possibility and erosion protection is necessary for the downstream channel, the following design procedure is suggested:

   - Design a conventional basin for low tailwater conditions in accordance with the instructions above.

   - Estimate centerline velocity at a series of downstream cross sections using the information shown in Figure 9.4.5.1.

   - Shape downstream channel and size rip-rap using Figure 9.2.1.1 and the stream velocities obtained above.

Material, construction techniques, and design details for rip-rap should be in accordance with specifications in the Federal Highway publication HEC No. 11 entitled Use of Rip-rap For Bank Protection.

Figure 9.4.2.1: Details of Rip-Rap Outlet Basin (Source: HEC-14, 1983)

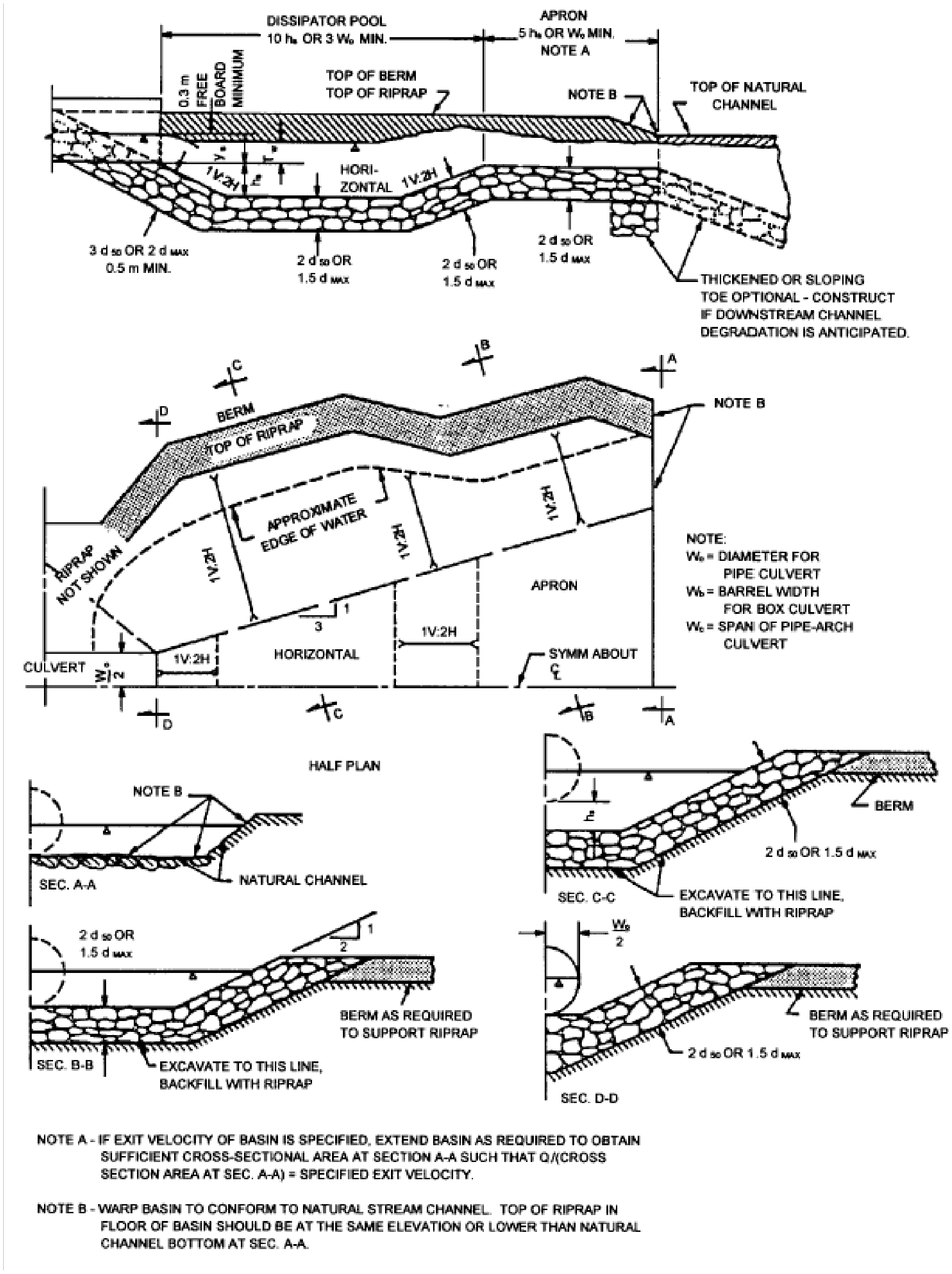


Figure 9.4.2.2: Dimensionless Rating Curves for the Outlets of Rectangular Culverts on Horizontal and Mild Slopes (Source: USDOT, FHWA, HEC-14, 1983)

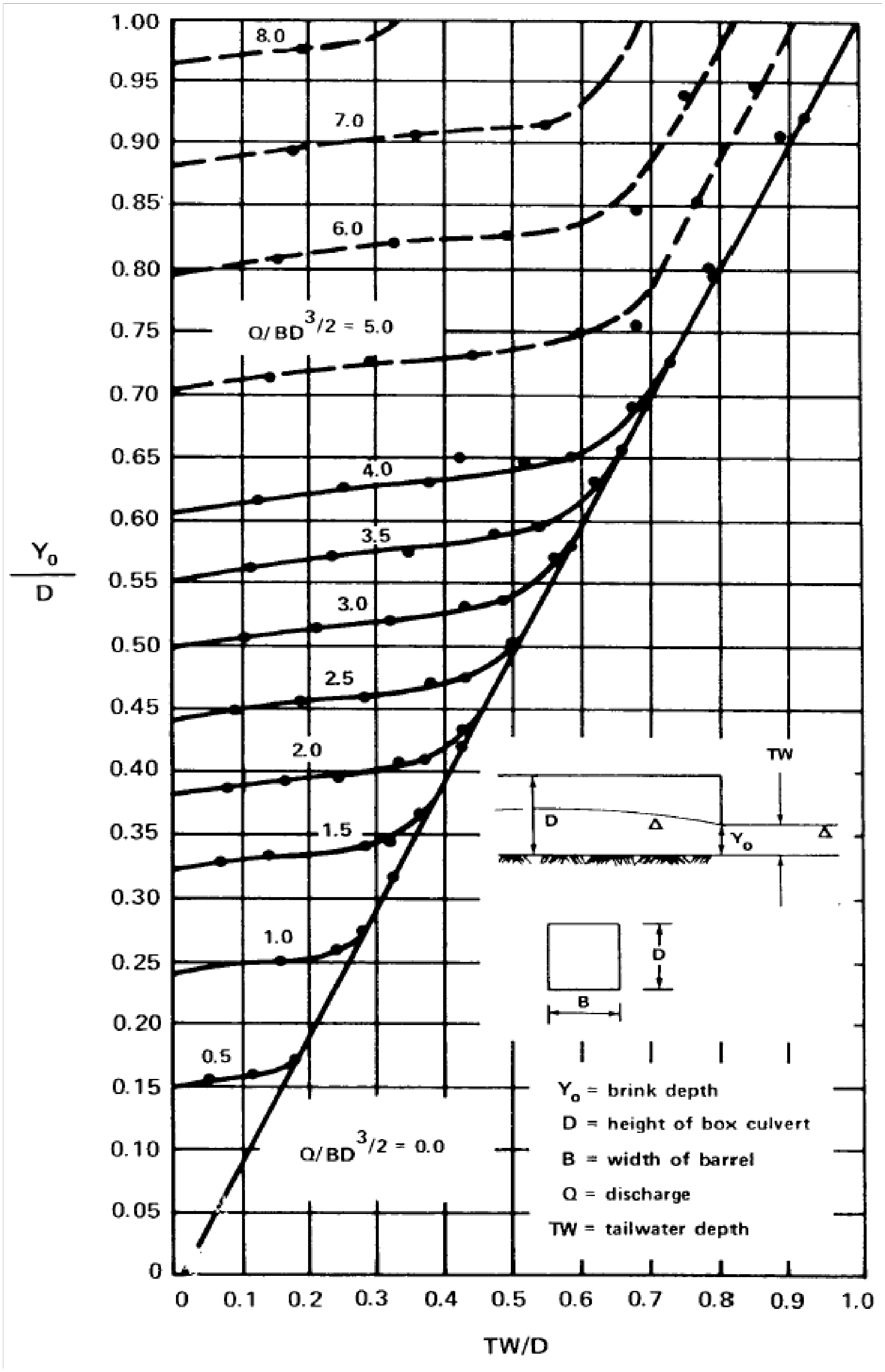


Figure 9.4.2.3: Dimensionless Rating Curves for the Outlets of Circular Culverts on Horizontal and Mild Slopes (Source: USDOT, FHWA, HEC-14, 1983)

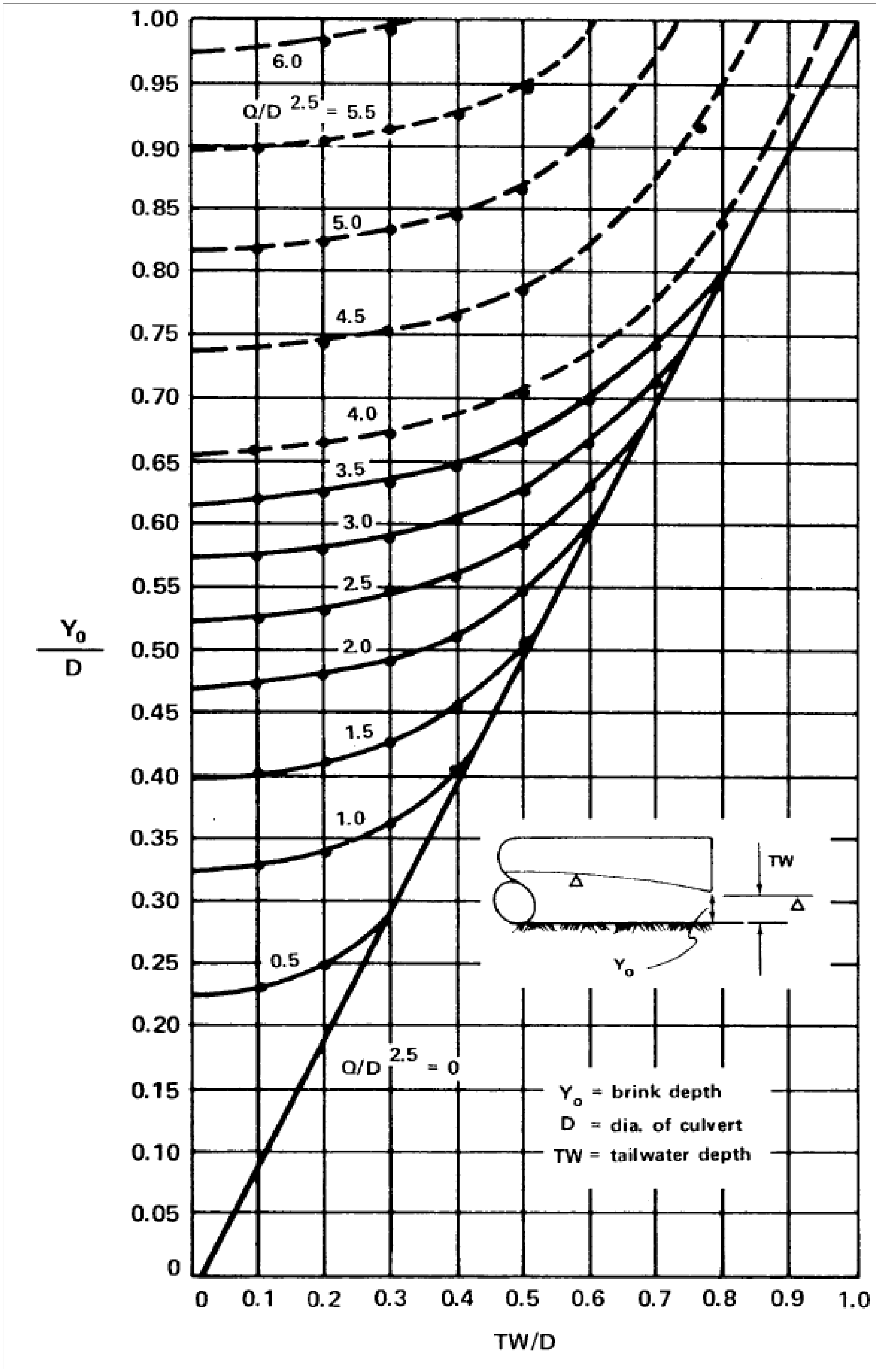
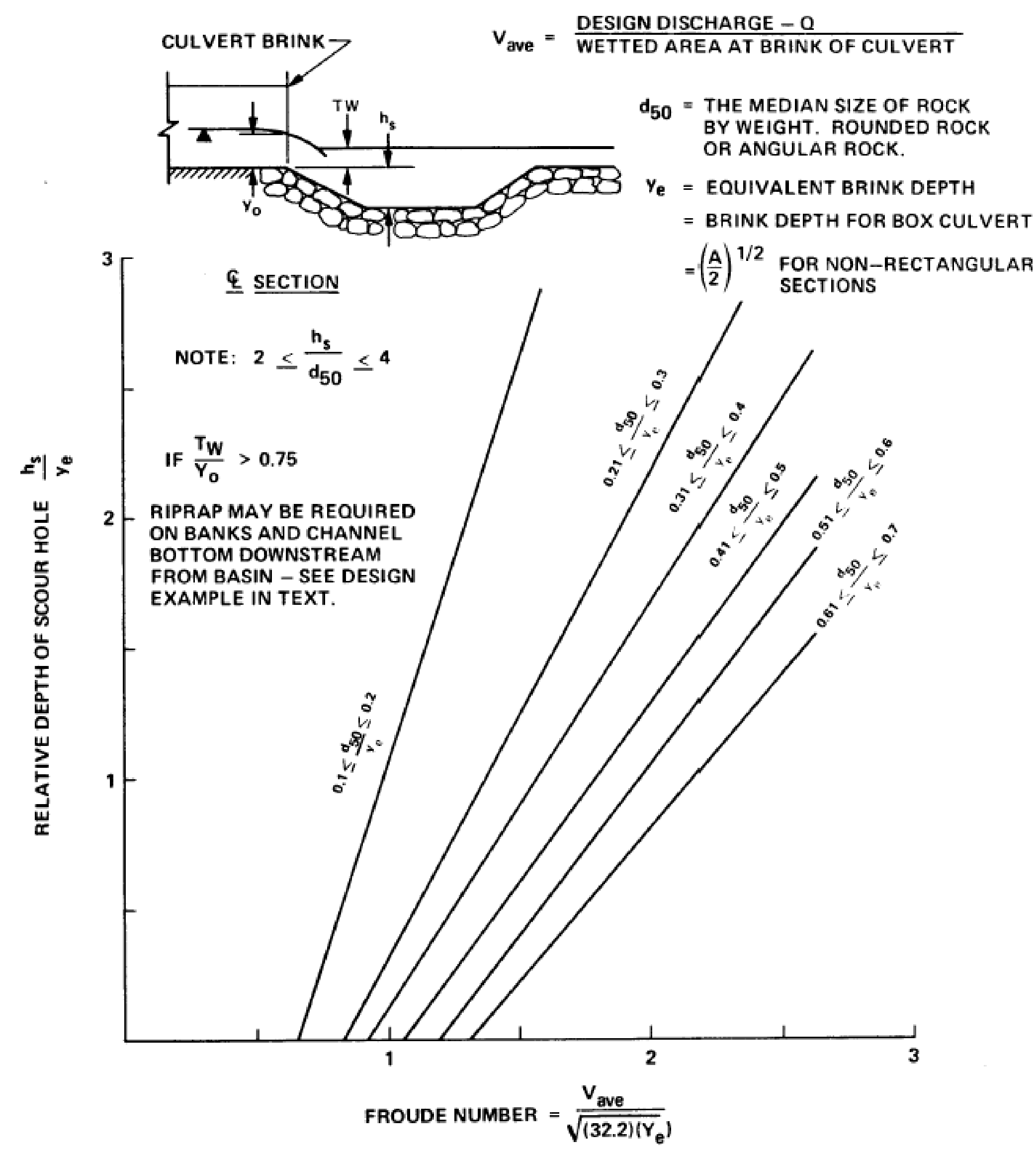


Figure 9.4.2.4: Relative Depth of Scour Hole Versus Froude Number at Brink of Culvert with Relative Size of Rip-Rap as a Third Variable (Source: USDOT, FHWA, HEC-14, 1983)



9.4.4 Design Considerations

Rip-rap basin design should include consideration of the following:

- The dimensions of a scour hole in a basin constructed with angular rock can be approximately the same as the dimensions of a scour hole in a basin constructed of rounded material when rock size and other variables are similar.

- When the ratio of tailwater depth to brink depth, TW/yo, is less than 0.75 and the ratio of scour depth to size of rip-rap, hs/d50, is greater than 2.0, the scour hole should function very efficiently as an energy dissipator. The concentrated flow at the culvert brink plunges into the hole, a jump forms against the downstream extremity of the scour hole, and flow is generally well dispersed leaving the basin.

- The mound of material formed on the bed downstream of the scour hole contributes to the dissipation of energy and reduces the size of the scour hole; that is, if the mound from a stable scoured basin is removed and the basin is again subjected to design flow, the scour hole will enlarge.

- For high tailwater basins (TW/yo greater than 0.75), the high velocity core of water emerging from the culvert retains its jet-like character as it passes through the basin and diffuses similarly to a concentrated jet diffusing in a large body of water. Therefore, the scour hole is much shallower and generally longer. Consequently, rip-rap may be required for the channel downstream of the rock-lined basin.

- It should be recognized that there is a potential for limited degradation to the floor of the dissipator pool for rare event discharges. With the protection afforded by the 2*(d50) thickness of rip-rap, the heavy layer of rip-rap adjacent to the roadway prism, and the apron rip-rap in the downstream portion of the basin, such damage should be superficial.

- See Standards in the in FHWA HEC No. 11 for details on rip-rap materials and use of filter fabric.

- Stability of the surface at the outlet of a basin should be considered using the methods for open channel flow as outlined in Chapter Open Channel Hydraulics.

9.4.5 Example Designs

Example 1

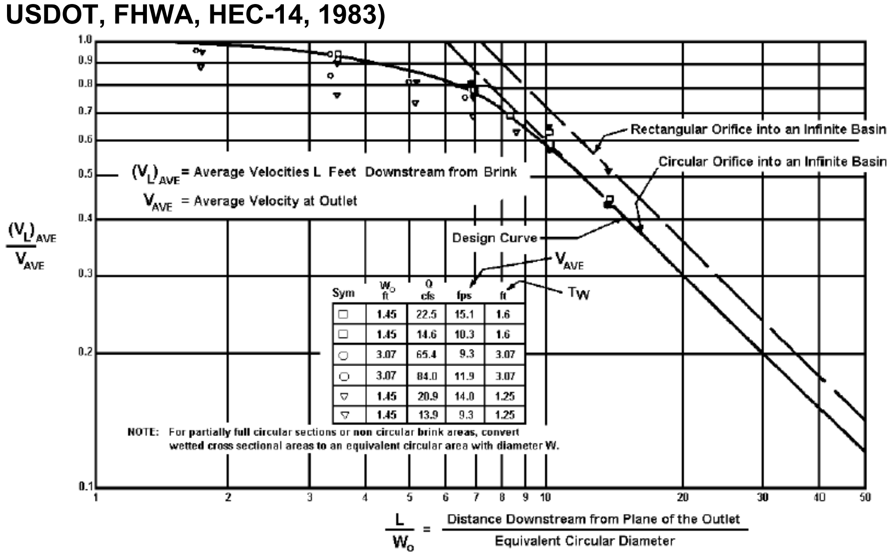
Given: Box culvert - 8 ft by 6 ft | Design Discharge Q = 800 cfs
Supercritical flow in culvert | Normal flow depth = brink depth
y_o = 4 ft | Tailwater depth TW = 2.8 ft

Find: Rip-rap basin dimensions for these conditions

Solution:

(1) $y_o = y_e$ for rectangular section; therefore, with y_o given as 4 ft, y_e = 4 ft.
(2) $V_o = Q/A = 800/(4 \times 8) = 25$ ft/s
(3) Froude Number = $Fr = V/(g \times y_e)^{0.5}$ ($g = 32.2$ ft/s^2)
$Fr = 25/(32.2 \times 4)^{0.5} = 2.20 < 2.5$ O.K.

Figure 9.4.5.1: Distribution of centerline velocity for flow from submerged outlets to be used for predicting channel velocities downstream from culvert outlet where high tailwater prevails (Source: USDOT, FHWA, HEC-14, 1983)



(4) $TW/y_e = 2.8/4.0 = 0.7$ Therefore, $TW/y_e < 0.75$ O.K.
(5) Try $d_{50}/y_e = 0.45$, $d_{50} = 0.45 \times 4 = 1.80$ ft
From Figure 9.4.2.4, $h_s/y_e = 1.6$, $h_s = 4 \times 1.6 = 6.4$ ft
$h_s/d_{50} = 6.4/1.8 = 3.6$ ft, $2 < h_s/d_{50} < 4$ O.K.
6) $L_s = 10 \times h_s = 10 \times 6.4 = 64$ ft (L_s = length of energy dissipator pool)
L_s min = $3 \times W_o = 3 \times 8 = 24$ ft; therefore, use $L_s = 64$ ft
$L_B = 15 \times h_s = 15 \times 6.4 = 96$ ft (L_B = overall length of rip-rap basin)
L_B min = $4 \times W_o = 4 \times 8 = 32$ ft; therefore, use $L_B = 96$ ft
(7) Thickness of rip-rap: On the approach = $3 \times d_{50} = 3 \times 1.8 = 5.4$ ft
Remainder = $2 \times d_{50} = 2 \times 1.8 = 3.6$ ft
Other basin dimensions designed according to details shown in Figure 9.4.5.1.

Example 2

Same design data as Example 1 except:
Tailwater depth TW = 4.2 ft
Downstream channel can tolerate only 7 ft/s discharge

Find: Rip-rap basin dimensions for these conditions

Solutions: Note -- High tailwater depth, $TW/y_o = 4.2/4 = 1.05 > 0.75$
(1) From Example 1: $d_{50} = 1.8$ ft, $h_s = 6.4$ ft, $L_s = 64$ ft, $L_B = 96$ ft.
(2) Design rip-rap for downstream channel. Use Figure 9.4.5.1 for estimating average velocity along the channel. Compute equivalent circular diameter D_e for brink area from:
$A = 3.14D_e$
$2/4 = y_o \times W_o = 4 \times 8 = 32$ ft^2
$D_e = ((32 \times 4)/3.14)^{0.5} = 6.4$ ft
$V_o = 25$ ft/s (From Example 1)
(3) Set up the following table:

L/D_e (Assume) $D_e = W_o$	L (ft) (Compute)	V_L/V_o (Fig. 9.4.5.1)	v_1 (ft/s)	Rock Size d_{50} (ft) (Fig. 9.2.1.1)
10	64	0.59	14.7	1.4
15*	96	0.37	9.0	0.6
20	128	0.30	7.5	0.4
21	135	0.28	7.0	0.4

*L/Wo is on a logarithmic scale so interpolations must be done logarithmically.

Rip-rap should be at least the size shown but can be larger. As a practical consideration, the channel can be lined with the same size rock used for the basin. Protection must extend at least 135 ft downstream from the culvert brink. Channel should be shaped and rip-rap should be installed in accordance with details shown in the HEC No. 11 publication.

Example 3

Given: 6-ft diameter CMC
Design discharge Q = 135 cfs
Slope channel So = 0.004
Manning's n = 0.024
Normal depth in pipe for Q = 135 cfs is 4.5 ft
Normal velocity is 5.9 ft/s
Flow is subcritical
Tailwater depth TW = 2.0 ft

Find: Rip-rap basin dimensions for these conditions.

Solution:

(1) Determine y_o and V_o

From Figure 9.4.2.3, $y_o/D = 0.45$

$Q/D^{2.5} = 135/6^{2.5} = 1.53$

$TW/D = 2.0/6 = 0.33$

$y_o = .45 \times 6 = 2.7$ ft

$TW/y_o = 2.0/2.7 = 0.74$ $TW/y_o < 0.75$ O.K.

Determine Brink Area (A) for $y_o/D = 0.45$

From Figure 6.4.2.5 Area, Wetted Perimeter, and Hydraulic Radius of Partially Filled Circular Pipes:

For $y_o/D = d/D = 0.45$

$A/D^2 = 0.3428$; therefore, $A = 0.3428 \times 6^2 = 12.3\ ft^2$

$V_o = Q/A = 135/12.3 = 11.0$ ft/s

(2) For Froude number calculations at brink conditions,

$y_e = (A/2)^{1/2} = (12.3/2)^{1/2} = 2.48$ ft

(3) Froude number = $Fr = V_o/(32.2 \times y_e)^{1/2} = 11/(32.2 \times 2.48)^{1/2} = 1.23 < 2.5$ O.K.

(4) For most satisfactory results - $0.25 < d_{50}/ye < 0.45$

Try $d_{50}/ye = 0.25$

$d_{50} = 0.25 \times 2.48 = 0.62$ ft

From Figure 9.4.2.4, $h_s/y_e = 0.75$; therefore, $h_s = 0.75 \times 2.48 = 1.86$ ft

Uniform Flow in Circular Sections Flowing Partly Full (From Chapter 5 Open Channel Hydraulics)

Check: $h_s/d_{50} = 1.86/0.62 = 3$, $2 < h_s/d_{50} < 4$ O.K.

(5) $L_s = 10 \times h_s = 10 \times 1.86 = 18.6$ ft or $L_s = 3 \times W_o = 3 \times 6 = 18$ ft;
therefore, use $L_s = 18.6$ ft

$L_B = 15 \times h_s = 15 \times 1.86 = 27.9$ ft or $L_B = 4 \times W_o = 4 \times 6 = 24$ ft;
therefore, use $L_B = 27.9$ ft

$d_{50} = 0.62$ ft or use $d_{50} = 8$ in

Other basin dimensions should be designed in accordance with details shown on Figure 9.4.2.1. Figure 9.4.5.2 is provided as a convenient form to organize and present the results of rip-rap basin designs.

Note: When using the design procedure outlined in this section, it is recognized that there is some chance of limited degradation of the floor of the dissipator pool for rare event discharges. With the protection afforded by the 3 x d50 thickness of rip-rap on the approach and the 2 x d50 thickness of rip-rap on the basin floor and the apron in the downstream portion of the basin, the damage should be superficial.

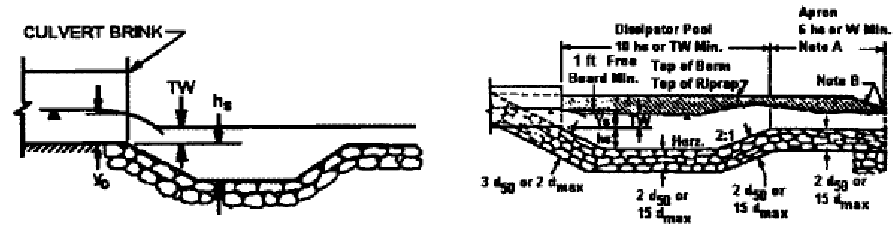
Figure 9.4.5.2: Rip-Rap Basin Design Form (Source: USDOT, FHWA, HEC-14, 1983)

RIPRAP BASIN

Project No. ______________________________

Designer __________________________ Date ________

Reviewer __________________________ Date ________



DESIGN VALUES	TRIAL 1	FINAL TRIAL
Equi. Depth, d_E		
D_{50}/d_E		
D_{50}		
Froude No., Fr		
h_s/d_E		
h_s		
h_s/D_{50}		
$2 < h_s/D_{50} < 4$		

BASIN DIMENSIONS		FEET	
Pool length is the larger of:	$10h_s$		
	$3W_o$		
Basin length is the larger of:	$15h_s$		
	$4W_o$		
Approach Thickness	$3D_{50}$		
Basin Thickness	$2D_{50}$		

TAILWATER CHECK	
Tailwater, TW	
Equivalent depth, d_E	
TW/d_E	
IF $TW/d_E > 0.75$, calculate riprap downstream	
$D_E = (4A_c/\pi)^{0.5}$	

DOWNSTREAM RIPRAP

L/D_E	L	V_L/V_o	V_L	D_{50}

9.5 References

Federal Highway Administration, 1983. Hydraulic Design of Energy Dissipators for Culverts and Channels. Hydraulic Engineering Circular No. 14.

Federal Highway Administration, 1967. Use of Rip-rap for Bank Protection. Hydraulic Engineering Circular No. 11.

Searcy, James K., 1967. Use of Rip-rap for Bank Protection. Federal Highway Administration.

U.S. Department of Interior, Bureau of Reclamation, 1978. Design of Small Canal Structures.

Greenville, South Carolina Storm Water Management Design Manual, January 1992

CHAPTER 10 – BEST MANAGEMENT PRACTICES

10.1 Stormwater Ordinance Review

10.1.1 Best Management Practice Summary

Plan Requirements for Stormwater Management and Sediment Control Plans

The following Best Management Practice information was taken from the Zoning Ordinance of Rock Hill, South Carolina, and must be provided on all Stormwater Management and Sediment Control Plans submitted to the City of Rock Hill for construction approval. This information can be found in its entirety in Chapter 3 of this manual.

Mandatory Standards for All Stormwater Management and Sediment Control Plans

- Install permanent vegetative cover and other long-term measures as soon as practical in the construction process

Grading Permits

- Plans shall require all sediment and erosion controls to be inspected by the contractor at least once every seven calendar days and after any storm event of greater than 0.5 inches of precipitation during any 24-hour period.
- The following note should appear on all plans submitted to City of Rock Hill:
  - The responsibility for maintaining all permanent erosion and sediment control measures and facilities after site land disturbing activity is completed shall lie with the landowner or person in possession or control, except facilities and measures installed within road or street right-of-ways or easements accepted for maintenance by the City of Rock Hill.
- Sediment basins and traps shall be designed to achieve eighty (80) percent efficiency in removing total suspended solids from the discharge effluent from a site.
- The use of measures other than ponds to achieve water quality improvement are recommended on sites containing less than ten acres.
- When work in a live waterway is performed, precautions shall be taken to minimize encroachment, to control sediment transport, and to stabilize the work area to the greatest extent possible during construction.
- Vehicle tracking of sediments from land disturbing activities onto paved roads shall be minimized and continuously monitored.
- Ease of maintenance must be considered as a site design component. Access to the stormwater management structure must be provided.
- Infiltration practices have certain limitations on their use on certain sites. These limitations include the following items:
  - o Areas draining to these practices must be stabilized and vegetative filters established prior to runoff entering system. Infiltration practices shall not be used if a suspended solids filter system does not accompany the practice. If vegetation is the intended filter, there shall be, at least a twenty (20) foot length of vegetative filter prior to stormwater runoff entering the infiltration practice;

- The bottom of the infiltration practice shall be at least 1.0 feet above the seasonal high water table, whether perched or regional, determined by direct piezometer measurements which can be demonstrated to be representative of the maximum height of the water table on an annual basis during years of normal precipitation, or by the depth in the soil at which mottling first occurs;

- The infiltration practice shall be designed to completely drain of water within seventy-two (72) hours;

- Soils must have adequate permeability to allow water to infiltrate. Infiltration practices are limited to soils having an infiltration rate of at least 0.5 inches per hour a minimum of four (4) feet below the infiltration practice's bottom. Initial consideration will be based on a review of the appropriate soil survey, and the survey may serve as a basis for rejection. On-site soil borings and textural classifications must be accomplished to verify the actual site and seasonal high water table conditions when infiltration is to be utilized;

- Infiltration practices greater than three (3) feet deep shall be located at least ten (10) feet from basement walls;

- Infiltration practices designed to handle runoff from impervious parking areas shall be a minimum of one hundred fifty (150) feet from any public or private water supply well;

- The design of an infiltration practice shall provide an overflow system with measures to provide a non-erosive velocity of flow along its length and at the outfall;

- The slope of the bottom of the infiltration practice shall not exceed five (5%) percent. Also, the practice shall not be installed in fill material as piping along the fill/natural ground interface may cause slope failure;

- An infiltration practice shall not be installed on or atop a slope whose natural angle of incline exceeds 20 percent.

- Pet waste stations are required to be installed for all trail installations.

Provide clean outs at minimum of every seventy-five (75) feet along the infiltration practice to allow for access and maintenance. A cleanout is required at each end of the practice at a minimum.

10.2 Introduction

10.2.1 Purpose

The first step in addressing stormwater management begins in the site planning and design stage of the development project. By implementing Best Management Practices (BMPs) during the site planning process, the amount of runoff and pollutants generated from a site can be reduced by minimizing the amount of impervious area and utilizing natural on-site treatments. The minimizing of adverse stormwater runoff impacts by the use of BMPs and site planning should be a major consideration for a design professional.

The reduction of runoff volumes and stormwater pollutants reduces the total number and size of stormwater management controls that must be implemented under the guidelines set forth in this Design Manual. BMPs reduce the amount of total post-development impervious areas and maintains natural characteristics of the pre-development site conditions. Therefore, the post-development curve number and time of concentrations are maintained more closely to the pre-development conditions which reduces the overall hydrologic and hydraulic impact of the development.

10.3 Erosion Protection and Sediment Control Requirements

10.3.1 EPSC Development Standards

EPSC plans shall be developed to achieve an 80 percent design removal efficiency goal. Simply applied, when a site is completely denuded of vegetation, the structural and nonstructural EPSC measures are designed to trap 80 percent of the total suspended solids (TSS) that are generated by the site. The design storm event associated with this level of control is the 10-year, 24-hour SCS Type II storm event.

SCS procedures should be used to determine runoff amounts. It is important to note when a BMP is designed for the 10-year, 24-hour storm event, the BMP will have a greater trapping efficiency for more frequent events such as the 2-year, 24-hour storm event.

- Each EPSC Plan must delineate the following elements:
- All Sensitive Features.
- Sources of sediment that may potentially leave the site.
- The location dimensions and depth of all structural and nonstructural BMPs necessary to achieve the 80 percent design removal efficiency goal to protect receiving water bodies, off-site areas and all Sensitive Features.
- Installation and maintenance of required BMPs.
- The sequencing of construction activities to be utilized on the project.

  The following nonstructural site management practices shall be utilized on the plans where applicable:

- Minimize site disturbance to preserve and maintain existing vegetative cover.
- Limit the number of temporary access points to the site for land disturbing activities.
- Phase and sequence construction activities to minimize the extent and duration of disturbed soil exposure. Multiple plan sheets may be required.
- Locate temporary and permanent soil disposal areas, haul roads and construction staging areas to minimize erosion, sediment transport and disturbance to existing vegetation.

Detailed EPSC plans shall comply with the following specific standards and review criteria:

Sediment Tracking Control. Stabilized construction entrances shall be located and utilized at all points of ingress/egress on a construction site. The transfer of soil, mud and dust onto public rights-of-ways shall be prevented.

Crossings of waterways during construction should be minimized and must be approved by the City of Rock Hill. Encroachment into stream buffers, riparian areas and wetlands should be avoided when possible.

Topsoil shall be stockpiled and preserved from erosion or dispersal both during and after site grading operations when applicable.

Temporary Stabilization Measures. Where construction or land disturbance activity will or has temporarily ceased on any portion of a site, temporary site stabilization measures shall be required as soon as practicable, but no later than 14 calendar days after the activity has ceased.

Final Stabilization. Final Stabilization of the site shall be required within 14 calendar days of construction completion. All slopes 2:1 and steeper shall be matted with geotextile fabric.

Temporary Structural Controls installed during construction shall be designed to accomplish maximum stabilization and control of erosion and sedimentation, and shall be installed, maintained, and removed according to the specifications set forth in the Design Manual, Standard Specifications, and Standard Drawings. All temporary structural controls shall be designed to control the peak runoff resulting from the storm event identified in the Design Manual, Standard Specifications, and Standard Drawings.

All Permanent Structural Controls, including drainage facilities such as channels, storm sewer inlets, and detention basins, shall be designed according to the standards set forth in the Design Manual, Standard Specifications, and Standard Drawings.

10.3.2 Alternative Erosion Prevention and Sediment BMPs

To encourage the development and testing of innovative alternative EPSC BMPs, alternative management practices that are not included in the Design Manual, Standard Specifications and Standard Drawings may be allowed upon review and approval. To use an alternative BMP, the design professional shall submit substantial evidence that the proposed measure will perform at least equivalent to currently approved BMPs contained in the Design Manual, Standard Specifications, and Standard Drawings. Evidence may include, but is not limited to:

- Supporting hydraulic and trapping efficiency calculations.
- Peer-review by a panel of licensed professional engineers.
- Research results as reported in professional journals.
- Manufacturer literature.

To justify the efficiency of innovated EPSC BMPs, the owner may be required to monitor the trapping efficiency of the structure. If satisfactory results showing that trapping efficiencies of greater than 80 percent are obtained, the innovative BMP may be used and no other monitoring studies shall be required. If monitoring shows that a certain BMP is not sufficient or if the City of Rock Hill finds that a BMP fails or is inadequate to contain sediment, other upstream and downstream BMPs shall be implemented to reach the required efficiency.

10.4 Best Management Practices

10.4.1 BMP's

Table 10.4.1.1: EPSC Practices

BMP	Definition	Purpose	Where Applicable	Planning Consider-ation	Design Criteria
Mulching	Use of a protective blanket of straw, residue, gravel or synthetic material on soil surface	To protect soil surface from forces of raindrop impacts, overland or sheet water flow	May be used on beds for temporary or permanent seeding and on areas of bare soil when seeding or planting must be delayed	Avoid organic mulch that contain weed seeds Choice of mulch should be based season, type of vegetation, soil condition, and size of area	Organic mulches are most effective when uniformly spread and to the soil structure
Temporary Seeding	Planting fast-growing vegetation to provide temporary erosion control	To provide stabilization of bare soil areas that will not be brought to final grade for a period of more that 30 working days	May be used on cleared, unvegetated areas where temporary erosion control is needed	Selection of appropriate plant species, use of quality seed, and proper bed preparation are important	No design criteria is necessary
Permanent Seeding	Control of runoff and erosion with permanent vegetation	To economically control erosion and sedimentation	May be used in fine-graded areas	Planting should occur immediately following final grading	No design criteria is necessary
Outlet Stabilization Structure (Figure 10.5.1)	Structure designed to control erosion at the outlet of a channel of conduit	To prevent erosion by reducing water velocity from the outlet of a channel or conduit	May be used at locations where water velocity from a conduit, channel, pipe, diversion, etc. exceeds permissible velocity of the receiving channel or disposal area	Riprap aprons are relatively low cost and easy to install. Riprap stilling basins or plunge pools are used where overfalls exit the ends of pipes or where high flow would require excessive apron lengths	Capacity: 10 years peak runoff or design discharge of conveyance – whichever is greatest
Filter Fabric Burial Detail (Figure 10.5.2)	Temporary fabric barrier placed around a drop inlet	To prevent sediment from entering the storm drains during construction activities; allows early use of storm drain	May be used where storm drains inlets are to be operational before permanent stabilization of the drainage area occurs. This method is used where inlet drains a nearly level re with slopes less than 5%	This method must not be used near the edge of fill material and must not divert water over cut or fill slopes	Drainage Area: Not greater than 1 acre unless site conditions allow for frequent removal of sediment Height of Barrier: At least 18'' – but no greater than 24'' Do not use mortar

Stabilized Construction Entrance (Figure 10.5.3)	A gravel driveway or pad located at a point where vehicles enter and exit a construction site	Provides a suitable location for vehicles to drop mud and sediment before entering public roads; controls erosion from surface runoff and to help controls erosion from surface runoff and to help control dust	May be used wherever traffic leaves a construction site and enters a public road or other paved areas	Construction plans should limit traffic to properly constructed entrances to the site	Aggregate Size: 2'' – 3'' washed stone Pad Thickness: 6'' minimum Pad Widths: 24' minimum Pad Length: 100' minimum
Slit Fence (Figure 10.5.4)	Temporary sediment barrier consisting of filter fabric or burlap stretched across the area	To catch and hold small amounts of sediment from disturbed areas by reducing the velocity of sheet flow	May be used below small disturbed areas less than ¼ acre per 100' of fence where runoff can not damage area	Slit fences should be located in areas where only shallow pools can form behind them	Should be stable for a 10-year storm, impounded water not exceed 1.5' at any fence
Rock Check (Figure 10.5.5)	Small, temporary stone dam constructed across a drainage way	To reduce erosion of the channel by restricted the velocity of flow in the channel	May be used as a temporary or emergency to limit erosion by reducing flow in a small open channel	Check dams should not be used in live streams, check dams installed in grass-lined channels may kill vegetative lining	Drainage area above the check dam should not exceed 2 acres Maximum Height: 2' at the center of dam, Keep center 6'' lower than outer edges of ground elevation
Temporary Sediment Trap (Figure 10.5.6)	A small temporary pond basin formed by excavation or by an embankment	To detain sediment-laden runoff and to trap the sediment; to protect receiving waters from sedimentation	May be used at all outlets of drains, channels, and other runoff conveyances; may be installed during early development	Access to the basin must be maintained to periodically remove sediment for proper disposal, Limited life span 2 years	Used to received water drained from areas of 5 acres or less, Side slopes of excavated basins – 2:1 or flatter, Clean-out trap when sediment reaches 50% of storage volume or reaches top of cleanout stake.
Sediment Basin	A suitably located earthen embankment designed to capture sediment	To retain sediment on the construction site and to prevent sedimentation of offsite waterbodies	May be used where erosion control measures are not adequate to prevent offsite sedimentation	This practice applies to structures 15' or less in height and whose failure would not jeopardize property or lives, limited life span 3 years or less permanent design	Drainage area: less than 100 acres; flow length to basin width ratio should be greater than 2:1 to improve trapping efficiency

Stormwater Management Systems

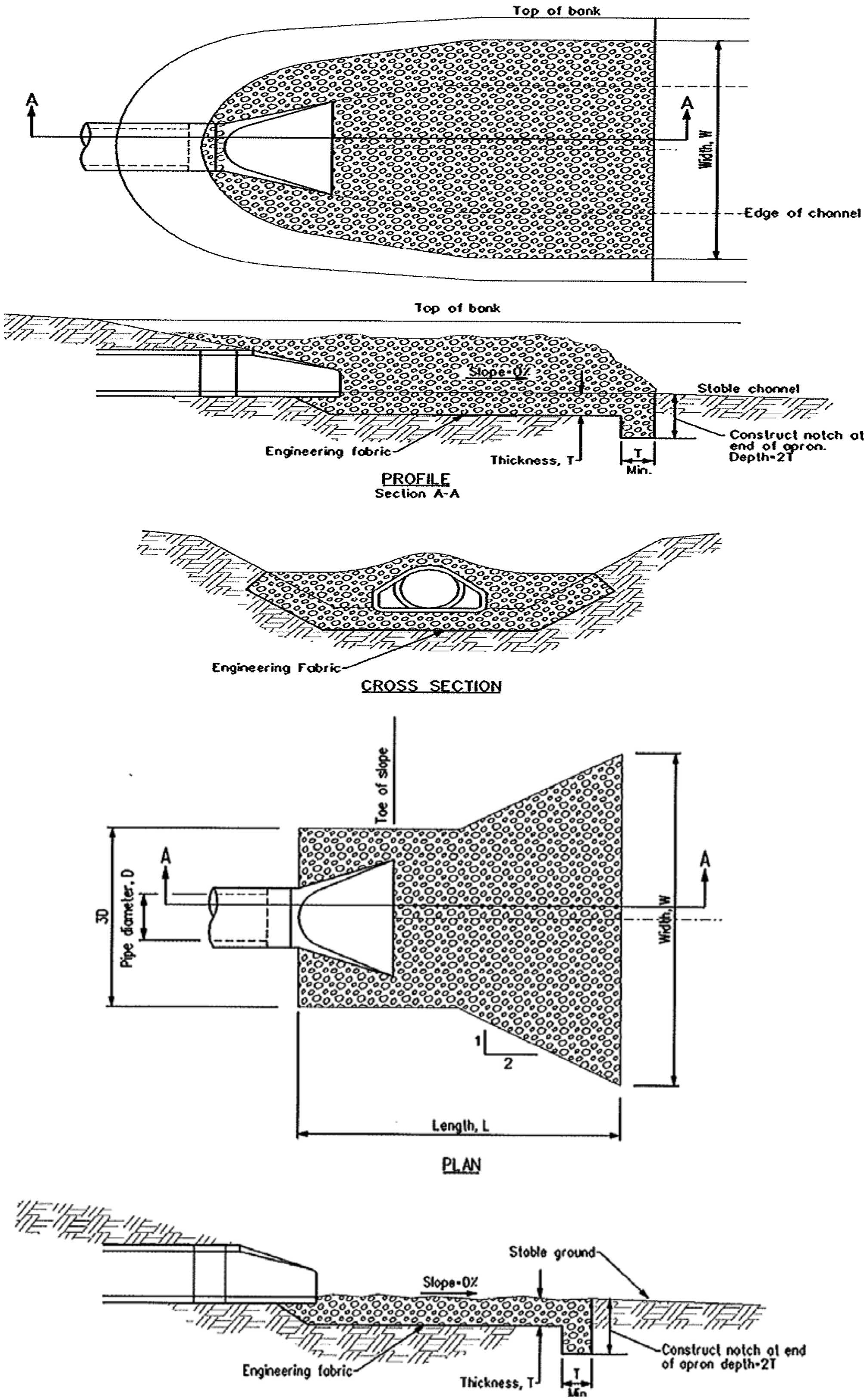
BMP	Definition	Purpose	Where Applicable	Planning Consider-ation	Design Criteria
Grass-lined Channels (Grass Swale)	A channel with vegetative lining for conveyance of stormwater runoff	To convey and infiltrate concentrated surface runoff without damage from flooding, deposition or erosion	May be used as roadside ditches, channels along property boundaries, outlets for diversion, and as drainage for low level areas	Should be located to conform with and use the natural drainage system; Avoid crossing ridges or watershed; Avoid sharp changes in grade or direction of channel	Peak capacity minimum of 10 year storm w/o eroding; Velocity: No more than 2 ft/sec w/o a channel liner; Side slope: 3:1 or flatter
Wet Extended Detention Pond **(Figure 10.5.7)**	A channel pool system containing a forebay near the inlet to trap sediments and deep pool for storage	To provide temporary storage of stormwater runoff before it is discharged downstream; protects the downstream channels from erosion and sedimentation; functions as a sediment trap and pollution filter	Most effective in large, intensely developed sites, usually greater than 10 acres; This is generally the most cost effective practice for urban/coastal areas	Pond should be designed o hold post-development peak stormwater runoff 24hours or more for 90% particulate-form or suspended solid pollutant removal	Depth: 6' - 8' for permanent pool and aquatic life; Littoral Shelf: Extend side slopes out 2' - 3' with slope 6:1 or flatter; Inlet structures designed to dissipate energy of water entering the pool
Wet Pond	A pond with all of its storage as a permanent pool	To provide a high level of urban pollutant removal through biological uptake of aquatic wetland vegetation	May be used in areas where a combination of water quality treatment, stream-bank erosion protection; and flood protection is needed	Shallow areas around the pond should be designed to encourage growth of emergent wetland vegetation, which functions as biological filter and sediment trap	Surface Area and Volume: Minimum of 1.5% of the contributing catchment area; Geometry: Length-to-width ration of 3:1 or 5:1
Dry Extended Detention Pond	An open pond system that temporarily stores excess runoff from the site prior to gradual release after the peak of stormwater inflow has passed	To temporarily store excess stormwater runoff from a site before gradual release into a receiving water body; provides removal of sediments through settling	May be used on large development sites where water quality treatment and flood control are needed	Generally, the completed pond should be planned to provide safety for people, protection of property, improved stormwater runoff control and provide wildlife habitats	Requires a minimum of 24 hours detention time for settling of urban pollutants and sediment from a 1" storm event; Pond depth and geometry same as for a wet pond
Grass Filter Strip	A grassed surface area designed to accept overland sheet flow	Used to remove sediment, organic materials, and trace metals from stormwater runoff	May be used to protect surface infiltration trenches from clogging with sediment, parking lot perimeters, on side of roadways, etc.	To be effective, the depth of stormwater during treatment should not exceed the height of the grass; Runoff should be a uniform sheet flow	Grade should be uniform, even, with a relatively low slope. A shallow stone trench along the top of the grassed filter strip may serves as a level spreader

Infiltration Trench	A shallow, excavated trench back-filled with stone to form an underground reservoir to infiltrate stormwater runoff into the subsoil or drain into pipes and be diverted to a suitable collection point	To provide control of stormwater runoff, preserve on-site ground water and remove sediments and pollutants	May be used for residential lots, commercial areas, parking lots, and open areas	If infiltration is desired, soils and depth to the ground water table must be suitable	Drainage Area: 5 to 10 acres; Trench Depth: 3' to 8'; Stone fill material shall consist of washed aggregate 1.5" to 3" in diameter
Fertilizer/ Pesticide Control	Proper use of fertilizer and pesticides to avoid water quality impacts	To reduce nutrient loading and toxic chemical loading of stormwater runoff	Develop and developing sites	Developments adjacent to sensitive water bodies should provide lawn care	Fertilizers and pesticides should be stored in sheds and away from water sources and pervious soil

The previous BMP tables were modified from Appendix H Sample Stormwater Management and Sediment Reduction Best Management Practices of the South Carolina Stormwater Management and Sediment Control Handbook For Land Disturbance Activities.

10.5.1 Standard Drawings - Outlet Stabilization Structure

Figure 10.5.1: Outlet Stabilization Structure



When and Where to Use It

Outlet protection should be installed at all pipe, interceptor dike, swale, or channel section outlets where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel. Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools (small permanent pools located at the inlet to or the outfall from BMPs). Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

Important Considerations

The exit velocity of the runoff as it leaves the outlet protection structure should be reduced to levels that minimize erosion. Outlet protection should be inspected on a regular schedule to look for erosion and scouring. Repairs should be made promptly.

Installation

- The subgrade for the filter, riprap or gabion shall be prepared to the required lines and grades as shown on the plan. Any fill required in the subgrade shall be compacted to a density of approximately that of the surrounding undisturbed material.

- The riprap shall conform to the grading limits as shown on the plan.

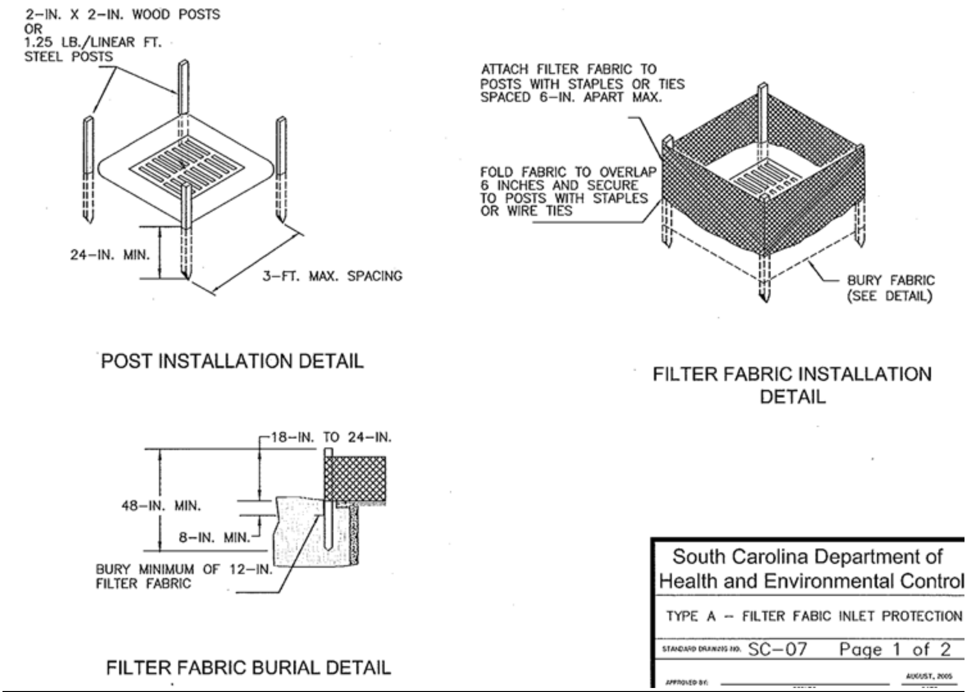
- Filter cloth shall be protected from punching, cutting or tearing. Any damage other than an occasional small hole shall be repaired by placing another piece of cloth over the damaged area. All connecting joints should overlap a minimum of 1 ft. If the damage is extensive, replace the entire filter cloth.

- Stone for the riprap or gabion outlets may be place by equipment. Riprap shall be place in a manner to prevent damage to the filter cloth. Hand placement will be required to the extent necessary to prevent damage to the conduits, structures, etc.

Inspection and Maintenance

Once a riprap outlet has been installed, the maintenance needs are very low. It should be inspected after high flows to see if scour beneath the riprap has occurred, or any stones have been dislodged. Repairs should be made immediately.

10.5.2 Filter Fabric Burial Detail



<u>**Installation:**</u>

Filter fabric is used for inlet protection when stormwater flows are relatively small (0.5 cfs or less) with low velocities and where the inlet drains a relatively flat area (slopes no greater than 5%). This practice cannot be used where inlets are paved or where inlets receive concentrated flows such as in streets or highway medians.

A trench shall be excavated 4-inches wide and 8-inches deep around the outside perimeter of the stakes.

Extra-strength filter cloth (50 lbs./linear inch minimum tensile strength) shall extend a minimum of 12-inches into the trench. The trench shall be backfilled with soil or crushed stone and compacted over the filter fabric.

Posts shall be 1.33 lb./linear foot steel posts with a minimum post length of 48-inches. The height of the filter barrier above grade shall be a minimum of 18-inches and shall not exceed 24-inches.

Posts shall be spaced around the perimeter of the inlet a maximum of 3-feet apart and driven into the ground a minimum of 24-inches.

Filter fabric should be purchased in a continuous roll and cut to the length of the barrier to avoid the use of joints. When joints are necessary, filter fabric should be wrapped together only at a support post with both ends securely fastened to the post, with a minimum 6-inch overlap.

Wire ties spaced a maximum of 6-inches apart, should be used to attach the fabric to steel posts.

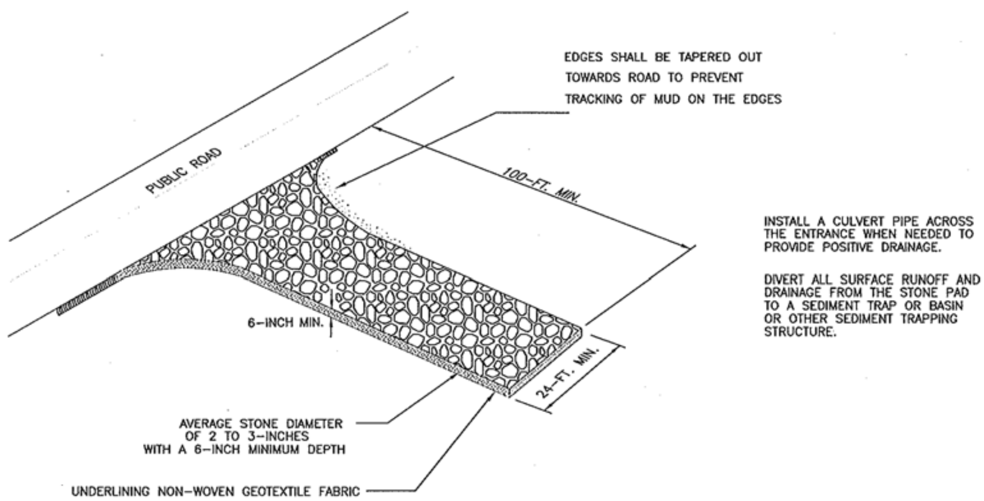
<u>**Inspection and Maintenance:**</u>

Inspections should be made every seven (7) calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Any needed repairs should be handled immediately.

If the fabric becomes clogged, it should be replaced. Sediment should be removed when it reaches approximately 1/3 the height of the fence. If a sump is used, sediment should be removed when it fills approximately 1/3 the depth of the hole. Maintain the pool area, always providing adequate sediment storage volume for the next storm. Take care not to damage or undercut fabric when removing sediment.

Storm drain inlet protection structures should be removed only after the disturbed areas are permanently stabilized. Remove all construction material and sediment, and dispose of them properly. Grade the disturbed area to the elevation of the drop inlet structure crest. Use appropriate permanent stabilization methods to stabilize bare areas around the inlet.

10.5.3 Stabilized Construction Entrance



<u>When and Where to Use It</u>

Stabilized construction entrances should be used at all points where traffic will be leaving a construction site and moving directly onto a public road.

<u>Important Considerations</u>

If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried offsite. Washdown facilities shall be required as directed by the City of Rock Hill as needed. Washdown areas in general must be established with crushed gravel and drain into a sediment trap or sediment basin. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.

<u>Installation:</u>

- Remove all vegetation and any objectionable material from the foundation area.
- Divert all surface runoff and drainage from stones to a sediment trap or basin.
- Install a non-woven geotextile fabric prior to placing any stone.
- Install a culvert pipe across the entrance when needed to provide positive drainage.
- The entrance shall consist of 2-inch to 3-inch D50 stone placed at a minimum depth of 6-inches.
- Minimum dimensions of the entrance shall be 24-feet wide by 100-feet long, and may be modified as necessary to accommodate site constraints.

- The edges of the entrance shall be tapered out towards the road to prevent tracking of mud at the edge of the entrance.

Inspection and Maintenance:

- Inspect construction entrances every seven (7) calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation, or after heavy use. Check for mud and sediment buildup and pad integrity. Make daily inspections during periods of wet weather. Maintenance is required more frequently in wet weather conditions. Reshape the stone pad as needed for drainage and runoff control.

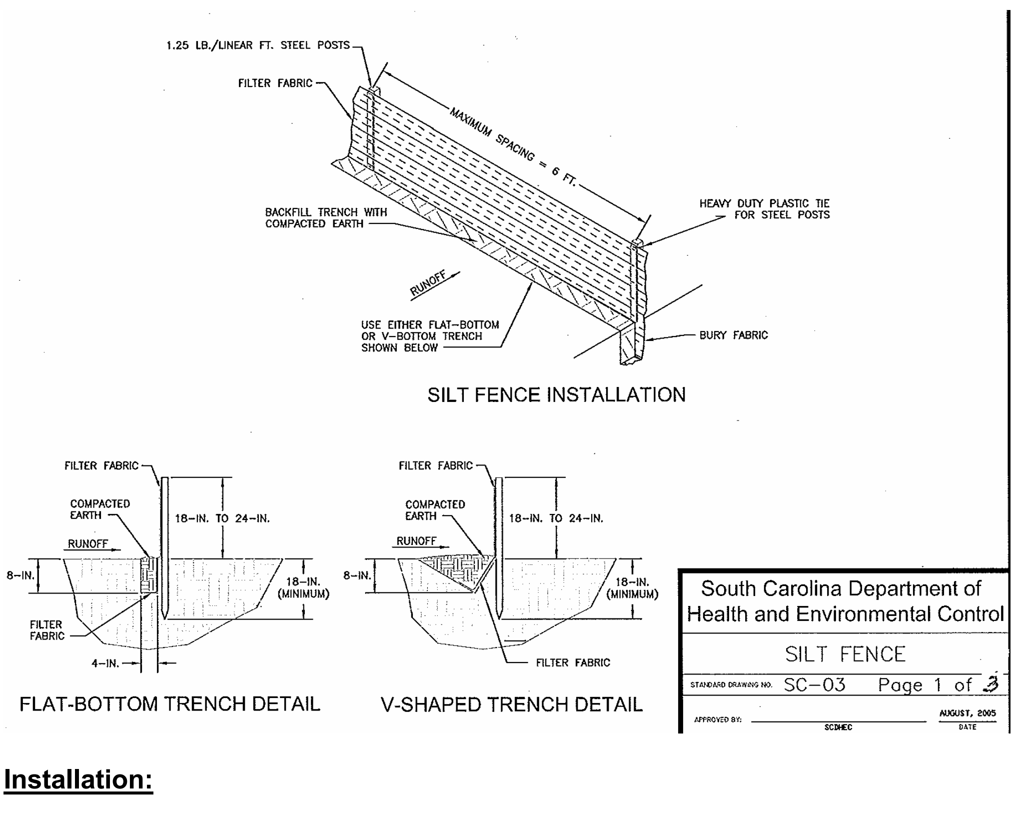
- Wash or replace stones as needed and as directed by the inspector. The stone in the entrance should be washed or replaced whenever the entrance fails to reduce mud being carried off-site by vehicles. Frequent washing will extend the useful life of stone.

- Immediately remove mud and sediment tracked or washed onto public roads by brushing or sweeping. Flushing should only be used when the water can be discharged to a sediment trap or basin.

- Repair any broken pavement immediately.

10.5.4 Silt Fence

Figure 10.5.4: Silt fence



Installation:

The fence should be placed across the slope along a line of uniform elevation (perpendicular to the direction of flow). The fence should be located at least 10-feet from the toe of steep slopes to provide sediment storage and access for maintenance and cleanout.

A flat-bottom trench approximately 4-inches wide and 8-inches deep, or a V-shaped trench 8-inches deep should be excavated.

Place 12-inches of extra-strength filter fabric (50 pounds / linear inch minimum tensile strength) into the 8-inch deep trench, extending the remaining 4-inches towards the up-slope side of the trench and backfill the trench with soil or gravel and compact.

On the downslope side of the trench, drive 1.33 lb./linear foot steel posts at least 18-inches into the ground, spacing them no further than 6-feet apart without wire backing and 8 feet with wire backing.

Posts should be installed with 1- to 2-inches of the post protruding above the top of the fabric and no more than 36-inches of the post should protrude above the ground. The minimum fence height (height of filter fabric above grade) shall be 18-inches. The maximum fence height (height of filter fabric above grade) shall be 24-inches.

The filter fabric should be purchased in a continuous roll and cut to the length of the barrier to avoid the use of joints. When joints are necessary, filter fabric should be wrapped together only at a support post with both ends securely fastened to the post, with a minimum 6-inch overlap.

Wire ties spaced a maximum of 6-inches apart, should be used to attach the fabric to steel posts.

Inspection and Maintenance:

Inspect silt fence every seven (7) calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Check for areas where runoff has eroded a channel beneath the fence, or where the fence was caused to sag or collapse by runoff overtopping the fence.

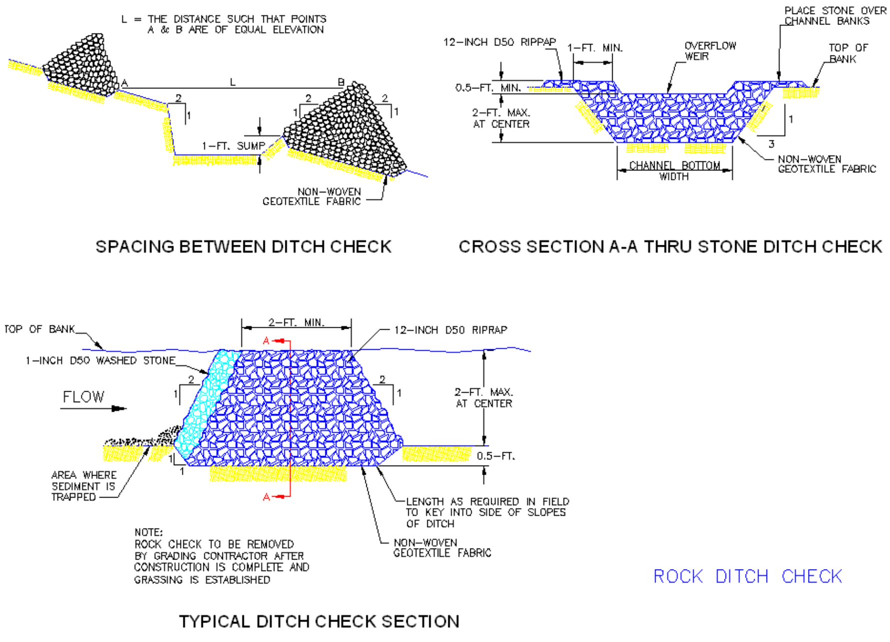
If the fence fabric tears, begins to decompose, or in any way becomes ineffective, replace the affected section of fence immediately.

Sediment must be removed when it reaches approximately 1/3 the height of the fence, especially if heavy rains are expected.

Silt fence should be removed within 30 days after final site stabilization is achieved or after temporary BMPs are no longer needed. Trapped sediment should be removed or stabilized on site. Disturbed areas resulting from fence removal shall be permanently stabilized.

10.5.5 Check Dam

Figure 10.5.5: Check dam



<u>When and Where to Use It</u>

A rock ditch check should be installed in steeply sloped swales, or in swales where adequate vegetation cannot be established. Rock ditch checks should be used only in small open channels. Rock ditch checks should not be placed in waters of the state or USGS blue-line streams (unless approved by the City of Rock Hill, State, or Federal authorities).

<u>Installation:</u>

- A non-woven geotextile fabric shall be installed over the soil surface where the rock ditch check is to be placed.
- The body of the rock ditch check shall be composed of 12-inch D50 Riprap.
- The upstream face of the rock ditch check may be composed of 1-inch D50 washed stone.
- Rock ditch checks should not exceed a height of 2-feet at the centerline of the channel.
- Rock ditch checks should have a minimum top flow length of 2-feet.
- Stone should be placed over the channel banks to prevent water from cutting around the ditch check.
- The rock must be placed by hand or mechanical placement (no dumping of rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the check is lower than the edges.
- The maximum spacing between the dams should be such that the toe of the upstream check is at the same elevation as the top of the downstream check.

Inspection and Maintenance:

Inspect rock ditch checks every seven (7) calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation. Inspect for sediment and debris accumulation. Inspect ditch check edges for erosion and repair promptly as required.

Sediment should be removed when it reaches 1/3 the original check height.

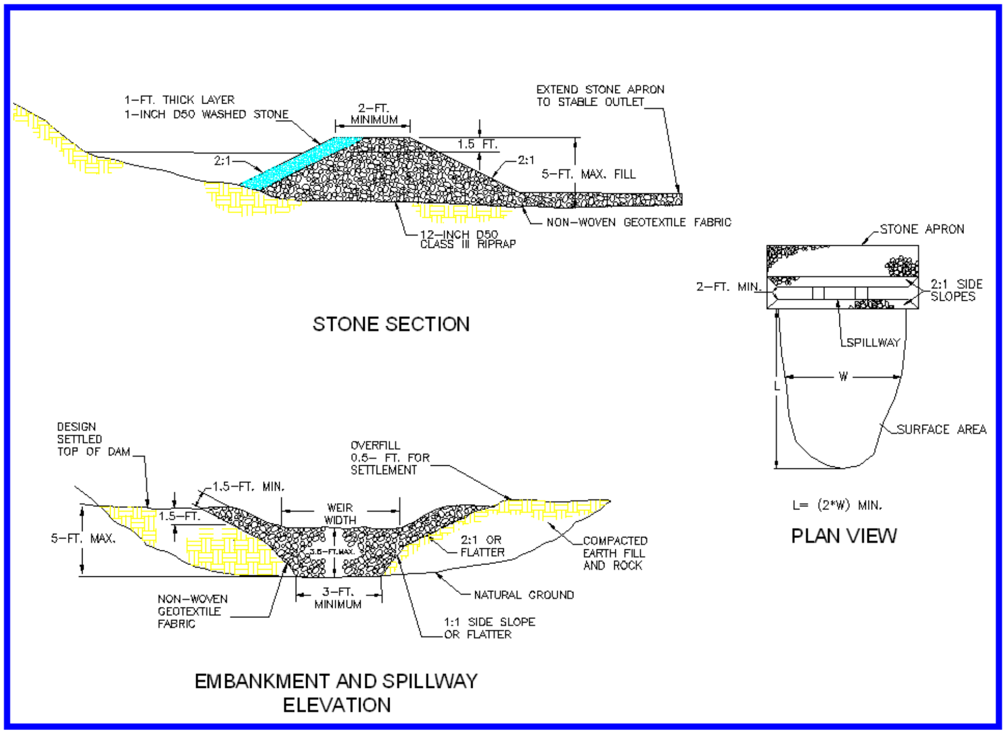
In the case of grass-lined ditches and swales, rock ditch checks should be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4%.

After construction is complete, all stone should be removed by the grading contractor if vegetation will be used for permanent erosion control measures.

The area beneath the rock ditch checks should be seeded and mulched immediately after rock check dam removal.

10.5.6 Temporary Sediment Trap

Figure 10.5.6: Temporary sediment trap



When and Where to Use It

Sediment traps should not be placed in waters of the state or USGS blue-line streams (unless approved by City of Rock Hill, State, or Federal authorities).

Installation:

Rock Outlet Structure Requirements:

- The maximum sediment trap height shall be 5-feet.
- The maximum stone height of the outlet weir shall be 3.5-feet.
- The minimum bottom flow width of the structure shall be 3-feet.
- The minimum top flow length of the structure shall be 2-feet.

The main body of the outlet structure shall consist of 12-inch D50 class III riprap. The upstream face of the outlet structure shall consist of a 1-foot thick layer of 1-inch D50 washed stone. The maximum sideslope of the rock structure shall be 2:1.

Install a non-woven geotextile filter fabric before installing the stone for the outlet structure. Allow the stone to extend downstream past the toe of the
embankment.

All inside sediment trap slopes should be 3:1 or flatter.

Mark the sediment cleanout level of trap with a stake in the field. Seed and mulch all disturbed areas.

Inspection and Maintenance:

The key to a functional sediment trap is continual monitoring, regular maintenance and regular sediment removal.

Remove sediment when it reaches 50% of storage volume or reaches the top of cleanout stake.

Regular inspections should be done every seven (7) calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.

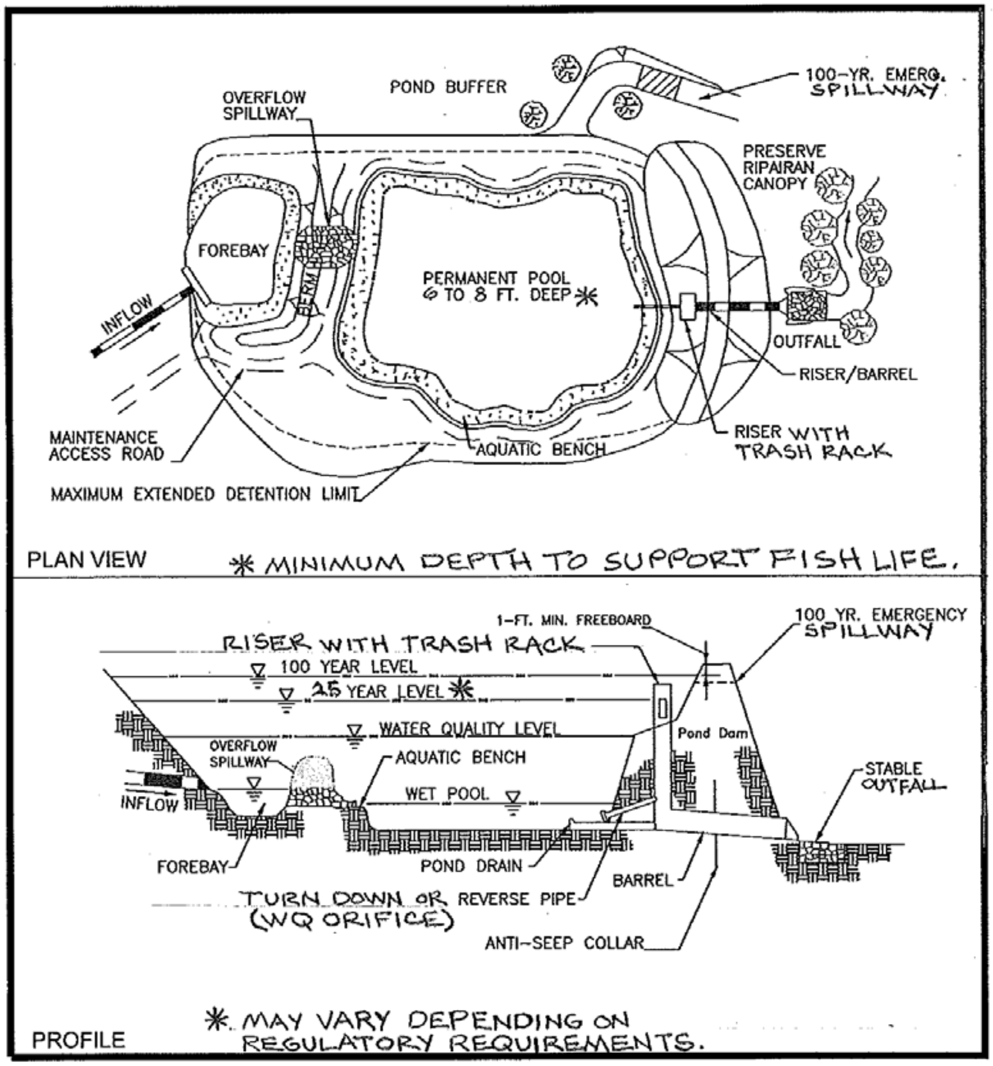
All temporary sediment traps should be removed within 30 days after final site stabilization is achieved or after it is no longer needed.

Trapped sediment should be removed from, or stabilized on site.

Disturbed areas resulting from the removal of the sediment trap should be permanently stabilized.

10.5.7 Wet Extended Detention Pond

Figure 10.5.7: Wet extended detention pond



WET EXTENDED DETENTION POND

A wet extended pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention storage provided above the permanent pool. During storm events, water is stored above permanent pool and released over 24-hours. The design has similar pollutant removal efficiencies as traditional wet ponds, but consumes less space.

Installation:

A forebay shall be provided for all inlets to a wet extended water quality pond and shall be placed upstream of the main wet pond area. The forebay is separated from the larger wet detention pond area by a berm that may be constructed of earth, stones, riprap, gabions, or geotextiles. The top of the forebay barrier shall be equal to the normal pool elevation, and may extend above the elevation of the permanent pool. A spillway shall be constructed to convey flow from the forebay to the wet detention pond area.

The permanent pool shall be six (6) to eight (8) feet in depth.

A low flow orifice shall be installed to slowly release the water quality capture volume. The low flow orifice shall be protected from clogging by designing appropriate trash guards. Acceptable trash guards include:

Hoods that extend at least 6-inches below the permanent pool water surface elevation.

Reverse flow pipes where the outlet structure inlet is located at least 6-inches below the permanent pool water surface elevation.

Trash boxes made of sturdy wire mesh.

Emergency spillways shall be installed to safely pass the post-development 100-year, 24-hour storm event without overtopping any dam structures.

Inspection and Maintenance:

The side slopes of the pond shall be mowed monthly.

Since decomposing vegetation captured in the wet pond can release pollutants, especially nutrients, it may be necessary to harvest dead vegetation annually.
Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur.

Debris shall be cleared from all inlet and outlet structures monthly.

All eroded or undercut areas shall be repaired as needed.

A sediment marker shall be placed in the forebay to determine when sediment removal is required.

Sediment accumulations in the main pond area shall be monitored and sediment shall be removed when the permanent pool volume has been significantly filled and/or the pond becomes eutrophic.

10.6 Updating BMPs

10.6.1 Updating

The BMPs in this chapter may be updated and revised, as necessary, to reflect up-to-date engineering practices and information applicable to the City of Rock Hill area. Manual users can find updated BMP information on the City of Rock Hill Planning and Development webpage at www.cityofrockhill.com.

10.7 References

Federal Highway Administration, 1983. Hydraulic Design of Energy Dissipators for Culverts and Channels. Hydraulic Engineering Circular No. 14.
Federal Highway Administration, 1967. Use of Riprap for Bank Protection. Hydraulic Engineering Circular No. 11.
Searcy, James K., 1967. Use of Riprap for Bank Protection. Federal Highway Administration.
U.S. Department of Interior, Bureau of Reclamation, 1978. Design of Small Canal Structures.
Greenville, South Carolina Storm Water Management Design Manual, January 1992

CHAPTER 11 – THE EROSION AND SEDIMENT CONTROL PLAN

11.1 Elements of the Sediment and Erosion Control Plan

11.1.1 Introduction

The erosion and sediment control plan submitted to the approving agency with the project application should contain all the pertinent information for review and implementation. The following elements should be present and are required with the submittal:

1. Narrative and checklists—see www.cityofrockhill.com
2. Map / Site plan
3. Construction details
4. Calculations and drainage area maps

11.1.2 The Narrative

The narrative is a brief description of the overall strategy for erosion and sediment control. It should summarize for the plan reviewer and the project superintendent the aspects of the project that are important for erosion control and should include:

a. A brief description of the proposed land-disturbing activities, existing site conditions, and adjacent areas (such as creeks and buildings) that might be affected by the land disturbance.
b. A description of critical areas on the site - areas that have potential for serious erosion problems such as severe grades, highly erodible soils, and areas near wetlands or water bodies.
c. A construction schedule that includes the date grading will begin and the expected date of stabilization.
d. A brief description of the measures that will be used to minimize erosion and control sediment on the site, when they will be installed, and where they will be located. Is a phased plan required?
e. A maintenance program: including frequency of inspection, provisions for repair of damaged structures, and routine maintenance of erosion and sediment control practices.

11.1.3 The Map/Site Plan

The map is the key item in an erosion and sediment control plan. It should show:

a. Existing and final elevation contours at an interval and scale sufficient for distinguishing runoff patterns before and after disturbance.
b. Critical areas within or near the project area, such as streams, lakes, wetlands, highly erodible soils, public streets, and residences.
c. Existing vegetation.
d. Limits of clearing and grading.
e. Locations and names of erosion and sediment control measures, with dimensions.
   It is strongly recommended that standard symbols be used on the map to denote erosion and sediment control measures and the symbols are shown in a legend. Use of standardized symbols will speed up plan review time and make it easier for site superintendents and inspectors to understand plans quickly. These symbols were designed to be both pictorially representative of the control measures and easy to draw.

11.1.4 Construction Details, Specifications, and Notes

Construction details, often in large-scale, detailed drawings, provide key dimensions and spatial information that will not fit on the map. Other important information should also be provided; examples are seeding and mulching specifications; equivalent opening size (EOS) and strength requirements for filter fabric; specifications for wire mesh, fence posts, and rock checks; installation procedures for control measures; and maintenance instructions.

11.1.5 Calculations

Include the calculations used to size the control measures, particularly the data for the design storm (recurrence interval, duration and magnitude, and peak intensity for the time of concentration) and the design assumptions for sediment basins and traps (design particle size, trap efficiency, discharge rate, dewatering time, antiflotation block, etc.). Also include calculations to support the sizing of storm drain systems and gutter spread when an engineered design is necessary.

11.2 Preparing an Erosion and Sediment Control Plan

11.2.1 Introduction

Preparing an erosion and sediment control plan is a four-step process:

Step 1: Collect data
Step 2: Analyze data
Step 3: Develop site plan
Step 4: Develop erosion and sediment control plan

This process is described step by step in the following section. It is primarily designed for relatively large projects (i.e., more than one building) on several acres or more. For very small sites, such as a single-home site, a more streamlined process may be appropriate. For example, doing a soil particle size analysis for sizing a sediment basin for a very small site would be overkill. It would also be unnecessary to do runoff calculations for sizing conveyances, since runoff from the site would probably be very minimal and a standard design would do the job in most cases.

11.2.2 STEP 1: Collect Data

The purpose of data collection is to gather the information on site conditions that will enable you to develop an effective erosion and sediment control plan. Most of this data describes the natural environment of the site. Drainage information is particularly important (see Step 2).

It is best to collect all data in map form, if possible, and to plot it on one or more site maps at the same scale. Mapping the data at the same scale greatly facilitates the planning process by enabling you to overlay different maps and read through them on a light table. Use of a modern Geographic Information Systems (GIS) can greatly facilitate this process.

Topography

A good topographic map should form the basis of any kind of land planning, including site development planning and erosion and sediment control planning. From a topographic base map, you can determine drainage patterns, slope lengths and angles, and locations of sensitive features on or adjacent to the site such as water bodies, buildings, and streets.

All of these are critical concerns in erosion control. Prepare a topographic map of the site which shows the existing contours at a suitable interval for determining drainage patterns over small areas. The contour lines must be close enough together to show which way water will flow. On relatively flat sites, a 2-ft (0.6-m) or smaller interval will probably be needed. On a sloping site, a 10-ft (3-m) interval may be acceptable.

Drainage

The drainage pattern of a site has two components: overland flow and channel flow. Both are important in erosion control. In the data collection stage, it is helpful to clearly mark all existing streams and major conveyances on the topographic base map. Major watercourses are shown as blue lines on U.S. Geological Survey topographic maps, but lesser drainageways will also be important to show. Delineating drainageways now will make it easier to determine watershed boundaries in the data analysis stage (Step 2).

Rainfall
In erosion control, rainfall data is primarily used for sizing large conveyances and sediment basins. Rainfall frequency and intensity are the key types of data. Rainfall intensity determines the i value used in runoff calculations. Rainfall intensity is also a component of the R factor in the universal soil loss equation. This equation can be used to estimate the sediment storage requirements of sediment basins. Rainfall frequency data is used for determining "a design storm". The use of rainfall data for designing stormwater and erosion/sediment control measures is described in detail in Chapter 4 Hydrology.

On small sites and in small drainage areas it is often unnecessary to size control measures by using rainfall data. Most of the control measures described in this handbook have been designed to handle a major storm in a small drainage area [typically 1 to 5 acres (0.4 to 2 ha)]. Since a fairly large margin of error has been incorporated in the standard designs, these structures, if used properly in small watersheds within the specified size limits should be able to withstand major storms in Rock Hill.

Project planners should use their knowledge of the yearly pattern of rainfall to schedule construction during the times of year when erosion potential is lowest. Although March and July are usually the wettest months of the year for South Carolina, there is no real dry season. In eastern South Carolina, however, winter precipitation is greater than summer precipitation. Statewide, minimum precipitation is received in October and November. During summer and early fall of most years, the state receives the effects of one or more tropical storms or hurricanes. Special attention to BMP installation and maintenance must be made when grading or construction must take place during periods of high erosion hazard and a phased plan approach may be required. Rainfall data for the Rock Hill area can be obtained from the below agency;

National Weather Service
Weather Forecast Office Greenville-Spartanburg
GSP International Airport
1549 GSP Drive
Greer, SC 29651-6631
(864) 848-9970

Soils
Soils data is used to locate highly erodible areas on a site, where extra erosion control precautions may be needed. It also shows the distribution of particle sizes in the soil, a critical factor in sizing sediment basins and traps. A high content of clay and fine silt in a soil should suggest a strategy of erosion control by using vegetation and mulch rather than a strategy of sediment control by using silt fence and sediment basins. Soils data for many parts of the country can be obtained from soil surveys published by the U.S. Natural Resources Conservation Service (NRCS).

For many projects, a soils report is specially prepared by a soils engineer. On hillside sites, many jurisdictions routinely require a soils report. If a soils report is to be prepared, it is desirable to include in it a particle size analysis for sediment basin or trap design. Such an analysis can be performed for a nominal extra cost.

Ground Cover
"Ground cover" primarily refers to existing vegetation, which should be preserved to the greatest extent possible because it is the most effective form of erosion prevention. Many communities also wish to preserve trees and certain vegetation for aesthetic and other reasons. Ground cover, along with other physical characteristics of the watershed, is used to determine the C factor in the rational method for calculating runoff (Chapter 4 Hydrology). It is also used to calculate the erosion rate in the universal soil loss equation.

Adjacent Areas
Off-site features, such as streams, lakes, wetlands, buildings, and roads, are particularly sensitive to erosion and sediment damage. Such areas should therefore be noted on the site map. If including the off-site features on the same map would result in an unwieldy document, one of the following options can be chosen:

a. Describe on the margin of the map the nature and location of the adjacent feature.
b. Draw a smaller-scale map (vicinity map) showing the site and all the pertinent adjacent features.

11.2.3 STEP 2: Analyze Data

The purpose of this step is to interpret the data collected in Step 1 for its significance in erosion and sediment control. This interpretation may require stating the data in a different form (e.g., translating a topographic map into a slope map). The result of this step is a map that highlights areas of importance in erosion and sediment control.

Drainage Areas

The most important part of Step 2 is to understand the site's surface water flow pattern. You must determine:

a. Where will concentrated and sheet flows enter the site?
b. How will runoff, both concentrated and sheet flow, travel across the site?
c. Where will runoff leave the site and will it be concentrated or sheet flow?
d. How much water will flow?

Map the drainage boundaries of each of the water courses delineated in Step 1, and then estimate the area of each major watershed. If the site is larger than 5 acres (2 ha), you may have to subdivide the watersheds into smaller units. Bear in mind that many control measures discussed in this handbook have a 5 acre (2 ha) maximum drainage area and that straw bale dikes, silt fences, and most inlet protection structures have a 1 acre (0.4 ha) limit. Define watersheds that are appropriate for the control measures to be used. If grading will alter natural watershed boundaries, you will later need to map the drainage boundaries that will exist after grading is completed (see Step 4). If grading will not be completed before the rainy season, you may have to have several interim drainage plans.

Rainfall and Runoff

Examine the rainfall data collected in Step 1 to determine the times of year when erosion potential is at its lowest and highest. Try to schedule grading during times of low erosion potential and take extra precautions during times when heavy, intense rainfalls are likely.

If a project will require permanent waterways and sediment basins draining large areas, rainfall frequency and intensity data will be used to calculate runoff volumes to be expected. Since these calculations must be based on specific watershed areas that drain to each planned facility, the calculations must be done at a later stage of plan development (see Step 4).

Slope Steepness and Slope Length

Slope steepness and slope length are critical factors in erosion control. The longer and steeper the slope is the greater the erosion potential. If an existing long or steep slope is disturbed or a new one is created by grading, carefully designed and installed erosion control measures will be required. These measures may include benches or ditches at regular intervals, temporary vegetative stabilization, or stabilization using a covering of punched straw or other mulch material.

Erosion potential is closely related to slope steepness. The slope categories shown in Table 11.2.3.1 can be used as a rough guide for evaluating erosion potential:

Table 11.2.3.1: Slope Categories/Erosion Potential

Percent Slope	Potential for Erosion
0-7 %	Low to moderate potential
7-15 %	Moderate to high potential
Over 15 %	High to very high potential

It is a good idea to outline on the topographic base map the above slope categories. Slopes that are over 15 percent and 7 to 15 percent slopes that are very long [over 100 ft (30 m)] should be highlighted as critical.

Soils
A soils report or soil survey covering the site should indicate soil erodibility. The K factor in NRCS soil surveys is an estimate of soil erodibility. Highly erodible soils should be left undisturbed. If they must be disturbed, they should be mulched and revegetated as soon as possible after grading is completed.

If the soils report gives a soil particle size distribution, check what percentage of the soil is composed of fine particles (typically 0.02 mm or smaller). If a high percentage of the soil is smaller than 0.02 mm, much of the suspended sediments will escape capture unless a very large sediment basin is constructed. Remember that grading will mix topsoils with subsoils and move them around the site. If fill will be imported, this material should be analyzed also.

Ground Cover
Note any areas of critical vegetation. Vegetation on or above long or steep slopes and on highly erodible soils is particularly important for erosion control.

Adjacent Areas
Examine areas downslope from the project. Note any watercourses or other sensitive features which receive runoff from the site. Analyze the potential for sediment pollution of these watercourses and the potential for downstream channel erosion due to increased volume, velocity, and peak flow of storm runoff from the site.

11.2.4 STEP 3: Develop Site Plan

When a site plan is developed, erosion and sediment control should be considered along with such traditional planning criteria as economics, utility access, and traffic patterns. After analyzing the erosion hazards on site in Step 2, develop a site plan with erosion control in mind. Consider the following points when preparing a site plan.

Fit Development to the Terrain
Tailor the locations of building pads and roads to the existing contours of the land as much as possible. Locate them to take advantage of the natural strengths of the site and to minimize disturbance.

Confine Construction Activities to the Least Critical Areas
Land disturbance in critically erodible areas, such as steep slopes, will require installation of costly control measures. Keeping construction out of these areas will minimize the costs.

Cluster Buildings Together
Clustering buildings minimizes land disturbance for roads and utilities and reduces erodible area. Other benefits of clustering are reduced runoff, preservation of open space, and reduced development costs.

Minimize Impervious Areas
Make paved areas, such as streets, driveways, and parking lots, as small as possible. Preserve trees, grass, and other natural vegetation. Consider paving driveways with gravel or porous paving stones. French drains, infiltration trenches, and dry wells can be used to percolate runoff from impervious surfaces into the soil if soil conditions allow. Gravel-filled trenches can be located along drip lines below roof eaves. These measures will keep runoff volumes low and minimize the need for conventional storm drains - drop inlets and underground pipes. However, to prevent these infiltration practices from failing it is crucial heavy equipment be kept away from these areas to prevent soil compaction. Additionally, infiltration areas should never be used for erosion and sediment control.

In many communities, residential streets are wider than they need to be. Typically, these streets are designed to carry two lanes of traffic and two rows of parked cars, one on each side of the street. An alternate approach, if parking is not a critical problem, is to eliminate the space for the two rows of parked cars and, instead, provide parking bays at regular intervals. This approach will substantially reduce the size of paved areas.

Low Impact Development (LID)

Low Impact Development (LID) was created in reaction to existing engineering practices. LID has been found to be particularly useful in designing for site stormwater runoff. Where traditional engineering practices tended to design measures to control stormwater off site, LID utilizes measures to control stormwater within the site. Traditional stormwater designs tend to direct rainfall over impermeable land coverages and discharge rainfall into a storm sewer. The primary manner LID uses to reduce runoff is to percolate rainfall into the soil. As rainfall slowly permeates through the soil and into the ground water it adds nutrients and increases interception by the soil. Some common LID practices are building rooftop gardens, bioretention cells, sidewalk storage, and permeable pavers. Other common LID practices attempt to reduce runoff by minimizing the impact to the site. For example, those practices attempt to preserve existing trees, incorporate vegetation, and reduce impermeable surfaces. In all, LID is an effective alternative to traditional designs that are steadily becoming more complex and expensive to safely discharge stormwater.

LID Control objectives are to:

1. Minimize disturbance
2. Preserve and recreate natural landscape features
3. Reduce effective impervious cover
4. Increase hydrologic disconnects
5. Increase drainage flow paths
6. Enhance off-line storage
7. Facilitate detention and infiltration opportunities

Retain the Natural Stormwater System

Use the natural stormwater system to convey runoff from the site wherever possible. If possible, augment the natural system with vegetated swales rather than storm sewers or concrete channels. If impervious surfaces are kept to a minimum and runoff from these surfaces is percolated into the soils on-site, it may be possible, without installing channel protection measures, to use the natural stormwater system to drain a development. The cost of using the natural drainage system can be substantially lower than the cost of constructing a conventional storm drain system. Preserving the natural stormwater system can also retain a visual amenity that will enhance the value of a development.

If runoff flows will be increased by development, route these augmented flows into a stormwater conveyance system and preserves the natural stormwater system in its preexisting condition. If the stability of the natural system is upset, it may be very difficult to prevent a long-term erosion process from beginning. A constructed stormwater conveyance system can be designed to resemble a natural creek.

11.2.5 STEP 4: Develop the Erosion and Sediment Control Plan

Determine Limits of Clearing and Grading

Start with a topographic base map that shows existing and finished contours and proposed improvements. On this base map, delineate the limits of the disturbed area. This line defines the area that must be protected.

Reexamine Drainage Areas

Check to see if the drainage boundaries defined in Step 2 have been altered by the development plan. If so, outline the drainage areas that will exist after grading. Since many control measures have a 1-acre (0.4-ha) or a 5-acre (2-ha) drainage area limit, you may want to break large watersheds into smaller units (see the following subsection). Enlarged drainage areas and/or increased impervious surface within a drainage area will produce increased flows. Discharging the increased flows to existing swales and watercourses will cause channel erosion, unless/until the conveyances are adequately prepared.

As was done in Step 2, determine where concentrated flows will originate on and off-site, how runoff will cross the site, and where runoff will leave the site. Check for and avoid unnaturally concentrated flows in natural swales created by pipes, ditches, berms, etc.

Apply the Principles of Erosion and Sediment Control

1. Fit development to the terrain
This principle is applied in the site development process (see Step 3).

2. Time grading and construction to minimize soil exposure
Schedule the project so that grading is done during a time of low erosion potential. On large projects, stage the construction, if possible, so that one area can be stabilized before another is disturbed. Apply erosion control measures as soon after land disturbance is completed as is practical.

3. Retain existing vegetation wherever possible
When laying out site improvements, try to site buildings between existing tree clusters and build roads around trees. Show construction traffic routed to avoid existing or newly planted vegetation. Avoid unnecessary clearing of vegetation around building pads, where construction will not be taking place. Also, avoid disturbing vegetation on steep slopes or in other critical areas. Physically mark off the limits of land disturbance on the site with rope, fencing, surveyors' flags, or signs so that workers can clearly see areas to be protected. A bulldozer operator will probably not know to protect a clump of trees that is only noted on a set of plans.

4. Vegetate and mulch denuded areas
Reestablish vegetation on all denuded areas that will not be covered with buildings or pavement. If graded areas are to be paved or built upon at a later date they must be stabilized temporarily by mulching or establishing a temporary vegetative cover on those areas. It is often cheaper to establish and remove a temporary cover on such an area than to repair the gullying and sediment damage that is likely to occur. Before seeding an area, make sure necessary stormwater controls are installed (see the following subsection). Plant establishment will be more successful if graded slopes are roughened or scarified before seeding.

5. Divert runoff away from denuded areas
Determine how runoff should be conveyed from the top to bottom of each drainage area. Is a diversion or a slope drain required? If so, locate it where it can intercept potentially erosive flows and route them to a well-protected outlet such as a storm drain or a lined channel. Do not allow runoff to cross a denuded or newly seeded slope or other critical areas.

All conveyances and systems should be fully stabilized before allowing flows into them. If there is a significant drainage area above a cut or fill slope construct a diversion and slope drain at the top of the slope to convey the water to the bottom without causing erosion. Diversions and conveyances also can be used at the base of a disturbed slope to protect downstream areas by diverting sediment-laden runoff to a sediment trap or basin. It is often good strategy to construct a diversion or swale all the way around a disturbed area to prevent clean runoff from entering the area and also to prevent silt-laden runoff from escaping before being desilted.

6. Minimize length and steepness of slopes
On long or steep disturbed or constructed slopes construct benches, diversions, or swales at regular intervals to intercept runoff. Each bench should be tilted at a gentle grade into the hill to channel the flow along the inner edge of the bench. Route the intercepted runoff to a protected outlet.

7. Keep runoff velocities low
Keep runoff velocities low by:
a. Minimizing flow path lengths
b. Constructing channels with gentle gradients
c. Lining channels with rough surfaces
d. Using check dams in channels

8. Prepare conveyances and outlets to handle concentrated or increased flows
Design stormwater conveyance channels to withstand the expected flow volume and velocity from a design storm. Compute the expected discharge and velocity for both existing and newly constructed swales and for on- and off-site channels which will carry increased flow as a result of the project. By using these

calculations, determine whether any drainage channels will require protection. If the computations indicate the runoff flow will be erosive, first determine whether a vegetative lining will be sufficient. If the expected velocity exceeds the limit for the specified grasses, choose between rock, asphalt, or concrete linings. Remember that grass and rock linings are desirable because they keep velocities low, allow runoff to percolate into the soil, and are aesthetically pleasing. Because they resemble natural conveyances, they can enhance the appearance of a development.

Also, determine whether outlet protection will be needed. Pay particular attention to transitions from pipes or paved channels to natural or unlined channels. Locate riprap aprons or other energy-dissipating devices at discharge points where erosion is likely.

9. Trap sediment on site

Install sediment basins or traps, silt fences, or straw bale barriers below denuded areas so that runoff will be detained long enough for suspended sediment to settle out. Try to locate sediment barriers in relatively level areas or in natural depressions. A flat area at the base of a slope is a good location for a silt fence or straw bale dike because the runoff can slow down before reaching the barrier and the sediment has a place to settle. Avoid placing sediment barriers where their construction would cause excessive soil disturbance. For example, excavating a sediment trap on a hillside is likely to cause more soil erosion and sedimentation than the device was intended to prevent. Also, locate sediment barriers above sensitive areas such as streams, lakes, public streets, and adjacent properties. Make sure there will be adequate access in wet weather for maintenance and sediment removal.

Individual lots can be surrounded by dikes to create small sediment traps called lot ponds. Gravel- or fabric-covered driveway aprons can serve as the outlets. If standing water on lots will interfere with construction activities, this type of sediment control should not be used. However, lots are often graded but are not built upon for months or even years. In these situations, lot ponding may be a good approach. It should be realized, however, that lot ponding may necessitate recompaction of pads prior to building construction. Consult the soils report for the soil engineer's recommendation on this issue.

The size of the drainage area determines which type of sediment barrier should be used. Silt fences normally have a 1-acre (0.4-ha) drainage area limit. A sediment trap is generally adequate in drainage areas of less than 5 acres (2 ha). A sediment basin is needed if the drainage area exceeds 5 acres (2 ha). Unless the basin is designed as a permanent pond, its maximum drainage area should be less than 150 acres (60 ha). Drainage areas larger than 150 acres (60 ha) can be subdivided into smaller subcatchments by creating barriers to trap runoff in stages, perhaps in a group of basins. Basins must drain in parallel, not in series. When a watershed is subdivided into smaller drainage areas, each with its own sediment basin, the degree of risk is likely to be substantially lower. That is, the damage which could be caused by the failure of a small basin in a small watershed is minor compared to the damage potential of the failure of a large basin in a large watershed.

Dividing a watershed into smaller drainage areas also can save money. Sediment basins are more costly than simple sediment traps to construct. In addition, sediment basins require an engineered design, whereas sediment traps are typically based on standard designs.

Sediment basins and traps are commonly located below large disturbed areas, at the lowest point in a watershed, and in swales and small conveyances. Do not locate a sediment basin in a major stream, such as one designated with a blue line on a U.S. Geological Survey topographic map or in a wetland. It is unnecessary, costly, and dangerous to impound runoff from large, undisturbed areas. Trap the sediment-laden runoff before it enters a stream.

10. Inspect and maintain control measures

Develop a maintenance schedule and instructions for maintaining control measures. The instructions should specify where sediment dredge spoils should be placed, what spare materials (such as extra filter fabric, silt fence, stakes, and gravel) are needed, and where they should be stockpiled.

It is the responsibility of the contractor to make sure all workers understand the major provisions of the erosion and sediment control plan. If they understand the plan, they are less likely to disturb drainage patterns and control measures, as by running over a dike with a truck. A routine end-of-day maintenance check is strongly advised, while inspections are required after any storm with a half inch or more of rainfall. In particular, the site superintendent should look for breaches in dikes and for erosion or sedimentation near wetlands, waterbodies, discharge points, or roads. All maintenance procedures and the maintenance schedule should be specified on the plans. The plans should also remind the contractor of his or her responsibility to inform construction site workers about the erosion and sediment control features on the site.

11.2.6 Checklist for Erosion and Sediment Control Plans

The checklist on the city's website (www.cityofrockhill.com) illustrates the necessary components of all erosion and sediment control plans. This list must be completed and signed by the plan preparer and must accompany all erosion and sediment control plans submitted to the City of Rock Hill for review. This checklist can be used by a site planner, as well as the plan reviewer, as a quick reference to determine if all the major items are included in the erosion and sediment control plan.

11.3 Evaluating an Erosion and Sediment Control Plan

11.3.1 General Approach

Responsibility
It is not the responsibility of the plan reviewer to see that the plan is the best possible one. The reviewer can only ensure that the plan meets the minimum standards set by the reviewing agency and its authorizing regulations.

Communications
Encourage informal communications between the plan reviewer and the plan preparer. This will enable the reviewer to make informal suggestions that may save the developer money and the preparer time, and it may result in a better, more effective plan. It will also enable the preparer to explain and justify the plan. Pre-application conferences are strongly encouraged.

Required Information
Make sure all the required information has been submitted. Checklists can be used by both plan reviewers and plan preparers. However, checklists can encourage laziness. Having everything checked off does not necessarily mean that everything is in order.

Incomplete Plans
Do not review seriously incomplete plans. Send them back with a request for the missing information.

First Review
The first review should be a complete review. In subsequent reviews, deal only with items identified in the first review. It is unfair to the developer to keep injecting new requirements in subsequent reviews.

Plan Concept
The concept should be examined first, starting with the general and moving to the specific. Does the plan make sense?

Schedule
Examine the construction schedule. Will grading be completed before the rainy season? When will stormwater management facilities, paving, and utilities be installed in reference to the rainy season? If grading will take place during months when there is a high probability of heavy rains, what extra precautions will be taken to protect against erosion, sedimentation, and changing drainage patterns?

Site Stormwater
Make sure you understand where all runoff, including rooftop runoff, comes from on and above the site, where it goes, and how it traverses the site. For large sites, require or prepare a drainage area map. If runoff patterns are unclear, ask for clarification.

Sediment Basins and Traps
Locate all sediment basins and traps, and define their contributing areas.

Erosion Control
Check the method used to prevent erosion. Hydraulic seeding and mulching may adequately stabilize some areas, but other areas, because of their proximity to sensitive features such as watercourses or their steepness or lack of backup protection such as sediment basins, may need far more intensive revegetation efforts. On critical slopes, a reliable backup system for hydraulic seeding, such as punched straw, is strongly recommended. Even better, these areas should be soded.

Channels and Outlets
Examine all conveyances where concentrated flows will occur. Be sure adequate erosion protection is provided both along channels and at channel and pipe outlets. Check the sources of runoff to be sure that all the runoff comes from undisturbed or stabilized areas or has been desilted by sediment basins or other sediment retention devices.

Miscellaneous
Look for haul roads, stockpile areas, and borrow areas. They are often overlooked and can have a substantial effect on drainage patterns. Look at all points of vehicle access to the site and be sure mud and dirt will not be tracked onto paved streets and that sediment-laden runoff will not escape from the site at these points. Pay particular attention to watercourses and their protection.

Plan Details
Once the plan concept has been shown to be sound, check the details to be sure the concept is adequately executed in the plans.

Structural Details
Be sure that sufficiently detailed drawings of each structure (sediment basin, dike, swale, silt fence, etc.) are included so there is no doubt about locations, dimensions, or method of construction.

Calculations
See if calculations have been submitted to support the capacity and structural integrity of all structures. Were the calculations made correctly?

Vegetation
Look at seed, fertilizer, and mulch specifications. Check quantities and methods of application to be sure they are appropriate and consistent with local guidelines.

Maintenance
Be sure that general maintenance requirements and specific maintenance criteria, such as the frequency of sediment basin cleaning, are included. Are there stockpiles of spare materials (filter fabric, straw bales, stakes, gravel, etc.) to repair damaged control measures? Routine maintenance inspections should be part of the plans.

Contingencies
The plan must provide for unforeseen field conditions, scheduling delays, and other situations that may affect the assumed conditions.

Technical Review
The erosion and sediment control plan should be reviewed by the soils or geotechnical consultant for the project, if there is one.

Signature
The erosion and sediment control plan should be signed by a qualified design professional.

11.4 Implementing the Plan

11.4.1 Introduction

Installation of an erosion and sediment control plan will be discussed in seven distinct steps, primarily from the standpoint of the job superintendent. The steps are:

(1) Study of the plan and site to organize implementation.
(2) Pre-construction conference between the job superintendent and inspector.
(3) Site preparation
(4) Inspection and maintenance
(5) Grading and utilities installation
(6) Building construction
(7) Permanent stabilization.

11.4.2 STEP 1: Study the Plan and the Site

The job superintendent must be thoroughly familiar with both the erosion and sediment control plan and the construction site. Note all of the critical areas indicated in the plan and then actually identify their location and extent on the ground. These should include stream channels and associated flood plain areas, drainage ways, and outlets into streams, points where land-disturbing activities are adjacent to or must cross steams and drainage ways, steep slopes and highly erodible soils, and runoff entering the site from adjacent areas. Note what practices are specified to protect these areas. Also, be aware of critical areas not specifically treated in the plan; and discuss these with the inspector at the pre-construction conference.

Next determine the locations of all control measures and determine their "fit" on the land. Note any needed adjustments, and plan to discuss these at the pre-construction conference.

Check the schedule for the installation of erosion and sediment control practices, the schedule for all earth-disturbing activities, and the relationship between the sequence and timing of BMP installation and the earth-disturbing activities. The timing and sequence of installation are important elements of an erosion and sediment control plan. The site must be ready for rain before the earth-disturbing activities are started. For this reason, certain practices must be in place and ready to provide protection before other areas are exposed. The staging of major earth-disturbing activities to limit the size of bare area exposed at any time is another important element of the plan which should be noted.

11.4.3 STEP 2: The Pre-Construction Meeting

The next step is a pre-construction conference and site review with the erosion and sediment control inspector. It should be called for by the job superintendent and should be held on the construction site. The conference may also include the design professional, the owner, and inspectors from other agencies. The site review will help all parties in meeting their responsibilities. All aspects of the plan should be discussed to ensure that the job superintendent and the inspector are in agreement in interpreting the plan, scheduling, procedures, and practices which are to be used. They should agree particularly on the critical problem areas and on the perimeter practices specified to prevent damage to adjacent properties.

The location of all measures should be discussed. If the study of the plan indicates that adjustments in location are needed, these should be discussed with the permitting agency and the inspector. The inspector may authorize minor adjustments such as moving a diversion from a property line to a grading limit, or shifting an outlet to match a natural depression in the land. Major adjustments will require formal revision of the plan and should be approved by the permitting agency.

The sequence of installation of practices and earth-disturbing activities should also be discussed. The guidelines for erosion and sediment control planning require that sediment basins and other appropriate erosion and sediment control measures be installed prior to or as a first phase of land grading. Other appropriate measures include construction entrances, diversion dikes, interceptor dikes, perimeter dikes, gravel outlet structures, level spreaders, swales, protected outlets, and grade stabilization structures. The superintendent and the inspector must be firm about establishment of these practices before grading begins.

11.4.4 STEP 3: Site Preparation

One of the first things to do in preparing the site is to lay out all traffic circulation routes and storage areas. Route locations should be chosen to pose the least threat to the critical areas which have been identified. Well-vegetated areas should be damaged as little as possible. Soil stockpiles should be located a safe distance from waterways and streams. Barriers may be required to keep traffic within the delineated areas or at least out of the critical areas. If needed, barriers should be installed before opening the site to general construction traffic.

Required sediment trapping practices should be installed. Note that compacting, seeding, and mulching are required to stabilize these practices. Next, waterways and outlets should be installed with the vegetation or lining material called for in the plan.
The work force should be instructed about the location of critical areas and sediment control practices and the need to protect these areas from damage.

11.4.5 STEP 4: Inspection and Maintenance of Erosion Control Measures

Maintenance differs from the other activities. It must begin as soon as the first practice is installed and must continue through all the succeeding activities until the permanent erosion control measures are established and functioning. The features of a maintenance program are described in the narrative part of the plan. All structural measures should be checked at the close of each workday and, particularly, at the end of the workweek. Also, they must be checked before and after each rainstorm of one quarter inch or more. Diversion berms should be checked to see that they have not been breached by equipment. The condition of level spreader areas, waterways, and other outlets should also be checked. Traffic should be moving within the established access routes. Channels should be checked for sediment deposits or other impeding material. Repairs should be made promptly when damages are discovered. When repairing swales or other channels, the new lining material should be at least as erosion resistant as the original material. Vegetative practices and vegetative cover on structural practices require maintenance fertilizer and, perhaps, mowing. All sediment traps should be checked and cleaned out after each storm. Sediment basins should be cleaned out when the deposited material reaches the level designated in the plan or standards and specifications.

11.4.6 STEP 5: Grading and Utility Construction

The fifth major step is the grading and utility installation. If stockpiling of fill or topsoil is planned, a pre-selected, relatively safe stockpile area should be used. To minimize the hazard of erosion, the slopes of the stockpile should be flattened at the end of each working period. The stockpile should be mulched and seeded as soon as it is completed.

Disturbed areas which can be brought to final grade at this stage during a satisfactory season for seeding should be seeded, soded, or otherwise stabilized with the permanent material and techniques indicated in the plan. If they cannot be seeded, they should be stabilized with anchored mulch. Areas, which are to remain at rough grade for more than 14-days before permanent stabilization, must be mulched and seeded to temporary cover immediately following rough grading.

Utilities such as storm sewers, sanitary sewers, electrical conduits, water mains, and gas mains are usually installed at this time. To minimize the amount of area disturbed, the work should be organized and the trenches sized to take several utilities in one trench. The installation should be carefully coordinated to reduce the time that the trenches must stay open. Excavated materials should be placed on the side of the trench away from streams and conveyances. If sediment-laden water must be pumped from utility trenches, it should be conveyed safely to a sediment trap or basin. As soon as possible, trenches should be filled, compacted, mulched, and seeded to temporary or permanent vegetation.

As soon as the storm sewers are installed, inlet sediment traps should be installed to prevent sediment from entering the system. If called for, storm drain outlet protection should be installed.

11.4.7 STEP 6: Building Construction

The sixth major step or stage is building construction. Two major hazards are common during this step. The first major hazard is that additional equipment and work force bring added risks to areas which should be protected. Efforts to control traffic must be increased during this period. All types of traffic should be made to stay on the established travel routes.

The second major hazard is from the excavated material. This phase usually results in high volumes of soil for disposal and stockpiling. Stockpiles should be located where they will not wash into drainageways or onto previously stabilized areas. The slopes on these areas should be flattened and they should be protected by anchored mulch and temporary seeding. Excavations should be backfilled as soon as possible, and appropriate surface protection should be provided.

Runoff from rooftops should be directed to stabilized areas upon completion of the structure. Whenever possible the runoff should be treated or infiltrated in swales or retention facilities. Rooftop runoff should never be tied in to sanitary sewers.

11.4.8 STEP 7: Permanent Stabilization

The seventh and last step is permanent stabilization. As mentioned earlier, this need not and should not be delayed until the entire development is completed. A significant reduction in erosion damage repair costs and regrading costs can be made if smaller areas are stabilized with permanent vegetation as soon as they are ready.

Most sediment basins, dikes, sediment traps, and other control structures should be removed, regraded, mulched, and seeded before leaving the site. However, the inspector should be consulted before removing them--they should not be removed until the surrounding area is stabilized and they are no longer needed.

In some cases, sediment basins, diversions, and swales are to remain as part of the permanent runoff management system. In such cases, sediment basins should be cleaned out to provide the required capacity and stabilized with suitable permanent vegetation. Diversions and swales should be checked, repaired if needed, and left in good condition. The inspector will check on the final condition of measures which are to be retained.

When final grading is completed, all bare areas should be stabilized with permanent vegetation. Standards and specifications for permanent vegetative practices can be found in the SCDHEC BMP Manual. The manual gives information on various materials and methods for permanent stabilization.

11.5 References

Delaware Technical and Community College Terry Campus, 1991. Sediment and Stormwater Management Certified Construction Reviewer Course. Dover, DE

Goldman, S.J., K. Jackson, and T.A. Bursztynsky, 1986. Erosion and Sediment Control Handbook. McGraw-Hill, Inc. New York, NY 7-21

Florida Erosion and Sediment Control Inspector's Manual

S.C. Department of Natural Resources, Office of the State Climatology Website http://www.dnr.state.sc.us/climate/sco/climatechange.html

CHAPTER 12 – DOCUMENTATION PROCEDURES

12.1 Documentation Procedures

12.1.1 Introduction

The following items should be included in the documentation file. The intent is not to limit the data to only those items listed, but rather establish a minimum requirement consistent with the design procedures as outlined in this handbook. If circumstances are such that the drainage facility is sized by other than normal procedures or if the size of the facility is governed by factors other than hydrologic or hydraulic factors, a narrative summary detailing the design basis should appear in the documentation file. Additionally, the design engineer should include in the documentation file items not listed below but which are useful in understanding the analysis, design, findings and final recommendations.

12.1.2 Hydrology

The following items should be included in the documentation file if applicable:

- Contributing watershed area size and identification of sources (map name, etc.),
- Physical characteristics of watershed (i.e., slope, land use, soil data, impervious area),
- Design frequency used for design and analysis,
- Hydrologic discharge and hydrograph estimating method and findings including any computer analysis,
- Design flood hydrograph, 100-year flood hydrograph, discharge hydrographs, and any historical floods,
- Any other data related to flooding and drainage within the contributing watershed or at the facility site, and
- Location of adjacent structures, roadway elevations, etc.

12.1.3 Culverts

The following items should be included in the documentation file if applicable:

- Culvert performance curves,
- Allowable headwater location,
- Cross-section(s) used in the design highwater determinations,
- Roughness coefficient assignments ("n" values),
- Observed highwater, dates, and discharges,
- Stage discharge curve for existing and proposed conditions,
- Channel performance curve to include the depth and velocity measurements or estimates and locations for the design and 100-year floods,
- Outlet velocities and scour for the design and 100-year floods,
- Type of culvert entrance condition,
- Culvert outlet appurtenances and energy dissipation calculations and designs,
- Copies of all computer analyses,
- Roadway geometry (plan and profile),
- Potential flood hazard to adjacent properties, and
- Culvert materials and specifications.

12.1.4 Open Channels

The following items should be included in the documentation file if applicable:

- Stage discharge curves for the design storm events and water surface elevation(s),
- Cross-section(s) used in the design water surface determinations and their locations,
- Roughness coefficients assignments ("n" values),
- Information on the method used for design water surface determinations,

- Observed high-water, dates, and discharges,
- Channel velocity measurements or estimates and locations,
- Water surface profiles through the reach for the design and 100-year floods,
- Location and extent of any floodway encroachments,
- Design or analysis (including erosion control) of materials proposed for the channel bed and banks,
- Energy dissipation calculations and designs,
- Copies of all computer analyses, and
- Maintenance plan.

12.1.5 Storm Drainage Lines

The following items should be included in the documentation file if applicable:

- Complete drainage area map,
- Design frequency,
- Information concerning outfalls, existing storm drainage lines (including inverts and grate elevations), and other design considerations,
- A schematic indicating storm drainage system layout,
- Computations for inlets and pipes, including hydraulic grade lines,
- Computations of any energy dissipation designs, and
- Copies of all computer analyses.

12.1.6 Storage

The following items should be included in the documentation file if applicable:

- Routing calculations including inflow and outflow hydrographs and volumes for the design and Base (100-year) floods,
- Design calculations of any riser pipes and outflow devices,
- Design calculations of anti-flotation block,
- Computations for dam design including typical cross-section,
- Storage volume calculations,
- Design or analysis of materials proposed for the slopes and bottom of the storage facility,
- Emergency spillway design including 1' of freeboard,
- Outlet velocity estimates,
- Energy dissipation calculations and designs,
- Maintenance plan, and
- Copies of all computer analyses.

12.1.7 Application Forms

All plans submitted to the City of Rock Hill should also include a completed SCDHEC Notice of Intent (NOI) form and appropriate SCDHEC fees for review and approval.

12.2 References

American Association Of State Highway And Transportation Officials.
1982. Highway Drainage Guidelines.
Greenville, South Carolina Storm Water Management Design Manual, January 1992.

CHAPTER 13 – GLOSSARY

13.1 Glossary

13.1.1 Introduction

The following is a list of definitions for many of the terms used in this manual, but is not intended to be a complete list. For additional references, see referenced publications listed at the end of each chapter.

13.1.2 Definitions

A

Accretion
Outward growth of bank or shore by sedimentation. Increase or extension of boundaries of land by action of natural forces.

Acre-foot
A volume equal to an area of one acre times a depth of one foot.

Adverse Impact
A significant negative impact to land, water and associated resources resulting from a land disturbing activity. The negative impact includes increased risk of flooding; degradation of water quality; increased sedimentation; reduced groundwater recharge; negative impacts on aquatic organisms; negative impacts on wildlife and other resources; and threatened public health.

Alluvial
Deposits of silt, sands, gravels and similar detrital material having been transported by running water.

Antecedent Moisture Condition (AMC)
A qualitative indication of the moisture content of surficial soils at the beginning of a storm event.

Antecedent Precipitation Index (API)
An indication of the amount of water, in inches, present in soil at a given time.

Anti-Seep Collar
A device installed around a culvert, pipe or conduit through an embankment, which lengthens the path of seepage along the exterior of the conduit.

Applicant
A person, firm, or governmental agency that executes the necessary forms to obtain approval or a permit for a land disturbing activity.

Apron
A covering or structure along a shoreline for protection against erosion. Also a platform serving a similar purpose below a dam or in a sluiceway.

As-Built Plans or Record Documents
A set of engineering or site drawings that delineate the specific permitted stormwater management facility as actually constructed.

Attenuation
Increasing the time it takes water to move through a site to a point of discharge by lengthening the flow path, and routing stormwater through vegetated surfaces, thereby increasing the time of concentration and lowering the peak rate of discharge.

Avulsion
The sudden removal of land from one property to another by a sudden change in flow or a sudden shift in channel location.

B

Backwater Area
The low-lying lands adjacent to a stream that becomes flooded during periods of high water.

Baffle
A pier, vane, sill, fence, wall, or mound built on the bed of a stream to parry, deflect, check, or disturb the flow or to float on the surface to deflect or dampen cross currents or waves.

Bank
The part of the soil next to a stream, lake, or body of water where the soil elevation adjacent to the water is higher than the water level; also embankment.

Bankfull
The elevation (or stage) of a river at which the flow (discharge) actively creates, modifies, and maintains the river's channel. During bankfull discharge, the water is moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in morphologic change to the river system.

Barrel
The pipe or conduit that passes runoff from the riser portion to an outlet structure, through the embankment, and finally discharges to an outfall point.

Base Flow
The portion of stream flow that is not due to storm runoff, and is supported by interflow and groundwater outflow into a channel.

Basin
The largest single watershed management unit for water planning, it combines the drainage of a series of subbasins. Often have a total area more than a thousand square miles.

Bed
The bottom of a channel, creek, river, stream, or other body of water.

Bed Load
Sediment that moves by rolling, sliding, or skipping along the stream bed and is essentially in contact with the stream bed. The sediment in a stream channel that mainly moves by sliding or rolling on or very near the bottom during normal flows and bankfull events.

Bed Slope
The inclination of the channel bottom.

Best Management Practice (BMP)
In stormwater management, a structure or practice designed to prevent the discharge of one or more pollutants to the land surface and thus minimize their availability for wash-off by stormwater, or a structure or practice to temporarily store or treat urban stormwater runoff to reduce flooding, remove pollutants, and provide other amenities.

Build-out
The total percentage of development in a watershed based on current zoning.

C

Catchment
An area confined by drainage divides usually having only one stream flow outlet. In the UK, "catchment" refers to what in the US is called a watershed.

Certified Plan Reviewer
A person with the responsibility for reviewing stormwater management and sediment control plans for an appropriate plan approval agency as certified by passing an exam.

Channel
A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Channel Erosion
The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by moderate to larger floods.

Channel Stabilization/Channel Protection
Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

Check Dam
A temporary dam across a swale or gully to reduce velocity and prevent erosion, often used in series.

Clay (Soils)
A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter; A soil texture class; (Engineering) A fine grained soil (more than 50% passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System).

Clean Water Act
Federal Water Pollution Control Act enacted by Public Law 92-500 as amended by Public Laws 95-217, 95-576, 96-483, and 97-117; 33 USC 1251 et seq.

Compaction
The pressing together of soil particles into a more dense mass.

Comprehensive Drainage Plan
A stormwater management plan that covers all current and anticipated development on a site greater than 10 acres and sites planned for phased development.

Conservation
The protection, improvement, and use of natural resources according to principles resulting in the greatest economic and social benefits.

Conservation Easement
Voluntary agreements that allow an individual to set aside private property to limit the type or amount of development on their property. Easements relieve property owners of the burden of managing these areas by shifting responsibility to a private organization or government agency better equipped to handle maintenance and monitoring issues.

Construction
The erection of any building or structure or any preparations for the same.

Contributing Watershed Area
Geographic extent of land area contributing its runoff of the point of interest, also referred to as catchments and subbasins.

Conveyance
Any natural or manmade channel or pipe in which concentrated water flows.

Critical Root Zone (CRZ)
The area around a tree required for the tree's survival, usually the drip line.

Crushed Stone
Aggregate consisting of angular particles produced by mechanically crushing rock.

Cul-de-Sac
A local access street with a closed circular end which allows for vehicle turnarounds.

Curve Number (CN)
A numerical representation of a given area's hydrologic soil group, plant cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall depth into runoff volume.

Cut
Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

Cut and Fill
Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

D

Dam
A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

Day
Calendar day, unless otherwise specified by the ordinance.

Degredation
General and progressive lowering of the longitudinal profile of a channel by erosion.

Deposit
An earth mass of particles settled or stranded from moving water or wind.

Design Storm
For the purpose of the ordinance, a storm of a given return frequency as specified by this ordinance to be used to compute peak flow, volumes and design required structures or measures.

Designated Watershed
A watershed designated by a local government and approved by the Department of Health and Environmental Control and the South Carolina Water Resources Commission and identified as having an existing or potential stormwater, sediment control, or nonpoint source pollution problem.

Detention
The temporary storage of runoff in a structure or waterbody for later release to receiving waters.

Detention Structure
A permanent stormwater management structure whose primary purpose is to temporarily store stormwater runoff and release the stored run off at controlled rates.

Detention Time

The average amount of time a volume of water is detained in a BMP. This time may differ from the amount of time it takes to completely drain a particular BMP.

Developer
A person undertaking, or for whose benefit, activities covered by these regulations are commenced and/or carried out.

Development
Any construction, reconstruction, conversion, structural alteration, relocation, or enlargement of any structure within the jurisdiction of Rock Hill as well as any manmade change or alteration to the landscape, including but not limited to mining, drilling, dredging, grading, paving, excavating and filling.

Dike
A structure designed either to reduce the water velocity as stream flow passes through the dike so that sediment deposition occurs instead of erosion (permeable dike) or to deflect erosive currents away from the stream bank (impermeable dike); similar to groins, palisades, spurs, jetties, or deflectors.

Direct Runoff
When precipitation falls on the earth, the water remaining after the combined effects of interception, depression storage, and infiltration. This water flows over the surface of the ground; also referred to as excess precipitation, stormwater runoff, or runoff)

Directly Connected Impervious Areas (DCIA)
Impervious surfaces that create runoff from almost all precipitation events due to the connectivity of the surface to the storm drainage system. An example is a rooftop that when rain occurs, runoff is directed to the driveway, which is sloped toward the street and runoff is aimed down the gutter and into a stormwater inlet or other structure. These areas do not allow infiltration and can be a major contributor of the runoff volume and pollutant load

Discharge Rate
Rate at which runoff is moving through or exiting from some structure, normally expressed as ft3/second.

Discharge Structure
Structure installed in storage facilities to remove stored runoff at some predetermined release, or discharge, rate; see also *Outlet structure*.

Disconnected Impervious Surfaces
Discontinuous impervious surfaces that allow for the infiltration and filtration of precipitation. An example is a residential subdivision in which each dwelling's roof top drains through a vegetative strip before reaching the road surface. Also known as indirectly connected impervious areas.

District
Any soil and water conservation district created pursuant to Chapter 9, Title 48, S.C. Code of Laws.

Disturbed Area
An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

Drainage
A general term applied to the removal of surface or resurface water from a given area either by gravity via natural - or by systems constructed so as to remove water, and is commonly applied herein to surface water.

Drainage Area
The area contributing runoff to a single point.

Drainage System
A system of aboveground and underground conduits and collector structures that flow to a single point of discharge.

Dry Pond
A stormwater pond design with no permanent pool. Stormwater is detained in the practice temporarily to settle pollutants, protect downstream channels, and prevent flooding. These practices typically provide poor pollutant removal.

Dry Swale
An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media.

Duration
See Storm Duration.

E

Easement
A grant or reservation by the owner of land for the use of such land by others for a specific purpose or purposes, and which must be included in the conveyance of land affected by such easement.

Embankment or Fill
A deposit of soil, rock or other material placed by man.

Emergency Spillway
The channel of a pond-type BMP, designed to pass a storm event exceeding the design capacity of the primary discharge structure.

Energy Dissipator
A designed device such as an apron of rip-rap or a concrete structure placed at the end of a water transmitting apparatus such as pipe, paved ditch or paved chute for the purpose of reducing the velocity, energy and turbulence of the discharged water.

Erosion
The wearing away of land surface by the action of wind, water, gravity, ice, or any combination of those forces.

Erosion and Sediment Control
The control of solid material, both mineral and organic, during a land disturbing activity to prevent its transport out of the disturbed area by - air, water, gravity, or ice.

Erosion Control Blanket
Blanket made from straw, coir, excelsior, or synthetic material and enveloped in plastic or biodegradable netting. Used to stabilize disturbed or highly erosive soils while vegetation is established. Temporary blankets made from biodegradable or photodegradable components last several months to a year, and permanent blankets (also called turf reinforcement mats) can last for several years.

Erosive Velocities
Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural, or vegetative stabilization used to protect the soil.

Evaporation
The process whereby water returns to the atmosphere as water vapor, from the surfaces of the land and water bodies.

Evapotranspiration
The combined loss of water from a given area over a specified time by evaporation and by transpiration from plants, the biological process whereby plants take up water and release it as water vapor.

Excess Rainfall
See *Direct Runoff.*

Exemption
Those land disturbing activities that are not subject to the sediment and stormwater requirements contained in these regulations.

Extended Detention
A stormwater management BMP that provides for the gradual release of a volume of water over a time interval designed to increase settling of urban pollutants, and protect downstream channels from frequent flooding.

F

Fecal Coliform
Applied to Escherichia coli (Ecoli) and similar bacteria that are found in the intestinal tract of humans and animals and found in soil. Coliform bacteria are commonly used as indicators of the presence of pathogenic organisms. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.

FEMA
United States Federal Emergency Management Agency.

Fill Material
Soil, rock, gravel or other matter that is placed at a specified location to bring the ground surface up to a desired elevation.

Filter
Layer of fabric, sand, gravel, or graded rock placed between the bank revetment or channel lining and soil for one or more of three purposes: to prevent the soil from moving through the revetment; to prevent the revetment from sinking into the soil; and to permit natural seepage from the stream bank, thus preventing buildup of excessive groundwater pressure.

Filter Fabric
Textile of relatively small mesh or pore size that is used to allow water to pass through while keeping sediment out or to prevent both runoff and sediment from passing through.

Fine Particles
Silt and clay particles; also called fines.

Flood Insurance Rate Map (FIRM MAP)
Maps established by the Federal Emergency Management Agency (FEMA) that identifies the Base (100-year) floodplain for flood insurance purposes.

Floodplain
Land area subject to inundation by water from any flooding source.

Floodway
The channel of a river or other watercourse and the adjacent land area, the capacity of which shall be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one (1) foot.

Flow Splitter
An engineered, hydraulic structure designed to divert a percentage of stormwater to a BMP located out of the primary channel or conveyance system, to a parallel pipe system, or to a bypass.

Forebay
An extra storage area provided near an inlet of a pond BMP to trap incoming sediment before it accumulates in a pond BMP.

Freeboard
The space from the top of an embankment to the highest water elevation expected for the largest design storm stored. The space is required as a safety margin in a pond or basin.

French Drain
A drainage device in which a hole or trench is backfilled with sand or gravel to allow infiltration.

G

Geographic Information System (GIS)
System that links spatial information such as satellite images and maps with alphanumeric information to produce a geographically referenced database.

Global Positioning System (GPS)
Network of satellites that emit continuous location--finding radio signals; GPS receivers use the signals from multiple satellites to determine their exact three--dimensional coordinates (latitude, longitude, and height).

Grade
The slope of a land surface, road, or stream bottom.

Gradient
The change of elevation, velocity, pressure, or other characteristic per unit length.

Grading
Excavating, filling (including hydraulic fill) or stockpiling of earth material or any combination thereof, including the land in its excavated or filled condition.

Grading Permit
A City of Rock Hill permit issued pursuant to an approved Stormwater Management and Sediment Control Plan prepared under the provisions of this ordinance. A grading permit is required prior to initiating a land disturbing activity for residential and non-residential sites.

Grass Channel
An open vegetated channel used to convey runoff and to provide treatment by filtering pollutants and sediments.

Grass Filter Strip
A grassy slope located adjacent and parallel to a paved area such as a parking lot, driveway, or roadway to provide a path that allows runoff to infiltrate and remove some pollutants, mainly sediments, from the runoff. The strip must be twenty (20') feet wide minimum to be counted as meeting water quality requirements.

Green Space
The proportion of open space that is retained in an undisturbed vegetative state.

Greenway
A planning study that creates a linked and linear network of trails, accesses, and passive and possibly active recreational facilities along an aquatic corridor.

Ground Cover
Any vegetative growth including trees or geotechnical materials which render the soil surface stable against erosion.

Groundwater
Water stored underground that fills the spaces between soil particles or rock fractures. A zone underground with enough water to withdraw and use for drinking water or other purposes is called an aquifer.

Groundwater Flow
The saturated flow of water through the ground (this process occurs within the groundwater table).

Groundwater Table
The zone within the soil where the void spaces between soil particles are filled with water. This zone is also referred to the "saturated zone."

Gully Erosion
An advanced form of rill erosion in which large channels are incised into the soil by water runoff.

H

Head
In hydraulics, the height of water above a reference plane.

Head Loss
Energy loss in hydraulic flow due to friction, turbulence, velocity change or flow direction.

Head Water, Head Water Depth
In hydraulics, the difference in elevation between the water elevation at the inlet of a pipe, and the invert of the pipe.

Headwaters
The source of a river or stream or the water upstream of a structure or point in a stream.

Heavy metals
Metals with high molecular weights that are generally toxic to animal life and human health if naturally occurring concentrations are exceeded. Examples include arsenic, chromium, lead, and mercury.

Herbicides
Chemicals developed to control or eradicate plants.

Hydraulic Conductivity
The rate at which water can move through a permeable medium.

Hydraulic Gradient
The slope of the hydraulic grade line. That includes static and potential head.

Hydraulics
The physical science and technology of the static and dynamic behavior of fluids. Hydraulics deals with practical applications of fluids in motion (such as the transmission of energy associated with water flowing through pipes and culverts).

Hydrograph
A graph or table relating discharge, depth (stage), velocity, or another property of flowing water to time.

Hydrologic Cycle
The circulation of water between the earth's atmosphere, surface, and subsurface.

Hydrologic Soil Group (HSG)
A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from soils with high permeability and little runoff production to soils with low permeability rates and produce much more runoff.

Hydrology
The study of the movement of water between the earth's atmosphere, surface, and subsurface.

Hydroseeding
A method of seeding by mixing seed with water and fertilizer and then spraying the solution onto a seedbed.

Hyetograph
A plot of cumulative rainfall or rainfall intensity versus time for a particular precipitation event.

I

Illicit Connection
Any physical connection to a publicly maintained storm drain system composed of non-stormwater which has not been permitted by the public entity responsible for the operation and maintenance of the system.

Illicit Discharge
Any discharge to a storm drain system that is not composed entirely of stormwater except discharge pursuant to a NPDES permit, discharges resulting from fire fighting activities, and discharges further exempted in the Zoning Ordinance.

Impermeable Material
A soil or material whose properties prevent movement of water through it, such as a compacted clay liner.

Impervious Surface
Hard ground cover that prevents or retards the entry of water into the soil and increases runoff, such as asphalt, concrete, rooftops.

Impoundment
The body of water retained by a berm, dam, or dike.

Industrial Stormwater Permit
A NPDES permit issued to a commercial industry or group of industries, which regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

Infiltration
The portion of rainfall or surface runoff that moves downward into the soil.

Infiltration Rate
The rate at which stormwater percolates into the subsoil.

Inflow Protection
A water handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment trapping device.

Inlet
An entrance into a ditch, storm sewer, or other waterway.

Inlet Control
In culvert design, the condition where inlet shape and material controls the rate of flow in the culvert.

Insecticides
Chemicals developed to control or eradicate insects.

Intensity-Duration-Frequency (IDF) Curves
Graphical plots showing the relationship between rainfall intensity, storm duration, and frequency (return period) for a geographic location or region.

Invert
The lowest point on the inside of a culvert or pipe.

L

Land
Any ground, soil, or earth, including marshes, swamps, drainage ways, and areas not permanently covered by water within the municipality's limits.

Land Disturbing Activity
Any use of the land by any person that results in a change in the natural cover or topography that may cause erosion and contribute to sediment and alter the quality and quantity of stormwater runoff.

Landscape Plan
A plan showing the form and species of plants and procedures for planting to stabilize and beautify earthwork or to increase the functionality of a drainage structure.

Level Spreader
A device used to spread out stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders is to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

Littoral
The land between the highest and lowest tide marks on the seashore.

Load Allocation (LA)
The portion of a receiving water's loading capacity that is estimated to come from either existing or future nonpoint sources of pollution or natural background sources.

Loam
An easily crumbled soil consisting of a mixture of clay, silt, and sand.

Local Agency
One or more of the agencies involved with providing review, approval or oversight of the site's (a) activities, (b) pollution prevention controls, or (c) stormwater discharge.

Local Government
Any county, municipality, or any combination of counties or municipalities, acting through a joint program pursuant to the provisions of this manual.

Low-flow Channel
An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or base flow, directly to the outlet without detention.

M

Mean Depth
The average depth described as the cross-sectional area of an inundated channel divided by its surface width. For a water body or storage basin, mean depth is the volume of the basin divided by its surface area.

Municipal NPDES Permit
An area-wide NPDES permit issued to a government agency or agencies for the discharge of stormwater from a storm drain system.

Municipal Separate Storm Sewer System (MS4)
Includes, but is not limited to, those facilities located within the City and owned and operated by a public entity by which stormwater may be collected and conveyed to waters of the United States, including any roads with drainage systems, public streets, inlets, curbs, gutters, piped storm drains and retention or detention basis, which are not part of a Publicly Owned Treatment Works ("POTW) as defined at 40 CFR Section 122.2.

N

National Pollutant Discharge Elimination System (NPDES)
Mandated by Congress under the Clean Water Act, a two--phased national program to address nonagricultural sources of stormwater discharge and prevent harmful pollutants from being washed into local water bodies by stormwater runoff.

Natural Resources Conservation Service (NRCS)
Natural Resources Conservation Service (formerly the Soil Conservation Service) under the US Department of Agriculture.

Navigable Streams
Waterways of sufficient depth and width to handle a specified traffic load.

Non-erodible
A material, e.g., natural rock, rip-rap, concrete, plastic, etc., that will not experience surface wear due to natural forces of wind, water, ice, gravity or a combination of those forces.

Nonpoint Source Pollution
Pollution caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or from the atmosphere, which are carried to surface waterbodies by runoff. Nonpoint Source (NPS) Pollution occurs when the rate at which these materials entering water bodies exceeds natural levels.

Non-stormwater Discharge
See *Illicit discharge.*

Non-structural BMPs
Stormwater runoff treatment techniques which use natural measures to reduce pollution levels, do not require extensive construction efforts and/or promote pollutant reduction by eliminating the pollutant source. Examples are site management, employee education, and maintenance.

Notice of Intent (NOI)
A formal notice to the EPA or a state agency having delegated NPDES authority a construction project seeking coverage under a General Permit is about to begin.

Notice of Termination (NOT)
A formal notice to the EPA or delegated state agency for General Permit site terminating coverage under the permit.

NRDC
Natural Resources Defense Council.

Nutrient
A substance that provides food or nourishment, such as usable proteins, vitamins, minerals or carbohydrates. Fertilizers, particularly phosphorus and nitrogen, are the most common nutrients that contribute to eutrophication.

O

Oil/water (or oil/grit) separator
An underground retention system designed to separate trash, debris, sediments, and oil and grease from stormwater runoff.

One hundred year storm
An extreme flood event that has a statistical probability of 1% of occurring in a given year. The Base Flood.

On-line
A stormwater management system designed to manage stormwater in its original stream or drainage channel.

Off-line Treatment
A stormwater management system designed to manage a storm event by diverting a percentage of stormwater events from a stream or storm drainage system.

Open Channels
Also known as swales, grass channels, and biofilters. These systems are used for the conveyance, detention, retention, infiltration, and filtration of stormwater.

Open Space
A portion of a development that is not to be developed, set aside for public or private use. The space may be used for passive or active recreation, or may be reserved to protect or buffer natural areas.

Ordinance
A law, a statute, a decree enacted by a municipal body, such as a city council or county council. Ordinances often govern matters not already covered by state or federal laws (such as local zoning, safety and building regulations), but may also be used to require stricter standards in local communities than those imposed by state or federal law.

Outfall
The point or structure of a conduit discharging to a waterbody.

Outlet Control
In culvert design, the condition where flow in the culvert is not governed solely by inlet conditions, but may also be affected by friction losses in the culvert barrel and/or downstream water elevations.

Outlet Protection
Stone, rip-rap, concrete or asphalt aprons installed to reduce the speed of concentrated stormwater flows, thereby reducing erosion and scouring at stormwater outlets and paved channel sections.

Outlet Structure
The outlet structure of a structural BMP, such as a pond, designed to release water at a design flow rate (or multiple flow rates, depending on depth of storage).

Overflow Rate
Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.

Overseeding
Seeding into a dormant turf with cool season turf grass in order to provide a playable surface (on a golf course) during winter months in the South, or for aesthetics.

Overtopping
The passing of water over the top of a natural or artificial structure because of wave runup or surge.

P

Peak Discharge
Also referred to as peak discharge rate, peak flow rate, peak runoff rate. The maximum flow for a given hydrologic event at specified location.

Perennial Stream
A stream channel that has running water throughout the year.

Permeable Surfaces
Areas characterized by materials that allow stormwater to infiltrate the underlying soils (e.g., covered soil or vegetated area).

Person
Any State or federal agency, individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, municipality or other political subdivision of this State, any interstate body or any other legal entity.

Pervious Surface
A vegetated area of the urban landscape where rainfall is intercepted by vegetation and infiltrated into soil.

Phased Development
A large project that will be developed in stages over a period. It may encompass one or more drainage basins.

Photodegradable
Materials that are not resistant to ultraviolet radiation and therefore break down relatively quickly when exposed to sunlight.

Plan
Stormwater Management and Sediment Control Plan required by this manual to be a prerequisite to obtaining a grading permit. The plan willfully indicate necessary land management and treatment measures, including drawings and supporting calculations, BMPs, maintenance guidelines, and a timetable for installation. Implementation of the plan will effectively minimize soil erosion and sedimentation and provide for the successful management of excess stormwater.

Planning Commission
The Planning Commission of Rock Hill, South Carolina.

Point of Concentration
The point at which water flowing from a given drainage area concentrates.

Point Source
A distinct, identifiable source of pollutants.

Point Source Pollution
Direct pollution from industries and sewage; also called single point--source pollution.

Pollution
The presence in the environment of any substance, including, but not limited to, sewage, sediment, industrial and other waste, air contaminant, or any combination thereof in such quantity and of such characteristics and duration as may cause the environment to be contaminated, unclean, noxious, odorous, impure or degraded, or which tends to be injurious to human health or welfare; or which damages property, plant, animal or use of property.

Porosity
Ratio of pore volume to total solids volume.

Porous Pavement
Permeable pavement surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil.

Post-Development
The conditions which exist following the completion of the land disturbing activity in terms of topography, vegetation, land use and rate, volume or direction of stormwater runoff.

Precipitation
Water from the earth's atmosphere (where it is stored as water vapor) that falls on the earth's surface (rain, snow, hail, fog).

Pre-Development
The conditions which existed prior to the initiation of the land disturbing activity in terms of topography, vegetation, land use and rate, volume or direction of stormwater runoff.

Pretreatment
Techniques employed in stormwater BMPs to provide storage or filtering to help trap coarse materials before they enter the system.

Proctor curve
Curve showing the relationship between the density and water content of soil for a given compaction; also called compaction curve.

R

Rainfall Distribution
The variation in rainfall intensity over the duration of a particular storm event.

Rainfall Intensity
The rate at which precipitation occurs at a given instant.

Rapid Drawdown
Lowering the elevation of water against a bank or wall faster than the structure can drain, leaving a pressure imbalance that may cause the bank or wall to fail

Rational Method
A method for estimating peak rates of runoff from small watersheds (drainage areas less than 20 acres). The method is typically used for the sizing of storm drainage pipes, culverts, and channels. The method relates peak discharge to rainfall intensity/duration/frequency, time of concentration, and land-use cover.

Recharge
Of water that infiltrates into the ground, the portion that moves deeper into the ground and moves through the ground as interflow (unsaturated flow) and groundwater flow (saturated flow). Recharge results in the replenishment of groundwater.

Recurrence Interval
The time between occurrences of an event equal to or greater than a given magnitude. See *Return Period*.

Registered Landscape Architect
A person who is registered by the State of South Carolina pursuant to Chapter 28, Title 40, Code of Laws of South Carolina, 1976, as amended.

Registered Professional Engineer
A person who is registered by the State of South Carolina pursuant to Chapter 22, Title 40, Code of Laws of South Carolina, 1976, as amended.

Registered Tier B Land Surveyor
A person who is registered by the State of South Carolina pursuant to Chapter 22, Title 40, Code of Laws of South Carolina, 1976, as amended.

Release Rate
The rate of discharge in volume per unit time from a detention facility.

Retention
The holding of runoff in a basin without release except by means of evaporation, infiltration, or emergency bypass.

Return Period
The expected or average value of the recurrence interval (time between occurrences) of an event equal to or greater than a given magnitude, also referred to as storm frequency.

Riparian
The land area which borders a stream or river and which directly affects and is affected by the water quality. This land area often coincides with the maximum water surface elevation of the 1% storm (Base Flood).

Riprap
A layer, facing, or protective mound of stones, randomly placed to prevent erosion or scour at a structure or embankment; also the stone so used.

Riser
The vertical portion of an inlet to a conduit, extending from the barrel to the water surface.

Rock
Soil particles greater than 3 inches in diameter.

Rooted
Expression indicating that a bank has been excavated and the end of a structure (check dam, dike, etc.) has been placed in the cavity, thus retarding future stream flow around the end of the structure (flanking).

Roughness Coefficient
A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

Runoff
That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water.

Runoff Coefficient (C)
A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff volume.

Runoff Curve Number Method
A method developed by the SCS (now known as the NRCS) for estimating runoff, accounting for soils characteristics and land-use cover. In this method the Curve Number relates volume of runoff to interception, depression storage, soil storage, and rainfall depth.

Runoff Rate
Also referred to as discharge rate. The measure of the volume of runoff per unit of time, reaching a particular point of interest on the earth's surface.

Runoff Volume
The total volume of water that occurs as "Direct Runoff" during a particular storm event. This volume is usually measured in inches of depth over the extent of the contributing watershed.

Runon
The flow of stormwater from impervious cover to pervious cover.

Runup
The rush of water up a beach or structure, associated with the breaking of a wave; measured according to the vertical height above still water that level that the rush of water reaches.

S

Safety Bench
A flat area above the permanent pool and surrounding a stormwater pond designed to provide a separation to adjacent slopes.

Sand
Soil particles ranging from 0.05 to 2.0 mm in diameter; individual particles are visible to the unaided human eye.

Sand Filter
A technique for treating stormwater, whereby runoff is diverted into a self contained bed of sand.

Scour
The erosive action of flowing water in streams that removes and carries away material from the bed and banks.

SCS
United States Department of Agriculture – Soil Conservation Service. Now known as the Natural Resource Conservation Service (NRCS).

Sediment
Solid particulate matter, both mineral and organic, that has been or is being transported by water, air, ice, or gravity from its site of origin.

Sediment Basin
A pond created to retain runoff long enough to allow excess sediment to settle out.

Sediment Load
The soil particles transported through a channel by stream flow.

Sedimentation
The process or action of depositing sediment, debris and other materials on the ground surface or in water channels.

Seepage
Groundwater emerging on the face of a stream bank.

Setbacks
The minimum distance requirements for location of a structural stormwater practice in relation to roads, wells, septic fields, or other structures.

Shear
Force parallel to a surface as opposed to directly on the surface. An example of shear would be the tractive force that removes particles from a streambank as flow moves over the surface of the slope; on the other hand, a floating log that directly strikes the bank would not be a shear force.

Sheet Flow
Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Short-Circuiting
The passage of runoff through a BMP in less than the theoretical or design treatment time.

Silt
(Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter; A soil textural class; (Engineering) According to the Unified Soil Classification System a fine grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

Silt fence
Temporary sediment barrier consisting of filter fabric, sometimes backed with wire mesh, attached to supporting posts and partially buried.

Slope
A ratio of run (horizontal) to rise (vertical), usually expressed as a ratio (e.g. 3:1).

Soil
Soil finer than sand but coarser than clay, but not so fine that it can remain suspended in water for long periods. The grain size is considered to be less than 0.0625 mm.

Soil and Water Conservation District or Conversation District
A governmental subdivision of the State of South Carolina created pursuant to Chapter 9, Title 48, Code of Laws of South Carolina, 1976, as amended; and Soil and Water Conservation District Board - the governing body of the Soil and Water Conservation District.

Soil moisture
Water that is stored in the soil on the surfaces of soil particles.

Source control
A practice or structural measure to prevent pollutants from entering stormwater runoff or other environmental media.

Spillway
The open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

Stabilization
The installation of vegetative or structural measures to establish a soil cover to reduce soil erosion by stormwater runoff, wind, ice, and gravity.

Stage
The elevation of the water surface in a storage structure (e.g., reservoir, detention basin) or water body.

Stage/Discharge Relationship
A table, graph, or mathematical equation that relates the discharge rate from a reservoir or other water body to the elevation (stage) of the water surface in the water body.

Stage/Storage Relationship
A table, graph, or mathematical equation that relates the volume of storage in a reservoir or water body to the elevation (stage) of the surface of the stored water.

Storm Duration
The length of time from the beginning of rainfall to the point when there is no more additional accumulation of precipitation.

Stormwater
The direct runoff response of a watershed to rainfall including the surface and subsurface runoff and any associated material that enters a ditch, stream, or storm sewer during a rainfall event.

Stormwater management
The process of collection, conveyance, storage, treatment, and disposal of stormwater to ensure control of the magnitude and frequency of runoff to minimize the hazards associated with flooding and impact of water quality caused by manmade changes to the land.

Stormwater Management and Sediment Control Plan
A set of drawings, other documents, and supporting calculations submitted by a person as a prerequisite to obtaining a permit to undertake a land disturbing activity, which contains all of the information and specifications required by an implementing agency.

Stormwater Utility
An administrative organization that has been created for the purposes of planning, designing, constructing, and maintaining stormwater management, sediment control and flood control programs and projects.

Straw Bale
Temporary barriers made of straw bales are sometimes installed across a slope or around the perimeter of a construction site to intercept and detain sediment transported by runoff. Generally not allowed as an adequate BMP.

Stream Bank
The side slopes of a channel between which the stream flow is normally confined.

Structural BMPs
Devices which are constructed to provide treatment of stormwater runoff.

Subwatershed
A smaller geographic section of a larger watershed unit with a drainage area of between 2 to 15 square miles and whose boundaries include all the land area draining to a point where two second order streams combine to form a third order stream.

Swale
A structural measure with a lining of grass, riprap or other materials which can function as a detention structure and convey stormwater runoff without causing erosion.

T

Tailwater
In hydraulics, the difference between the theoretical or actual elevation of the water surface at the outlet end of a pipe and the invert of the pipe.

Technical Release No. 20 (TR-20)
Technical Release No. 20, Project Formulation – Hydrology. This publication comprises the watershed computer model developed by the SCS (now NRCS) for hydrologic analysis. The method uses runoff hydrographs and hydrograph routing to estimate runoff volumes, runoff rates, and storage structure performance for any specified precipitation event.

Technical Release No. 55 (TR-55)
A watershed hydrology model developed by the Soil Conservation Service (now NRCS) used to calculate runoff volumes and provide a simplified routing for storm events through stream valleys and/or ponds.

Ten-Year Frequency Storm
A storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in 10 years. It may also be expressed as an exceedence probability with a 10 percent chance of being equaled or exceeded in any given year.

Time of Concentration
The time required for runoff to travel from the hydraulically most distance point to the outlet of a watershed.

Total Maximum Daily Load (TMDL)
The maximum allowable loading of a pollutant that a designated water body can assimilate and still meet numeric and narrative water quality standards. TMDLs were established by the 1972 Clean Water Act. Section 303(d) of the US Water Quality Act requires states to identify water bodies that do not meet federal water quality standards. In 1996, the states developed (with EPA approval) a list of water bodies that failed to meet section 303(d) standards. These are the focus of TMDLs. Allocation of named pollutants is on percentage basis.

Total Suspended Solids (TSS)
The total amount of particulate matter which is suspended in the water column.

Technical Paper-40 Atlas (TP-40)
Rainfall Frequency Atlas of the United States. This atlas relates rainfall depth to storm duration and frequency, by geographic location, based on statistical analysis of rainfall records. This information is used in a number of methods for estimating runoff volumes and runoff rates for given design storm events.

Trash Rack
Grill, grate or other device at the intake of a channel, pipe, drain or spillway for preventing oversized debris from entering the structure.

Travel Time
The time interval required for water to travel from one point to another through a part (reach) of a watershed.

Treatment
The act of applying a procedure or chemicals to a substance to remove undesirable pollutants.

Two-Year Frequency Storm
A storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in two years. It may also be expressed as an exceedence probability with a 50 percent chance of being equaled or exceeded in any given year.

U

Ultra-Urban
A region dominated by highly developed areas in which very little pervious surface exists.

Underdrain
Plastic pipes with holes drilled through the top, installed on the bottom of an infiltration BMP, or sand filter, which are used to collect and remove excess runoff.

Uniform Flow
A state of steady flow where the mean velocity and cross-sectional area remain constant.

V

Vadose Zone
The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Also called the unsaturated zone.

Variance
The modification of the minimum sediment and stormwater management requirements for specific circumstances where strict adherence of the requirements would result in unnecessary hardship and not fulfill the intent of these regulations.

Variance
A modification of the requirements of the Ordinance.

Vegetation
All plant growth, including trees, shrubs, mosses and grasses.

W

Waiver
The relinquishment from sediment and stormwater management requirements by the appropriate plan approval authority for a specific land disturbing activity on a case-by case review basis.

Wasteload Allocation (WLA)
The portion of a receiving water's loading capacity that is estimated to come from present or future point sources of pollution and is regulated by the NPDES program.

Water Balance
The quantitative description of the movement of water through a wetland or water body, accounting for all pathways of water moving into (inputs) and out of (outputs) the water body. Also referred to as "Water Budget."

Water Quality
Those characteristics of stormwater runoff from a land disturbing activity that relate to the physical, chemical, biological, or radiological integrity of water.

Water Quality Capture Volume (WQCV)
The volume needed to capture and treat 80% of the average annual stormwater runoff volume.

Water Quantity
Those characteristics of stormwater runoff that relate to the rate and volume of the stromwater runoff to downstream areas resulting from land disturbing activities.

Watershed
An area confined by drainage divides usually having only one stream flow outlet. In the UK the term "watershed" refers to what in the US is called the drainage divide, and the term "catchment" refers to what in the US is called a watershed.

Wedges
Design feature in stormwater wetlands that increases flow path length to provide for extended detention and treatment of runoff. Also called baffles.

Wetlands
Swampy or marshy areas where water stands at or near the ground surface, forming a habitat for different types of plants and wildlife. Wetlands can act as reservoirs for flood control, taking in excess water from urban streams during rainy seasons.

Wetted Perimeter
The length of the wetted surface of the channel.

Wingwall
The end portion of a bulkhead, sea wall, or revetment that cuts back in toward the bank, usually at a right angle to the main structure, to help retard or prevent flanking.

X

Xeriscaping
Landscaping that uses drought-tolerant vegetation instead of turf to reduce the amount of water required to maintain a lawn.

Z

Zoning
A set of regulations and requirements that govern the use, placement, spacing and size of buildings and lots within a specific area or in a common class (zone).

13.2 References

Massachusetts Department of Environmental Protection, Division of Watershed Management Wetlands and Waterways Program, Hydrology handbook for conservation commissioners, A Guide to understanding hydrologic and hydraulic data and calculations under the Massachusetts Wetlands Protection Act, March 2002

Virginia Department of Conservation and Recreation, Division of Soil and Water Commission, Virginia Erosion and Sediment Control Handbook, 3rd Edition, 1992.

APPENDIX A – EROSION RELATED INFORMATION FOR SOUTH CAROLINA SOILS

EROSION RELATED INFORMATION FOR SOUTH CAROLINA SOILS

Depth	D15(mm)	K	Particle Sizes (mm) 1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: AILEY (B)										
0 - 24	0.0462	0.15	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
24 - 36	0.0268	0.24	100.0	79.6	32.9	16.5	16.5	6.8	4.9	0.0
36 - 50	0.0473	0.24	100.0	78.4	29.1	11.5	11.5	6.6	4.9	0.0
50 - 72	0.0472	0.15	100.0	79.3	32.1	10.8	10.8	6.0	4.4	0.0
SOIL: ALAGA (A)										
0 - 6	0.0315	0.10	100.0	91.4	71.6	16.4	16.2	2.2	1.4	0.0
6 - 99	0.0315	0.10	100.0	91.4	71.6	16.4	16.2	2.2	1.4	0.0
SOIL: ALAMANCE (B)										
0 – 11	0.0069	0.43	100.0	93.6	78.9	53.8	49.8	3.9	2.4	0.0
11 - 35	0.0053	0.43	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
35 - 46	0.0065	0.43	100.0	94.9	83.2	60.0	55.1	3.9	2.4	0.0
46 - 64	0.0068	0.32	100.0	93.8	79.6	54.8	50.6	3.9	2.4	0.0
SOIL: ALBANY (C)										
0 - 48	0.0445	0.10	100.0	92.7	76.1	13.2	12.9	1.7	1.1	0.0
48 - 56	0.0228	0.20	100.0	88.3	61.5	18.5	18.5	3.2	2.0	0.0
56 - 88	0.0237	0.24	100.0	80.1	34.6	17.2	17.2	6.6	4.7	0.0
SOIL: ALBERTVILLE (C)										
0 - 6	0.0068	0.37	100.0	90.5	68.9	48.9	46.8	5.2	3.2	0.0
6 - 15	0.0058	0.32	100.0	85.2	51.3	45.1	45.1	8.9	5.8	0.0
15 - 47	0.0046	0.37	100.0	85.6	52.7	49.2	48.6	12.7	8.8	0.0
SOIL: ALPIN (A)										
0 - 3	0.0459	0.10	100.0	91.1	70.6	7.7	7.7	1.9	1.3	0.0
3 - 54	0.0453	0.10	100.0	94.3	81.2	9.1	9.0	1.2	0.8	0.0
54 - 99	0.0451	0.10	100.0	91.3	71.5	10.7	10.7	2.0	1.3	0.0
SOIL: ALTAVISTA (C)										
0 - 12	0.0066	0.32	100.0	90.6	69.3	51.1	49.0	5.5	3.4	0.0
12 - 42	0.0067	0.24	100.0	84.3	48.5	39.2	39.2	7.8	5.2	0.0
SOIL: ANGIE (D)										
0 - 10	0.0071	0.49	100.0	94.2	81.1	53.6	49.2	3.4	2.1	0.0
10 - 65	0.0045	0.32	100.0	85.1	51.1	48.0	47.5	13.3	9.3	0.0
SOIL: ANNEMAINE (C)										
0 - 9	0.0064	0.43	100.0	93.3	78.1	57.5	53.7	4.7	2.9	0.0
9 - 37	0.0048	0.37	100.0	86.1	54.2	50.4	49.8	12.1	8.3	0.0
37 - 49	0.0067	0.37	100.0	83.9	47.2	38.0	38.0	8.0	5.4	0.0
49 - 90	0.0117	0.32	100.0	85.9	53.8	26.5	26.5	4.6	2.9	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: APPLING (B)										
0 - 9	0.0070	0.24	100.0	86.3	54.9	15.8	15.8	3.6	2.4	0.0
9 - 35	0.0053	0.28	100.0	79.5	32.7	30.4	30.4	12.9	9.3	0.0
35 - 46	0.0069	0.28	100.0	81.0	37.4	31.6	31.6	9.8	6.8	0.0
SOIL: ARENTS (Z)										
0 - 60	0.0049	0.28	100.0	86.7	56.2	53.3	53.3	11.3	7.5	0.0
SOIL: ARGENTPO (D)										
0 - 5	0.0057	0.32	100.0	90.7	69.4	58.2	56.5	7.0	4.4	0.0
5 - 64	0.0046	0.32	100.0	82.7	43.1	41.3	41.3	13.2	9.3	0.0
64 - 76	0.0063	0.32	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
SOIL: ARGENT (D)										
0 - 5	0.0057	0.32	100.0	90.7	69.4	58.2	56.5	7.0	4.4	0.0
5 - 64	0.0046	0.32	100.0	82.7	43.1	41.3	41.3	13.2	9.3	0.0
64 - 76	0.0063	0.32	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
SOIL: ASHE (B)										
0 - 7	0.0091	0.24	100.0	88.9	63.5	34.6	33.6	4.2	2.6	0.0
7 - 25	0.0097	0.17	100.0	88.4	61.8	31.9	31.5	4.2	2.6	0.0
25 - 30	0.0120	0.17	100.0	90.3	68.3	28.6	27.5	3.1	1.9	0.0
SOIL: ASHLAR (B)										
0 – 18	0.0137	0.24	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
18 - 34	0.0151	0.24	100.0	89.5	65.4	23.8	23.3	3.1	1.9	0.0
SOIL: ASHLARGR (B)										
0 - 18	0.0137	0.24	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
18 - 34	0.0151	0.24	100.0	89.5	65.4	23.8	23.3	3.1	1.9	0.0
SOIL: ASHLARSS (B)										
0 - 18	0.0303	0.20	100.0	88.6	62.6	16.3	16.3	3.0	1.9	0.0
18 - 34	0.0151	0.24	100.0	89.5	65.4	23.8	23.3	3.1	1.9	0.0
SOIL: ASHLARST (B)										
0 - 18	0.0137	0.24	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
18 - 34	0.0151	0.24	100.0	89.5	65.4	23.8	23.3	3.1	1.9	0.0
SOIL: ATLEE (C)										
0 - 10	0.0079	0.37	100.0	92.6	75.6	44.8	41.7	3.4	2.1	0.0
10 - 26	0.0062	0.37	100.0	90.0	67.2	52.7	51.1	6.2	3.9	0.0
26 - 52	0.0055	0.37	100.0	88.8	63.2	56.0	55.5	8.2	5.2	0.0
52 - 87	0.0052	0.37	100.0	88.3	61.4	55.6	54.6	9.6	6.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: AUTRYVILLE (A)										
0 - 26	0.0457	0.10	100.0	91.7	72.7	8.1	8.1	1.7	1.2	0.0
26 - 41	0.0469	0.10	100.0	81.8	40.0	9.6	9.6	4.7	3.4	0.0
41 - 58	0.0455	0.10	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
58 - 85	0.0219	0.17	100.0	80.8	37.1	17.8	17.8	6.2	4.4	0.0
SOIL: AXIS (D)										
0 - 7	0.0063	0.10	100.0	89.5	65.5	51.0	49.6	6.2	3.9	0.0
7 - 40	0.0080	0.10	100.0	92.0	73.6	43.2	40.4	3.6	2.2	0.0
40 - 72	0.0077	0.10	100.0	88.3	61.6	40.1	39.3	5.2	3.2	0.0
SOIL: AYCOCK (B)										
0 - 12	0.0079	0.37	100.0	93.8	79.7	46.8	42.9	3.0	1.9	0.0
12 - 80	0.0055	0.43	100.0	88.8	63.2	56.0	55.5	8.2	5.2	0.0
SOIL: AYNOR (B/D)										
0 - 8	0.0126	0.20	100.0	85.8	53.4	25.0	25.0	4.5	2.9	0.0
8 - 42	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
42 - 58	0.0146	0.20	100.0	80.2	35.0	20.8	20.8	7.2	5.1	0.0
SOIL: BADIN (C)										
0 - 6	0.0053	0.28	100.0	86.0	54.0	49.8	49.8	9.9	6.5	0.0
6 - 25	0.0049	0.24	100.0	82.6	42.8	40.7	40.7	12.5	8.8	0.0
SOIL: BLANEY (B)										
0 - 25	0.0443	0.10	100.0	92.2	74.4	13.9	13.7	1.9	1.2	0.0
25 - 50	0.0342	0.28	100.0	78.8	30.3	15.4	15.4	7.1	5.2	0.0
50 - 65	0.0188	0.28	100.0	83.6	46.1	19.6	19.6	5.0	3.4	0.0
SOIL: BLANTON (A)										
0 - 58	0.0448	0.10	100.0	88.9	63.4	12.3	12.3	2.6	1.8	0.0
58 - 62	0.0456	0.15	100.0	84.4	48.8	11.1	11.1	3.9	2.7	0.0
62 - 80	0.0197	0.20	100.0	79.6	33.1	18.3	18.3	7.1	5.1	0.0
SOIL: BLANTONMW (B)										
0 - 50	0.0448	0.10	100.0	88.9	63.4	12.3	12.3	2.6	1.8	0.0
50 - 56	0.0456	0.15	100.0	84.4	48.8	11.1	11.1	3.9	2.7	0.0
56 - 68	0.0143	0.20	100.0	82.4	42.0	22.0	22.0	5.9	4.1	0.0
68 - 80	0.0155	0.24	100.0	79.7	33.4	20.0	20.0	7.4	5.3	0.0
SOIL: BLANTONOF (B)										
0 - 7	0.0460	0.10	100.0	94.0	80.4	5.5	5.5	1.2	0.8	0.0
7 - 52	0.0459	0.10	100.0	93.4	78.5	6.7	6.7	1.3	0.9	0.0
52 - 80	0.0143	0.24	100.0	82.4	42.0	22.0	22.0	5.9	4.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: BOHICKET (D)										
0 - 10	0.0046	0.28	100.0	87.2	57.8	53.1	51.9	12.7	8.8	0.0
10 - 49	0.0045	0.24	100.0	84.4	48.8	46.3	46.0	13.3	9.3	0.0
SOIL: BOJACFL (B/D)										
0 - 8	0.0102	0.28	100.0	95.3	84.4	37.3	33.6	1.7	1.1	0.0
8 - 47	0.0085	0.28	100.0	89.7	66.0	38.1	36.6	4.2	2.6	0.0
47 - 85	0.0444	0.49	100.0	94.0	80.2	13.4	12.8	1.4	0.9	0.0
SOIL: BOLLING (C)										
0 – 11	0.0079	0.28	100.0	91.4	71.7	43.3	40.8	3.9	2.4	0.0
11 - 35	0.0064	0.28	100.0	84.6	49.3	41.1	41.1	8.1	5.4	0.0
35 - 63	0.0057	0.28	100.0	81.4	39.0	35.4	35.4	11.1	7.8	0.0
SOIL: BONNEAU (A)										
0 - 22	0.0246	0.10	100.0	88.6	62.7	17.9	17.9	3.0	1.9	0.0
22 - 50	0.0133	0.20	100.0	81.2	38.3	22.2	22.2	6.7	4.7	0.0
50 - 74	0.0126	0.20	100.0	80.1	34.6	22.1	22.1	7.6	5.4	0.0
SOIL: BRADSON (B)										
0 - 6	0.0085	0.17	100.0	89.7	66.0	38.1	36.6	4.2	2.6	0.0
6 - 65	0.0048	0.24	100.0	81.5	39.3	37.3	37.3	13.1	9.3	0.0
65 - 75	0.0065	0.32	100.0	91.2	71.2	52.5	50.0	5.3	3.3	0.0
SOIL: BREVARD (D)										
0 - 4	0.0066	0.24	100.0	90.6	69.0	50.7	48.6	5.5	3.4	0.0
4 - 76	0.0064	0.24	100.0	84.7	49.6	41.4	41.4	8.1	5.4	0.0
76 - 80	0.0464	0.10	100.0	81.9	40.6	10.6	10.6	4.7	3.4	0.0
SOIL: BROGDON (B)										
0 - 12	0.0303	0.15	100.0	88.6	62.6	16.3	16.3	3.0	1.9	0.0
12 - 27	0.0156	0.17	100.0	86.8	56.5	22.2	22.2	3.9	2.5	0.0
27 - 43	0.0441	0.15	100.0	92.3	74.6	14.6	14.3	1.9	1.2	0.0
43 - 72	0.0098	0.17	100.0	83.2	44.8	28.0	28.0	6.5	4.4	0.0
SOIL: BROOKMAN (D)										
0 – 15	0.0068	0.24	100.0	89.8	66.5	48.0	46.3	5.5	3.4	0.0
15 - 58	0.0049	0.28	100.0	82.3	41.9	39.7	39.7	12.5	8.8	0.0
58 - 65	0.0057	0.24	100.0	82.6	42.8	38.8	38.8	10.6	7.3	0.0
SOIL: BROOKMANDE (D)										
0 – 15	0.0068	0.24	100.0	89.8	66.5	48.0	46.3	5.5	3.4	0.0
15 - 58	0.0049	0.28	100.0	82.3	41.9	39.7	39.7	12.5	8.8	0.0
58 - 65	0.0057	0.24	100.0	82.6	42.8	38.8	38.8	10.6	7.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: BUNCOMBE (A)										
0 - 10	0.0441	0.10	100.0	90.7	69.5	14.5	14.5	2.3	1.5	0.0
10 - 55	0.0441	0.10	100.0	90.7	69.5	14.5	14.5	2.3	1.5	0.0
SOIL: BUTTERS (B)										
0 – 18	0.0455	0.10	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
18 - 29	0.0174	0.15	100.0	85.5	52.4	20.7	20.7	4.4	2.9	0.0
29 - 48	0.0458	0.10	100.0	92.2	74.5	7.4	7.4	1.6	1.1	0.0
48 - 62	0.0125	0.17	100.0	84.6	49.5	24.7	24.7	5.1	3.4	0.0
SOIL: BYARS (D)										
0 – 13	0.0055	0.28	100.0	90.4	68.6	60.3	59.0	7.8	4.9	0.0
13 - 43	0.0046	0.32	100.0	83.0	44.0	42.4	42.4	13.2	9.3	0.0
43 - 73	0.0045	0.32	100.0	85.6	52.6	49.1	48.3	13.3	9.3	0.0
SOIL: BYARSFL (D)										
0 - 13	0.0055	0.28	100.0	90.4	68.6	60.3	59.0	7.8	4.9	0.0
13 - 43	0.0046	0.32	100.0	83.0	44.0	42.4	42.4	13.2	9.3	0.0
43 - 73	0.0045	0.32	100.0	85.6	52.6	49.1	48.3	13.3	9.3	0.0
SOIL: CAHABA (B)										
0 - 9	0.0073	0.28	100.0	91.3	71.5	46.9	44.3	4.4	2.7	0.0
9 - 53	0.0069	0.28	100.0	84.0	47.4	37.6	37.6	7.8	5.2	0.0
53 - 80	0.0445	0.24	100.0	86.4	55.2	13.6	13.6	3.4	2.3	0.0
SOIL: CAINHOY (A)										
0 - 55	0.0468	0.10	100.0	88.6	62.5	5.2	5.2	2.3	1.7	0.0
55 - 99	0.0469	0.10	100.0	91.9	73.3	2.4	2.4	1.5	1.1	0.0
SOIL: CALLISON (Z)										
0 - 5	0.0067	0.43	100.0	94.5	81.9	57.2	52.6	3.7	2.3	0.0
5 - 34	0.0053	0.43	100.0	91.2	71.0	62.8	61.1	8.2	5.2	0.0
34 - 37	0.0051	0.37	100.0	91.0	70.3	62.9	60.9	9.4	6.1	0.0
SOIL: CANDOR (A)										
0 - 21	0.0455	0.10	100.0	96.2	87.6	7.3	7.0	0.8	0.5	0.0
21 - 34	0.0453	0.10	100.0	88.7	62.9	10.8	10.8	2.6	1.8	0.0
34 - 56	0.0455	0.10	100.0	96.2	87.6	7.3	7.0	0.8	0.5	0.0
56 - 72	0.0162	0.20	100.0	81.4	38.8	20.3	20.3	6.3	4.4	0.0
SOIL: CANTEY (D)										
0 - 6	0.0071	0.37	100.0	90.8	69.9	47.0	44.7	4.7	2.9	0.0
6 - 52	0.0047	0.24	100.0	82.3	41.7	39.8	39.8	13.1	9.3	0.0
52 - 72	0.0055	0.24	100.0	80.0	34.4	31.7	31.7	12.3	8.8	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: CANTEYFL (D)										
0 - 6	0.0071	0.37	100.0	90.8	69.9	47.0	44.7	4.7	2.9	0.0
6 - 52	0.0047	0.24	100.0	82.3	41.7	39.8	39.8	13.1	9.3	0.0
52 - 72	0.0049	0.24	100.0	80.8	36.9	34.8	34.8	13.0	9.3	0.0
SOIL: CAPEFE (D)										
0 – 16	0.0072	0.15	100.0	94.7	82.6	53.5	48.8	3.1	1.9	0.0
16 - 52	0.0048	0.32	100.0	81.5	39.3	37.3	37.3	13.1	9.3	0.0
SOIL: CAPERS (D)										
0 – 16	0.0047	0.28	100.0	87.1	57.4	52.9	51.8	12.1	8.3	0.0
SOIL: CAROLINE (C)										
0 - 9	0.0052	0.43	100.0	86.0	54.0	50.2	50.2	10.3	6.8	0.0
9 - 84	0.0048	0.32	100.0	82.9	43.8	41.7	41.7	12.6	8.8	0.0
84 - 99	0.0061	0.32	100.0	84.3	48.5	41.5	41.5	8.8	5.8	0.0
SOIL: CARTECAY (C)										
0 - 9	0.0057	0.32	100.0	87.2	58.0	51.4	51.2	8.4	5.4	0.0
9 - 40	0.0122	0.24	100.0	87.3	58.3	26.2	26.1	4.0	2.5	0.0
40 - 60	0.0445	0.15	100.0	89.0	63.8	13.3	13.3	2.7	1.8	0.0
SOIL: CARTECAYPO (C)										
0 - 9	0.0057	0.32	100.0	87.2	58.0	51.4	51.2	8.4	5.4	0.0
9 - 40	0.0122	0.24	100.0	87.3	58.3	26.2	26.1	4.0	2.5	0.0
40 - 60	0.0445	0.15	100.0	89.0	63.8	13.3	13.3	2.7	1.8	0.0
SOIL: CATAULA (B)										
0 - 7	0.0091	0.32	100.0	81.4	38.9	27.6	27.6	7.7	5.4	0.0
7 - 27	0.0044	0.24	100.0	80.3	35.2	33.6	33.6	14.2	10.2	0.0
27 - 55	0.0053	0.24	100.0	83.0	44.0	40.9	40.9	11.3	7.8	0.0
55 - 75	0.0070	0.32	100.0	83.5	45.8	36.0	36.0	8.0	5.4	0.0
SOIL: CECIL (B)										
0 - 7	0.0066	0.28	100.0	84.1	47.9	39.0	39.0	8.1	5.4	0.0
7 - 11	0.0066	0.28	100.0	84.1	47.9	39.0	39.0	8.1	5.4	0.0
11 - 50	0.0043	0.28	100.0	81.0	37.6	36.1	36.1	14.3	10.2	0.0
SOIL: CENTENARY (A)										
0 - 9	0.0465	0.10	100.0	93.3	77.9	3.7	3.7	1.2	0.9	0.0
9 - 58	0.0454	0.10	100.0	93.6	78.9	8.7	8.7	1.4	0.9	0.0
58 - 72	0.0460	0.10	100.0	91.6	72.4	7.1	7.1	1.7	1.2	0.0
SOIL: CHANDLER (B)										
0 - 4	0.0101	0.32	100.0	89.9	66.8	32.7	31.4	3.6	2.2	0.0
4 - 66	0.0101	0.32	100.0	89.9	66.8	32.7	31.4	3.6	2.2	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: CHARLESTON (C)										
0 - 16	0.0125	0.15	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
16 - 44	0.0128	0.20	100.0	86.4	55.1	25.1	25.1	4.3	2.7	0.0
44 - 80	0.0458	0.15	100.0	89.0	63.7	8.7	8.7	2.4	1.7	0.0
SOIL: CHASTAIN (C)										
0 - 5	0.0049	0.28	100.0	87.8	59.8	54.7	53.6	11.1	7.5	0.0
5 - 52	0.0044	0.37	100.0	87.0	57.3	52.6	51.3	13.3	9.3	0.0
52 - 72	0.0453	0.10	100.0	91.8	73.2	10.1	10.1	1.8	1.2	0.0
SOIL: CHENNEBYPO (C)										
0 – 16	0.0052	0.32	100.0	90.6	69.1	61.8	60.0	9.3	6.0	0.0
16 - 55	0.0056	0.32	100.0	91.5	71.9	61.8	59.9	7.3	4.6	0.0
55 - 72	0.0092	0.24	100.0	84.8	49.9	30.9	30.9	5.7	3.7	0.0
SOIL: CHEWACLA (C)										
0 - 8	0.0056	0.28	100.0	91.1	70.7	59.7	58.8	7.2	4.4	0.0
8 - 24	0.0056	0.32	100.0	88.5	62.1	54.9	54.5	8.2	5.2	0.0
24 - 34	0.0074	0.28	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0
34 - 58	0.0056	0.28	100.0	88.5	62.1	54.9	54.5	8.2	5.2	0.0
SOIL: CHIPLEY (C)										
0 - 6	0.0457	0.10	100.0	95.5	85.1	6.6	6.5	0.9	0.6	0.0
6 - 77	0.0459	0.10	100.0	94.1	80.5	6.0	6.0	1.2	0.8	0.0
SOIL: CHIPOLA (A)										
0 – 35	0.0445	0.17	100.0	93.3	78.1	13.1	12.7	1.6	1.0	0.0
35 - 56	0.0126	0.24	100.0	82.0	41.0	23.3	23.3	6.4	4.4	0.0
56 - 75	0.0266	0.20	100.0	88.6	62.7	17.3	17.3	3.0	1.9	0.0
75 - 94	0.0465	0.10	100.0	92.0	73.8	4.4	4.4	1.5	1.1	0.0
SOIL: CHISOLM (A)										
0 - 25	0.0447	0.15	100.0	89.4	65.2	12.7	12.7	2.5	1.7	0.0
25 - 36	0.0101	0.15	100.0	81.3	38.5	25.9	25.9	7.4	5.2	0.0
36 - 45	0.0078	0.15	100.0	80.7	36.4	28.9	28.9	9.0	6.3	0.0
45 - 57	0.0193	0.15	100.0	80.0	34.4	18.5	18.5	6.8	4.9	0.0
57 - 80	0.0468	0.15	100.0	86.3	55.0	6.9	6.9	3.0	2.1	0.0
SOIL: CLARENDON (C)										
0 - 15	0.0159	0.20	100.0	89.4	65.1	22.7	22.5	3.1	1.9	0.0
15 - 40	0.0101	0.20	100.0	81.3	38.5	25.9	25.9	7.4	5.2	0.0
40 - 80	0.0160	0.20	100.0	79.5	32.6	19.6	19.6	7.5	5.4	0.0
SOIL: CLAYCREEK (C)										
0 - 4	0.0067	0.43	100.0	94.5	81.9	57.2	52.6	3.7	2.3	0.0
4 - 22	0.0053	0.43	100.0	91.2	71.0	62.8	61.1	8.2	5.2	0.0
22 - 33	0.0049	0.37	100.0	88.0	60.7	55.4	54.2	11.1	7.5	0.0
33 - 39	0.0053	0.37	100.0	91.2	71.0	62.8	61.1	8.2	5.2	0.0
39 - 63	0.0057	0.37	100.0	91.2	71.2	60.0	58.0	7.0	4.4	0.0

Depth	D15(mm)	K	Particle Sizes (mm) 1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: CLEVELAND (C)										
0 - 14	0.0141	0.24	100.0	86.8	56.7	23.7	23.7	4.0	2.5	0.0
SOIL: CLIFTON (B)										
0 - 5	0.0054	0.17	100.0	85.5	52.4	47.8	47.8	9.8	6.5	0.0
5 - 10	0.0059	0.17	100.0	85.8	53.2	46.5	46.5	8.3	5.4	0.0
10 - 45	0.0049	0.17	100.0	82.2	41.4	39.2	39.2	12.5	8.8	0.0
45 - 65	0.0077	0.17	100.0	88.6	62.5	40.1	39.1	5.0	3.1	0.0
SOIL: CLOUDLAND (C)										
0 – 22	0.0077	0.37	100.0	92.9	76.7	46.6	43.2	3.4	2.1	0.0
22 - 36	0.0064	0.32	100.0	89.0	63.9	49.3	48.1	6.2	3.9	0.0
36 - 62	0.0064	0.28	100.0	89.0	63.9	49.3	48.1	6.2	3.9	0.0
SOIL: COLFAX (C)										
0 - 7	0.0073	0.32	100.0	89.5	65.4	43.6	42.1	5.0	3.1	0.0
7 - 18	0.0066	0.28	100.0	84.2	48.1	39.4	39.4	8.1	5.4	0.0
18 - 25	0.0068	0.28	100.0	84.6	49.3	39.1	39.1	7.4	4.9	0.0
25 - 67	0.0083	0.28	100.0	83.9	47.2	32.5	32.5	6.6	4.4	0.0
SOIL: COMPASS (B)										
0 – 16	0.0448	0.24	100.0	88.9	63.4	12.3	12.3	2.6	1.8	0.0
16 - 33	0.0442	0.24	100.0	85.0	50.6	14.6	14.6	4.0	2.7	0.0
33 - 57	0.0268	0.32	100.0	79.6	32.9	16.5	16.5	6.8	4.9	0.0
57 - 74	0.0104	0.28	100.0	76.5	22.7	19.2	19.2	11.9	8.8	0.0
SOIL: CONGAREE (B)										
0 - 8	0.0066	0.37	100.0	90.6	69.3	51.1	48.9	5.5	3.4	0.0
8 - 62	0.0063	0.37	100.0	85.1	50.9	42.7	42.7	7.9	5.2	0.0
SOIL: COOSAW (B)										
0 – 32	0.0302	0.10	100.0	89.8	66.6	16.4	16.4	2.6	1.7	0.0
32 - 35	0.0260	0.24	100.0	83.1	44.6	17.0	17.0	4.9	3.4	0.0
35 - 72	0.0207	0.24	100.0	79.4	32.3	17.9	17.9	7.2	5.2	0.0
72 - 99	0.0272	0.10	100.0	92.7	75.9	18.1	17.3	1.9	1.2	0.0
SOIL: CORONACA (B)										
0 - 6	0.0067	0.24	100.0	84.4	48.8	39.2	39.2	7.7	5.1	0.0
6 - 81	0.0042	0.24	100.0	82.5	42.5	41.1	41.1	14.4	10.2	0.0
81 - 97	0.0047	0.24	100.0	83.6	46.1	44.2	44.2	12.6	8.8	0.0
SOIL: COXVILLE (D)										
0 - 11	0.0073	0.24	100.0	89.6	65.7	43.9	42.4	5.0	3.1	0.0
11 - 72	0.0051	0.32	100.0	80.1	34.6	32.3	32.3	12.9	9.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: CRAGGEY (D)										
0 - 12	0.0130	0.15	100.0	86.3	55.1	24.8	24.8	4.3	2.7	0.0
SOIL: CRAVEN (C)										
0 - 9	0.0051	0.37	100.0	88.4	61.8	57.3	56.9	10.1	6.5	0.0
9 - 54	0.0045	0.32	100.0	84.1	47.8	45.6	45.3	13.3	9.3	0.0
54 - 80	0.0248	0.32	100.0	81.8	40.3	17.2	17.2	5.5	3.9	0.0
SOIL: CREEDMOOR (C)										
0 - 8	0.0112	0.28	100.0	87.3	58.4	28.0	27.8	4.2	2.6	0.0
8 - 19	0.0059	0.32	100.0	85.8	53.2	46.5	46.5	8.3	5.4	0.0
19 - 56	0.0045	0.32	100.0	84.4	48.8	46.3	46.0	13.3	9.3	0.0
56 - 77	0.0064	0.37	100.0	89.0	63.9	49.3	48.1	6.2	3.9	0.0
SOIL: CREVASSE (A)										
0 - 10	0.0302	0.17	100.0	89.8	66.6	16.4	16.4	2.6	1.7	0.0
10 - 60	0.0455	0.15	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
SOIL: DALEVILLE (D)										
0 - 16	0.0066	0.32	100.0	92.5	75.3	54.0	50.7	4.7	2.9	0.0
16 - 70	0.0055	0.37	100.0	88.6	62.4	55.6	55.2	8.5	5.4	0.0
SOIL: DAVIDSON (B)										
0 - 7	0.0043	0.28	100.0	81.0	37.6	36.1	36.1	14.3	10.2	0.0
7 - 12	0.0058	0.32	100.0	84.1	47.8	42.2	42.2	9.7	6.5	0.0
12 - 53	0.0039	0.24	100.0	79.8	33.7	32.5	32.5	15.5	11.2	0.0
53 - 72	0.0054	0.28	100.0	81.4	39.0	36.0	36.0	11.8	8.3	0.0
SOIL: DAWHOO (B/D)										
0 - 30	0.0388	0.10	100.0	95.4	85.0	16.1	14.8	1.1	0.7	0.0
30 - 60	0.0441	0.15	100.0	92.9	76.6	14.5	14.1	1.7	1.1	0.0
SOIL: DELOSS (B/D)										
0 – 18	0.0094	0.24	100.0	89.6	65.7	34.5	33.3	3.9	2.4	0.0
18 - 56	0.0074	0.24	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0
SOIL: DOTHAN (B)										
0 - 13	0.0175	0.24	100.0	86.1	54.3	20.7	20.7	4.1	2.7	0.0
13 - 33	0.0271	0.28	100.0	79.0	31.1	16.4	16.4	7.2	5.2	0.0
33 - 60	0.0149	0.10	100.0	79.2	31.6	20.0	20.0	7.9	5.7	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: DOTHANGR (B)										
0 – 13	0.0175	0.20	100.0	86.1	54.3	20.7	20.7	4.1	2.7	0.0
13 - 33	0.0446	0.28	100.0	78.6	29.5	14.4	14.4	7.1	5.2	0.0
33 - 60	0.0135	0.28	100.0	79.4	32.4	21.0	21.0	7.9	5.7	0.0
SOIL: DUCKSTON (A/D)										
0 - 72	0.0459	0.10	100.0	96.9	89.7	4.8	4.7	0.6	0.4	0.0
SOIL: DUNBAR (D)										
0 - 8	0.0137	0.32	100.0	85.2	51.4	23.5	23.5	4.7	3.1	0.0
SOIL: DUPLIN (C)										
0 - 8	0.0123	0.24	100.0	89.4	65.1	26.9	26.6	3.5	2.1	0.0
SOIL: DURHAM (B)										
0 - 16	0.0187	0.17	100.0	87.0	57.2	20.2	20.2	3.7	2.4	0.0
16 - 36	0.0121	0.20	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0
36 - 42	0.0080	0.20	100.0	79.8	33.5	27.1	27.1	9.6	6.8	0.0
42 - 48	0.0187	0.20	100.0	82.8	43.4	19.4	19.4	5.4	3.7	0.0
48 - 60	0.0161	0.17	100.0	87.0	57.4	21.9	21.9	3.8	2.4	0.0
SOIL: DURHAMMW (B)										
0 – 16	0.0187	0.17	100.0	87.0	57.2	20.2	20.2	3.7	2.4	0.0
16 - 36	0.0121	0.20	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0
36 - 42	0.0080	0.20	100.0	79.8	33.5	27.1	27.1	9.6	6.8	0.0
42 - 48	0.0187	0.20	100.0	82.8	43.4	19.4	19.4	5.4	3.7	0.0
48 - 60	0.0161	0.17	100.0	87.0	57.4	21.9	21.9	3.8	2.4	0.0
SOIL: ECHAW (A)										
0 - 5	0.0251	0.10	100.0	91.1	70.7	18.3	17.9	2.3	1.5	0.0
5 - 40	0.0443	0.10	100.0	92.4	74.9	13.8	13.8	1.9	1.2	0.0
40 - 50	0.0457	0.10	100.0	91.7	72.7	8.1	8.1	1.7	1.2	0.0
50 - 65	0.0443	0.10	100.0	92.4	74.9	13.8	13.8	1.9	1.2	0.0
SOIL: ECONFINA (A)										
0 - 49	0.0460	0.05	100.0	95.4	84.9	5.3	5.3	0.9	0.6	0.0
49 - 73	0.0458	0.05	100.0	97.6	92.3	5.4	5.1	0.5	0.3	0.0
73 - 77	0.0465	0.15	100.0	90.9	69.9	5.2	5.2	1.8	1.3	0.0
77 - 80	0.0459	0.10	100.0	91.1	70.6	7.7	7.7	1.9	1.3	0.0
SOIL: EDDINGS (D)										
0 - 44	0.0446	0.10	100.0	92.7	75.9	12.8	12.6	1.7	1.1	0.0
44 - 66	0.0118	0.15	100.0	83.6	46.2	25.0	25.0	5.8	3.9	0.0
66 - 84	0.0075	0.10	100.0	82.9	43.9	33.2	33.2	7.9	5.4	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: EDISTO (C)										
0 - 14	0.0116	0.17	100.0	88.1	60.9	27.6	27.3	3.9	2.4	0.0
14 - 27	0.0128	0.24	100.0	86.4	55.1	25.1	25.1	4.3	2.7	0.0
27 - 36	0.0155	0.24	100.0	87.8	59.9	22.6	22.6	3.6	2.2	0.0
36 - 70	0.0093	0.24	100.0	85.3	51.8	31.2	31.2	5.3	3.4	0.0
70 - 84	0.0457	0.17	100.0	91.7	72.7	8.1	8.1	1.7	1.2	0.0
SOIL: EDNEYTOWN (B)										
0 - 4	0.0088	0.20	100.0	92.3	74.5	39.5	36.8	3.1	1.9	0.0
4 - 29	0.0066	0.24	100.0	84.2	48.1	39.4	39.4	8.1	5.4	0.0
29 - 36	0.0108	0.24	100.0	85.6	52.7	28.0	28.0	4.9	3.1	0.0
36 - 60	0.0113	0.17	100.0	91.1	70.8	30.7	29.1	3.0	1.9	0.0
SOIL: EDNEYTOWNGR (B)										
0 - 4	0.0246	0.15	100.0	88.6	62.7	17.9	17.9	3.0	1.9	0.0
4 - 29	0.0074	0.24	100.0	83.4	45.3	34.3	34.3	7.7	5.2	0.0
29 - 36	0.0108	0.24	100.0	85.6	52.7	28.0	28.0	4.9	3.1	0.0
36 - 60	0.0113	0.17	100.0	89.4	65.0	20.2	20.1	3.0	1.9	0.0
SOIL: EDNEYTOWNVS (B)										
0 - 4	0.0137	0.15	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
4 - 29	0.0066	0.24	100.0	84.2	48.1	39.4	39.4	8.1	5.4	0.0
29 - 36	0.0107	0.24	100.0	86.3	54.8	28.5	28.5	4.6	2.9	0.0
36 - 60	0.0194	0.17	100.0	89.4	65.0	20.2	20.1	3.0	1.9	0.0
SOIL: EDNEYVILLE (B)										
0 - 7	0.0093	0.24	100.0	90.5	68.8	35.8	34.1	3.6	2.2	0.0
7 - 30	0.0089	0.20	100.0	89.1	64.2	35.6	34.5	4.2	2.6	0.0
30 - 60	0.0109	0.20	100.0	88.5	62.3	29.1	28.8	3.9	2.4	0.0
SOIL: EDNEYVILLEST (B)										
0 - 7	0.0107	0.17	100.0	88.6	62.5	29.9	29.4	3.9	2.4	0.0
7 - 30	0.0089	0.20	100.0	89.1	64.2	35.6	34.5	4.2	2.6	0.0
30 - 60	0.0109	0.20	100.0	88.5	62.3	29.1	28.8	3.9	2.4	0.0
SOIL: ELLOREE (D)										
0 - 6	0.0288	0.15	100.0	93.8	79.6	18.0	16.9	1.6	1.0	0.0
6 - 23	0.0445	0.10	100.0	95.2	84.3	12.9	12.1	1.1	0.7	0.0
23 - 42	0.0454	0.15	100.0	82.6	42.8	12.4	12.4	4.7	3.3	0.0
42 - 69	0.0174	0.17	100.0	85.5	52.4	20.7	20.7	4.4	2.9	0.0
SOIL: EMPORIA (C)										
0 – 15	0.0098	0.28	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
15 - 32	0.0081	0.28	100.0	82.7	43.3	31.2	31.2	7.6	5.2	0.0
32 - 57	0.0066	0.20	100.0	83.1	44.5	36.5	36.5	8.8	5.9	0.0
57 - 70	0.0126	0.20	100.0	82.0	41.0	23.3	23.3	6.4	4.4	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: EMPORIAGR (C)										
0 - 15	0.0098	0.28	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
15 - 32	0.0081	0.28	100.0	82.7	43.3	31.2	31.2	7.6	5.2	0.0
32 - 57	0.0066	0.20	100.0	83.1	44.5	36.5	36.5	8.8	5.9	0.0
57 - 70	0.0126	0.20	100.0	82.0	41.0	23.3	23.3	6.4	4.4	0.0
SOIL: ENON (C)										
0 - 8	0.0065	0.28	100.0	86.5	55.6	44.6	44.4	6.9	4.4	0.0
8 - 11	0.0062	0.24	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
11 - 33	0.0045	0.28	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
SOIL: ENONGR (C)										
0 - 8	0.0070	0.15	100.0	83.5	45.8	36.0	36.0	8.0	5.4	0.0
8 - 11	0.0062	0.24	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
11 - 33	0.0045	0.28	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
SOIL: ENONST (C)										
0 - 8	0.0205	0.15	100.0	86.9	57.1	19.3	19.3	3.7	2.4	0.0
8 - 11	0.0062	0.24	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
11 - 33	0.0047	0.28	100.0	82.3	41.7	39.8	39.8	13.1	9.3	0.0
SOIL: ENOREE (D)										
0 - 7	0.0062	0.32	100.0	90.0	67.2	52.7	51.1	6.2	3.9	0.0
7 - 27	0.0106	0.20	100.0	85.0	50.6	27.9	27.9	5.2	3.4	0.0
27 - 50	0.0137	0.20	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
SOIL: EULONIA (C)										
0 - 13	0.0100	0.24	100.0	89.1	64.3	31.5	31.0	4.0	2.4	0.0
13 - 48	0.0060	0.24	100.0	80.7	36.7	32.9	32.9	11.1	7.8	0.0
48 - 58	0.0334	0.20	100.0	79.3	32.1	15.5	15.5	6.8	4.9	0.0
SOIL: EUNOLA (C)										
0 – 10	0.0117	0.20	100.0	85.9	53.8	26.5	26.5	4.6	2.9	0.0
10 - 26	0.0103	0.28	100.0	81.2	38.1	25.4	25.4	7.4	5.2	0.0
26 - 52	0.0097	0.32	100.0	79.8	33.5	24.7	24.7	8.7	6.1	0.0
52 - 56	0.0136	0.24	100.0	85.0	50.6	23.5	23.5	4.8	3.2	0.0
56 - 65	0.0445	0.20	100.0	91.7	72.6	13.3	13.3	2.0	1.3	0.0
SOIL: EUSTIS (A)										
0 - 6	0.0462	0.10	100.0	91.5	72.1	6.1	6.1	1.7	1.2	0.0
6 - 24	0.0462	0.17	100.0	91.5	72.1	6.1	6.1	1.7	1.2	0.0
24 - 76	0.0448	0.17	100.0	88.0	60.4	12.6	12.6	2.9	1.9	0.0
76 - 98	0.0462	0.17	100.0	93.4	78.2	5.2	5.2	1.3	0.9	0.0
SOIL: EVARD (B)										
0 - 5	0.0069	0.28	100.0	90.8	69.7	48.8	46.6	5.0	3.1	0.0
5 - 29	0.0077	0.24	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
29 - 37	0.0143	0.24	100.0	82.4	42.0	22.0	22.0	5.9	4.1	0.0
37 - 72	0.0157	0.24	100.0	87.1	57.5	22.2	22.2	3.8	2.4	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: EVARDGR (B)										
0 - 5	0.0331	0.15	100.0	86.3	54.9	15.8	15.8	3.6	2.4	0.0
5 - 29	0.0077	0.24	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
29 - 37	0.0125	0.24	100.0	85.3	51.8	25.0	25.0	4.8	3.1	0.0
37 - 72	0.0157	0.24	100.0	87.1	57.5	22.2	22.2	3.8	2.4	0.0
SOIL: EXUM (C)										
0 – 12	0.0075	0.37	100.0	92.4	75.2	47.0	43.9	3.7	2.3	0.0
12 – 70	0.0055	0.37	100.0	88.8	63.2	56.0	55.5	8.2	5.2	0.0
SOIL: FACEVILLE (B)										
0 - 5	0.0082	0.32	100.0	83.5	45.6	31.9	31.9	7.0	4.7	0.0
5 - 11	0.0069	0.37	100.0	83.6	46.0	36.8	36.8	8.1	5.5	0.0
11 - 72	0.0066	0.37	100.0	78.2	28.3	25.2	25.2	12.1	8.8	0.0
SOIL: FANNIN (B)										
0 - 7	0.0075	0.32	100.0	89.9	66.8	43.2	41.4	4.7	2.9	0.0
7 - 32	0.0065	0.24	100.0	84.7	49.7	41.0	41.0	7.9	5.2	0.0
32 - 60	0.0107	0.24	100.0	86.3	54.8	28.5	28.5	4.6	2.9	0.0
SOIL: FLUVAQUENTS (Z)										
0 - 6	0.0078	0.20	100.0	93.5	78.6	46.5	42.8	3.1	1.9	0.0
6 - 20	0.0381	0.10	100.0	93.0	76.9	15.6	15.0	1.7	1.1	0.0
20 - 60	0.0137	0.37	100.0	89.8	66.5	25.5	24.8	3.1	1.9	0.0
SOIL: FORESTON (C)										
0 – 12	0.0302	0.15	100.0	89.8	66.6	16.4	16.4	2.6	1.7	0.0
12 - 40	0.0308	0.10	100.0	85.2	51.4	16.1	16.1	4.0	2.7	0.0
40 - 51	0.0456	0.10	100.0	89.6	65.8	9.6	9.6	2.3	1.6	0.0
51 - 85	0.0162	0.20	100.0	81.4	38.8	20.3	20.3	6.3	4.4	0.0
SOIL: FORTESCUE (C/D)										
0 - 6	0.0064	0.37	100.0	91.7	72.7	54.2	51.5	5.3	3.3	0.0
6 - 26	0.0054	0.32	100.0	90.6	69.0	61.1	59.6	8.2	5.2	0.0
SOIL: FOXWORTH (A)										
0 - 10	0.0462	0.10	100.0	93.4	78.2	5.2	5.2	1.3	0.9	0.0
10 - 52	0.0462	0.10	100.0	93.4	78.2	5.2	5.2	1.3	0.9	0.0
52 - 80	0.0463	0.10	100.0	94.6	82.4	3.9	3.9	1.0	0.7	0.0
SOIL: FRIPP (A)										
0 - 5	0.0467	0.10	100.0	96.0	86.7	0.6	0.6	0.6	0.5	0.0
5 - 80	0.0467	0.10	100.0	96.0	86.7	0.6	0.6	0.6	0.5	0.0
SOIL: FUQUAY (B)										
0 - 34	0.0441	0.15	100.0	92.3	74.6	14.6	14.3	1.9	1.2	0.0
34 - 45	0.0237	0.20	100.0	80.7	36.7	17.4	17.4	6.2	4.4	0.0
45 - 96	0.0196	0.20	100.0	79.1	31.4	18.1	18.1	7.5	5.4	0.0

Depth	D15(mm)	K	Particle Sizes (mm) 1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: FUQUAYGR (B)										
0 – 34	0.0369	0.15	100.0	92.4	75.0	15.6	15.2	1.9	1.2	0.0
34 - 45	0.0237	0.20	100.0	80.7	36.7	17.4	17.4	6.2	4.4	0.0
45 - 96	0.0196	0.20	100.0	79.1	31.4	18.1	18.1	7.5	5.4	0.0
SOIL: GARCON (C)										
0 - 8	0.0452	0.17	100.0	92.4	75.1	9.9	9.9	1.7	1.1	0.0
8 - 31	0.0452	0.17	100.0	92.4	75.1	9.9	9.9	1.7	1.1	0.0
31 - 51	0.0454	0.24	100.0	83.2	44.7	12.2	12.2	4.4	3.1	0.0
51 - 58	0.0454	0.17	100.0	90.2	67.6	9.9	9.9	2.2	1.5	0.0
58 - 80	0.0465	0.17	100.0	93.3	77.9	3.7	3.7	1.2	0.9	0.0
SOIL: GEORGEVILLE (B)										
0 - 6	0.0053	0.49	100.0	88.4	62.0	55.8	54.9	9.3	6.0	0.0
6 - 10	0.0053	0.32	100.0	89.1	64.1	57.6	56.4	9.3	6.0	0.0
10 - 53	0.0043	0.28	100.0	85.0	50.6	47.5	46.9	13.9	9.8	0.0
53 - 63	0.0057	0.32	100.0	87.2	58.0	51.4	51.2	8.4	5.4	0.0
SOIL: GEORGEVILLERO (B)										
0 - 6	0.0072	0.24	100.0	89.9	66.8	45.3	43.6	5.0	3.1	0.0
6 - 10	0.0053	0.32	100.0	89.1	64.1	57.6	56.4	9.3	6.0	0.0
10 - 53	0.0043	0.28	100.0	85.0	50.6	47.5	46.9	13.9	9.8	0.0
53 - 63	0.0057	0.32	100.0	87.2	58.0	51.4	51.2	8.4	5.4	0.0
SOIL: GILEAD (C)										
0 - 5	0.0206	0.20	100.0	87.3	58.1	19.3	19.3	3.6	2.3	0.0
5 - 8	0.0130	0.24	100.0	81.9	40.6	22.9	22.9	6.3	4.4	0.0
8 - 42	0.0056	0.28	100.0	78.7	29.8	27.4	27.4	12.8	9.3	0.0
42 - 72	0.0092	0.24	100.0	83.4	45.6	29.4	29.4	6.5	4.4	0.0
SOIL: GILLS (C)										
0 - 15	0.0061	0.37	100.0	90.5	68.8	54.5	52.6	6.2	3.9	0.0
15 - 31	0.0044	0.28	100.0	87.0	57.3	52.6	51.3	13.3	9.3	0.0
31 - 60	0.0066	0.43	100.0	84.9	50.4	40.8	40.8	7.5	4.9	0.0
SOIL: GOLDSBORO (B)										
0 – 15	0.0159	0.20	100.0	89.4	65.1	22.7	22.5	3.1	1.9	0.0
15 - 45	0.0133	0.24	100.0	81.2	38.3	22.2	22.2	6.7	4.7	0.0
45 - 65	0.0073	0.24	100.0	83.3	45.2	34.7	34.7	7.8	5.3	0.0
SOIL: GOLDSBOROHS (B)										
0 - 10	0.0395	0.10	100.0	93.6	78.8	15.6	14.8	1.6	1.0	0.0
10 - 39	0.0121	0.20	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0
SOIL: GOLDSTON (C)										
0 - 7	0.0080	0.15	100.0	88.1	60.9	37.9	37.4	5.0	3.1	0.0
7 - 16	0.0115	0.05	100.0	85.5	52.2	26.5	26.5	4.8	3.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: GOURDIN (C)										
0 - 6	0.0066	0.28	100.0	89.6	66.0	49.1	47.5	5.8	3.6	0.0
6 - 24	0.0057	0.24	100.0	85.6	52.7	47.0	47.0	8.9	5.8	0.0
24 - 55	0.0049	0.20	100.0	80.8	36.9	34.8	34.8	13.0	9.3	0.0
SOIL: GRADY (D)										
0 - 5	0.0066	0.24	100.0	84.9	50.4	40.8	40.8	7.5	4.9	0.0
5 - 11	0.0062	0.10	100.0	85.0	50.8	43.2	43.2	8.2	5.4	0.0
11 - 62	0.0041	0.10	100.0	79.7	33.3	31.8	31.8	14.8	10.7	0.0
SOIL: GRADYDR (D)										
0 - 5	0.0066	0.24	100.0	84.9	50.4	40.8	40.8	7.5	4.9	0.0
5 - 11	0.0062	0.10	100.0	85.0	50.8	43.2	43.2	8.2	5.4	0.0
11 - 62	0.0041	0.10	100.0	79.7	33.3	31.8	31.8	14.8	10.7	0.0
SOIL: GRANTHAM (D)										
0 – 11	0.0072	0.37	100.0	93.1	77.3	50.2	46.6	3.7	2.3	0.0
11 - 80	0.0053	0.43	100.0	90.5	68.8	61.5	60.8	8.3	5.2	0.0
SOIL: GREENVILLE (B)										
0 - 9	0.0071	0.24	100.0	85.0	50.7	38.9	38.9	6.8	4.4	0.0
9 - 80	0.0062	0.17	100.0	78.6	29.7	26.7	26.7	12.1	8.8	0.0
SOIL: GRIFTON (D)										
0 - 15	0.0157	0.20	100.0	87.1	57.5	22.2	22.2	3.8	2.4	0.0
15 - 40	0.0101	0.24	100.0	81.3	38.5	25.9	25.9	7.4	5.2	0.0
40 - 58	0.0188	0.20	100.0	88.8	63.3	20.5	20.4	3.1	1.9	0.0
SOIL: GRITNEY (C)										
0 - 7	0.0312	0.20	100.0	82.1	41.2	15.9	15.9	5.3	3.7	0.0
7 - 12	0.0119	0.32	100.0	77.6	26.3	20.3	20.3	10.1	7.3	0.0
12 - 31	0.0069	0.32	100.0	77.2	25.1	22.4	22.4	12.6	9.3	0.0
31 - 50	0.0093	0.28	100.0	81.3	38.5	27.1	27.1	7.7	5.4	0.0
SOIL: GROVER (B)										
0 - 6	0.0076	0.28	100.0	82.9	43.7	32.9	32.9	7.9	5.4	0.0
6 - 25	0.0071	0.32	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
25 - 65	0.0129	0.32	100.0	86.1	54.2	24.8	24.8	4.4	2.8	0.0
SOIL: GUNDY (C)										
0 - 4	0.0055	0.32	100.0	86.1	54.3	49.3	49.3	9.3	6.0	0.0
4 - 32	0.0047	0.32	100.0	82.3	41.7	39.8	39.8	13.1	9.3	0.0
32 - 52	0.0068	0.28	100.0	83.9	46.9	37.7	37.7	8.0	5.4	0.0
SOIL: GWINNET (B)										
0 - 8	0.0063	0.28	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
8 - 35	0.0063	0.28	100.0	79.5	32.7	30.4	30.4	12.9	9.3	0.0
35 - 50	**0.0053**	**0.28**	**100.0**	**83.4**	**45.3**	**38.4**	**38.4**	**9.2**	**6.2**	**0.0**

|---------------- Particle Sizes (mm) ----------------|										
Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: HAPLAQUENTS (Z)										
0 – 60	0.0091	0.20	100.0	81.4	38.9	27.6	27.6	7.7	5.4	0.0
SOIL: HAYESVILLE (B)										
0 - 5	0.0067	0.24	100.0	83.2	44.7	36.4	36.4	8.6	5.8	0.0
5 - 38	0.0055	0.24	100.0	82.1	41.3	37.9	37.9	11.2	7.8	0.0
38 - 48	0.0067	0.20	100.0	83.2	44.7	36.4	36.4	8.6	5.8	0.0
48 - 60	0.0084	0.17	100.0	88.5	62.1	36.6	36.1	4.7	2.9	0.0
SOIL: HAYESVILLEST (C)										
0 - 5	0.0066	0.15	100.0	84.2	48.1	39.4	39.4	8.1	5.4	0.0
5 - 38	0.0044	0.28	100.0	82.4	42.0	40.5	40.5	13.8	9.8	0.0
38 - 48	0.0073	0.28	100.0	81.2	38.1	30.9	30.9	9.1	6.3	0.0
48 - 60	0.0089	0.24	100.0	90.0	67.1	36.6	35.0	3.9	2.4	0.0
SOIL: HAYWOOD (B)										
0 - 60	0.0085	0.24	100.0	86.1	54.3	34.3	34.2	5.4	3.4	0.0
SOIL: HELENAGR (C)										
0 - 12	0.0106	0.20	100.0	80.7	36.6	24.6	24.6	7.7	5.4	0.0
12 - 19	0.0066	0.28	100.0	84.1	47.9	39.0	39.0	8.1	5.4	0.0
19 - 43	0.0049	0.28	100.0	81.1	37.9	35.8	35.8	13.0	9.3	0.0
SOIL: HERNDON (B)										
0 - 9	0.0053	0.49	100.0	88.1	60.7	54.8	54.0	9.3	6.0	0.0
9 - 48	0.0045	0.28	100.0	84.8	50.2	47.3	46.8	13.3	9.3	0.0
48 - 68	0.0063	0.32	100.0	90.7	69.5	53.0	50.8	5.8	3.6	0.0
SOIL: HIWASSEE (B)										
0 - 7	0.0061	0.28	100.0	88.0	60.5	49.5	49.0	7.0	4.4	0.0
7 - 61	0.0048	0.28	100.0	81.7	39.8	37.8	37.8	13.1	9.3	0.0
61 - 70	0.0081	0.28	100.0	84.6	49.5	34.3	34.3	6.3	4.1	0.0
SOIL: HIWASSEEGR (B)										
0 - 7	0.0061	0.24	100.0	90.1	67.4	52.7	51.8	6.4	3.9	0.0
7 - 61	0.0048	0.28	100.0	81.7	39.8	37.8	37.8	13.1	9.3	0.0
61 – 70	0.0081	0.28	100.0	84.6	49.5	34.3	34.3	6.3	4.1	0.0
SOIL: HOBCAW (D)										
0 - 18	0.0094	0.17	100.0	89.6	65.7	34.5	33.3	3.9	2.4	0.0
18 - 46	0.0074	0.24	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0
SOIL: HOBCAWFL (D)										
0 – 18	0.0094	0.17	100.0	89.6	65.7	34.5	33.3	3.9	2.4	0.0
18 - 46	0.0074	0.24	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: HOBCAWPO										
0 - 18	0.0094	0.17	100.0	89.6	65.7	34.5	33.3	3.9	2.4	0.0
18 - 46	0.0074	0.24	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0
SOIL: HOBONNY (D)										
0 - 2	0.0049	0.28	100.0	88.7	62.9	57.1	55.7	11.1	7.5	0.0
SOIL: HOCKLEY (C)										
0 - 23	0.0071	0.32	100.0	91.7	72.8	48.7	45.8	4.4	2.7	0.0
3 - 50	0.0063	0.32	100.0	85.1	51.2	43.1	43.1	7.9	5.2	0.0
50 - 80	0.0074	0.28	100.0	83.4	45.5	34.6	34.6	7.7	5.2	0.0
SOIL: HORNSVILLE (C)										
0 - 9	0.0116	0.20	100.0	90.0	67.2	29.0	28.0	3.3	2.0	0.0
9 - 43	0.0069	0.28	100.0	77.2	25.1	22.4	22.4	12.6	9.3	0.0
43 - 76	0.0266	0.24	100.0	80.2	34.8	16.6	16.6	6.4	4.6	0.0
SOIL: HYDE (B/D)										
0 - 17	0.0070	0.17	100.0	94.0	80.3	53.6	49.4	3.6	2.2	0.0
17 - 54	0.0054	0.43	100.0	90.6	69.0	61.1	59.6	8.2	5.2	0.0
SOIL: INVERSHIEL (C)										
0 - 6	0.0331	0.17	100.0	86.3	54.9	15.8	15.8	3.6	2.4	0.0
6 - 30	0.0062	0.32	100.0	79.5	32.5	29.1	29.1	11.6	8.3	0.0
SOIL: IREDELL (C/D)										
0 - 7	0.0068	0.32	100.0	84.6	49.5	39.4	39.4	7.5	4.9	0.0
7 - 24	0.0045	0.20	100.0	81.6	39.6	38.0	38.0	13.7	9.8	0.0
24 - 27	0.0071	0.28	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0
SOIL: IREDELLVA (C/D)										
0 - 8	0.0063	0.32	100.0	84.0	47.5	40.1	40.1	8.7	5.8	0.0
8 - 38	0.0045	0.20	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
38 - 42	0.0065	0.28	100.0	83.6	46.0	38.0	38.0	8.7	5.8	0.0
SOIL: IRVINGTON (C)										
0 - 6	0.0095	0.28	100.0	88.5	62.2	32.8	32.1	4.2	2.6	0.0
6 - 33	0.0071	0.28	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
33 - 61	0.0085	0.28	100.0	81.3	38.4	28.5	28.5	8.1	5.7	0.0
61 - 82	0.0079	0.24	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0
SOIL: IZAGORA (C)										
0 - 11	0.0066	0.37	100.0	92.5	75.3	54.0	50.7	4.7	2.9	0.0
11 - 46	0.0057	0.32	100.0	89.6	65.9	56.7	55.6	7.5	4.7	0.0
46 - 91	0.0047	0.32	100.0	85.0	50.8	47.8	47.4	12.7	8.8	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: JEDBURG (C)										
0 – 15	0.0079	0.32	100.0	90.1	67.6	41.7	39.8	4.4	2.7	0.0
15 - 75	0.0056	0.28	100.0	90.8	69.6	60.1	58.6	7.5	4.7	0.0
75 - 80	0.0063	0.28	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
SOIL: JOHNS (C)										
0 – 15	0.0140	0.20	100.0	89.7	66.3	25.1	24.5	3.1	1.9	0.0
15 - 32	0.0081	0.24	100.0	82.7	43.3	31.2	31.2	7.6	5.2	0.0
32 - 60	0.0453	0.10	100.0	91.8	73.2	10.1	10.1	1.8	1.2	0.0
SOIL: JOHNSTON (D)										
0 – 30	0.0076	0.17	100.0	91.8	73.1	45.3	42.5	3.9	2.4	0.0
30 - 34	0.0445	0.17	100.0	91.2	71.1	13.3	13.3	2.2	1.4	0.0
34 - 60	0.0120	0.17	100.0	87.9	60.3	26.8	26.6	3.9	2.4	0.0
SOIL: KALMIAWS (B)										
0 - 22	0.0209	0.15	100.0	90.8	69.8	20.0	19.5	2.5	1.6	0.0
22 - 34	0.0159	0.24	100.0	79.9	33.8	19.9	19.9	7.3	5.2	0.0
34 - 72	0.0453	0.10	100.0	91.8	73.2	10.1	10.1	1.8	1.2	0.0
SOIL: KEMPSVILLE (B)										
0 – 14	0.0083	0.32	100.0	91.6	72.5	41.4	38.9	3.6	2.2	0.0
14 - 20	0.0089	0.24	100.0	85.3	51.6	32.4	32.4	5.5	3.5	0.0
20 - 55	0.0074	0.24	100.0	83.4	45.3	34.3	34.3	7.7	5.2	0.0
55 - 68	0.0188	0.24	100.0	83.6	46.1	19.6	19.6	5.0	3.4	0.0
SOIL: KENANSVILLE (A)										
0 - 24	0.0445	0.15	100.0	91.7	72.6	13.3	13.3	2.0	1.3	0.0
24 - 36	0.0125	0.15	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
36 - 80	0.0446	0.10	100.0	92.7	75.9	12.8	12.6	1.7	1.1	0.0
SOIL: KENANSVILLEWS (A)										
0 – 23	0.0445	0.15	100.0	91.7	72.6	13.3	13.3	2.0	1.3	0.0
23 - 56	0.0178	0.15	100.0	87.6	59.4	20.8	20.8	3.5	2.2	0.0
56 - 72	0.0446	0.10	100.0	92.7	75.9	12.8	12.6	1.7	1.1	0.0
SOIL: KERSHAW (A)										
0 – 80	0.0466	0.10	100.0	95.3	84.4	1.8	1.8	0.8	0.6	0.0
SOIL: KIAWAH (B/D)										
0 – 15	0.0445	0.15	100.0	92.7	76.1	13.1	12.9	1.7	1.1	0.0
15 - 32	0.0442	0.10	100.0	86.9	56.9	14.5	14.5	3.3	2.2	0.0
32 - 48	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
48 - 72	0.0462	0.10	100.0	92.1	74.1	5.9	5.9	1.6	1.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			|---------------- Particle Sizes (mm) ----------------|							

SOIL: KIRKSEY (C)

0 - 6	0.0067	0.43	100.0	94.5	81.9	57.2	52.6	3.7	2.3	0.0
6 - 38	0.0053	0.43	100.0	91.2	71.0	62.8	61.1	8.2	5.2	0.0
38 - 45	0.0069	0.43	100.0	91.7	72.6	50.5	47.7	4.7	2.9	0.0

SOIL: LAKELAND (A)

0 – 43	0.0463	0.10	100.0	92.7	75.9	4.8	4.8	1.4	1.0	0.0
43 - 80	0.0463	0.10	100.0	94.6	82.4	3.9	3.9	1.0	0.7	0.0

SOIL: LAKELANDGR (A)

0 – 80	0.0458	0.05	100.0	95.5	85.1	6.3	6.2	0.9	0.6	0.0

SOIL: LEAF (D)

0 - 9	0.0069	0.28	100.0	90.8	69.7	48.8	46.6	5.0	3.1	0.0
9 - 72	0.0045	0.32	100.0	85.1	51.1	48.0	47.5	13.3	9.3	0.0

SOIL: LEAKSVILLE (D)

0 - 9	0.0064	0.43	100.0	89.0	63.9	49.3	48.1	6.2	3.9	0.0
9 - 18	0.0045	0.24	100.0	81.6	39.6	38.0	38.0	13.7	9.8	0.0
18 - 24	0.0061	0.24	100.0	86.0	53.9	46.1	46.1	7.6	4.9	0.0

SOIL: LENOIR (D)

0 - 8	0.0070	0.37	100.0	93.0	76.9	52.1	48.4	4.1	2.5	0.0
8 - 75	0.0047	0.32	100.0	82.3	41.7	39.8	39.8	13.1	9.3	0.0

SOIL: LEON (B/D)

0 - 3	0.0461	0.10	100.0	95.4	84.9	4.8	4.8	0.9	0.6	0.0
3 - 15	0.0458	0.10	100.0	97.6	92.2	5.0	4.8	0.5	0.3	0.0
15 - 30	0.0457	0.15	100.0	92.9	76.6	7.8	7.8	1.5	1.0	0.0
30 - 80	0.0459	0.10	100.0	96.1	87.3	5.2	5.2	0.8	0.5	0.0

SOIL: LEONFL (D)

0 - 3	0.0461	0.10	100.0	95.4	84.9	4.8	4.8	0.9	0.6	0.0
3 - 15	0.0451	0.10	100.0	97.6	92.2	5.0	4.8	0.5	0.3	0.0
15 - 23	0.0457	0.15	100.0	92.9	76.6	7.8	7.8	1.5	1.0	0.0
23 - 80	0.0459	0.10	100.0	96.1	87.3	5.2	5.2	0.8	0.5	0.0

SOIL: LEVY (D)

0 - 8	0.0044	0.32	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0
8 - 44	0.0044	0.32	100.0	87.3	58.2	53.3	52.0	13.3	9.3	0.0

SOIL: LIGNUM (C)

0 - 4	0.0065	0.37	100.0	91.0	70.5	52.5	50.2	5.5	3.4	0.0
4 - 37	0.0049	0.28	100.0	82.2	41.4	39.2	39.2	12.5	8.8	0.0
37 - 51	0.0097	0.28	100.0	80.2	35.0	25.3	25.3	8.3	5.8	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: LOCKHART (B)										
0 - 6	0.0448	0.15	100.0	88.0	60.4	12.6	12.6	2.9	1.9	0.0
6 - 54	0.0342	0.17	100.0	78.8	30.3	15.4	15.4	7.1	5.2	0.0
SOIL: LOUISA (B)										
0 - 4	0.0099	0.28	100.0	85.1	51.1	29.4	29.4	5.3	3.4	0.0
4 - 12	0.0220	0.24	100.0	82.3	41.7	18.1	18.1	5.4	3.8	0.0
12 - 18	0.0260	0.17	100.0	83.1	44.6	17.0	17.0	4.9	3.4	0.0
SOIL: LOUISBURG (B)										
0 - 7	0.0159	0.24	100.0	89.4	65.1	22.7	22.5	3.1	1.9	0.0
7 - 24	0.0157	0.24	100.0	87.1	57.5	22.2	22.2	3.8	2.4	0.0
SOIL: LOUISBURGGR (B)										
0 - 7	0.0207	0.24	100.0	88.7	62.7	19.4	19.4	3.1	1.9	0.0
7 - 24	0.0177	0.24	100.0	87.0	57.3	20.7	20.7	3.8	2.4	0.0
SOIL: LOUISBURGST (B)										
0 - 7	0.0448	0.10	100.0	89.3	65.0	12.2	12.2	2.5	1.7	0.0
7 - 24	0.0161	0.24	100.0	87.0	57.4	21.9	21.9	3.8	2.4	0.0
SOIL: LOYD (B)—use HIWASSEE (B)										
	N/A	N/A	100.0	89.5	54.6	53.4	53.2	9.3	6.0	0.0
SOIL: LUCY (A)										
0 – 24	0.0265	0.10	100.0	92.1	74.2	18.1	17.5	2.0	1.3	0.0
24 - 35	0.0230	0.24	100.0	81.9	40.7	17.7	17.7	5.6	3.9	0.0
35 - 70	0.0507	0.28	100.0	76.0	21.2	10.9	10.9	8.5	6.3	0.0
SOIL: LUGOFFGR (B)										
0 – 14	0.0456	0.10	100.0	91.7	72.8	8.6	8.6	1.8	1.2	0.0
14 - 34	0.0571	0.20	100.0	74.4	15.8	13.0	13.0	13.0	9.8	0.0
34 - 65	0.0047	0.24	100.0	80.5	35.8	34.0	34.0	13.6	9.8	0.0
SOIL: LUMBEE (B/D)										
0 – 14	0.0065	0.32	100.0	90.1	67.6	50.8	49.0	5.8	3.6	0.0
14 - 36	0.0080	0.32	100.0	82.8	43.5	31.5	31.5	7.6	5.2	0.0
36 - 60	0.0449	0.10	100.0	92.7	76.0	11.3	11.3	1.7	1.1	0.0
SOIL: LYNCHBURG (C)										
0 - 10	0.0100	0.20	100.0	89.1	64.3	31.5	31.0	4.0	2.4	0.0
10 - 62	0.0098	0.20	100.0	81.4	38.8	26.4	26.4	7.5	5.2	0.0
SOIL: LYNCHBURGFL (D)										
0 – 10	0.0098	0.20	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
10 - 62	0.0099	0.20	100.0	81.2	38.1	26.0	26.0	7.6	5.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			|---------------- Particle Sizes (mm) ----------------|							
SOIL: LYNNHAVEN (B/D)										
12 – 16	0.0457	0.10	100.0	97.7	92.3	5.7	5.4	0.5	0.3	0.0
16 - 30	0.0455	0.15	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
30 - 75	0.0459	0.10	100.0	96.1	87.3	5.2	5.2	0.8	0.5	0.0
SOIL: MADISON (B)										
0 - 6	0.0060	0.28	100.0	84.6	49.3	42.6	42.6	8.8	5.8	0.0
6 - 30	0.0053	0.32	100.0	83.1	44.4	41.4	41.4	11.3	7.8	0.0
30 - 35	0.0060	0.28	100.0	84.7	49.9	43.3	43.3	8.8	5.8	0.0
35 - 66	0.0098	0.37	100.0	89.3	65.0	32.3	31.8	4.0	2.4	0.0
SOIL: MADISONBS (B)										
0 - 4	0.0127	0.24	100.0	90.1	67.5	27.3	26.3	3.1	1.9	0.0
4 - 20	0.0052	0.28	100.0	82.4	42.2	39.5	39.5	11.9	8.3	0.0
SOIL: MALBIS (B)										
0 - 7	0.0083	0.28	100.0	86.3	55.1	35.1	34.9	5.4	3.4	0.0
7 - 26	0.0066	0.28	100.0	83.9	47.0	38.5	38.5	8.3	5.6	0.0
26 - 54	0.0063	0.28	100.0	84.7	49.8	41.8	41.8	8.2	5.4	0.0
54 - 72	0.0063	0.28	100.0	84.7	49.8	41.8	41.8	8.2	5.4	0.0
SOIL: MANDARIN (C)										
0 - 26	0.0460	0.15	100.0	96.8	89.6	4.4	4.4	0.6	0.4	0.0
26 - 40	0.0462	0.20	100.0	92.1	74.1	5.9	5.9	1.6	1.1	0.0
40 - 73	0.0462	0.15	100.0	96.8	89.5	3.0	3.0	0.6	0.4	0.0
73 - 80	0.0467	0.15	100.0	91.9	73.5	3.4	3.4	1.5	1.1	0.0
SOIL: MANTEO (C/D)										
0 - 6	0.0072	0.28	100.0	89.0	63.7	43.7	42.5	5.3	3.3	0.0
6 - 15	0.0204	0.28	100.0	81.0	37.4	18.4	18.4	6.2	4.4	0.0
SOIL: MARLBORO (B)										
0 - 9	0.0098	0.20	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
9 - 60	0.0058	0.20	100.0	77.4	25.8	23.5	23.5	13.3	9.8	0.0
60 - 72	0.0069	0.20	100.0	77.9	27.4	24.2	24.2	12.1	8.8	0.0
SOIL: MARLBOROVA (B)										
0 - 14	0.0456	0.10	100.0	91.7	72.8	8.6	8.6	1.8	1.2	0.0
14 - 34	0.0571	0.20	100.0	74.4	15.8	13.0	13.0	13.0	9.8	0.0
34 - 65	0.0047	0.24	100.0	80.5	35.8	34.0	34.0	13.6	9.8	0.0
SOIL: MARLBOROWS (B)										
0 - 9	0.0098	0.20	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
9 - 60	0.0058	0.20	100.0	77.4	25.8	23.5	23.5	13.3	9.8	0.0
60 - 72	0.0069	0.20	100.0	77.9	27.4	24.2	24.2	12.1	8.8	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: MASADA (C)										
0 – 10	0.0075	0.32	100.0	86.8	56.7	39.0	38.7	5.7	3.6	0.0
10 - 55	0.0057	0.24	100.0	81.1	38.0	34.7	34.7	11.4	8.0	0.0
55 - 72	0.0057	0.24	100.0	84.6	49.4	43.8	43.8	9.5	6.3	0.0
SOIL: MASADAGR (C)										
0 – 10	0.0103	0.24	100.0	80.8	37.0	25.1	25.1	7.7	5.4	0.0
10 - 55	0.0173	0.24	100.0	75.8	20.3	16.7	16.7	11.8	8.8	0.0
55 - 72	0.0093	0.24	100.0	79.0	30.9	24.1	24.1	9.5	6.8	0.0
SOIL: MAYODAN (B)										
0 – 12	0.0065	0.32	100.0	85.2	51.5	42.5	42.5	7.5	4.9	0.0
12 - 18	0.0054	0.32	100.0	87.3	58.3	52.8	52.6	9.1	5.8	0.0
18 - 47	0.0047	0.28	100.0	82.0	40.7	38.8	38.8	13.1	9.3	0.0
SOIL: McCOLL (D)										
0 - 9	0.0073	0.24	100.0	83.9	47.2	35.8	35.8	7.3	4.9	0.0
9 - 13	0.0081	0.24	100.0	76.6	23.2	20.4	20.4	12.6	9.3	0.0
13 - 42	0.0130	0.24	100.0	77.9	27.4	20.1	20.1	9.4	6.8	0.0
42 - 80	0.0160	0.32	100.0	79.5	32.6	19.6	19.6	7.5	5.4	0.0
SOIL: MECKLENBURG (C)										
0 - 8	0.0062	0.28	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
8 - 25	0.0043	0.28	100.0	84.5	49.2	46.5	46.0	13.9	9.8	0.0
25 - 36	0.0062	0.32	100.0	85.0	50.6	42.9	42.9	8.2	5.4	0.0
SOIL: MEGGETT (D)										
0 - 8	0.0064	0.28	100.0	89.0	63.9	49.3	48.1	6.2	3.9	0.0
8 - 16	0.0050	0.32	100.0	81.6	39.5	37.2	37.2	12.4	8.8	0.0
16 - 52	0.0049	0.32	100.0	81.0	37.4	35.3	35.3	13.0	9.3	0.0
52 - 65	0.0060	0.28	100.0	81.6	39.6	35.3	35.3	10.5	7.3	0.0
SOIL: MINTER (B)										
0 - 5	0.0058	0.37	100.0	90.8	69.9	58.2	56.4	6.9	4.3	0.0
5 - 72	0.0048	0.32	100.0	86.3	55.1	51.2	50.3	12.1	8.3	0.0
SOIL: MOLENA (A)										
0 - 7	0.0459	0.10	100.0	93.4	78.5	6.7	6.7	1.3	0.9	0.0
7 - 51	0.0453	0.17	100.0	90.2	67.8	10.4	10.4	2.2	1.5	0.0
51 - 60	0.0459	0.15	100.0	96.1	87.3	5.2	5.2	0.8	0.5	0.0
SOIL: MOLENAVA (B)										
0 - 6	0.0460	0.10	100.0	92.8	76.3	6.3	6.3	1.4	1.0	0.0
6 - 44	0.0450	0.17	100.0	87.5	58.8	12.2	12.2	3.0	2.0	0.0
44 - 64	0.0474	0.17	100.0	87.9	60.1	3.3	3.3	2.4	1.8	0.0

Depth	D15(mm)	K	|---- 1.4	1.0	0.063	Particle Sizes (mm) 0.044	0.038	0.004	0.003	----| 0.001
SOIL: MOUZON (D)										
0 – 11	0.0077	0.20	100.0	88.6	62.5	40.1	39.1	5.0	3.1	0.0
11 - 31	0.0074	0.20	100.0	83.4	45.3	34.3	34.3	7.7	5.2	0.0
31 - 46	0.0096	0.20	100.0	82.9	43.9	28.0	28.0	6.7	4.6	0.0
46 - 72	0.0353	0.15	100.0	85.8	53.4	15.4	15.4	3.7	2.5	0.0
SOIL: MULAT (D)										
0 – 10	0.0450	0.17	100.0	93.2	77.8	10.9	10.9	1.6	1.0	0.0
10 - 27	0.0450	0.17	100.0	93.2	77.8	10.9	10.9	1.6	1.0	0.0
27 - 49	0.0452	0.24	100.0	81.3	38.5	13.1	13.1	5.3	3.8	0.0
49 - 80	0.0466	0.17	100.0	92.6	75.6	3.3	3.3	1.4	1.0	0.0
SOIL: MURAD (B)										
0 – 49	0.0445	0.10	100.0	91.2	71.1	13.3	13.3	2.2	1.4	0.0
49 - 60	0.0123	0.20	100.0	84.7	49.6	25.0	25.0	5.1	3.4	0.0
60 - 80	0.0084	0.20	100.0	81.4	38.8	29.0	29.0	8.2	5.7	0.0
80 - 85	0.0331	0.17	100.0	86.3	54.9	15.8	15.8	3.6	2.4	0.0
SOIL: MUSELLAGR (B)										
0 - 4	0.0076	0.32	100.0	83.6	46.2	34.2	34.2	7.3	4.9	0.0
4 - 14	0.0076	0.32	100.0	81.3	38.7	30.6	30.6	8.7	6.0	0.0
14 - 18	0.0203	0.28	100.0	78.1	27.9	17.6	17.6	8.3	6.0	0.0
SOIL: MUSELLAST (B)										
0 - 4	0.0181	0.20	100.0	80.1	34.8	19.0	19.0	6.9	4.9	0.0
4 - 14	0.0076	0.32	100.0	81.3	38.7	30.6	30.6	8.7	6.0	0.0
14 - 18	0.0203	0.28	100.0	78.1	27.9	17.6	17.6	8.3	6.0	0.0
SOIL: MULLERS (Z)										
0 - 2	0.0051	0.32	100.0	88.9	63.5	57.5	56.2	10.0	6.6	0.0
2 - 16	0.0054	0.37	100.0	90.1	67.3	59.8	58.4	8.4	5.4	0.0
16 - 64	0.0041	0.37	100.0	85.1	51.1	48.6	48.1	14.6	10.2	0.0
SOIL: MYATT (D)										
0 – 10	0.0064	0.32	100.0	91.5	72.0	54.3	51.7	5.5	3.4	0.0
10 - 50	0.0067	0.28	100.0	84.3	48.5	39.2	39.2	7.8	5.2	0.0
50 - 72	0.0088	0.24	100.0	85.1	51.1	32.4	32.4	5.6	3.6	0.0
SOIL: NAHUNTAVA (B)										
0 - 7	0.0077	0.20	100.0	94.1	80.7	48.5	44.4	3.0	1.9	0.0
7 - 20	0.0066	0.20	100.0	90.0	67.0	49.4	47.6	5.6	3.5	0.0
20 - 55	0.0053	0.20	100.0	90.5	68.8	61.5	60.8	8.3	5.2	0.0
SOIL: NAKINA (B/D)										
0 – 14	0.0100	0.20	100.0	89.1	64.3	31.5	31.0	4.0	2.4	0.0
14 - 49	0.0245	0.28	100.0	79.2	31.5	16.9	16.9	7.2	5.2	0.0

|---------------- Particle Sizes (mm) ----------------|

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: NANKIN (C)										
0 - 8	0.0087	0.32	100.0	82.8	43.6	29.9	29.9	7.2	4.9	0.0
8 - 13	0.0268	0.24	100.0	79.6	32.9	16.5	16.5	6.8	4.9	0.0
13 - 38	0.0078	0.24	100.0	77.9	27.4	23.5	23.5	11.4	8.3	0.0
38 - 65	0.0139	0.24	100.0	80.7	36.6	21.5	21.5	6.9	4.9	0.0
SOIL: NANSEMOND (C)										
0 - 8	0.0116	0.20	100.0	90.0	67.2	29.0	28.0	3.3	2.0	0.0
8 - 29	0.0114	0.17	100.0	86.7	56.5	27.4	27.3	4.3	2.7	0.0
29 - 66	0.0163	0.15	100.0	91.3	71.5	23.5	22.5	2.5	1.6	0.0
66 - 70	0.0219	0.15	100.0	91.8	73.1	19.9	19.2	2.2	1.4	0.0
SOIL: NASON (C)										
0 - 9	0.0052	0.49	100.0	87.3	58.3	54.0	53.8	10.0	6.5	0.0
9 - 38	0.0049	0.28	100.0	84.2	48.2	45.9	45.8	12.1	8.3	0.0
38 - 50	0.0087	0.28	100.0	85.9	53.5	33.5	33.4	5.4	3.4	0.0
SOIL: NASONGR (B)										
0 - 9	0.0063	0.24	100.0	83.4	45.5	38.3	38.3	9.1	6.1	0.0
9 - 38	0.0050	0.32	100.0	84.8	49.9	47.1	47.0	11.6	7.9	0.0
38 - 50	0.0083	0.24	100.0	83.9	47.2	32.5	32.5	6.6	4.4	0.0
SOIL: NEESES (C)										
0 - 8	0.0246	0.24	100.0	88.6	62.7	17.9	17.9	3.0	1.9	0.0
8 - 28	0.0065	0.28	100.0	79.0	31.1	27.6	27.6	11.5	8.3	0.0
28 - 54	0.0069	0.28	100.0	80.1	34.7	29.8	29.8	10.3	7.3	0.0
54 - 85	0.0139	0.24	100.0	80.7	36.6	21.5	21.5	6.9	4.9	0.0
SOIL: NEMOURS (C)										
0 - 9	0.0114	0.20	100.0	86.7	56.5	27.4	27.3	4.3	2.7	0.0
9 - 44	0.0039	0.28	100.0	80.6	36.2	35.0	35.0	15.5	11.2	0.0
44 - 55	0.0073	0.28	100.0	83.2	44.7	34.4	34.4	7.9	5.4	0.0
55 - 80	0.0120	0.28	100.0	84.0	47.5	25.0	25.0	5.5	3.7	0.0
SOIL: NOBOCO (B)										
0 – 13	0.0347	0.15	100.0	87.0	57.4	15.5	15.5	3.4	2.2	0.0
13 - 47	0.0096	0.24	100.0	81.5	39.2	26.9	26.9	7.5	5.2	0.0
47 - 72	0.0075	0.24	100.0	81.3	38.5	30.7	30.7	8.8	6.1	0.0
SOIL: NORFOLKHS (B)										
0 – 18	0.0395	0.10	100.0	93.6	78.8	15.6	14.8	1.6	1.0	0.0
18 - 44	0.0121	0.20	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0
SOIL: OCHLOCKONEE (B)										
0 - 6	0.0069	0.24	100.0	91.9	73.4	50.5	47.5	4.5	2.8	0.0
6 - 44	0.0082	0.20	100.0	90.4	68.5	40.2	38.2	4.1	2.5	0.0
44 - 72	0.0101	0.17	100.0	90.8	69.9	33.6	31.9	3.3	2.0	0.0

|---------------- Particle Sizes (mm) ----------------|

Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: OCILLA (C)										
0 – 28	0.0346	0.10	100.0	91.3	71.3	15.8	15.6	2.2	1.4	0.0
28 – 59	0.0181	0.24	100.0	80.1	34.8	19.0	19.0	6.9	4.9	0.0
59 - 67	0.0091	0.24	100.0	81.4	38.9	27.6	27.6	7.7	5.4	0.0
SOIL: OCILLAFL (D)										
0 – 28	0.0346	0.10	100.0	91.3	71.3	15.8	15.6	2.2	1.4	0.0
28 - 59	0.0181	0.24	100.0	80.1	34.8	19.0	19.0	6.9	4.9	0.0
59 - 67	0.0091	0.24	100.0	81.4	38.9	27.6	27.6	7.7	5.4	0.0
SOIL: OCILLAVA (C)										
0 – 24	0.0346	0.15	100.0	91.3	71.3	15.8	15.6	2.2	1.4	0.0
24 - 52	0.0115	0.17	100.0	81.3	38.5	24.0	24.0	7.0	4.9	0.0
52 - 65	0.0045	0.32	100.0	79.6	32.8	31.1	31.1	14.2	10.2	0.0
SOIL: OGEECHEE (B/D)										
0 - 8	0.0349	0.10	100.0	90.7	69.4	15.5	15.5	2.3	1.5	0.0
8 - 23	0.0093	0.15	100.0	81.3	38.5	27.1	27.1	7.7	5.4	0.0
23 - 42	0.0078	0.15	100.0	79.2	31.6	26.3	26.3	10.2	7.3	0.0
42 - 60	0.0204	0.15	100.0	81.0	37.4	18.4	18.4	6.2	4.4	0.0
SOIL: OGEECHEEPO (B/D)										
0 - 8	0.0281	0.10	100.0	90.9	70.2	17.2	17.0	2.3	1.5	0.0
8 - 23	0.0106	0.15	100.0	80.7	36.6	24.6	24.6	7.7	5.4	0.0
23 - 42	0.0078	0.15	100.0	79.2	31.6	26.3	26.3	10.2	7.3	0.0
42 - 60	0.0204	0.15	100.0	81.0	37.4	18.4	18.4	6.2	4.4	0.0
SOIL: OKEETEE (D)										
0 - 7	0.0091	0.24	100.0	89.8	66.4	35.5	34.2	3.9	2.4	0.0
7 - 50	0.0049	0.32	100.0	81.0	37.4	35.3	35.3	13.0	9.3	0.0
50 - 78	0.0055	0.24	100.0	84.6	49.4	44.7	44.7	10.1	6.8	0.0
SOIL: OLANTA (B)										
0 – 11	0.0450	0.10	100.0	93.1	77.4	11.0	10.9	1.6	1.0	0.0
11 - 42	0.0442	0.10	100.0	85.0	50.6	14.6	14.6	4.0	2.7	0.0
42 - 75	0.0466	0.10	100.0	90.2	67.9	4.8	4.8	1.9	1.4	0.0
SOIL: OLUSTEE (B/D)										
0 - 8	0.0459	0.20	100.0	93.4	78.5	6.7	6.7	1.3	0.9	0.0
8 - 21	0.0457	0.20	100.0	92.9	76.6	7.8	7.8	1.5	1.0	0.0
21 - 35	0.0460	0.20	100.0	92.8	76.3	6.3	6.3	1.4	1.0	0.0
35 - 62	0.0207	0.32	100.0	79.4	32.3	17.9	17.9	7.2	5.2	0.0
62 - 74	0.0109	0.28	100.0	77.3	25.3	20.4	20.4	10.7	7.8	0.0
SOIL: ONSLOW (B)										
0 – 17	0.0111	0.20	100.0	90.7	69.5	30.7	29.3	3.1	1.9	0.0
17 - 53	0.0115	0.24	100.0	81.3	38.5	24.0	24.0	7.0	4.9	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: ORANGE (D)										
0 – 10	0.0067	0.28	100.0	89.2	64.4	47.3	46.0	5.8	3.6	0.0
10 - 28	0.0051	0.28	100.0	80.1	34.6	32.3	32.3	12.9	9.3	0.0
28 - 42	0.0071	0.28	100.0	85.0	50.7	38.9	38.9	6.8	4.4	0.0
SOIL: ORANGEST (D)										
0 – 10	0.0067	0.24	100.0	89.2	64.4	47.3	46.0	5.8	3.6	0.0
10 - 28	0.0046	0.24	100.0	83.0	44.0	42.4	42.4	13.2	9.3	0.0
28 - 42	0.0065	0.24	100.0	86.5	55.6	44.6	44.4	6.9	4.4	0.0
SOIL: ORANGEBURG (B)										
0 - 7	0.0112	0.24	100.0	81.8	40.2	24.7	24.7	6.8	4.7	0.0
7 - 12	0.0177	0.20	100.0	87.0	57.3	20.7	20.7	3.8	2.4	0.0
12 - 54	0.0080	0.24	100.0	82.8	43.5	31.5	31.5	7.6	5.2	0.0
54 - 64	0.0080	0.24	100.0	80.5	36.0	28.4	28.4	9.0	6.3	0.0
SOIL: ORANGEBURGOW (B)										
0 – 14	0.0074	0.24	100.0	88.5	62.2	42.0	41.0	5.3	3.3	0.0
14 - 54	0.0080	0.24	100.0	82.8	43.5	31.5	31.5	7.6	5.2	0.0
54 - 64	0.0080	0.24	100.0	80.5	36.0	28.4	28.4	9.0	6.3	0.0
SOIL: ORTEGA (A)										
0 - 5	0.0461	0.15	100.0	96.8	89.6	4.0	4.0	0.6	0.4	0.0
5 - 82	0.0462	0.15	100.0	96.8	89.5	3.0	3.0	0.6	0.4	0.0
SOIL: OSIER (A/D)										
0 - 8	0.0460	0.15	100.0	85.4	52.0	9.8	9.8	3.4	2.4	0.0
8 - 48	0.0456	0.10	100.0	92.3	74.7	8.4	8.4	1.6	1.1	0.0
48 - 75	0.0464	0.05	100.0	94.6	82.3	3.4	3.4	1.0	0.7	0.0
SOIL: OSIERFL (D)										
0 - 8	0.0460	0.15	100.0	85.4	52.0	9.8	9.8	3.4	2.4	0.0
8 - 48	0.0456	0.10	100.0	92.3	74.7	8.4	8.4	1.6	1.1	0.0
48 - 75	0.0464	0.05	100.0	94.6	82.3	3.4	3.4	1.0	0.7	0.0
SOIL: OSIERPO (A/D)										
0 - 8	0.0460	0.15	100.0	85.4	52.0	9.8	9.8	3.4	2.4	0.0
8 - 48	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
48 - 75	0.0464	0.05	100.0	94.6	82.3	3.4	3.4	1.0	0.7	0.0
SOIL: PACOLET (B)										
0 - 3	0.0121	0.24	100.0	80.2	35.0	22.6	22.6	7.6	5.4	0.0
3 - 29	0.0053	0.28	100.0	78.1	28.2	26.0	26.0	13.4	9.8	0.0
29 - 52	0.0092	0.28	100.0	83.4	45.6	29.4	29.4	6.5	4.4	0.0
52 - 70	0.0113	0.28	100.0	84.7	49.6	25.0	25.0	5.1	3.4	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: PACOLETGR (B)										
0 - 3	0.0143	0.20	100.0	78.7	30.0	20.1	20.1	8.4	6.0	0.0
3 - 29	0.0053	0.28	100.0	78.1	28.2	26.0	26.0	13.4	9.8	0.0
29 - 52	0.0092	0.28	100.0	83.4	45.6	29.4	29.4	6.5	4.4	0.0
52 - 70	0.0113	0.28	100.0	84.8	50.1	26.4	26.4	5.2	3.4	0.0
SOIL: PACTOLUS (A)										
0 – 40	0.0444	0.10	100.0	91.2	71.0	13.6	13.6	2.2	1.4	0.0
40 - 80	0.0445	0.10	100.0	91.2	71.1	13.3	13.3	2.2	1.4	0.0
SOIL: PAGELAND (C)										
0 - 7	0.0065	0.43	100.0	93.7	79.3	57.4	53.3	4.4	2.7	0.0
7 - 26	0.0053	0.43	100.0	91.2	71.0	62.8	61.1	8.2	5.2	0.0
26 - 33	0.0051	0.37	100.0	91.0	70.3	62.9	60.9	9.4	6.1	0.0
SOIL: PALEAQUULTS (Z)										
0 – 35	0.0080	0.17	100.0	87.3	58.3	37.5	37.1	5.3	3.3	0.0
35 - 60	0.0070	0.24	100.0	83.9	47.0	36.9	36.9	7.8	5.2	0.0
SOIL: PAMLICO (D)										
0 – 30	Data Not Available									
30 – 60	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
SOIL: PAMLICOFL (D)										
0 - 30	Data Not Available									
30 - 60	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
SOIL: PAMLICOLS (D)										
0 – 24	Data Not Available									
24 – 48	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
SOIL: PAMLICOPO (D)										
0 - 30	Data Not Available									
30 – 60	0.0462	0.10	100.0	89.9	66.7	7.0	7.0	2.1	1.5	0.0
SOIL: PANTEGO (B/D)										
0 – 18	0.0096	0.10	100.0	91.6	72.5	36.0	33.8	3.1	1.9	0.0
18 - 42	0.0071	0.28	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
42 - 65	0.0065	0.28	100.0	83.6	46.2	38.4	38.4	8.7	5.8	0.0
SOIL: PANTEGOPO (D)										
0 - 5	0.0096	0.20	100.0	91.6	72.5	36.0	33.8	3.1	1.9	0.0
5 - 32	0.0071	0.28	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
32 - 64	0.0065	0.28	100.0	83.6	46.2	38.4	38.4	8.7	5.8	0.0

|---------------- Particle Sizes (mm) ----------------|

SOIL: PAXVILLE (B/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 15	0.0100	0.20	100.0	85.5	52.4	29.4	29.4	5.0	3.2	0.0
15 - 40	0.0094	0.15	100.0	83.7	46.5	29.4	29.4	6.3	4.2	0.0
40 - 48	0.0458	0.10	100.0	85.1	51.0	10.4	10.4	3.6	2.5	0.0
48 - 99	0.0454	0.10	100.0	90.7	69.4	9.8	9.8	2.1	1.4	0.0

SOIL: PELHAM (B/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 27		0.10	100.0	91.2	71.0	17.7	17.5	2.4	1.5	0.0
0 - 27		0.10	100.0	93.9	80.0	12.7	12.2	1.4	0.9	0.0
0 - 27		0.10	100.0	93.7	79.3	10.3	10.1	1.4	0.9	0.0
27 - 56		0.24	100.0	81.7	39.9	21.8	21.8	6.3	4.4	0.0
56 - 68		0.24	100.0	80.9	37.4	25.6	25.6	7.7	5.4	0.0

SOIL: PELHAMFL (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 27	0.0260	0.10	100.0	91.2	71.0	17.7	17.5	2.4	1.5	0.0
27 - 56	0.0141	0.24	100.0	81.7	39.9	21.8	21.8	6.3	4.4	0.0
56 - 68	0.0100	0.24	100.0	80.9	37.4	25.6	25.6	7.7	5.4	0.0

SOIL: PELHAMPO (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 27	0.0260	0.10	100.0	91.2	71.0	17.7	17.5	2.4	1.5	0.0
27 - 56	0.0141	0.24	100.0	81.7	39.9	21.8	21.8	6.3	4.4	0.0
56 - 68	0.0100	0.24	100.0	80.9	37.4	25.6	25.6	7.7	5.4	0.0

SOIL: PELION (B/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 10	0.0221	0.24	100.0	88.7	62.7	18.8	18.8	3.1	1.9	0.0
10 - 22	0.0151	0.17	100.0	80.0	34.2	20.4	20.4	7.3	5.2	0.0
22 - 39	0.0201	0.20	100.0	77.4	25.6	17.3	17.3	9.1	6.6	0.0
39 - 65	0.0153	0.15	100.0	80.5	35.9	20.5	20.5	6.9	4.9	0.0

SOIL: PENDER (C)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 13	0.0331	0.17	100.0	86.3	54.9	15.8	15.8	3.6	2.4	0.0
13 - 54	0.0121	0.24	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0

SOIL: PERSANTI (C)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 6	0.0079	0.28	100.0	89.2	64.4	40.0	38.7	4.7	2.9	0.0
6 - 60	0.0040	0.20	100.0	82.0	41.0	39.8	39.8	15.0	10.7	0.0
60 - 72	0.0048	0.20	100.0	82.9	43.8	41.7	41.7	12.6	8.8	0.0

SOIL: PICKNEY (A/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 34	0.0441	0.10	100.0	92.3	74.6	14.6	14.3	1.9	1.2	0.0
34 - 80	0.0452	0.10	100.0	92.4	75.1	9.9	9.9	1.7	1.1	0.0

SOIL: PICKNEYFL (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 34	0.0443	0.10	100.0	92.4	74.9	13.8	13.8	1.9	1.2	0.0
34 - 80	0.0452	0.10	100.0	92.4	75.1	9.9	9.9	1.7	1.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							

SOIL: PINKSTON (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 8	0.0080	0.37	100.0	92.0	73.6	43.2	40.4	3.6	2.2	0.0
8 - 19	0.0090	0.24	100.0	88.6	62.4	34.7	33.8	4.4	2.7	0.0
19 - 26	0.0138	0.24	100.0	85.7	53.1	23.6	23.6	4.5	2.9	0.0

SOIL: PINKSTONGR (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 8	0.0444	0.10	100.0	86.8	56.7	14.0	14.0	3.3	2.2	0.0
8 - 19	0.0090	0.24	100.0	88.6	62.4	34.7	33.8	4.4	2.7	0.0
19 - 26	0.0138	0.24	100.0	85.7	53.1	23.6	23.6	4.5	2.9	0.0

SOIL: PLUMMER (B/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 50	0.0442	0.10	100.0	92.8	76.4	14.2	13.8	1.7	1.1	0.0
50 - 72	0.0237	0.15	100.0	80.7	36.7	17.4	17.4	6.2	4.4	0.0

SOIL: PLUMMERPO (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 8	0.0442	0.10	100.0	92.8	76.4	14.2	13.8	1.7	1.1	0.0
8 - 50	0.0448	0.10	100.0	94.4	81.7	11.3	10.8	1.2	0.8	0.0
50 - 72	0.0237	0.15	100.0	80.7	36.7	17.4	17.4	6.2	4.4	0.0

SOIL: POCALLA (A)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 23	0.0442	0.10	100.0	91.2	71.0	14.2	14.2	2.2	1.4	0.0
23 - 36	0.0469	0.10	100.0	81.8	40.0	9.6	9.6	4.7	3.4	0.0
36 - 46	0.0457	0.10	100.0	91.7	72.7	8.1	8.1	1.7	1.2	0.0
46 - 72	0.0135	0.15	100.0	81.8	40.3	22.4	22.4	6.3	4.4	0.0

SOIL: POCOMOKE (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 28	0.0141	0.28	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
28 - 40	0.0463	0.20	100.0	86.1	54.2	8.5	8.5	3.1	2.2	0.0
40 - 60	0.0282	0.28	100.0	83.0	44.3	16.5	16.5	4.9	3.4	0.0

SOIL: POCOMOKEDR (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 10	0.0141	0.20	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
10 - 28	0.0125	0.20	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
28 - 40	0.0449	0.10	100.0	90.3	68.3	11.9	11.9	2.2	1.5	0.0
40 - 60	0.0282	0.20	100.0	83.0	44.3	16.5	16.5	4.9	3.4	0.0

SOIL: POCOMOKEPO (B/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 10	0.0141	0.20	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
10 - 28	0.0125	0.20	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
28 - 40	0.0449	0.10	100.0	90.3	68.3	11.9	11.9	2.2	1.5	0.0
40 - 60	0.0282	0.20	100.0	83.0	44.3	16.5	16.5	4.9	3.4	0.0

SOIL: POINDEXTER (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 14	0.0062	0.24	100.0	83.8	46.9	39.9	39.9	9.0	6.0	0.0
14 - 20	0.0066	0.24	100.0	84.2	48.1	39.4	39.4	8.1	5.4	0.0
20 - 26	0.0083	0.24	100.0	83.9	47.2	32.5	32.5	6.6	4.4	0.0

Depth	D15(mm)	K	Particle Sizes (mm) 1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: POLAWANA (A/D)										
0 – 30	0.0315	0.10	100.0	91.4	71.6	16.5	16.2	2.2	1.4	0.0
30 - 80	0.0460	0.10	100.0	90.5	68.6	7.3	7.3	2.0	1.4	0.0
SOIL: PONZER (D)										
24 – 52	0.0073	0.24	100.0	90.4	68.5	45.3	43.2	4.7	2.9	0.0
SOIL: PORTERS (B)										
0 - 7	0.0073	0.28	100.0	88.3	61.6	42.3	41.5	5.5	3.4	0.0
7 - 42	0.0088	0.24	100.0	89.3	64.7	36.4	35.1	4.2	2.6	0.0
SOIL: PORTERSST (B)										
0 - 7	0.0107	0.17	100.0	86.3	54.8	28.5	28.5	4.6	2.9	0.0
7 - 42	0.0090	0.24	100.0	89.9	66.9	36.3	34.8	3.9	2.4	0.0
SOIL: PORTSMOUTH (B/D)										
0 – 19	0.0057	0.32	100.0	89.7	66.0	56.3	55.6	7.4	4.6	0.0
19 - 35	0.0072	0.28	100.0	83.3	45.0	34.8	34.8	8.0	5.4	0.0
35 - 38	0.0443	0.17	100.0	85.7	52.9	14.4	14.4	3.7	2.5	0.0
38 - 72	0.0454	0.17	100.0	91.8	73.1	9.6	9.6	1.8	1.2	0.0
SOIL: PUNGO (D)										
0 – 72	Data Not Available									
72 – 84	0.0049	0.24	100.0	80.8	36.9	34.8	34.8	13.0	9.3	0.0
SOIL: PUNGOPO (D)										
0 – 72	Data Not Available									
72 – 84	0.0049	0.24	100.0	80.8	36.9	34.8	34.8	13.0	9.3	0.0
SOIL: QUARTZIPSAMMENTS (Z)										
0 – 60	0.0461	0.10	100.0	89.9	66.8	7.4	7.4	2.1	1.5	0.0
SOIL: QUITMAN (C)										
0 – 11	0.0111	0.28	100.0	90.7	69.5	30.7	29.3	3.1	1.9	0.0
11 - 18	0.0071	0.28	100.0	83.7	46.3	35.9	35.9	7.7	5.2	0.0
18 - 65	0.0074	0.28	100.0	83.4	45.3	34.3	34.3	7.7	5.2	0.0
SOIL: RABUN (B)										
0 - 9	0.0069	0.32	100.0	84.0	47.4	37.6	37.6	7.8	5.2	0.0
9 - 37	0.0039	0.28	100.0	79.1	31.3	30.0	30.0	15.4	11.2	0.0
37 - 48	0.0055	0.28	100.0	82.7	43.1	39.5	39.5	10.9	7.5	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: RABUNSE (B)										
0 - 4	0.0053	0.32	100.0	83.0	44.0	40.9	40.9	11.3	7.8	0.0
4 - 28	0.0039	0.28	100.0	79.1	31.3	30.0	30.0	15.4	11.2	0.0
28 - 39	0.0055	0.28	100.0	82.7	43.1	39.5	39.5	10.9	7.5	0.0
SOIL: RABUNST (B)										
0 - 9	0.0093	0.20	100.0	81.3	38.5	27.1	27.1	7.7	5.4	0.0
9 - 37	0.0039	0.28	100.0	78.5	29.4	27.9	27.9	15.3	11.2	0.0
37 - 48	0.0057	0.28	100.0	82.0	40.9	37.0	37.0	10.8	7.5	0.0
SOIL: RAINSFL (D)										
0 – 12	0.0078	0.28	100.0	88.9	63.4	40.0	38.9	4.8	3.0	0.0
12 - 40	0.0077	0.24	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
40 - 62	0.0069	0.28	100.0	83.2	44.7	35.6	35.6	8.4	5.7	0.0
62 - 79	0.0114	0.28	100.0	79.6	33.0	22.8	22.8	8.2	5.8	0.0
SOIL: REDBAY (B)										
0 - 6	0.0176	0.20	100.0	86.4	55.2	20.7	20.7	4.0	2.6	0.0
6 - 20	0.0188	0.15	100.0	83.6	46.1	19.6	19.6	5.0	3.4	0.0
20 - 52	0.0224	0.17	100.0	79.3	31.9	17.4	17.4	7.2	5.2	0.0
52 - 72	0.0080	0.24	100.0	80.5	36.0	28.4	28.4	9.0	6.3	0.0
SOIL: REMBERT (D)										
0 - 5	0.0064	0.24	100.0	86.8	56.6	45.6	45.3	7.0	4.4	0.0
5 - 33	0.0049	0.20	100.0	80.8	36.9	34.8	34.8	13.0	9.3	0.0
33 - 54	0.0133	0.17	100.0	78.2	28.4	20.2	20.2	9.0	6.5	0.0
54 - 65	0.0136	0.17	100.0	85.0	50.6	23.5	23.5	4.8	3.2	0.0
SOIL: RESOTA (A)										
0 – 80	0.0467	0.02	100.0	96.7	89.3	0.5	0.5	0.5	0.4	0.0
SOIL: RIDGELAND (B/D)										
0 - 8	0.0455	0.10	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
8 - 15	0.0459	0.15	100.0	92.8	76.4	6.8	6.8	1.5	1.0	0.0
15 - 35	0.0463	0.15	100.0	92.7	75.9	4.8	4.8	1.4	1.0	0.0
35 - 80	0.0463	0.15	100.0	92.7	75.9	4.8	4.8	1.4	1.0	0.0
SOIL: RIMINI (A)										
0 - 58	0.0463	0.10	100.0	97.6	92.0	2.4	2.4	0.4	0.3	0.0
58 - 70	0.0462	0.10	100.0	95.4	84.8	4.3	4.3	0.9	0.6	0.0
70 - 80	0.0463	0.10	100.0	97.6	92.0	2.4	2.4	0.4	0.3	0.0
SOIL: RION (B)										
0 - 7	0.0120	0.24	100.0	87.9	60.3	26.8	26.6	3.9	2.4	0.0
7 - 38	0.0103	0.20	100.0	81.2	38.1	25.4	25.4	7.4	5.2	0.0
38 - 60	0.0144	0.20	100.0	88.6	62.6	23.9	23.7	3.4	2.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: RIONGR (B)										
0 - 7	0.0447	0.20	100.0	85.9	53.7	13.3	13.3	3.5	2.4	0.0
7 - 38	0.0462	0.17	100.0	78.2	28.4	12.9	12.9	7.1	5.2	0.0
38 - 60	0.0206	0.17	100.0	87.9	60.4	19.3	19.3	3.3	2.1	0.0
SOIL: RIONVB (B)										
0 - 7	0.0100	0.24	100.0	89.1	64.3	31.5	31.0	4.0	2.4	0.0
7 - 38	0.0101	0.20	100.0	81.6	39.6	26.1	26.1	7.2	5.0	0.0
38 - 60	0.0144	0.20	100.0	88.6	62.6	23.9	23.7	3.4	2.1	0.0
SOIL: RIVERVIEW (B)										
0 - 6	0.0065	0.32	100.0	90.1	67.6	50.8	49.0	5.8	3.6	0.0
6 - 39	0.0053	0.24	100.0	90.5	68.8	61.5	60.8	8.3	5.2	0.0
39 - 70	0.0179	0.17	100.0	88.0	60.5	20.9	20.9	3.4	2.1	0.0
SOIL: ROANOKEPO (D)										
0 - 7	0.0052	0.37	100.0	90.0	67.0	60.0	58.5	9.3	6.0	0.0
7 - 50	0.0045	0.24	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
50 - 72	0.0073	0.24	100.0	83.2	44.7	34.4	34.4	7.9	5.4	0.0
SOIL: ROSEDHU (B/D)										
0 – 11	0.0460	0.10	100.0	94.7	82.6	5.4	5.4	1.0	0.7	0.0
11 - 25	0.0462	0.10	100.0	93.4	78.2	5.2	5.2	1.3	0.9	0.0
25 - 53	0.0462	0.10	100.0	94.7	82.5	4.4	4.4	1.0	0.7	0.0
53 - 70	0.0462	0.10	100.0	93.4	78.2	5.2	5.2	1.3	0.9	0.0
70 - 80	0.0462	0.10	100.0	94.7	82.5	4.4	4.4	1.0	0.7	0.0
SOIL: RUTLEGE (B/D)										
0 – 18	0.0441	0.17	100.0	92.3	74.6	14.6	14.3	1.9	1.2	0.0
18 - 60	0.0455	0.17	100.0	91.8	72.9	9.1	9.1	1.8	1.2	0.0
SOIL: RUTLEGEPO (B/D)										
0 – 18	0.0441	0.17	100.0	92.3	74.6	14.6	14.3	1.9	1.2	0.0
18 - 60	0.0455	0.17	100.0	91.8	72.9	9.1	9.1	1.8	1.2	0.0
SOIL: SALUDA (C)										
0 - 5	0.0141	0.20	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
5 - 16	0.0151	0.20	100.0	80.0	34.2	20.4	20.4	7.3	5.2	0.0
SOIL: SANTEE (D)										
0 - 6	0.0065	0.28	100.0	85.5	52.2	42.8	42.8	7.3	4.7	0.0
6 - 48	0.0045	0.32	100.0	85.1	51.1	48.0	47.5	13.3	9.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							

SOIL: SANTUC (Z)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 3	0.0206	0.24	100.0	87.6	59.2	19.3	19.3	3.5	2.2	0.0
3 - 9	0.0207	0.24	100.0	88.7	62.7	19.4	19.4	3.1	1.9	0.0
9 - 26	0.0087	0.28	100.0	83.7	46.4	30.9	30.9	6.6	4.4	0.0
26 - 41	0.0073	0.28	100.0	81.2	38.1	30.9	30.9	9.1	6.3	0.0
41 - 60	0.0088	0.28	100.0	85.1	51.1	32.4	32.4	5.6	3.6	0.0

SOIL: SAPELO (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 17	0.0453	0.17	100.0	94.9	83.3	8.8	8.5	1.1	0.7	0.0
17 - 25	0.0452	0.15	100.0	92.4	75.1	9.9	9.9	1.7	1.1	0.0
25 - 49	0.0460	0.17	100.0	93.4	78.4	6.2	6.2	1.3	0.9	0.0
49 - 84	0.0204	0.24	100.0	81.0	37.4	18.4	18.4	6.2	4.4	0.0

SOIL: SATILLA (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 5	0.0053	0.24	100.0	89.5	65.4	58.5	57.3	9.0	5.8	0.0
5 - 24	0.0056	0.24	100.0	88.5	62.1	54.9	54.5	8.2	5.2	0.0

SOIL: SCRANTON (A/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 7	0.0194	0.15	100.0	90.6	69.0	20.5	20.2	2.7	1.7	0.0
7 - 41	0.0455	0.10	100.0	90.1	67.5	9.5	9.5	2.2	1.5	0.0
41 - 72	0.0467	0.10	100.0	91.3	71.5	3.6	3.6	1.6	1.2	0.0

SOIL: SEABROOK (C)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 8	0.0454	0.10	100.0	90.7	69.4	9.8	9.8	2.1	1.4	0.0
8 - 81	0.0454	0.10	100.0	90.7	69.4	9.8	9.8	2.1	1.4	0.0

SOIL: SEAGATE (A/D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 12	0.0452	0.10	100.0	97.8	92.6	8.9	8.1	0.5	0.3	0.0
12 - 28	0.0445	0.15	100.0	91.7	72.6	13.3	13.3	2.0	1.3	0.0
28 - 36	0.0452	0.10	100.0	95.6	85.6	9.1	8.6	0.9	0.6	0.0
36 - 40	0.0312	0.28	100.0	80.4	35.6	15.8	15.8	6.1	4.4	0.0
40 - 64	0.0054	0.32	100.0	88.0	60.6	54.9	54.6	9.1	5.8	0.0

SOIL: SEEWEE (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 – 21	0.0452	0.10	100.0	93.8	79.7	9.9	9.9	1.4	0.9	0.0
21 - 30	0.0459	0.10	100.0	94.7	82.7	5.9	5.9	1.1	0.7	0.0
30 - 65	0.0460	0.10	100.0	94.7	82.6	5.4	5.4	1.0	0.7	0.0

SOIL: SHELLBLUFF (B)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 5	0.0052	0.28	100.0	89.3	64.9	58.3	57.0	9.3	6.0	0.0
5 - 70	0.0054	0.28	100.0	90.0	67.1	59.3	58.1	8.2	5.2	0.0

SOIL: SMITHBORO (D)

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
0 - 6	0.0064	0.37	100.0	93.3	78.1	57.5	53.7	4.7	2.9	0.0
6 - 75	0.0045	0.32	100.0	84.4	48.8	46.3	46.0	13.3	9.3	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: SPRAY (B)										
0 - 6	0.0061	0.43	100.0	85.4	51.9	44.7	44.7	8.2	5.4	0.0
6 - 17	0.0046	0.28	100.0	83.0	44.0	42.4	42.4	13.2	9.3	0.0
SOIL: STALLINGS (C)										
0 – 12	0.0125	0.20	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
12 - 42	0.0155	0.17	100.0	87.8	59.9	22.6	22.6	3.6	2.2	0.0
42 - 80	0.0159	0.17	100.0	89.4	65.1	22.7	22.5	3.1	1.9	0.0
SOIL: STONEVILLE (B)										
0 - 5	0.0081	0.32	100.0	85.8	53.5	35.5	35.4	5.7	3.6	0.0
5 - 13	0.0062	0.32	100.0	88.9	63.6	50.5	49.8	6.6	4.1	0.0
13 - 38	0.0048	0.28	100.0	81.7	39.8	37.8	37.8	13.1	9.3	0.0
38 - 48	0.0064	0.24	100.0	86.8	56.6	45.6	45.3	7.0	4.4	0.0
SOIL: STONO (B/D)										
0 – 17	0.0084	0.24	100.0	88.5	62.1	36.6	36.1	4.7	2.9	0.0
17 - 37	0.0121	0.15	100.0	80.6	36.1	22.9	22.9	7.4	5.2	0.0
37 - 54	0.0454	0.10	100.0	90.8	69.7	10.8	10.8	2.1	1.4	0.0
SOIL: SUCHES (B)										
0 - 9	0.0072	0.24	100.0	88.3	61.6	42.0	41.4	5.5	3.4	0.0
9 - 31	0.0059	0.28	100.0	85.7	53.1	46.6	46.6	8.4	5.5	0.0
31 - 42	0.0077	0.28	100.0	84.7	49.7	35.6	35.6	6.5	4.2	0.0
SOIL: SUFFOLK (B)										
0 – 11	0.0075	0.32	100.0	92.1	74.1	46.7	43.8	3.9	2.4	0.0
11 - 47	0.0084	0.24	100.0	84.2	48.1	32.4	32.4	6.4	4.2	0.0
47 - 65	0.0233	0.15	100.0	91.7	72.8	19.3	18.6	2.2	1.4	0.0
SOIL: SUMMERTON (B)										
0 - 8	0.0088	0.32	100.0	88.9	63.5	35.4	34.8	4.4	2.7	0.0
8 - 72	0.0046	0.28	100.0	78.8	30.4	28.6	28.6	14.1	10.2	0.0
SOIL: SUNSWEET (C)										
0 - 4	0.0277	0.24	100.0	88.6	62.7	16.9	16.9	3.0	1.9	0.0
4 - 11	0.0080	0.37	100.0	77.3	25.5	22.1	22.1	11.9	8.7	0.0
11 - 60	0.0053	0.28	100.0	80.8	36.7	34.2	34.2	12.4	8.8	0.0
SOIL: SYLACAUGA (D)										
0 - 5	0.0068	0.37	100.0	93.1	77.4	53.9	50.1	4.2	2.6	0.0
5 - 50	0.0053	0.32	100.0	91.8	72.9	64.6	62.6	8.2	5.2	0.0
50 - 60	0.0174	0.17	100.0	88.0	60.5	21.2	21.2	3.4	2.1	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: TALLADEGA (C)										
0 - 9	0.0085	0.32	100.0	84.3	48.5	32.4	32.4	6.2	4.1	0.0
9 - 22	0.0231	0.28	100.0	78.9	30.7	17.1	17.1	7.4	5.4	0.0
SOIL: TALLAPOOSA (C)										
0 - 4	0.0100	0.32	100.0	85.8	53.4	29.7	29.6	4.9	3.1	0.0
4 - 10	0.0070	0.37	100.0	84.7	49.8	39.0	39.0	7.2	4.7	0.0
10 - 19	0.0091	0.20	100.0	86.2	54.6	32.3	32.1	5.1	3.2	0.0
SOIL: TALLAPOOSAGR (C)										
0 - 4	0.0115	0.24	100.0	85.5	52.2	26.5	26.5	4.8	3.1	0.0
4 - 10	0.0078	0.37	100.0	83.8	46.9	34.1	34.1	7.0	4.7	0.0
10 - 19	0.0100	0.20	100.0	85.5	52.4	29.4	29.4	5.0	3.2	0.0
SOIL: TATE (B)										
0 - 7	0.0075	0.24	100.0	90.0	67.1	43.5	41.7	4.7	2.9	0.0
7 - 46	0.0069	0.28	100.0	85.3	51.7	40.5	40.5	6.9	4.4	0.0
46 - 72	0.0118	0.17	100.0	90.4	68.5	29.0	27.8	3.1	1.9	0.0
SOIL: TATUM (B)										
0 - 6	0.0053	0.32	100.0	86.0	54.0	49.8	49.8	9.9	6.5	0.0
6 - 42	0.0043	0.28	100.0	81.0	37.6	36.1	36.1	14.3	10.2	0.0
SOIL: TATUMGR (B)										
0 - 6	0.0079	0.20	100.0	85.4	52.0	36.0	35.9	6.0	3.8	0.0
6 - 42	0.0046	0.28	100.0	78.8	30.4	28.6	28.6	14.1	10.2	0.0
SOIL: TAWCAW (C)										
0 - 5	0.0043	0.32	100.0	85.0	50.6	47.5	46.9	13.9	9.8	0.0
5 - 58	0.0043	0.37	100.0	80.9	37.2	35.6	35.6	14.3	10.2	0.0
SOIL: TETOTUM (C)										
0 - 9	0.0070	0.37	100.0	90.3	68.2	47.1	45.1	5.0	3.1	0.0
9 - 48	0.0067	0.32	100.0	84.3	48.5	39.2	39.2	7.8	5.2	0.0
48 - 72	0.0099	0.32	100.0	85.1	51.1	29.4	29.4	5.3	3.4	0.0
SOIL: TIFTON (B)										
0 – 10	0.0443	0.10	100.0	92.8	76.3	13.9	13.5	1.7	1.1	0.0
10 - 18	0.0442	0.24	100.0	82.7	43.1	14.6	14.6	4.8	3.4	0.0
18 - 33	0.0231	0.24	100.0	78.9	30.7	17.1	17.1	7.4	5.4	0.0
33 - 64	0.0133	0.17	100.0	78.5	29.2	20.4	20.4	8.8	6.3	0.0
64 - 85	0.0147	0.17	100.0	77.6	26.5	19.1	19.1	9.4	6.8	0.0
SOIL: TOCCOA (B)										
0 - 10	0.0074	0.24	100.0	92.7	76.1	48.5	45.1	3.7	2.3	0.0
10 - 60	0.0109	0.20	100.0	90.3	68.2	30.8	29.5	3.3	2.0	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: TOISNOT (B/D)										
0 – 13	0.0070	0.15	100.0	91.2	71.2	48.8	46.2	4.7	2.9	0.0
13 - 28	0.0120	0.32	100.0	90.3	68.3	28.6	27.5	3.1	1.9	0.0
28 - 45	0.0140	0.43	100.0	89.7	66.3	25.1	24.5	3.1	1.9	0.0
45 - 80	0.0086	0.37	100.0	83.7	46.5	31.2	31.2	6.6	4.4	0.0
SOIL: TOMAHAWK (A)										
0 – 24	0.0441	0.10	100.0	93.5	78.5	14.5	13.9	1.6	1.0	0.0
24 - 42	0.0140	0.15	100.0	89.7	66.3	25.1	24.5	3.1	1.9	0.0
42 - 80	0.0455	0.10	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
SOIL: TOMOTLEY (B/D)										
0 – 13	0.0065	0.20	100.0	92.0	73.7	53.7	50.8	5.0	3.1	0.0
13 - 44	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
44 - 59	0.0079	0.20	100.0	81.5	39.1	30.3	30.3	8.5	5.8	0.0
SOIL: TORHUNTA (C)										
0 – 15	0.0130	0.10	100.0	88.6	62.4	25.6	25.4	3.6	2.2	0.0
15 - 40	0.0178	0.15	100.0	87.6	59.4	20.8	20.8	3.5	2.2	0.0
40 - 80	0.0448	0.10	100.0	88.0	60.4	12.6	12.6	2.9	1.9	0.0
SOIL: TOTNESS (Z)										
0 - 7	0.0155	0.10	100.0	87.8	59.9	22.6	22.6	3.6	2.2	0.0
7 - 48	0.0460	0.05	100.0	90.5	68.6	7.3	7.3	2.0	1.4	0.0
48 - 74	0.0077	0.28	100.0	86.1	54.3	37.5	37.3	5.8	3.7	0.0
74 - 80	0.0151	0.10	100.0	89.5	65.4	23.8	23.3	3.1	1.9	0.0
SOIL: TRANSYLVANIA (B)										
0 – 27	0.0065	0.37	100.0	92.9	76.7	55.8	52.2	4.7	2.9	0.0
27 - 60	0.0058	0.32	100.0	90.1	67.6	56.5	55.0	7.0	4.4	0.0
SOIL: TROUP (A)										
0 – 53	0.0258	0.10	100.0	91.6	72.4	18.2	17.7	2.2	1.4	0.0
53 - 80	0.0146	0.20	100.0	80.6	36.3	21.0	21.0	6.9	4.9	0.0
SOIL: TURBEVILLE (C)										
0 – 10	0.0079	0.32	100.0	87.1	57.5	37.7	37.3	5.4	3.4	0.0
10 - 72	0.0048	0.24	100.0	82.9	43.8	41.7	41.7	12.6	8.8	0.0
SOIL: TUSQUITEE (B)										
0 – 10	0.0079	0.28	100.0	90.4	68.5	41.6	39.6	4.2	2.6	0.0
10 - 48	0.0087	0.20	100.0	89.3	65.0	36.7	35.4	4.2	2.6	0.0
48 - 60	0.0169	0.17	100.0	87.0	57.3	21.3	21.3	3.8	2.4	0.0
SOIL: TUSQUITEEST (B)										
0 – 10	0.0141	0.17	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
10 - 48	0.0087	0.20	100.0	89.3	65.0	36.7	35.4	4.2	2.6	0.0
48 - 60	0.0169	0.15	100.0	87.0	57.3	21.3	21.3	3.8	2.4	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: UCHEE (A)										
0 – 26	0.0325	0.10	100.0	91.9	73.4	16.4	16.0	2.0	1.3	0.0
26 - 39	0.0120	0.24	100.0	84.0	47.5	25.0	25.0	5.5	3.7	0.0
39 - 47	0.0075	0.28	100.0	79.5	32.5	27.3	27.3	10.3	7.3	0.0
47 - 66	0.0093	0.28	100.0	81.3	38.5	27.1	27.1	7.7	5.4	0.0
66 - 84	0.0303	0.24	100.0	88.6	62.6	16.3	16.3	3.0	1.9	0.0
SOIL: UDIPSAMMENTS (Z)										
0 - 60	0.0461	0.10	100.0	89.9	66.8	7.4	7.4	2.1	1.5	0.0
SOIL: UDORTHENTS (Z)										
0 - 60	0.0063	0.28	100.0	83.9	47.2	39.7	39.7	8.7	5.8	0.0
SOIL: VANCE (C)										
0 - 5	0.0070	0.28	100.0	83.5	45.8	36.0	36.0	8.0	5.4	0.0
5 - 29	0.0048	0.28	100.0	81.5	39.3	37.3	37.3	13.1	9.3	0.0
SOIL: VARINA (C)										
0 – 14	0.0144	0.17	100.0	86.8	56.7	23.4	23.4	4.0	2.5	0.0
14 - 38	0.0290	0.28	100.0	75.2	18.5	15.3	15.3	12.4	9.3	0.0
38 - 80	0.0098	0.28	100.0	77.1	24.6	20.5	20.5	11.3	8.3	0.0
SOIL: VARINAGR (C)										
0 – 14	0.0299	0.17	100.0	90.3	68.1	16.5	16.5	2.5	1.6	0.0
14 - 38	0.0078	0.28	100.0	77.9	27.4	23.5	23.5	11.4	8.3	0.0
38 - 80	0.0089	0.28	100.0	77.4	25.6	21.5	21.5	11.4	8.3	0.0
SOIL: VAUCLUSE (C)										
0 – 15	0.0081	0.32	100.0	83.6	46.0	32.5	32.5	7.0	4.7	0.0
15 - 29	0.0207	0.24	100.0	79.4	32.3	17.9	17.9	7.2	5.2	0.0
29 - 58	0.0491	0.24	100.0	76.4	22.6	11.7	11.7	8.3	6.1	0.0
58 - 72	0.0188	0.17	100.0	83.6	46.1	19.6	19.6	5.0	3.4	0.0
SOIL: VAUCLUSEGR (C)										
0 – 15	0.0154	0.15	100.0	85.6	52.7	22.1	22.1	4.4	2.9	0.0
15 - 29	0.0207	0.24	100.0	79.4	32.3	17.9	17.9	7.2	5.2	0.0
29 - 65	0.0491	0.24	100.0	76.4	22.6	11.7	11.7	8.3	6.1	0.0
65 - 80	0.0188	0.17	100.0	83.6	46.1	19.6	19.6	5.0	3.4	0.0
SOIL: WADMALAW (D)										
0 – 13	0.0098	0.20	100.0	89.2	64.5	32.8	31.8	3.9	2.4	0.0
13 - 33	0.0069	0.17	100.0	84.0	47.4	37.6	37.6	7.8	5.2	0.0
33 - 83	0.0055	0.17	100.0	85.6	52.8	48.0	48.0	9.6	6.3	0.0
SOIL: WAGRAM (A)										
0 - 24	0.0369	0.15	100.0	92.4	75.0	15.6	15.2	1.9	1.2	0.0
24 - 75	0.0126	0.20	100.0	82.0	41.0	23.3	23.3	6.4	4.4	0.0

Depth	D15(mm)	K	1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
			Particle Sizes (mm)							
SOIL: WAHEE (D)										
0 – 11	0.0068	0.28	100.0	88.8	63.1	46.0	44.8	5.8	3.6	0.0
11 - 56	0.0048	0.28	100.0	81.2	38.4	36.3	36.3	13.0	9.3	0.0
SOIL: WAKULLA (A)										
0 – 24	0.0455	0.10	100.0	93.0	76.8	8.8	8.8	1.5	1.0	0.0
24 - 42	0.0445	0.10	100.0	93.3	78.0	12.8	12.4	1.6	1.0	0.0
42 - 80	0.0461	0.10	100.0	92.7	76.2	5.8	5.8	1.4	1.0	0.0
SOIL: WALHALLABO (B)										
0 - 5	0.0113	0.10	100.0	89.2	64.6	29.1	28.4	3.6	2.2	0.0
5 - 46	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
46 - 65	0.0151	0.10	100.0	84.8	50.2	22.1	22.1	4.8	3.2	0.0
SOIL: WANDO (A)										
0 – 51	0.0458	0.10	100.0	89.0	63.7	8.7	8.7	2.4	1.7	0.0
51 - 72	0.0459	0.10	100.0	92.2	74.4	6.9	6.9	1.6	1.1	0.0
SOIL: WATAUGA (B)										
0 - 7	0.0084	0.24	100.0	88.4	61.9	36.8	36.0	4.7	2.9	0.0
7 - 28	0.0071	0.28	100.0	84.2	48.2	37.4	37.4	7.4	4.9	0.0
28 - 72	0.0157	0.24	100.0	87.1	57.5	22.2	22.2	3.8	2.4	0.0
SOIL: WATEREE (B)										
0 - 3	0.0178	0.20	100.0	87.6	59.4	20.8	20.8	3.5	2.2	0.0
3 - 22	0.0155	0.20	100.0	87.8	59.9	22.6	22.6	3.6	2.2	0.0
22 - 27	0.0441	0.17	100.0	89.8	66.6	14.8	14.8	2.6	1.7	0.0
SOIL: WEDOWEE (B)										
0 – 10	0.0068	0.28	100.0	84.6	49.3	39.1	39.1	7.4	4.9	0.0
10 - 14	0.0074	0.28	100.0	84.8	50.2	37.2	37.2	6.6	4.3	0.0
14 - 32	0.0064	0.28	100.0	80.1	34.4	30.4	30.4	11.0	7.8	0.0
32 - 60	0.0092	0.28	100.0	83.4	45.6	29.4	29.4	6.5	4.4	0.0
SOIL: WEDOWEEBO (B)										
0 – 10	0.0141	0.20	100.0	87.1	57.7	23.7	23.7	3.8	2.4	0.0
10 - 14	0.0074	0.28	100.0	84.8	50.2	37.2	37.2	6.6	4.3	0.0
14 - 32	0.0064	0.28	100.0	80.1	34.4	30.4	30.4	11.0	7.8	0.0
32 - 60	0.0092	0.28	100.0	83.4	45.6	29.4	29.4	6.5	4.4	0.0
SOIL: WEHADKEE (D)										
0 - 8	0.0059	0.32	100.0	89.3	64.9	54.5	53.4	7.2	4.5	0.0
8 - 40	0.0059	0.32	100.0	86.5	55.7	48.6	48.6	8.1	5.2	0.0

			Particle Sizes (mm)							
Depth	**D15(mm)**	**K**	**1.4**	**1.0**	**0.063**	**0.044**	**0.038**	**0.004**	**0.003**	**0.001**
SOIL: WHITESTORE (Z)										
0 - 6	0.0052	0.37	100.0	86.0	53.9	49.9	49.6	10.5	7.0	0.0
6 - 35	0.0038	0.37	100.0	84.0	47.4	46.5	46.5	15.9	11.2	0.0
35 - 53	0.0061	0.32	100.0	85.9	53.6	46.3	46.3	7.9	5.1	0.0
SOIL: WICKHAM (B)										
0 - 6	0.0077	0.24	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
6 - 50	0.0077	0.24	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
SOIL: WICKSBURG (B)										
0 – 26	0.0245	0.10	100.0	90.6	69.0	18.3	18.0	2.5	1.6	0.0
26 - 30	0.0062	0.20	100.0	83.4	45.5	38.8	38.8	9.3	6.3	0.0
30 - 65	0.0052	0.24	100.0	83.5	45.8	42.9	42.9	11.3	7.8	0.0
SOIL: WILKES (C)										
0 - 6	0.0070	0.28	100.0	83.5	45.8	36.0	36.0	8.0	5.4	0.0
6 - 13	0.0058	0.32	100.0	85.2	51.3	45.1	45.1	8.9	5.8	0.0
SOIL: WILKESST (C)										
0 - 6	0.0144	0.17	100.0	87.1	57.6	23.4	23.4	3.8	2.4	0.0
6 - 13	0.0058	0.28	100.0	85.2	51.3	45.1	45.1	8.9	5.8	0.0
SOIL: WILLIMAN (B/D)										
0 – 26	0.0219	0.15	100.0	91.8	73.1	19.9	19.2	2.2	1.4	0.0
26 - 80	0.0097	0.15	100.0	80.2	35.0	25.3	25.3	8.3	5.8	0.0
SOIL: WINNSBORO (D)										
0 - 9	0.0068	0.32	100.0	89.7	66.2	47.6	46.0	5.5	3.4	0.0
9 - 20	0.0045	0.20	100.0	83.7	46.4	44.5	44.5	13.3	9.3	0.0
20 - 51	0.0082	0.28	100.0	83.2	44.7	31.7	31.7	7.2	4.9	0.0
SOIL: WITHERBEE (A/D)										
0 – 25	0.0456	0.10	100.0	95.5	85.3	7.3	7.1	0.9	0.6	0.0
25 – 99	0.0461	0.10	100.0	93.4	78.3	5.7	5.7	1.3	0.9	0.0
SOIL: WOODINGTON (B/D)										
0 – 12	0.0125	0.20	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
12 - 47	0.0125	0.20	100.0	88.8	63.0	26.4	26.1	3.6	2.2	0.0
47 - 85	0.0172	0.10	100.0	88.5	62.3	21.4	21.4	3.3	2.0	0.0
SOIL: WORSHAM (D)										
0 - 8	0.0066	0.37	100.0	90.6	69.0	50.7	48.6	5.5	3.4	0.0
8 - 50	0.0059	0.28	100.0	80.0	34.3	31.1	31.1	11.6	8.3	0.0
50 - 70	0.0080	0.28	100.0	83.3	45.3	32.6	32.6	7.3	4.9	0.0

Depth	D15(mm)	K	Particle Sizes (mm) 1.4	1.0	0.063	0.044	0.038	0.004	0.003	0.001
SOIL: YAUHANNAH (D)										
0 - 9	0.0126	0.20	100.0	85.8	53.4	25.0	25.0	4.5	2.9	0.0
9 - 52	0.0151	0.24	100.0	80.0	34.2	20.4	20.4	7.3	5.2	0.0
52 - 62	0.0118	0.24	100.0	83.6	46.2	25.0	25.0	5.8	3.9	0.0
62 - 75	0.0207	0.17	100.0	88.7	62.7	19.4	19.4	3.1	1.9	0.0
SOIL: YEMASSEE (C)										
0 – 12	0.0126	0.20	100.0	85.8	53.4	25.0	25.0	4.5	2.9	0.0
12 - 50	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
50 - 75	0.0146	0.20	100.0	80.2	35.0	20.8	20.8	7.2	5.1	0.0
SOIL: YEMASSEEFL (C)										
0 – 12	0.0126	0.20	100.0	85.8	53.4	25.0	25.0	4.5	2.9	0.0
12 - 50	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
50 – 75	0.0146	0.20	100.0	80.2	35.0	20.8	20.8	7.2	5.1	0.0
SOIL: YEMASSEEOCFL (C)										
0 – 12	0.0126	0.20	100.0	85.8	53.4	25.0	25.0	4.5	2.9	0.0
12 - 50	0.0077	0.20	100.0	83.0	44.3	32.8	32.8	7.6	5.2	0.0
50 - 75	0.0146	0.20	100.0	80.2	35.0	20.8	20.8	7.2	5.1	0.0
SOIL: YONGES (D)										
0 - 14	0.0084	0.20	100.0	88.5	62.1	36.6	36.1	4.7	2.9	0.0
14 - 42	0.0068	0.17	100.0	83.3	45.1	36.2	36.2	8.4	5.7	0.0
42 - 60	0.0079	0.20	100.0	84.2	48.0	34.0	34.0	6.7	4.4	0.0
SOIL: YONGESFL (D)										
0 - 14	0.0063	0.28	100.0	91.1	70.7	54.3	52.0	5.8	3.6	0.0
14 - 42	0.0068	0.17	100.0	83.3	45.1	36.2	36.2	8.4	5.7	0.0
42 - 60	0.0079	0.20	100.0	84.2	48.0	34.0	34.0	6.7	4.4	0.0

- Hydrologic soil group “Z” denotes that this information was missing from available databases.

References

South Carolina Department of Health and Environmental Control. 1996. South Carolina Stormwater and Sediment Control Handbook for Land Disturbance Activities. South Carolina Department of Health and Environmental Control. Columbia, SC.

APPENDIX B – CONSTRUCTION DETAILS

Please see the City's website for current standard details, www.cityofrockhill.com.

APPENDIX C – CULVERT DESIGN CHARTS AND NOMOGRAPHS

All of the figures in this section are from the AASHTO Model Drainage Manual, 1991.

Chart 1 – Headwater Depth for Concrete Pipe Culverts with Inlet Control

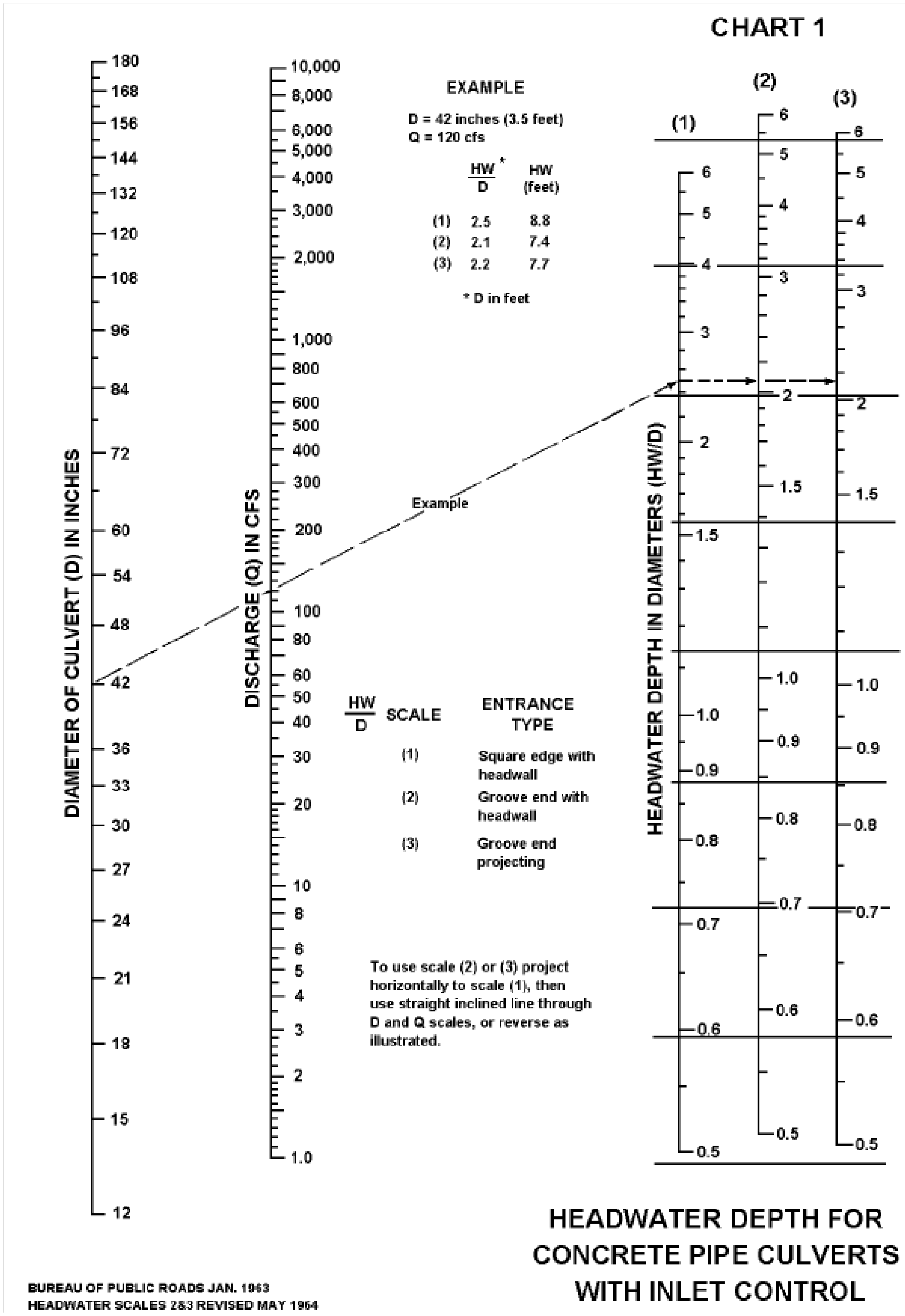


Chart 2 – Headwater Depth for C.M. Pipe Culverts with Inlet Control

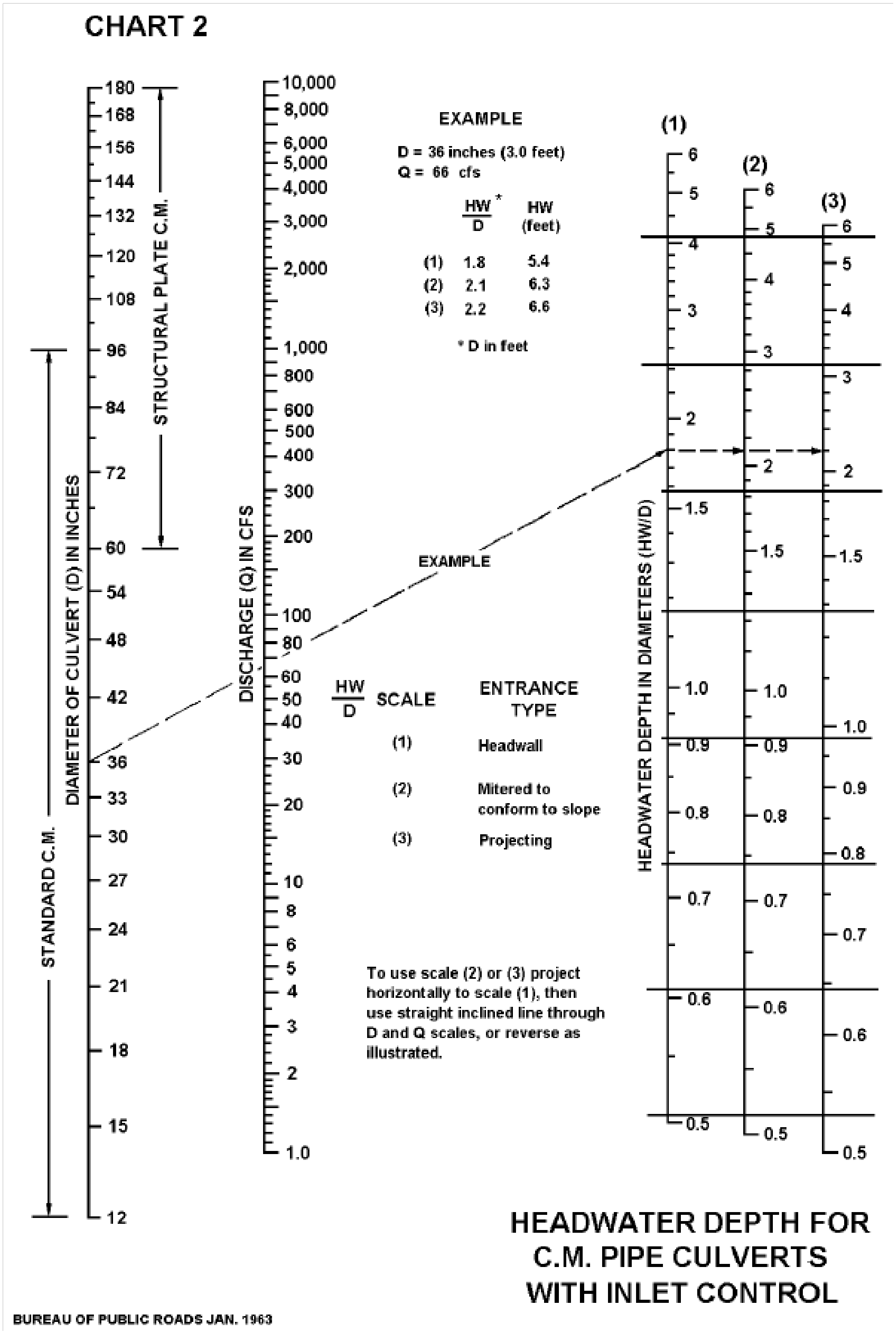
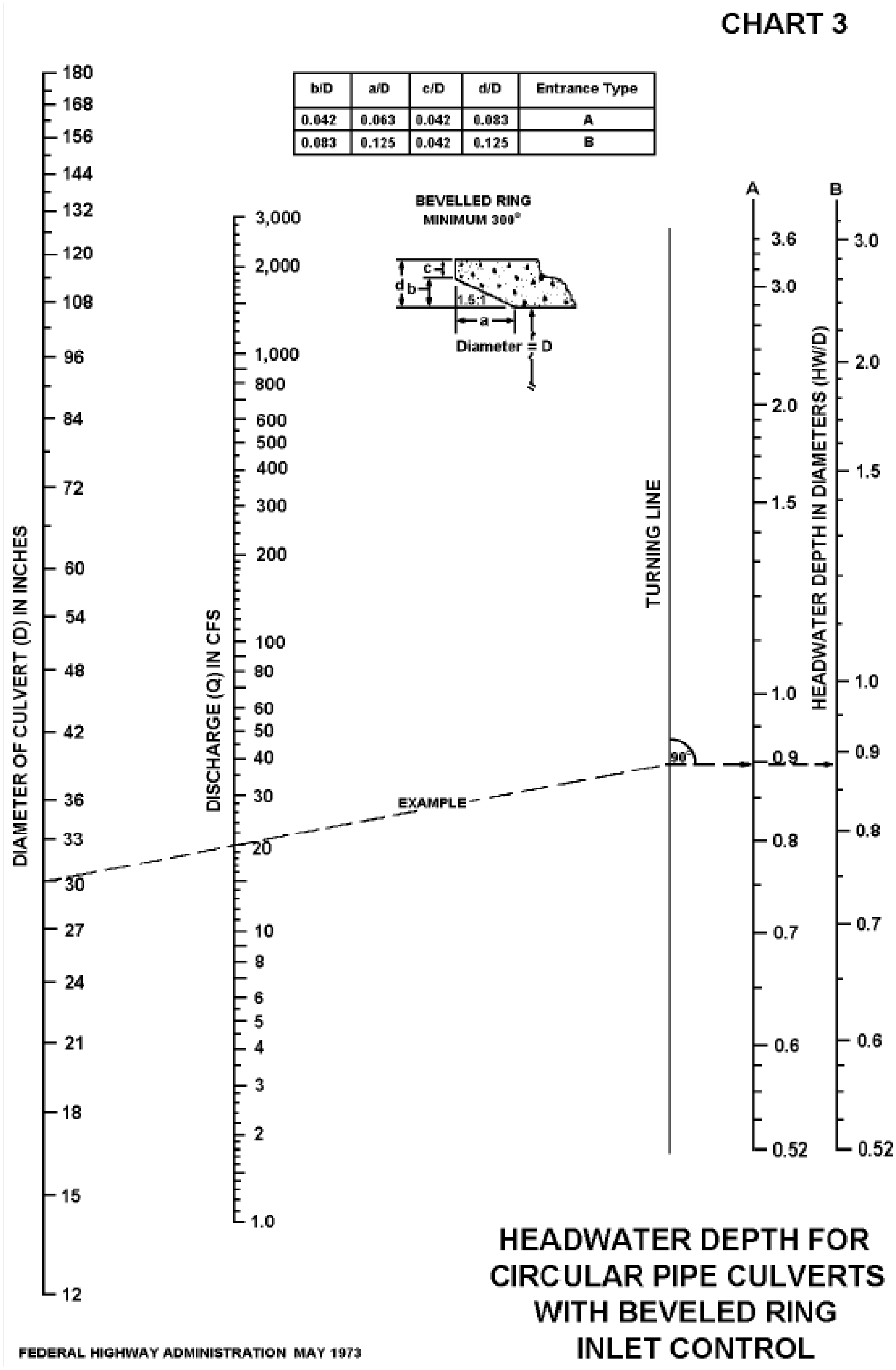


Chart 3 – Headwater Depth for Circular Pipe Culverts with Beveled Ring Inlet Control



b/D	a/D	c/D	d/D	Entrance Type
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B

Chart 4 – Critical Depth Circular Pipe

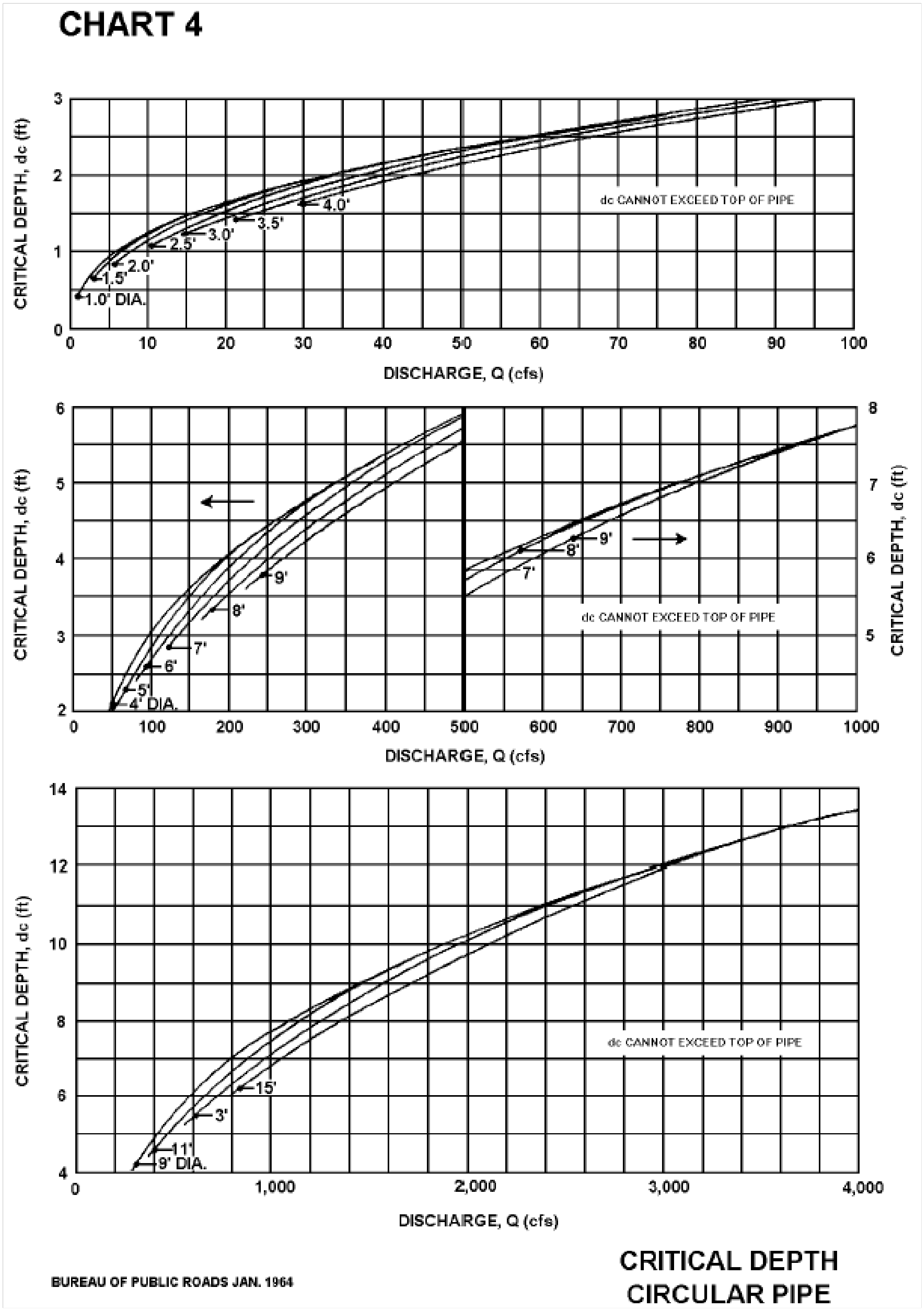


Chart 5 – Head for Concrete Pipe Culverts Flowing Full n=0.012

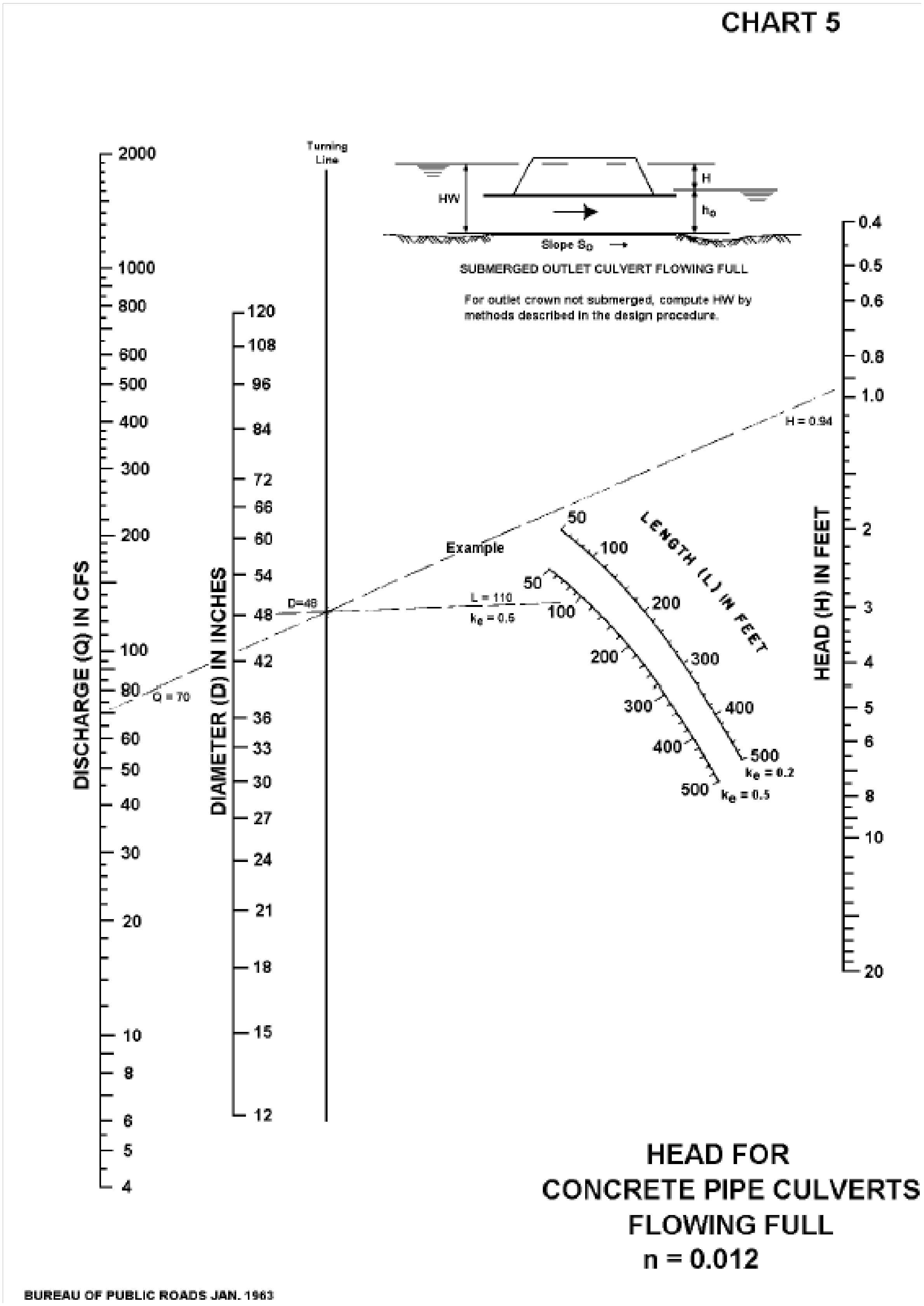


Chart 6 - Head for Standard C.M. Pipe Culverts Flowing Full n = 0.024

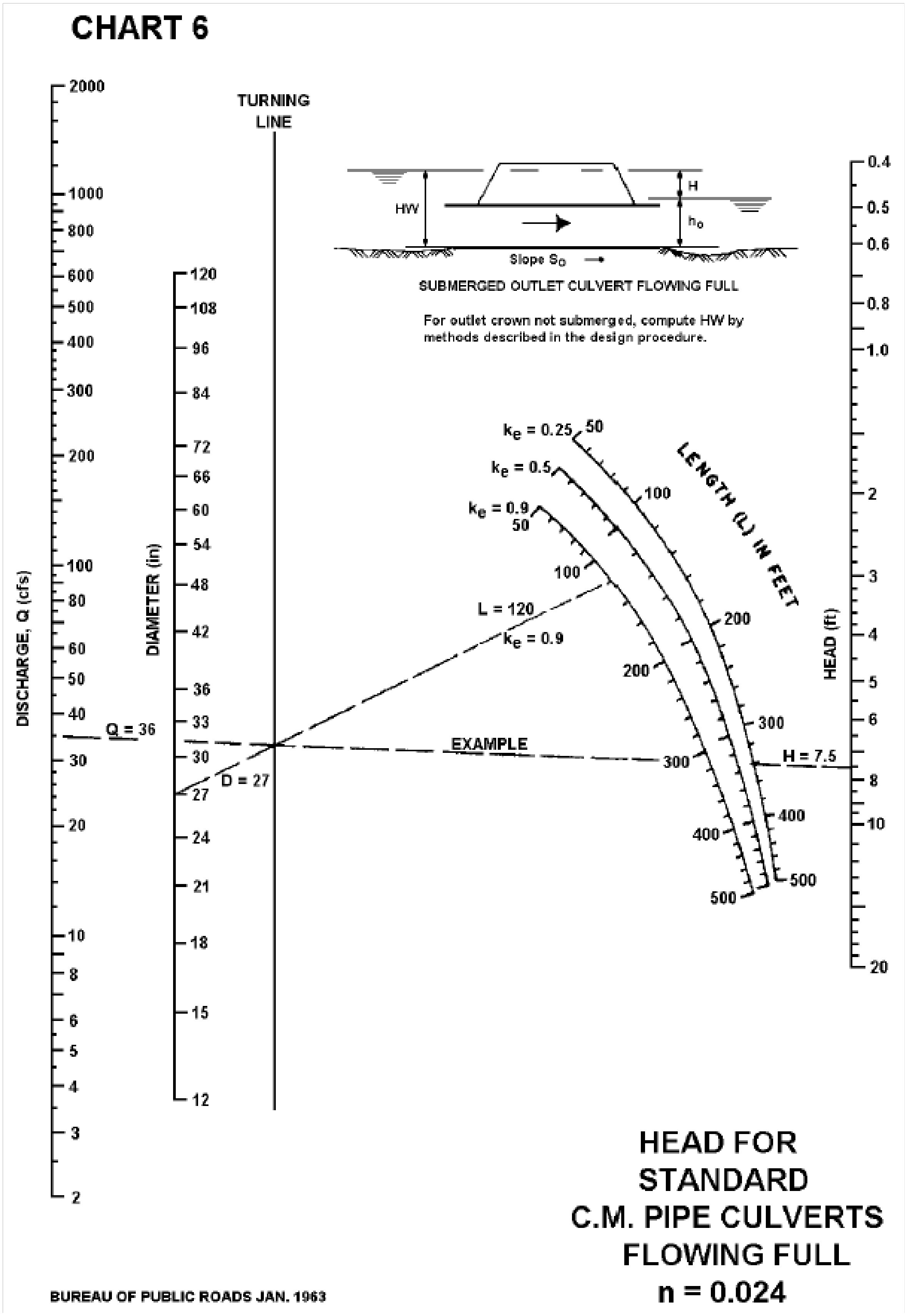


Chart 7 - Head for Structural Plate Corr. Metal Pipe Culverts Flowing Full n = 0.0328 to n = 0.0302

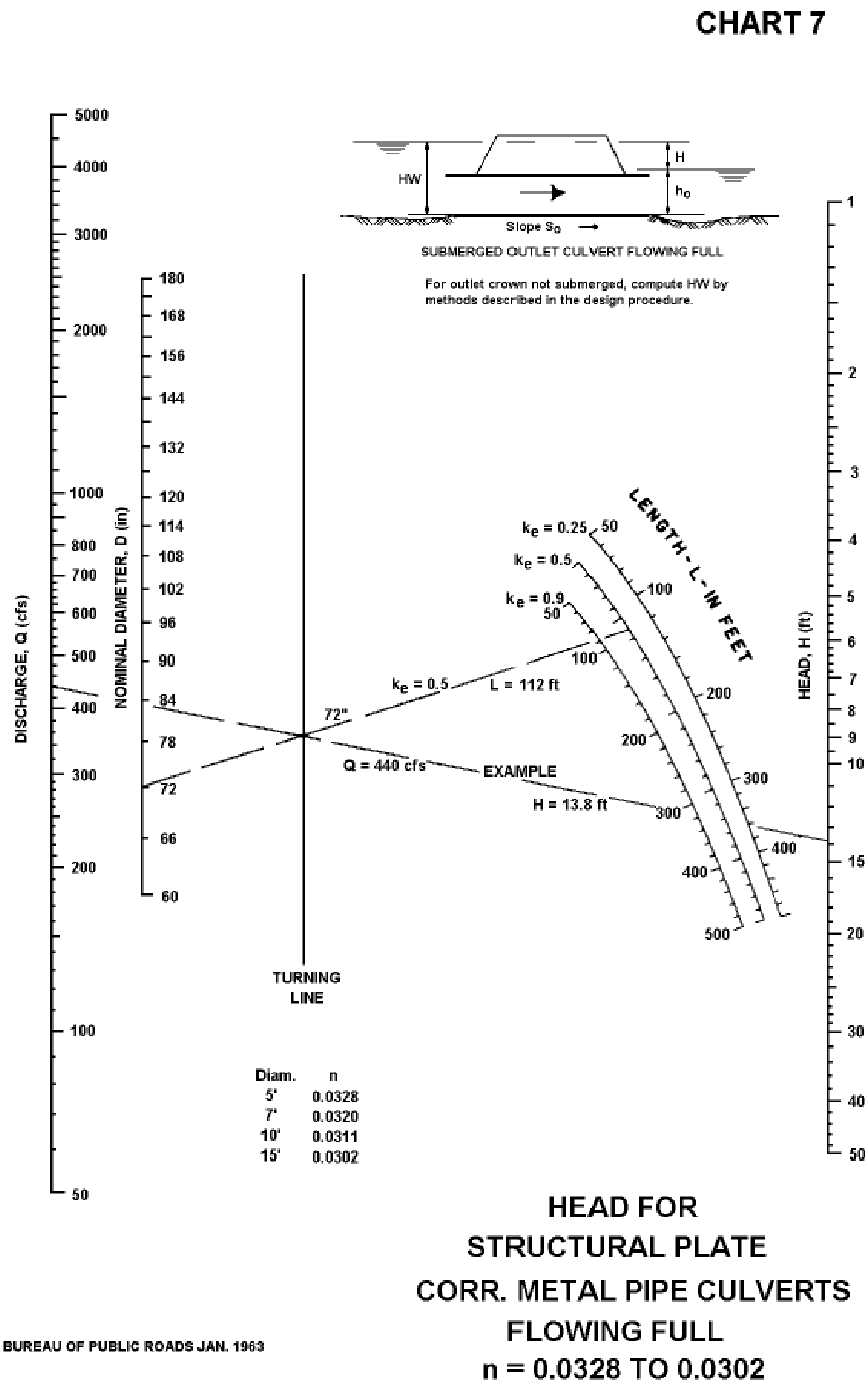


Chart 8 - Headwater Depth for Box Culverts with Inlet Control

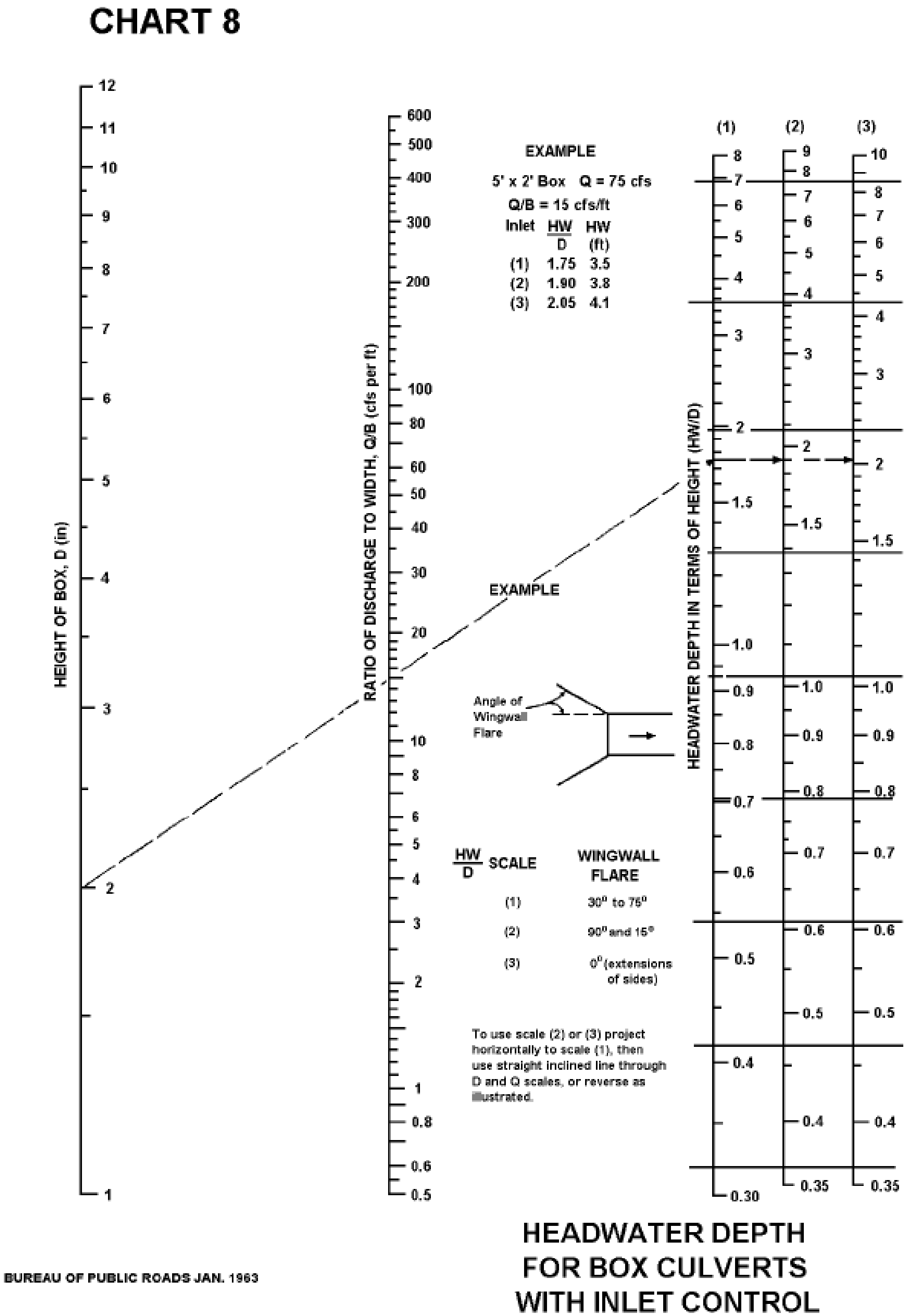


Chart 9 - Headwater Depth for Inlet Control Rectangular Box Culverts Flared Wingwalls 18° to 33.7° & 45° with Beveled Edge at Top of Inlet

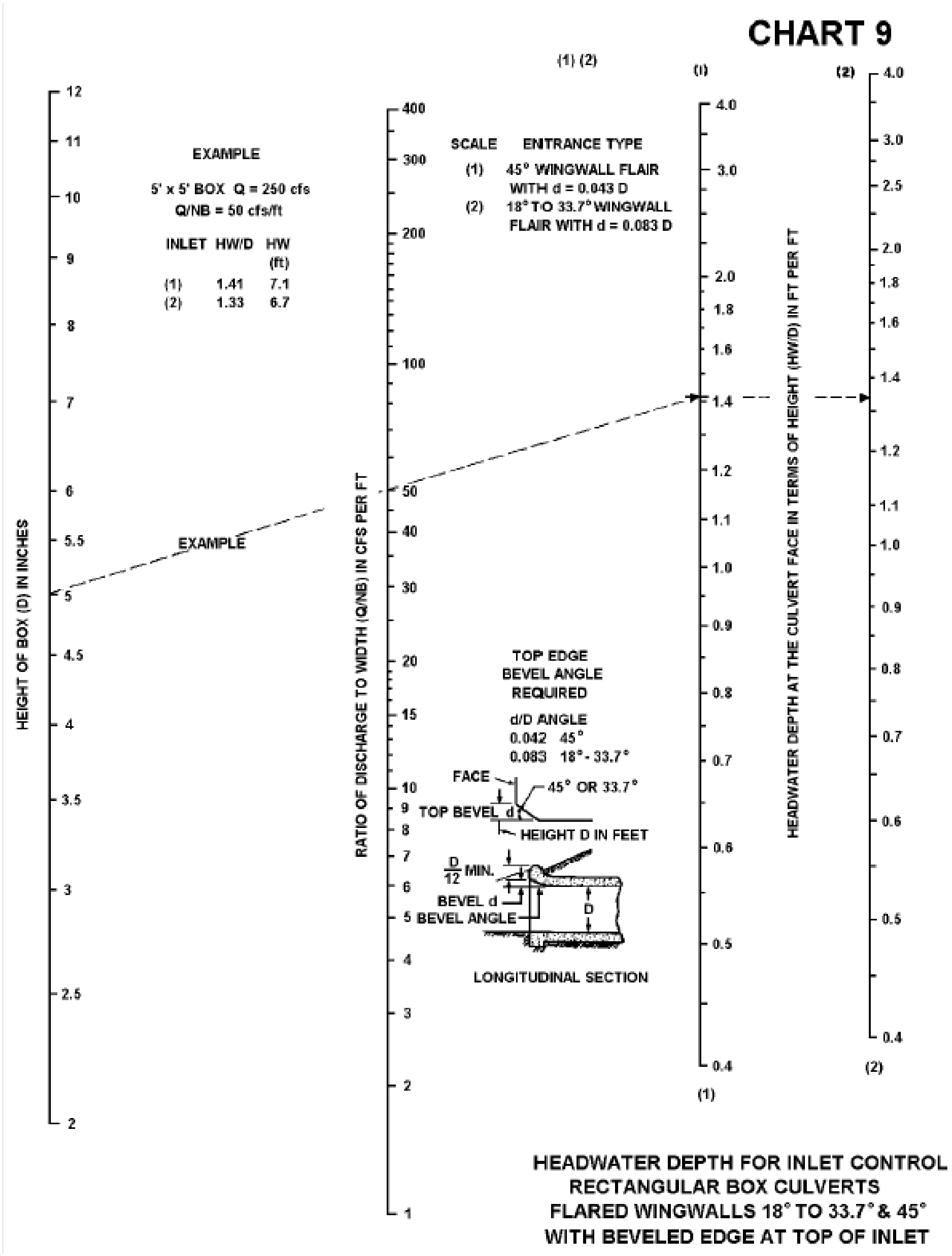


Chart 10 - Headwater Depth for Inlet Control Rectangular Box Culverts 90° Headwall Chamfered or Beveled Inlet Edges

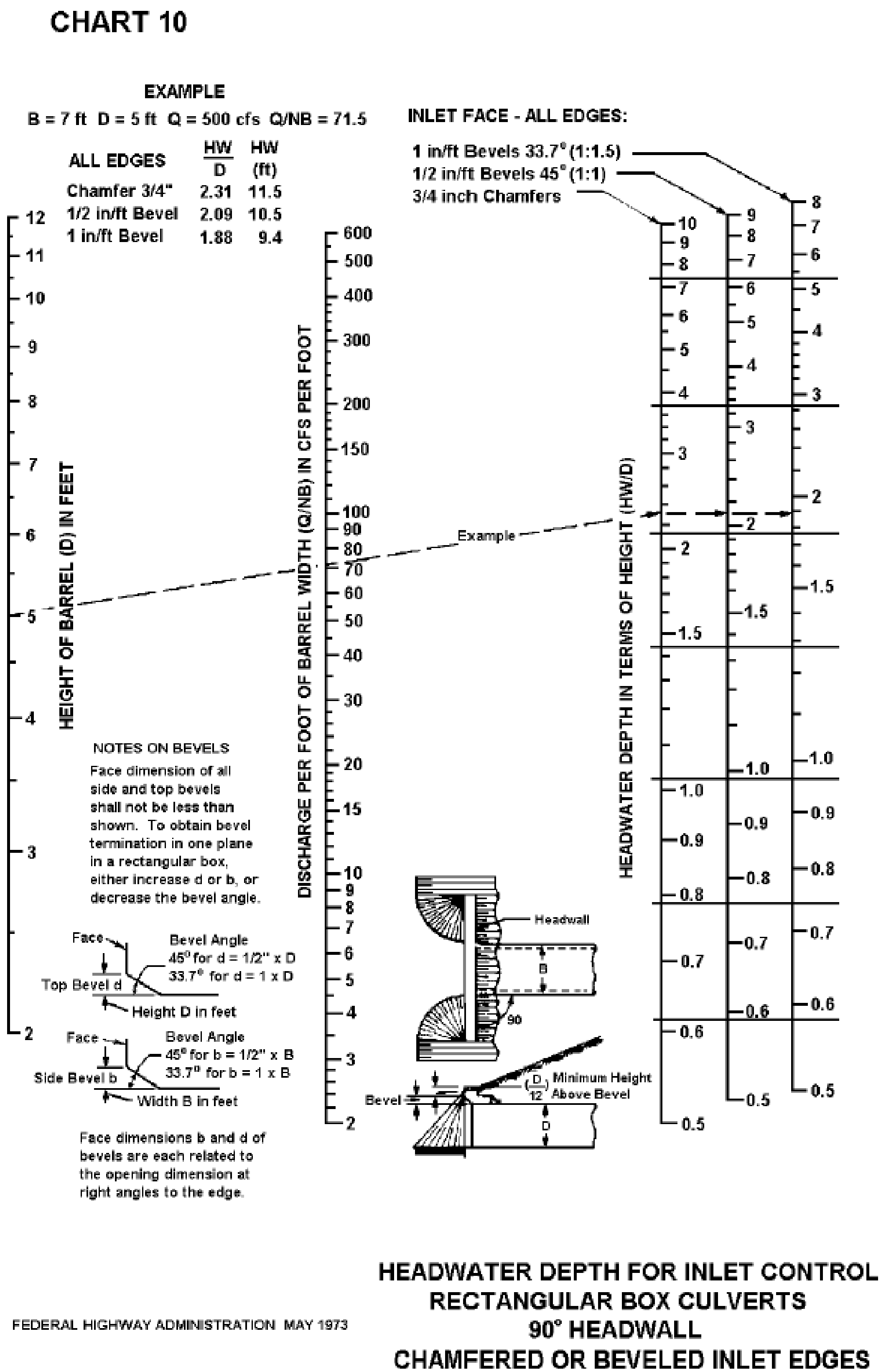


Chart 11 - Headwater Depth for Inlet Control Single Barrel Box Culverts Skewed Headwalls Chamfered or Beveled Inlet Edges

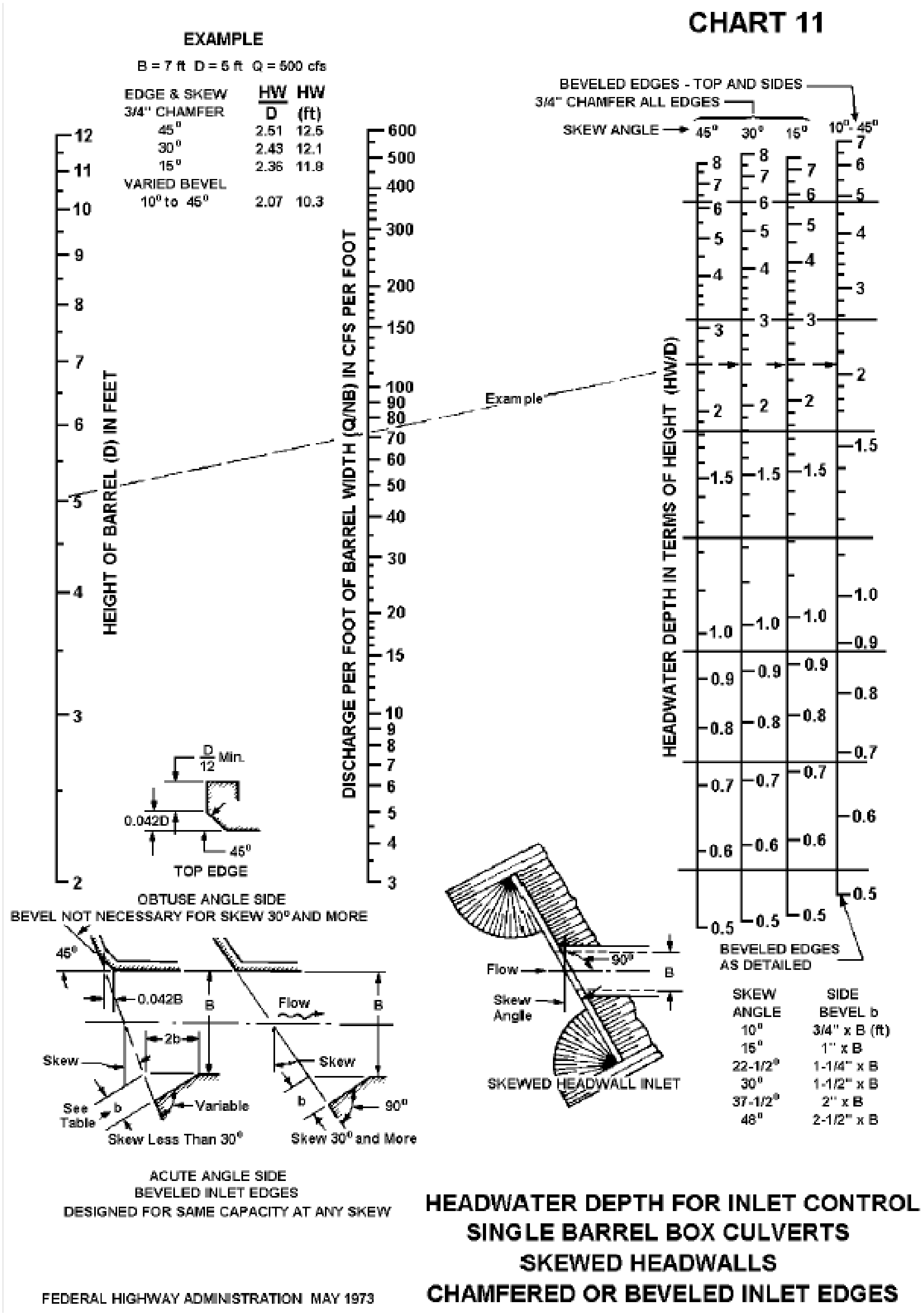


Chart 12 - Headwater Depth for Inlet Control Rectangular Box Culverts Flared Wingwalls Normal and Skewed Inlets ¾" Chamfer at Top of Opening

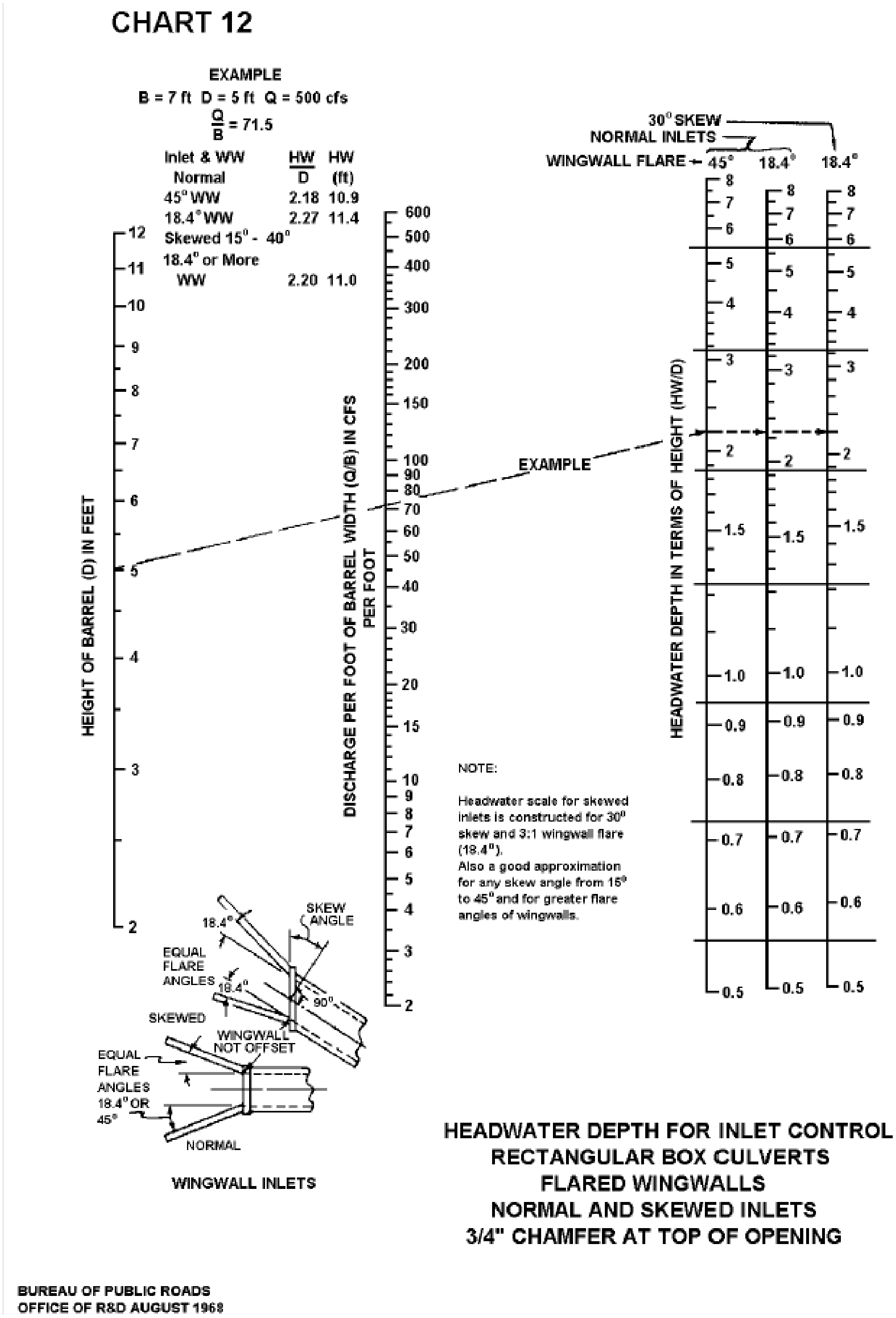


Chart 13 - Headwater Depth for Inlet Control Rectangular Box Culverts Offset Flared Wingwalls and Beveled Edge at Top of Inlet

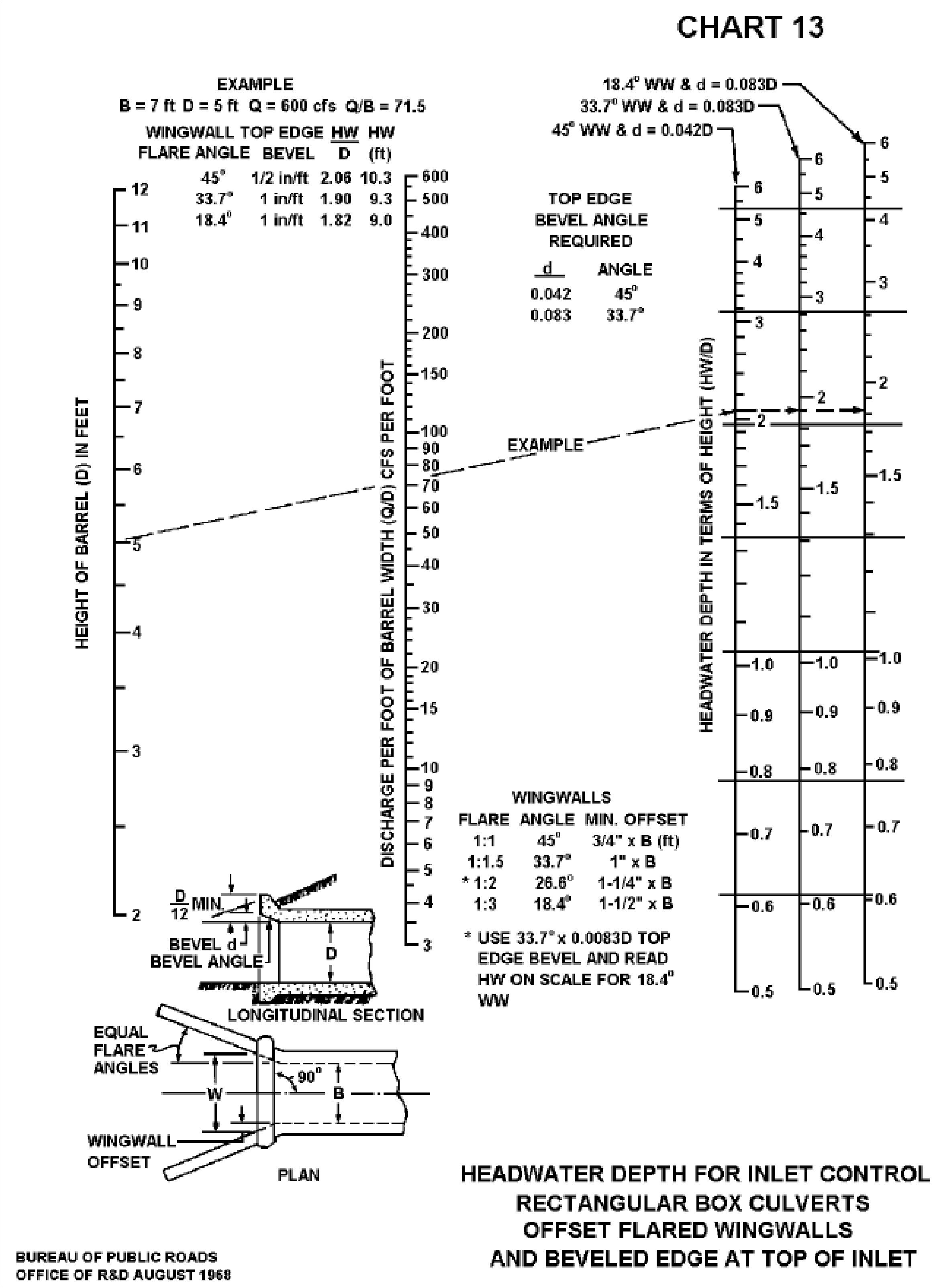


Chart 14 - Critical Depth Rectangular Section

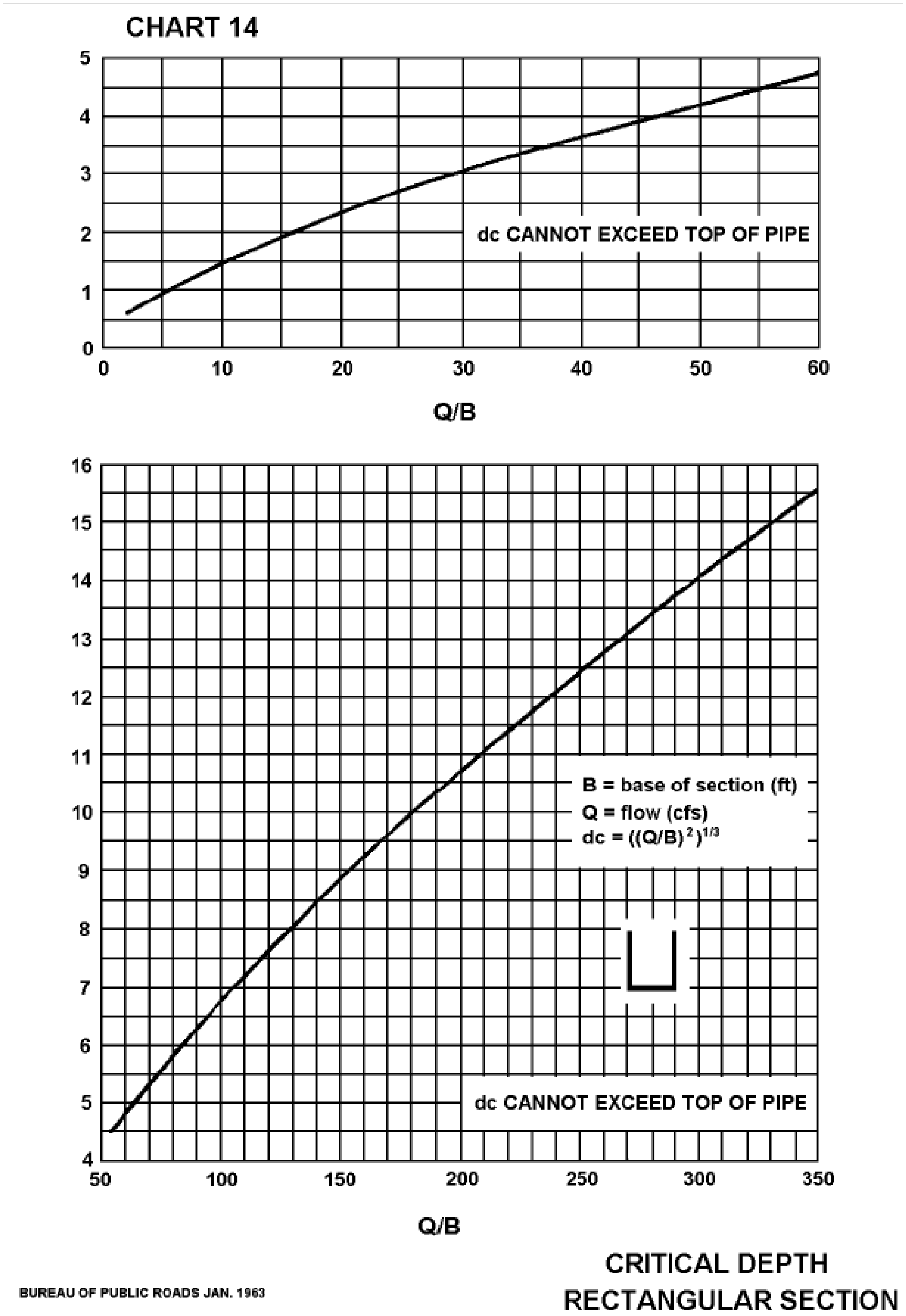


Chart 15 - Head for Concrete Box Culverts Flowing Full n = 0.012

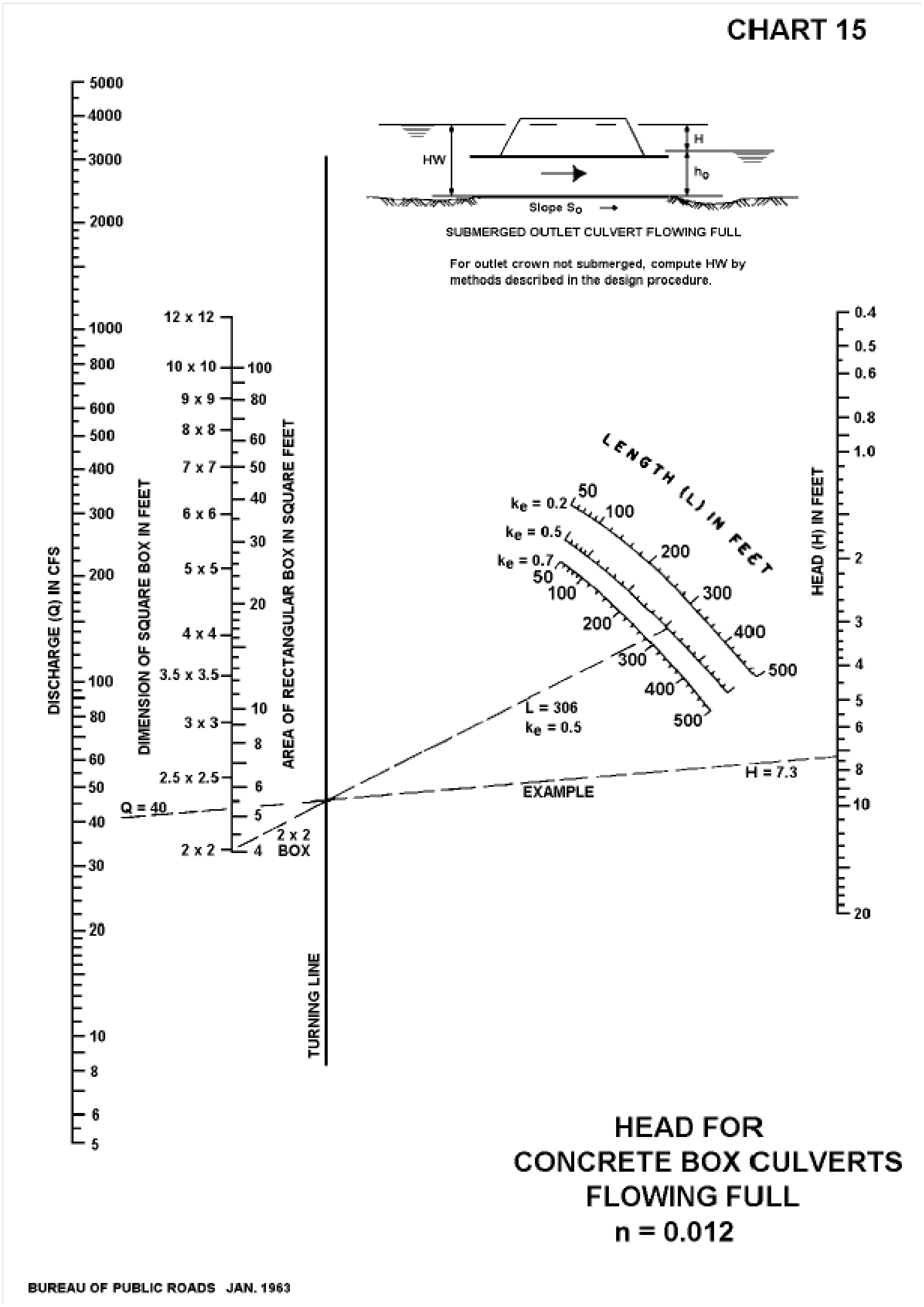


Chart 16 - Headwater Depth for C.M. Box Culverts Rise/Span < 0.3 with Inlet Control

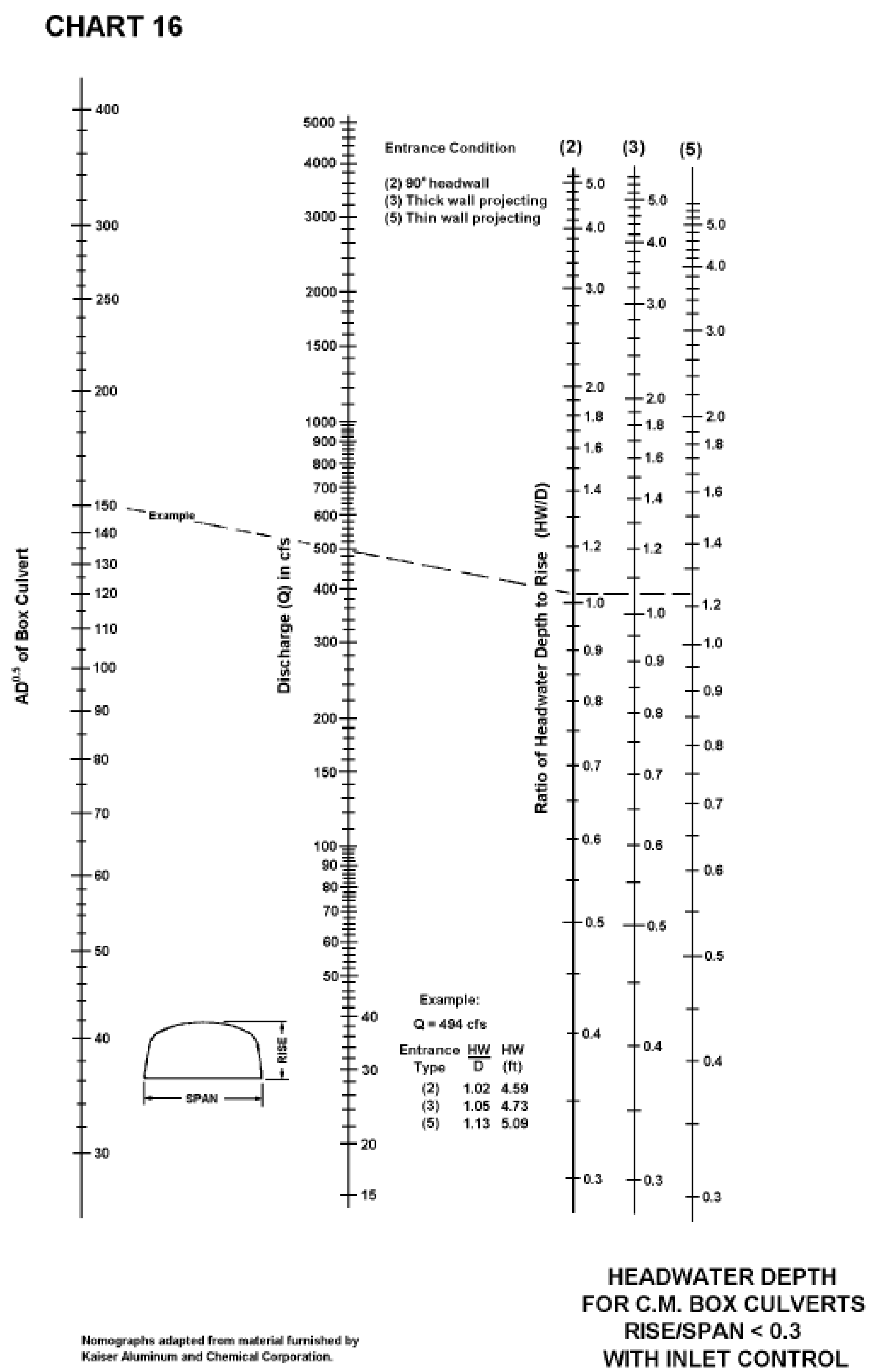
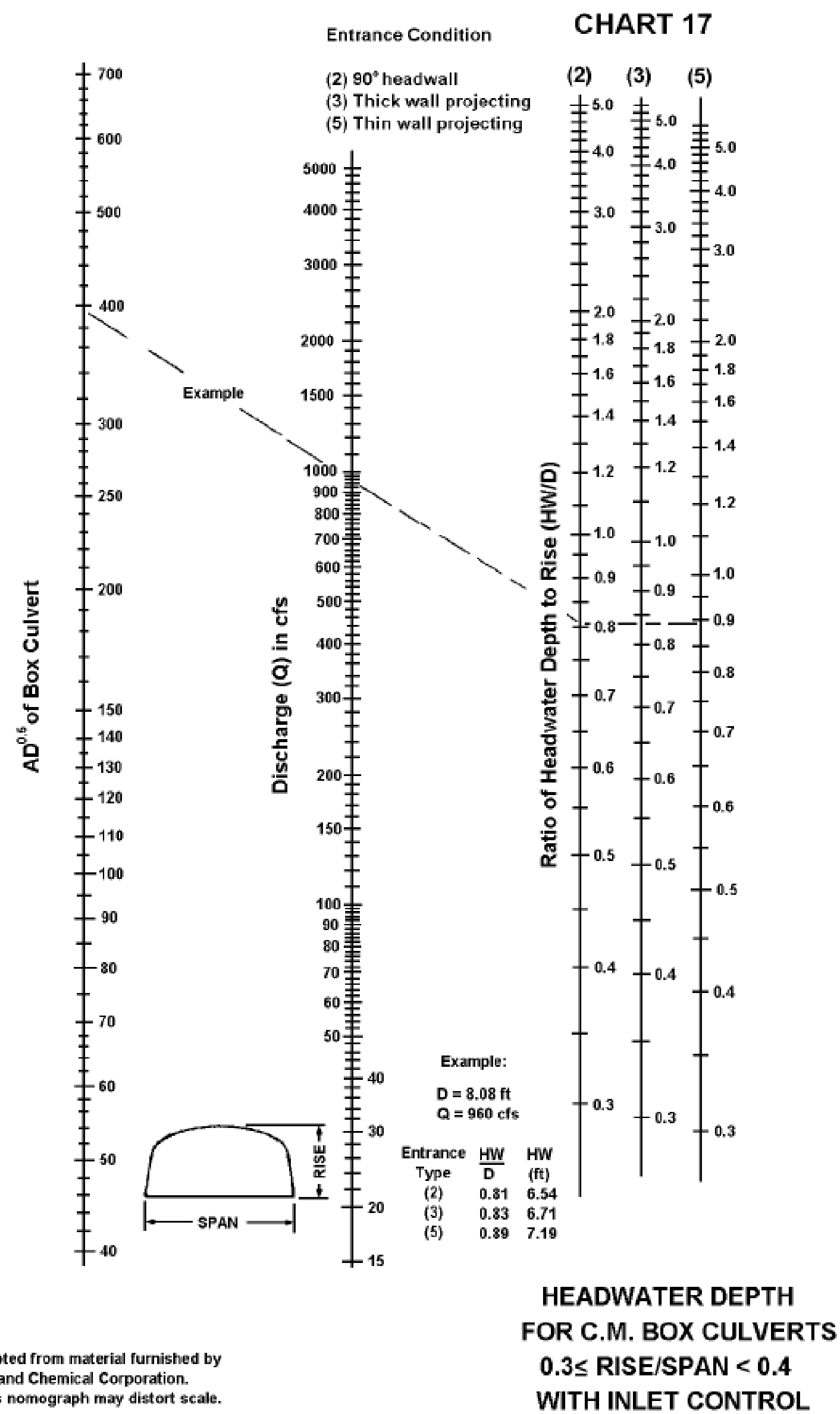


Chart 17 - Headwater Depth for C.M. Box Culverts 0.3 ≤ Rise/Span < 0.4 with Inlet Control



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation. Duplication of this nomograph may distort scale.

Chart 18 - Headwater Depth for C.M. Box Culverts 0.4 ≤ Rise/Span < 0.5 with Inlet Control

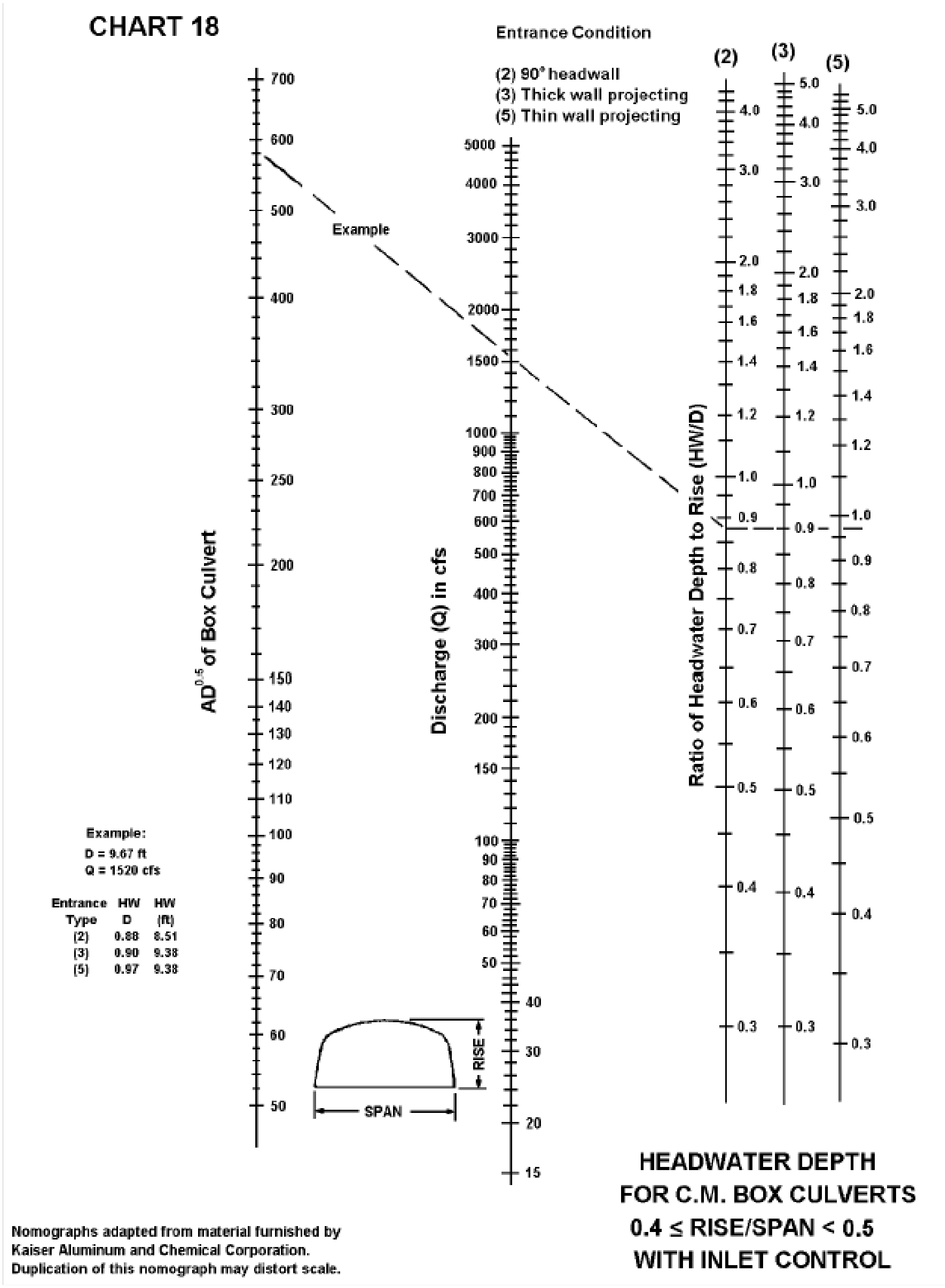


Chart 19 - Headwater Depth for C.M. Box Culverts 0.5 ≤ Rise/Span with Inlet Control

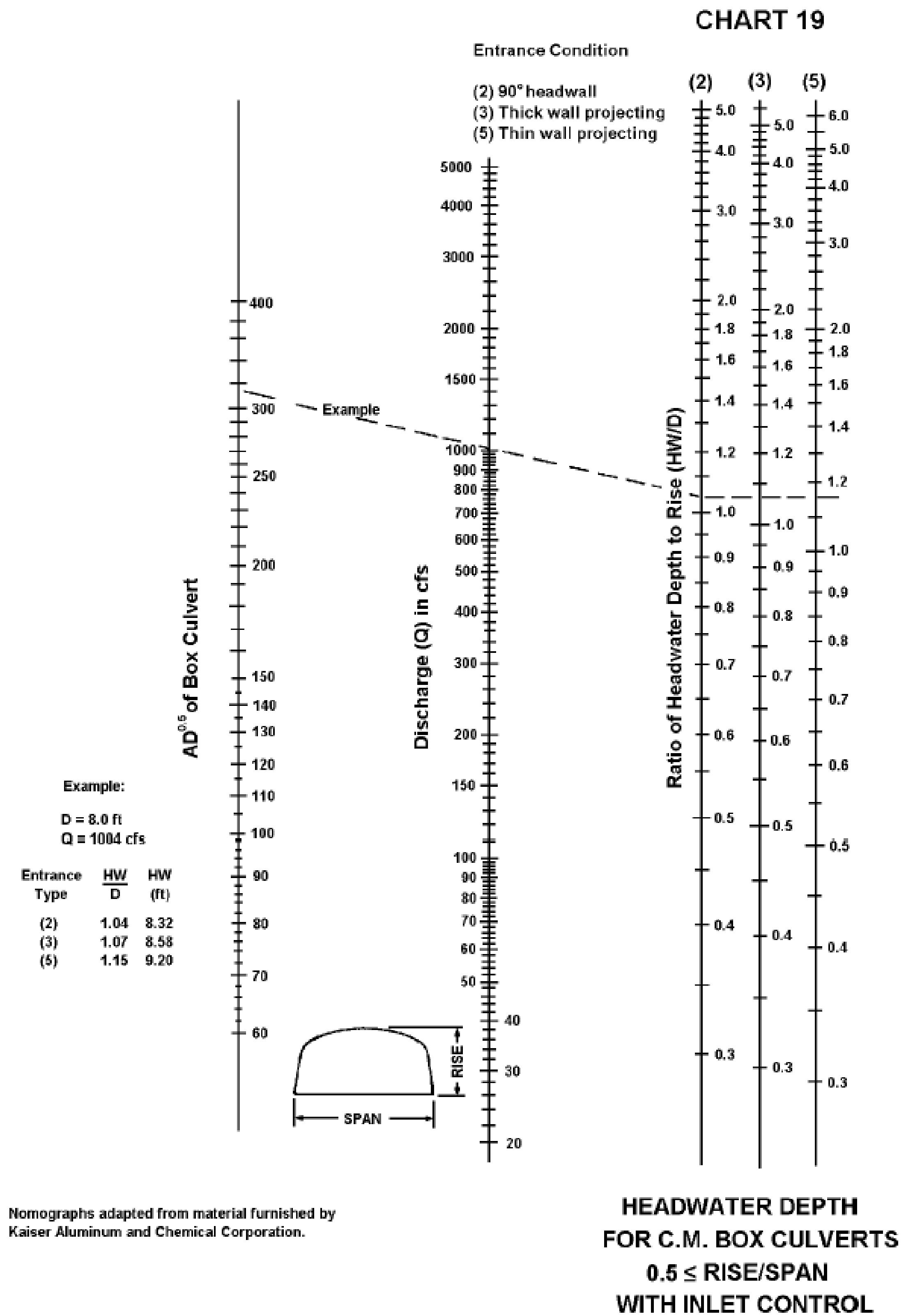


Chart 20 - Dimensionless Critical Depth Chart for C.M. Box Culverts

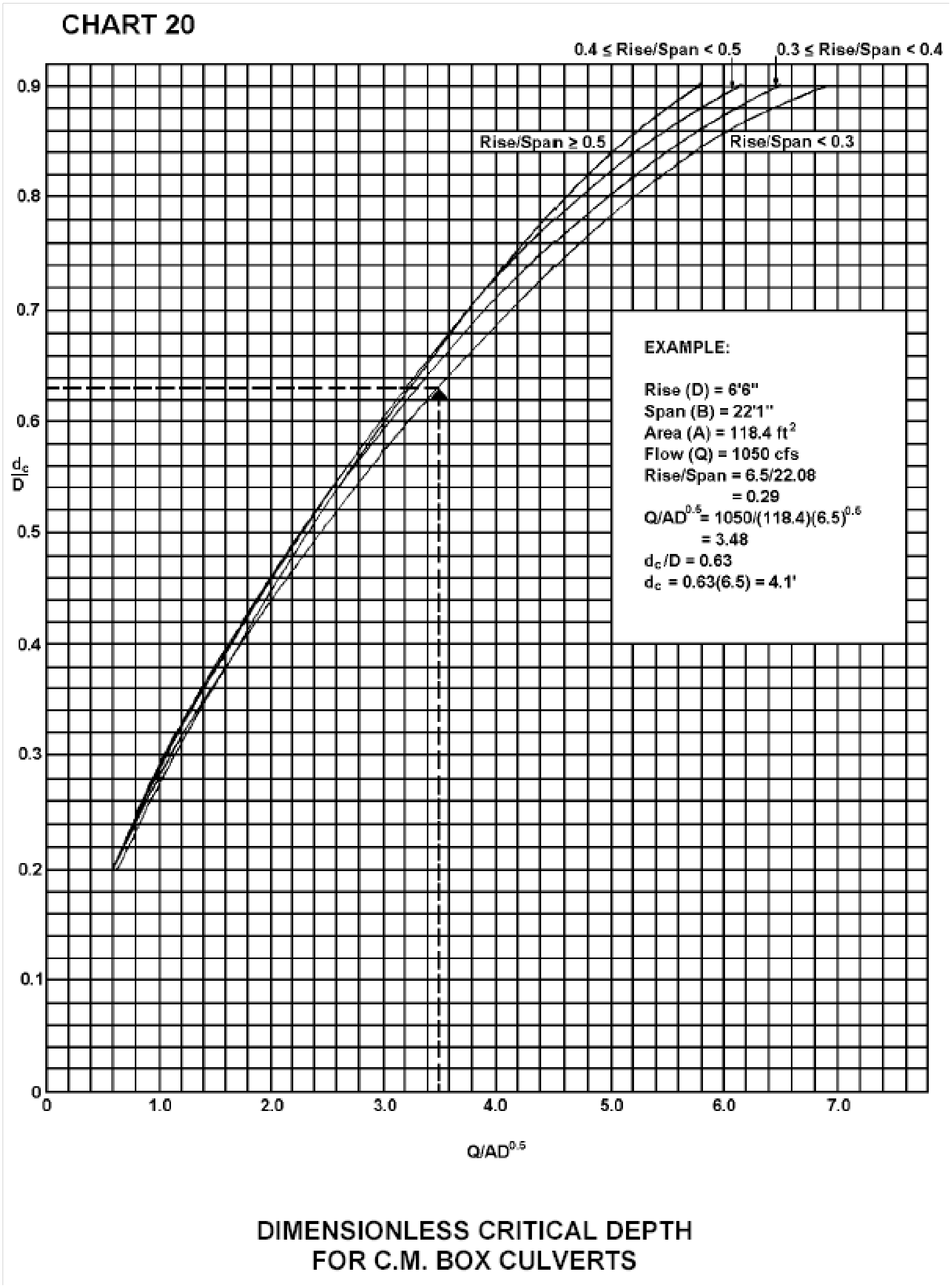


Chart 21 - Head for C.M. Box Culverts Flowing Full Concrete Bottom Rise/Span < 0.3

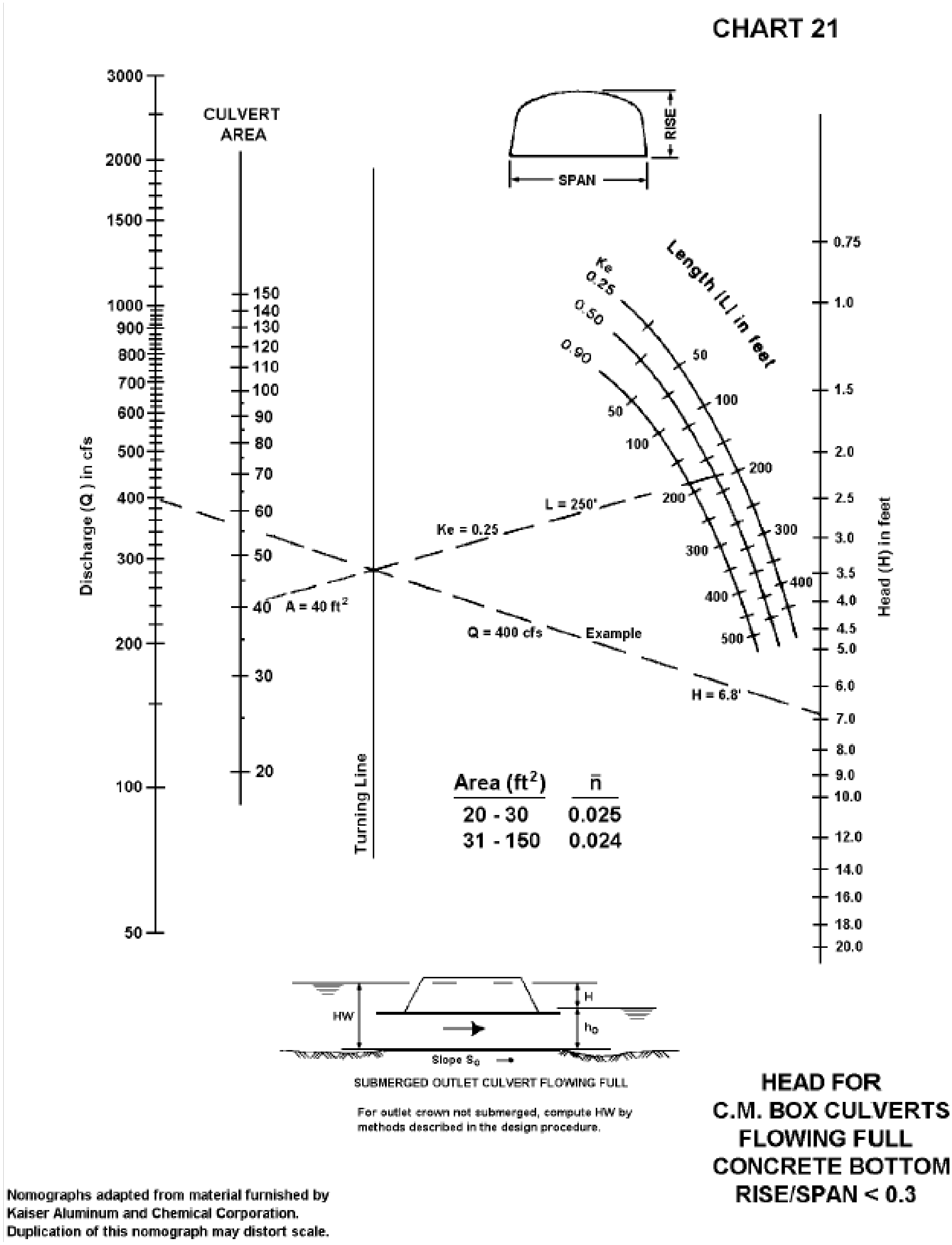


Chart 22 - Head for C.M. Box Culverts Flowing Full Concrete Bottom 0.3 ≤ Rise/Span < 0.4

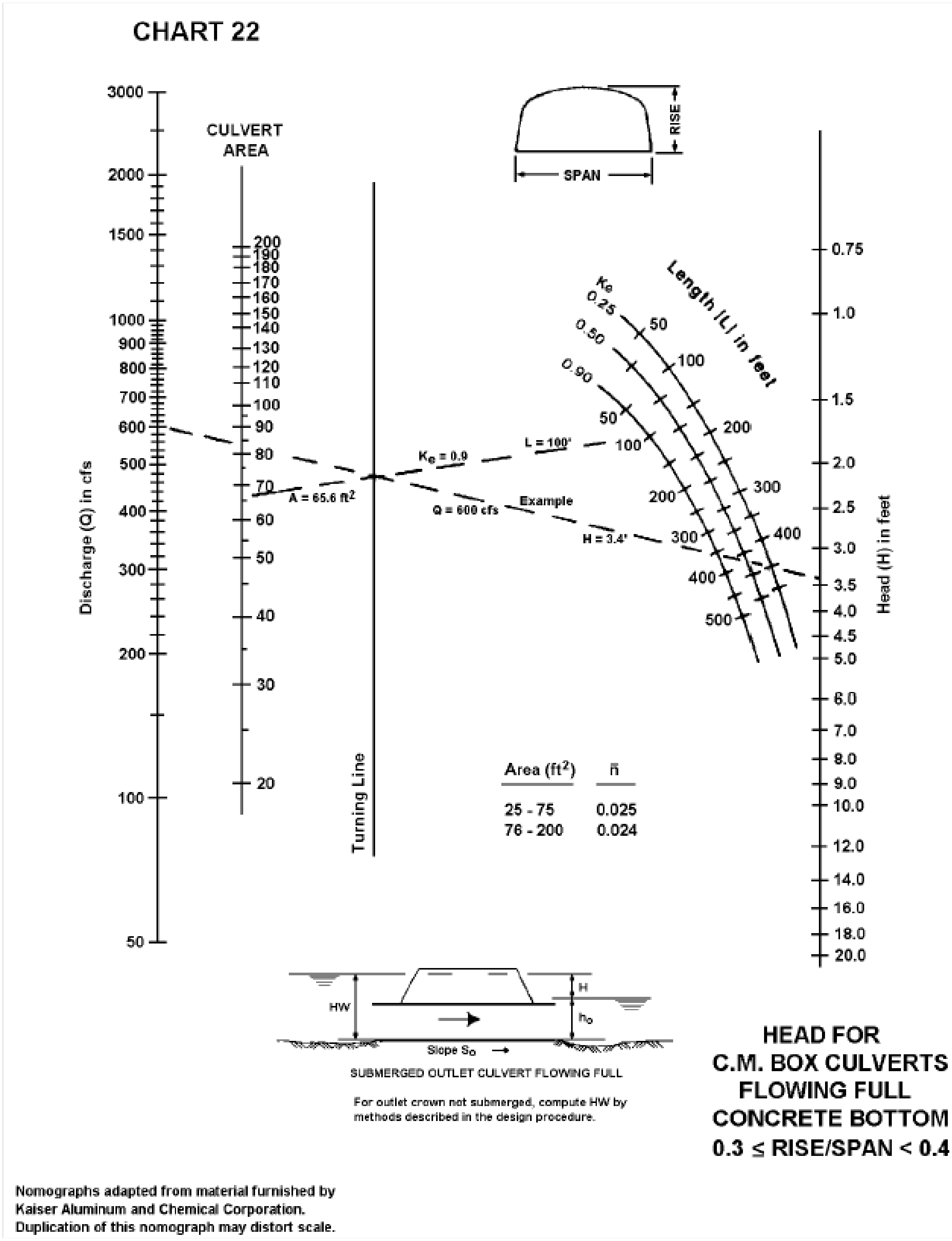


Chart 23 - Head for C.M. Box Culverts Flowing Full Concrete Bottom 0.4 ≤ Rise/Span < 0.5

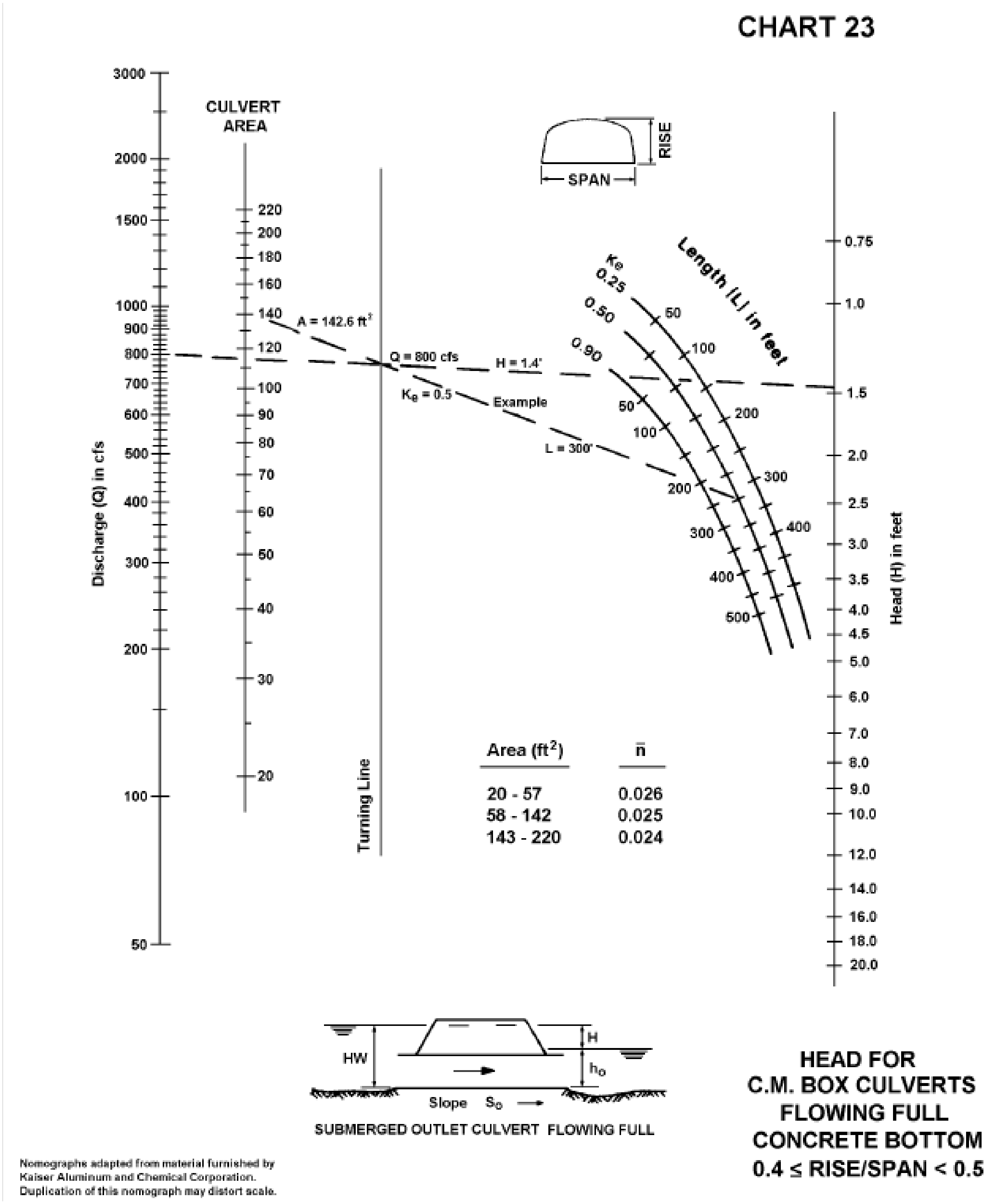


Chart 24 - Head for C.M. Box Culverts Flowing Full Concrete Bottom 0.5 ≤ Rise/Span

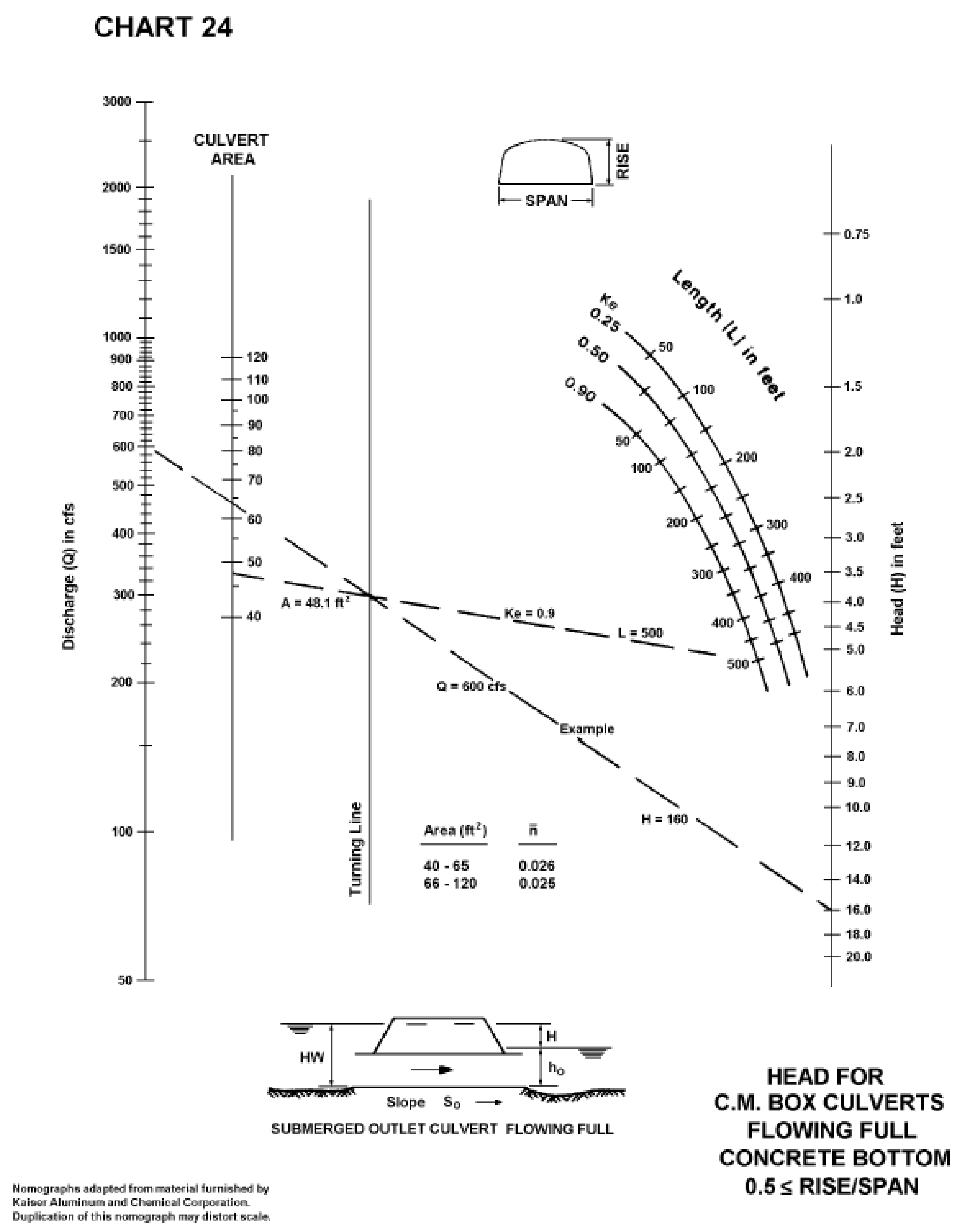


Chart 25 - Head for C.M. Box Culverts Flowing Full Corrugated Metal Bottom 0.3 < Rise/Span

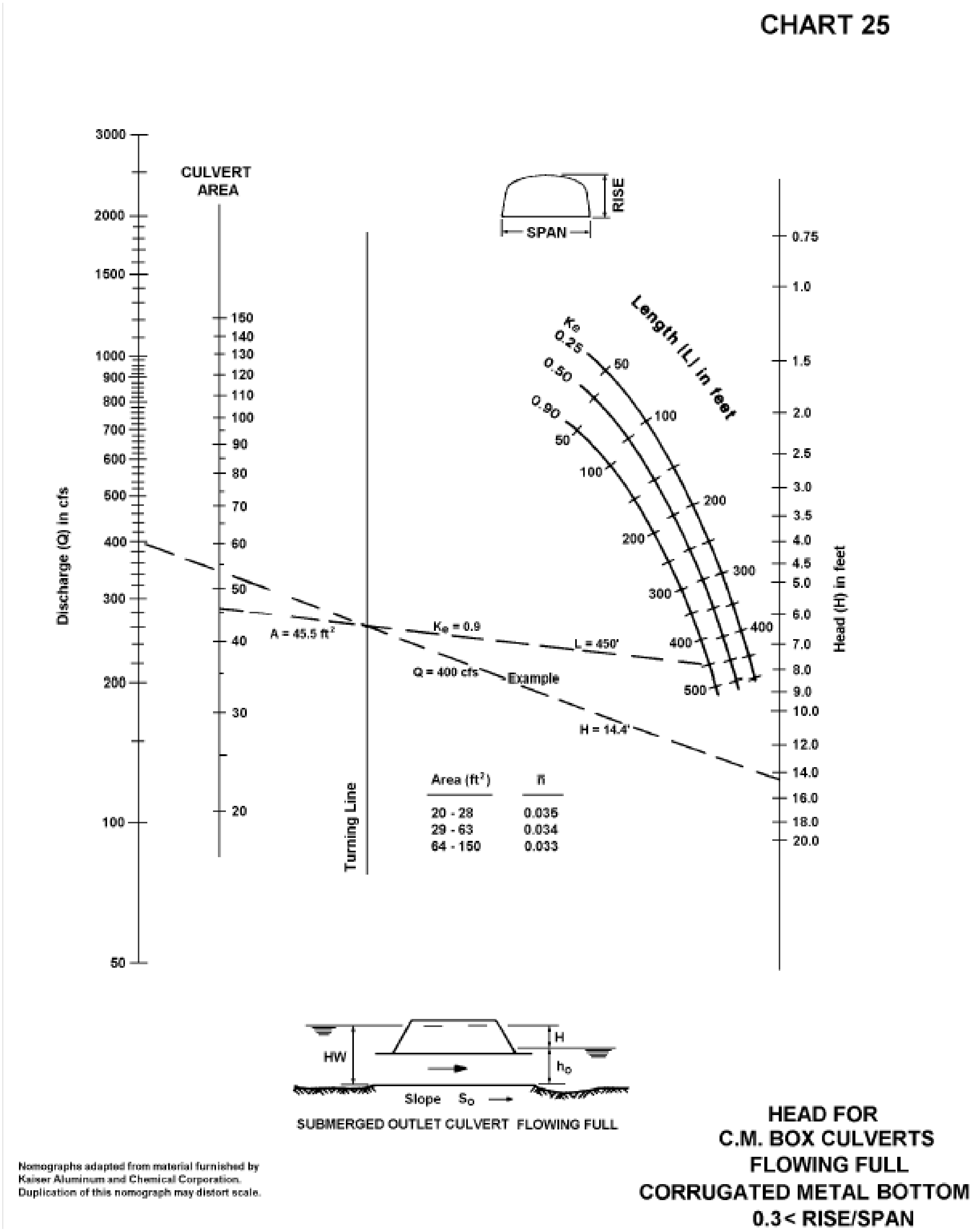
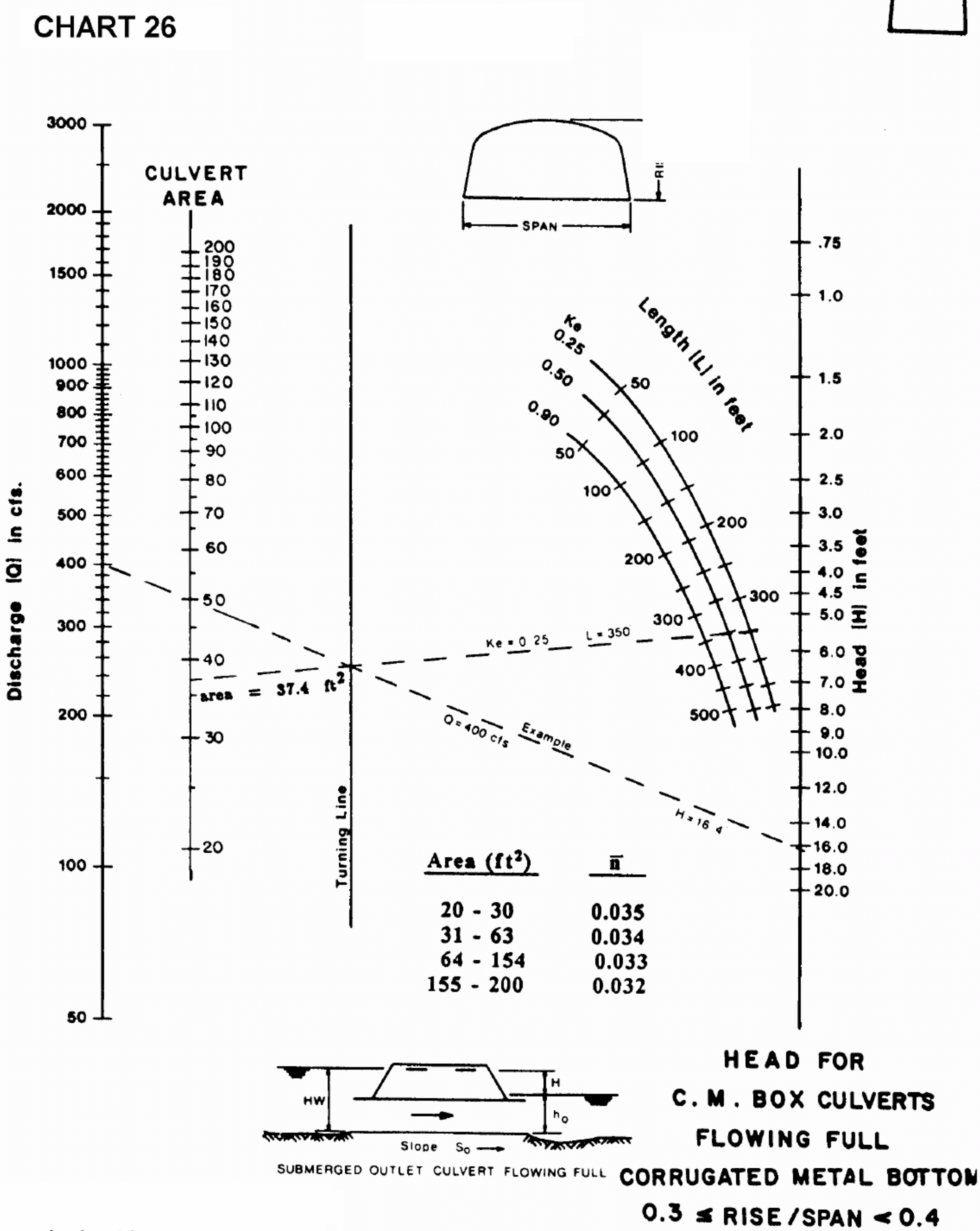


Chart 26 - Head for C.M. Box Culverts Flowing Full Corrugated Metal Bottom 0.3 ≤ Rise/Span < 0.4



Area (ft^2)	$\bar{n}$
20 - 30	0.035
31 - 63	0.034
64 - 154	0.033
155 - 200	0.032

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

Chart 27 - Head for C.M. Box Culverts Flowing Full Corrugated Metal Bottom 0.4 ≤ Rise/Span < 0.5

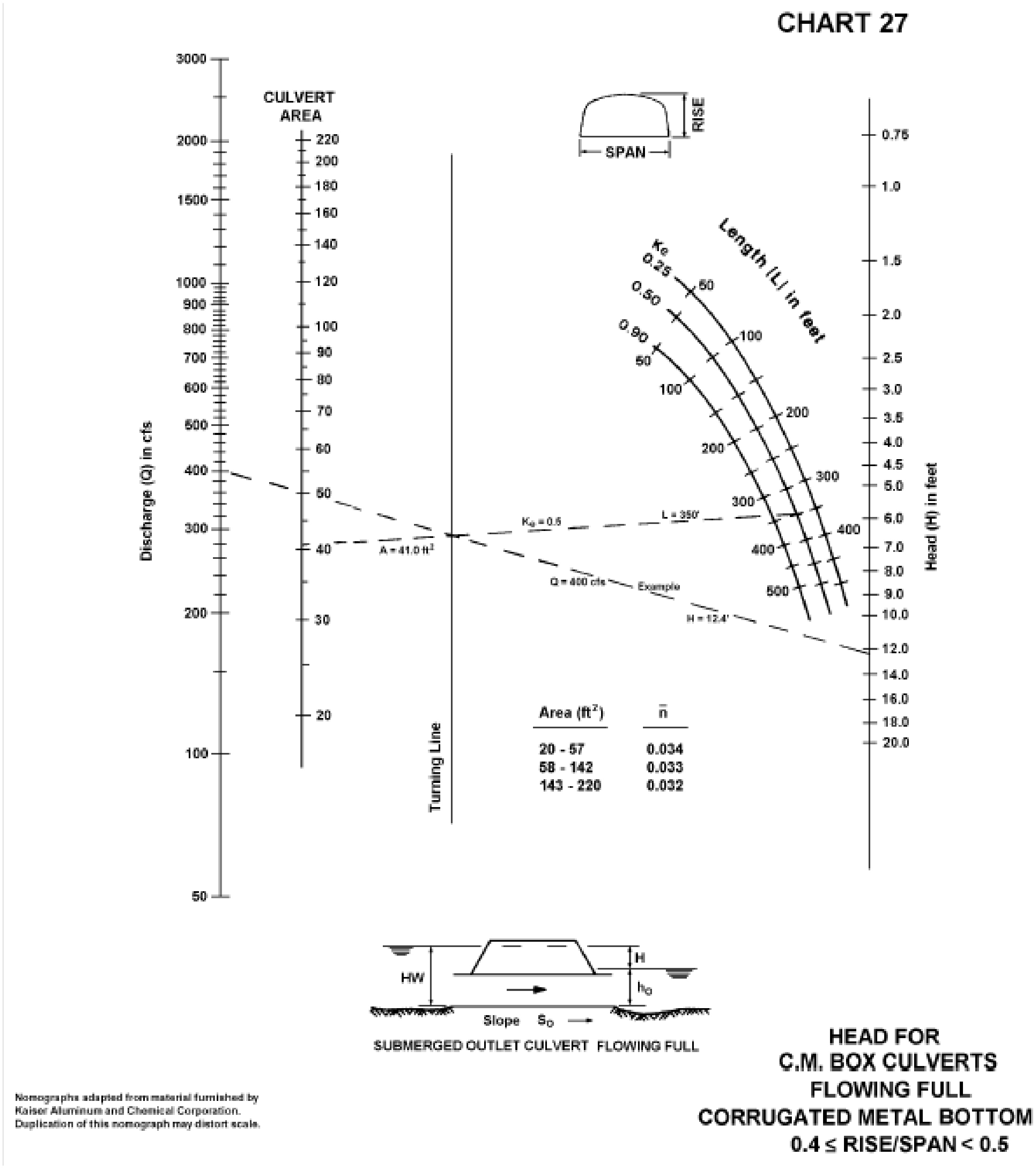


Chart 28 - Head for C.M. Box Culverts Flowing Full Corrugated Metal Bottom 0.5 ≤ Rise/Span

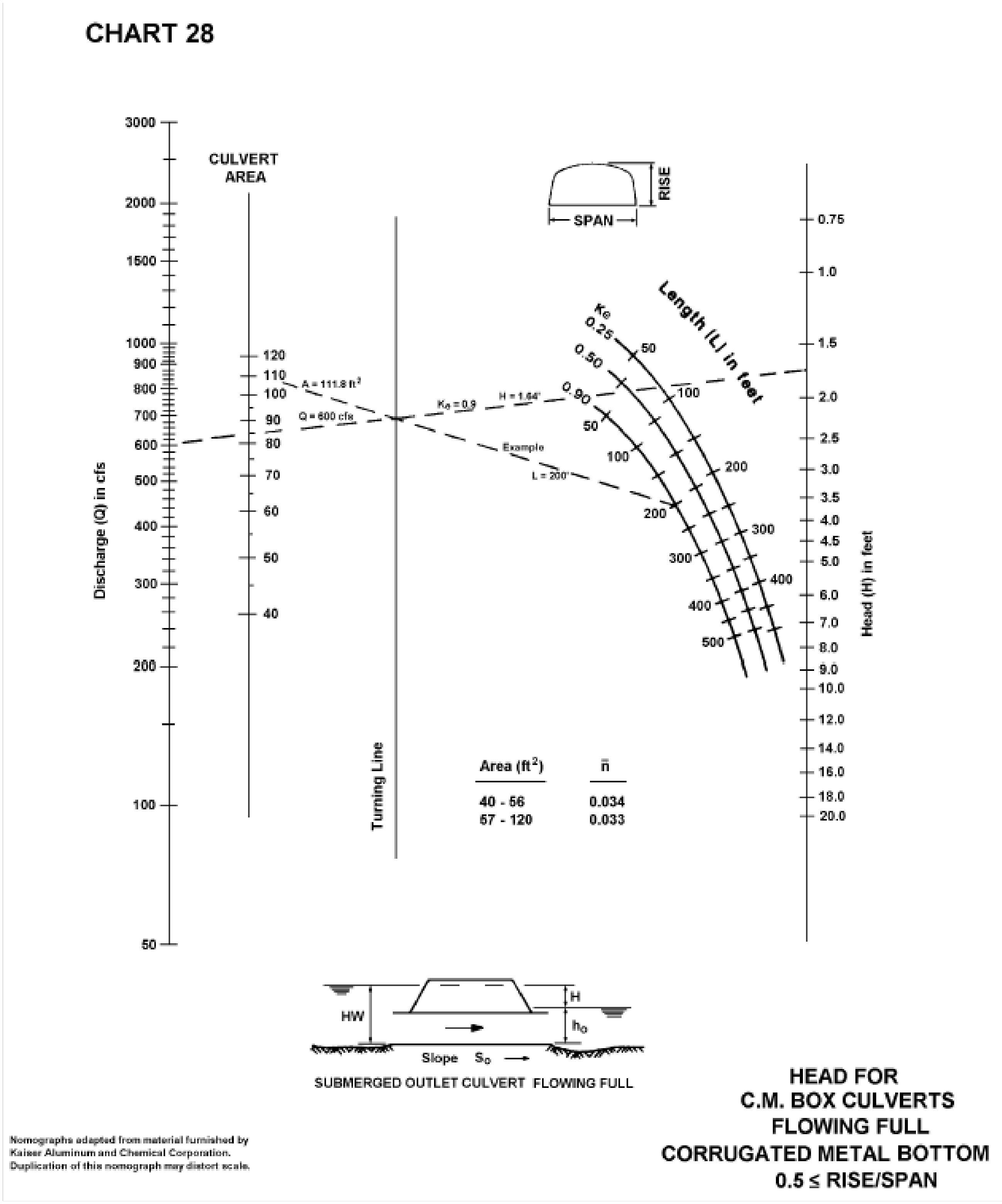


Chart 29 - Headwater Depth for Oval Concrete Pipe Culverts Long Axis Horizontal with Inlet Control

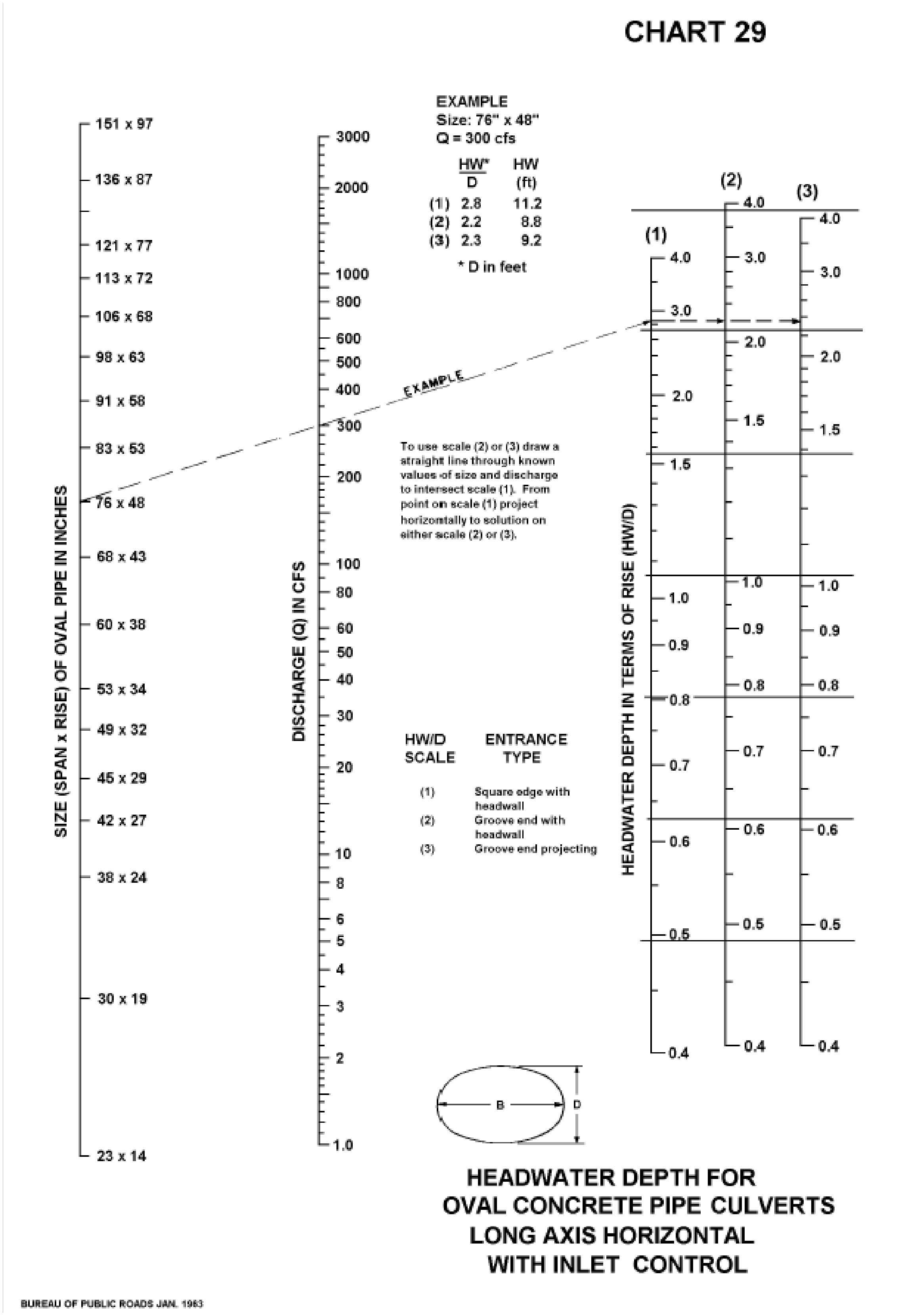


Chart 30 - Headwater Depth for Oval Concrete Pipe Culverts Long Axis Vertical with Inlet Control

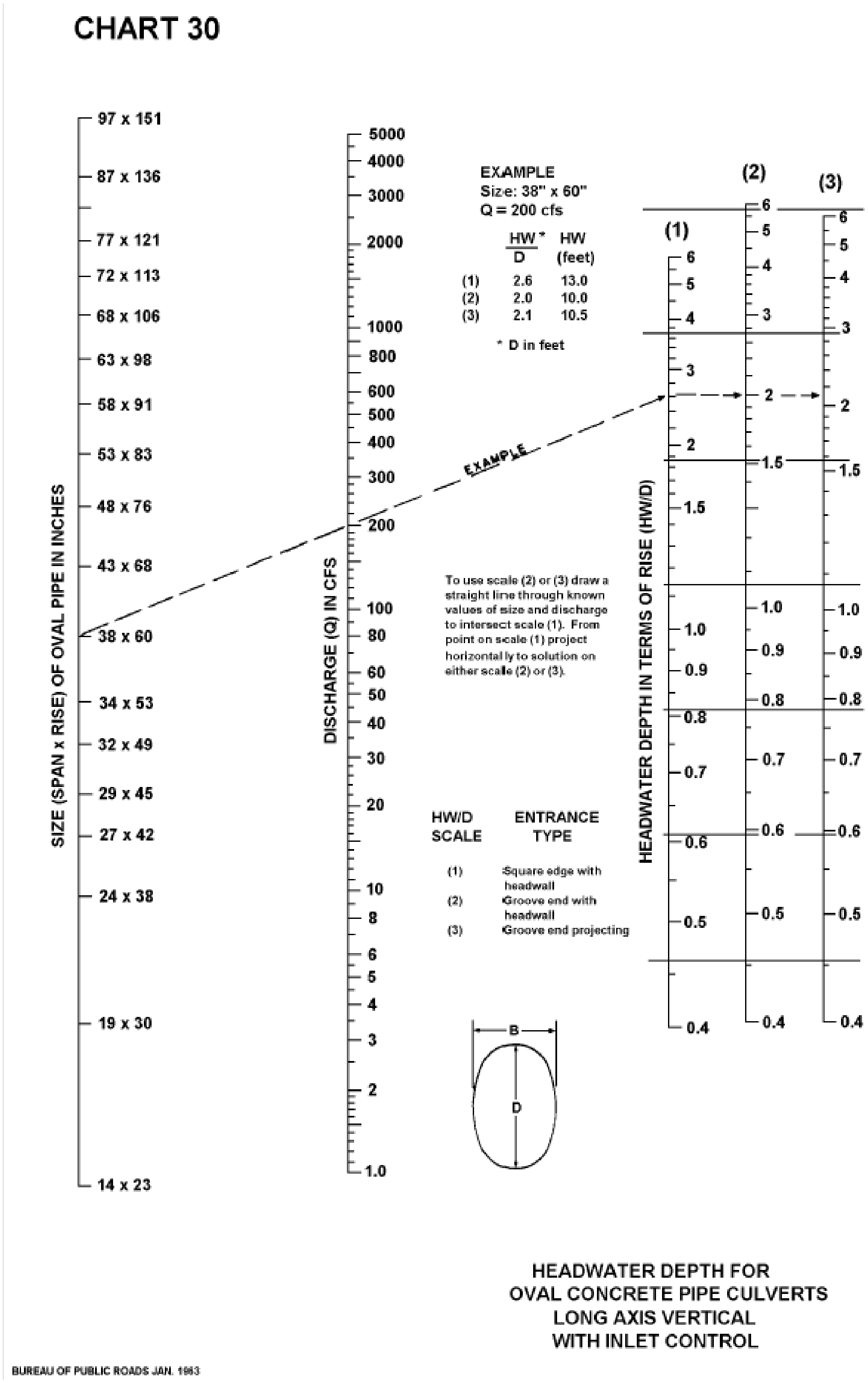


Chart 31 - Critical Depth Oval Concrete Pipe Long Axis Horizontal

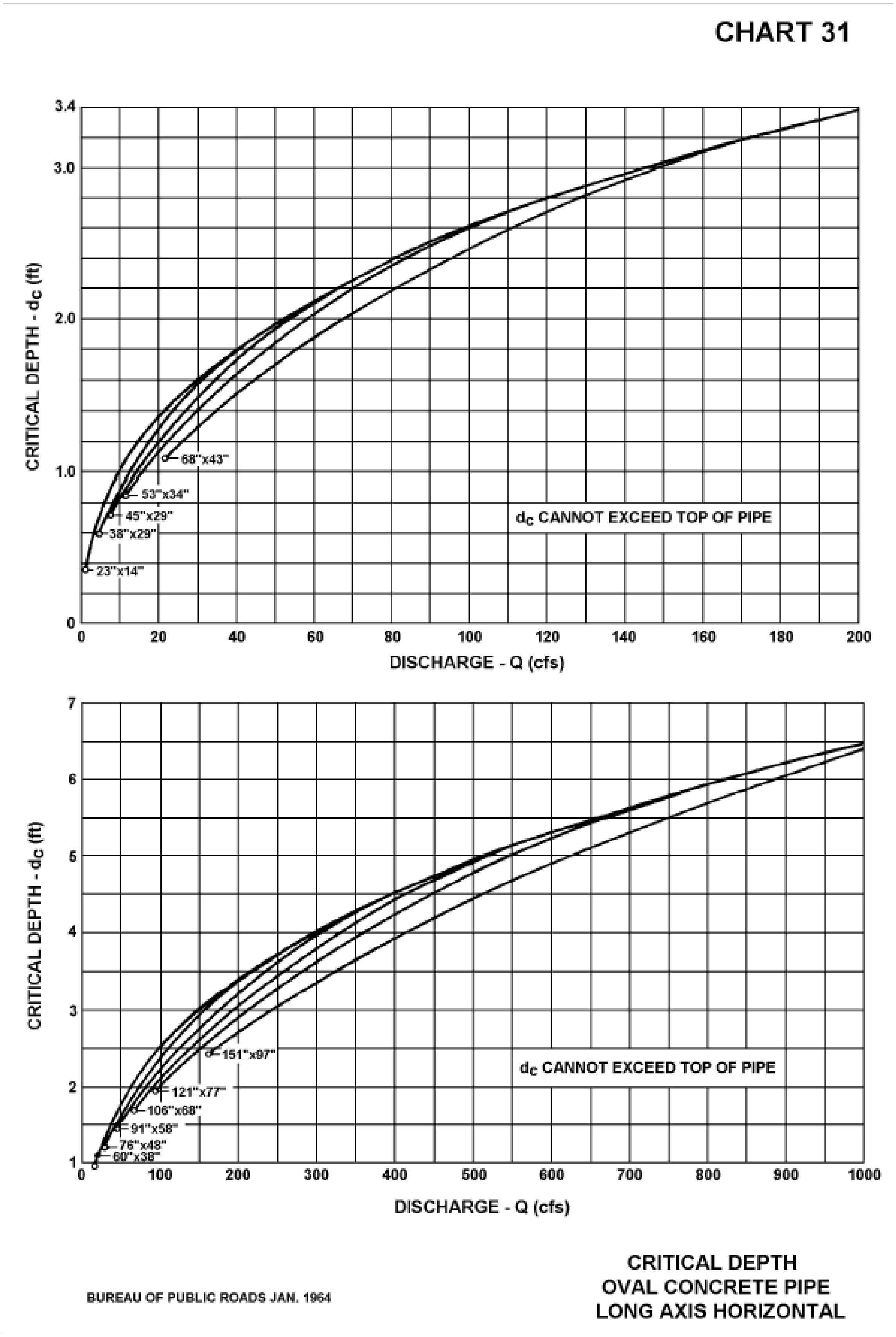


Chart 32 - Critical Depth Oval Concrete Pipe Long Axis Vertical

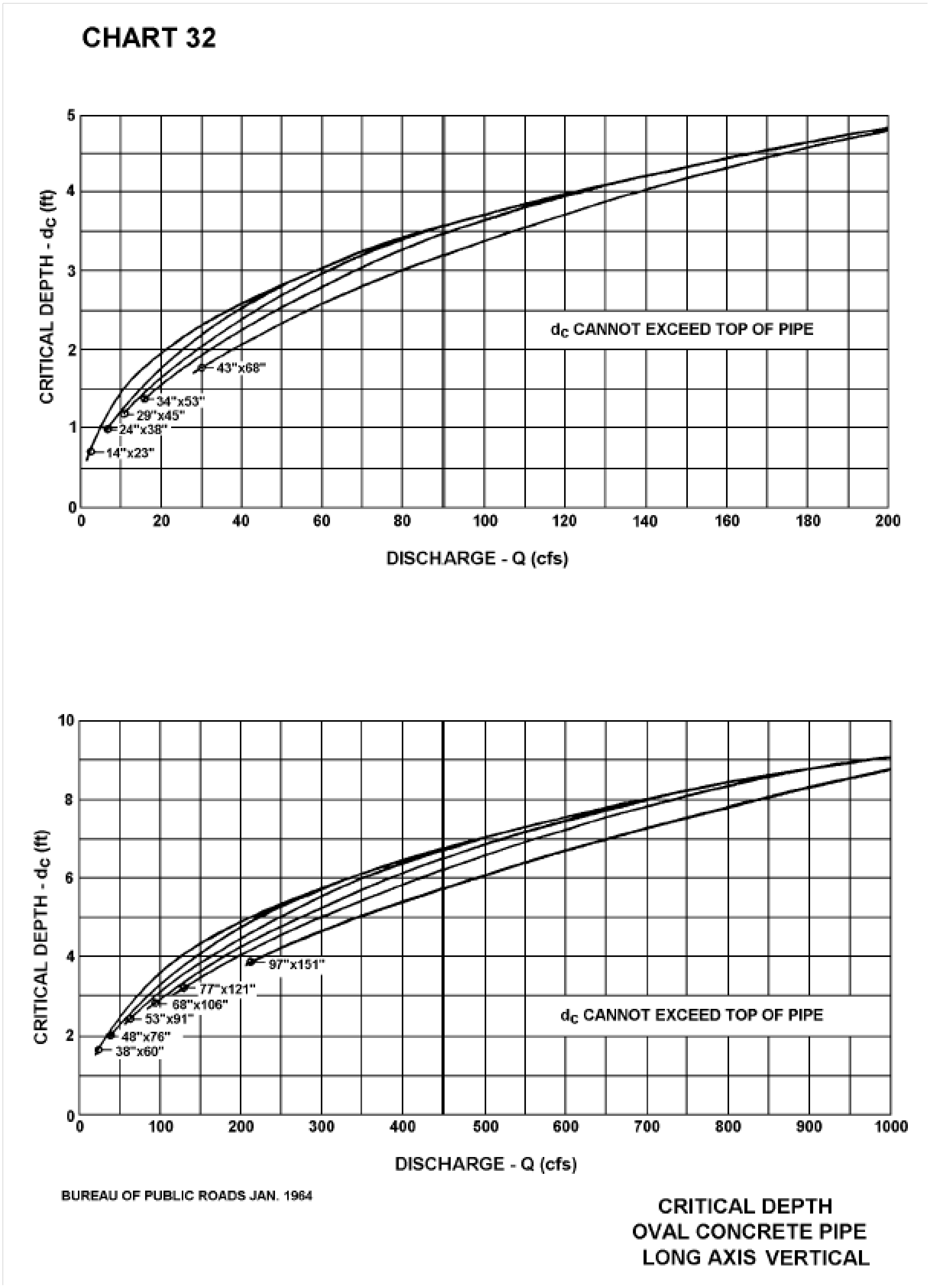


Chart 33 - Head for Oval Concrete Pipe Culverts Long Axis Horizontal or Vertical Flowing Full n = 0.012

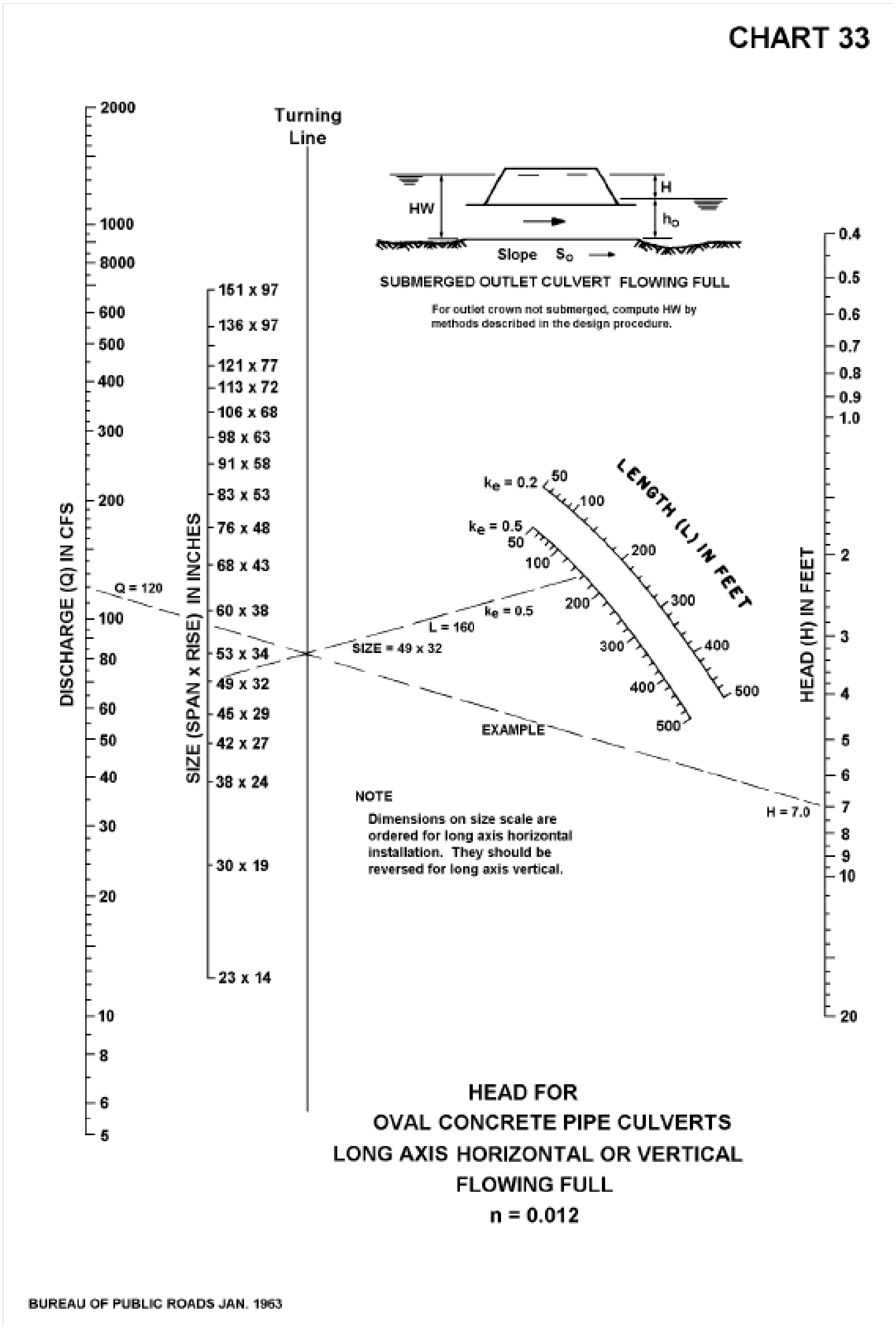


Chart 34 - Headwater Depth for C.M. Pipe-Arch Culverts with Inlet Control

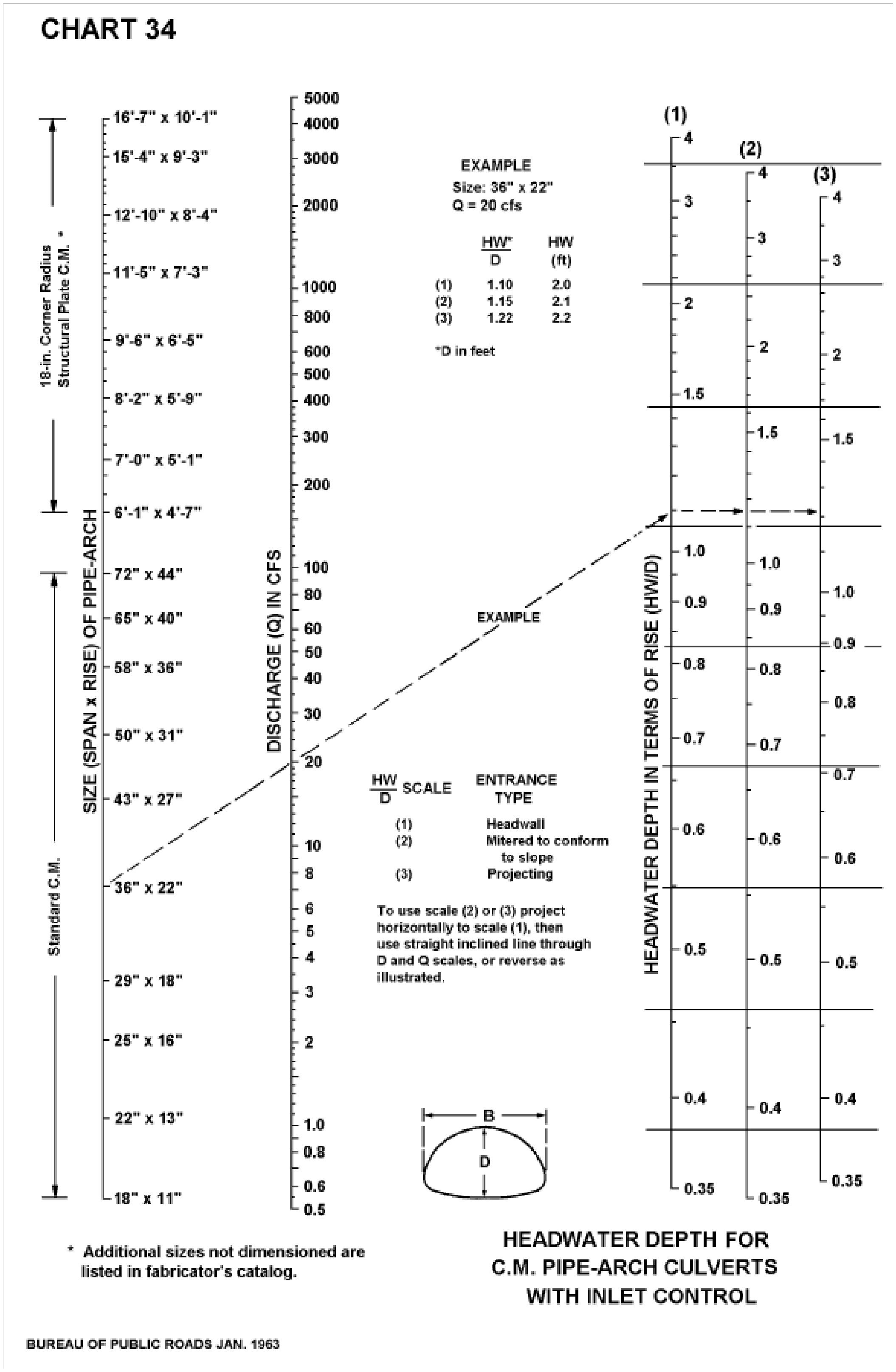


Chart 35 - Headwater Depth for Inlet Controls Structural Plate Pipe-Arch Culverts 18 in. Radius Corner Plate Projecting or Headwall Inlet Headwall with or without Edge Bevel

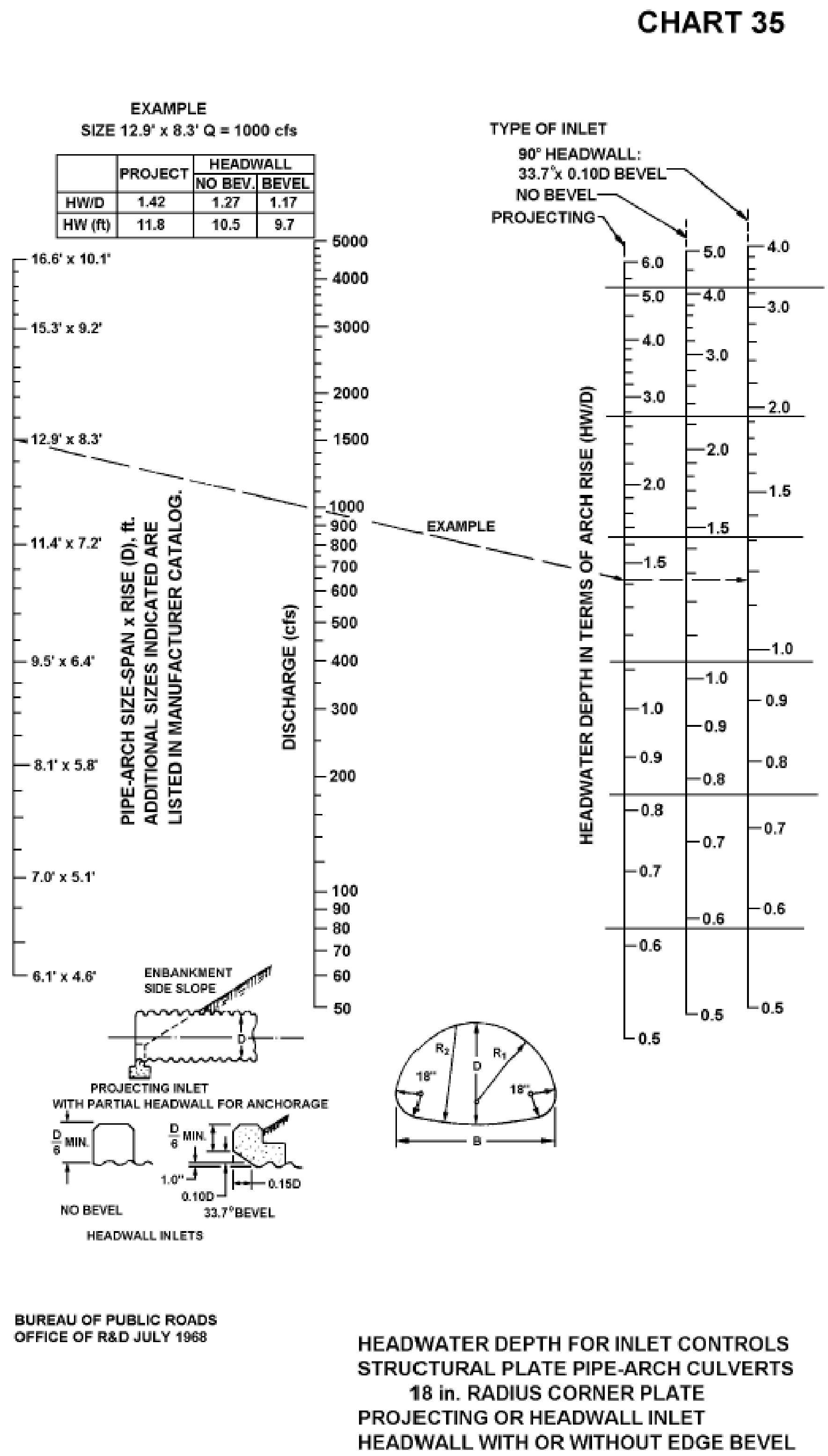
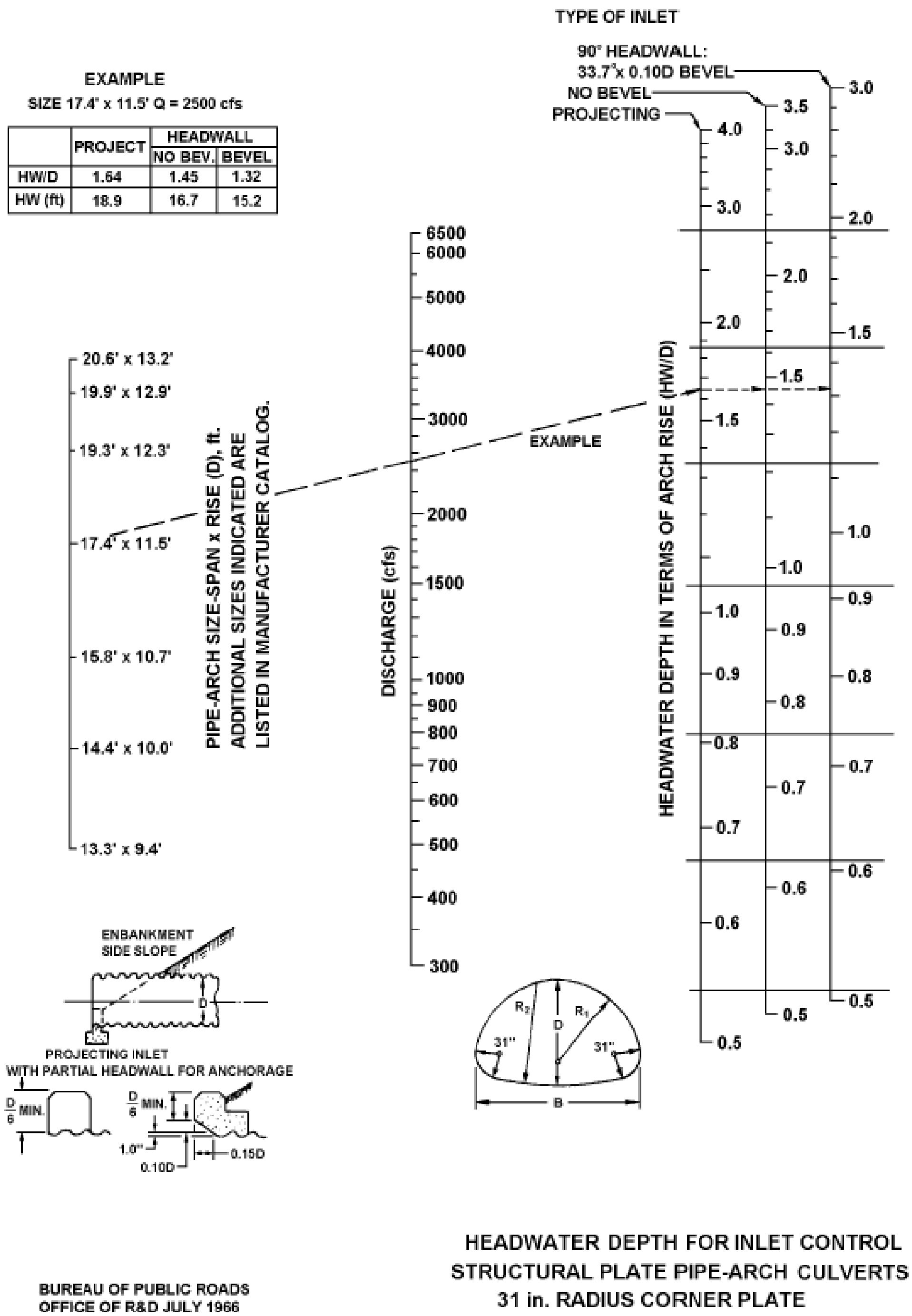


Chart 36 - Headwater Depth for Inlet Control Structural Plate Pipe-Arch Culverts 31 in. Radius Corner Plate Projecting or Headwall Inlet Headwall with or without Edge Bevel

CHART 36



HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS
31 in. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

Chart 37 - Critical Depth Standard C.M. Pipe Arch

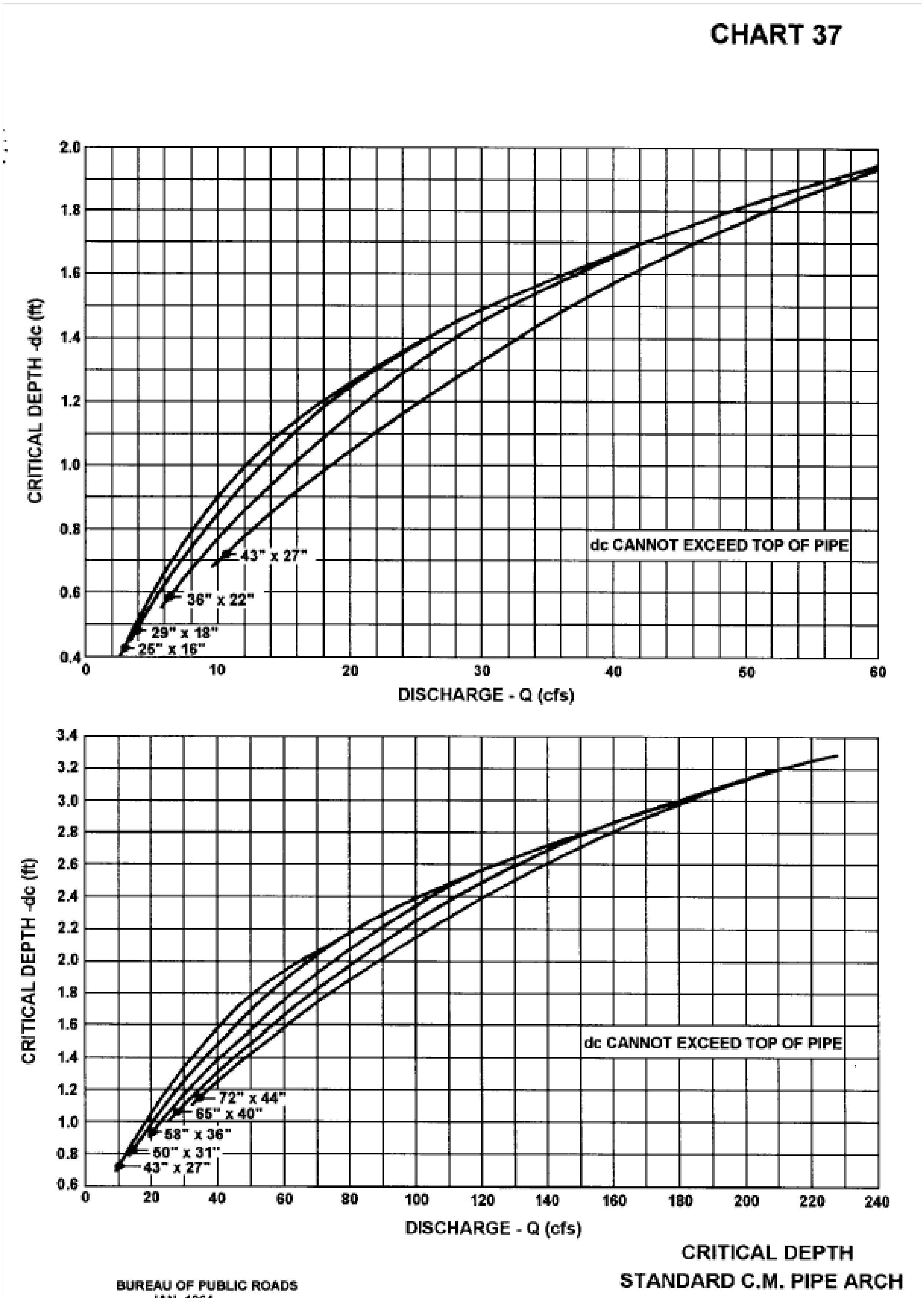


Chart 38 - Critical Depth Structural Plate C.M. Pipe Arch 18 in. Corner Radius

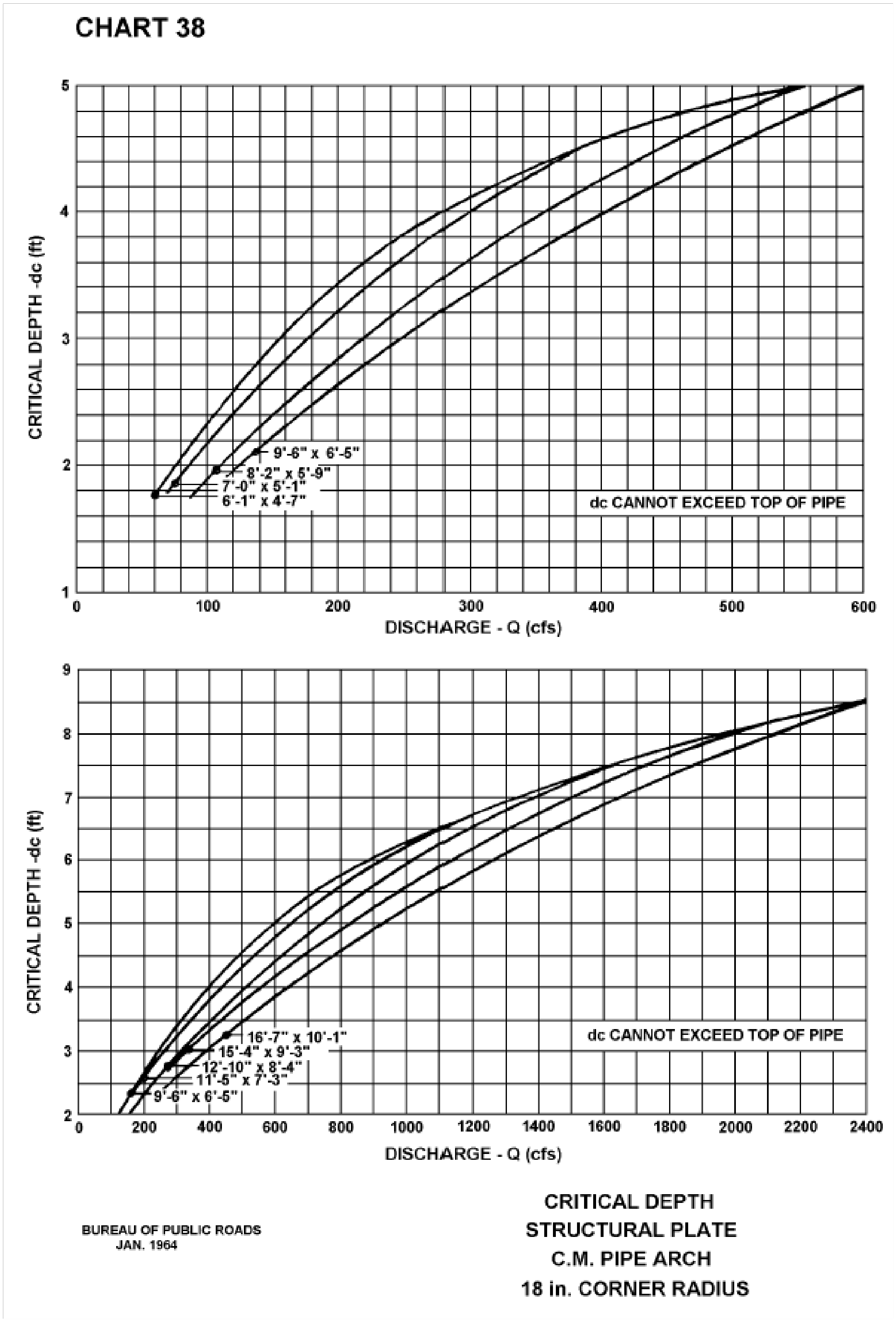
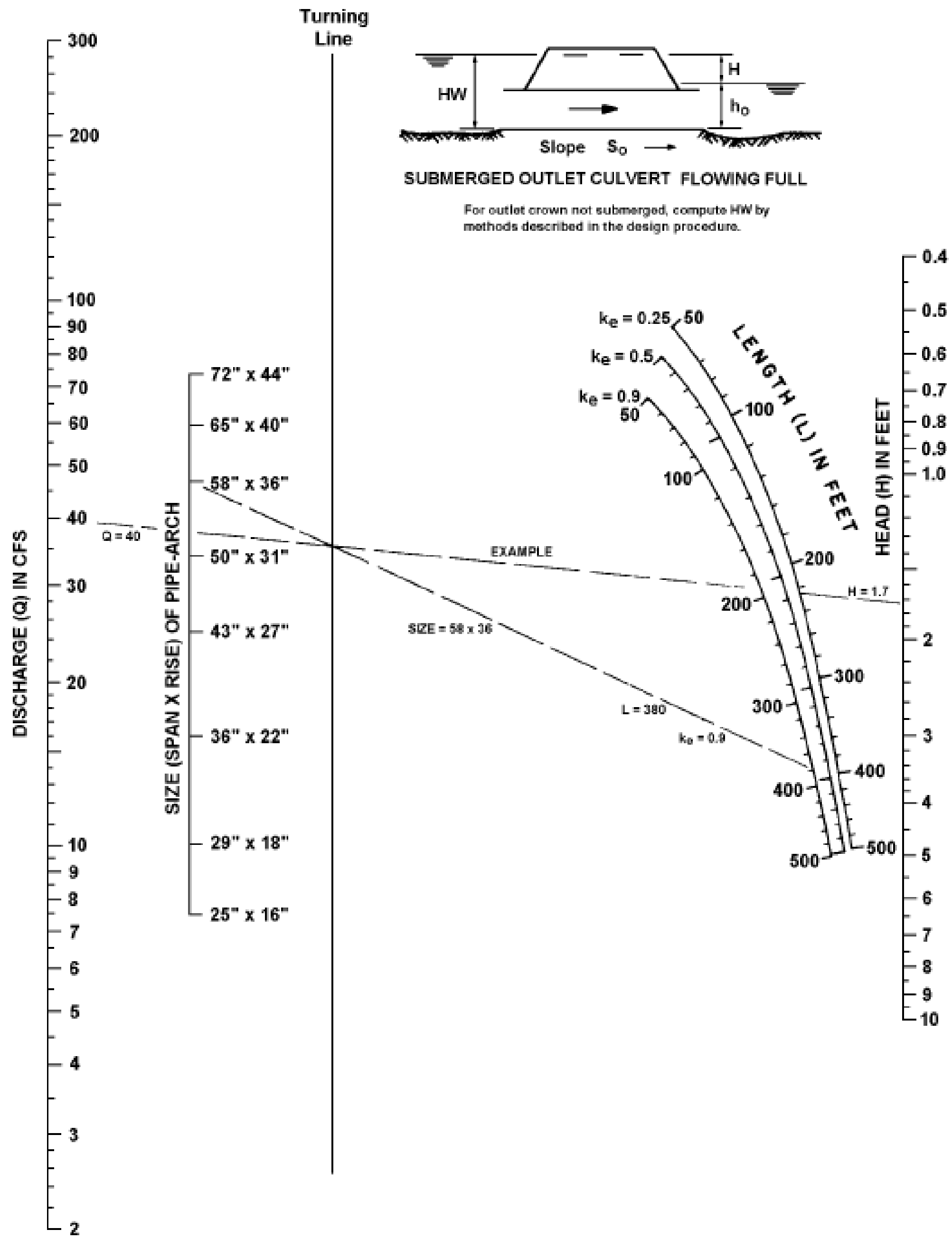


Chart 39 - Head for Standard C.M. Pipe-Arch Culverts Flowing Full n = 0.024

CHART 39



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HEAD FOR STANDARD C.M. PIPE-ARCH CULVERTS FLOWING FULL
n = 0.024

Chart 40 - Head for Structural Plate C.M. Pipe Arch Culverts 18 in. Corner Radius Flowing Full n = 0.0327 to 0.0306

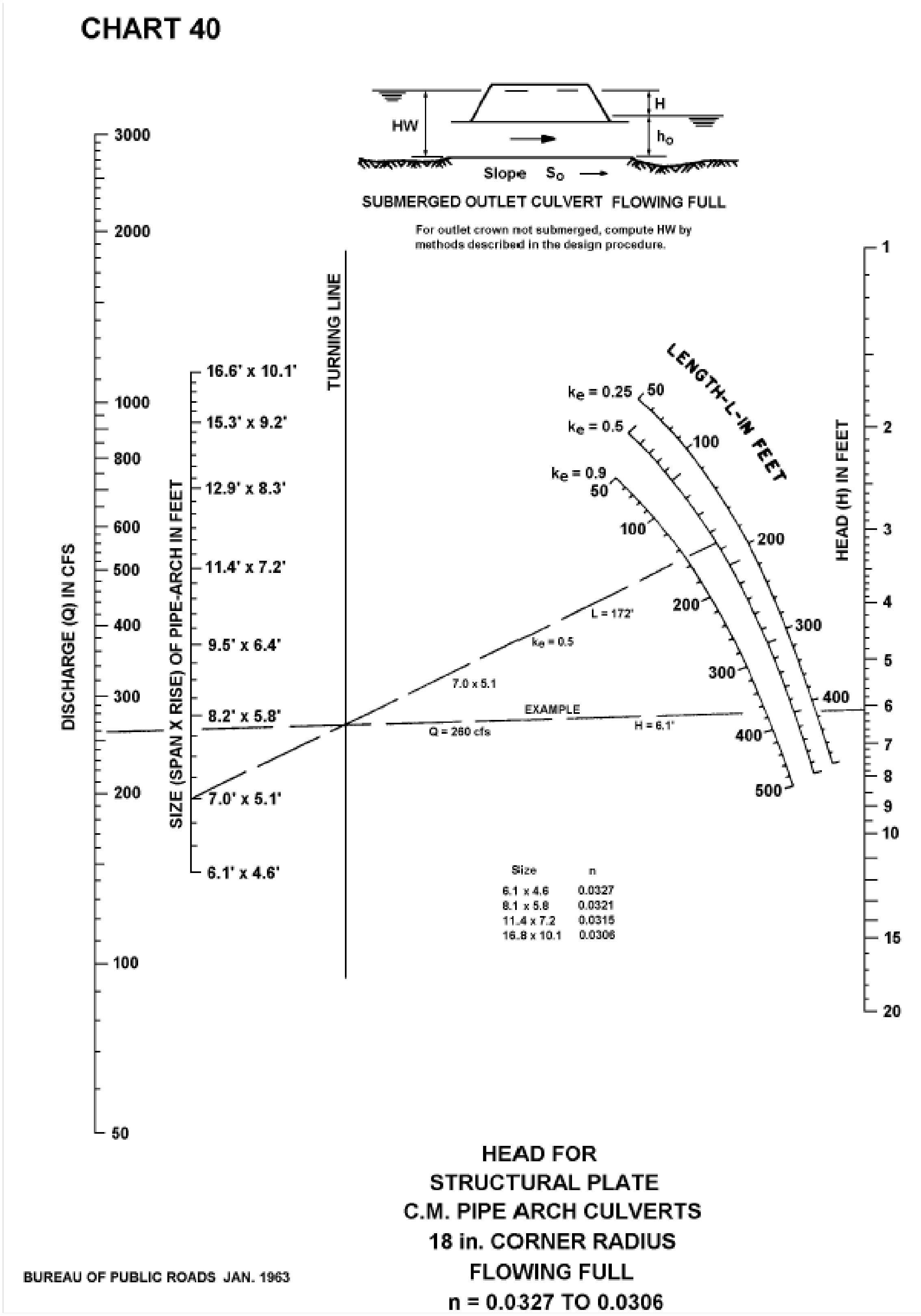


Chart 41 - Headwater Depth for C.M. Arch Culverts 0.3 ≤ Rise/Span < 0.4 with Inlet Control

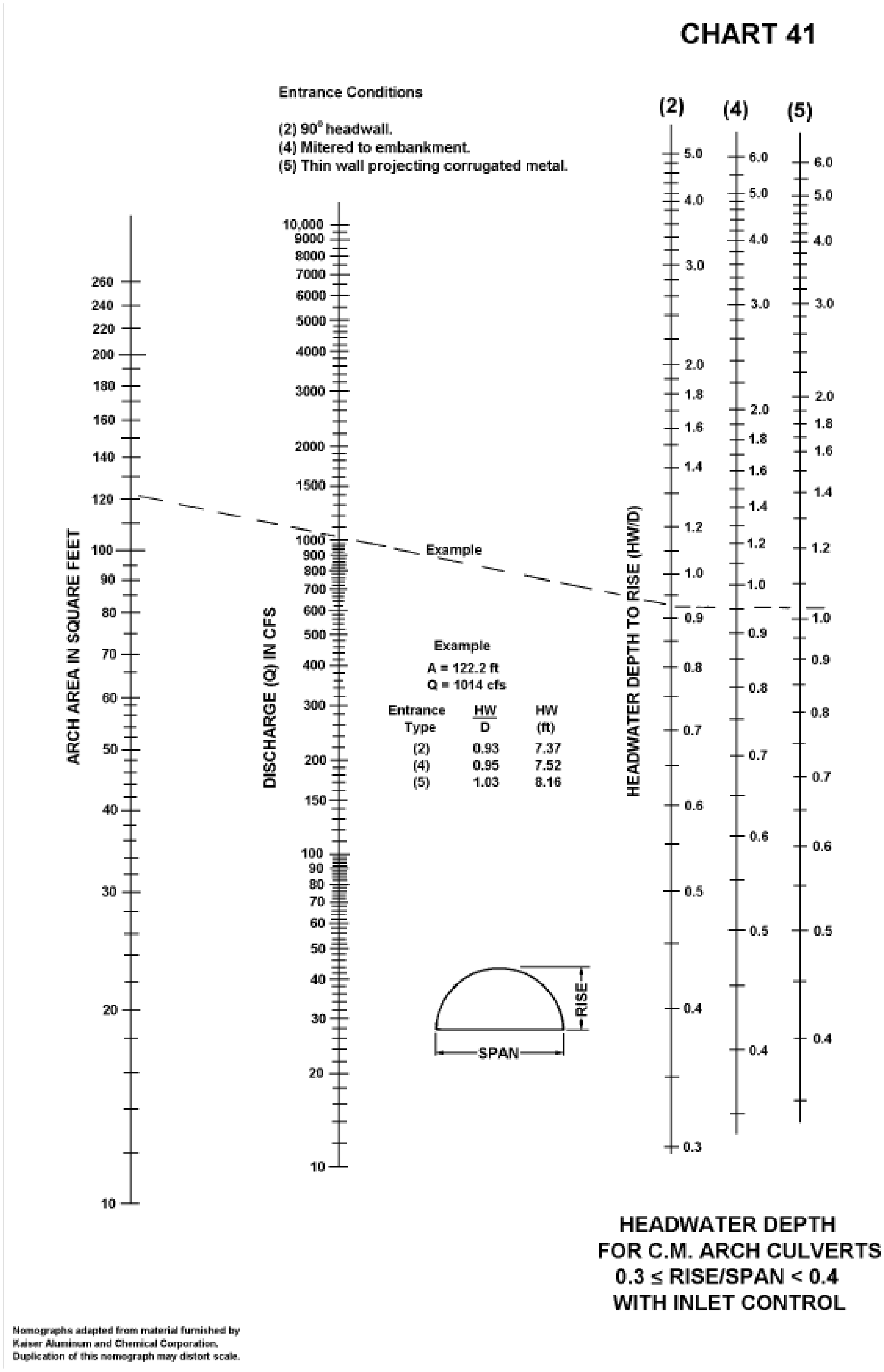


Chart 42 - Headwater Depth for C.M. Arch Culverts 0.4 ≤ Rise/Span < 0.5 with Inlet Control

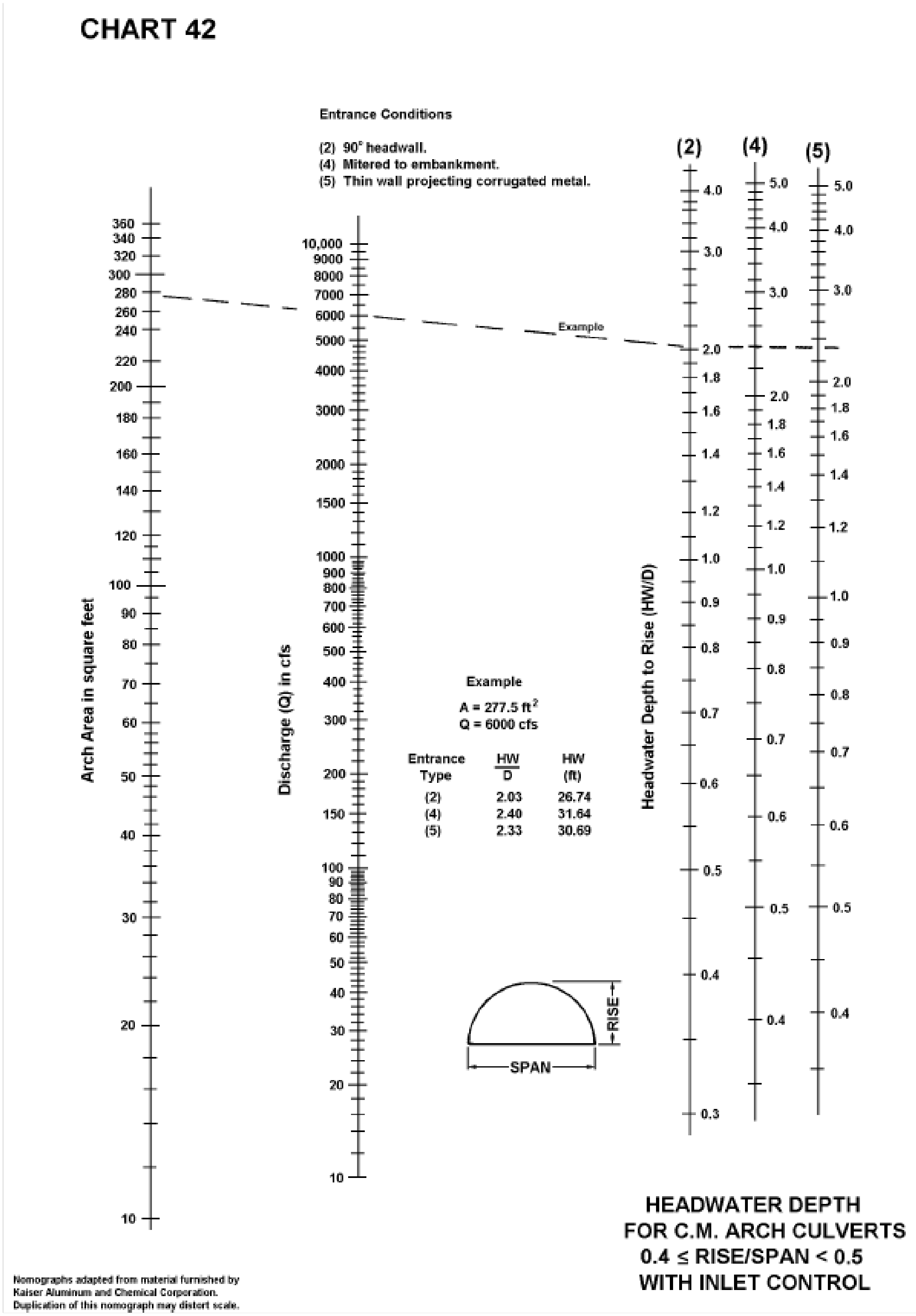


Chart 43 - Headwater Depth for C.M. Arch Culverts 0.5 ≤ Rise/Span with Inlet Control

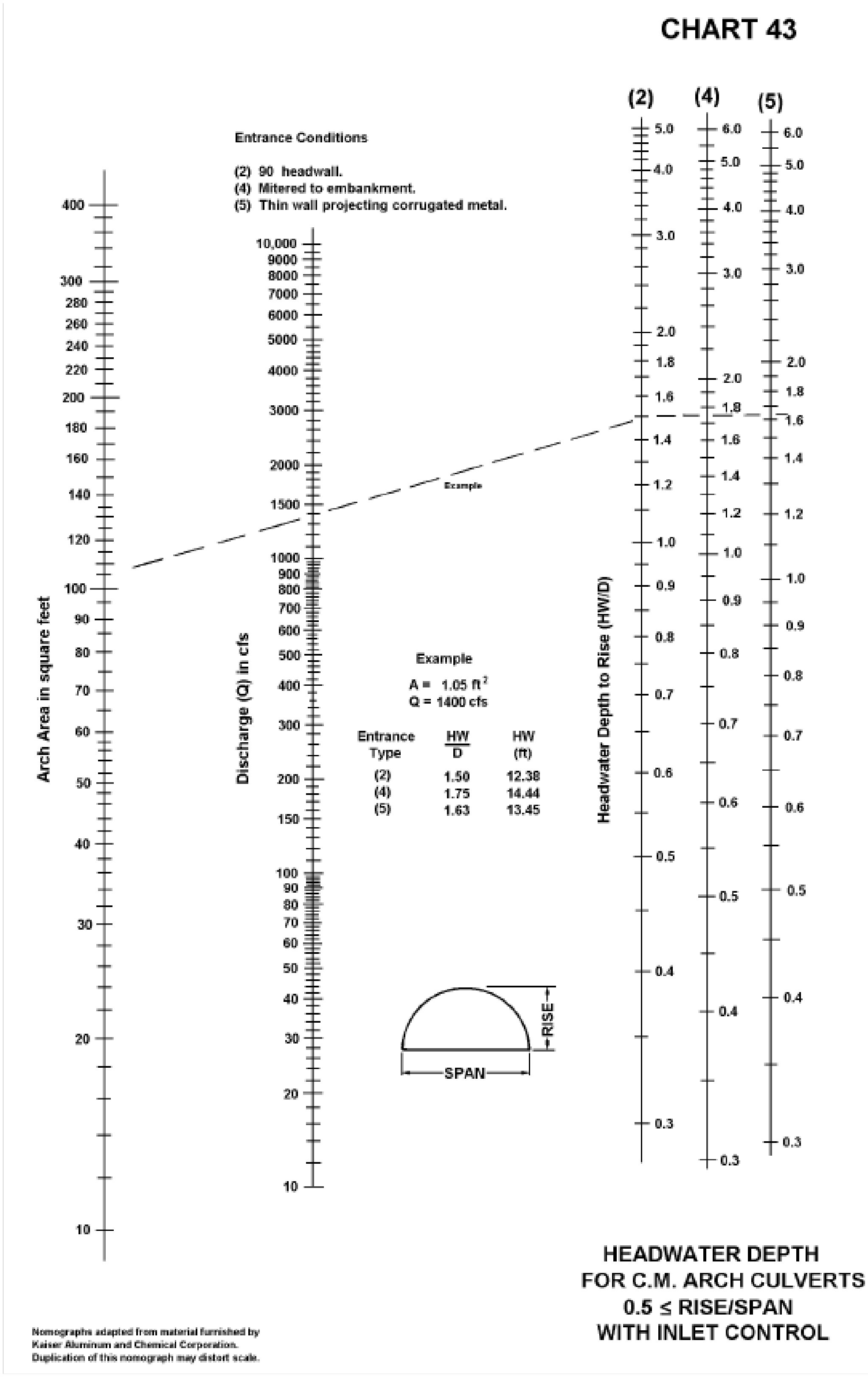


Chart 44 - Dimensionless Critical Depth Chart for C.M. Arch Culverts

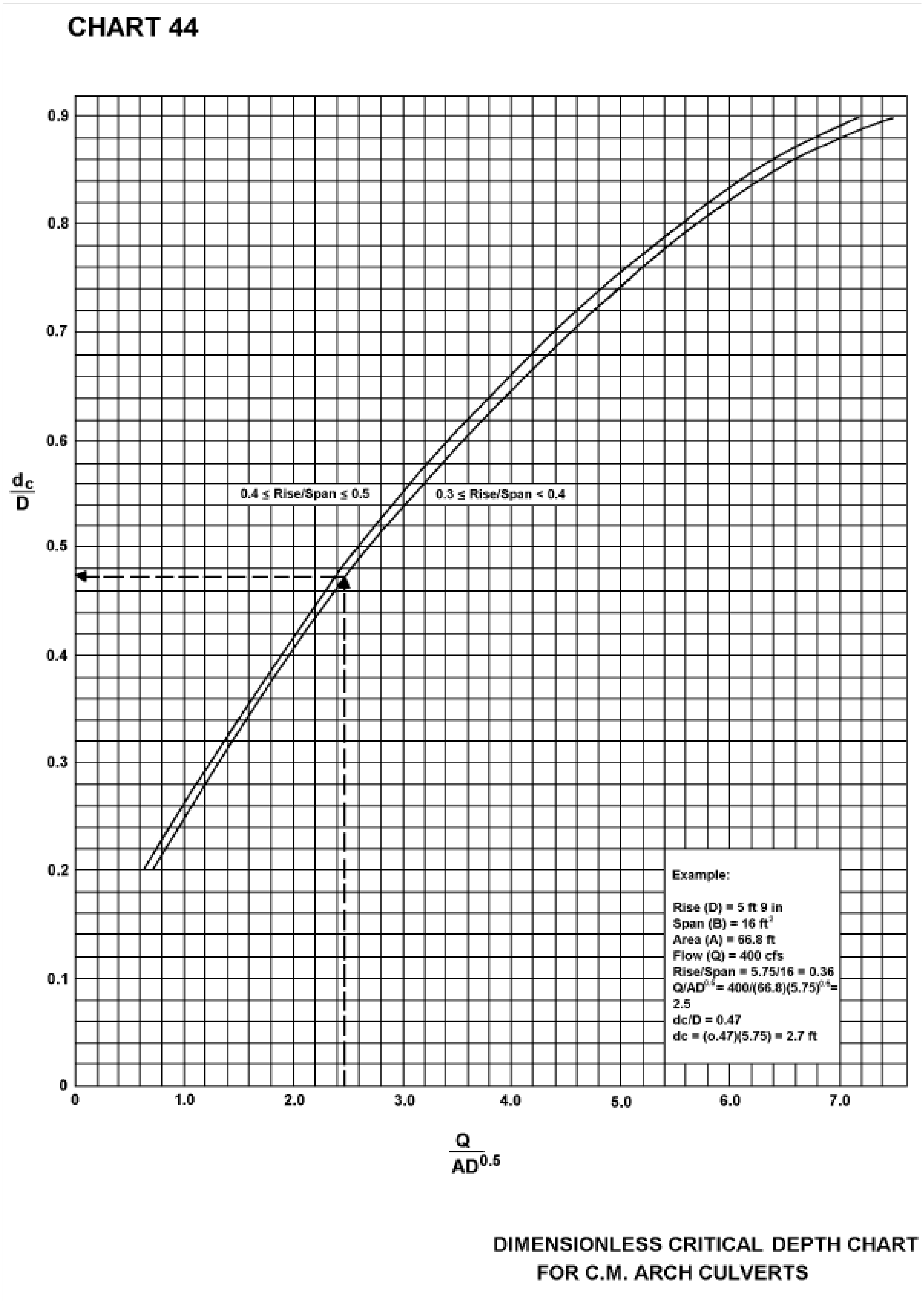
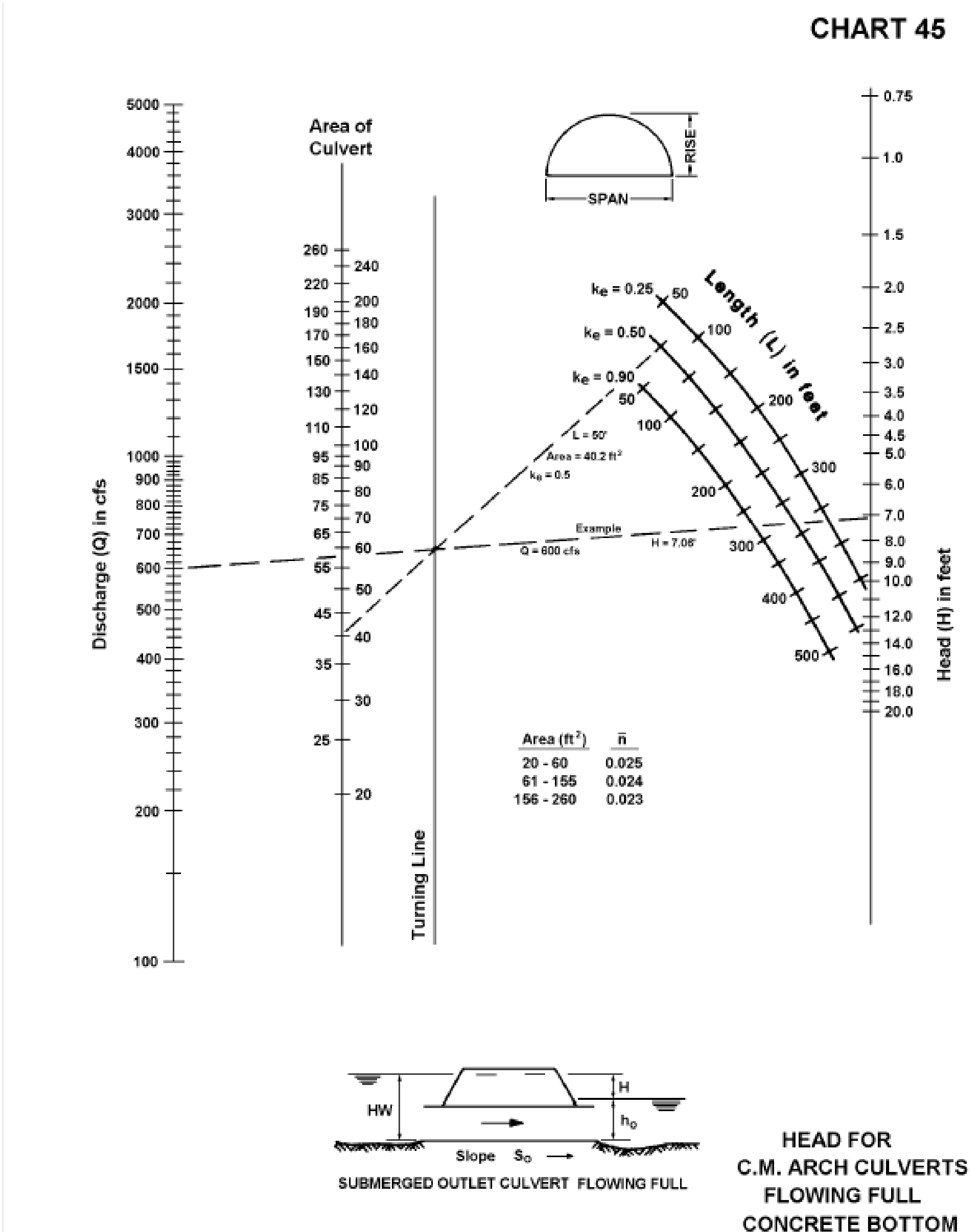


Chart 45 - Head for C.M. Arch Culverts Flowing Full Concrete Bottom 0.3 ≤ Rise/Span < 0.4



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation. Duplication of this nomograph may distort scale.

Chart 46 - Head for C.M. Arch Culverts Flowing Full Concrete Bottom 0.4 ≤ Rise/Span < 0.5

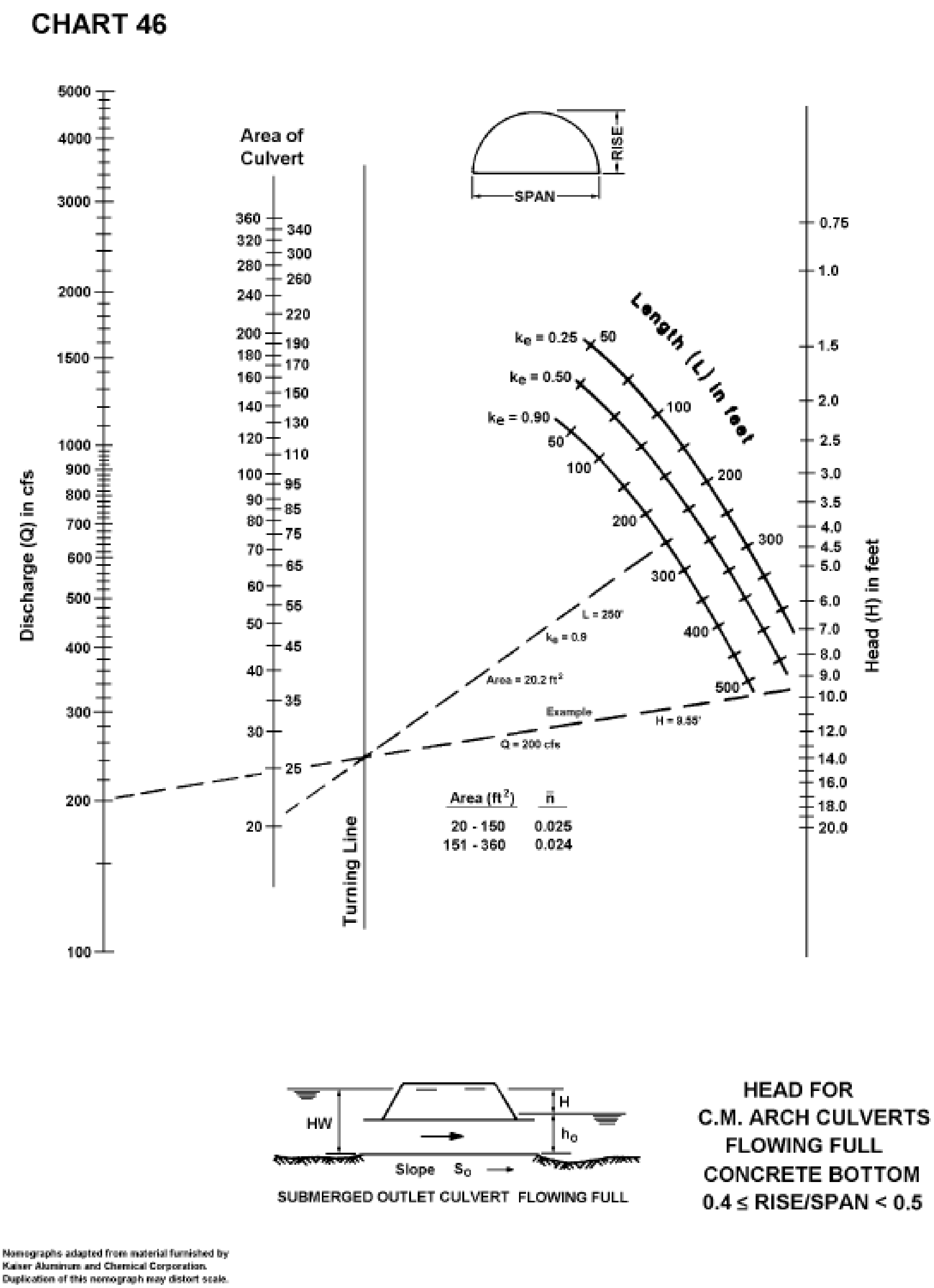
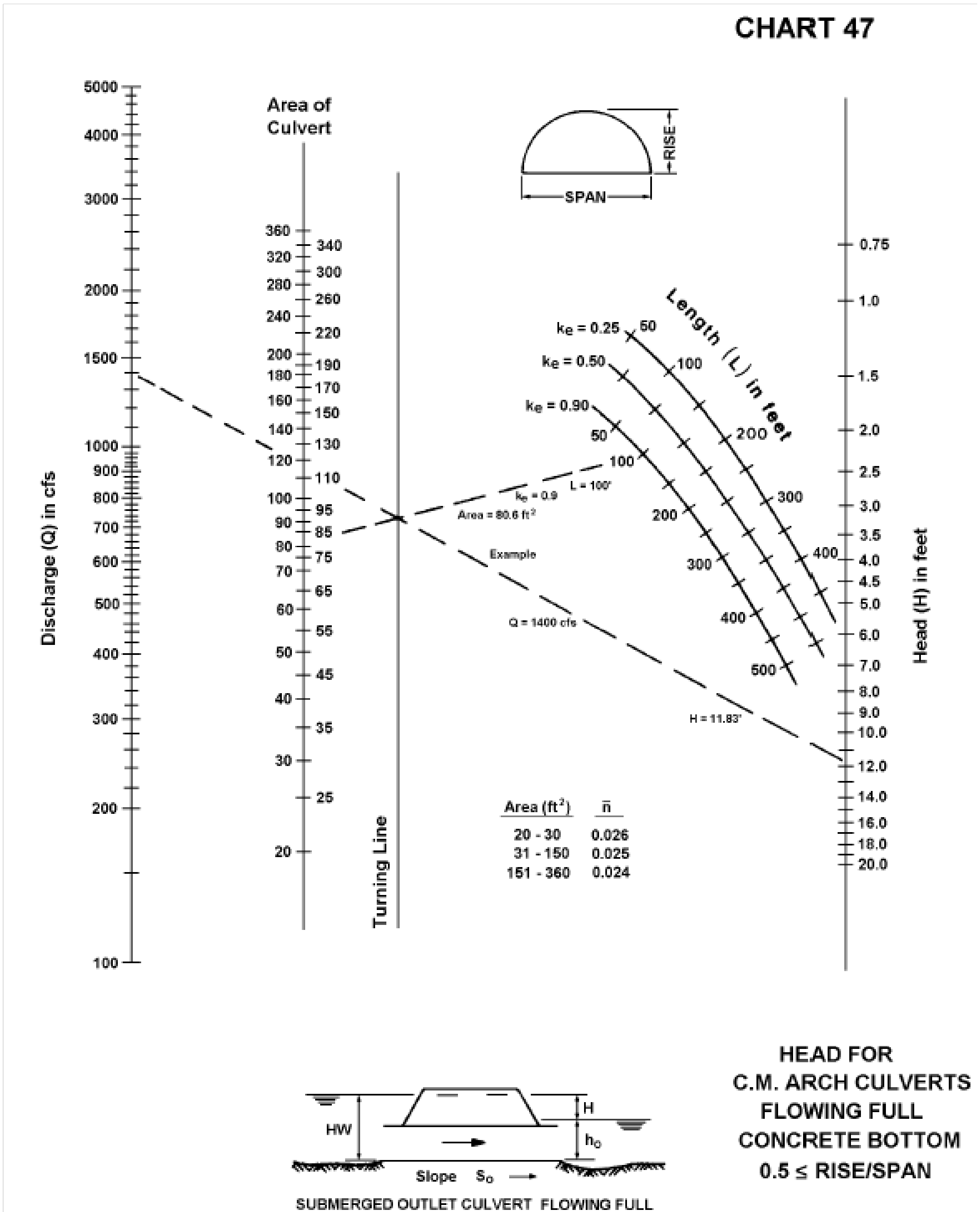


Chart 47 - Head for C.M. Arch Culverts Flowing Full Concrete Bottom 0.5 ≤ Rise/Span



Nomographs adapted from material furnished by
Kaiser Aluminum and Chemical Corporation.
Duplication of this nomograph may distort scale.

Chart 48 - Head for C.M. Arch Culverts Flowing Full Earth Bottom ($n_b = 0.022$) 0.3 ≤ Rise/Span < 0.4

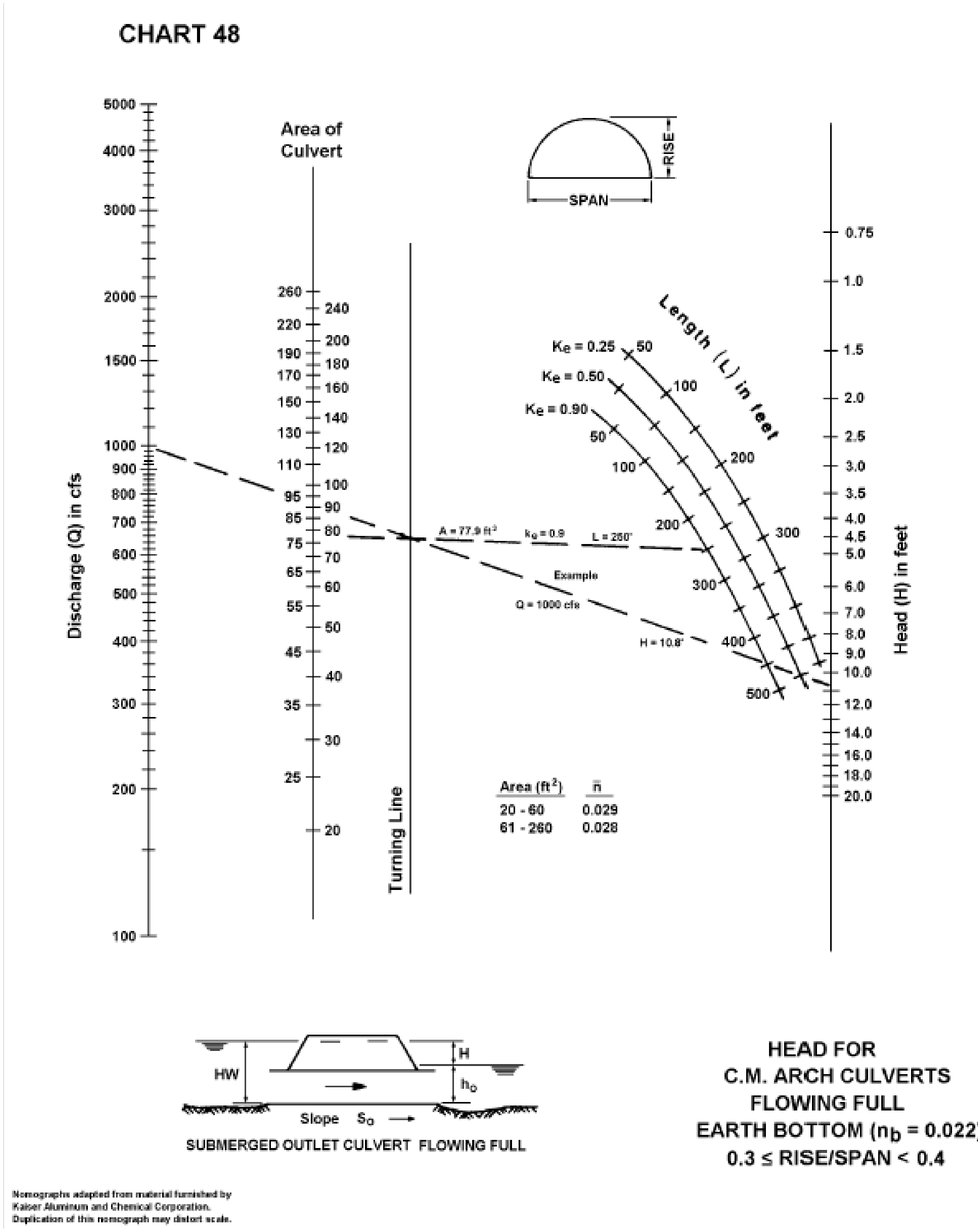


Chart 49 - Head for C.M. Arch Culverts Flowing Full Earth Bottom (n_b = 0.022) 0.4 ≤ Rise/Span < 0.5

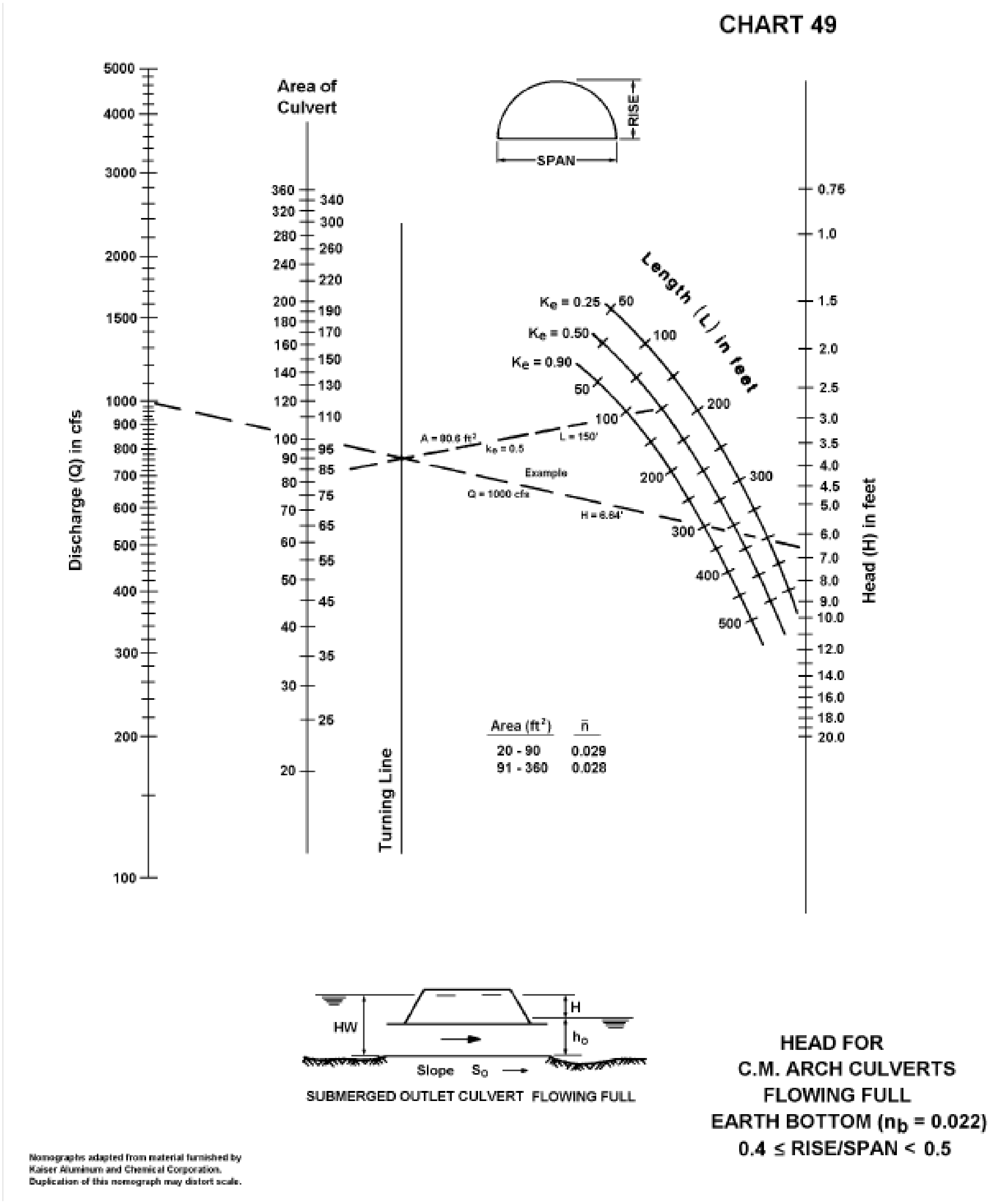


Chart 50 - Head for C.M. Arch Culverts Flowing Full Earth Bottom (n_b = 0.022) 0.5 ≤ Rise/Span

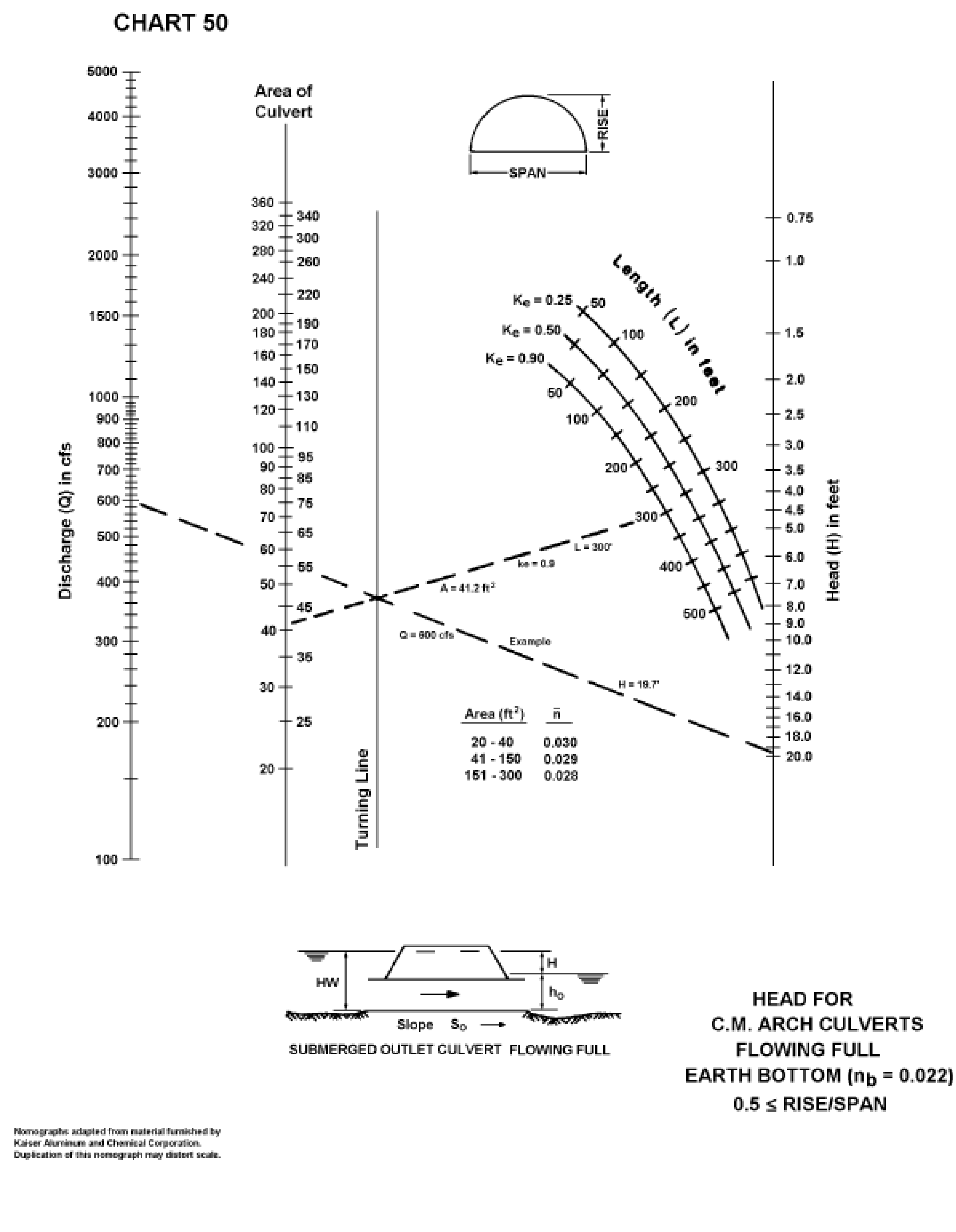


Chart 51 - Inlet Control Headwater Depth for Circular or Elliptical Structural Plate C.M. Conduits

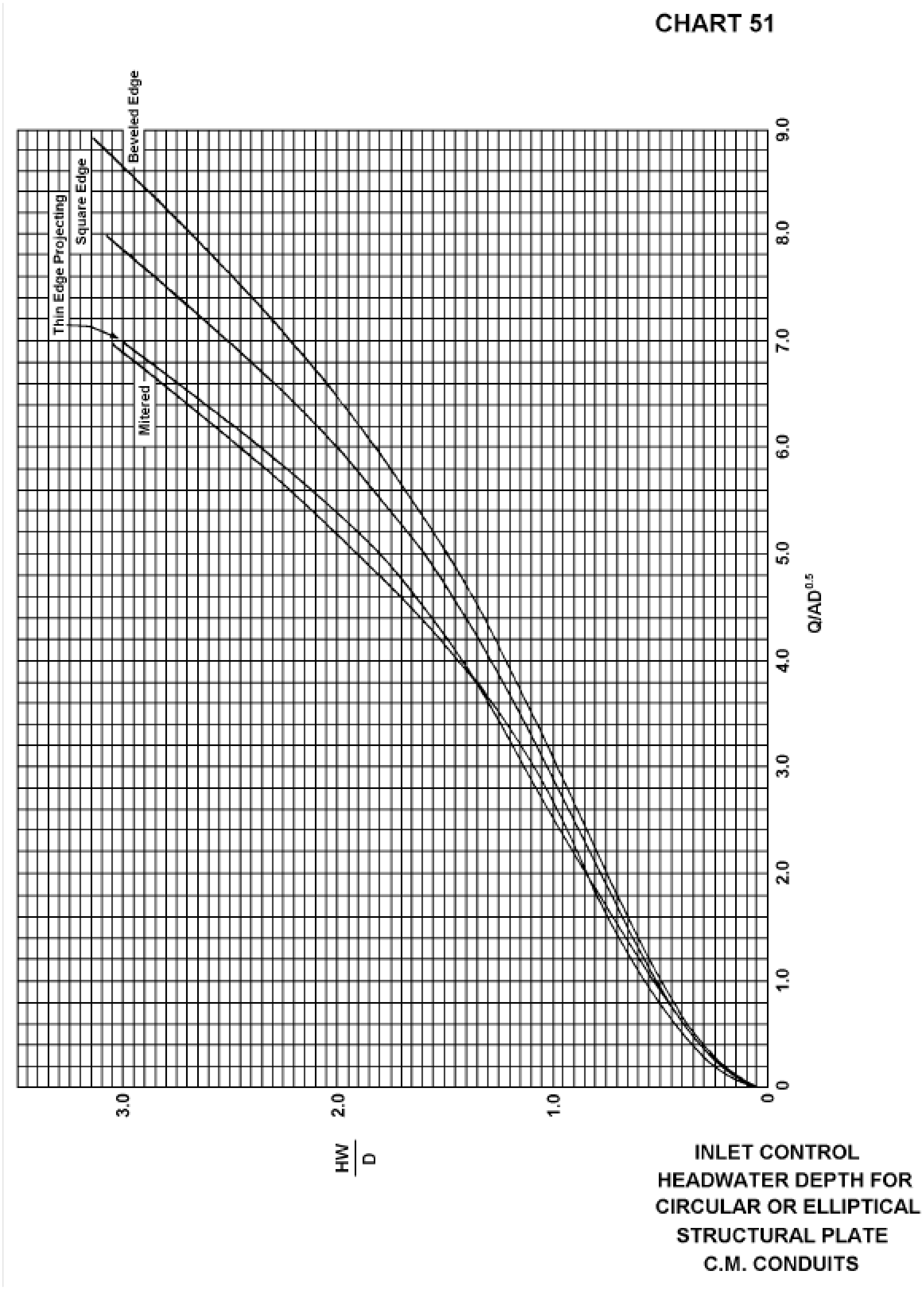


Chart 52 - Inlet Control Headwater Depth for High and Low Profile Structural Plate C.M. Plate

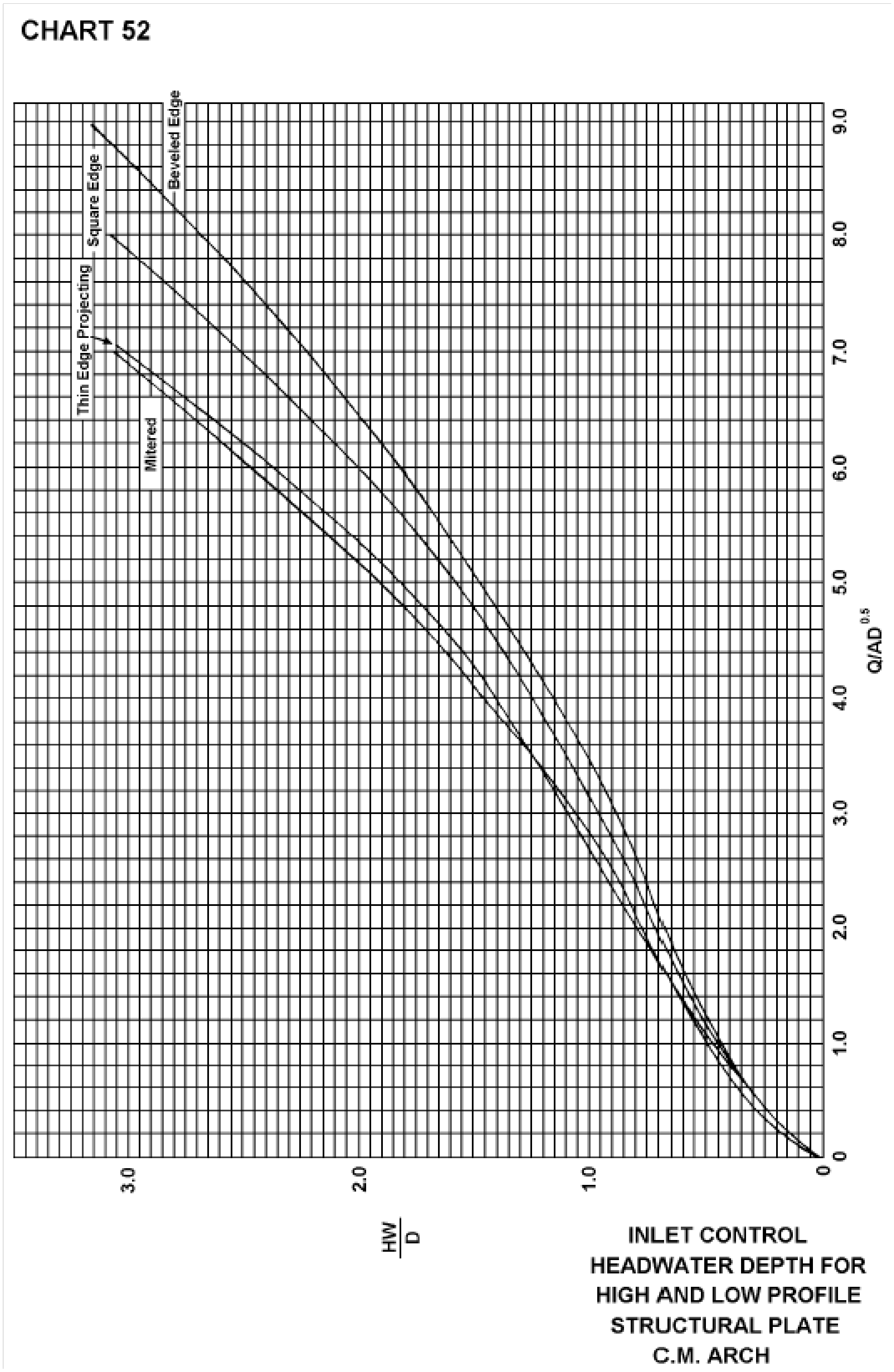


Chart 53 - Dimensionless Critical Depth Chart for Structural Plate Ellipse Long Axis Horizontal

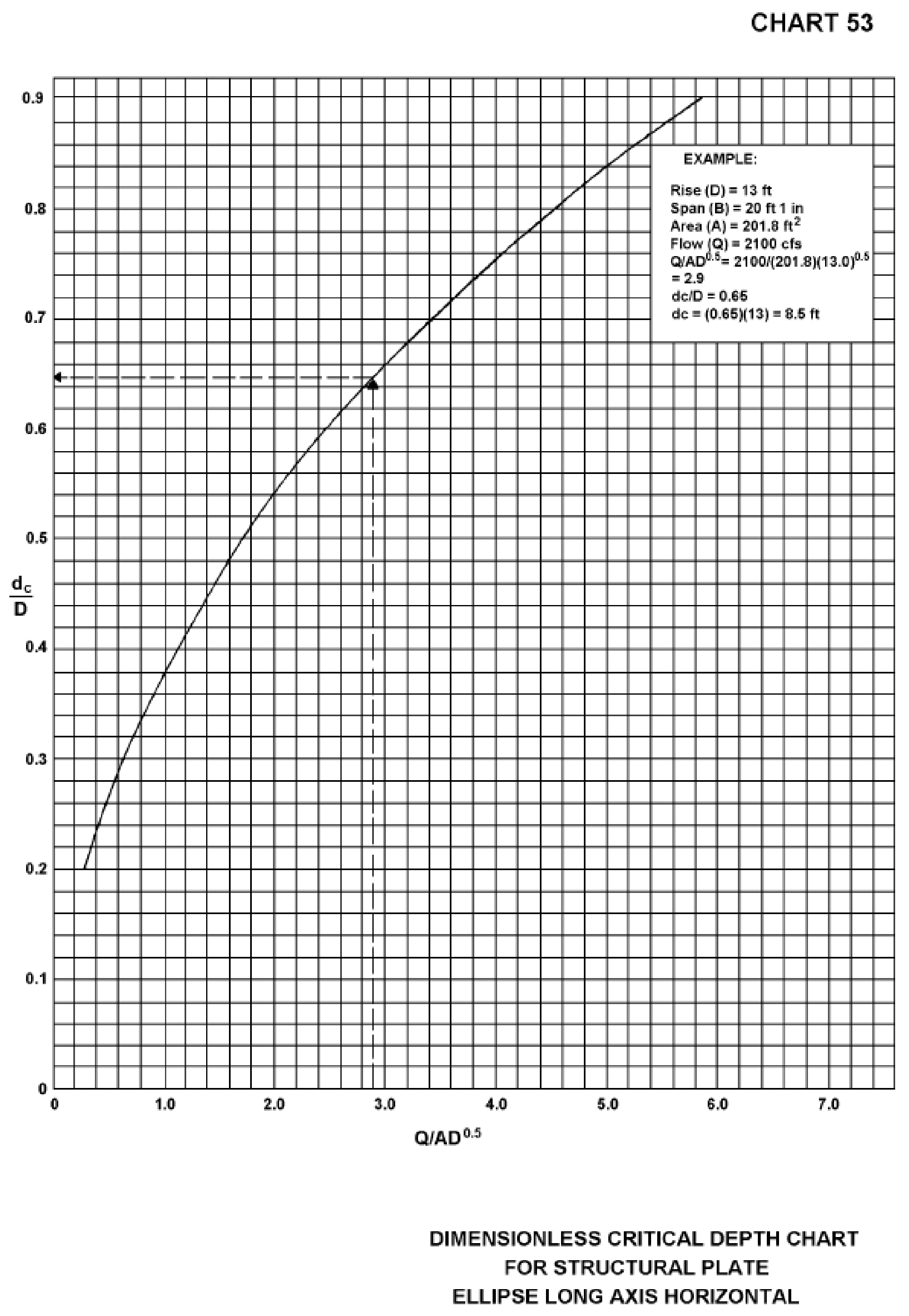
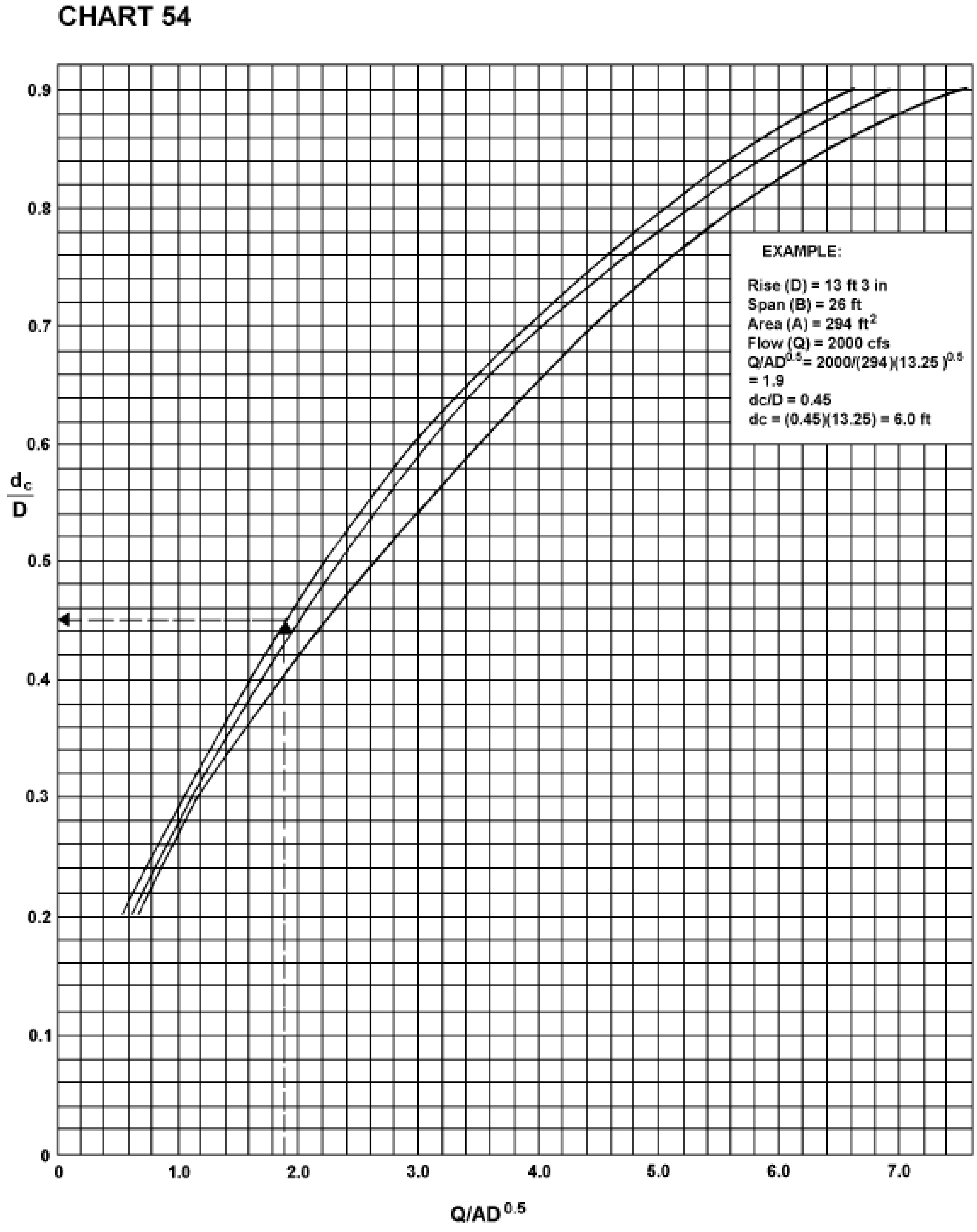
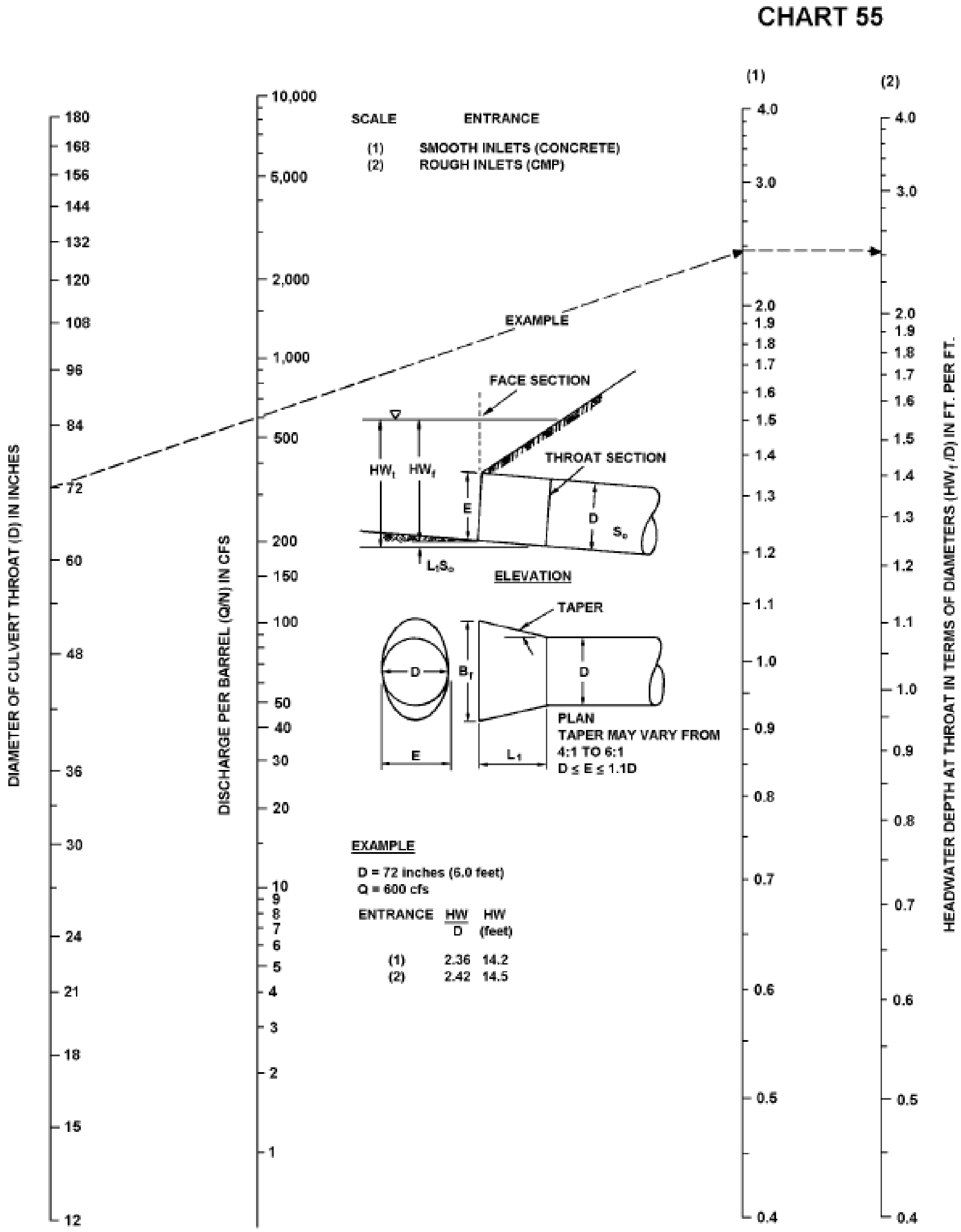


Chart 54 - Dimensionless Critical Depth Chart for Structural Plate Low- and High-Profile Arches



DIMENSIONLESS CRITICAL DEPTH CHART
FOR STRUCTURAL PLATE
LOW- AND HIGH-PROFILE ARCHES

Chart 55 - Throat Control for Side-Tapered Inlets to Pipe Culvert (Circular Section Only)



THROAT CONTROL
FOR SIDE-TAPERED INLETS
TO PIPE CULVERT
(CIRCULAR SECTION ONLY)

Chart 56 - Face Control for Side-Tapered Inlets to Pipe Culverts (Non-Rectangular Sections Only)

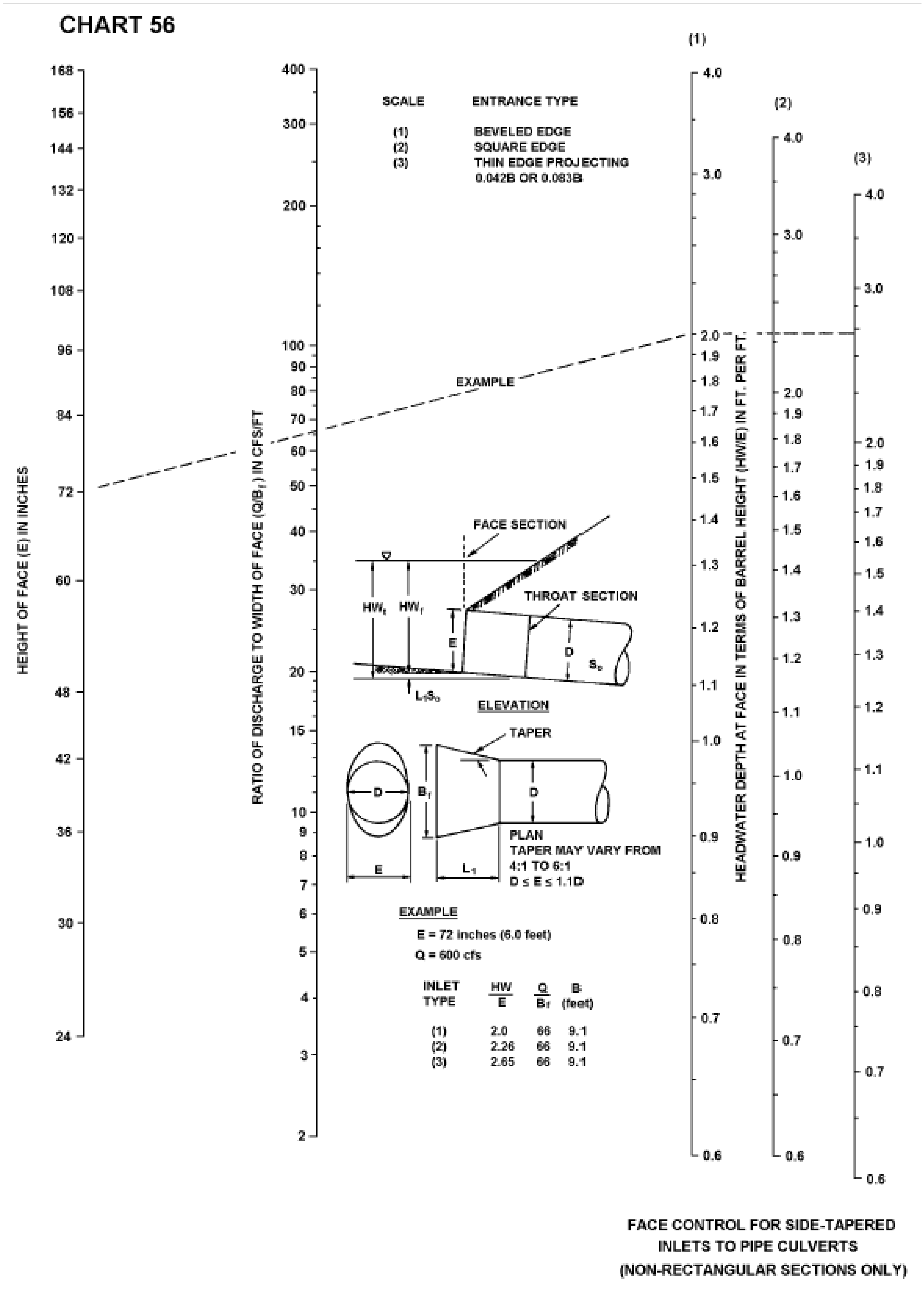


Chart 57 - Throat Control for Box Culverts with Tapered Inlets

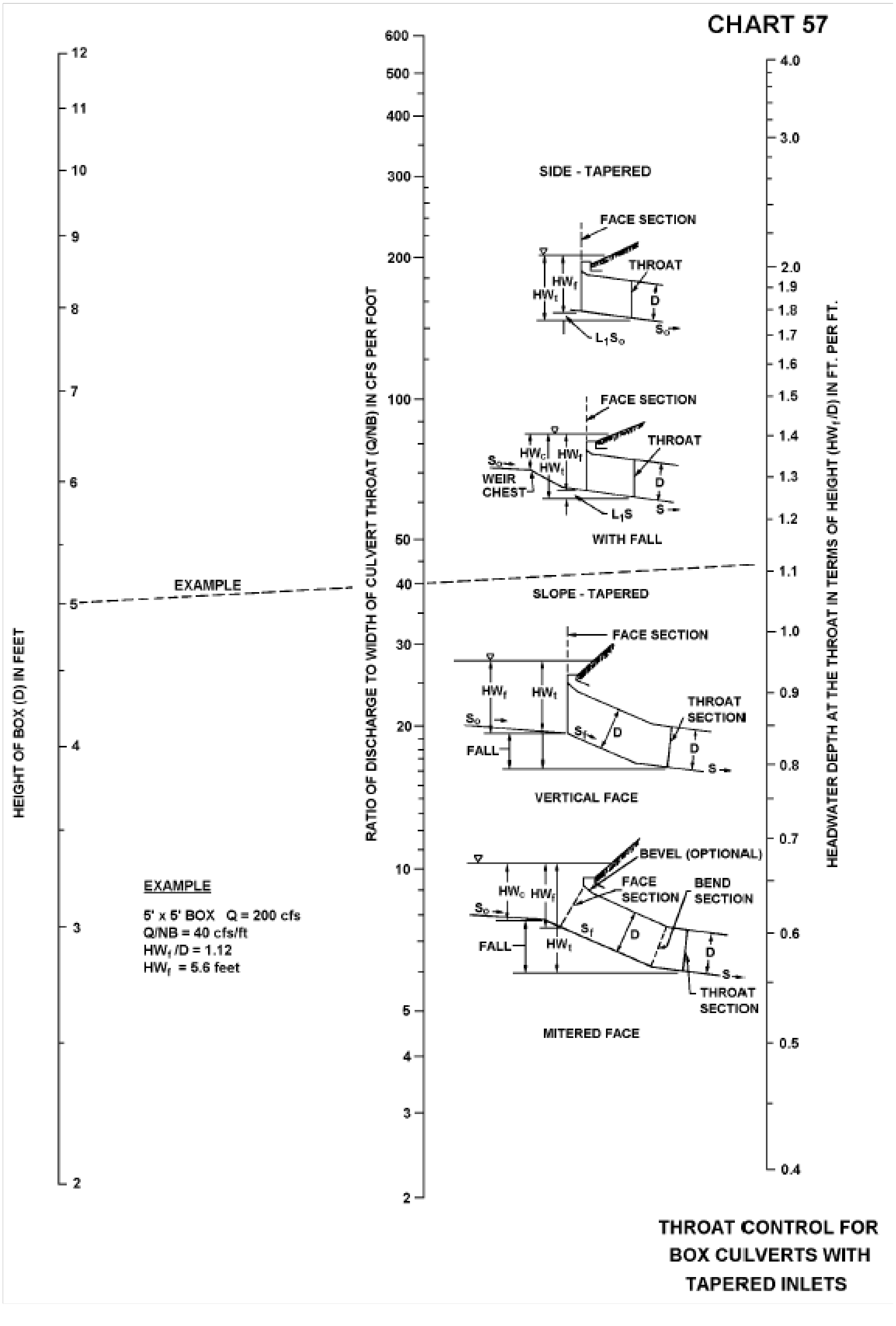


Chart 58 - Face Control for Box Culverts with Side-Tapered Inlets

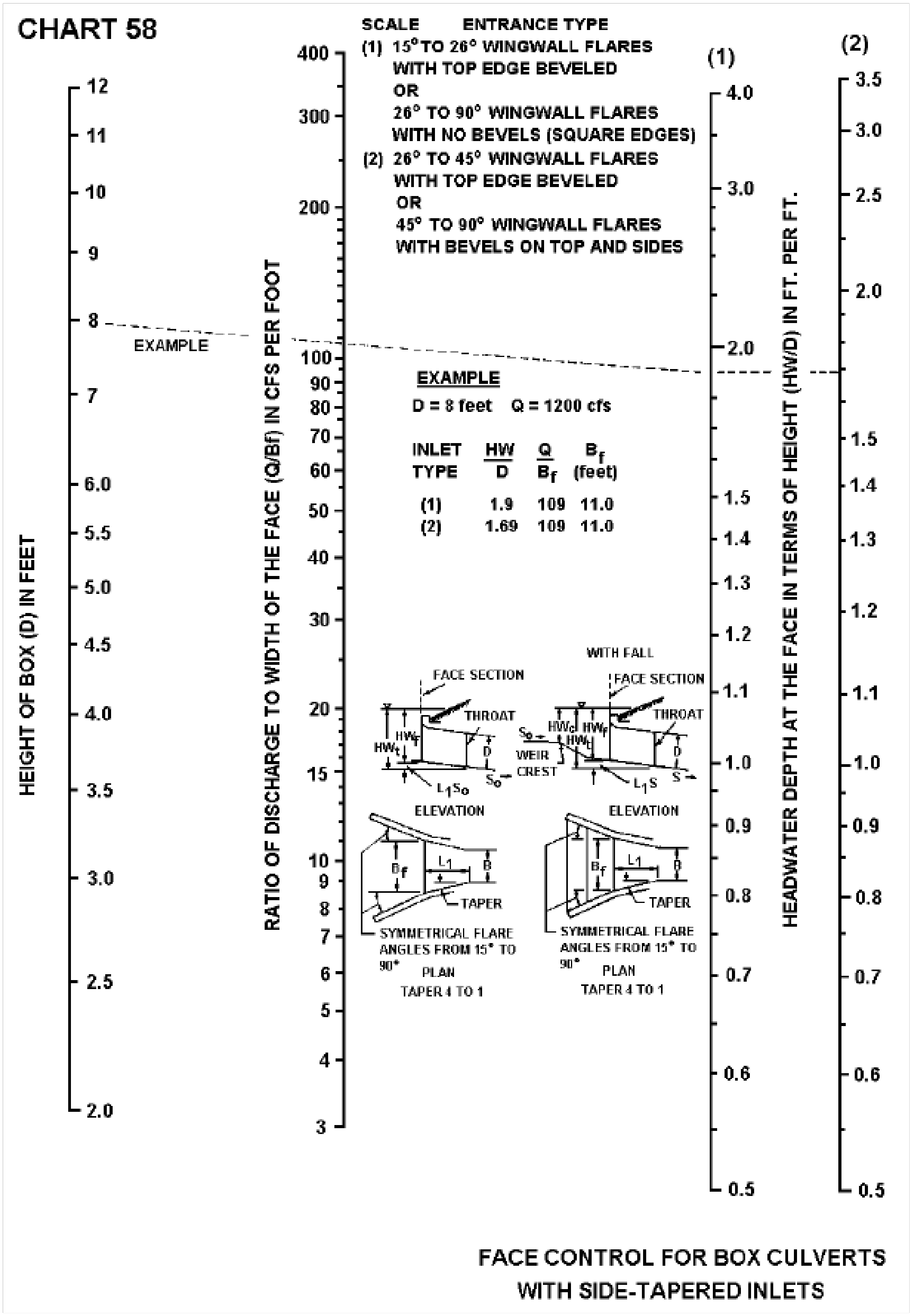


Chart 59 - Face Control for Box Culverts with Slope Tapered Inlets

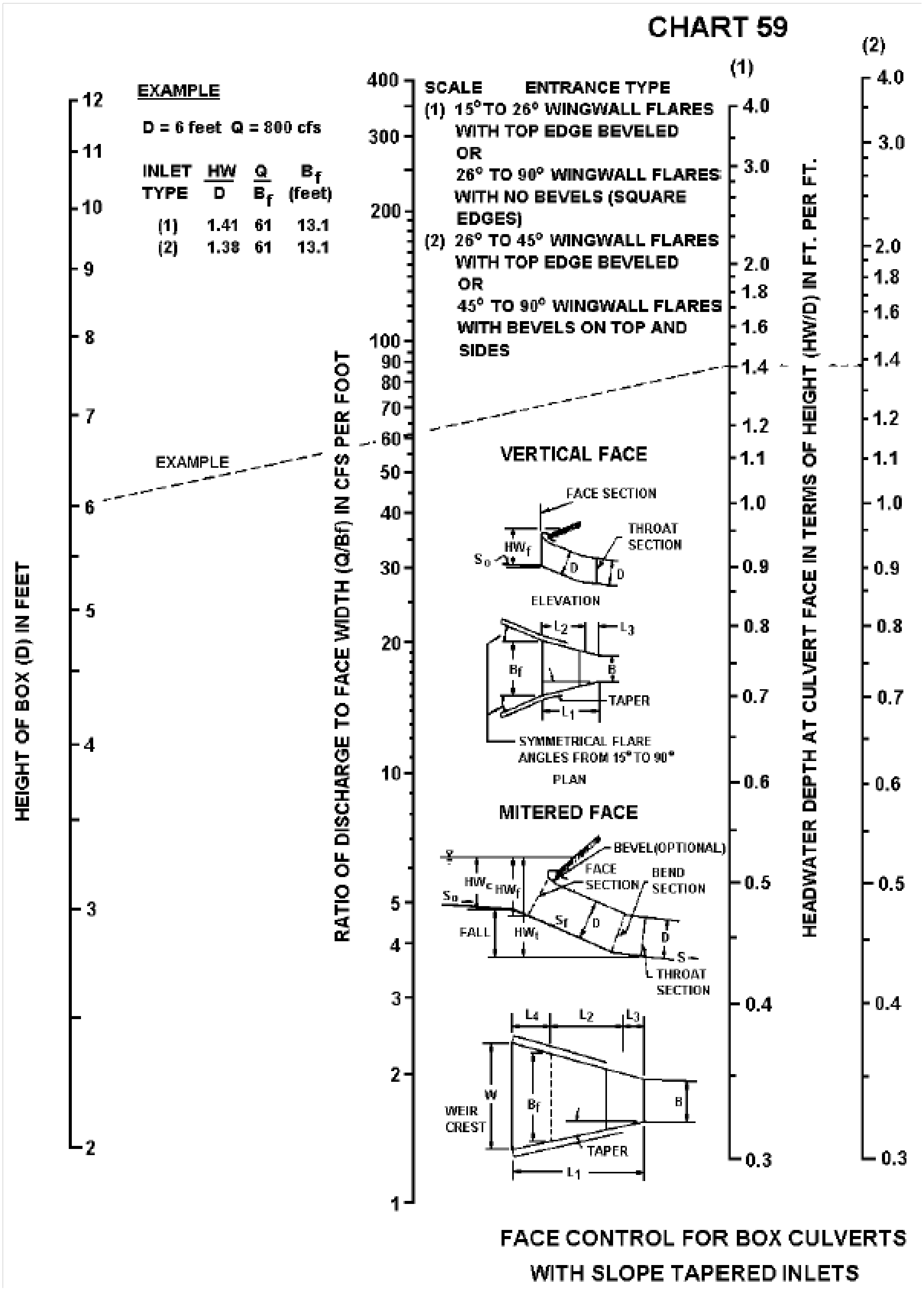
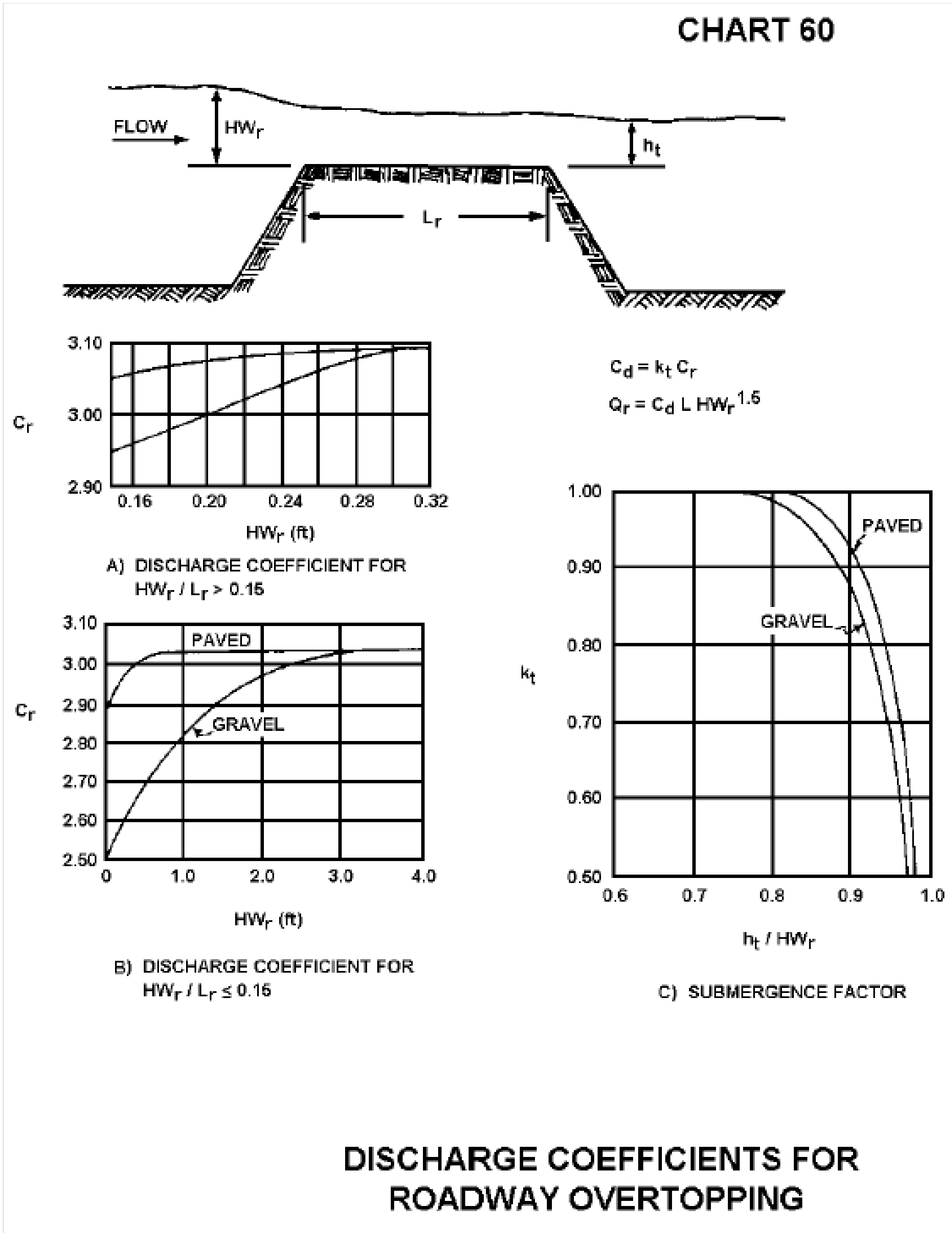


Chart 60 - Discharge Coefficients for Roadway Overtopping



References

Federal Highway Administration, 1985. Hydraulic Design of Highway Culverts. Hydraulic Design Series No.5.